Water quality sampling at Tomahawk Creek

Water samples for parasite analysis were collected by pumping about 100 L of creek water through a cartridge filter. Raw and treated drinking water samples were also put through cartridge filters connected to taps at each drinking water treatment plant. Sewage effluent samples were collected in 20 L jugs directly from the effluent flow. Samples for bacteria and water chemistry were also collected from the creeks. Samples were analyzed for parasites, fecal coliform bacteria, nutrients, turbidity, and colour. Standard scientific methods were used for all analyses.

Flow volume was measured or estimated for each surface water and effluent sample. Flow measurement is essential to calculate the total number of organisms entering the river so that the different watershed sources can be compared. This is called a total **mass load** (or just "load") – the amount in kilograms or numbers of organisms over a given time period. It is calculated by multiplying the concentration in a sample by the flow rate of the creek or effluent at the time of sampling (e.g., 5000 giardia cysts per cubic metre (m^3) of sample water times a flow of 5 m^3 per second = 25000 cysts per second). The total mass load of parasites and other water quality contaminants were calculated for all study streams and municipal sewage effluent discharges.

The data for various chemical, biological and physical water quality characteristics were statistically compared with stream parasite concentrations. If a close relationship could be found, it might allow future monitoring programs to predict levels of parasites from a particular chemical constituent rather than analyzing them directly, which is expensive and time-consuming.

It is essential, when complex studies such as this one are undertaken, to make sure the data are reliable and accurate. A variety of procedures were done throughout the study to assure the quality of the data, including a rigorous sampling protocol, analyzing two or more samples of the same water with different labels, sending the same water sample to two different laboratories and sending laboratories samples with known concentrations.

Longitudinal Survey. The 20 streams sampled during the study are shown in Figure 3. Samples were collected once during spring runoff and summer rainfall events for the three years. Mass loads were calculated for a one-week period during each runoff.

Figure 4 shows the proportion of the average total load for cryptosporidium and giardia from the major sources during spring and summer. For these pie charts, loads for the three spring surveys were averaged, as well as loads for the three summer surveys. The greatest proportion of the total amount of cysts and oocysts entering the North Saskatchewan River was from agricultural streams, except for cryptosporidium in the summer of 1998. The cryptosporidium concentration in the sample collected from the Baptiste River at the end of June 1998 was very high. As well, flow in the river was also high, resulting in a large quantity of oocysts from this non-agricultural watershed. The source of these organisms is unknown. The overall average percentage of the total load (see total load on each pie graph) entering the river from agricultural streams was 56% for cryptosporidium and nearly 80% for giardia (spring and summer combined).

