Appendix C1

Source Water Hydrology Study

Appendix C1
Source Water Hydrology

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Appendix C1-A 2024 Placentia Regional Water Supply Study - Progressive Engineering & Consulting Inc.

Appendix C1-B Climate Change Projections for Placentia, NL

List of Abbreviations

Abbreviation	Description
AMEC	AMEC Environment & Infrastructure
CPL	Canadian Projects Limited
DFO	Fisheries and Oceans Canada
ECCC	Environment and Climate Change Canada
FEL	Front-End Loading
HEC-HMS	Hydrologic Engineering Center Hydrologic Modeling System
km	kilometre
L/s	litres per second
m	metre
MW	megawatt
NL	Newfoundland and Labrador
NL DECC	Newfoundland and Labrador Department of Environmental and Climate Change
PAANL	Protected Areas Association of Newfoundland and Labrador
PEC	Progressive Engineering & Consulting Incorporated
POA	Port of Argentia
PPWSA	Protected Public Water Supply Area
USACE	United States Army Corps of Engineers
WSC	Water Survey of Canada

1.0 Introduction

Argentia Renewables Wind Limited Partnership ("Argentia Renewables") is planning to develop the Argentia Renewables Project (the "Project") which consists of a renewable energy powered green hydrogen and ammonia production and export facility at the Port of Argentia (POA). The Argentia Green Fuels Facility will utilize energy generated by the associated Argentia Wind Facility, comprising approximately 300 megawatts (MW) of installed capacity from up to 46 wind turbines located throughout private lands owned by the POA. The Argentia Green Fuels Facility will require water at a rate of 13.7 litres per second (L/s) for various plant operations, including electrolysis to produce hydrogen (AtkinsRéalis, 2023).

A source water hydrology analysis for the Project was completed for the selected watersheds and ponds which comprise the Town of Placentia's municipal water supply and are situated within the Protected Public Water Supply Area (PPWSA). Clarke's Pond and Larkins Pond form Placentia's operational water sources, with a protected watershed expansion area for Clarke's Pond consisting of Barrows Pond (also referred to as Barrons Pond) and Gull Pond (PEC, 2024). Argentia Pond is currently inactive as a water source (PEC, 2024).

A hydrologic model was devised for the source water system using Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) by the United States Army Corps of Engineers (USACE, 2024). The hydrologic model included considerations for existing municipal water withdrawal and proposed Project water withdrawal and performed daily meteorological data analysis.

1.1 Objectives and Scope

The objective of this report is to support sustainable water management for both the Town of Placentia and the Project. The scope of this report is to review regional hydrologic and climate conditions, assess the source water availability in the PPWSA, and analyze the effect of municipal and Project-related water withdrawal rates on pond water levels.

1.2 Available Data and Reports

This report was prepared based on publicly available data sourced from Environment and Climate Change Canada (ECCC) and the Water Survey of Canada (WSC). Available data are outlined in the following sections. In addition, the following reports pertaining to the region and the Project were incorporated into the study:

- Argentia Renewables FEL 1 Study – Feasibility Study Report, AtkinsRéalis, October 24, 2023.
- Placentia Regional Water Supply Study, Progressive Engineering & Consulting Inc. (PEC), March 12, 2024. (Included in Appendix C1-A).

- Water Resources Atlas of Newfoundland, Newfoundland and Labrador Department of Environment and Climate Change (NL DECC), January 1992.
- Hydrogeology of Eastern Newfoundland, AMEC Environment & Infrastructure, January 2013.
- Projected Impacts of Climate Change for the Province of Newfoundland and Labrador: 2018 Update, Finnis & Daraio, 2018.

1.2.1 Climate Data

Climate data sourced for this report are as follows:

- Temperature and Precipitation:
  - Canadian Climate Normals data from Environment and Climate Change Canada (ECCC) for the 30-year period of 1971 to 2000 were obtained from the Long Harbour climate station (ID 8402569), which is located 25 kilometres (km) from the Project site. This is the most up to date and complete Canadian Climate Normals dataset that is closest to the region.
  - Historical daily temperature and precipitation data from 1971 to 1999 were obtained from the Long Harbour climate station (ID 8402569) and from 2004 to 2016 from the Argentia (AUT) climate station (ID 8400104). These records were selected due to their consistent measurements during these periods, whereas other nearby ECCC climate stations exhibited inconsistent and missing data.

- Climate Change:
  - Projected climate change indices for the Project Area were based on the Projected Impacts of Climate Change for the Province of Newfoundland and Labrador: 2018 Update (Finnis & Daraio, 2018). The projections covered two future intervals, 2041 to 2070 and 2071 to 2100.
  - Projected climate change daily temperature and precipitation from 2025 to 2100 in Placentia were incorporated into the continuous hydrological simulation. This dataset is derived from the IPSL-CM6A-LR climate model with a moderate global emissions trend (Boucher et al., 2020).

1.2.2 Hydrologic Data

Natural hydrologic conditions and water availability were evaluated for the region using data from the WSC. Regional streamflow monitoring stations with historical information were selected to characterize local hydrologic conditions. Regional stations that were considered and analyzed in this report include:

- 02ZK002 – Northeast River near Placentia (1979 to 2023, 89.6 km² drainage area).
- 02ZK003 – Little Barachois River near Placentia (1983 to 2023, 37.2 km² drainage area).
- 02ZK004 – Little Salmonier River near North Harbour (1983 to 2023, 104.0 km² drainage area).
- 02ZK006 – Rattling Brook below Bridge (2007 to 2023, 32.7 km² drainage area).

2.0 Project Area Conditions

The Project Area is located within the Southeastern Barrens Subregion of the Maritime Barrens Ecoregion (PAANL, 2008), and is characterized by sparse stands of black spruce, balsam fir, tamarack, and shrubs. The landscape is a mosaic of barren, scrub forests, bogs, and wetland. The overburden thickness is expected to be typically 1 to 2 m and would rarely exceed 3 m except in some valleys. Bog/peatland is common throughout the area (CPL, 2023).

The Project will include a hydrogen and ammonia facility on the northeastern area of the Argentia Peninsula (Figure C1-2.0-1). Water supply for this facility is planned to be sourced from the Placentia PPWSA, specifically Clarke's Pond. The drainage areas of the ponds in the PPWSA were delineated in the 2024 Placentia Regional Water Supply Study (PEC, 2024); individual pond characteristics are summarized in Table C1-2.0-1.

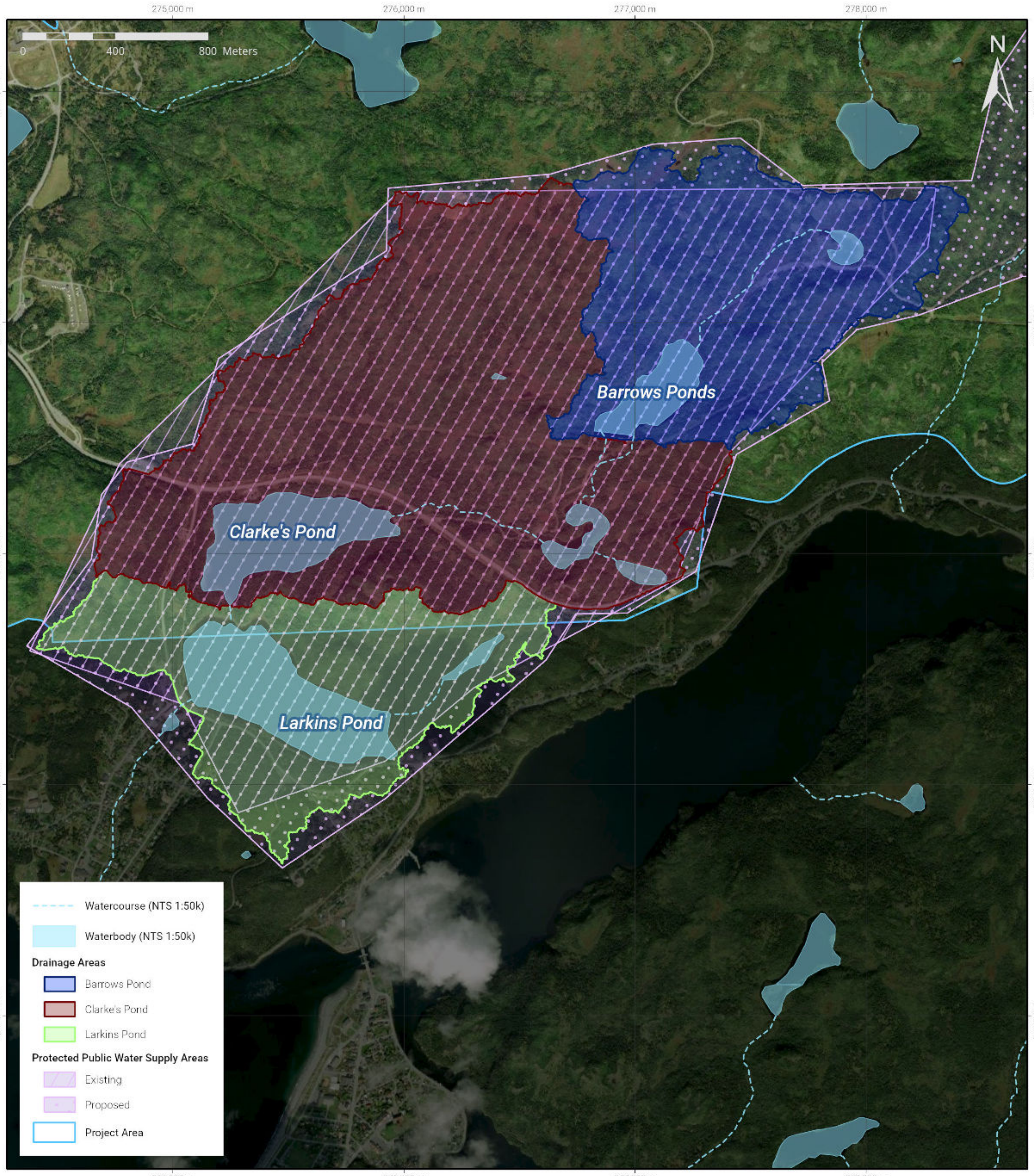
Table C1-2.0-1 Characteristics of Ponds in the Placentia PPWSA.

Pond	Immediate Drainage Area (km²)	Total Drainage Area (km²)	Pond Surface Area (km²)
Clarke's Pond	2.90	4.33	0.232
Larkins Pond	1.26	5.59	0.319
Barrows Pond	1.43	1.43	0.094
Gull Pond	0.98	0.98	0.247

The Clarke's Pond water supply currently services Freshwater, Argentia, and Dunville. Clarke's Pond has piped connections to allow for inflow from Barrows Pond and Gull Pond (PEC, 2024: Figures C1-2.0-2 and C1-2.0-3). The Larkins Pond water supply currently services Jerseyside, Ferndale, Placentia Proper, and Southeast Placentia (PEC, 2024). There is a connection between the distribution systems of Clarke's Pond and Larkins Pond, primarily used for emergency situations, which permits Clarke's Pond to serve as a backup if the Larkins Pond intake should freeze in the winter season or if water levels are low (PEC, 2024). There is existing industrial development in Argentia, and the municipal water supply currently serves the Port of Argentia, therefore this infrastructure would logistically be available for the Project to avail of (PEC, 2024).

Pattern | Argentia Renewables	FIGURE NUMBER: C1 - 2.0 - 1	COORDINATE SYSTEM: NAD 1983 CSRS UTM Zone 22N	PREPARED BY: J. Crocker	DATE: 24/07/27
	FIGURE TITLE: Project Overview	NOTES: Protected Public Water Supply areas, Hydrometric Stations and Climate Stations sourced from Government of NL Water Resources Management Division. Watercourse and Waterbodies sourced from National Topographic Service (CanVec).	REVIEWED BY:	
	PROJECT TITLE: Argentia Renewables		APPROVED BY:	

SEM MAP ID: 238-005-GIS-104-Rev1



Pattern | Argentia Renewables

FIGURE NUMBER:
C1 - 2.0 - 2

FIGURE TITLE:
Clarke's Pond, Larkins Pond, and Barrows Pond

PROJECT TITLE:
Argentia Renewables

COORDINATE SYSTEM:
NAD 1983 CSRS UTM Zone 22N

NOTES:
Protected Public Water Supply areas sourced from Government of NL Water Resources Management Division.
Watercourse and Waterbody data sourced from National Topographic Service (NTS) 1:50k series.

PREPARED BY: C. Burke

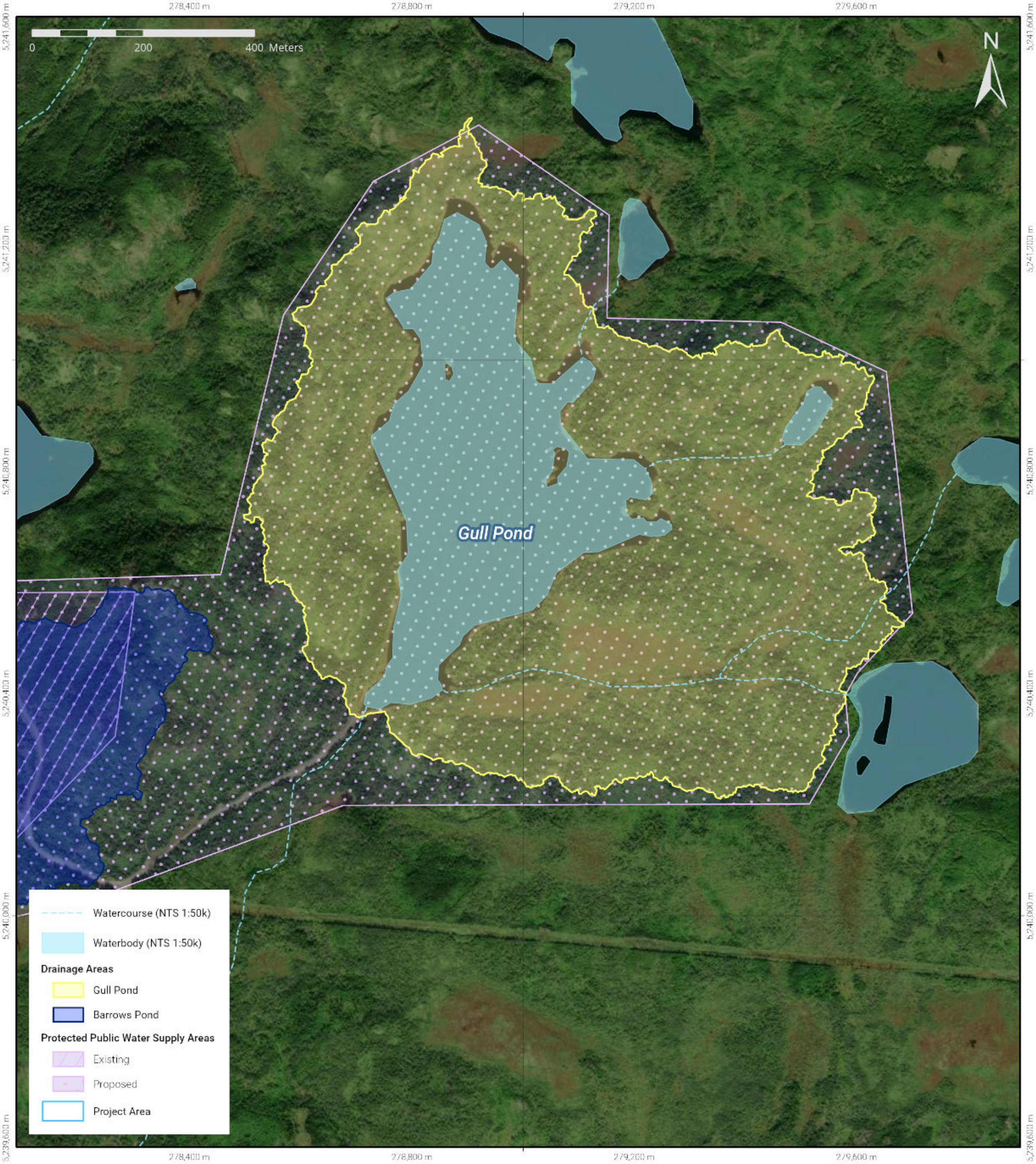
DATE: 24/07/27

REVIEWED BY: C Burke

APPROVED BY: C Burke

sem

SEM MAP ID: 238-005-GIS-105-Rev1



Pattern | Argentia Renewables	FIGURE NUMBER: C1 - 2.0 - 3	COORDINATE SYSTEM: NAD 1983 CSRS UTM Zone 22N	PREPARED BY: C. Burke	DATE: 24/07/27
	FIGURE TITLE: Gull Pond	NOTES: Protected Public Water Supply areas sourced from Government of NL Water Resources Management Division. Watercourse and Waterbody data sourced from National Topographic Service (NTS) 1:50k series.	REVIEWED BY: CBurke	
	PROJECT TITLE: Argentia Renewables		APPROVED BY: CBurke	
			sem	

SEM MAP ID: 238-005-GIS-106-Rev1

2.1 Climate and Precipitation

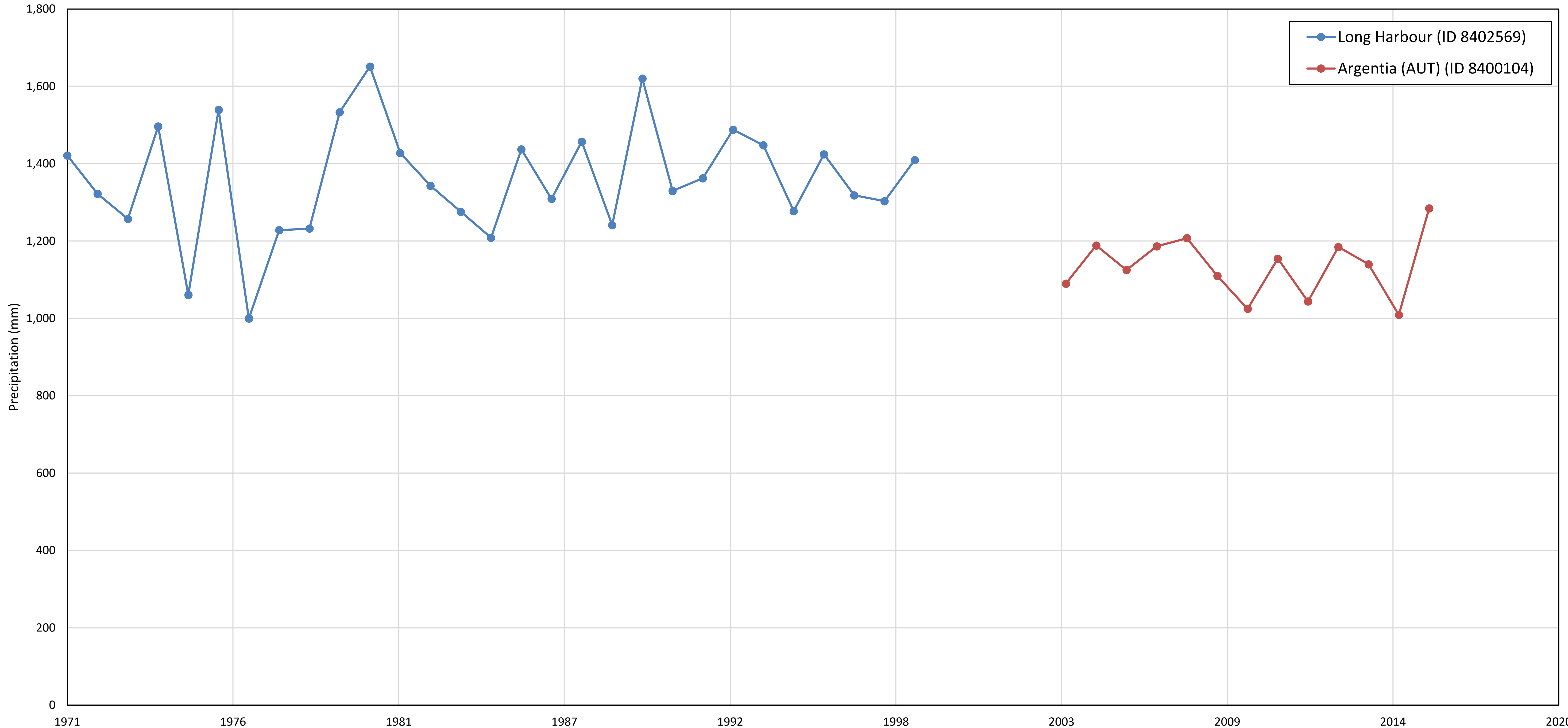
The Project Area lies within the South Coast and Avalon climate zone of NL, with mild winters and variation in snow cover. It is characterized by the climate surrounding Placentia Bay, which has been considered a homogeneous region (DFO, 2023).

Due to the shifting temperature and pressure gradients, global circulations affecting this region are strongest in the winter and weaken towards the summer (LGL Limited, 2007). While winds in this region are strong and from all directions, global circulation results in prevailing winds from the west and southwest from spring to fall, and from the west and northwest in winter. The passage of winds across the adjacent sea conveys precipitation that changes in intensity according to the strength of the wind.

The maritime climate modifies regional temperature variations, resulting in lower daily and seasonal variations compared to inland areas. As the land and sea are heated unevenly across diurnal cycles and seasons, temperature difference creates advective flows which readily exchange temperature between land and sea. Analysis of climate data in the summer months suggests that average maximum temperature across a month is correlated with mean temperature, but not so much with the extreme maximum temperature. This suggests that the regional climate governs the overall temperature, to the extent that singular hot events observed at the climate station have little effect on mean temperatures. Therefore, extreme high temperatures could be excluded from evapotranspiration analysis, as they are rapidly dampened and have little overall influence.

Precipitation is relatively consistent throughout the year, totaling 1366.6 mm annually on average, based on the latest Canadian Climate Normals data from Long Harbour (ECCC ID 8402569, Table C1-2.1-1, Figure C1-2.1.1). Canadian Climate Normals data for Argentia and Placentia are not available from ECCC, therefore the Long Harbour dataset was deemed to be representative of the Project Area as it is within 25 km from the Project. The Canadian Climate Normals data suggests a relatively even amount of rainfall throughout the year. Compared with an average month, summer months are typically drier, while the fall and winters are usually wetter. Summer days are often cooled by low clouds and fog along the coast (LGL Limited, 2007; DFO, 2023). Yearly total precipitation for Long Harbour and Argentia (AUT) climate stations are shown in Figure C1-2.1-1.

