BACTERIAL SURVEYS IN THE RED DEER RIVER (1996 - 1998)

Prepared for the PPWB
Committee on Water Quality

by:

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EXECUTIVE SUMMARY

This report addresses two issues concerning the bacterial quality of the lower Red Deer River: 1) the increase in fecal coliform counts and incidence of non-compliance with water quality objectives set by the Prairie Provinces Water Board (PPWBO) at the Alberta-Saskatchewan border, 2) the implications of discontinuing chlorine treatment of the Drumheller, East Coulee and Rosedale final municipal effluents on bacterial quality of the Red Deer River.

Water quality surveys were carried out in the summer of 1996 and 1998 in an attempt to identify sources which may be responsible for high fecal coliform counts and non-compliance with PPWBO at the border site. Results indicate that potential sources are located well downstream of the town of Drumheller; they include irrigation return flows and the wastewater treatment plant at Dinosaur Provincial Park. Over the three year sampling period, fecal coliform counts recorded by PPWB at Bindloss have exceeded the PPWBO occasionally, but maximum counts have remained low compared to previous years. Since the source(s) and the consequence of their contributions did not manifest themselves clearly, no-one source could be singled out as being the main cause of non-compliance at Bindloss; each has the potential of being a cause for non-compliance, either individually, or cumulatively.

A test water quality survey was conducted in the summer of 1996 and another one in the winter of 1996-97 to describe changes in bacterial quality which could be anticipated if Drumheller, East Coulee and Rosedale stopped adding chlorine to their municipal wastewater effluent. Disinfection with chlorine had been a license requirement because the hamlet of Rosedale withdrew water for domestic use below the effluent discharges; the hamlet now obtains drinking water from the Drumheller water treatment plant. Possible increases in the frequency of non-compliance at the PPWB site are a concern here. Results of the surveys indicated that when no chlorine was added to the effluent, fecal coliform counts remained elevated for a distance of about 30 km or 70 km below the discharge point in summer and winter, respectively. The PPWB site is located more than 200 km below the effluent discharges and bacterial counts at that site should not be affected by the discontinuation of chlorine treatment. However, follow-up surveys carried out in 1998 indicated that the longitudinal extent of the effects of municipal discharges on bacterial quality of the river could extend further downstream than originally expected. In 1998, Drumheller was upgrading its treatment system and relied on temporary lagoons for wastewater treatment; the effluent discharged in that year may have been of atypical quality. Further sampling is needed to describe the longitudinal extent of the impact zone under normal operating conditions of the wastewater treatment plant.

ACKNOWLEDGEMENTS

The assistance provided by Allan Kendrick (chief operator of Drumheller, East Coulee, Rosedale water treatment plants) and Mike MacDonald (operator of the Dinosaur Provincial Park treatment plant) is gratefully acknowledged; they facilitated access to the site for sampling staff and provided daily discharge data.

Treva Piekema and Rick Pickering, Monitoring Branch (AEP) carried out the water quality sampling program and conducted flow measurements in the Red Deer River and tributaries. Sean Douglas and Jim Ames, Water Sciences Branch (WSB, AEP) provided flow and travel time estimates. B. Halbig and D. LeClair (WSB, AEP) provided support in data management and in the preparation of the manuscript.

Bacterial analyses were conducted at the Provincial Laboratory of Public Health, Edmonton.

D.O. Trew (WSB, AEP) reviewed the manuscript. An earlier draft of the manuscript was reviewed by P. Lang, A. Pentney (Environmental Sciences Division, AEP), and David Hill, Eastern Irrigation District.

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1.0 BACKGROUND

This report addresses two issues concerning the bacterial quality of the Red Deer River: 1) non-compliance at the Alberta-Saskatchewan border with water quality objectives set by the Prairie Provinces Water Board (PPWB) associated with a trend towards increasing fecal coliform counts at that site and, 2) the need for continued chlorination of the Drumheller, East Coulee and Rosedale municipal effluents.

Incidences of non-compliance with the PPWBO for fecal coliforms have been reported relatively frequently by PPWB in the Red Deer River at Bindloss since 1980 and a trend towards increasing numbers was reported based on data from 1974-1993 (Dunn 1995). Counts, as well as frequency of non-compliance, tend to be highest during the summer months (Anderson 1996).

Several point and non-point sources are potential contributors of fecal coliforms, including municipal discharges, irrigation return flows, tributaries, and livestock or wildlife having direct access to the river for watering.

- In addition to the city of Red Deer, Drumheller and smaller municipalities such as East Coulee and Rosedale discharge their wastewater effluent directly and continuously to the Red Deer River. Up to 1997, chlorine treatment of the effluent was a license requirement for Drumheller, East Coulee and Rosedale.

- Some municipalities, such as Delia, Hanna, Duchess, Rosemary and Patricia discharge their effluent intermittently (spring and or fall) to tributaries. The town of Brooks has biannual discharges to One Tree Creek.

- In 1992, the sewage treatment plant at Dinosaur Provincial Park became operational. It treats wastewater that is produced by park visitors; visitor numbers influence frequency and duration of discharges to the Red Deer River. The plant only operates during the tourist season (June – September).

- High bacterial counts were reported in the early 1980's downstream of irrigation return flows (Cross 1991). More recently, water quality studies conducted for the Eastern Irrigation District (Madawaska Consulting 1998) have confirmed the occurrence of high fecal coliform levels in several irrigation return flows to the Red Deer River.

- Some irrigation return flows such as Little Sandhill Creek, which flows through Dinosaur Provincial Park, have recreational uses. High fecal coliform counts are a potential health concern and their sources are being investigated (Wayne Pedrini, Brooks Area Manager, Natural Resources Service, AEP, pers. comm.).

The City of Drumheller was required to add chlorine to its final municipal wastewater effluent because the Hamlet of Rosedale had been withdrawing river water for domestic uses at a location less than 10 km below Drumheller's wastewater outfall. The water supply for the hamlet has changed in recent years; it now receives water from the City of Drumheller water treatment plant. The reasons for disinfecting the effluent may no longer be relevant. Further justification to discontinue the use of chlorine came from the Federal Government which recently declared that chlorinated wastewater effluents are a toxic substance under the Canadian Environmental Protection Act.

The operating approvals for the wastewater treatment plants of the City of Drumheller and the hamlets of Rosedale and East Coulee came up for renewal in 1997. Water Sciences Branch was asked by Environmental Sciences Division (ESD, AEP) in July 1996 to advise on the effects of discontinuing the chlorination of these wastewater effluents. One concern is the possibility of a further increase in fecal coliform counts and non-compliance at the Alberta-Saskatchewan border.

2.0 METHODS

Since 1996, six longitudinal surveys and five monthly effluent surveys have been conducted in the Red Deer River. All, except one longitudinal survey, were carried out during the summer months because non-compliance had been recorded most often at that time and because it would then presumably be easier to identify sources.

Longitudinal Surveys of July 10 to 19 and August 21 to 30, 1996

These surveys were an initial attempt to identify potential fecal coliform sources which influence compliance with PPWBO at the border site. Surveys involved sample collection from the outfall of six sewage treatment plants, nine major tributaries (including five irrigation return flows) and three-point transects on the Red Deer River at 10 locations between Red Deer City and Bindloss (see Figures 1 and 5 for site location).

Bacterial samples from the Red Deer River were also collected upstream and downstream of cattle watering sites and from a sandbar where a flock of about 80 Canada geese were resting.

Test Surveys (Drumheller effluent not chlorinated) of July 23 to 24, 1996 and February 5 to 13, 1997

Tests surveys were conducted to define the longitudinal extent of the impact zone of Drumheller municipal wastewater effluent that is not treated with chlorine. Prior to and during these surveys, the chlorine addition to the Drumheller wastewater was interrupted, as outlined below.

July 23 – 24, 1996		
Survey	Start: July 23	End: July 24
Chlorination	Stop: July 19	On again: July 25
February 5 – 13, 1997		
Survey	Start: February 2	End: February 14
Chlorination	Stop: January 28	On again: February 12

The July survey provides an indication of bacterial quality under "high flow – warm temperature" conditions, whereas the February survey depicts bacterial quality during "low flow - low temperature" conditions. These surveys focussed on the reach between Drumheller and Bindloss and involved the sampling of four wastewater discharges, five major tributaries, including four irrigation return flows, and three-point transects on the Red Deer River at eight locations. Tributaries and irrigation return flows were not sampled in February. Refer to Figures 2 and 7 for site location.

Longitudinal Surveys of July 20 to 23 and August 18 to 21, 1998

The influence of sources upstream of Drumheller on bacterial counts in the Red Deer River at Bindloss had been ruled out in the 1996 surveys. Surveys carried out in 1998 focussed on the lower Red Deer River (Drumheller to Bindloss). They involved sample collections from four sewage treatment plants, nine tributaries (including five irrigation return flows) and three-point transects at six locations on the Red Deer River. (Refer to Figures 10 and 12 for site location).

An important difference between the surveys conducted in 1996 and 1998 was that municipal effluents from Drumheller, Rosedale and East Coulee were not treated with chlorine.

The decision to lift the chlorine treatment requirement from the license to operate for the Drumheller, East Coulee and Rosedale water treatment plants was made by Environmental Sciences Division after review of the test survey data with Water Sciences Branch staff.

Monthly Surveys of Sewage Discharges in 1998

These surveys started in July 1998 and are ongoing. Test surveys conducted in 1996 and 1997 had indicated that discharges from Drumheller should not influence bacterial quality of the Red Deer River more than 70 km below the effluent discharge point. The purpose of the monthly surveys was to confirm this for a broader range of river and effluent conditions. Refer to Figure 16 for site location.

All longitudinal surveys were conducted at a speed which approximated time of travel in the Red Deer River as defined by the Hydrology Section, Water Sciences Branch (WSB, AEP).

Samples were analyzed for fecal coliforms and *E. coli* and triplicate splits and blank samples were taken in each survey. In February, 1997 the Drumheller effluent was sampled on successive days to obtain an indication of day-to-day variability in bacterial counts. Bacterial samples were processed at the Provincial Laboratory of Public Health in Edmonton.

At sites where Water Survey of Canada did not record stream flow, flow was gauged by the Monitoring Branch (AEP) or calculated by the Hydrology Section (WSB). The operator of each wastewater treatment plant provided effluent discharge rates for the day(s) of sampling.

Fecal coliform and *E. coli* counts were compared with Prairie Provinces Water Board Objectives (PPWBO) or with Canadian Water Quality Guidelines (CCME 1997) for recreation (CWQG-REC) or for irrigation (CWQG-IRR).

Fecal Coliforms	**Guideline**	**Comments**
PPWBO = CWQG-IRR	100/100 mL	
CWQG-REC	400/100 mL	i.e., 're-sample' criterion
E. coli **(no PPWBO)**	**Guideline**	**Comments**
CWQG-REC	400/100 mL	i.e., 're-sample' criterion

3.0 RESULTS

3.1 POINT SOURCES

3.1.1 Municipal Effluents

With an average discharge of 0.342 m^3/s, Red Deer City is the largest municipal discharge to the Red Deer River; Blackfalds and Drumheller discharge about 1/10th of that volume (Table 1 and part (a) of all figures). Rosedale, East Coulee and Dinosaur Provincial Park have an average discharge of less than 0.001 m^3/s. The volume of effluent discharged by each municipality varied relatively little among surveys.

Municipal discharges consistently had high (1 to 4 orders of magnitude higher than the water quality guidelines) fecal coliform and *E. coli* counts which exhibited a high degree of temporal variability. Counts for the East Coulee and Rosedale discharges in 1996 were high, indicating that the chlorine treatment of the effluent was not applied efficiently.

In two instances, reported changes in the operation of the water treatment plant account for the observed variability. Bacterial counts in the disinfected wastewater effluent from Drumheller were generally at or below the detection level. When chlorine treatment was interrupted during the test surveys of July 1996 and February 1997, fecal coliform counts ranged from 7,600 (July) to 37,000 (February) per 100 mL. In 1998, a major upgrading of the lagoon system necessitated the use of temporary lagoons. During that period, bacterial quality of the effluent was highly variable, and perhaps atypical of the normal plant operation. Fecal coliform counts ranged from 9,000 to 2,000,000 per 100 mL. Fecal coliform counts in the effluent from the Dinosaur Provincial Park wastewater treatment plant were also variable and often high in 1996 (77,000 to 1,900,000 per 100 mL). Since 1998 the plant has not been treating 'bulk toilet' wastes which were overloading the treatment system. These wastes are now trucked away from the Park. Possibly as a result of this change, average fecal coliform counts recorded in 1998 are much lower than those recorded in 1997 (1997: 750,000 per 100 mL; 1998: 15,000 per 100 mL).

The City of Red Deer was the largest municipal point source of bacterial loading to the Red Deer River (Table 1 and part (b) of all figures). However, in 1998, the loading from the City of Drumheller was almost as high and apparently much more variable. On average, the treatment plant at Dinosaur Provincial Park contributes a larger load than the hamlets of East Coulee and Rosedale, respectively.

3.1.2 Irrigation Return Flows

On average, Matzihiwin Creek contributed the largest flow volume, followed by Rosebud River, Onetree, Sandhill and Threehills creeks (Table 1 and part (a) of all figures).

Although there was a high degree of temporal variability in the counts, most fecal coliform and *E. coli* samples collected from the irrigation return flows exceeded both PPWBO and CWQG-REC. Highest average bacterial counts were recorded in Onetree Creek, followed in descending order by counts in Threehills, Little Sandhill and Matzihiwin creeks; Rosebud River had the lowest average counts.

During the irrigation season, Onetree and Matzihiwin creeks contributed the largest average bacterial loads. Individually, these loads represented 25 to 50% of the load from the Drumheller wastewater treatment plant. Threehills Creek contributed the smallest load, about the equivalent of the load contributed by the hamlet of East Coulee or Rosedale.

3.1.3 Tributaries Which Do Not Convey Irrigation Return Flows

Kneehills, Bullpound, Berry and Blood Indian creeks had much lower flows than streams conveying irrigation return flows; Alkali Creek was dry throughout the surveys (Table 1, part 'a' of all Figures).

Generally, these streams had lower bacterial counts than irrigation return flows. However, counts in excess of PPWBO and CWQG-REC were recorded in Kneehills Creek and some samples from Berry and Blood Indian creeks exceeded PPWBO.

Associated with the lower flows and lower counts, the bacterial loading from tributaries was relatively low compared to that from municipal discharges and irrigation return flows.

3.1.4 Cattle and Bird Sites

Bacterial data collected upstream and downstream of cattle watering sites and geese resting areas are shown in Figure 9. Fecal coliform counts taken upstream and downstream of these sites were similar, but *E. coli* counts recorded downstream of the cattle site in July and downstream of the geese in August were slightly higher. Guidelines for irrigation and for recreation were met in all samples.

Although direct watering of cattle in the river and birds may contribute to non-compliance with irrigation guidelines at the PPWB long-term monitoring site, the data collected in this study do not prove this conclusively.

3.2 RED DEER RIVER

Flows in the Red Deer River at Drumheller ranged from 18 cms (February 1997) to 119 m^3s^{-1} (July 1998). Bacterial counts exhibited much variability from site to site and also among surveys.

3.2.1 July 10 to 19, 1996 Survey (Drumheller Effluent Treated With Chlorine)

One sample taken upstream of Red Deer City had fecal coliform counts which exceeded PPWBO (Figures 1 and 2).

High counts of fecal coliforms and *E. coli* were recorded at the three transect points at Joffre; they result from the loading from Red Deer City's and Blackfalds' wastewater discharges. At this transect, counts did not comply with PPWBO or with CWQG-REC. All samples taken at and between the Nevis and Finnegan transects had bacterial counts which complied with these guidelines. The low bacterial counts at Nevis indicate that effects of municipal discharges from Red Deer and Blackfalds do not persist this far downstream. The very gradual increase in counts and bacterial stream load below the Morrin transect is indicative of the influence of irrigation return flows and sewage treatment plant discharges (Rosedale and East Coulee).

All samples from the transect located upstream of Dinosaur Provincial Park and from transects further downstream had fecal coliform counts which did not comply with PPWBO, and several samples had *E. coli* counts which did not comply with CWQG-REC. Matzihiwin Creek is the first identified point source of bacteria in this reach; additional contributions from Onetree and Sandhill creeks and Dinosaur Provincial Park further downstream could account for the persistence of elevated counts in the lower Red Deer River.

3.2.2 August 21 to 30, 1996 Survey (Drumheller Treated With Chlorine)

In August, two transects (u/s Red Deer and u/s Dinosaur Provincial Park) had samples which did not comply with PPWBO for fecal coliforms (Figures 5 and 6). Sources upstream of

Red Deer City have not been identified, but non-compliance upstream of Dinosaur Provincial Park could be due to contributions from Matzihiwin Creek.

3.2.3 Test Survey (Drumheller Not Treated With Chlorine)

July 23 to 24, 1996

Two fecal coliform samples (transect near the hamlet of Buffalo) did not comply with PPWBO (Figures 3 and 4). All other samples, including those taken downstream of the unchlorinated effluent from Drumheller, complied with guidelines.

February 5 to 13, 1997

Fecal coliform counts exceeded PPWBO in the right bank samples from the transects near Cambria and East Coulee and in all three samples from the transect near Finnegan (Figures 7 and 8). Wastewater discharges from Drumheller, East Coulee and Rosedale are the most likely causes of these incidences of non-compliance. All samples taken downstream of the transect at Finnegan complied with guidelines.

These test surveys suggested that cessation of chlorine treatment of the Drumheller, East Coulee and Rosedale effluents was unlikely to result in non-compliance with PPWBO at the long-term monitoring site near Bindloss. At high flows in July, non-compliance was not observed at transects 30 km below the effluent outfall. At low flows in February, non-compliance was encountered no further than 70 km below the outfall. This information was conveyed to Environmental Sciences Division. In conjunction with environmental concerns associated with chlorinated organic compounds, which can be formed when wastewater is treated with chlorine, the survey data formed the basis for the decision to lift the requirement for chlorine treatment of the municipal wastewater effluents. It was emphasized that results of two surveys could not account for, or adequately describe, instream bacterial conditions that would result from the full range of variability in effluent quality and quantity, combined with the full range of conditions in the river. Further monitoring of the wastewater effluents and the three-point transect at Finnegan was recommended.

3.2.4 July 20 to 23, 1998 Survey (Chlorine Treatment of Municipal Effluents Permanently Terminated)

One single sample collected at the centre point of the transect downstream of Dinosaur Provincial Park had a fecal coliform count which equaled the PPWBO (Figures 10 and 11). All other samples collected in the Red Deer River during this survey had counts well below the PPWBO, despite the contributions from wastewater discharges, irrigation return flows and tributaries. The results of this survey did not help narrow down sources leading to non-compliance at Bindloss.

3.2.5 August 18 to 21, 1998 Survey (Chlorine Treatment of Municipal Effluents Permanently Terminated)

Bacterial counts in the Red Deer River were much higher in this survey than in July: all samples exceeded PPWBO for fecal coliforms and several fecal coliform and *E. coli* counts exceeded CWQG-REC (Figures 12 and 13).

High bacterial counts along the transect upstream of Drumheller may be related to contributions from Threehills and Kneehills creeks, and to other sources further upstream and not accounted for in this sampling program. At the next transect (near Finnegan), fecal coliform and *E. coli* numbers had nearly doubled, likely because of contributions from wastewater discharges from Drumheller, East Coulee and Rosedale and irrigation return flows from the Rosebud River. An additional increase occurred at the next transect, downstream of Matzihiwin Creek. Numbers remained elevated at the transect downstream of Dinosaur Provincial Park and downstream from Onetree and Sandhill creeks and the wastewater discharge from the Provincial Park. Numbers declined rapidly below this transect: at the transect near the hamlet of Buffalo and at Bindloss; counts met CWQG-REC even though PPWBO were still exceeded. Coincidentally, no significant point sources have been located in the lower Alberta portion of the river.

Although the effects from individual point sources can not be evaluated separately, data from this survey suggest that all point sources monitored are potential direct or indirect contributors to non-compliance at the PPWB monitoring site.

3.2.6 Monthly Effluent Surveys (Municipal Effluents Not Chlorinated Any More)

Data obtained from effluent sampling and transect sampling at Finnegan are complemented by monthly data obtained by PPWB at Bindloss (Gary Dunn, pers. comm.). Refer to Figures 14 to 21.

July 3, 1998

Samples at Finnegan did not comply with the PPWBO or CWQG-REC. The PPWB sample collected at Bindloss on July 13 exceeded the guideline as well.

August 1998 (i.e., part of longitudinal survey)

Samples at Finnegan did not comply with PPWBO or CWQG-REC. AEP samples at Bindloss exceed PPWBO, but the PPWB sample collected a few days earlier (August 25, fecal coliform count: 25 per 100 mL) complied.

September 14, 1998

Samples at Finnegan are well under the PPWBO; PPWB sample of September 21 exceeds objective.

October 15, 1998

Samples taken at Finnegan exceed PPWBO and CWQG-REC; PPWB sample of October 19 meets objective.

November 4, 1998

Samples at Finnegan and the PPWB sample of November 16 meet PPWBO.

Bacterial counts recorded in these monthly surveys at the transect near Finnegan appear somewhat unpredictable: non-compliance at Finnegan is not necessarily linked to high bacterial loading from the wastewater discharges or flows and temperature in the Red Deer River. It is possible that relationships are obscured by the high temporal variability of bacterial levels in the wastewater effluent from Drumheller which would compound inaccuracies in travel time estimates .

