LAKE MANITOBA LAKE ST. MARTIN

OUTLET CHANNELS PROJECT

MANITOBA TRANSPORTATION AND INFRASTRUCTURE

Groundwater Management Plan

June 30, 2022

Manitoba
Transportation and Infrastructure

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DISCLAIMER

This document was developed to support the Environmental Management Program (EMP) for the Lake Manitoba and Lake St. Martin Outlet Channels Project (the Project). It has been prepared by Manitoba Transportation and Infrastructure as a way to share information and facilitate discussions with Indigenous rights-holders, stakeholders and the public. It has been prepared using existing environmental and engineering information and professional judgement, as well as information from previous and ongoing public and Indigenous engagement and consultation. The contents of this document are based on conditions and information existing at the time the document was prepared and do not take into account any subsequent changes. The information, data, recommendations, and conclusions in this report are subject to change as the information has been presented as draft. This draft plan should be read as a whole, in consideration of the entire EMP, and sections or parts should not be read out of context.

Revisions to draft plans have been informed by and will be based on information received from the engagement and consultation process, the Environmental Assessment process, Project planning activities, and on conditions of provincial and federal environmental regulatory approvals received for the Project. As these will be living documents, any changes to the plans that occur after Project approvals are received will be shared with regulators, Indigenous rights-holders and stakeholders prior to implementation of the change. Either a revision number or subsequent amendment would be added to the specific environmental management plan to communicate the revision or change.

PREFACE

The Lake Manitoba and Lake St. Martin Permanent Outlet Channels Project (the Project) is proposed as a permanent flood control mitigation for Lake Manitoba and Lake St. Martin to alleviate flooding in the Lake St. Martin region of Manitoba. It will involve the construction and operation of two new diversion channels: the Lake Manitoba Outlet Channel (LMOC) will connect Lake Manitoba to Lake St. Martin and the Lake St. Martin Outlet Channel (LSMOC) will connect Lake St. Martin to Lake Winnipeg. Associated with these outlet channels are the development of bridges, control structures with power connections, a new realignment of Provincial Road (PR) 239, and other ancillary infrastructure.

Manitoba Transportation and Infrastructure is the proponent for the proposed Project. After receipt of the required regulatory approvals, Manitoba Transportation and Infrastructure will develop, manage and operate the Project. This Groundwater Management Plan (GWMP) is one component of the overall Environmental Management Program (EMP) framework, which describes the environmental management processes that will be followed during the construction and operation phases of the Project. The intent of the EMP is to facilitate the timely and effective implementation of the environmental protection measures committed to in the Environmental Impact Statement (EIS), the requirements and conditions of the provincial licence issued under *The Environment Act*, the federal Decision Statement issued under *The Canadian Environmental Act 2012*, and other approvals received for the Project. This includes the verification that environmental commitments are implemented, monitored, evaluated for effectiveness, and adjustments made if/as required. It includes a commitment that information is reported back in a timely manner for adjustment, if required.

A key component for the success of the EMP is environmental monitoring, such that environmental management measures are inspected and modified for compliance with environmental and regulatory requirements, including those set out in provincial and federal approvals received for the Project. As indicated, monitoring results will be reviewed and used to verify predicted environmental assessment conclusions and effectiveness of mitigation measures. If unanticipated effects occur, or if mitigation measures are inadequate, adaptive management measures and subsequent monitoring will be applied as described further in individual environmental management and monitoring plans.

Monitoring results and application of adaptive management measures will inform follow-up reporting to regulators and any required revisions to environmental management plans. Manitoba Transportation and Infrastructure has initiated discussions with Indigenous rights-holders and the Rural Municipality (RM) of Grahamdale in the Project area on the establishment of an Environmental Advisory Committee (EAC). The EAC would be a platform for sharing monitoring results and discussing issues of concern. In addition, Manitoba Transportation and Infrastructure anticipates that the EAC will coordinate Indigenous Environmental Monitors and communications during the construction period and will be working with Indigenous rights-holders and stakeholders on its structure and purpose.

Manitoba Transportation and Infrastructure remains committed to consultation and ongoing engagement with Indigenous rights-holders and stakeholders that are potentially impacted by the Project. Detailed EMP review discussions were incorporated into Indigenous group-specific consultation work plans. Engagement opportunities included virtual open house events, sharing draft environmental management and monitoring plans, sharing plan-specific questionnaires, and meetings to discuss related questions and recommendations. The intent has been to offer multiple avenues to share information about the Project so that rights-holders and stakeholders would be informed and could provide meaningful input into Project planning. The original draft EMP plans and questionnaires that were posted on the Project website for public review and comment are being replaced by the second draft of each plan as it becomes available. Feedback and recommendations received were used to update the current version of the draft plans, which are posted to the Project website at: https://www.gov.mb.ca/mit/wms/lmblsmoutlets/environmental/index.html.

Figure A displays a summary of the EMP process. The EMP provides the overarching framework for the Project Construction Environmental Management Program (CEMP) and the Operation Environmental Management Program (OEMP). These will be updated prior to Project construction and operation, respectively, and will consider applicable conditions of *The Environmental Act* provincial licence, *Canadian Environmental Assessment Act 2012* federal Decision Statement conditions and other approvals, any other pertinent findings through the design and regulatory review processes, and key relevant outcomes of the ongoing Indigenous consultation and public engagement processes. Until such time, these plans will remain in draft form.

The purpose of the CEMP and OEMP is to guide how environmental issues will be addressed during construction and operation, respectively, and how adverse effects of activities will be mitigated. The CEMP is supported by several specific or targeted management plans that will guide Manitoba Transportation and Infrastructure's development of the Project's contract documents and subsequently, the Contractor(s) activities, in an environmentally responsible manner and to meet regulatory compliance in constructing the Project. The OEMP will include some of the same targeted plans developed to manage issues during construction, but prior to construction completion, they would be revised and adapted to suit the specific needs during the operation phase.

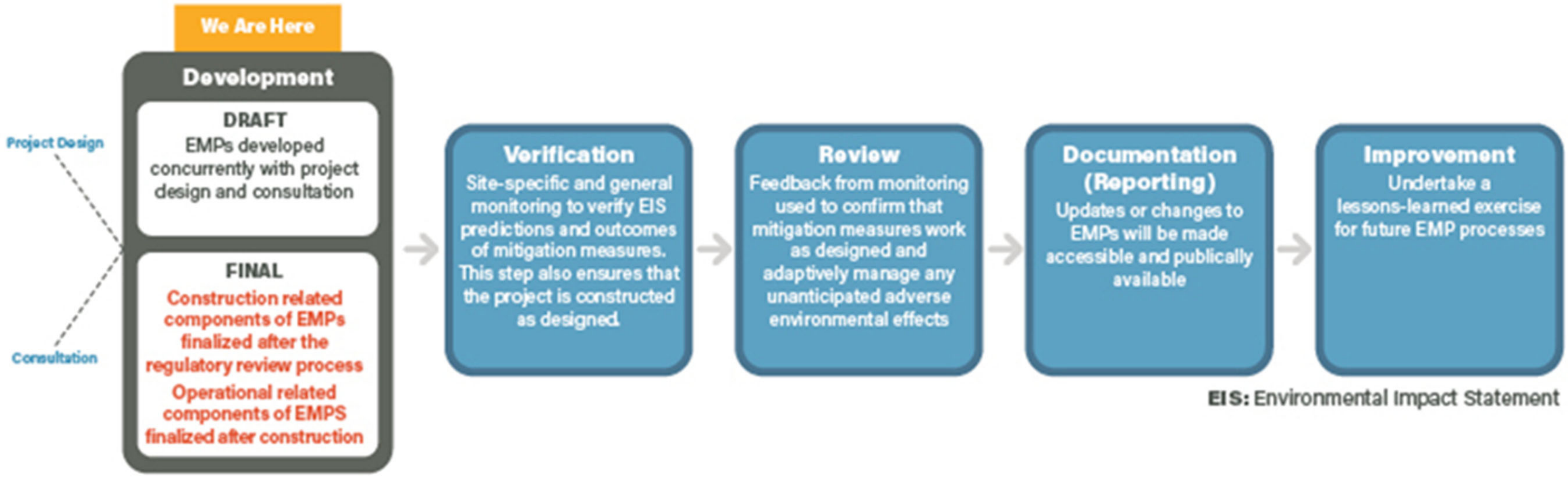

Figure A: EMP Process

LIST OF ACRONYMS AND GLOSSARY OF TERMS

Acronyms

%	percent
cfs	cubic feet per second
CCME	Canadian Council of Ministers of the Environment
CEAA	*Canadian Environmental Assessment Act*
CEMP	Construction Environmental Management Program
DO	Dissolved Oxygen
EA	environmental assessment
EAC	Environmental Advisory Committee
EIS	Environmental Impact Statement
EMP	Environmental Management Program
EPP	Environmental Protection Plan
GWMP	Groundwater Management Plan
HC-CDWQ	Health Canada – Canadian Drinking Water Quality Guidelines
km	kilometre
LAA	local assessment area
LMOC	Lake Manitoba Outlet Channel
LSMOC	Lake St. Martin Outlet Channel
m	metre
m^2/d	square metres per day
m^3/s	Cubic metres per second
masl	metres above sea level
MECP	Manitoba Environment, Climate and Parks
mg/L	milligrams per Litre
MWQSOG	Manitoba Water Quality Standards, Objectives and Guidelines Regulation
N	nitrogen

OEMP	Operation Environmental Management Program
ORP	oxygen reducing potential
PDA	Project development area
PER	Project Environmental Requirements
PR	Provincial Road
the Project	The Lake Manitoba and Lake St. Martin Permanent Outlet Channels Project
RM	Rural Municipality
SP	standpipe piezometer
Sta.	Station
SWMP	Surface Water Management Plan
TDS	Total Dissolved Solids
VW	Vibrating Wire Piezometer
WCS	water control structure
WCSB	Western Canada Sedimentary Basin
WetMP	Wetland Monitoring Plan

Glossary of Terms

Alkalinity: A pH value of greater than 7.0 (pH is a way to measure the acidity or alkalinity of a solution).

Aquifer: A body of rock or sediment that is sufficiently porous and permeable to store, transmit, and yield significant or economic quantities of groundwater to wells and springs.

Aquitard: A confining bed and/or formation composed of rock or sediment that retards but does not prevent the flow of water to or from an adjacent aquifer. It does not readily yield water to wells or springs, but stores groundwater.

Artesian Well: When the pressure is the well in above the top of the aquifer

Baseflow: The portion of the streamflow that is sustained between precipitation events, fed to streams by delayed pathways.

Baseline: Initial environmental conditions, prior to construction or anthropogenic actions.

Bedrock: The solid rock that lies beneath the soil and other loose material on the Earth's surface.

Carbonates: A rock made up primarily of carbonate minerals (minerals containing the CO3 anionic structure). Examples include limestone, dolostone, and marble (metamorphosed limestone or dolomite) are the most commonly encountered carbonate rocks.

Carbonate aquifer: See Aquifer; see Carbonates. Refers to an aquifer comprised of a carbonate bedrock.

Cofferdam: An enclosure, usually only partially obstructing a river, from which water is pumped to expose the bottom to permit construction.

Conductivity: A measure of the ability of a solution to conduct electrical flow; units are micro Siemens per centimeter.

Contract Administrator: refers to the individuals, entities or groups delegated by Manitoba Transportation and Infrastructure to provide professional Engineering and Consulting Services for the Permanent Outlet Channels Project. This includes oversight of construction and maintenance contracts and operations; review of contractor submittals, plans and proposals for compliance with Project commitments and restrictions and making recommendation for acceptance or rejection of such plans by the Owner; and monitoring, inspecting, documenting and enforcing compliance with contractual and regulatory requirements.

Contractor: refers to the individuals, entities or groups contracted by Manitoba Transportation and Infrastructure to undertake specific Project construction, operation or maintenance activities, and includes all subcontractors and affiliates.

Depressurization: Action of decreasing hydrostatic pressure. Active depressurization involves the use of pumps. Passive depressurization does not involve the use of pump, but rather uses a relation between hydrostatic pressure elevation and topographic elevation.

Detailed Design: The project phase where structural engineering design principles and applicable design codes are utilized to produce a structural design complete with Drawings and tender documents in sufficient detail to construct the specific structure/rehabilitation identified as the preferred alternative from the preliminary design phase. While detailed design is primarily structural in nature, it may also include the development of the hydraulic, hydrotechnical, geotechnical, environmental and traffic control aspects of the project to support the structural design of the bridge or structure.

Dewatering: Removal or draining groundwater or surface water from a riverbed, construction site, caisson, or mine shaft, by pumping or evaporation.

Discharge: Rate of outflow; volume of water flowing down a river, from a lake outlet, or man-made structure.

Dissolved oxygen: Oxygen molecules (O2) dissolved in water.

Dolomite: A sedimentary rock composed mostly of dolomite (CaMg (CO3)2) which often forms from limestone as the calcium is partly replaced by magnesium, usually as water solutions move through the limestone.

Domestic well: A water well used to supply water for the domestic needs of an individual residence or systems of four or fewer service connections.

Environmental Monitor: refers to the individuals, groups or designated representatives engaged by Manitoba Transportation and Infrastructure to monitor, inspect, and document compliance with contractual and regulatory requirements associated with the construction activities and associated works for the Project. The monitor may also be an active member (or representative) of the Project's Environmental Advisory Committee.

Flowing Wells: When the pressure in the well in above ground it is a flowing well.

Glaciolacustrine: Pertaining to, derived from, or deposited in glacial lakes; especially said of the deposits and landforms composed of suspended material brought by meltwater streams flowing into lakes bordering the glacier, such as deltas, kame deltas, and varved sediments.

Groundwater: Water that occurs beneath the land surface and fills the pore spaces of soil or rock below saturated zone.

Groundwater quality: Refers to the chemical composition of groundwater and its suitability for various uses and also varies widely depending upon the local geologic setting, hydrogeological conditions, and past/current land use practices that may contribute anthropogenic effects.

Groundwater quantity: Refers to the availability of groundwater at a given rate for production and use, and it varies widely depending upon the local geologic setting, hydrogeological conditions, and past/current groundwater use.

Hydraulic Conductivity: Symbolized as K, is a property of vascular plants, soils and rocks that describes the ease with which a fluid (usually water) can move through pore spaces or fractures. It depends on the intrinsic permeability of the material, the degree of saturation, and on the density and viscosity of the fluid.

Hydrogeology: The study of the interrelationships of geologic materials and processes with water, especially groundwater.

Invert (channel-): The stream bed or floor within a structure or channel.

Lacustrine: Of, or pertaining to, lakes; used in reference to soils deposited as sediments in a lake.

Management Threshold: A monitoring result that exceeds a pre-established value (e.g., guideline, deviation from historic variability) that triggers a response/action – in terms of closer examination and possibly additional mitigation measures.

Owner: refers to Manitoba Transportation and Infrastructure or a designated representative delegated by Manitoba Transportation and Infrastructure with overall responsibility for, and oversight of, Project design, construction and operation.

Piezometer: A piezometer is a device used to measure the pressure (more precisely, the piezometric head) of groundwater at a specific point.

Pool: A deep, slow-moving area of a stream; an artificially confined body of water above a dam or weir.

Preliminary Design: An engineering process undertaken at the pre-structural design phase. For structures, preliminary design includes some or all of the following: collection of survey information, preliminary foundation report (including soils investigation), hydrological analysis, hydraulic analysis and design, hydrogeological investigation, historical ice thickness and ice levels, condition assessment, geometric design, traffic forecasting, hazard protection, site location, environmental determinations, consideration of traffic accommodation, identification of constructability issues and possible construction staging, development of alternatives for advancement to structural design, life cycle cost analysis of alternatives, evaluation and selection of the preferred replacement structure/rehabilitation work. This phase of the design process typically supports the pre-construction engagement and consultation process with the public and Indigenous rights-holders, as well as the environmental submissions that satisfy environmental and/or regulatory requirements.

Recharge: Water added to an aquifer or the process of adding water to an aquifer.

Rights-holders: include First Nations, Metis Communities and other Indigenous communities who hold Aboriginal or Treaty rights that are protected under Section 35 of the Constitution Act 1982. Commonly, these include hunting, trapping, fishing or gathering rights.

Runoff: Surface water that flows overland and into streams, wetlands or waterbodies, or into drainage systems.

Shale: A clastic sedimentary rock that is made up of clay-size weathering debris. It typically breaks into thin flat pieces.

Stratigraphy: The science of rocks: it is concerned with the original succession and age relations of rock strata and their form, distribution, lithologic composition, fossil content, geophysical and geochemical properties-all characters and attributes of rocks as strata-and their interpretation in terms of environment and mode of origin and geologic history. Generic term referring to the sequential stacking of sediments / rocks in a region.

Till: An unstratified, unconsolidated mass of boulders, pebbles, sand and mud deposited by the movement or melting of a glacier.

Transmissivity: The rate of flow under a unit hydraulic gradient through a unit width of aquifer of thickness.

Turbidity: A measure of the relative clarity of water.

Water table: The upper surface of the zone of saturation in an unconfined aquifer.

Wetland: Refers to:

(a) a marsh, bog, fen, swamp or ponded shallow water, and

(b) low areas of wet or water-logged soils that are periodically inundated by standing water and that are able to support aquatic vegetation and biological activities adapted to the wet environment in normal conditions.

Part 1: Introduction

1.0 Purpose and Scope

The Groundwater Management Plan (GWMP) is a component of the overall Environmental Management Program (EMP) for the Lake Manitoba and Lake St. Martin Permanent Outlet Channels Project (the Project). The Project will involve the construction and operation of the Lake Manitoba Outlet Channel (LMOC), the Lake St. Martin Outlet Channel (LSMOC) and associated components such as bridges, control structures with power connections, a new realignment of Provincial Road (PR) 239, and other ancillary infrastructure, as described in the EMP Framework. The construction methodology for the LMOC and LSMOC is described in the Construction Environmental Management Program (CEMP).

This GWMP has been prepared for Manitoba Transportation and Infrastructure to describe the groundwater management measures that will be implemented to mitigate or protect against impacts to groundwater or from groundwater during the construction and operation of the LMOC and LSMOC. These may include water level changes in aquifers, water quality changes, and changes in the relationship of the groundwater aquifer discharge to the surface water system. Monitoring will be carried out to verify effect predictions, effectiveness of mitigation, and capture any unanticipated Project effects where adaptive measures need to be applied. Adaptive measures are also identified for implementation if monitoring indicates the need for additional mitigation.

The GWMP is intended to be a living document that will be reviewed over the life of the Project and will be updated during detailed design, incorporating applicable engagement feedback provided by landowners, rights-holders and regulators.

While the regional topography, geology and hydrogeology provides an overall context for the entire Project, there are local differences in land use and hydrogeology that require different management approaches. The LMOC and LSMOC components of the Project are located in two distinct areas. The LMOC is located near and through developed private farmland with drinking water and irrigation supply wells in proximity to the LMOC alignment. The LSMOC is located in isolated, undeveloped Crown land used predominantly for hunting and fishing, including traditional use activities, with no agricultural activity or supply wells in the area. Given the unique site characteristics of each of the channels, this GWMP is organized into three parts:

- Part 1 includes information that is common to both the LMOC and LSMOC
- Part 2 includes information that is specific to the LMOC
- Part 3 includes information that is specific to the LSMOC

1.1 Related Documents

The following Project documents will also contain groundwater-related topics and details, not necessarily included in this GWMP:

- The CEMP addresses contingency and emergency response measures, including items related to groundwater
- The Project Environmental Requirements include measures relating to drill holes and dewatering
- Detailed Design Documents will specify details of groundwater depressurization programs
- A Groundwater Depressurization Plan will be developed
- An Application for Temporary authorization for Groundwater Construction Depressurization will be developed by the Contract Administrator and submitted to Manitoba Environment, Climate and Parks (MECP) Water Licensing, which will contain Project specifics and an assessment of projected drawdown
- General/specific conditions addressing groundwater issues from the *Canadian Environmental Assessment Act (CEAA) 2012* Decision Statement and the provincial license under *The Environment Act* for the Project will also be incorporated into the management plan

2.0 Objectives

The main objectives of the GWMP are as follows:

- presenting an understanding of the hydrogeological conditions in the LMOC and LSMOC areas
- presenting descriptions of groundwater depressurization plans for construction and operation scenarios
- identifying potential impacts on groundwater supply wells and required mitigation measures
- describing the planned monitoring to confirm effectiveness of mitigation measures and to verify the Project Environmental Impact Statement (EIS) predictions
- describing the measures and protocols to address any unanticipated effects or areas of non-compliance (adaptive management).

3.0 Regional Setting

Manitoba is divided into four physiographic regions: the Precambrian shield, the Hudson Bay Lowland, the Manitoba Lowland, and the Manitoba Upland. The LMOC and LSMOC are located within the Manitoba Lowland region, which is an area of gentle relief located east of the Manitoba escarpment and extending to the eastern edge of Lake Winnipeg (Betcher et al., 1995). The major lakes (Lake Manitoba, Lake Winnipegosis, and Lake Winnipeg) occupy portions of the lowland area and act as collectors for surface drainage within the southern part of the province. The study area lies within the Lake Manitoba and Lake Winnipeg drainage basins in the Interlake. The lakes within the Manitoba Lowland collect drainage from the southern portion of the Province, which is directed through Lake Winnipeg into the Nelson River system, and ultimately discharges into Hudson Bay.