Drought months for the Long Harbour climate station were assessed using a threshold of the mean 30-day average precipitation minus one standard deviation to identify periods with below average precipitation. Based on this method, drought months were identified 56 times within the 348 months of the 1971 to 1999 time series (16% of the time). During this period, individual months of February to August experienced at least 5 drought occurrences, with April having the most droughts (9). The majority (71%) of the 56 droughts were characterized by low severity, with precipitation deficits ranging from 0.1 to 20 mm below the drought threshold, as shown in Figure C1-2.1-2.



Notes: Long Harbour and Argentia (AUT) climate stations were chosen for the respective period of records of 1979 to 1999 and 2004 to 2016 because of reliable data during these periods. Outside of these time periods, there are long lengths of missing data.

Pattern

Argentia Renewables

sem

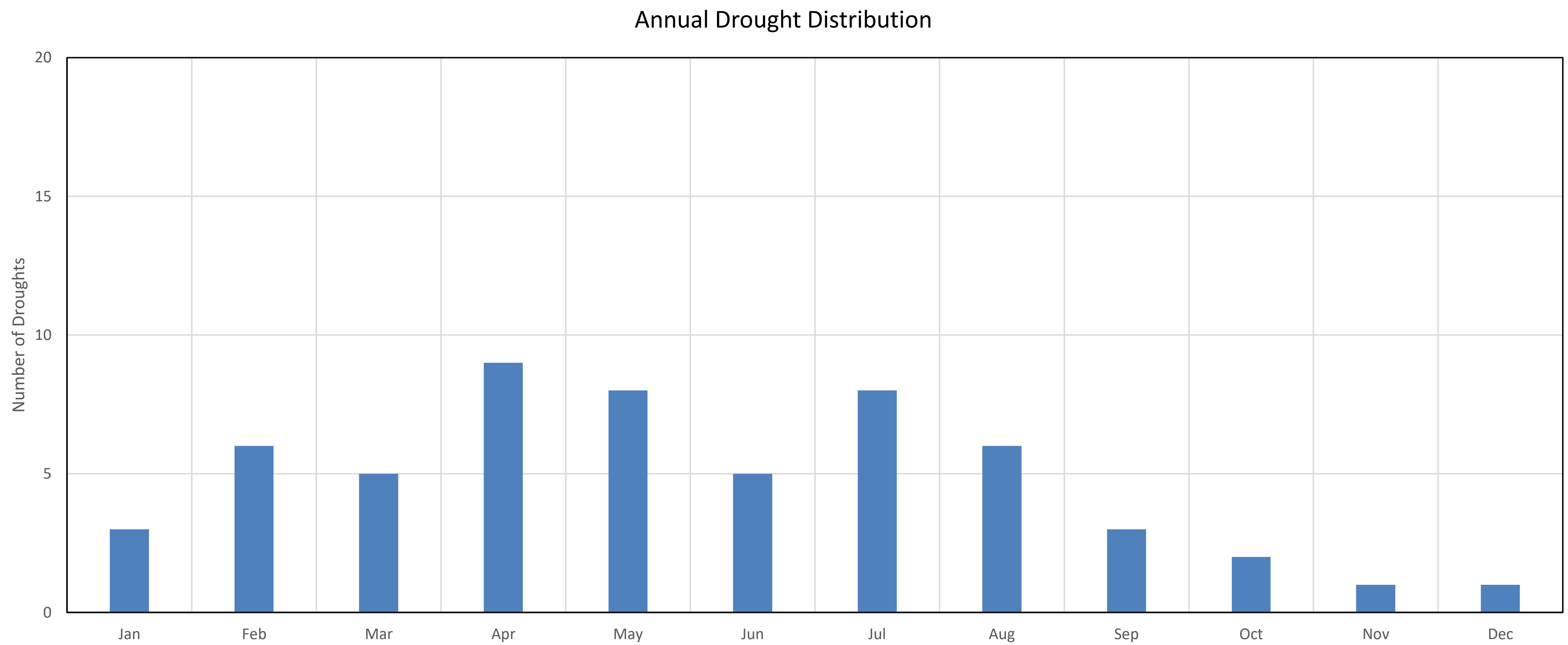
ARGENTIA RENEWABLES WIND LP

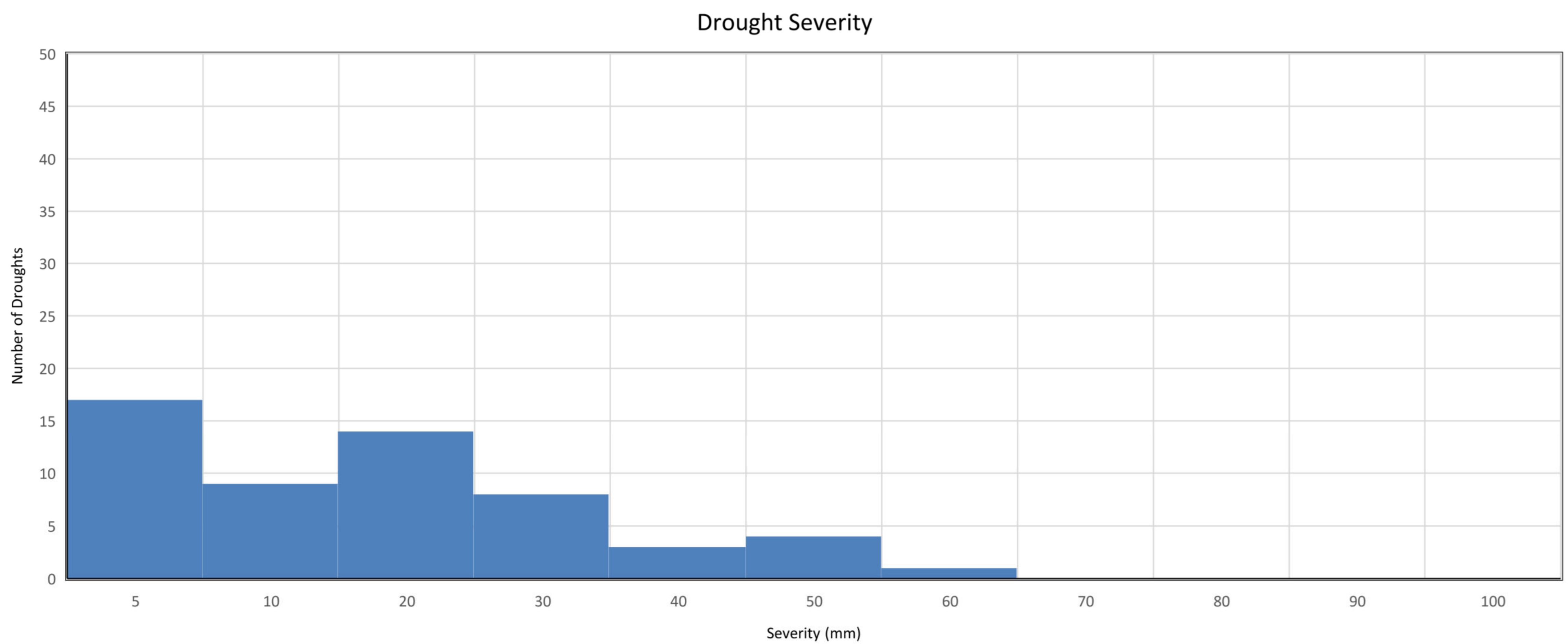
SOURCE WATER HYDROLOGY

TOTAL ANNUAL PRECIPITATION

DATE:	PROJECT:	SUBMITTER:	REVIEWER:
JULY 2024	238-001	Z.ZHAO	T.BRENTON

FIGURE: C1-2.1-1





Notes: Long Harbour climate station data from 1971 to 1999 was used to prepare these graphs.

Pattern
Argentia Renewables

sem

ARGENTIA RENEWABLES WIND LP
SOURCE WATER HYDROLOGY

MONTHLY DROUGHT DISTRIBUTIONS

DATE:	PROJECT:	SUBMITTER:	REVIEWER:
JULY 2024	238-001	Z.ZHAO	T.BRENTON

FIGURE: C1-2.2-1

Table C1-2.1-1 Representative Canadian Climate Normals for the Project Area.

Parameter	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Rainfall (mm)	86.9	67.6	83.6	92.7	89.9	112.0	93.5	102.4	123.8	149.8	117.4	86.5	1,205.9
Snowfall (cm)	43.6	40.5	27.3	9.6	1.7	0.0	0.0	0.0	0.0	0.4	7.8	29.7	160.4
Precipitation (mm)	130.5	108.1	110.9	102.3	91.5	112.0	93.5	102.4	123.8	150.2	125.2	116.2	1366.3
Extreme Daily Rainfall (mm)	53.8	59.2	80.2	82.0	55.0	92.4	63.0	78.5	68.0	119.0	66.4	41.0	-
Extreme Daily Snowfall (cm)	30.5	30.0	35.6	24.0	31.0	0.0	0.0	0.0	0.0	10.2	23.0	30.0	-
Extreme Daily Precipitation (mm)	53.8	59.2	80.2	82.0	55.0	92.4	63.0	78.5	68.0	119.0	66.4	41.0	-
Maximum Temperature (°C)	0.4	0.0	2.7	6.4	10.7	14.9	18.7	19.5	16.4	11.5	7.1	2.7	-
Mean Temperature (°C)	-3.5	-4.0	-1.1	3.0	6.8	10.8	14.9	15.9	12.9	8.2	4.0	-0.7	-
Minimum Temperature (°C)	-7.4	-7.8	-4.9	-0.5	2.9	6.7	11.1	12.2	9.3	4.9	0.8	-4.0	-

2.2 Geology and Hydrogeology

The surficial geology of the study area is primarily shaped by the latest glaciation period, the late Wisconsin, resulting in a till veneer covering most of the Project Area (AMEC, 2013). Bedrock exposed or beneath the thin layer of glacial till is composed of extrusive igneous rocks associated with the Bull Arm Formation with little or no primary permeability, resulting in a low to moderate groundwater yield (Newfoundland and Labrador Geoscience Atlas, 2024). Overall, the thin surficial unit and the aged volcanic bedrock make for a shallow groundwater system very sensitive to surface water supply in the ponds and rivers. Groundwater has little influence on the overall water balance in the region because of its limited capacity. No groundwater is anticipated to be used by the Project.

2.3 Climate Change

Climate change projections were generated for Argentia using available observations and regional climate models (Finnis & Daraio, 2018). A summary of projected climate change impacts for Argentia are presented in Table C1-2.3-1.

Table C1-2.3-1 Climate Change Projections for Argentia.

Climate Index	Season	20th Century Climate	Projection: 2041-2070		Projection: 2070-2100	
			Average	Uncertainty	Average	Uncertainty
Daily Mean Temperature (°C)	Winter	-1.0	2.3	1.3	4.3	1.7
	Spring	2.8	5.7	0.8	7.6	1.1
	Summer	13.6	16.6	1.3	18.4	1.8
	Fall	9.3	11.5	1.2	13.5	1.6
Daily Minimum Temperature (°C)	Winter	-3.8	0.0	1.5	2.2	1.9
	Spring	-0.2	3.1	0.7	5.1	1.0
	Summer	10.9	13.8	1.3	15.7	1.9
	Fall	6.7	8.8	1.2	10.9	1.6
Daily Maximum Temperature (°C)	Winter	1.7	4.6	1.1	6.4	1.5
	Spring	5.7	8.4	1.1	10.1	1.3
	Summer	16.4	19.4	1.3	21.1	1.8
	Fall	11.9	14.2	1.2	16.2	1.6
Number of Frost Days	Winter	72.5	44.3	14.9	22.9	18.7
	Spring	40.5	16.5	4.6	6.0	5.4
	Summer	0.0	0.0	0.0	0.0	0.0
	Fall	6.9	2.2	1.5	0.6	0.7
Maximum Heat Wave Duration (days)	Winter	0.0	0.2	0.2	0.1	0.2
	Spring	0.0	0.3	0.4	0.1	0.2
	Summer	0.0	0.0	0.1	0.1	0.1
	Fall	0.0	0.0	0.0	0.2	0.2
Mean Daily Precipitation (mm)	Winter	3.0	3.9	0.3	4.2	0.4
	Spring	2.1	2.9	0.2	3.1	0.2
	Summer	3.0	2.9	0.4	2.9	0.4
	Fall	3.4	3.7	0.2	3.6	0.3
Mean Precipitation Event Intensity (mm)	Winter	8.5	10.0	0.9	10.7	0.9
	Spring	8.0	8.8	0.3	9.3	0.3
	Summer	10.8	9.9	0.7	10.1	0.7
	Fall	10.8	11.7	0.5	11.9	0.7
Maximum 3-day Precipitation (mm)	Winter	44.0	58.6	7.7	63.6	9.2
	Spring	42.1	51.0	4.1	56.4	4.7
	Summer	63.5	58.6	7.1	63.2	9.3
	Fall	54.2	72.8	7.3	74.2	6.4
Maximum 5-day Precipitation (mm)	Winter	56.5	69.8	7.8	76.4	9.4
	Spring	48.9	60.1	4.1	67.1	4.9
	Summer	71.8	67.1	7.8	73.0	10.8
	Fall	66.3	83.0	7.7	85.3	8.0
Maximum 10-day Precipitation (mm)	Winter	84.8	101.9	10.1	111.6	12.5
	Spring	66.1	84.9	6.2	93.9	5.9
	Summer	91.2	93.9	12.0	98.0	14.0
	Fall	99.0	113.3	7.8	113.2	9.6
Number of Days with 10 mm or more Precipitation	Winter	8.5	11.9	1.0	13.0	1.2
	Spring	5.8	8.6	0.7	9.4	0.6
	Summer	8.9	8.3	0.9	8.3	0.7
	Fall	11.1	10.7	0.6	10.3	1.0

It is expected that temperature increases between 4.4 to 5.3°C will occur in Argentia over the next century. This region currently experiences temperatures near 0°C from September to May, thus, rising temperature trends indicate less precipitation in the form of snow and more in the form of rain. Precipitation analyses predict that there will be fewer but heavier snowstorms and more frequent and heavier occurrences of rain throughout the cold season. It is anticipated that the Avalon Peninsula will have a lower number of days with temperatures below freezing, particularly in the fall and spring. There are considerable increases in precipitation event intensity along the south coast; Argentia will see increases in precipitation intensity in the winter, spring, and fall. Projected changes in maximum 3-day, 5-day, and 10-day precipitation as well as the 90th percentile of precipitation events follow regional patterns similar to those described for mean precipitation intensity. Future climate projections generally show a trend that the Project Area is expected to become warmer and wetter over time, with precipitation events projected to become more frequent and intense than existing conditions (Appendix C1-B). However, the average dry spell is expected to remain stable during this period (NL DECC, 2018).

2.4 Water Withdrawal

Water withdrawal was separated in two categories, municipal withdrawal (existing conditions) and Project withdrawal (future proposed conditions, related to the Project). Municipal withdrawal focuses on the existing demands of residential and industrial users on the Town of Placentia water supply system, while Project withdrawal is the water withdrawal requirements for operation of the Project.

2.4.1 Municipal Withdrawal

The Town of Placentia's municipal water supply was evaluated in 2024 in the Placentia Regional Water Supply Study (PEC, 2024, Appendix C1-A). This study determined the theoretical (daily average and peak) water withdrawal rates in litres per second (L/s) for Clarke's Pond and Larkins Pond and compared them to measured (actual) water withdrawal rates from the ponds (Table C1-2.4-1). The study determined that the measured (actual) withdrawal being consumed was greater than both the theoretical daily average and the theoretical peak withdrawal rates. Actual water withdrawal records were reviewed by PEC and no seasonal or daily fluctuations for peak flow were identified. The lack of evidence of daily fluctuations implies there could be leakage in the water supply system (PEC, 2024). The 2024 Placentia Regional Water Supply Study recommended further investigation into leak detection to determine the extent and locations of leakage through a flow analysis field program, installation of flow meters, and a leak detection and repair program. Only measured municipal water withdrawal rates have been evaluated in hydrologic models in this report.

Table C1-2.4-1 Municipal Withdrawal Rates.

Water Supply	Daily Average Withdrawal (Theoretical) (L/s)	Peak Withdrawal (Theoretical) (L/s)	Measured Withdrawal (Actual) (L/s)
Clarke's Pond	10.6	22.8	45.8
Larkins Pond	17.4	27.5	54.3
Total	**28.0**	**50.3**	**100.1**

The population of Placentia was 3,289 according to the latest census completed in 2021. Compared with the 2021 census, a 6.0% decrease in population was observed since the 2016 census (3,498), and a 9.8% decrease was observed since the 2011 census (3,646). Forecasts for future water withdrawal rates related to the water supply were not completed in the Placentia Regional Water Supply study. Therefore, for the purpose of this analysis, it is assumed that in future the withdrawal rates from the water supply would not increase. Additional information on the Town of Placentia’s population decline is provided in Appendix G (Socio-Economic Baseline Study) of the Registration document. Further, the West White Rose Project located on the Argentia Peninsula is an existing user of municipal water supply in Placentia. This project is nearing completion and scheduled to come offline prior to the commissioning of the Argentia Renewables Project. This further supports the assumption that withdrawal rates from the water supply would not increase.

2.4.2 Project Water Withdrawal

The Argentia Renewables FEL 1 Study – Feasibility Study Report (AtkinsRéalis, 2023) concluded that the proposed peak ammonia production at 146,000 metric tonnes (t) per year would require a freshwater supply of 1,185 cubic metres (m^3) per day (13.7 L/s). Therefore, a constant water withdrawal rate of 13.7 L/s was used in this report, recognizing that instantaneous peak withdrawal rates could occasionally exceed this value due to operational demand, which will be characterized in more detail in future development phases. This withdrawal rate was withdrawn entirely from Clarke’s Pond in the hydrologic model.

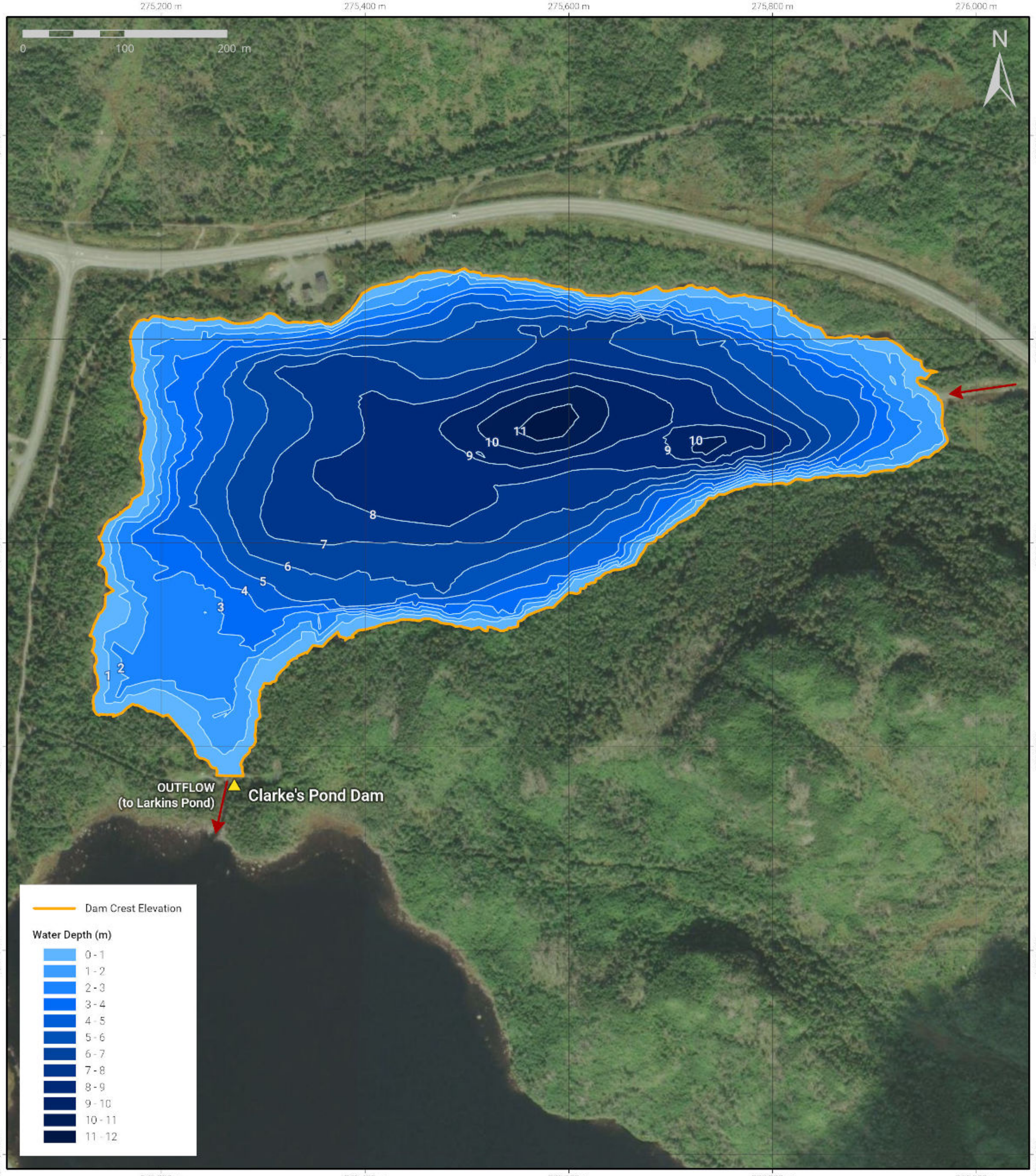
2.5 Bathymetry and Topographic Surveys

Bathymetry surveys were completed on four ponds in Placentia using an RTK GPS and an echosounder in July 2024 with 25 metre line spacing on the lakes to supplement topographic surveys completed in 2023. The bathymetry survey collected by the echosounder was interpolated using ArcGIS and plotted on Figures C1-2.5.1 to C1-2.5.4. Water intakes were not located during this survey and no as-built drawings are available for Clarke’s Pond or Larkins Pond. The bathymetric data allowed for elevation-volume-area curves (i.e., stage-storage-area curves) to be developed for each pond, which serves as a foundational dataset for ongoing and future hydrological assessments and infrastructure planning. The outlet from Clarke’s Pond flows through a 900 mm diameter pipe and overflow discharges over the dam crest through a channel to Larkins Pond. The outlet from Larkins Pond flows through a horseshoe-shaped weir structure, which has a 0.6 m wide and 0.2 m high notch with stoplog operation to the crest. The individual pond characteristics are summarized in Table C1-2.5.1.

Table C1-2.5-1 Pond Characteristic Summary.

