North Saskatchewan Watershed Alliance

ASSESSMENT OF EXISTING WATER SUPPLY AND DEMAND DATA FOR THE STURGEON RIVER BASIN

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The North Saskatchewan Watershed Alliance (NSWA) is a non-profit society whose purpose is to protect and improve water quality and ecosystem functioning in the North Saskatchewan River watershed in Alberta. The organization is guided by a Board of Directors composed of member organizations from within the watershed. It is the designated Watershed Planning and Advisory Council (WPAC) for the North Saskatchewan River under the Government of Alberta's *Water for Life Strategy*.

This report was prepared by Sal Figliuzzi and Associates Ltd. for the North Saskatchewan Watershed Alliance.

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ACKNOWLEDGEMENTS

The author gratefully acknowledges the contribution of the following persons for their help and support towards the completion of this report: Yaw Okyere of Alberta Environment and Parks for providing a listing of licenced water allocations within the gross and effective areas of the Sturgeon River basin, for providing help in the determination of active licences and for providing data associated with the WRMM model; and Michael Seneka for providing information on the status of the NATYIELD model. Their help and support is greatly appreciated.

EXECUTIVE SUMMARY

The North Saskatchewan Watershed Alliance (NSWA) was formed in 1999 and is one of 11 *"Watershed Planning and Advisory Councils" (WPACs)* created under the Government of Alberta's *"Water for Life Strategy"*. Under "*Water for Life*" the NSWA has responsibility for completing watershed management plans for the North Saskatchewan watershed and its tributary sub-basins – including the Sturgeon River basin. As part of this responsibility, and in response to ongoing concerns over declining summer flows in the Sturgeon River, the NSWA has identified the need to develop a water management model with which to assess the potential cause of declining summer flows and possible water management alternatives for the basin (NSWA 2014).

The assessment of water management alternatives for a given river basin is generally carried out by applying the current or future levels of water demand, including instream flow needs (IFN's) or objectives (IFO's), onto a time series of historical natural stream flows in order to assess the stream course's ability to meet both environmental objectives and consumptive use demands for water. Because of complexities introduced by the spatial variability in water supply and demand, and Alberta's "first in time first in right" (FITFIR) system of managing water access during periods of low flows, a conceptual water management model is often required to assess water management alternatives.

The required input to these models, among other items, includes:

i. Time series of historical hydroclimatic data including:
    a. A historical time series of natural local area and tributary inflows, and
    b. A historical time series of precipitation and gross evaporation if lakes or reservoirs are present,
ii. A historical time series of water demands for each simulated sub-basin area at the current or some future level of development, and
iii. Flow constraints and/or requirements (e.g. minimum flow requirements) for each reach.

As such, the first steps in any assessment of water management alternatives are:

1. Identify the model and model configuration (sub-basin units) to be used in the assessment,
2. Develop a time series of historical natural flows for each of the sub-basin units and local drainage areas being used in the model, and
3. Develop a time series of historical water demands, at the current or projected future level of water allocations, for each of the modeled sub-basin units.

A Water Resources Management Model (WRMM) was developed previously for the Sturgeon River basin along with a time series of historical natural flows and water demands. However, there is a need to review existing data to get a better understanding of its suitability for future studies and to resolve several inconsistencies that have been noted in the water use estimates. In this regard, the North Saskatchewan Watershed Alliance has retained Sal Figliuzzi and Associates Ltd to conduct a Phase I study to:

i. Review the previously developed WRMM model and make comment on its adequacy to assess current and future water management options,
ii. Review existing hydroclimatic data and comment on the suitability of the data for future assessments and, if necessary, make recommendations for future revisions or updates, and
iii. Review previous water allocation/use studies to resolve conflicting information and make recommendation for revising or updating the time series of water allocation data used in the WRMM model.

This report examines the hydroclimatic data, water use data and a water management model developed in 11 previous studies and makes the following recommendations on work required to update and/or improve the reliability of the data for future water quantity modeling:

Item #	Recommendation	Estimated Cost $
1	Update historical weekly evaporation and precipitation for each of four lakes, up to 2015	To be provided by Alberta Environment and Parks
2	Conduct a weekly lake water balance for Isle Lake and Lac St Anne	$25K-$30K
3	Determine historical weekly water use upstream of each mainstem gauging site and the current level of water use for each sub-basin area in the WRMM Model.	$30K-$40K
4	Determine historical weekly natural flows for the Sturgeon River near Magnolia Bridge, Villeneuve, St Albert, and Fort Saskatchewan. Revise and update the natural flows for 12 sub-basin areas used in the WRMM model.	$30K-$40K
5	Update historical weekly irrigation demands to 2015	To be provided by Alberta Agriculture
6	Conduct WRMM runs for three base scenarios to evaluate reliability of the model and to provide base case for evaluation of water management alternatives. These scenarios are: i. With "zero" water allocations, ii. With no minimum flow restrictions on any water allocation, and iii. With current minimum flow restriction on each licenced allocation.	$35K-$50K

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1. INTRODUCTION

1.1 Study Objectives

The Sturgeon River, one of 12 sub-basins of the North Saskatchewan River, is a prairie stream located in central Alberta to the west and north of the City of Edmonton (Figure 1). The river originates near the Hamlet of Entwistle, west of Wabamun Lake, and flows through four large lakes (Isle Lake, Lac Ste Anne, Matchayaw, and Big Lake) and two communities (City of St Albert and Town of Gibbons) to its confluence with the North Saskatchewan River, north of Fort Saskatchewan.

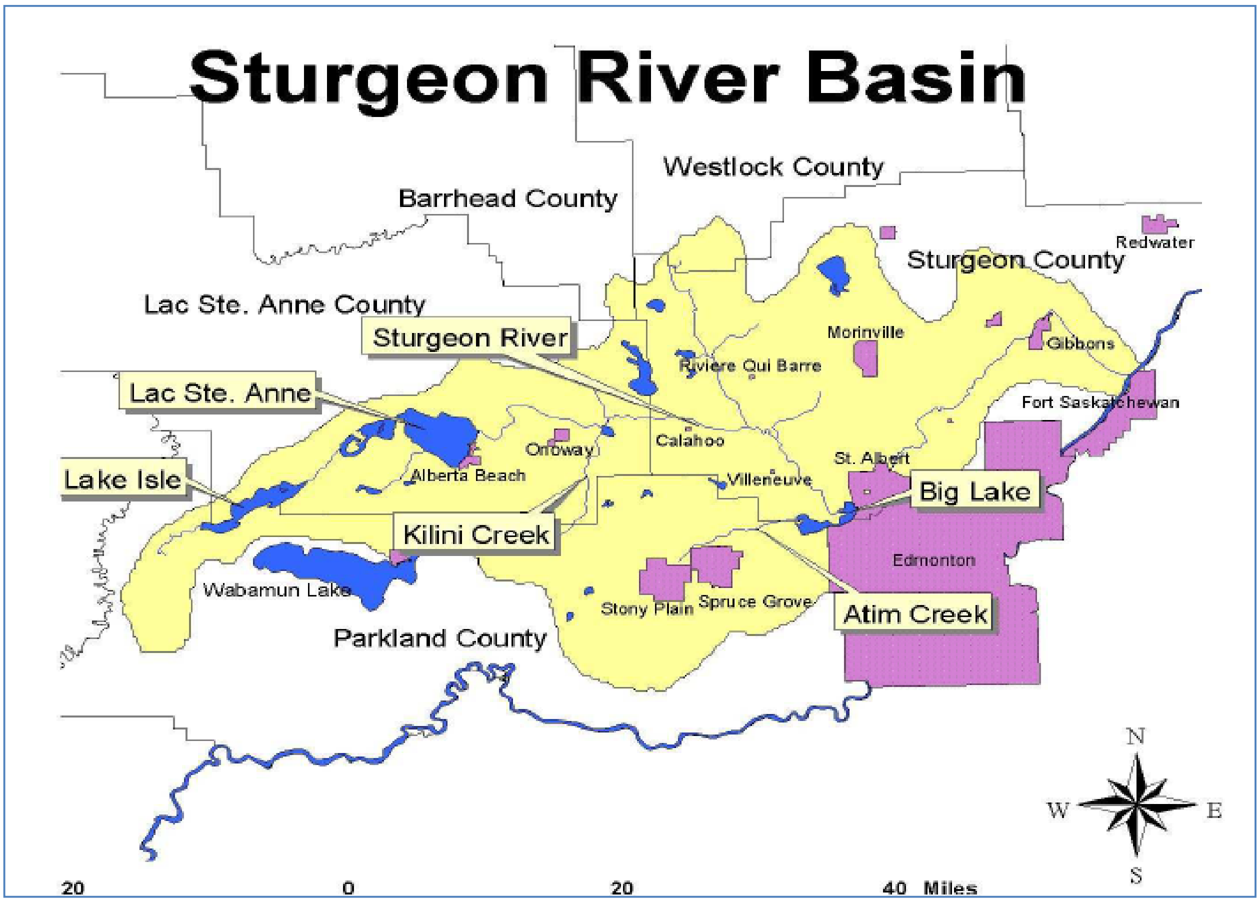

Figure 1 - Location map – Sturgeon River basin**.**

During the dry late 1980's and early 1990's, the Sturgeon River basin experienced shortages in water supply and inadequate instream flows. In recognition of these issues, and in response to concerns expressed in 1992 by irrigators and others, Alberta Environment undertook a water shortage analysis in 1995 to determine if the basin was approaching the limit for water allocations and to assist in the development of water allocation guidelines for the basin. As part of this analysis a time series of historical (1912-1991) weekly *natural flows* was developed for 12 local and sub-basin areas within the Sturgeon River basin. As part of the ongoing effort to address concern about water supply and low summer flows in the Sturgeon River basin Alberta Environment retained MPE Engineering and Hart Water Management Consulting in 2004 to develop estimates of current (2003) weekly consumptive water use *"… for 17 sub-basins considered to be important for water management planning in the basin*". In 2005 Unitech Solutions Inc. was retained to develop a Water Resource Management Model (WRMM) of the basin and to prepared a report entitled *"Water Management Analysis of Current (2003) Conditions*".

The North Saskatchewan Watershed Alliance (NSWA) was formed in 1999 and is one of 11 *"Watershed Planning and Advisory Councils" (WPAC's)* created under the Government of Alberta's *"Water for Life Strategy"*. Under "*Water for Life*", the NSWA has responsibility for completing watershed management plans for the North Saskatchewan watershed and its tributary sub-basins – including the Sturgeon River basin. As part of this responsibility, and in response to ongoing concerns over declining summer flows in the Sturgeon River (Figure 2), the NSWA has identified the need to develop a water management model with which to assess the potential cause of declining summer flows and possible water management alternatives for the basin (NSWA 2014).

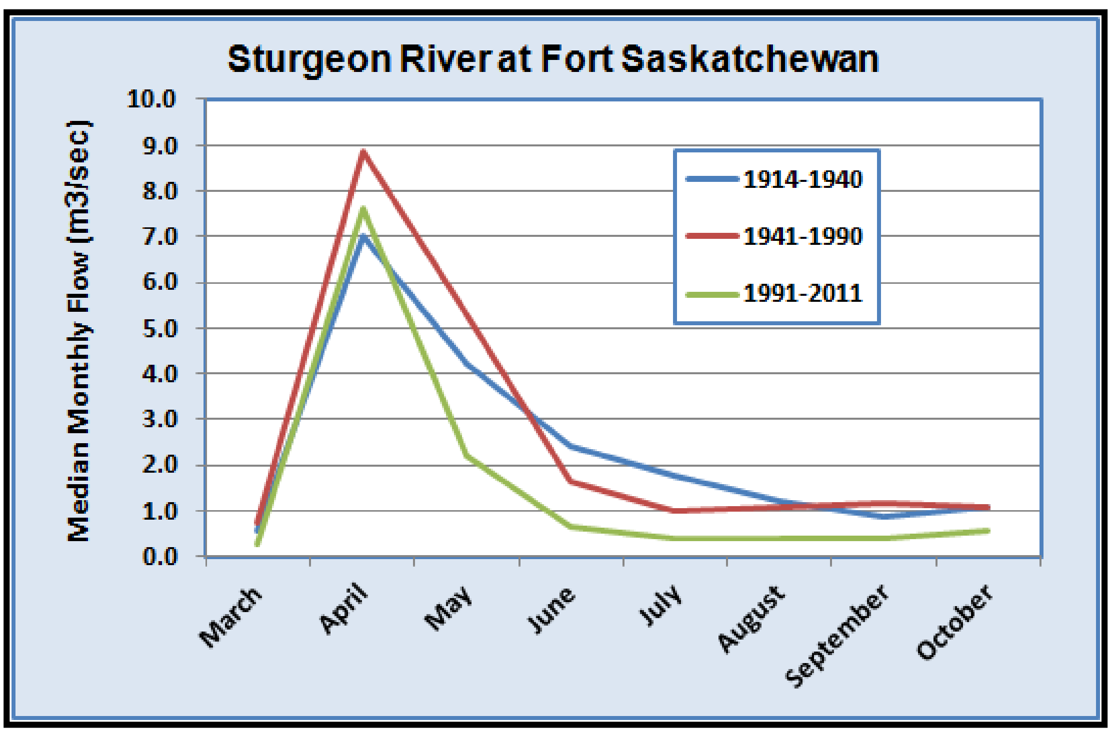

Figure 2 - Recorded median monthly flow - Sturgeon River at Fort Saskatchewan.

The assessment of water management alternatives for a given river basin is generally carried out by applying the current or a future level of water demand, including instream flow needs (IFN's) or objectives (IFO's), onto a time series of historical natural stream flows to assess the stream course's ability to meet both environmental objectives and consumptive use demands for water. Because of complexities introduced by the spatial variability in water demand and supply, and Alberta's "first in time first in right" (FITFIR) system of managing water access during periods of low flows, a conceptual water management model is often used to assess water management alternatives. The conceptual water management models, which may be viewed as water supply accounting models, generally consist of *summation nodes*, which are points at which tributary inflows, local inflows and/or water demands are applied and which are also used to track reservoir storage, and *reaches*, which are used to represent stream reaches and canals (Figure 3).

The required input to these models, among other items, includes:

i. A time series of historical hydrometeorology data for each node including:
    a. A historical time series of natural local and/or tributary inflows, and
    b. A historical time series of precipitation and gross evaporation, if lakes or reservoirs are present
ii. A historical time series of water demands along the reach upstream of each node for the current or some future level of development, which is applied at the downstream node, and
iii. Flow constraints and/or requirements (e.g. minimum (instream) flow requirements) for each reach.

