MANITOBA HYDRO
BRANDON THERMAL GENERATING STATION:

POTENTIAL EFFECTS OF ASH LAGOON AND STATION DRAIN EFFLUENTS ON WATER CHEMISTRY IN THE ASSINIBOINE RIVER

North/South Consultants Inc.
Aquatic Environment Specialists

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A Report Prepared for

Manitoba Hydro

by

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1.0 INTRODUCTION

The Brandon Thermal Generating Station (GS) was first commissioned in 1958 with four coal-fired generating units. A fifth unit (also coal-fired) was commissioned in 1969. In 1995, Units 1-4 were taken out of service, with Unit 5 remaining in operation to provide generation to the Manitoba Hydro power grid as needed. Ash recovered from the station's boilers is transported by water to an ash lagoon, which discharges by gravity through a gated earthen weir into a municipal ditch just upstream of the Assiniboine River. The ash lagoon also receives process water from two other sources: effluent from the station's water treatment system and blowdown from Unit 5's cooling tower, which began operation in 1996. The station drain discharges to the Assiniboine River separately from the ash lagoon. The station drain receives effluent from blowdown from the Unit 5 boiler, the ash hopper seal troughs, the lab sample heat exchanger and drains within the GS. Effluent passes through an oil mitigation system before discharge to the river.

Environment Act Licence 1703R (revised February 1994) for the Brandon GS stipulates limits on effluent released from the station drain in terms of pH, oil and grease content, and concentrations of acid-soluble copper and limits on effluent released from the ash lagoon in terms of pH and concentrations of suspended solids and residual chlorine. Additionally, Manitoba Hydro is required to provide to Manitoba Conservation monthly reports containing results from the aforementioned chemical analyses as well as reporting on levels of total dissolved solids (TDS), hardness, sulphates, total phosphorus (TP), soluble boron, total iron in the river, station drain and ash lagoon effluent, as well as copper, lead, zinc, cadmium, and selenium in the river and ash lagoon effluent.

Manitoba Hydro has undertaken an analysis of the ash lagoon and station drain effluent monitoring results as one component of the review of the Environment Act Licence.

In this report, Section 2 summarizes the results reported previously to Manitoba Conservation, and provides a brief assessment of estimated impacts of release from the ash lagoon and station drain on water chemistry in the Assiniboine River for the period 1996 - 2004. This information is intended to provide a general overview of concentrations of reported parameters in the ash lagoon effluent, station drain effluent and the Assiniboine River, with reference to licence limits, federal effluent guidelines, and provincial water quality objectives and guidelines.

Section 3 of this report provides estimates of potential impacts of ash lagoon and station drain effluent discharge on water chemistry in the Assiniboine River under median and low flow conditions. These estimates are developed using historical (1996 - 2004) ash lagoon effluent, station drain effluent and river chemistry data and median, $30Q_{10}$, $7Q_{10}$, and $1Q_{10}$ flows for the Assiniboine River.[1]

1.1 CHRONOLOGICAL SUMMARY OF CHANGES IN STATION OPERATION THAT MAY HAVE AFFECTED ASH LAGOON EFFLUENTS

The quantity and chemistry of effluent discharge from the Brandon GS ash lagoon and station drain is dependent upon precipitation, season and station operation. Upgrades and changes to station equipment and operation that may have impacted effluent quantity or chemistry since 1996 are listed below:

January 1996: An electrostatic precipitator replaced the mechanical cyclone dust collectors on the plant stack, resulting in reduced air emissions and corresponding increases in ash entering the ash lagoon.

March 1996: A closed-loop cooling tower replaced the station's once-through cooling system. Blowdown water from the cooling tower represented a new effluent stream to the ash lagoon containing elevated concentrations of dissolved solids and low concentrations of sulphuric acid and chlorine used for water treatment purposes.

1996-1997: The station changed its fuel source to sub-bituminous coal. Chemical differences between this and the lignite coal previously used, including higher alkalinity in the sub-bituminous coal, may have increased pH of the ash lagoon effluent.

2000-2001 The Brandon GS water treatment plant was expanded and upgraded to provide process water for Unit 5 and two new combustion turbine units (Units 6 & 7) on the Brandon site. No other process effluents from Units 6 & 7 are discharged to the ash lagoon.

May 2001 A CO_2 system was installed at the lagoon outfall to reduce pH in the effluent stream.

[1] For some parameters, a shorter period of record was utilized for one of several reasons including changes in analytical detection limits and alterations to station operation (e.g., installation of pH control). See Section 3.0 for details.

2.0 COMPARISON OF EFFLUENT AND RIVER CONCENTRATIONS WITH LICENCE LIMITS AND WATER QUALITY GUIDELINES

2.1 ASSESSMENT METHODS AND DATA SOURCES

2.1.1 Water chemistry data

Ash lagoon and station drain effluent samples were collected weekly for analysis of pH, TDS, hardness (as $CaCO_3$), sulphate (as SO_4), total phosphorus, and total iron. Soluble boron and acid-soluble copper were monitored weekly in station drain effluent and biweekly in the ash lagoon effluent. Furthermore, total suspended solids (TSS) and total residual chlorine were monitored weekly, and acid-soluble arsenic, acid-soluble lead, total zinc, acid-soluble cadmium, and total selenium were monitored biweekly in ash lagoon effluent. Additionally, weekly samples collected from the station drain effluent were analyzed for oil and grease content. Raw Assiniboine River water from the station's raw water pumphouse (upstream of the station drain and ash lagoon discharge) was collected weekly for analysis of TSS and monthly for all other parameters listed above (excluding oil and grease which is not monitored in the Assiniboine River). All samples were analyzed by Manitoba Hydro's accredited laboratory.

Monthly maximum and median values for water quality parameters in the effluents and river water samples were calculated for the period 1996 to 2004. All pH values were converted to hydronium ion concentrations prior to calculating medians, which were subsequently converted back to pH values. The datasets for each month are composed of one to five datapoints, depending on the number of samples analyzed during the month. The occurrence of, and explanations for, missed samples have been noted in the monthly reports provided to Manitoba Conservation. Effluent concentrations below the analytical detection limit were set at the analytical detection limit, to ensure that the highest potential effluent concentrations were assessed. However, in the river water samples, parameters measured at below the analytical detection limit were assigned a value of half the detection limit, which is a typical practice for describing natural water quality conditions.

Effluent and river water quality for projections under median and low flow conditions in the river were based on monthly median values for the period 1996 - 2004.[2]

As discussed in the report "Air Quality Impact Assessment Brandon Unit 5 Licence Review" the sources of coal in future may be different from those used during the period 1996 - 2004. The afore-mentioned report provides a listing of the concentrations of five parameters measured in the effluent

[2] For some parameters, a shorter period of record was utilized for one of several reasons including changes in analytical detection limits and alterations to station operation (e.g., installation of pH control). See Section 3.0 for details.

that are higher in the new coal source relative to the current coal source (boron, cadmium, copper, lead, and selenium). To determine potential effects to water chemistry in the Assiniboine River, the concentrations in the ash lagoon effluent was increased in proportion to the increase of the concentration in the ash (it should be noted that this is a very rough approximation as many other factors, such as pH could affect the concentration of metals in the effluent).

2.1.2 Discharge volume data

In order to generate conservative estimates of the potential effects of effluent loading from the Brandon GS on water chemistry in the Assiniboine River, ash lagoon and station drain discharge was based on maximum estimates presented in the report "Manitoba Hydro – Raw Water System Review". As discussed in the report, under the current lagoon configuration, discharge from the chemical sump enters an isolated cell of the lagoon and never flows to the river, so the ash lagoon discharge for the period 1996 - 2004 was estimated as 7,798 m^3/d. Future projections (i.e., median and low flow scenarios in Section 3 of this report) assume a fully connected lagoon, and a maximum discharge of 8,741 m^3/d. The station drain discharge was estimated as 2,974 m^3/d.

Total monthly discharge data for the Assiniboine River near Brandon were obtained from the following sources:

- 1 January 1996 to 31 December 2000: Environment Canada (2002);
- 1 January 2001 to 31 December 2003: Calculated from provisional daily discharge data provided by Manitoba Water Stewardship (MWS) Water Resources Branch; and,
- 1 January to 31 December 2004: Calculated from provisional weekly data posted by MWS Water Resources Branch at www.gov.mb.ca/conservation/watres/river_report on 24 February 2005.

All Assiniboine River discharge data were based on measurements from Water Survey of Canada Gauging Station 05MH013 at Grand Valley, and do not include discharge from drainage between Grand Valley and Brandon, including that from the Little Saskatchewan River.

2.1.3 Calculation of fully mixed concentrations

For each parameter monitored in the Assiniboine River during 1996 - 2004, monthly background loading was calculated based on river discharge measured near the City of Brandon and monthly median concentrations of the various parameters measured in the Assiniboine River near the Brandon GS raw water intake. Similarly, total loads for the various substances discharged in the ash lagoon and station drain effluent were calculated based on the estimated maximum daily effluent discharge rate and monthly median concentrations of effluent constituents recorded between 1996 and 2004.

Because the Assiniboine River is the source of water for the Brandon GS and is used to sluice ash to the ash lagoon, the loading removed from the river in this withdrawal was also calculated and subtracted from the effluent loads. The same was done for the station drain effluent. Accounting for this loading in the river water provides a more accurate representation of the actual incremental contribution of the ash lagoon and station drain effluent discharges in terms of loading to the Assiniboine River. While the Brandon GS ash lagoon and station drain effluents contribute to the loading of various substances to the river, they also concurrently reduce loading for some other substances because they are removed during water treatment and/or retained in the ash lagoon. Therefore, the net effect of the ash lagoon and station drain effluents should be considered as a relative change of loading from water withdrawn from and subsequently returned to the river.

Estimates of final (fully mixed) concentrations of parameters in the Assiniboine River were generated using the calculated loading rates in a mass balance approach. The ash lagoon and station drain effluent loads were added to loads in the Assiniboine River (accounting for loads withdrawn by the GS) and the sum was divided by the sum of Assiniboine River discharge and effluent discharge. It is important to note that values in the effluent below the detection limit were assigned a value of the detection limit, while values in upstream river water that were below the analytical detection limit were assigned a value of one half the detection limit. These estimates do not represent precisely the river conditions that actually occurred, as they do not match real-time (same-day) data for concentrations and discharge in the river, ash lagoon and station drain. However, the calculations provide a generalized estimate of fully mixed concentrations in the Assiniboine River during periods when the station is operating continuously for several days. In months with substantial changes in river discharge and/or water chemistry (particularly in spring), the estimates generated by these calculations are not necessarily representative of actual river conditions.

The mass balance calculations used to estimate the fully mixed concentration in the river downstream of the effluent outfalls for a given parameter Z ([Z] in mg/L) were as follows:

$$[Z]_{\text{downstream}} = (\text{Load}_{\text{ upstream}} - \text{Load}_{\text{ withdrawn}} + \text{Load}_{\text{ effluents}}) / \text{river discharge } (m^3/\text{day}) * 1000$$

Individual loading values for the components in this equation were determined as follows:

$$\text{Load}_{\text{ upstream}} \text{ (kg/day)} = [Z]_{\text{ water intake}} \text{ X river discharge } (m^3/\text{day})/1000$$

$\text{Load}_{\text{withdrawn}}$ (kg/day) = $[Z]_{\text{water intake}}$ X intake rate (m^3/day)/1000 *where intake rate was estimated from the effluent discharge rate (i.e., assumed to be equal on a given day)*

$\text{Load}_{\text{effluents}}$ (kg/day) = ($[Z]_{\text{station drain}}$ X station drain discharge (m^3/day) + $[Z]_{\text{ash lagoon}}$ X ash lagoon effluent discharge (m^3/day)) /1000

To calculate final (fully mixed) pH in the river, the monthly medians of pH measurements for the ash lagoon effluent, station drain effluent, and the river were converted to hydronium ion concentrations, which were used to calculate the mixed concentration assuming direct dilution / mixing as for the other parameters. This calculation provides a reasonably accurate estimate of mixed pH because the hardness (and therefore the buffering capacity) of the ash lagoon and station drain effluent was generally similar to that of the raw river water.

2.1.4 Determination of water quality objectives and guidelines

Comparison was made to Manitoba Water Quality, Standards, Objectives and Guidelines (MWQSOGs; Williamson 2002) for each parameter. For those Objectives or Guidelines that are dependent upon another parameter (i.e., that are calculated based on site-specific conditions), they were determined on a monthly basis using the monthly value of that parameter as presented elsewhere in this section. For example, as Objectives for several metals are dependent upon water hardness, monthly Objectives for these metals were calculated from the monthly Assiniboine River values for hardness using the calculations prescribed in Williamson (2002).

2.2 RESULTS: CONCENTRATIONS, LIMITS, AND GUIDELINES, 1996 - 2004

Figures 1.1 - 1.15 summarize the concentrations of the chemical parameters measured in water samples collected from the Assiniboine River and the ash lagoon and station drain effluent as well as concentrations in the river upstream and downstream of the effluent outfalls[3]. The measured and calculated concentrations are presented with comparison to Licence limits, effluent guidelines set by Environment Canada (1986) and MWQSOGs (Williamson 2002). Note that whereas the Licence limits and Environment Canada guidelines pertain to the ash lagoon and station drain effluent, the MWQSOGs apply to the fully mixed portion of the Assiniboine River, allowing for some degradation of habitat within the mixing zone (provided the mixing zone is not acutely toxic). Nevertheless, comparisons between MWQSOGs and effluent concentrations are made for some parameters in the discussion to provide context.

[3] As discussed previously, downstream concentrations are based on the sum of calculated loadings and not river water samples.

The Manitoba Water Quality Objectives for copper, lead, zinc and cadmium are calculated from water hardness and can be expressed as either total or dissolved forms. Manitoba Water Quality Objectives for arsenic for the protection of aquatic life refer to the dissolved form of the metalloid. The data collected by Manitoba Hydro and reported below are based on the acid-soluble forms of these metals (except those for zinc, which are based on total concentrations), and the dissolved concentrations would be lower than those reported. Therefore, comparisons between measured acid-soluble concentrations and Manitoba Water Quality Objectives for dissolved forms of the metals in the discussions below are more conservative than if dissolved concentrations had been analysed. Conversely, Manitoba Water Quality Guidelines are based on total concentrations, and comparisons between the Guidelines and measured concentrations of arsenic, copper, lead and cadmium are slightly less conservative than they would be if total concentrations had been measured.

2.2.1 pH

pH was monitored in both the ash lagoon and station drain effluent, and was generally higher than that of the Assiniboine River from 1996 through 2004 (Figure 1.1). However, the pH of the ash lagoon effluent was reduced after May 2001 through the installation of a carbon dioxide injection system at the lagoon outfall. Whereas pH ranged from 8.48 to 11.60 (median 9.22) prior to June 2001, it ranged from 6.78 to 10.25 (median 8.75) in samples collected from June 2001 to December 2004. Raw water samples collected from the river ranged from 7.62 to 9.12 (median 8.35) throughout the study period.

As shown in Figure 1.1, the Environment Act Licence stipulates an upper pH limit of 9.5 for the station drain effluent (same as the Environment Canada Environmental Codes of Practice Effluent Guideline). The pH of the station drain effluent only exceeded a pH of 9.5 in two of 453 samples (0.4% of samples, both values occurred in April 1997). The Environment Act Licence stipulates an upper pH limit of 10.0 for the ash lagoon effluent for 12 months following setting into service of the cooling tower (until March 1997), and 9.0 thereafter. The pH of the ash lagoon effluent regularly exceeded 10.0 prior to June 2001, but in only two of 134 samples (1.5% of measurements) collected after May 2001. Since May 2001, pH in the effluent exceeded the upper limit of the Environment Canada Environmental Codes of Practice Effluent Guideline (9.5) in four of 134 samples (3%), and the Licence limit of 9.0 in 27 of 134 samples (20%).

Effluent from both the ash lagoon and station drain regularly exceeded the Manitoba Water Quality Guidelines for aquatic life and recreation, and usually exceeded the Manitoba Water Quality Guideline for drinking water. However, the combined effects of the effluents never caused pH to increase noticeably and/or exceed Manitoba Water Quality Guidelines for recreation, aquatic life, and drinking water in the Assiniboine River (Figure 1.1).

2.2.2 Total Dissolved Solids (TDS)

TDS concentrations were monitored in both the ash lagoon and station drain effluent. Monthly median TDS concentrations from the ash lagoon and station drain effluent were similar to one another and noticeably higher relative to median concentrations calculated for the Assiniboine River between 1996 and 2004 (Figure 1.2). The background concentration of TDS in the river itself generally exceeded the Manitoba Water Quality Guideline for drinking water, and often exceeded the Objective for greenhouse irrigation. Between 1996 and 2004, the combined effects of the ash lagoon and station drain effluent did not noticeably elevate TDS concentrations in the Assiniboine River (maximum increase of 1.7% in November 2003, or 11.3 mg/L in December 2003), and did not cause TDS in the river to exceed MWQSOGs in any month. Objectives for field irrigation were never exceeded.

2.2.3 Total Suspended Solids (TSS)

TSS concentrations were monitored in the ash lagoon effluent but not the station drain effluent. From 1996 through 2004, TSS concentrations in the ash lagoon effluent were generally similar to those in Assiniboine River (Figure 1.3). However, suspended solids in the effluent were elevated (relative to the river) on numerous occasions, particularly from October 1999 to April 2001.

Based on TSS concentrations measured in river water samples collected concurrently with the ash lagoon effluent samples, the effluent exceeded the station's Environment Act Licence limit in 65 of 342 weekly samples collected between January 1996 and December 2004[4]. Based on the monthly medians of weekly raw river and effluent samples that were collected between 1996 and 2004, ash lagoon effluent increased TSS concentrations in the river by a maximum of 9% in February 2001. Ash lagoon effluent never increased TSS concentrations in the Assiniboine River above the Manitoba Water Quality Objective for the protection of aquatic life, which varies depending upon background suspended sediment concentrations (Figure 1.3).

2.2.4 Total Hardness

Total hardness was monitored in both the ash lagoon and station drain effluent. From 1996 to 2004, hardness levels in the ash lagoon and station drain effluent were generally similar and somewhat higher than those observed in the Assiniboine River (Figure 1.4). Based on monthly median concentrations, the effluent changed the hardness in the river by a maximum of 0.5% or 2.0 mg/L (January 2004) between 1996 and 2004.

[4] For visual clarity, Figure 1.3 represents the licence limit based on monthly median river TSS concentrations.

There are no MWQSOGs for hardness, and it is not inherently toxic to aquatic life. However, it affects the toxicity of some metals and, in this report, the monthly hardness levels were used to determine the Objectives for copper, lead, zinc and cadmium.

2.2.5 Sulphates

Sulphate concentrations were monitored in both the ash lagoon and station drain effluent, and were generally similar to one another. For the most part, sulphate concentrations in the ash lagoon and station drain effluent were noticeably higher than the concentrations observed in the Assiniboine River between 1996 and 2004 (Figure 1.5). Whereas the lagoon and station drain effluent (and therefore the effluent plume prior to complete mixing in the river) generally exceeded the Manitoba Water Quality Guideline (aesthetic) for drinking water, they did not cause the fully mixed river concentration to exceed this guideline or the guideline for livestock watering in any month from January 1996 to December 2004. Sulphate concentrations in the Assiniboine River were increased by a maximum of 2.9% or 6.6 mg/L (November 2003) as a result of the combined effects of the ash lagoon and station drain effluent.

2.2.6 Phosphorus

Total phosphorus concentrations were monitored in both the ash lagoon and station drain effluents. In general, the ranges of phosphorus concentrations were similar in the ash lagoon and station drain effluents. Although phosphorus concentrations in the Assiniboine River were sometimes higher than those recorded in both effluent streams, phosphorus concentrations were generally higher in the ash lagoon and station drain effluents relative to those observed in the Assiniboine River between 1996 and 2004 (Figure 1.6). The combined discharge from the ash lagoon and station drain increased phosphorus concentrations in the Assiniboine River by a maximum of 25.1% or 0.01 mg/L (December 2003). Phosphorus concentrations in the Assiniboine River usually exceeded the Manitoba Water Quality Guideline of 0.05 mg/L (with the exception of four occasions when concentrations were at or below the guideline); therefore inputs from the station did not cause an exceedence of the Guideline but rather increased the magnitude by which the Guideline was exceeded.

2.2.7 Iron

Total iron concentrations were monitored in both the ash lagoon and station drain effluent. Excluding some of the anomalously high iron concentrations measured in the ash lagoon effluent, the range of total iron concentrations observed in the ash lagoon effluent, station drain effluent, and Assiniboine River were similar. Iron concentrations analyzed weekly in the ash lagoon and station drain effluent exceeded the Environment Canada Guideline (1,000 µg/L; Environment Canada 1986) in 66 of 342, and 232 of 453 samples, respectively. The combined effects of the ash lagoon and station drain effluent streams increased iron concentrations in the Assiniboine River by a maximum of 12% or 181 μg/L (January 2001). However, both effluents typically had lower iron concentrations relative to the river, and therefore usually reduced iron concentrations. Monthly iron concentrations in the river generally exceeded the Manitoba Water Quality Guidelines for drinking water and the protection of aquatic life (300 μg/L) prior to mixing with the effluents (Figure 1.7). The guideline for irrigation was also occasionally exceeded, although the effluent did not cause the exceedences or notably increase iron concentrations.

