



Appendix E
Development of Whitemud River
Model

SECTION 1.0 INTRODUCTION

The Town of Neepawa retained Earth Tech (Canada) Inc. (Earth Tech) to produce a Notice of Alteration (NOA) describing the construction and operational effects of proposed upgrades to the Town of Neepawa's Industrial Wastewater Treatment Facility (IWWTF). This report summarizes the development of the water quality model for the study reach of the Whitemud River from Neepawa to Gladstone, Manitoba and has been prepared to compliment the Whitemud River aquatics review and assessment element of the NOA.

1.1 Introduction

The Town of Neepawa owns and operates the existing IWWTF, which currently provides wastewater treatment for the Springhill Farms pork processing facility. Currently the effluent produced by the IWWTF is periodically discharged to the Town of Neepawa municipal lagoon which periodically discharges the further treated IWWTF effluent to the Whitemud River under emergency orders granted by Manitoba Conservation. This is an interim measure employed to temporarily address historic issues of poor effluent quality from the existing IWWTF. The new IWWTF is proposed to continuously discharge to a low area near the Whitemud River via the existing outfall once the upgrades are complete. The existing and proposed upgraded IWWTF are both located in the southwest quarter section of 35-14-15 WPM. The proposed upgraded IWWTF will treat wastewater produced by the Springhill Farms pork processing facility (an equalized flow of up to 1,520 m³/day) prior to discharging treated effluent on a continuous basis.

A water quality model, using Qual2K software developed by the United States Environmental Protection Agency (Chapra et al. 2006), was developed as a tool to aid in the identification and description of potential effects on water quality of changes to effluent discharges to the Whitemud River in the vicinity of Neepawa. The model is based on site-specific hydraulic information gathered in 2007, climatological data obtained from the Environment Canada's online National Climate Data and Information Archive, and data obtained from Manitoba Conservation from their water-quality monitoring program on several stations on the Whitemud River.

Qual2K is a computational model that simulates water chemistry in a stream based on stated concentrations of various parameters at the upstream end of the modeled reach and instream processes that influence water chemistry as the water flows downstream. The model assumes steady-state conditions, in that it cannot account for significant changes in river flows or weather during the modeled time period as the water flows from the upstream to the downstream end of the reach. Processes accounted for by computations in the model include:

- Longitudinal dispersion;
- Aeration;
- Oxidation of organic matter;

- Nitrification,
- Denitrification and mineralization of phosphorus in sediments;
- Sediment oxygen demand;
- Cloud cover,
- Shade; and
- Heat transfer between water, air, and sediments, among others.

All of these processes are inter-related and dependent upon concentrations of modeled parameters and reaction rates that vary between waterbodies and can be adjusted to allow calibration of the model to match measured concentrations of modeled parameters in the stream.

1.2 Physical Environment

The Whitemud River watershed encompasses a total area of about 7,500 km² (AAFC-PFRA 2005). Approximately 1200 km² of this area lies upstream of Neepawa, primarily consisting of the Boggy Creek, Brookdale Drain, Franklin Creek, and Stony Creek drainages. Downstream of the Town of Neepawa, additional drainage from approximately 6300 km² enters the Whitemud River via the Spring, Pine, Squirrel, and Rat creeks, Big Grass Marsh Drain, and numerous smaller tributaries, before the river flows into Lake Manitoba approximately 15 km north of the community of Westbourne. The majority of this assessment focuses on the portion of the river between the Towns of Neepawa and Gladstone, at which point the river has an upstream drainage basin area of approximately 2010 km², including the 1200 km² upstream of the Town of Neepawa.

The major impoundments in the watershed include Lake Irwin, which is the water source for the Town of Neepawa, and Park Lake, a small recreational lake formed by a weir on Stony Creek just south of the Town of Neepawa. Prior to construction of the Lake Irwin dam in 1959, the Whitemud River was deemed to have started at the confluence of Stony Creek and Boggy Creek. Often now, literature refers to the origin of the river to be the Lake Irwin dam, although in fact the short 2-km channel from the dam to the intersection with Stony Creek is actually Boggy Creek, although several sections have been re-routed from the original channel as part of the construction of the dam.

Elevation within the watershed ranges from 720 metres above sea level (masl), where Stony Creek has its headwaters in the Riding Mountains, down to 246 masl where the Whitemud River empties into Lake Manitoba. Most of the change in elevation occurs where the Stony Creek descends from the Riding Mountains, with a more gradual decrease in elevation heading east through the watershed. In the Town of Neepawa, elevation of the river is approximately 348 masl.

1.3 Hydrology

The Whitemud River flows eastward to its junction with Lake Manitoba and forms part of the Nelson River drainage system. Throughout its run, there are several small dams and weirs, the largest being at Lake Irwin with another large weir just downstream of the Town of Gladstone.

Two active Water Survey of Canada (WSC) hydrometric gauging stations are operated on the Whitemud River, located near Westbourne (WSC Gauge 05LL002, near lake Manitoba) and near Keyes (WSC Gauge 05LL005, approximately 75 km downstream of Neepawa). No active gauging system exists on the river near the Neepawa effluent outfalls. Therefore, flows in the reach of the river that receives effluents from the Neepawa municipal lagoons and the IWWTF must be estimated based on operation of the Lake Irwin Dam and historical data measured at WSC Gauges 05LL011 on Boggy Creek (between Lake Irwin and the Town of Neepawa) and 05LL009 on Stony Creek (approximately 7 km west of the Town of Neepawa). These stations operated from July 1960 to May 1994 and March 1959 to July 1993, respectively, only for the March through October period of each year. Flows in the Whitemud River at the Town of Neepawa for March-October, 1961-1992 can be calculated and used to generate statistical flow values using data from these two stations according to the following relationship:

$$Q_{NEEPAWA} = Q_{BOGGY} + \frac{(163+171)}{171} Q_{STONY}$$

where: $Q_{NEEPAWA}$ is the estimated flow in the Whitemud River at Neepawa;

Q_{BOGGY} is the measured flow in Boggy Creek (WSC Gauge 05LL011);

Q_{STONY} is the measured flow in Stony Creek (WSC Gauge 05LL009); and,

$(163+171)/171$ is a correction factor to account for the drainage downstream in Stony Creek and including Franklin Creek, which enters Stony Creek downstream of the gauging station. The ratio is based on the drainage areas upstream and downstream of the gauging station in km², estimated by manually tracing watershed boundaries using AutoCAD software and Shape files obtained from the Manitoba Lands Initiative database. The ratio assumes that the runoff hydrographs of Stony and Franklin creeks are sufficiently similar to allow estimation of flows based on direct correlation with size of drainage basin. The relationship does not account for peak flow attenuation that may be provided by the Park Lake dam on Stony Creek in the Town of Neepawa.

Current operation of the Lake Irwin Dam (on Boggy Creek, just upstream of the Town of Neepawa) is based on a fixed release of 0.2 m³/s (7 cfs), although, as discussed in Appendix D of the Request for Alteration to the Town of Neepawa's Industrial Wastewater Treatment Facility, Neepawa, Manitoba lower flows have occurred in the historical dataset.

SECTION 2.0 STUDY AREA

A study of channel characteristics and morphology of the Whitemud River was undertaken by Earth Tech in 2007 within the reach approximately 75 km downstream from Neepawa. The Whitemud River is a highly meandering river with a sinuosity (ratio of actual channel length/straight line distance) of 2.6. This is indicative of a river that is relatively low in flow velocity (low slope) or whose original channel has not been artificially straightened, but is in a natural condition. Two types of sand/gravel bars, or areas of deposition, were observed on the river, namely point bars attached to the shore and extending into the channel (**Photo 1**) and mid stream bars with the channel moving down each side of the deposit area (**Photo 2**). Oxbow lakes, cutoffs, and small pools formed on outside convex bends were also observed along the Whitemud River.

Downstream of Neepawa, the majority of the Whitemud River channel comprises fine substrata (clay, silt and fine sand), reflective of the soils through which the river flows. In numerous areas, fine sediments accumulate as soft deposits in low-velocity areas, but flows along most of the channel keep the bottom substrate at a firm level of compaction. In several locations, short riffles have developed, and provide good habitat for a variety of fish species that use flowing water over gravel/cobble for key life cycle functions such as spawning or feeding (**Photo 2**). At the time of assessment, water depth in the main channel was variable, ranging from just a few centimeters to over 2 meters in deeper pools.

River banks along the Whitemud River tend to be deeply incised, with an average height of at least 2 m above the water level during the summer period. Though floodplains and intermittent wetlands do exist along the river at some locations, during the spring, water levels usually are sufficient to flood oxbow areas and under extreme conditions overtop the banks and cause flooding.

Instream vegetation observed during the 2007 study was patchy but extensive in some areas, dependent upon bottom substrate and flow conditions. The main channel did not appear to develop extensive vegetative cover, but slower back eddies and channel margins could reach as much as approximately 80% cover from emergent plants based upon observations.

Agricultural development has altered the upland and riparian vegetation along the majority of the Whitemud River through clearing and soil disturbance associated with crop production, haying, and pasture operations. Although treed buffers between the river and adjacent agricultural lands are present along large portions of the reach downstream of the Town of Neepawa (**Photo 3**), buffers are thin or absent in some areas, and erosion of the channel and streambanks is evident in many areas (**Photo 4**). In particular, unrestricted access of cattle to the river has resulted in destabilization of the streambed and banks at numerous locations (**Photo 5**). Existing riparian conditions in the reach of the river downstream of the Town of Neepawa are presented in **Figures 2.1** and **2.2**.

