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Cottage Development Planning for New Residential Subdivision in the Town of Whitbourne

Whitbourne, NL

GEMTEC Project: 102486.001

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Submitted to:

Daniel Gosse
Gosse Developments
Paradise, NL
A1L 1P9

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Submitted for Review: August 04, 2023 - Final Revision: June 10, 2024
GEMTEC Project: 102486.001

experience • knowledge • integrity

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File: 102486.001 – R01

June 10, 2024

Daniel Gosse
Gosse Developments
Paradise, NL
A1L 1P9

Attention: Daniel Gosse

Re: Cottage Development Planning
Whitbourne, NL

GEMTEC is pleased to submit our report for the Cottage Development Planning project in the Town of Whitbourne, NL. We remain available to discuss the attached report.

Regards,

Hans Arisz, M.Sc.E., P.Eng., FCSCE

HA/pb

Enclosures
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1.0 INTRODUCTION

The Island of Newfoundland's freshwater lakes are attractive recreational areas. Unguided development of these areas may result in social and environmental problems, and it is important to address these issues during the planning process. Gosse Developments Ltd. is planning to develop a residential subdivision in the Town of Whitbourne and retained GEMTEC to assess the natural carrying capacity of the lakes where the development is taking place.

1.1 Development Details

The proposed site is in the Town of Whitbourne, Newfoundland and consists of approximately 100 hectares of land. Junction Pond bounds the land at the west, Second Pond at the south, and Bethune's Pond and Hoopers Pond at the east. Well's Gully and Blockline Gully are smaller water bodies within the proposed development area. Figure 1 shows the proposed development site and the ponds in the scope of the study.

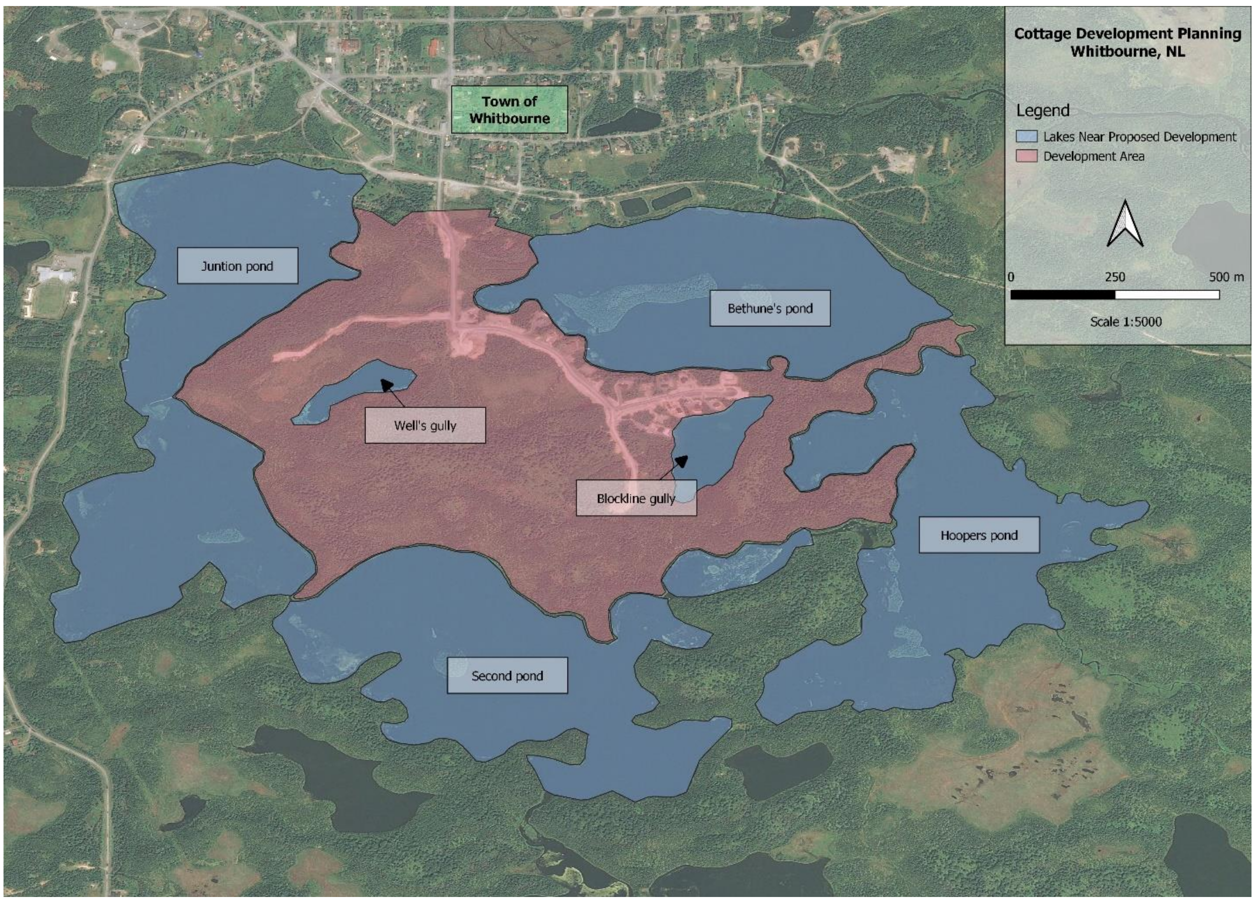

Figure 1 The Proposed Development Site and the Nearby Lakes

1.2 Watershed Details and Morphology

The required data to conduct this study include lake surface area, bathymetry and volume, inflow and outflow pattern, mean annual evaporation, mean annual precipitation, mean annual runoff, physiological characteristics of the watershed, land cover and land use, watershed characteristics, and population around the lake.

We used high-resolution aerial photos and GIS layers provided by the Government of Newfoundland and Labrador to measure the lake perimeter and surface area, and 1:50,000 elevation contour maps and the hydrometric network map of Newfoundland to delineate the watershed. We collected the mean annual precipitation data in the Avalon Peninsula from Environment Canada's 1981 to 2010 Climate Normals (Canada, 1981-2010), and mean annual evaporation from Statistics Canada's Energy and Transportation Statistic Division's publications (Statistics Canada, 2017) and Environment Canada's Climate Normals. Figure 1 to Figure 6 show the lakes within the scope of this study and the extent of their watersheds. Table 1 presents a summary of morphologic, hydrologic, and climatic information of the lakes.

Table 1 Summary of Morphologic, Hydrologic, and Climatic Information of The Lakes

Parameter	Junction Pond	Bethune's Pond	Hoopers Pond	Second Pond	Blockline Gully	Well's Gully
Drainage Area (m2)	5,234,000	54,021,000	63,548,000	70,375,000	175,000	158,000
Lake Surface Area (m2)	617,300	454,100	517,400	517,700	46,300	26,000
D.A./Lake Surface Area	8.5	4.2	122.8	135.9	3.8	6.1
Lake Perimeter (m)	5,430	3,084	5,415	5,016	1,018	808
Lake Average Depth (m)*	6.7	5.7	6.3	4.0	2.0	1.5
Lake Volume (m3)	9,030,000	5,650,000	7,211,000	4,557,000	206,300	81,600
Mean Annual Precipitation (m/year)	1.3	1.3	1.3	1.3	1.3	1.3
Mean Annual Runoff (m/year)	1.1	1.1	1.1	1.1	1.1	1.1
Mean Annual Evaporation (m/year)	0.2	0.2	0.2	0.2	0.2	0.2
Total Outflow Volume (m3/year)	6,437,000	59,423,000	69,903,000	77,413,000	243,000	202,000
Flushing Rate (1/year)**	0.71	10.52	9.69	16.99	1.18	2.48
Residence Time (year)***	1.40	0.10	0.10	0.06	0.85	0.40
Aerial Water Load (m/year)	10.43	130.85	135.10	149.54	5.26	7.79
Dissolved Oxygen (mg/l)	11.2	11.2	11.2	11.2	11.2	11.2
Settling Velocity (m/s)	12.4	12.4	12.4	12.4	12.4	12.4
Retention Coefficient	0.54	0.09	0.08	0.08	0.70	0.61