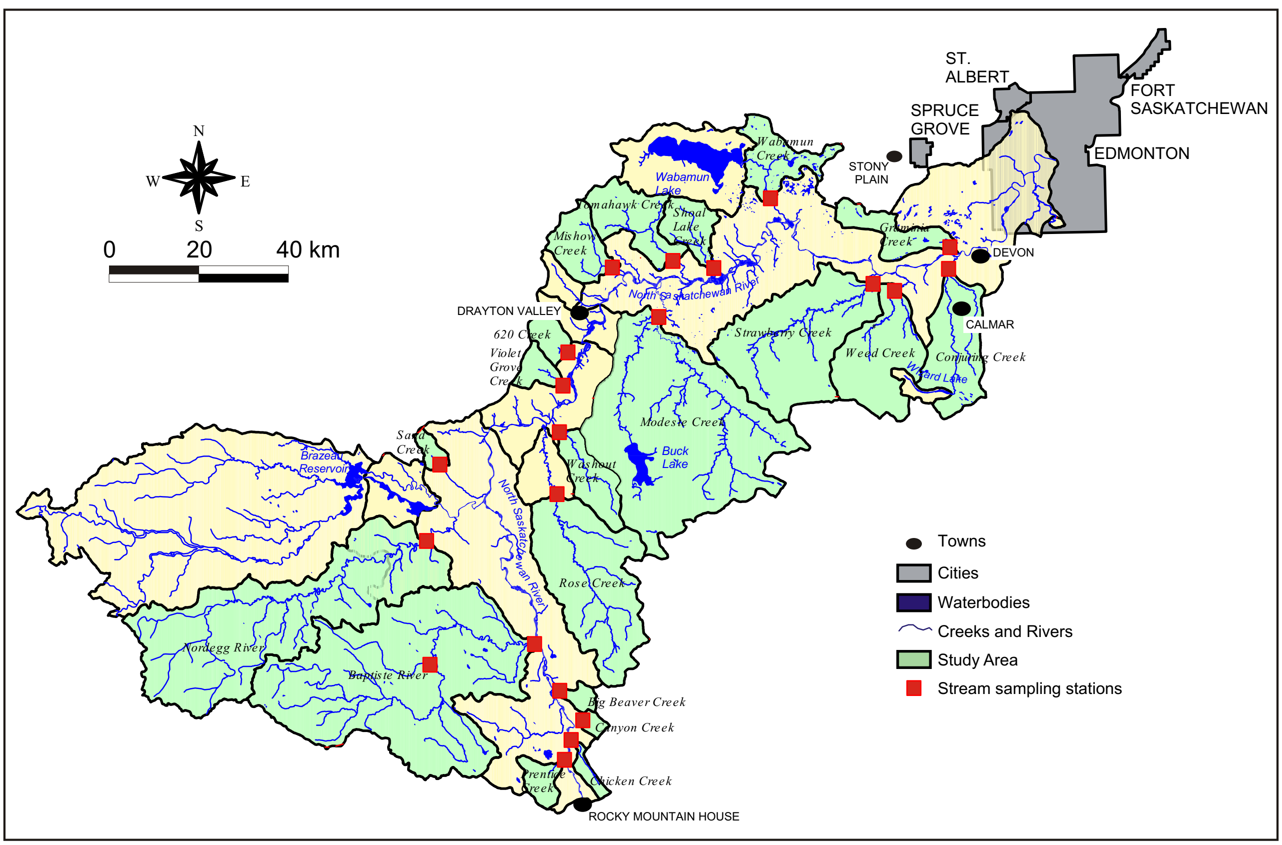


Figure 3: Map showing stream sampling sites.