2.2.8 Residual Chlorine

Total residual chlorine concentrations were monitored in the ash lagoon effluent but not the station drain effluent. All concentrations measured in the ash lagoon effluent were well below the Environment Act Licence limit of 0.2 mg/L (Figure 1.8). The background concentration in the Assiniboine River frequently exceeded the Manitoba Water Quality Objectives for the protection of aquatic life (71% of monthly measurements collected from 1996 - 2004 exceeded both the chronic and acute objective for the protection of aquatic life)[5]. Ash lagoon effluent addition caused a maximum increase in residual chlorine concentrations of 2% or 0.0002 mg/L (December 2003). Although background concentrations in the Assiniboine River frequently exceeded the Objectives, inputs of effluent had a negligible effect on fully mixed concentrations in the river, and at no time did the addition of ash lagoon effluent cause concentrations in the river to exceed the Objectives for the protection of aquatic life.

2.2.9 Boron

Soluble boron concentrations were monitored in both the ash lagoon and station drain effluent. Monthly median soluble boron concentrations from the ash lagoon were higher than those observed in the station drain effluent. Both effluent streams had much higher soluble boron concentrations relative to concentrations observed in the Assiniboine River between 1996 and 2004 (Figure 1.9). Ash lagoon effluent concentrations generally exceeded the Manitoba Water Quality Guideline for irrigation (500 μg/L for locally grown crops), while concentrations in the station drain effluent were usually in compliance with the guideline. Although soluble boron concentrations in both effluent streams were elevated relative to background concentrations in the Assiniboine River, the addition of effluents from the Brandon GS only increased boron concentrations in the river by a maximum of 11.5% (November 2003) or 0.019 mg/L (December 2003). A general decrease in boron concentrations in the ash lagoon effluent after 1997 may have been associated with the switch from lignite to sub-bituminous coal as the station's fuel source. The combined effects of the effluents on

[5] The analytical laboratory is currently investigating whether these unexpectedly high values could be erroneous measurements due to interference by other substances present in the water sample.

soluble boron concentrations in the river did not cause exceedences of the most stringent water quality guideline (0.5 mg/L for irrigation) over the period of 1996 - 2004.

2.2.10 Arsenic

Acid-soluble arsenic concentrations were only monitored in the ash lagoon effluent. Concentrations in the Assiniboine River were generally lower than those observed in the effluent, and were consistently well below Manitoba Water Quality Guidelines pertaining to drinking water, livestock, and protection of aquatic life. Furthermore, all samples collected from the river and ash lagoon effluent were below the Manitoba Water Quality Objectives for the protection of aquatic life (150 µg/L and 340 µg/L as dissolved for the chronic and acute Objectives, respectively) (Figure 1.10). The addition of ash lagoon effluent to the Assiniboine River increased acid-soluble arsenic concentrations in the river by a maximum of 24.5% or 1.0 µg/L (December 2003) and did not cause exceedences of any of the water quality objectives or guidelines.

2.2.11 Copper

Acid soluble copper concentrations were monitored in both the ash lagoon and station drain effluent. Monthly median concentrations from the ash lagoon and station drain effluent were similar to one another and noticeably higher than those observed in the Assiniboine River (Figure 1.11). Acid-soluble copper concentrations in the station drain effluent exceeded the Environment Act licence limit of 0.5 mg/L in 7 of 462 weekly samples collected between 1996 and 2004. In only one month (January 2002) the acid-soluble copper concentration in the river exceeded the acute (one-hour) Manitoba Water Quality Objective for the protection of aquatic life. However; the ash lagoon and station drain effluent copper concentration at this time were substantially lower than the river concentration and actually reduced the copper concentrations in the river downstream of the effluent outfalls.

Analysis of effluent and river concentrations prior to June 2001 is problematic because most samples were below the analytical detection limits. However, effluent discharges did not cause the river in the fully mixed zone to exceed any MWQSOGs in any month during the monitoring period.

2.2.12 Lead

Acid-soluble lead concentrations were only monitored in the ash lagoon effluent. Concentrations measured in the Assiniboine River and in the ash lagoon effluent were generally below analytical detection limits from 1996 to 2004, and were well below all MWQSOGs in all months except April 1999, when the river concentration (6.0 µg/L upstream and downstream of the ash lagoon outfall) slightly exceeded the Chronic (4-day) Manitoba Water Quality Objective of 5.4 µg/L (as dissolved) for the protection of aquatic life (Figure 1.12). In this month, the median ash lagoon effluent concentration was lower than that in the river upstream of the station and slightly decreased concentrations downstream of the ash lagoon outfall in the fully mixed zone of the river.

Ash lagoon effluent increased monthly lead concentrations in the river by a maximum of 3.3% (January 1997) or 0.2 µg/L (December 2003). Effluent discharge did not cause the river in the fully mixed zone to exceed any MWQSOGs in any month during the monitoring period. Note that the apparent increase in acid-soluble lead concentrations after May 2001 as shown in Figure 1.12 reflects the increase in the analytical detection limit to 20 µg/L, and was not likely associated with a true increase in lead concentrations in the river or the effluent. However, this increase in the analytical detection limit prevents a direct assessment of compliance with water quality guidelines which were below the detection limit of 20 µg/L.

2.2.13 Zinc

Total zinc was only monitored in the ash lagoon effluent, and concentrations were similar to those observed in the Assiniboine River between 1996 to 2004 except in late 2000 / early 2001, when effluent concentrations were anomalously high (maximum 480 µg/L in February 2001), and in 2003, when effluent concentrations were moderately elevated relative to those in the river (maximum 194 µg/L in July 2003) (Figure 1.13). Monthly river concentrations, which were increased through mixing with the effluent by a maximum of 15.9% or 0.8 µg/L (February 2001), remained well below all MWQSOGs throughout the monitoring period.

2.2.14 Cadmium

Cadmium concentrations in the Assiniboine River were generally below or very near the analytical detection limits from 1996 to 2004, and in all months remained well below all MWQSOGs both prior to and after mixing with the ash lagoon effluent (Figure 1.14). Note that the apparent increase in acid-soluble cadmium concentrations after May 2001 reflects an increase in the analytical detection limit to 1 µg/L, and was not likely associated with a true increase in cadmium concentrations in the river.

Cadmium was only monitored in the ash lagoon effluent, and concentrations were generally below analytical detection limits, except during a period of elevated concentrations (maximum of 5.5 µg/L) from December 1999 – March 2001. Elevated concentrations of cadmium and other metals during this period were likely associated with increased suspended sediment in the lagoon effluent, possibly due to re-suspension of bottom sediments in the lagoon, as discussed in Section 2.2.3. Monthly river concentrations were increased through mixing with the effluent by a maximum of 18.2% (February 2001) or 0.018 µg/L (March 2002), but remained well below all MWQSOGs throughout the monitoring period.

2.2.15 Selenium

Selenium was only monitored in the ash lagoon effluent, and concentrations were much higher than those observed in the Assiniboine River which were generally below the analytical detection limit of 2 μg/L (used by Manitoba Hydro) from 1996 to 2004 (Figure 1.15). Because the analytical detection limit for Se is higher than the most stringent water quality guideline of 1 μg/L for the protection of aquatic life, assessing the effects of the ash lagoon effluent on Se concentrations in the river is difficult, as the data prevent determination of whether upstream conditions comply with the guideline.

In consideration of these analytical limitations, data collected by Manitoba Water Stewardship from the Assiniboine River near Brandon were examined to provide a more precise measure of upstream Se concentrations and compliance with the guideline of 1 μg/L. Data collected from 2002-2004 indicate that Se exceeded the guideline on one occasion (of a total of 12 measurements) and the median concentration was <0.2 μg/L. Assuming median concentrations of Se upstream in the Assiniboine River were equal to the analytical detection limit of 0.2 μg/L, the ash lagoon effluent would not have caused an exceedence of the water quality guideline for the protection of aquatic life in the fully mixed portion of the river. It is recognized, however, that upstream concentrations of selenium have occasionally exceeded the water quality guideline (three measurements from 1999-2004) and discharge from the ash lagoon would have increased the concentrations further.

Concentrations of Se were at or slightly above the drinking water quality guideline on three occasions in the Assiniboine River (with or without the effluent). All other guidelines were consistently met in the river.

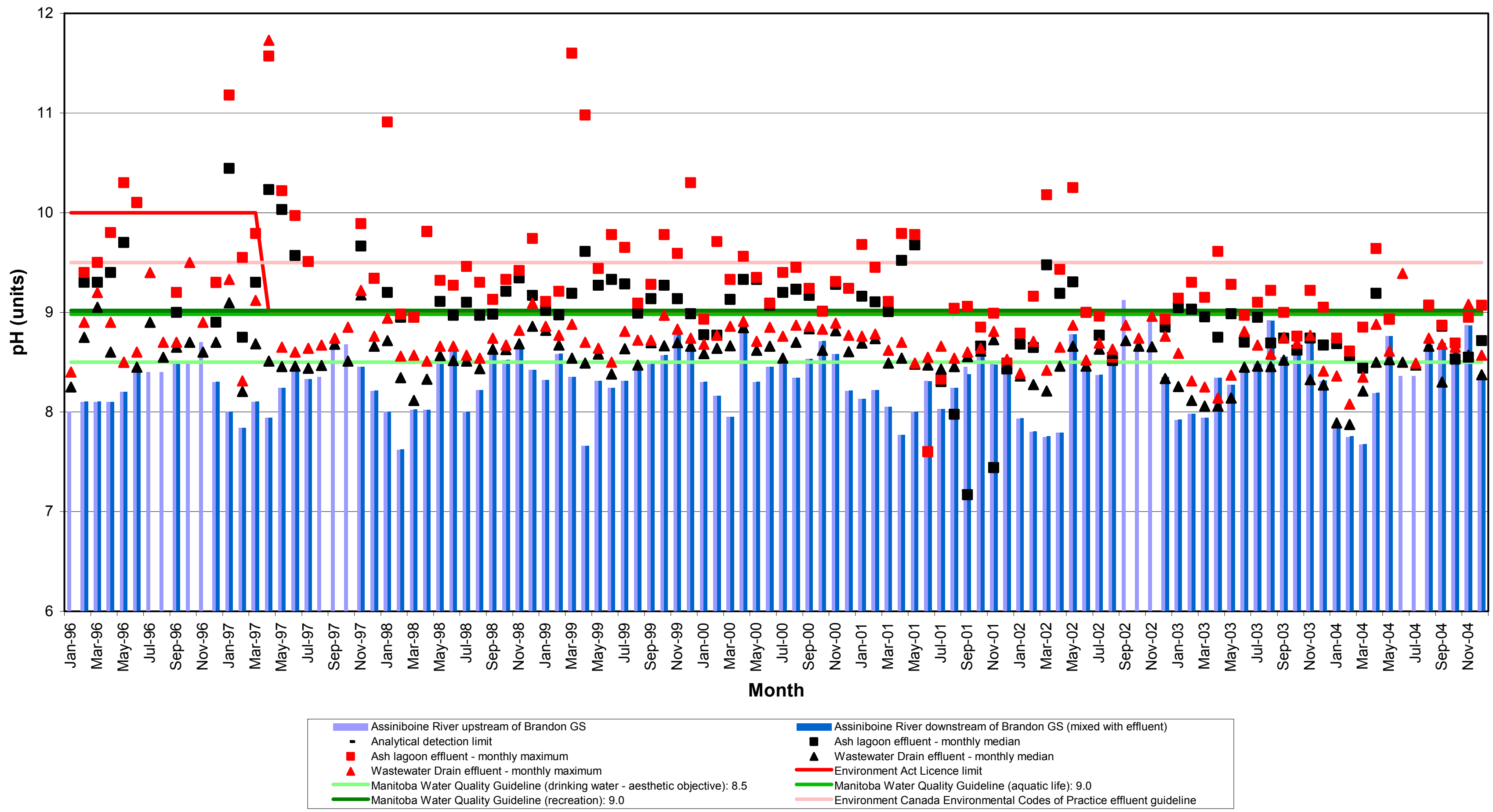

Figure 1.1 Comparison of pH in the Assiniboine River and Brandon GS ash lagoon and station drain effluents (1996 - 2004) with the Environment Act Licence 1703R limit, Environment Canada Environmental Codes of Practice guideline, and current Manitoba Water Quality Guidelines (note that only upper pH limits are indicated). The Licence limit and Environment Canada guideline pertain to effluent concentrations; the Manitoba Water Quality Guidelines pertain to river concentrations.

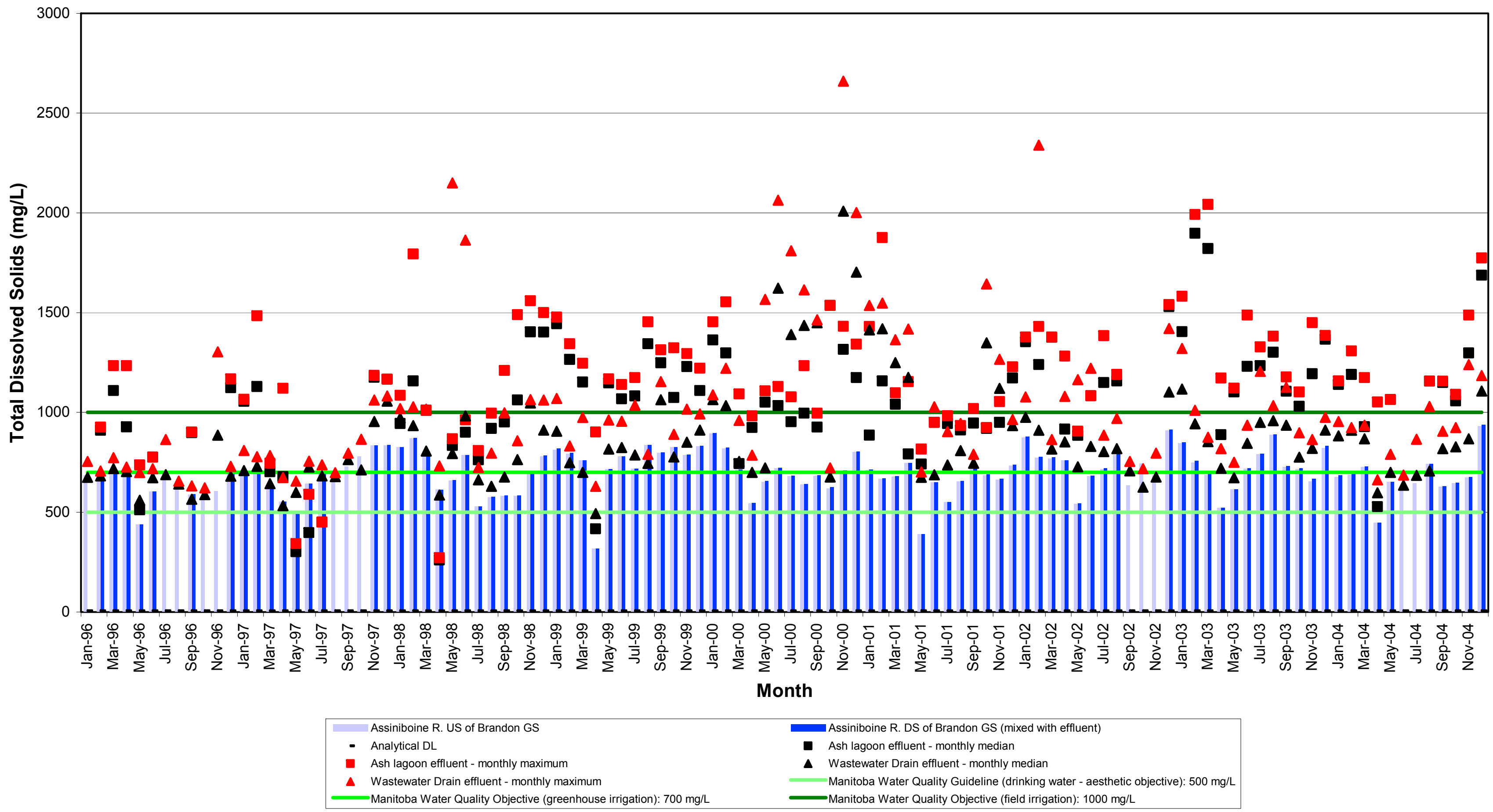

Figure 1.2 Comparison of total dissolved solids concentrations in the Assiniboine River and Brandon GS ash lagoon and station drain effluents (1996 - 2004) with current Manitoba Water Quality Objectives and Guidelines. The Objectives and Guidelines pertain to river concentrations.

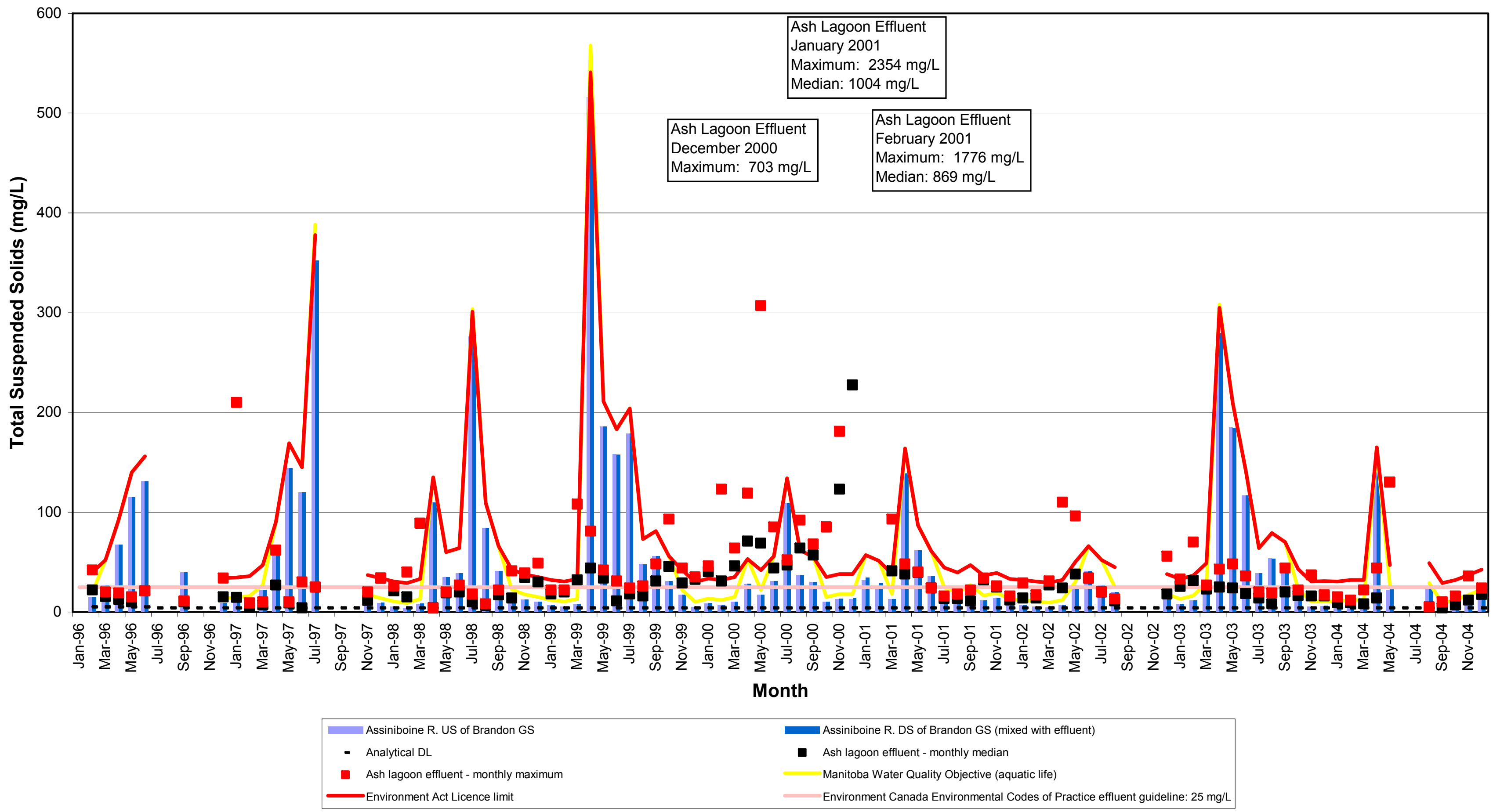

Figure 1.3 Comparison of total suspended solids concentrations in the Assiniboine River and Brandon GS ash lagoon effluent (1996 - 2004) with the Environment Act Licence 1703R limit, the Environment Canada Environmental Codes of Practice guideline, and the Manitoba Water Quality Objective for the protection of aquatic life. The Licence limit and Environment Canada guideline pertain to the effluent concentration; the Manitoba Water Quality Objective pertains to river concentrations. Whereas the Licence limit and Water Quality Objective are based on weekly river data, the monthly river concentrations (blue bars) represent single monthly measurements, usually collected during the first week of each month.