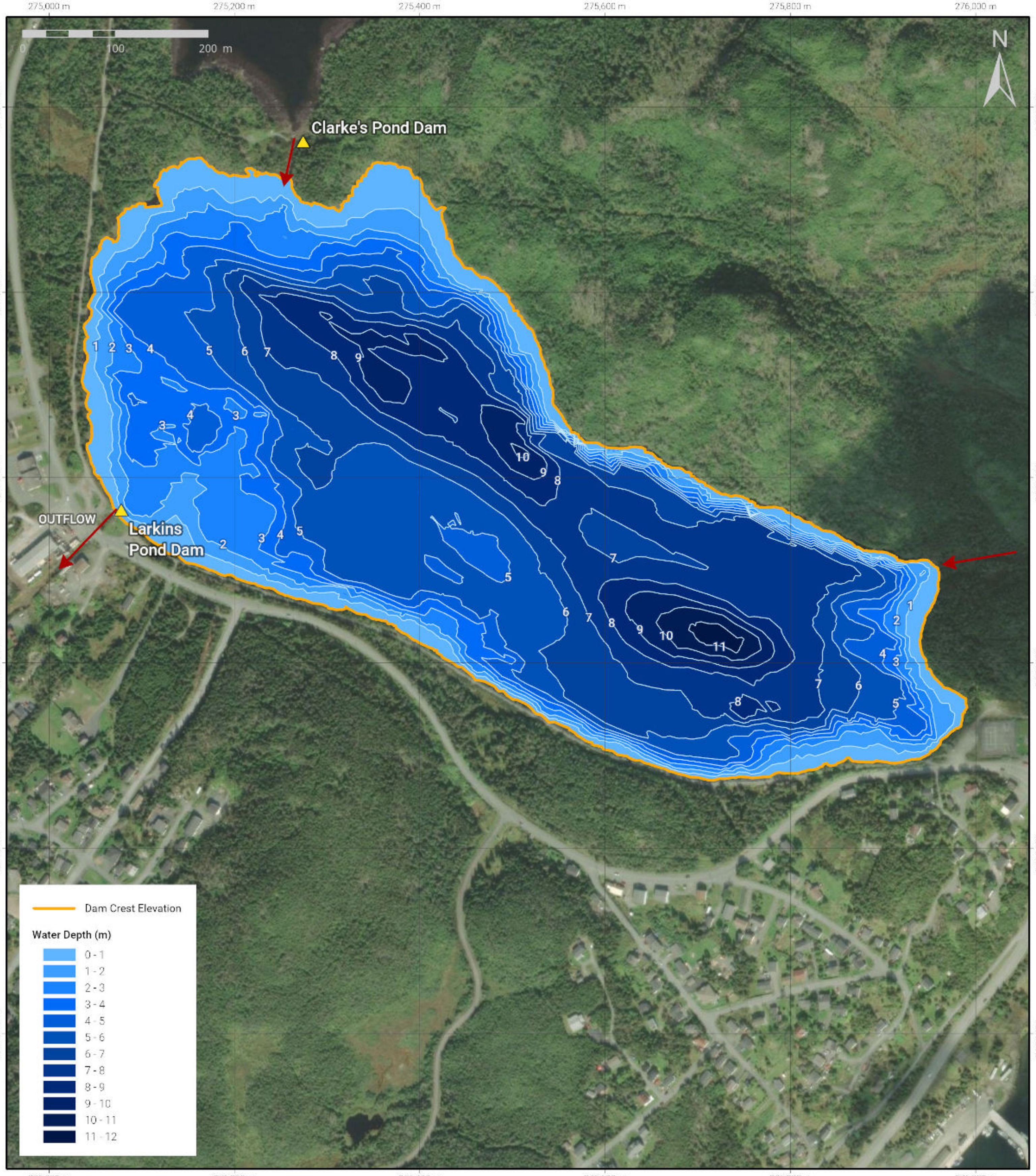
Pond	Dam Crest Elevation (masl)	Maximum Water Depth (m)	Total Volume (m^3)	Surface Area (m^2)
Clarke's Pond	41.5	11.2	1,135,000	224,000
Larkins Pond	40.9	11.4	1,593,700	319,000
Barrows Pond	74.8	10.9	423,200	96,000
Gull Pond	125.3	12.3	1,390,600	244,800

Given the reservoir volumes of Clarke's Pond and Larkins Pond, if water was being withdrawn for 30 days with no inflow at a rate of 59.5 L/s (totalling 155,000 m^3) at Clarke's Pond and 54.3 L/s (totalling 140,600 m^3) at Larkins Pond, these withdrawals would account for approximately 13.7% of Clarke's Pond volume and 8.8% of Larkins Pond volume.



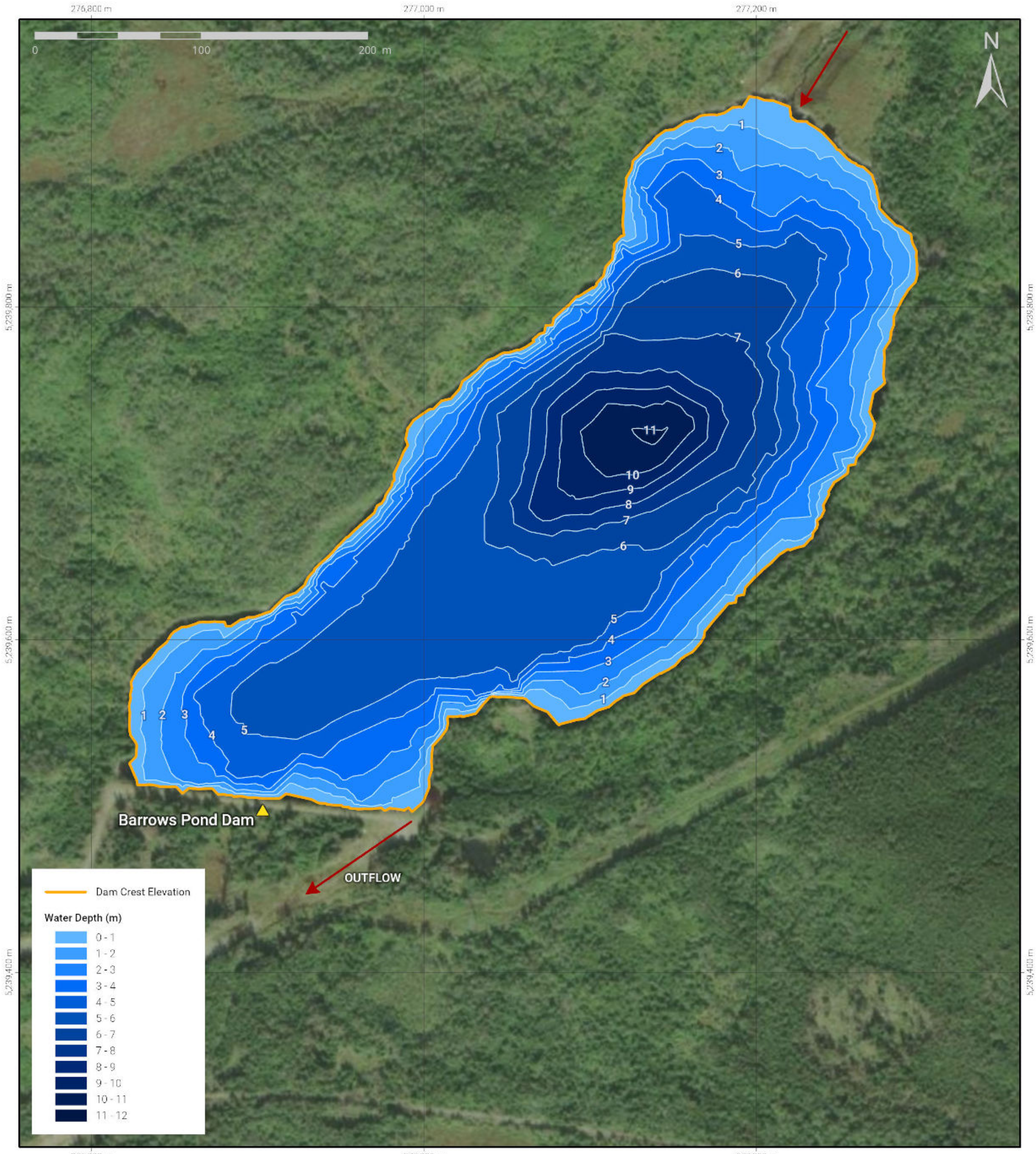
Pattern | Argentia Renewables	FIGURE NUMBER: C1 - 2.5 - 1	COORDINATE SYSTEM: NAD 1983 CSRS UTM Zone 22N	PREPARED BY: C. Burke	DATE: 24/07/27
	FIGURE TITLE: Clarke's Pond Bathymetric Survey	NOTES: Bathymetric data collected with single-beam transducer in July 2024.	REVIEWED BY: C.Burke	
	PROJECT TITLE: Argentia Renewables		APPROVED BY: C.Burke	
			sem	

SEM MAP ID: 238-005-GIS-153-Rev0



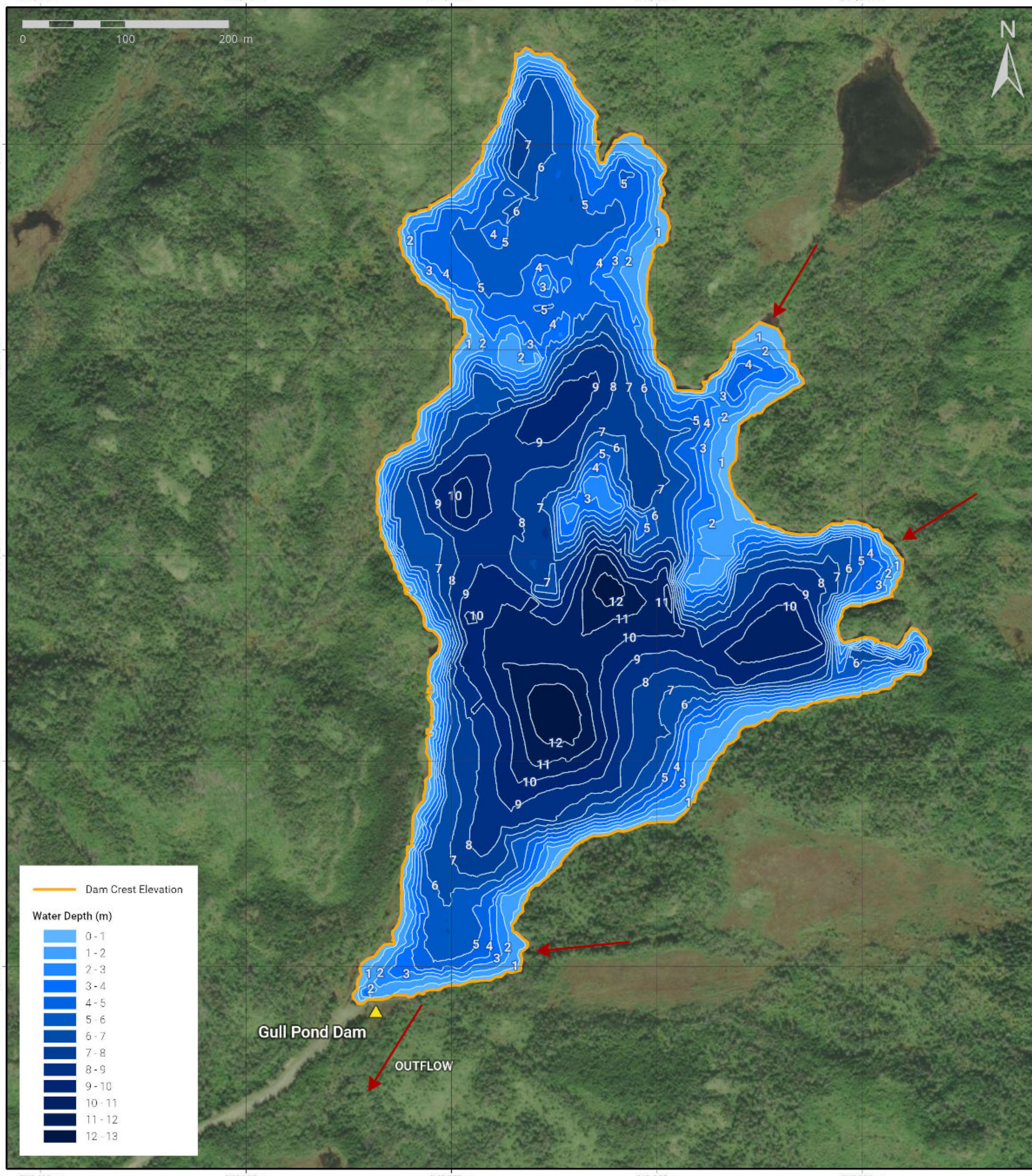
Pattern | Argentia Renewables	FIGURE NUMBER: C1 - 2.5 - 2	COORDINATE SYSTEM: NAD 1983 CSRS UTM Zone 22N	PREPARED BY: C. Burke	DATE: 24/07/27
	FIGURE TITLE: Larkins Pond Bathymetric Survey	NOTES: Bathymetric data collected with single-beam transducer in July 2024.	REVIEWED BY: CBurke	
	PROJECT TITLE: Argentia Renewables		APPROVED BY: CBurke	
			sem	

SEM MAP ID: 238-005-GIS-154-Rev0



Pattern | Argentia Renewables	FIGURE NUMBER: C1 - 2.5 - 3	COORDINATE SYSTEM: NAD 1983 CSRS UTM Zone 22N	PREPARED BY: C. Burke	DATE: 24/07/27
	FIGURE TITLE: Barrows Pond Bathymetric Survey	NOTES: Bathymetric data collected with single-beam transducer in July 2024.	REVIEWED BY: CBurke	
			APPROVED BY: CBurke	
	PROJECT TITLE: Argentia Renewables		sem	

SEM MAP ID: 238-005-GIS-155-Rev0



Pattern | Argentia Renewables	FIGURE NUMBER: C1 - 2.5 - 4	COORDINATE SYSTEM: NAD 1983 CSRS UTM Zone 22N	PREPARED BY: C. Burke; DATE: 24/07/27
	FIGURE TITLE: Gull Pond Bathymetric Survey	NOTES: Bathymetric data collected with single-beam transducer in July 2024.	REVIEWED BY: C Burke
	PROJECT TITLE: Argentia Renewables		APPROVED BY: C Burke
			sem

SEM MAP ID: 238-005-GIS-156-Rev0

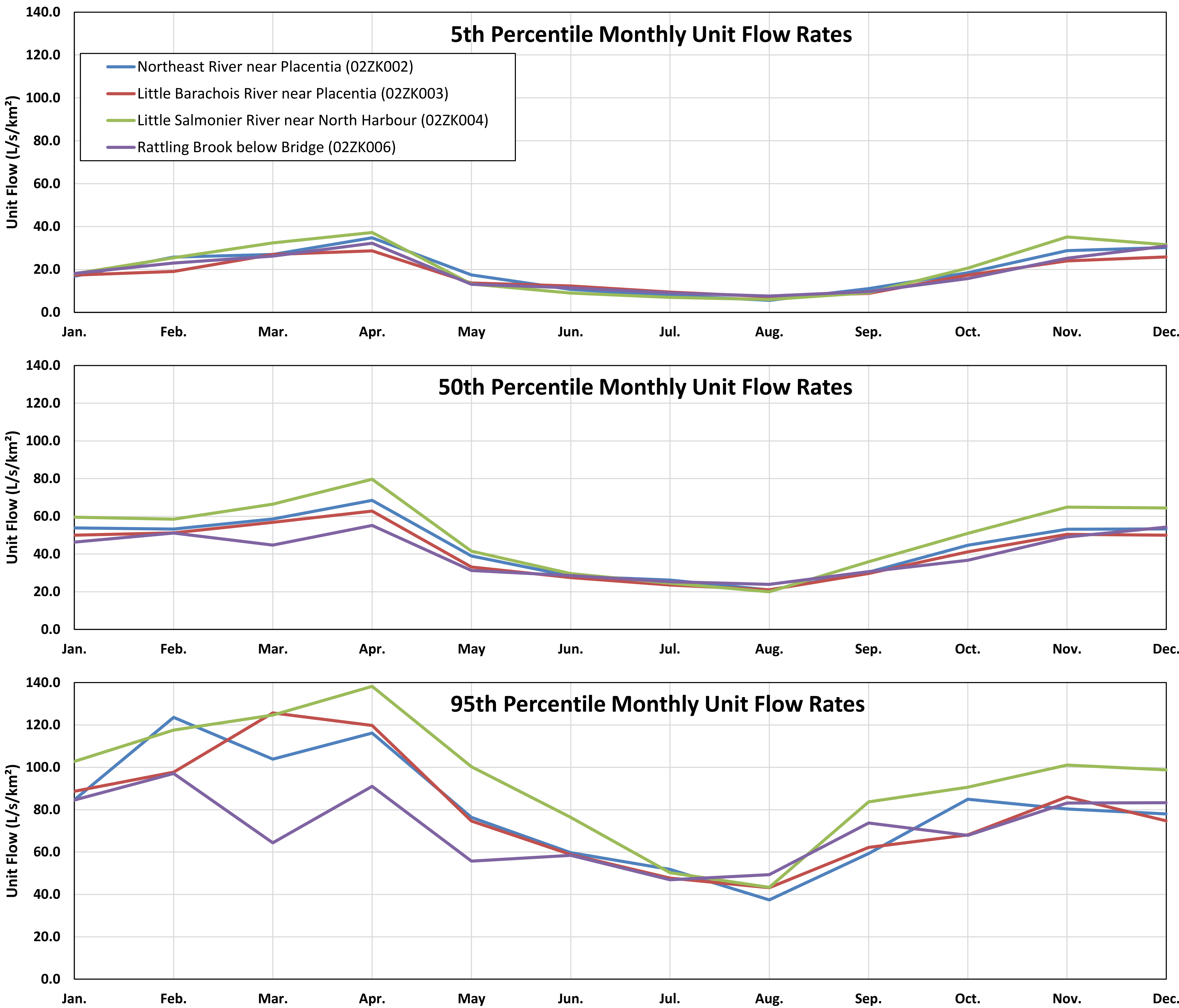
3.0 Regional Streamflow Patterns

Monthly unit runoff rates and regional streamflow patterns were analyzed using data from nearby WSC stations with drainage areas less than 250 km². Historical daily streamflow records were acquired and aggregated to facilitate the analysis of monthly unit runoff rates. This methodology aimed to provide insight into the natural hydrological dynamics and water resource availability within the Project Area. Based on previous analyses of streamflow data, the regional runoff factor (i.e., the fraction of precipitation that appears as runoff) is suggested to be 80% (NL DECC, 1992) and 81% (AMEC, 2013).

3.1 Monthly Streamflow Patterns

Streamflow patterns were analyzed on a percentile basis to establish minimum (5th), mean (50th), and maximum (95th) monthly flow rates, expressed as unit flow rates (L/s/km², Table C1-3.1-1). The 5th, 50th, and 95th percentiles were highlighted to represent the range of streamflow conditions. This approach outlines the flow variability in the Project Area, encompassing low flow conditions for drought analysis, typical median flows for average conditions, and high flow extremes for assessing peak flow events. Average monthly flow rates are higher in November, December, January, February, and April and recede during the summer period of June, July, and August (Figure C1-3.1-1). The lowest flow rate occurs in August.

Average monthly unit flow rates were scaled to the PPWSA pond drainage areas to provide estimated natural water availability based on observed streamflows in the region (Table C1-3.1-2). These monthly flows were compared against the proposed Project water withdrawal and the measured municipal withdrawal rates. It was determined that the total withdrawal at Clarke's Pond would be greater than the monthly 5th percentile natural water availability from June to September, however the total withdrawal rate does not exceed the 50th percentile natural availability in any given month. In August, which marks the peak of the low flow period, the Project's withdrawal rate is 17% of the minimum (5th percentile) mean annual flow and 7% of the 50th percentile mean annual flow.