As such, the first steps in any assessment of water management alternatives are:

1. Identify the model and model configuration (sub-basin units) to be used in the assessment,
2. Develop a time series of historical natural flows for each of the sub-basin units and local drainage areas being used in the model, and
3. Develop a time series of historical water demands, at the current or some projected future level of water allocations, for each of the modeled sub-basin units and reaches.

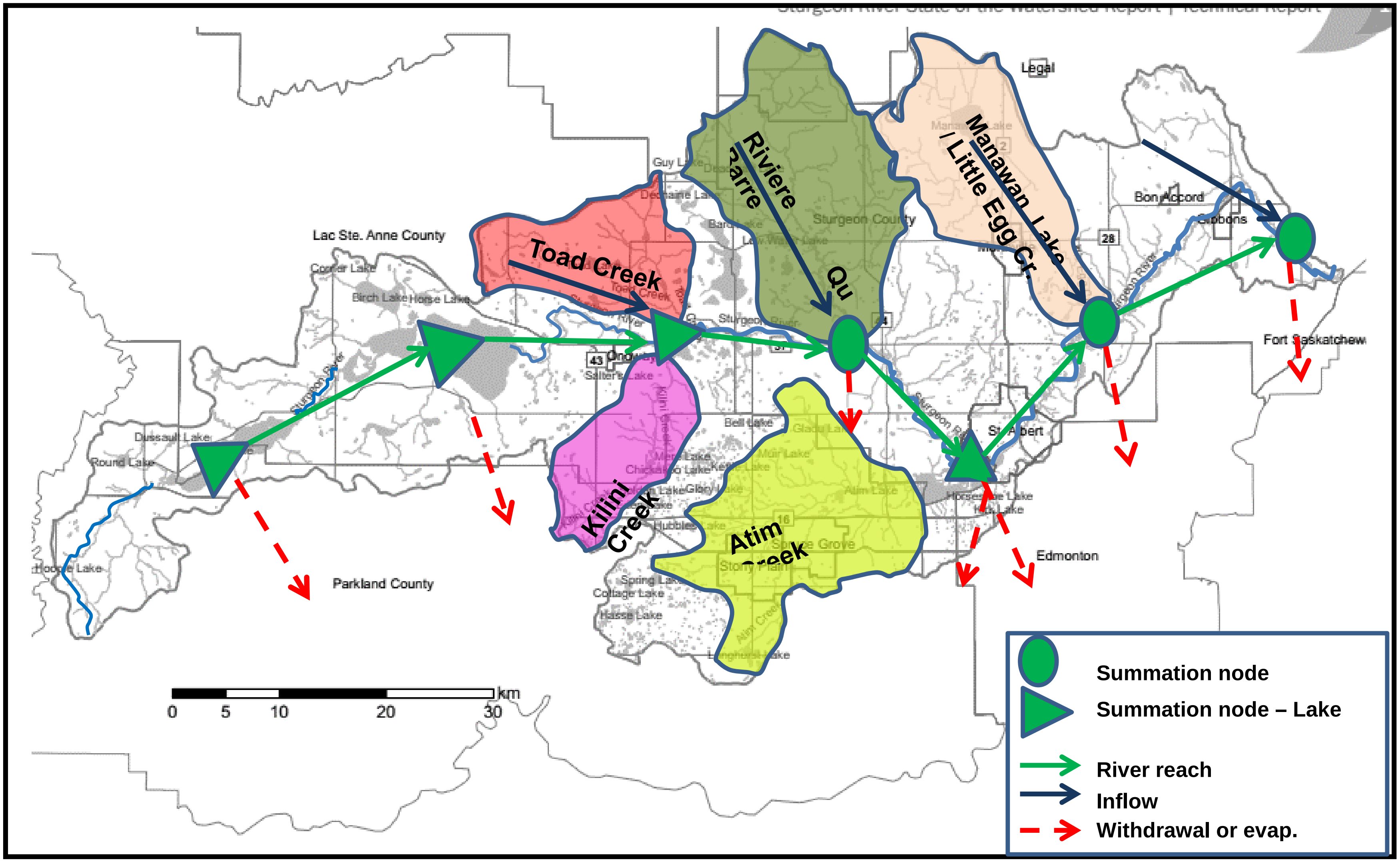

Figure 3 - Example of conceptual water management model (See Figure 6 for detailed schematic).

A WRMM model along with a time series of historical natural flows and water demands for the Sturgeon River basin was developed previously. However, there is a need to review the data to get a better understanding of its suitability for future studies, and to resolve several conflicts that have been noted in the water use estimates to identify any required updates or revisions. In this regard, the North Saskatchewan Watershed Alliance has retained Sal Figliuzzi and Associates Ltd to conduct a Phase I study to:

i. Review the previously developed WRMM model and make comment on its adequacy to assess water management options,
ii. Review existing hydrometeorology data and comment on the suitability of the data for future assessments and, if necessary, make recommendations for future revisions or updates, and
iii. Review previous water allocation studies to resolve conflicting information and make recommendation for revising or updating the time series of water allocation data used in the WRMM model.

This report examines the suitability of hydrometeorology data, water allocation/use data, and water management models developed in the following reports. This report makes recommendations on work required to update and improve their reliability for future water quantity modeling:

Water Supply Reports:

- "*Isle Lake/Lac Ste Anne- Study of Regulation by Outlet Control*" Figliuzzi S.J. and Card J.R., Alberta Environment, Technical Services Division. November 1979.

- "*Historical Monthly Natural Flows – North Saskatchewan River Basin 1912-1985*". DeBoer A. and Mustapha A.M., Alberta Environment, Water Resources Management Services, Technical Services Division, Hydrology Branch. March 1988.

- "*Historical Weekly Natural Flows – Sturgeon River Basin*". DeBoer A. and Bothe R.A., Alberta Environmental Protection, Water Resources Service, Surface Water Assessment Branch. April 1994.

Water Use Reports:

- "*Industrial Water Use Survey – Sturgeon Basin Study Area*". Clancy, J.F., Department of Industry and Tourism. September 1969.

- "*Sturgeon River Basin – Surface Water Allocation Guidelines*". Simonton J.K., Alberta Environmental Protection, Water Evaluation Branch. April 1995.

- "Sturgeon *River Basin – Current Consumptive Water Use Estimates – Final Report*". MPE Engineering and HART Water Management Consulting. Prepared for Alberta Environment, Central Region. June 2004.

- "*Current and Future Water Use in the North Saskatchewan River Basin*". AMEC Earth and Environmental, prepared for the North Saskatchewan Watershed Alliance. September 2007.

- "*Sturgeon River State of the Watershed Report – Technical Report*", prepared for the City of St Albert. November 2012.

Water Management Modeling Reports:

- "*Sturgeon River Basin – Surface Water Allocation Guidelines*". Simonton J.K., Alberta Environmental Protection, Water Evaluation Branch. April 1995.

- "*Sturgeon River Basin Water Management Plan – Phase I – Water Management Analysis Current Conditions*". Unitech Solutions Inc. March 2005.

Other Related Reports:

- "*Big Lake Stormwater Management Plan"*. Associated Engineering. Prepared for the Big Lake Task Force. May 2004.

- "*Sturgeon River Instream Flow Needs Scoping Study – Final Report*". Golder Associates. Prepared for Alberta Environment Central Region. June 2004.

- "*Preliminary Steps for the Assessment of Instream Flow Needs in the North Saskatchewan River Basin*. Prepared by NSWA. March 2014.

1.2 Glossary of Terms and Definitions

A number of terms associated with the diversion, consumption and use of water may be used interchangeably in the various reports. The following definitions, many adopted from AMEC (2007), are used in this report to provide clarity:

Water allocation – refers to the maximum amount of water that can be diverted in a calendar year, as set out in a water licence and/or registration.

Water diversion – refers to the actual amount of water being diverted from a surface or groundwater source in a given time period - generally a calendar year. The actual amount of water diverted during any one year is generally less than the allocation, it may vary with weather conditions and or changes in operations.

Water consumption or consumptive use – refers to the amount of water that is expected applied to the intended purpose. An estimate of the maximum consumptive use for each licence is included in Alberta's Environmental Management System (EMS) database. The value is for information purposes only and is not enforceable.

Losses – refers to that portion of a diversion which is lost due to factors such as evaporation, seepage, leakage etc. An estimate of the maximum losses is included for each licence and registration in the EMS database. The value is for information purposes only and is not enforceable.

Return flow – refers to that portion of a diversion that is returned to a water body, be it the source water body or some other water body, and is available for reuse. An estimate of the maximum return flow is included for each licence in the EMS database. The value is for information purposes only and is not enforceable.

Water use – refers to the sum of water consumption and losses or, alternatively, represents the difference between water diverted and returns.

Flow depletion – refers to the actual quantity of water removed from a water body or reach of a river. It is comprised of water consumption, water losses and return flow to another water body or river reach, it represents the actual quantity of water which has been removed from a water body or stream reach.

Natural Flow – refers to the quantity of water that would naturally flow in a water course had the flow not been affected by human interference or intervention.

Gross drainage area is the land surface area which can be expected to contribute surface runoff to a given body of water under extremely wet conditions. It is defined by the topographic divide (height of land) between the water body under consideration and adjoining watersheds.

Effective drainage area is that portion of the gross drainage area that can be expected to contribute surface runoff to a body of water under average conditions. The effective drainage area excludes portions of the gross drainage area that drain to peripheral marshes, sloughs and other natural depressions that prevent runoff from reaching the water body in a year of "average" runoff.

2. REVIEW OF EXISTING WATER SUPPLY REPORTS

2.1 Streamflow and Lake Level Data

A summary of Water Survey of Canada (WSC) streamflow and lake level data available within the Sturgeon River basin is presented in Table 1; locations of WSC gauging stations are identified in Figure 4.

There are four active gauging stations on the Sturgeon River (Sturgeon near Magnolia, Villeneuve, St. Albert, and Fort Saskatchewan), two on tributaries (Atim Creek and Carrot Creek), and two lake level stations (Isle Lake and Lac Ste. Anne). Most of the stations have relatively short periods of records and many data gaps, and in most cases only have records for the open water period (April-October for streamflow stations and May-October for lake level stations). In addition, while not reflected in the Table 1 summary, the available streamflow data does not represent “natural” flow but rather the residual or “observed” flow as measured after water use withdrawals, which have varied over time.

Given the aforementioned, a starting point in the assessment of water management alternatives is the development of a continuous time series of natural flows against which various water demands, including instream flow needs, can be assessed. This analysis provides insight as to the spatial and temporal distribution of available water supplies in a basin, and for the development of water management plans.

The procedure generally used to develop a continuous time series of historical natural flows is one which is referred to as the “project depletion method”. In this procedure, water use by upstream projects during each time period (be it daily, weekly, or monthly) is added to the recorded flows to compute the natural flow for the period(s) when recorded flows are available (equation 1):

$$NF=RF+CU_1+CU_2+\ldots+CU_n \qquad \langle 1 \rangle$$

Where:
NF = the natural flow
RF = the recorded flow, and
CU = water use by upstream projects 1, 2... n

Data gaps (time periods when recorded flows are not available) are then “void filled” using a regression equation which correlates the natural flow at the station of interest to the natural flow at a station(s) having similar physiographic characteristics and a more complete period of record. The flows of the Sturgeon River are heavily influenced by the attenuation effects of the four large lakes. It is, therefore, unlikely that regression would produce reliable estimates.

The following sections examine the procedures that have been used in previous reports to develop a time series of natural flows, comment on the suitability of estimates for future assessments and make recommendations for further refinement.

Table 1 – Summary of Streamflow and Lake Level Data Available for Sturgeon River Basin.

Station Name	Station #	Drainage Area (Km^2)	Effective D.A. (Km^2)
Sturgeon Main Stem	Sturgeon Main Stem		
Sturgeon River near Magnolia Bridge	05EA010	121.2	121.2
Sturgeon River near Darwell	05EA003	322.0	318.9
Sturgeon River near Onoway	05EA004	738.0	607.2
Sturgeon River near Villeneuve	05EA005	1889.5	1550.4
Sturgeon R. near St Albert	05EA002	2590.9	1922.7
Sturgeon River near Fort	05EA001	3247.1	2324.4
Tributaries	Tributaries		
Atim Creek near Spruce Grove	05EA009	315.0	80.5
Carrot Creek near The Mouth	05EA011	97.1	39.2
Atim Creek at Century Road	05EA012	287.8	77.8
Lakes	Lakes		
Isle Lake at Eureka	05EA008	275.6	275.6
lac Ste Anne at Alberta Beach	05EA006	687.0	568.7

Legend

Blue	complete Record
Orange	incomplete Record
Green	Data for open water period
Light purple	At least 1 reading per week during the May 1- Oct 31 period
Dark purple	Reading for most days during the May 1- Oct 31 period

Station #	Station Name
05EA010	Sturgeon River near Magnolia Bridge
05EA003	Sturgeon River near Darwell
05EA004	Sturgeon River near Onoway
05EA005	Sturgeon River near Villeneuve
05EA002	Sturgeon R. near St Albert
05EA001	Sturgeon River near Fort Saskatchewan
05EA009	Atim Creek near Spruce Grove
05EA011	Carrot Creek near The Mouth
05EA012	Atim Creek at Century Road
05EA008	Isle Lake at Eureka
05EA006	lac Ste Anne at Alberta Beach