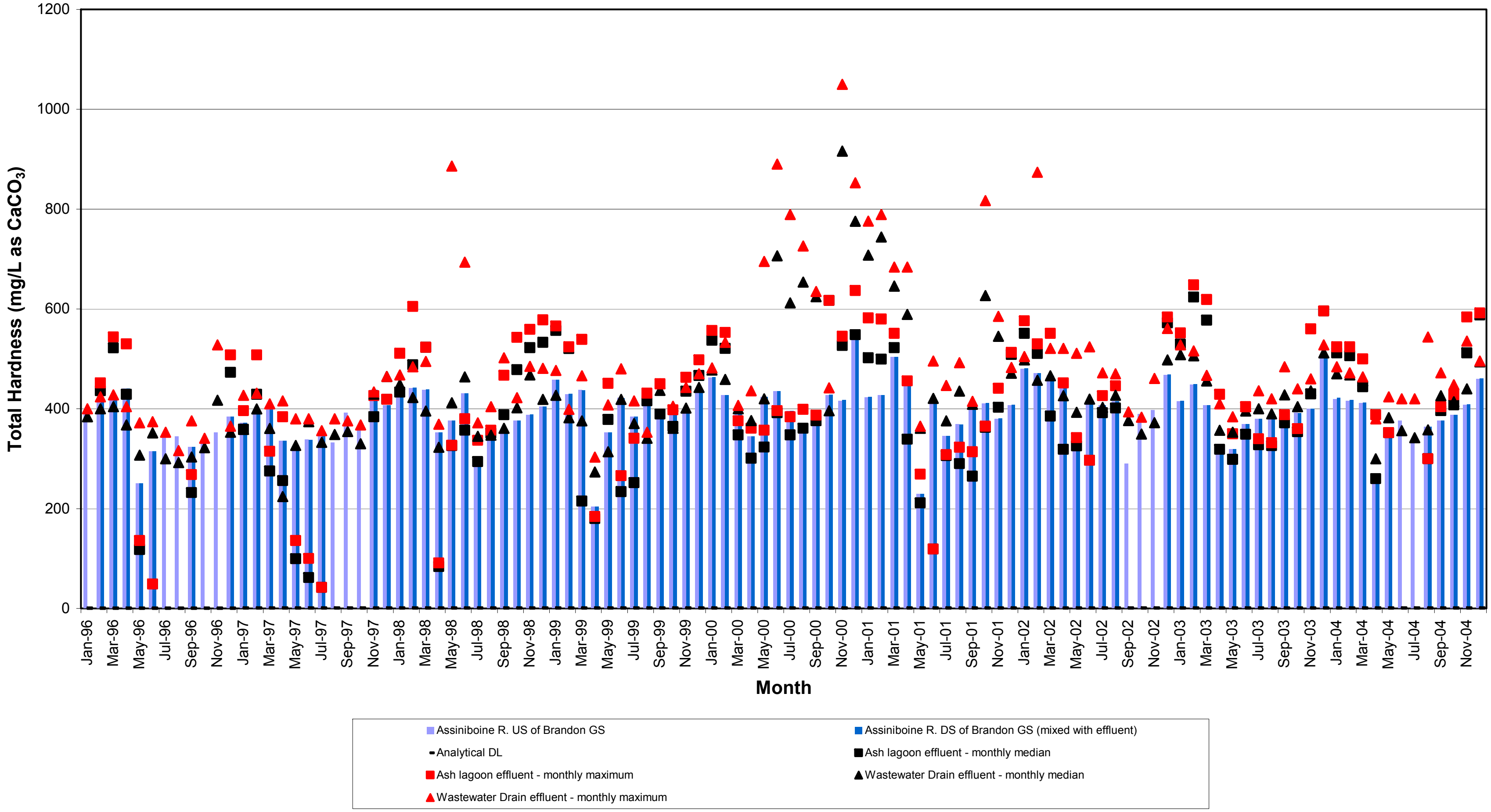

Figure 1.4 Comparison of hardness (as CaCO3) in the Assiniboine River and Brandon GS ash lagoon and station drain effluents (1996 - 2004). Note that there are no Manitoba Water Quality Objectives or Guidelines for hardness.

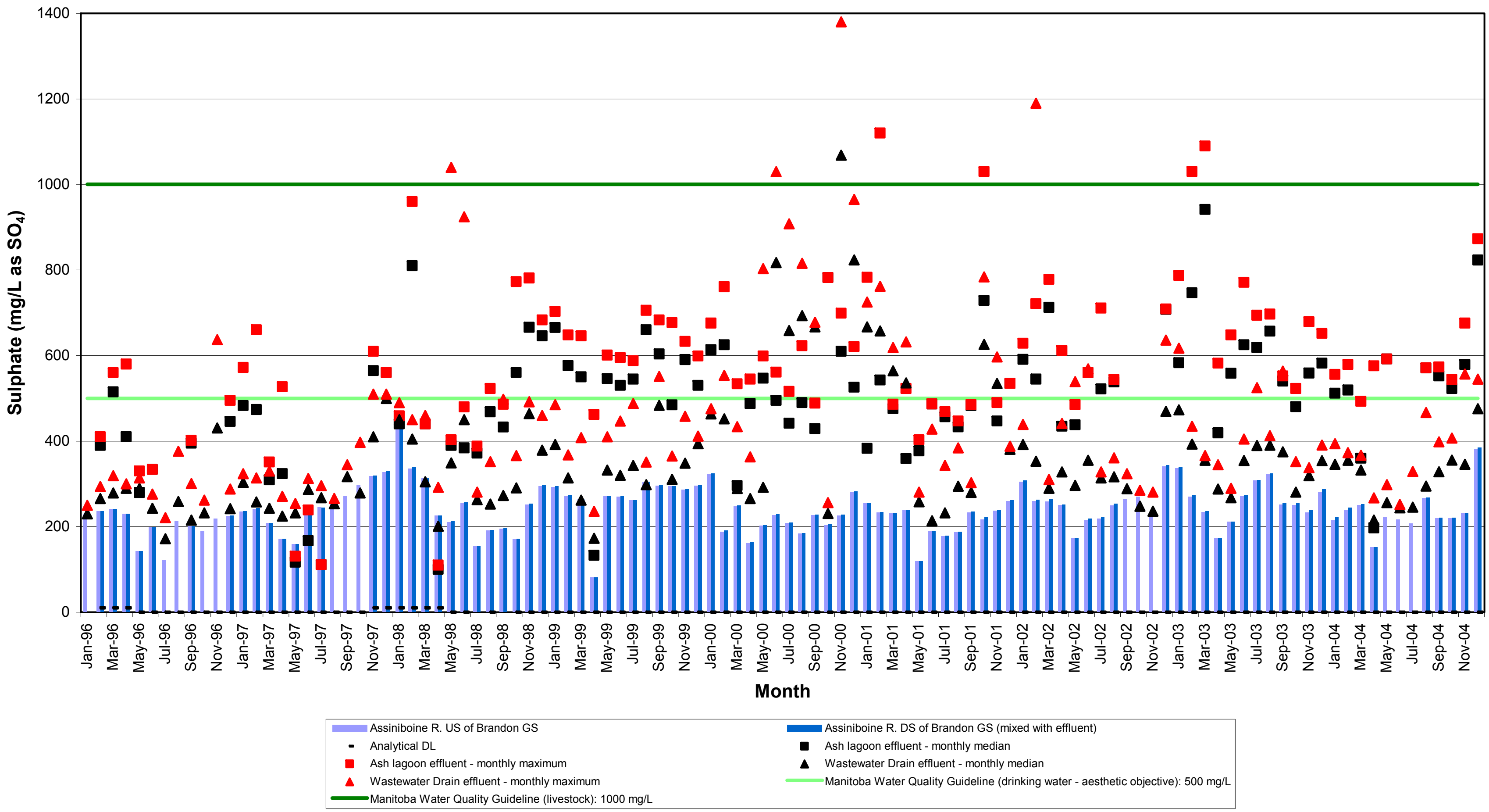

Figure 1.5 Comparison of sulphate concentrations in the Assiniboine River and Brandon GS ash lagoon and station drain effluents (1996 - 2004) with current Manitoba Water Quality Guidelines. The Guidelines pertain to river concentrations

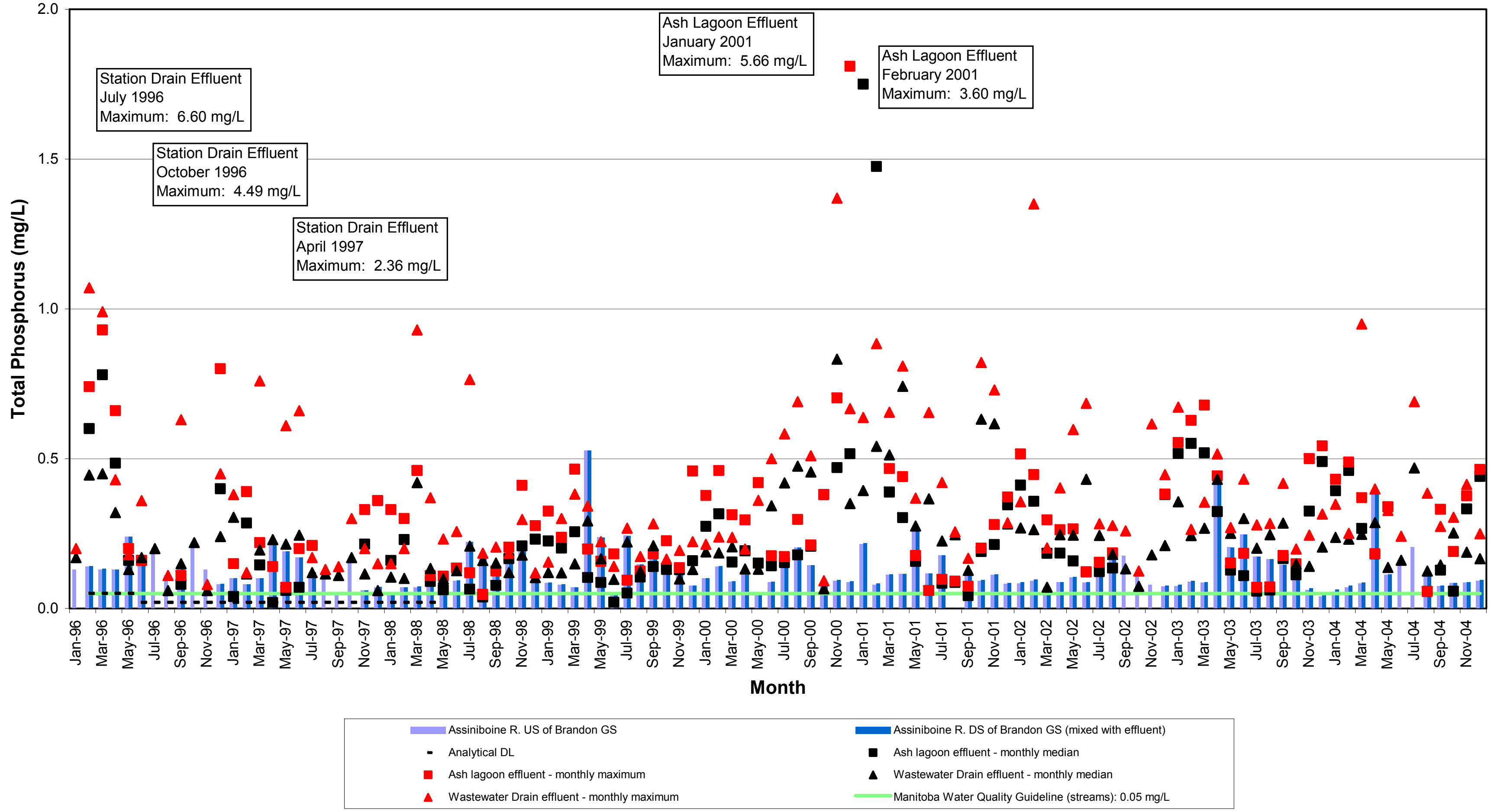

Figure 1.6 Comparison of total phosphorus concentrations in the Assiniboine River and Brandon GS ash lagoon and station drain effluents (1996 - 2004) with the current narrative Manitoba Water Quality Guideline for streams. The Guideline pertains to river concentrations.

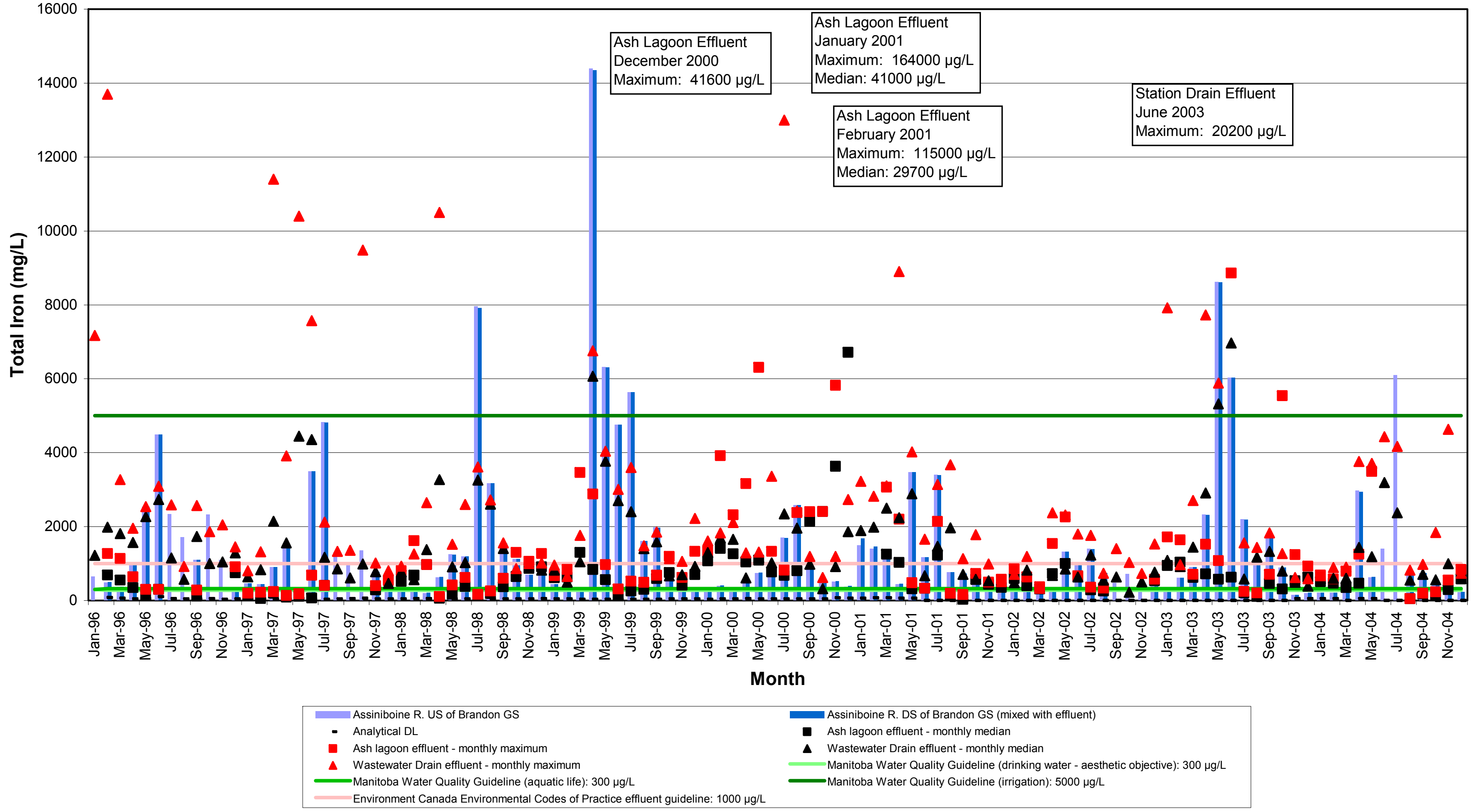

Figure 1.7 Comparison of total iron concentrations in the Assiniboine River and Brandon GS ash lagoon and station drain effluents (1996 - 2004) with the Environment Canada Environmental Codes of Practice guideline and current Manitoba Water Quality Guidelines. The Environment Canada guideline pertains to effluent concentrations; the Manitoba Water Quality Guidelines pertain to river concentrations.

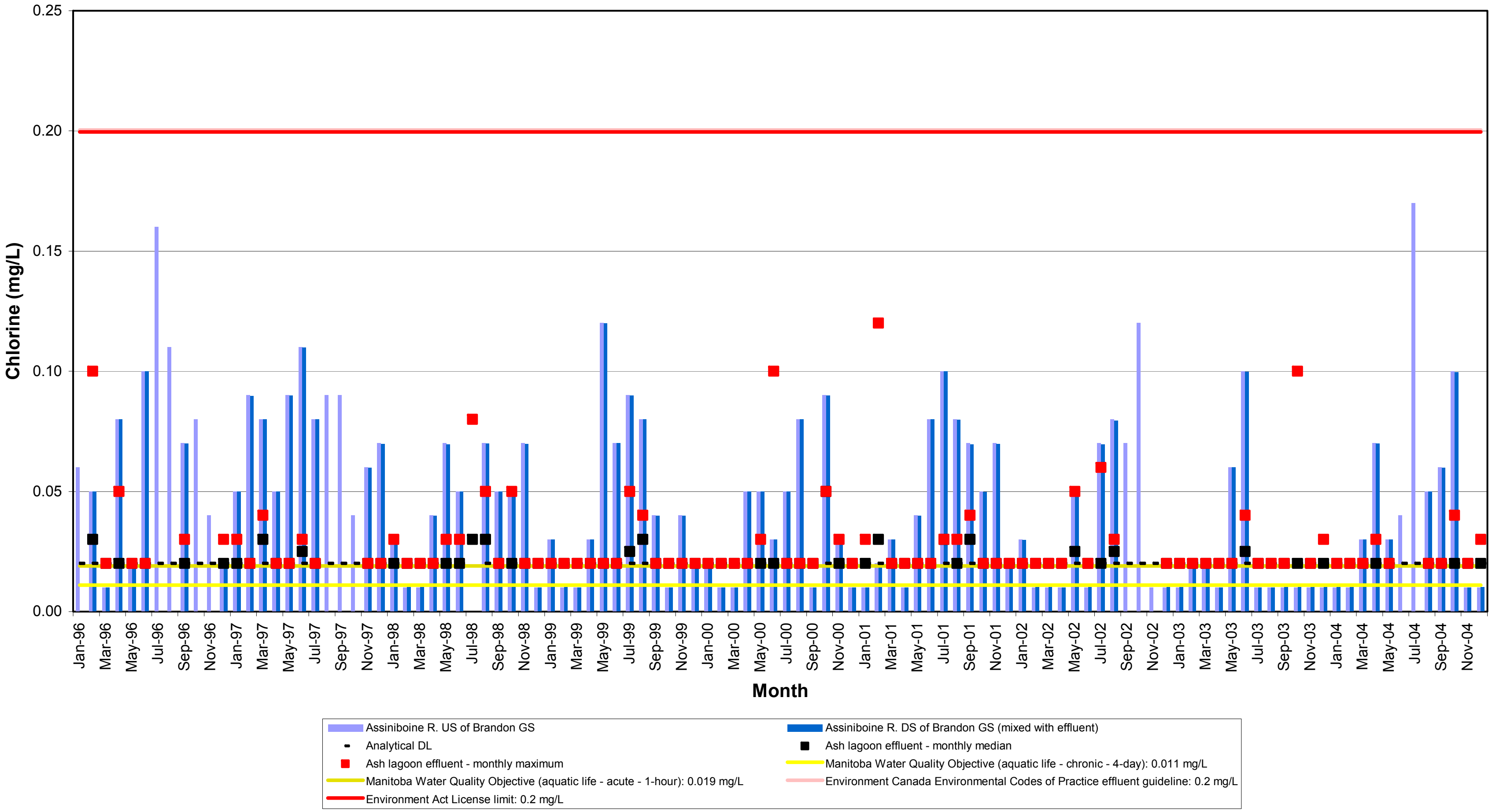

Figure 1.8 Comparison of total residual chlorine concentrations in the Assiniboine River and Brandon GS ash lagoon effluent (1996 - 2004) with the Environment Act Licence 1703R limit, Environment Canada Environmental Codes of Practice guideline, and current Manitoba Water Quality Objectives for the protection of aquatic life. The Licence limit and Environment Canada guideline pertain to effluent concentrations; the Manitoba Water Quality Objectives pertain to river concentrations.