3.1 Geological Setting

The Manitoba Lowlands are underlain by Paleozoic and Mesozoic carbonate rocks with some clastic (granular) and argillaceous (clay-rich) units (Betcher et al., 1995). The bedrock units gently dip southwestward and form the eastern edge of the Western Canada Sedimentary Basin (WCSB), located along the eastern edge of Lake Winnipeg. In southcentral Manitoba, Paleozoic rocks are primarily carbonates with minor clastics and evaporites that dip gently at 2 to 10 metres (m)/kilometre (km) with the dip increasing to the southwest. Bedrock is overlain by glacial tills and proglacial lacustrine sediments.

Drift (surficial sediment) thickness in the Lowland area is quite variable, ranging between less than 10 m through large parts of the western and northern areas of the Lowland to more than 100 m thick southwest of Lake Manitoba and near the Manitoba-US border (Betcher et al., 1995). The surficial sediments comprise primarily glacial till, proglacial lacustrine and shallow marine sediments. In the Manitoba Lowlands, drift thickness is quite variable, ranging between 100 m southwest of Lake Manitoba and near the Manitoba-US border and less than 10 m in the Interlake. Inter- and intra-till sand and gravel deposits are found extensively in the tills of southern Manitoba. Sand and gravel deposits tend to be less common in the thinner tills of the Interlake region and, where found, are typically located at the bedrock-till interface and generally of limited areal extent.

3.2 Hydrogeology

The most extensive bedrock aquifer system in the province is the carbonate-evaporite unit which consists of a gently dipping layered sequence of dolostones and limestones with minor shales, sandstones and evaporites of Ordovician through Mississippian age (Betcher et al, 1995). The carbonate-evaporite unit is present throughout the Manitoba portion of the WCSB and where it is overlain by a clastic unit comprising Mesozoic and Cenozoic shales, sandstones and evaporites, the groundwater is saline and non-potable. The eastern extent of the clastic unit generally lies west of the western edge of Lakes Manitoba and Winnipegosis and associated saline springs are present along the western edge of Lake Winnipegosis. Neither the clastic unit nor the associated saline groundwater are present within the Interlake area where the proposed developments are planned.

Primary hydraulic conductivity is quite low in the carbonate aquifer and groundwater movement occurs largely through an interconnected network of secondary and dissolution-enhanced features such as fractures, joints, bedding planes, etc. (Betcher et al, 1995). In the Interlake area, where the carbonate rock aquifer forms the uppermost bedrock unit, the upper 10 m is frequently heavily fractured and highly permeable. Below this, fractures are commonly present and will typically be intersected at similar depths in nearby wells suggesting the presence of areally extensive features of increased permeability. This is commonly referred to as the upper carbonate aquifer.

Regional recharge to the upper carbonate aquifer occurs in the central portion (See Figure 2) of the Interlake where the overlying till layer is thin or bedrocks outcrops at surface. This has created a local groundwater mound or divide, east of which groundwater flows towards Lake Winnipeg and west of which, groundwater flows toward Lake Manitoba and Lake Winnipegosis. Groundwater discharge occurs as seeps and springs and may also discharge into streams, marshes and lakes where the overlying till is thin. The confined aquifer is under positive pressure and typically exhibits artesian conditions which may or may not result in flowing springs and wells at surface, depending on local conditions.

Groundwater from the upper carbonate aquifer is typically calcium-magnesium-bicarbonate type with total dissolved solids (TDS) values between 400 milligrams per Litre (mg/L) and 800 mg/L. The aquifer is a major source of groundwater for municipal, industrial, rural residential and agricultural uses.

There are a few scattered and minor sand and gravel aquifers in the Interlake region; however much of the sand and gravel that is found tends to be in isolated lenses with limited storage capacity. Where present, groundwater in these aquifers is calcium-magnesium-bicarbonate type with aTDS of less than 600 mg/L. The hydro-chemical similarity between this and the groundwater in the underlying upper carbonate aquifer reflects the influx of groundwater from the underlying aquifer into the overlying sediments due to positive pressure within the confined aquifer. Details on Hydrogeologic conditions can be found in Appendix 1A (LMOC) and 1B (LSMOC).

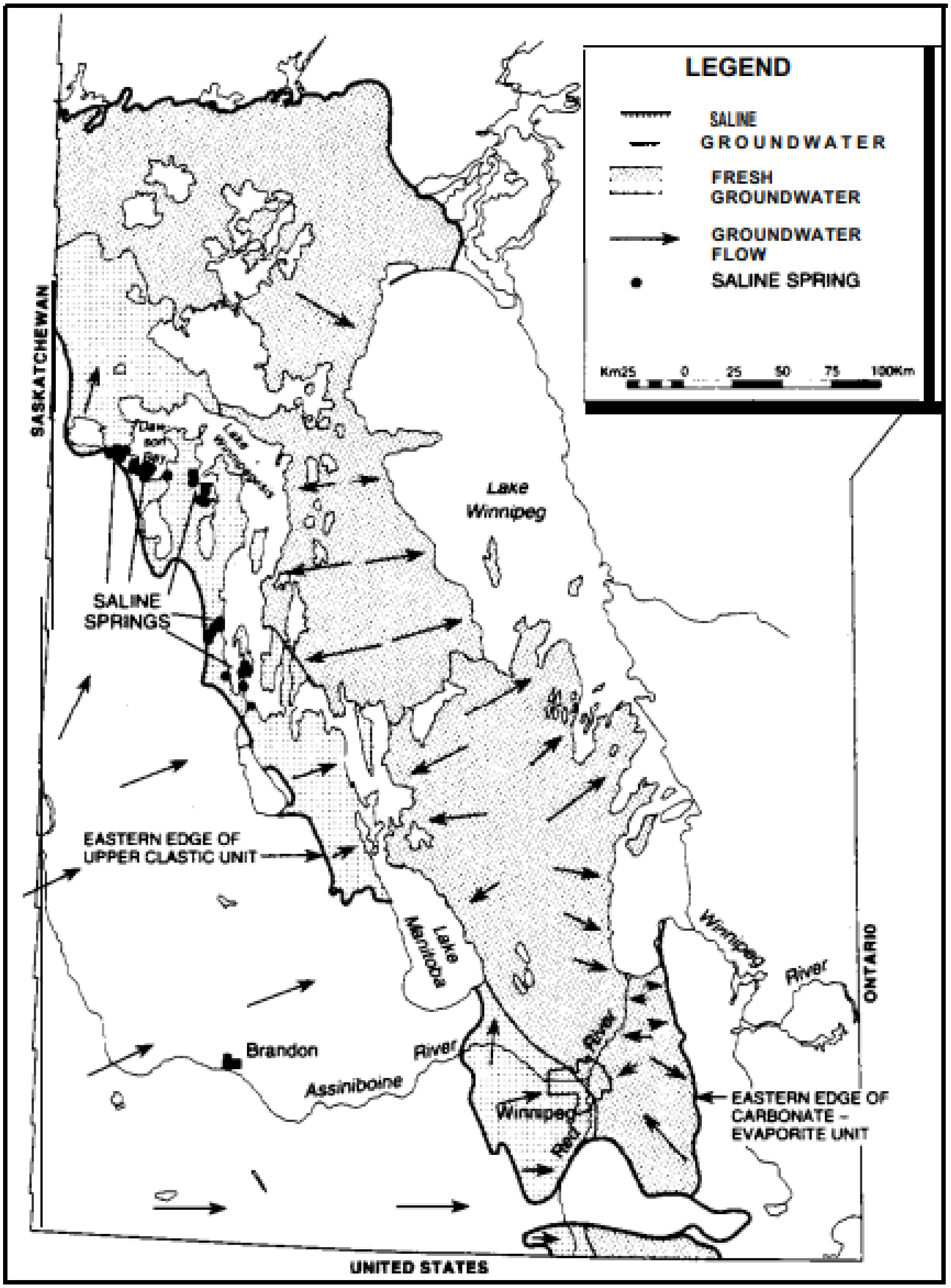

Figure 1: Regional Groundwater Flow in Carbonate-Evaporite Unit (Betcher et al., 1995)

4.0 MANAGEMENT CRITERIA

Groundwater management controls for this GWMP are designed to focus on addressing the following potential Project effects:

- Changes to groundwater piezometric pressure head
- Changes to groundwater quality
- Changes to groundwater surface water interactions

As indicated, adjustments may be made to the GWMP so that the Project is constructed and maintained in accordance with the terms and conditions of *The Environment Act* provincial license, and conditions of the CEAA 2012 Decision Statement as effects may impact elements within federal and provincial jurisdiction, once the Project is approved. This section describes the various management criteria associated with the three listed types of effects.

4.1 Piezometric Head

The Project will require depressurization of the confined bedrock aquifer during construction to reduce the risk of basal heave. Aquifer depressurization will continue post-construction during operation. Although long term depressurization (i.e., during operation) will be focused on areas within the Project development area (PDA), the reduced piezometric pressure head may impact the operation of private water wells within the RM of Grahamdale and located up to 5 km from the Project PDA.

Some key considerations for adaptive management are:

- Reduction in piezometric pressure head at flowing (non-pumped) wells to a level that will reduce but will not stop flow.
- Reduction in piezometric pressure head at flowing (non-pumped) wells to a level that will cause flowing wells to stop flowing.
- Reduction in piezometric pressure head at non-flowing (pumped) wells to an elevation below the pump intake that will cause the pump to stop operating.
- Reduction in piezometric pressure head at either flowing or non-flowing wells to an elevation below the well bottom that would require well deepening or a new installation.
- Reduction in piezometric pressure head to an elevation which impacts groundwater – surface water interactions.

For the LMOC, Project monitoring wells will be located near private water wells. The adaptive management response in this region will primarily focus on changes (reductions) in piezometric pressure head and their impacts on private water supplies. For the LSMOC, the focus will be on the potential impacts of changes in piezometric pressure head may on groundwater interactions with surface water. For both channels, the trigger that initiates adaptive management will be a change in piezometric pressure head; however, the thresholds will vary to address the specific Project effects for each channel. For a detailed list of thresholds and associated actions and mitigations please see Sections 9.2.2 (LMOC) and 15.2.2 (LSMOC).

4.2 Water Quality

Groundwater quality is not expected to be affected by the Project; however, water quality criteria will be used to interpret groundwater quality data where required (i.e., for detailed design or to verify compliance with regulatory approvals). The criteria used to make management decisions are developed to suit the predominant usage of groundwater in the areas surrounding each channel. The predominant groundwater uses in the LMOC area are domestic and livestock watering. Therefore, the Health Canada – Canadian Drinking Water Quality Guidelines (HC-CDWQG)(Health Canada 2019) and the applicable Canadian Council of Ministers of the Environment (CCME 2011) and Manitoba Water Quality Standards, Objectives and Guidelines (MWQSOG) (Manitoba Water Stewardship 2011) pathways will be applied. Groundwater quality triggers to implement adaptive management measures for LMOC and LSMOC will be different as the potential effects from changes in water quality are different. LMOC water quality protection is focussed on drinking water and/or livestock water protection, whereas water quality protection around the LSMOC is related to groundwater surface water interactions and how quality changes may potentially affect wetlands.

The primary adaptive management trigger will be exceedances in applicable water quality guidelines. Statistical trend analysis (such as Mann Kendall) will be run on water quality data which exceed the current baseline variability and/or the applicable regulatory criteria or guideline. Mitigation responses will be initiated if the effects are verified to be Project-related. Thresholds and associated actions and mitigations specific to each channel are presented in Section 9.2. (LMOC) and 15.2.2 (LSMOC).

4.3 Groundwater-Surface Water Interactions

The Project EIS documented changes to groundwater-surface water interactions as potential Project effects, but these effects are predicted to be limited in both extent and duration. A decrease in bedrock aquifer pressure may reduce groundwater discharge to the surface and may affect adjacent wetlands in the region. Groundwater monitoring will assist with understanding the groundwater pressure variations during construction and information on groundwater piezometric head and quality will be shared with surface water and wetland teams as it is collected. This information will aid in the further refinement of the adaptive management plan led by wetlands monitoring and management team, and therefore, threshold triggers will be established for those components in the wetland monitoring plan, and not be set in the GWMP.

Part 2: Lake Manitoba Outlet Channel

5.0 LMOC EXISTING CONDITIONS

5.1 Overview

In 2019, several field programs were conducted for the Project to provide baseline ground water quality and quantity information needed for environmental assessment (EA) and Project planning. These included: test hole and well installation, instrumentation, pumping tests, groundwater monitoring and water quality sampling. Groundwater monitoring and water quality sampling was also completed in 2020 and 2021 (Stantec 2020a, Stantec 2021b) and will continue on an annual basis through construction and the first two years of operation, as described in Section 8. Installation of an expanded monitoring well network will be completed in advance of construction start and will be incorporated into the monitoring and sampling program. Details on hydrogeologic conditions can be found in Appendix 1A.

The LMOC and LSMOC portions of the Project local assessment area (LAA) each display a unique response, and overall range in observed seasonal (i.e., year-to-year) and intra-seasonal (i.e., within season) aquifer piezometric pressure variability. Piezometric pressure changes that occur within the LAA portion of each channel have a different set of implications, in terms of receptors. In terms of groundwater quality, while the existing regional conditions surrounding the LMOC and LSMOC are generally comparable, the implications of any water quality changes with respect to the receptors in the vicinity (LAA portion) of each channel are different. Importantly, the implications for piezometric pressure variability/changes and/or groundwater quality changes within the LAA portion of the LMOC are related to a large number of private domestic and agricultural well users, along with the natural environment and nearby wetlands. Within the LSMOC portion of the LAA, the key sensitivity of groundwater discharge related to aquifer piezometric pressures and/or any groundwater quality changes is connected directly to groundwater contributions to the wetlands and fens that are pervasive in the LAA of the LSMOC. Because of these unique differences between the LMOC and LSMOC, adaptive management planning and associated setting of trigger levels within the adaptive management plans are somewhat unique and are directly reflective of the key needs within each LAA portion, to facilitate timely mitigative actions that are triggered appropriately and effectively.

5.2 Groundwater Piezometric Head

Bedrock Monitoring Wells

Groundwater level monitoring was conducted in conjunction with groundwater quality sampling during the 2019, 2020 and 2021 field seasons. Groundwater monitoring was completed in the spring (May/June) summer (July/August) and fall (September/October) of each year. Groundwater piezometric pressure head monitoring was conducted at a total of six locations along the LMOC alignment. These include four 2019 pump test locations (each comprising one pump well and two observations wells for a total of 12 wells) and two long term monitoring wells developed in earlier studies (KGS, 2017a). Table 1 lists the 14 monitoring wells used for the 2019, 2020 and 2021 piezometric pressure head monitoring program and the purpose of each well. Six of these wells, as indicated, are used for long-term groundwater pressure or groundwater quality monitoring, as indicated. In addition, data for two provincial wells (WRB-116766 and WRB-122050) located in the vicinity of the LMOC was provided by the Government of Manitoba (Hydata 2020) to provide long-term data from 2005 to present. Monitoring well locations are shown on Figure 2.

Table 1: Summary of Groundwater Wells in the LMOC LAA

Well ID	UTM Easting	UTM Northing	Ground Elevation (masl)	Purpose	Comment
Project Wells installed in 2019 for Preliminary Engineering					
PW19-17	5701488	5701488	248.876	Pumping Test well Long Term Pressure Monitoring	Flowing; Data Logger # C30274
OW19-16	5701488	532344	248.785	Observation well Long Term Quality Sampling	Flowing
OW19-18	5701488	532304	248.924	Observation well	Flowing
PW19-06	5696645	531018	250.472	Pumping Test well Long Term Pressure Monitoring	Flowing; Data Logger #C30288
OW19-05	5696655	531019	250.472	Observation well Long Term Quality Sampling	Flowing
OW19-07	5696695	531010	250.743	Observation well	Flowing

Well ID	UTM Easting	UTM Northing	Ground Elevation (masl)	Purpose	Comment
PW19-22	5688122	530695	248.514	Pumping Test well Long Term Pressure Monitoring	Flowing; Data Logger# C30065
OW19-23	5688132	530695	248.701	Observation well Long Term Quality Monitoring	Flowing
OW19-24	5688174	530694	249.171	Observation well	Flowing
PW19-39	530823	5683152	247.811	Pumping Test well Long Term Pressure Monitoring	Flowing; Data Logger# C30351
OW19-40	530823	5683152	247.909	Observation well Long Term Quality Sampling	Flowing
OW19-41	530823	5683152	247.844	Observation well	Flowing
Project Wells installed in 2016 & 2017 for Conceptual Design					
TH-ED-01W (TH-ED-01P) **KGS WELL**	530503	5692376	249.49	Long Term Pressure Monitoring	Groundwater Hydrographs from 2016 to present
15-RD-PW1 (TH-GD-07) **KGS WELL**	531900	5699454	252.05	Long Term Pressure Monitoring	Groundwater Hydrographs from 2017 to present

Figure 2: LMOC Baseline Groundwater Monitoring and Sampling Locations

Long-term monitoring wells installed into the bedrock are equipped with transducers to continuously monitor and record groundwater level, electrical conductivity, and temperature data. Four wells, previously used for pump testing (PW19-17, PW-19-06, PW19-22, PW19-39) were selected for long-term groundwater level monitoring along with two wells developed in earlier studies (15-RD-PW1 (TH-GD-07) & TH-ED-01W (TH-ED-01P); KGS 2017a).

The average annual groundwater pressure along the LMOC is plotted against the ground elevation in Figure 3. The pressure head remains about 3-5 m higher than ground level on average along the LMOC. The groundwater pressure decreases along the profile moving north (towards Lake St. Martin) and south (towards Lake Manitoba), indicating groundwater flow moving in those directions.

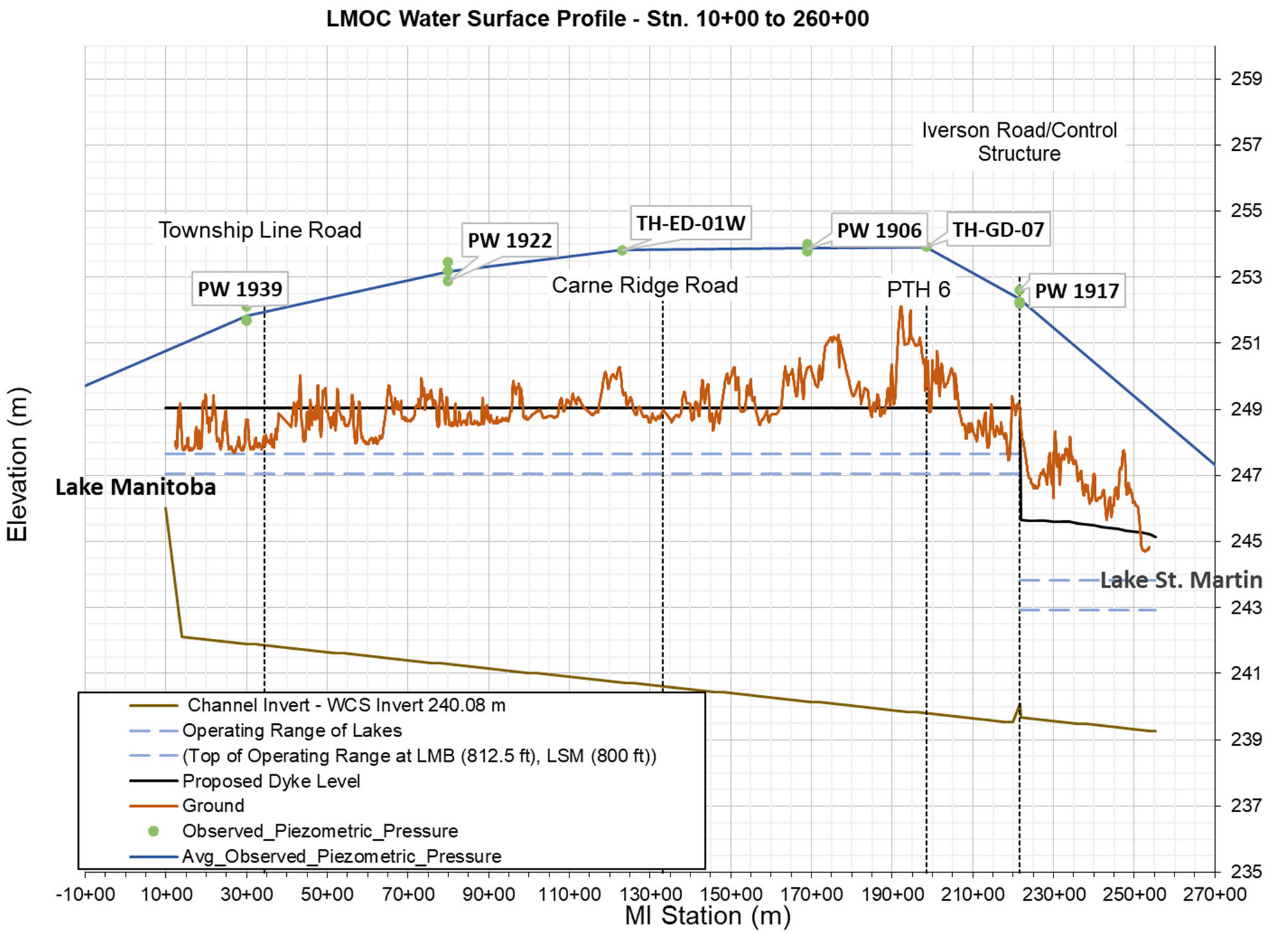

Figure 3: Groundwater Piezometric Head along LMOC profile

Based on the monitoring of piezometric pressure head along the channel alignment, the existing groundwater piezometric pressure head in the region of the LMOC was extrapolated and is shown in Figure 4. The direction of groundwater flow is controlled by the pressure head with the flow moving downgradient, perpendicular to the piezometric pressure head contour lines. Recharge occurs on both side of the channels (See Figure A-1 in Appendix 1A for location of recharge areas). The groundwater flow direction in the vicinity of the LMOC is to the north towards Lake St Martin and to the west and southwest towards Lake Manitoba.