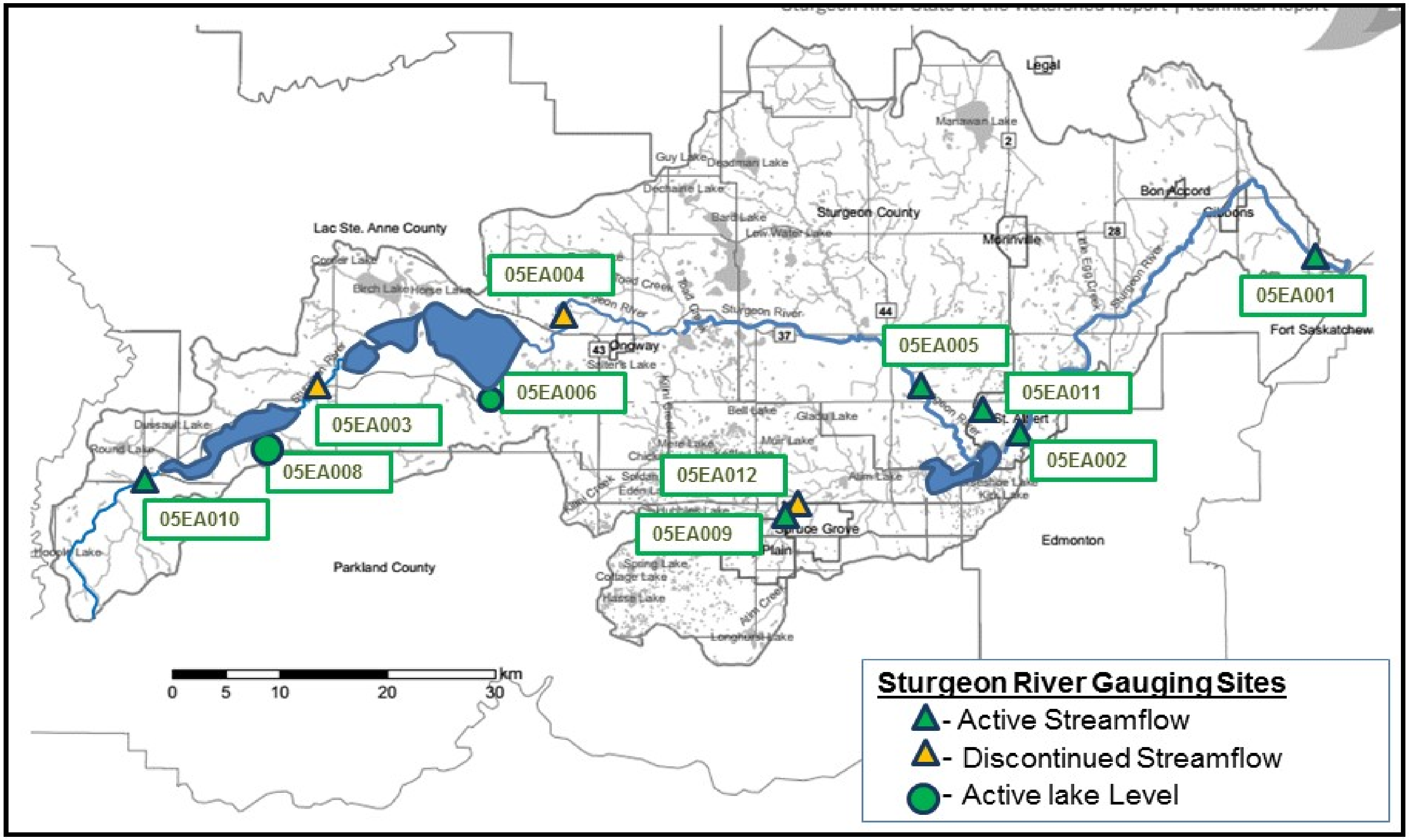

Figure 4 - Location of WSC streamflow and lake level gauging sites.

2.2 Review of 1979 Report: "*Isle Lake/Lac Ste Anne - Study of Regulation by Outlet Control*"

This report examines the feasibility of regulating Lac Ste Anne and Isle Lake within specified upper and lower limits in order to meet recreational needs. The report notes that previous investigations into the feasibility of regulating the two lakes utilized a single stage discharge relation, developed on the basis of several discharge measurements taken during the early spring and on channel hydraulics for each of the two lakes. As these rating curves likely overestimated outflows, these early studies generally concluded surface water inflows were inadequate to offset the computed outflow, evaporation, and rise in lake levels during the summer months, and that groundwater inflow must be substantial. This study utilized stage discharge measurements carried out after 1975, which indicated that the outflow function for the two lakes undergo what may be considered an annual cycle consisting of:

a. A spring period when the outflow channel is free of ice and vegetation,
b. A summer period when the outflow is greatly reduced due to weed growth in the outlet channel,
c. A fall period when the choking effect is greatly reduced due to withering of vegetation, and
d. A winter period when outflow is again greatly reduced due to the formation of an ice cover on the outlet,

A family of rating curves was developed to represent the annual cycle in the outflow function. The report notes that a timber and rock weir was constructed at the outlet of Lac St Anne in 1951 and partially removed in 1954 due to high water levels. The report further notes that while the weir is believed to have had some influence on low lake levels, its influence was likely small as the control point for high levels continued to be the downstream channel.

The report also utilizes hydrologic data from nearby stations outside the Sturgeon basin, adjusted for drainage area, to simulate monthly inflows to the two lakes and regional data to develop monthly precipitation and evaporation estimates for the 1963-1977 period. The report then utilizes a continuous water balance model along with the generated hydrologic and climate data to simulate historical (1963-1977) monthly lake levels for Isle Lake and Lac Ste Anne, under natural conditions and for various outlet modifications.

The close agreement between simulated and observed water levels (Figure 5) for the two lakes indicated that a family of stage discharge outflow curves is likely required to estimate outflow from Isle Lake and Lac St Anne and that regional data, in this case flows Paddle River near Rochfort Bridge, Little Paddle near Mayerthorpe, and Lobstick River near Styal, can be used to estimate the flow for sub-basins in the headwaters of the Sturgeon River.

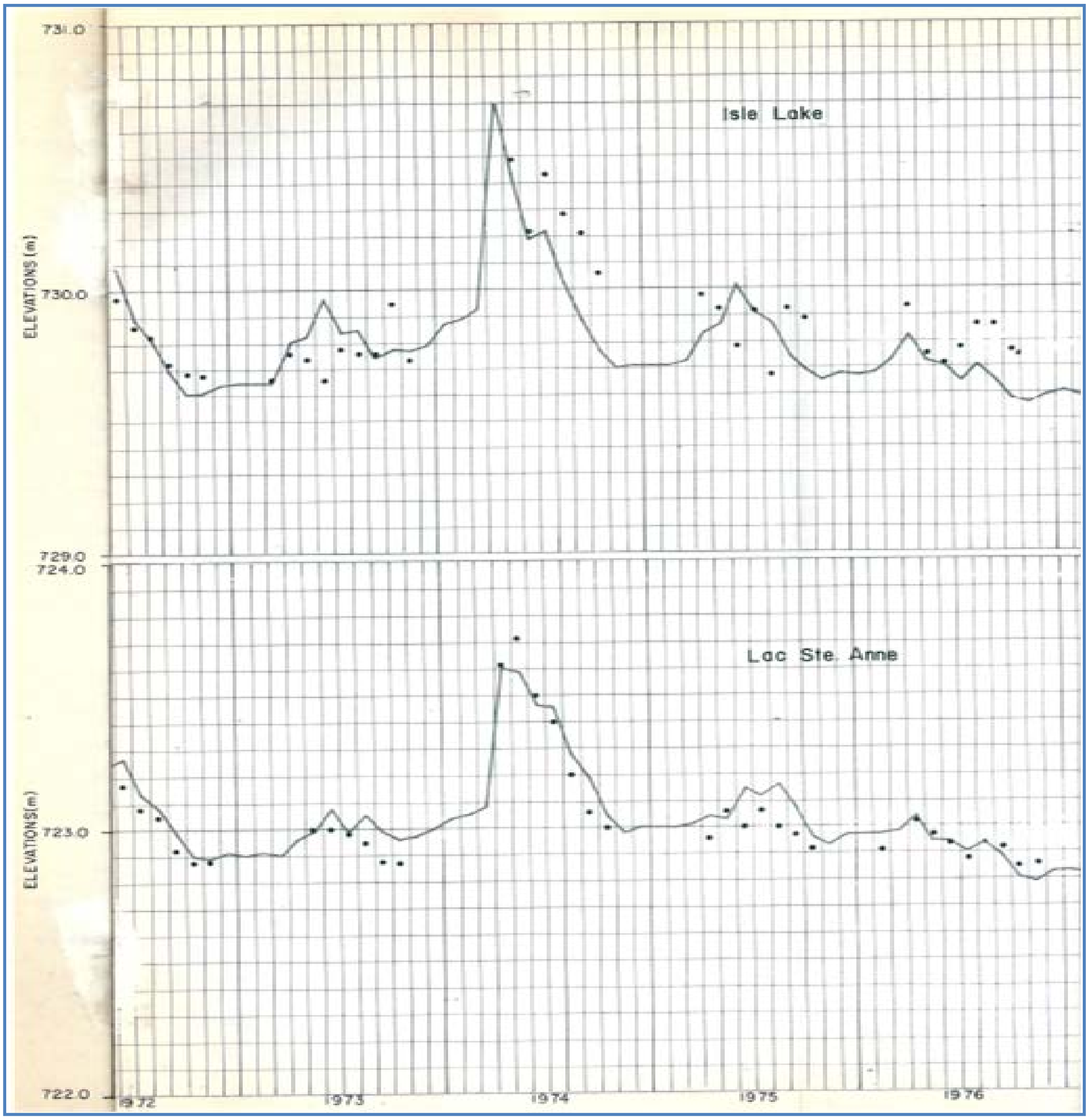

Figure 5 - Comparison of observed and simulated (1979) water levels for Isle Lake and Lac Ste. Anne.

2.3 Review of 1988 Report: "*Historical Monthly Natural Flows - North Saskatchewan River Basin 1912-1985*".

This report generates 1912-1985 historical monthly natural flows for 14 locations on the North Saskatchewan River and tributary stream courses, including the Sturgeon River at Fort Saskatchewan. While the report states that weekly natural flows were generated and subsequently aggregated to produce monthly natural flows, only monthly flow data for water use and naturalized flows are presented in the report. The weekly values were apparently provided to Alberta Environment on a CD.

The procedures used for the generation of historical weekly natural flows for the Sturgeon River at Fort Saskatchewan were as follows:

i. Naturalize recorded weekly flows by adding weekly water use adjustments (only monthly adjustments are provided in the report) to the recorded flows. While the report does not identify the source of the weekly flow adjustments, it is believed they were obtained from a referenced 1987 report prepared by J.P. Erxleben entitled "*Consumptive Use of Water in the North Saskatchewan River Basin*". The report does not specify if the consumptive uses are for all allocations or only for allocations within the "effective area".
ii. Void fill periods when recorded flows are missing, primarily 1912, 1913, 1923-1927 and 1931-1934 and winter months (generally November-March), using regression analysis. The priority of regression used to void fill missing values are as follows:
    a) Missing weeks 14-18 void filled using a simple logarithmic regression to Brazeau below the Brazeau Dam local inflows (r^2=0.4), the latter being estimated as the difference in natural flows between the North Saskatchewan at Edmonton and at Rocky Mountain House.
    b) Missing values for weeks 11-43 void filled using multiple logarithmic regression to natural flows for the Sturgeon River at St Albert and the previous week's flow for Sturgeon River at Fort Saskatchewan (r^2=0.70).
    c) For residual gaps, other winter flows (weeks 40 to 13), use multiple logarithmic regression to natural local inflows computed for the North Saskatchewan River and previous week's flow for the Sturgeon River at Fort Saskatchewan (r^2=0.91).
    d) Winter flows (weeks 40 to 13) void filled using a simple logarithmic regression to previous week's flow on Sturgeon near Fort Saskatchewan.

As indicated previously, while weekly historical natural flows were generated in the study and provided to Alberta Environment on a CD, the report provides monthly values of the following for the Sturgeon River at St Albert and Fort Saskatchewan:

i. Water use adjustments,
ii. Naturalized monthly flows, and
iii. Historical (1912-1985) monthly natural flows for the Sturgeon River at Fort Saskatchewan

2.4 Review of 1994 Report: "*Historical Weekly Natural Flows – Sturgeon River Basin*".

The "NATYIELD" model was developed by Alberta Environment in the mid 1980's. A 1912-1991 update of the weekly natural flows for the Sturgeon River at Fort Saskatchewan was used to generate weekly specific yields (runoff per unit effective area) for twelve sub-basin and local areas of the Sturgeon River basin. The weekly specific yields, when multiplied by the effective drainage area of the sub-basin, produce weekly natural flows for each of the sub-basin/local areas.

The NATYIELD model computes each week's specific yields by going through a series of iterations in which the first estimate of the specific yield is equal to the naturalized flow at Fort Saskatchewan divided by the effective drainage area. Using this first estimate of specific yield, the model performs a water balance for all nodes (storage device nodes, diversion nodes, and confluences) down to the Sturgeon River at Fort Saskatchewan. If the computed flow at Fort Saskatchewan is equal to the observed flow (+/- 1dam^3), the computed specific yield is assumed to be the true specific yield. If not, the model enters an iteration subroutine which provides a second estimate of specific yield to be used in the water balance. The model continues this iteration process until it computes the specific yield required in the water balance to produce a flow similar (+/-1dam^3) to the observed flow at Fort Saskatchewan.

The modifications to the "NATYIELD" model included in the estimation of specific yields for sub-basin and local areas of the Sturgeon River basin were:

i. Nodes for points of diversion - the NATYIELD model generally utilizes the recorded flow and requires diversion nodes to account for water use projects. However, as the current report utilizes the naturalized flow at Fort Saskatchewan in its water balance, all diversions are set to "zero" as the impact of diversions is deemed to have been accounted for by the addition of water uses to the observed flow at Fort Saskatchewan.
ii. Lake routing – the initial NATYIELD model was developed for small prairie streams having relatively small lakes/ponds and sloughs that could be assumed to release all flows in excess of their sill storage capacity in a single time step. Due to the size of Isle Lake, Lac St Anne, Matchayaw Lake and Big Lake the assumption that all flow in excess of the sill elevation is released in a single time step was not valid and a lake routing subroutine was introduced to simulate the gradual outflow of stored water.
iii. Non-homogeneity in specific yield – the initial NATYIELD model was developed for small prairie streams having relatively homogeneous runoff such that a single estimate of specific yield could be applied to the entire basin. Due to the size and variability of annual yields across the Sturgeon River basin (89 mm in the upper (western) reaches versus 24 mm in the lower (eastern) reaches) the assumption of homogeneity of runoff was not valid and a modification was introduced to account for this variation. The modification consisted of the model being represented by three homogeneous runoff areas, these being:

a. Effective sub-basin areas upstream of the Isle Lake outlet,
b. Effective sub-basin areas between the outlet of Isle Lake and the Sturgeon River at Villeneuve which, based on recorded flows, were estimated as having a specific yield equal to about 58.3% of sub-basin areas upstream of Isle Lake, and
c. Effective sub-basin areas between the Villeneuve and the North Saskatchewan confluence which, based on recorded flows, were estimated as having a specific yield equal to about 27.2% of sub-basin areas upstream of the Isle Lake outlet.

The weekly natural flows for each of the local and sub-basin areas were subsequently computed by multiplying specific yield resulting from the described model by the sub-basin effective area. It is noted that while there were water level records for Isle Lake (1972-1991) and Lac Ste Anne (1933-1991) and streamflow records for the Sturgeon River at Magnolia Bridge (1981-1991), Villeneuve (1914-1915, 1928-1930, 1968-1991) and St Albert (1913-1927, 1976-1986) they were not utilized in the estimation of specific yields or natural flows.