* *Bathymetry not available*

** $\text{Flushing Rate } (\rho) = \text{Total Outflow (Q)} / \text{Lake Volume (V)}$

*** $\text{Residence Time } (T_R) = \text{Lake Volume (V)} / \text{Total Outflow (Q)}$

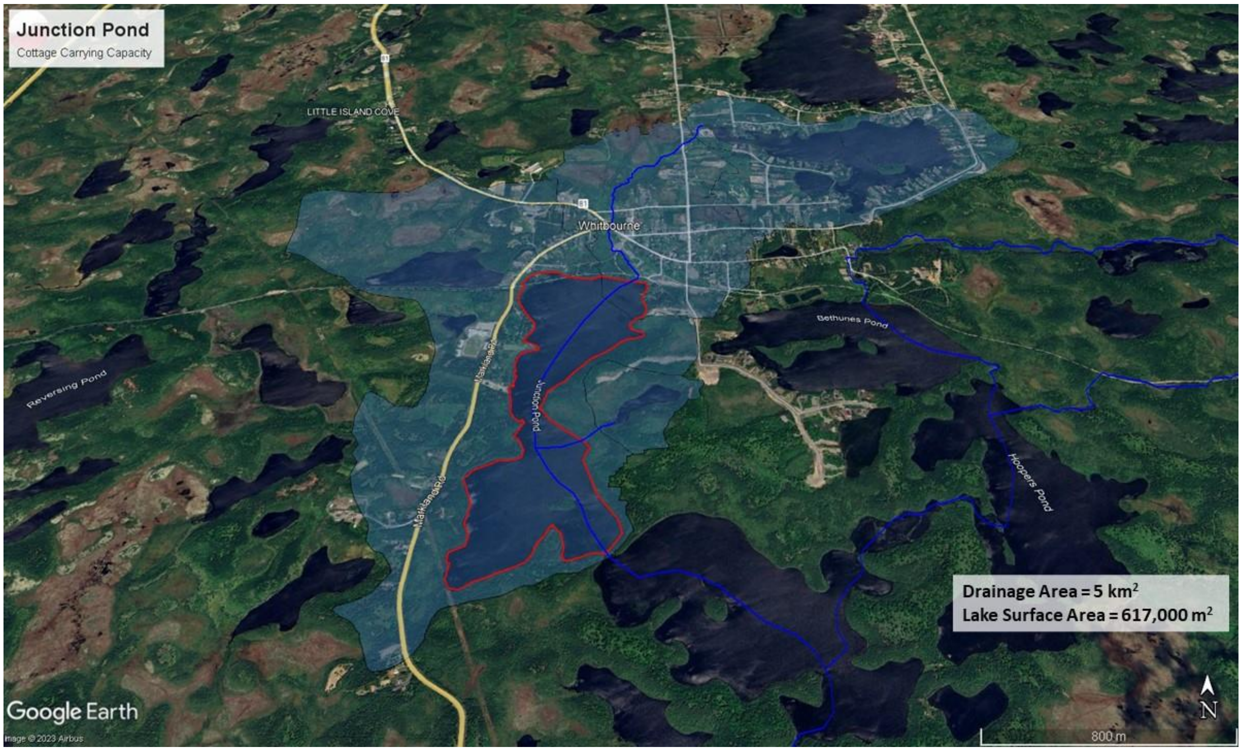

Figure 2 Junction Pond and its Watershed

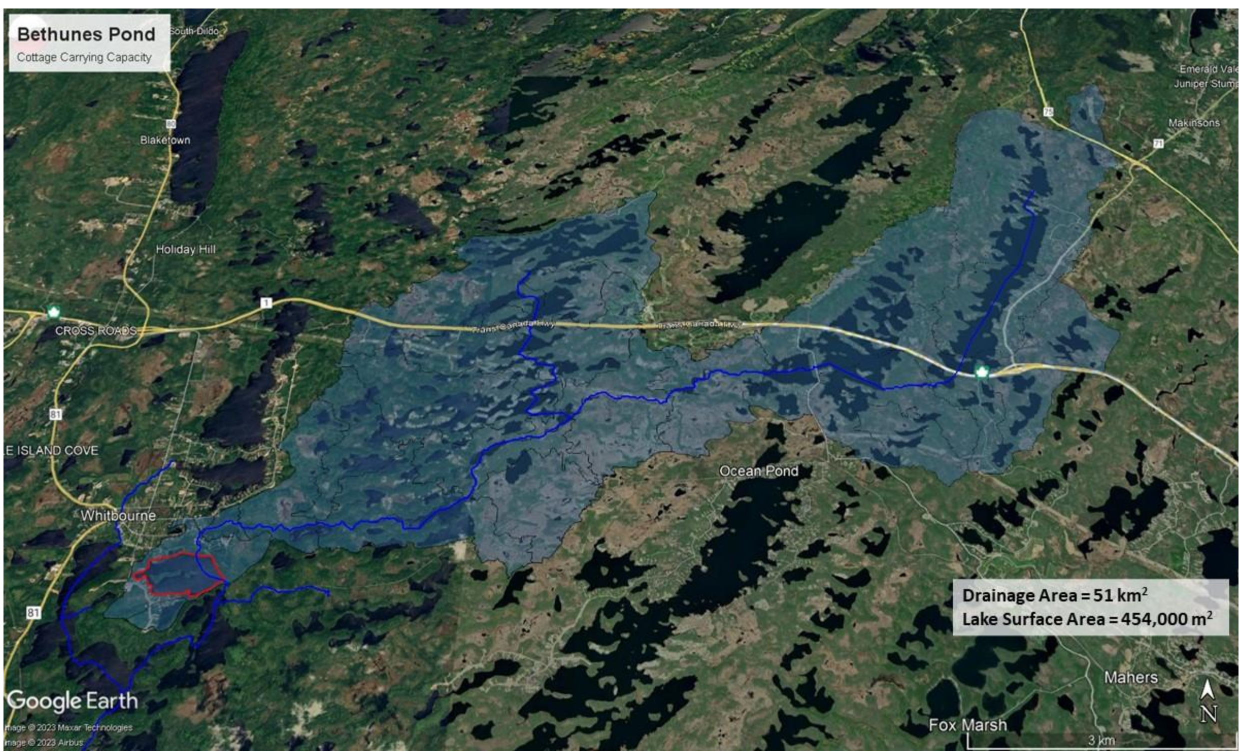

Figure 3 Bethunes Pond and its Watershed

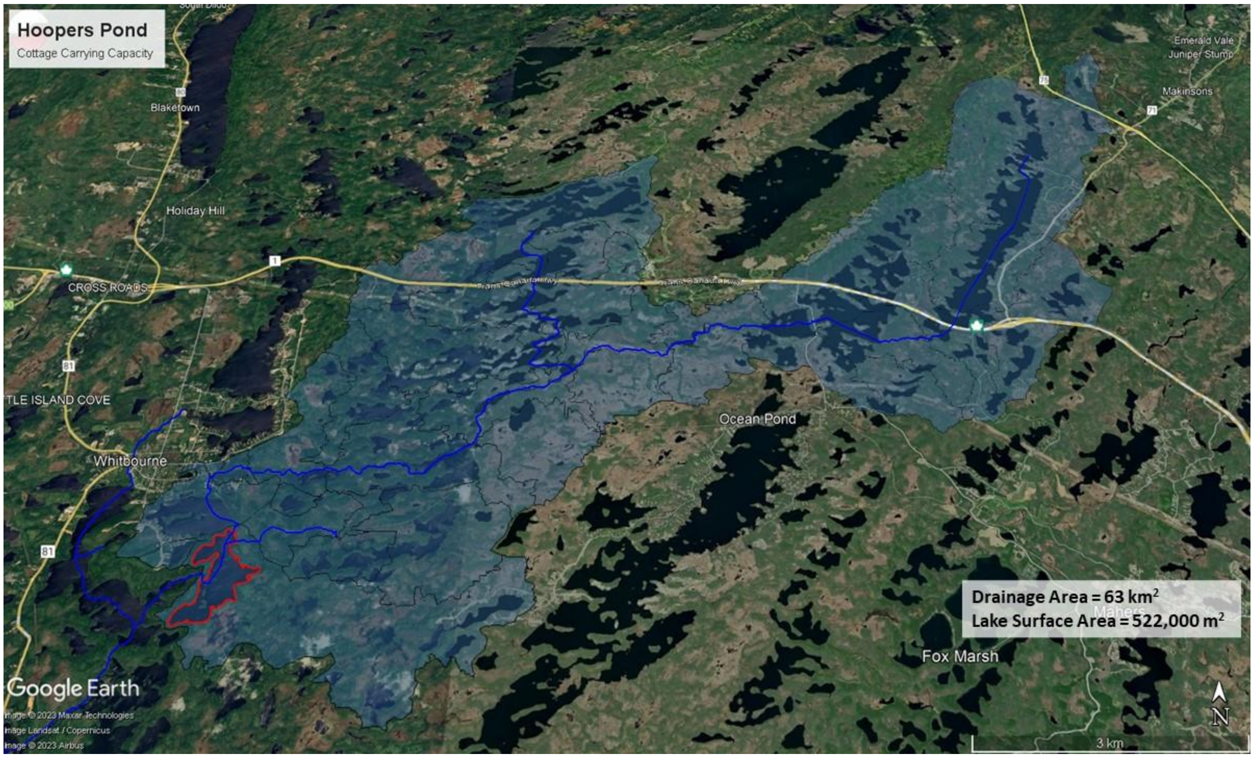

Figure 4 Hoopers Pond and its Watershed

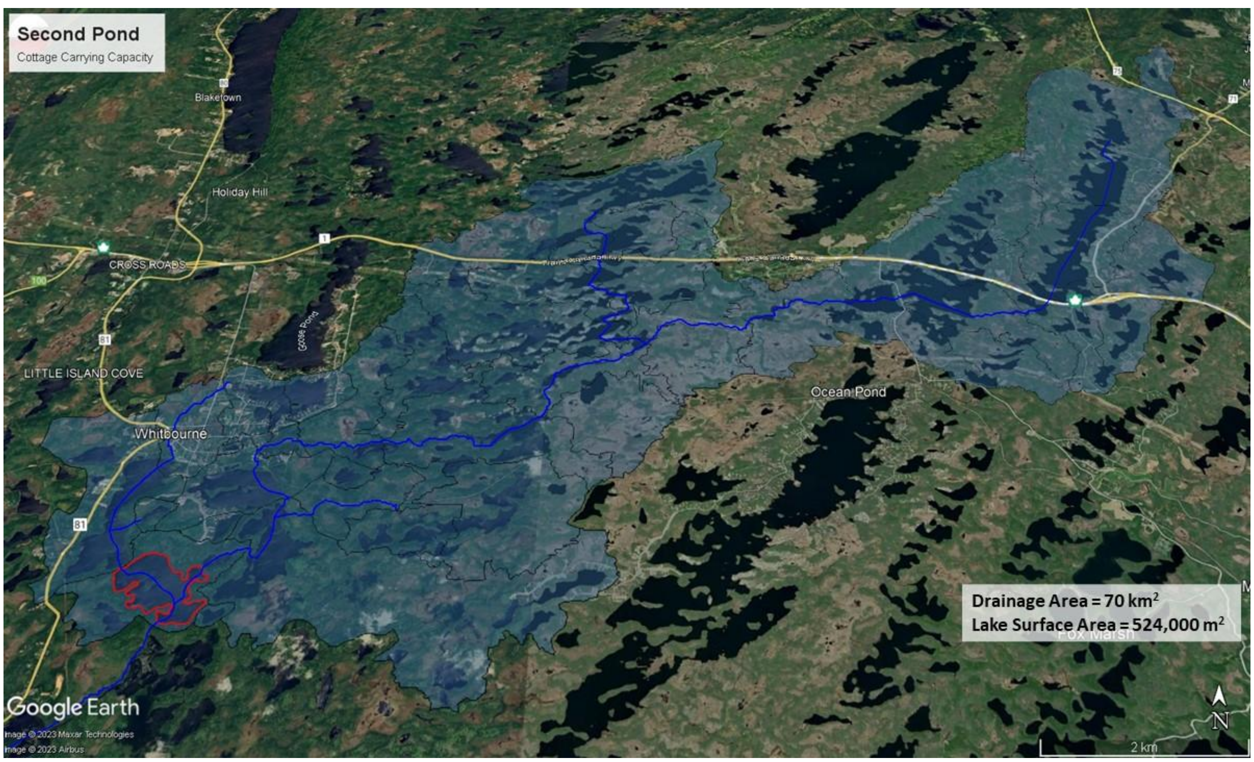

Figure 5 Second Pond and its Watershed

Figure 6 **Well's Gully and its Watershed**

Figure 7 **Blockline Gully and its Watershed**

2.0 METHODOLOGY

The methodology used to estimate the Cottage Carrying Capacity of lakes in Newfoundland and Labrador is outlined in the document titled “Cottage Development Planning in Newfoundland”, published in 1994 by the Surface Water Section of the Water Resources Management Division of the Newfoundland and Labrador Department of Environment and Lands. This document presents assessment methodologies in seven separate sections along with a Spectrum Analysis (section 8.0) to determine the maximum permittable development along a lake. The Cottage Carrying Capacity methodology is based on assessing three development impact criteria: Water Quality, Shoreline Conditions and Boating/Angling.

- The impacts to Water Quality are assessed using a methodology to determine the Lake Tropic State (section 2.0),
- the impacts to Shoreline Conditions are assessed using the Natural Shoreline Reserve Method (section 3.0) or the Shoreline Capability Method (section 4.0) and the Low Energy Recreation Cottage Pond Capacity Method (section 7.2.2), while
- the impacts from Boating/Angling are assessed using the Boat Density Method (section 5.0) and the Sports Fisheries Approach (if applicable, section 6.0) and the High Energy Recreation Cottage Pond Capacity Method (section 7.2.1).

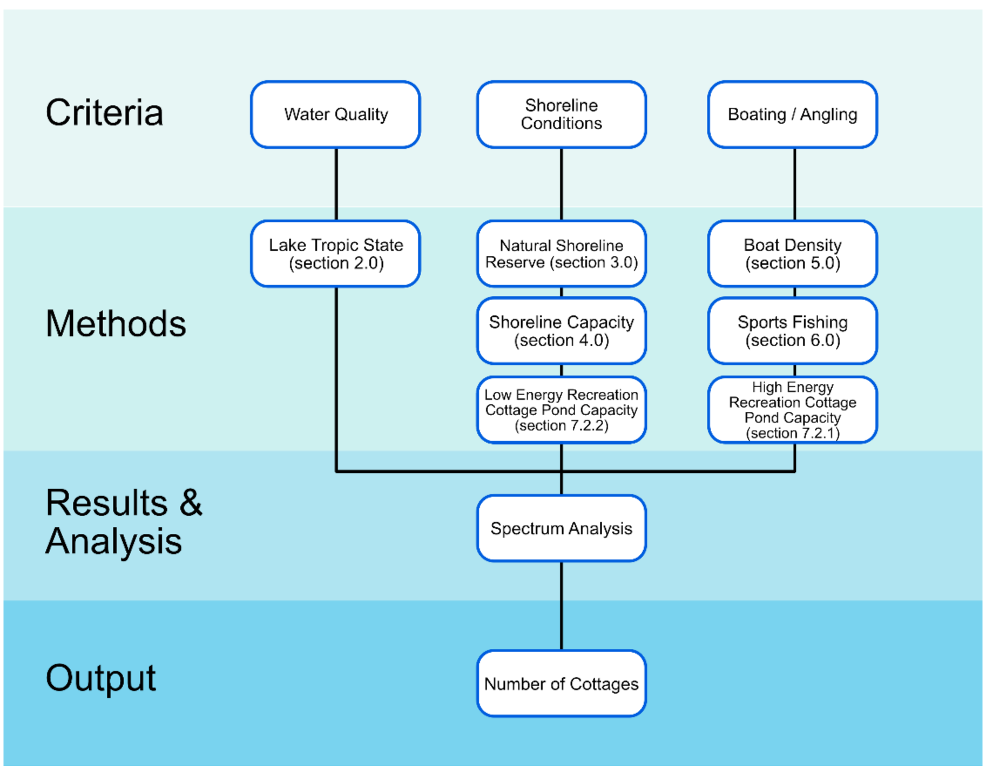

Figure 8 Flowchart of Methodology Presented by the Government of Newfoundland

Each of these methods will estimate the maximum permittable development along a lake and the most restrictive (lowest) level of development will govern during the Spectrum Analysis (section 8.0). The Natural Shoreline Reserve Method was deemed to be better suited than the Shoreline Capability Method to the Goose Pond Development and the surrounding lakes, and the Sports Fisheries Approach was deemed not to apply the residential development. A flow chart illustrating the three development impact criteria and the seven potential assessment methodologies is presented in figure 8 for clarity.

2.1 Lake Trophic State Method

The Water Quality criteria governing the maximum permittable development along a lake is based on the Lake Tropic State, which is a function of the average Summer chlorophyll a concentrations (indicator for the presence and severity of algae and algae-blooms), which in-turn is a function of the Total Phosphorus Supply (from both natural sources including direct precipitation, overland drainage and upstream sources, and artificial (man-made) sources). The above information is supplemented by the Lake Tropic State Index and the Lake Vulnerability Index to quantify the general aquatic lake health. A flow chart illustrating the above Lake Tropic State calculations is presented below for clarity.

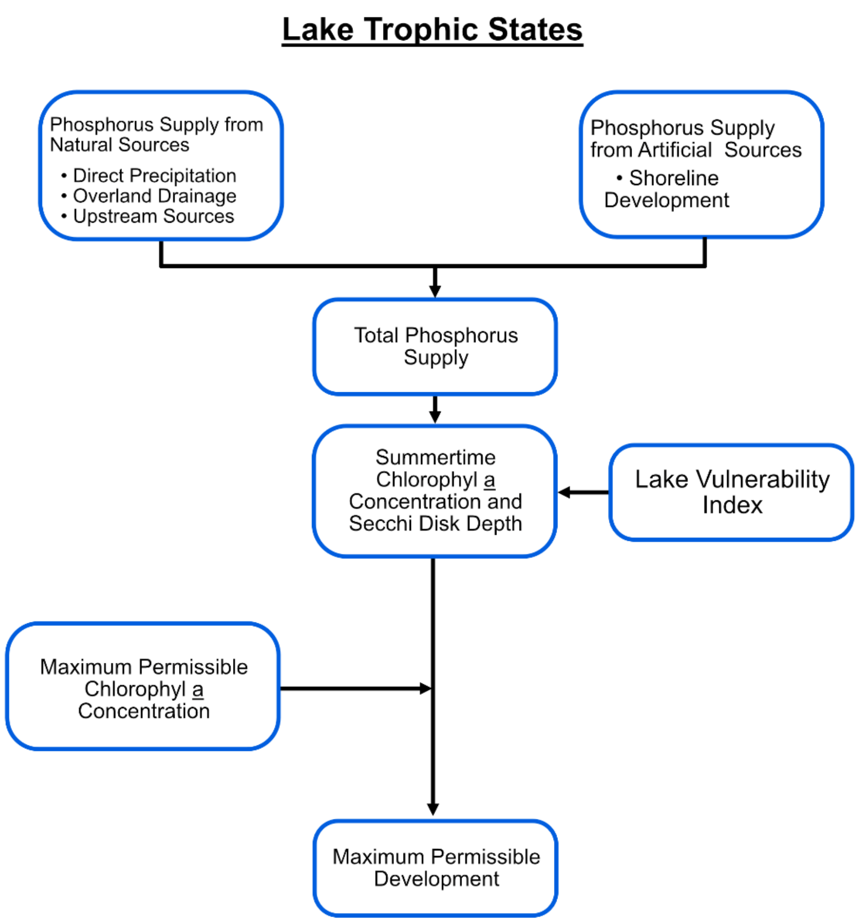

Figure 9 Lake Trophic State Method Flowchart

The steps of this methodology include the following:

A. Estimate the total phosphorus load to the lake from its watershed.
B. Estimate the total phosphorus in the precipitation falling directly on the lake.
C. Estimate the total natural phosphorus load to the lake.
D. Estimate the total man-made or artificial phosphorus loading to the lake.
E. Estimate the total phosphorus loading to the lake.
F. Predict the springtime total phosphorus concentration.
G. Predict the average summertime chlorophyll a concentration.
H. Predict the summer Secchi disc transparency.

The results obtained from the above are used to define the permissible level of phosphorus loading, which in turn is used to calculate the permissible level of cottage development.

Two principal sources of phosphorus supply to any water body are:

1. Phosphorus supply from natural sources (precipitation, drainage area and upstream sources)
2. Phosphorus supply from artificial sources (shoreline development)

2.1.1 Phosphorus Supply from Natural Sources

Precipitation and overland drainage are the primary sources of phosphorus supply from natural sources. In cases where a pond is connected to another lake/pond upstream, the phosphorus entering the pond from the upstream lake/pond should also be calculated.

Direct Precipitation: We used the equation below to calculate the phosphorus supply from direct precipitation:

$$J_{pr} = L_{pr} \times A_0$$

J_{pr} is phosphorus contribution through precipitation, L_{pr} Is the phosphorus loading value for precipitation and A_0 is the lake's surface area. L_{pr} ranges between 30 to 70 mg/m^2/year and a value of 50 mg/m^2/year has been recommended as a reasonable value. Table 2 presents the selected values and results.