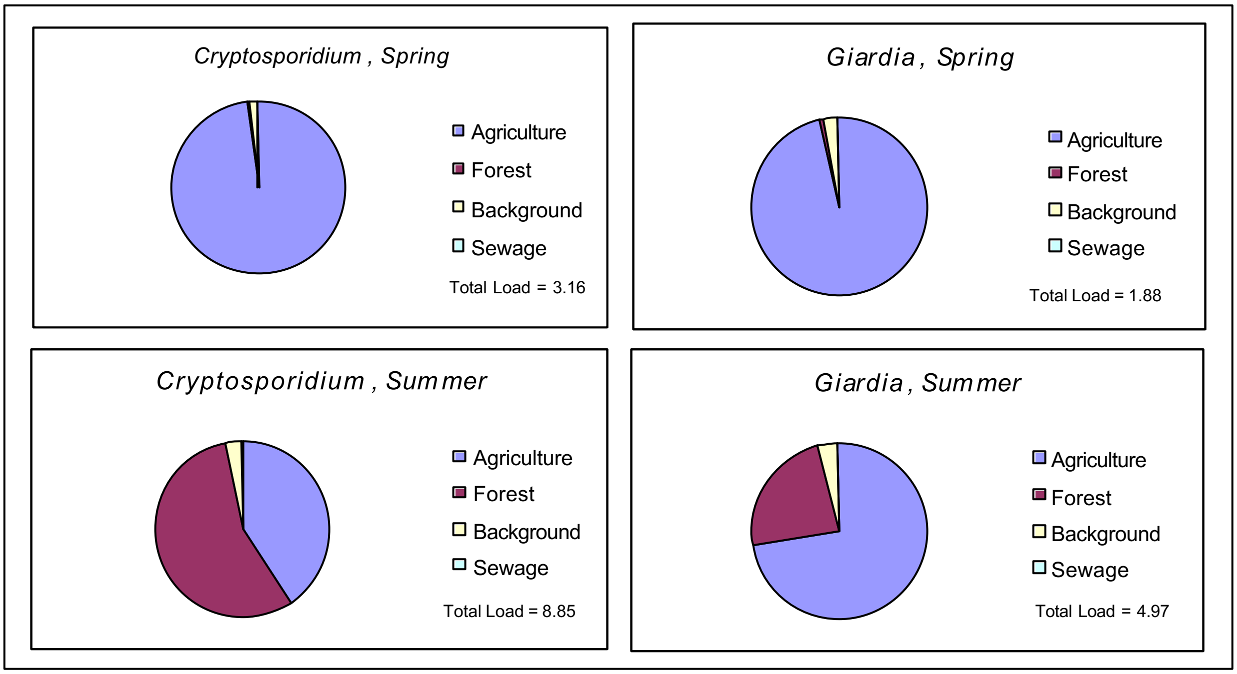


Figure 4: Proportion of average total loads of Cryptosporidium and Giardia in Longitudinal Survey streams for one week during spring and summer. (Total load is in trillion of oocysts for the time period.)

To compare agricultural and non-agricultural streams further, the average concentration from the non-agricultural watersheds was multiplied by the flow volume from all of the agricultural streams. This resulted in total loads that averaged about 20 times lower than measured from all sources, except in summer 1998. Although this estimate is very rough, it does suggest that the concentration of parasites in the river has increased since the watershed was cleared for human and agricultural development.

Nearly 50% of the flow in the North Saskatchewan River at Edmonton was derived from above Rocky Mountain House during the study weeks. In comparison, the parasite load from the watershed above this town, which represents background concentrations in the river, amounted to only about 2% of the total load at Edmonton. The average contribution from sewage effluent is not apparent on these charts, because the average load for giardia in effluent accounted for less than 2% of the total average load entering the river. The contribution of cryptosporidium from sewage effluent was very low, amounting to only a fraction of one percent for both spring and summer. Based on these data, the agricultural streams are major contributors to the number of parasites in the river during runoff periods. But the non-agricultural streams can also occasionally contribute large quantities during summer rains.

To make sure no major sources were missed during the study, mass loads from streams, municipal sewage effluent, background and unmonitored parts of the watershed were added. It was not possible to sample every stream that drains into the river, so concentrations from neighboring measured streams were used to extrapolate to unmeasured ones. Then, concentrations of various biological and chemical substances that would be expected in the river at Devon (based on these loads) were calculated as in diagram 1 on the next page:

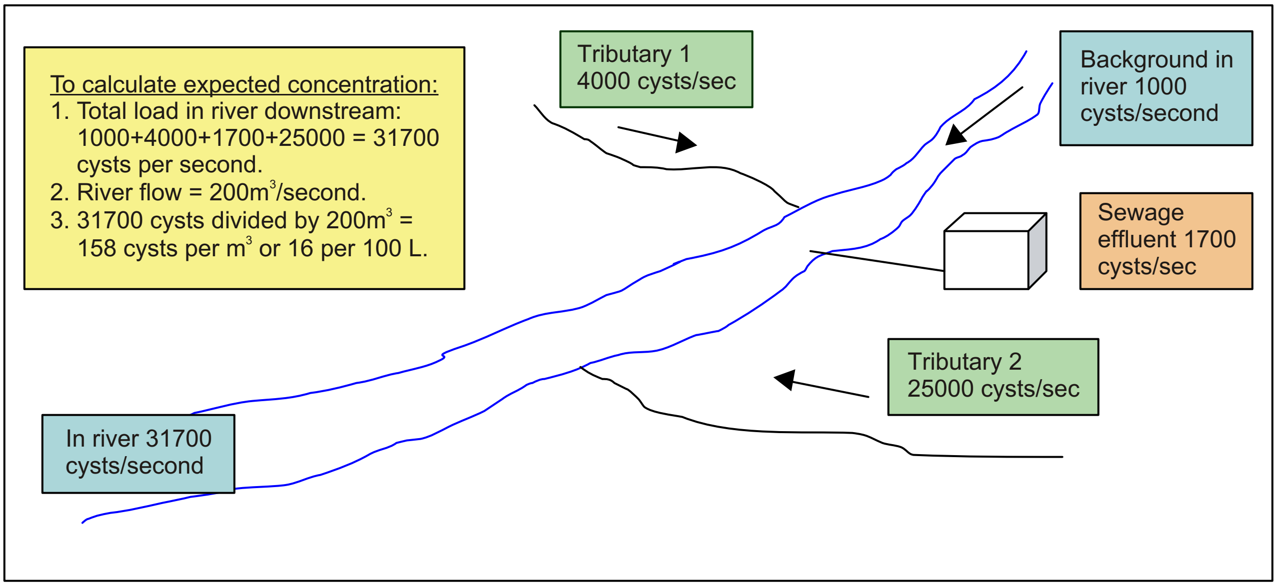


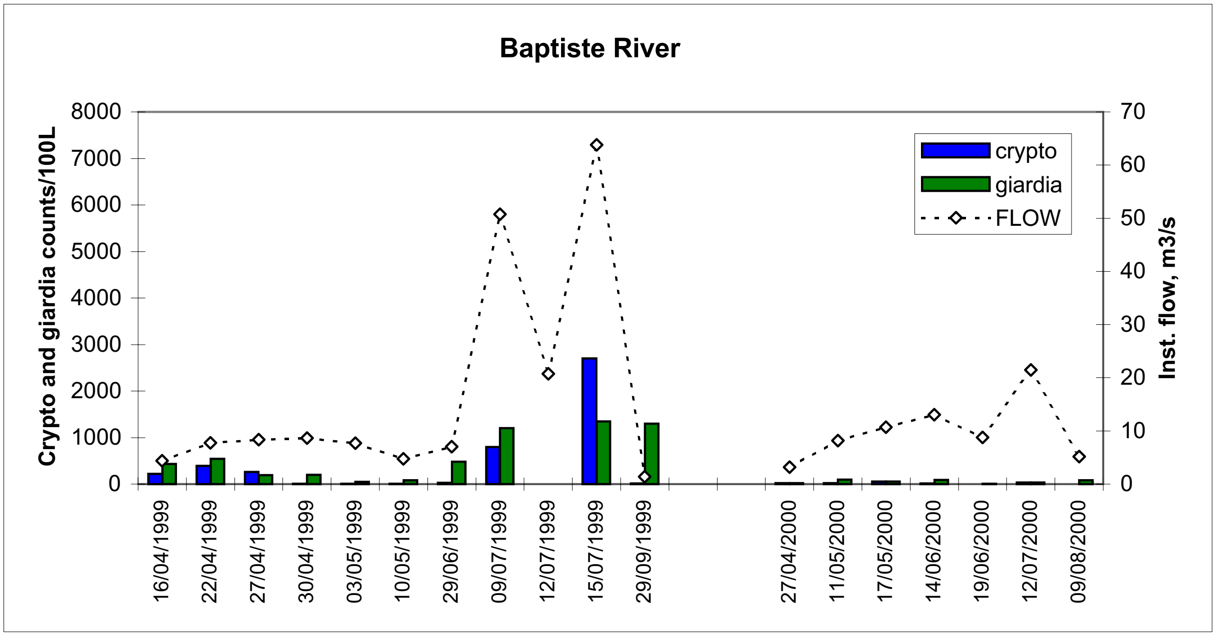
Diagram 1: Diagram explaining how biological and chemical loads were calculated in the river.

These concentrations were compared with actual concentrations in the river at the time of each survey, as sampled in the raw water at the Devon Water Treatment Plant or the E.L. Smith Water Treatment Plant upstream of Edmonton. Expected concentrations were usually higher or similar to measured concentrations. If they had been substantially lower, it might indicate that a major source had been missed. Thus, it appears that the major sources in the watershed were accounted for, in spite of uncertainties in sampling, analyses and flow measurements, as well as extrapolation to streams that were not sampled.

Intensive Watershed Survey. Six streams were chosen from the 20 Longitudinal Survey streams for more intensive study: Baptiste and Nordegg rivers (non-agricultural), Mishow and Tomahawk creeks (mainly cow-calf production) and Strawberry and Weed creeks (all types of livestock). They were sampled about twice per week during peak runoff, and less frequently as flows declined. About 145 samples were collected from these streams during 1999 and 2000.

Figure 5 shows parasite concentrations and flow in two of these streams, Baptiste River and Tomahawk Creek. Note that the concentration of both parasites generally increased when flows increased. Flows in the Baptiste River were highest in summer, whereas flows in Tomahawk Creek were highest in spring. As well, the concentration of cryptosporidium in Tomahawk Creek tended to be highest in spring. These graphs show a great amount of variability in concentrations, which is typical of these parasites.