2.4.1 Discussion on Inputs to the NATYIELD Model of the Sturgeon Basin

The modified NATYIELD model requires the following inputs in its computation of natural weekly specific yields:

- A system model which describes the basin configuration including the sub-basins and local drainage areas,
- Elevation- area- storage-discharge relations for each of the four major lakes,
- Weekly precipitation and gross evaporation for each lake, and
- Historical weekly streamflow (either natural or observed) records at a gauging site.

The data and information related to these parameters used for the computation of specific yields in the Sturgeon River basin are discussed in the sections that follow.

NATYIELD Model Configuration

The NATYIELD configuration of the Sturgeon River basin used in the computation of specific yields for sub-basins and local areas of the Sturgeon River basin is shown in Figure 6.

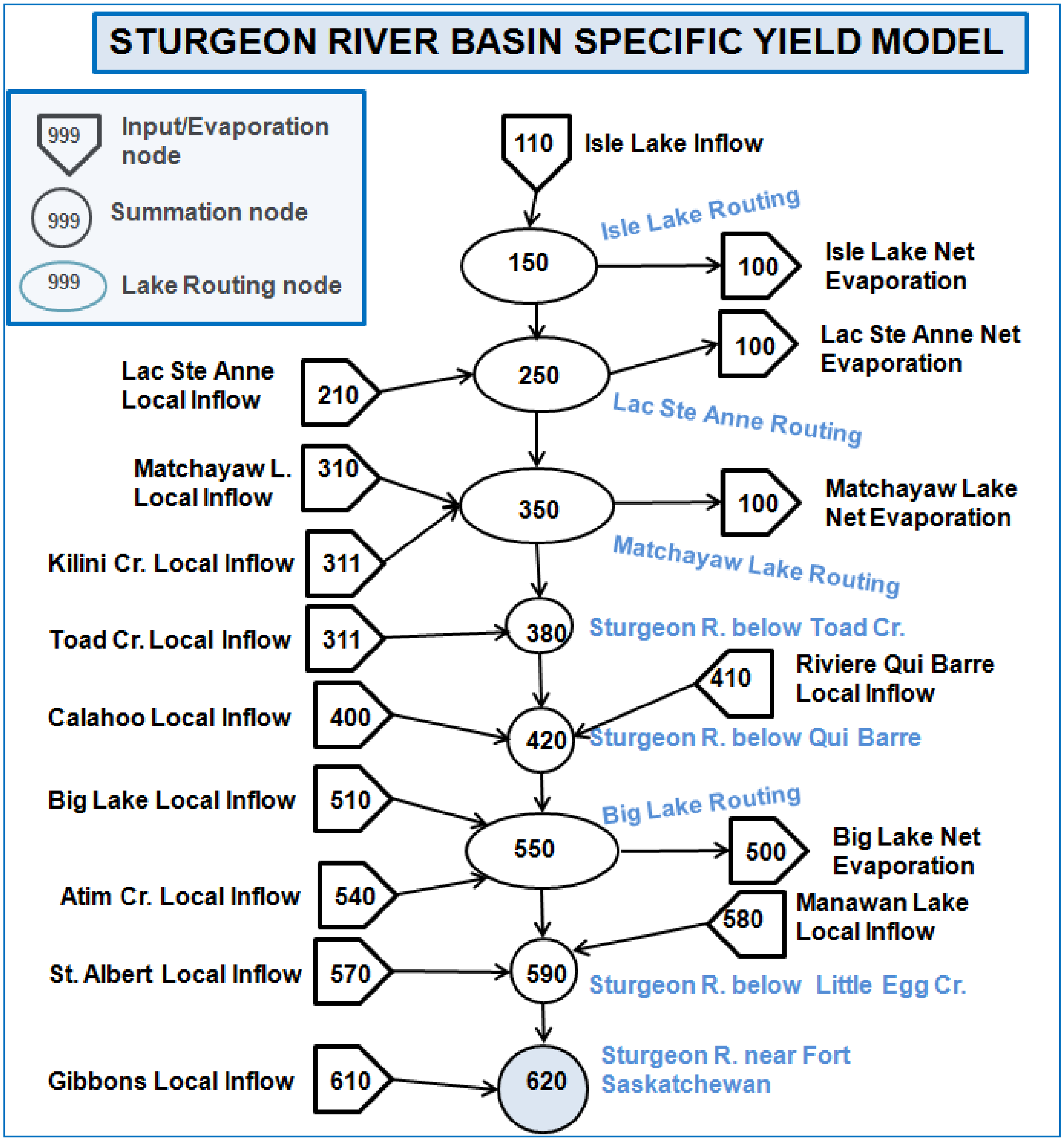

Figure 6 - Schematic of NATYIELD representation of Sturgeon River Basin.

Figure 6 shows that the NATYIELD model configuration of the Sturgeon River basin is comprised of 12 contributing areas (the same 5 sub-basins areas and 7 local areas used in the WRMM model) for which specific yields are computed, and eight summation nodes four which represent Isle Lake, Lac Ste Anne, Matchayaw Lake, and Big Lake and four which represent a confluence point. The contributing sub-basin/local drainage areas include:

- Isle Lake local inflow
- Lac Ste Anne local inflow
- Matchayaw Lake local
- Kilini Creek
- Toad Creek
- Calahoo local inflow
- Riviere Qui Barre
- Atim Creek
- Big Lake local inflow
- St Albert local inflow
- Manawan Lake local inflow
- Gibbons local inflow

Elevation-Discharge Relation for Lakes in the Sturgeon River Basin

The elevation-discharge relations used in the NATYIELD model to estimate outflow from Isle Lake and Lac Ste Anne is comprised of a single stage-discharge curve. However, previous studies had indicated that the use of a single stage discharge relation could not explain the lake level fluctuations while a 1979 study *("Isle Lake/Lac Ste Anne – Study of Regulation by Outlet Control".*) has shown that the stage-discharge relation for Isle Lake and Lac Ste Anne vary throughout the year due to weed and/or ice growth at the outlet (Figures 7 and 8) and that a family of curves may be required to reflect the seasonal variability in the stage discharge relation.

As neither the NATYIELD model nor the subsequent WRMM model has examined how well lake levels were simulated, the reliability of estimated specific yields into the two lakes is unknown.

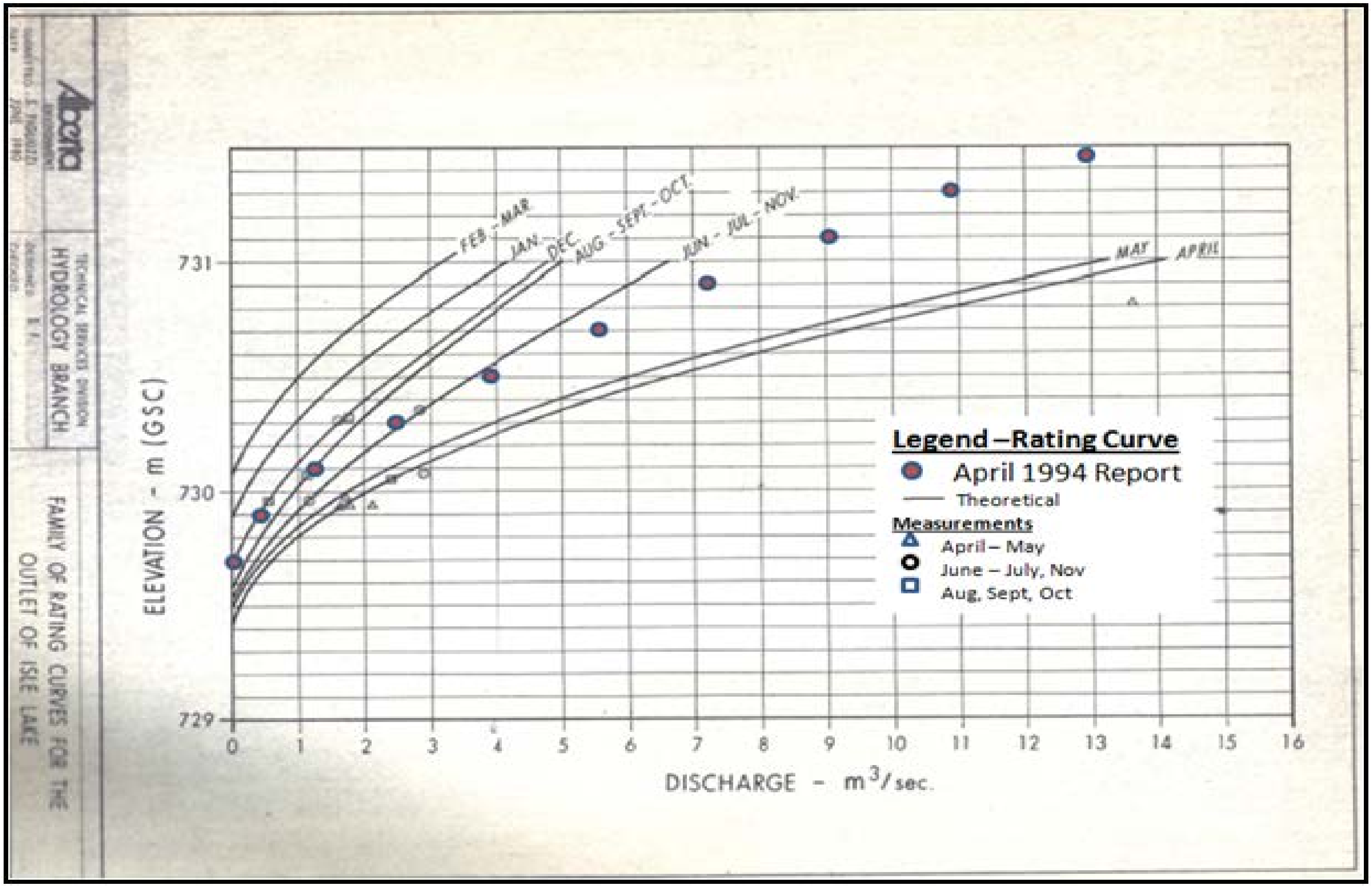

Figure 7 - Isle Lake stage-discharge relation.

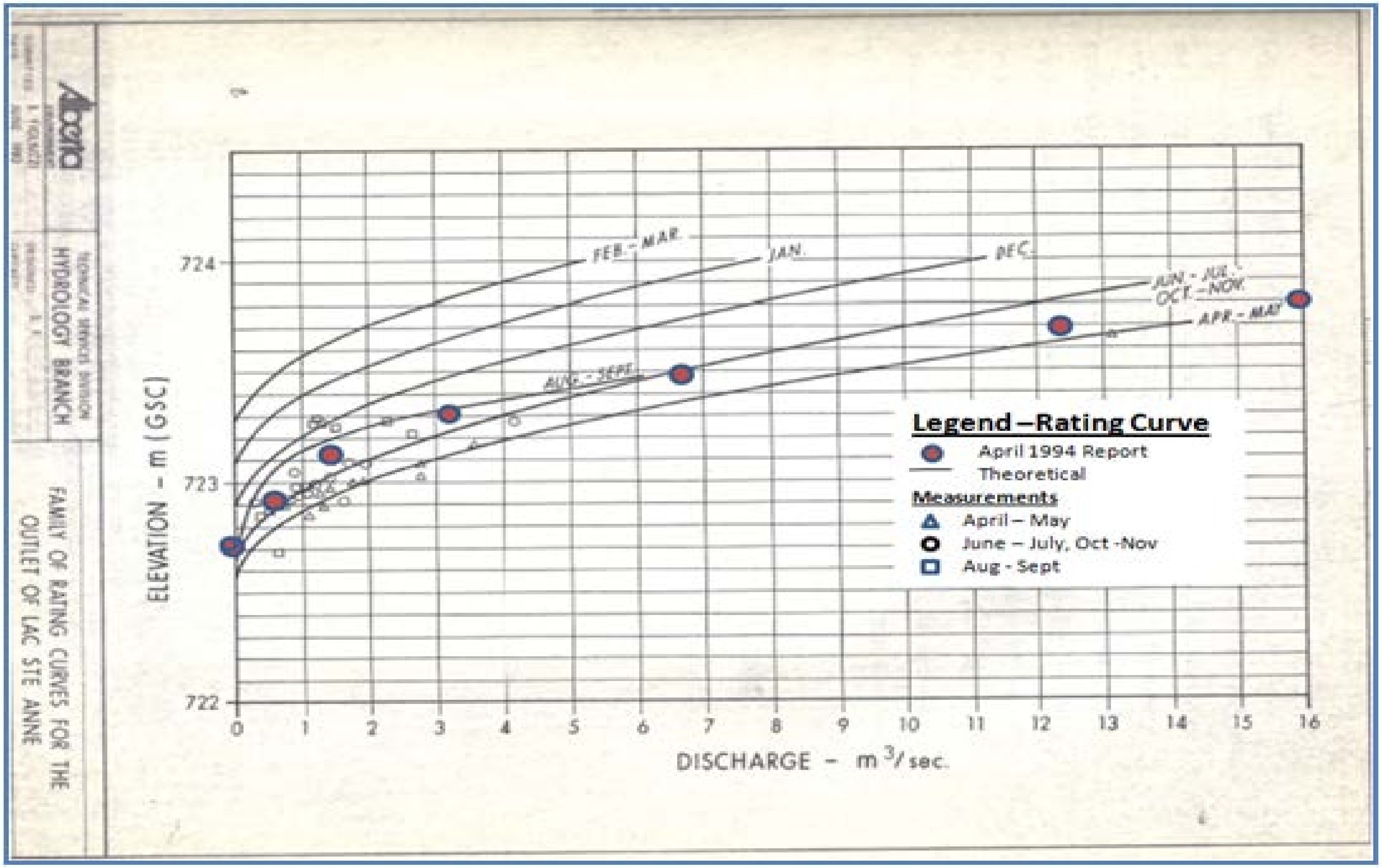

Figure 8 - Lac Ste Anne stage-discharge relation.

Precipitation and Evaporation

Weekly precipitation and evaporation for each of the four lakes (Isle Lake, Lac Ste Anne, Matchayaw Lake and Big Lake) is provided in the report. It is noted however that the precipitation for weeks 45-13, when precipitation is generally in the form of snow, was set to "0" and that the actual precipitation during this period was distributed over weeks 14-16. This is a practice generally used in the assessment of reservoir operations to reflect the non-accessibility to downstream users of this frozen water. This practice is not required for lake water balances and its use can result in errors in the temporal distribution of lake outflows.

2.5 Suitability of Computed Historical Weekly Natural Flows and Climate Data for Use in Future Studies

Currently, there is only one set of historical weekly natural flows for the sub-basin areas used in the modeling of the Sturgeon River basin; this being the historical (1912-1991) weekly natural flows (specific yield times effective drainage) generated by Alberta Environment using the NATYIELD model.