Table 2 Phosphorus Loading Through Precipitation

Parameter	Junction Pond	Bethune's Pond	Hoopers Pond	Second Pond	Blockline Gully	Well's Gully
Lake Surface Area (m2)	617,000	454,000	517,000	517,000	46,000	26,000
Phosphorus Loading Value for Precipitation (mg/m2.year)	50	50	50	50	50	50
Phosphorus Loading from Precipitation (kg/year)	**30.9**	**22.7**	**25.9**	**25.9**	**2.3**	**1.3**

Overland Drainage: Phosphorus is also transported from watersheds to lakes through streamflow. We used the equation below to calculate the phosphorus supply from overland drainage:

$$J_D = A_{D.A.} \times E$$

In this equation J_D is phosphorus supply from overland drainage, $A_{D.A.}$ is the overland drainage area, and E is the phosphorus export coefficient corresponding to each land use type. Table 3 presents the export coefficients used for calculating the phosphorus supply from overland drainage and Table 4 presents the phosphorus supply from overland drainage to each pond.

Table 3 Phosphorus Export Coefficients

Phosphorus Export Value for Each Land Use Type	(mg/m2.year)
Lakes/Wetlands	5
Forest	14
Pasture	40
Agriculture/Rural	60
Urban	70

Table 4 Phosphorus Supply from Overland Drainage

Land Type	Junction Pond	Bethune's Pond	Hoopers Pond	Second Pond	Blockline Gully	Well's Gully
Lakes/Wetlands	117,000	47,000	975,000	110,000	-	-
Forest	2,192,000	1,585,000	7,980,000	6,200,000	129,000	132,000
Pasteur	-	41,000	-	-	-	-
Agriculture/Rural	62,000	-	-	-	-	-
Urban	718,000	73,000	55,000	-	-	-
Phosphorus Supply from Overland Drainage (kg/year)	**85.3**	**40.6**	**120.4**	**87.3**	**1.8**	**1.8**

Upstream Sources: We used the equation below to calculate the phosphorus supply from Upstream sources:

$$J_u = J_T(1 - R^{-1})$$

In this equation J_u is the phosphorus supply from upstream sources, J_T is the total phosphorus entering the upstream lake, R is the upstream lake's retention coefficient.

Four out of six ponds in the scope of this study are connected to a lake or chain of lakes and bogs upstream. There are four other lakes in Junction Pond's watershed and numerous lakes, ponds and wetlands upstream of Bethune's Pond, Hoopers Pond and Second Pond. Therefore, the total phosphorus supply and retention coefficient of each of the upstream lakes/ponds should be calculated. However, we made conservative assumptions to simplify the network and find the phosphorus supply from overland drainage. More details and the calculation steps are presented in Appendix A.

Tabe 5 presents phosphorus loadings from direct precipitation over the ponds, overland drainage, and upstream sources.

Table 5 Phosphorus Loading From Natural Sources

Parameter	Junction Pond	Bethune's Pond	Hoopers Pond	Second Pond	Blockline Gully	Well's Gully
Phosphorus Loading from Precipitation (kg/year)	30.9	22.7	25.9	25.9	2.3	1.3
Phosphorus Supply from Overland Drainage (kg/year)	85.3	40.6	120.4	87.3	1.8	1.8
Phosphorus from Upstream Sources (kg/year)	21.5	469.8	488.8	644.7	-	-
Total Phosphorus from Natural Sources (kg/year)	**137.7**	**533.1**	**635.1**	**758.0**	**4.1**	**3.1**

2.1.2 Phosphorus Supply from Artificial Sources

The artificial phosphorus supply from shoreline development can be calculated as:

$$J_A = S \times N_{cy}(1 - R_s) \times N$$

In this equation, J_A is the phosphorus supply from artificial sources, S is the phosphorus contribution per capita year, N_{cy} is the number of capita years per year per unit, R_s is the retention coefficient of the existing sewage treatment facilities, and N is the number of cottages near the shoreline. We used Statistics Canada's Census 2021 profile of the Town of Whitbourne to obtain population data. The total population of the Town of Whitbourne in 2021 was 955; the number of total private dwellings is 584, of which 419 of them are occupied by usual residents. As there was no available data on the dwellings with seasonal occupants, we assumed all the dwellings were occupied and calculated the N_{cy} of 1.63. The Town of Whitbourne operates a wastewater treatment plant with a secondary treatment lagoon. However, insufficient data is available to calculate the retention coefficient of the sewage treatment facility. Therefore, we selected a conservative retention coefficient of 0.9 for dwellings within the municipal boundary of the Town of Whitbourne. No data was available about the sewage disposal system and treatment level of upstream and out-of-town cottages. Therefore, we assumed a retention coefficient 0.5, corresponding with a typical septic well. A summary of selected parameters and results is presented in Table 6.

Table 6 Phosphorus Supply from Artificial Sources and Total Phosphorus Supply

Parameter	Junction Pond	Bethune's Pond	Hoopers Pond	Second Pond	Blockline Gully	Well's Gully
Number of Cottages	24	15	-	-	4	-
Number of Capita-Year/Year/Unit (Total Population/Number of Dwellings)	1.63	1.63	1.63	1.63	1.63	1.63
Retention Coefficient of Existing Sewage Treatment	0.9	0.9	0.9	0.9	0.9	0.9
Amount of Phosphorus Contributed per Capita-Year (kg/capita-year) *	0.8	0.8	0.8	0.8	0.8	0.8
Total Phosphorus from Artificial Sources (kg/year)	**0.4**	**2.0**	**-**	**-**	**0.5**	**-**
Total Phosphorus from Natural Sources (kg/year)	137.7	533.1	635.1	758	4.1	3.1
Total Phosphorus Supply (kg/year)	**138.0**	**535.1**	**635.1**	**758.0**	**4.6**	**3.1**

** Ranges between 0.3 to 1.8 kg/capita-year. The recommended value is 0.8 kg/capita-year* (Government of Newfoundland and Labrador, 1994)

2.1.3 Average Summertime Chlorophyll a Concentration

The total phosphorus supply, average summer Chlorophyll a concentration, and Secchi disc depth are baseline parameters in defining the trophic status of a water body. The guideline published by the Government of Newfoundland and Labrador (1994) presented relationships to calculate these parameters. We calculated the existing springtime phosphorus concentration based on the amount of nutrients the ponds receive, which in turn, we used to calculate summertime Chlorophyll a concentration and Secchi disc depth.

We calculated the springtime phosphorus concentration using the following equation:

$$P = \frac{L(1-R)}{0.956\,q_s}$$

In the equation, P is the springtime phosphorus concentration, L is the total phosphorus supply divided by the ponds surface area, R is the pond's retention coefficient, and q_s is aerial water load (presented in Table 1).

We calculated the summertime Chlorophyll a concentration using the following equation:

$$\log[chl\ \mathrm{a}] = 1.45\log[P] - 1.14$$

We calculated the Secchi disc depth using the equation below:

$$SD_{SS} = \frac{1}{(0.1138 + 0.386[chl\ \mathrm{a}])}$$

Table 7 shows a summary of the calculation process and results.

Table 7 Chlorophyll a Concentration and Secchi Disc Depth

Parameter	Junction Pond	Bethune's Pond	Hoopers Pond	Second Pond	Blockline Gully	Well's Gully
Springtime Phosphorus Concentration µg/l	10.25	8.60	8.70	9.46	5.94	6.28
Average Summer Chlorophyll a Concentration (µg/l)	2.12	1.64	1.67	1.88	0.96	1.04
Secchi Disk Depth (m)	5.12	5.64	5.61	5.36	6.63	6.50

2.1.4 Trophic State Indices

The trophic state index (TSI) is a summary statistic which is intended to allow the trophic state of and impoundment to be estimated based on a numerical value. Several attempts have been made to establish a TSI based on commonly available water quality parameters. We calculated TSIs using the following equations:

$$TSI_{(TP)} = 4.14 + 14.43\ln(TP)$$

$$TSI_{(CHL)} = 30.56 + 9.81\ln(CHL)$$

$$TSI_{(SD)} = 60 - 14.43\ln(SD)$$

We compared the calculated TSIs (Table 8) with the general trophic classification of lakes and reservoirs (Table 9) to determine the trophic state of the ponds (Table 10).

Table 8 Trophic State Index of the Ponds

Parameter	Junction Pond	Bethune's Pond	Hoopers Pond	Second Pond	Blockline Gully	Well's Gully
TSI (TP)	75.24	94.80	97.27	99.82	26.28	20.69
TSI (CHL)	37.91	35.42	35.59	36.77	30.14	30.94
TSI (SD)	36.44	35.03	35.11	35.77	32.70	33.00

Table 9 General Trophic Classification of Lakes and Reservoirs (After Reckher, 1978)

Parameters	Oligotrophic	Mesotrophic	Eutrophic	Hypereutrophic
TSI (TP)	*=< 40*	*41-51*	*51-70*	*>70*
TSI (CHL)	*=< 12*	*13-25*	*26-99*	*>=100*
TSI (SD)	*< 3*	*3-7*	*8-54*	*>=55*
Secchi Disk Depth (m)	*>13*	*13-6.5*	*6.5-1.5*	*<1.5*

Table 10 General Trophic State of the Ponds

Parameters	Junction Pond	Bethune's Pond	Hoopers Pond	Second Pond	Blockline Gully	Well's Gully
TSI (TP)	Hypereutrophic	Hypereutrophic	Hypereutrophic	Hypereutrophic	Oligotrophic	Oligotrophic
TSI (CHL)	Eutrophic	Eutrophic	Eutrophic	Eutrophic	Eutrophic	Eutrophic
TSI (SD)	Eutrophic	Eutrophic	Eutrophic	Eutrophic	Eutrophic	Eutrophic
Secchi Disk Depth (m)	Eutrophic	Eutrophic	Eutrophic	Eutrophic	Mesotrophic	Mesotrophic

The results show the trophic state of all the ponds is eutrophic based on at least two indices. The results indicate that the total phosphorus supply to Junction Pond, Bethune's Pond, Hoopers Pond and Second Pond is very high due to their large watershed. Blockline Gully and Well's Gully's watersheds are undeveloped; however, the watersheds are very small and generate low mean annual outflows. This results in the summertime eutrophication of the lakes.

Determining the trophic state of the ponds was the first step of the water quality assessment. The next step is to find how sensitive the ponds are to development.

2.1.5 Lake Vulnerability Index

We assessed the lakes' vulnerability to development using hydrologic and morphologic data along with lake vulnerability index criteria presented by Sargent (Frederic O. Sargent, 1977) (Table 11). This index is used as an indicator of the lake's relative vulnerability to eutrophication. Five parameters are considered in the calculation of the index:

1. The Ratio of Watershed Area to Lake Volume: The larger ratio indicates the lake is more vulnerable to development since nutrient and sediment loadings into the lake vary with the size of the watershed.

2. Shoreline Configuration: This parameter is obtained by dividing the total shoreline length by the circumference of a circle with an area equal to the area of the lake. A higher value of this parameter indicates higher productivity of the water body due to the higher number of bays retaining nutrients (shallower bays).

$$S = \frac{L}{2\pi\sqrt{A/\pi}}$$

   In this equation, S is shoreline configuration, L is the length of the shoreline, and A is the area of the lake.

3. Mean Depth: Deeper lakes have a greater capacity to assimilate nutrients and trap them in sediments where they are not available for growth.
4. Shoalness Ratio: This ratio is the percentage of the lake bottom area with a depth of lesser than 4.5 meters, which is approximately the maximum area depth of light

penetration and plant growth. A lake with a high percentage of the bottom at depths greater than 4.5 meters is less vulnerable to human-caused eutrophication.

5. Water Transport: Mean hydrologic residence time is the time required for a volume of water equal to the volume of the lake to flow through the system. It indicates the rate at which a lake is flushed. With respect to hydraulic residence time, lakes are classified in three groups:
    a. Flowage Lakes: These lakes are part of a river system and typically have a short residence time ranging from 0.04 to 0.76 years.
    b. Drainage Lakes: These lakes have well-defined outlets and a residence time between 0.08 to 2 years.
    c. Inflow Lakes: Lakes with inlets but no outlets receive nutrients from their watershed but have no immediate means of release and, therefore, are more vulnerable to development.

An index point from 1 to 3 is assigned to each of the parameters based on the criteria presented by Sargent (1977). So the vulnerability index of a water body ranges between 5 to 15.

Table 11 Lake Vulnerability Index Criteria (Sargent 1977)

Parameter	Index Points		
	1	2	3
The Ratio of Watershed to Lake Volume	<0.3	0.3-1.0	>1.0
Shoreline Configuration	<1.5	1.5-2.0	>2.0
Mean Depth (m)	<3	3-9	>9
Shoalness	0-40%	40-80%	80-100%
Water Transport	Flowage	Drainage	No outlet

Table 12 presents the parameters and values used for calculating the vulnerability index of the ponds.

Table 12 Lake Vulnerability Index Parameters and Results

Parameter	Junction Pond	Bethune's Pond	Hoopers Pond	Second Pond	Blockline Gully	Well's Gully
The ratio of Watershed Area to Lake Volume	0.58	9.56	8.81	15.44	0.85	1.94
Shoreline Configuration	0.62	0.41	0.68	0.63	0.43	0.45
Mean Depth (m)	6.7	5.7	6.3	4	2	1.5
Shoalness Ratio	40%-80%	80%-100%	40%-80%	100%	100%	100%
Water Transport	Drainage	Flowage	Flowage	Flowage	Drainage	Drainage
Vulnerability Index	**9**	**10**	**9**	**10**	**9**	**10**

Based on the vulnerability index of the lakes, all of them are moderately vulnerable to cottage development.

2.1.6 Maximum Permissible Development

The calculation for the maximum permissible development of a lake depends on the maximum acceptable Chlorophyll a value related to the lake's biological, physical, and morphological characteristics and desired uses. The maximum permissible average summer Chlorophyll a concentration for various desired uses of lakes is presented in the Cottage Development Planning guideline (Table 2.9 page 21, Cottage Development Planning in Newfoundland, 1994).