It is apparent, however, that since chlorine use has been discontinued at the wastewater treatment facilities, bacterial counts at Finnegan have increased and compliance with guidelines has decreased noticeably. It is also apparent that the influence of wastewater discharges on bacterial quality of the Red Deer River extends further downstream than was originally estimated from test surveys, possibly because bacterial counts in the Drumheller effluent were much lower during the test surveys. However, there is no clear relationship between the level of compliance at Finnegan and at Bindloss.

4.0 LONG -TERM FECAL COLIFORM DATA AT BINDLOSS

Figure 22 represents PPWB fecal coliform data for the Red Deer River at Bindloss. The graph illustrates an apparent step-trend with relatively low numbers before 1980 and frequent occurrences of high numbers after 1980. To date, the specific cause of high counts recorded on occasion since 1980 is still unidentified.

When the period of record from 1980 to 1998 is considered, maximum annual records appear to follow a declining trend. Although a few samples were non-compliant, there were no very high records in 1996, 1997 and 1998 – the years during which we conducted longitudinal surveys. For the purpose of identifying sources, this is unfortunate, as high numbers might have made it easier to actually pinpoint key sources.

5.0 CONCLUSIONS

1. Sources of fecal coliform bacteria, which, in the past, may have induced non-compliance of fecal coliforms at the PPWB site, appear to be located between Matzihiwin Creek and the PPWB site. These include a number of identified point-sources such as several irrigation return flows, and wastewater discharges from Dinosaur Provincial Park and non-point sources which were not quantified in this study. The wastewater treatment plant at Dinosaur Provincial Park only started discharging in 1992 and cannot be the cause of incidences of non-compliance recorded in the 1980's. Each point and non-point source has the potential of being a cause for non-compliance, either individually or cumulatively.
2. Discontinuing the chlorine treatment of municipal discharges from Drumheller, East Coulee and Rosedale has resulted in an increase in fecal coliform and *E. coli* counts in the Red Deer River downstream of the discharge points. Based on test surveys, the influence of municipal discharges on bacterial quality of the Red Deer River were not expected to stretch further than 70 km downstream of the effluent. However, surveys carried out in 1998, indicate that the impact zone stretched further downstream than

expected, when Drumheller was upgrading its system and discharging effluent that may be of atypically variable in quality.

3. It is relevant to note that this study addresses the need to disinfect effluents to control fecal coliform contamination; other issues related to microbiological contaminants may come up in the future and may require a reassessment of the need to disinfect effluents.
4. High fecal coliform counts have occurred occasionally in the Red Deer River at Bindloss since 1980, the year with the highest count on record. Since 1980, maximum annual records appear to have declined. During the survey years (1996 to 1998), no really high fecal coliform counts were recorded at Bindloss and this may have reduced our ability at clearly identifying the specific source(s) of fecal coliforms causing non-compliance at Bindloss.
5. Longitudinal patterns in bacterial counts in the Red Deer River were highly variable from survey to survey and relationships with river flow or water temperature were not apparent.

6.0 FURTHER MONITORING REQUIREMENTS

It is recommended that monthly monitoring of municipal discharges in the Drumheller area continue in 1999 as well as transect monitoring of the Red Deer River at Finnegan and upstream of Dinosaur Provincial Park. This information is necessary to confirm the impact zone of Drumheller under normal and stabilized operating conditions. Coordination with the PPWB sampling program would be of special value, particularly if the sampling effort at the PPWB site could be increased so that there is sufficient data to evaluate cross-sectional and temporal variability in fecal coliform counts.

In addition to the monthly surveys, AEP will in 1999 investigate possible sources of high fecal coliform counts in Little Sandhill Creek which flows through Dinosaur Provincial Park.

7.0 LITERATURE CITED

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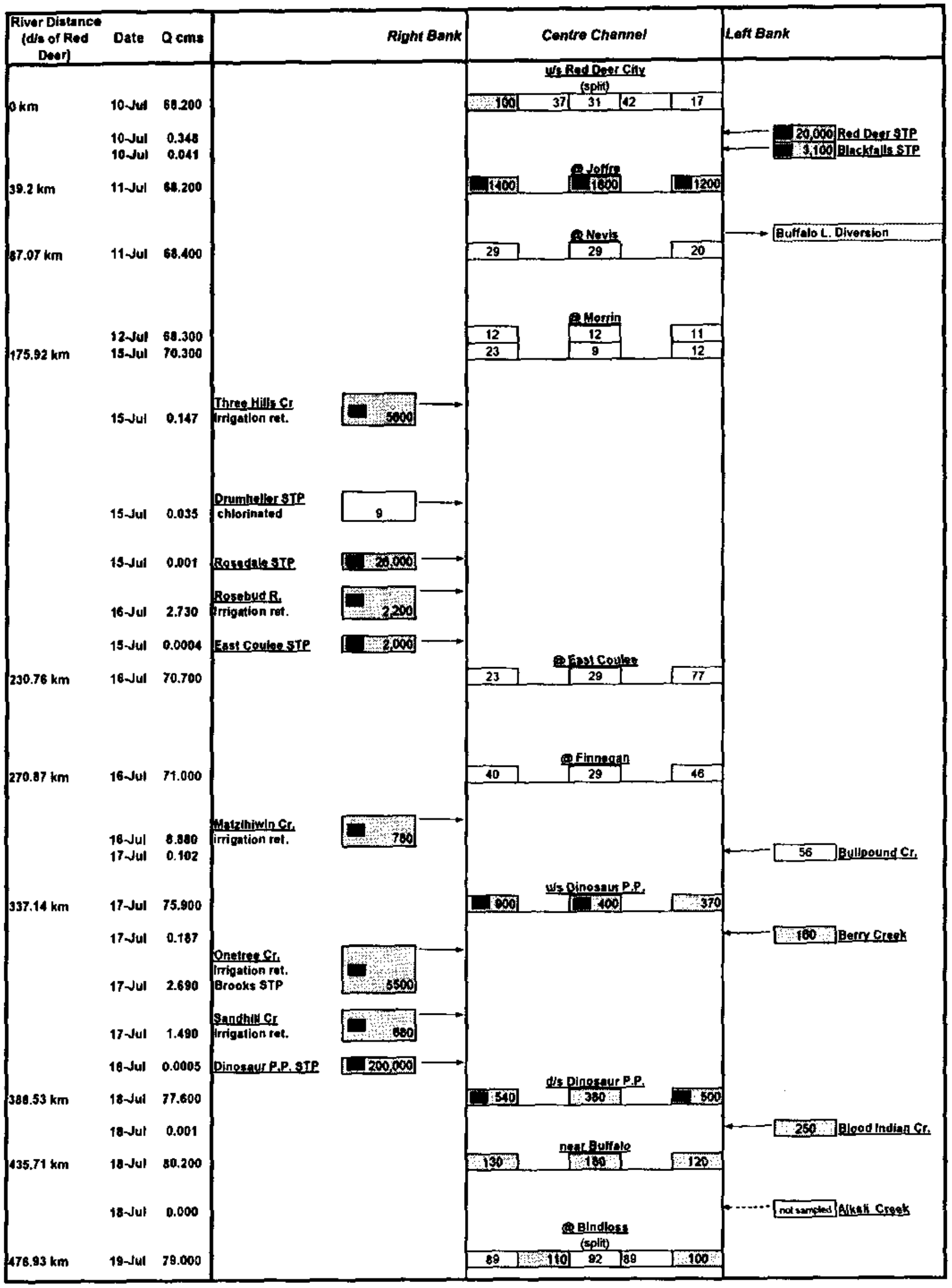
Table 1. Summary of discharge volume, bacterial counts and loads to the Red Deer River from point sources.

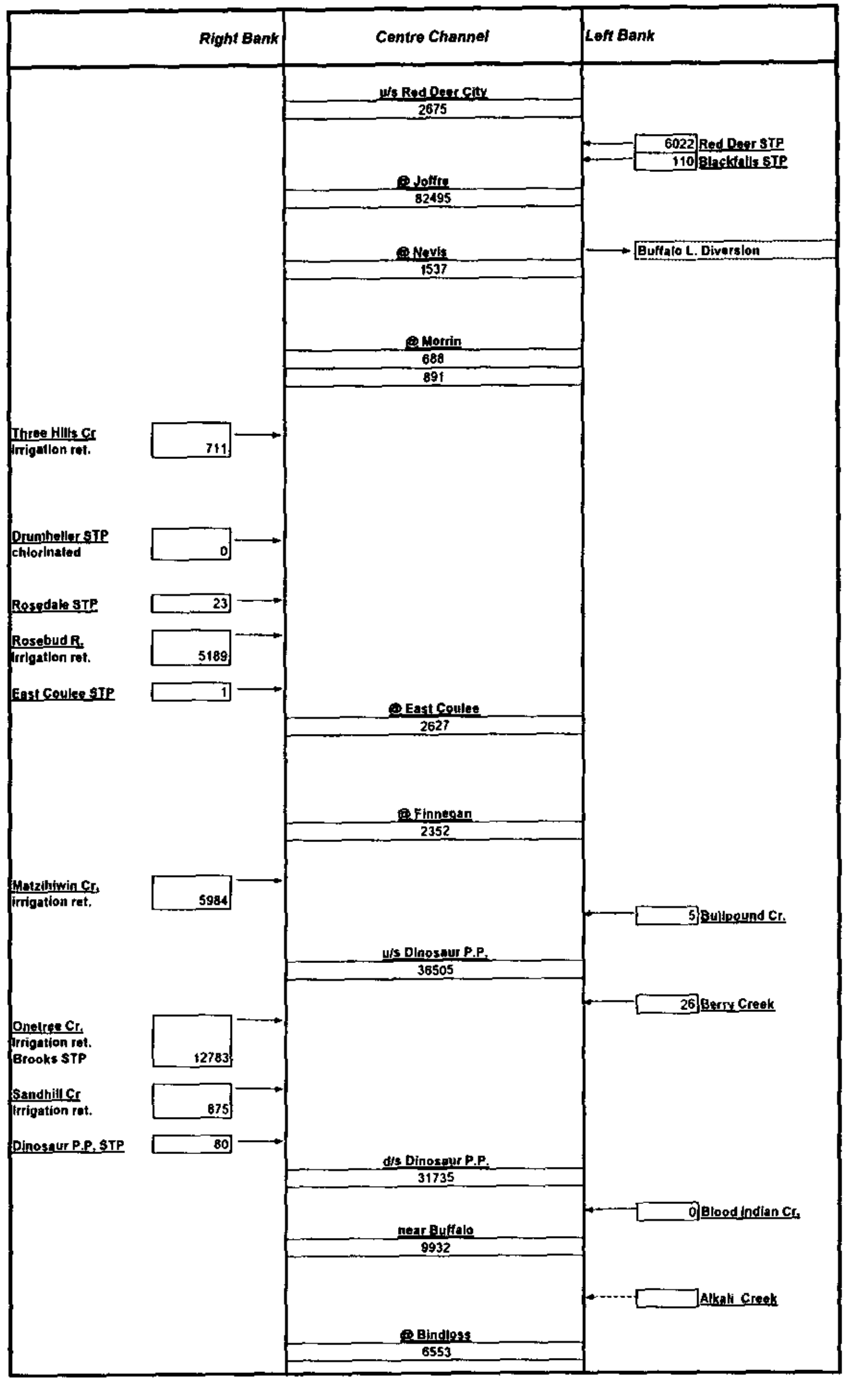
	No. Samples	Discharge (m^3/s)		Bacterial Counts: Fecal Coliforms (# per 100 mL)		Bacterial Counts: E. Coli (# per 100 mL)		Bacterial Loads: Fecal Coliforms (1,000,000,000 per day)		Bacterial Loads: E. Coli (1,000,000,000 per day)	
		Average	St. Dev.	Average	St. Dev.	Average	St. Dev.	Average	St. Dev.	Average	St. Dev.
Municipal Wastewater Discharges											
RED DEER CITY SEWAGE EFFLUENT	2	0.342	0.010	22,000	5,657	33,000	18,385	6,473	1,489	9,668	5,156
BLACKFALDS SEWAGE LAGOON EFFLUENT	2	0.022	0.027	105	64	190	170	3	4	6	8
DRUMHELLER SEWAGE EFFLUENT: overall	16	0.030	0.007	170,075	493,095	279,245	718,425	5,297	14,691	7,974	20,321
not chlorinated	14	0.029	0.007	194,371	524,846	319,136	762,778	4,931	14,691	9,113	21,570
ROSEDALE WASTEWATER FINAL EFFLUENT	10	0.0005	0.0004	196,649	360,642	282,320	513,197	59	99	83	144
EAST COULEE WASTEWATER FINAL EFFLUENT	6	0.0005	0.0000	98,333	148,848	108,167	144,124	45	73	50	71
DINOSAUR PROVINCIAL PARK WASTEWATER FINAL EFFLUENT	8	0.0008	0.0003	370,375	553,712	523,875	776,207	309	482	434	679
Irrigation Return Flows											
THREEHILLS CREEK NEAR MOUTH	4	0.226	0.318	749	866	761	860	88	114	95	128
ROSEBUD RIVER AT HIGHWAY 10	5	2.918	0.941	166	75	208	112	459	268	589	423
MATZIHIWIN CREEK NEAR MOUTH	5	6.308	1.641	303	205	345	290	1,868	1,879	2,194	2,530
ONETREE CREEK NEAR THE MOUTH	5	1.962	0.539	966	1,529	1,370	2,310	2,068	3,653	2,970	5,488
LITTLE SANDHILL CREEK NEAR THE MOUTH	5	1.184	0.190	442	122	778	694	459	171	798	690
Tributaries Not Conveying Irrigation Return Flows											
KNEEHILLS CREEK (sampled in 1998, only)	2	0.285	0.179	555	516	560	509	97	41	98	39
BLOOD INDIAN CREEK NEAR MOUTH	3	0.002	0.002	144	125	174	140	0	0	0	0
BULLPOUND CREEK NEAR MOUTH	2	0.052	0.071	58	3	60	6	3	3	3	3
BERRY CREEK NEAR MOUTH	4	0.241	0.170	119	83	151	112	30	31	44	55

Figure 1a. Fecal coliform counts (#/100 mL) in July 1996 (longitudinal survey).



PPWB OBJECTIVE: 100 (= CWQG irrigation guideline) compliant / non-compliant CWQG-recreation: 400 (resample criterion) non-compliant

Figure 1b. Fecal coliform loads (1,000,000,000/day).



Note: Criteria are normally applied only to surface waters; in this case they are applied to effluents for illustrative purposes.

Figure 2a. *E. coli* counts (#/100 mL) in July 1996 (longitudinal survey).

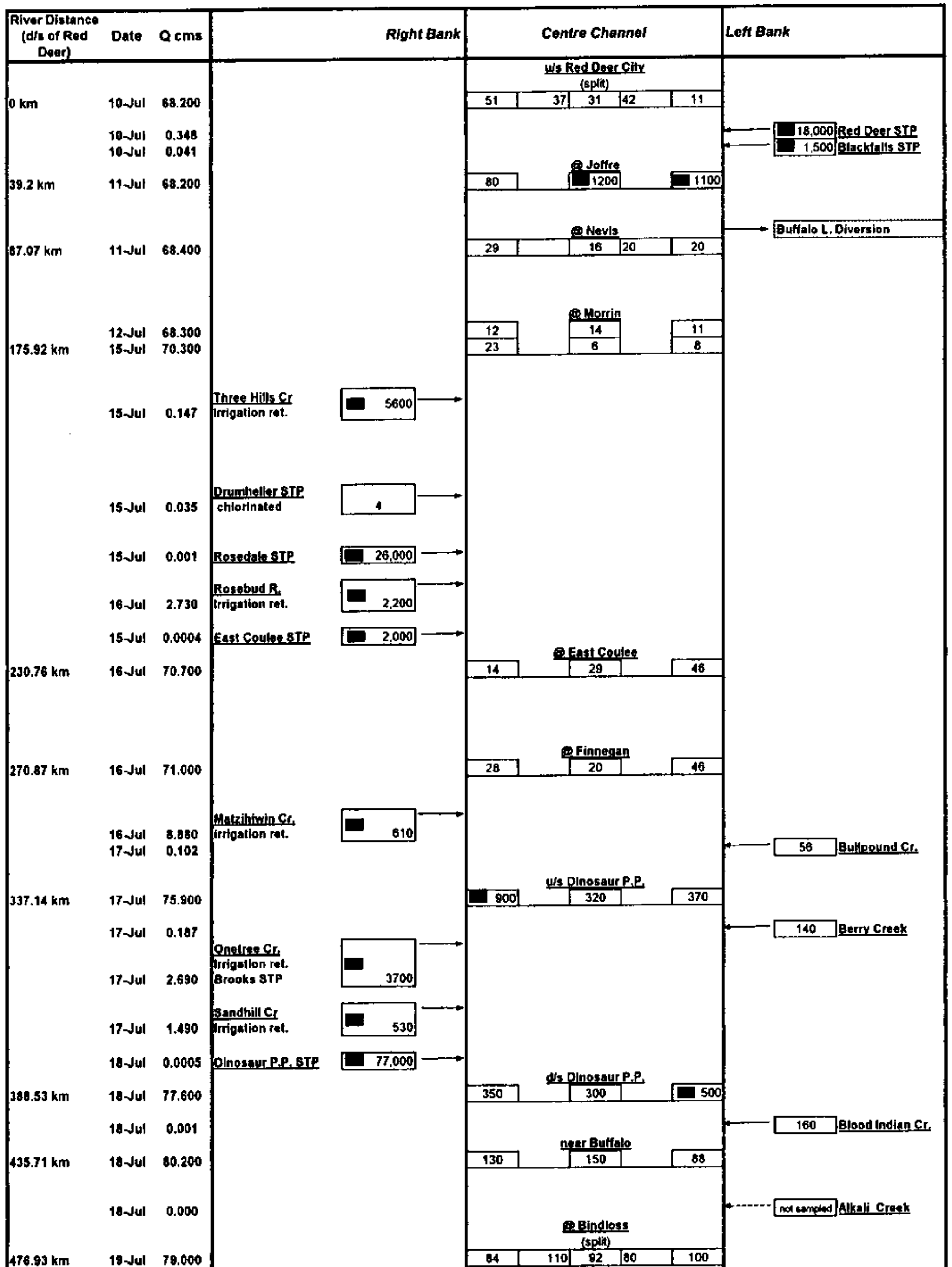
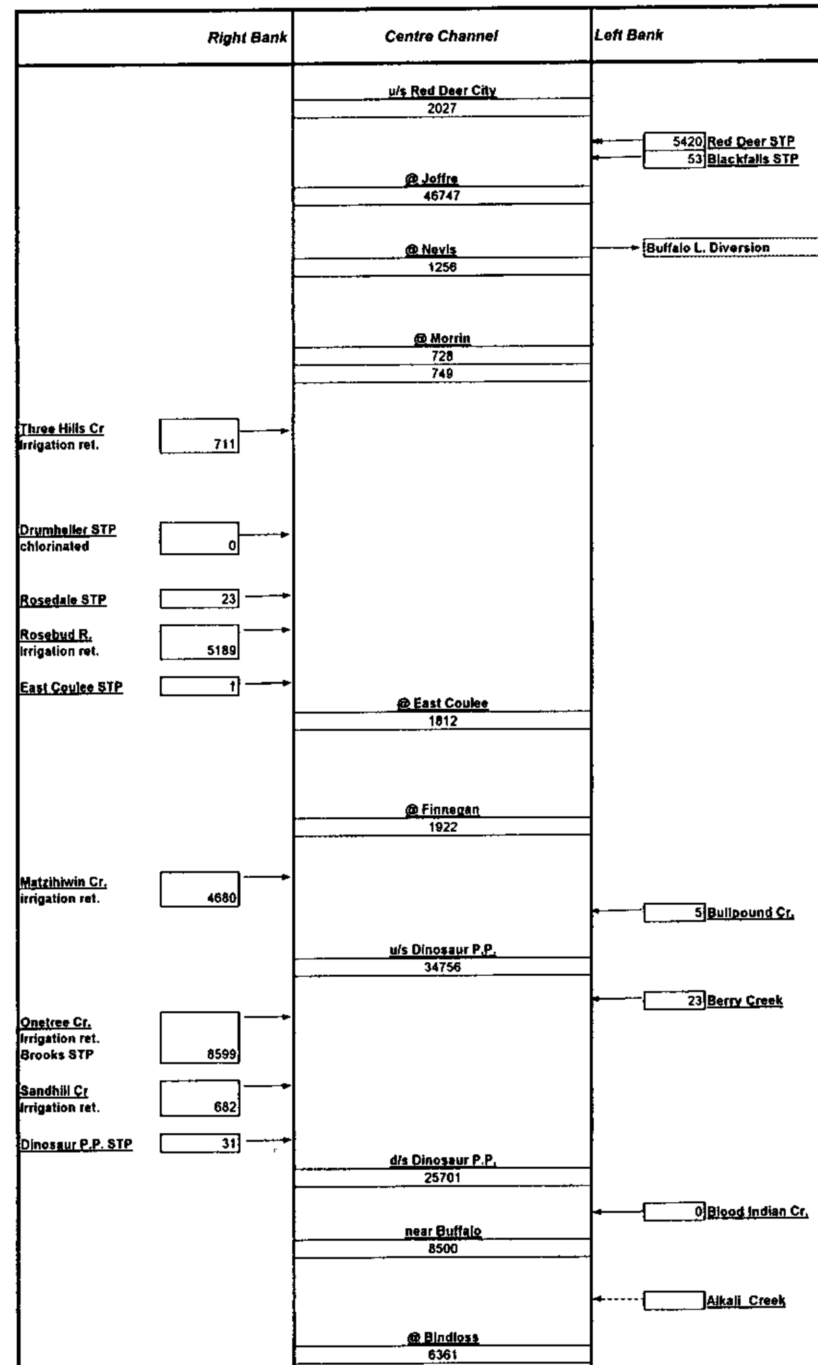