Figure 2.1
Riparian Evaluation of Whitemud River

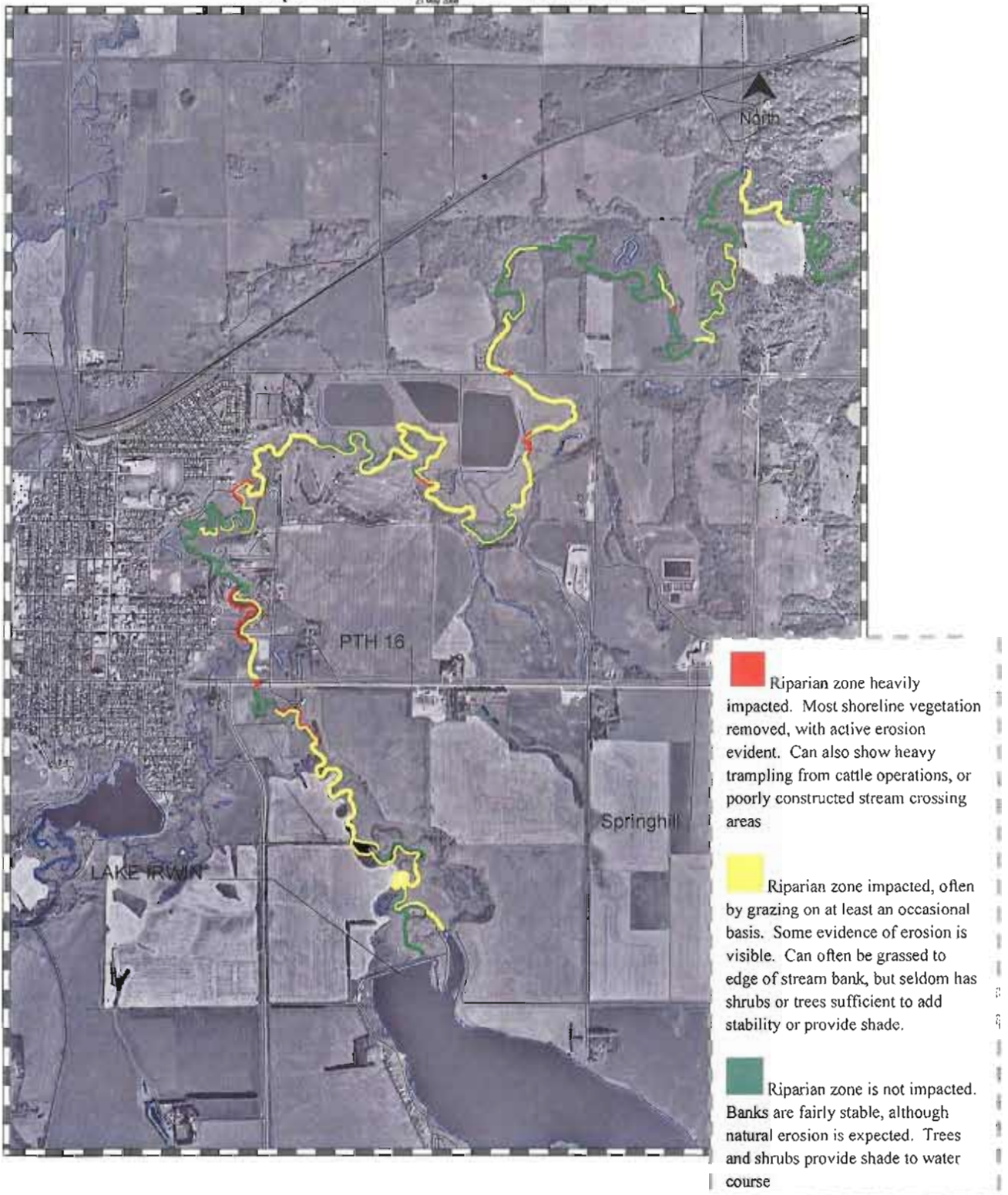
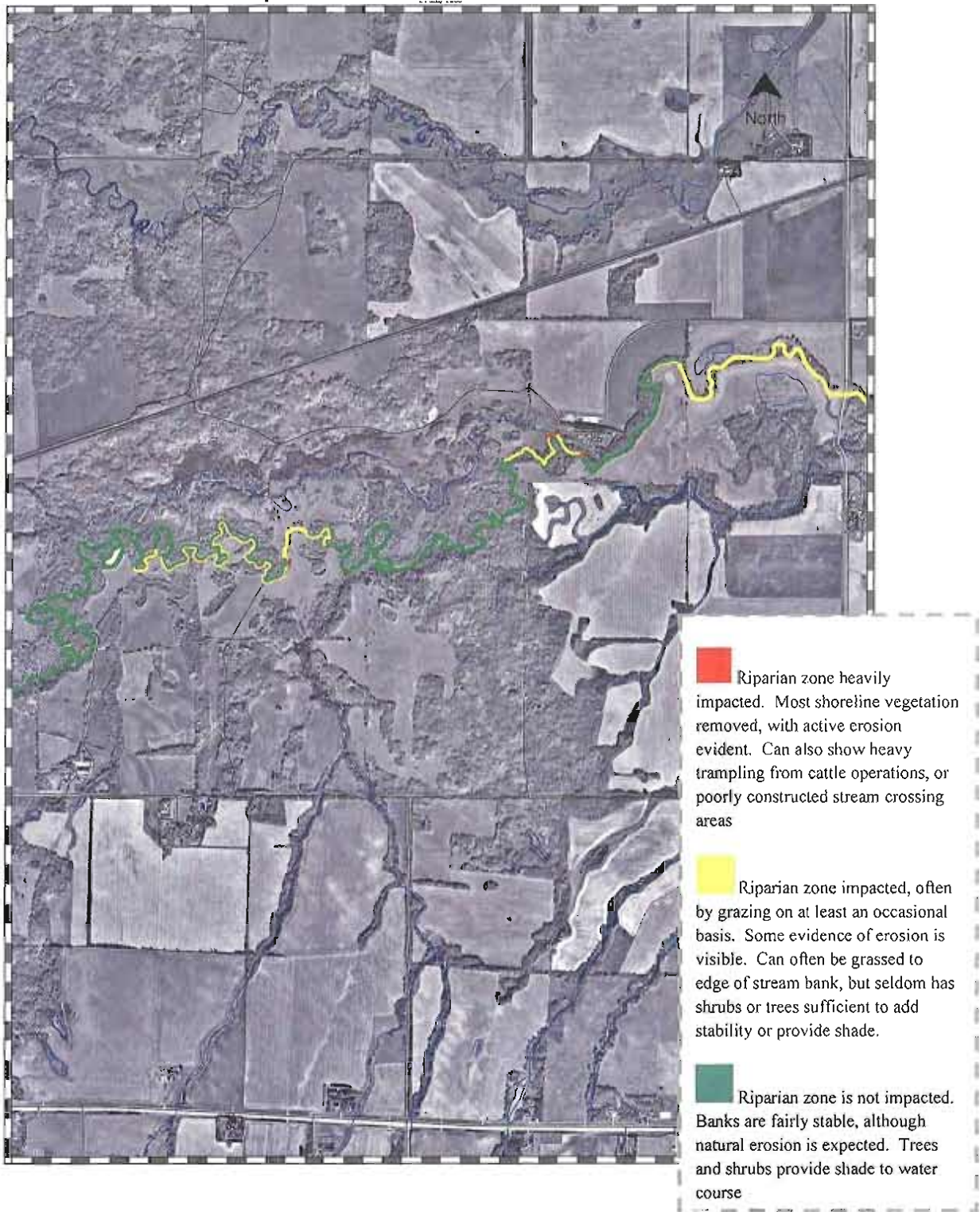


Figure 2.2
Riparian Evaluation of Whitemud River





Photograph No. 1: Point bar on the inside of a bend on the Whitemud River near Neepawa.



Photograph No. 2: Example of sand/gravel bar and riffles at cross-section 12.



Photograph No. 3: Dense vegetation along river bank at cross-section 19.



Photograph No. 4: Cleared riparian vegetation results in stream bank erosion along much of the Whitemud River.



Photograph No. 5: Example of altered riparian vegetation due to cattle grazing.

SECTION 3.0

CROSS-SECTION DATA METHODOLOGY

The cross-section survey was conducted between October 29 and November 13, 2007 including 19 cross-sections along the Whitemud River, covering a total river distance of approximately 88.5 km. The cross-sections were numbered consecutively from cross-section 1, a control structure in Neepawa's Lions Park, to cross-section 19, located approximately 22.5 km upstream of the town of Gladstone (downstream survey reach). Cross-section 1 included only the survey of the control structure to provide a flow measurement location within the town of Neepawa, therefore cross-section 2, situated just south of municipal sewage lagoon cell 2, describes hydraulic channel characteristics of the upstream study reach for the purposes of this assessment. The cross-section locations are illustrated in **Figures 2, 2A** and **2B** in **Attachment 1**. Select cross-section photographs (**Photos 1 to 17**) are presented in **Attachment 1**.

Cross-section locations along the Whitemud River were selected based on downstream distance and proximity to river features such as outfalls and potential spawning grounds. Cross-sections were surveyed using a combination of GPS and Total Station technology. A control point survey was first conducted from October 29-31, 2007 using GPS equipment to transfer points of known elevation (bench marks) to a minimum of two (2) control points positioned at or near each of the cross-section locations. Bench mark locations and elevation information was provided by Manitoba Conservation, Survey Services Branch. Once the control points were established, the cross-sections were surveyed using a Total Station instrument from November 5-9, 2007 and GPS equipment from November 12-13, 2007. The GPS equipment used for the survey was a Topcon HiPer Lite Plus rover/base station system with real time kinematic correction. The Total Station equipment used for the survey was a Trimble Total Station.

On November 9, 2007 flow was measured at the control structure opening at cross-section 1. Water surface elevations were also surveyed at a number of cross-sections to correlate water surface elevations and river flow and are summarized in **Table 3.1** along with the measurement date. Throughout the survey, water depth in the main channel varied from approximately 0.6 m (at cross-section 7) to approximately 1.6 m (at cross-section 6). Select photographs for each cross-section are included in **Attachment 1**.

Table 3.1: Surveyed Water Surface Elevations

| Cross-Section | Surveyed Water Surface Elevation (m) | Date (mm/dd/yr) |
|----------------------|---|------------------------|
| 1 | 348.51 | 10/31/2007 |
| 2 | 344.49 | 10/30/2007 |
| 3 | 344.51 | 10/30/2007 |
| 4 | 343.93 | 10/30/2007 |
| 5 | 342.83 | 10/30/2007 |
| 6 | 342.80 | 10/30/2007 |
| 7 | 342.47 | 10/30/2007 |
| 8 | 342.52 | 10/30/2007 |
| 9 | 341.71 | 10/30/2007 |
| 10 | 340.74 | 10/30/2007 |
| 11 | 338.77 | 10/30/2007 |
| 12 | 335.84 | 10/29/2007 |
| 13 | 332.92 | 11/6/2007 |
| 14 | 331.03 | 10/31/2007 |
| 15 | 323.70 | 11/9/2007 |
| 16 | 309.29 | 11/5/2007 |
| 17 | 295.45 | 11/12/2007 |
| 18 | 288.08 | 11/9/2007 |
| 19 | 277.80 | 11/9/2007 |

The control structure and cross-sections 1 to 9 were all located on Town of Neepawa property with access granted via local roads and highways. The remaining cross-sections (10 to 19) were all accessed via privately owned land with owner permission obtained prior to access.

Travel to each cross-section was accomplished using a 4 wheel drive vehicle and/or small water craft. Each cross-section was surveyed using a conventional survey range pole and prism for the banks and channel bottom as the water depth did not exceed 1.6 m. Channel bottom depths were obtained by either wading across the river or by small water craft when the water level exceeded approximately one metre in depth.

Typically the survey of a cross-section extended from an apparent high point approximately 2 metres above the surveyed water surface elevation on one side of the river to the same on the opposite side, except in those cases where significant changes in elevation were at a distance greater than 500 metres from the cross-section centerline. In these cases, the survey would end at approximately 500 metres from the river.

Survey information was processed using AutoCAD and combined with aerial photographs obtained from the Manitoba Land Initiative website. The product (referred to previously in

this document as **Figures 2A** and **2B** included in **Attachment 1**) illustrated the locations of the various cross-sections in the study area and assisted in the identification of other visible features such as weirs along the Whitemud River.

SECTION 4.0 DEVELOPMENT OF HYDRAULIC MODEL

The main objective of the survey was to generate the hydraulic characteristics of the Whitemud River to develop the hydraulic model portion of the Qual2K water quality model. The characteristics were developed from the cross-section data and flow estimates.

4.1 HYDRAULIC MODEL PHYSICAL CHARACTERISTICS

The first task to be completed during the development of the hydraulic model is to provide the modeling program with a physical description of the river. The river is described with cross-section information including coordinate and elevation information for cross-section points, distance between cross-sections, Manning's roughness coefficients, bottom width, side slopes, and other characteristics from the surveyed cross-sections.

The cross-section coordinate and elevation point information obtained during the survey program was combined with designated drain watercourse digital maps and aerial photographs obtained from the Manitoba Land Initiative website. The designated drain watercourse map provided a line along the approximate centerline of the Whitemud River channel that was measured between cross-sections for input into the hydraulic model. The river distances between cross-sections together with cumulative distances are presented in **Table 4.1**.

Table 4.1: Cross-section Distances

| Surveyed Cross-section Reaches | Distance between Cross-Sections (m) | Cumulative Distance between Cross-Sections (m) |
|--------------------------------|-------------------------------------|--|
| 1 to 2 | 4069 | 4069 |
| 2 to 3 | 119 | 4188 |
| 3 to 4 | 759 | 4947 |
| 4 to 5 | 712 | 5660 |
| 5 to 6 | 171 | 5831 |
| 6 to 7 | 430 | 6261 |
| 7 to 8 | 422 | 6684 |
| 8 to 9 | 434 | 7119 |
| 9 to 10 | 1102 | 8221 |
| 10 to 11 | 1885 | 10107 |
| 11 to 12 | 3971 | 14078 |
| 12 to 13 | 4368 | 18447 |
| 13 to 14 | 5991 | 24439 |
| 14 to 15 | 15890 | 40329 |
| 15 to 16 | 12914 | 53244 |
| 16 to 17 | 16568 | 69812 |
| 17 to 18 | 7667 | 77480 |
| 18 to 19 | 10993 | 88473 |

Manning's roughness coefficients were also selected using general literature and adjusted based on first hand observations made during the survey and from the previous channel characterization study. The "n" values along the Whitemud River channel were initially estimated to be in the range of 0.050 to 0.100, representative of winding natural channels that can exhibit the following characteristics: weedy, stony, sluggish reaches, deep pools, with heavy strands of timber and brush. As these empirically-derived roughness coefficients are intended to represent bankfull conditions in a stream, they were established as first step in characterizing differences between the various defined reaches of the hydraulic model, and adjusted to represent low-flow conditions simulated in successive runs of the model.