Table 13 Maximum Permissible average summer Chlorophyll a Concentration

Lake Level	Chlorophyll Concentration (mg/l)	Use of Lake	Remarks
Level 1	2.00	Primarily for body contact and water recreation	1. Lake will be unproductive 2. Lake will be extremely clear with Secchi disk depth >5 m
Level 2	**5.00**	**Primarily for body contact and water recreation**	**1. Lake will be moderately productive** **2. Secchi disk depth will range from 2 - 5 m**
Level 3	20.00	No body contact and recreation No fisheries	1. Development of algae and rooted aquatic problems 2. Secchi disk depth <2 m
Level 4	25.00	No recreation Hypolimnetic depletion will occur in the summer	1. Extensive algae bloom

We selected a maximum Chlorophyll a concentration of 5 mg/l to calculate the maximum permissible phosphorus concentration for each pond using the equation below.

$$\log[chl\ \mathrm{a}]_{Perm} = 1.45 \log[P]_{Perm} - 1.14$$

In this equation, $[chl\ \mathrm{a}]_{Perm}$ is the maximum permissible Chlorophyll Concentration and $[P]_{Perm}$ is the maximum permissible phosphorus concentration. Next, using the equation below, we used the calculated maximum permissible phosphorus concentration to find the maximum permissible phosphorus supply.

$$J_{Perm} = \frac{P_{Perm}.Q}{(1-R)}$$

In this equation, J_{Perm} is the maximum permissible phosphorus supply, P_{Perm} is the maximum permissible phosphorus concentration, and R is the retention coefficient of the pond. If the existing total phosphorus supply J_t is lower than the maximum permissible phosphorus supply J_{Perm}, then additional development can be calculated using the equation below.

$$N_{Perm} = \frac{J_{Perm} - J_T}{S.N_{cy}.(1-R_s)}$$

In this equation, N_{Perm} is the number of additional development, J_T is the total phosphorus supply, S is the amount of phosphorus contribution per capita-year, $N_{cy}$is the number of capita-years per year per unit, and R_s is the retention coefficient of the sewage treatment system.

Table 14 presents a summary of the calculations for the maximum permissible Chlorophyll a concentration, maximum permissible phosphorus concentration and supply, and the maximum number of additional development.

Table 14 Additional Development Capacity Using Trophic State Method

Parameter	Junction Pond	Bethune's Pond	Hoopers Pond	Second Pond	Blockline Gully	Well's Gully
Maximum Permissible Average Summer Chlorophyll a (µg/l)	5.00	5.00	5.00	5.00	5.00	5.00
Maximum Permissible Phosphorus Concentration (µg/l)	18.55	18.55	18.55	18.55	18.55	18.55
Maximum Permissible Phosphorus Supply (kg/year)	261.3	1206.5	1415.4	1554.8	15.2	9.7
Maximum Number of Additional Development (units)	**202**	**564**	**653**	**661**	**27**	**14**

The results of this methodology show all the lakes have additional development capacity.

2.2 Natural Shoreline Reserve Method

The rationale of this methodology is to preserve the visual and aesthetic beauty of the ponds, to preserve the natural vegetation cover, to protect and enhance the livability and economic value of cottages along the shorelines, to maintain the ecological balance of the ponds, to protect the water quality of the pond, and to prevent development in sensitive areas such as floodplains and erodible slopes. The method is easy to apply and requires little background information.

This method recommends 25%-40% of the natural shoreline linear length should be reserved in its natural state to preserve the natural and aesthetic beauty of the water body (Table 15).

Table 15 Natural Shoreline Reserve Method Parameters and Results

Parameter	Junction Pond	Bethune's Pond	Hoopers Pond	Second Pond	Blockline Gully	Well's Gully
Lake Perimeter (m)	5,430	3,080	5,420	5,020	1,020	810
Existing Length of Developed Shoreline (m)	1,190	1,390	0	0	330	0
Maximum Permissible Developed Length (m)	4,070	2,310	4,060	3,760	760	610
Remaining Permissible Length (m)	2,880	930	4,060	3,760	440	610
Cabin Lot Size Width (m)	35	35	35	35	35	35
Maximum Number of Additional Cottages	**82**	**27**	**116**	**107**	**13**	**17**

The results of this methodology show all the lakes have more development capacity.

2.3 Boat Density Method

The boat limit system is designed to estimate a water body's capacity to handle boating use. In the boat density method, the surface area and shape of the pond is the limiting factor for the number of boats that can use the lake simultaneously. The central idea of this method is to determine the usable surface area of the lake, considering boating space standards.

The available boating space is determined by subtracting the following segments of a water body:

- A 60-meter band around the shore and all subdivided islands.
- A 20-meter band around all marinas, public beaches, and access points.
- A 30-meter band around all non-subdivided islands.
- The central area of large water bodies at a distance more than 1.6 km from the shore.

We assumed a single boating space standard of 4 hectares per boat, a threshold of 10% of the boats in use at peak times, and one boat per cottage owner. Table 16 presents a summary of steps, parameters, and results.

Table 16 Boat Density Method Parameters and Results

Parameter	Junction Pond	Bethune's Pond	Hoopers Pond	Second Pond	Blockline Gully	Well's Gully
Lake Surface Area (ha)	61.7	45.4	51.7	51.8	4.6	2.6
Available Boating Space (ha)	31.2	29	23.4	25.4	0.5	0
Boat Spacing Requirement (ha)	4	4	4	4	4	4
Boating Capacity	8	7	6	6	0	0
Number of Permitted Boats for Cottage Owners	5	4	4	4	0	0
Cottage Carrying Capacity	47	44	35	38	1	0
Existing Cottages	3	15	0	0	4	0
Number of Permissible Additional Development	**44**	**29**	**35**	**38**	**-3**	**0**

The results from this method show that Junction Pond, Bethunes Pond, Hoopers Pond and Second Pond have further development capacity, Well's Gully is unsuitable for boating, and Blockline Gully is overdeveloped.

2.4 High Energy – Low Energy Recreation Method

This method was proposed by the Land Use Management Division in 1978, and its main purpose in calculating the capacity of a pond or lake in this method is:

- to minimize the conflict of recreation use between such activities as motor boating, swimming, water skiing and fishing,
- to preserve the ecological balance of the water body, and
- to preserve non-developed public reserves adjacent to the water body.

This method classifies the water bodies in two groups:

1. Ponds which are suitable for motorboat activity because of the water surface area, shape, and depth (high-energy recreation ponds), and
2. Ponds which are not suitable for motorboat activity because of the water surface area, shape, and depth (low-energy recreation ponds).

In high-energy recreation ponds, the assumptions are as follows:

- Four hectares of pond surface area is allocated to each boat.
- Maximum use of only 10% of the total boats on the pond at any time.
- Each cottage owns two boats.
- 40% of the pond capacity is reserved for future non-cottagers and development.

In low-energy recreation ponds, the assumptions are as follows:

- 25% of the shoreline is reserved as a natural habitat, and 75% is allocated for development (development length).
- 25% of the development length is reserved for future development.

We calculated both the ponds' high-energy and low-energy recreation cottage development potential and presented the parameters and results in Table 17 and Table 18.

Table 17 High-Energy Recreation Method

Parameter	Junction Pond	Bethune's Pond	Hoopers Pond	Second Pond	Blockline Gully	Well's Gully
Surface Area (ha)	61.7	45.4	51.7	51.8	4.6	2.6
Pond's Capacity for Boating	15.4	11.4	12.9	12.9	1.2	0.6
Number of Boats for Non-Cottagers	6.2	4.5	5.2	5.2	0.5	0.3
Number of Boats for Cottagers	9.3	6.8	7.8	7.8	0.7	0.4
Total Allowable Cottage Boats	93	68	78	78	7	4
Cottage Capacity of the Lake	46	34	39	39	3	2
Existing Cottages	3	15	0	0	4	0
Additional Cottage Development Capacity	**43**	**19**	**39**	**39**	**-1**	**2**

Table 18 Low-Energy Recreation Method

Parameter	Junction Pond	Bethune's Pond	Hoopers Pond	Second Pond	Blockline Gully	Well's Gully
Lake Perimeter (m)	5,400	3,100	5,400	5,000	1,000	810
Natural Shoreline Reserve (m)	1,400	770	1,400	1,300	260	200
Future Development Reserve (m)	3,050	1,730	3,050	2,820	570	460
Cabin Lot Width (m)	35	35	35	35	35	35
Existing Cottages	3	15	0	0	4	0
Additional Cottage Development Capacity	**84**	**35**	**87**	**81**	**12**	**13**

The results from the High-Energy method show Junction Pond, Bethune's Pond, Hoopers Pond, and Second Pond have additional development capacity. However, Blockline Gully is already overdeveloped (4 existing cottages seen on the latest aerial images available in July 2023), and Well's Gully is a small water body with limited development capacity. The Low-Energy method indicates there is more development capacity if the lake is intended to be used for low-energy recreation.

2.5 Spectrum Analysis

In the concluding step of the cottage carrying capacity study, we reviewed the carrying capacity results calculated from each of the methods to provide a range of development-level choices concerning the pond's intended use. The advantages of using a spectrum approach are:

- more than one development constraint is used to determine the carrying capacity,
- a range of development-level choices are available to the planner to decide the potential development type, and
- the extent of limiting factors is identified and available to planners for preventional or remediation measures.

Table 19 compares the additional cottage development capacity calculated using every method in the previous sections.

Table 19 Additional Development Capacity of Ponds

Parameter	Junction Pond	Bethune's Pond	Hoopers Pond	Second Pond	Blockline Gully	Well's Gully
Trophic State	202	564	653	661	27	14
Natural Shoreline Reserve	82	27	116	107	13	17
Boat Density	44	29	35	38	0	0
High-Energy Recreation	43	19	39	39	0	2
Low-Energy Recreation	84	35	87	81	12	13
Additional Development Capacity (Least of All Above)	**43**	**19**	**35**	**38**	**0**	**0**

3.0 CONCLUSION

The aquatic health of all five ponds in the project area is classified as moderate based on the natural eutrophic state of the ponds and Lake Vulnerability Indices of 9 and 10 (on a scale of 5 to 15).

The Spectrum Analysis indicated a total additional development capacity of 135 residential units (43 for Junction Pond, 19 for Bethune's Pond, 35 for Hoopers Pond and 38 for Second Pond, with zero each for Blockline Gully and Well's Gully based on the Boat Density and High Energy Recreation Pond Capacity methods). If boating activity on Blockline Gully and Well's Gully was removed, the total additional development capacity would increase to 160 residential units (43 for Junction Pond, 19 for Bethune's Pond, 35 for Hoopers Pond, 38 for Second Pond, 12 for Blockline Gully and 13 for Well's Gully).

4.0 SIGNATURE

We trust this draft report provides sufficient information for your present purposes. If you have any questions concerning this report, please do not hesitate to contact our office.

Hans Arisz, M.Sc.E., P.Eng., FCSCE
Water Resources Lead

June 10, 2024

Nima Agh, M.Ap.Sc., M.Eng., EIT
Water Resources

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APPENDIX A

Phosphorus Loading From Upstream Sources

Report to: Daniel Gosse
GEMTEC Project: 102486.001 (June 10, 2024)

Bethunes Pond Total Phosphorus Loading Calculation

Parameter	Section 1	Section 2	Section 3	
Drainage Area (m2)	4,892,200	14,387,300	4,233,800	
Lake Surface Area (m2)	229,700	1,922,900	509,700	
D.A./Lake Surface Area	21.3	7.5	8.3	
Lake Perimeter (m)	2,850	18,200	7,350	
Mean Annual Precipitation (m/year)	1.3	1.3	1.3	
Mean Annual Runoff (m/year)	1.1	1.1	1.1	
Mean Annual Evaporation (m/year)	0.2	0.2	0.2	
Total Outflow (m3/year)	5,381,400	17,941,300	5,217,900	
Aerial Water Load (m/year)	23.42	9.33	10.24	
Dissolved Oxygen (mg/l)	11.2	11.2	11.2	
Settling Velocity (m/s)	12.4	12.4	12.4	
Retention Coefficient	0.35	0.57	0.55	
Phosphorus Loading Value for Precipitation (mg/m2.year)	50	50	50	
Phosphorus Loading from Precipitation (kg/year)	11.5	96.1	25.5	
Phosphorus Export Value for Each Land Use Type (mg/m2.year)				
Lakes/Wetlands	5	5	5	7
Forest	14	14	14	#
Forest-Pasteur (15% watershed cleared)	20	20	20	#
Pasteur	40	40	40	#
Agriculture/Rural	60	60	60	#
Urban	70	70	70	#
Total Area of Each Land Type Within the Watershed (m2)				
Lakes/Wetlands	379,900	502,500	325,200	
Forest	4,189,100	6,602,800	3,111,200	
Forest-Pasteur (15% watershed cleared)	-	-	-	
Pasteur	46,900	-	-	
Agriculture/Rural	-	143,300	206,200	
Urban	46,300	323,400	81,200	
Phosphorus Supply from Watershed (kg/yaer)	65.7	126.2	63.2	
Total Phosphorus from NATURAL Sources (kg/year)	77.2	222.3	88.7	
Total Phosphorus from UPSTREAM Sources (kg/year)	0	58.1	-	
Number of Cottages	18	121	28	
Number of Capita-Year/Year/Unit	1.63	1.63	1.63	
Retention Coefficient of Exising Sewage Treatment	0.5	0.5	0.5	
Amount of Phosphorus Contributed per Capita-Year (kg/capita-year)	0.8	0.8	0.8	
Total Phosphorus from ARTIFICIAL Sources (kg/year)	12	79	18	
Total Phosphorus Supply (kg/year)	88.9	359.4	107.0	