As indicated previously, while there were water level records for Isle Lake (1972-1991) and Lac Ste Anne (1933-1991) and streamflow records for the Sturgeon River at Magnolia Bridge (1981-1991), Villeneuve (1914-1915, 1928-1930, 1968-1991) and St Albert (1913-1927, 1976-1986) these were not utilized in the estimation of specific yields; rather the specific yields were estimated using solely naturalized flows for the Sturgeon River at Fort Saskatchewan with the assumption that flows in the middle and lower reaches were at 58.3% and 27.2% of the specific yield in the headwaters for weeks and all years. In addition, while a previous study had shown that a family of curves may be required to accurately reflect outflow conditions for Isle Lake and Lac Ste Anne a single rating curve for each of the two lakes was used throughout the year. Given the aforementioned there is concern that the generated natural flow values may not accurately reflect the spatial and temporal variability of flows in the sub-basins.

In order to evaluate the reliability of the estimated flows a comparison was made of the generated and observed specific yields for the Sturgeon River near Magnolia Bridge for the 1981-1991 period (Table 2) and of the simulated lake levels (estimated from the computed lake outflows) to observed lake levels for Isle Lake during the 1974-1975 and 1981-1982 period (Table 3).

Table 2 shows the following:

- the 1981-1991 average specific yield estimated using the NATYIELD model compares quite well with the observed 1981-1991 specific yield for the Sturgeon River near Magnolia Bridge (80.18 vs 78.09 dam^3/km^2),

- the NATYIELD model does not appear to replicate the temporal distribution very well in that it appears to overestimate flows during the February, March, April, September, and October periods while underestimating the specific yields for May and June,
- while the annual specific yield generated by the NATYIELD are in close agreement to the observed annual specific yields for many years, there are many years when the NATYIELD model significantly over or under estimates the annual runoff and numerous times when the specific yield for a given week or series of weeks is many times larger, or smaller than the observed values.

Table 3 shows the following:

- the WRMM simulation using the weekly natural flows generated by the NATYIELD model and a single outlet rating curve appears to overestimate water levels in Isle lake during the May period while underestimating them during the July-August period.
- While the over/under estimation of water levels for Isle lake is generally relatively small, there are periods when differences between observed and simulated lake levels are in excess of +/-0.5 meters.

The above noted shortfalls are believed to likely be due to a) a single rating curve not reliably representing outflow and storage conditions for Isle Lake and Lac Ste Anne and b) winter precipitation being all introduced in weeks 14-16.

Table 2. Comparison of Computed to Observed Specific Yields for Sturgeon River near Magnolia Bridge.

Week	1981		1982		1983		1984		1985		1986		1987		1988		1989		1990		1991		Average		Computed /Observed	Dates
	Recorded	Estimated	Recorded	Estimated	Recorded	Estimated	Recorded	Estimated	Recorded	Estimated	Recorded	Estimated	Recorded	Estimated	Recorded	Estimated	Recorded	Estimated	Recorded	Estimated	Recorded	Estimated	Recorded	Estimated		
8															0.00	0.62	0.00	0.51								
9			0.00	0.11	0.01	0.00	0.03	0.00	0.12	0.15	5.27	0.00	0.07	0.00	0.00	0.51	0.00	0.44	2.91	0.15	0.24	0.29	0.79	0.15	0.19	Feb 24 -Mar 2
10			0.00	0.00	0.06	0.26	0.13	0.00	0.15	0.15	2.70	2.50	0.05	0.00	0.01	0.00	0.01	0.00	1.65	1.58	0.21	0.00	0.45	0.41	0.90	Mar 3-9
11			0.00	0.00	0.08	0.40	0.11	0.00	0.51	0.59	1.56	3.05	0.05	0.00	0.04	0.00	0.01	0.00	3.63	2.42	0.14	0.00	0.56	0.59	1.05	mar 10-16
12			0.00	0.00	0.03	0.07	2.34	1.54	2.56	8.12	5.35	18.54	0.09	0.11	0.22	0.00	0.01	0.00	4.21	4.99	0.28	0.00	1.37	3.03	2.21	Mar 17-23
13			0.03	0.00	1.61	1.18	5.64	3.78	3.97	7.20	5.39	13.04	2.53	0.84	0.61	0.00	1.03	0.00	9.31	5.62	2.65	0.18	2.98	2.89	0.97	Mar 24 -30
14			0.56	0.07	19.34	4.15	2.56	7.97	20.00	32.31	2.47	19.68	6.98	12.34	0.46	2.05	11.84	3.93	6.24	3.16	11.05	5.25	7.41	8.26	1.12	Mar 31- Apr 6
15			0.87	0.29	5.97	6.39	0.69	0.84	16.31	18.98	1.12	6.21	1.61	13.55	0.26	3.86	15.03	5.62	1.99	6.43	6.95	32.35	4.62	8.59	1.86	Apr 7-13
16			14.40	10.28	2.95	7.93	0.67	0.00	4.62	9.88	3.21	7.05	0.72	7.12	0.15	0.00	5.89	6.02	2.36	2.31	2.77	7.86	3.43	5.31	1.55	Apr 14-20
17			45.12	54.46	1.36	0.00	0.50	0.51	6.51	10.28	4.20	4.19	0.46	4.66	0.11	0.00	1.60	1.36	3.76	3.82	6.73	4.70	6.40	7.63	1.19	Apr 21-27
18			7.80	14.50	0.82	1.43	2.94	0.15	2.34	8.04	2.59	3.34	0.80	1.58	0.13	0.00	0.75	0.73	1.87	4.63	2.71	3.62	2.07	3.46	1.67	Apr 28-May4
19			2.62	15.09	0.84	0.66	4.38	0.29	0.82	6.21	2.73	2.79	0.41	1.36	0.26	0.00	0.83	0.88	1.47	2.90	4.68	3.23	1.73	3.04	1.75	May 5-11
20			2.47	5.66	0.43	1.21	6.60	0.70	0.11	4.22	3.83	2.39	0.95	0.00	0.06	0.00	4.34	1.40	1.06	2.39	26.65	9.29	4.23	2.48	0.59	May 12-18
21			1.96	4.55	0.28	1.10	3.43	0.84	0.09	1.28	2.60	1.87	1.29	2.50	0.05	0.00	10.80	4.44	2.82	1.54	2.05	6.61	2.31	2.25	0.97	May 19-25
22			0.80	3.01	0.19	0.37	2.51	0.55	0.35	0.77	0.91	0.00	0.80	1.21	0.22	0.00	1.89	3.34	1.88	0.00	1.21	5.18	0.98	1.31	1.34	May 26-June 1
23			0.63	2.13	0.23	0.33	5.10	1.98	0.30	0.00	0.65	0.00	0.24	0.00	0.66	0.00	2.19	0.95	3.38	0.00	0.95	3.56	1.30	0.81	0.62	June 2-8
24			0.22	0.00	0.21	0.00	3.12	0.70	0.40	0.00	0.16	0.00	0.19	0.00	1.25	2.06	3.94	0.00	8.79	0.00	0.51	3.89	1.71	0.60	0.35	June 9-15
25			0.08	0.00	1.20	1.95	0.32	0.15	1.54	0.00	0.13	0.00	0.15	0.00	0.12	0.00	1.09	0.37	1.16	0.00	0.51	0.00	0.57	0.22	0.39	June 16-22
26			0.08	0.07	2.54	18.21	0.21	0.22	1.88	1.36	0.01	0.00	0.22	0.00	1.07	0.00	11.38	0.11	0.52	0.00	0.00	0.00	1.63	1.82	1.11	June 23-29
27			36.48	2.39	4.21	7.09	0.20	0.00	0.16	0.00	0.04	0.00	0.18	0.00	27.89	5.36	11.63	0.22	24.93	4.77	1.54	0.00	9.75	1.80	0.18	June 30- July 6
28			9.21	1.51	5.87	5.03	0.16	0.11	0.15	0.00	0.63	0.00	0.12	0.00	11.96	11.13	44.11	3.38	1.34	0.00	0.74	0.00	6.75	1.92	0.28	July 7-13
29			10.20	2.75	5.36	4.70	0.01	0.00	0.14	0.00	50.76	5.03	0.21	0.00	1.24	3.93	2.52	0.00	0.18	0.00	0.07	0.00	6.43	1.49	0.23	July 14-20
30	3.96	0.00	1.88	3.93	0.94	3.34	0.01	0.00	0.08	0.00	2.58	0.00	0.03	0.00	0.45	6.06	0.61	0.18	0.10	1.32	0.26	0.00	0.99	1.35	1.36	July 21-27
31	3.40	0.00	0.81	2.39	0.60	0.55	0.00	0.07	0.03	0.00	1.22	3.60	6.35	0.66	0.27	3.42	11.33	0.99	0.02	1.36	0.20	0.00	2.20	1.19	0.54	July 28-Aug. 3
32	0.77	0.00	0.63	1.32	0.19	0.07	0.01	0.44	0.01	0.18	0.87	2.53	9.06	0.18	1.14	1.95	5.80	1.10	0.00	1.95	0.28	0.00	1.71	0.88	0.52	Aug. 4-10
33	0.18	0.11	0.79	1.91	0.08	0.48	0.03	0.22	0.10	0.81	0.14	1.73	1.88	0.00	1.07	0.00	7.22	2.09	0.00	1.91	0.03	0.44	1.05	0.88	0.84	Aug. 11-17
34	0.17	1.18	0.50	1.69	0.06	0.15	0.03	0.26	0.15	0.59	0.13	1.87	0.77	0.26	1.28	2.75	6.22	2.83	0.03	1.58	0.00	0.18	0.85	1.21	1.43	Aug. 18-24
35	0.17	0.00	0.85	1.98	0.04	0.55	0.02	0.22	0.13	0.70	0.08	1.98	0.54	0.48	0.05	0.00	2.18	2.86	0.05	2.13	0.00	0.51	0.37	1.04	2.78	Aug 25-31
36	0.24	0.00	1.03	2.06	0.04	0.00	0.03	0.07	0.09	0.51	0.03	2.20	0.31	3.67	0.03	0.29	4.76	3.19	0.01	1.65	0.00	0.59	0.60	1.29	2.17	Sept 1-7
37	0.15	0.00	0.49	1.10	0.14	0.00	0.20	0.29	0.42	0.84	0.03	2.94	0.11	0.00	0.02	0.15	1.62	3.78	0.00	1.84	0.00	0.66	0.29	1.05	3.64	Sept 8-14
38	0.25	0.00	0.22	1.36	0.06	0.00	0.71	0.04	0.13	0.48	0.02	2.06	0.06	0.44	0.11	0.00	1.29	4.08	0.00	2.06	0.00	0.62	0.26	1.01	3.90	Sept 15-21
39	0.26	0.44	0.00	2.75	0.07	0.00	0.66	0.48	0.11	0.59	0.46	3.19	0.01	1.21	0.30	0.00	1.06	4.48	0.00	2.17	0.00	0.70	0.27	1.46	5.45	Sept 22-28
40	0.25	0.22	0.29	2.68	0.15	0.00	0.45	0.15	0.05	0.07	0.87	2.42	0.14	0.15	0.29	0.00	0.99	4.74	0.00	2.06	0.00	0.88	0.32	1.22	3.83	Sept 29 -Oct 5
41	0.69	0.62	0.21	1.95	0.19	0.00	0.34	0.51	0.10	0.00	0.68	3.27	0.22	0.37	0.34	0.00	1.24	4.92	0.02	1.73	0.00	0.73	0.37	1.28	3.51	Oct 6-12
42	0.47	0.00	0.33	2.13	0.33	0.00	0.44	0.73	0.14	0.81	0.50	3.60	0.23	0.51	0.55	0.00	1.37	4.70	0.10	1.80	0.07	0.51	0.41	1.34	3.27	Oct 13-19
43	0.42	0.40	0.47	1.98	0.41	0.26	0.57	0.37	0.07	0.26	0.44	2.97	0.47	0.44	0.11	0.00	3.49	5.14	0.03	1.65	0.10	0.55	0.60	1.27	2.13	Oct 20-26
44	0.26	0.37	0.56	1.80	0.31	0.22	0.39	0.40	0.08	1.21	0.49	8.92	0.36	15.86	0.15	0.00	1.15	6.43	0.02	12.56	0.11	13.99	0.35	5.61	15.92	Oct 27-Nov 2
TOTAL	11.63	3.34	142.59	147.90	57.21	68.08	45.56	24.58	64.71	116.59	104.84	132.96	38.67	69.50	52.96	43.52	181.25	84.70	85.86	84.48	73.69	106.37	78.09	80.18	1.03	

Table 3 – Comparison of Computed to Observed Isle Lake Water Levels.