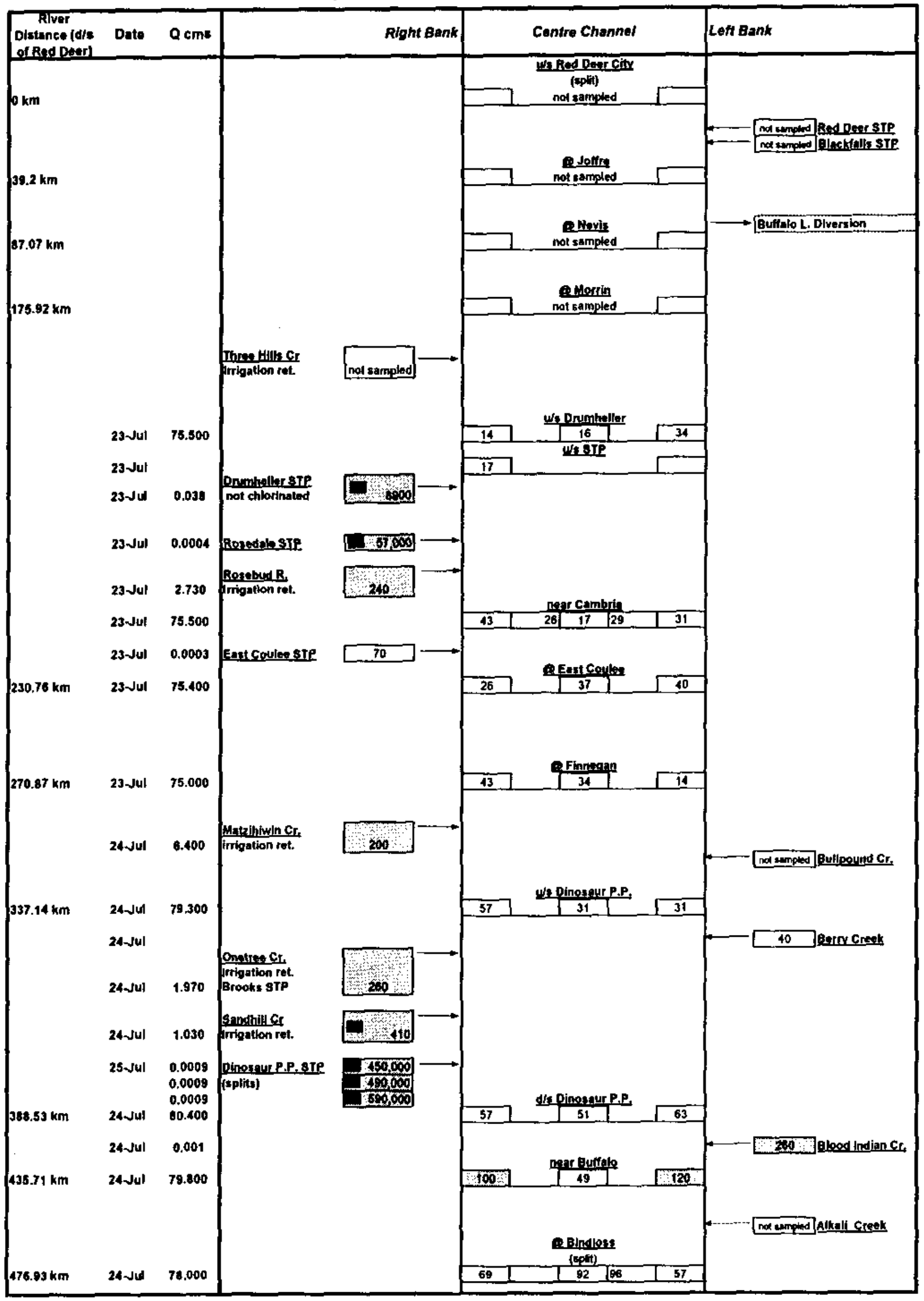
Figure 2b. *E.coli* loads (1,000,000,000/day).



CWQG-recreation: 400 (resample strategy) ■ non-compliant

Note: Criteria are normally applied only to surface waters; in this case they are applied to effluents for illustrative purposes.

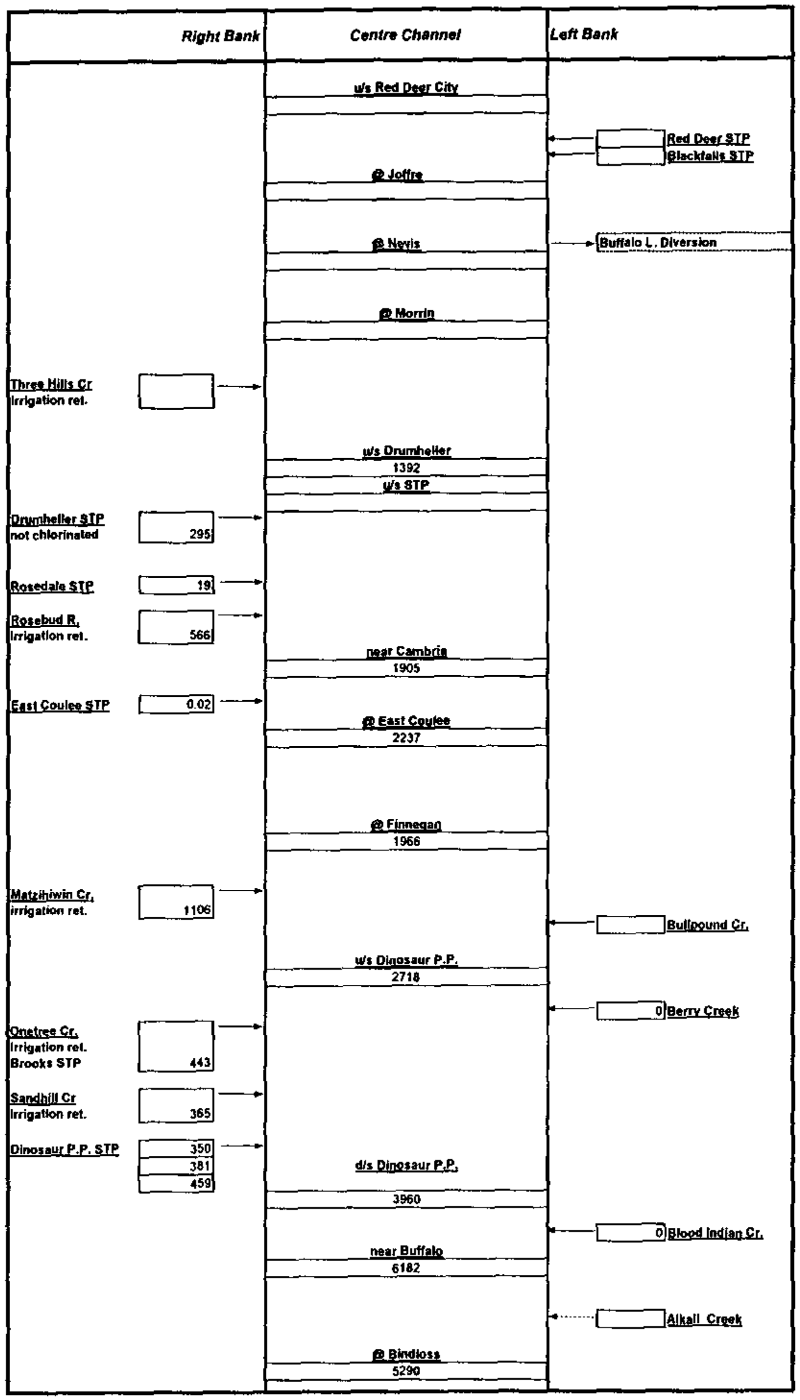
Figure 3a. Fecal coliform counts (#/100 mL) in July 1996 (test survey: Drumheller STP effluent not chlorinated).



PPWB OBJECTIVE: 100 (= CWQG irrigation guideline) — compliant / non-compliant

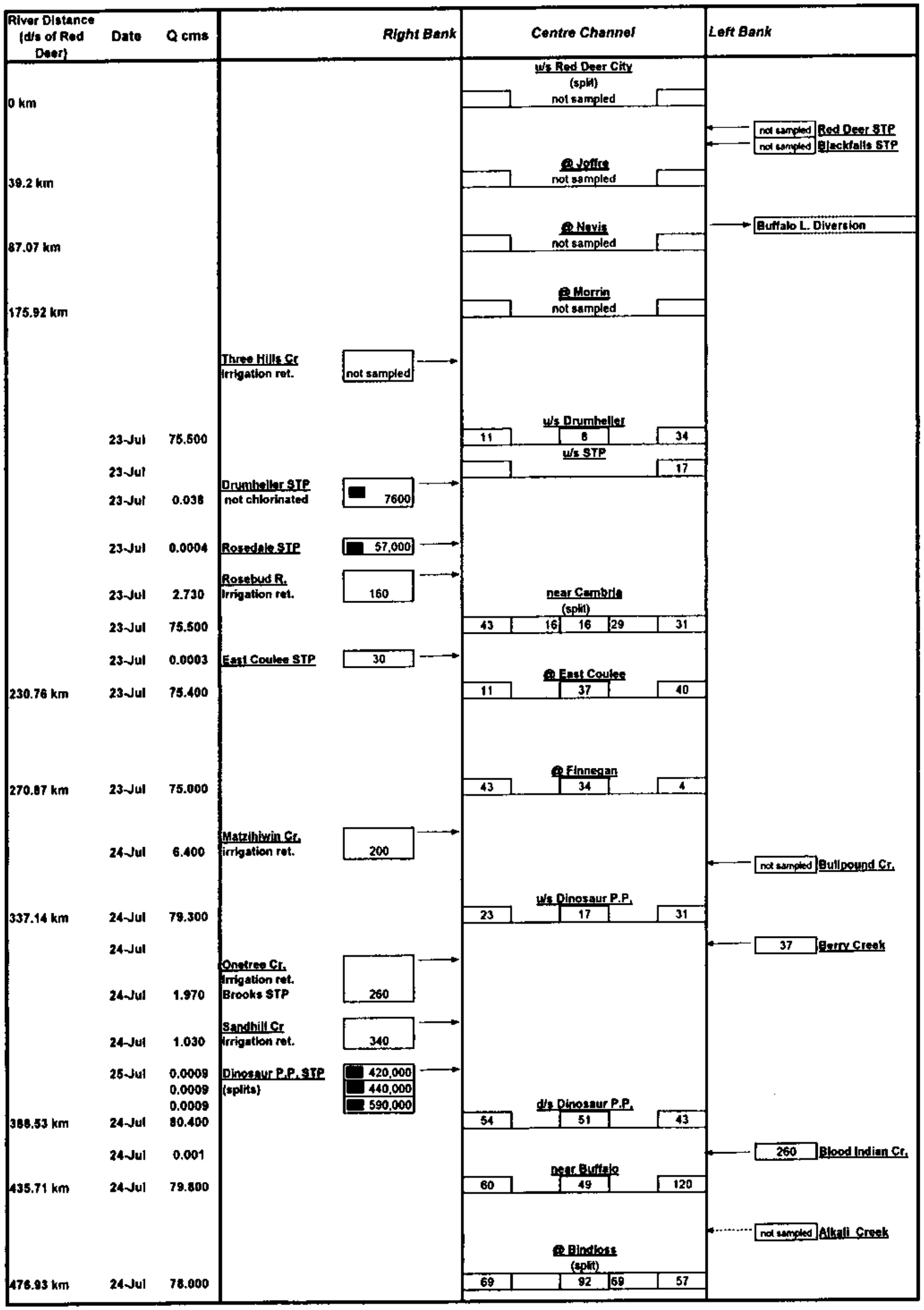
CWQG-recreation: 400 (resample criterion) ■ non-compliant

Figure 3b. Fecal coliform loads (1,000,000,000/day).



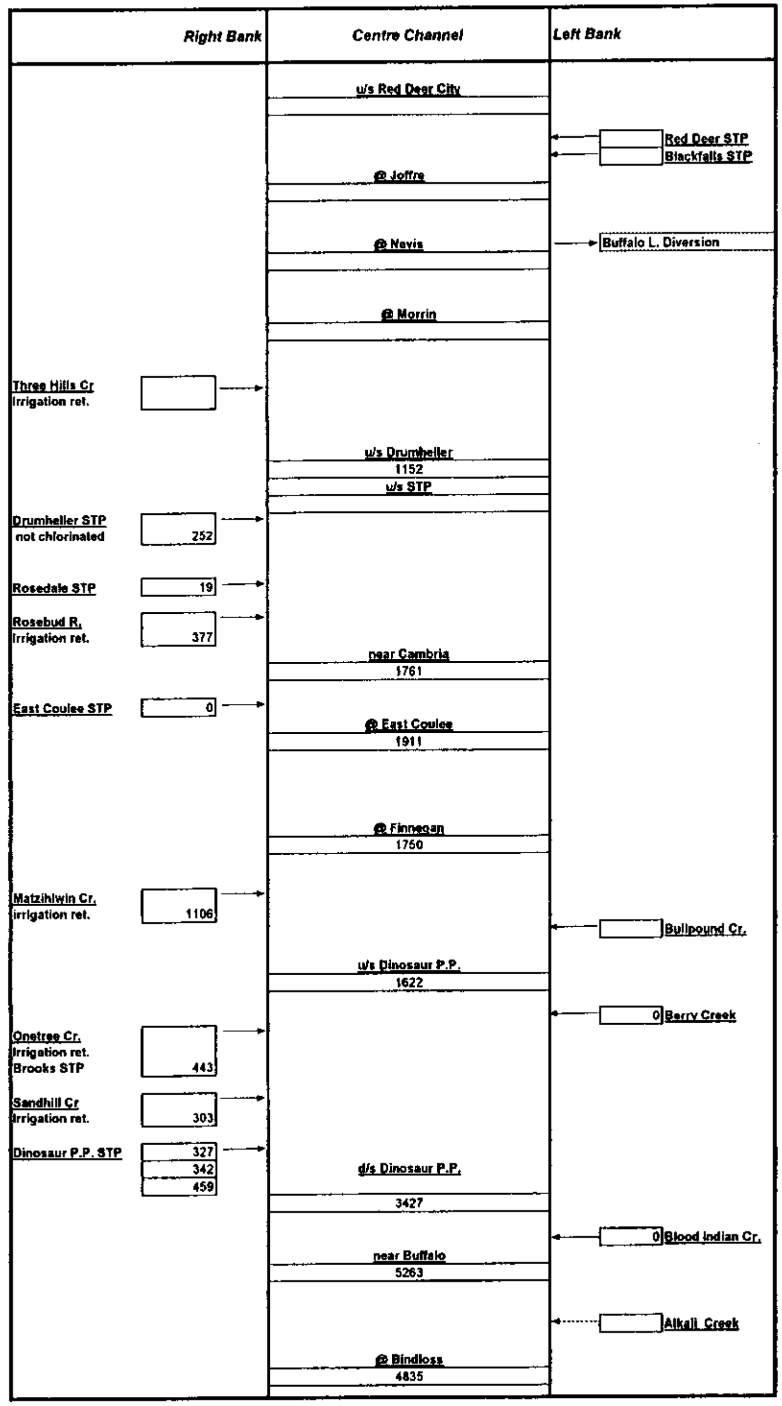
Note: Criteria are normally applied only to surface waters; in this case they are applied to effluents for illustrative purposes.

Figure 4a. *E. coli* counts (#/100 mL) in July 1996 (test survey: Drumheller STP effluent not chlorinated).



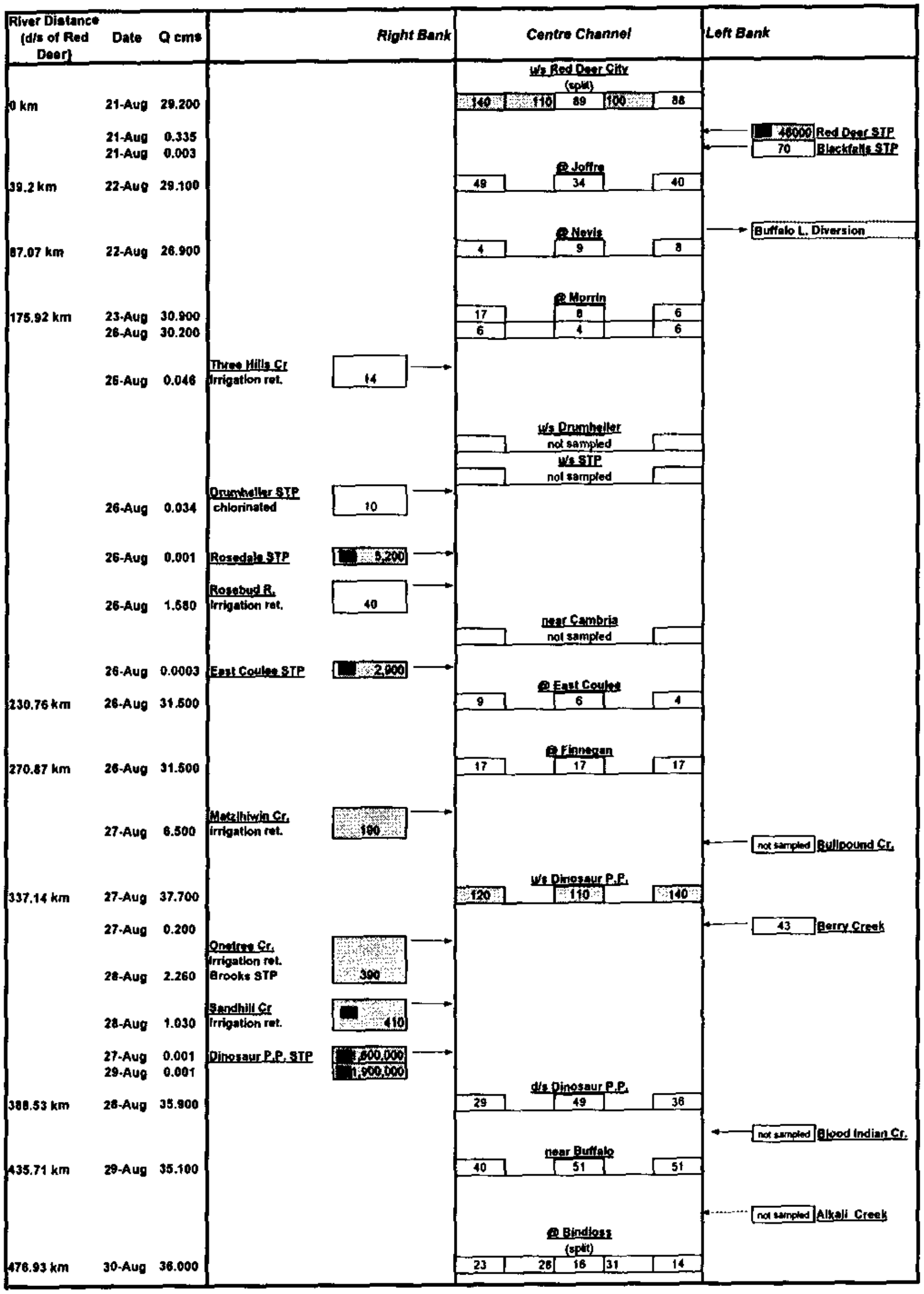
CWQG-recreation: 400 (resample strategy) ■ non-compliant

Figure 4b. *E. coli* loads (1,000,000,000/day).



Note: Criteria are normally applied only to surface waters; in this case they are applied to effluents for illustrative purposes.

Figure 5a. Fecal coliform counts (#/100 mL) in August 1996 (longitudinal survey).