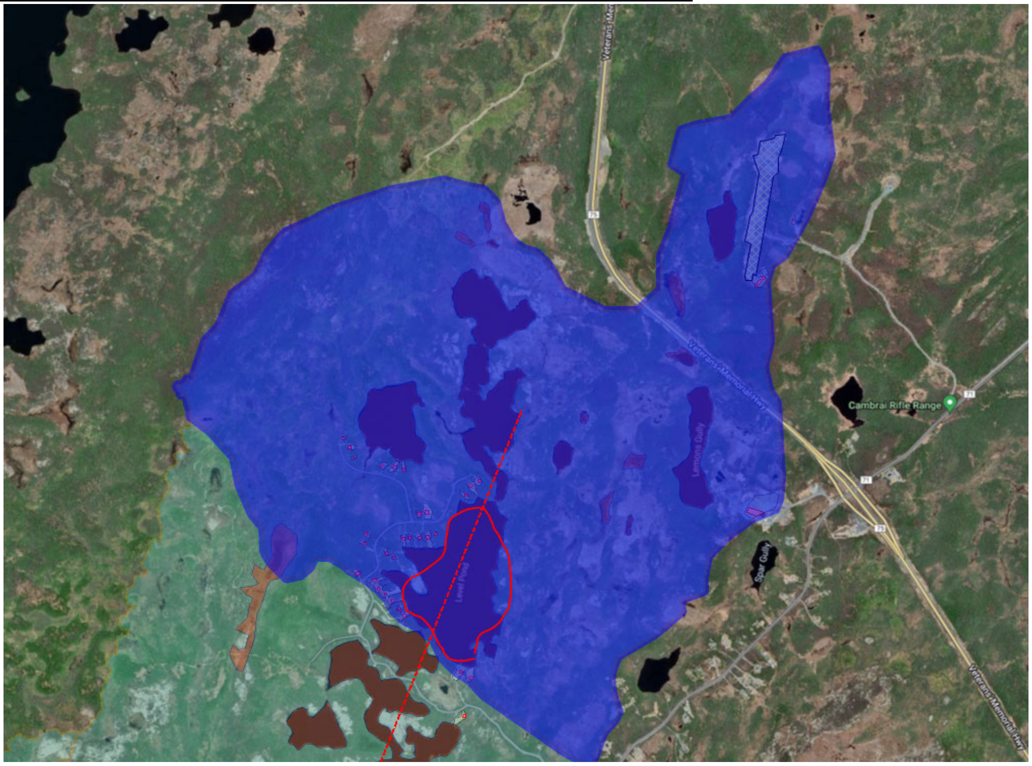
Parameter	Section 4	Section 5	Section 6
Drainage Area (m2)	24,325,593	25,059,476	27,349,562
Lake Surface Area (m2)	1,078,727	303,134	55,046
D.A./Lake Surface Area	22.6	82.7	496.8
Lake Perimeter (m)	10,409	2,700	2,031
Mean Annual Precipitation (m/year)	1.3	1.3	1.3
Mean Annual Runoff (m/year)	1.1	1.1	1.1
Mean Annual Evaporation (m/year)	0.2	0.2	0.2
Total Outflow (m3/year)	26,758,152	27,565,424	30,084,518
Aerial Water Load (m/year)	24.81	90.93	546.53
Dissolved Oxygen (mg/l)	11.2	11.2	11.2
Settling Velocity (m/s)	12.4	12.4	12.4
Retention Coefficient	0.33	0.12	0.02
Phosphorus Loading Value for Precipitation (mg/m2.year)	50	50	50
Phosphorus Loading from Precipitation (kg/year)	53.9	15.2	2.8
Phosphorus Export Value for Each Land Use Type (mg/m2.year)			
Lakes/Wetlands	*5*	*5*	*5*
Forest	*14*	*14*	*14*
Forest-Pasteur (15% watershed cleared)	*20*	*20*	*20*
Pasteur	*40*	*40*	*40*
Agriculture/Rural	*60*	*60*	*60*
Urban	*70*	*70*	*70*
Total Area of Each Land Type Within the Watershed (m2)			
Lakes/Wetlands	548,460	10,000	125,000
Forest	3,917,006	335,250	2,110,040
Forest-Pasteur (15% watershed cleared)	-	-	-
Pasteur	-	-	-
Agriculture/Rural	-	15,500	-
Urban	160,188	70,000	-
Phosphorus Supply from Watershed (kg/yaer)	97.1	10.6	30.2
Total Phosphorus from NATURAL Sources (kg/year)	151.0	25.7	32.9
Total Phosphorus from UPSTREAM Sources (kg/year)	248.6	284.3	291.2
Number of Cottages	41	32	-
Number of Capita-Year/Year/Unit	1.63	1.63	1.63
Retention Coefficient of Exising Sewage Treatment	0.5	0.5	0.5
Amount of Phosphorus Contributed per Capita-Year (kg/capita-year)	0.8	0.8	0.8
Total Phosphorus from ARTIFICIAL Sources (kg/year)	27	21	-
Total Phosphorus Supply (kg/year)	426.4	330.9	324.1

Parameter	Section 7	Section 8	Section 9
Drainage Area (m2)	3,715,830	6,077,170	7,553,138
Lake Surface Area (m2)	1,366,699	198,159	332,253
D.A./Lake Surface Area	2.7	30.7	22.7
Lake Perimeter (m)	16,091	2,804	4,150
Mean Annual Precipitation (m/year)	1.3	1.3	1.3
Mean Annual Runoff (m/year)	1.1	1.1	1.1
Mean Annual Evaporation (m/year)	0.2	0.2	0.2
Total Outflow (m3/year)	5,590,783	6,684,887	8,308,452
Aerial Water Load (m/year)	4.09	33.74	25.01
Dissolved Oxygen (mg/l)	11.2	11.2	11.2
Settling Velocity (m/s)	12.4	12.4	12.4
Retention Coefficient	0.75	0.27	0.33
Phosphorus Loading Value for Precipitation (mg/m2.year)	50	50	50
Phosphorus Loading from Precipitation (kg/year)	68.3	9.9	16.6
Phosphorus Export Value for Each Land Use Type (mg/m2.year)			
Lakes/Wetlands	*5*	*5*	*5*
Forest	*14*	*14*	*14*
Forest-Pasteur (15% watershed cleared)	*20*	*20*	*20*
Pasteur	*40*	*40*	*40*
Agriculture/Rural	*60*	*60*	*60*
Urban	*70*	*70*	*70*
Total Area of Each Land Type Within the Watershed (m2)			
Lakes/Wetlands	164,313	117,023	94,847
Forest	2,124,818	2,046,158	1,048,867
Forest-Pasteur (15% watershed cleared)	-	-	-
Pasteur	-	-	-
Agriculture/Rural	60,000	-	-
Urban	-	-	-
Phosphorus Supply from Watershed (kg/yaer)	34.2	29.2	15.2
Total Phosphorus from NATURAL Sources (kg/year)	102.5	39.1	31.8
Total Phosphorus from UPSTREAM Sources (kg/year)	-	25.4	47.2
Number of Cottages	-	-	-
Number of Capita-Year/Year/Unit	1.63	1.63	1.63
Retention Coefficient of Exising Sewage Treatment	0.5	0.5	0.5
Amount of Phosphorus Contributed per Capita-Year (kg/capita-year)	0.8	0.8	0.8
Total Phosphorus from ARTIFICIAL Sources (kg/year)	-	-	-
Total Phosphorus Supply (kg/year)	102.5	64.6	79.0

Parameter	Section 10	Section 11	Section 12
Drainage Area (m2)	11,225,222	15,197,316	45,088,385
Lake Surface Area (m2)	226,843	809,268	69,378
D.A./Lake Surface Area	49.5	18.8	649.9
Lake Perimeter (m)	5,250	-	-
Mean Annual Precipitation (m/year)	1.3	1.3	1.3
Mean Annual Runoff (m/year)	1.1	1.1	1.1
Mean Annual Evaporation (m/year)	0.2	0.2	0.2
Total Outflow (m3/year)	12,347,744	16,717,048	49,597,223
Aerial Water Load (m/year)	54.43	20.66	714.89
Dissolved Oxygen (mg/l)	11.2	11.2	11.2
Settling Velocity (m/s)	12.4	12.4	12.4
Retention Coefficient	0.19	0.38	0.02
Phosphorus Loading Value for Precipitation (mg/m2.year)	50	50	50
Phosphorus Loading from Precipitation (kg/year)	11.3	40.5	3.5
Phosphorus Export Value for Each Land Use Type (mg/m2.year)			
Lakes/Wetlands	*5*	*5*	*5*
Forest	*14*	*14*	*14*
Forest-Pasteur (15% watershed cleared)	*20*	*20*	*20*
Pasteur	*40*	*40*	*40*
Agriculture/Rural	*60*	*60*	*60*
Urban	*70*	*70*	*70*
Total Area of Each Land Type Within the Watershed (m2)			
Lakes/Wetlands	1,894,986	378,325	129,011
Forest	1,439,476	2,784,502	2,343,118
Forest-Pasteur (15% watershed cleared)	-	-	-
Pasteur	-	-	-
Agriculture/Rural	96,139	-	-
Urban	14,639	-	-
Phosphorus Supply from Watershed (kg/yaer)	36.4	40.9	33.4
Total Phosphorus from NATURAL Sources (kg/year)	47.8	81.3	36.9
Total Phosphorus from UPSTREAM Sources (kg/year)	52.8	81.9	376.3
Number of Cottages	-	-	-
Number of Capita-Year/Year/Unit	1.63	1.63	1.63
Retention Coefficient of Exising Sewage Treatment	0.5	0.5	0.5
Amount of Phosphorus Contributed per Capita-Year (kg/capita-year)	0.8	0.8	0.8
Total Phosphorus from ARTIFICIAL Sources (kg/year)	-	-	-
Total Phosphorus Supply (kg/year)	100.6	163.2	413.2

Parameter	Section 13	Section 14	Bethunes
Drainage Area (m2)	48,225,076	50,962,025	54,021,032
Lake Surface Area (m2)	60,440	132,618	454,130
D.A./Lake Surface Area	797.9	384.3	119.0
Lake Perimeter (m)	-	-	3,084
Mean Annual Precipitation (m/year)	1.3	1.3	1.3
Mean Annual Runoff (m/year)	1.1	1.1	1.1
Mean Annual Evaporation (m/year)	0.2	0.2	0.2
Total Outflow (m3/year)	53,047,584	56,058,227	59,423,135
Aerial Water Load (m/year)	877.70	422.70	130.85
Dissolved Oxygen (mg/l)	11.2	11.2	11.2
Settling Velocity (m/s)	12.4	12.4	12.4
Retention Coefficient	0.01	0.03	0.09
Phosphorus Loading Value for Precipitation (mg/m2.year)	50	50	50
Phosphorus Loading from Precipitation (kg/year)	3.0	6.6	22.7
Phosphorus Export Value for Each Land Use Type (mg/m2.year)			
Lakes/Wetlands	*5*	*5*	*5*
Forest	*14*	*14*	*14*
Forest-Pasteur (15% watershed cleared)	*20*	*20*	*20*
Pasteur	*40*	*40*	*40*
Agriculture/Rural	*60*	*60*	*60*
Urban	*70*	*70*	*70*
Total Area of Each Land Type Within the Watershed (m2)			
Lakes/Wetlands	245,517	363,106	128,470
Forest	2,830,735	2,241,224	2,360,183
Forest-Pasteur (15% watershed cleared)	-	-	-
Pasteur	-	-	40,929
Agriculture/Rural	-	-	-
Urban	-	-	75,296
Phosphorus Supply from Watershed (kg/yaer)	40.9	33.2	40.6
Total Phosphorus from NATURAL Sources (kg/year)	43.9	39.8	63.3
Total Phosphorus from UPSTREAM Sources (kg/year)	406.2	443.8	469.8
Number of Cottages	-	-	15
Number of Capita-Year/Year/Unit	1.63	1.63	1.63
Retention Coefficient of Exising Sewage Treatment	0.5	0.5	0.9
Amount of Phosphorus Contributed per Capita-Year (kg/capita-year)	0.8	0.8	0.8
Total Phosphorus from ARTIFICIAL Sources (kg/year)	-	-	2
Total Phosphorus Supply (kg/year)	450.1	483.6	535.1

Section 1



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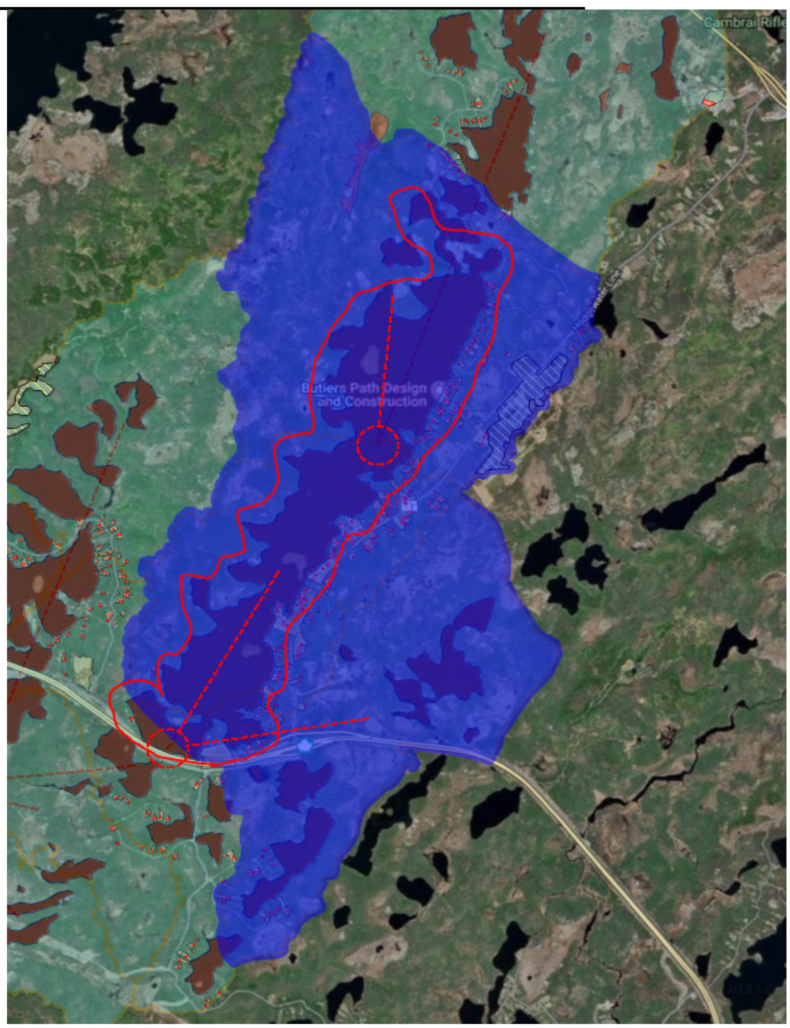