4.2 ADJUSTMENT OF THE HYDRAULIC MODEL

After the physical information from the survey program was entered into the hydraulic model portion of the program, water surface elevations predicted by the model were compared, in a general fashion, to observed water surface elevations. Upon examination, the resulting modeled water levels did not represent the river well (levels were considered too low), indicating the need for further model adjustment.

Several perceived blockages or weirs were observed during the cross-section survey and identified during the river characterization study, and would account for water surface elevation discrepancies. The aerial photographs obtained from the Manitoba Land Initiative website were used to verify and to locate these theoretical weirs or blockages along the Whitemud River. The model was then adjusted by inserting six theoretical broad crested weirs in the places where blockages or restrictions were known to exist. Furthermore, the roughness coefficients were further modified to compensate for the effects of unidentified river blockages (weirs, etc.) over the entire length of the study area. The resulting model outputs and hydraulic characteristics were used for development of the Qual2K water quality model and are summarized in Section 5 of this document.

SECTION 5.0 DEVELOPMENT OF WATER QUALITY MODEL

5.1 WATER QUALITY MODEL REACH

The reach of the Whitemud River chosen for development of the water quality portion of the model extends from Neepawa (upstream of the effluent outfalls from the Municipal lagoon system and the proposed IWWTF) to Gladstone. Gladstone was chosen as the downstream model boundary due to the presence of a nearby Manitoba water quality monitoring station (MB05SLL003) and two representative Water Survey of Canada (WSC) streamflow gauges (05LL005 near Keyes and 05LL810 upstream of Gladstone Dam) (**Figure 5.1**). Downstream of Gladstone, several large tributaries, identified in **Section 1.2**, add considerable drainage to the river that dilutes measurable effects of effluent inputs at Neepawa and would greatly increase the complexity and data requirements of a water quality model.

5.2 MODEL GEOMETRY AND SEGMENTATION

The Qual2K water quality model developed for the Whitemud River has a total length of 110.1 km, extending downstream from Cross-section 2 surveyed in 2007 (km 110.1) to the Gladstone Dam (km 0). The river mainstem is modeled without tributaries, but Spring Creek (at km 73.8) and four smaller tributaries entering the river from the south and west (at km 95.2, 88.1, 67.0 and 48.2) were assigned as point-source inputs to the river. The proposed IWWTF outfall is located at approximately km 108.31, and the Town of Neepawa Municipal Lagoon Cell #3 outfall is located at km 108.34.

The model is divided into 19 reaches, each consisting of between 1 and 6 segments ranging in length from 0.4 to 5.1 km. Assignment of reaches was based primarily on the locations of weirs identified through observation or inferentially during development of the hydraulic model. All weirs represented downstream reach boundaries, while point sources (tributaries) were located near the upstream end of segments to effect as accurately as possible the fully-mixed conditions assumed by the model at the downstream end of each element. **Table 5.1** is an extract from the Qual2K model summarizing the locations, lengths, and elevations of the assigned reaches.

5.3 IMPLEMENTATION OF HYDRAULIC DATA

Qual2K simulates hydraulics of a stream by individual reach, based on channel geometry and either the Manning equation, rating curves, or the height and width of a weir at the end of the reach. For the Whitemud River model, weir and channel geometry information and Manning

coefficients were used as inputs to configure the hydraulics of the model, as described in **Section 4** and shown in **Table 5.2**.

5.4 BOTTOM SUBSTRATE AND BENTHIC ALGAE

Benthic primary productivity and sediment-water interactions factor highly into water quality in small rivers, such as the Whitemud River, due to the large surface area of wetted bottom substrate relative to water volume. As no data exist describing densities of benthic algae in the Whitemud River, bottom coverage by benthic algae was estimated based on approximate proportions of hard and soft substrata observed during field surveys in 2007 and experience with nearby rivers. Similarly, bottom SOD (sediment oxygen demand) was estimated as the proportion of riverbed not comprising coarse rock or clean gravel, based on qualitative notes from field surveys. The estimates of benthic algae and SOD coverage used in initial calibration of the model are provided in **Table 5.3**.

5.5 SELECTION OF CALIBRATION DATASET

During initial development of the model, it is important that measured data be available for the upstream boundary plus one or more locations further downstream in the modeled reach, to ensure that simulations match the actual (measured) conditions in the modeled stream. It is also important during this calibration stage of model development that environmental conditions (e.g. weather and river flow) remain fairly steady before and during the measured data collection period, as changes in water chemistry associated with environmental influences can confound identification and selection of appropriate rates for instream processes.

Several water-quality monitoring stations in the Whitemud River watershed have been used at various times by Manitoba Conservation. Unfortunately, only those stations upstream of Neepawa (on Boggy Creek between Lake Irwin and the Stony Creek confluence) and near Westbourne (near Lake Manitoba) have been used in recent years. A watershed water quality study conducted by Manitoba Conservation from 1996 to 1998 (Hughes 1999) examined water quality at numerous sites along the Whitemud River and its tributaries; however, it did not include the sites just upstream and downstream of Neepawa, and the dataset produced from it lacks many of the parameters necessary for input into a Qual2K model. Therefore, the most recent period for which data exist for development of a Qual2K model for the Neepawa-Gladstone reach of the Whitemud River is 1990-1991, during which time samples were collected at Station MB05SLL011 just upstream of Neepawa, Station MB05SLL010 downstream of the Neepawa IWWTF effluent outfall, MB05SLL004 near the middle of the Neepawa-Gladstone reach, and MB05SLL003 just upstream of Gladstone (**Figure 5.1**).

Although water samples were collected monthly at the four stations listed above, not all data collected during the 1990-1991 period have equal value in developing a water quality model. Samples collected on dates that immediately followed large precipitation events and/or increases in river flow were not selected, due to confounding effects of local surface runoff and scouring of riverbed sediments. The following considerations were made in selection of the dataset to be used for calibration of the initial Qual2K model for the Whitemud River between Neepawa and Gladstone:

- Numerous spikes in river flows in March, April, May and June 1990 made the data from those periods problematic for model development, as flows fluctuated substantially during the sampling events.
- The August 1990 water-quality dataset suggested that wide fluctuations in BOD and nutrient loading were occurring in the river just prior to sampling.
- A 73.2-mm rainfall event occurred during the two days prior to the late-June 1991 sampling event, likely resulting in considerable unmeasured local surface runoff to the river that was apparent in the water quality dataset.
- Unusually high dissolved oxygen concentrations near Gladstone in February 1990 were suggestive of a significant thaw that would not be representative of typical winter conditions intended for representation by the model.

Based on considerations including those listed above, the June 3 1991, August 6 1991 and February 4 1991 water-quality datasets were chosen as those most likely to support successful development of the water-quality model for the early summer, late summer and late winter seasons, respectively. Upon further inspection, the available data indicated that municipal lagoon effluent discharges were likely occurring during the June 3 1991 sampling event, and this dataset was selected for initial setup and calibration of the model.

5.6 FLOWS FOR CALIBRATION DATASET

On the date of the calibration dataset (June 3 1991), the recorded flow in the Whitemud River at WSC Gauge 05LL005, near the midpoint of the modeled reach (km 40), was 0.335 m³/s. Flow at Neepawa was estimated based on the relationship described in **Section 1.3**, repeated here as follows:

$$Q_{NEEPAWA} = Q_{BOGGY} + \frac{(163+171)}{171} Q_{STONY}$$

For June 3 1991, the above calculation produced an estimated flow at Neepawa of 0.265 m³/s. Although no wastewater discharge data was available for the June 1991 period, effluent discharge at Neepawa was indicated by water quality monitoring data, and likely represented the majority of the flow entering the river between Neepawa and WSC Gauge 05LL005.

Within this reach, the largest tributary is Spring Creek, which drains the Riding Mountain escarpment immediately east of the Stony Creek watershed, and likely represents the majority of any additional flow to the Whitemud River that may occur between Neepawa and Gladstone during dry periods. Although Spring Creek has a larger watershed (420 km²) than Stony Creek, it is more highly branched, and likely has lower flows during dry periods. Based on the flow estimates described above, the flows used for the June 3, 1991 calibration dataset were 0.265 m³/s in the Whitemud River at Neepawa, 0.05 m³/s for wastewater discharges in Neepawa, plus 0.02 m³/s in Spring Creek to produce a total flow downstream of the Spring Creek confluence of 0.335 m³/s. All other potential influents were set at 0 m³/s.

5.7 WATER QUALITY PARAMETERS – CALIBRATION DATASET

Water quality data used in development of the Whitemud River Qual2K model were obtained from the datasets for Monitoring stations MB05LLS012 on Stony Creek and MB05LLS011, MB05LLS010, MB05LLS004 and MBLLS003 on the Whitemud River. Headwater (upstream boundary) concentrations were obtained from MB05LLS011, and loads attributable to inputs at Neepawa (Municipal and Industrial effluent discharges) were estimated through subtraction of the headwater loads from those measured at MB05LLS010 based on the estimated flow of 0.265 m³/s. This calculation likely underestimates loads discharged to the river at Neepawa, as some loads (of nutrients, BOD, etc.) were likely attenuated within the stream between the outfalls and the monitoring station, and adjustment of the loading rates of some parameters were made during model calibration. Loads in Spring Creek were based on concentrations measured in Stony Creek at MB05SLL012 and the estimated flow of 0.02 m³/s.

Whereas several water quality parameters required for the Whitemud River Qual2K model were obtained directly from the provincial monitoring datasets, the data for some parameters required estimation or transformation to make them compatible with Qual2K, as described in the following paragraphs.

- Phytoplankton: As the June 3 1991 dataset contained no phytoplankton (chlorophyll *a*) data, a headwater value of 2 µg/L was used, based on several values recorded in early June samples at the Stony Creek and Boggy Creek monitoring stations between 1998 and 2001.
- Inorganic suspended solids (ISS) and detritus: For the June 3 1991 dataset, ISS, phytoplankton and detritus (suspended organic matter) data did not exist. Values input into the model were based on total suspended solids (TSS) concentrations and Total and Dissolved Organic Carbon (TOC and DOC) concentrations measured on other dates, based on the relationship:
$$\text{TSS} = \text{ISS} + (\text{TOC} - \text{DOC}) / 0.4 + [\text{chlorophyll } a] * 1000,$$
where the factors 0.4 and 1000 account for the stoichiometry of organic matter.
- Based on subtraction between the upstream and downstream monitoring stations, a load of 4 mg/L TSS entered the river with the wastewater effluents at Neepawa. Considering the nature of the effluents and the fact that the industrial effluent

Table 5.1: Qual2K model reaches for the Whitemud River, Neepawa-Gladstone.