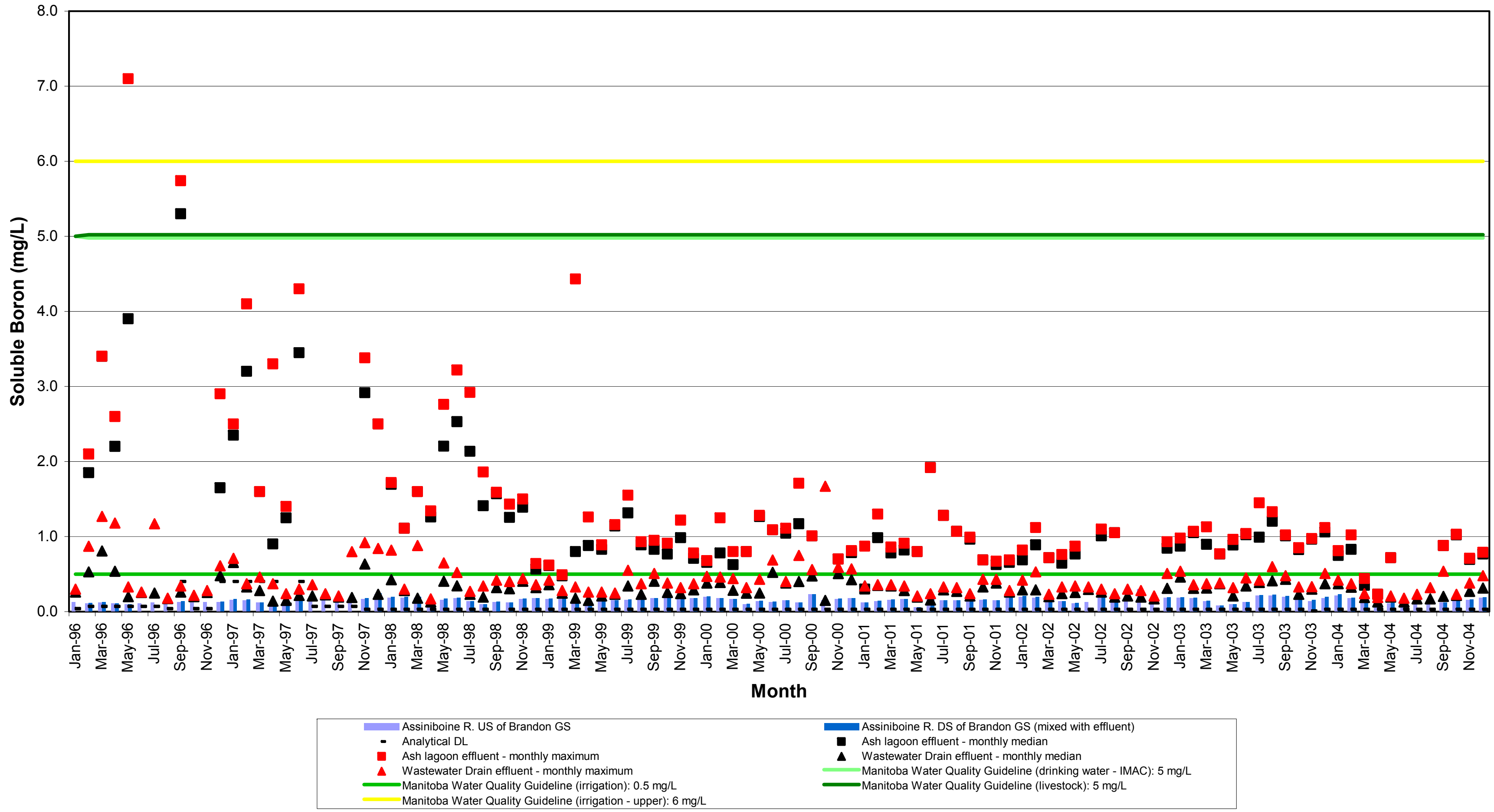

Figure 1.9 Comparison of soluble boron concentrations in the Assiniboine River and Brandon GS ash lagoon and station drain effluents (1996 - 2004) with current Manitoba Water Quality Guidelines. The Guidelines pertain to river concentrations. IMAC = Interim Maximum Acceptable Concentration. Note that all Guidelines refer to total concentrations.

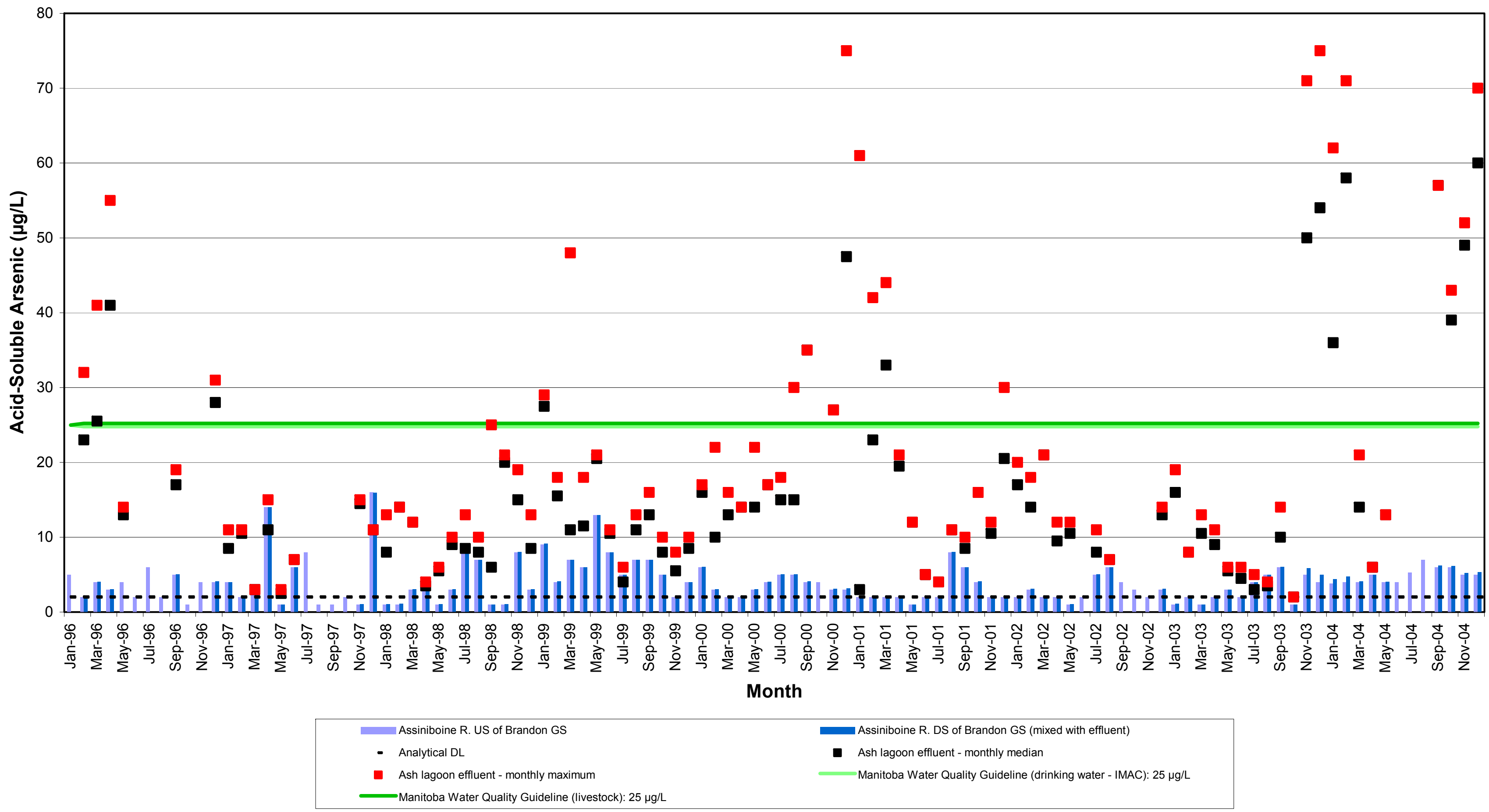

Figure 1.10 Comparison of acid-soluble arsenic concentrations in the Assiniboine River and Brandon GS ash lagoon effluent (1996 - 2004) with current Manitoba Water Quality Guidelines. The Guidelines pertain to river concentrations. IMAC = Interim Maximum Acceptable Concentration. Note that all Guidelines refer to total concentrations. The Manitoba Water Quality Objectives for arsenic (as dissolved arsenic) are 150 µg/L (4-day) and 240 µg/L (1 hour, not depicted).

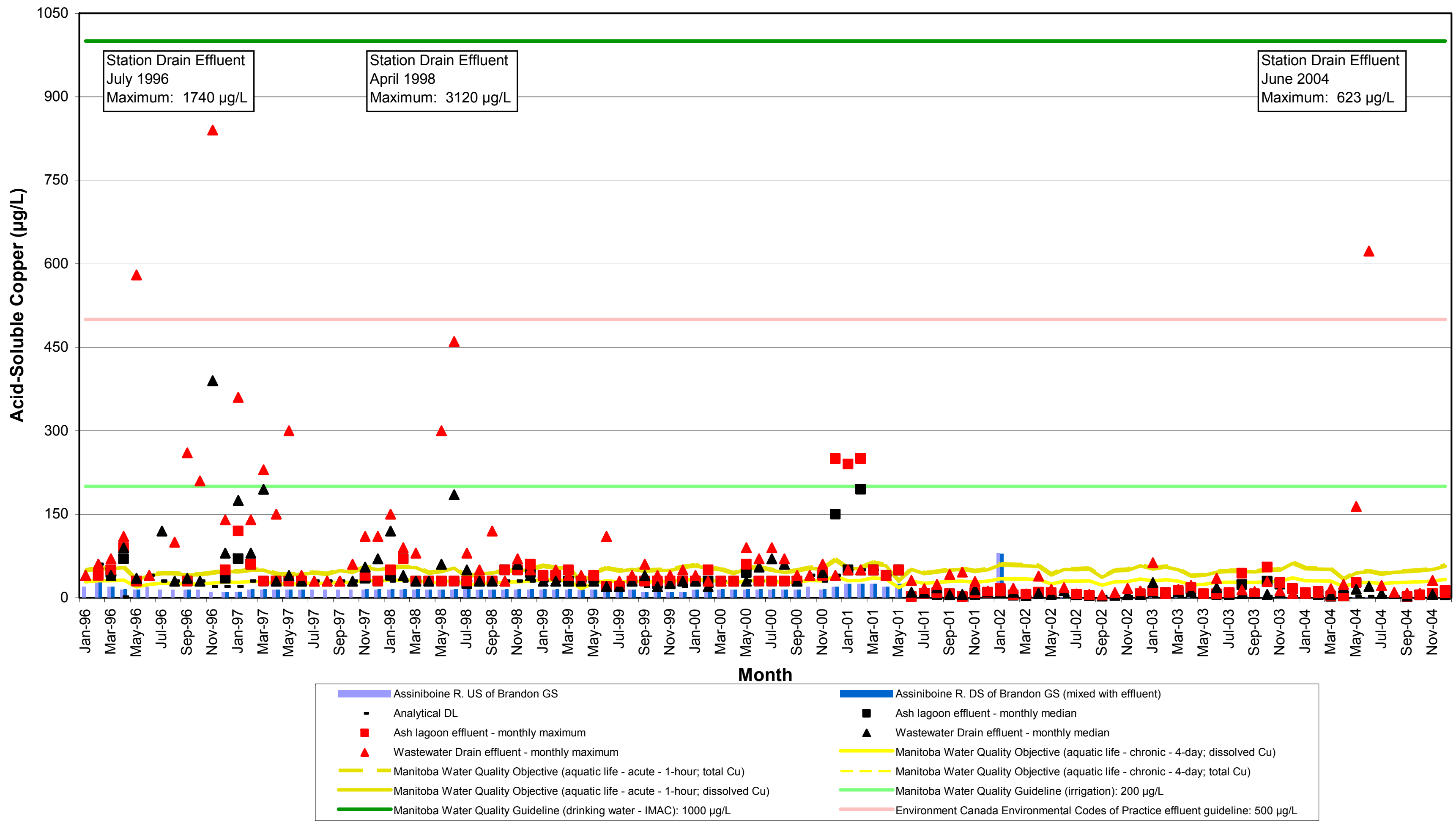

Figure 1.11 Comparison of acid-soluble copper concentrations in the Assiniboine River and Brandon GS ash lagoon and station drain effluents (1996 - 2004) with current Manitoba Water Quality Objectives and Guidelines. The Environment Canada guideline pertains to effluent concentration; the Manitoba Water Quality Objectives and Guidelines pertain to river concentrations. Note that the Manitoba Water Quality Objectives refer to total or dissolved concentrations, and the Environment Canada and Manitoba Water Quality Guidelines refer to total concentrations.

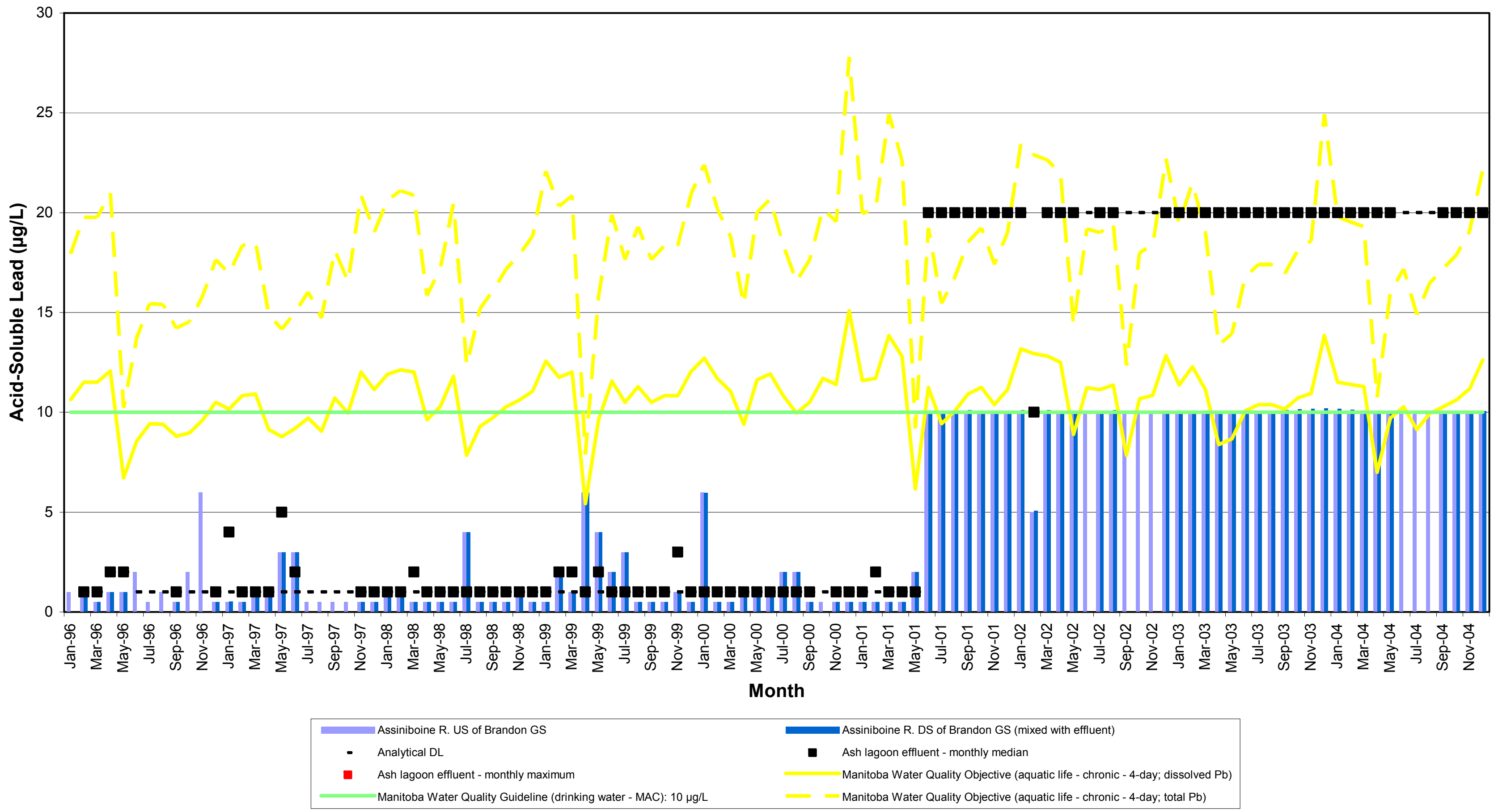

Figure 1.12 Comparison of acid-soluble lead concentrations in the Assiniboine River and Brandon ash lagoon effluent (1996 - 2004) with current Manitoba Water Quality Objectives and Guidelines. MAC = Maximum Acceptable Concentration. All Objectives and Guidelines pertain to river concentrations. Note that the Manitoba Water Quality Objectives refer to total or dissolved concentrations, and the Manitoba Water Quality Guidelines refer to total concentrations. 1-hour objectives for the protection of aquatic life are outside the range of the figure and are not depicted.

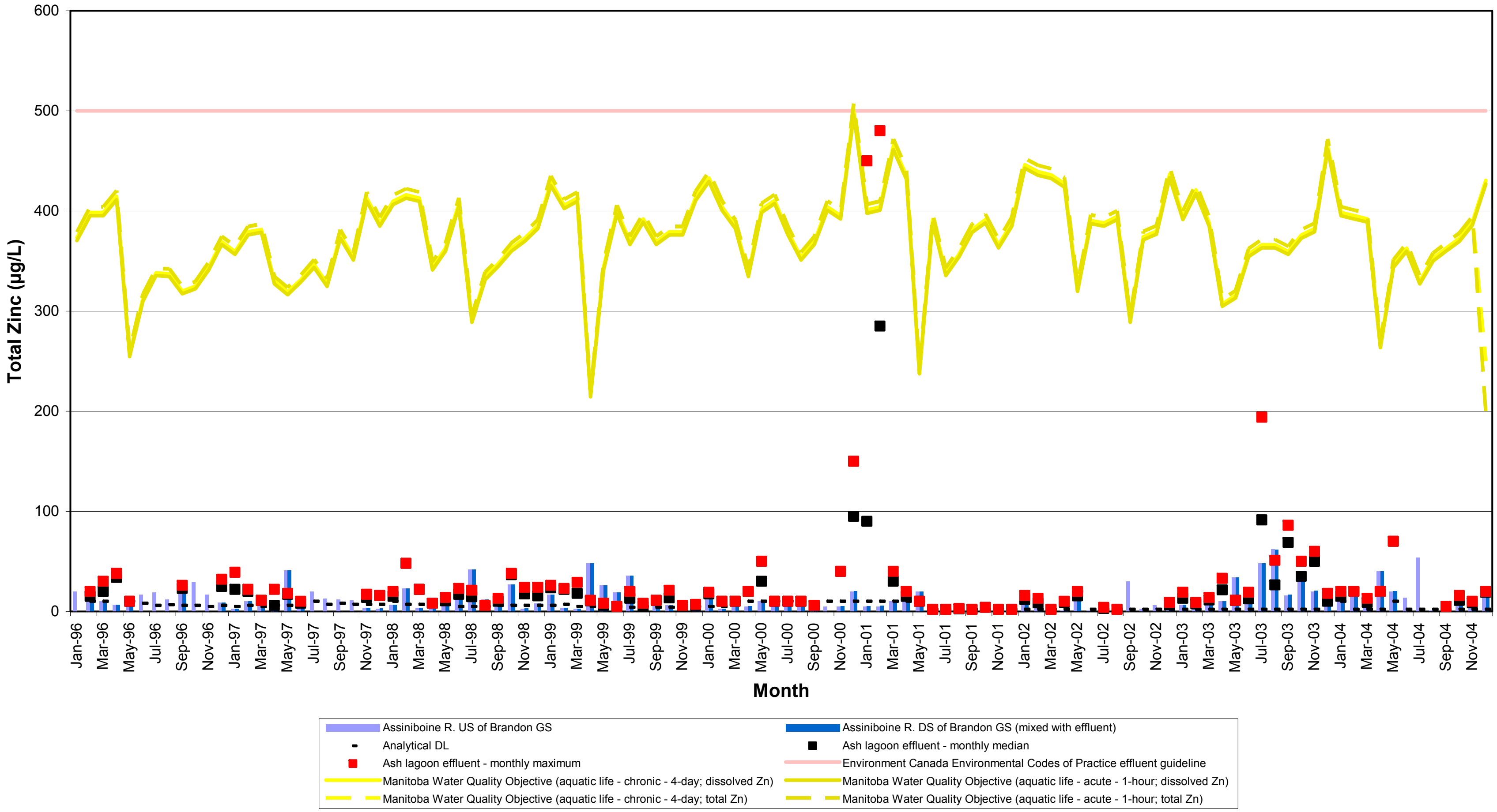

Figure 1.13 Comparison of total zinc concentrations in the Assiniboine River and Brandon GS ash lagoon effluent (1996 - 2004) with the Environment Canada Environmental Codes of Practice guideline and current Manitoba Water Quality Objectives and Guidelines. The Environment Canada guideline pertains to effluent concentration; the Manitoba Water Quality Objectives and Guidelines pertain to river concentrations. Note that the Manitoba Water Quality Objectives refer to total or dissolved concentrations.