Pattern
Argentia Renewables

sem

ARGENTIA RENEWABLES WIND LP
SOURCE WATER HYDROLOGY

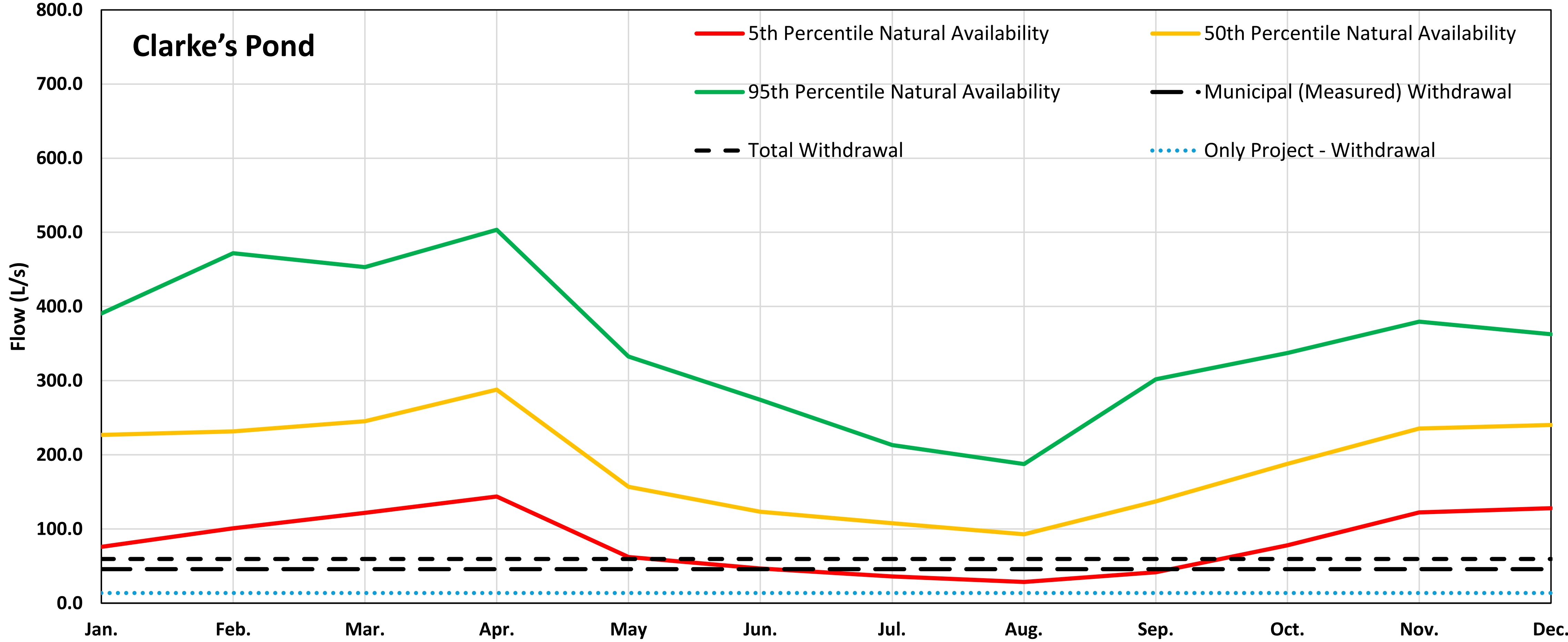
REGIONAL WSC STATION UNIT FLOW RATES

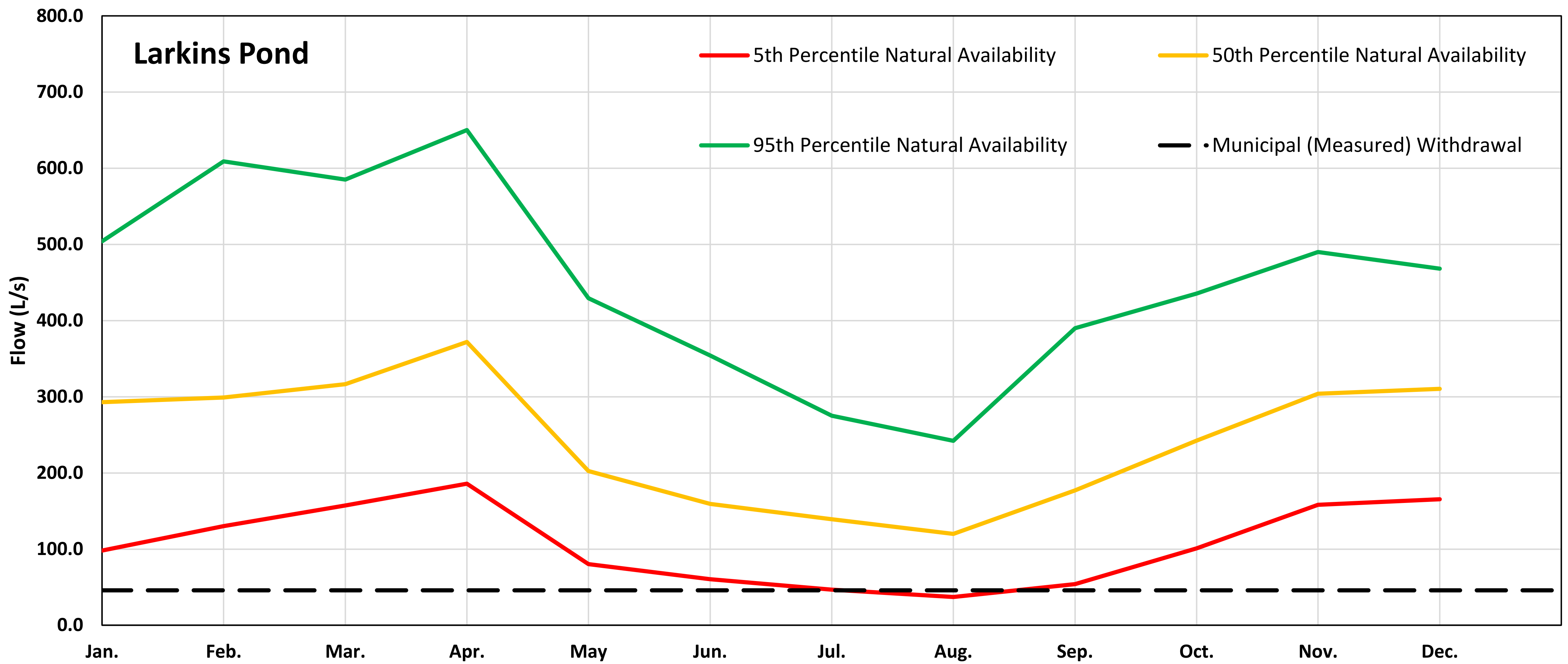
DATE:	PROJECT:	SUBMITTER:	REVIEWER:
JULY 2024	238-001	Z.ZHAO	T.BRENTON

FIGURE: C1-3.1-1

Table C1-3.1-1 Monthly Unit Flow Rates at Nearby WSC Stations.

WSC Station	Drainage Area (km²)	Unit Flow Rate (L/s/km²)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean Annual Unit Flow	Annual Runoff (mm/year)
02ZK002 (2000 to 2019)	89.6	5th Percentile	16.8	25.8	27.0	34.8	17.5	10.6	7.9	5.6	11.0	18.4	28.8	30.2	36.3	614
		50th Percentile	53.9	53.2	58.6	68.4	39.0	28.3	26.2	20.9	30.4	44.7	53.2	53.4	44.1	1,392
		95th Percentile	84.7	123.6	103.9	116.2	76.4	59.7	51.8	37.4	59.3	85.0	80.3	78.1	55.3	2,505
02ZK003 (1983 to 2019)	37.2	5th Percentile	17.3	19.0	27.0	28.7	13.7	12.3	9.4	7.3	8.9	17.4	24.0	25.8	35.5	554
		50th Percentile	50.0	51.2	56.8	62.8	33.2	27.5	23.6	21.0	29.7	41.2	50.4	50.0	41.4	1,305
		95th Percentile	88.7	97.7	125.7	119.8	74.7	58.8	47.8	43.2	62.2	68.1	86.0	74.7	49.7	2,486
02ZK004	104.0	5th Percentile	18.0	25.5	32.4	37.3	13.2	9.0	7.0	6.0	9.2	20.6	35.1	31.5	40.6	642
		50th Percentile	59.5	58.5	66.5	79.7	41.5	29.6	24.5	20.0	35.9	51.0	64.9	64.4	49.6	1,564
		95th Percentile	102.8	117.6	124.7	138.2	100.3	76.4	50.3	43.3	83.7	90.7	101.1	98.9	61.4	2,959
02ZK006 (2007 to 2022)	32.7	5th Percentile	18.1	22.9	26.2	32.2	13.1	11.4	9.1	7.6	9.6	15.8	25.2	30.9	31.4	583
		50th Percentile	46.3	51.1	44.7	55.1	31.2	28.6	25.4	23.9	30.7	36.7	49.0	54.3	39.7	1,251
		95th Percentile	84.5	97.0	64.4	91.0	55.8	58.5	47.0	49.4	73.8	67.9	83.2	83.3	48.0	2,243
WSC Station Average		5th Percentile	17.6	23.3	28.1	33.3	14.4	10.8	8.3	6.6	9.7	18.0	28.3	29.6	19.0	598
		50th Percentile	52.4	53.5	56.7	66.5	36.2	28.5	24.9	21.5	31.7	43.4	54.4	55.5	43.8	1,378
		95th Percentile	90.2	109.0	104.7	116.3	76.8	63.4	49.2	43.3	69.7	77.9	87.7	83.7	81.0	2,548





Pattern Argentia Renewables

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ARGENTIA RENEWABLES WIND LP
SOURCE WATER HYDROLOGY

NATURAL AVAILABILITY AND WATER WITHDRAWAL FLOW RATES

DATE:	PROJECT:	SUBMITTER:	REVIEWER:
JULY 2024	238-001	Z.ZHAO	T.BRENTON

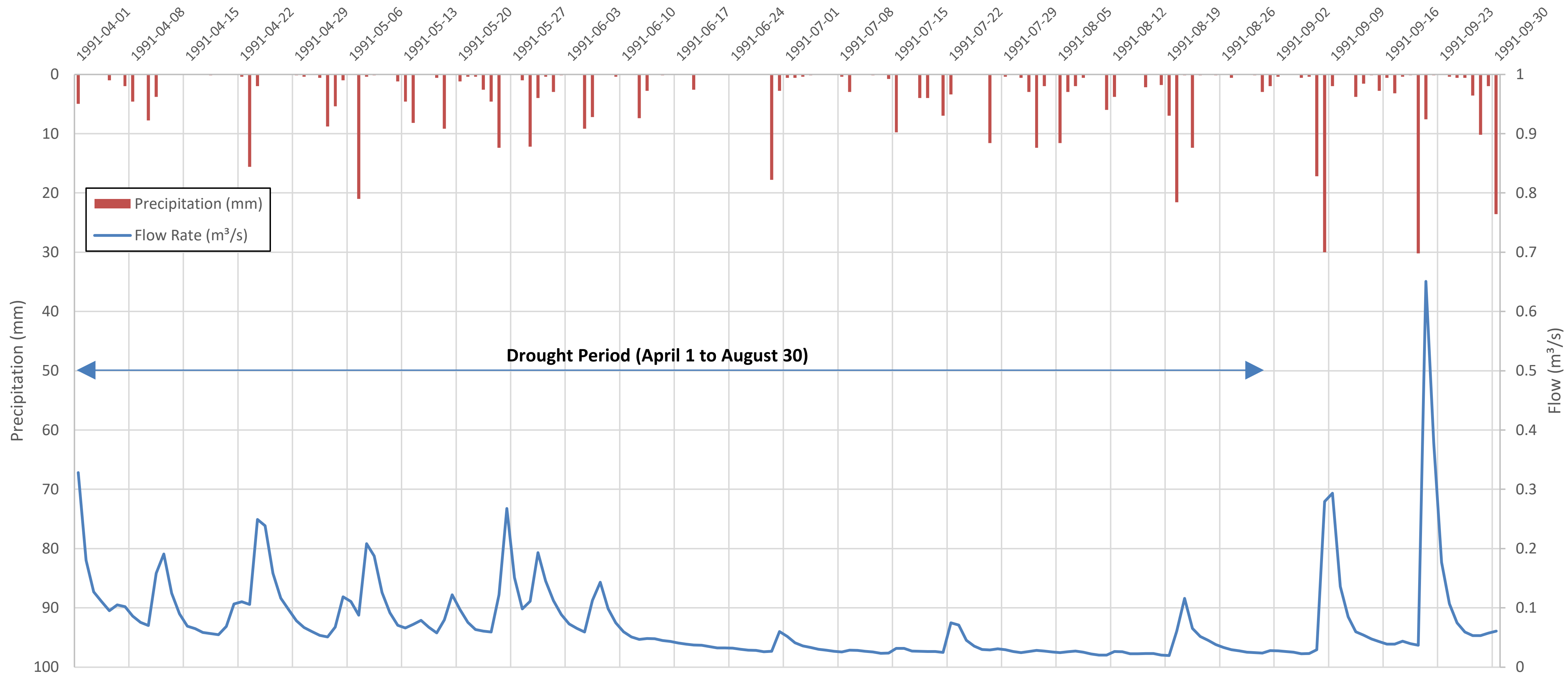
FIGURE: C1-3.1-2

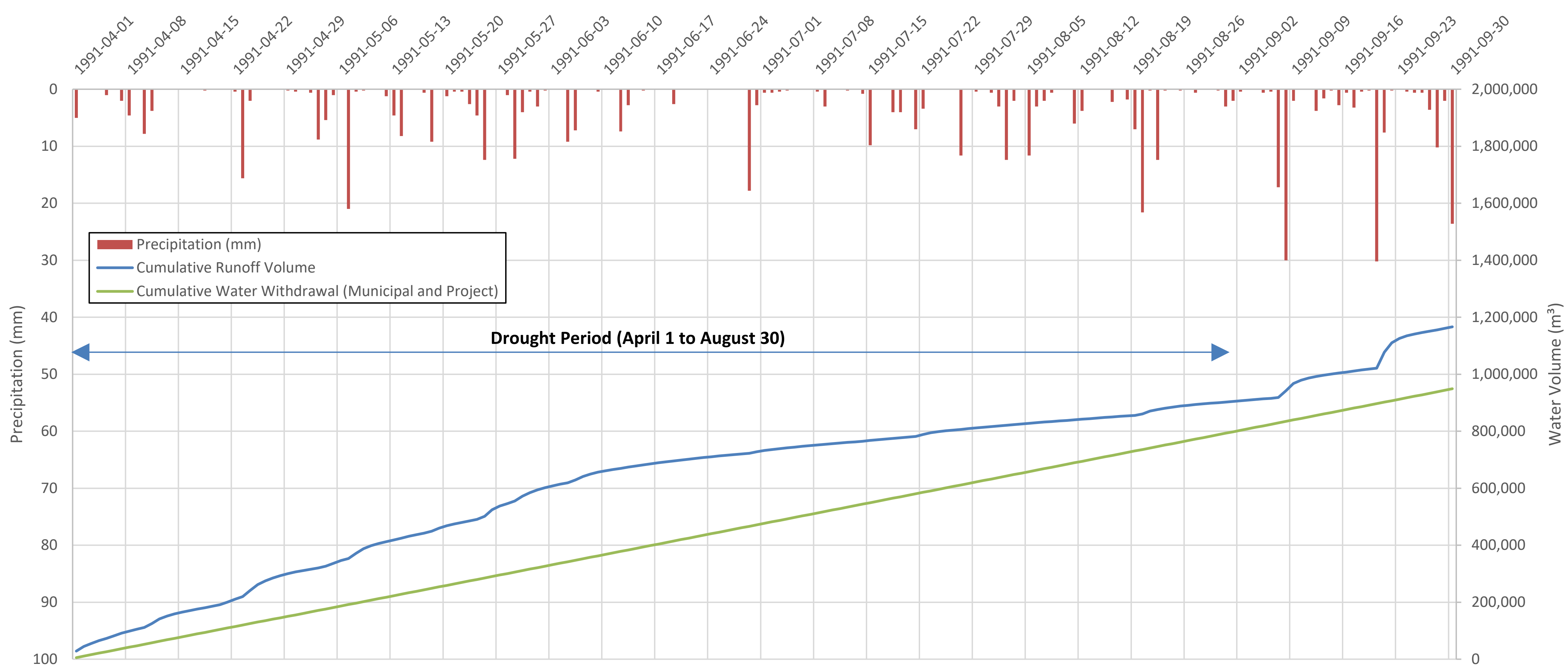
Table C1-3.1-2 Monthly Flow Rates at Placentia PPWSA Ponds.

Pond	Flow Rate (L/s)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean Annual Flow
Clarke's Pond	5th Percentile	76.0	100.9	121.9	144.0	62.2	46.9	36.2	28.7	41.9	78.2	122.4	128.2	82.3
	50th Percentile	227.0	231.7	245.3	287.9	156.9	123.4	107.9	92.9	137.2	187.9	235.4	240.4	189.5
	95th Percentile	390.5	471.9	453.2	503.6	332.5	274.3	213.1	187.6	302.0	337.4	379.5	362.6	350.7
Larkins Pond	5th Percentile	98.1	130.2	157.4	185.9	80.4	60.5	46.7	37.0	54.1	100.9	158.1	165.5	106.2
	50th Percentile	293.1	299.1	316.7	371.7	202.5	159.3	139.3	119.9	177.1	242.6	304.0	310.4	244.6
	95th Percentile	504.1	609.2	585.1	650.1	429.3	354.1	275.2	242.2	389.9	435.6	490.0	468.2	452.7
Barrows Pond	5th Percentile	25.1	33.3	40.3	47.5	20.6	15.5	11.9	9.5	13.8	25.8	40.4	42.3	27.2
	50th Percentile	75.0	76.5	81.0	95.1	51.8	40.8	35.6	30.7	45.3	62.1	77.8	79.4	62.6
	95th Percentile	129.0	155.8	149.7	166.3	109.8	90.6	70.4	62.0	99.7	111.4	125.3	119.8	115.8
Gull Pond	5th Percentile	17.2	22.8	27.6	32.6	14.1	10.6	8.2	6.5	9.5	17.7	27.7	29.0	18.6
	50th Percentile	51.4	52.4	55.5	65.2	35.5	27.9	24.4	21.0	31.0	42.5	53.3	54.4	42.9
	95th Percentile	88.4	106.8	102.6	114.0	75.3	62.1	48.2	42.5	68.4	76.4	85.9	82.1	79.4

3.2 Water Yield

Storage-yield curves developed by NL DECC under the Guide to Storage Yield Analysis at Ungauged River Sites (NL DECC, 1997) were used to provide an estimate of required live storage. This estimate can be used to provide a preliminary estimate of storage requirements for a desired yield at the Placentia PPWSA. The drainage area of the Clarke's Pond watershed (4.33 km^2) was analyzed with a desired yield equivalent to measured public water withdrawal from Clarke's Pond (45.8 L/s) and the proposed Project water withdrawal (13.7 L/s) and a mean annual runoff of 1378 mm per year (as outlined in Section 3.1). Nearby streamflow gauges near the Project Area were selected and a live storage estimate of 280,000 m^3 was determined, which would represent 1.4 m of drawdown below the Clarke's Pond dam crest.





Notes: Long Harbour climate station precipitation data and Little Barachois River near Placentia (02ZK003) hydrometric station flow rate data (scaled to the total Clarke's Pond drainage area) were used to prepare this graph.

Pattern
Argentia Renewables

sem

ARGENTIA RENEWABLES WIND LP
SOURCE WATER HYDROLOGY

1991 DROUGHT PERIOD
FLOW RATE AND MASS-FLOW CURVES

DATE:	PROJECT:	SUBMITTER:	REVIEWER:
JULY 2024	238-001	Z.ZHAO	T.BRENTON

FIGURE: C1-3.2-1

3.3 Low Flows and Drought

The Newfoundland and Labrador Low Flows Estimation Calculator (NL DECC, 2017) was used to calculate 1-day and 7-day low flows for 10-year, 50-year, and 100-year return periods, otherwise known as 1Q10, 7Q10, 1Q50, 7Q50, 1Q100, and 7Q100 flows (Table C1-3.3-1).

Table C1-3.3-1 PPWSA Ponds Low Flows.

Pond	Drainage Area (km^2)	1Q10 (L/s)	7Q10 (L/s)	1Q50 (L/s)	7Q50 (L/s)	1Q100 (L/s)	7Q100 (L/s)
Clarke's Pond	4.33	10.2	12.7	2.2	2.9	1.3	1.8
Larkins Pond	5.59	13.5	16.8	2.9	3.8	1.7	2.4
Barrows Pond	1.43	3.0	3.8	0.6	0.9	0.4	0.5
Gull Pond	0.98	2.0	2.5	0.4	0.6	0.3	0.4

The 2024 Placentia Regional Water Supply Study evaluated the drawdown of the ponds in the PPWSA under a 7Q100 low flow condition (PEC, 2024). With the existing municipal withdrawal at the measured rate of 100.1 L/s, Clarke’s Pond exhibited a drawdown of 0.26 m. A combined watershed area of Clarke’s Pond, Gull Pond, and Barrows Pond showed a reduced drawdown of 0.10 m, suggesting that the amount of drawdown during low flow conditions is mitigated with inclusion of additional ponds. Further inclusion of Larkins Pond with Clarke’s Pond, Gull Pond, and Barrows Pond resulted in a drawdown of 0.07 m, demonstrating the effectiveness of a larger integrated pond system in sustaining water levels during low flow conditions.

A drought period in 1991 was examined to understand the impact of a drought on cumulative runoff when compared with the water withdrawal rate (including proposed Project withdrawal). In 1991, the months of April, June, and July were determined to be drought periods. Flow recorded by the Little Barachois River near Placentia (02ZK003) were scaled to the total Clarke’s Pond drainage area and a cumulative runoff volume graph (i.e., mass-flow curve) for this period was generated to compare against the cumulative water withdrawal volume that would be withdrawn from Clarke’s Pond (Figure C1-3.1-1). During this drought period, runoff volumes flowing into Clarke’s Pond were greater than the water volume that is proposed to be withdrawn.

4.0 Hydrologic Model

A hydrologic model was developed for the Placentia PPWSA using HEC-HMS to integrate precipitation and temperature data to model runoff and evapotranspiration, while managing reservoir storage and outflows based on their surveyed conditions. The hydrologic model included considerations for existing municipal water withdrawal and proposed Project water withdrawal and performed daily meteorological data analysis. The Placentia PPWSA was modelled in HEC-HMS as a basin model. A drainage network was defined to represent the Placentia PPWSA. The basin model consisted of three sub-basins, listed from upstream to downstream at Barrow's Pond, Clarke's Pond, and Larkins Pond. The drainage area and connection from Gull Pond was not included in the model.

The pond reservoirs were modelled by inputting bathymetric stage-storage-area data collected for each pond. Discharge relationships for the outlets of each pond were calculated in the hydrologic model based on either orifice or broad-crested weir equations.

Water withdrawal rates were modelled in HEC-HMS as constant daily rates. Municipal measured water withdrawal rates (as outlined in Section 2.4.1) were analysed being withdrawn from Clarke's Pond and Larkins Pond in scenarios with and without the proposed Project withdrawal rate (as outlined in Section 2.4.2) being withdrawn only from Clarke's Pond. Only measured municipal water withdrawal rates were analysed in the hydrologic model, with the understanding that elevated municipal flow rates may be reduced in the future through the investigation and implementation of a leak detection and repair program (PEC, 2024).

Climate and precipitation data were used as inputs into a meteorologic model in HEC-HMS. The Specified Hyetograph Method and The Specified Thermograph Method in HEC-HMS were selected to input precipitation and temperature conditions at the sub-basins. The Hamon method (Hamon, 1961) is used to estimate potential evapotranspiration daily. The following time periods were continuously simulated on a daily basis:

- 1971 to 1999 using historical data recorded at the Long Harbour climate station;
- 2004 to 2016 using historical data recorded by the Argentia (AUT) climate station; and
- 2025 to 2100 using climate change projected data for Argentia (Boucher et al., 2020).

5.0 Results and Discussion

Simulations were completed on a daily timescale to assess the dynamics of water availability within the Project Area with historical and climate change datasets. The historical context is important for model validation and understanding past trends. Climate change projections help evaluate potential scenarios in the future. These projections provide insights into how changing climate patterns may alter hydrologic responses in the Project Area.

5.1 Historical Data

Based on the stage-storage relationship of Clarke's Pond and Larkins Pond, hydrologic simulations were performed to evaluate the dynamic drawdown and recharge of these ponds for two historical periods (i.e., 1971 to 1999 and 2004 to 2016). Daily simulations were conducted with and without Project water withdrawal.

5.1.1 1971 to 1999

Average monthly water levels for Clarke's Pond and Larkins Pond are shown in the tables below. The minimum water level during this period was 36.8 masl at Clarke's Pond and 38.7 masl at Larkins Pond. Figure C1-5.1-1 shows precipitation and water level for this continuous period of record and depicts the annual recharge The data indicates that water levels remain relatively stable, even with Project withdrawal, though slight reductions are observed during summer months with low precipitation and above average temperatures.

Table C1-5.1.1-1 1971 to 1999 Average Monthly Data.