| Reach | | | Reach | | | Location | | Element | Elevation | |
|--------|--------------------------|--------------------|--------|------------|-----------|----------|------------|---------|-----------|------------|
| Number | Reach | Downstream | length | Downstream | | Upstream | Downstream | Number | Upstream | Downstream |
| | Label | end of reach label | (km) | Latitude | Longitude | (km) | (km) | >=1 | (m) | (m) |
| 1 | Pool 1 Golf Course | W1 | 1.53 | 50.23 | 99.44 | 110.089 | 108.556 | 1 | 343.690 | 342.030 |
| 2 | Pool 2 Municipal Lagoon | W2 | 0.40 | 50.24 | 99.44 | 108.556 | 108.154 | 1 | 342.030 | 341.480 |
| 3 | IWWTF Outfall | Old W5 | 0.89 | 50.24 | 99.44 | 108.154 | 107.267 | 1 | 341.480 | 341.060 |
| 4 | Pool 3 North from Lagoon | W3 | 0.94 | 50.25 | 99.44 | 107.267 | 106.330 | 1 | 341.060 | 340.190 |
| 5 | Pool 4 | W4 | 1.75 | 50.24 | 99.43 | 106.330 | 104.579 | 1 | 340.190 | 338.610 |
| 6 | Pool 5 | W5 | 0.47 | 50.24 | 99.42 | 104.579 | 104.104 | 1 | 338.610 | 338.140 |
| 7 | InTheTrees Stream 1 | EndOfTrees | 10.80 | 50.25 | 99.38 | 104.104 | 93.300 | 5 | 338.140 | 331.574 |
| 8 | Pool 6 | W6 | 1.45 | 50.26 | 99.37 | 93.300 | 91.845 | 1 | 331.574 | 330.690 |
| 9 | Pool 7 | W7 culvert | 2.25 | 50.26 | 99.35 | 91.845 | 89.596 | 1 | 330.690 | 329.740 |
| 10 | Stream 2 | Road | 6.48 | 50.27 | 99.33 | 89.596 | 83.116 | 3 | 329.740 | 326.640 |
| 11 | Flats | Spring Creek | 9.12 | 50.28 | 99.28 | 83.116 | 74.000 | 4 | 326.640 | 319.994 |
| 12 | Arden Ridge Spring Creek | S3 | 6.90 | 50.24 | 99.25 | 74.000 | 67.096 | 3 | 319.994 | 314.960 |
| 13 | Stream 3 | S4 | 3.11 | 50.23 | 99.23 | 67.096 | 63.981 | 1 | 314.960 | 311.560 |
| 14 | Stream 4 | Old W12 | 3.48 | 50.22 | 99.21 | 63.981 | 60.504 | 1 | 311.560 | 307.870 |
| 15 | Southbound | S5 | 12.13 | 50.17 | 99.18 | 60.504 | 48.374 | 3 | 307.870 | 297.900 |
| 16 | Stream 5 | Old W13 | 4.50 | 50.17 | 99.16 | 48.374 | 43.878 | 1 | 297.900 | 294.120 |
| 17 | Above WSC Gauge | WSC05LL005 | 8.94 | 50.19 | 99.10 | 43.878 | 34.943 | 2 | 294.120 | 288.636 |
| 18 | South of Yellowhead | MB05LLS003 | 30.36 | 50.23 | 98.97 | 34.943 | 4.582 | 6 | 288.636 | 270.000 |
| 19 | Pool 14 Gladstone | Gladstone Dam | 4.58 | 50.23 | 98.93 | 4.582 | 0.000 | 1 | 270.000 | 267.138 |

Table 5.2. Hydraulic parameters used in the Whitemud River Qual2K model.

| Reach Number | Weir | | Manning Formula | | | | | Surveyed X-Sections (2007) Used for Reach Data |
|--------------|------------|-----------|-----------------|-----------|-------------|------------|------------|--|
| | Height (m) | Width (m) | Channel Slope | Manning n | Bot Width m | Side Slope | Side Slope | |
| 1 | 1.8200 | 13.1800 | 0.0011 | 0.3888 | 7.57 | 2.0341 | 3.0034 | 2, 3, 4 |
| 2 | 1.2200 | 15.4000 | 0.0014 | 0.3888 | 6.35 | 2.2502 | 5.5631 | 5, 6 |
| 3 | | | 0.0005 | 0.3888 | 10.85 | 2.9659 | 1.6360 | 7, 8 |
| 4 | 1.4100 | 13.7400 | 0.0009 | 0.4500 | 8.90 | 1.0184 | 3.2540 | 8, 9, 10 |
| 5 | 0.7900 | 12.5600 | 0.0009 | 0.4000 | 8.40 | 1.1106 | 3.0777 | 10 |
| 6 | 0.8600 | 13.5100 | 0.0010 | 0.5000 | 7.40 | 1.3252 | 5.6110 | 10, 11 |
| 7 | | | 0.0006 | 0.4500 | 5.90 | 3.5614 | 4.4530 | 11, 12, 13 |
| 8 | 0.5100 | 7.3500 | 0.0006 | 0.4500 | 6.35 | 1.5252 | 2.9383 | 13, 14 |
| 9 | 1.2600 | 10.9800 | 0.0004 | 0.5000 | 5.60 | 2.0503 | 2.1445 | 14 |
| 10 | | | 0.0005 | 0.4500 | 7.35 | 1.2071 | 2.5244 | 14, 15 |
| 11 | | | 0.0007 | 0.5000 | 7.35 | 1.2071 | 2.5244 | 14, 15 |
| 12 | | | 0.0007 | 0.5000 | 11.25 | 0.8455 | 1.6243 | 15, 16 |
| 13 | | | 0.0011 | 0.4888 | 11.25 | 0.8455 | 1.6243 | 15, 16 |
| 14 | | | 0.0011 | 0.4888 | 13.40 | 1.3270 | 0.3443 | 16 |
| 15 | | | 0.0008 | 0.4888 | 11.65 | 3.0158 | 1.1973 | 16, 17 |
| 16 | | | 0.0008 | 0.4888 | 9.90 | 4.7046 | 2.0503 | 17 |
| 17 | | | 0.0006 | 0.4888 | 8.90 | 2.0503 | 4.3315 | 18 |
| 18 | | | 0.0006 | 0.4888 | 8.60 | 2.0503 | 1.8040 | 19 |
| 19 | 1.2800 | 18.0700 | 0.0006 | 0.3888 | 8.75 | 2.0503 | 3.0678 | 18, 19 |

Table 5.3. Estimates of benthic algae and sediment oxygen demand coverage used in initial calibration of the Qual2K model.

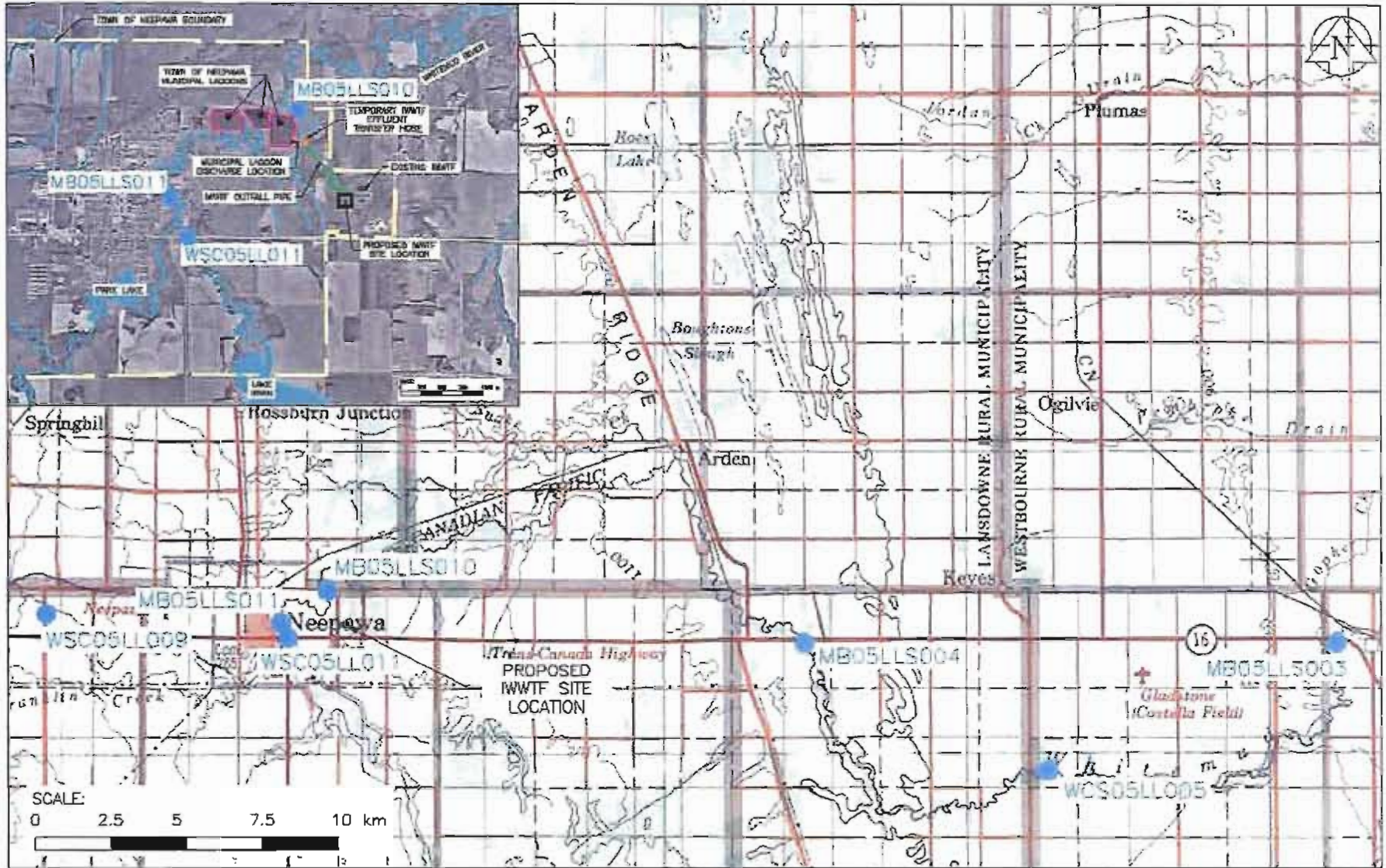
| <i>Reach Number</i> | <i>Bottom Algae Coverage</i> | <i>Bottom SOD Coverage</i> |
|---------------------|------------------------------|----------------------------|
| 1 | 20.00% | 90.00% |
| 2 | 50.00% | 60.00% |
| 3 | 30.00% | 60.00% |
| 4 | 20.00% | 80.00% |
| 5 | 20.00% | 80.00% |
| 6 | 40.00% | 70.00% |
| 7 | 35.00% | 65.00% |
| 8 | 30.00% | 70.00% |
| 9 | 20.00% | 80.00% |
| 10 | 20.00% | 80.00% |
| 11 | 20.00% | 80.00% |
| 12 | 20.00% | 80.00% |
| 13 | 30.00% | 80.00% |
| 14 | 30.00% | 80.00% |
| 15 | 20.00% | 80.00% |
| 16 | 20.00% | 80.00% |
| 17 | 20.00% | 80.00% |
| 18 | 20.00% | 80.00% |
| 19 | 20.00% | 80.00% |

Table 5.4: Concentrations of water chemistry parameters used in initial calibration of the Whitemud River Qual2K model based on the June 3 1991 dataset.

| | | Mainstem headwater | | | |
|----------------------------|------------|--------------------|------------|------------|------------|
| | | MB05SLL011 | MB05SLL010 | MB05SLL004 | MB05SLL003 |
| | | 11:00 AM | | | |
| Distance (km) | | 110.1 | 107.56 | 61.45 | 4.58 |
| | Units | | | | |
| Temperature | C | 21.50 | | | |
| Conductivity | umhos | 496.00 | 703.00 | 642.00 | 639.00 |
| Inorganic Solids | mgD/L | 7.00 | 9.00 | 18.00 | 18.00 |
| Dissolved Oxygen | mg/L | 10.00 | 1.80 | 5.70 | 6.80 |
| CBODslow | mgO2/L | 9.00 | 24.30 | 24.30 | 21.60 |
| CBODfast | mgO2/L | 1.50 | 2.90 | 1.90 | 1.00 |
| Organic Nitrogen | ugN/L | 820.00 | 1100.00 | 985.00 | 995.00 |
| NH4-Nitrogen | ugN/L | 40.00 | 3160 | 575 | 45 |
| NO3-Nitrogen | ugN/L | 40.00 | 140.00 | 340.00 | 10.00 |
| Organic Phosphorus | ugP/L | 13.75 | | 78.75 | 43.75 |
| Inorganic Phosphorus (SRP) | ugP/L | 41.25 | 1350.00 | 236.25 | 131.25 |
| Phytoplankton | ugA/L | 2.00 | | | |
| Detritus (POM) | mgD/L | 1.00 | | | |
| Pathogen | cfu/100 mL | | | | |
| Alkalinity | mgCaCO3/L | 190.00 | | 200.00 | |
| pH | s.u. | 8.32 | 7.77 | 7.97 | 8.26 |

Table 5.5: Estimates of shade used in Qual2K model calibration.