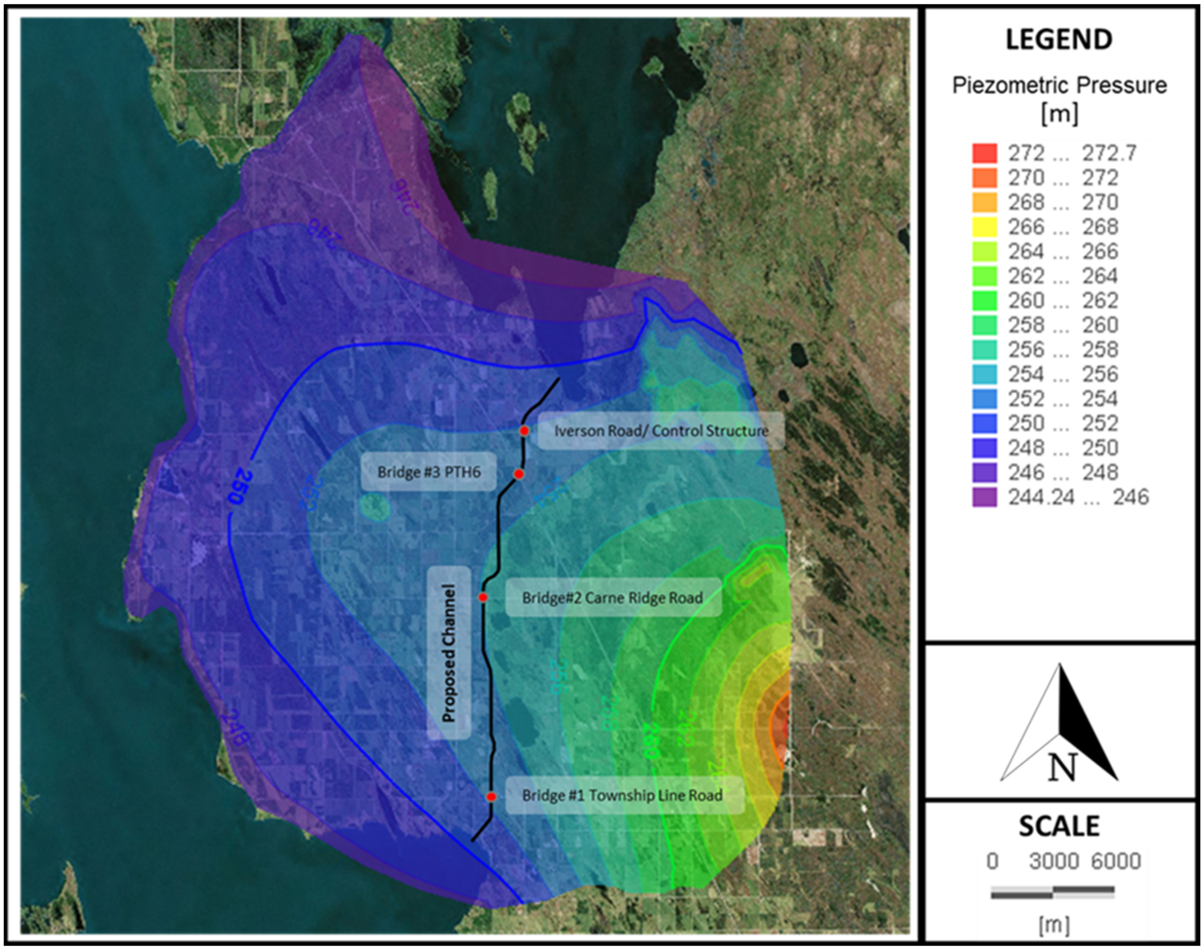

Figure 4: Existing Groundwater Piezometric Pressure Head Contours in the LMOC LAA

In much of the area the piezometric pressure in the aquifer is under artesian pressure. An estimate of the average annual piezometric pressure head above ground was calculated by subtracting the ground elevation from the pressure head elevation in Figure 4. To the east of the LMOC the piezometric head may be 5-8 m above the ground surface in some areas (Figure 5) and groundwater wells in this area would be flowing artesian wells.

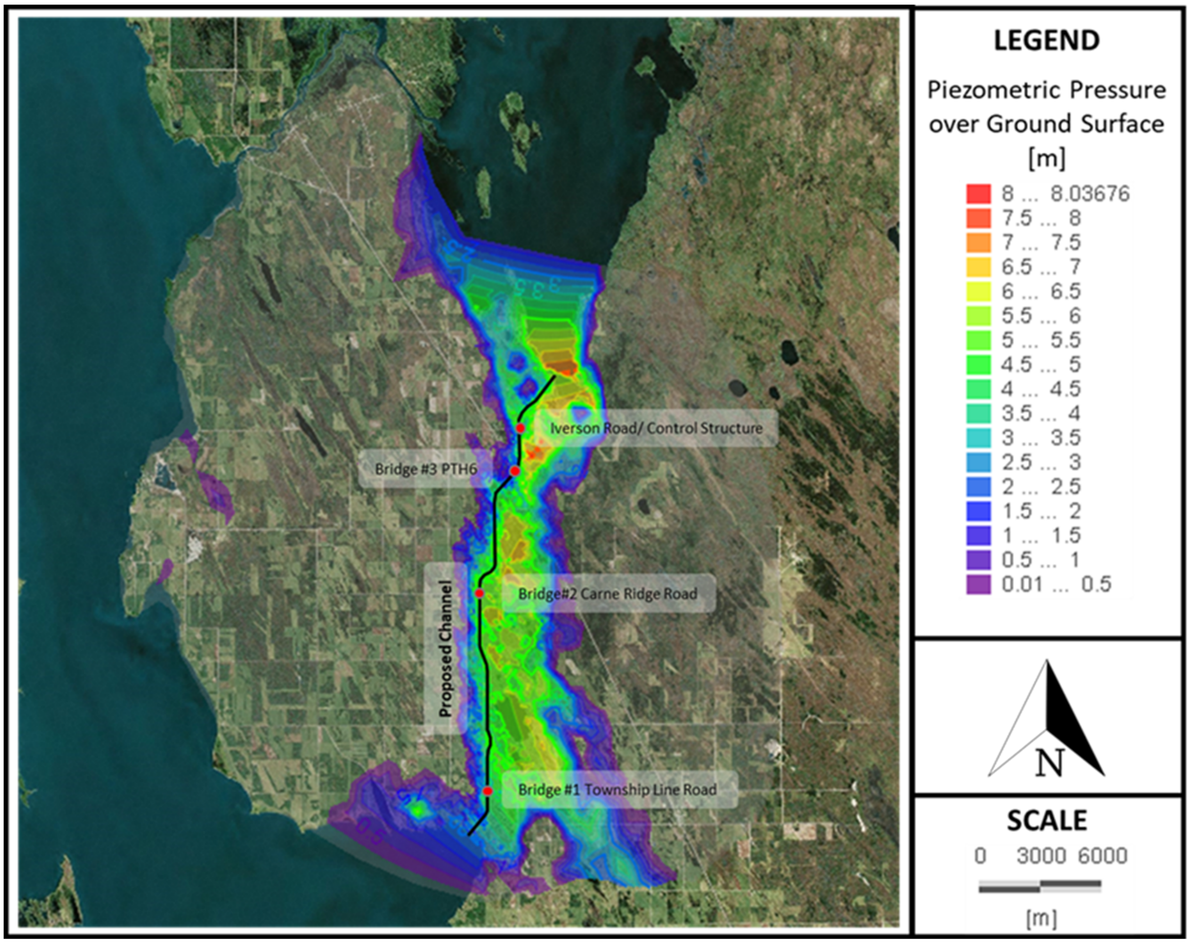

Figure 5: Piezometric Pressure Above Ground Surface near the LMOC Alignment

5.3 Groundwater Quality

Existing groundwater quality in the LMOC portion of the LAA was characterized using data collected from wells previously installed between 2016 and 2019. The purpose of collecting and characterizing the data was to:

- establish a preconstruction baseline of the groundwater quality so that changes occurring during or after construction can be identified
- assess the potential effects of groundwater being discharged to the surface during depressurization on surface water quality

In the LMOC portion of the LAA, available groundwater quality monitoring data is a compilation of data collected during field programs conducted between 2016 and 2018 (KGS 2017a, 2017b, 2018) and data collected in 2019, 2020 and 2021, as part of the ongoing pre-construction monitoring program (Stantec 2021a and Stantec 2021b). In 2019, 2020 and 2021, groundwater sampling was conducted at 13 sites (CH-19-08, OW19-18, PW19-17, OW19-16, CH19-11, BH19-12, OW19-05, PW19-06, BH19-29, OW19-23, PW19-22, CH19-37, OW19-40; Figure 2). Water quality results from these programs were compared to applicable CCME and MWQSOG criteria and guidelines. As the upper carbonate aquifer is a common source of local drinking water, the data were also compared against HC-CDWQG.

Based on reviewing existing data and the Project-specific sampling data, groundwater quality in the aquifer provides good quality drinking water. The groundwater quality generally meets the applicable CCME and MWQSOG criteria and/or guidelines.

5.4 Groundwater-Surface Water Interactions

The Birch Creek and Watchorn Creek valley is in a region of high piezometric pressure (4 to 8 m above ground) from the underlying confined bedrock aquifer. A thick impermeable till layer is present under most of the valley, limiting upward groundwater seepage flow to surface. An exception exists to the east of Reed Lake, further from the LMOC, where bedrock is present closer to the surface (See Figure A-1 in Appendix 1A). An analysis was done of groundwater and surface water quality to estimate the percentage of the surface water that could be influencing the water bodies east of the LMOC along Birch Creek (Stantec 2021c). The percentage of groundwater discharge in the upper reaches of the Birch Creek wetland lakes (from Reed Lake to Clear Lake) is in the range of 6 percent (%) to 13% of the flow to these lakes. Further downstream the percent of groundwater discharging into Birch Creek would be even less, representing less than 1% of the surface water flow.

6.0 LMOC SUMMARY OF EFFECTS

6.1 Overview

In order to safely and successfully construct, operate and maintain the LMOC, depressurization of the bedrock aquifer is required. Groundwater conditions along and in the vicinity of the LMOC are complex and driven by the regional groundwater aquifer system in the Interlake (i.e., between Lake Manitoba and Lake Winnipeg). Management of the groundwater conditions is important for the successful construction and long-term operation of the Project as discussed below. Responsible management of the groundwater conditions has been identified as important to Aboriginal treaty rights, health, social conditions and sustainability of these communities.

Stratigraphy beneath the LMOC portion of the LAA (as described in Appendix 1A) comprises a confined carbonate bedrock aquifer which is overlain by 5 m to 18 m of till. Flowing artesian wells are present along the LMOC alignment, with piezometric pressure head elevations that can be up to 5 m above the ground surface. The bedrock aquifer is recharged regionally via rainfall and snowmelt. Groundwater local to the LMOC recharges regionally in upland areas as well as from local recharge zones to the east and west of the LMOC. Groundwater flow in the carbonate aquifer is interpreted to be from the LMOC area south towards Lake Manitoba and north towards Lake St. Martin (see Figure 4).

Construction and operation of the LMOC will result in potential changes to the existing groundwater conditions within the till and confined aquifer piezometric pressure conditions along the LMOC between Lake Manitoba and Lake St. Martin. These may include water level (pressure) changes in aquifers and changes to the amount of groundwater discharge to Lake Manitoba and Lake St. Martin. However, no change to the overall water balance of either lake is expected because of construction and operation of the LMOC.

In areas where the bedrock aquifer pressures are elevated relative to the thickness of the confining till aquitard units there is a potential for basal heave/hydraulic fracturing of the till to occur, particularly during channel excavation and unloading of the confining aquitard units. This may induce some localized fracturing of the overlying till where the layer has become thinner because of construction activities, allowing groundwater from the bedrock aquifer to discharge at the base of the excavation. Areas where basal heave occurs during construction will be over-excavated and backfilled with filter material and coarse gravel, if and as they occur.

The creation of new groundwater discharge pathways into the LMOC will locally increase the direct connection of exfiltrating groundwater from the underlying bedrock aquifer to channel surface water. Groundwater currently flows towards and discharges into Lake Manitoba and Lake St. Martin under the existing pre-Project conditions.

Based on the long-term groundwater balance, the operation of the channel (with water control structure [WCS] gates open or closed) is not expected to alter the groundwater flow direction towards the lakes. The fraction of the bedrock groundwater flow that would have otherwise discharged into the lakes will be captured by the depressurization wells and reverse drain and be transported to the lakes via the LMOC. The regional groundwater flow direction will remain consistent, although local groundwater gradients and velocity may be increased by the Project depressurization. Further analyses and details will contribute to advancing the preliminary design.

6.2 Groundwater Piezometric Head

The LMOC is located on the west side of Birch Creek valley (Figure 2). The average piezometric head elevation in this area ranges between 249 metres above sea level (masl) and 255 masl and is artesian, with piezometric pressures of up to 5 m above ground level along the LMOC. The bedrock aquifer is fully saturated. The flowing artesian pressures (i.e., where the piezometric head is above ground) present in the Birch Creek valley extend approximately 5 km to the east of the LMOC (Figure 5). As the ground elevation is lower along Birch Creek, the existing piezometric pressure head above ground will be higher (5 to 8 m) in these areas.

Currently, the groundwater aquifer is recharged in the uplands between Lake Manitoba and Lake Winnipeg (and locally in recharge areas away from the channel) and discharges into Lake Manitoba and Lake St. Martin. With the construction dewatering and long-term depressurization in place, the aquifer will continue to recharge in the same areas, feed the domestic and livestock wells in the area (although at a reduced pressure), and discharge to both Lake Manitoba and Lake St Martin either directly or indirectly via the LMOC.

During and after construction, in all areas along the channel and for several kilometers to each side, the piezometric pressure head is expected to remain above the upper surface of the bedrock (i.e., will remain artesian) and the aquifer is expected to remain fully saturated. All known registered wells in the LMOC area, for domestic or livestock consumption, draw from the bedrock aquifer. While depressurization activities will lower the aquifer piezometric pressure head, it is not expected to be lower than the top of the bedrock unit and therefore the wells are anticipated to continue to be wet. However, the decreased pressures may cause the cessation of flow in some wells when the piezometric pressure drops below the local ground elevation. In these instances, pumping would be required for water supply. In some cases, the pump intake may need to be lowered in the well to improve well function. If the well capacity is insufficient and well operation is impaired, mitigation will be necessary, as described in Section 7.

The construction and long-term depressurization system planned for the LMOC will reduce the groundwater piezometric pressure head in the LMOC portion of the LAA (See Section 7.3). Throughout the Birch Creek valley area where flowing artesian wells exist (5 km east of the LMOC as shown on Figure 5 where the piezometric head is above ground), the artesian pressure will be reduced, and in most of this area flowing artesian pressure may be lost. This will have a direct effect on artesian-dependent well operation and some wells will not operate without pumping. The location of the wells used for monitoring during construction is discussed in section 8.3 and the process for identification of wells that may require mitigation are discussed in Section 9.

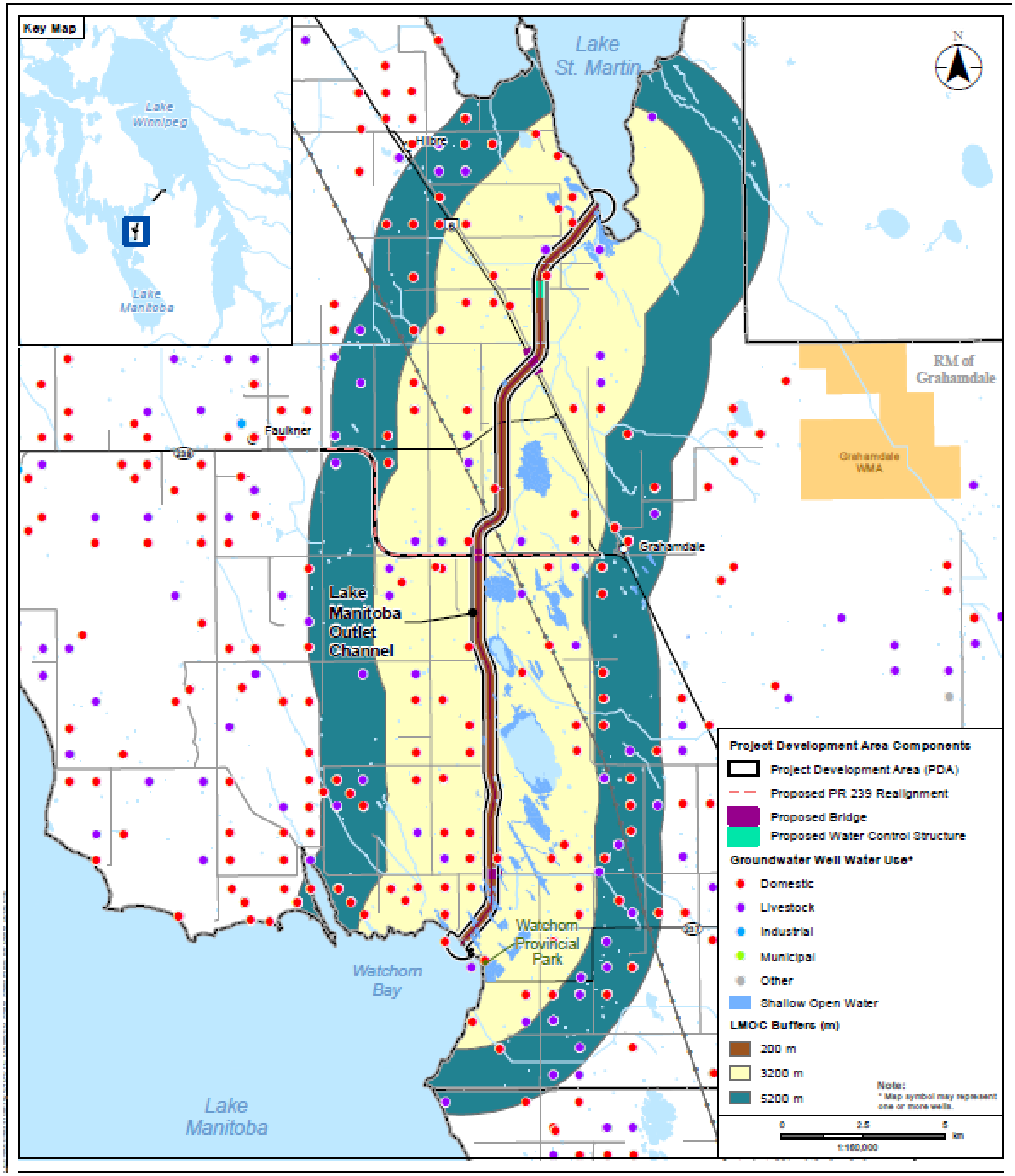

Figure 6: Area of Effect of Depressurization

6.3 Groundwater Quality

No effects to groundwater quality are expected due to the Project. The LMOC channel was located to take advantage of the natural artesian conditions which exist along the LMOC channel alignment, as discussed in Section 5.2, which will reduce the risk of surface water influences on groundwater quality. Construction and operation of the LMOC will require depressurization of the aquifer to reduce the potential for basal heave, till fracturing and slope failure. However, even with active depressurization during construction, the bedrock aquifer in the LMOC area will remain under positive pressure, although the pressure will be reduced, and the piezometric pressure head elevation may no longer exceed the local ground elevation. Recharge of the aquifer via the base of the LMOC is not expected to occur as the upward pressure of the groundwater in the upper carbonate aquifer will promote groundwater discharge at this location.

Should a change occur such that groundwater pressure decreases and the elevation of the piezometric head drops below the elevation of the ground surface (at the base of the channel), the overlying till and passive drains would act as filters for the surface water. Pressure changes are anticipated to be rare and transient events and not sufficient to cause any change to the groundwater quality. Regular monitoring of the aquifer in the region will be conducted both during and post-construction.

6.4 Groundwater-Surface Water Interactions

The percentage of groundwater discharge in the upper reaches of the Birch Creek wetland lakes (from Reed Lake to Clear Lake) in the range of 6% to 13% of the flow to these lakes; (Stantec 2021c). Further downstream the percent of groundwater discharging into Birch Creek would be even less, representing less than 1% of the surface water flow. The loss of flowing piezometric head in the region is expected to stop this flow; in addition, surface water flow from the west will be affected by the Project as the LMOC will intercept this drainage in the Birch Creek watershed.

7.0 LMOC MITIGATION MEASURES

7.1 Overview

A construction sequencing plan for the LMOC is being developed prior to construction start and will require information on temporary bedrock depressurization at construction locations specific to each construction contract. Because depressurization requirements for one contract area have the potential to influence another, the timing of a group of construction contracts needs are being considered to optimize the depressurization plan. Accordingly, active aquifer depressurization plans will be developed for each year of construction (short-term) based on construction progress and local conditions and will include the installation of temporary depressurization wells near the construction area perimeter(s) to reduce groundwater pressure to the required targets. Groundwater quality will be monitored and mitigated as required prior to discharge to the surface, with surface water issues being addressed in the Surface Water Management Plan [SWMP]. Triggers, thresholds and mitigation for local area wells is discussed in Section 9.0.