Levels of cryptosporidium and giardia were positively and strongly correlated with each other, turbidity and total phosphorus. Therefore, when streams looks muddy, the chances are good that there will be many parasites in the water as well.



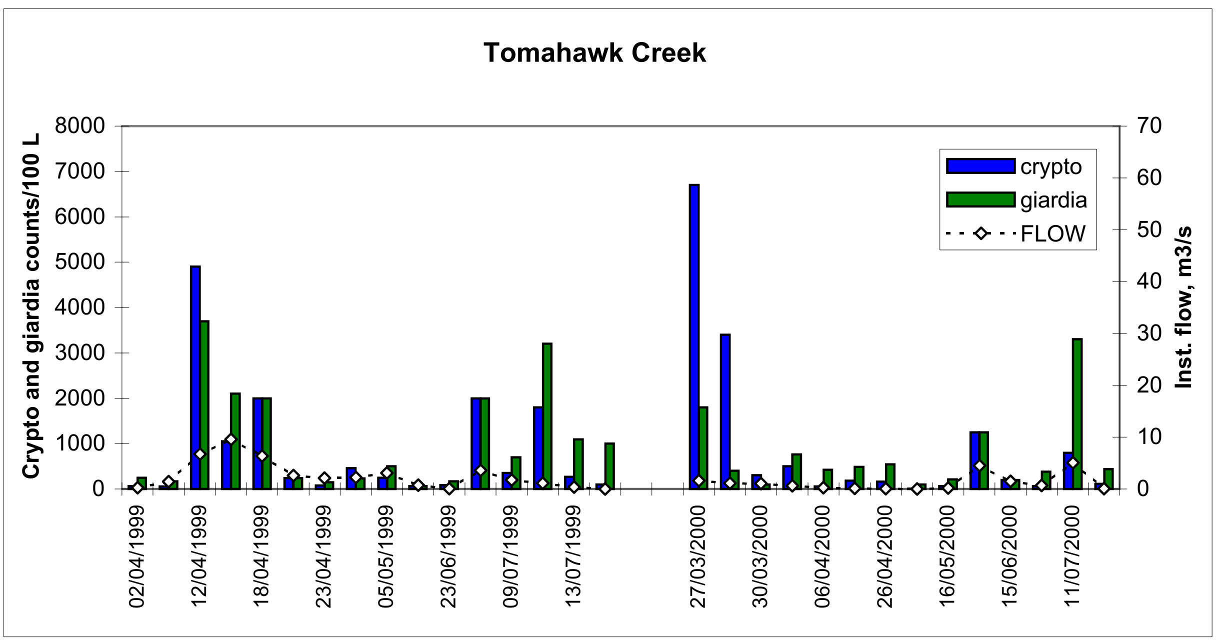


Figure 5. Flow and concentration of cryptosporidium and giardia in Tomahawk Creek and Baptiste River.

Upstream-Downstream. With the cooperation of three landowners, sampling sites were set up above and below cattle operations on Mishow, Tomahawk and Weed creeks. These sites were located as close as possible to the farm, to avoid contributions from other sources, such as inflow from small tributaries of the creek. Samples were collected frequently during runoff in spring and summer, and flow was measured or estimated for all samples.

Concentrations of several chemical characteristics were slightly higher at the downstream site, compared with the upstream site, although the difference was statistically significant for only a few. Average concentrations of giardia in Weed Creek were significantly higher downstream than upstream (Figure 6). But concentrations of most chemical characteristics were similar above and below the farm. Further study will be needed to determine whether individual cattle operations contribute substantially to parasites in creeks, as well as how different livestock management practices affect water quality in streams.

Synoptic Survey. During the upstream-downstream study, the research team noted that the concentration of many substances was higher at the stream outlet than at the two sites upstream. They decided to take an initial look at the entire lengths of two streams in 2000 to pinpoint areas of the watershed that might be contributing more parasites than other areas.

This was investigated by conducting a synoptic water quality survey - a "synoptic" survey is a point-in-time look at water quality along a stretch of creek or river, including point source contributions. Stream samples are collected from the upstream part of the stretch first, and then samplers work their way downstream.