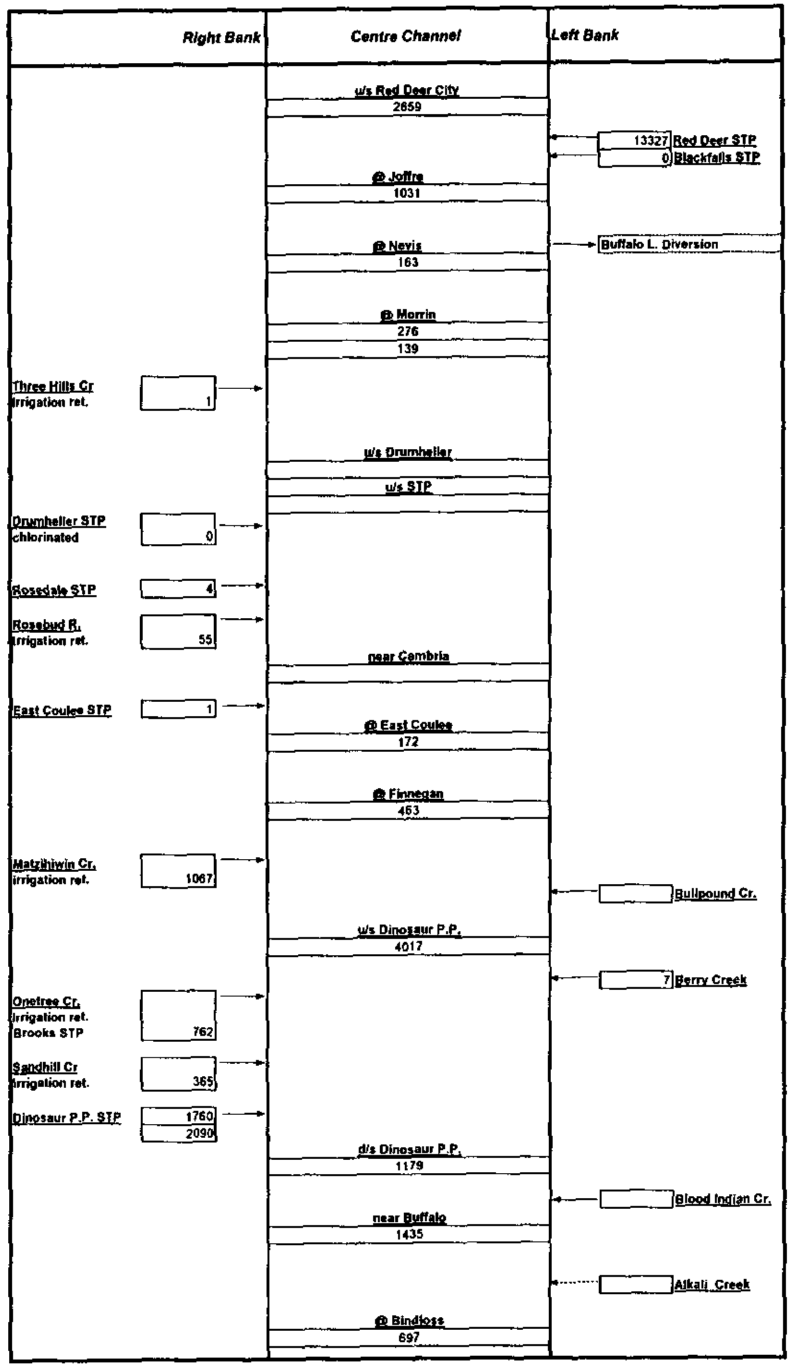


PPWB OBJECTIVE: 100 (= CWQG irrigation guideline) — compliant / non-compliant

CWQG-recreation: 400 (resample criterion) — non-compliant

Blanks: 8/21/96 = F.coli = <4
E.coli = <4

Figure 5b. Fecal coliform loads (1,000,000,000/day).



Note: Criteria are normally applied only to surface waters; in this case they are applied to effluents for illustrative purposes.

Figure 6a. *E. coli* counts (#/100 mL) in August 1996 (longitudinal survey).

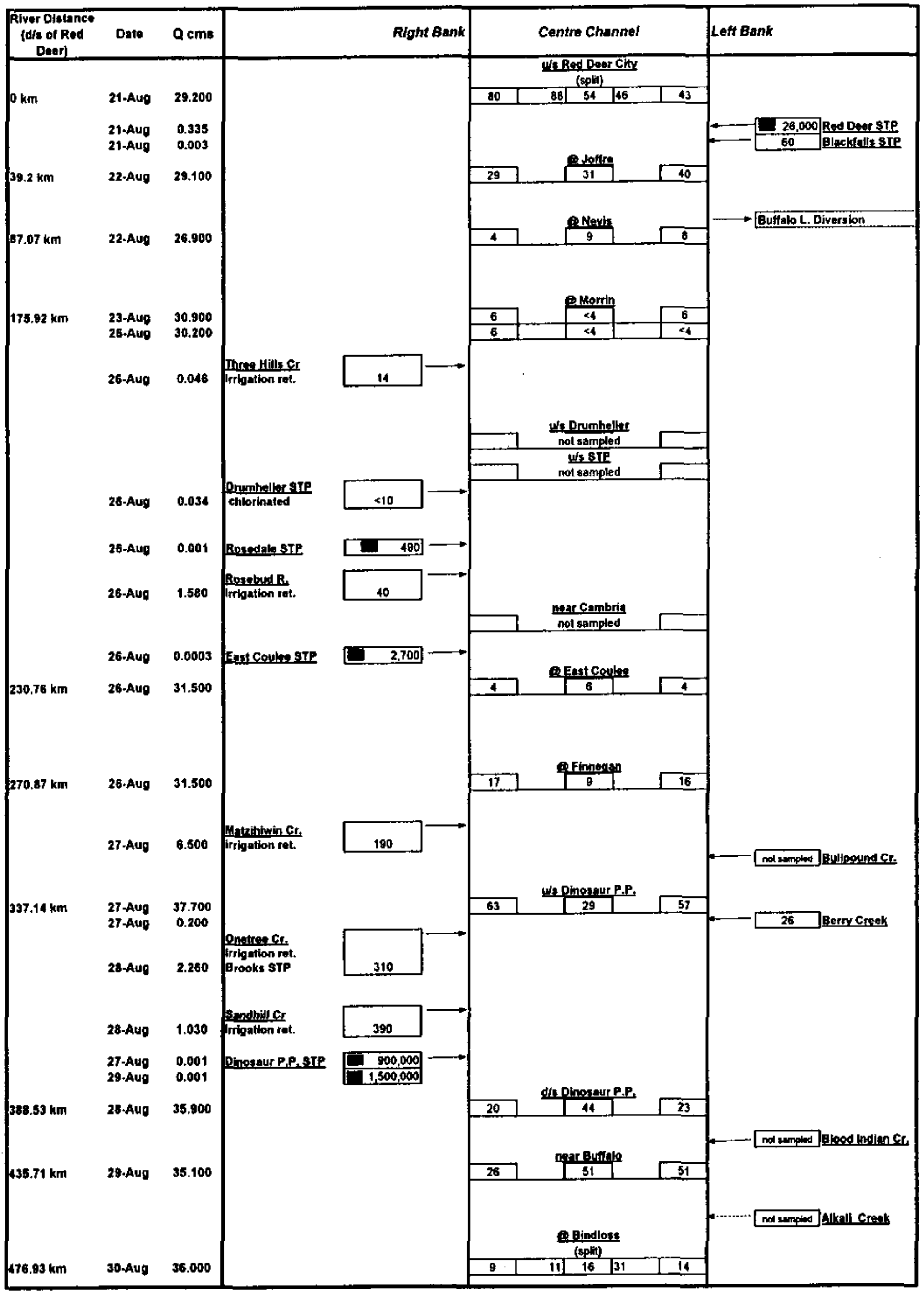
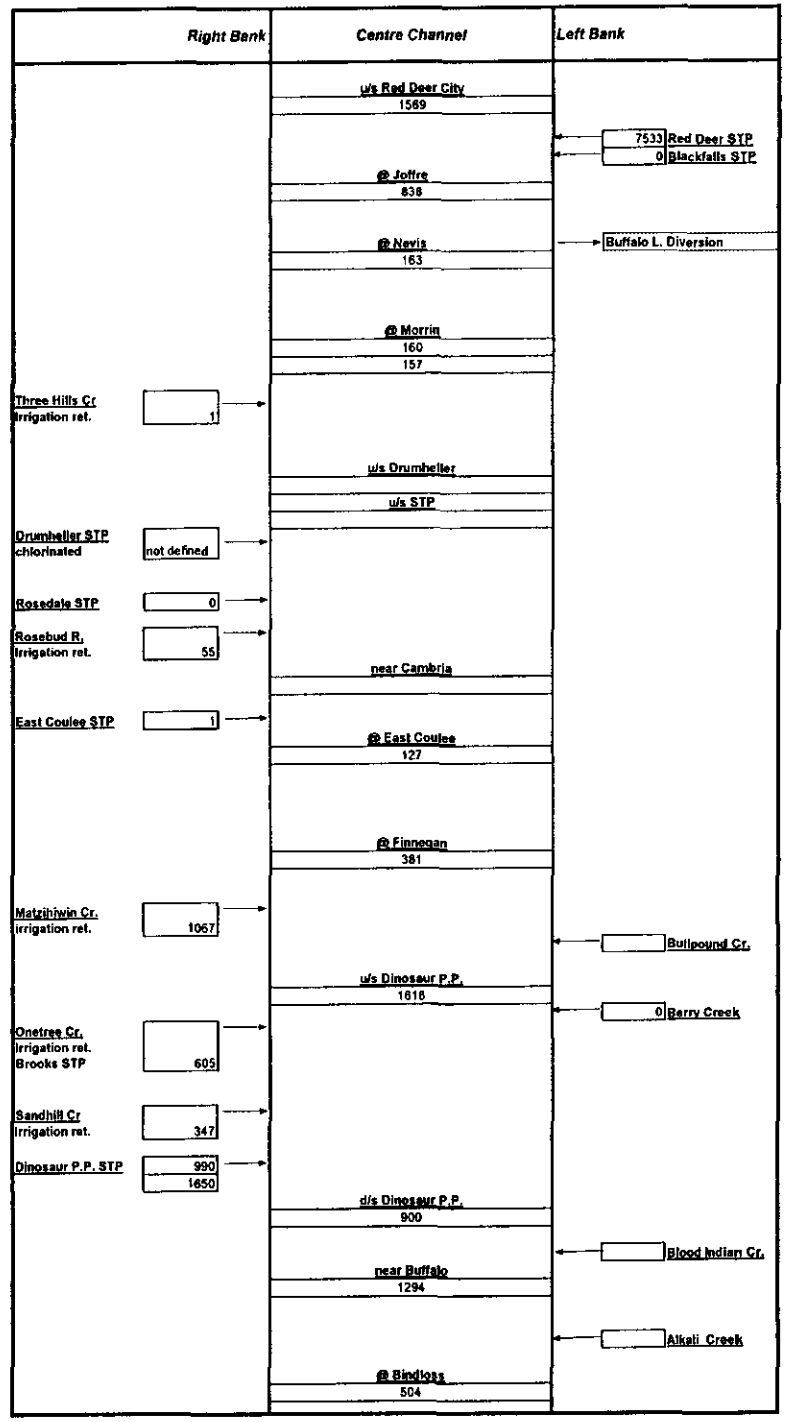


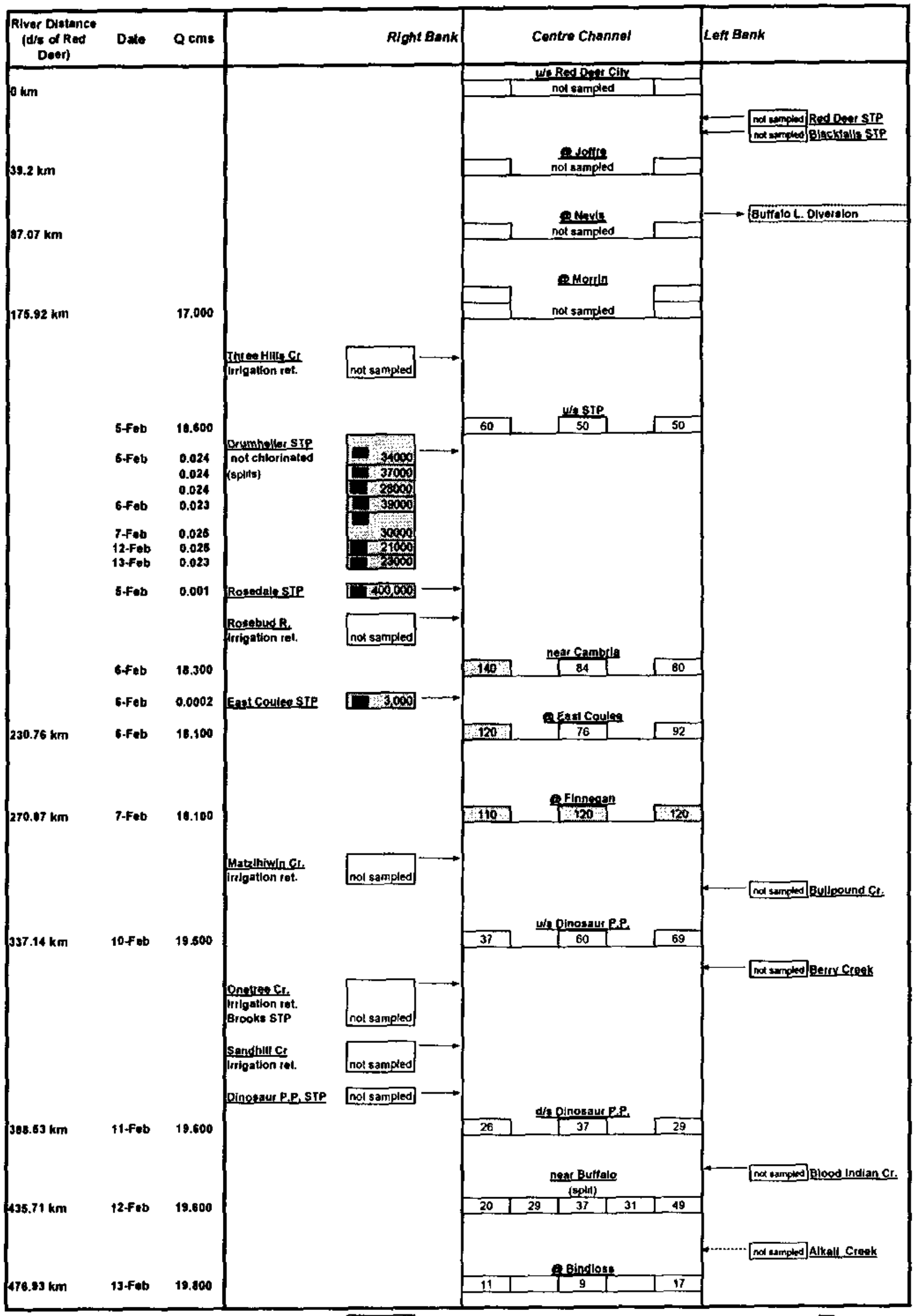
Figure 6b. *E. coli* loads (1,000,000,000/day).



CWQG-recreation: 400 (resample strategy) ■ non-compliant

Note: Criteria are normally applied only to surface waters; in this case they are applied to effluents for illustrative purposes.

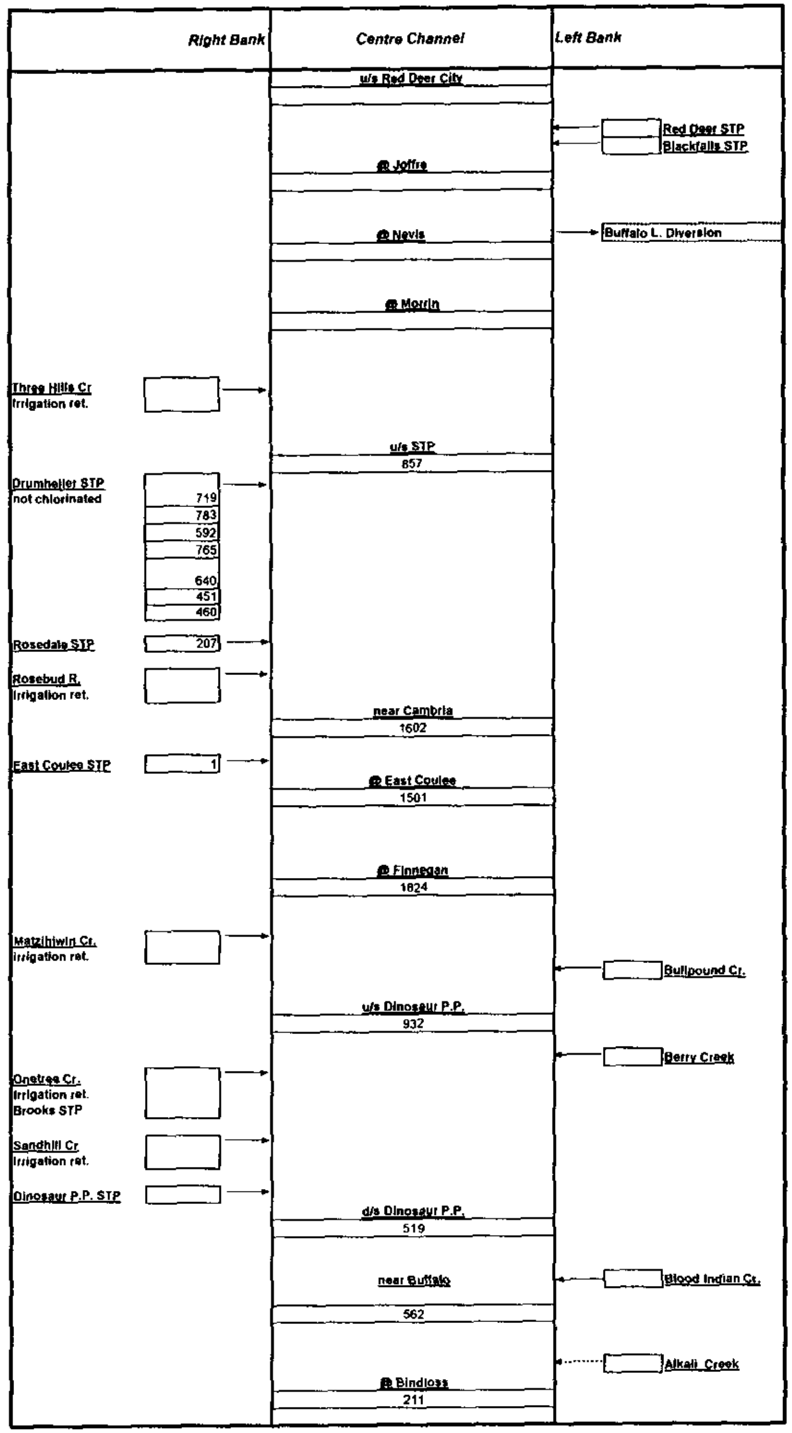
Figure 7a. Fecal coliform counts (#/100 mL) in February 1997 (test survey: Drumheller STP effluent not chlorinated).



PPWB OBJECTIVE: 100 (= CWQG irrigation guideline) — compliant / non-compliant

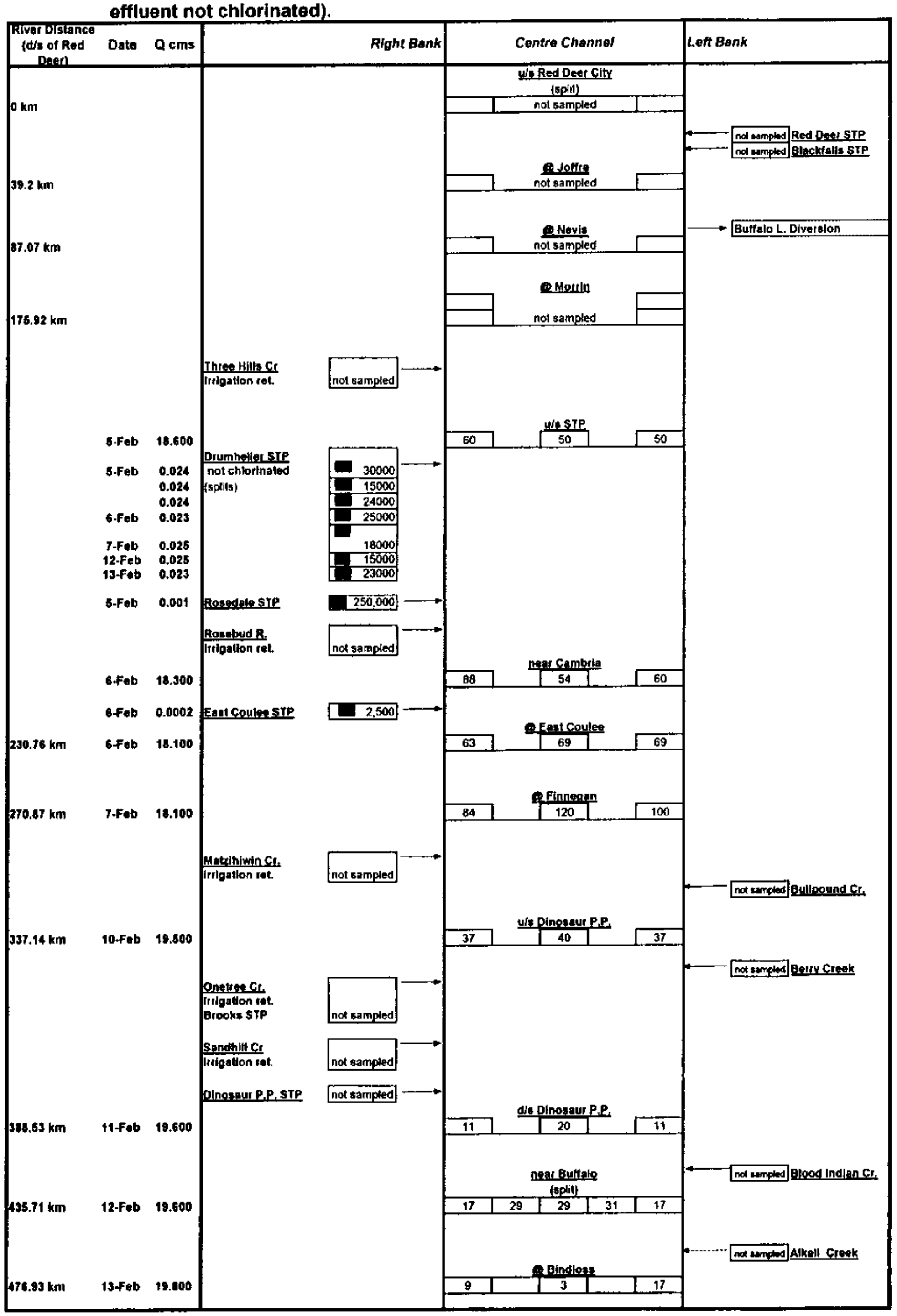
CWQG-recreation: 400 (resample criterion) — non-compliant

Figure 7b. Fecal coliform loads (1,000,000,000/day).