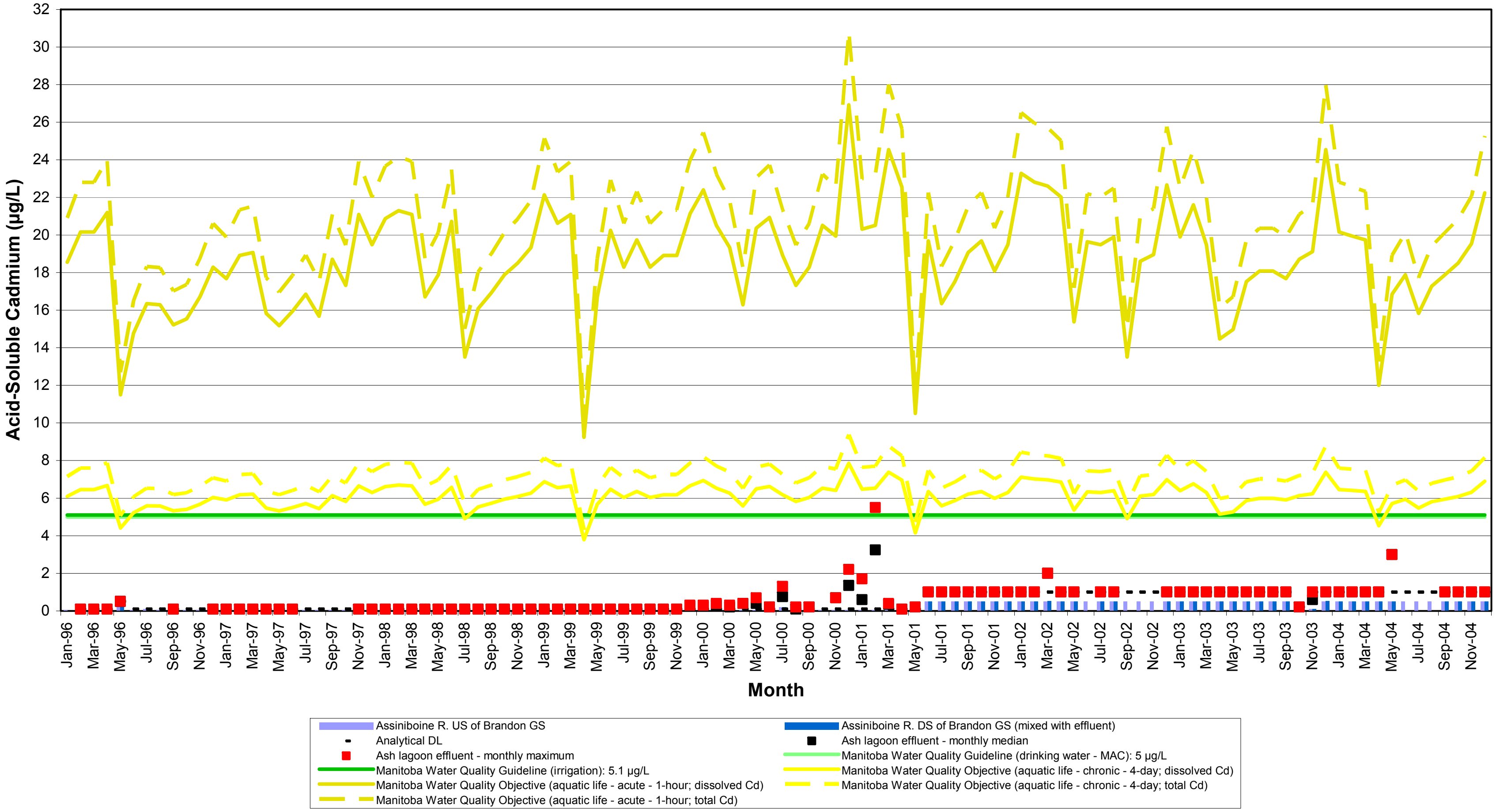

Figure 1.14 Comparison of acid-soluble cadmium concentrations in the Assiniboine River and Brandon GS ash lagoon effluent (1996 - 2004) with current Manitoba Water Quality Objectives and Guidelines. MAC = Maximum Acceptable Concentration. All Objectives and Guidelines pertain to river concentrations. Note that the Manitoba Water Quality Objectives refer to total or dissolved concentrations, and the Manitoba Water Quality Guidelines refer to total concentrations.

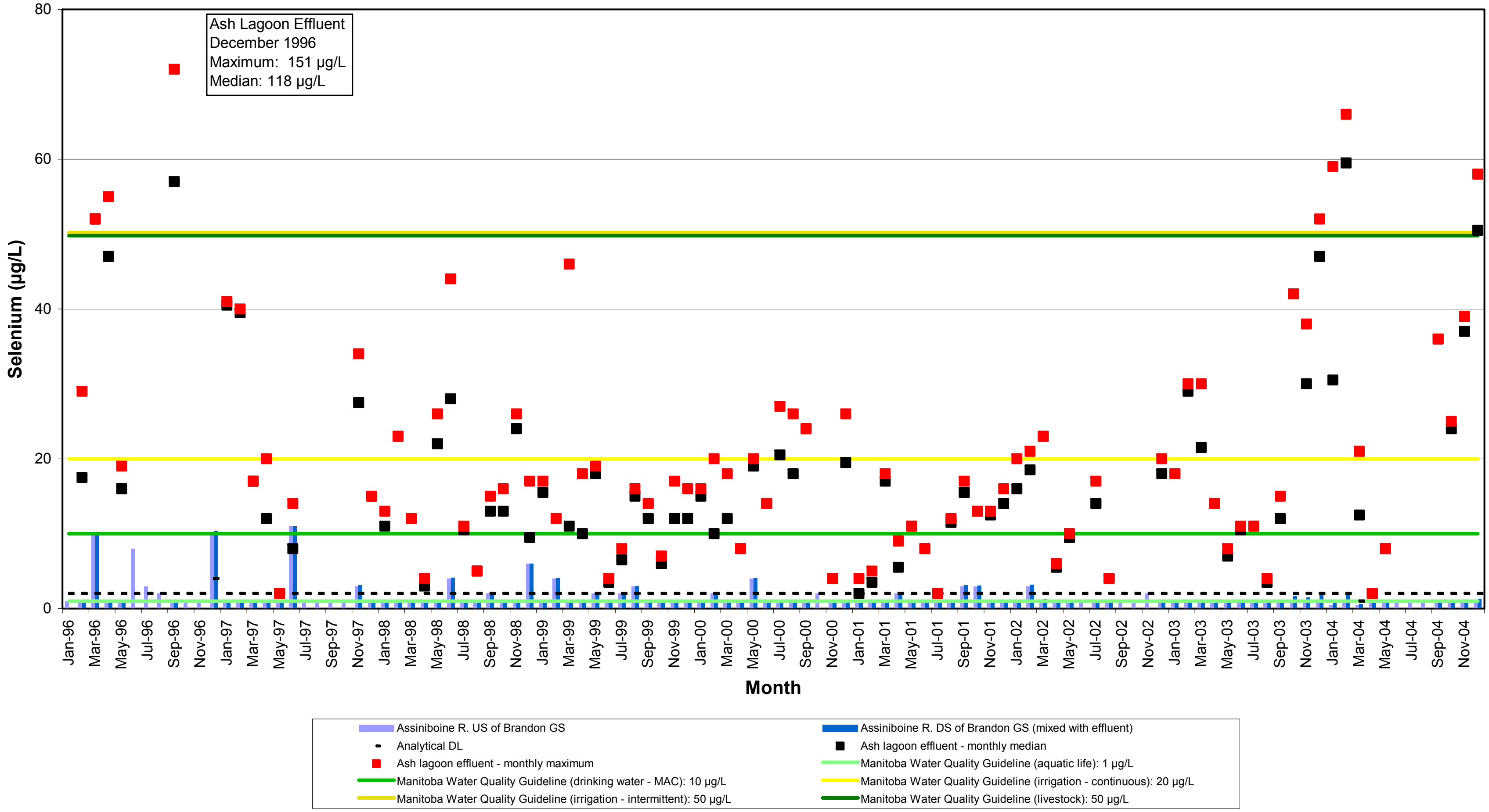

Figure 1.15 Comparison of total selenium concentrations in the Assiniboine River and Brandon GS ash lagoon effluent (1996 - 2004) with current Manitoba Water Quality Guidelines. The Guidelines pertain to river concentrations. MAC = Maximum Acceptable Concentration.

3.0 PROJECTION OF IMPACTS UNDER LOW-FLOW CONDITIONS

The potential effects of ash lagoon and station drain effluent discharge on water chemistry in the Assiniboine River were estimated by calculating the fully mixed river concentrations using monthly median effluent and river concentrations, maximum estimated daily effluent discharge rates, and median and low flow data for the Assiniboine River.

3.1 ASSESSMENT METHODS AND DATA SOURCES

3.1.1 River and effluent discharge data

Monthly median (1970 - 2000), $30Q_{10}$ (one-in-ten year, 30-day average low flow), $7Q_{10}$ (one-in-ten year, 7-day average low flow) and $1Q_{10}$ (one-in-ten year, 1-day average low flow) discharge data for the Assiniboine River at Brandon were obtained from MWS Water Science and Management Branch, and are presented in Table 1.1.

As described in Section 2.1.2, estimated maximum ash lagoon and station drain effluent discharges of 8,741 and 2,974 m^3/d, respectively, were used in the analysis.

3.1.2 Effluent concentrations

To determine the effects of the ash lagoon and station drain effluents on the river under median and low flow conditions, mass balance calculations similar to those described in Section 2.1.3 were conducted based on monthly median river and effluent concentrations calculated from data collected during 1996 - 2004.

As discussed in Section 2, the detection limits of the analytical methods used in portions of the datasets for some parameters were much higher than typical river and/or effluent concentrations observed in the samples analyzed with lower detection limits. For this reason, the following data were removed from the datasets when deriving the monthly river and effluent concentrations used in this section:

- Copper: All data prior to June 2001 were removed;
- Lead: All data after May 2001 were removed; and,
- Cadmium: All data after May 2001 were removed.

Table 1.1. Monthly median (1970 - 2000), $30Q_{10}$, $7Q_{10}$ and $1Q_{10}$ values for the Assiniboine River at Brandon (m^3/s).

	MEDIAN	$30Q_{10}$	$7Q_{10}$	$1Q_{10}$
January	14.89	6.44	6.14	6.03
February	15.49	5.60	6.18	6.11
March	19.60	5.74	3.11	2.83
April	61.25	9.65	6.04	3.96
May	53.15	6.55	5.78	5.27
June	33.51	5.78	4.92	4.51
July	28.71	5.56	4.43	4.02
August	16.11	3.79	3.92	3.83
September	12.16	3.34	3.00	2.83
October	14.72	4.32	3.00	2.83
November	16.10	5.77	4.60	3.65
December	14.61	6.27	5.60	5.29

Additionally, due to the high analytical detection limits for Se, data collected by MWS in the Assiniboine River near Brandon were used to represent 'background' river conditions. The median value for measurements collected from 2002-2004 (when the analytical detection limit was consistently 0.2 µg/L) was applied for Se mass-balance calculations.

As discussed in the report "Air Quality Impact Assessment Brandon Unit 5 Licence Review" the sources of coal in future may be different from those used during the period 1996 - 2004. The afore-mentioned report provides a listing of the concentrations of five parameters measured in the effluent that would be higher in some of the potential coal source relative to the current coal source (boron, cadmium, copper, lead, and selenium). Concentrations of boron, cadmium, copper, lead, and selenium were 47, 50, 61, 21, and 4% higher in the ash produced from the new coal sources relative to the current coal source, respectively. The effect of switching to the new coal source on fully mixed concentrations in the Assiniboine River was calculated by multiplying the median monthly concentrations of the ash lagoon effluent by factors of 1.47, 1.50, 1.61, 1.21, and 1.04 for boron, cadmium, copper, lead, and selenium, respectively. For brevity, this analysis is referred to as the "new coal" source though no single coal was represented by this analysis.

3.2 *RESULTS: PROJECTED CONCENTRATIONS AT LOW FLOWS*

Figures 2.1 – 2.15 present the monthly median river concentrations and projected (based on monthly median effluent concentrations adjusted as indicated above) fully mixed concentrations in the

Assiniboine River of parameters monitored in the river, ash lagoon effluent, and station drain effluent, with comparison to MWQSOGs. Fully mixed river concentrations were projected using $1Q_{10}$, $7Q_{10}$, and $30Q_{10}$ design flows as well as monthly median discharge (1970 - 2000). As discussed in Section 2.2, whereas the data collected by Manitoba Hydro (presented below) represent the acid-soluble fractions of copper, lead and cadmium and total concentrations for zinc, the Manitoba Water Quality Objectives for these metals for the protection of aquatic life can be expressed as either dissolved or total forms, but not as the acid-soluble fractions. The Water Quality Objectives for As for the protection of aquatic life are expressed as the dissolved form only. Also as previously indicated, Manitoba Water Quality Guidelines refer to total concentrations. The acid-soluble fractions of metals likely represent a concentration that falls somewhat intermediate between the dissolved and total forms of the metals. Therefore, comparisons between the measured values and Objectives and Guidelines should be considered approximate.

For the sake of brevity, the following discussions refer largely to $1Q_{10}$ design flows because the ash lagoon and station drain effluents would have the greatest effect on fully mixed river concentrations under these conditions. Should the mass-balance modeling estimates indicate that all water quality criteria would be met under this low flow condition, they would necessarily be met under higher flow conditions.

3.2.1 pH

Based on monthly median background river pH, monthly median ash lagoon effluent pH from June 2001 to December 2004 (after installation of pH controls), and station drain effluent pH from 1996 to 2004, the pH in the Assiniboine River would increase by a maximum of 0.000001% (February) or 0.018 pH units (March) under $1Q_{10}$ river flows (Figure 2.1). The effluent would not cause pH in the river to exceed any MWQSOGs. However, the background pH, based on monthly median values, exceeds the aesthetic guideline for drinking water in September, October and November. At these times, the effluents would alter pH by considerably less than 1% and in some instances would actually lower pH. River pH would remain within the Manitoba Water Quality Guidelines for the protection of aquatic life and recreation in all months and under all flows.

3.2.2 Total Dissolved Solids (TDS)

Based on monthly median background river concentrations ash lagoon and station drain effluent concentrations, TDS concentrations in the Assiniboine River would increase by a maximum of 2.2% or 15 mg/L (in November) under $1Q_{10}$ river flows (Figure 2.2).

Existing conditions in the river (i.e., upstream water quality) are such that the aesthetic guideline for drinking water is not met in any month Additionally, the guideline for greenhouse irrigation is exceeded under background conditions, and the TDS concentrations are projected to increase slightly more downstream of the effluent discharges, in January, February, March, and December. In the open-water season, the effluents would slightly increase TDS concentrations in the river but would only cause the guideline for greenhouse irrigation to be marginally exceeded (i.e., increased to 703 mg/L) in August under $1Q_{10}$, $7Q_{10}$, and $30Q_{10}$ flows and under $1Q_{10}$ flows in November. The guideline for field irrigation would be consistently met in the river.

3.2.3 Total Suspended Solids (TSS)

Based on monthly median background river concentrations and ash lagoon effluent concentrations, TSS concentrations in the Assiniboine River would increase by a maximum of 3% (November) and 0.61 mg/L (March) under $1Q_{10}$ river flows (Figure 2.3). Discharge of the ash lagoon effluent is not projected to result in an exceedence of the Manitoba Water Quality Objectives for the protection of aquatic life in any month or under any flow scenario. In fact, effluent discharge from the ash lagoon effluent is predicted to slightly reduce fully mixed TSS concentrations in the Assiniboine River from April to September under $1Q_{10}$ river flows.

3.2.4 Total Hardness

Hardness in the Assiniboine River is projected to be marginally increased as a result of discharge of the ash lagoon and station drain effluents in the fully mixed portion of the river under most flow conditions and months. However, as the effluent concentrations are at times lower than those in the river (e.g., June and July), hardness is projected to be slightly reduced in some months. The maximum magnitude of change is a decrease of approximately 0.8% in June under low flow (i.e., $1Q_{10}$). As hardness is not inherently detrimental to aquatic life or water uses, no MWQSOGs exist for this parameter, and it is monitored primarily to allow the determination of objectives for other parameters (e.g. metals).

3.2.5 Sulphate

Discharge of the ash lagoon and station drain effluents would slightly increase (maximum increase of 5.6% in October) sulphate concentrations in the Assiniboine River but would not result in an exceedence of the aesthetic guideline for drinking water or for livestock watering (Figure 2.5).

3.2.6 Phosphorus

Monthly median phosphorus concentrations in the Assiniboine River exceed the narrative Manitoba Water Quality Guideline for streams (0.05 mg/L) in all months prior to receiving effluent discharge from the ash lagoon and station drain (Figure 2.6). The ash lagoon and station drain effluents would increase phosphorus concentrations in the Assiniboine River by a maximum of 9.7% or 0.008 mg/L (in March) under $1Q_{10}$ river flows (Figure 2.6).

3.2.7 Iron

Monthly median iron concentrations in the Assiniboine River exceed the Manitoba Water Quality Guidelines for drinking water and aquatic life (300 µg/L) in all months (Figure 2.7). Ash lagoon and station drain effluents (based on median concentrations) would increase iron concentrations in the Assiniboine River by a maximum of 6.6% under $1Q_{10}$ flows (March; Figure 2.7). Conversely, the effluents are predicted to cause a slight reduction in iron concentrations in the river in the open-water season (April - October). The guideline for irrigation would be met under all conditions.

3.2.8 Residual Chlorine

Monthly median residual chlorine concentrations in the Assiniboine River exceed the acute (1-hour) and chronic (4-day) Manitoba Water Quality Objectives for the protection of aquatic life in all months except February, March, and December (Figure 2.8). Under $1Q_{10}$ flows and based on monthly median background river concentrations and maximum monthly median ash lagoon effluent concentrations from 1996 to 2004, residual chlorine concentrations in the Assiniboine River are predicted to increase by a maximum of 3.6% (in March; Figure 2.8). However, in all but three months (February, March, and December), ash lagoon effluent discharge is predicted to decrease the concentration of residual chlorine in the Assiniboine River, as the median concentrations in most months are lower in the ash lagoon effluent than the river.

3.2.9 Boron

Ash lagoon (adjusted for the new coal) and station drain effluents are predicted to increase boron concentrations in the river by a maximum of 32% or 0.05 mg/L in March under $1Q_{10}$ river flows (Figure 2.9). In all months, the projected fully mixed river concentrations are well below all Manitoba Water Quality Guidelines (i.e., the interim maximum acceptable drinking water quality guideline and guidelines for irrigation and livestock watering, Figure 2.9).

3.2.10 Arsenic

Predicted effects of the ash lagoon and station drain effluents on As in the river indicate that the effluents would not cause any increases in water quality objectives or guidelines (i.e., interim maximum acceptable concentration for drinking water and the guidelines for livestock watering and the protection of aquatic life) and only marginal absolute changes to concentrations; the maximum change relative to background would occur in October under $1Q_{10}$ flows where As would be increased by 15.5% (Figure 2.10).

3.2.11 Copper

Similar to arsenic, predicted effects of the ash lagoon (based on the new coal) and station drain effluents on Cu in the river indicate that the effluents would not cause any increases in water quality objectives and only marginal absolute changes to concentrations; the maximum change relative to background would occur in March under $1Q_{10}$ flows where Cu would be increased by 36%, or approximately 0.36 µg/L (Figure 2.10).

3.2.12 Lead

In all months, the fully mixed river concentrations are predicted to remain well below the acute [1-hour] and chronic [4-day] Manitoba Water Quality Objectives for the protection of aquatic life, as well as the maximum acceptable concentration for drinking water of 10 µg/L, the guideline for irrigation of 200 µg/L, and the guideline for livestock watering of 100 µg/L, even considering potentially higher than current lead levels in the effluent as a result of a new coal source (Figure 2.12). The maximum magnitude of change in lead concentrations in the Assiniboine River would occur in March, September, and October (approximately a 5% increase is projected) under low flows which represents an absolute increase of approximately 0.03 µg/L. In June and July the ash lagoon effluent discharge is predicted to decrease the concentration of lead in the Assiniboine River. Overall, predicted effects would likely be undetectable.

3.2.13 Zinc

Projected effects of the ash lagoon and station drain effluents on, zinc concentrations in the Assiniboine River indicate a marginal increase or decrease (depending on the month); the maximum increase is predicted to be approximately 5% or 0.25 µg/L above background (November) under $1Q_{10}$ river flows (Figure 2.13). In all months, the fully mixed river concentrations would remain well below the acute [1-hour] and chronic [4-day] Manitoba Water Quality Objectives for the protection of aquatic life (Figure 2.13), and, therefore, also the guidelines for drinking water (aesthetic), irrigation, and livestock watering which are an order of magnitude higher than those for aquatic life.

3.2.14 Cadmium

Monthly median background river concentrations of cadmium are low and typically represent values below the analytical detection limit. Although median ash lagoon effluent concentrations adjusted for the new coal source are higher than upstream river concentrations, discharge of the effluent has a negligible effect on fully mixed concentrations under all flows and months (Figure 2.14). In fact, predicted fully mixed concentrations are lower than the analytical detection limit for the associated datasets indicating that the effects would likely be of insufficient magnitude to result in detection of

Cd. All predicted concentrations are also well below Manitoba Water Quality Objectives and Guidelines for drinking water, irrigation, livestock watering, and aquatic life.

3.2.15 Selenium

Monthly median (1996 - 2004) selenium concentrations in the Assiniboine River were generally below the analytical detection limit of 2 µg/L. As the analytical detection limit exceeded the Manitoba Water Quality Guideline of 1.0 µg/L for the protection of aquatic life, the background river dataset collected by Manitoba Hydro was not sufficient to quantitatively examine the potential effects of effluent discharges on concentrations in the river and compliance with guidelines. As a result, Se measurements collected by MWS in the Assiniboine River upstream of the Brandon GS, which employed a more sensitive analytical detection limit of 0.2 µg/L, were used to define background conditions. The median concentration from 2002-2004 (the period for which the analytical detection limit of 0.2 µg/L was applied) was <0.2 µg/L; to provide a more conservative approach, background conditions were assigned a concentration of 0.2 µg/L (i.e., value at the detection limit).