Eleven sampling sites were set up along Strawberry Creek as it contributed large parasite loads to the North Saskatchewan River. Tomahawk Creek was one of the upstream-downstream study streams, and seven sites were set up along it. Each site was sampled once in March, June and July, during runoff. Loads were calculated for each site on the two creeks. To isolate the part of the watershed between the sites, upstream loads were subtracted from downstream loads. For example, the load at site T6 on Tomahawk Creek was subtracted from the load at site T7. This should result in a load from only the area of land between the sites.

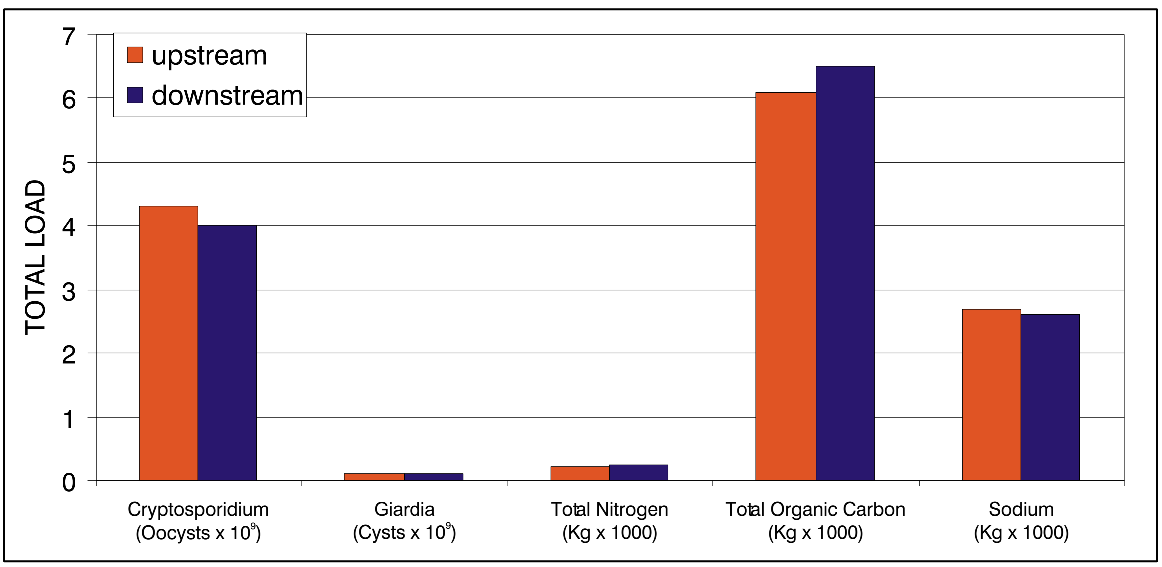


Figure 6. Total loads of five variables upstream and downstream of a cattle operation on one of the study creeks, summer 1999.

For some of the surveys and watershed areas, however, the subtraction of the upstream load resulted in a negative value – meaning that the upstream load was higher than the downstream load. This mainly resulted from a difference in stream flow between the sampling sites; for example, water might become trapped in small pools and reduce flow at the downstream site for a time. However, a few areas of the Tomahawk Creek watershed seemed to produce more parasites and other substances than other areas, such as the part of the watershed above site T7. On Strawberry Creek, there were no obvious parts of the watershed that consistently contributed more parasites than others.

Municipal Sewage Effluent. Two main types of municipal sewage treatment facilities are in the basin (see Figure 7):

- Those that discharge treated effluents continuously to the North Saskatchewan River (larger facilities); and

- Those that treat sewage in lagoons, which are discharged to creeks that drain to the river (these service smaller towns and villages). Discharges occur once a year or every other year, for a two to three week period in spring or fall. Rural residents outside of towns have private disposal systems.