Month	Temperature (°C)	Precipitation (mm)	Water Level (masl)			
			Clarke's Pond		Larkins Pond	
			Without Project Withdrawal	With Project Withdrawal	Without Project Withdrawal	With Project Withdrawal
Jan.	-3.4	131.4	40.7	40.7	40.9	40.9
Feb.	-4	108.6	40.7	40.7	40.9	40.9
Mar.	-1.2	110.9	40.7	40.7	40.9	40.9
Apr.	2.9	98	40.7	40.6	40.8	40.8
May	6.7	92.8	40.6	40.6	40.8	40.7
Jun.	10.7	109.1	40.6	40.5	40.7	40.7
Jul.	14.9	93.5	40.5	40.4	40.6	40.5
Aug.	15.9	102.4	40.4	40.2	40.4	40.3
Sep.	12.9	123.8	40.5	40.3	40.5	40.4
Oct.	8.2	150.2	40.7	40.6	40.7	40.6
Nov.	4	124.7	40.7	40.7	40.8	40.7
Dec.	-0.5	114	40.7	40.7	40.9	40.8

Pattern

Argentia Renewables

sem

ARGENTIA RENEWABLES WIND LP

SOURCE WATER HYDROLOGY

PRECIPITATION AND WATER LEVEL 1971 TO 1999

DATE:	PROJECT:	SUBMITTER:	REVIEWER:
JULY 2024	238-001	Z.ZHAO	T.BRENTON

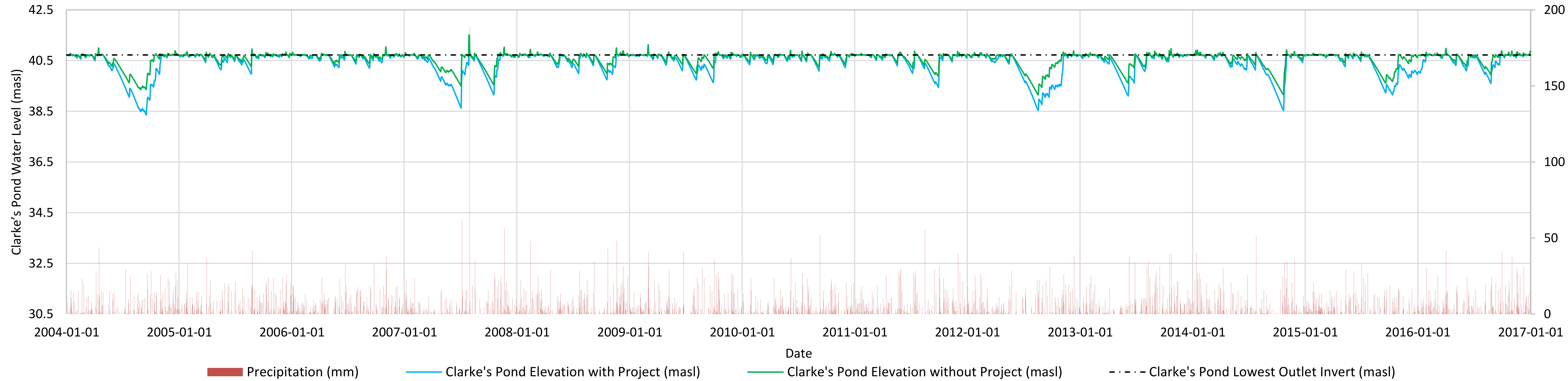
FIGURE: C1-5.1-1

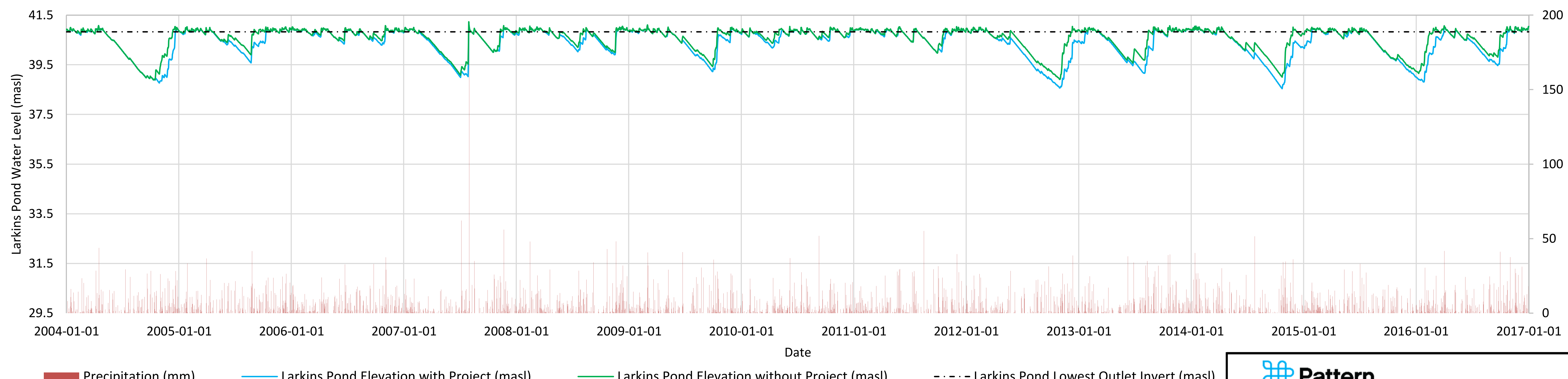
5.1.2 2004 to 2016

Average monthly water levels for Clarke's Pond and Larkins Pond are shown in the tables below. The minimum water level during this period was 38.3 masl at Clarke's Pond and 38.5 masl at Larkins Pond. Figure C1-5.1-2 shows precipitation and water level for the continuous period of record. This period's data reflects similar trends to the 1971 to 1999 period, with slightly lower water levels during the summer months.

Table C1-5.1-2 2004 to 2016 Average Monthly Data.

Month	Temperature (°C)	Precipitation (mm)	Water Level (masl)			
			Clarke's Pond		Larkins Pond	
			Without Project Withdrawal	With Project Withdrawal	Without Project Withdrawal	With Project Withdrawal
Jan.	-1.6	107.5	40.7	40.7	40.8	40.7
Feb.	-2.2	77.3	40.7	40.7	40.9	40.8
Mar.	-1.0	74.4	40.7	40.6	40.8	40.7
Apr.	3.1	81.2	40.6	40.6	40.7	40.7
May	6.7	78.6	40.5	40.4	40.6	40.5
Jun.	10.4	80.5	40.5	40.3	40.4	40.3
Jul.	14.8	105.6	40.4	40.3	40.3	40.2
Aug.	16.6	97.8	40.4	40.1	40.3	40.1
Sep.	13.8	81.6	40.3	40.0	40.2	40.0
Oct.	9.4	117.9	40.4	40.2	40.2	40.0
Nov.	5.7	120.2	40.7	40.6	40.6	40.3
Dec.	0.9	111.7	40.7	40.6	40.8	40.6





Pattern

Argentia Renewables

sem

ARGENTIA RENEWABLES WIND LP

SOURCE WATER HYDROLOGY

PRECIPITATION AND WATER LEVEL 2004 TO 2016

DATE:	PROJECT:	SUBMITTER:	REVIEWER:
JULY 2024	238-001	Z.ZHAO	T.BRENTON

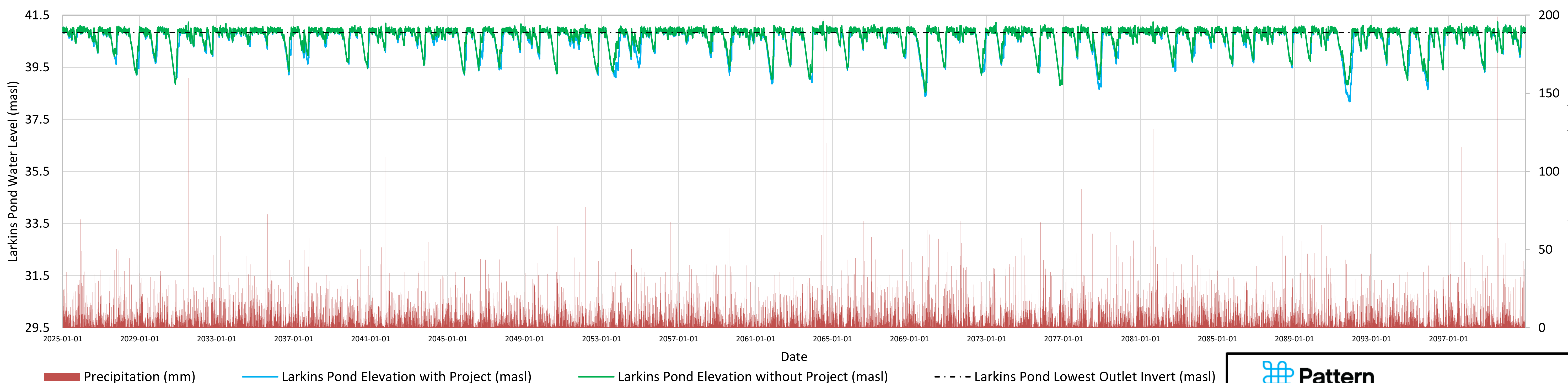
FIGURE: C1-5.1-2

5.1.3 Climate Change Period

Average monthly water levels for Clarke's Pond and Larkins Pond are shown in the tables below. The minimum water level during this period was 36.6 masl at Clarke's Pond and 38.2 masl at Larkins Pond. Figure C1-5.1-3 shows precipitation and water level for the continuous period of record. The ponds are still projected to maintain adequate water levels compared to historical data, with Project withdrawals resulting in minimal impact.

Table C1-5.1.3-1 Climate Change Average Monthly Data.

Month	Temperature (°C)	Precipitation (mm)	Water Level (masl)			
			Clarke's Pond		Larkins Pond	
			Without Project Withdrawal	With Project Withdrawal	Without Project Withdrawal	With Project Withdrawal
Jan.	-0.4	137.5	40.7	40.7	40.9	40.9
Feb.	-0.3	110.7	40.7	40.7	40.9	40.9
Mar.	1.0	112.0	40.7	40.7	40.9	40.9
Apr.	4.3	94.8	40.7	40.6	40.8	40.8
May	7.8	99.7	40.6	40.6	40.8	40.7
Jun.	12.0	106.8	40.6	40.5	40.7	40.7
Jul.	17.2	102.6	40.5	40.4	40.6	40.6
Aug.	19.2	83.0	40.3	40.1	40.4	40.3
Sep.	15.9	101.0	40.2	39.9	40.2	40.1
Oct.	11.3	121.0	40.4	40.1	40.2	40.1
Nov.	6.5	125.2	40.6	40.5	40.5	40.3
Dec.	2.3	152.9	40.7	40.7	40.8	40.7



Pattern

Argentia Renewables

sem

ARGENTIA RENEWABLES WIND LP

SOURCE WATER HYDROLOGY

PRECIPITATION AND WATER LEVEL
2025 TO 2100

DATE:	PROJECT:	SUBMITTER:	REVIEWER:
JULY 2024	238-001	Z.ZHAO	T.BRENTON

FIGURE: C1-5.1-3

5.2 Summary and Comparison with WSC Streamflow

5.2.1 Drawdown

Generally, drawdown on the ponds is less than 1 m below the outlet invert during all scenarios, which is in support of the water yield outlined in Section 3.2. Drawdown at Clarke's Pond and Larkins Pond resulting from water withdrawal in the hydrologic model is summarized in Table C1-5.2.1-1. Without Project withdrawal, neither Clarke's Pond nor Larkins Pond experience greater than 3 m of drawdown. When factoring in Project withdrawal, drawdown greater than 3 m does not occur at Larkins Pond and occurs only 0.5% (1971 to 1999), 0% (2004 to 2016), and 0.2% (2025 to 2100) of the time at Clarke's Pond.

When comparing the continuous simulation cases with and without Project withdrawal, average water depths are between 0.7% and 1.3% lower in Clarke's Pond, and 0.5% to 1.2% lower in Larkins Pond with proposed Project withdrawal. These percentages indicate that the proposed Project withdrawal have a minor impact on water levels at both ponds and suggest that the ponds can sustain this withdrawal with minimum effects on water depths.

In addition, the hydrologic model does not account for the potential supplemental water supply from Gull Pond, which can provide a buffer during drought periods to minimize drawdown on the ponds. This indicates that the current model may be conservative in its estimates. The percentage of drawdown exceeding threshold drawdown values during the continuous hydrologic simulation period are detailed in Table C1-5.2.1-1.

Table C1-5.2.1-1 Hydrologic Model Drawdown Summary.

Scenario		1971 to 1999				2004 to 2016				2025 to 2100			
		Without Project		With Project		Without Project		With Project		Without Project		With Project	
		Clarke's Pond	Larkins Pond	Clarke's Pond	Larkins Pond	Clarke's Pond	Larkins Pond	Clarke's Pond	Larkins Pond	Clarke's Pond	Larkins Pond	Clarke's Pond	Larkins Pond
Drawdown Exceedance Percentage	> 1 m drawdown	1.6%	3.1%	2.9%	5.3%	3.3%	11.4%	10.0%	17.4%	4.2%	7.6%	8.9%	10.4%
	> 2 m drawdown	0.6%	0.1%	1.2%	0.2%	0.0%	0.0%	1.1%	1.4%	0.4%	0.1%	1.8%	0.8%
	> 3 m drawdown	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%
Average Water Level (masl)		40.6	40.7	40.6	40.7	40.6	40.5	40.4	40.4	40.6	40.6	40.5	40.6
Average Water Depth (m)		10.3	11.2	10.3	11.2	10.3	11.0	10.1	10.9	10.3	11.1	10.2	11.1
Minimum Water Level (masl)		38.0	38.7	36.8	38.7	39.1	38.9	38.3	38.5	37.8	38.5	36.6	38.2
Date of Minimum Water Level		1975-09-27	1975-09-30	1975-09-27	1975-09-30	2014-10-23	2004-10-11	2004-09-17	2014-10-23	2076-10-31	2069-10-27	2076-10-31	2091-11-10

5.2.2 Hydrologic Model Compared with Streamflow Data

Water availability derived from the hydrologic model totals averaged between 152.5 L/s to 201.6 L/s during the historical and climate change periods (Table 5.2.2-1). The unit flow rate derived by the hydrologic model for the PPWSA sub-basins ranges from 27.3 L/s/km² to 36.1 L/s/km², which is lower than observed streamflow data from nearby WSC streamflow stations in the 50^{th} percentile, with unit flow rates ranging from 39.7 L/s/km² to 49.6 L/s/km². This difference indicates that the model is conservative in estimating water availability. During operation of the Project, this model could be calibrated and validated against observed data to improve the accuracy.

An additional source of underestimation of water availability between the hydrologic model (using historical and climate change data) and observed WSC streamflow data may be caused overestimation of evapotranspiration with the Hamon equation (Tam et al., 2023). This overestimation of evapotranspiration could be particularly high, considering that the Project Area typically has a high percentage of daytime cloud and fog coverage during the summer months (LGL Limited, 2007; DFO, 2023). The higher unit flow rate derived from observed WSC streamflow data might suggest a potentially higher source water availability. In addition, the hydrologic model did not include connection with Gull Pond, which could provide supplemental water during drought periods.

Table 5.2.2-1 Hydrologic Model Water Availability.

Scenario		1971 to 1999	2004 to 2016	2025 to 2100
Flow Rate (L/s)	Barrow's Pond Sub-basin	51.6	39.0	48.4
	Clarke's Pond Sub-basin	104.6	79.1	98.1
	Larkins Pond Sub-basin	45.5	34.4	42.6
	Water Availability	**201.6**	**152.5**	**189.2**
Average Unit Flow Rate (L/s/km²)		36.1	33.8	27.3

6.0 Conclusion

The Source Water Hydrology report provides an analysis of water availability and drawdown at Placentia PPWSA ponds under various scenarios, incorporating historical and climate change data, current municipal water withdrawal, and proposed Project water withdrawal. Bathymetry surveys revealed an available water depth of 11.2 m with reservoir volume of 1,135,000 m^3 in Clake's Pond, and an available water depth of 11.4 m with reservoir volume of 1,593,700 m^3 in Larkins Pond. Given these total volumes, the projected withdrawals over a 30-day period with no inflow for Clarke's Pond and Larkin's Pond would be 155,000 m^3 and 140,600 m^3 respectively. These withdrawal volumes represent approximately 13.7% of Clarke's Pond volume and 8.8% of Larkins Pond volume. These withdrawal quantities are relatively minor in comparison to the overall storage capacities.

Hydrologic model simulations conducted using HEC-HMS determined that the inclusion of Project water withdrawal would result in minor reductions in average water depths This report, along with the Placentia Regional Water Supply Study prepared by Progressive Engineering & Consulting Inc. (PEC, 2024) confirmed sufficient water availability for the needs of the Project. The inclusion of the Project on the existing municipal withdrawal was shown to decrease the average water depth by 0.5% to 1.3%.

Droughts were determined to generally be low in frequency and severity. During a drought period in 1991, runoff inflows to Clarke's Pond exceeded the combined municipal and Project withdrawal rates, confirming adequate water availability. Long-term climate change projections indicated that drawdown exceeding 3 m would only occur 0.2% of the time, which is mitigated by the connection with Gull Pond and pond water depths exceeding 10 m. While the active storage volumes are not known because of the absence of surveyed intake elevations, the water volumes and minimal drawdowns observed in hydrologic simulations indicate the PPWSA is able to support existing and proposed Project water demands.

During future operation of the Argentia Renewables Project it is recommended to develop water level monitoring thresholds and adaptive water management strategies to ensure the protection of Placentia's PPWSA, to mitigate against excessive drawdown during drought conditions, and to support the Project long-term. The 2024 Placentia Regional Water Supply Study recommends the implementation of leak detection and repair strategies to reduce municipal withdrawal rates. By coupling these strategies with defined water monitoring thresholds, water usage in the PPWSA can be optimized, enhancing the source water's resilience against variable hydrologic conditions and the impact of climate change.

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Appendix A

2024 Placentia Regional Water Supply Study - Progressive Engineering & Consulting Inc.

Pattern Energy - Phase 1

Placentia Regional Water Supply Study
PLACENTIA, NL

REV. 1

Submitted by:
Progressive Engineering & Consulting Inc.

PEC#: **2024-002**
Submission Date: **March 12th, 2024**

Submitted to: **SEM Ltd.**

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APPENDICES

Appendix A: Watershed Areas
Appendix B: Summary of Measured Flow Data

1.0 INTRODUCTION

Argentia, a commercial/industrial region within the Town of Placentia, has become a popular spot in recent years for industrial business and operations. Historically an old US military base, Argentia has the land mass and deep-water port to attract a lot of global attention for major industrial projects and operations. The latest company to target Argentia is Pattern Energy with their Argentia Renewables project. This project will be a green hydrogen and ammonia production as well as an export facility that will be powered by the renewable energy resource of wind. The beginning phases of the project will require environmental studies, which includes, but are not limited to, the water supply and distribution system within Placentia. In January 2024, SEM Ltd. (SEM) engaged Progressive Engineering and Consulting Inc. (PEC) to investigate the current water supply to ensure the quantity of water will be able to serve both the Town of Placentia and the future industrial usage by Pattern Energy, and to also provide the potential options for any necessary upgrades. Phase 1 of the study encompasses investigating the water distribution system, completing a watershed analysis, determining the existing and future water demand, and providing a high-level opinion on possible infrastructure upgrades.

Pattern Energy stands out as a leading force in the renewable energy sector, counted among the globe's foremost privately-owned developers and operators of wind, solar, transmission, and energy storage projects. With a robust operational portfolio comprising 30 renewable energy facilities across North America, boasting an operating capacity nearing 6,000 MW, Pattern Energy harnesses proven, best-in-class technology to power a sustainable future. Their endeavors are underscored by a steadfast commitment to serving customers, safeguarding the environment, and fostering community resilience, aligning with a vision for long-term positive impact.

The Town of Placentia is presently comprised of the communities of Freshwater, Argentia, Dunville, Jerseyside, Ferndale, Placentia Proper, and Southeast Placentia. The 2021 census[1] indicated a population of 3,289 people which was a 5.9% decline compared to the previous 2016 census. With the potential increase of industrial activity in Argentia as well as the ongoing water distribution system leaking issues within the regions of Placentia, the current water supply is to be analyzed to ensure the water sources are sustainable for future usage. There has been a strong need to address the water quantity issues associated with their water supplies

[1] *Census Profile, 2021 Census of Population,* Government of Canada (2023)

for about a decade and the Town of Placentia has been taking steps to complete the necessary upgrades as funding allows.

2.0 DESCRIPTION OF EXISTING WATER SUPPLY SYSTEMS

The current potable water system in the Town of Placentia consists of two operational water sources: Clarke's Pond and Larkins Pond. Additionally, there is a watershed expansion area for Clarke's Pond which includes Barrons and Gull Ponds, and an inactive water source of Argentia Pond.

See the figure below which outlines the subregions of Placentia as well as the active and inactive water supply sources.

Figure 1: **Placentia Regional Map – Subregions & Water Supply Sources**

The following is a brief description of the two active water supplies.

2.1 CLARKE'S POND

The Clarke's Pond water supply presently supplies Freshwater, Argentia, and Dunville, which totals an approximate population of 1,480 people. It also has the capacity to supply the remainder of Town through a connection from Freshwater to the old Larkins Pond intake building near the Jerseyside pumphouse, that appears not to be currently in use. The Clarke's Pond watershed has an area of 2.90 km^2, as shown in Appendix A, which includes newly piped connections from two inside ponds, Barron Pond with a watershed area of 1.43 km^2 and Gull Pond with a watershed area of 0.98 km^2. This watershed contains approximately 59% of forested area, 27% of barren area, and 14% of lakes and wetlands area.

The Clarke's Pond water is pumped via a triplex submersible turbine pumping arrangement to three buried concrete tanks known as 1032, 418, situated in Argentia, and a concrete tank that was formerly a part of the independent Dunville water supply system. Water is also pumped to a glass lined, bolted steel tank installed in Freshwater in 2016. The Dunville system is now connected to the Clarke's Pond pumping station via a 300mm diameter PVC watermain. The water storage reservoirs, 1032 and 418, and the Argentia water distribution system were built during the construction of the American military base in the early 1940's. The primary water pipe network in the Clarke's Pond system consists of 250mm, 300mm and 350mm diameter water mains which generally follow Route 100, and the Argentia-Cape Shore highway, into Freshwater and Argentia. These water mains are approximately 50 years old. Tank 418 has 500,000 US gallons (1.89 million liters) of storage and tank 1032 has 360,000 US gallons (1.36 million liters) of storage. There is a connection between the Clarke's Pond and the Larkins Pond distribution systems to permit Clarke's Pond to serve as a backup if the Larkins Pond intake should freeze in the winter season or if water levels are low. This connection is normally closed except for emergency situations.