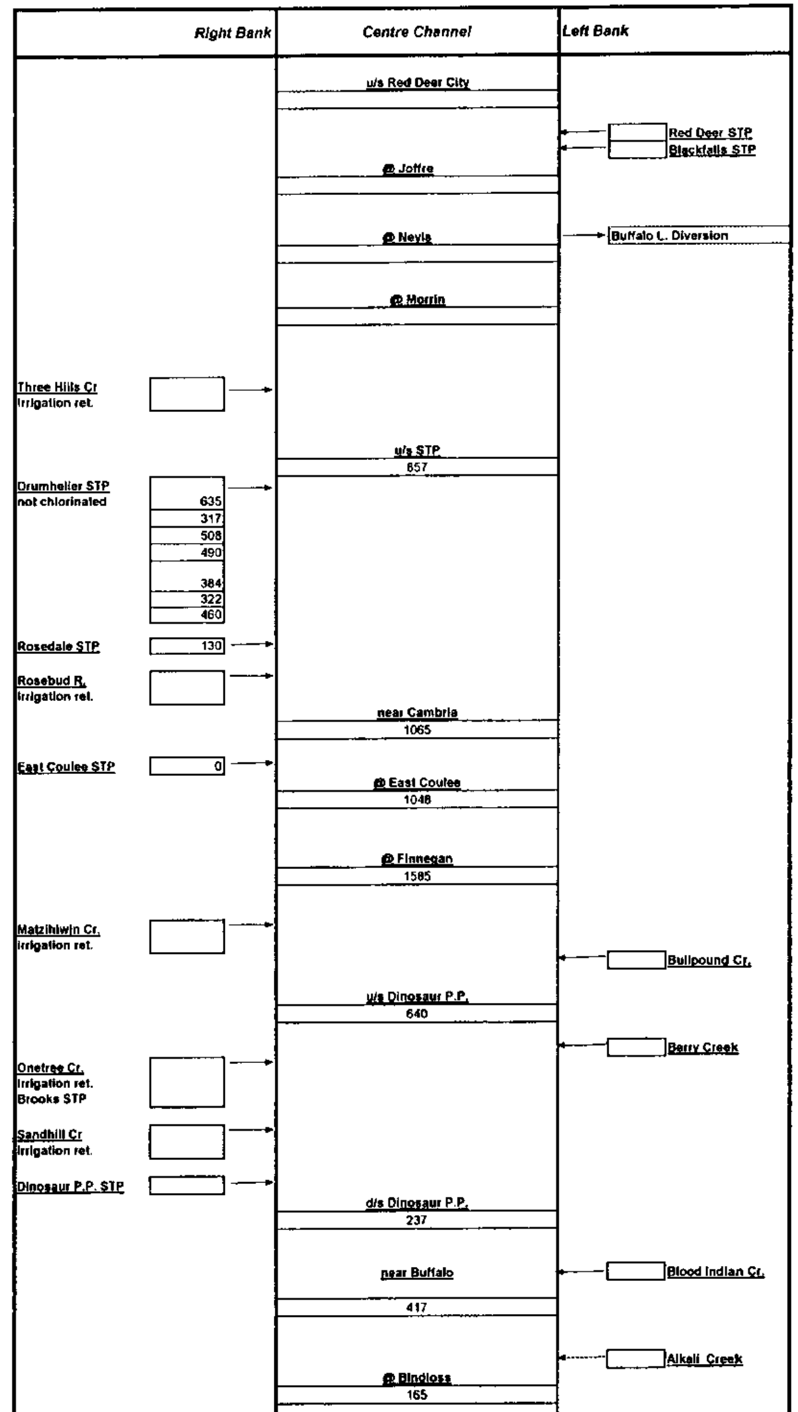
Note: Criteria are normally applied only to surface waters; in this case they are applied to effluents for illustrative purposes.

Figure 8a. *E. coli* counts (#/100 mL) in February 1997 (test survey: Drumheller STP effluent not chlorinated).



CWQG-recreation: 400 (resample strategy) ■ non-compliant

Figure 8b. *E. coli* loads (1,000,000,000/day).



Note: Criteria are normally applied only to surface waters: in this case they are applied to effluents for illustrative purposes.

Figure 9. Fecal coliform and E. coli counts upstream and downstream of cattle and birds.

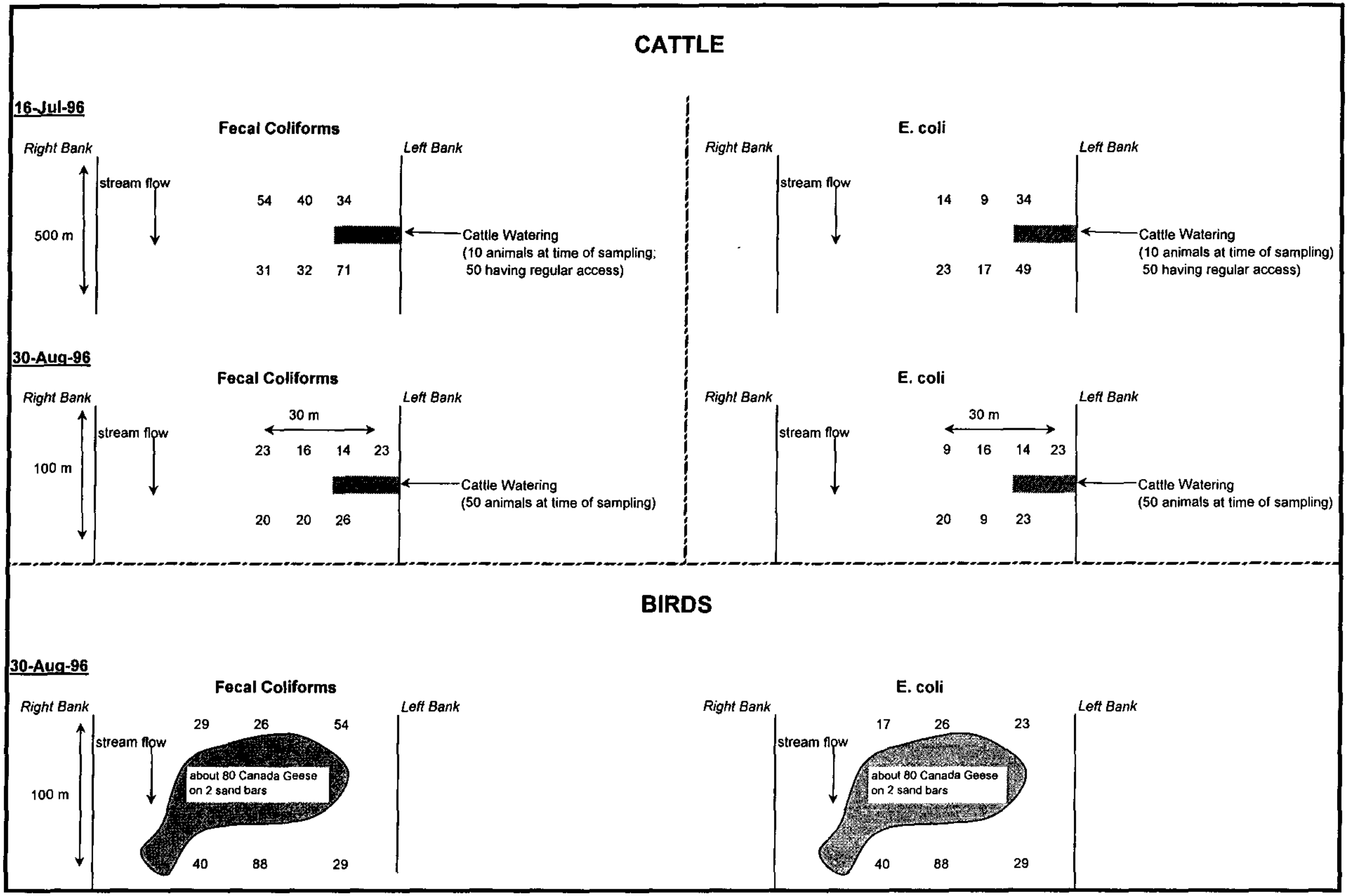
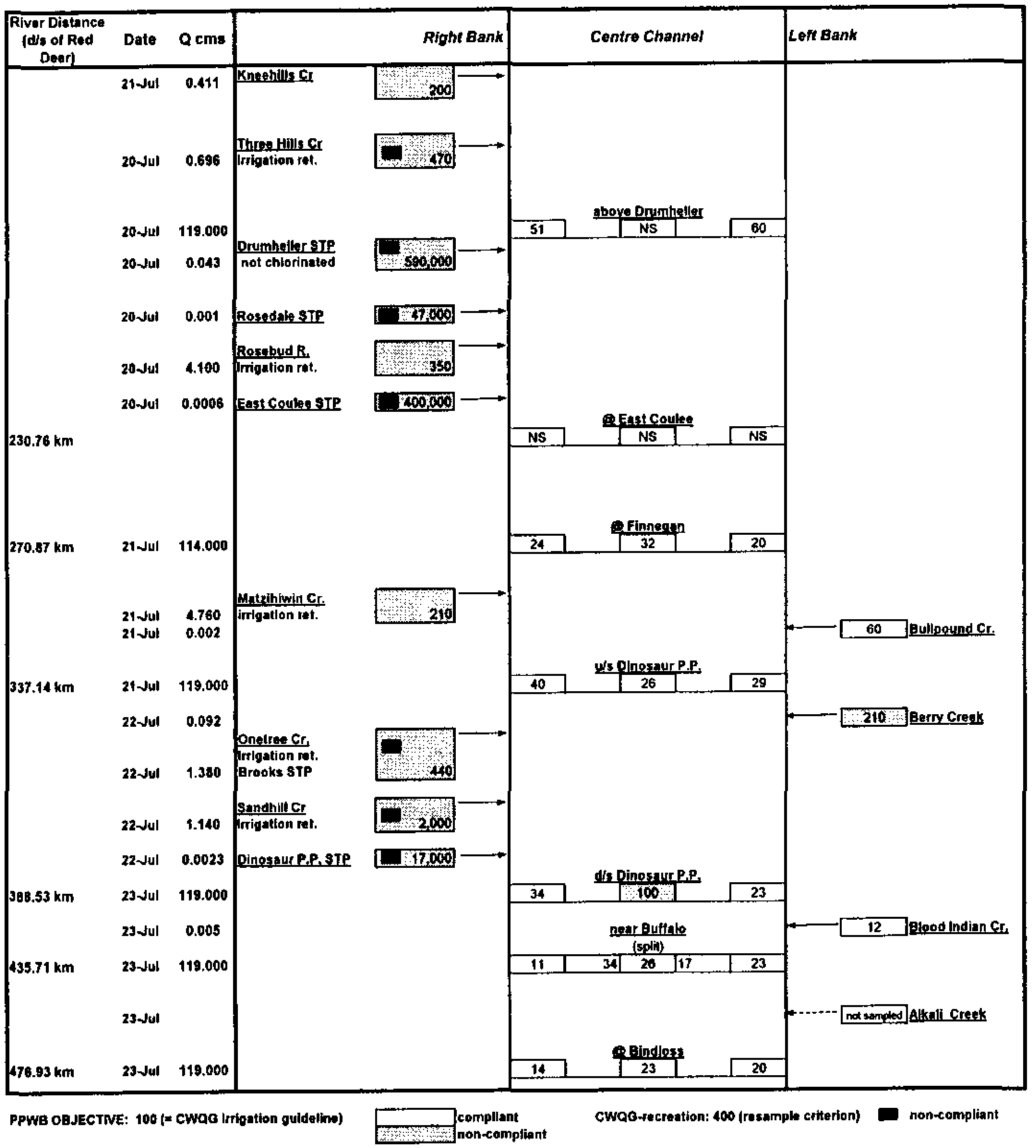


Figure 10a. Fecal coliform counts (#/100 mL) in July 1998 (longitudinal survey).



PPWB OBJECTIVE: 100 (= CWQG irrigation guideline) — compliant / non-compliant

CWQG-recreation: 400 (resample criterion) — non-compliant

Note: Criteria are normally applied only to surface waters; in this case they are applied to effluents for illustrative purposes.

Figure 10b. Fecal coliform loads (1,000,000,000/day).

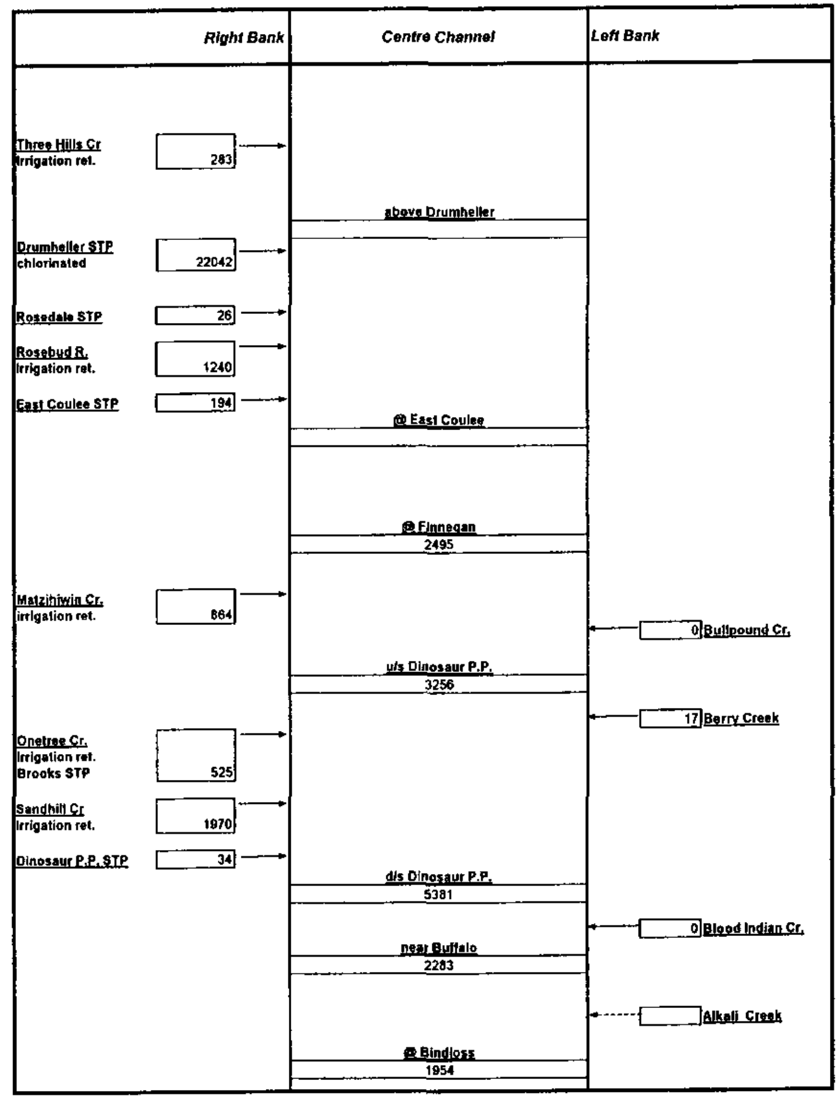
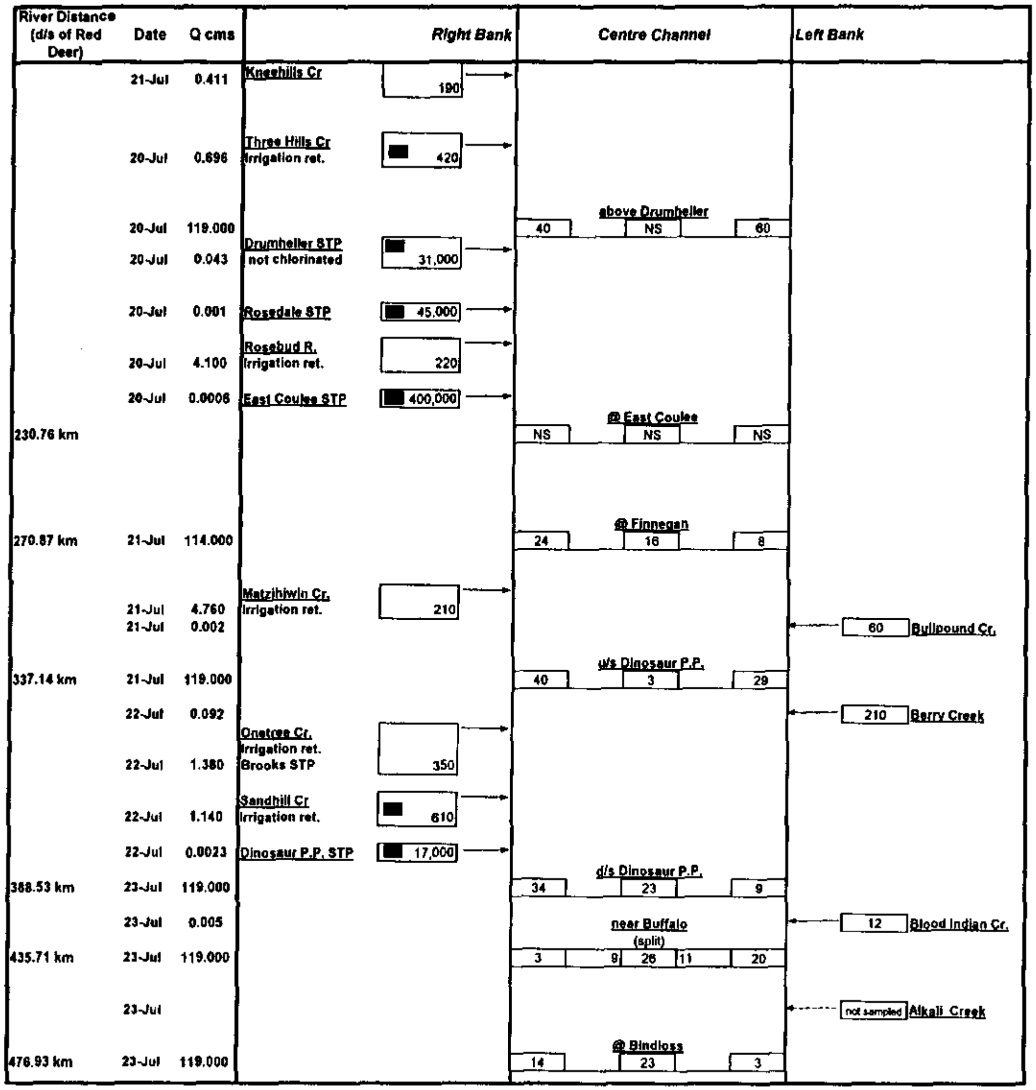


Figure 11a. *E. coli* counts (#/100 mL) in July 1998 (longitudinal survey).



CWQG-recreation: 400 (resample criterion) ■ non-compliant

Note: Criteria are normally applied only to surface waters; in this case they are applied to effluents for illustrative purposes.

Figure 11b. *E. coli* loads (1,000,000,000/day).