As the channel is built sequentially, the long-term depressurization measures (for use during channel operation) for each section of the channel under construction will be installed. Whereas short-term depressurization will require a combination of active pumping and passive depressurization, long-term measures will rely on passive depressurization via reverse drains or passive (non-pumped) wells. Therefore, both short-term construction-related effects and long-term operation-related effects from depressurization will need to be considered concurrently. In addition, mitigation measures for domestic or livestock wells during construction (see Section 7.3.2) may need to remain in place for the long-term.

Groundwater dewatering wells will be installed in the confined bedrock aquifer according to the depressurization requirements of the construction sequencing plan. Groundwater will be pumped out to lower the piezometric pressure head in the aquifer, to an elevation below the base of the channel and held there during construction. As indicated, aquifer depressurization will continue in the long-term during operation. An estimate of the drawdown using analytical models was developed as part of the conceptual design (KGS Group 2017a). Sensitivity analysis was performed by varying transmissivity and storativity coefficients. The depressurization will be highest at the channel site during construction, with an estimated reduction in piezometric pressure head of about 14 m to reach the invert of the channel at the WCS. The magnitude of the effect of depressurization will reduce with distance from the channel alignment. The estimated reduction in piezometric pressure head at a distance of 3 km from the segments of the channel being actively depressurized is estimated to be between 1.5 m and 3.3 m and between 0.9 m and 2.7 m at 5 km distance (Figure 6). Typical seasonal piezometric head variation in the aquifer near the LMOC is predicted to be 2.5 m to 3 m per year. In most cases (at a distance greater than 3 km) and in all cases (at a distance greater than 5 km), the decrease in pressure (piezometric head) from the Project dewatering depressurization is expected to be within the typical seasonal variation of pressure and would likely have no impact on domestic well operation. Away from the WCS, mitigation will entail to raising the depressurization target above the invert along the LMOC to reduce the magnitude of the regional groundwater effects. The process is ongoing, and each target adjustment will be site specific and depend upon site-specific geotechnical analyses.

7.2 Aquifer Depressurization During Construction

7.2.1 LMOC Groundwater Depressurization

Design work related to the depressurization measures that are required during construction of the LMOC is ongoing. In general, these measures are expected to consist of the installation of temporary wells that will be actively pumped during construction of the LMOC and its associated structures to protect against unplanned groundwater discharge and basal heave in open excavations.

A groundwater depressurization plan to achieve the design requirements will be developed and other specifications listed in the tender will be developed. Activities to be conducted may include:

- design and location of drilling and testing programs to further define aquifer conditions, and analysis of associated pump test results
- development of pumping system configuration for required combined total pump flow rate and individual flow rates, and discharge water requirements and associated handling of discharge groundwater
- supply, installation and testing of bedrock pumping wells and associated observation wells according to types, sizes, materials, and construction specifications
- supply, installation and testing and commissioning of a bedrock groundwater depressurization pumping system at the WCS, including such items as pumps, power supply, drop piping, wellhead connections, well system header discharge piping, well caps and flow meters
- bedrock groundwater depressurization system operation including preparation of discharge area for erosion control and aeration at discharge header outlet
- on-site monitoring (groundwater flow and piezometric pressure) in the work area
- water quality testing of the WCS depressurization system pump discharge water during pump test and depressurization operations
- regional monitoring of groundwater elevations

Work will be supervised by the Contract Administrator and undertaken by the Contractor Administrator, their designate, or the contractor.

The impact of depressurization on the surrounding groundwater system will be monitored during construction, as identified in Section 8.4.1, and assessed to inform the implementation of mitigation measures and adaptive management strategies. Where predictions indicate that impact is possible, mitigation planning will be initiated prior to construction. Adaptive management measures will be applied where impacts occur that were not predicted prior to construction, and/or exceed thresholds. Follow-up measures will be implemented to drive continuous improvement.

7.2.2 Groundwater Piezometric Head

The depressurization of the aquifer at the LMOC will cause a decrease in groundwater piezometric head at wells nearby. A measurable loss of piezometric head greater than natural variation is expected within 3 km from the LMOC and is likely up to 5 km away. Beyond 5 km effects greater than natural variation are not expected.

The specific impact at each well will depend upon the amount of change in regional piezometric head, the well installation details, and well use. Mitigations will be unique to each well circumstance and will include consideration of several issues. Wells that were flowing but are no longer flowing may require pumps. Pumped wells where the piezometric pressure head has dropped below the pump intake level may need either a new pump set up or to lower the pump intake level. Piezometric head monitoring of sentinel wells will occur during construction, as discussed in section 8.4, and thresholds, actions and mitigations for water supply effects are summarized in Section 9.2.2 (LMOC Adaptive Management and Follow-up).

To mitigate the impact to the regional aquifer, reducing the amount of active pumping required at locations away from the WCS and bridges along the LMOC is being investigated. If successful, this mitigation measure may reduce regional depressurization in the southern half of the LMOC.

7.2.3 Groundwater Quality

As indicated, the key mitigation to protect groundwater quality in the LMOC portion of the LAA was siting the LMOC to take advantage of local artesian conditions and reduce the risk of surface water influences on groundwater quality. Depressurization measures involve actively pumping groundwater out of the aquifer and will not change the water quality of the aquifer. All wells that are not actively used for supply (private wells), or monitoring (Project wells), should be capped and locked or decommissioned to reduce the risk of aquifer contamination. Groundwater quality monitoring will be conducted during construction (see Section 8.4.2). Thresholds, actions, and possible mitigations for unanticipated project-related private water well quality effect are discussed in Section 9.2.3.

7.2.4 Groundwater-Surface Water Interactions

As stated in Section 6.4, the proportion of groundwater discharge to the Birch Creek wetland lakes is between 6-13% of the overall water balance and that proportion decreases downstream (i.e., into Birch Creek). Once the channel is constructed, loss of flowing piezometric head in this area is expected to eliminate groundwater discharge to these lakes and drainage in the Birch Creek watershed from the west will be intercepted by the LMOC. Monitoring of piezometric head in the bedrock and till in the vicinity of the Birch Creek lakes will be conducted both during construction and post construction. No mitigation is planned in the GWMP; however, groundwater data will be shared with surface water and wetland teams as it is collected to inform Project planning and adaptive management, with mitigation issues being addressed in other plans, such as the SWMP, and in measures to address effects to wetlands.

7.3 Aquifer Depressurization During Operations.

7.3.1 Design of Operation Depressurization Plan

Aquifer depressurization is required to reduce the potential for post-construction basal heave and slope instability within the channel. A long-term target level for piezometric pressure head has been developed that meets these requirements (see Section 9.2.2). As a mitigation, these targets may be raised to reduce impacts to regional groundwater. Areas south of the WCS and between the bridge cross may require less depressurization than originally assessed.

To depressurize the bedrock aquifer along the LMOC a hydraulic connection to the surface is required. Two passive depressurization options will be used at various locations:

- depressurization via reverse drains
- depressurization via wells

Reverse Drains

In some reaches of the LMOC the excavation of the channel will intersect the bedrock directly (i.e., at the WCS) or only a relativity thin layer of till will remain between the channel invert and the top of bedrock. In these areas pressure relief can be effectively provided by excavating to the bedrock and infilling with fine- to medium-grained clastic material. This material will provide a cover on the bedrock aquifer while increasing the hydraulic conductivity to allow water to flow upward from the bedrock aquifer into the channel base. This will provide passive depressurization along and perpendicular to the channel.

As with the depressurization wells, the reverse drains along the channel will flow year-round under positive pressure. The reverse drains would not pose a threat of contaminating the aquifer as they will be installed in aquifer discharge zone(s) and not in recharge zone(s). Should the groundwater pressure decrease, allowing surface water to recharge the aquifer, the drain will act as a filter for surface water as it enters the subsurface.

Wells

Depressurization wells will be installed outside the LMOC channel limits and each well will be pumped to reduce groundwater piezometric pressure in the confined aquifer during construction only. Passive depressurization wells/reverse drains, for long-term operation, will be located within the LMOC channel and will be designed for passive relief directly into the channel. These wells would remain under artesian pressure post construction; therefore, groundwater will flow upward year-round, and the reverse drains will act as a discharge zone for the aquifer. There will be no active pumping wells long-term. As a result, a portion of the aquifer groundwater, currently naturally discharging into Lake Manitoba or Lake St. Martin, will be artificially discharged to the LMOC through these wells. The positive pressure in the aquifer depressurization wells will protect against aquifer contamination.

As an added contingency measure to avoid unanticipated effects to groundwater, each passive depressurization location will have a layer of granular (sand and gravel) filter material installed on top. During operation, groundwater will discharge upward through the reverse drain. If the groundwater in the aquifer near the LMOC is depressurized (e.g., by unauthorized pumping that depressurizes the aquifer in an area adjacent to the LMOC to below the water level of the LMOC) the water entering from the LMOC will be filtered through the sand and gravel filter on top of the passive well. There will be no active depressurization pumping long term (i.e., post-construction).

7.3.2 Groundwater Piezometric Heads

The long-term depressurization system planned for the LMOC will reduce the groundwater piezometric pressure head elevation in the LMOC portion of the LAA. Active depressurization during construction was required to minimize the potential for basal heave and till instability in the channel walls. Once the channel is complete and operating the weight of the water in the channel will counteract some of the upward pressure effects from the confined bedrock aquifer and active depressurization will no longer be required. Passive depressurization (via reverse drains) will continue and will help the groundwater system stabilize. This will allow for some rebound in piezometric pressure head elevation; however, the overall pressure head elevations will remain lower than prior to construction.

Throughout the Birch Creek valley area, where flowing artesian wells currently exist (within 5 km of the LMOC, as shown on Figure 6), the artesian pressure will be reduced and in most of this area, flowing artesian pressure may be lost. All registered wells in the LMOC area are for either domestic or livestock consumption and draw from the bedrock aquifer. Some wells that will be impacted and mitigated during construction may need some adjustments to optimize performance once the piezometric pressure head in the bedrock aquifer stabilizes. These will be revisited on a case by case basis. While a return of flowing well conditions is not anticipated, there is no anticipated long term loss of groundwater in the LMOC portion of the LAA.

7.3.3 Groundwater Quality

As previously described, the siting of the LMOC to take advantage of local artesian conditions will reduce the risk of surface water influences on groundwater. The greatest risk for water quality impacts is through aquifer recharge at the base of the channel during operations. This is not expected to occur as the upward pressure of the groundwater in the upper carbonate aquifer will continue to promote groundwater discharge into the channel post construction. Should a change occur such that groundwater pressure decreases and the elevation of the piezometric head drops below the elevation of the surface, the overlying till and passive drains would act as filters for the surface water. Pressure changes are considered to be rare and transient events and not sufficient to cause any change to the groundwater quality. Regular monitoring of the aquifer in the region will be conducted during, and post-construction.

7.3.4 Groundwater-Surface Water Interaction

Once the channel is constructed, the loss of flowing piezometric head in the Birch Creek valley may reduce groundwater discharge. In addition, surface water flow from the west will be intercepted by the LMOC thereby reducing recharge to the Birch Creek valley. Monitoring of piezometric head in the bedrock and till in the vicinity of the Birch Creek lakes will be conducted both during construction and post construction. As indicated previously, no mitigation is planned in the GWMP; however, groundwater data will be an input to the Wetland Monitoring Plan (WetMP), and mitigation issues will be addressed in other plans, such as the SWMP, and in measures to address effects to wetlands. The additional data may help to refine the adaptive management strategies for these other plans.

To mitigate the impact to the regional aquifer, reducing long-term passive depressurization to the WCS and bridges along the LMOC is being investigated. Less depressurization may be used at and between the bridges. If successful, this mitigation measure may reduce regional depressurization in the southern half of the LMOC and may reduce impact to groundwater-surface water interactions.

8.0 LMOC MONITORING

8.1 Objectives

The objectives of the LMOC groundwater monitoring program include:

- pre-construction monitoring of groundwater quality to determine baseline conditions and support engineering design
- verify anticipated effects to groundwater quality, quantity and based on the EA completed for the Project
- determine the effectiveness of mitigation measures
- assess the need for additional mitigation measures if initial measures are not adequate
- determine the effectiveness of any additional / adapted measure(s)
- confirm compliance with regulatory requirements relevant to groundwater quality and quantity

Groundwater monitoring in the LMOC portion of the LAA has and will generally be conducted three times per year, in the spring, summer and fall - prior to, during, and for two years following construction (including a flood year and one year post-flood). Additional groundwater monitoring will be required during active depressurization (construction) to understand the migration of the depressurization front within the bedrock aquifer and monitoring / sampling programs will be adjusted to meet the requirements of the GWMP. In all Project phases, groundwater will be monitored for both quality and quantity (i.e., groundwater level [pressure head]). Standard field and laboratory quality assurance/quality control (QA/QC) protocols will be followed, including the use of trip blanks and collection of field blanks and blind duplicate samples. Monitoring results and analysis will be completed and communicated via written report on an annual basis. Multi-year/trend analysis may also be needed.

8.2 Baseline Monitoring

8.2.1 Groundwater Piezometric Head

Groundwater piezometric head data for the LMOC was collected from wells shown in Table 1 and Figure 2 during Project-specific monitoring programs between 2016 and 2021. Data for two provincial wells (WRB-116766 and WRB-122050) located in the vicinity of the LMOC was provided by the Government of Manitoba (Hydata 2020) to provide long-term data from 2005 to present. These 16 wells were used to define the piezometric groundwater head in the region.

8.2.2 Groundwater Quality

Groundwater quality samples are collected three times per year from the groundwater wells shown in Table 1. Collected samples are analyzed for the suite of parameters listed in Table 2 to characterize baseline groundwater quality conditions. The analytical suite of parameters was selected to characterize the groundwater and includes:

- field monitoring to determine aquifer conditions [temperature, pH, dissolved oxygen (DO) and oxygen reducing potential (ORP)
- potability testing to determine the quality and type of groundwater
- trace metal analyses
- petroleum hydrocarbon constituents and microbiological components due to the proximity of developed areas to the LMOC (to assess potability and risk of surface water- groundwater interactions)

The results of the groundwater sampling program are documented in annual monitoring reports (Stantec 2020a, Stantec 2021b).

Table 2: Groundwater Parameters Measured in LMOC Pre-Construction Monitoring Program

Category	Parameters
Field Monitoring	temperature, pH, electrical conductivity (EC), DO, oxygen reduction potential, TDS, turbidity, pressure, nitrate
Potable Water	electrical conductivity, hardness, pH, TDS, turbidity, alkalinity, ammonium (as nitrogen [N]), bicarbonate, carbonate, chloride, fluoride, hydroxide, nitrate and nitrite (as N), nitrate (as N), nitrite (as N), phosphorus, sulfate, TDS, total Kjeldahl nitrogen, total suspended solids
Total & Dissolved Metals	aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, calcium, cesium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, phosphorus, potassium, rubidium, selenium, silicon, silver, sodium, strontium, sulfur, tellurium, thallium, thorium, tin, titanium, tungsten, uranium, vanadium, zinc, zirconium
Petroleum Hydrocarbons	BTEX (Benzene, Toluene, Ethylbenzene, Xylenes), and Hydrocarbon Fractions F1 through F4
Microbiological	*Escherichia coli (E. coli)*, total and fecal coliforms

8.2.3 Groundwater-Surface Water Interactions

Groundwater/ Surface water interactions were estimated using information collected from the annual monitoring reports on groundwater and surface water quality (Stantec 2021a, Stantec 2022a). This information includes static water levels and piezometric pressure head (groundwater), surface water elevations, and surface water and groundwater quality.

8.3 Pre-Construction Monitoring

Baseline groundwater monitoring activities will continue during the detailed design phase of the Project to support the finalization of engineering design prior to Project tendering and construction. These activities include:

- continued monitoring of groundwater levels (static water levels and piezometric head) at existing instrumentation
- collection of groundwater samples for laboratory analysis of the parameters in Table 2 (above)

The Project monitoring well network will be expanded as described in Section 8.3.1 below. The expansion includes replacement wells for those currently installed within the LMOC right-of-way, which are expected to be decommissioned prior to construction start and monitoring wells at additional locations to support piezometric pressure head and water quality modeling during and post-construction. This section describes the planned additions to the current baseline monitoring program and how the baseline and pre-construction baseline monitoring data for the wells within the LMOC right-of-way will be integrated to that from their replacement wells.

8.3.1 Network Expansion

The groundwater monitoring network includes wells located proximal to the WCS, Birch Creek wetland lakes, a possible groundwater recharge area, near Federal lands (i.e., Pinaymootang First Nation), and landowners in the LMOC portion of the LAA. The purposes of well site selections proximal to these features or areas are described below.

Groundwater Piezometric and Groundwater Quality Data

Baseline Replacement Wells

The existing baseline monitoring well network is nearly all located within the LMOC Right of Way (ROW). These monitoring wells will be decommissioned because they are located within the areas to be excavated during the preliminary stages of construction and therefore will be lost as data points. New monitoring well locations have been selected adjacent to the LMOC ROW so that consistent data collection can continue during construction and operations. The replacement groundwater wells will retain the same function as the baseline monitoring wells (i.e., collection of groundwater quality and/or groundwater level data) and will be installed at locations proximate to the existing baseline monitoring wells to address/confirm potential construction/operation groundwater effects in comparison to the pre-construction data program. An overlap period of monitoring is ideal to allow for integration for the two data sets.

Water Control Structure

During construction, the largest drawdown is expected to occur around the WCS due to the required depth of excavation and relatively shallow depth to the top of the bedrock aquifer surface below grade. Active groundwater depressurization will occur continually at this location throughout construction and a reverse drain will be installed to allow for passive depressurization during channel operation. An array of groundwater monitoring wells, located near and radiating outward from the WCS, is proposed to facilitate monitoring of effects of the WCS dewatering on groundwater piezometric pressure and quality. Wells no longer required for monitoring (post-construction once aquifer conditions have stabilized) will be decommissioned as part of future works.

Private Wells in the LMOC Portion of the LAA

Project monitoring wells will be located in areas close to landowner wells that have a potential to be affected by depressurization. Based on the groundwater modeling analysis (see Figure 6), landowners with water wells within 3 km of the Project are likely to experience changes to their water supply as a result of the required aquifer depressurization activities during construction. Between 3 km and 5 km, some effects may be identified in some areas; however, at a distance of 5 km or more away from the Project, the induced change to water levels is anticipated to be within the range of seasonal variability and measurable changes to the water supply at these locations are not anticipated. The monitoring network will include wells within the 0-3 km zone of influence, wells within the 3-5 km zone of potential influence and wells beyond the 5 km buffer to confirm the expected limited aquifer response beyond this point. Monitoring wells installed at or greater than 5 km from the channel will be important sources of information regarding the detection of any unexpected impacts if they do occur.

Groundwater-Surface Water Interactions

Wetland Lakes

Surface water and groundwater interaction effects in the small wetland lakes to the east of the proposed LMOC (i.e., Reed Lake and Clear Lake) have been raised as a concern by various stakeholders and First Nations communities. A Wetland Monitoring Plan has been established to examine changes to wetlands. To monitor changes to groundwater discharge that could impact the potential for surface water infiltration into the subsurface, well clusters will be installed near the wetland complex. The well clusters or well pairs will comprise a deep well completed in the bedrock aquifer and a shallow well completed in the overlying unconsolidated sediments. Where appropriate, a third even shallower well location may be included if there is a peat layer present. It is anticipated that both water level and water quality data would be collected from these well installations to support the wetlands monitoring program.

Control locations

Recharge Area

One well is proposed to monitor groundwater levels between the LMOC and a model-predicted recharge area to the northeast of the LMOC. This, in addition to the long-term provincial government monitoring wells, will provide information relating to factors external to the LMOC (e.g., climate change), which could influence groundwater levels within the Project RAA. The monitoring well will also allow collection of data to confirm that impacts related to depressurization are not extending to the groundwater recharge area northeast of the LMOC.

Federal Lands

Groundwater modeling analysis predicts that the active depressurization pumping zone of measurable influence will not extend beyond 10 km from the LMOC during construction. Pinaymootang First Nation, the nearest Indigenous community to the Project, is located greater than 10 km away from the LMOC and therefore no measurable effects on wells on Indigenous lands are expected. One well, located at a distance greater than 10 km from the LMOC but outside of the First Nation Reserve land, will be installed to monitor groundwater levels and quality at this location to provide early warning if unexpected depressurization effects are detected at this distance.

Manitoba Government Well

Manitoba Government Well 116766 has provided long-term piezometric pressure head data in the region since 2004. This well (shown on Figure 2) is located 14 km from the LMOC and will not be affected by the Project and will provide an understanding of how the natural changes in recharge affect piezometric pressure head in the region. This control well data can be compared to other Project-impacted wells to determine whether identified changes in piezometric pressure head are due to natural conditions or Project effects.

8.3.2 Groundwater Piezometric Head

Continuous level monitoring gauges (transducers) will be installed and maintained at select locations (see Section 8.3.1), and new wells will be installed, as required, for construction depressurization monitoring. Monitoring will be initiated before the bedrock depressurization begins.

8.3.3 Groundwater Quality

Continued monitoring of groundwater quality at existing sites (discussed in Section 5.3.2) and new sites (discussed in Section 8.3.1) will be undertaken during spring, summer and fall, with reporting completed annually. Collected samples will be analyzed for the suite of parameters listed in Table 2 to characterize baseline groundwater quality conditions. New wells discussed in Section 8.3.1 will be monitored at least once prior to the initiation of depressurization.