| Reach Number | 5:00 AM | 6:00 AM | 7:00 AM | 8:00 AM | 9:00 AM | 10:00 AM | 11:00 AM | 12:00 PM | 1:00 PM | 2:00 PM | 3:00 PM | 4:00 PM | 5:00 PM | 6:00 PM | 7:00 PM | 8:00 PM | 9:00 PM | 10:00 PM |
|--------------|---------|---------|---------|---------|---------|----------|----------|----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|----------|
| 1 | 50.0% | 50.0% | 30.0% | 20.0% | 10.0% | 5.0% | 5.0% | 4.0% | 2.0% | 3.0% | 4.0% | 5.0% | 8.0% | 10.0% | 20.0% | 30.0% | 30.0% | 30.0% |
| 2 | 50.0% | 50.0% | 30.0% | 20.0% | 10.0% | 3.0% | 2.0% | 1.0% | 0.0% | 1.0% | 2.0% | 3.0% | 5.0% | 10.0% | 20.0% | 30.0% | 30.0% | 30.0% |
| 3 | 50.0% | 50.0% | 30.0% | 20.0% | 10.0% | 3.0% | 2.0% | 1.0% | 0.0% | 1.0% | 2.0% | 3.0% | 5.0% | 10.0% | 20.0% | 30.0% | 30.0% | 30.0% |
| 4 | 50.0% | 50.0% | 30.0% | 20.0% | 10.0% | 4.0% | 2.0% | 1.0% | 0.0% | 1.0% | 2.0% | 4.0% | 10.0% | 15.0% | 20.0% | 30.0% | 30.0% | 30.0% |
| 5 | 50.0% | 50.0% | 30.0% | 20.0% | 10.0% | 4.0% | 3.0% | 2.0% | 1.0% | 2.0% | 3.0% | 4.0% | 5.0% | 15.0% | 20.0% | 30.0% | 30.0% | 30.0% |
| 6 | 50.0% | 50.0% | 30.0% | 20.0% | 10.0% | 5.0% | 3.0% | 2.0% | 1.0% | 2.0% | 3.0% | 5.0% | 5.0% | 15.0% | 20.0% | 30.0% | 30.0% | 30.0% |
| 7 | 90.0% | 90.0% | 80.0% | 60.0% | 40.0% | 35.0% | 25.0% | 20.0% | 15.0% | 20.0% | 25.0% | 35.0% | 40.0% | 60.0% | 80.0% | 90.0% | 90.0% | 90.0% |
| 8 | 100.0% | 100.0% | 90.0% | 80.0% | 75.0% | 70.0% | 50.0% | 40.0% | 30.0% | 40.0% | 50.0% | 70.0% | 75.0% | 80.0% | 90.0% | 100.0% | 100.0% | 100.0% |
| 9 | 80.0% | 80.0% | 60.0% | 40.0% | 35.0% | 30.0% | 20.0% | 15.0% | 10.0% | 15.0% | 20.0% | 30.0% | 35.0% | 40.0% | 60.0% | 80.0% | 80.0% | 80.0% |
| 10 | 50.0% | 50.0% | 30.0% | 20.0% | 10.0% | 5.0% | 3.0% | 2.0% | 1.0% | 2.0% | 3.0% | 5.0% | 8.0% | 10.0% | 20.0% | 30.0% | 30.0% | 30.0% |
| 11 | 70.0% | 70.0% | 50.0% | 30.0% | 20.0% | 10.0% | 8.0% | 6.0% | 4.0% | 6.0% | 8.0% | 10.0% | 20.0% | 30.0% | 50.0% | 70.0% | 70.0% | 70.0% |
| 12 | 100.0% | 100.0% | 100.0% | 90.0% | 85.0% | 80.0% | 60.0% | 50.0% | 40.0% | 50.0% | 60.0% | 80.0% | 85.0% | 90.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| 13 | 100.0% | 100.0% | 90.0% | 80.0% | 70.0% | 60.0% | 50.0% | 40.0% | 30.0% | 40.0% | 50.0% | 60.0% | 70.0% | 80.0% | 90.0% | 100.0% | 100.0% | 100.0% |
| 14 | 90.0% | 90.0% | 80.0% | 70.0% | 65.0% | 60.0% | 40.0% | 30.0% | 25.0% | 30.0% | 40.0% | 60.0% | 65.0% | 70.0% | 80.0% | 90.0% | 90.0% | 90.0% |
| 15 | 80.0% | 80.0% | 70.0% | 60.0% | 50.0% | 40.0% | 35.0% | 30.0% | 20.0% | 30.0% | 40.0% | 60.0% | 70.0% | 80.0% | 90.0% | 100.0% | 100.0% | 100.0% |
| 16 | 90.0% | 90.0% | 80.0% | 60.0% | 50.0% | 40.0% | 40.0% | 30.0% | 20.0% | 30.0% | 40.0% | 40.0% | 50.0% | 60.0% | 80.0% | 90.0% | 90.0% | 90.0% |
| 17 | 90.0% | 90.0% | 80.0% | 60.0% | 50.0% | 40.0% | 40.0% | 30.0% | 20.0% | 30.0% | 40.0% | 40.0% | 50.0% | 60.0% | 80.0% | 90.0% | 90.0% | 90.0% |
| 18 | 90.0% | 90.0% | 80.0% | 60.0% | 50.0% | 40.0% | 40.0% | 30.0% | 20.0% | 30.0% | 40.0% | 40.0% | 50.0% | 60.0% | 80.0% | 90.0% | 90.0% | 90.0% |
| 19 | 90.0% | 90.0% | 80.0% | 60.0% | 50.0% | 40.0% | 40.0% | 30.0% | 20.0% | 30.0% | 40.0% | 40.0% | 50.0% | 60.0% | 80.0% | 90.0% | 90.0% | 90.0% |



Source: Etopo, E70113 – Southern Manitoba; Manitoba Land Initiative, Digital Imagery: 4605560neg, 4605560seg, 4705560nwg, 4705560swg.

| | | | |
|--|---|-------------------------------|---------------------------|
|  Earth Tech (Canada) Inc. Winnipeg, Manitoba 204.477.8281 |  Neepawa <i>Land of Plenty</i> | designed scale yy-mm-dd | BAR 08-06-13 |
| | | drawn AZ | project no. 97297 |
| IWWTF UPGRADE ENVIRONMENTAL IMPACT ASSESSMENT NEEPAWA, MANITOBA | | checked SJB | drawing no. FIGURE 5.1 |
| | | approved | |
| HYDROMETRIC AND WATER QUALITY STATIONS INDUSTRIAL WASTEWATER TREATMENT FACILITY NEEPAWA, MANITOBA | | | |

SECTION 6.0

WATER QUALITY MODEL RESULTS

6.1 DEFINITION OF EXISTING CONDITIONS

The calibration dataset from June 1991 was used to refine understanding of interactions between the various water quality parameters in the river that were not included in the provincial monitoring dataset, such as fast and slow reacting forms of BOD, particulate organic matter and nutrients. Once the rates associated with the processes were identified and refined, the median June-early September concentrations of measured parameters in the 1990-1991 dataset were input to the model to represent existing summer conditions in the Whitemud River for the assessment. These data are summarized in **Table 6.1**.

Flows used in model simulations for the assessment were 0.2 m³/s at Neepawa (upstream of effluent discharges), with zero inputs other than the Town of Neepawa effluents, to represent base flow conditions in the river. Estimates of existing concentrations and discharge rates for the Town of Neepawa municipal and industrial effluents were derived from data provided by the Town of Neepawa and reported to Manitoba Conservation between 2004 and 2007, as described in **Section 2.6** of the main body of this report.

As the datasets describing river water quality and effluent discharges were not collected simultaneously and do not include all parameters simulated by Qual2K, their use does not provide a model calibrated to a measured set of conditions in the river. However, the model developed as described above allows a model-based assessment of effects of the municipal and industrial effluents on water quality in the river under approximated mid-summer conditions. This assessment, which simulates biological processes not accounted for in simple mass-balance calculations, provides a more robust estimation of biologically-moderated parameters such as dissolved oxygen and ammonia, as described below.

6.2 DISSOLVED OXYGEN

A primary process characterized by the model is the decay of BOD and its impact on dissolved oxygen concentrations, which have been identified as a potential historic concern with respect to water quality in the river. The model indicates that, even in the absence of effluents at Neepawa, dissolved oxygen concentrations in summer tend to be below saturated levels throughout the reach of the Whitemud River from Neepawa to Gladstone, as indicated in **Figure 6.1A**. Model results indicate that the proposed effluent discharges from the upgraded IWWTF will have little effect on these “zero-discharge” dissolved oxygen concentrations (**Figure 6.1B**), and will not cause fully-mixed dissolved oxygen concentrations

in the river to drop below the Manitoba Water Quality (MWQ) Objective instantaneous minimum or 7-day concentrations of 5.0 mg/L or 6.0 mg/L, respectively.

Figure 6.2 shows the modeled improvement in dissolved oxygen concentrations in the Whitemud River anticipated to result from the improved quality of the Town of Neepawa municipal effluent that will result from the project. As shown, minimum dissolved oxygen concentrations in the river below the effluent outfall are expected to increase by approximately 1 mg/L, and the modeled distance of dissolved oxygen depression downstream of the outfall is expected to decrease from approximately 35 km to approximately 20 km.

Considering the combined effects of the anticipated improvements to both the municipal and industrial effluents, the discharge of both effluents simultaneously under mid-summer conditions (**Figure 6.3B**) is expected, based on model results, to result in dissolved oxygen concentrations in the Whitemud River that are higher than those currently experienced with discharge of either individual effluent (**Figures 6.3A and 6.2A**). However, a substantial reach of the river channel (approximately 20 km based on model output) is anticipated to be below the MWQO of 6.0 mg/L during discharge of the municipal effluent, with the incremental effect of the upgraded IWWTF effluent being negligible.

6.3 AMMONIA

Ammonia is produced in surface waters through the degradation of organic material and excretion as a waste product. It is therefore naturally present in surface waters, where it is consumed by plants and algae, lost through volatilization to the atmosphere, and converted to nitrate through bacterial nitrification. Although limitations in the available datasets prevent detailed characterization of these processes in the Whitemud River, the model developed from these datasets provides a rough characterization of the balance between organic nitrogen, nitrate and ammonia that accounts for chemical and biological processes. Therefore, the modeled results represent an appropriate means of estimating instream ammonia concentrations as an alternative to the more conservative mass-balance analysis presented in **Section 6.4** of the Request for Alteration to the Town of Neepawa's Industrial Wastewater Treatment Facility, Neepawa, Manitoba.

Figure 6.4 shows the modeled reduction in fully-mixed ammonia concentrations in the Whitemud River anticipated to result from the discharge of industrial effluent from the upgraded IWWTF in comparison to that currently discharged from Municipal Cell #3. Similarly, **Figure 6.5** shows the modeled reduction in Whitemud River ammonia concentrations expected to result from project-related improvements to the Town of Neepawa municipal effluent.

Due to anticipated improvements in both the industrial and municipal effluents as described above, the model indicates that mid-summer ammonia concentrations in the Whitemud River

during simultaneous discharge of both the industrial and municipal effluents (following completion of the project, **Figure 6.6**), will be lower than existing ammonia concentrations that occur during discharge of either individual effluent (**Figures 6.4** and **6.5**). The chronic (30-day and 4-day) MWQ Objectives (1.3 mg/L and 3.2 mg/L at background conditions listed in **Table 6.1**) are likely to be exceeded in the river over distances of approximately 1 km and 4 km, respectively, during discharge of the municipal effluent, but exceedences of the 1-hour Objective (6.3 mg/L) are no longer expected to occur following project completion. Effluents from the upgraded IWWTF are not expected to elevate ammonia concentrations in the river above the Objectives, and will have lower concentrations than the fully-mixed concentration in the river below the outfall during periods of municipal effluent discharge from the Municipal lagoon.