Year	Period	May 5-11	May 12-18	May 19-25	May 26-June 1	June 2-8	June 9-15	June 16-22	June 23-29	June 30-July 6	July 7-13	July 14-20	July 21-27	July 28-Aug. 3	Aug. 4-10	Aug. 11-17	Aug. 18-24
	Week	Wk19	Wk20	Wk21	Wk22	Wk23	Wk24	Wk25	Wk26	Wk27	Wk28	Wk29	Wk30	Wk31	Wk32	Wk33	Wk34
1974	Simulated Outflow (m^3/s)	7.3619	5.9028	4.4643	1.7609	2.1536	0.3183	0	2.9431	0.0455	13.0994	13.6781	8.2589	0.3638	1.8353	0.6531	1.1533
	Computed Water level (m)	730.93	730.74	730.57	730.21	730.23	729.86	<729.7	730.37	729.70	731.50	731.58	731.02	729.86	730.21	729.94	730.07
	Observed Level (m)	730.67	730.65	730.60	730.51	729.91	-	730.27	730.22	-	-	-	730.43	730.42	730.39	730.34	730.32
	Difference (m)	0.26	0.09	-0.03	-0.30	0.32	-	-	0.15	-	-	-	0.59	-0.56	-0.18	-0.40	-0.25
1975	Simulated Outflow (m^3/s)	2.6868	1.2153	1.1533	0.3803	0.2108	0.1529	0.1364	1.1367	1.3517	0.9425	0.4258	0.1653	0.3803	0.3018	0.3472	0.3927
	Computed Water level (m)	730.35	730.08	730.07	729.86	729.80	729.78	729.78	730.07	730.12	730.00	729.88	729.78	729.86	729.86	729.86	729.86
	Observed Level (m)	730.02	730.00	729.96	729.93	729.91	729.88	729.84	729.84	730.05	730.05	729.98	729.97	729.91	729.88	729.93	729.94
	Difference (m)	0.33	0.08	0.11	-0.07	-0.11	-0.10	-0.06	0.23	0.07	-0.05	-0.10	-0.19	-0.05	-0.02	-0.07	-0.08
1981	Simulated Outflow (m^3/s)	0.9259	0.4547	0	0	0	0	0	0	0	0	0.0289	0	0	0	0.0455	0.4878
	Computed Water level (m)	730.02	729.88	<729.7	<729.7	<729.7	<729.7	<729.7	<729.7	<729.7	<729.7	729.71	<729.7	<729.7	<729.7	729.7	729.89
	Observed Level (m)	729.76	729.77	729.77	729.77	729.82	729.83	729.83	729.83	729.81	729.79	729.79	729.87	729.94	729.97	729.95	729.93
	Difference (m)	0.26	0.11	-	-	-	-	-	-	-	-	-0.08	-	-	-	-0.25	-0.04
1982	Simulated Outflow (m^3/s)	6.2376	2.3396	1.8808	1.2442	0.8805	0	0	0.0289	0.9879	0.6242	1.1367	1.6245	0.9879	0.5456	0.7895	0.6986
	Computed Water level (m)	730.78	730.30	730.22	730.08	730.01	<729.7	<729.7	729.70	730.00	729.93	730.07	730.17	730.00	729.89	729.97	729.98
	Observed Level (m)	730.14	730.09	730.04	729.97	729.92	729.87	729.83	729.81	729.93	730.37	730.39	730.38	730.3	730.21	730.18	730.13
	Difference (m)	0.64	0.21	0.18	0.11	0.09	-	-	-0.11	0.07	-0.44	-0.32	-0.21	-0.3	-0.32	-0.21	-0.15

Given the above findings and the fact that there is now an additional 25 years of data, it is recommended that the following studies, data refinements and updates be carried out:

i. That historical weekly precipitation and evaporation tables for the four lakes be updated to 2015, or to as recent a date as possible and with precipitation values being assigned to the week in which they occurred rather than the winter precipitation being assigned to weeks 14-16.
ii. That the stage-discharge relation for each of the four lakes be updated using all available stage-discharge measurements with particular attention to whether a single or family of curves is required to represent the stage discharge relation for Isle Lake and Lac Ste Anne.
iii. That a weekly water balance be carried out for Isle Lake and Lac Ste Anne for as long a period as possible utilizing all available lake level and streamflow information in order to obtain a better understanding of the specific yield of sub-basins in this headwater area and of the relative contribution from this area to downstream flows.
iv. That historical observed flows for the Sturgeon River at Villeneuve, St Albert, and Fort Saskatchewan be naturalized (which first requires the estimation of historical weekly consumptive uses upstream of these sites) and that this data in combination with other regional information and Lac Ste Anne outflows be used as much as possible in the revision and updating of historical weekly natural flows for sub-basins and local areas in the middle and lower portions of the Sturgeon River basin.

3. REVIEW OF EXISTING WATER ALLOCATION AND WATER USE REPORTS

3.1 Water Allocation in Alberta

In Alberta, water is allocated under the Water Act through a licence or registration. A complete list of active, cancelled, expired renewable and expired non-renewable surface and ground water licences and registrations is maintained by Alberta Environment and Parks and by the Alberta Energy Regulator in the Environmental Management System (EMS) database. The EMS database includes the following enforceable terms and conditions associated with each licence and registration:

- The quantity of water allocated
- The maximum rate of withdrawal
- The water source, including the location of the diversion
- The purpose for which the water is to be used

The EMS database also includes the following, non-enforceable items considered when granting an allocation:

- Consumptive use
- Losses
- Return flow

It is noted that the values entered in the EMS database for these parameters are estimates for conditions where the full allocation is being diverted and that actual values can vary considerably due to climate, or changes in the operations and/or delivery systems. The main source of information on actual diversions and water use is Alberta Environment and Parks Water Use Reporting System (WURS). The WURS is an electronic database that was implemented in the early 2000's and which contains voluntarily submitted information on monthly and annual diversions and, in some cases, water use from a small percentage of licence holders (generally those licence holders having relatively large allocations).

In addition to the water diversion and water use information contained in the WURS database, there are hard copy annual reports which some water licence holders, generally the larger ones, were required to submit on an annual basis. While a small percentage of this data has been summarized and entered into the WURS database, most remains solely in report form and difficult to access. Given the above, the task of determining water allocations, diversions and actual use is often a time consuming and difficult task.

The following sections provide a summary of water allocations, diversions, and use estimated in previous studies. It is noted that at times it is difficult to compare the results within the various reports as some reports estimate these parameters only for allocations within the "effective" drainage area while others estimate them for the "gross" drainage area. It is further noted that while the reports often use the terms "diversion", "water use", "water consumption" and "flow depletion" interchangeably, the reviews provided within the sections that follow have altered the terms so as to conform with the definitions provided in Section 1.2.

3.2 Review of 1969 Report: "*Industrial Water Use Survey – Sturgeon Basin Study Area*"

The report presents the results of a survey of industrial water use within the "Sturgeon Basin Study Area" (SBSA) during the 1963-1967 period. The report finds industrial water use comprised primarily of oil well injection. The report estimates annual water use in 1963, 1964, 1965, 1966 and 1967 to have been 4700, 4660, 4220, 3870, and 4610 dam^3 respectively of which 76% was from surface water. The report also finds that the monthly distribution of water use was uniform throughout the year. However, it is unclear from the report if the SBSA refers to the Sturgeon River Basin or to counties bordering the Sturgeon basin (I.D.77, M.D.90, M.D.92, County 11, 17, and 28), although it would appear it is the latter.

3.3 Review of 1995 Report: "*Historical Monthly Natural Flows – North Saskatchewan River Basin 1912-1985*"

This report, which was discussed in Section 2.2, presents 1912-1985 historical monthly natural flows, although weekly flows were generated and provided to Alberta Environment on a CD, for 14 locations on the North Saskatchewan River and tributary stream courses including the Sturgeon River at Fort Saskatchewan. The report states that natural weekly flows were computed by adding weekly water use to the recorded flow; although only the aggregated monthly values are presented in the report.

While the report does not specifically identify the source of the weekly water use adjustments, it is believed they were obtained from a referenced 1987 report by J. P. Erxleben entitled "Consumptive Use of Water in the North Saskatchewan River Basin." The annual water use adjustments, which are believe to be for the gross drainage area, are as follows:

Table 4 – Annual Water Use Estimates Presented in the 1995 Report "Historical Monthly Natural Flows – North Saskatchewan River Basin 1912-1985".

Year(s)	Water Use (dam^3)
1912-1927	0
1928-1938	259
1939-1956	518
1957-1968	2108
1969	2376
1970	2903
1971-1974	3162
1975-1976	2903
1977	2376
1978	2367
1979-1980	2635
1981	2367
1982	2635
1983	2162
1984	3171
1985	2635

3.4 Review of 1995 Report: "*Sturgeon River Basin – Surface Water Allocation Guidelines*"

The report examines water supply and use within 12 local and sub-basin areas of the Sturgeon River basin towards developing recommendations on minimum instream flows for the Sturgeon River basin. While the report states that historical water uses were estimated so as to enable the conversion of gauged data to natural flows, the historical water uses are not presented in the report. The report identifies the following 1995 level of monthly water use from the "effective" area of each sub-basin in the Sturgeon River basin.

Table 5 – 1995 Surface Water Use in the Sturgeon River Basin – based on report "Sturgeon River Basin – Surface Water Allocation Guidelines".

Sub-basin/Reach	Irrigation (dam^3)	Stockwater (dam^3)	Storage (dam^3)	Industry (dam^3)	Domestic (dam^3)	Total (dam^3)
Isle Lake	27	17	0	0	0	44
Lac Ste Anne	22	6	0	0	0	28
Matchayaw	12	0	0	0	0	12
Kilini Cr	232	9	0	358	0	599
Toad Creek	0	7	0	0	0	7
Calahoo	11	15	1	0	0	27
R. Qui Barre	102	65	110	0	2	279
Atim Creek	97	17	0	0	0	114
Big Lake	896	31	0	0	0	927
St Albert	223	26	4	0	0	253
Manawan	380	22	44	0	0	446
Gibbons	1390	21	0	0	0	1411
Total	3393	237	159	358	2	4149

3.5 Review of 2004 Report: "*Sturgeon River Basin – Current (2003) Consumptive Water Use Estimates – Final Report*"

The report estimates the 2003 level of monthly surface and ground water use within the effective area of 17 local and sub-basin areas being used in a WRMM model of the Sturgeon River basin. The local and sub-basin areas include:

- Sturgeon River above Isle Lake
- Isle Lake to Lac Ste Anne local area
- Lac Ste Anne to Matchayaw Lake local
- Matchayaw Lake to R. Qui Barre local
- Toad Creek
- Riviere Qui Barre to Big Lake local
- Big Lake Local
- Little Egg Creek
- Sturgeon below Gibbons local
- Isle Lake Local
- Lac Ste Anne local
- Kilini Creek
- Matchayaw Lake local
- Riviere Qui Barre
- Atim Creek
- Big L. to Little Egg Cr. local
- Little Egg Creek to Gibbons

In its estimation of water use, the report only considers projects that are within the effective area of each local and sub-basin since these are what would be significant in modeling water management alternatives; projects outside of the effective area having no effect on streamflows during average and below average runoff years. Wells and surface water projects registered for traditional agricultural use are also included in the summary.

The report concludes that in 2003:

- There were 290 water licences (124 surface water and 166 groundwater) and 1120 water registrations (552 surface water and 568 groundwater) within the "effective" area and 28 licences (10 surface water and 18 groundwater) and 123 water registrations (67 surface water and 56 groundwater) within the "non-contributing" area for a combined total of 1,561 licences and registrations (Table 6).

Table 6 – Number of Water Licences and Registrations (2003).

		Surface Water	Groundwater	Total
Within Effective Areas	Licences	124	166	290
	Registrations	552	568	1120
Within Non Contributing Areas	Licences	10	18	28
	Registrations	67	56	123

- In 2003 a total of 12,080 dam^3, (7016 dam^3 through surface water licences and registrations, and 5064 dam^3 through groundwater licences and registrations) had been allocated from the "effective" areas of the basin and an additional 764 dam^3 (597 dam^3 from surface water and 167 dam^3 groundwater) from "non-contributing" drainage areas for a combined total allocation of 12,844 dam^3.

- Actual 2003 water use from licences and registration in the effective areas were estimated to be 8,825 dam^3 (5,434.5 dam^3 from surface water and 3390.4 dam^3 from groundwater) (Table 7).

Table 7 – Summary of estimated (2003) actual water uses.

Purpose	Surface Water		Groundwater	
	(dam3)	%	(dam3)	%
Drainage	-851.5	-15.7	922.7	27.2
Water Management	2014.3	37.1	92.9	2.7
Aggregate Washing	356.5	6.6	58.5	1.7
Irrigation	3557.1	65.5	0.0	0.0
Municipal	-144.9	-2.7	866.3	25.6
Livestock	499.0	9.2	1435.3	42.3
Other	3.8	0.1	14.8	0.4
Total	5434.5	100.0	3390.4	100.0

Note - Negative surfacw water use under the drainage and municipal categories are due to return of groundwater to the surface water system

- Table 8 provides a summary of monthly surface water use, excluding groundwater returns to the surface water system. Table 8 shows that water use is estimated to peak during July at about 0.56 m^3/sec and that summer (May-August) water use is estimated at about 4,300 dam^3 thus potentially accounting for more than 50% of the reduction in flows observed in the Sturgeon River during the summer months (Figure 2).

- Table 9 provides a summary of the number of licences, allocations and water use for each of the 17 sub-basin and local areas. Table 9 shows that the largest surface water allocation is in the Kilini Creek basin and the largest groundwater allocation is in the Atim Creek basin and that, with the exception of Kilini Creek, there is minimal water allocation and use for areas upstream of the Riviere Qui Barre and Sturgeon River confluence.

Table 8 – Monthly Surface Water Use Estimates from 2004 "Sturgeon River Basin – Current Consumptive Use Estimates – Final Report".

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rate (m3/s)	0.0116	0.0127	0.0116	0.6273	0.4293	0.352	0.5667	0.2755	0.0825	0.0409	0.012	0.0116	
Volume (dam3)	31	31	31	1626	1150	912	1518	738	214	110	31	31	6422

Table 9 – Summary of 2003 Water Allocations and Use from "Sturgeon River Basin – Current Consumptive Use Estimates" Report.

Sub- basin / Local area	Surface Water			Groundwater		
	# of Licences	Allocat. (dam3)	Use (dam3)	# of Licences	Allocat. (dam3)	Use (dam3)
Above Isle L	37	45.2	35.0	35	38.9	12.3
Isle L. local	29	22.0	7.4	27	34.9	14.7
Isle L. to Lac Ste	41	19.9	2.5	21	24.7	2.0
L. Ste Anne local	51	45.1	25.9	68	91.0	57.5
Lac Ste Anne to Matchayaw L	44	20.6	4.9	60	153.4	49.3
Kilini Creek	52	2030.6	1456.1	59	670.2	107.3
Matchayaw L local	0	0.0	0.0	1	0.3	0.3
Local area below Matchayaw L.	21	26.5	23.4	28	32.7	8.4
Toad Creek	65	338.3	315.8	32	37.8	9.5
R Qui Barre	139	1384.9	1346.9	88	175.0	99.6
R. Qui Barre to Big Lake	42	351.2	336.8	70	693.5	387.9
Atim Creek	47	118.9	106.4	121	2558.2	182.6
Big Lake local	6	210.0	210.0	0	0.0	0.0
local below Big L	13	293.8	293.6	7	75.3	74.1
Little Egg Cr	32	536.6	526.3	51	76.9	37.1
local below Little Egg Creek	44	1003.4	993.6	63	400.0	180.7
local area below Gibbons	13	566.7	567.4	3	1.8	1.8
Total	676	7013.8	6252.0	734	5064.7	1225.2

3.6 Review of 2007 Report: "*Current and Future Water Use in the North Saskatchewan River Basin*"

The objective of this report, among other things, is to "*establish current [2005] water use patterns in the basin [the North Saskatchewan River and its sub-basins including the Sturgeon River basin] by examining how much water can be withdrawn, consumed or lost under the terms of existing and cancelled surface and groundwater licences and registrations … based on the review of the database [Environmental Management System (EMS)] maintained by Alberta Environment*", and to "*determine actual water withdrawals and use through a review of Alberta Environment's Water Use Reporting System (WURS) plus any applicable available information*".

The analysis of current water demand was based on active water licences and registries plus expired licences which are expected to be renewed, although cancelled and expired [non-renewable] licences were used to determine historical trends.

The report finds the total active allocations in the basin in 2005 to have been 26,184 dam^3 with groundwater accounting for 4,099 dam^3 or 16% of the total (the remaining 22,085 dam^3 being surface water). The distribution between Sectors is shown in Table 10. The report also provides estimates of future (up to 2025) water use for a low, medium and high growth scenario. However, the future water use projections, even for the high growth scenario, are within 10% relative to the estimated 2005 water use.