8.3.4 Groundwater-Surface Water Interactions

The Birch Creek wetland lakes monitoring wells (See Section 8.3.1) will be monitored prior to depressurization to determine the preconstruction vertical groundwater gradients. Clustered well sets will comprise a well completed in the bedrock and a second well completed in the overlying unconsolidated sediments. A third well may be installed and completed in a surficial peat layer if present. The clustered well sets will be located near the wetland lakes.

8.4 Construction Monitoring

Construction start, for purposes of this GWMP, is defined as the initiation of clearing in support of construction operations. During construction, groundwater levels will be monitored, and the results will be used to adjust depressurization activities and determine mitigation measures. This will be accomplished through interactions with landowners and Contractors, as required, throughout the construction process. Continuous level monitoring gauges will be maintained, and groundwater quality monitoring will continue annually in spring, summer and fall during construction, with reporting completed annually. Groundwater quality samples may be collected at other times if a need is identified.

During the course of LMOC construction, threshold exceedances (see Section 9.2) on Project monitoring wells will prompt collection of well-specific information from well owners in each area. This information will be used to determine piezometric pressure elevations unique to each well that will require mitigation. Information of well water elevations will include groundwater surface (at the well), pump intake and bottom of the well. Identification of flowing wells and pumped wells will also be important considerations when determining well-specific mitigations.

It is likely that all private well information will not be easily obtained. Other sources of data, such as the provincial well data base (GWDrill) can be used to estimate the top of well and the screened (i.e., bottom of well) level for wells in the area. The well intake level is not readily available however could be assumed to be 2 m below the average piezometric head or the ground level, whichever is lower.

8.4.1 Groundwater Piezometric Head

As construction begins, groundwater depressurization will occur in a phased approach along segments of the LMOC. The estimated decrease in piezometric pressure head (i.e., the pressure drawdown) that may occur as a result of depressurization activities has been estimated based on groundwater modelling. Monitoring of pressures within the Project monitoring wells will be actively ongoing during depressurization activities. This will confirm that the aquifer pressures are changing as predicted and will provide information necessary to mitigate water supply changes for private well owners. For wells that are close (i.e., within 3 km) to the construction site, a loss of flow in wells is anticipated at most wells and these wells are expected to be the first impacted by the Project. However, aquifers are very complex and monitoring of actual conditions (especially as distance from the zone of active depressurization increases) will be key in identification of the need for mitigation.

From the collected information, a unique set of mitigations, as described Section 9.0 will be developed for each private well that is registered in the Project mitigation plan. The mitigations will be based on the groundwater supply effects identified at that well location.

8.4.2 Groundwater Quality

Groundwater quality will be monitored in the established Project monitoring well network and at select private wells based on location and proximity to the Project as part of the ongoing domestic well monitoring program. Regular monitoring and water quality sampling of groundwater quality at the wells will continue to occur three times per year. Special events such as a substantial change in quality or a spill in the area may warrant an increased frequency in groundwater quality monitoring at certain wells. All groundwater samples will be collected following standard procedures, will be submitted to an accredited laboratory for analysis and subject to standard laboratory quality assurance (QA)/quality control (QC) processes.

The groundwater water quality is not expected to change beyond current variation as a result of the Project and is expected to maintain a stable trend into the future. Monitoring of groundwater quality will continue throughout construction and for 2 years post-construction (including one flood event and one-year post flood). Water quality changes in private wells not included as part of the domestic well monitoring program will be identified by the landowners.

Parameters will be reviewed after each monitoring event during construction and post-construction. In some cases, groundwater concentrations of some parameters (e.g., iron, manganese, fluoride) may be present at concentrations above the HC-DWQG during the baseline period. In these instances, the threshold would be the presence of a statistically significant increasing trend. Associated actions and mitigations would be situation and well dependent.

Special events such a substantial change in water quality or a spill in the area may warrant an increased frequency in groundwater quality monitoring at certain wells to characterize the effect. All groundwater samples will be collected following standard procedures, will be submitted to an accredited laboratory for analysis, and will be subjected to standard laboratory quality assurance (QA)/quality control (QC) processes.

Groundwater removed during depressurization will be discharged to surface and /or surface water. Once discharged groundwaters are part of the surface water system, the water quality management monitoring triggers and thresholds are also addressed in the SWMP.

8.4.3 Groundwater-Surface Water Interactions

The Birch Creek wetland lakes monitoring wells (See Section 8.3.1) will be monitored prior to and during depressurization to identify any changes in vertical gradients from the preconstruction to the construction phase. Clustered well sets will comprise a deep well completed in the bedrock aquifer and a shallow well completed in the overlying unconsolidated sediments. Any identified change (i.e., reversal of vertical gradient) will be communicated to the wetlands monitoring team. Monitoring results would be used to inform mitigation planning and may include mitigations or execution of adaptive management processes identified in the SWMP, the CEMP, Operation Environmental Management Program (OEMP), Project Environmental Requirements (PER), Environmental Protection Plan (EPP) and/or others, depending on the nature of the change experienced.

8.5 Operations Monitoring

Groundwater monitoring and sampling during operations will follow the same frequency of occurrence as during pre-construction and construction. Groundwater monitoring and sampling will continue for the first two years post-commissioning and including one flood event and one-year post-flood. Groundwater conditions are expected to stabilize within two years. A plan for long-term groundwater monitoring beyond two years post- commissioning will be developed based on the previous monitoring data, an assessment of any possible LMOC effects and public engagement. The plan will include monitoring the effects of the channel on groundwater quantity (i.e., piezometric pressure head) and quality during channel operating and non-operating conditions. On-site and regional monitoring of the effects of any long-term passive aquifer depressurization will also be included in the plan.

8.5.1 Groundwater Piezometric Head

Continuous level monitoring gauges will be maintained with data downloaded at regular intervals (three times per year) for the first two years post-commissioning. Groundwater levels will also be monitored at provincial monitoring well locations, WRB122050 and WRB116766 located approximately 2 km and 14 km from the LMOC. These wells are indicated on Figure 2. Trends identified in the Project LAA will be compared against these regional monitoring locations to decouple any naturally-occurring environmental variation from potential Project-related impacts.

After commissioning, the regional groundwater piezometric head is expected to stabilize at a lower elevation than exists pre-construction but higher than during construction, as discussed in Section 6.2. There will be some natural seasonal variation in piezometric pressure head as was identified during the baseline (pre-construction) period. Monitoring will continue for 2 years post-commissioning. No well mitigations related to quantity / supply changes are expected during operation once any construction phase well mitigations are refined post-construction. It may be possible that pump intake elevations may need to be reset on some private wells after the piezometric head stabilizes to a new range of seasonal variation post-commissioning. If any unanticipated effects are identified, adaptive management processes will be triggered (see Section 9.2.1).

The Project can potentially affect the piezometric pressure head in the aquifer due to the operation of the WCS. The WCS will change the surface water level in the channel by dropping the surface water level in the channel 2 m upstream of the gate and raising it 2 m downstream of the gate. The Project monitoring wells previously installed around the WCS will provide the necessary data to determine the impact on aquifer piezometric pressure head away from the WCS. The magnitude of piezometric pressure variation is expected to be similar to current seasonal variation in piezometric head (2-3 m) caused by recharge of snowmelt and rainfall. If any unanticipated effects are identified during WCS operation, adaptive management processes will be triggered (see Section 9).

8.5.2 Groundwater Quality

Operation phase groundwater quality parameters are expected to remain consistent with those analyzed during the pre-construction and construction phases and identified in Table 3. The frequency and locations of sampling may be adjusted based on monitoring results and environmental conditions. Similarly, analytical parameters may be adjusted depending on water quality results. Groundwater quality during operations is expected to be consistent with that measured during the pre-construction phase.

Groundwater water quality is not expected to change beyond natural variation and to maintain a stable trend into the future. Monitoring of groundwater quality will continue through 2 years post-construction and reported annually. The suite of analytical parameters will be reviewed each year post-construction. If an unanticipated water quality effect is identified, adaptive management processes will be triggered (see Section 9.2.2).

8.5.3 Groundwater-Surface Water Interactions

The Birch Creek wetland lakes monitoring wells (See Section 8.3.1) will continue to be monitored post-construction. Any identified change (i.e., reversal of vertical gradient) will be shared with the wetlands monitoring team and Manitoba Transportation and Infrastructure.

9.0 LMOC ADAPTIVE MANAGEMENT AND FOLLOW-UP

9.1 General

A follow up process is a form of adaptive management to improve practices by learning about their effects and then making changes in those practices as new information is available. The CEAA *2012* defines a follow up program as "a program for verifying the accuracy of the impact assessment of a designated project and determining the effectiveness of any mitigation measures." An associated Operational Policy Statement (https://www.canada.ca/content/dam/iaac-acei/documents/ops/ops-follow-up-programs-2011.pdf) indicated that "a follow-up program is used to:

- verify predictions of environmental effects identified in the EA
- determine the effectiveness of mitigation measures in order to modify or implement new measures where required
- support the implementation of adaptive management measures to address previously unanticipated adverse environmental effects
- provide information on environmental effects and mitigation that can be used to improve and/or support future EAs including cumulative environmental effects assessments, and
- support environmental management systems used to manage the environmental effects of projects."

Follow-up is one step in the overall continuous improvement process which aims to evolve practices and processes based on feedback. Continuous improvement is generally a four-stage process: Plan, Do, Check and Act. This loop allows work to be planned, executed, reported on, and then corrected as required.

In the context of groundwater management for the Project, the design will be implemented while managing risks with monitoring, as generally described in Section 7.0 and 8.0. As described in Section 12.4.1.1 of the Project EIS, the objective of the groundwater follow-up and monitoring program is to determine whether there are changes to the volume and accessibility or quality of the groundwater in the groundwater LAA as a result of construction or operations and update and implement mitigation measures and responses accordingly. The predicted residual effects during construction and operation of the Project include:

- a change in local groundwater piezometric pressure head due to depressurization operations,
- a change in local groundwater quality due to depressurization operations; and
- a change in groundwater–surface water interaction due to bedrock aquifer depressurization.

The monitoring and analysis program described in Section 8 will provide information to better predict and quantify potential effects and confirm which locations of the groundwater LAA should be further monitored during aquifer depressurization. Existing data collection or monitoring programs will be applicable to inform development of new monitoring plans, where identified, to the extent feasible. Baseline groundwater quantity and quality will be established during the pre-construction monitoring program (in progress) which will form the basis for comparison to determine what, if any, effects are occurring. A few select domestic water wells may be monitored for their quality if the Project monitoring wells indicate a potential issue in the region. Knowledge obtained from field performance will be used to modify programs as necessary as construction progresses.

Mitigations will be well-specific and determined based on the predicted effects to groundwater quality and quantity from construction depressurization activities. Management thresholds will establish actions to be undertaken once a threshold level has been exceeded at a specific location and are based on the logical next steps. Early threshold exceedances typically initiate additional information gathering to collect the required information to determine the appropriate next steps or to prepare for future mitigations, if required. Follow-up responses will evaluate the effectiveness of the overall program, including the thresholds, planned actions and proposed mitigations.

Monitoring programs implemented for the Project will produce data that will be assessed to evaluate environmental impact. Based on the results, changes in the monitoring program locations, analytical parameters or frequency of monitoring may be warranted. The monitoring program will be designed with this flexibility in mind and consideration of all factors which could influence changes in well performance. Regional (i.e., external to the Project area) provincial monitoring wells are incorporated into the monitoring program to decouple regional environmental effects due to climate variability from Project-related effects.

Groundwater water quality effects are not expected; therefore, any effect would be considered an unanticipated event and would trigger the adaptive management process shown in Figure 7. Unanticipated Project-related effects to groundwater could include changes to water supply and/or water quality, which may or may not be related to surface water-groundwater interactions. To design appropriate mitigations for unanticipated Project-related effects, the cause of the effect will need to be understood. This process will often be triggered by receiving information regarding unanticipated effects from stakeholders (i.e., well owners – through the Complaint Resolution Process) in the area, or could be triggered through analysis of data from monitoring wells. This will then trigger the adaptive management process shown in Figure 7. The threshold would be any change in water quality from the baseline beyond the historic range or exceeding drinking water guidelines.

Changes to groundwater surface water interactions could occur due to the Project; however, are not expected to have any material impact on local groundwater quality. As indicated, data will be provided to the wetland monitoring program and addressed as part of the wetland management activities.

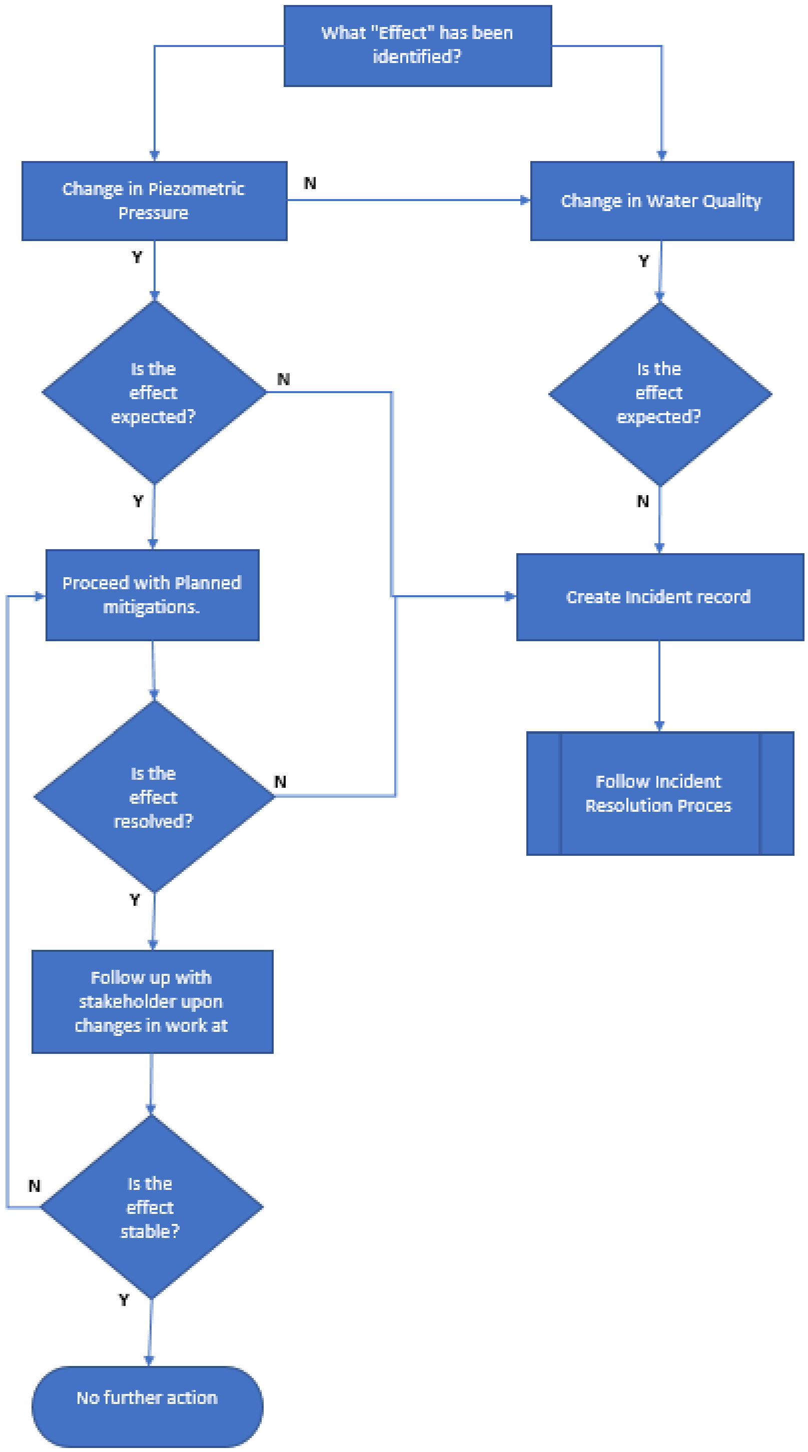

Figure 7: Adaptive Management Process

9.2 Follow-up

9.2.1 Stakeholder Complaint Resolution Process

The Complaint Resolution Process will be implemented to allow private well owners to record any issues that they encounter with respect to their well performance or water quality. Complaints will be investigated, and mitigations determined on a case-by-case basis.

Changes in groundwater piezometric pressures (level) are expected in areas within 5 km of the channel. The greatest changes will be seen at the wells most proximal to the channel alignment with an expected decrease reduction in the effect with distance from the channel. As previously stated, wells located > 5 km from the channel alignment, are expected to report variations in piezometric pressure within normal seasonal variation. These variations are not anticipated to impact well users. If a change is identified that is not anticipated, an incident will be created and investigated as shown in Figure 8. This investigation will determine whether the change is Project-related, the cause for the change and the parameters required to determine any required mitigations. In the short-term, the effects can be mitigated by supplying a fresh water source, a pump and/or by lowering the pump intake (where applicable) until the circumstances and required actions are understood. Possible mitigation will be developed on a case-by-case basis, as required. Once the incident is resolved and stakeholder signoff is obtained, the report will be closed.

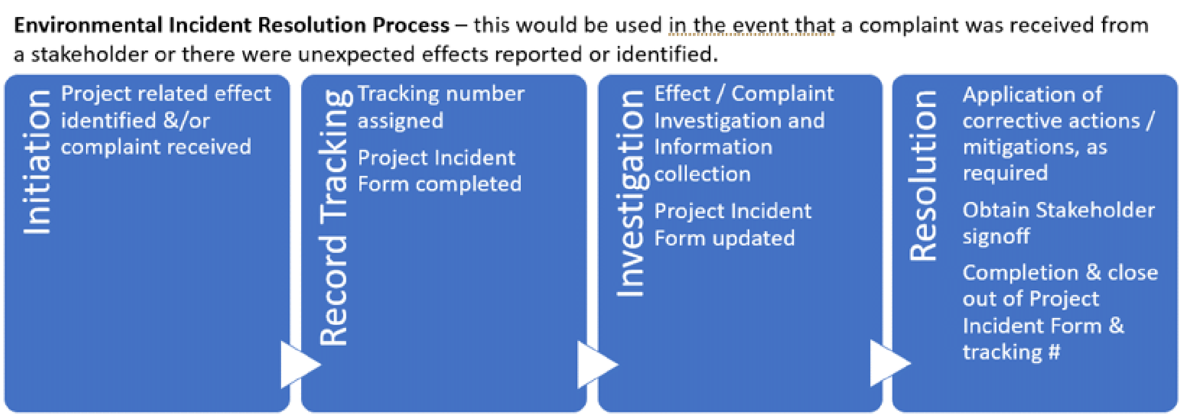

Figure 8: Incident Resolution Process

9.2.2 Groundwater Piezometric Head

The main trigger related to water supply is a change (typically a reduction) in aquifer piezometric pressure. A reduction in piezometric pressure will potentially change the well performance which would impact private water supplies and may require system modifications (i.e., addition of a pump) for some (flowing) wells. Project monitoring wells will be actively monitored during the start of depressurization and following any change to depressurization activities. When piezometric pressure reductions are identified in the Project monitoring wells, it is expected that similar changes are occurring in the nearby / surrounding private wells.

Thresholds, actions and mitigations for water supply effects are summarized in Table 3. Thresholds have been set to be conservative. Threshold one (10-15% change) has been set as an initial detectable change in piezometric pressure head which will permit Manitoba Transportation and Infrastructure to collect the necessary data from surrounding private wells and establish unique well action levels based on the piezometric pressure head at that location. A 10-15% change (decrease) in the piezometric pressure head has been set at an initial threshold that indicates the arrival of the depressurization front at that well. There are no mitigations required at this time; however, the threshold exceedance will trigger collection of information that is key to determining well specific mitigations to private wells through collection and verification of well specific information. Threshold two (45% change in piezometric pressure head) was selected as a mid-point value that would trigger more frequent monitoring at individual private wells to facilitate timely well mitigations. Localized heterogeneities (i.e., variation in geology or primary/secondary porosity) can impact the rate of depressurization at individual wells; therefore, once the piezometric pressure head drops by 45% more frequent monitoring at individual wells is warranted to support mitigation planning and execution. This threshold was set to be conservative to allow time for mitigation preparation and execution.

Once an initial threshold of a 10-15% change in groundwater piezometric pressure is identified in a sentinel well, Manitoba Transportation and Infrastructure will contact the surrounding landowners to confirm available well system data or collect well system data if it is not already known. This information will include:

- well records, including the age of the well, completion interval, total depth, pump intake depth (if pumped)
- ground and top of casing elevation
- type of pump / water supply system the landowner currently has in place
- collection of current data (groundwater pressure) where possible
- water supply observations from the landowner

The timing for implementation of individual water supply well mitigations will be based on a combination of regional observations through the overall Project monitoring well network as well as local changes in groundwater pressure at both the closest Project monitoring well and the individual private wells.

Table 3: Thresholds, Actions and Possible Mitigations for Anticipated Project-Related Private Water Supply Effects

Threshold	Action	Possible mitigations
10-15% change in piezometric pressure at Project monitoring wells	Meet with surrounding landowners and collect well specific information. Well-specific data will be entered into Project database and unique well action levels will be established.	No required mitigations are expected at this time.
45% change in piezometric pressure at Project monitoring wells	Previously gathered information, including unique well action levels, will be checked against local/regional piezometric pressure trends. Individual well monitoring frequency will increase as required to support mitigation planning and execution.	Mitigations will be unique to each well circumstance and will include consideration of the following. Flowing wells which are no longer flowing may require pumps. Pumped wells where the piezometric pressure head has dropped below the pump intake level may need either a new pump set up or to lower the pump intake level. Where water supply has been temporarily lost (i.e., water supply system requires adjustment) provide clean water for consumption and other domestic/livestock uses.
Unanticipated rate of change in piezometric pressure	Discuss rate of change with construction crews and pumping crews to determine if the pumping rates can be adjusted	Adjust pumping rates at the LMOC to lower rate of change.
Landowner initiated incident	Log and investigate incident.	Mitigations may be required if the incident is determined to be Project related. Where water supply has been temporarily lost (i.e., water supply system requires adjustment) provide clean water for consumption and other domestic/livestock uses.