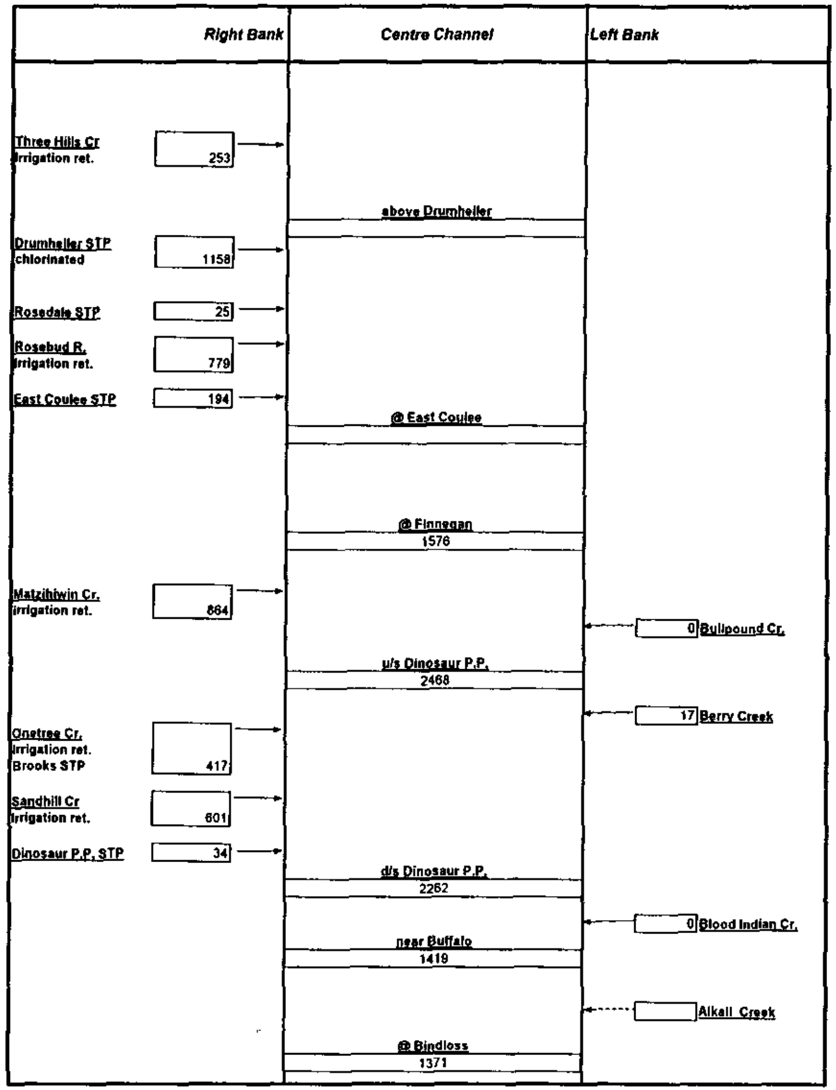
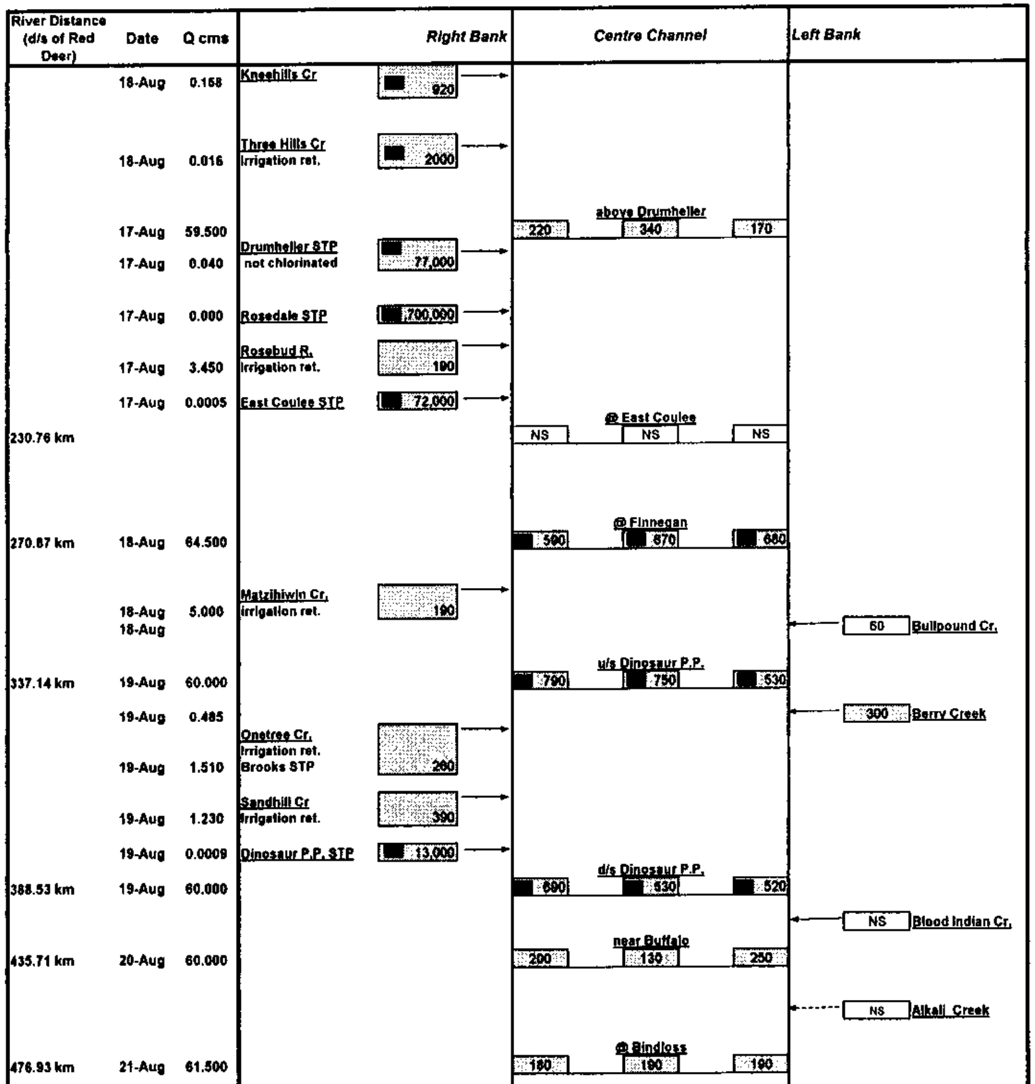


Figure 12a. Fecal coliform counts (#/100 mL) in August 1998 (longitudinal survey).



PPWB OBJECTIVE: 100 (= CWQG irrigation guideline) compliant / non-compliant CWQG-recreation: 400 (resample criterion) non-compliant

Note: Criteria are normally applied only to surface waters; in this case they are applied to effluents for illustrative purposes.

Figure 12b. Fecal coliform loads (1,000,000,000/day).

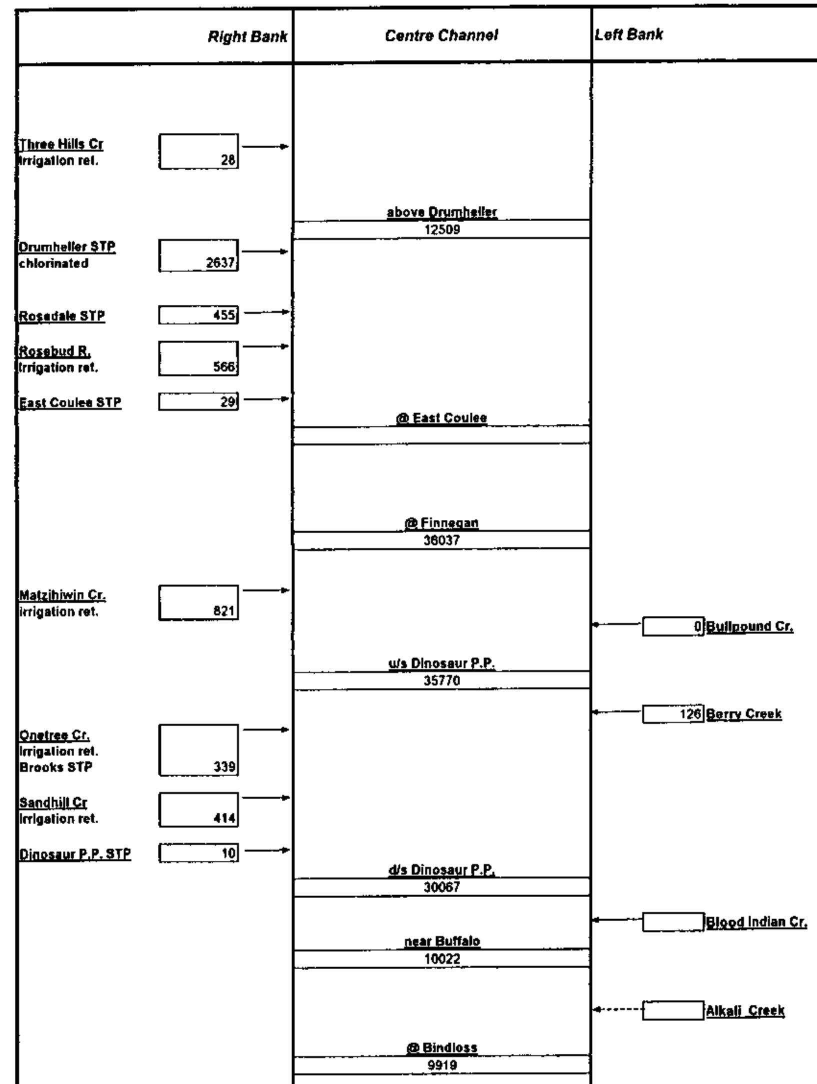


Figure 13a. *E. coli* counts (#/100 mL) in August 1998 (longitudinal survey).

River Distance (d/s of Red Deer)	Date	Q cms	Right Bank	Right Bank count	Centre Channel	Centre: right	Centre: centre	Centre: left	Left Bank count	Left Bank
	18-Aug	0.158	Kneehills Cr	■ 920						
	18-Aug	0.016	Three Hills Cr irrigation ret.	■ 2000						
	17-Aug	59.500			above Drumheller	220	210	170		
	17-Aug	0.040	Drumheller STP not chlorinated	■ 51,000						
	17-Aug	0.000	Rosedale STP	■ 200,000						
	17-Aug	3.450	Rosebud R. irrigation ret.	190						
	17-Aug	0.0005	East Coulee STP	■ 68,000						
230.78 km					@ East Coulee	NS	NS	NS		
270.87 km	18-Aug	64.500			@ Finnegan	330	■ 510	■ 680		
	18-Aug	5.000	Matzhiwin Cr. irrigation ret.	190						
	18-Aug								60	Bullpound Cr.
337.14 km	19-Aug	60.000			u/s Dinosaur P.P.	■ 500	■ 750	■ 530		
	19-Aug	0.485							180	Berry Creek
	19-Aug	1.510	Onetree Cr. irrigation ret. Brooks STP	210						
	19-Aug	1.230	Sandhill Cr irrigation ret.	340						
	19-Aug	0.0009	Dinosaur P.P. STP	■ 3,000						
388.53 km	19-Aug	60.000			d/s Dinosaur P.P.	■ 450	380	■ 420		
									NS	Blood Indian Cr.
435.71 km	20-Aug	60.000			near Buffalo	200	130	220		
									NS	Alkali Creek
476.93 km	21-Aug	61.500			@ Bindloss	180	190	190		

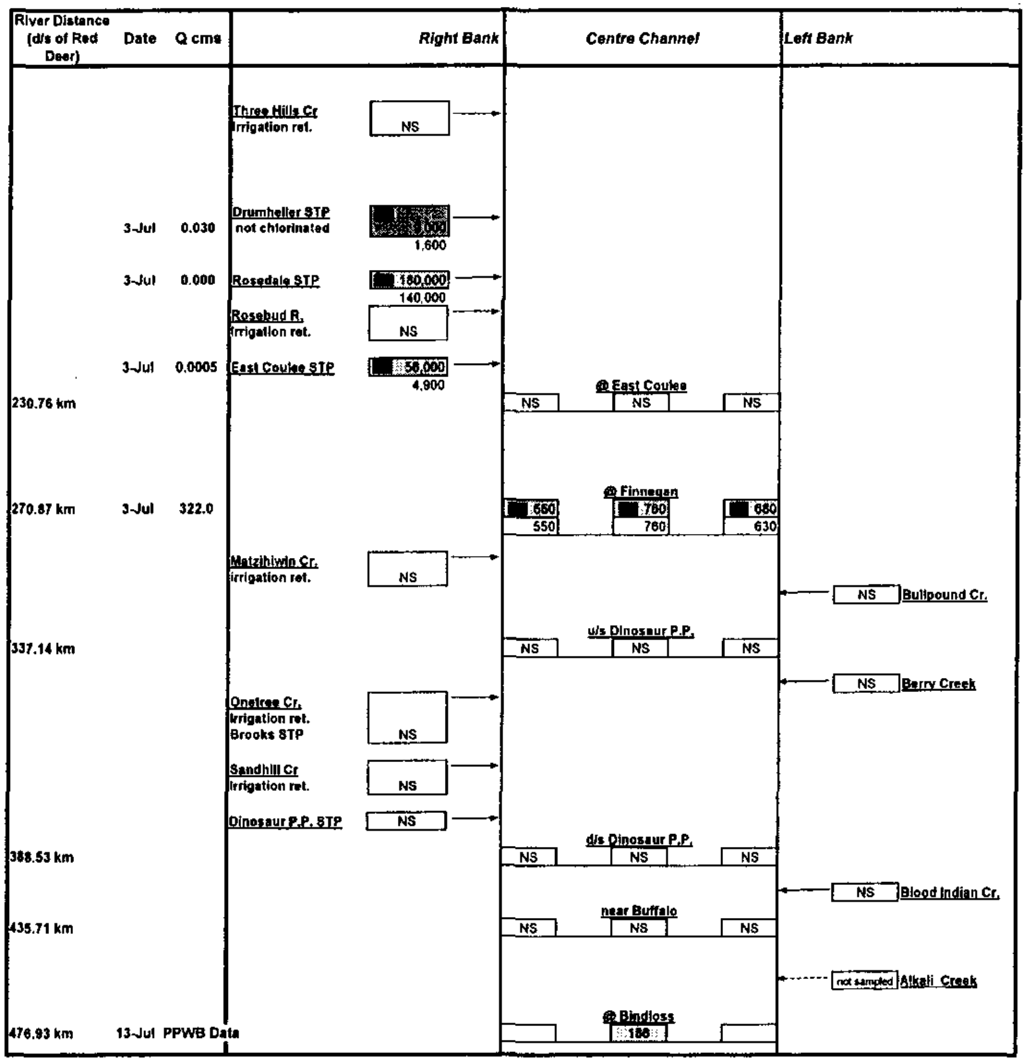
CWQG-recreation: 400 (resample criterion) ■ non-compliant

Note: Criteria are normally applied only to surface waters; in this case they are applied to effluents for illustrative purposes.

Figure 13b. *E. coli* loads (1,000,000,000/day).

Right Bank	Right Bank load	Centre Channel	Centre load	Left Bank load	Left Bank
Three Hills Cr irrigation ret.	28				
		above Drumheller	10282		
Drumheller STP chlorinated	1746				
Rosedale STP	321				
Rosebud R. irrigation ret.	566				
East Coulee STP	28				
		@ East Coulee			
		@ Finnegan	28236		
Matzhiwin Cr. irrigation ret.	821				
				0	Bullpound Cr.
		u/s Dinosaur P.P.	30758		
				75	Berry Creek
Onetree Cr. irrigation ret. Brooks STP	274				
Sandhill Cr irrigation ret.	381				
Dinosaur P.P. STP	2				
		d/s Dinosaur P.P.	21600		
					Blood Indian Cr.
		near Buffalo	9504		
					Alkali Creek
		@ Bindloss	9919		

Figure 14a. Fecal coliform counts (#/100 mL) in July 1998 (STP discharges).



PPWB OBJECTIVE: 100 (= CWQG irrigation guideline) compliant / non-compliant   CWQG-recreation: 400 (resample criterion) ■ non-compliant

Note: Criteria are normally applied only to surface waters; in this case they are applied to effluents for illustrative purposes.

Figure 14b. Fecal coliform loads (1,000,000,000/day).

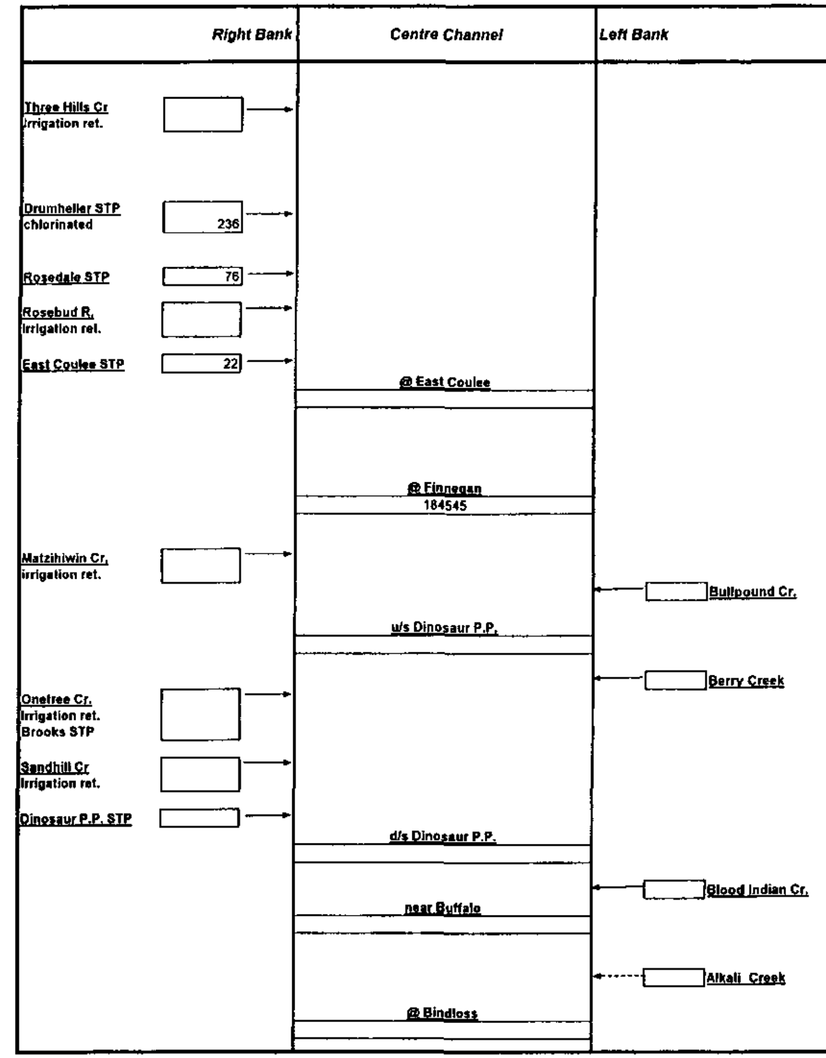
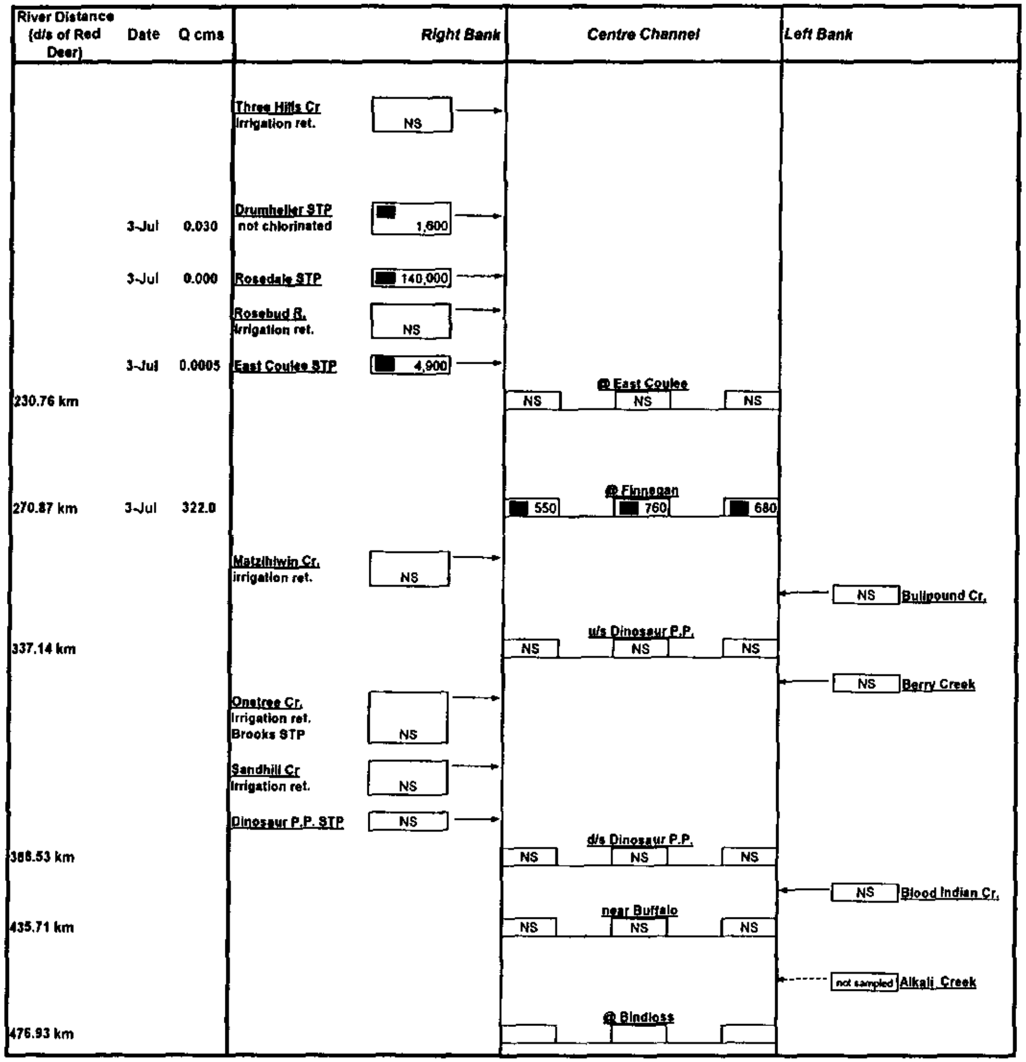


Figure 15a. *E. coli* counts (#/100 mL) in July 1998 (STP discharges).



CWQG-recreation: 400 (resample criterion) ■ non-compliant

Note: Criteria are normally applied only to surface waters; in this case they are applied to effluents for illustrative purposes.

Figure 15b. *E. coli* loads (1,000,000,000/day).