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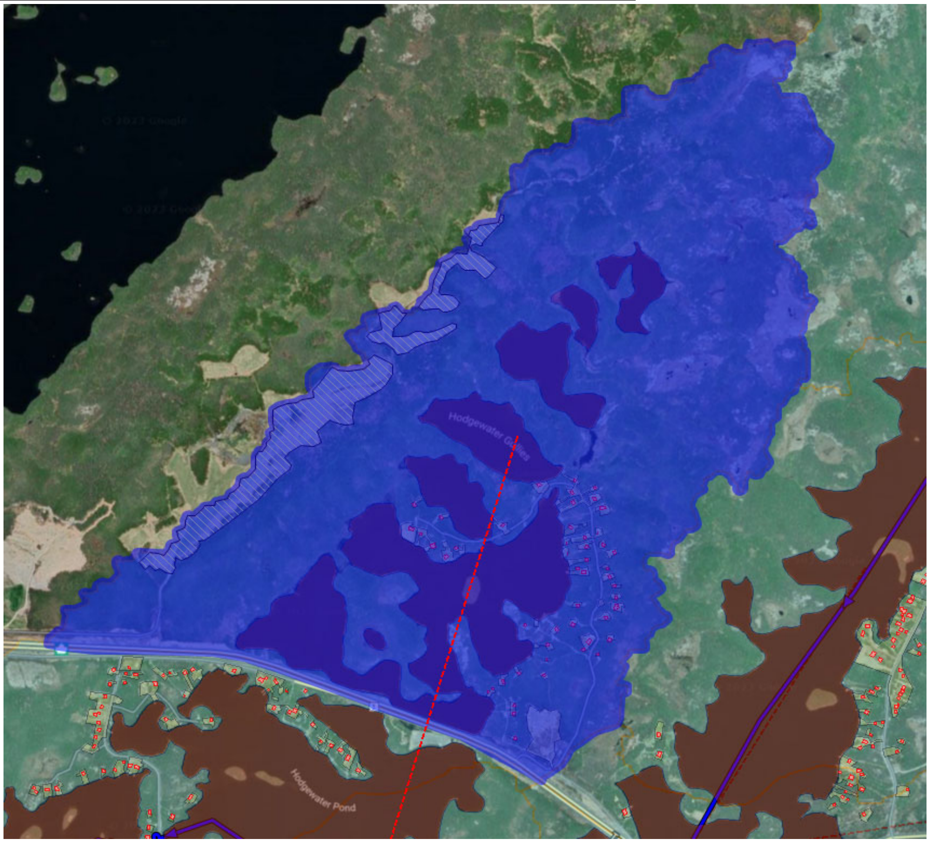

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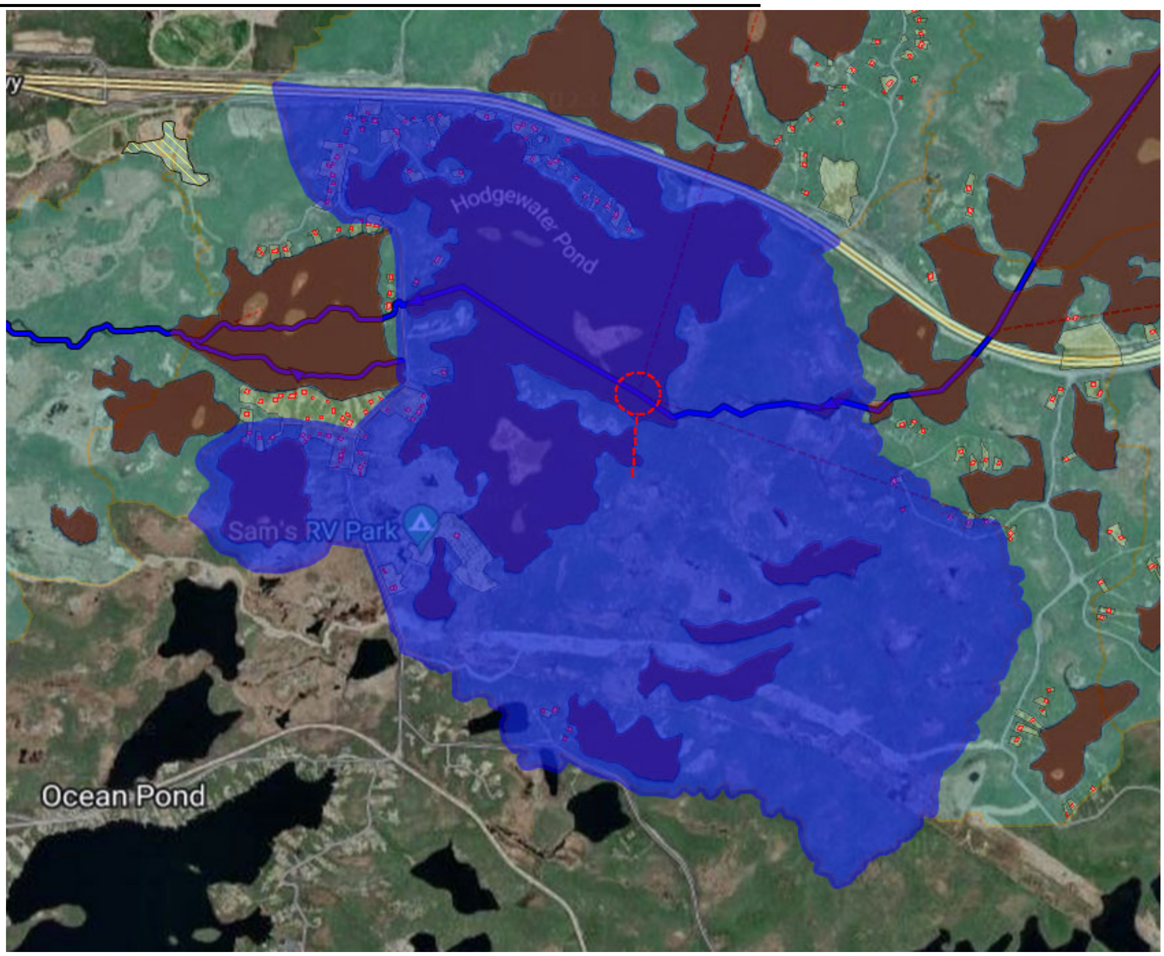

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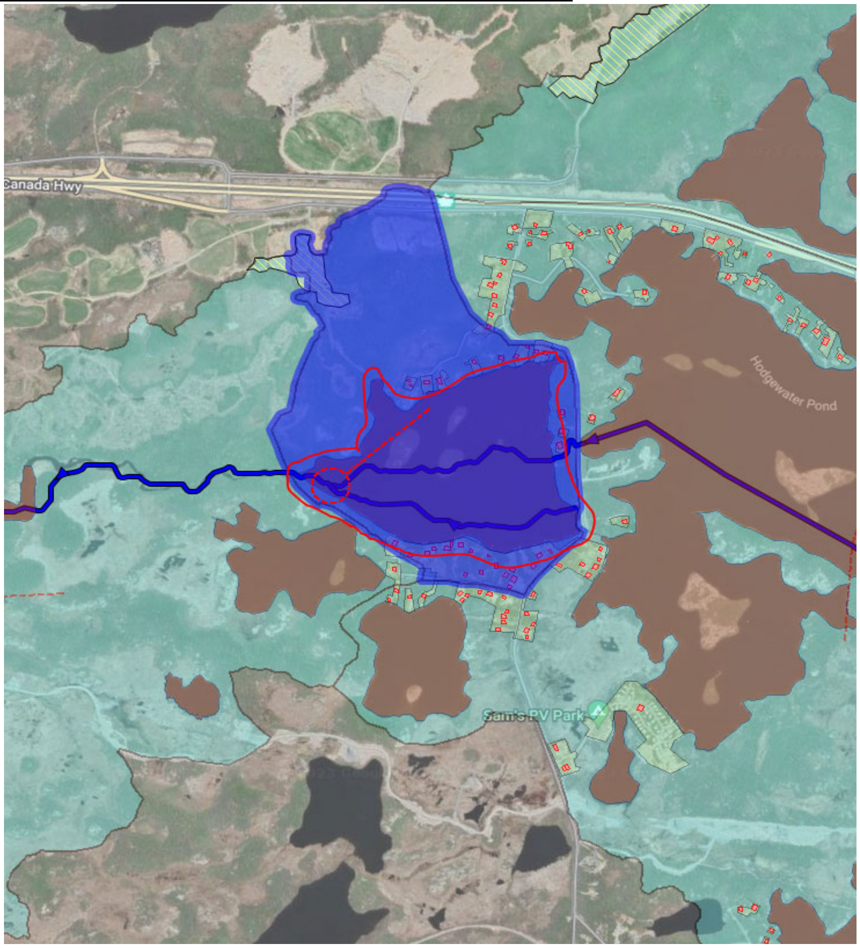

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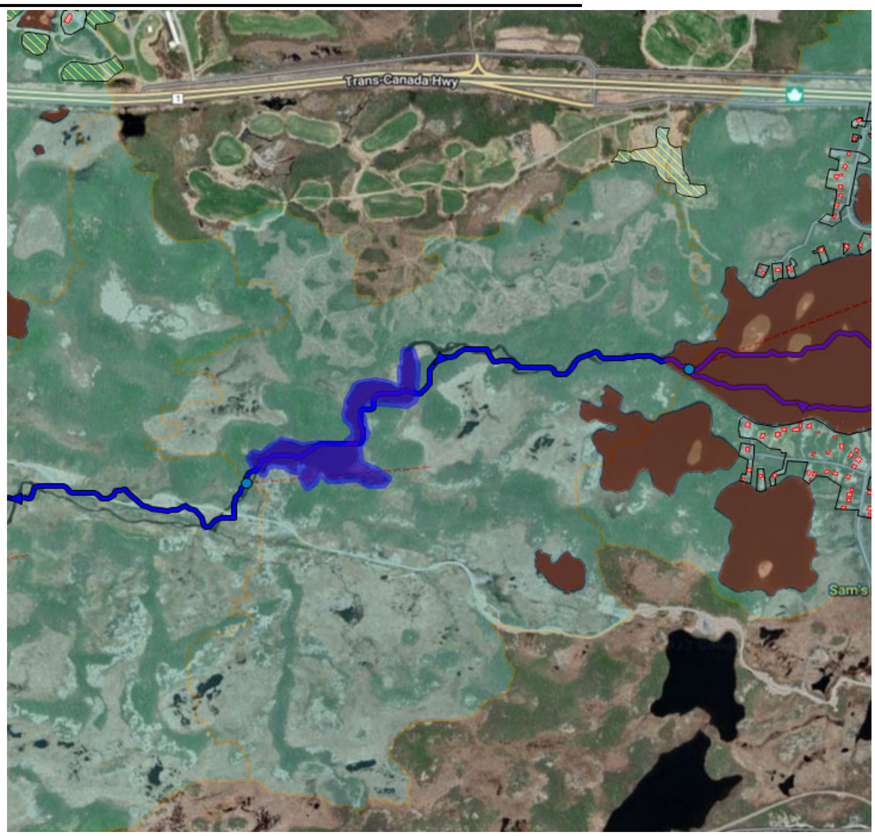

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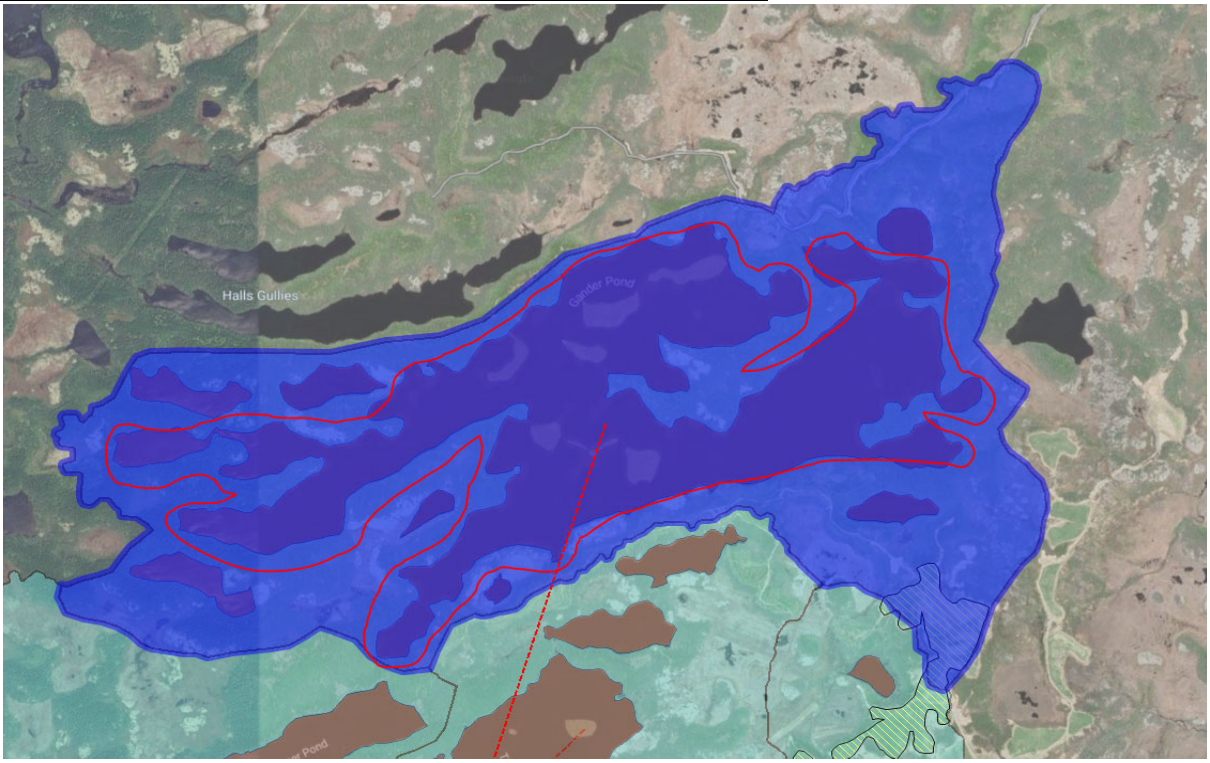