Once a 45% change in groundwater pressure is observed at the Project monitoring well, mitigations may be required at the nearby private wells. The previously collected information (elevations of top of well, depth to pump and depth to well bottom) can be checked against the piezometric pressure of the nearby Project monitoring wells. There may be need to interpolate between two Project monitoring wells to estimate the elevation of the piezometric pressure head (masl) at some private wells. A spreadsheet database will be developed and used to manage the water supply well information, including the relationship between individual water supply wells and the local piezometric pressure head. Monitoring frequency at individual wells may be increased, as required, to check against expected pressure changes and potentially adapt programs. Ideally, mitigations will be implemented ahead of water supply impairment; however, circumstances may impact the rate of piezometric pressure head decrease at individual wells. Therefore, the rate of drop of the piezometric pressure head and the seasonal nature of groundwater head variation will need to be considered in mitigation timing.

During depressurization programs, nearby Project monitoring wells will be actively monitored to confirm that required drawdown is achieved in the work area. If monitoring programs indicate groundwater quantity effects in excess of the management thresholds (i.e., the rate of decline in aquifer piezometric pressure is greater than expected) then pumping rates will be adjusted or additional wells will be installed at the construction site to maintain the required drawdown in the immediate work area while limiting the amount of off-site drawdown which could affect local residents. Continued monitoring will determine the need for additional adaptive management measures. Other mitigation measures will be developed, as required, based on further investigation and monitoring data collected during the Project construction.

9.2.3 Groundwater Quality

Groundwater quality monitoring will continue during construction and operations phases, although there are no anticipated effects to groundwater quality resulting from the Project construction or operation activities. Data collected from private water wells as a result of a landowner-initiated incident will be compared against provincial and federal livestock watering or drinking water quality guidelines (see Section 4.2) and notifications will be made if any results which indicate adverse effects and risk to human or livestock health will be communicated to local private well owners. Regional changes to water quality identified through the regular Project monitoring and sampling program will be managed as shown in Table 4. Groundwater quality thresholds have been set to trigger additional monitoring/sampling as a result of a statistically significant change (i.e., 20% increase over baseline) and to determine well specific mitigations if a parameter of concern increases to 75% of the regulatory criteria, guideline or objective and represent industry standard threshold levels. The response to the initial threshold exceedance identified in a Project monitoring well could include additional sampling of private water wells to confirm the quality of the water supply. If concentrations continued to increase and exceeded the second threshold (75% of the applicable guideline), well specific mitigations would need to be investigated and implemented, as required.

Table 4: Thresholds, Actions and Possible Mitigations for Unanticipated Project-Related Private Water Quality Effects

Threshold	Action	Possible mitigations
Unanticipated changes in water quality reported by private well owner.	Log and investigate incident. Complete groundwater monitoring and sampling activities at private well location. Determine if there are any threshold exceedances and action accordingly Investigate if the change is Project related.	Mitigations will be unique to each well and well system and are dependent upon confirming that the perceived and identified change is a result of Project activities, the parameter and the individual water supply system. Where water quality has been temporarily impacted (i.e., a change in water quality has been detected in the well) provide clean water for consumption and other domestic/livestock uses during the initial investigation. If the change is due to the Project, water supply should continue until the issue is mitigated.
Concentration of parameter increases to a concentration that is 20% higher than the baseline geometric mean concentration	Assess whether the maximum parameter concentration exceeded this threshold during baseline period. Complete statistical trend analysis (requires minimum 4 data points) if possible, to determine if there is a trend in the data.	If the maximum parameter concentration during the baseline did not exceed the threshold and there is not sufficient data to complete a statistical trend analysis, complete weekly groundwater monitoring and sampling at this location for a minimum of four weeks. If the maximum parameter concentration exceeded this threshold during the baseline period, no further actions are required at this time. If an increasing trend is identified in the data set, an increased frequency of sampling should be implemented until the parameter reaches the next threshold or the increasing trend resolves over four consecutive sample dates. If the parameter threshold exceedance could present a risk to a receptor (i.e., exceeds a regulatory criteria, objective or guideline), initiate a groundwater testing program in nearby landowner wells.

Threshold	Action	Possible mitigations
Concentration of parameter increases to 75% of the applicable guideline (HC-DWQG, CCME, MWQGOS)	Assess whether parameter concentrations exceeded the threshold or the guideline during baseline. Complete statistical trend analysis (requires a minimum of four data points) if possible, to determine if there is a trend in the data. Complete an investigation to determine the cause of the change in water quality and whether the change is Project related.	If the data set is not sufficiently large, complete additional sampling weekly until enough data are collected to permit statistical trend analysis. If the parameter concentration exceeded the guideline or criteria during the baseline period, and there is no increasing trend, no further action is required. If the parameter concentration exceeded the guideline or criteria during the baseline period, an increasing trend is identified and an investigation into the cause has determined that the change is related to the Project, mitigation options will be investigated. Mitigations will be well-specific and based on the specific effect (e.g., water supply trucks, new deeper wells, reverse osmosis, decommissioning a nearby well that is causing problem). Potable water will be supplied, if required (i.e., groundwater parameter concentrations are reported at concentrations that exceed the applicable regulatory criteria, objective or guideline).

9.2.4 Groundwater-Surface Water Interactions

As discussed in Section 8.4.3, data collected during monitoring of these well clusters will be provided at regular intervals (i.e., following each monitoring and sampling event) to the wetlands monitoring team for incorporation into their assessment and decision making. Any identified change (i.e., reversal of vertical gradient) will be cause for immediate notification to the wetlands monitoring team and Manitoba Infrastructure and Transportation. Monitoring identified in wetland monitoring plan would be used to inform mitigation planning and may include mitigations or execution of adaptive management processes identified in the SWMP, the CEMP, OEMP, PERs, EPP and or others depending on the nature of the change experienced.

9.2.5 Operations and Maintenance Plan

Based on experience gained through construction, an operations and maintenance plan will be developed for groundwater management components such as monitoring wells and depressurization works as part of long-term operations and maintenance activities.

9.3 Contingency Measures and Emergency Response

Contingency measures and emergency response will be included for unforeseen events or circumstances related to groundwater in various planning documents for the program. These will be developed and finalized prior to construction, and include the following:

- Groundwater Depressurization Plan – The Groundwater depressurization plan will include contingency measures for loss of power during depressurization and will include provisions to increase pumping rates if possible or longer-term measures such as additional wells to provide additional depressurization if needed.
- Safety and Health Plan – The health and safety plan for the Project and individual contractors must address hazards associated with channel and deeper excavations where unplanned discharge of groundwater may occur in an emergency situation..
- Construction Environmental Management Program – The CEMP provides specific measures to address the potential contamination of groundwater from hazardous materials and waste, including materials and waste management and emergency spill response and reporting procedures
- Complaint Resolution Process – The complaint resolution plan describes the processes and procedures for receiving and responding to private well owner complaints related to groundwater quantity and/or quality issues identified within private water wells. The process describes the complaint response and investigation process. Mitigations will be determined on a case-by-case basis and determined by the outcome of the investigation.

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Part 3: Lake St. Martin Outlet Channel

11.0 LSMOC EXISTING CONDITIONS

11.1 Overview

Since 2011, with the initiation of the EOC Reach 3 channel, and between 2015 and 2019 for the current LSMOC, several field programs were conducted within the LSMOC portion of the LAA. These included test hole and monitoring well installation, instrumentation, pumping tests, groundwater monitoring and water quality sampling. Groundwater monitoring and water quality sampling was also completed up to 2021 (KGS 2021a, KGS 2021b, KGS 2022). Further details on hydrogeologic conditions of the LSMOC can be found in Appendix 1B and are summarized below.

The LMOC and LSMOC portions of the LAA each display a unique response, and overall range in observed seasonal (i.e., year-to-year) and intra-seasonal (i.e., within season) aquifer piezometric pressure variability. Piezometric pressure changes that occur within the LAA portion of each channel have a different set of implications, in terms of receptors. In terms of groundwater quality, while the existing regional conditions surrounding the LMOC and LSMOC are generally comparable, the implications of any water quality changes with respect to the receptors in the vicinity (LAA portion) of each channel are different. Importantly, the implications for piezometric pressure variability/changes and/or groundwater quality changes within the LAA portion of the LMOC are related to a large number of 3rd party domestic and agricultural well users, along with the natural environment and nearby wetlands. Within the LSMOC portion of the LAA, the key sensitivity of groundwater discharge related to aquifer piezometric pressures and/or any groundwater quality changes is connected directly to groundwater contributions to the wetlands and fens that are pervasive in the LAA portion of the LSMOC. Because of these unique differences between the LMOC and LSMOC, adaptive management planning and associated setting of trigger levels within the adaptive management plans are somewhat unique and are directly reflective of the key needs within each LAA portion, to facilitate timely mitigative actions that are triggered appropriately and effectively.

Locations available for groundwater measurements within the LAA portion of the LSMOC are provided in Figure 9. Key regional recharge areas of note for the confined bedrock aquifer occur near Gypsumville, and along outcrop areas that occur immediately to the north-northwest and south of the Lake St. Martin Narrows (Figure 10). In addition, the high elevation bedrock bluff area approximately 10 km southeast of Lake St. Martin also functions as a sub-regional bedrock aquifer recharge area, with the bedrock surface in this location situated well above the aquifer piezometric pressure surface. In the region surrounding the LSMOC, in the Dauphin River area, or in any location in proximity to Lake Winnipeg or Lake St. Martin, the confined piezometric pressure within the bedrock aquifer is measured (KGS 2021b) very near, and in some cases above, the ground surface (i.e., flowing artesian). This occurs because Lake Winnipeg and Lake St. Martin, and associated near-lake low-lying wet areas, are key discharge areas for the bedrock aquifer. Because of this, a strong upward gradient for discharge is anticipated and has been observed to be present in areas close to Lake Winnipeg, including within the region of the LSMOC.

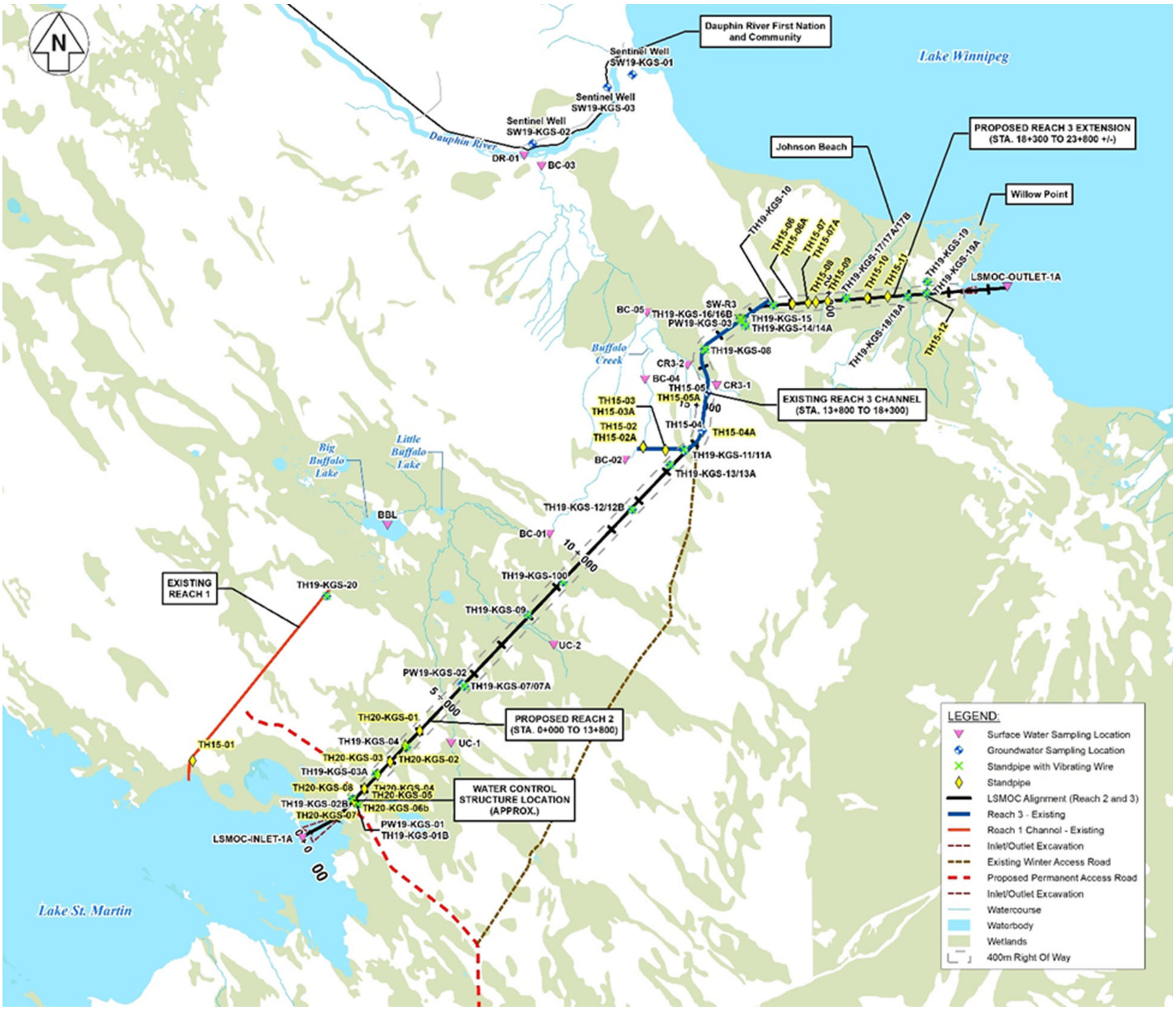

Figure 9: Monitored Well and Test Hole Locations

Detailed contours of the bedrock aquifer piezometric pressures observed in instrumented test holes and monitoring have been contoured, and a schematic of these piezometric pressure contours for the confined bedrock aquifer are presented in Figure 10. This figure also includes the locations of artesian groundwater spring sites as interpreted from aerial photography and field observations.

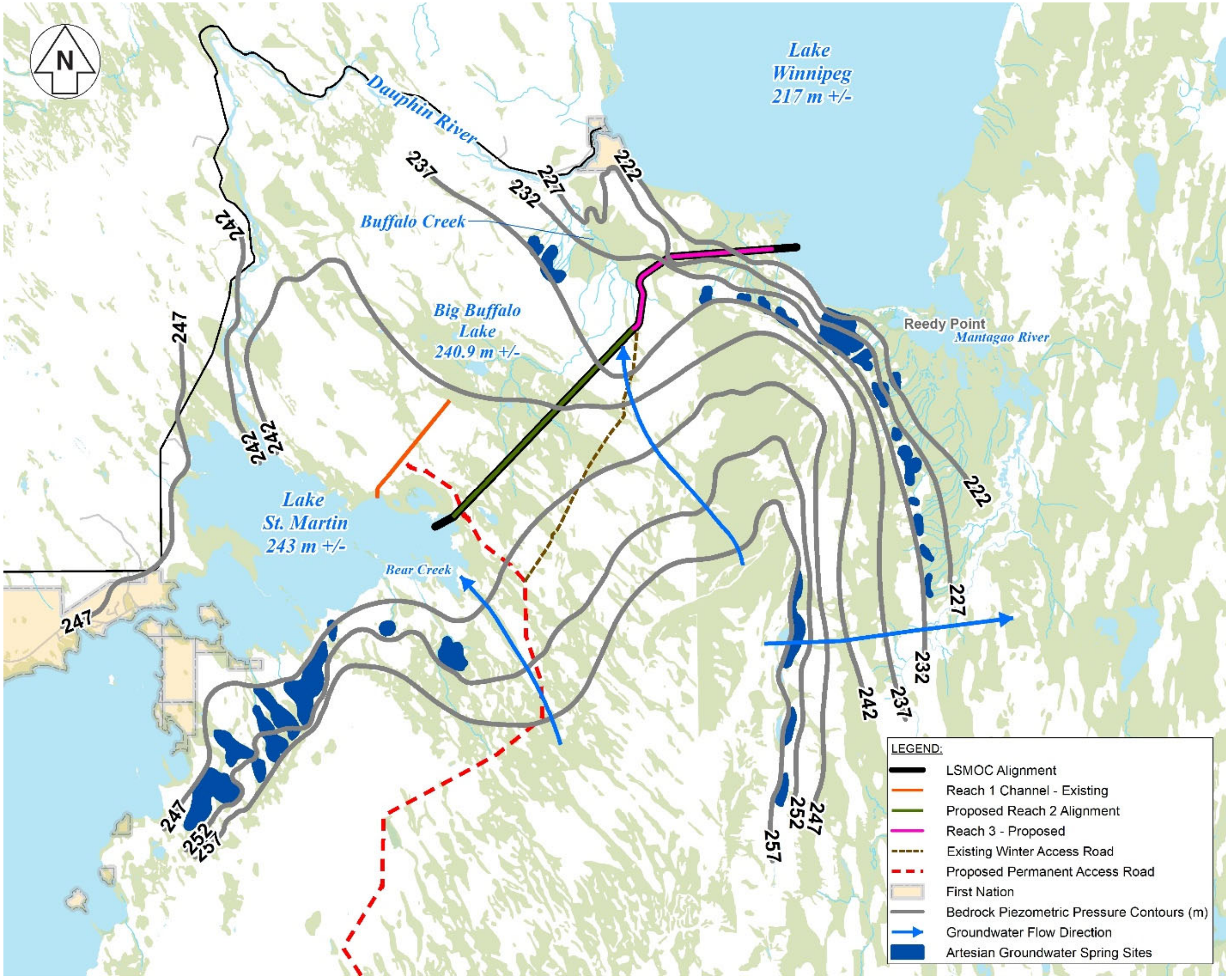

Figure 10: Schematic of Regional Artesian Spring Sites and Contoured Bedrock Aquifer Piezometric Pressures

Artesian spring sites form when bedrock is relatively close to surface (e.g., at escarpments and/or where the till is also thin), and importantly, where the underlying bedrock aquifer pressure is sufficient to overcome the confining weight of the overlying aquitard soils. Discharge of the confined bedrock aquifer in the form of artesian groundwater springs are noted in the region surrounding the LSMOC as follows:

- As baseflow to Lake St. Martin and Lake Winnipeg, limited by the condition of the overlying till aquitard found below the recent lake sediments.
- As baseflow through exposed bedrock to the existing Reach 3 Channel.
- A series of flowing artesian springs draining northwestward to Lake St. Martin and discharging at ground surface elevations between approximately invert elevation 250 m to El. 255 m at the west toe of slope of the high ground area located immediately east-southeast of Lake St. Martin narrows.

- A series of flowing artesian springs draining northerly to Lake St. Martin in the vicinity of the north basin and forming tributaries of Bear Creek and discharging at ground surface elevations of approximately El. 250 m at the west-northwest toe of slope of the high ground area located immediately east-southeast of Lake St. Martin narrows and the north basin of the lake.
- A series of flowing artesian springs draining easterly to the Mantagao River and discharging at ground surface elevations of approximately El. 255 m at the easterly toe of slope of the high ground area located immediately east-southeast of Lake St. Martin narrows and the north basin of the lake.
- Based on the peat morphology and surface water elevation relationships of the Big Buffalo Lake Complex (El. 240.9 m to El. 241.5 m), and bedrock piezometric pressure conditions measured along the LSMOC channel in adjacent areas (e.g., minimum of El. 242.6 m), there is an inferred aquifer discharge condition at the Big Buffalo Lake Complex.
- A series of flowing artesian springs draining northeasterly, forming tributaries that connect to Big Buffalo Creek, and discharging at ground surface elevations of approximately El. 235 m and located north-northeast of the big Buffalo Lake Complex.
- A series of flowing artesian springs draining northeasterly to Lake Winnipeg and forming tributaries of the Mantagao River and discharging at ground surface elevations of approximately El. 220 m to El. 230 m, at the northern and northeasterly toe of slope located immediately along the shoreline of Lake Winnipeg, near Reedy Point.
- Piezometric Pressure Conditions and Variability Along LSMOC.
- The confined bedrock aquifer pressure condition, driven by infiltration within aquifer recharge areas of relatively high bedrock elevation and thin overburden cover, results in strong gradients for groundwater discharge, or exfiltration (to flowing artesian conditions) along the Lake St. Martin channel alignment, and with regional bedrock groundwater flows toward discharge at Lake St. Martin and Lake Winnipeg (Figure 9).