Table 10 – AMEC Estimates of 2005 Water Allocations and Use in the Sturgeon River Basin.

Sector		Licenced Allocations and Use				Water Use (dam^3)
		Allocation	Water Use	Return	% of Total Use	
Municipal		958	530	428	2	1,239
Agriculture	Stockwater	1,729	1,729	0	8	1,157
	Irrigation	2,034	2,034	0	9	2,034
Commercial		2,371	2,371	0	10	2,371
Petroleum		999	999	0	4	252
Industrial		68	68	0	0	68
Other		18,023	15,151	2,873	66	15,151
Total		26,183	22,882	2,301	100	22,272

The report states "*In the Sturgeon River sub-basin there are active 24 licences which allocate 18,024 dam^3 of water to the "Other" sector …Almost all of the water allocated [in the "Other sector] is for surface water (16,770 dam^3) …The County of Westlock's licence is substantial (13,900 dam^3) and it accounts for 92 percent of the Sturgeon Sub-basin's licenced "Other" sector allocations in the Sturgeon sub-basin …"*.

3.7 Review of 2012 Report: "*Sturgeon River – State of the Watershed Report – Technical Report" and "Final Report*"

This report provides a summary of current [2012] knowledge of the Sturgeon River Watershed and comments on its environmental integrity. The report states that:

- Within the Sturgeon River basin, a total (surface water and groundwater) annual maximum of 33,500 dam^3 of water is allocated of which 13,000 dam^3 of water is allocated as a consumptive use, 6,900 dam^3 is allocated to losses, indicating a water use of 19,900 dam^3, and 13,000 dam^3 being allocated as return flow.

- A total of 1,682 surface water licences were issued with a total allocation of 24,000 dam^3 which is comprised of 10,300 dam3 of consumptive use, 6,200 dam3 being losses (giving a water use of 16,500 dam3), and 7,500 dam3 return flow.
- A total of 959 groundwater licences were issued with a total allocation of 9,500 dam^{3}of which 3,300 were allocated for consumptive use, 700 dam^3 were for losses and 5,500 dam^3 being return flow.

These reported values are summarized in Table 11.

Table 11 – Water Allocations Reported in the 2012 "State of the Watershed Report".

	Allocations	Consumptive Use	Losses	Water Use	Return Flow
	(dam^3)	(dam^3)	(dam^3)	(dam^3)	(dam^3)
Groundwater	9,500	3,300	700	4,000	5,500
Surface Water	24,000	10,300	6,200	16,500	7,500
Total	33,500	13,600	6,900	20,500	13,000

3.8 Review of Alberta Environment and Parks EMS Database for the Sturgeon River Basin

Given the large discrepancy in water allocations and use estimated in the State of the Watershed Report and AMEC's "Current and Future Water Use" report relative to earlier reports, a listing of surface water licences and registrations within the effective and gross drainage area of the Sturgeon River basin was obtained from Alberta Environment and Parks.

A cursory assessment of the data was subsequently carried to estimate the licenced allocations that would have existed at the time for which each of the previous reports have provided an estimate of water allocations. The cursory assessment, which was carried out with support from Alberta Environment and Parks staff, involved the following clean up steps:

i. Remove all allocations having a more recent "effective date" than the date of the estimate in the previous report for which a comparison was being made,
ii. Remove all cancelled allocations,
iii. Remove all expired, non-renewable allocations with a renewable date that is earlier than the date under consideration,
iv. Remove all projects having "0" allocation; consisting generally of flood control projects.

This cursory assessment indicated the following:

i. In March 1995 there were 89 surface water licences with a total water allocation of about 6,092 dam^3 of which 4,723 dam^3 was allocated for water use (consumptive use plus losses). This value compares reasonably well with the 80 licences and 4,146 dam^3 of water use estimated in the April 1995 report "Sturgeon River basin – Surface Water Allocation Guidelines".
ii. At the end of 2003, within the Sturgeon basin "effective" area, there was a total of 701 licences and registries with a total water allocation of 6,752 dam^3. This compares reasonably well with the 676 licences and registries having a total water allocation of 7,016 dam^3 reported within the June 2004 report "Sturgeon River Basin – Current Consumptive Water Use Estimates – Final Report".
iii. At the end of 2005 there was a total of 928 surface water licences and registrations within the Sturgeon gross drainage area having a total water allocation of 9,913 dam^3 as compared to the 22,085 dam^3 reported in the 2007 report "*Current and Future Water Use in the North Saskatchewan River Basin*". In 2005, the single largest allocation was for 1,764 dam^3 and there were no allocations from the Sturgeon Basin to the County of Westlock as compared to the 13,900 dam^3 allocation to the County of Westlock reported in the 2007 AMEC report.
iv. In July 2015 there were 1,232 surface water licences and registrations with a total water allocation of about 15,000 dam^3 within the Sturgeon gross drainage area as compared to the 1,682 surface water licences with a total allocation of 24,000 dam^3 reported in the 2012 "State of the Watershed Report".

This cursory assessment indicates the following trend in water allocations:

Table 12 – Water Allocations over Time

Year	# of Licences	Allocations (dam^3)	Comment
1995	89	6092	
2003	701	6752	(within effective area) Increase in # of allocations reflects the registration of traditional use
2005	928	9913	
2015	1232	15000	

3.9 Suitability of Computed Water Use Estimates for Use in Future Studies

Three types of water use data are generally required for a WRMM simulation of a basin. These are:

i. Historical weekly water uses upstream of each streamflow gauging site to be added to the observed flow to develop naturalized flows,
ii. Current level of allocation and water use for all sectors, other than irrigation, within each sub-basin and local area being modeled so they can be applied to the historical natural flows to determine what impact the current level of demand would have had on historical flows, and
iii. Historical weekly irrigation demands because irrigation demands vary from week to week and year to year; and
iv. Groundwater return flows to the surface water system.

Given that the recorded streamflows for the Sturgeon River reflect the residual flow after water use withdrawals, that there is significant discrepancy between the water allocations reported in the various reports, that the “current levels of water use” applied to the 2005 simulation corresponds to 2003, and that water allocations appear to have more than doubled since 2003, it is recommended that the following water use studies, data refinements, and updates be carried out:

i. Determine the historical weekly water use for upstream of the Sturgeon River at Magnolia, Villeneuve and St Albert for the available period of streamflow records at these sites and that historical water use estimates for upstream of the Sturgeon River at Fort Saskatchewan be updated to 2015 or as recent as possible.
ii. Determine the current level of allocation and water use for all sectors other than irrigation, for each of the 13 sub-basins and local areas in the previously developed WRMM model.
iii. Contact Alberta Environment and Parks and Alberta Agriculture to see if historical weekly irrigation demands, generated by Alberta Agriculture for the 2005 study, are available and can be updated to 2015 (the 2005 study indicates that this data was contained on a CD provided to Alberta Environment).
iv. Determine the current level and location of groundwater returns to the surface water system.

4. REVIEW OF WATER MANAGEMENT MODELLING REPORTS

4.1 Review of 1995 Report: "*Sturgeon River Basin – Surface Water Allocation Guidelines*"

When water allocation licences were first issued for the Sturgeon River basin there were no conditions placed on them to stop diverting when flows fell below a given level. In the late 1970's all new licences had a condition placed on them that they must stop diverting if the flow fell below 5 cubic feet per second (cfs) (0.142 m^3/s).

While this minimum flow condition has been maintained for all licences issued after the late 1970's, licences issued after the early 1990's had the additional provision allowing this minimum flow requirement to be further modified if deemed necessary for environmental objectives.

The 1995 report was undertaken in response to concerns expressed in the early 1990's with respect to low flows being experienced in the Sturgeon River. The study objectives were to develop water allocation guidelines for each reach of the Sturgeon River and its tributaries, in the form of instream flow objectives that could be placed on future licences, and to determine if the limit to water allocations was being approached or exceeded.

The report utilized the following to assess water availability and water management alternatives:

- A WRMM model comprised of 12 local and sub-basin areas, for which historical natural flows had been generated in the April 1994 report, "Historical Weekly Natural Flows – Sturgeon River Basin", and 7 reaches to simulate the basin (Figure 9),
- Hydrometeorology (flows, precipitation, evaporation) and storage data generated within the April 1974 report, "Historical Weekly Natural Flows – Sturgeon River Basin", and
- Constant 1995 surface water use estimates, which were estimated as part of the 1995 report, for all sectors except irrigation for which weekly values for each year were provided by Alberta Agriculture.

The WRMM model was run without consideration of priority or flow constraints on licenced diversions. In addition, the model was forced to meet as many of the demands as possible with residual flows then being compared to estimates of instream flow requirements, based on the Tessman modification of the Tennent Method, to determine what, if any, water was available to meet instream flow objectives after meeting consumptive use demands.

The report concludes that:

- While there was ample water to meet demands in the spring, in heavily allocated basins (such as Kilini Creek) summer supplies could not meet the 1995 level of demand even before considerations for instream flows.
- While the Sturgeon River is not over allocated on the basis of annual water availability, due to lack of storage devices, there are many periods during the June to September period when the system cannot meet the 1995 level of water demand even prior to placing an instream flow requirement.

The report cautions that a potential conflict between supply and demand would occur if one or more of the following conditions occurred:

- licence holders withdrew the allocated quantities,
- licence holders attempt to fill their storage during period of low runoff or flow,
- There is an increase in allocation particularly in Kilini Creek, Manawan Lake, and the Riviere Qui Barre sub-basins, and/or
- Approval is given for water withdrawal in winter.

While the study assessed the feasibility of implementing a Tessman Modification of the Tennant Method as an instream flow condition of future licenced allocations, this requirement was never adopted.

4.2 Review of 2005 Report: "*Sturgeon River basin – Phase I – Water Management Analysis Current Conditions*".

The report utilizes the following to assess water availability and water management alternatives:

- A WRMM model comprised of 13 local and sub-basin areas, for which historical natural flows had been generated in the April 1994 report, "Historical Weekly Natural Flows – Sturgeon River Basin" and 3 drainage/ municipal discharges points to represent the basin (Figure 10),
- Hydrometeorology (flows, precipitation, evaporation) and storage data generated within the April 1994 report, "Historical Weekly Natural Flows – Sturgeon River Basin", and
- Estimates of 2003 surface water use and groundwater return flows to the surface system generated in the 2004 report, "Sturgeon River Basin – Current Consumptive Use Estimates – Final Report" for all sectors except irrigation,

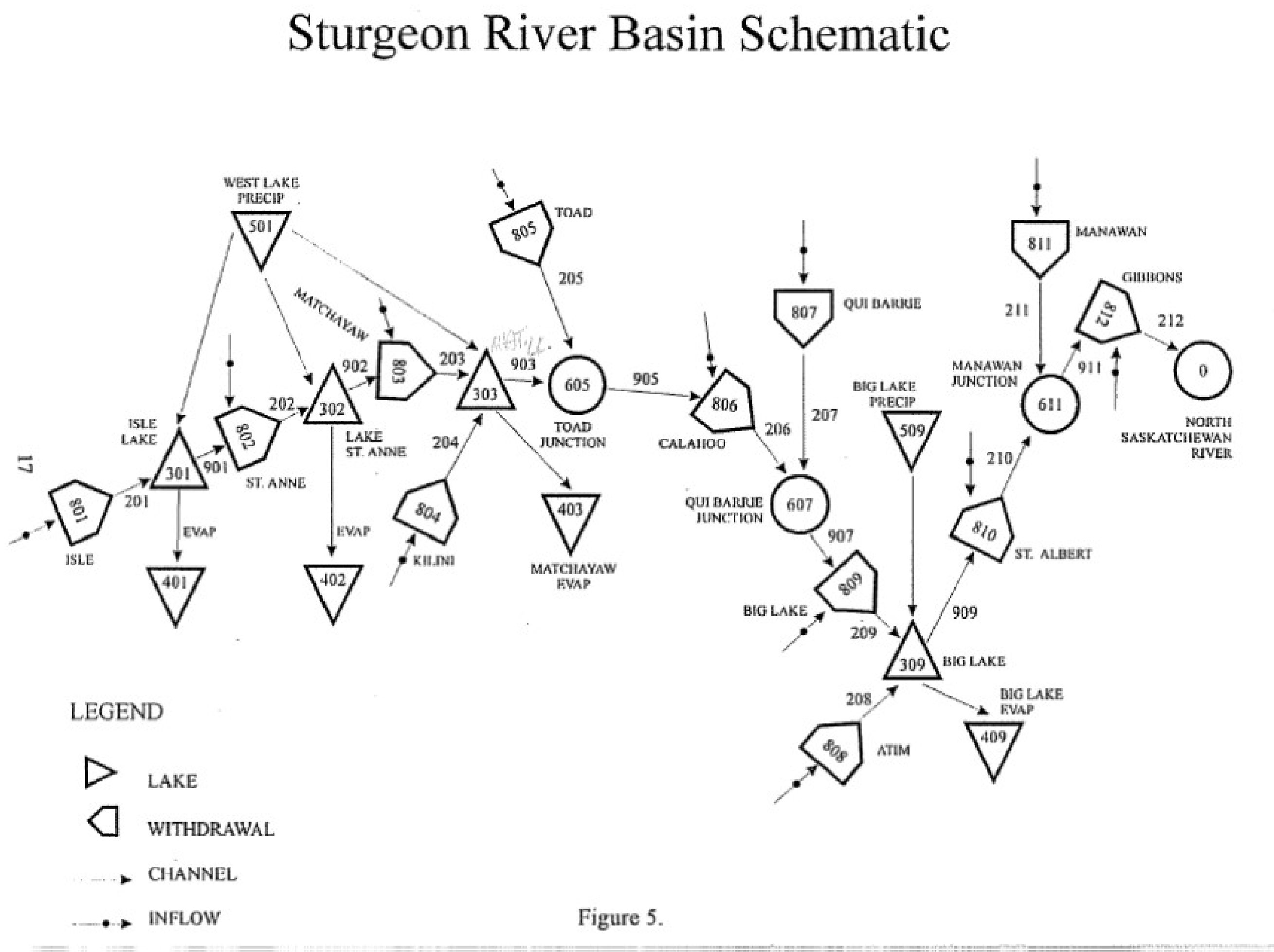

Figure 9– Schematic of Sturgeon River Basin used in the 1995 study.

- Weekly values of irrigation demands for each year which were provided by Alberta Agriculture and Rural Development.

The WRMM model was initially run with all water use allocations being set to zero to simulate natural conditions and the results compared to observed mean annual flows to determine its reliability. The model was subsequently run with the 2003 level of demands and a 5 cfs (0.142 m^3/s) minimum flow condition on all licences including licences issued prior to the 1970's.