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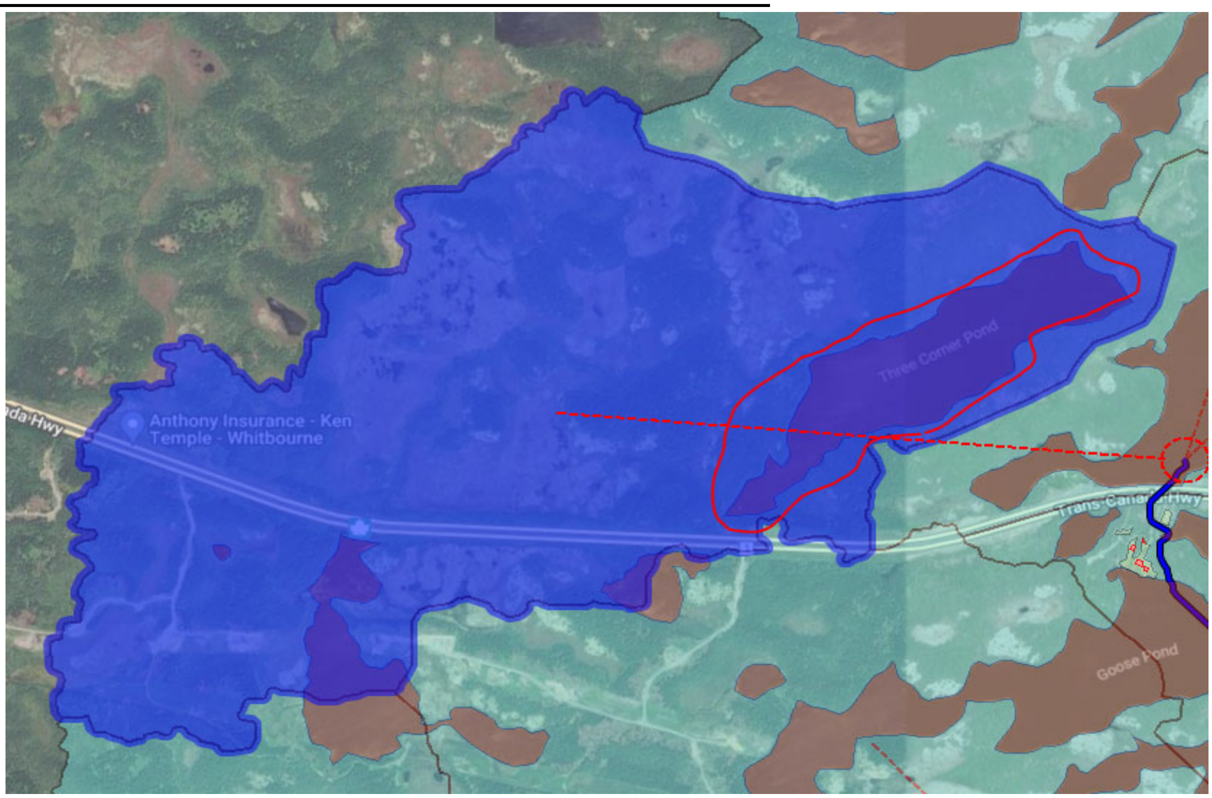

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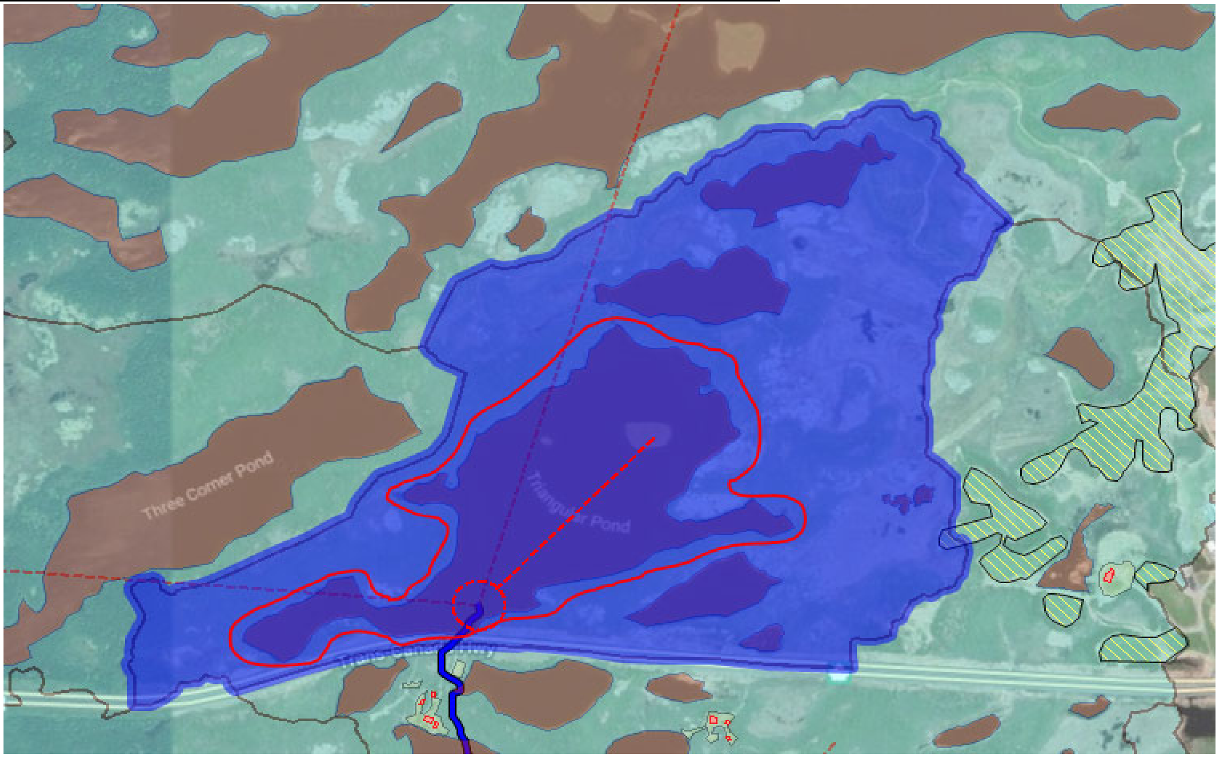

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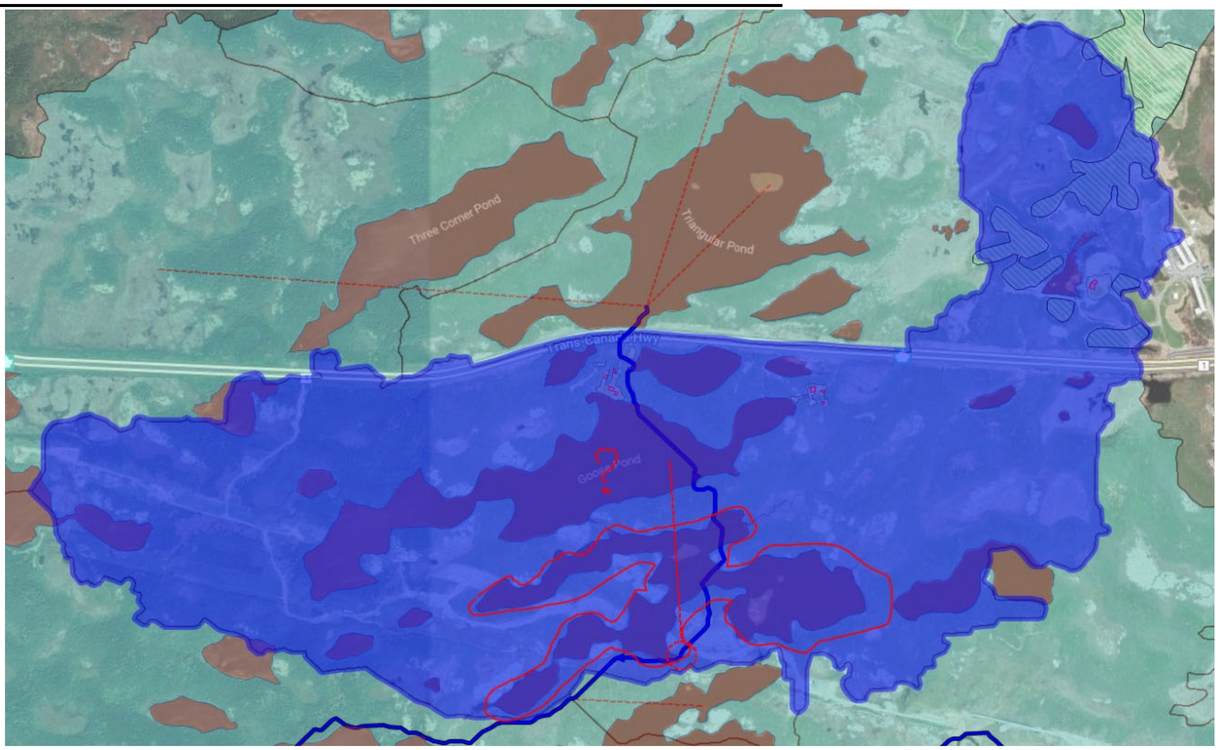

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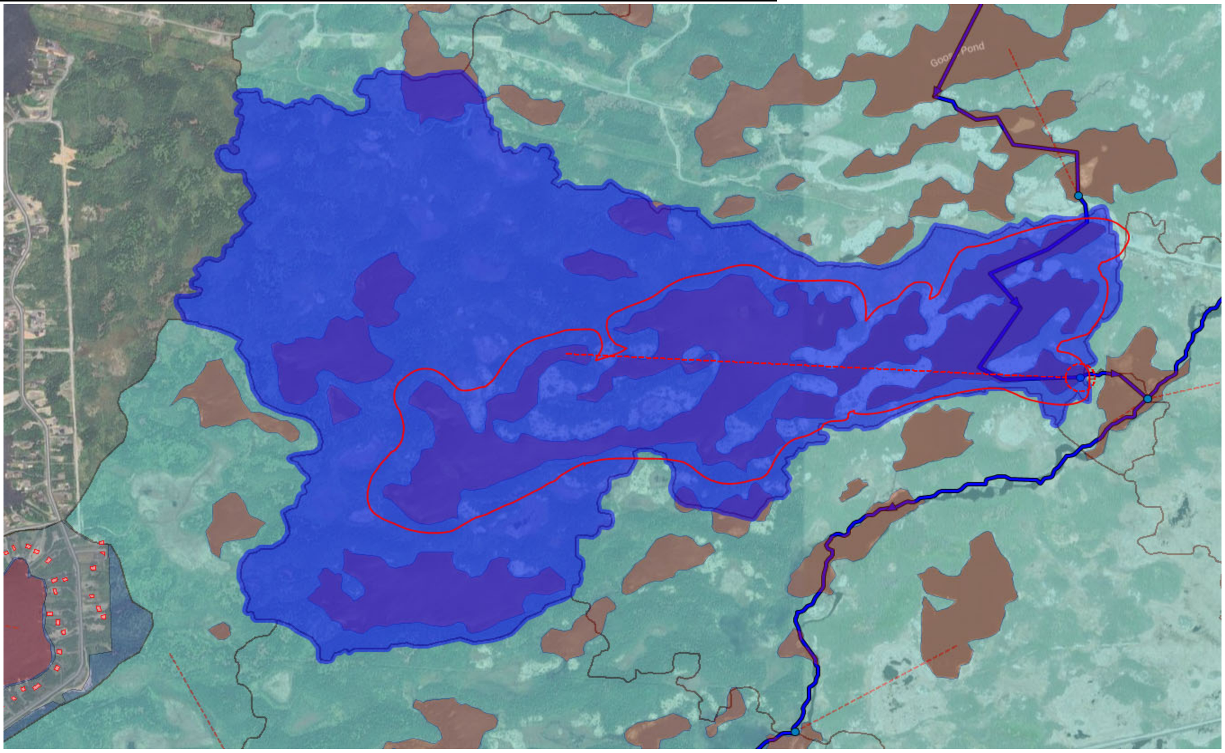