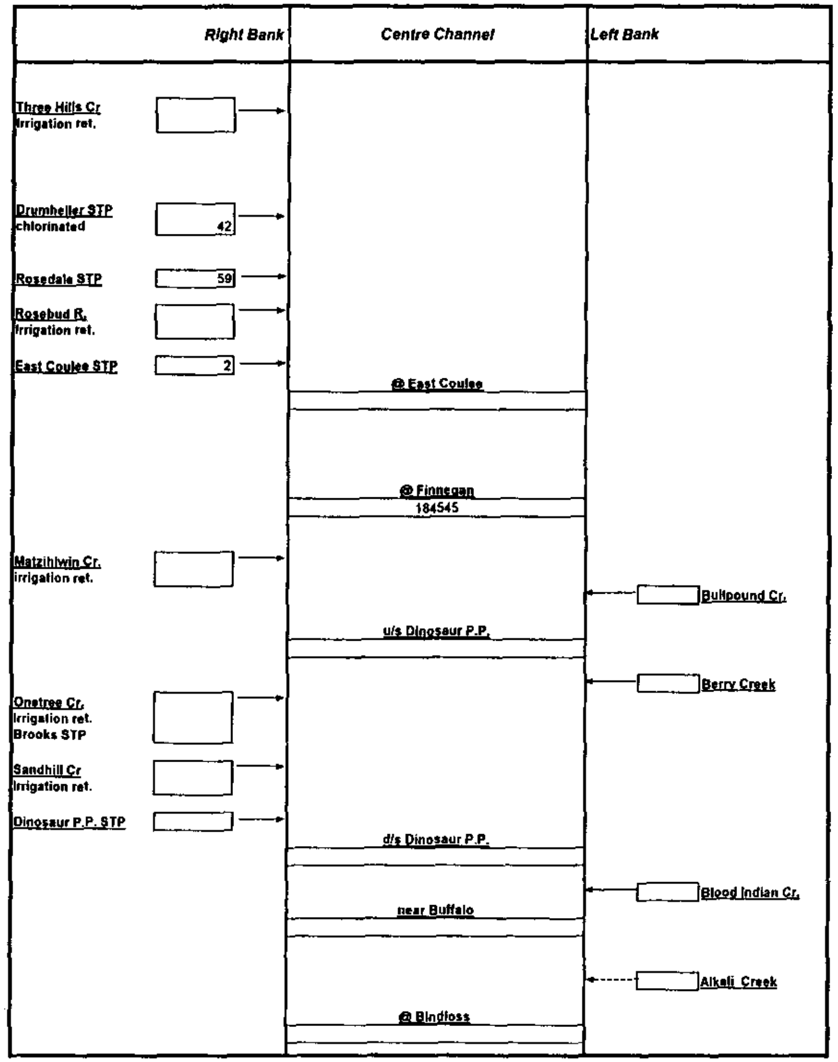
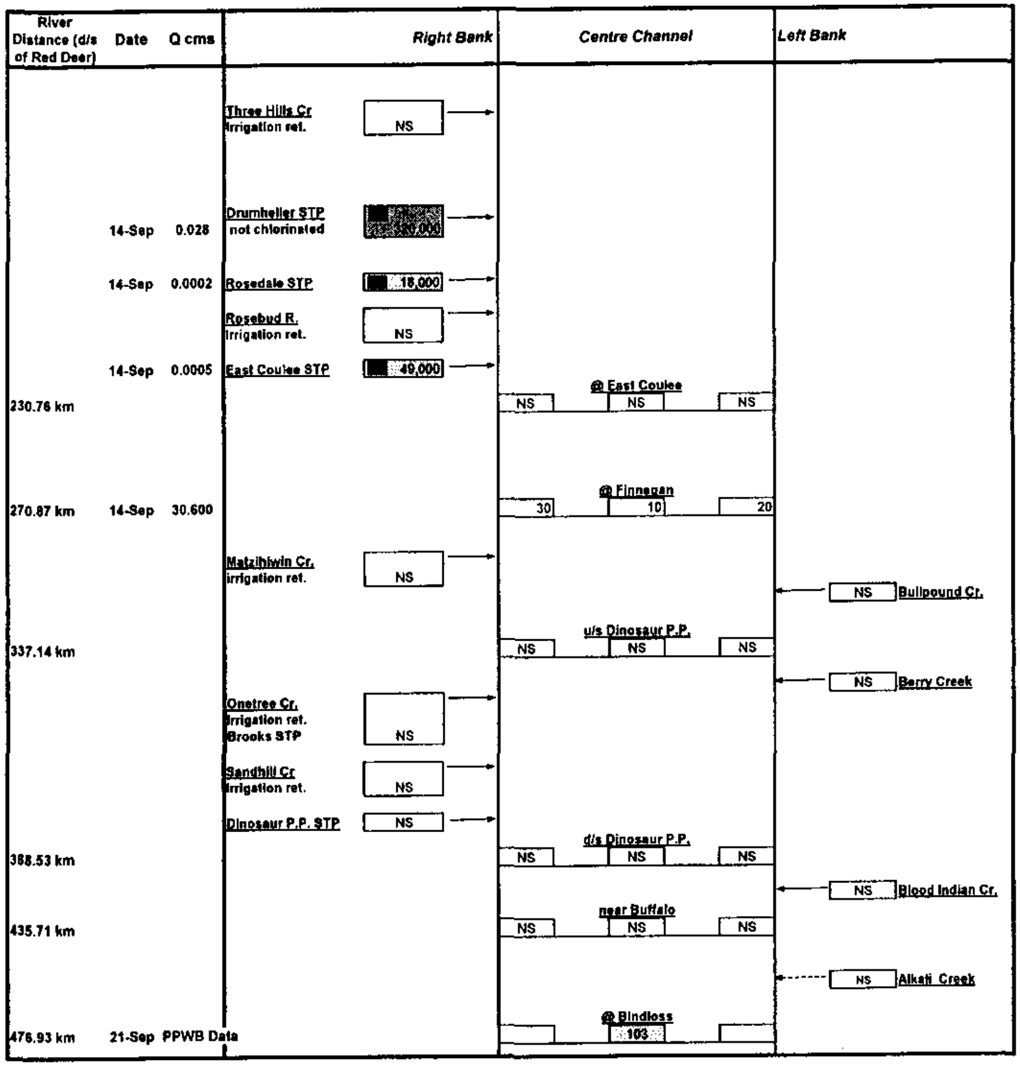


Figure 16a. Fecal coliform counts (#/100 mL) in September 1998 (STP discharges).



PPWB OBJECTIVE: 100 (= CWQG irrigation guideline) — compliant / non-compliant

CWQG-recreation: 400 (resample criterion) — non-compliant

Note: Criteria are normally applied only to surface waters; in this case they are applied to effluents for illustrative purposes.

Figure 16b. Fecal coliform loads (1,000,000,000/day).

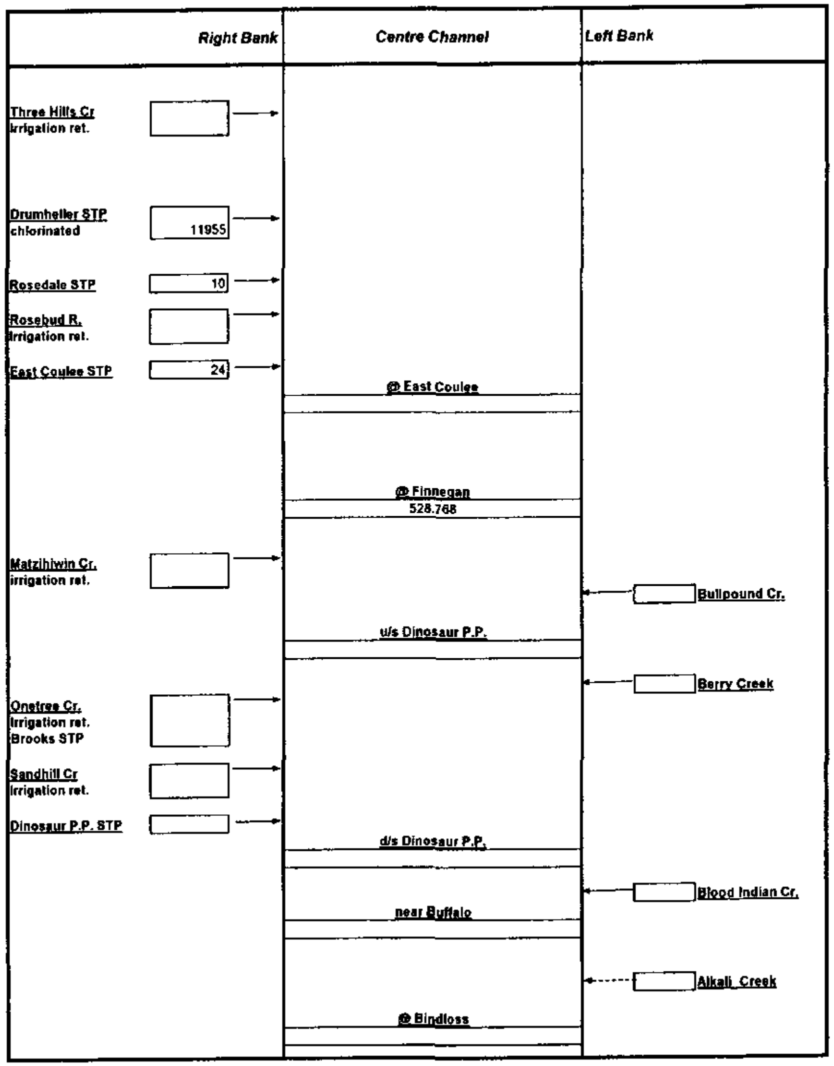
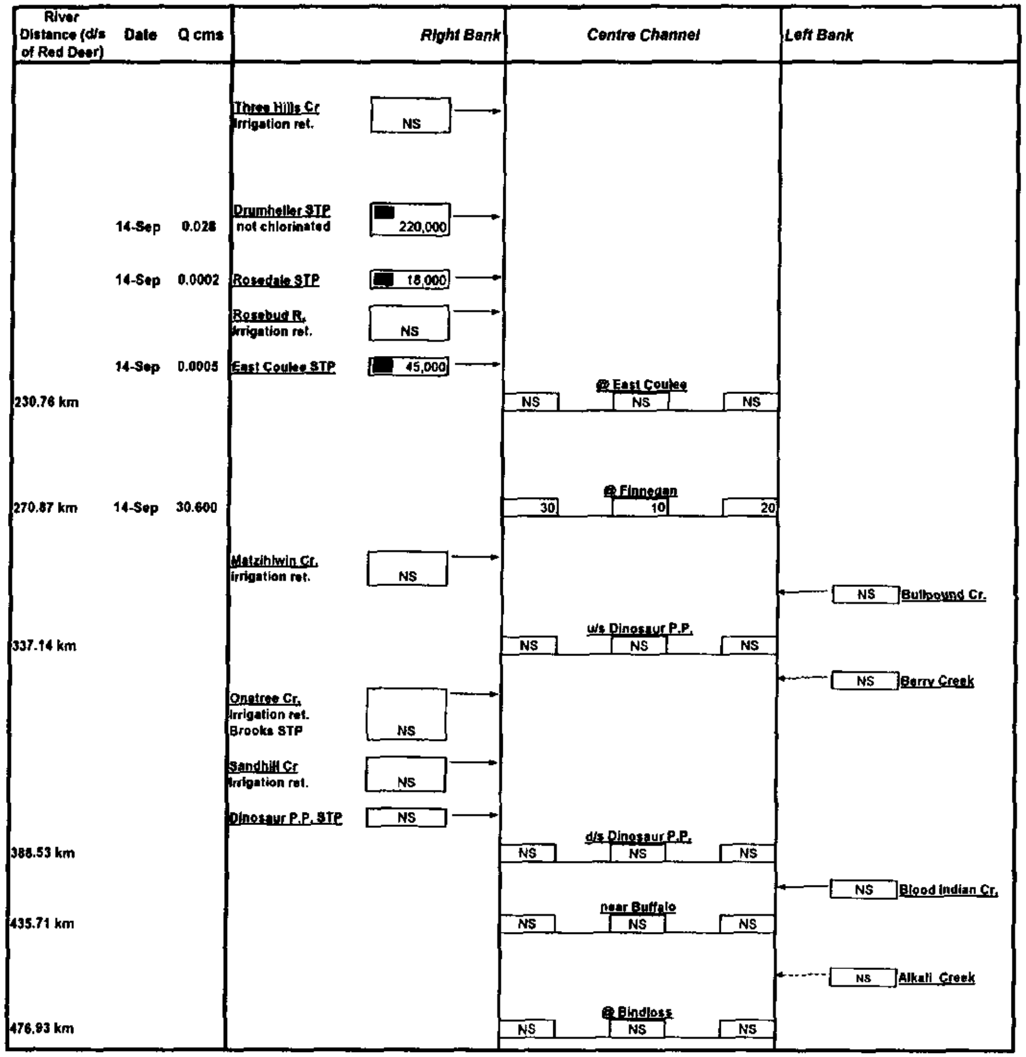


Figure 17a. *E. coli* counts (#/100 mL) in September 1998 (STP discharges).



CWQG-recreation: 400 (resample criterion) ■ non-compliant

Note: Criteria are normally applied only to surface waters; in this case they are applied to effluents for illustrative purposes.

Figure 17b. *E. coli* loads (1,000,000,000/day).

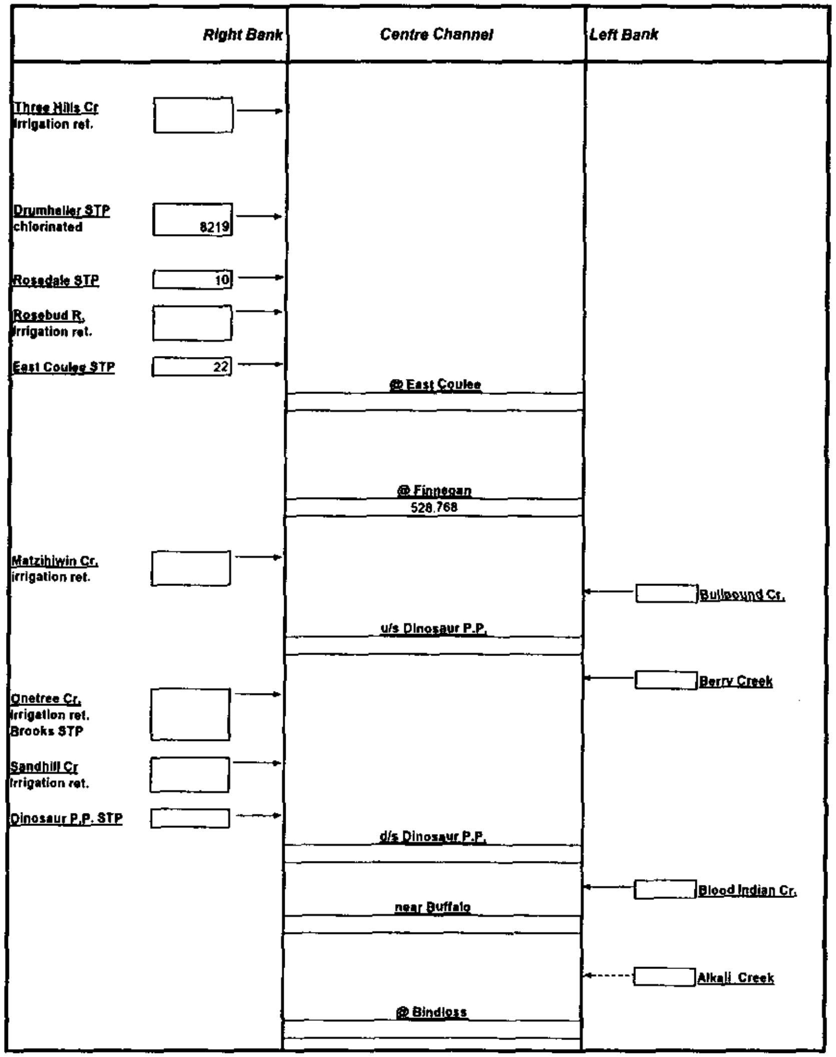
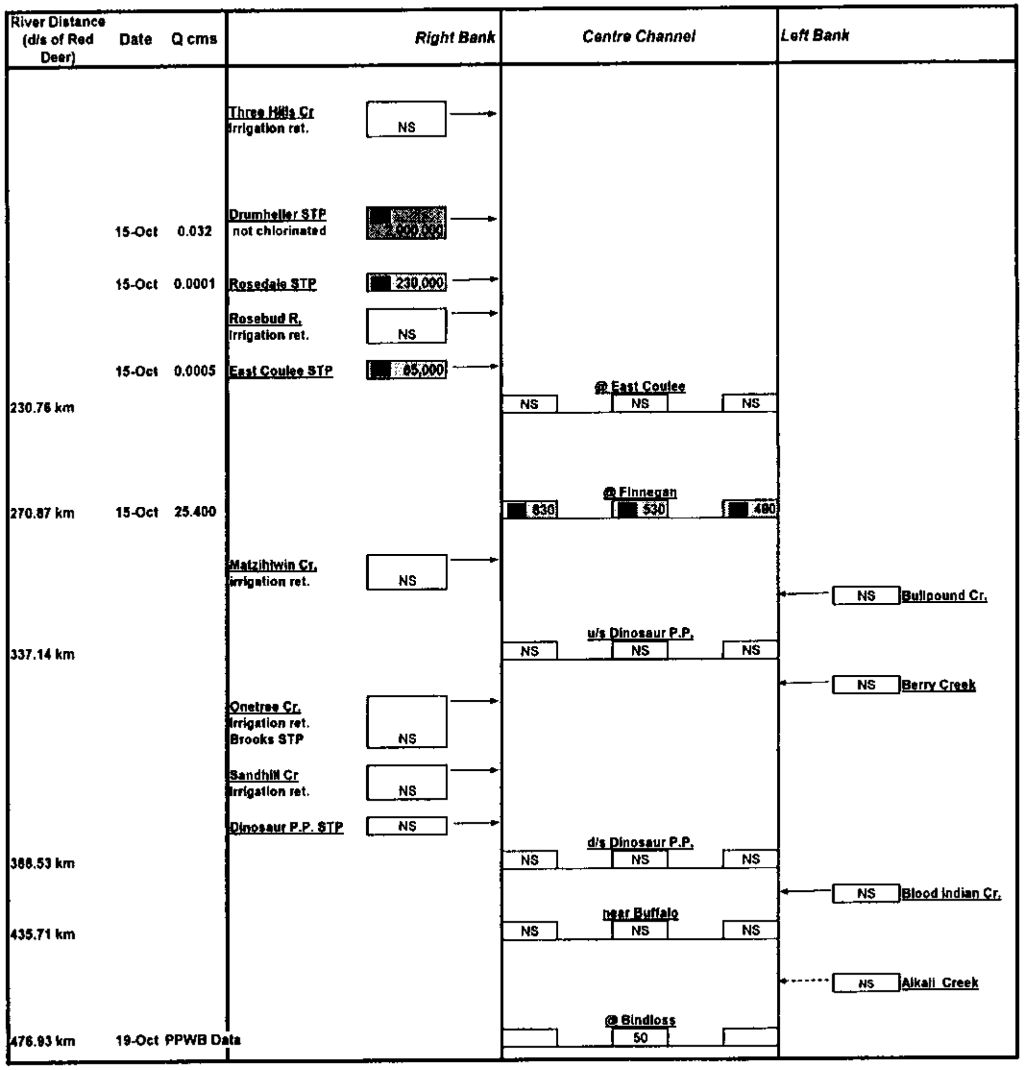


Figure 18a. Fecal coliform counts (#/100 mL) in October 1998 (STP discharges).



PPWB OBJECTIVE: 100 (= CWQG irrigation guideline) compliant non-compliant CWQG-recreation: 400 (resample criterion) non-compliant

Note: Criteria are normally applied only to surface waters; in this case they are applied to effluents for illustrative purposes.

Figure 18b. Fecal coliform loads (1,000,000,000/day).