11.2 Groundwater Piezometric Head

Figure B-2 (Appendix 1B) is a longitudinal stratigraphic profile of the LSMOC. Along the base of the drawing (i.e., X-axis), the channel stationing (in meters) is shown, which provides the location along channel in lineal meters, where the inlet area within Lake St. Martin is station (Sta.) 0+000, and the outlet area within Lake Winnipeg is station 24+500. Bedrock aquifer pressure conditions are broadly defined as follows, based on channel reaches, defined by the channel stations noted below (Refer also to Figures 9 and 10):

- Lake St. Martin – Sta.10+500: Between approximately El. 245.0 m (Sta. 1+618) - El. 242.6 m (Sta. 8+000); and in places exhibiting flowing artesian conditions; influenced by the surface water elevation at the Big Buffalo Lake Complex (El. 240.9 m – El. 241.5 m) and its possible interconnection to the bedrock aquifer; vertical gradients within the bedrock aquifer are upward (i.e. a discharge condition), and vertical gradients between the bedrock aquifer and overlying till aquitard are also upward;

- Sta. 10+500 – Sta. 18+000: Between approximately El. 236.5 m (Sta. 11+716) - El. 230.5 m (Sta. 17+673); comparable in general to ground surface elevations; influenced by artesian spring discharges at ground surface elevations of approximately El. 235 m, and located north-northeast of the Big Buffalo Lake Complex; influenced by artesian spring discharges at ground surface elevations of approximately El. 230 m, and draining northeasterly to Lake Winnipeg and forming tributaries of the Mantagao River, and near Reedy Point; vertical gradients within the bedrock aquifer are upward (i.e., a discharge condition), and vertical gradients between the bedrock aquifer and overlying till aquitard are also upward, in particular within the existing Reach 3 channel area (however this can vary locally); and
- Sta. 18+000 – Lake Winnipeg: Between approximately El. 222.5 m (Sta. 20+416) - El. 218.3 m (Sta. 22+490); typically well below ground surface elevations; influenced by artesian spring discharges at ground surface elevations of approximately El. 220 m, and draining northeasterly to Lake Winnipeg and forming tributaries of the Mantagao River, and near Reedy Point; vertical gradients within the bedrock aquifer are upward (i.e. a discharge condition), and while the bedrock aquifer remains confined by the till, vertical gradients between the bedrock aquifer and overlying till aquitard are in general downward, reflecting the enhanced decrease in piezometric pressure of the bedrock aquifer in the lower reaches of the channel alignment, and the strong influence of aquifer drainage through the artesian spring sites near Lake Winnipeg and the Mantagao River. However, where the bedrock is deeper, and in closest proximity to Lake Winnipeg, the vertical gradients between the bedrock and the overlying aquitard can be strongly upward, reflecting the strong exfiltration or discharge conditions for the bedrock aquifer at Lake Winnipeg.
- Flowing artesian well conditions from the bedrock aquifer system have also been observed in the Dauphin River area along the west slopes to Lake Winnipeg, and below Lake St. Martin and Lake Winnipeg, during drilling programs completed at the LSMOC inlet and outlet areas, by Manitoba Transportation and Infrastructure. These conditions are also consistent with the 2011 and 2015 field investigation results along the LSMOC where artesian flow conditions were encountered up to 1 m above ground surface (KGS Group 2021b).

Based on regionally-available multi-year data (KGS 2016, KGS 2021b), bedrock aquifer piezometric pressure conditions in the RAA of the LSMOC generally fluctuate (rise) by approximately 1.0 m to 1.2 m during the spring freshet. The duration and timing of the aquifer rise can vary, but in general these pressure changes are noted to occur between approximately mid-March and about mid-May to the end of May, each year. Additional monitoring of the bedrock aquifer in the region of the Project indicates that the bedrock aquifer piezometric pressure can vary by approximately 1.5 m +/- 0.5 m (i.e., 1.0 m to 2.0 m) due to seasonal conditions and as a response to high intensity precipitation events in the region (KGS 2021b).

11.3 Groundwater Quality

Existing groundwater quality in the LAA portion of the LSMOC was characterized using data from groundwater samples collected from on-site wells installed since 2019 (KGS 2021a, KGS 2022). The purpose was to:

- establish a preconstruction baseline of the groundwater quality so that changes occurring during or after construction can be identified
- assess the potential effects of groundwater being discharged to the surface during depressurization on surface water quality

In the LSMOC portion of the LAA, groundwater quality monitoring data is a compilation of data collected in field programs conducted between 2019 and 2020 and as part of the ongoing pre-construction monitoring program where monitoring and groundwater samples were collected during 2021 field programs (KGS 2022). Four sampling events were conducted during 2019, two during 2020, and two during 2021, including both groundwater and surface water monitoring and sampling during the field programs (KGS 2022, KGS 2021a).

Water quality results from these programs were assessed, using multiple lines of evidence, during 2021 (KGS 2021a), and also in general compared to applicable CCME and HC-CDWQG criteria (KGS 2022). Based on reviewing existing data and the Project-specific monitoring, groundwater quality in the aquifer appears to be good and the aquifer currently provides good quality groundwater of drinking water. The groundwater quality generally meets applicable CCME and MWQSOG criteria and is comparable to the existing surface water quality in the area.

Detailed assessment of pre-construction water level data and water quality data are provided in separate memos (KGS 2021a, KGS 2021b) and are summarized below:

- The geochemistry of surface water samples collected from the perched peat (fen) deposits show a similar chemistry to the bedrock groundwater, including a more neutral pH and a carbonate geochemical signature. These samples were collected prior to the spring melt in 2019 when surface water contribution would be lowest and groundwater contribution would be highest. Groundwater discharge to artesian springs at numerous locations in the LSMOC watershed appears to control the surface water chemistry in the perched peat and fen surface water system overall, as well as the chemistry of the wetlands and fens themselves. Even in areas where the thick low permeability till aquitard prevents direct discharge of bedrock groundwater to the surface, the water quality in the peat and fens has a bedrock groundwater signature, presumably due to artesian spring discharge in other locations in the region of the LSMOC.
- The till groundwater geochemistry is unique from the bedrock aquifer groundwater geochemistry, and surface water geochemistry, and shows generally higher dissolved solids and more frequent elevated percentages of sulphate and chloride than in the bedrock groundwater or surface water system. One well at the proposed location of the WCS is atypically high in dissolved solids and sulphate. The low permeability of the till limits any water influx into the till, either from discharge from fresher groundwater below, or recharge from fresher surface water and wetland sources perched above the till. The integrity and functioning of the till aquitard is demonstrated by its thickness and low

permeability characteristics, combined with its unique groundwater geochemistry, and with the observation of upward gradients (to flowing artesian conditions) and because it demonstrates a confining condition for the underlying bedrock aquifer throughout the region of the LSMOC.

- Bedrock groundwater geochemistry north of the Dauphin River in the community of Dauphin River First Nation (including domestic wells and Project sentinel wells) is distinct from groundwater found south of the river (including a sentinel well and bedrock wells along the channel alignment). A higher proportion of sulphate and chloride is found in the wells north of the Dauphin River. This would indicate that the Dauphin River is a discharge boundary condition of the regional aquifer.
- Bedrock groundwater geochemistry along the channel alignment is generally similar and consistent, with a few wells showing more mineralized conditions, with higher dissolved solids and sulphate. One well near the end of the channel towards Lake Winnipeg shows significant fluctuations in water type seasonally, which could indicate connection with surface water sources, or seasonal changes in groundwater flow paths.
- Stable isotope results for oxygen indicate a generally recent recharge source for the groundwater system, and relatively short aquifer residence times, which is also consistent with the overall geochemical results. Tritium results also indicate that groundwater at two locations is representative of very recent, modern recharge (i.e., post-1950), and that the groundwater in the vicinity of the WCS has had the longest residence time in the region of the LSMOC (which is furthest away from the observed artesian spring sites in the region of the LSMOC).

11.4 Groundwater-Surface Water Interactions

Two distinct groundwater systems are known to be present within the LSMOC portion of the LAA - an upper saturated peatland/fen system, and a lower confined carbonate bedrock aquifer. Glaciolacustrine clays/clay tills, and silt tills form a low permeability aquitard between the perched peat groundwater flow system, and the underlying confined carbonate bedrock aquifer system. A detailed assessment of the water level conditions monitored at the available site instrumentation was completed in 2021 (KGS 2021b).

The upper, saturated peat and fen unit is perched above the clays (where present) and underlying till units. The peat is recharged directly from surface rainfall and snowmelt. Groundwater flows within the peat are locally controlled. Small-scale flow systems develop from raised bog/peat mound areas, flowing radially outward toward relatively lower-lying depressions and other associated open water areas. The water table within the peat is at, or near, ground surface, with an overall hydraulic gradient, including surficial flow, to the east.

Water levels within the perched peat and fen wetlands are largely impacted by surface water measures and drainage modifications described within the Project SWMP. Any changes in bedrock piezometric pressures as a result of the LSMOC are not predicted to cause measurable effects on the peatlands in areas in proximity to the LSMOC, due to the presence of the extensive silty clay and dense silt till aquitard in most of the Project region. Changes in groundwater piezometric pressures within the confined bedrock aquifer could possibly alter the total discharge of groundwater to the surface wetlands and in particular the fens that are directly interconnected via artesian springs, such as in proximity to the Big Buffalo Lake complex and Big Buffalo Creek, and along the shores of Lake Winnipeg near Willow Point. These possible changes in baseflow discharge of bedrock aquifer groundwater to the surface water system could potentially impact the associated aquatic and terrestrial habitat. Analysis of the geochemistry of the artesian spring discharge groundwater data (KGS 2021a) shows that it is typical of bedrock groundwater geochemistry found in Project wells along the LSMOC channel alignment.

The geochemistry of surface water samples collected from the perched peat (fen) deposits show a similar chemistry to the bedrock groundwater, including a more neutral pH and a carbonate geochemical signature. These samples were collected prior to the spring melt in 2019 when surface water contribution would be lowest and groundwater contribution would be highest (KGS 2021a). Groundwater discharge to artesian springs at numerous locations in the LSMOC watershed appears to control the surface water chemistry in the perched peat and fen surface water system overall, as well as the chemistry of the wetlands and fens themselves. Even in areas where the thick low permeability till aquitard prevents direct discharge of bedrock groundwater to the surface, the water quality in the peat and fens has a bedrock groundwater signature, presumably due to artesian spring discharge in other locations in the region of the LSMOC.

Glaciolacustrine clays/clay tills, and silt tills form a low permeability aquitard between the perched peat and fen groundwater flow system, and the underlying confined carbonate bedrock aquifer system. The perched water levels in the surficial peat are maintained by the regional surface water drainage patterns combined with the influence of the underlying low permeability aquitard, restricting any downward drainage. The aquitard also maintains confined piezometric pressure, to flowing artesian pressures, within the bedrock aquifer. The piezometric pressures confined within the bedrock, over geologic time, have also given rise to relatively high piezometric pressures within the overlying till aquitard as well. Along the upper reaches of the LSMOC, piezometric pressures within the till aquitard are very near the top of the aquitard itself, and near the base of the overlying peat. In these areas there is an upward gradient between the bedrock aquifer and till aquitard piezometric pressures.

The till groundwater geochemistry is unique from the bedrock aquifer groundwater geochemistry, and surface water geochemistry, and shows generally higher dissolved solids and more frequent elevated percentages of sulphate and chloride than in the bedrock groundwater or surface water system (KGS 2021a). The low permeability of the till limits any water influx into the till, either from discharge from fresher groundwater below, or recharge from fresher surface water and wetland sources perched above the till. The integrity and function of the till aquitard is demonstrated by its thickness and low permeability characteristics, combined with its unique groundwater geochemistry, and with the observation of upward gradients (to flowing artesian conditions) and because it demonstrates a confining condition for the underlying bedrock aquifer throughout the region of the LSMOC.

In areas closer to the artesian spring sites and down channel from the existing EOC Reach 3 channel, bedrock aquifer pressures remain confined but are somewhat reduced, due to the natural discharges of bedrock groundwater to the surface water system at the artesian spring sites (KGS 2021b). In these areas, the till and clay aquitard pressures are somewhat higher than those measured in the bedrock aquifer. Here, downward gradients from the aquitard to the bedrock aquifer are more common. Negligible recharge through the aquitard to the bedrock is expected, as recharge to the bedrock occurs regionally within bedrock outcrop areas, and/or where the bedrock topography is high, and the overlying till cover is thin.

Oxygen stable isotope results indicate a generally recent recharge source for the groundwater system, and relatively short aquifer residence times, which is also consistent with the overall geochemical results (KGS 2021a). Tritium results also indicate that groundwater at two locations is representative of very recent, modern recharge (i.e., post-1950), and that the groundwater in the vicinity of the WCS has had the longest residence time in the region of the LSMOC (which is furthest away from the observed artesian spring sites in the region of the LSMOC).

12.0 LSMOC SUMMARY OF EFFECTS

12.1 Overview

Groundwater conditions along and in the vicinity of the LSMOC are complex and driven by the regional groundwater aquifer system in the Interlake (i.e., between Lakes Manitoba and Winnipeg), and particularly between groundwater recharge and discharge areas associated with Lake St. Martin and Lake Winnipeg. Management of the groundwater conditions is critical for the successful construction of the Project as discussed below. Responsible management of the groundwater conditions has been identified as critical to aboriginal treaty rights, health, social conditions and sustainability of these communities.

Confined to flowing artesian bedrock aquifer conditions are present in most areas of the LSMOC as shown by 2015 and 2019 groundwater elevation/pressure data that is shown on Figure 10 In areas where the excess confined bedrock aquifer pressures are elevated relative to the thickness of the confining till and silty clay aquitard units, there is a potential for basal heave/hydraulic fracturing of the till. The potential for this to occur is greatest during channel excavation, due to unloading of the confining aquitard units, which may in turn heave due to the underlying confined bedrock aquifer piezometric pressures, thereby inducing a connection of the bedrock aquifer to discharge at the base of the channel excavation. Under these conditions, there is a possibility for groundwater discharge to the channel excavation area(s), which will require management during construction of the channel. This condition is known to have developed naturally and has been observed in the region of the LSMOC where artesian spring sites are common (Figure 10). The total flow of groundwater from the bedrock aquifer to the LSMOC is anticipated to be limited by the low transmissivity of the fractured bedrock observed to date within existing exploration areas, and within the base of EOC Reach 3. There remains potential for variability and localized karstic and higher transmissivity bedrock within other areas of the Project. Because these excess bedrock aquifer piezometric pressure conditions cannot be avoided in the LSMOC portion of the LAA, one of the Project design considerations is that there will be some groundwater discharge baseflow to the channel excavation, originating from discrete and somewhat limited source areas.

In general, consideration of groundwater piezometric pressures and any associated aquifer depressurization requirements during the design phases of the Project will apply not only to the channel excavation, but also to the channel inlet/outlet excavations, the channel drop structure installations, and the channel WCS foundations (including associated long-term WCS uplift pressure mitigation measures).

In terms of geotechnical stability, groundwater discharge areas along the centerline and base of the channel may pose fewer short- and long-term challenges than if they were to occur near the channel side slope, or near (or beneath) an engineered structure. Minimizing and mitigating groundwater discharges is being addressed as part of detailed design and in construction sequencing.

Active depressurization of high groundwater pressures with temporary groundwater depressurization systems pumping from bedrock wells are anticipated to be required to facilitate deep foundation excavations for construction of concrete structures (i.e., the WCS). Following construction, passive sub drains are planned to lower piezometric pressures beneath the base of the WCS to protect against uplift.

The LSMOC is currently directly interconnected with the exposed bedrock in a portion of the existing EOC Reach 3 channel. Additional interconnection will occur as the channel is deepened and widened through the Reach 3 area. Groundwater discharge will occur with this work; however, the degree of groundwater discharge will be controlled by the low bulk transmissivity of the bedrock encountered, which to-date has been calculated based on water well pump testing results, and with measurement of baseflow along the existing Reach 3 channel.

The excess bedrock piezometric pressures will be considered during the excavation of the channel inlet, and outlet, within the cofferdam areas, depending on the depth of lake bottom excavation determined during design optimization. Seepage discharge areas may develop at the base of the excavation from the confined bedrock aquifer foundations or from Lake St. Martin and Lake Winnipeg via lake bottom deposits, and the resulting discharge must be managed.

Drop structures are being designed to account for excess piezometric pressures, specifically within construction excavations, so that the hydraulic, geotechnical and constructability requirements are satisfied throughout the short and long-term timeframes.

The nearest groundwater well users are at the Dauphin River First Nation community, 5 to 6 km north and northeast of the channel (Figure 9). Most of the community wells are on the north side of the Dauphin River, which serves as a groundwater discharge, hydraulically isolating domestic wells on the north side. A few wells are located on the south side (i.e., Project side) of the Dauphin River.

Although the development and operation of the LSMOC is very unlikely to result in any temporary or permanent water quality or water level impacts to domestic wells in the region, protection of the regional groundwater aquifer must be considered as practicable during design optimization. The monitoring of potential effects of the Project on groundwater (levels and quality) is provided at sentinel wells located in the community on both sides of the Dauphin River (Figure 9). Continuous monitoring of groundwater elevations will be provided to track any long-term groundwater elevation changes. Water quality monitoring in the Sentinel wells will establish baseline and long-term trends.

Water levels within the perched peat wetlands are largely impacted by surface water measures and drainage modifications described within the SWMP. Any changes in bedrock piezometric pressures as a result of the LSMOC are not estimated to cause any measurable effect on the peatlands as a whole in any areas in proximity to the LSMOC, due to the presence of the extensive silty clay and dense silt till aquitard.

Changes in groundwater piezometric pressures could possibly alter the total discharge of groundwater to wetlands that are directly interconnected via artesian springs, such as in proximity to Big Buffalo Lake, and along the shores of Lake Winnipeg near Willow Point. These possible changes in baseflow discharge to surface could potentially impact the associated aquatic and terrestrial habitat. However, there is no scenario where these naturally occurring spring discharge sites would cease to flow entirely because of the LSMOC.

12.2 Groundwater Piezometric Head

The bedrock aquifer piezometric pressure conditions will rise in response to the change in boundary conditions – specifically the staging or rise of surface water within the LSMOC channel in these interconnected channel areas. This will act to return the bedrock aquifer system to a discharge (exfiltrating) condition at the channel in these interconnected channel areas, even with the channel full, and in operation. With repeated, short-lived pressure conditions favoring infiltration from the channel to the bedrock aquifer, development of a localized influx of infiltrated channel surface water, local to the channel and moving further down gradient in the bedrock aquifer groundwater system near the channel, is a possibility (KGS 2021b). These mixed surface and ground waters are expected to migrate through the aquifer system to the next available discharge area, located either within the LSMOC channel itself, at an existing downgradient artesian spring site, or possibly in the longer term as baseflow to Lake Winnipeg.

12.3 Groundwater Quality

Repeated infiltration of small quantities of surface water may cause local and short-lived water quality changes to the regional bedrock aquifer resource in close proximity to the LSMOC. It is important to distinguish that infiltration may only occur in areas where there is a physical connection from the channel to the bedrock aquifer. These interconnections are localized and will occur only where the till aquitard has been fractured or heaved during excavation of the channel, or where bedrock is exposed within the channel (such as at Reach 3, currently). However, there are no nearby domestic well users and the overall hydraulic gradient (groundwater flow direction) in the area is to the east northeast, with discharge to existing downgradient artesian spring sites, and ultimately into Lake Winnipeg.

12.4 Groundwater-Surface Water Interactions

The creation of new groundwater discharge pathways into the LSMOC channel will locally increase the direct connection of exfiltrating groundwater to channel surface water, originating from the underlying bedrock aquifer. The bedrock aquifer in the LAA portion of the LSMOC is confined, and as such responds quickly in piezometric pressure to changes in aquifer boundary conditions (i.e., changes to water levels or pressure conditions at aquifer recharge and discharge areas). The LSMOC is situated in an area of high confined bedrock aquifer groundwater pressures, which drives groundwater discharge to the LSMOC channel as baseflow under virtually all scenarios of variability in aquifer boundary conditions. However, during certain times of channel operation, such as the rapid staging of surface water within the channel as it is opened, downward vertical gradients may be temporarily developed between the surface water within the operating channel and the underlying bedrock groundwater aquifer, resulting in short-term (hours) and localized infiltration of surface water to the bedrock aquifer. This will only occur in locations where there is a physical interconnection of the LSMOC channel to the bedrock through the till aquitard, or where the bedrock aquifer is directly exposed within the LSMOC channel base, and only during the limited period of time when the water level within the LSMOC channel is higher in elevation than the piezometric pressure of the underlying confined bedrock aquifer.

The channel optimization through the detailed engineering design phase will include consideration to mitigate the potential for any downward vertical gradients to the bedrock aquifer by minimizing the difference between the operating (staged) channel water level, and the current static piezometric pressure in the underlying bedrock aquifer, particularly in the exposed bedrock area of EOC Reach 3.

Water levels within the perched peat wetlands adjacent to the LSMOC are largely impacted by local surface water conditions. Based on water quality analyses, the perched peat wetlands (fens) are also fed by carbonate bedrock aquifer groundwater at artesian spring sites that are visible in the region, and possibly other diffuse seepage areas that are harder to identify without the surface expression of the spring sites themselves. Many peatland areas in the region of the LSMOC are fens, due to these naturally occurring water regime conditions where the bedrock aquifer is discharging to the surface water (fen) system. Measures to address surface water drainage modifications are included in the SWMP. Any changes in bedrock piezometric pressures as a result of the construction and operation of the LSMOC are not expected to cause any measurable effect on the peatlands and fens as a whole in any areas in proximity to the LSMOC, where there is an extensive silty clay and dense silt till aquitard.

Changes in groundwater piezometric pressures could alter the discharge of groundwater to wetlands that are directly interconnected via artesian springs, such as in close proximity to Big Buffalo Lake, and along the shores of Lake Winnipeg near Willow Point. These possible changes in baseflow discharge to surface have the potential to impact the associated aquatic and terrestrial habitat. Some change in artesian spring site flows to the wetlands are expected to occur naturally with seasonal variability in the aquifer piezometric pressure conditions, and with LSMOC construction activities, where there may be some limited bedrock aquifer piezometric pressure reductions in the confined bedrock aquifer. It is highly unlikely that these naturally occurring spring discharge sites would cease to flow entirely as a result of only the estimated bedrock piezometric pressure reductions related to LSMOC.