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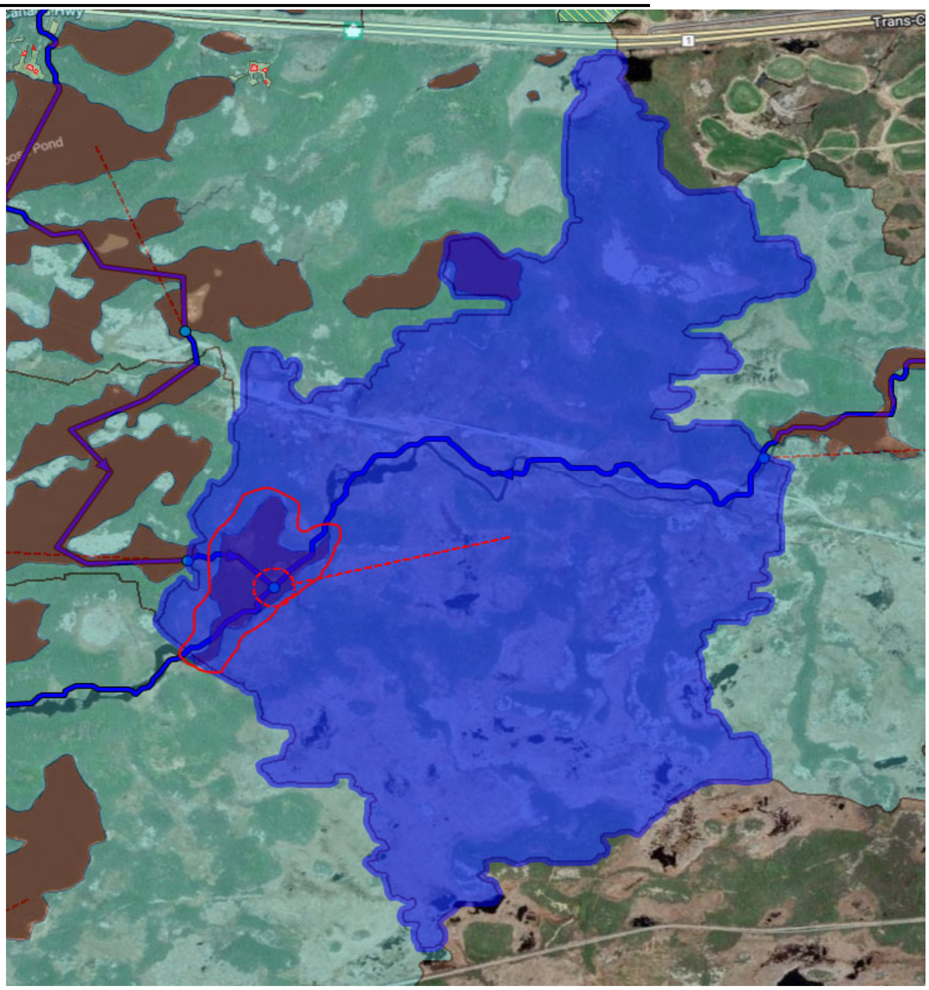
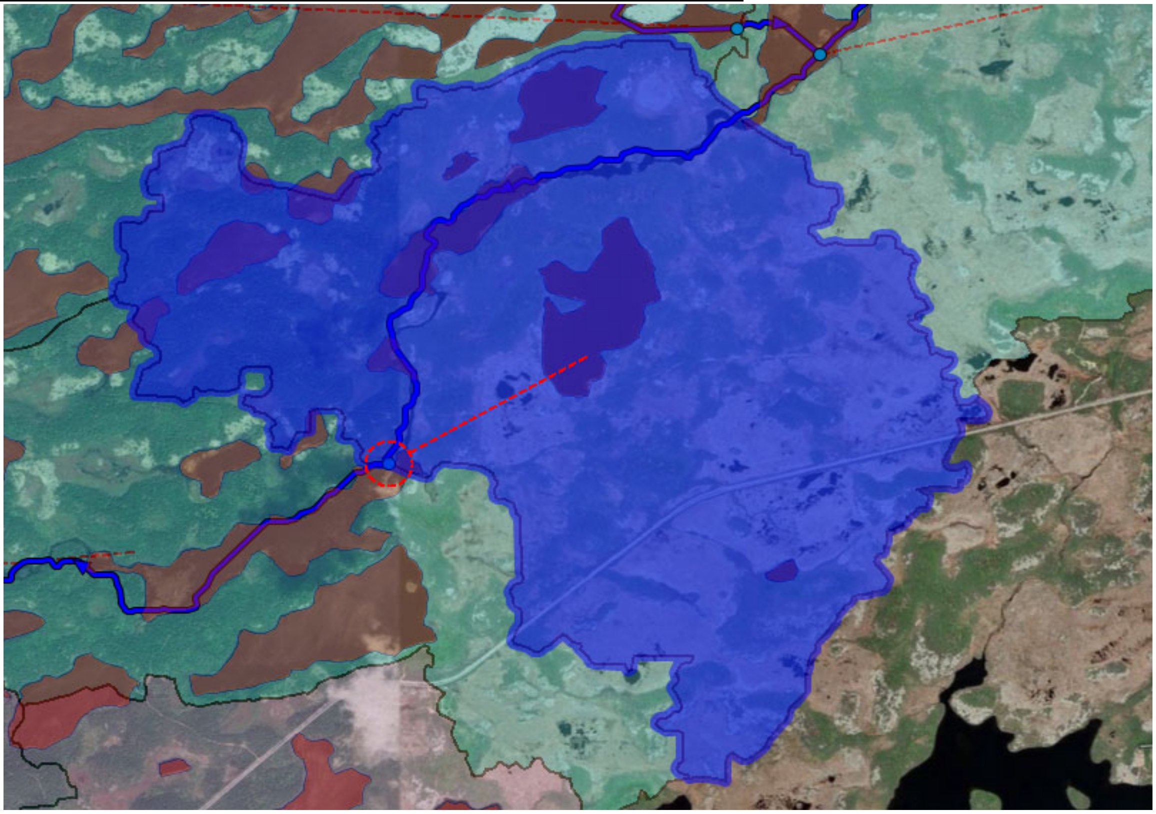
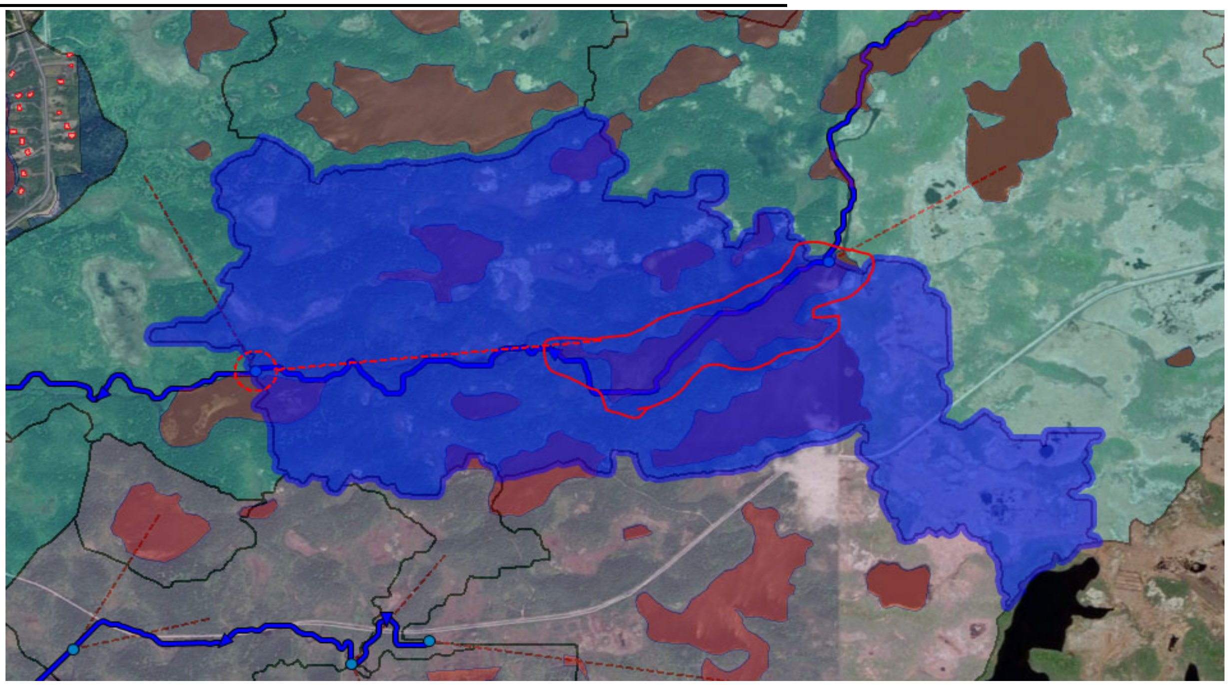


Section 13



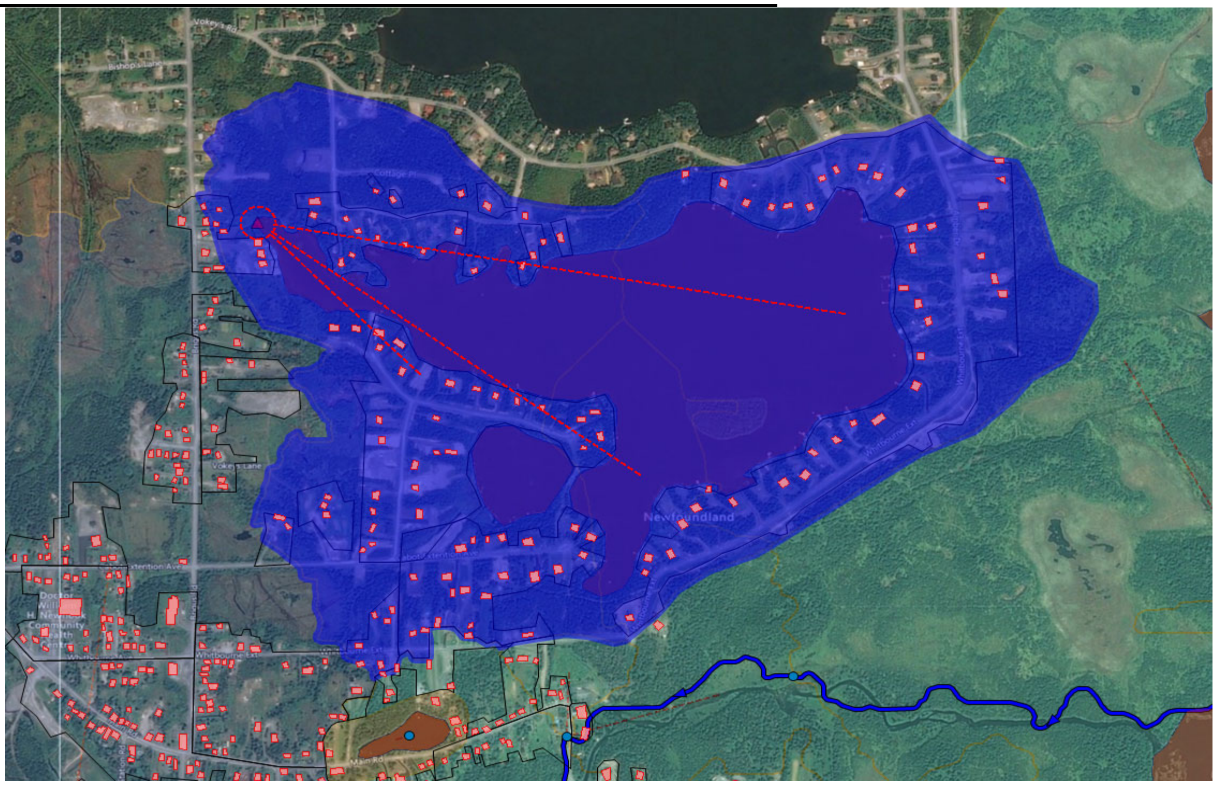
Section 14



Junction Pond Total Phosphorus Loading Calculation

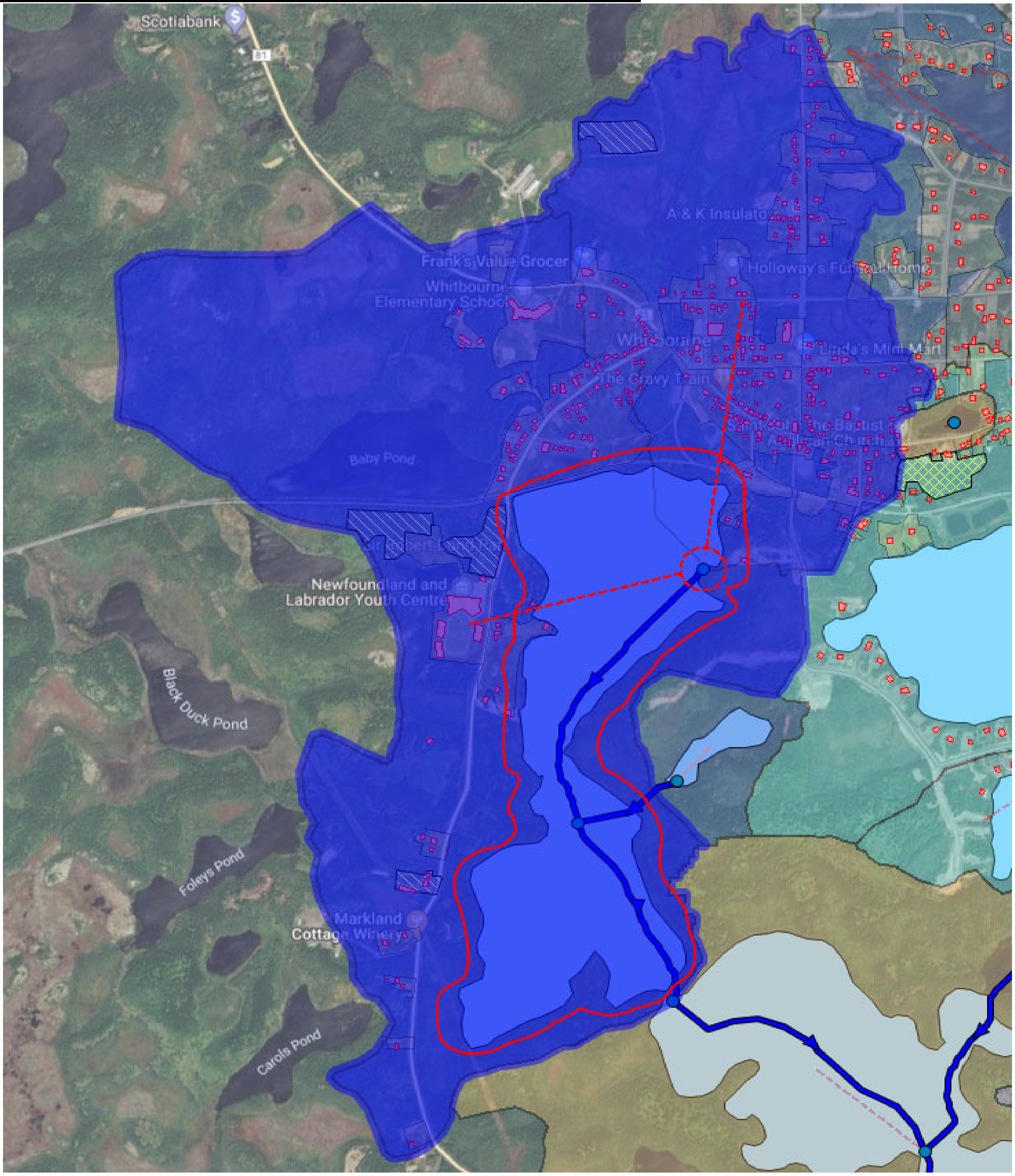
Parameter	Little Goose P	Well's Gully	Junction Pond
Drainage Area (m2)	1,368,910	158,304	5,234,050
Lake Surface Area (m2)	441,781	24,935	617,324.2
D.A./Lake Surface Area	3.1	6.3	8.5
Lake Perimeter (m)	4,418	808	5,430
Mean Annual Precipitation (m/year)	1.3	1.3	1.3
Mean Annual Runoff (m/year)	1.1	1.1	1.1
Mean Annual Evaporation (m/year)	0.2	0.2	0.2
Total Outflow (m3/year)	1,991,759	201,563	6,436,512
Aerial Water Load (m/year)	4.51	8.08	10.43
Dissolved Oxygen (mg/l)	11.2	11.2	11.2
Settling Velocity (m/s)	12.4	12.4	12.4
Retention Coefficient	0.73	0.61	0.54
Phosphorus Loading Value for Precipitation (mg/m2.year)	50	50	50
Phosphorus Loading from Precipitation (kg/year)	22.1	1.2	30.9
Phosphorus Export Value for Each Land Use Type (mg/m2.year)			
Lakes/Wetlands	*5*	*5*	*5*
Forest	*14*	*14*	*14*
Forest-Pasteur (15% watershed cleared)	*30*	*30*	*30*
Pasteur	*40*	*40*	*40*
Agriculture/Rural	*60*	*60*	*60*
Urban	*70*	*70*	*70*
Total Area of Each Land Type Within the Watershed (m2)			
Lakes/Wetlands	29,638	-	117,136
Forest	387,492	127,414	2,192,299
Forest-Pasteur (15% watershed cleared)	-	-	-
Pasteur	-	-	-
Agriculture/Rural	-	-	62,077
Urban	510,000	5,955	718,000
Phosphorus Supply from Watershed (kg/yaer)	41.3	2.2	85.3
Total Phosphorus from NATURAL Sources (kg/year)	63.4	3.4	137.7
Total Phosphorus from UPSTREAM Sources (kg/year)	-	-	21.5
Number of Cottages	94	-	3
Number of Capita-Year/Year/Unit	1.63	1.63	1.63
Retention Coefficient of Exising Sewage Treatment	0.9	0.9	0.9
Amount of Phosphorus Contributed per Capita-Year (kg/capita-year)	0.8	0.8	0.8
Total Phosphorus from ARTIFICIAL Sources (kg/year)	12	-	0
Total Phosphorus Supply (kg/year)	75.6	3.4	138.0

Little Goose Pond



Will's Gully

Junction Pond



Sources

Population and Dwelling

2021 Census of Population, Whitbourne, NL https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/details/page.cfm?Lang=E&SearchText=Whitbourne&DGUIDlist=2021A00051001298&GENDERlist=1,2,3&STATISTIClist=1&HEADERlist=0

Antropogenic Phosphorus

Cottage Development Planning in Newfoundland, 1994 - Page13 experience • knowledge • integrity

civil	civil
geotechnical	géotechnique
environmental	environnement
structural	structures
field services	surveillance de chantier
materials testing	service de laboratoire des matériaux

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