6.4 CONCLUSION

As described above, the water quality model developed for the Whitemud River indicates the proposed improvements to the IWWTF treatment and discharge processes will adequately mitigate water quality impacts such as those currently caused by its intermittent discharge from Municipal Cell #3, (with respect to dissolved oxygen and ammonia concentrations in the Whitemud River under typical summer conditions). However, model results show that the current Town of Neepawa municipal wastewater effluent likely causes water quality degradation in the Whitemud River through depression of dissolved oxygen to concentrations below the Manitoba Water Quality Objectives for protection of cool-water aquatic life and elevation of ammonia concentrations to concentrations above the Objectives. Reductions in discharge rates and improvements in the quality of the municipal effluent are anticipated to be made possible by the proposed IWWTF upgrades. Although the changes are expected to moderate these effects to a significant extent, model simulations indicate exceedences of MWQ Objectives will still occur, but will likely be less severe. Model results also indicate that incremental effects of the industrial effluent to those associated with the municipal effluent will be negligible.

Table 6.1: Water chemistry used to represent existing conditions for model simulations, based on median values of the June-September, 1990-1991 datasets.

| <i>Number of Headwaters*</i> | 1 | |
|--------------------------------|---------------------------|---|
| <i>Reach No.*</i> | <i>Headwater Name</i> | <i>Flow* Rate (m³/s)</i> |
| 1 | Mainstem headwater | 0.200 |
| <i>Headwater Water Quality</i> | <i>Units</i> | |
| Temperature | C | 20.75 |
| Conductivity | umhos | 375.00 |
| Inorganic Solids | mgD/L | 3.00 |
| Dissolved Oxygen | mg/L | 7.40 |
| CBODslow | mgO ₂ /L | 20.00 |
| CBODfast | mgO ₂ /L | 1.85 |
| Organic Nitrogen | ugN/L | 938.00 |
| NH ₄ -Nitrogen | ugN/L | 88.00 |
| NO ₃ -Nitrogen | ugN/L | 80.00 |
| Organic Phosphorus | ugP/L | 48.00 |
| Inorganic Phosphorus (SRP) | ugP/L | 58.00 |
| Phytoplankton | ugA/L | 2.00 |
| Detritus (POM) | mgD/L | 3.00 |
| Pathogen | cfu/100 mL | |
| Alkalinity | mgCaCO ₃ /L | 194.00 |
| pH | s.u. | 8.15 |

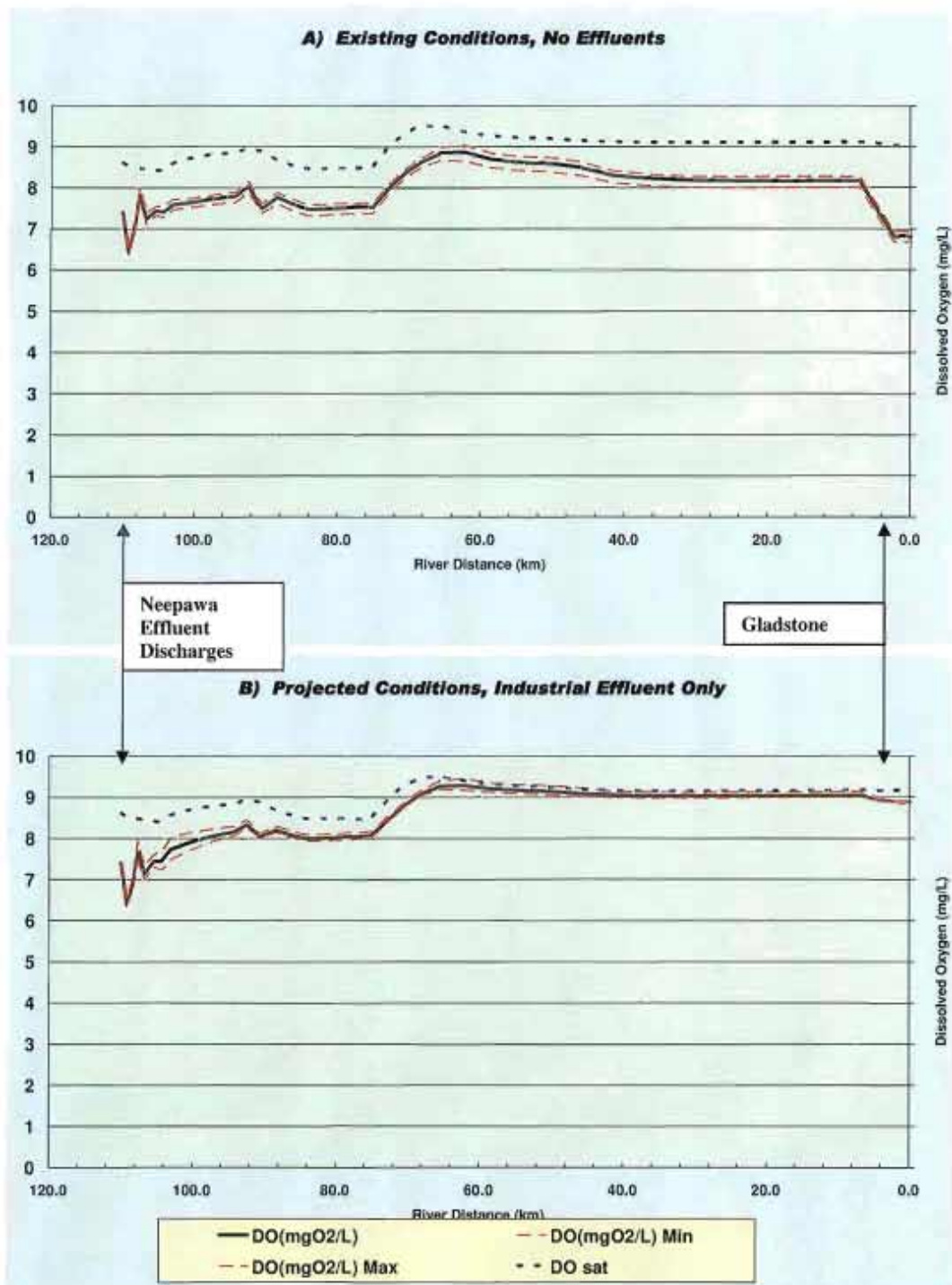


Figure 6.1 Modeled mid-summer dissolved oxygen concentrations in the Whitemud River with no effluent loading (A) and with proposed upgraded IWWTF effluent loading (B).

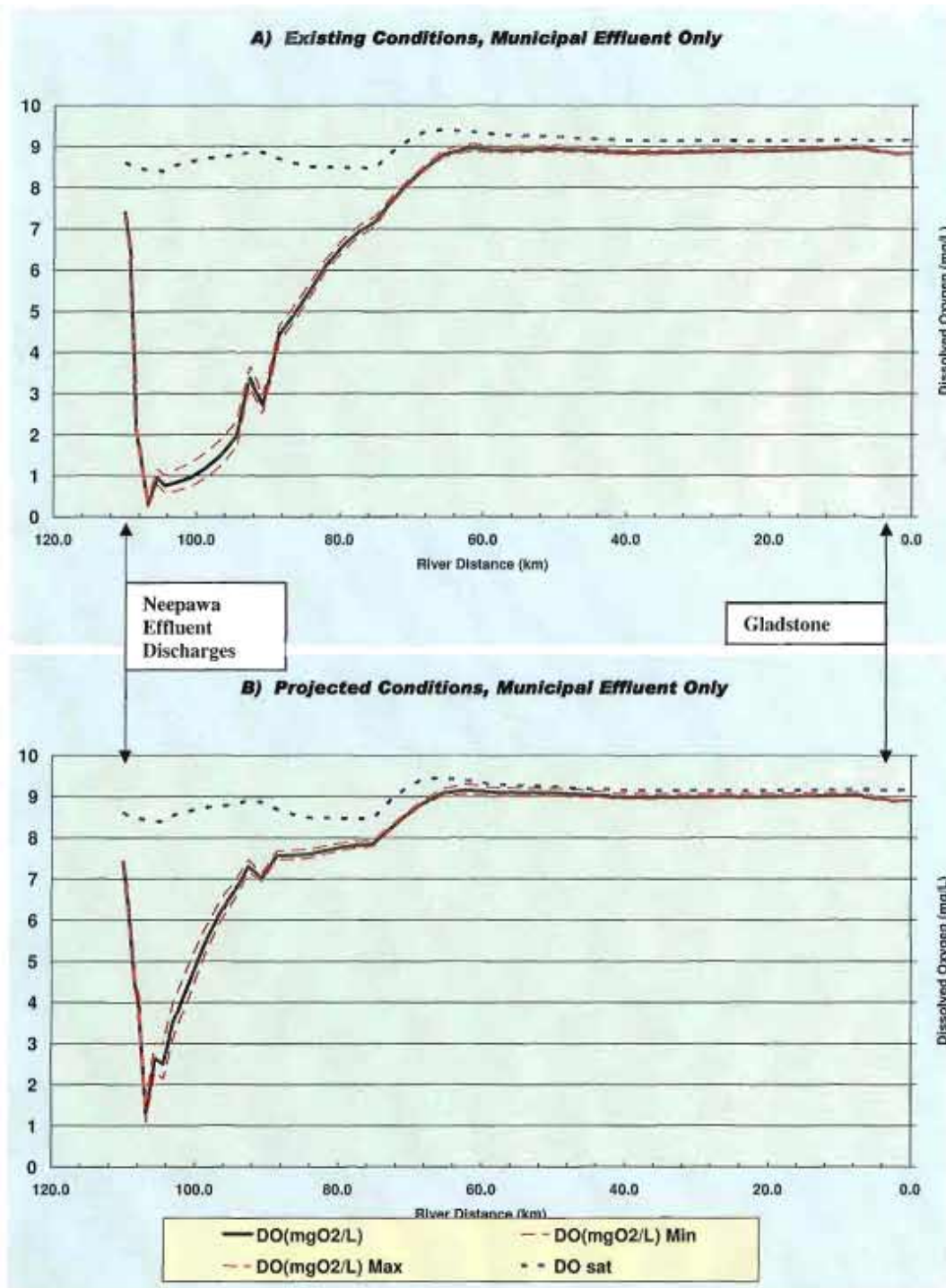


Figure 6.2 Modeled mid-summer dissolved oxygen concentrations in the Whitemud River with existing (A) and proposed (B) Neepawa municipal effluent loadings.

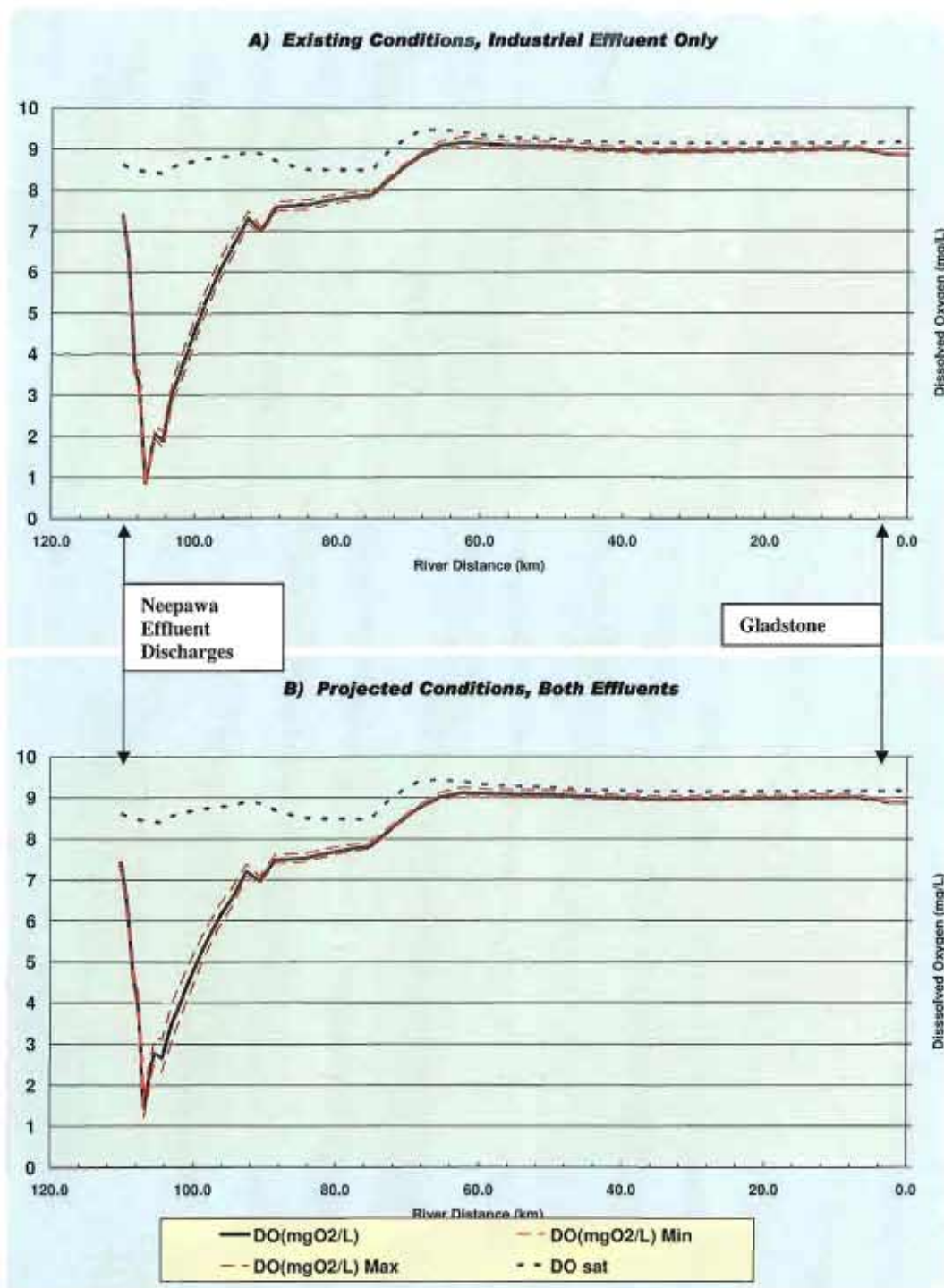


Figure 6.3 Modeled mid-summer dissolved oxygen concentrations in the Whitemud River with existing industrial effluent loading (A) and proposed loading of both municipal and industrial effluents (B).