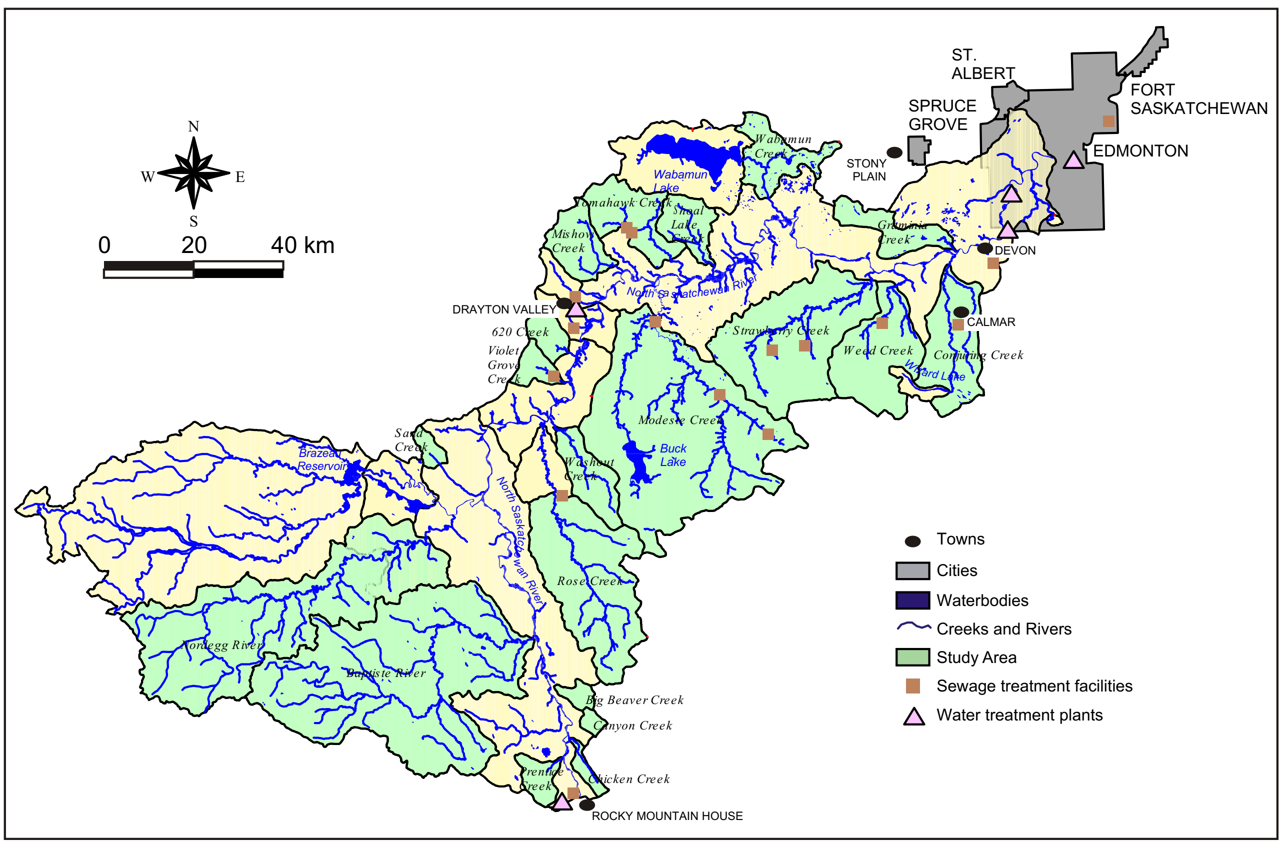


Figure 7. Sewage and water treatment facilities in the study area. Only those water treatment plants that use the North Saskatchewan River as a source are shown.

During the study, the continuous effluents were sampled monthly or every other month year-round. Although the Gold Bar plant is downstream of the water treatment plants, it was also sampled so that data from all four continuously discharging plants could be compared. Effluent from lagoons was sampled whenever they discharged. Twelve lagoons were sampled; one other was not sampled because it did not discharge during the study.

Levels of cryptosporidium were higher in the effluents at Rocky Mountain House and Gold Bar than at Drayton Valley and Devon, whereas giardia levels were higher at Devon and Gold Bar. It is not known whether the differences in parasite concentrations reflect differences in how the plants are operated, or higher levels of parasite infections in people living there. At all of the plants however, average concentrations of giardia ranged from 5 to 75 times higher than concentrations of cryptosporidium.

Concentrations of fecal coliform bacteria were significantly higher in the effluent from Rocky Mountain House compared with effluent from Drayton Valley, Devon and Gold Bar. Rocky Mountain House is the only one of the four plants that does not disinfect its effluent with chlorine. Parasite levels, however, were quite high in the Devon and Gold Bar effluents in spite of disinfection.