This analysis indicates that the ash lagoon effluent (incorporating the marginally higher values in the new coal) would notably increase Se concentrations in the fully mixed portion of the river under all Q_{10} flow conditions, particularly in March, September, October, and November. The maximum percentage increase is predicted to be approximately 343%, or an absolute increase of 0.69 µg/L, in November under $1Q_{10}$ flows. Despite the projected magnitude of increases in selenium, the effluent is not predicted to result in an exceedence of the most stringent water quality objective (i.e., 1.0 µg/L for the protection of aquatic life) under any flows. However, the historical record of Se concentrations measured in the Assiniboine River by MWS indicates that exceedences of the guideline for the protection of aquatic life occur upstream of the station on occasion (i.e., three measurements in the period of 1999 - 2004) and discharge of the effluent would increase the concentrations further, thus exacerbating a pre-existing condition. Mass balance analysis indicates that guidelines for drinking water, irrigation, and livestock watering would be met in the river.

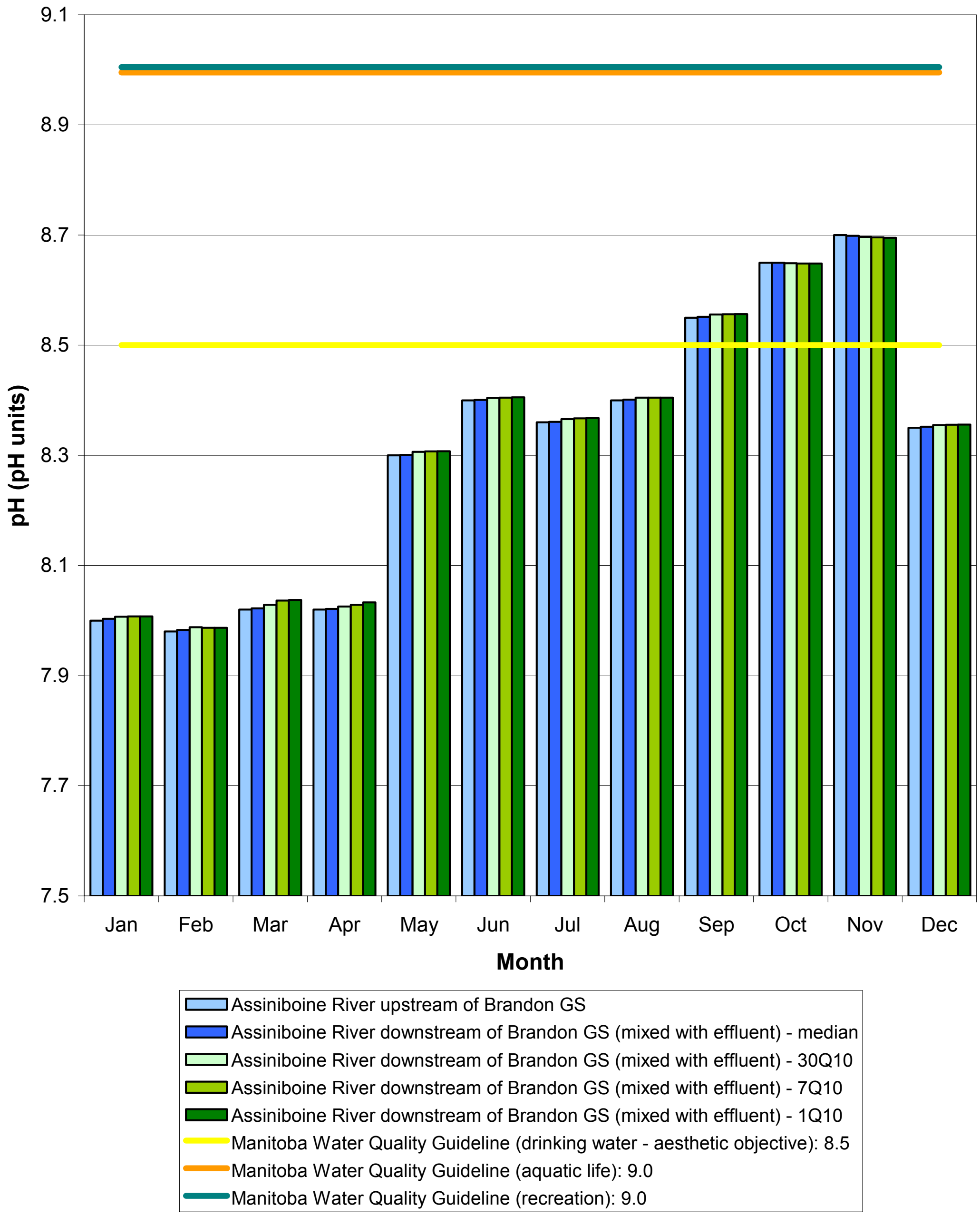

Figure 2.1 Projected fully mixed pH in the Assiniboine River at median (1970 - 2000), $30Q_{10}$, $7Q_{10}$, and $1Q_{10}$ flows, based on monthly median upstream river concentrations (June 2001-December 2004) and monthly median concentrations from the Brandon GS ash lagoon and station drain effluents between 1996 and 2004, with comparison to current Manitoba Water Quality Guidelines (upper limits). Water quality guidelines depicted represent the upper pH limit indicated in Williamson (2002); all values for pH are above the lower limits of pH indicated in the guidelines (i.e., above 6.5).

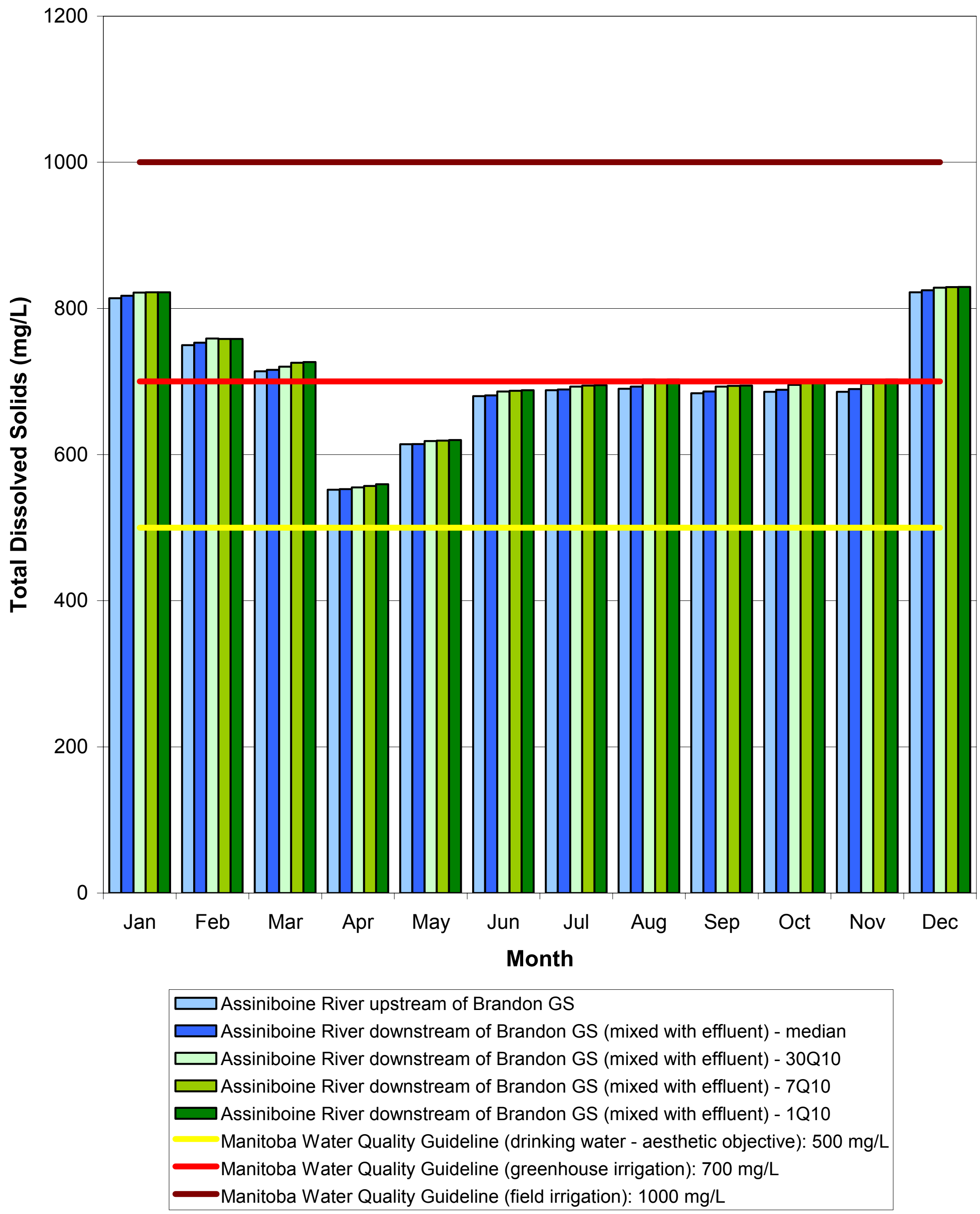

Figure 2.2 Projected fully mixed concentrations of total dissolved solids in the Assiniboine River at median (1970 - 2000), $30Q_{10}$, $7Q_{10}$, and $1Q_{10}$ flows, based on monthly median upstream river concentrations and monthly median concentrations from the Brandon GS ash lagoon and station drain effluents between 1996 and 2004, with comparison to current Manitoba Water Quality Objectives and Guidelines.

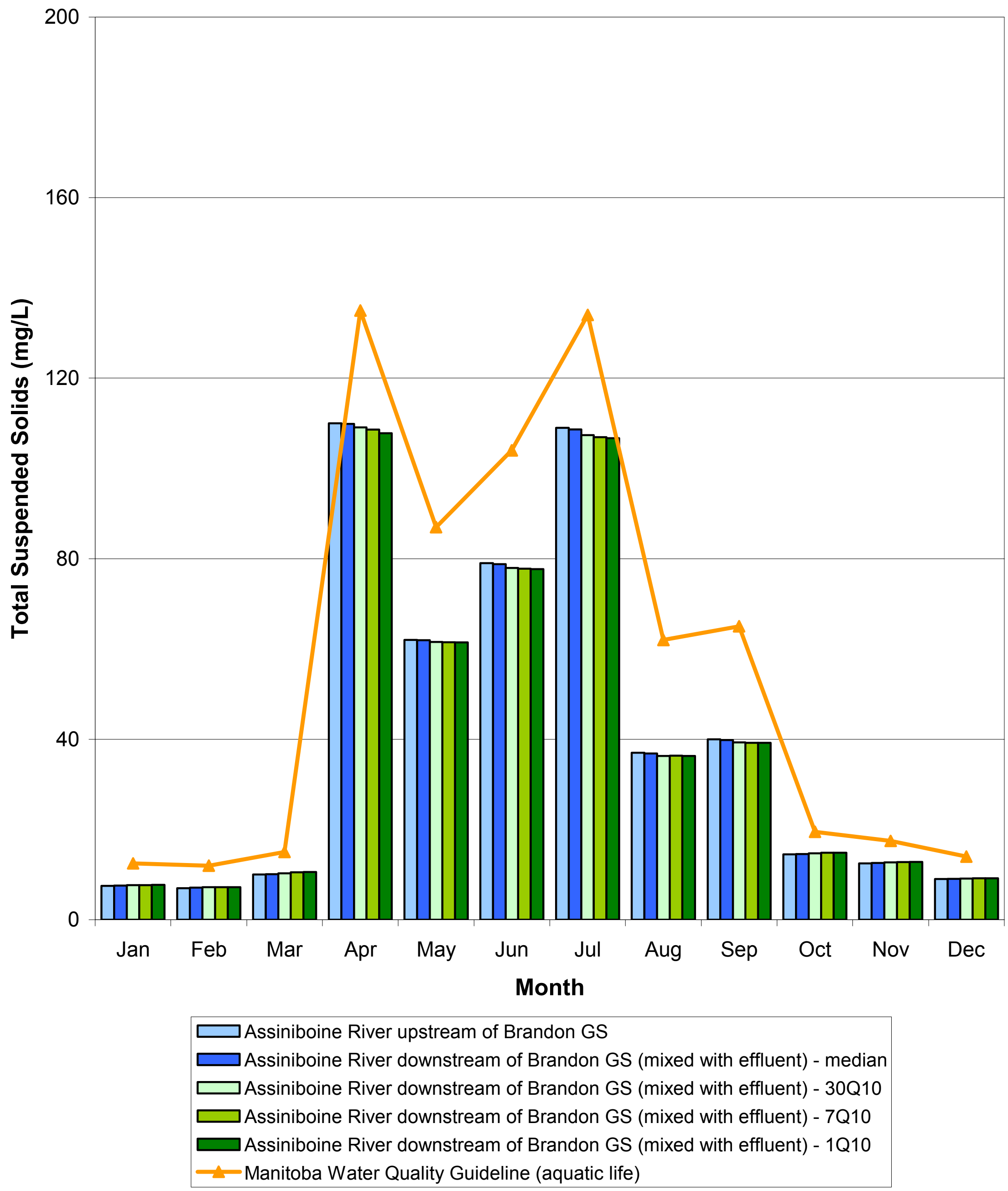

Figure 2.3 Projected fully mixed concentrations of total suspended solids in the Assiniboine River at median (1970 - 2000), $30Q_{10}$, $7Q_{10}$, and $1Q_{10}$ flows, based on monthly median upstream river concentrations and maximum monthly median concentrations from the Brandon GS ash lagoon effluent between 1996 and 2004, with comparison to the current Manitoba Water Quality Objective for the protection of aquatic life.

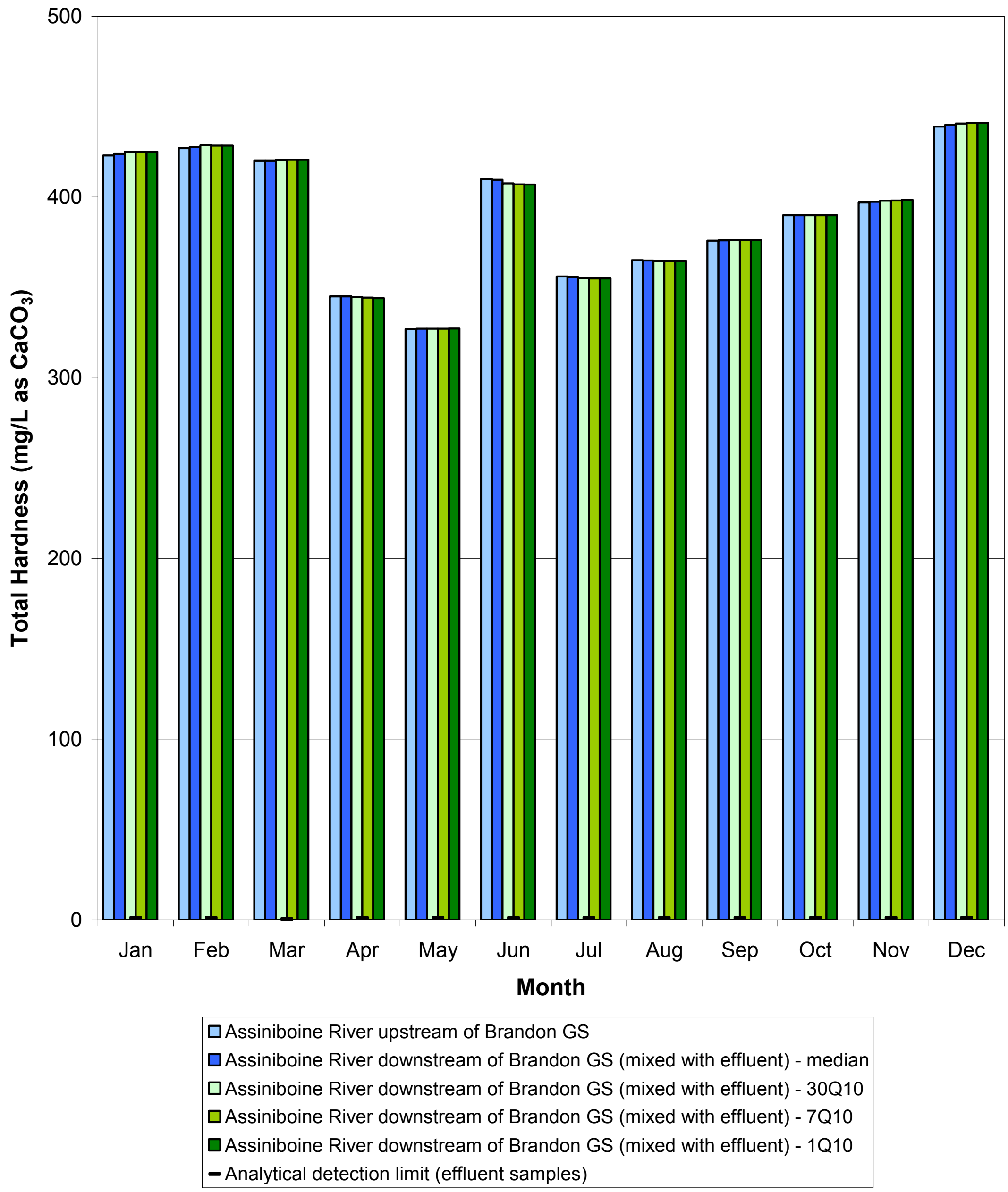

Figure 2.4 Projected fully mixed total hardness in the Assiniboine River at median (1970 - 2000), $30Q_{10}$, $7Q_{10}$, and $1Q_{10}$ flows, based on monthly median upstream river concentrations and monthly median concentrations from the Brandon GS ash lagoon and station drain effluents between 1996 and 2004. Note that there are no Manitoba Water Quality Guidelines or Objectives for hardness.

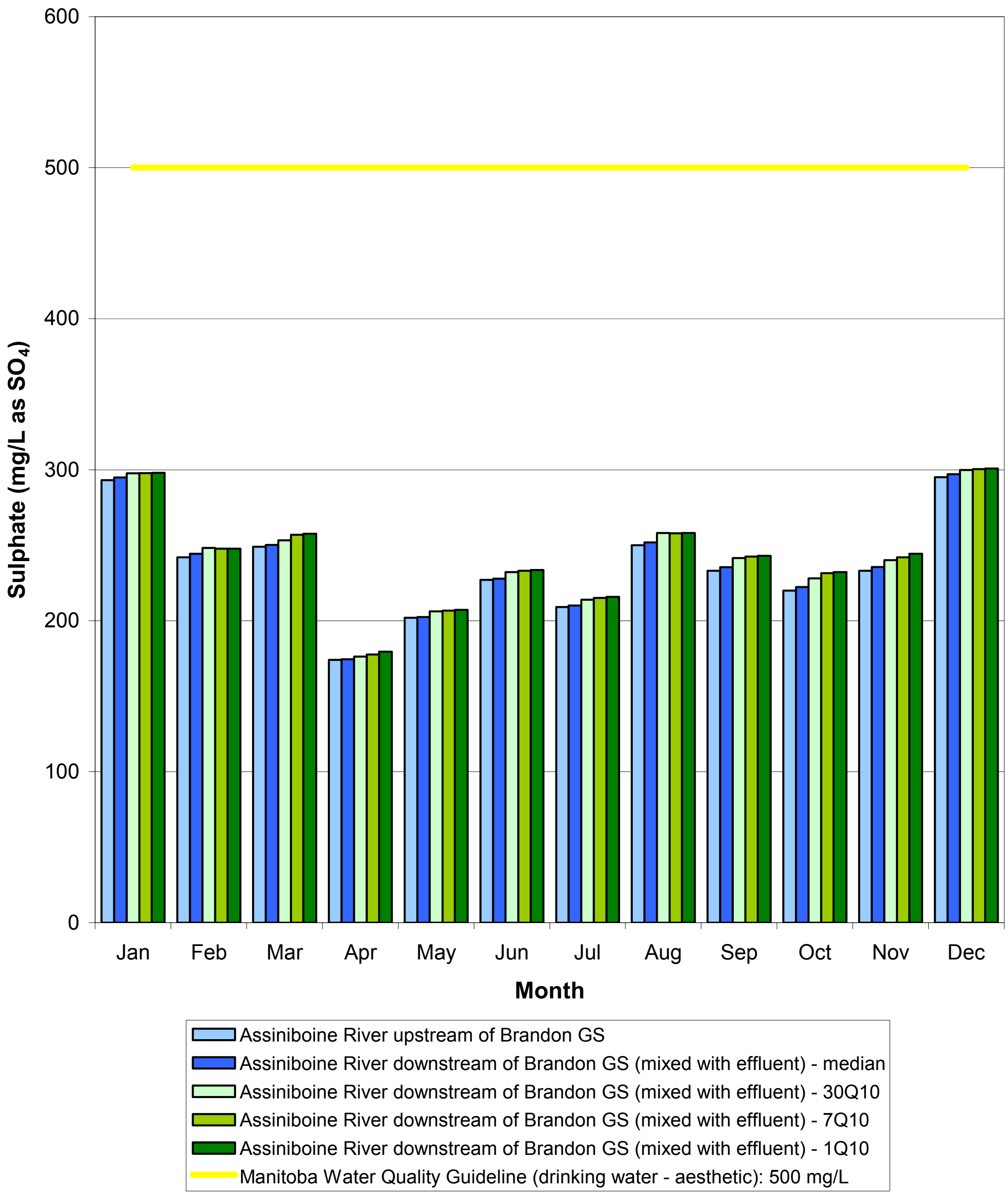

Figure 2.5 Projected fully mixed concentrations of sulphate in the Assiniboine River at median (1970 - 2000), $30Q_{10}$, $7Q_{10}$, and $1Q_{10}$ flows, based on monthly median upstream river concentrations and monthly median concentrations from the Brandon GS ash lagoon and station drain effluents between 1996 and 2004, with comparison to the current Manitoba Water Quality Guideline for drinking water (aesthetic).