The Argentia military base also had a domestic freshwater system supplied from Argentia Pond and a seawater fire system from Argentia Harbour. The fire water system had an independent pipe network and a series of underground concrete storage tanks and pumps to deliver fire flows. It is our understanding that much of this system is still in place and in good condition, however not in use, but further investigations and tests will be needed to confirm.

2.2 LARKINS POND

The Larkins Pond water system presently supplies a population of approximately 1809 people in Jerseyside/Ferndale, Placentia Proper and Southeast Placentia. Southeast Placentia is fed Larkins Pond water via the Blockhouse booster pump system which re-doses the water with chlorine and pumps the water up to an underground concrete water storage tank having a volume of 108,000 US gallons (0.41 million liters). Water flows back from the tank via gravity flow when the pumps are not running.

The primary water pipe network delivering water from Larkins Pond through Placentia is 200mm diameter and a 300mm diameter pipe that extends up to the Southeast Placentia tank from the Blockhouse building.

The watershed area of Larkins Pond is 1.26 km^2, however it is lower than Clarke's Pond and connected via a natural brook with a control structure. This watershed contains approximately 60% of forested area, 26% of barren area, and 14% of lakes and wetlands area.

3.0 THEORETICAL DEMAND AND MEASURED FLOWS

The majority of the municipalities in the province of Newfoundland have excessive water leakage through their water distribution system due to aging infrastructure spread over a significant land mass with low density populations. Highly variable soil conditions, a high ground water table, extreme freeze/thaw cycles and aging infrastructure tax the longevity of the buried pipe systems. Many residents also 'bleed' water during the wintertime to prevent pipes from freezing. Excessive leaking water use places a huge strain on the available capacity of water supplies. It is common for Newfoundland municipalities to have leakage that is greater than the average daily water demand required for the day to day needs of the residents. These high flows result in a direct increase in operation and maintenance costs, and it dramatically reduces the life of the pumps, pipes, and other infrastructure.

To quantify the leakage and the excessive water demand component of the daily flow we must calculate the theoretical demand of the residents, any commercial, and industrial users and compare that demand to the provided actual measured flows recorded by the town's flow meters. The standard[2] average design flow per capita used is 340 liters per day per person. As well, the peak theoretical flow can be derived using peaking factors and the Harmon Formula in conjunction with the calculated theoretical average daily flow. This theoretical peak flow is computed to only illustrate the potential peak water demand on the system. As a note, the provided measured flow data analyzed for this report is from April 1st, 2023 to February 11th, 2024. Upon analyzing this data, there is little evidence of any seasonal or daily fluctuations for peak flow that would be apparent in a typical water distribution system. This indicates that

[2] *Guidelines for the Design, Construction and operation of Water and Sewerage Systems,* Government of Newfoundland and Labrador (2005)

there is considerable leakage in the system as the baseline flow of the system does not fluctuate like a typical system, a system that has normal leakage characteristics.

Upon determining the severity of the excessive flows, practical and sustainable measures for reducing the flow can be implemented. The following sections outline the theoretical and actual measured flows for Placentia's existing water systems. Summary data of the provided measured flows can also be seen in Appendix B.

3.1 CLARKE'S POND

The Clarke's Pond water supply is split between three regions specifically Freshwater, Argentia, and Dunville. At the Clarke's Pond Pumphouse, the total flow is individually metered for both Dunville and for Freshwater/Argentia. The average daily measured flow is currently 17.84 l/s for Dunville and 27.95 l/s for Freshwater/Argentia. Comparing this measured flow data to the calculated theoretical flow, shown in Table 1, Dunville is 134% greater and Freshwater/Argentia is 119% greater.

The regions of Dunville and Freshwater are solely comprised of residential development. The water flowing to Freshwater is to be metered separately so the flow to Argentia can be deduced, but the meter was currently inoperative at the time of the field investigation, therefore the flows will be combined in this report for those two areas. The area of Argentia is comprised of heavy industrial development with such tenants as Canadian Coast Guard, Marine Atlantic, Cenovus, Argentia Freezers & Terminals, Newco Metal & Auto Recycling Argentia, and so on. The provided metered flow data for the Cenovus activities in Argentia showed limited variance in water usage during a concrete pour (occurred April 1st to June 5th, 2023) compared to the usage throughout the rest of the year. From this flatline behavior, it can be inferred that there is leakage in the system between Clarke's Pond to the Cenovus site, as there should be a distinct peak in flow within the data during a concrete pour. Therefore, a peak industrial flow to Argentia cannot be determined.

Freshwater, Dunville, and Argentia have an approximate population of 742, 888, and 148 people respectively using the 2021 Census data as well as town provided data. A theoretical flow was determined for both residential and industrial use, as seen in Table 1 below. The industrial theoretical flow was determined by approximating the current daily water use of Husky Energy through the existing flow meter on their site, as well as including the past water usage provided by Argentia Freezers and Terminals.

3.2 LARKINS POND

The Larkins Pond water supply essentially services three regions; Ferndale/Jerseyside, Placentia Proper and Southeast Placentia. There are two flow meters in the Larkins Pond Pumphouse. One flow meter measures the total flow out of Larkins Pond while the other flow meter measures the flow to Jerseyside/Ferndale. The flow to Placentia Proper is the difference between the two meter readings which includes the flow to Southeast Placentia.

The average daily measured flow to Jerseyside/Ferndale is approximately 6.36 l/s while the flow to Placentia Proper is 39.58 l/s which includes approximately 8.34 l/s to Southeast Placentia. The total approximate population for Jerseyside/Ferndale, Placentia Proper and Southeast Placentia is 395, 1151 and 263 people respectively using the 2021 Census data as well as town provided data. Calculating the theoretical flow and comparing them to the actual measured flows it is noted that the average daily measured flow to Jerseyside/Ferndale is approximately 122% higher than calculated, the flow to Placentia Proper is 91% higher than calculated and the flow to Southeast Placentia is 156% higher than calculated.

The theoretical and measured flows for both systems have been tabulated below for your reference.

Table 1: Theoretical Flows versus Actual Flows

Water Supply	Sub Areas	Population *using 2021	Average Daily Flow (Theoretical)		Peak Flow (Theoretical)		Measured (Actual) Flow		% Difference Actual vs. Theoretical Flow
			GPM	l/s	GPM	l/s	GPM	l/s	%
Clarke's Pond		1480	168.46	10.63	360.80	22.76	725.82	45.79	125
	Freshwater	493	30.77	1.94	122.39	7.72	443.07	27.96	119
	Argentia	99	6.15	0.39	26.13	1.65			
	Industrial/Commercial Use [1]	-	76.14	4.80	-	-			
	Dunville	888	55.39	3.49	212.29	13.39	282.75	17.84	134
Larkins Pond		1809	275.53	17.38	436.37	27.53	860.34	54.28	103
	Jerseyside/Ferndale	395	24.62	1.55	99.08	6.25	100.88	6.37	122
	Placentia Proper	1151	71.80	4.53	269.96	17.03	627.29	39.58	91
	Commercial Use [2]	-	162.70	10.27	-	-			
	Southeast Placentia	263	16.41	1.04	67.32	4.25	132.17	8.34	156
Totals		3289	444.00	28.01	797.17	50.29	1586.16	100.07	113

Notes:
[1]Clarke's Pond Industrial/Commercial Use includes average daily 2023/2024 measured flow meter data for Cenovus consumption, as well as past 2014 Argentia Freezers and Terminals usage data.
[2]Larkins Pond Commercial Use includes the theoretical calculations for the Arena chiller, Harold Hotel, and the Health Centre.

In a typical water system, the diurnal patterns and/or seasonal variations should be seen within the flow data. In the case of Placentia's system, the data was provided as a singular total daily flow, so the diurnal patterns could not be determined without having more detailed hourly data. In terms of the seasonal variations, the average daily measured flow for each respective season showed little variation between them. A typical system would likely show less water usage during the winter/fall months, and during the spring/summer months, the usage would increase. This type of behavior is a clear indicator of leakage in the system.

4.0 FIRE FLOW REQUIREMENTS AND IMPACT

Along with evaluating the Placentia water supply system for daily use, the reliability of the infrastructure will also need to support the future fire demand associated with the new Pattern Energy industrial activity in Argentia. To quantify and estimate the future effective required fire flow water demand, the criteria outlined by the Canadian Classification Standard for Public Fire Protection (CCSPFP)[3] and the Fire Underwrites Survey guideline will be followed.

4.1 PATTERN ENERGY FUTURE FIRE FLOW

The Fire Underwriters Survey (FUS) uses the following criteria of the building to determine the Required Fire Flow (RFF): the type of construction of the building, the total effective floor area, the type of occupancy and contents, the type of automatic sprinkler protection, and the exposure to surrounding buildings. Where specific building details were not available for the future Pattern Energy plant site, a conservative estimate for the building materials, fire separations, and contents was assumed. From the 'Concept Plot Plan' (2023) provided by Pattern Energy, it was determined that the largest building on the plant site was the Electrolyser building, with a footprint area of 5,040 m^2. Therefore, for the purpose of these calculations, the plant site RFF will be based off this building. The assumptions for this building include that the building will be made from noncombustible construction, it will be two storeys high, it will be of high hazard industrial occupancy, and there will be a fully automatic sprinkler protection system in accordance with NFPA 13. Considering these assumptions, the estimated RFF will be 221 l/s for a minimum duration of 2.8 hours. This implies a fire water volume of over 2.23 million liters, or 591,000 US gallons, which would place a high demand on the regional water supply especially if water treatment is implemented by the Town in the future.

At this stage, knowing that this plant site will require an estimated 221 l/s of water for 2.8 hours, additional investigation and acquiring more information is necessary to comprehensively assess how this fire flow impacts the overall Town of Placentia's water system. It appears that the system has sufficient volume to supply the estimated volume, however it is unknown if the existing pipe network has the ability to deliver the required flow rate. A complete hydraulic model of the water supply and distribution system could provide the insights needed to

[3] *Water Supply for Public Fire Protection,* Fire Underwriters Survey (2020)

determine whether the current system can accommodate flows of this size or if other options need to be assessed for this future demand.

A potential option to accommodate this amount of required fire flow is an onsite fire water tank, as this type of storage could alleviate the regional water system in the event of an emergency. For this to be a viable option, it will need to be confirmed that the fire water tank could be filled within 8 hours of an emergency event as required by The National Fire Protection Association (NFPA).

5.0 AVAILABLE YIELD OF THE PROPOSED REGIONAL WATER SUPPLY

To determine the low flows and if there is sufficient water yield for the region, the watersheds were outlined for each water supply. The Clarke's Pond water supply has the largest watershed. The watershed has the reserve from Gull Pond and Barron Pond which makes it a much larger supply than Larkins Pond.

5.1 WATERSHED YIELD – THE 2017 LOW FLOW ESTIMATIONS CALCULATOR ANALYSIS

The available yield of watersheds in the province of Newfoundland and Labrador may be completed using the current Low Flows Estimation Calculator as published in the 2017 user guide 'Estimation of Low Flows for the Province of Newfoundland and Labrador'[4] by the Department of Municipal Affairs and Environment Water Resources Management Division. The analysis used to produce the Low Flow Estimation Calculator takes into consideration the historical Environment Canada gauged flow data as well as the physiographic characteristics of the watershed including the area of the watershed, area of the lakes, marshes and ponds, the total forested area, and the area of the barrens. Using this physiographic data, and the drainage area, regression equations were developed to compute the low flows for a watershed in a homogeneous region.

The above noted parameter of the watershed drainage area is entered into an excel spreadsheet and the output lists the 2, 10, 20, 50, and 100 year low flows for 1 and 7 day return

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[4] *Estimation of Low Flows for the Province of Newfoundland and Labrador,* Government of Newfoundland and Labrador (2017)

periods. For the purpose of the analysis outlined below, the worst case scenario of 100 year - 7 day low will be used. If the proposed watershed has the capacity to survive the 100 year - 7 day low flow, which is the equivalent of the driest week recorded for a 100 year return period, then the regional water supply is viable.

Based on the current measured daily flows, the total regional water demand placed on both Clarke's and Larkins Pond is 100.07 l/s as noted in Table 2 below. Three scenarios were considered to analyze with the Low Flows Estimation Calculator. The first scenario only considers Clarke's Pond and the immediate watershed and excluded the reserves of Gull Pond, Barron Pond, and Larkins Pond. The second scenario includes Clarke's Pond watershed area as well as the watershed areas of both Gull and Barron Ponds to represent the recent interconnection upgrades completed in 2022. The third scenario includes Clarke's, Barron, Gull, and Larkins Pond as one combined area in the event that all ponds would need to be used to supply the region. The resulting 100 year – 7 day low flows for each of the described scenarios are shown in Table 2 below.

Using the computed low flows, a comparison can be made to the measured regional demand flow to determine the water deficit and the resulting drawdown of the pond water levels. This drawdown is necessary to predict and determine if the capacity of the ponds can accommodate the daily water demand during a low flow event. If the drawdown forces the water level to be below the water intake, the Town could be in an emergency situation with no way to draw water out of the ponds. To calculate the drawdowns on the ponds over the 7-day low flow period, the resulting water deficit is divided by the overall pond areas. Table 2 below outlines the low flow calculator analysis results for the watershed scenarios noted above including the low flows and the resulting drawdowns on the ponds.

Table 2: **100 year – 7 day Low Flow Summary for each Regional Watershed Scenario**

	Watershed	Watershed Area (km^2) Combined	Pond Area (km^2) Individual	Pond Area (km^2) Combined	Regional Demand (l/s)	Low Flow 100yr-7day (l/s)	Water Deficit (l/s)	Drawdown on Ponds (m)
1	Clarke's Pond - 2.90km²	2.90	0.232	0.232	100.07	1.17	98.9	0.258
2	Gull Pond - Barron Pond - 2.41km²	5.31	0.341	0.573	100.07	2.26	97.81	0.103
3	Larkins Pond - 1.26 km²	6.57	0.319	0.892	100.07	2.85	97.22	0.066

5.2 WATERSHED YIELD – LOW FLOW ANALYSIS USING HISTORICAL DATA

To gain better insight on the watershed and to estimate the typical low flow for the region of Placentia, an additional analysis was done using the historical gauged flow data of the Northeast River. The historical hydrometric station data on the Northeast River near Placentia was chosen to analyze, as the surrounding topography would be the most similar to the Clarke's Pond watershed.

Compiling and using the daily discharge data[5] from the years 1979 to 2019, the minimum 1-day and 7-day low flow were determined for each year and from that, a flow per area factor was computed to relate back to the project specific watershed area. The tables below in Figure 2 show a side-by-side comparison between the results of the superseded low flow calculator, the updated 2017 low flow calculator, and a 40-year return period from historical flow data of the Northeast River. Since the historical data provides a total of 40 years, and the two low flow calculators do not provide a 40-year return period, those flow values were interpolated in the interest of having a better comparison between the three data sources.

Region Clarke's/Gull/Barron Ponds
Drainage Area 5.31 km^2

2014 Low Flow Calculator

T	Low Flow (L/s)	
(year)	1-day	7-day
2	13.17	16.14
10	6.14	7.69
20	5.05	6.46
40	*3.96**	*5.88**
50	3.41	5.59
100	2.32*	3.88*

2017 Low Flow Calculator

T	Low Flow (L/s)	
(year)	1-Day	7-Day
2	12.77	15.85
10	6.04	7.65
20	4.41	5.65
40	*3.27**	*4.26**
50	2.70	3.57
100	1.63	2.26

Historical Analysis from Northeast River Flow Station Data

T	Low Flow (L/s)	
(year)	1-Day	7-Day
2	16.62*	18.80*
10	9.74*	16.50*
20	8.38*	13.63*
40	*7.26*	*7.88*
50	6.71*	7.38*
100	5.63*	5.87*

Notes:
* Interpolated or extrapolated value

Figure 2: **Low Flow Results from Three Different Analyses**

Using the calculated low flow values above for the three various analyses, a summary of the resulting water deficit and drawdown on the ponds can be computed. The results are shown in Table 3 below.

[5] *Water Level and Flow* – Government of Canada, Environment Canada (2023)

Table 3: 40 year – 7 day Low Flow Summary for Each Low Flow Analysis Type

	Watershed	Watershed Area (km²)	Pond Area (km²)	Regional Demand (l/s)	Low Flow 40yr-7day (l/s)	Water Deficit (l/s)	Drawdown on Ponds (m)
	Clarke's - Gull Pond - Barron Pond - 5.31km²						
1	2014 Low Flow Calculator	5.31	0.573	100.07	5.88	94.19	0.099
2	2017 Low Flow Calculator	5.31	0.573	100.07	4.26	95.81	0.101
3	Historical Data Analysis - Northeast River	5.31	0.573	100.07	7.88	92.19	0.097

Comparing the results, it can be seen that the drawdown on the ponds during the 40 year – 7 day low flow event is only marginally different between each of the analyses. Although using the current 2017 Low Flow Estimations Calculator provides a larger drawdown on the ponds during this event, it is comparable to the drawdown needed on the ponds based off the historical data of the Northeast River near Placentia as there is only a 4mm difference. Therefore, there can be greater confidence in using the current 2017 Low Flow Estimations calculator to compute the low flows in the Placentia region.

From the initial findings of only analyzing the 7-day low flow and the resulting drawdowns outlined in the sections above, it can be said that the Placentia region water system would have sufficient water yield, with the drawdowns on each pond predicted to be approximately 0.1 metres. Although, it is important to note that there are certain limitations to analyzing the pond drawdown the way it is described in the above sections. It assumes that the pond will remain at a constant full level throughout the year and will only have a drawdown during the 7-day low flow scenario. This is unrealistic considering the dynamic nature of how watersheds behave with the varying precipitation, infiltration, evaporation, and soil types for example. Typically, the watersheds would replenish the ponds during the wettest months and may be more depleted during the warmer months. To further investigate and quantify a realistic low flow scenario as it relates the remainder of the yearly duration, it would be highly suggested that a hydrological water model, using software such as XPSWMM, be completed for the area surrounding the gauge station on the Northeast River. As mentioned previously, this data provides a comparable correlation from a topographical standpoint to the Placentia region. By using the recorded flow data within a model, a more accurate variable flow per area factor can be deduced to relate back to the project specific pond areas. This model would provide confirmation and a greater confidence that the regional water system has sufficient yield for all users in the area.

6.0 RECOMMENDATIONS

The initial assessments outlined within this report suggest that the Placentia water supply appears to have sufficient water yield to provide for the current demand as well as for the future demand from the Pattern Energy Renewables project. However, further modelling is essential to confirm these findings. Along with the current daily flow data showing excessive leakage within many regions of Placentia, it is vital to carry out a strategic leak detection plan to optimize and upgrade the current water system, which would overall improve the system for the future.

The following sections detail the recommendations that stemmed from the initial findings.

6.1 COMPLETE PHASE 2 STUDY

Looking forward to Phase 2, the study will build upon the findings in this initial Phase 1 report to gain a deeper understanding of the current water supply system and its potential to support the addition of the Pattern Energy Renewables project. Phase 2 will include compiling a water model of the existing supply and distribution system, completing further investigations in the field to determine the location and the extent of leakage, as well as gathering relevant field information through a topographic survey, and preparing a quotation package for potential water meter installations.

6.2 LEAK DETECTION

With the existing system experiencing major water losses, getting the leakage under control will result in a more reliable water source for the planned Pattern Energy Renewables project. Further analysis will be required to determine the extent and locations of leakage in the existing system, which is outlined in the sections below.

6.2.1 Flow Analysis Field Program

This program is a systematic approach by isolating and controlling flow in specific regions of the water system by using the existing flow meters, tank levels and SCADA information. This isolation allows the water usage to be monitored in real time to determine the areas of severe leakage. This will provide valuable knowledge to aid in forecasting and focusing on the areas that need more attention to establish and install flow meters for further leak detection efforts.

6.2.2 Flow Meter Installation

Upon completion of the Flow Analysis Field Program, as described in the above section, a flow metering program is recommended. Flow meters with LED displays and SCADA ready connections, housed in concrete chambers will be installed in strategic locations to deliver data to identify areas that are suspected to have higher leakage than others.

It is recommended that these flow meters, along with the existing flow meters, be connected to the Town SCADA system to allow remote monitoring and trending analysis to make troubleshooting system issues much easier.

6.2.3 Leak Detection/Repair Program

Once the leaks are identified, further technologies can be deployed to pinpoint the exact source of leaks. There are different technologies available for leak detection that will be evaluated based on the specific needs. These technologies include Noise Loggers, Listening Sticks, Smart Water Meters, Thermal Imaging, In-Pipe, Fiber Optics, Satellite and Ground Penetrating Radar.

Once leaks are identified, there are likely two probable solutions:

Solution 1: Excavate to expose the water infrastructure and perform an inspection to ensure it is not beyond its useful life. If the infrastructure appears to be in good condition, perform a spot repair at the source of the leak.

Solution 2: If the infrastructure is beyond its useful life, full system replacement will likely be recommended. This is similar to the undertaking that the Town of Placentia has already completed in parts of Freshwater and Dunville.

6.3 POSSIBLE EXPANSION OF THE WATER SUPPLY

Expansion of the water supply is another option that will be analyzed in Phase 2 of the study should it be required after conducting further engineering efforts, such as the results of the water modeling or leak detection programs. There are ponds in the area, such as Argentia Pond, Hickeys Pond, and an unnamed pond, as indicated on the drawing in Appendix A, that could be utilized to supplement the existing water supply to increase the available yield of the water source. It should be noted that the option of Argentia Pond would require significant mechanical upgrades/installation, as well as long term operating and maintenance costs. The options of incorporating these new water sources will need to be further determined, but any new water source that is developed will need to be piped and potentially pumped so that it enters the Clarke’s Pond Watershed. This is necessary to align with the one source treatment goal of the Town of Placentia.

7.0 CONCLUSION

The analyses conducted during this Phase 1 study provided crucial insights into the current state of the water supply system in the Town of Placentia, laying the foundation to guide the appropriate next steps.

To get an overall sense of how much water the town should be using daily, the theoretical flow was calculated and compared to the actual 2023/2024 metered flow data collected from the town. The results of the comparison show that there is significant leakage throughout the town, in some areas more than others, with the biggest difference being in the communities of Dunville and Southeast Placentia. The severity and locations of the leakage, however, cannot be confirmed without further investigation including installing flow meters and conducting leak detection. The Town expects to proceed to tender in the early spring with the next phase of the Dunville Water System Replacement, thereby potentially addressing a significant portion of the Dunville leakage.