Concentrations of cryptosporidium in effluent from the municipal sewage lagoons were somewhat higher than from the continuous discharges. Sewage effluent from the municipal sewage lagoon in Warburg had higher cryptosporidium levels than any other municipal sewage lagoon. It was thought that the meat packing plant in Warburg, which directs waste to the town sewage treatment facility, might be the source of these high concentrations. An investigation to identify the source of cryptosporidium to the sewage lagoon was inconclusive.

Loads of parasites and other biological and chemical substances from sewage treatment plants are fairly small compared with loads from the watershed. Although lagoon discharges would increase parasite concentrations in the receiving creek somewhat, the volume of effluent from these facilities is much smaller than the volume of runoff from streams. Therefore, the loads from sewage lagoons are too small to affect water quality in the North Saskatchewan River.

To assess the effect of the continuously discharging sewage treatment plants on the river, parasite loads were calculated for each plant during winter, when stream contributions were minimal, lagoons were not discharging and river flow was low. Then, expected river concentrations were calculated from these loads (see diagram under Longitudinal Survey, above).

Expected river concentrations were 28 giardia cysts per 100 L, and 1 cryptosporidium oocyst per 100 L. These concentrations were compared with average concentrations measured in the raw water at the E.L. Smith Water Treatment Plant for winter (December – February): 34 giardia cysts/100 L and 8 cryptosporidium oocysts./100 L. It appears that the continuous sewage effluents are likely responsible for levels of giardia in the raw water in winter.

The situation for cryptosporidium is less clear, because even a worst-case situation (highest concentration and effluent discharge, and lowest river flow) would result in an expected concentration of only 6 oocysts/100 L. Because the concentration and flows from the continuous effluents are relatively similar year-round, the contribution from the sewage treatment plants is also similar year round. When river flows are higher, however, the concentration in the raw water that could be attributed to the effluents would be lower. Thus, sewage effluents are a relatively minor source of parasites, compared with the non-point sources from the watershed.

Even though the contribution of cryptosporidium and giardia from continuous sewage effluents to the river is small, they do represent a year-round base load of both parasites to the North Saskatchewan River.

Raw and Treated Water. There are five drinking water treatment plants in the study area that use the North Saskatchewan River as a water source. These include Rocky Mountain House, Drayton Valley, Thorsby, Devon and Edmonton (E.L. Smith Water Treatment Plant) (see Figure 7). Edmonton's other treatment plant, Rossdale, was not included in the study. Other municipalities in the upper basin use groundwater or other surface water sources for their water supply. The raw water at these facilities was not sampled.

Nineteen raw and 16 treated water samples were collected from each of the major water treatment plants upstream of Edmonton. Three samples were collected from Thorsby. These were analyzed for parasites, fecal coliform bacteria, water chemistry and turbidity. As well, 41 samples were collected from the E.L. Smith Water Treatment Plant in Edmonton and analyzed for turbidity, parasites and colour.

Average levels of parasites in the raw water at Devon and E.L. Smith were about twice those of the two plants further upstream. Average giardia concentrations were higher than average cryptosporidium concentrations at all plants. During heavy runoff periods, however, levels of cryptosporidium tended to be similar to or higher than levels of giardia.

Most of the time, parasites are not detected in the treated water. During the study, none were detected in the treated water at Rocky Mountain House and Drayton Valley. At Devon, there were four occasions when giardia in the treated water exceeded the 0.1 cysts/100 L detection limit (see box below), with the maximum observed level at 0.5 cysts/100 L. Cryptosporidium exceeded the detection limit in one sample, also at 0.5 oocysts/100 L. This level would not cause an outbreak, although the ideal situation would be to have none in the water people drink. The critical level is 5 organisms/100 L in the treated water. If the number of organisms exceeded this level, the utility would increase monitoring, and possibly have a boil-water advisory issued. At present, Alberta Environment does not require monitoring of treated water for protozoan parasites.

DETECTION LIMITS

For both protozoan and chemical analyses, a detection limit is the lowest level that a particular analytical method can measure down to. For example, total phosphorus can be measured to 0.001 milligrams per liter (parts per million). If the amount in the sample is lower than this, it is reported as "less than 0.001 mg/L"). But the actual number is unknown. To be able to use a real number in calculations, all "less than" values were converted to one-half the detection limit (e.g., for total phosphorus 0.0005 mg/L).