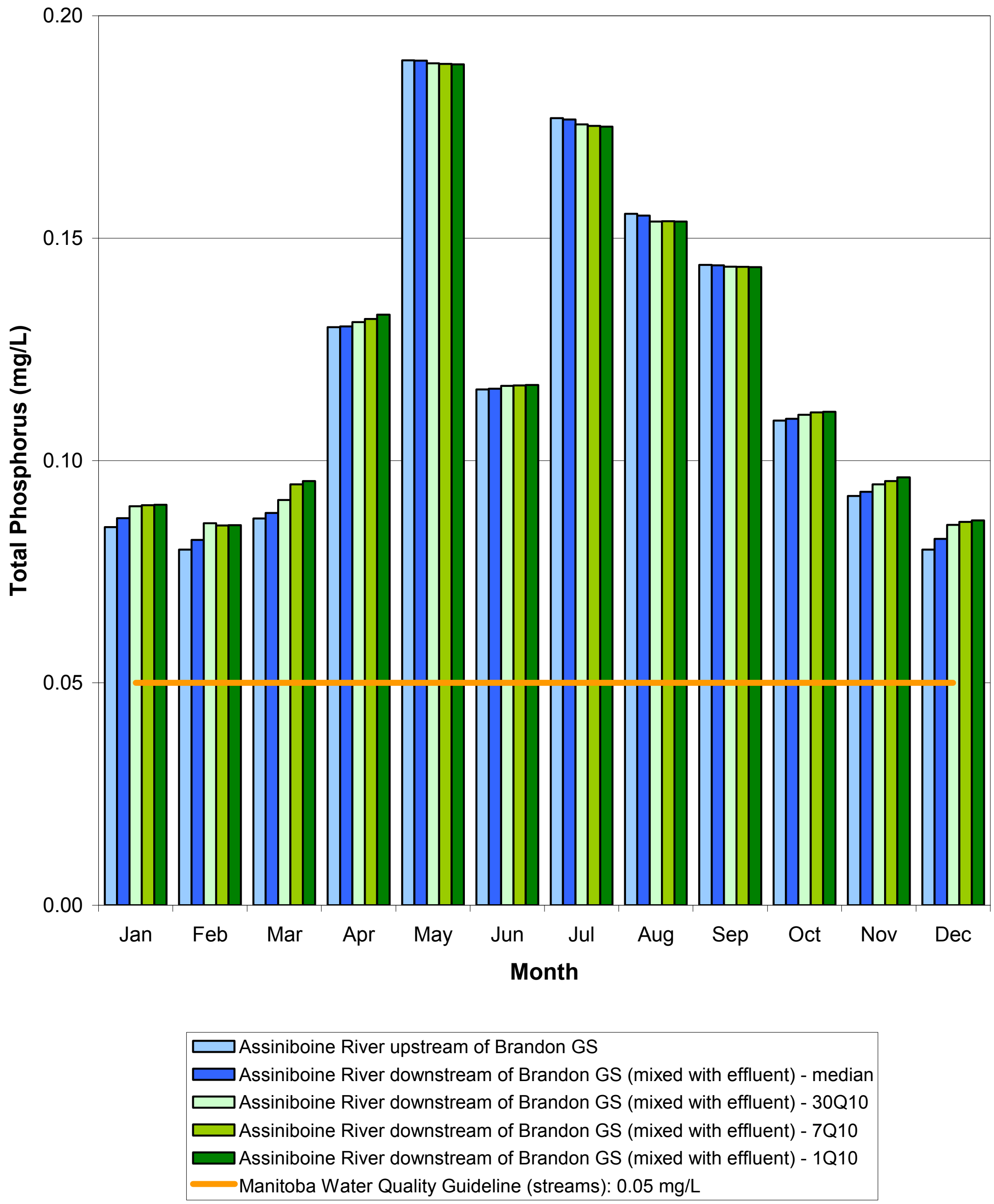

Figure 2.6 Projected fully mixed concentrations of total phosphorus in the Assiniboine River at median (1970 - 2000), $30Q_{10}$, $7Q_{10}$, and $1Q_{10}$ flows, based on monthly median upstream river concentrations and monthly median concentrations from the Brandon GS ash lagoon and station drain effluents between 1996 and 2004, with comparison to the current narrative Manitoba Water Quality Guideline for streams.

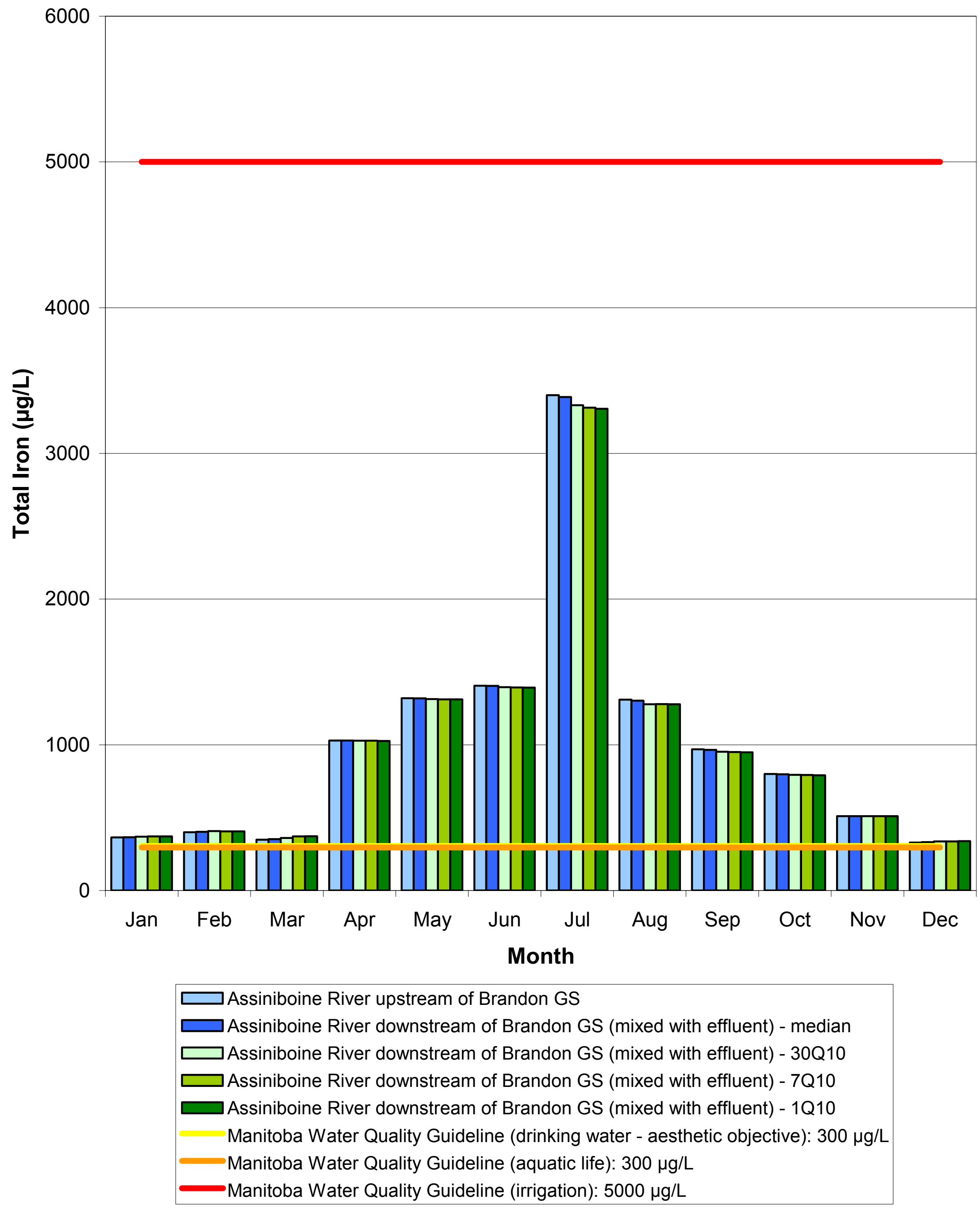

Figure 2.7 Projected fully mixed concentrations of total iron in the Assiniboine River at median (1970 - 2000), $30Q_{10}$, $7Q_{10}$, and $1Q_{10}$ flows, based on monthly median upstream river concentrations and maximum monthly median concentrations from the Brandon GS ash lagoon and station drain effluents between 1996 and 2004, with comparison to current Manitoba Water Quality Guidelines.

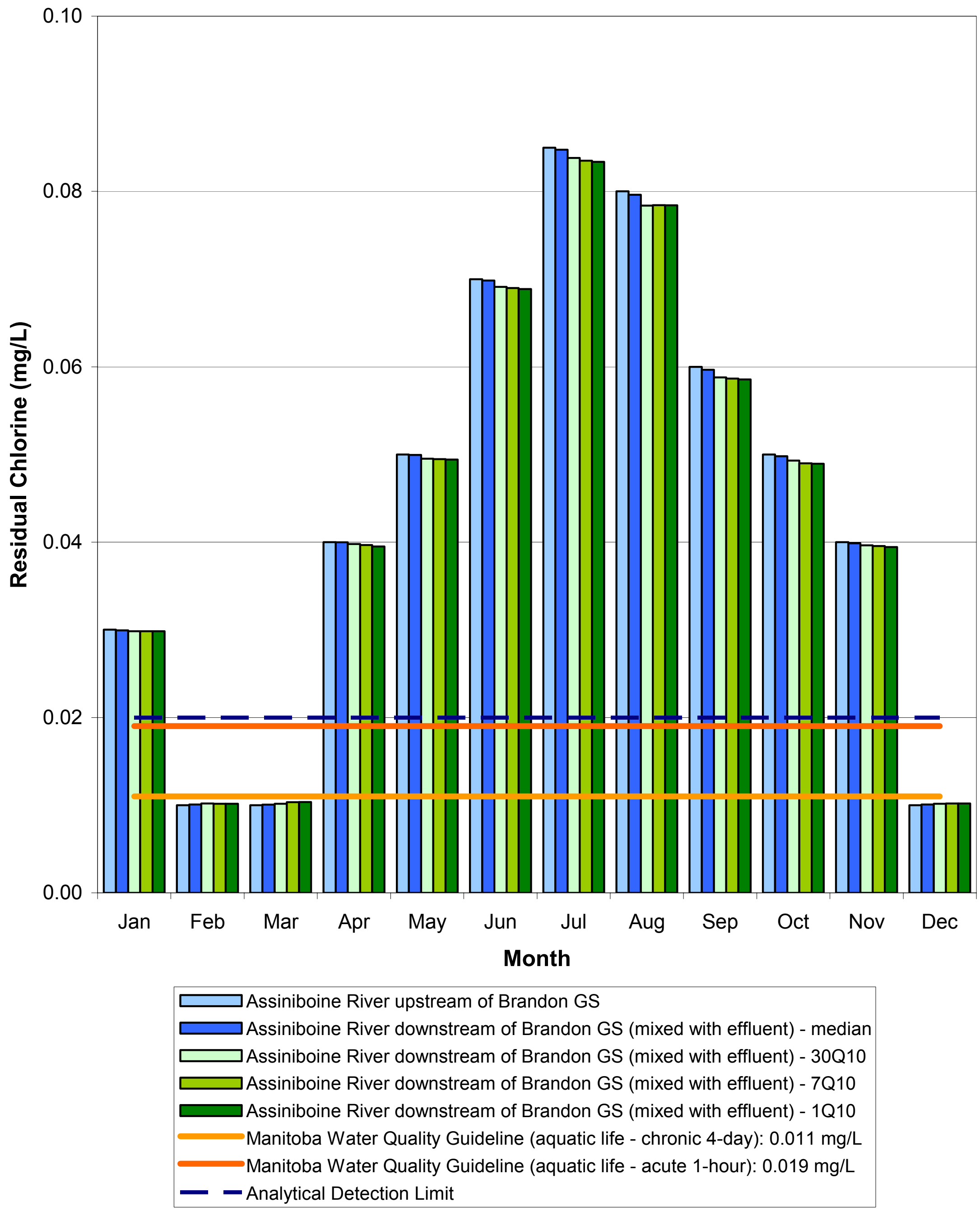

Figure 2.8 Projected fully mixed concentrations of total residual chlorine in the Assiniboine River at median (1970 - 2000), $30Q_{10}$, $7Q_{10}$, and $1Q_{10}$ flows, based on monthly median upstream river concentrations and maximum monthly median concentrations from the Brandon GS ash lagoon effluent between 1996 and 2004, with comparison to current Manitoba Water Quality Objectives for the protection of aquatic life.

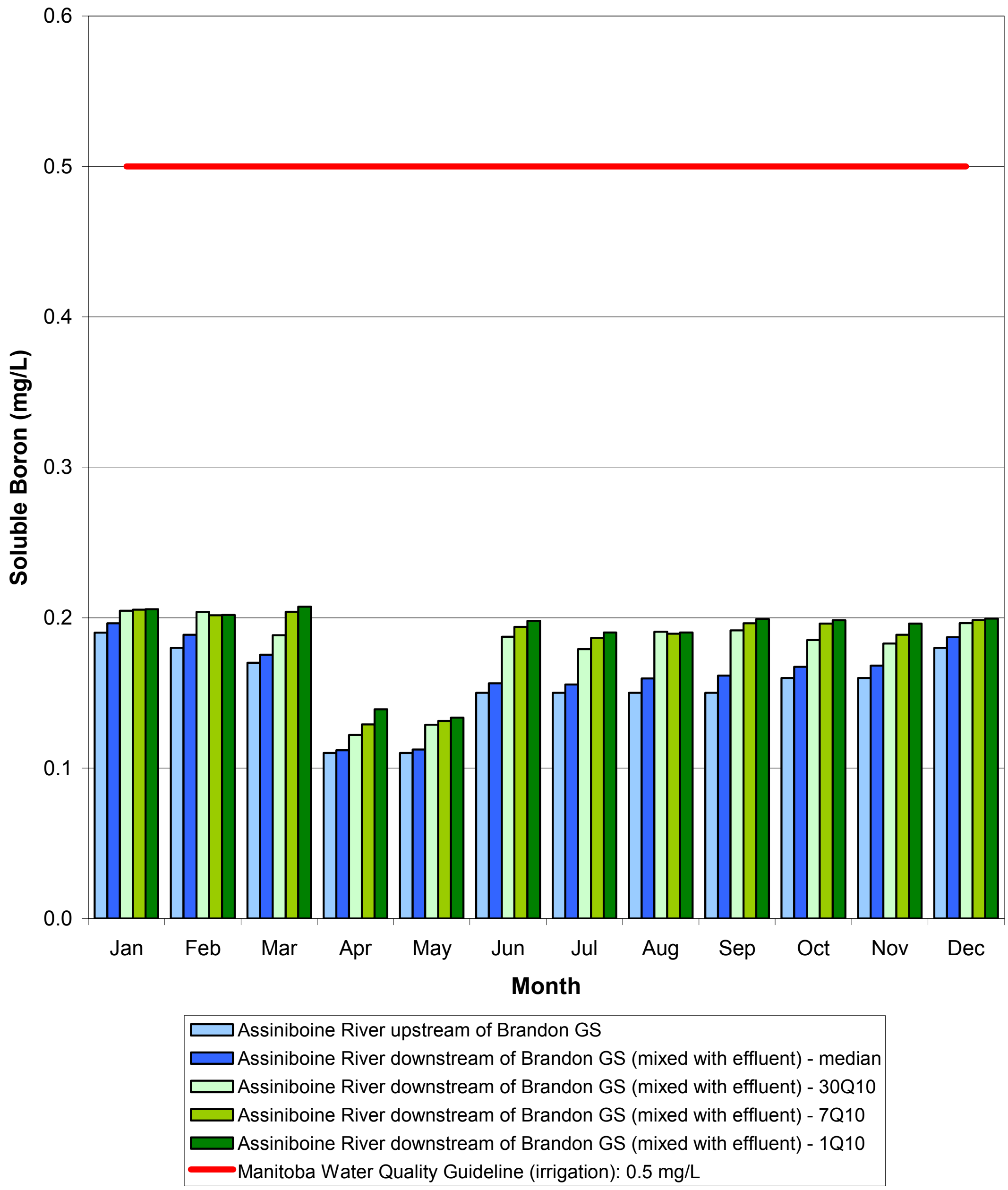

Figure 2.9 Projected fully mixed concentrations of soluble boron in the Assiniboine River at median (1970 - 2000), $30Q_{10}$, $7Q_{10}$, and $1Q_{10}$ flows, based on monthly median upstream river concentrations and monthly median concentrations from the Brandon GS ash lagoon (adjusted by a factor of 1.47 to account for the new coal) and station drain effluents between 1996 and 2004, with comparison to the current lowest (i.e., most stringent) Manitoba Water Quality Guideline for irrigation.

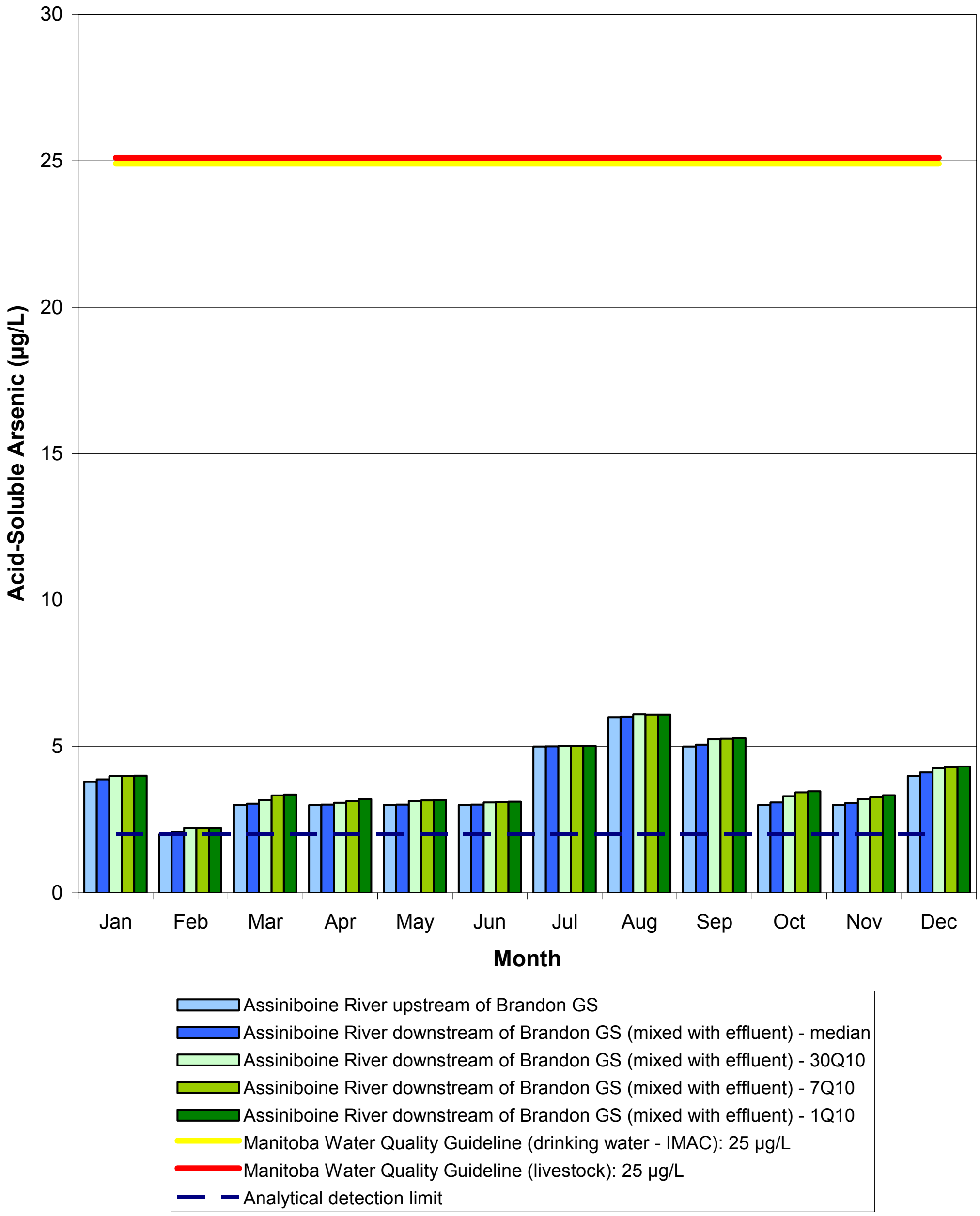

Figure 2.10 Projected fully mixed concentrations of acid-soluble arsenic in the Assiniboine River at median (1970 - 2000), $30Q_{10}$, $7Q_{10}$, and $1Q_{10}$ flows, based on monthly median upstream river concentrations and maximum monthly median concentrations from the Brandon GS ash lagoon effluent between 1996 and 2004, with comparison to current Manitoba Water Quality Guidelines. IMAC = Interim Maximum Acceptable Concentration. Note that all Guidelines depicted refer to total concentrations. The Manitoba Water Quality Objective for arsenic (in dissolved form) for the protection of aquatic life is 150 µg/L (not depicted).