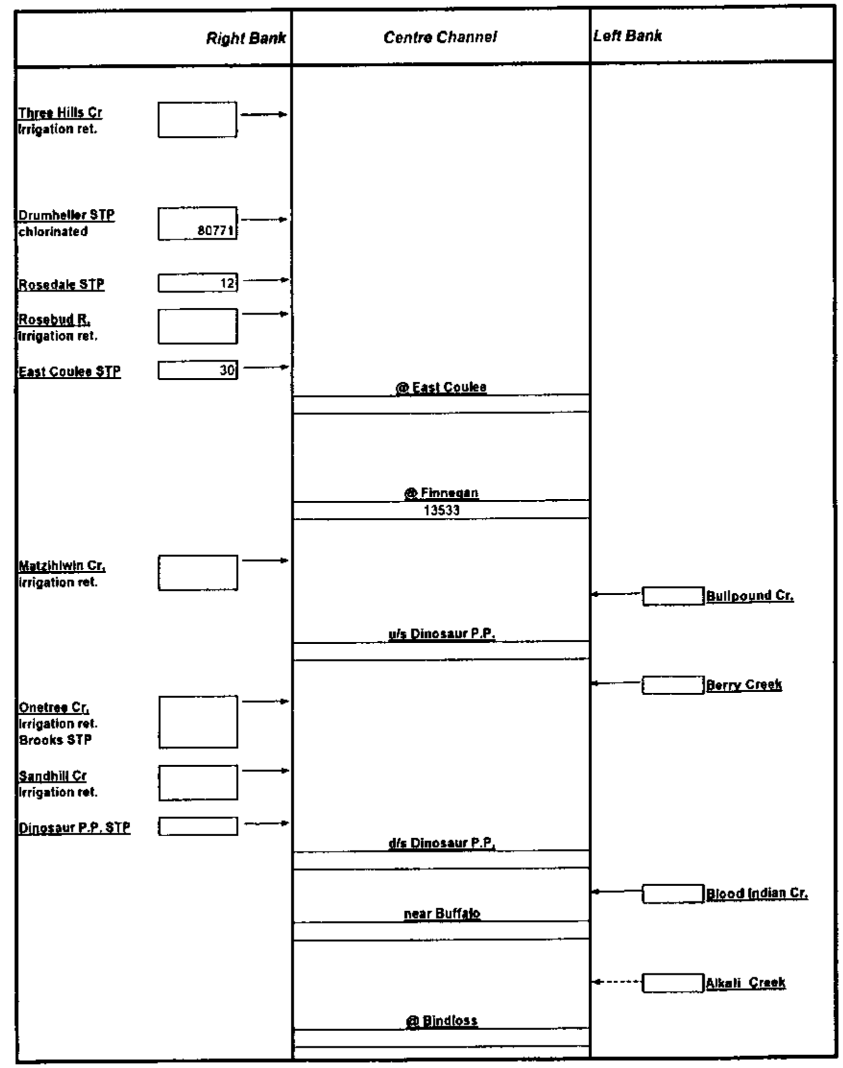
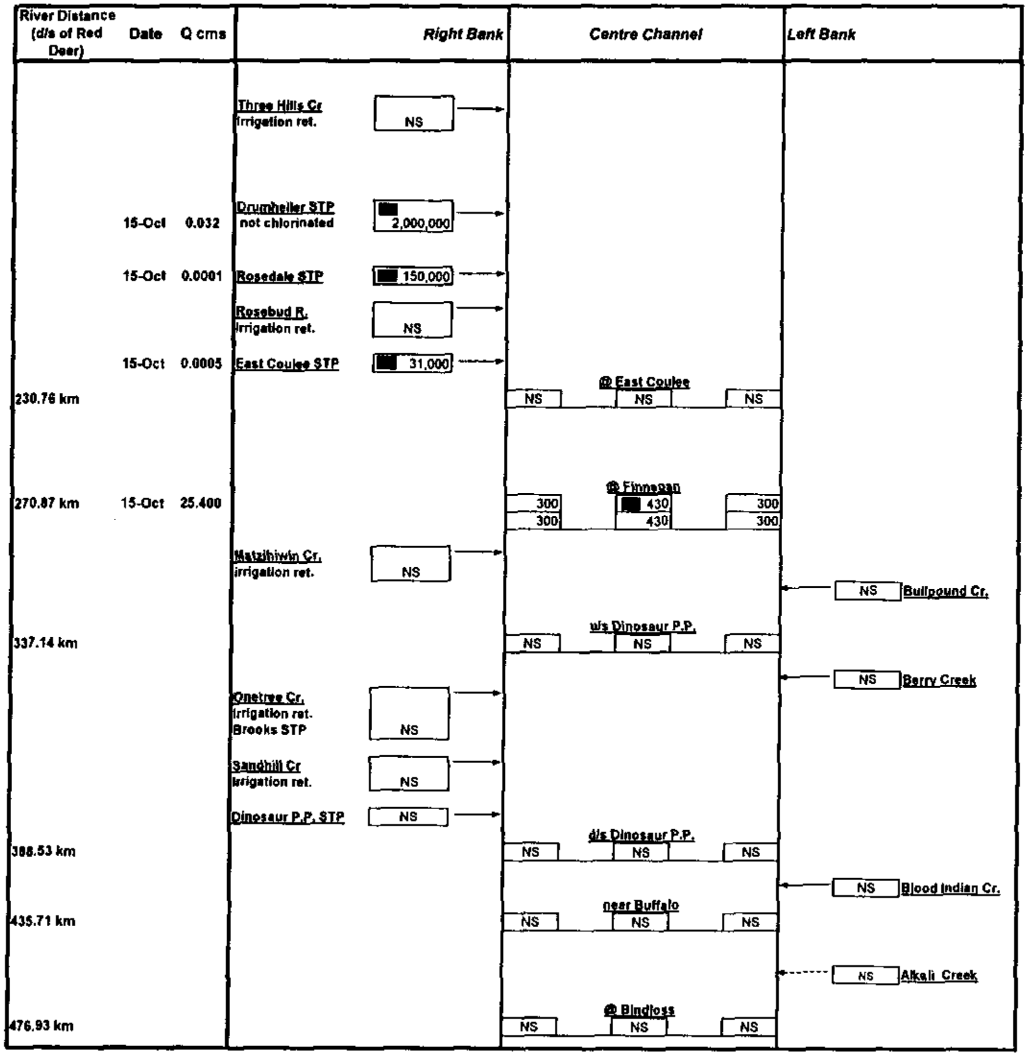


Figure 19a. *E. coli* counts (#/100 mL) in October 1998 (STP discharges).



CWQG-recreation: 400 (resample criterion) ■ non-compliant

Note: Criteria are normally applied only to surface waters; in this case they are applied to effluents for illustrative purposes.

Figure 19b. *E. coli* loads (1,000,000,000/day).

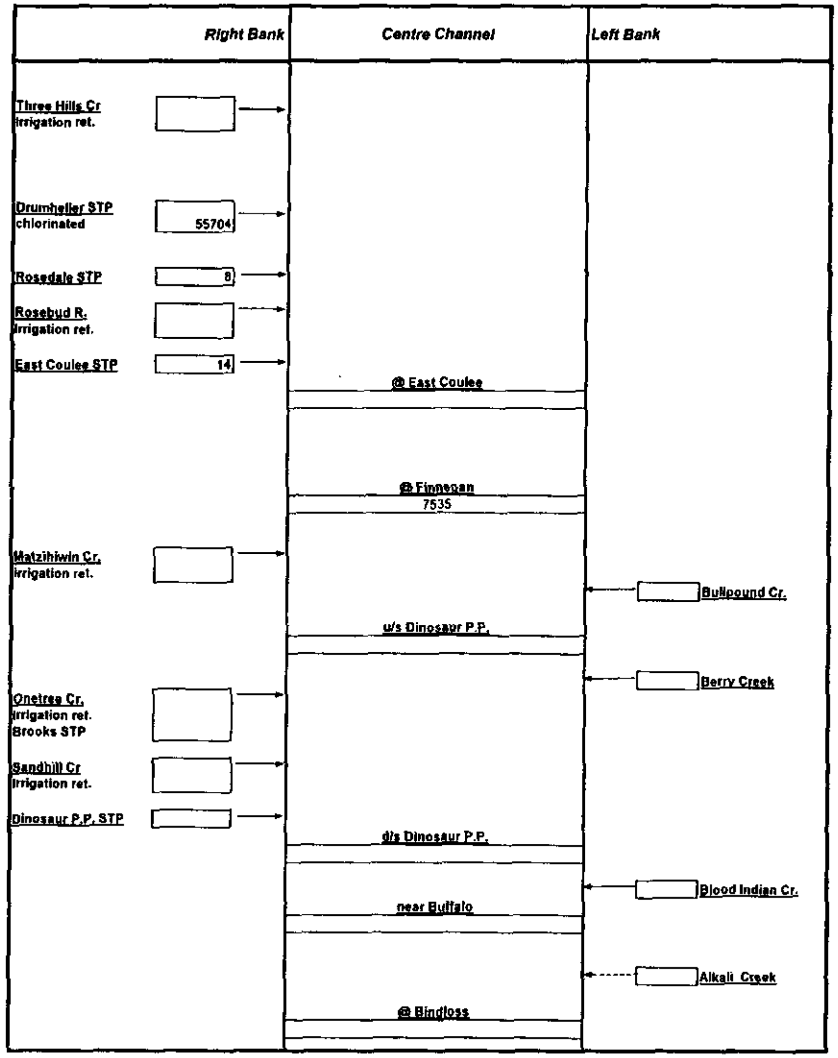
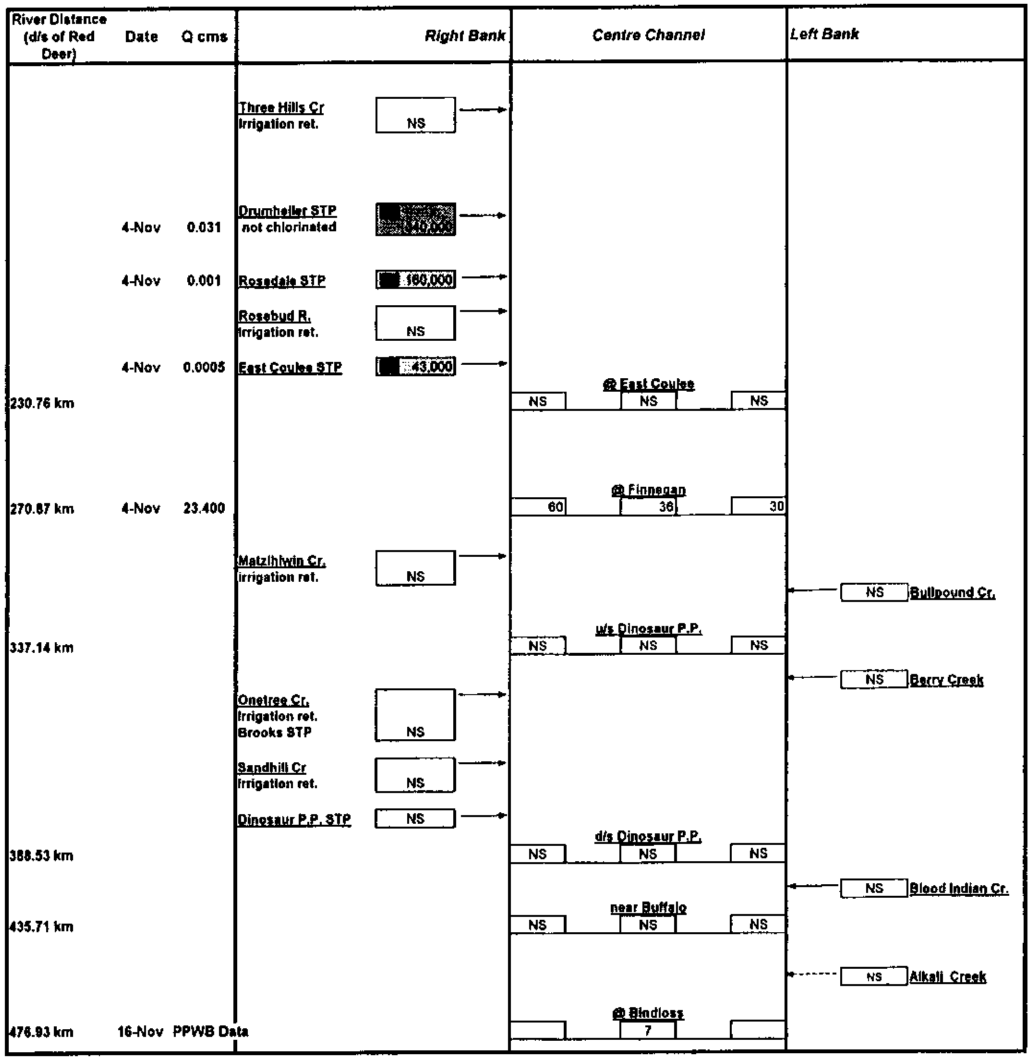


Figure 20a. Fecal coliform counts (#/100 mL) in November 1998 (STP discharges).



PPWB OBJECTIVE: 100 (= CWQG irrigation guideline) compliant non-compliant CWQG-recreation: 400 (resample criterion) non-compliant

Note: Criteria are normally applied only to surface waters; in this case they are applied to effluents for illustrative purposes.

Figure 20b. Fecal coliform loads (1,000,000,000/day).

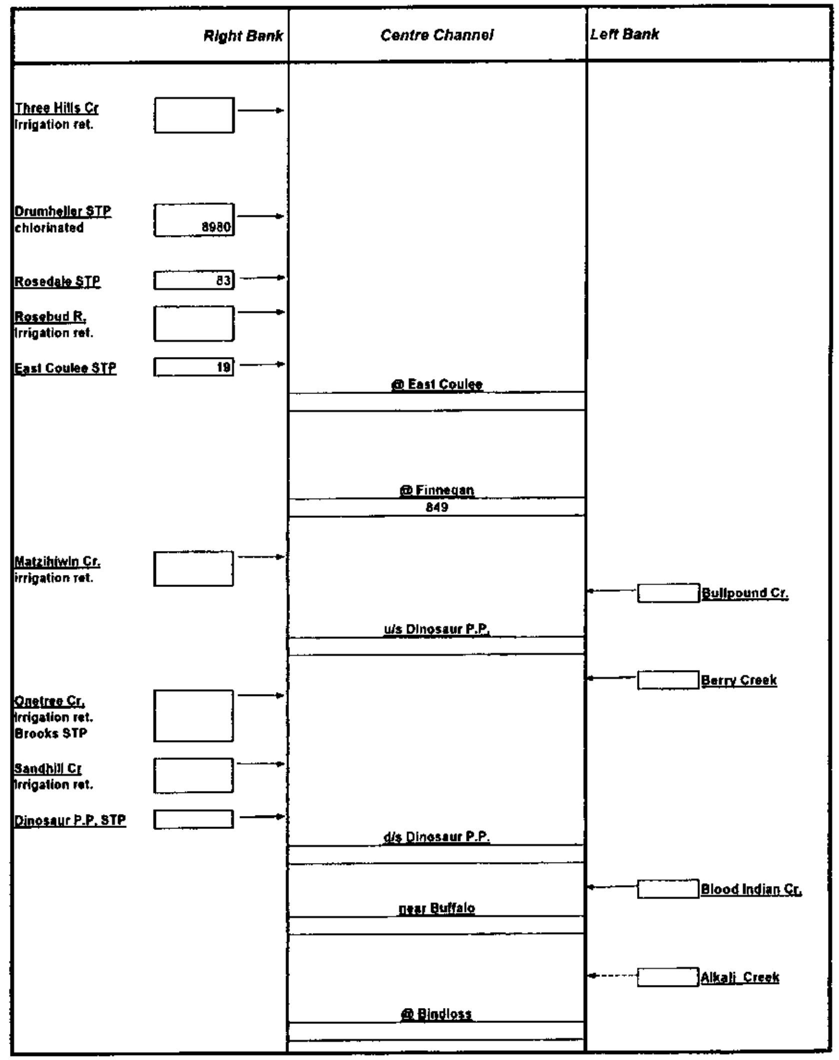
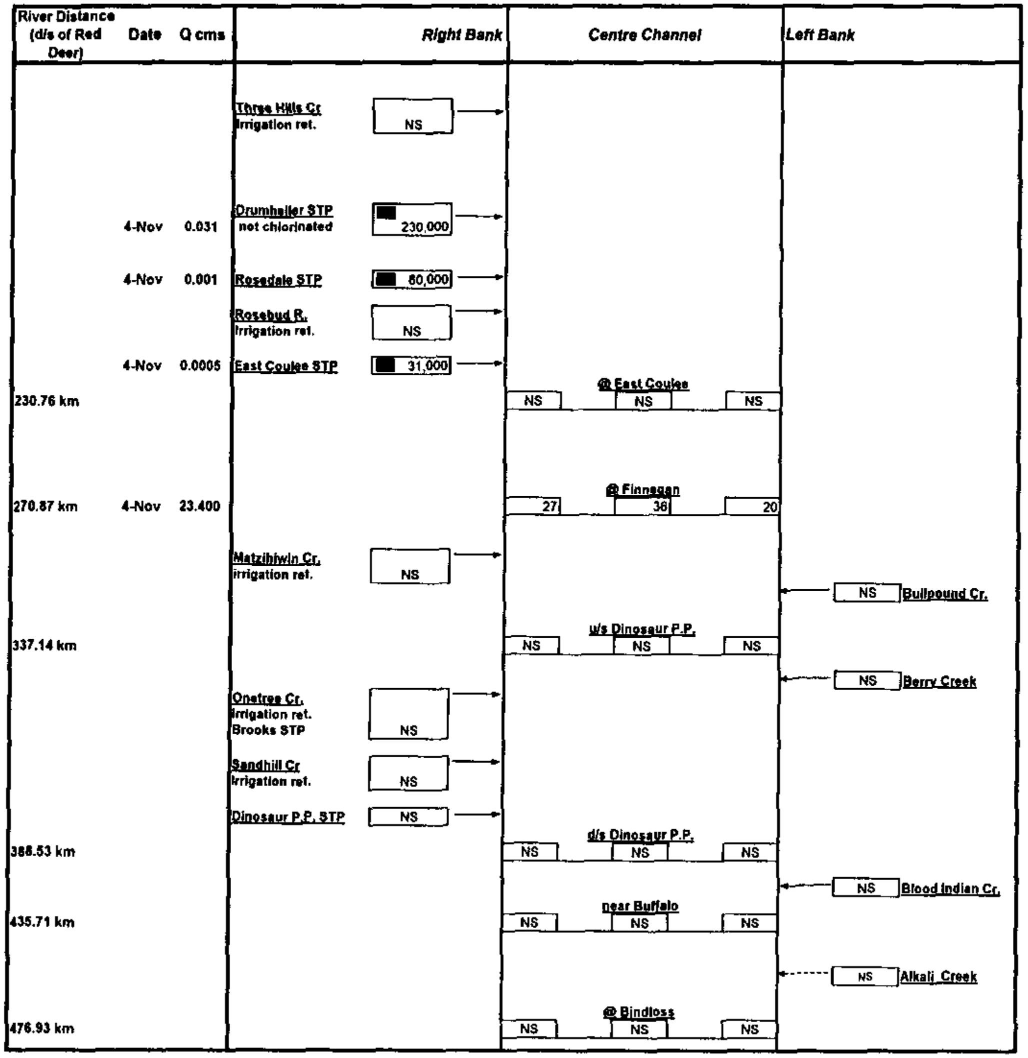


Figure 21a. *E. coli* counts (#/100 mL) in November 1998 (STP discharges).



CWQG-recreation: 400 (resample criterion) ■ non-compliant

Note: Criteria are normally applied only to surface waters; in this case they are applied to effluents for illustrative purposes.

Figure 21b. *E. coli* loads (1,000,000,000/day).

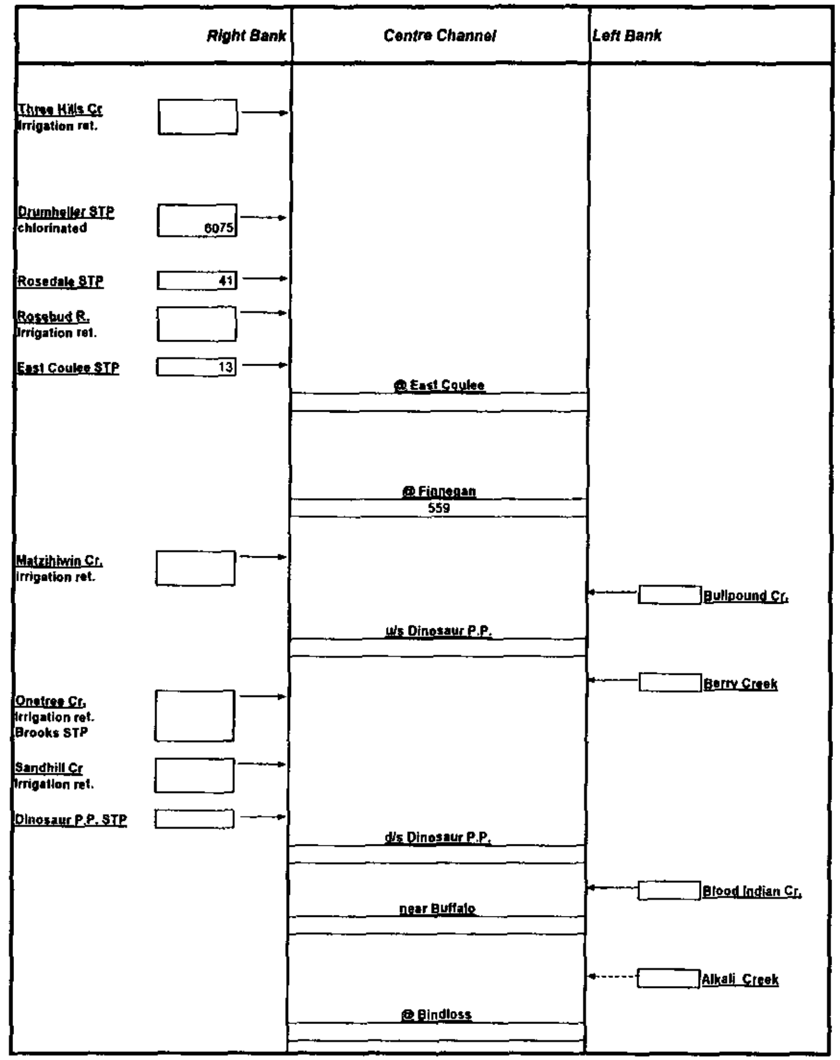


Figure 22. PPWB records of fecal coliform counts in the Red Deer River near Bindloss (1974-1998).