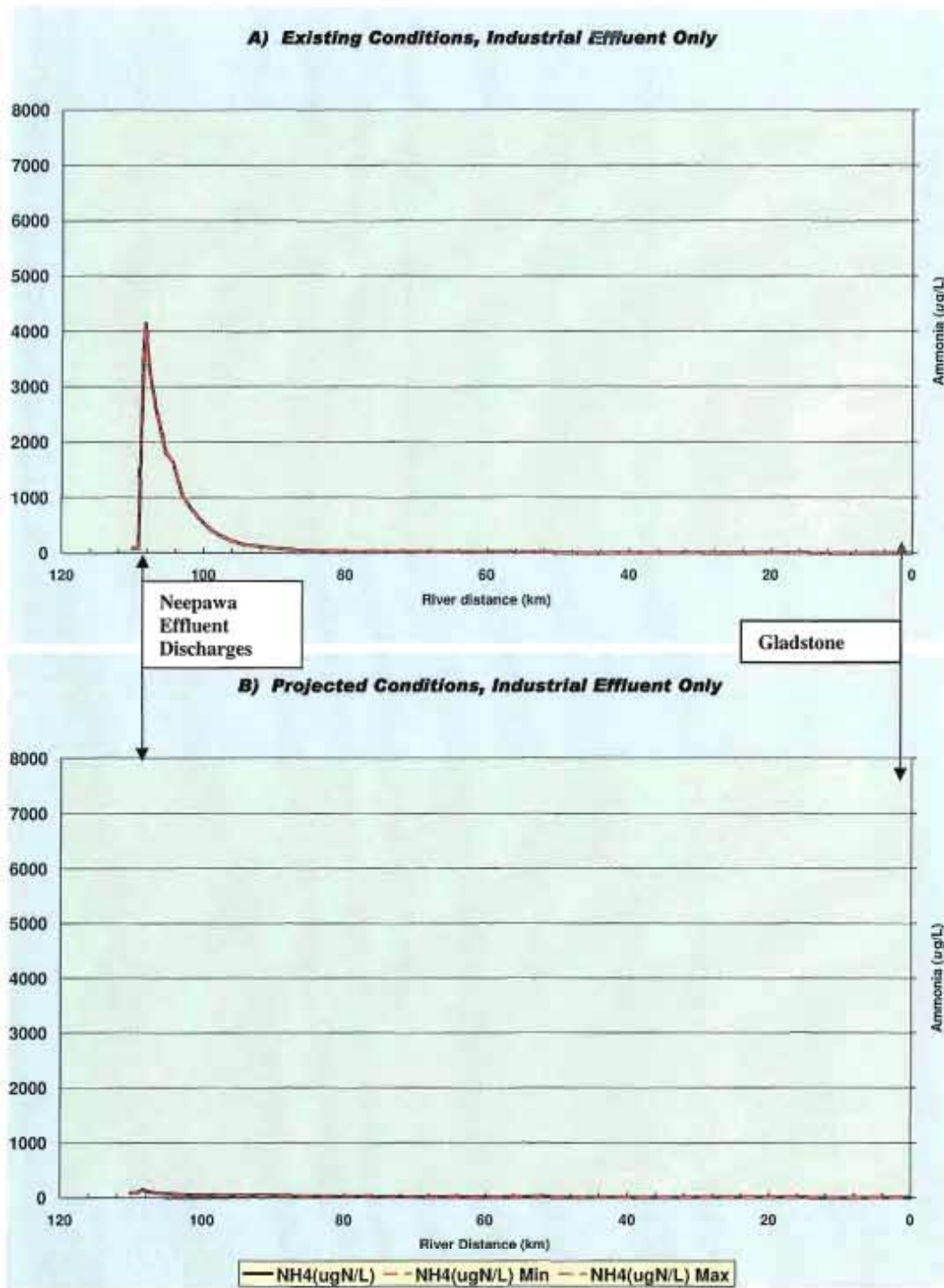


Figure 6.4 Modeled mid-summer ammonia concentrations in the Whitemud River with existing (A) and proposed (B) industrial effluent loading.

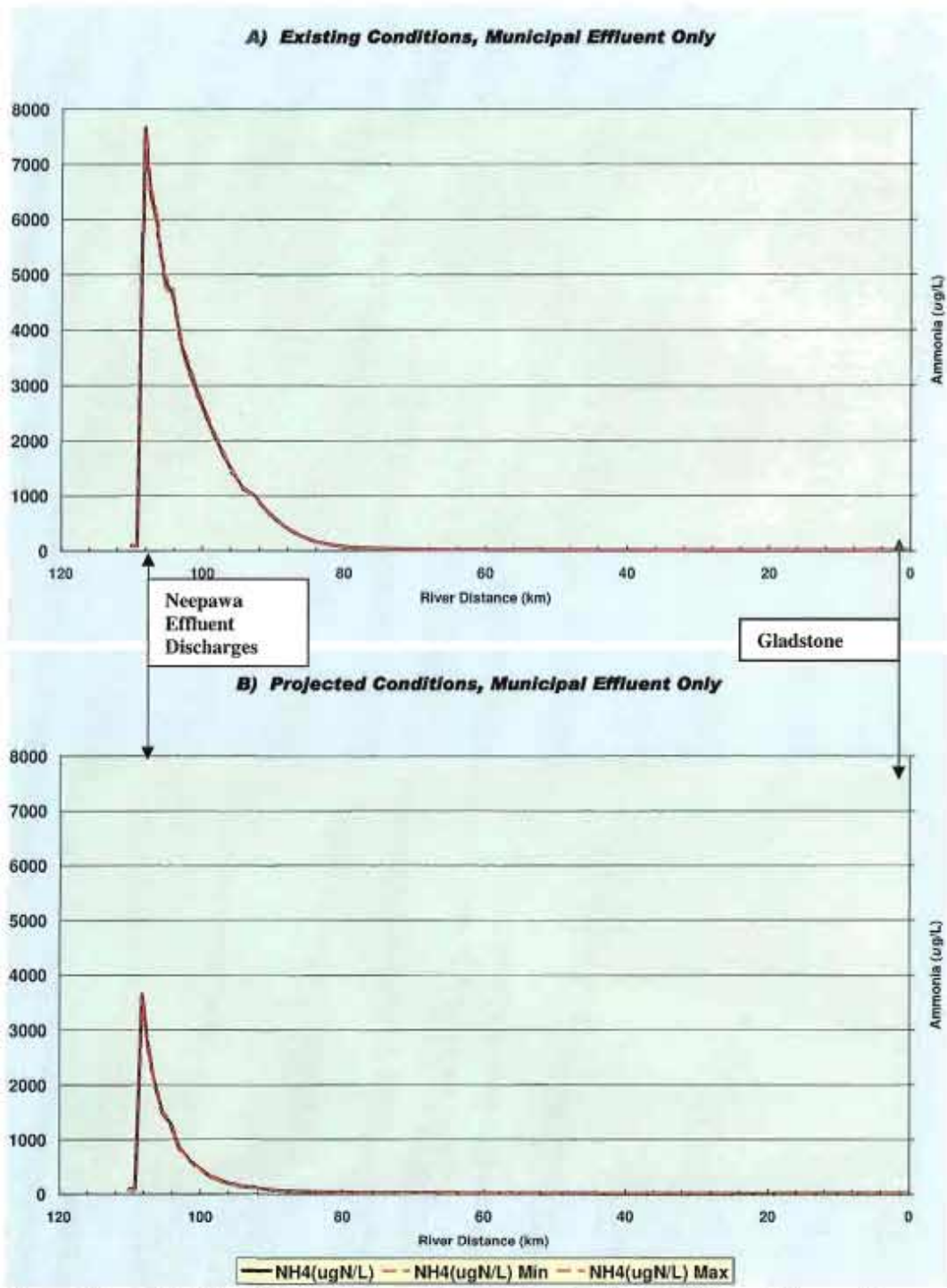


Figure 6.5 Modeled mid-summer ammonia concentrations in the Whitemud River with existing (A) and proposed (B) Neepawa municipal effluent loading.

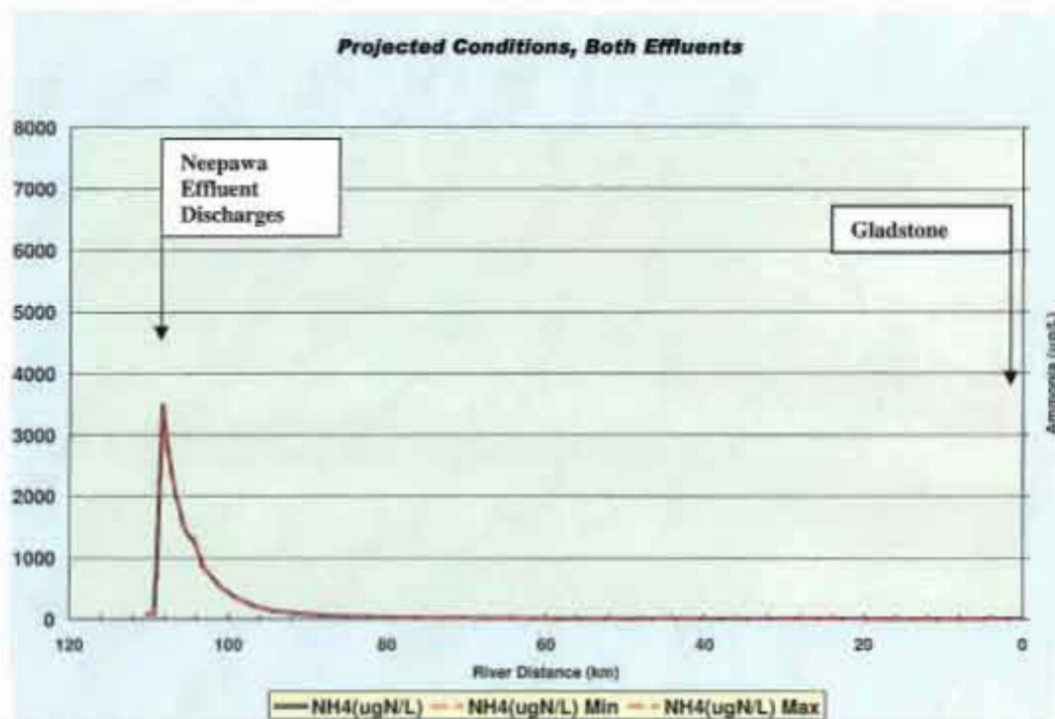


Figure 6.6 Modeled mid-summer ammonia concentrations in the Whitemud River with proposed loading of both municipal and industrial effluents.