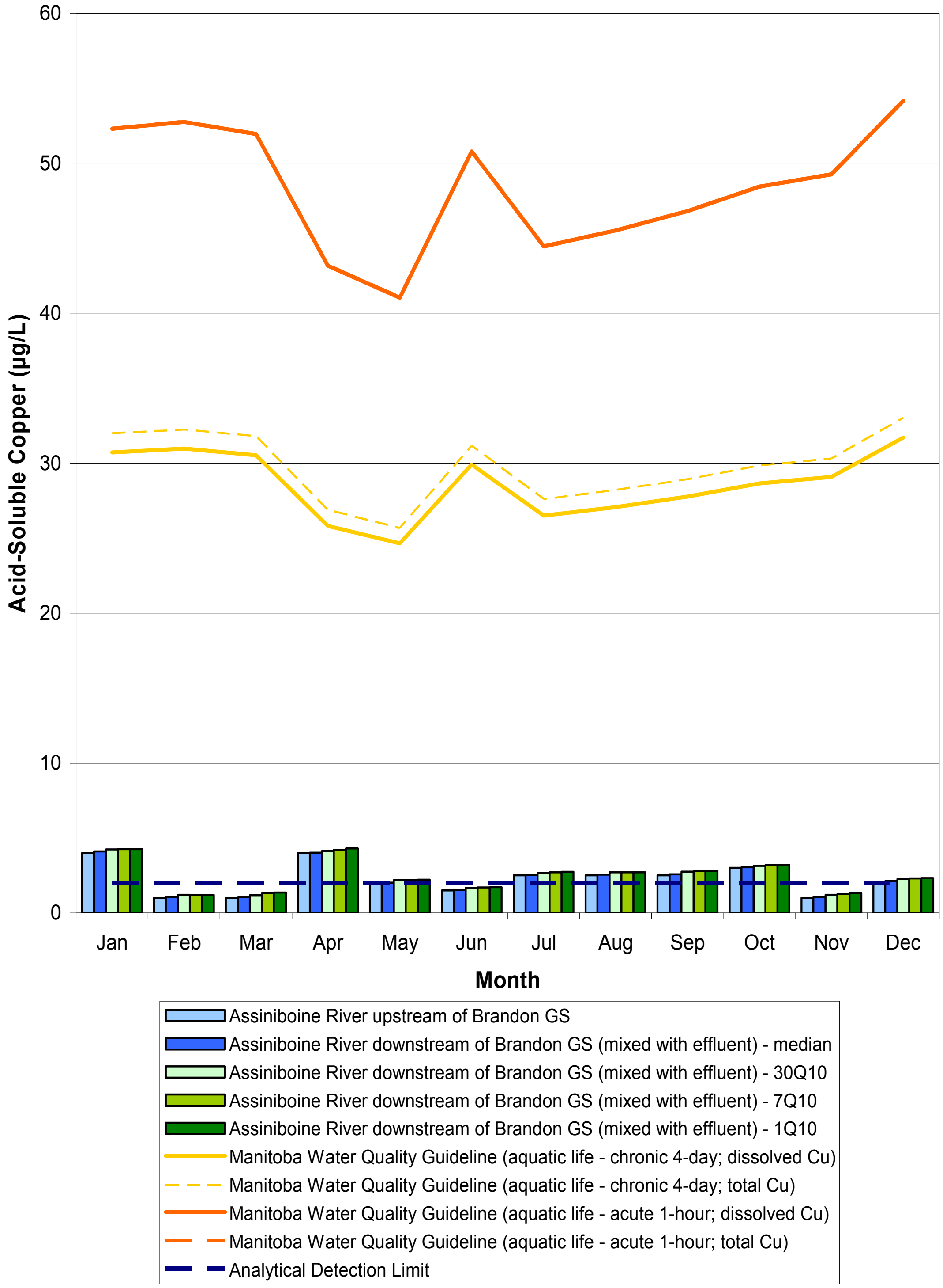

Figure 2.11 Projected fully mixed concentrations of acid-soluble copper in the Assiniboine River at median, $30Q_{10}$, $7Q_{10}$, and $1Q_{10}$ flows, based on monthly median upstream river concentrations and monthly median concentrations from the Brandon GS ash lagoon (adjusted by a factor of 1.61) and station drain effluents between 2001 and 2004.

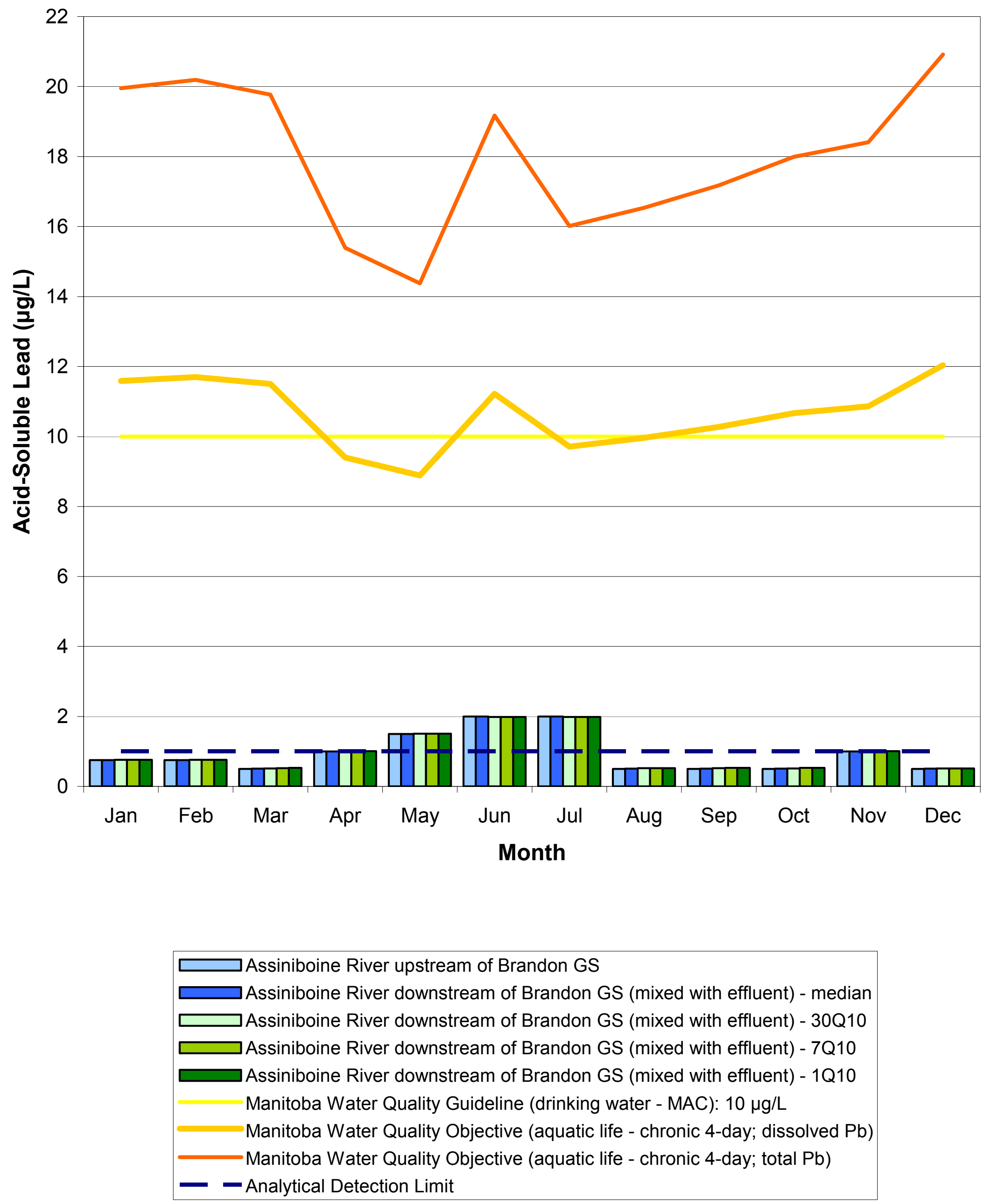

Figure 2.12 Projected fully mixed concentrations of acid-soluble lead in the Assiniboine River at median (1970 - 2000), $30Q_{10}$, $7Q_{10}$, and $1Q_{10}$ flows, based on monthly median upstream river concentrations and monthly median concentrations from the Brandon GS ash lagoon effluent between 1996 and 2001 (adjusted by a factor of 1.21 to account for the new coal), with comparison to current Manitoba Water Quality Objectives and Guidelines. MAC = Maximum Acceptable Concentration.

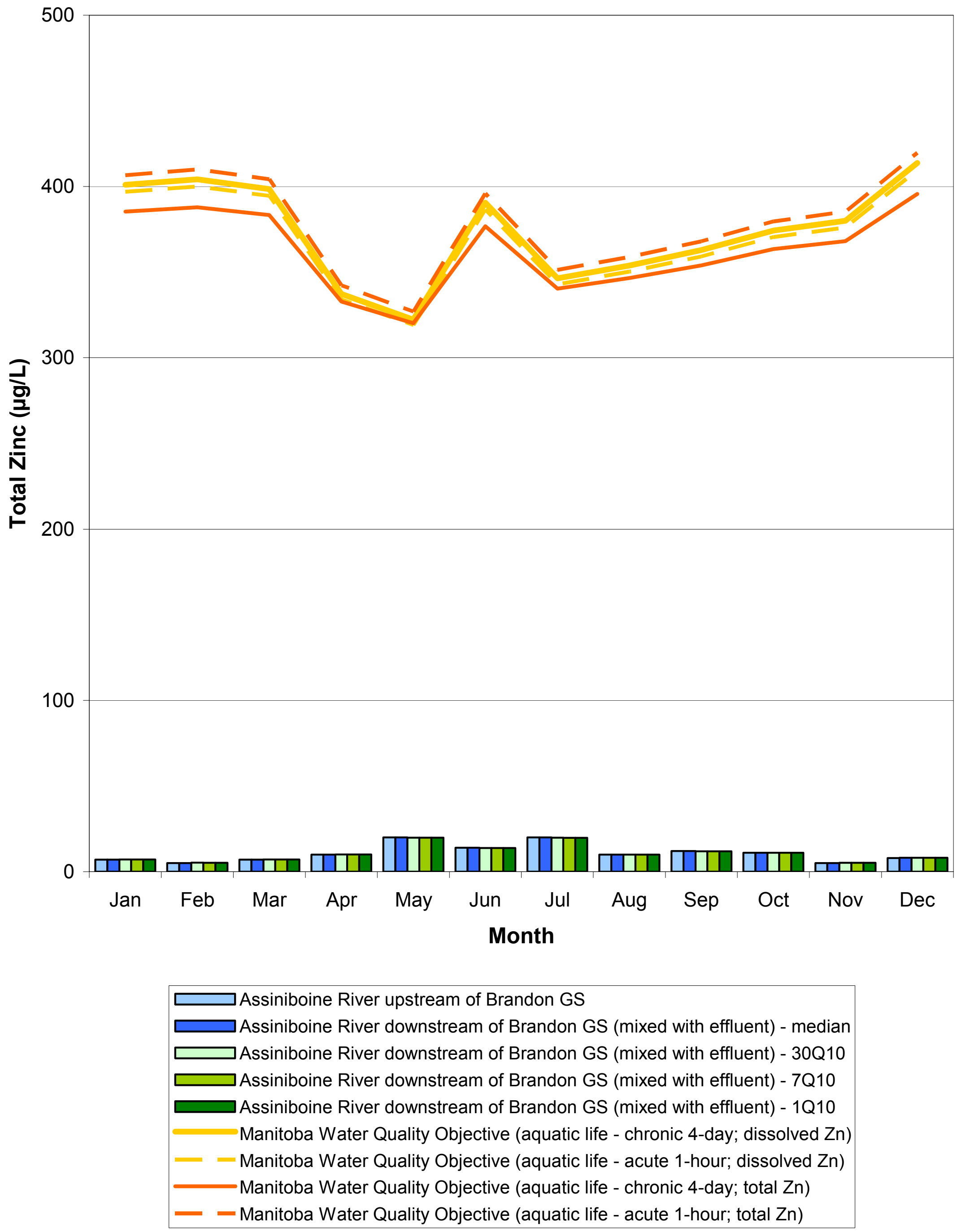

Figure 2.13 Projected fully mixed concentrations of total zinc in the Assiniboine River at median (1970 - 2000), $30Q_{10}$, $7Q_{10}$, and $1Q_{10}$ flows, based on monthly median upstream river concentrations and monthly median concentrations from the Brandon GS ash lagoon effluent between 1996 and 2004, with comparison to current Manitoba Water Quality Objectives for the protection of aquatic life. Note that analytical detection limits varied.

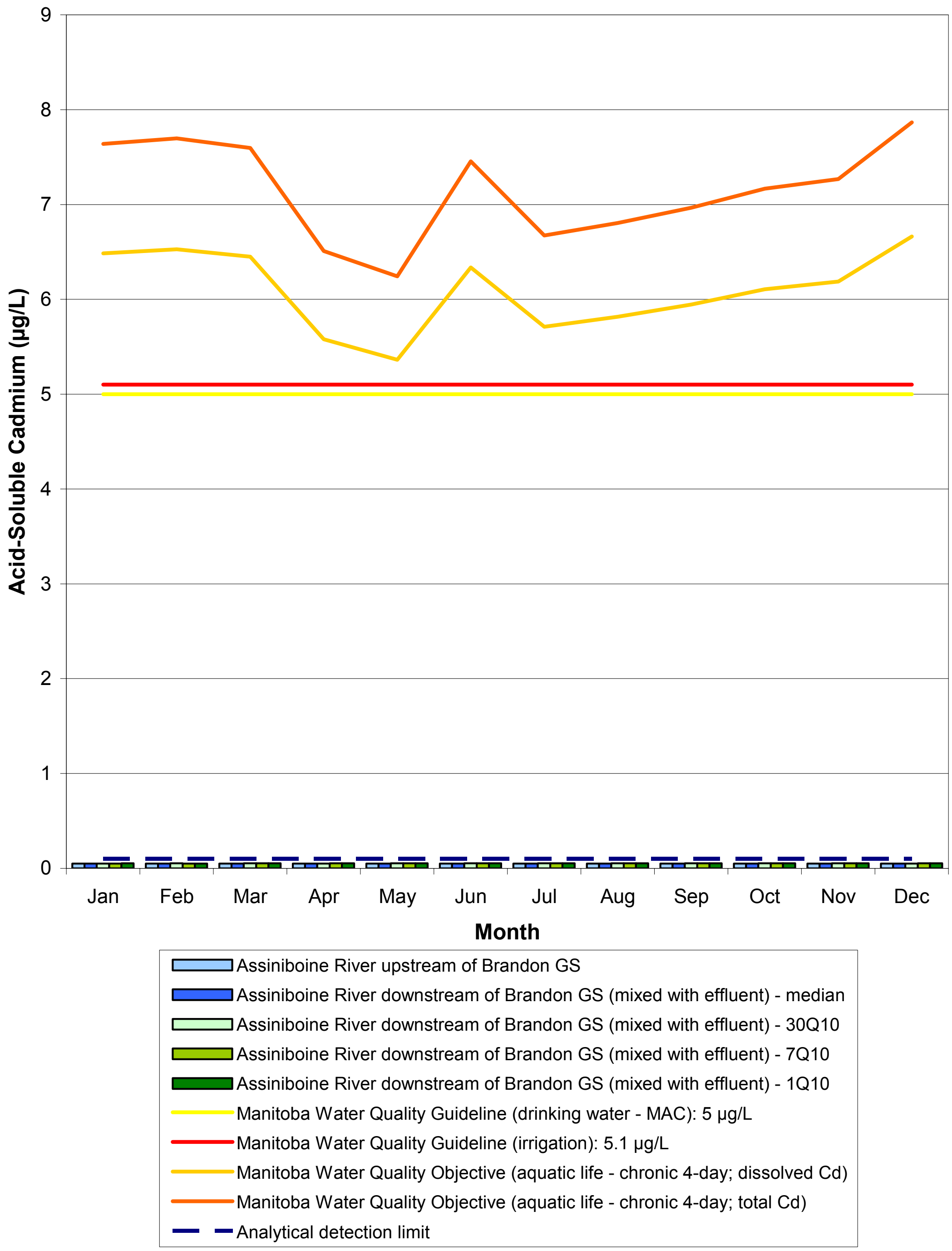

Figure 2.14 Projected fully mixed concentrations of acid-soluble cadmium in the Assiniboine River at median (1970 - 2000), $30Q_{10}$, $7Q_{10}$, and $1Q_{10}$ flows, based on monthly median (1996-2001) upstream river concentrations and monthly median (1996 - 2004) concentrations from the Brandon ash lagoon effluent (adjusted by a factor of 1.50 to account for the new coal), with comparison to current Manitoba Water Quality Objectives and Guidelines. MAC = Maximum Acceptable Concentration.

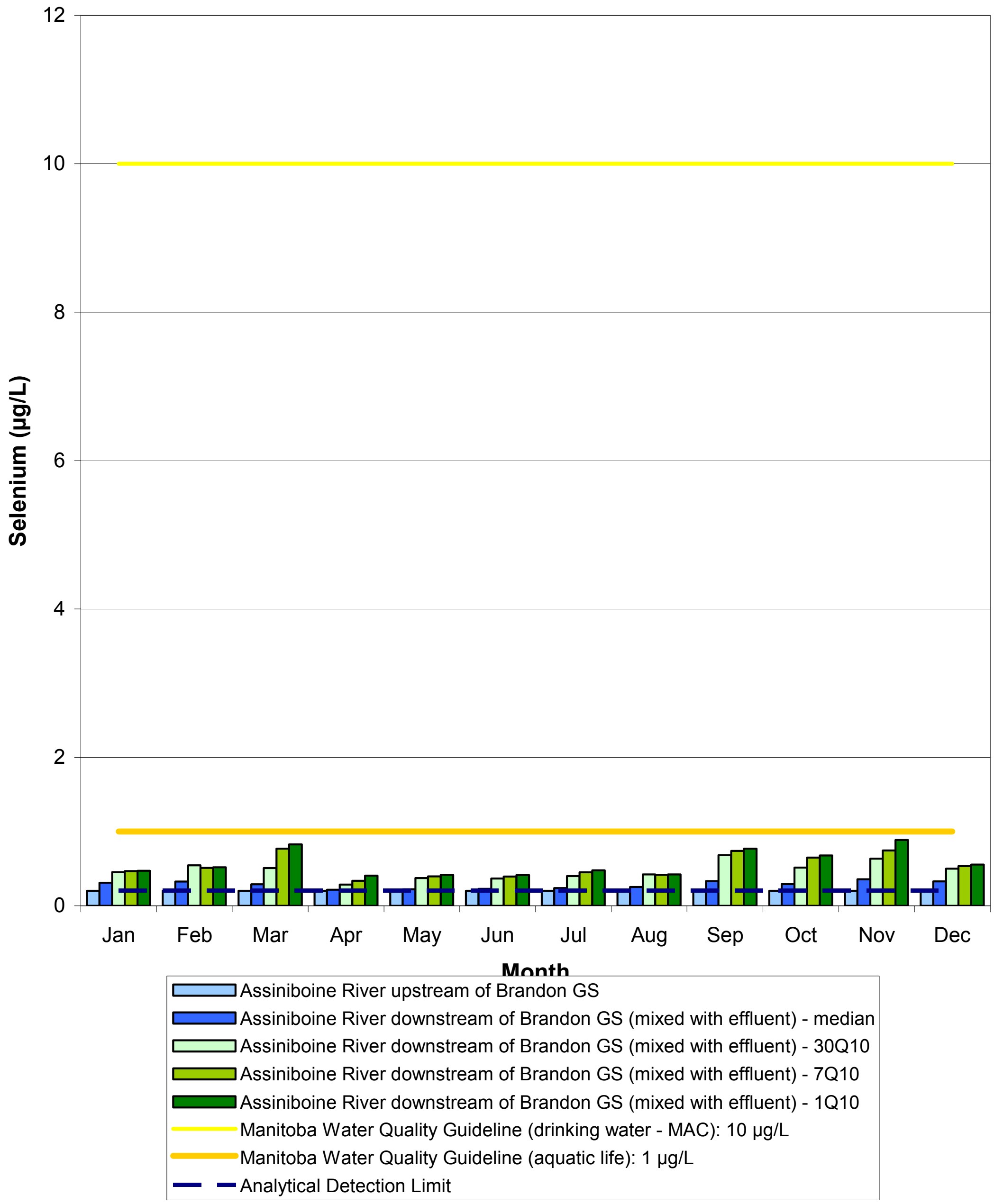

Figure 2.15 Projected fully mixed concentrations of total selenium in the Assiniboine River at median (1970 - 2000), $30Q_{10}$, $7Q_{10}$, and $1Q_{10}$ flows, based on monthly median upstream river concentrations (2002-2004) and monthly median concentrations from the Brandon ash lagoon effluent from 1996 to 2004 (adjusted by a factor of 1.04 to account for the new coal), with comparison to current Manitoba Water Quality Guidelines. MAC = Maximum Acceptable Concentration.

4.0 REFERENCES

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