The Study concludes that:

- Above Isle Lake and in all five major tributaries any new allocations have a very poor chance of success (obtaining their allocation at least 50% of years). Also the ability to maintain an instream flow objective of 5 cfs is limited.
- In the entire main stem, except above Isle Lake, successful consumptive use and instream flow objectives could be achieved if outlet structures were built on major storages to permit more sustained and managed releases of water.

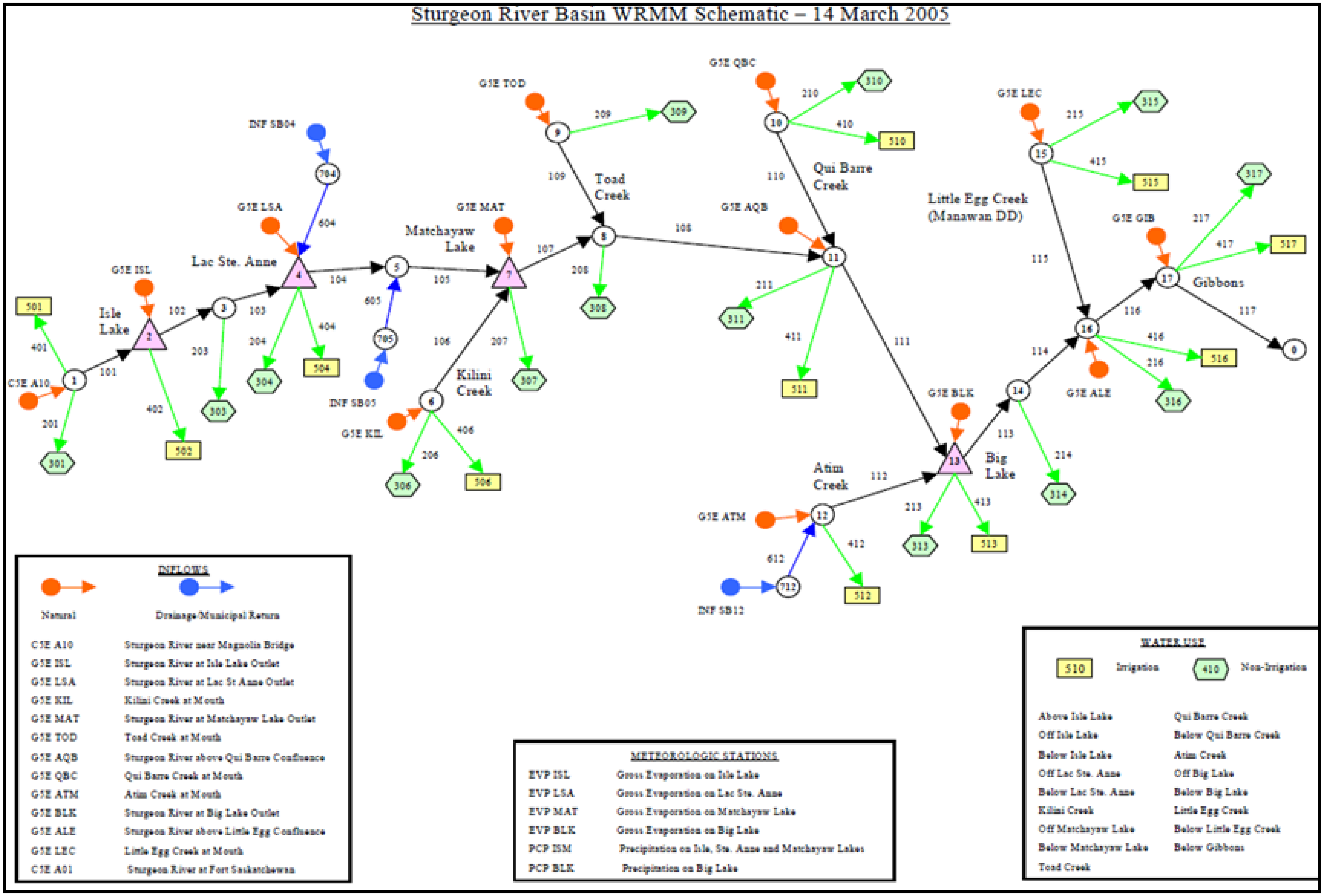

Figure 10– Schematic of Sturgeon River Basin used in the 2005 study.

4.3 Suitability of 2005 WRMM Model for Use in Future Studies

A review of the WRMM model developed for the 2005 study suggest that the model adequately represents sub-basins, and local areas contributing flow to the Sturgeon River and that it adequately represents the critical reaches of the Sturgeon River system; as such the model is considered adequate for future studies. However, a review of the input data indicates that the stage-storage and stage-discharge relations entered for the four lakes contained significant errors and will need to be revised to at least agree with the stage-storage-discharge presented in the 1994 natural flow study. Given this data entry error, all input data should be reviewed to ensure it has been entered correctly.

It was recommended in Section 2.5 that the stage-discharge relation for the four lakes be reviewed to ascertain if a single or family of curves is required to adequately represent their outflow throughout the year. Should the review of stage discharge relations for Isle Lake or Lac Ste Anne indicate that a family of curves is required to adequately represent their outflow, the WRMM model will need to be modified to accommodate such a requirement.

Given that the WRMM model is suitable for future studies the following model runs are proposed once all input data has been reviewed for accuracy and once all required data has been updated:

i. A simulation run with all water uses set to “zero” which would replicate historical natural flows and lake levels and a comparison to observed lake levels and naturalized flows to ensure the simulation is adequate.
ii. A simulation using the current level of water use with no restrictions, other than the licenced allocation, to simulate the condition where water mastering is not applied.
iii. A simulation using the current level of water use and restrictions (i.e. the 5 cfs restriction on some licences) to simulate the condition where water mastering is applied.

5. REVIEW OF OTHER RELATED REPORTS

5.1 Review of 2004 Report: "*Sturgeon River Instream Flow Needs Scoping Study – Final Report*".

The objective of this report was to develop a scope of work required for conducting an instream flow needs study. This included:

- Reviewing and summarizing existing data,
- Identifying potential data gaps necessary for completing an IFN assessment,
- Providing a work plan for completing any additional field work necessary for the development of an IFN determination for the Sturgeon River, and
- Proposing a flow evaluation framework for assessing year-round IFN's with consideration of including public involvement throughout the process where possible.

The study concluded that:

- The hydrology data, at that time, was not in a form that would be necessary for completing an IFN evaluation. While the study notes that Alberta Environment was modeling naturalized flows and creating a synthetic time series representing natural flows, this is in reference to the March 2005 WRMM modeling study utilizing the 1912-1991 specific yields generated in the 1994 "Historic Weekly Natural Flow" study to develop 1912-1991 weekly natural flows at various points along the Sturgeon River rather than an update of the 1994 study. The report later notes that the generated natural flows "… indicated declining flow in a downstream direction for several segments" and that "this trend should be investigated and confirmed prior to ... using the naturalized or synthesized flow time series".
- Numerous water quality parameters exceeded guideline criteria and that some of these parameters, particularly nutrients, were not sensitive to changes in flow suggesting water quality issues may be problematic within the context of an IFN study and should be resolved prior to initiating a detailed IFN program.

The study recommended that primary considerations should be given to:

- Establishing a public advisory group and an IFN technical committee to oversee any future tasks conducted for the Sturgeon River IFN study.
- The development of a naturalized and recorded flow time series to satisfy the data requirements for the hydrologic [modeling] component of an IFN study, and
- that AENV develop the simulated flow series accounting for current consumptive uses and water allocations and that both the naturalized and simulated flow series be extended to the current date.

6. CONCLUSIONS AND RECOMMENDATIONS

The sections that follow provide a summary of recommended future studies and their associated costs. The purpose of the proposed work is to evaluate future supply and demand scenarios and to provide recommendations on water resources management for the Sturgeon River basin. The steps are illustrated in the figure below:

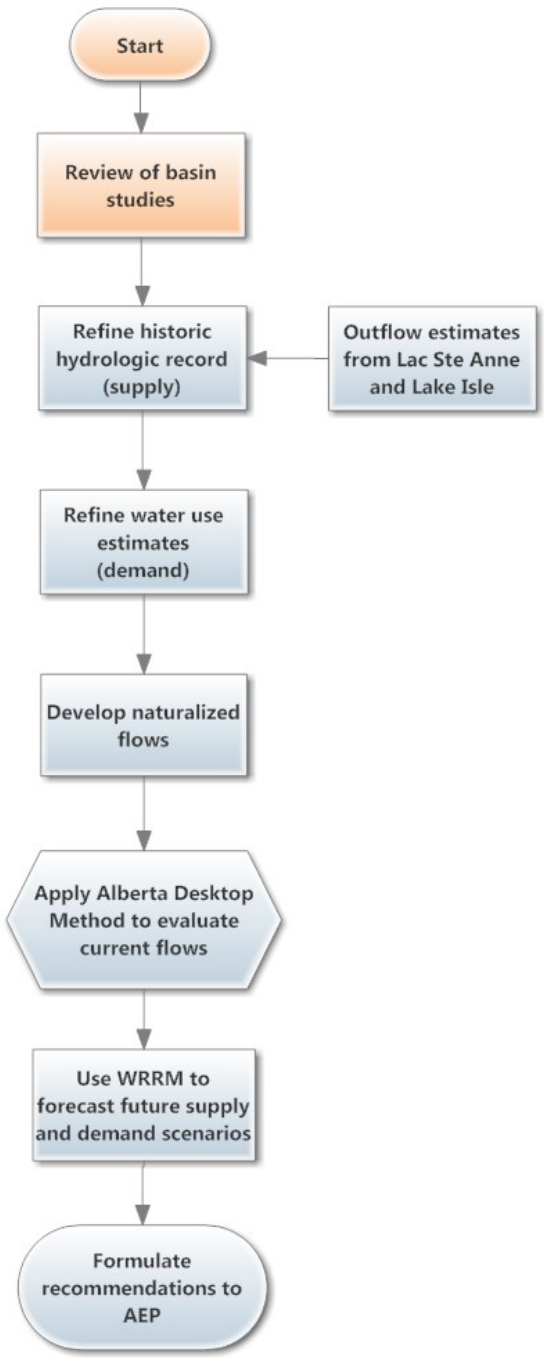

Figure 11 – Hydrology work flow for the Sturgeon River.

6.1 Hydroclimatic Data

The current time series of historical weekly natural flows, precipitation and evaporation are nearly 25 years old. The previous natural flow computation procedures only used a small portion of available data, a single stage-discharge relation for each of the four lakes that may not have accurately represented the seasonal variability of the outflows, and precipitation data in which the winter precipitation (weeks 43-13) was assigned to weeks 14-16. Given the aforementioned, it is recommended that the following hydroclimatic studies and data updates be carried out:

Table 13 – Recommended Hydroclimatic Studies and Data Updates.

Item #	Recommendation	Estimated Cost $	Comment
1	Update historical weekly Evaporation and precipitation for each of four lakes to 2015	-	Alberta Environment has provided this data in the past and should be able to provide an update. Winter (weeks 43-13) precipitation to be assigned to week in which it occurred rather than to weeks 14-16.
2	Weekly lake water balance for Isle Lake and Lac St Anne	$25K-$30K	Critical to understanding the role of Isle Lake and Lac St Anne to downstream flows. Study should include a review of stage-discharge measurements to determine if a single or family of curves is required to represent seasonal outflows.
3	Determine historical weekly natural flows for Sturgeon River at Villeneuve, St Albert, and Fort Saskatchewan and for 12 sub-basin areas used in the WRMM model.	$30K-$40K	This item requires that weekly consumptive uses upstream of each sited be computed first in order to naturalize recorded flows at these sites. Natural flow at these sites along with regional information and Lac Ste Anne outflows generated in item “2” should then be used to reconstruct historical weekly specific yields and flows for sub-basins and local areas in the middle and lower portions of the Sturgeon River basin.

6.2 Water Use Data

Three types of water use data are generally required for a WRMM simulation of a basin. These are:

i. Historical weekly water use, including groundwater returns to the surface water system, upstream of each streamflow gauging site which can be added to the observed flows so as to develop naturalized flows for periods when flow data is available,
ii. Current level of allocation and water use for all sectors, other than irrigation, within each sub-basin and local area being modeled so they can be applied to the historical natural flows to determine what impact the current level of demand would have had on historical flows, and
iii. Historical weekly irrigation demands, due to their weekly and annual variability.

Given that the recorded stream flows for the Sturgeon River reflect the residual flow after water use withdrawals, that there is significant discrepancy between the water allocations reported in the various reports, that the "current levels of water use" applied to the 2005 simulation corresponds to water use in 2003, and that water allocations appear to have more than doubled since 2003, it is recommended that the following water use studies, data refinements, and updates be carried out:

Table 14 – Recommended Water Use Studies and Data Updates.

Item #	Recommendations	Estimated Cost $	Comment
1	Update historical weekly irrigation demands to 2015	-	Data up to 1991 was previously prepared by Alberta Agriculture and provided to Alberta Environment on a CD. The 1912-91 data should be requested from AE along with an update from Alberta Agriculture.
2	Determine historical weekly water use upstream of each gauging site, current level of water use, irrigation demand, for each sub-basin area in the WRMM Model.	$30K-$40K	Water use should include historical groundwater returns to surface water system.

6.3 Water Management Model

A review of the WRMM model developed for the 2005 study suggest that the model adequately represents sub-basins, and local areas flow contributing to the Sturgeon River and that it adequately represents the critical reaches of the Sturgeon River system; as such the model is considered adequate for future studies. However, a review of the input data indicates that the stage-storage and stage-discharge relations entered for the four lakes contained significant errors and will need to be revised to at least agree with the stage-storage-discharge presented in the 1994 natural flow study. Given this data entry error, all input data should be reviewed to ensure it has been entered correctly.

Given that the WRMM model is suitable for future studies the following model runs are recommended once all input data has been reviewed for accuracy and once all required data has been updated:

i. A simulation run with all water uses set to “zero” which would have replicated historical natural flows and lake levels and a comparison to observed lake levels and naturalized flows to ensure the simulation is adequate.
ii. A simulation using the current level of water use with no restrictions, other than the licenced allocation, to simulate the condition where water mastering is not applied.
iii. A simulation using the current level of water use and restrictions (i.e. the 5cfs restriction on some licences) to simulate the condition where water mastering is applied.

The estimated cost of setting up the WRMM model to the more recent data, running it for the three indicated scenarios and carrying out necessary modifications to operate with varying seasonal rating curves if necessary is estimated at approximately $35,000-$50,000.