REFERENCES

Agriculture and Agri-Food Canada – Prairie Farm Rehabilitation Administration, Prairies East Region. 2005. Summary of resources and land use issues related to riparian areas in the Whitemud River watershed study area. 70 pp.

Chapra, S., G. Pelletier and H. Tao. 2006. Qual2K: A modeling framework for simulating river and stream water quality, version 2.04. Documentation and user's manual. Civil and Environmental Engineering Dept., Tufts University, Medford, MA., Steven.Chapra@tufts.edu

Hughes, C.E. 1999. Water quality assessment of the Whitemud River watershed, 1996 through 1998, Manitoba, Canada. Manitoba Conservation, Water Quality Management Section. Manitoba Environment Report No. 99-06.

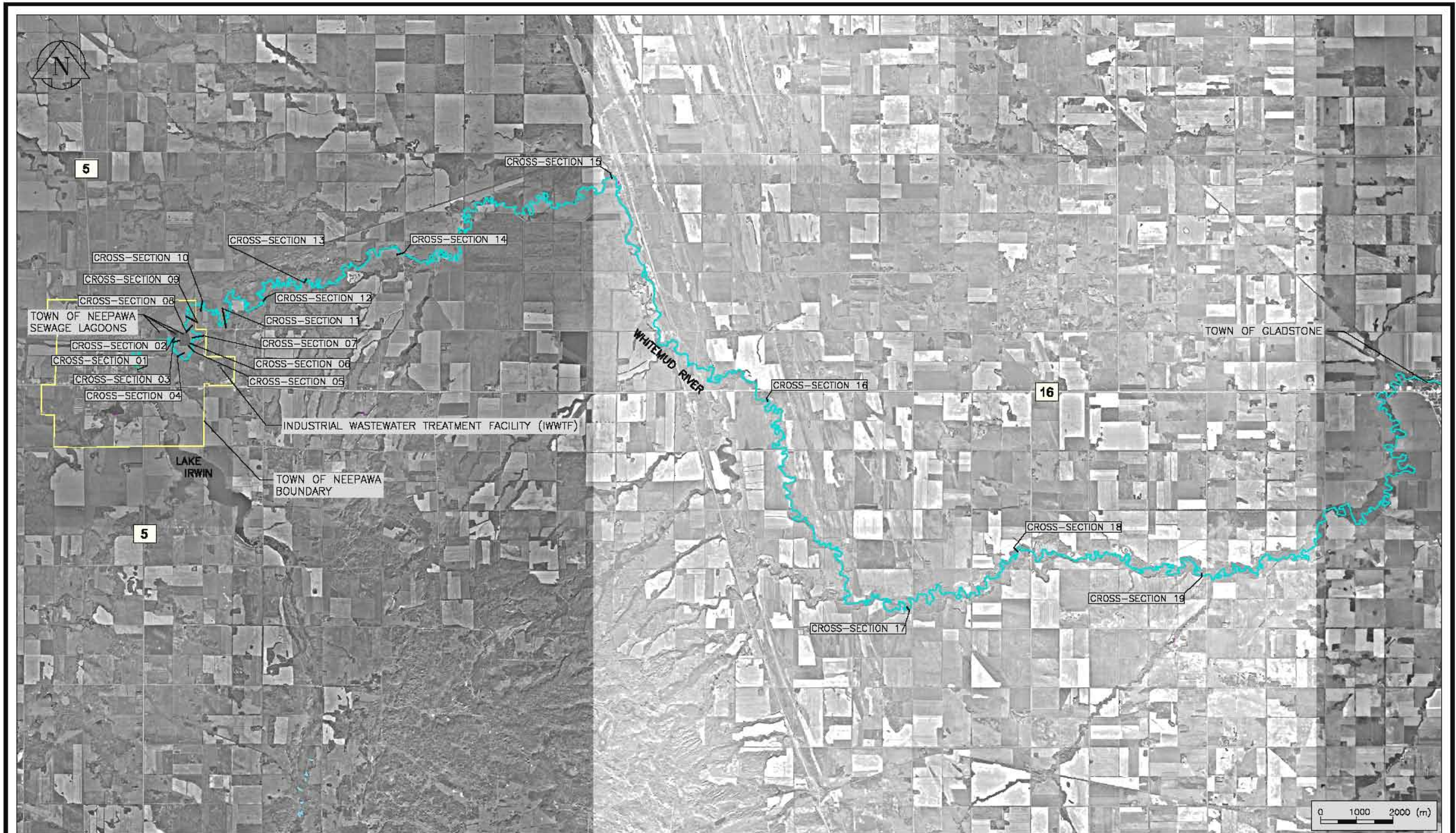
Manitoba Land Initiative website provided by Manitoba Conservation:
<https://web2.gov.mb.ca/mli/index.html>

Manitoba Water Stewardship. Water Quality Management Section. 2007. Surface water quality data. Government of Manitoba, Winnipeg.

Water Survey of Canada Data Products & Services website:
http://www.wsc.ec.gc.ca/products/main_e.cfm?cname=products_e.cfm



Attachment 1



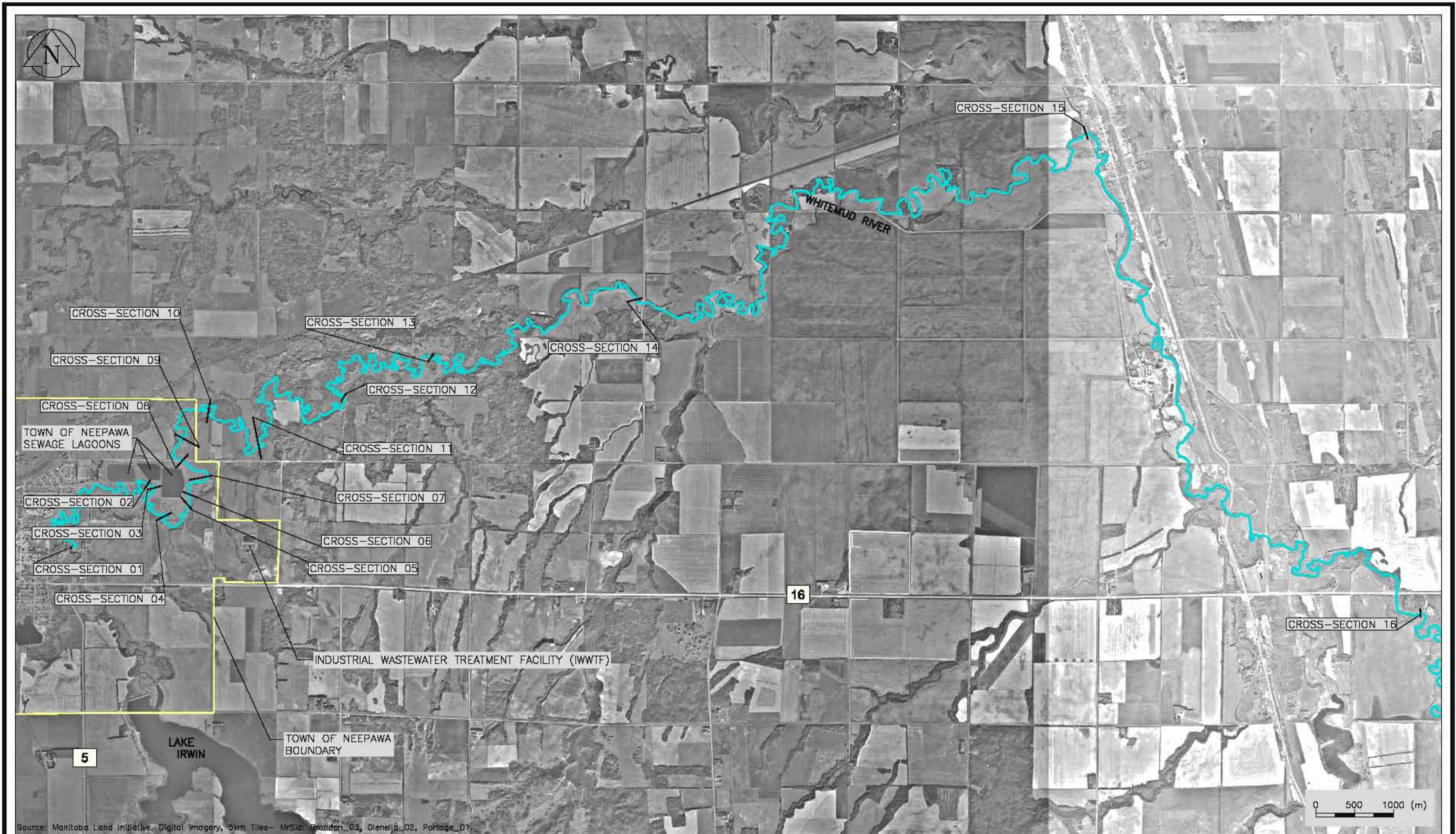
Source: Manitoba Land Initiative, Digital Imagery, 5km Tiles- MrSid: Brandon_03, Glenella_02, Partage_01.

LEGEND:
 CROSS-SECTION 14 CROSS-SECTION NUMBER
 ———— CROSS-SECTION EXTENTS

Earth Tech
 Earth Tech (Canada) Inc. Winnipeg, Manitoba 204.477.5091
 IWWTF UPGRADE
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 NEEPAWA, MANITOBA

Neepawa
Land of Plenty
 WHITEMUD RIVER
 CROSS-SECTIONS 1-19

| | | |
|----------------|----------------------|------------------------|
| designed AW | scale BAR | yy-mm-dd 2008-06-27 |
| drawn LB | project no. 97297 | |
| checked SJB | drawing no. | rev. |
| approved | FIGURE 2 | |



LEGEND:
 CROSS-SECTION 14 CROSS-SECTION NUMBER
 ———— CROSS-SECTION EXTENTS

EarthTech
 Earth Tech (Canada) Inc. Winnipeg, Manitoba 904.477.5081
 IWWTF UPGRADE
 ENVIRONMENTAL IMPACT ASSESSMENT
 NEEPAWA, MANITOBA

Neepawa
 Land of Plenty
 WHITEMUD RIVER
 CROSS-SECTIONS 1-16

| | | |
|----------------|----------------------|------------------------|
| designed AW | scale BAR | yy-mm-dd 2008-06-27 |
| drawn LB | project no. 97297 | |
| checked SJB | drawing no. | rev. |
| approved | FIGURE 2A | |



Source: Manitoba Land Initiative, Digital Imagery, 5km Tiles - MrSid: Brandon_03, Glenella_02, Portage_01

LEGEND:
 [CROSS-SECTION 14] CROSS-SECTION NUMBER
 [THICK LINE] CROSS-SECTION EXTENTS

EarthTech
 Earth Tech (Canada) Inc. Winnipeg, Manitoba 204.497.8581
 IWWTF UPGRADE
 ENVIRONMENTAL IMPACT ASSESSMENT
 NEEPAWA, MANITOBA

Neepawa
Land of Plenty
 WHITEMUD RIVER
 CROSS-SECTIONS 17-19

| | | |
|----------------|--------------------------|------------------------|
| designed AW | scale BAR | yy-mm-dd 2008-06-27 |
| drawn LB | project no. 97297 | |
| checked SJB | drawing no. FIGURE 2B | rev. |
| approved | | |



Photograph No. 1: Cross-section 1 Control Structure.



Photograph No. 2: Cross-section 2.



Photograph No. 3: Cross-section 3.



Photograph No. 4: Cross-section 4.



Photograph No. 5: Cross-section 5.



Photograph No. 6: Cross-section 6.



Photograph No. 7: Cross-section 7.



Photograph No. 8: Cross-section 8.



Photograph No. 9: Cross-section 9.



Photograph No. 10: Cross-section 10.



Photograph No. 11: Cross-section 11.



Photograph No. 12: Cross-section 12.



Photograph No. 13: Cross-section 13.



Photograph No. 14: Cross-section 14.



Photograph No. 15: Cross-section 17.



Photograph No. 16: Cross-section 18.



Photograph No. 17: Cross-section 19.