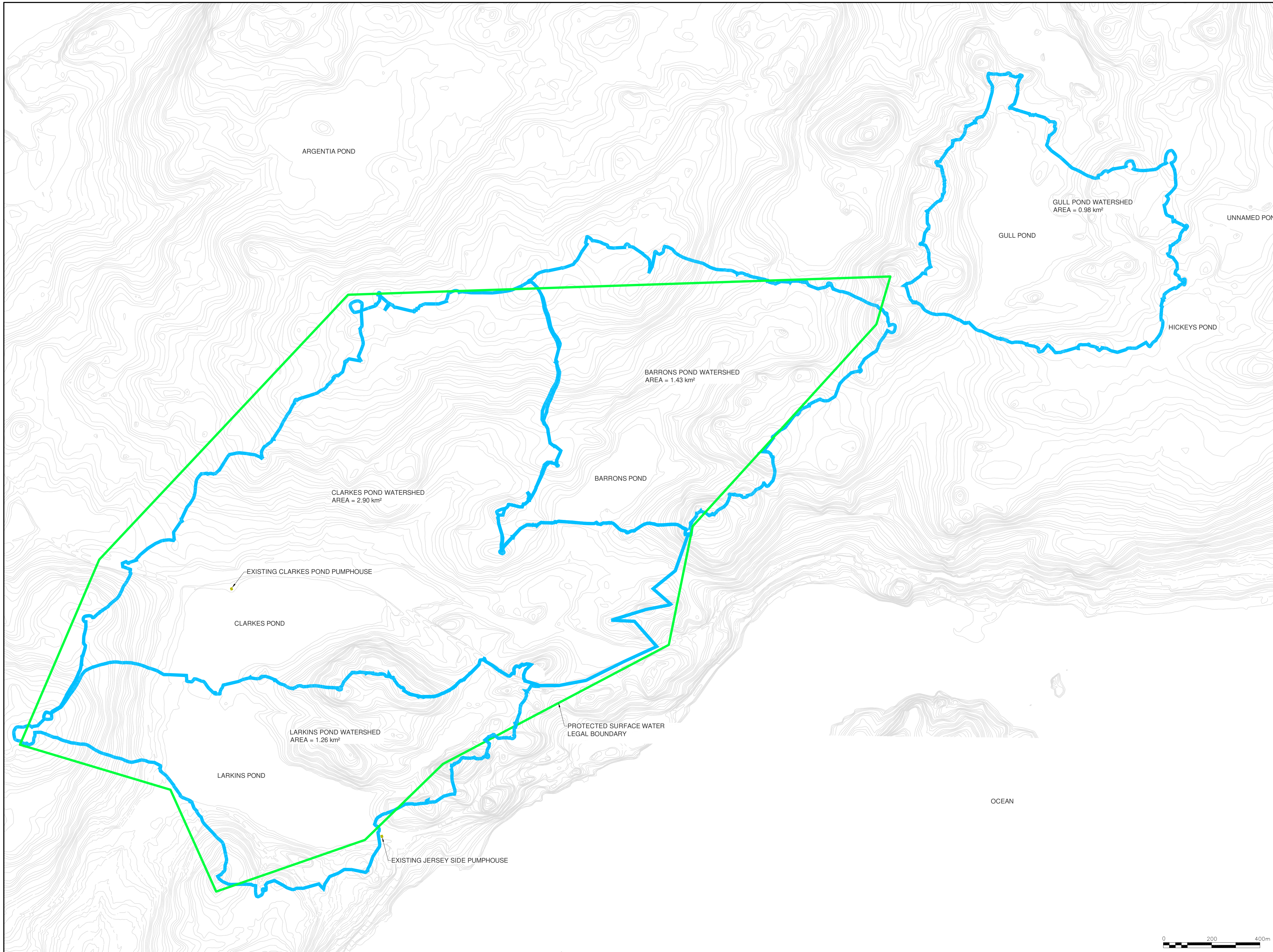
Along with the daily water consumption, the water supply must be able to maintain the required fire flow. In the case of Pattern Energy's Argentia Renewables plant site, the required fire flow was based off the largest building, the Electrolyser. Using the standard criteria outlined by the FUS, the total fire flow was determined to be 221 l/s of water for 2.8 hours. With the information known at this time, it is not possible to say with certainty that the current system will be able to support this amount of water demand if a fire event is to occur. For this reason, it is suggested that further analysis be done through a water distribution model to provide more accurate recommendations regarding the impact the required fire flow will have on the system. Another viable option would be to utilize an onsite fire water storage tank, which could lessen the immediate impact on the water system in the event of an emergency.

The catchment area of both Clarke's and Larkins Ponds were defined to get an estimation of the regional low flows into the pond using the current estimations calculator for a 100 year – 7 day return period. This low flow value was extremely low that it resulted in a drawdown of the ponds to sustain the current regional daily flow demand of 97.94 l/s. Although the low flow described above is the most current method for estimation, an additional analysis was done on the Northeast River near Placentia using the historical daily discharge data from the years 1979 to 2019. This resulted in a 40 year – 7 day low flow that was higher compared to the current estimation calculator. Although, the simplicity of these calculations does not account for the dynamic nature of a typical watershed. For this reason, it is recommended that a further water model, using XPSWMM, be conducted using the Northeast River data to correlate back to the Placentia ponds.

The recommendations outlined aim to address existing issues and enhance the overall water supply system. Firstly, an evaluation comparing theoretical flow data to measured flow indicates significant losses in the existing system due to leakage. To remedy this, it is crucial to implement measures to control and identify the extent and locations of the leakage within the system. A recommended solution is the initiation of a flow analysis field program which uses the existing infrastructure to control and isolate the system to identify the areas of leakage. Once identified, a flow metering program can be implemented by strategically placing new flow meters within the system to gather data, to enable the identification of areas with suspected higher leakage. From there, specific leak detection technology can be utilized to pinpoint the exact locations so that they may be repaired. Additionally, if required, the possibility of using the nearby ponds to augment the available yield of source water will be explored.

Overall, from these preliminary analysis results described within this report, it can be determined that the current water supply does provide a sufficient yield for the current water demand and the future water needs of Pattern Energy's Renewables project. However, further investigations will need to be made to further confirm these initial findings as there is leakage currently in the system. Moving forward, the attention will be directed at continuing the investigation of Placentia's water supply and distribution system by conducting field inspections to identify areas of leakage and by completing a water model to understand the capabilities and limitations of the system. This will provide valuable and necessary data to analyze the system deeper to provide any potential upgrade options. These recommendations collectively aim to ensure the efficiency, reliability, and sustainability of the water supply system in the Town of Placentia for the future.

APPENDIX A: Watershed Areas



CONTRACTOR MUST VERIFY ALL DIMENSIONS AND CONDITIONS ON SITE BEFORE PROCEEDING WITH ANY PORTION OF THIS WORK. REPRODUCTIONS OF THIS DRAWING MAY HAVE BEEN REDUCED OR ENLARGED. REFER TO GRAPHIC SCALE. DO NOT SCALE DRAWINGS FOR CONSTRUCTION.

A - PLAN, SECTION, ELEVATION, OR DETAIL No.
B - No. OF DRAWING WHERE 'A' IS ON SITE PLAN
C - No. OF DRAWING WHERE 'A' IS DETAILED

No.	REVISIONS	APP	DWN	DATE
A	ISSUED FOR REPORT			24/03/08

NORTH:

STAMP: REGISTERED PROFESSIONAL ENGINEER, PEG Newfoundland and Labrador, VANESSA L. BARRY, SIGNATURE, DATE 24/03/08, NEWFOUNDLAND & LABRADOR

Progressive Engineering & Consulting Inc.

PERMIT STAMP:

PROVINCE OF NEWFOUNDLAND AND LABRADOR
PERMIT HOLDER
This Permit Allows
PROGRESSIVE ENGINEERING & CONSULTING INC
To practice Professional Engineering in Newfoundland and Labrador.
Permit No. as issued by PEG N0566 which is valid for the year 2024

OWNER/CLIENT NAME:

PATTERN ENERGY

PROJECT TITLE:

PLACENTIA WATER SUPPLY STUDY PLACENTIA, NL

DRAWING TITLE:

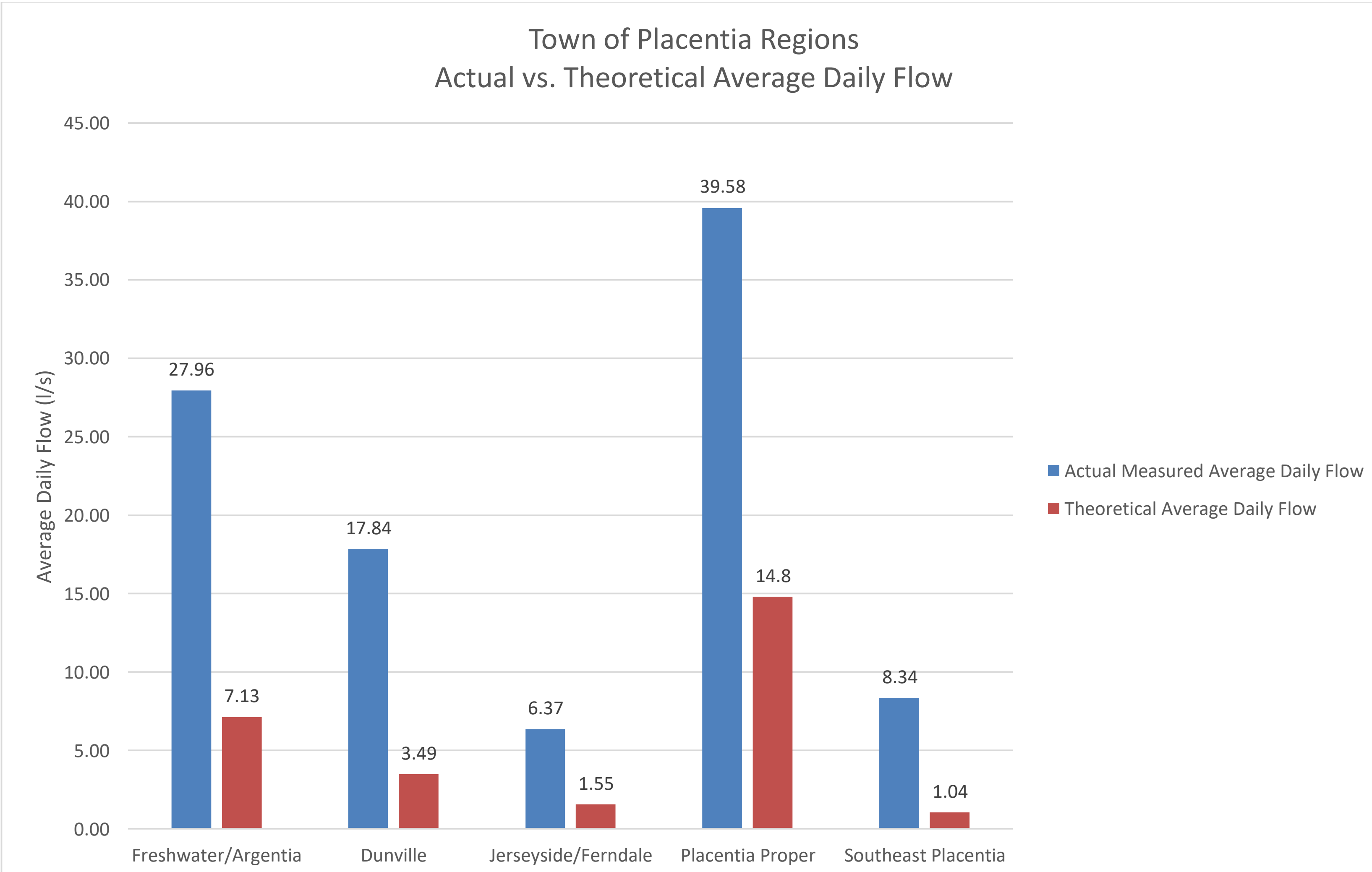
WATER SHED AREAS

DRAWN BY:	DESIGNED BY:	APPROVED BY:
J.D.	J.D.	

TI-MI:	DATE:	SCALE:
N/A	MAR 2023	AS SHOWN

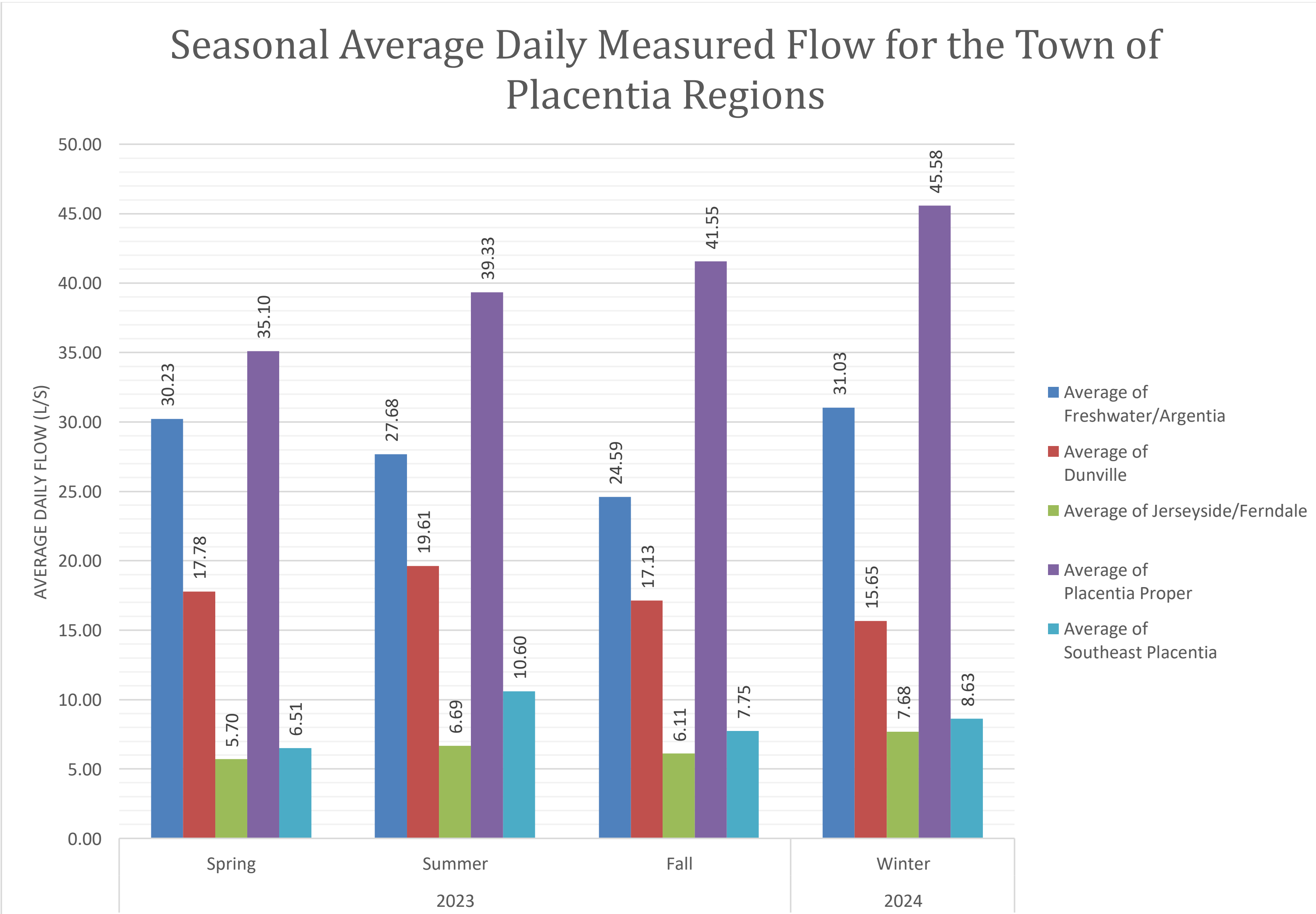
PROJECT No:	DRAWING No:	REV:
2024-002	SK-1	A

APPENDIX B: SUMMARY OF MEASURED FLOW DATA


Town of Placentia Regions
Actual vs. Theoretical Average Daily Flow
Average Daily Flow (l/s)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
27.96
7.13
17.84
3.49
6.37
1.55
39.58
14.8
8.34
1.04
Freshwater/Argentia
Dunville
Jerseyside/Ferndale
Placentia Proper
Southeast Placentia
Actual Measured Average Daily Flow
Theoretical Average Daily Flow

Seasonal and Monthly Average Daily Measured Flow for the Town of Placentia Regions

	Average of Freshwater/Argentia	Average of Dunville	Average of Jerseyside/Ferndale	Average of Placentia Proper	Average of Southeast Placentia
2023	**27.49**	**18.18**	**6.16**	**38.66**	**8.30**
Spring	**30.23**	**17.78**	**5.70**	**35.10**	**6.51**
Apr	30.04	16.91	5.98	36.90	6.17
May	28.81	18.26	5.65	32.69	6.15
Jun	31.88	18.17	5.47	35.78	7.23
Summer	**27.68**	**19.61**	**6.69**	**39.33**	**10.60**
Jul	29.11	18.78	5.72	39.01	10.27
Aug	26.59	23.42	7.30	41.70	11.29
Sep	27.33	16.55	7.06	37.15	10.23
Fall	**24.59**	**17.13**	**6.11**	**41.55**	**7.75**
Oct	23.84	16.31	5.93	40.17	7.56
Nov	24.28	17.88	6.01	42.54	7.84
Dec	25.63	17.22	6.37	42.00	7.85
2024	**31.03**	**15.65**	**7.68**	**45.58**	**8.63**
Winter	**31.03**	**15.65**	**7.68**	**45.58**	**8.63**
Jan	31.37	16.16	7.31	45.09	8.51
Feb	30.10	14.21	8.73	46.96	8.98
Overall Average (l/s)	**27.96**	**17.84**	**6.37**	**39.58**	**8.34**

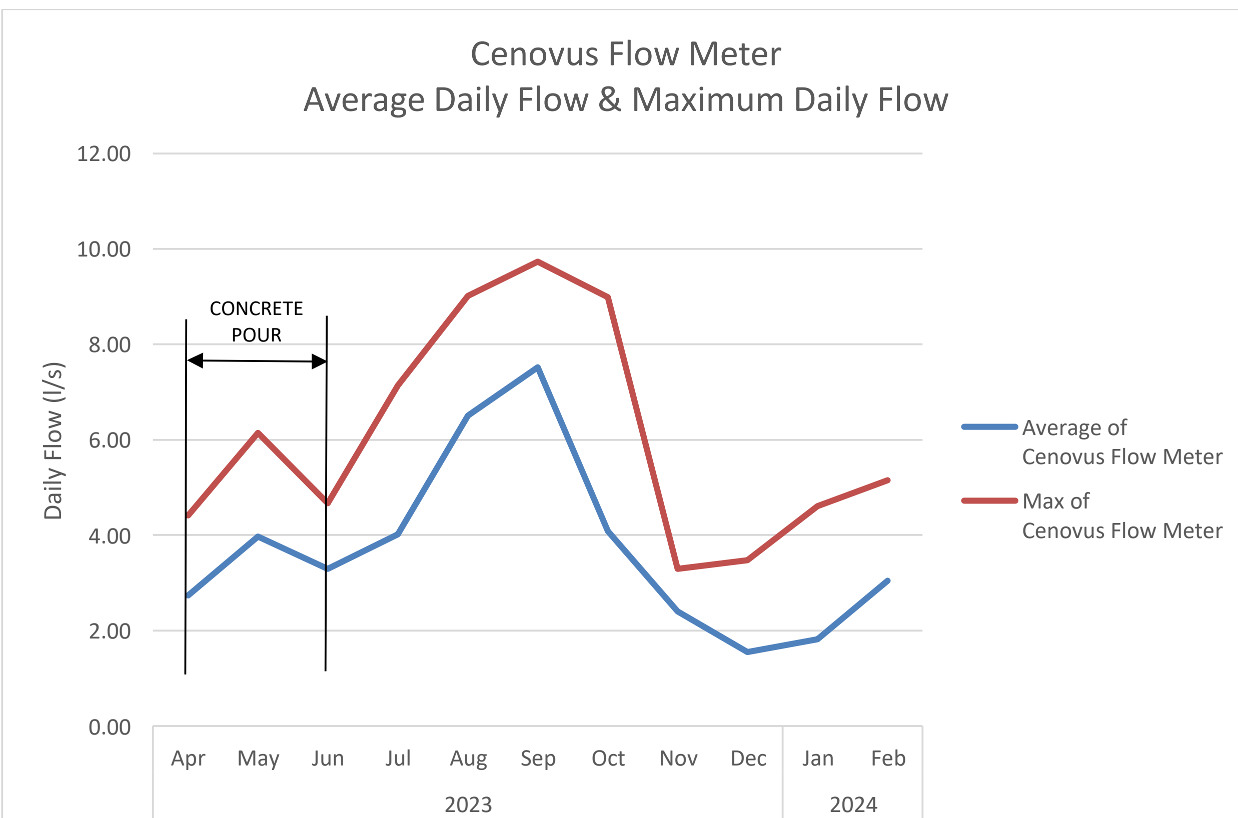

Seasonal Average Daily Measured Flow for the Town of Placentia Regions
AVERAGE DAILY FLOW (L/S)
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
30.23
17.78
5.70
35.10
6.51
27.68
19.61
6.69
39.33
10.60
24.59
17.13
6.11
41.55
7.75
31.03
15.65
7.68
45.58
8.63
Spring
Summer
Fall
Winter
2023
2024
Average of Freshwater/Argentia
Average of Dunville
Average of Jerseyside/Ferndale
Average of Placentia Proper
Average of Southeast Placentia

Cenovus Flow Meter

Average Daily Flow & Maximum Daily Flow

	Average of Cenovus Flow Meter	Max of Cenovus Flow Meter
2023		
Apr	2.73	4.41
May	3.97	6.15
Jun	3.29	4.66
Jul	4.02	7.14
Aug	6.51	9.01
Sep	7.52	9.73
Oct	4.08	8.99
Nov	2.40	3.29
Dec	1.55	3.47
2024		
Jan	1.82	4.60
Feb	3.04	5.15
Grand Total (l/s)	**3.76**	**9.73**

*Latest concrete pour occurred from April 1st, 2023 to June 5th, 2023 (indicated by red text)



Appendix B Climate Change Projections for Placentia, NL

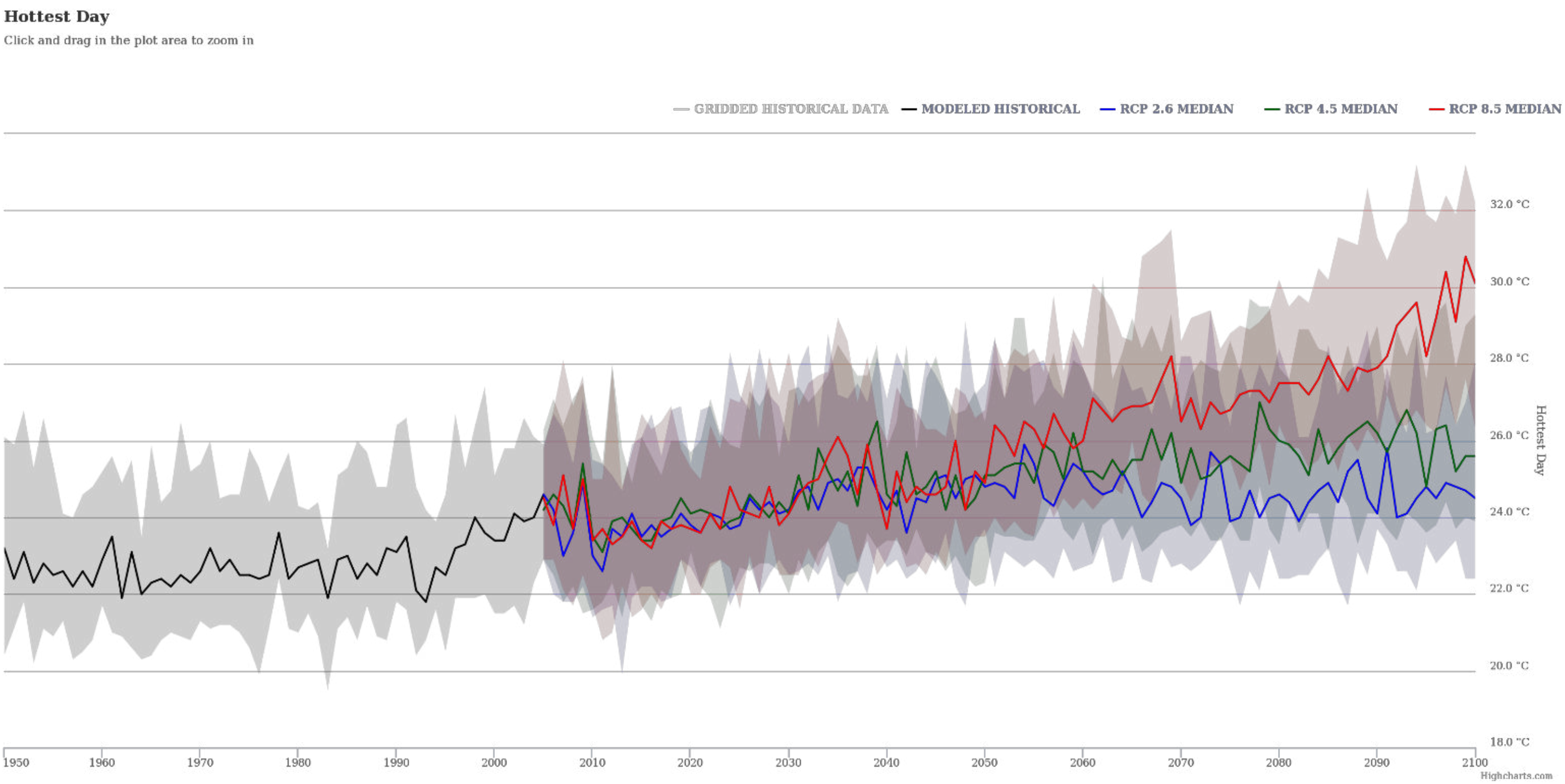


Figure 1 **Hottest Day Climate Change Projection.**

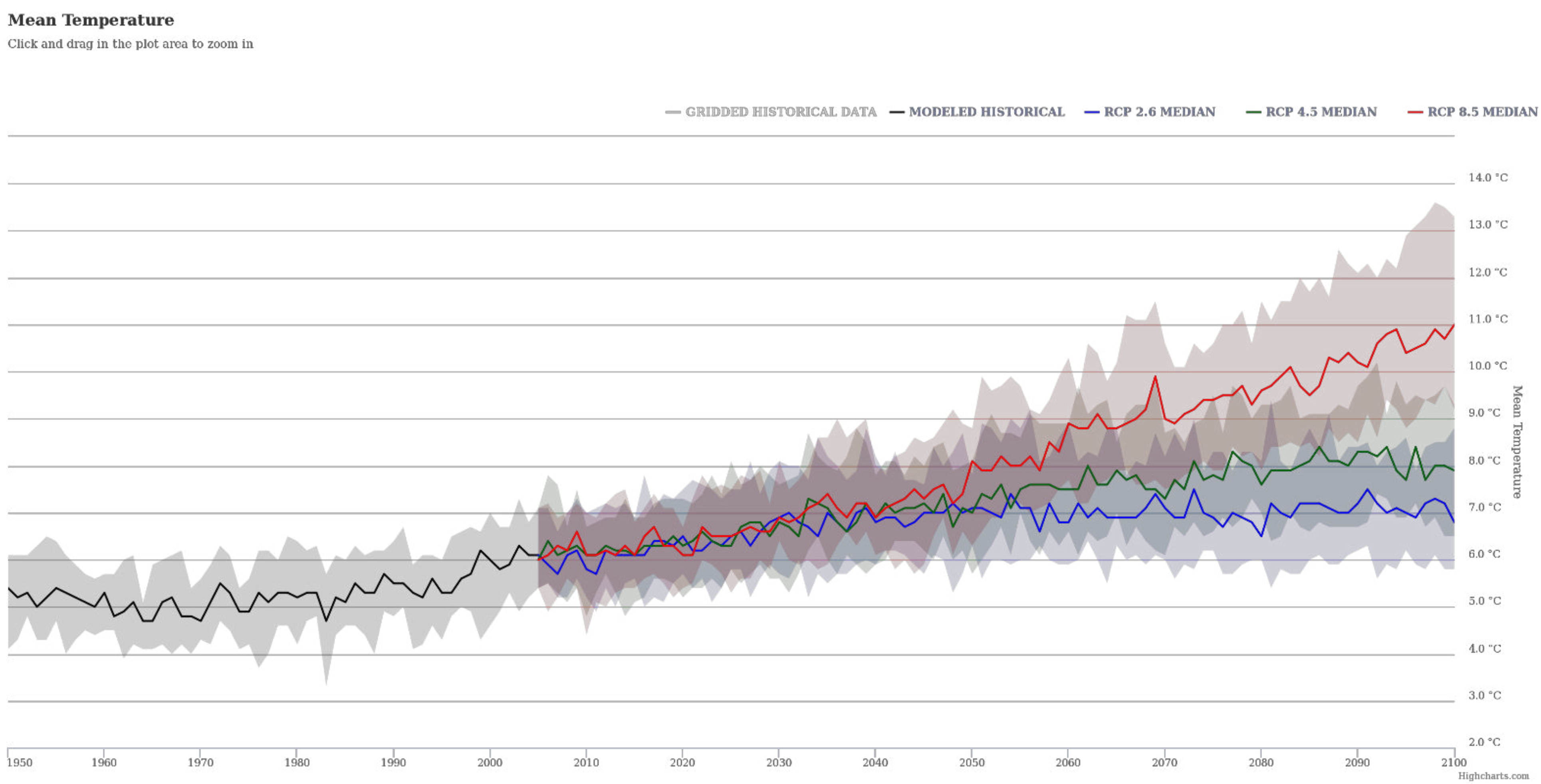


Figure 2 **Mean Temperature Climate Change Projection.**

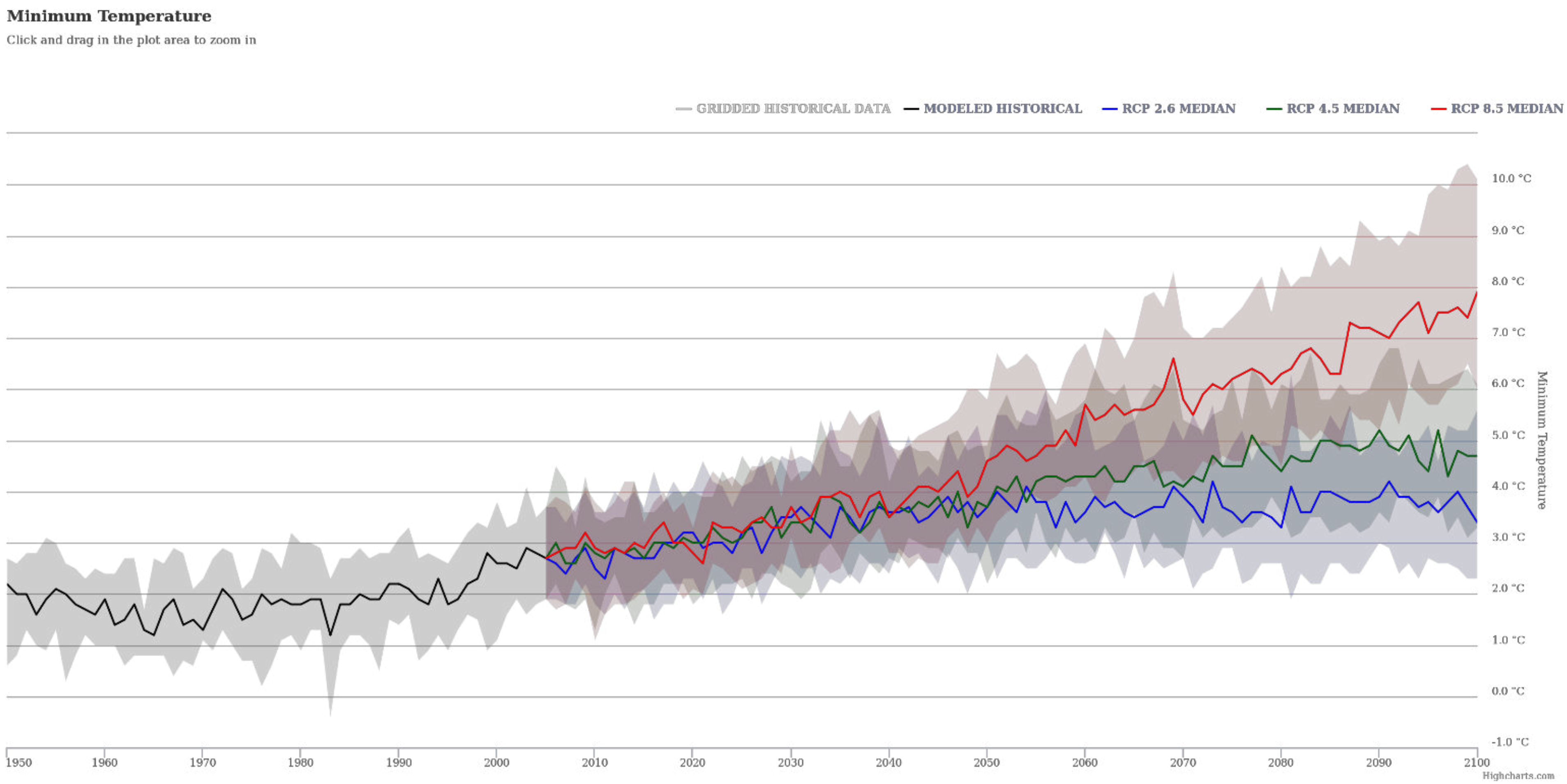


Figure 3 Minimum Temperature Climate Change Projection.

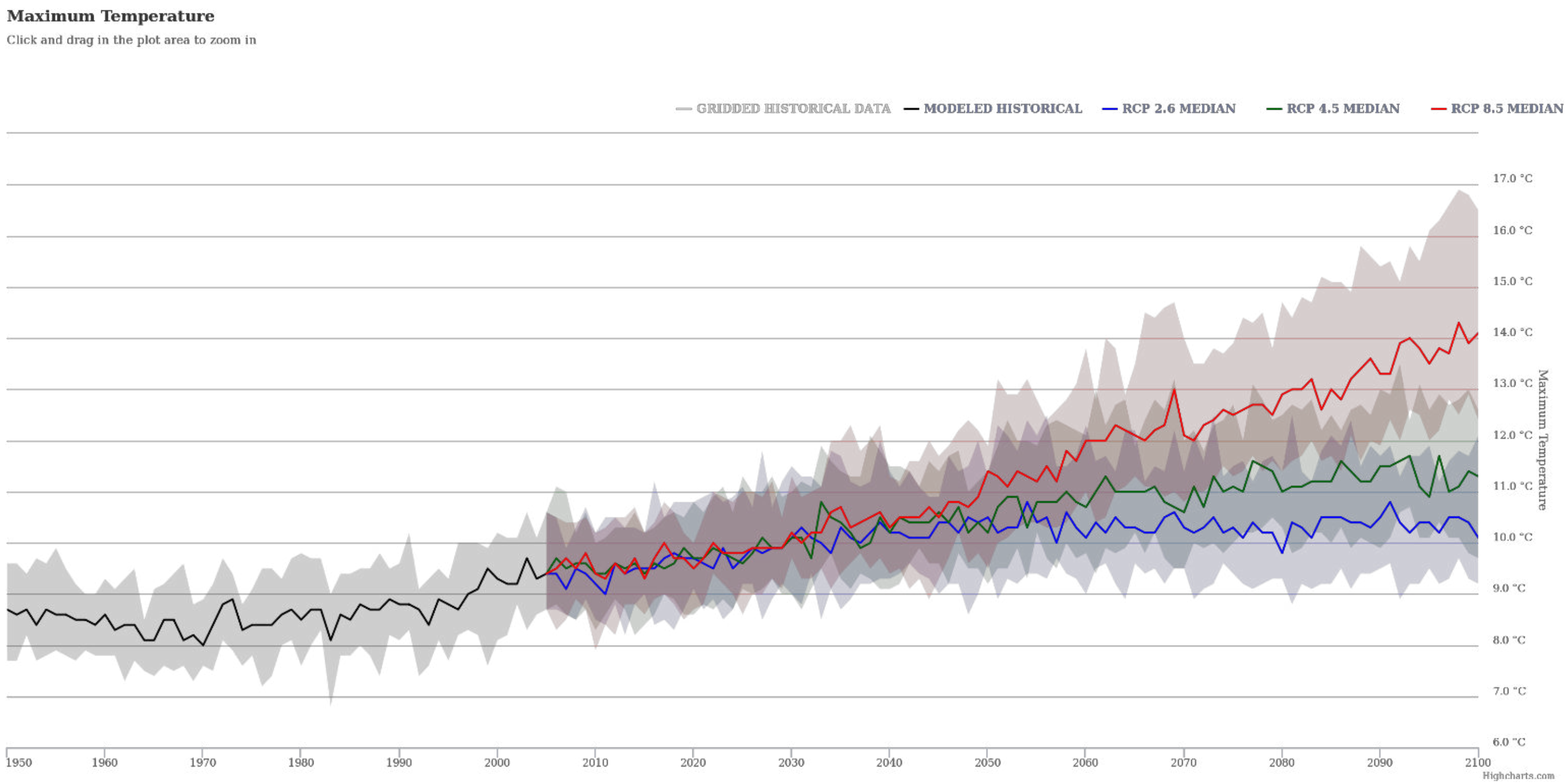


Figure 4 **Maximum Temperature Climate Change Projection.**

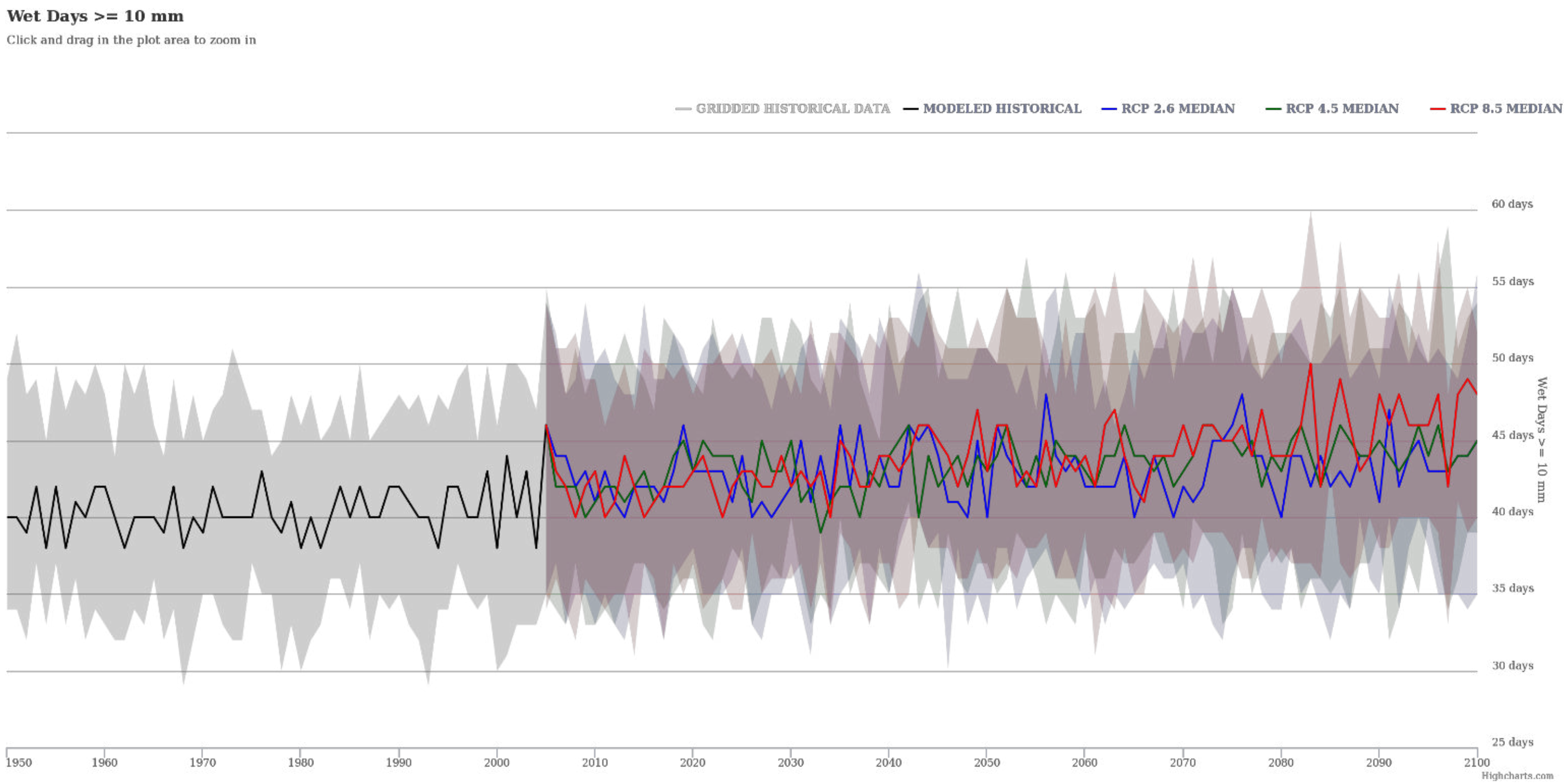


Figure 5 Wet Days ≥ 10 mm Climate Change Projection.

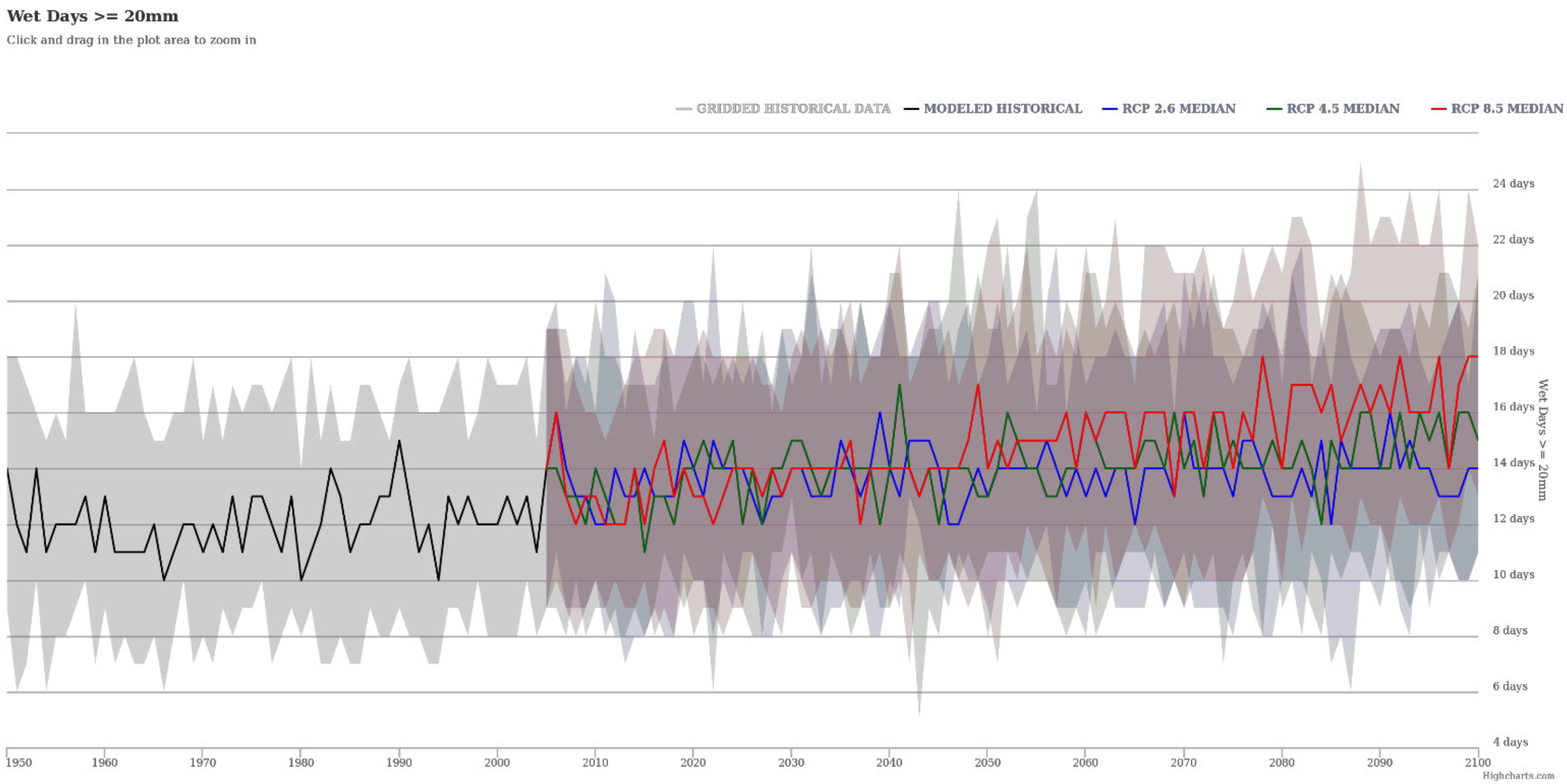


Figure 6 Wet Days ≥ 20 mm Climate Change Projection.