13.0 LSMOC MITIGATION MEASURES

13.1 Overview

The effect of the hydrogeologic conditions on construction and long-term operation of the outlet channel and structures has been considered in the design, as described below. This includes consideration of the baseline groundwater flow system, and changes to the flow system estimated to be a result of LSMOC construction, and/or when the channel is operated. All depressurization designs were developed in conjunction with geotechnical engineering specialists, with the goal to mitigate the magnitude and duration of any potential impacts to the bedrock aquifer piezometric pressures in the region of the LSMOC.

The channel profile optimization process includes considerations to minimize the potential for interconnection of the channel invert with the bedrock aquifer groundwater system. The maximum channel water elevation within EOC Reach 3 (where bedrock is exposed within the channel and is directly interconnected) has been constrained so that it is comparable to the current, naturally occurring piezometric pressure elevation of the bedrock aquifer at this location. Groundwater-surface water interconnections currently exist and are expected to remain at Reach 3 due to exposed bedrock and thinner overburden conditions. Limiting the channel water elevation serves to minimize the potential for the development of short-term downward gradients from the surface water to the bedrock groundwater system in the Reach 3 area. Reducing the maximum channel water elevation at this location also lowers the potential for channel-induced increased bedrock aquifer piezometric pressures in down-channel areas, where the potential could be increased for uncontrolled groundwater discharge (i.e., artesian spring breakouts) in downstream areas, where the topography drops markedly to the east.

In the remainder of the channel, the proposed invert is based in till; however, areas are present along the channel where excavating to the design invert would result in an increased potential for basal heave and fracturing of the till in the base of the channel. This could result in uncontrolled groundwater discharge from the underlying bedrock aquifer.

Construction sequencing is proposed to help manage this risk by promoting interconnections in a concentrated, central channel, area, should they occur. Channel excavation will proceed such that full excavation to design invert in these higher risk areas would proceed using a central pilot ditch and progress outwards to the full channel excavation width, as detailed in Section 12.3.

This excavation staging will minimize the potential for uncontrolled discharge in large areas of the channel base, particularly in areas closer to the channel side slopes, whose stability conditions are most sensitive in terms of overall channel excavation.

Excavation of the channel Inlet at Lake St. Martin and the channel Outlet at Lake Winnipeg will occur in the lake bottom till sediments. At the Inlet and Outlet works, groundwater discharge may occur within the construction area. If this area must be dewatered for ease of construction, any groundwater discharge will be directed to a sump and pumped out during construction. After construction, the water elevation of Lake St.

Martin and Lake Winnipeg will control the long-term rate of any groundwater discharge baseflow to the lakes. Since groundwater discharge baseflow is already occurring to both lakes from the surrounding regional bedrock aquifer, development of additional discharge zones within the inlet are considered to be acceptable where it cannot be avoided. There is no scenario where these naturally occurring groundwater baseflows to the lakes would cease to flow entirely as a result of the LSMOC. Control of surface water within the cofferdams is discussed in the SWMP.

Active groundwater depressurization (i.e., bedrock aquifer depressurization pumping with wells) will be required during construction of deeper excavations at the WCS. Design of the LSMOC is based on the WCS being located and founded on bedrock. As such, active pumping will be required to maintain the integrity of excavation as it progresses to completion and exposure of the underlying bedrock, and thereafter to dewater the excavation and exposed bedrock, in preparation for, and throughout the WCS construction activity. Long-term subsurface passive drainage of groundwater beneath the foundation will be incorporated into the active depressurization pumping well design to relieve any long-term uplift pressures on the foundation from bedrock aquifer groundwater contributions.

The drop structures incorporate a sheet pile seepage cut-off wall within the foundations, and across the width of the structure. The sheet pile wall also forms the crest, which acts as a weir to concentrate normal channel baseflow within the LSMOC. It is likely the sheet pile installation below the channel invert will require some groundwater control, anticipated to be achieved with pumping from surface sumps, or similar means. However, there is one exception to the above construction configuration at the channel drop structure founded on bedrock. The drop structure in this scenario will be comprised of a concrete weir founded on a shallow footing bearing directly on bedrock. Bedrock grouting may be required to limit seepage beneath this structure and is under evaluation in the Detailed Design.

Additional measures are required to mitigate groundwater pressures acting on the tills at the channel excavation base, and some associated structures during construction (WCS and drop structures). These are described below.

Channel

Construction sequencing will use an initial central drainage channel to control and direct areas of groundwater discharge and allow for controlled pressure relief of the bedrock aquifer groundwater system. Bedrock aquifer discharge from the existing Emergency Reach 3 channel exists currently. Groundwater discharge from other portions of the channel may also occur, with construction of the LSMOC. Bedrock aquifer groundwater conditions will equilibrate beneath, and in the vicinity of, the LSMOC channel, creating a post-construction groundwater flow system that remains in an overall discharge condition to the LSMOC, and to Lake St. Martin, Lake Winnipeg, and associated artesian spring sites. Depending on the total amount of additional bedrock aquifer baseflow to the LSMOC, the piezometric pressure condition of the aquifer may decline locally, however the regional recharge-discharge relationships will remain the same.

Water Control Structure

Active temporary groundwater depressurization will use pumping wells installed in the bedrock aquifer. Subsurface passive drainage of groundwater piezometric pressures may also be required long term at the WCS to relieve uplift pressures on the foundation.

Drop Structures

Active temporary groundwater depressurization will occur by pumping seepage from the open excavation for the sheet pile cut-off wall, during installation. No long-term measures are planned.

13.2 Aquifer Depressurization During Construction

13.2.1 LSMOC Depressurization

A construction sequencing plan is under development for construction of the LSMOC. This construction sequencing plan will require temporary bedrock depressurization at construction locations specific to each construction contract; notably at the WCS, and possibly at the channel drop structures. Because depressurization requirements for one contract area have the potential to influence other channel construction areas, the timing of a group of construction contracts and their limits needs to be considered in order to optimize the depressurization plan. Accordingly, active aquifer depressurization plans will be developed for each year of construction as a requirement of the Contractor on the various construction contracts to meet the needs of the design, which will involve the installation of temporary depressurization wells in the required areas to reduce bedrock aquifer groundwater pressure to the required targets. Groundwater quality will be monitored and mitigated as required prior to discharge to the surface drainage system.

Groundwater depressurization wells will be installed in the confined aquifer in the area of construction and groundwater will be actively pumped out to lower the pressure in the bedrock aquifer during construction, in key areas such as the WCS and at drop structures. The depressurization will continue long-term, but passively, during long-term channel operations. An estimate of the drawdown using analytical models was developed, and sensitivity analysis was performed by varying transmissivity and storativity coefficients (KGS 2021c). Typical seasonal piezometric head variation in the aquifer in the area of the LSMOC is 1.5 m +/- 0.5 m (i.e., 1.0 m to 2.0 m) per year. At the WCS, the piezometric pressure drawdown would be about 10 m during construction, reducing to a drawdown of 1.0 m at approximately 4 km distance from the WCS. Along the channel, if all drop structures were being actively depressurized during construction, approximately 8 m to 9 m of depressurization at the drop structures would reduce to 1.0 m within about 4 km of the channel. In most cases (at a distance of approximately 3 km) and in all cases (at a distance greater than 5 km), the decrease in piezometric pressure) from the Project depressurization will be well within the typical season variation of pressure and is not expected to have any impacts on domestic well operation.

13.2.2 Groundwater Piezometric Head

General

The piezometric head elevation in the LAA of the LSMOC area ranges from 245 masl near Lake St. Martin to 218.5 masl near Lake Winnipeg and is up to approximately 1.5 m to 2.0 m above ground level nearest Lake St. Martin. While still confined, the bedrock aquifer pressures decline to below ground surface below the existing EOC Reach 3 channel, due to the drawdown influence of existing artesian spring sites, in close proximity to Lake Winnipeg. The bedrock aquifer is fully saturated. In all areas along the channel and for a distance to each side, the bedrock aquifer piezometric pressure will remain above the physical bedrock surface (i.e., under a confined condition). The typical confined condition bedrock aquifer response to a project with similar conditions as for the LSMOC, and as is expected at LSMOC, is described in detail elsewhere (KGS 2021b).

Key regional recharge areas of note for the confined bedrock aquifer occur near Gypsumville, and along outcrop areas that occur immediately to the north-northwest and south of the Lake St. Martin narrows. In addition, the high elevation bedrock bluff area approximately 10 km southeast of Lake St. Martin, also functions as a sub-regional bedrock aquifer recharge area, with the bedrock surface in this location situated well above the aquifer piezometric pressure surface. In the region of the LSMOC, in the Dauphin River area, or in any location in proximity to Lake Winnipeg or Lake St. Martin, the confined piezometric pressure within the bedrock aquifer has been observed to be very near, and in some cases above, the ground surface (i.e., flowing artesian). This occurs because Lake Winnipeg and Lake St. Martin, and associated near-lake low-lying wet areas, are key discharge areas for the bedrock aquifer. Because of this, a strong upward gradient for discharge is anticipated and has been observed to be present in areas close to Lake Winnipeg, including within the region of the LSMOC. With the construction depressurization and long-term depressurization in place, the aquifer is expected to continue to recharge in the same areas, and discharge to both Lake St. Martin and Lake Winnipeg - either directly or via the LSMOC.

Channel

As the channel is constructed, any long-term (operation) depressurization measures for any section of the channel under construction, or at the WCS, will be installed. Therefore, both the short-term (during construction) and the long-term (post-construction) depressurization effects will need to be considered. Long-term measures may include passive drainage via wells at the WCS, and granular filters at individual channel drop structures and/or channel areas where groundwater baseflow may occur within the channel excavation itself.

Water Control Structure

A temporary construction aquifer depressurization system consisting of pumping wells is anticipated to be required during construction of the WCS. This will be a temporary measure used to protect against uncontrolled groundwater discharge and basal heave in open excavations during the construction phase of the WCS.

Specific depressurization requirements in the construction work area will be established during the final design of the WCS and will be specified in the tender. The Contractor would then be responsible for developing a system capable of meeting the design depressurization requirements.

Activities during the final design process will include those items needed to further define aquifer conditions, design depressurization target elevations and assess regional drawdown effects for the purpose of groundwater licensing. These may include:

- finalize detailed design of the WCS, and depressurization requirements
- design and location of additional drilling and testing programs to be carried out to further define aquifer conditions within the ROW of the Project (to be determined prior to construction).
- analysis of associated pump test results
- design of depressurization target elevations
- specify discharge water requirements (discharge point, quality, quantity, and turbidity)
- drawdown assessment in the area of work
- regional drawdown assessment
- preparation and submission of an Application for Temporary Aquifer Depressurization to MECP Water Licensing
- development of tender documents

The Contractor will be responsible for developing a construction depressurization system to achieve the design requirements and other specifications listed in the tender. Activities to be conducted by the Contractor typically include:

- design and location of drilling and testing programs to further define aquifer conditions. Analysis of associated pump test results (in consultation with the Contract Administrator)
- development of pumping system configuration for required combined total pump flow rate and individual flow rates, and discharge water requirements and associated handling of discharge groundwater (in consultation with the Contract Administrator)
- development of a groundwater depressurization plan to be approved by the Contract Administrator.
- Supply, installation and testing of bedrock pumping wells and associated observation wells according to types, sizes, materials and construction specifications, as required in the tender documents or otherwise approved by the Contract Administrator for the WCS
- supply, installation and testing and commissioning of a bedrock groundwater depressurization pumping system at the WCS, including such items as pumps, power supply, drop piping, wellhead connections, well system header discharge piping, well caps and flow meters
- bedrock groundwater depressurization system operation including preparation of discharge area for erosion control and aeration at discharge header outlet
- on-site monitoring (flow and water levels) in the area of work

In addition to monitoring the environmental effects of the construction phase depressurization program, the Contract Administrator will, as part of the adaptive management plan, monitoring, and follow-up, will conduct the following activities:

- oversight and verification of Contractor monitoring in work area
- water quality testing of the WCS and channel excavation depressurization system pump discharge water during pump test and channel construction operations
- regional monitoring of groundwater elevations at the adaptive management sites (See section 14.3.1) and sentinel wells (Figure 9)

Drop Structures

A temporary construction aquifer depressurization system consisting of pumping from a sump within the excavation area at each of the drop structures will likely be required. This is a temporary measure used to protect against uncontrolled groundwater discharge and basal heave in open excavations during the construction phase of the drop structures.

The specific depressurization requirements in the area of work will be defined during the final design and will be specified in the tender documents. The Contractor will be responsible for developing a system capable of meeting the design requirements.

Activities during the final design process will include those items needed to further define aquifer conditions, design depressurization target elevations to facilitate construction. The contractor will be responsible for developing a construction depressurization system to achieve the design requirements and other specifications listed in the tender. Activities to be conducted by the Contractor may include:

- development of a sump configuration and required combined flow rate and discharge water requirements and associated handling of discharge groundwater
- development of a groundwater depressurization plan to be approved by the contract administrator.
- Supply, installation and testing of sump materials, sump pumps according to types, sizes, materials and construction specifications, as required in the tender documents or otherwise approved by the contract administrator for the drop structure(s)
- supply, installation, testing and commissioning of the sump dewatering system at the drop structure(s), including such items as sump pumps, power supply, piping, connections, discharge piping and flow meters
- sump dewatering system operation including preparation of discharge area for erosion control and aeration at discharge header outlet
- on-site monitoring (flow and water levels) in the work area

13.2.3 Groundwater Quality

The key mitigation to protect groundwater quality in the LSMOC portion of the LAA will be to maintain channel operating water levels within the range of existing bedrock aquifer groundwater piezometric pressures and reduce the risk of surface water influences on groundwater quality, where the surface water system and groundwater systems may be interconnected due to channel excavation, specifically along the reach of the existing EOC Reach 3 channel. Construction and operation of the LSMOC will require depressurization of the aquifer to reduce the potential for basal heave, till fracturing and channel side slope failures. However, even with active depressurization during construction, the bedrock aquifer in the LAA portion of the LSMOC will remain under positive pressure, although the pressure elevation may no longer exceed the ground elevation (i.e., may no longer be under a flowing artesian condition), in places. Recharge of the aquifer via the base of the LSMOC is not expected to occur as the upward pressure gradient of the groundwater in the upper carbonate aquifer will promote groundwater discharges with re-equilibration of the groundwater system with channel construction and operations (KGS 2021b).

Should a change occur such that bedrock aquifer groundwater pressure decreases and the elevation of the piezometric pressure drops below the elevation of the bedrock surface (which is not anticipated anywhere along the LSMOC), the overlying till aquitard and passive reverse granular drains (which will be installed where interconnections through the aquitard might occur) would act as filters and as a reduced permeability for flow, for the infiltrating surface water. Pressure changes are considered to be transient events and not sufficient to cause any substantive change to the groundwater quality (KGS 2021b). Regular monitoring of the aquifer in the region will be conducted during, and post-construction.

13.2.4 Groundwater-Surface Water Interaction

An estimate in changes in groundwater flow and discharge rates was made for the construction phase of the LSMOC (Stantec 2021). Total flows are anticipated to stay the same as current conditions in the analyzed system but will be re-allocated from one discharge area to another with construction of the LSMOC. Approximately 30% of the overall annual average discharge contributions to Lake Manitoba, Lake St. Martin, and Lake Winnipeg is planned to be redirected back to the lakes during operation via the Project depressurization system and channels. The total discharge (including the channels discharge) will be the same as during baseline conditions, equal to the average annual baseline discharge (Stantec 2021). The discharge into the Project channels (LMOC and LSMOC together) that may occur during construction or operation is also predicted to be very small relative to the size of these channels. The groundwater discharge into the channels ranges from 2,000 m^3/d to 3,600 m^3/d (0.023 m^3/s to 0.045 m^3/s). These flows would be difficult to detect in the channels that have capacities of 212 to 326 m^3/s (7,500 cubic feet per second [cfs] and 11,500 cfs) (Stantec 2021). Total discharge estimated to the LSMOC during construction is approximately 0.037 cubic metres per second (m^3/s) (Stantec 2021).

13.3 Aquifer Depressurization During Operations

13.3.1 Design of Operation Depressurization Plan

To depressurize the bedrock aquifer along the LSMOC a hydraulic connection through the relatively low permeability aquitard is required. Two depressurization options are estimated to be required, including passive wells at the WCS and reverse granular drains within channel excavation and channel drop structure areas.

In some reaches of the LSMOC the excavation of the channel will intersect the bedrock directly (i.e., at the WCS, and at the existing EOC Reach 3 channel), or only a relativity thin layer of till will remain between the channel invert and the top of bedrock. In these areas pressure relief can be effectively provided by excavating to the bedrock and infilling with fine to medium grained free draining granular material. This filter material will act as a cover and provide the free drainage required to allow water to flow upward from the bedrock. This provides passive depressurization along of the bedrock where these filters are installed.

As with the passive depressurization wells at the WCS, the reverse drains along the channel will flow year-round under positive pressure (i.e., an upward gradient relative to the channel surface water levels). The reverse drain is not expected to pose a threat of contaminating the aquifer as it will be installed in aquifer discharge zone(s), not recharge zone(s). Should the groundwater pressure decrease, allowing transient surface water to infiltration to the aquifer, the drain will act as a filter for surface water as it enters the subsurface (KGS 2021b).

Depressurization wells or sumps will be placed at the LSMOC WCS with each well pumped to release groundwater from the confined bedrock aquifer into the channel, thereby reducing aquifer pressure. These wells would remain under artesian pressure and therefore flow upward year-round and will act as a discharge zone for the bedrock aquifer. As a result, a portion of the aquifer groundwater, currently naturally discharging into Lake St. Martin continuously, will be artificially discharged to the LSMOC through these passive WCS wells. The positive pressure in the aquifer depressurization wells and continuous discharge condition, will protect against surface water infiltration and associated potential for aquifer contamination.

13.3.2 Operations and Maintenance Plan

Based on experience gained through construction, an operations and maintenance plan will be developed for groundwater management components such as monitoring wells and depressurization works as part of long-term operations and maintenance activities.

13.3.3 Groundwater Piezometric Head

The piezometric head elevation in the LAA portion of the LSMOC ranges from 245 masl near Lake St. Martin to 218.5 masl near lake Winnipeg and is up to approximately 1.5 m to 2.0 m above ground level nearest Lake Saint Martin. While still confined, the bedrock aquifer pressures decline to below ground surface below the existing EOC Reach 3 channel, due to the drawdown influence of existing artesian spring sites, in close proximity to Lake Winnipeg. The bedrock aquifer is fully saturated. In all areas along the channel and at distance from the LSMOC channel, the bedrock aquifer piezometric pressure will remain above the physical bedrock surface (i.e., under a confined condition). The typical confined condition bedrock aquifer response to a project such at this at LSMOC, and as is expected at LSMOC, is described in detail elsewhere (KGS 2021b).

Passive confined bedrock aquifer depressurization is required to reduce the potential for post-construction basal heave. A long-term target level for operating piezometric pressures remains similar to conditions currently observed (i.e., pre-construction); however, it is estimated that up to approximately 2.0 m of long-term aquifer piezometric pressure reduction may occur with construction of the LSMOC (KGS 2021c), within approximately 1 km of the LSMOC.

Key regional recharge areas of note for the confined bedrock aquifer occur near Gypsumville, and along outcrop areas that occur immediately to the north-northwest and south of the Lake St. Martin Narrows. In addition, the high elevation bedrock bluff area approximately 10 km southeast of Lake St. Martin also functions as a sub-regional bedrock aquifer recharge area, with the bedrock surface in this location situated well above the aquifer piezometric pressure surface. In the region of the LSMOC, in the Dauphin River area, or in any location in proximity to Lake Winnipeg or Lake St. Martin, the confined piezometric pressure within the bedrock aquifer has been observed to be very near, and in some cases above, the ground surface (i.e., flowing artesian). This occurs because Lake Winnipeg and Lake St. Martin, and associated near-lake low-lying wet areas, are key discharge areas for the bedrock aquifer. Because of this, a strong upward gradient for discharge is anticipated and has been observed to be present in areas close to Lake Winnipeg, including within the region of the Lake St. Martin Outlet Channel. With the construction depressurization and long-term depressurization in place, the aquifer will continue to recharge in the same areas, and discharge to both Lake St. Martin and Lake Winnipeg either directly or via the LSMOC.

13.3.4 Groundwater Quality

The key mitigation to protect groundwater quality in the LAA portion of the LSMOC was to maintain channel operating water levels within the range of existing bedrock aquifer groundwater piezometric pressures and reduce the risk of surface water influences on groundwater quality, where the surface water system and groundwater systems may be interconnected due to channel excavation, specifically at the existing EOC reach 3 channel. Construction and operation of the LSMOC will require depressurization of the aquifer to reduce the potential for basal heave, till fracturing and channel side slope failures. However, even with active depressurization during construction, the bedrock aquifer in the LAA portion of the LSMOC will remain under positive pressure although the pressure elevation may no longer exceed the ground elevation (i.e., may no longer be under a flowing artesian condition), in places. Recharge of the aquifer via the base of the LSMOC is not expected to occur as the upward pressure gradient of the groundwater in the upper carbonate aquifer will promote groundwater discharges with re-equilibration of the groundwater system with channel construction and operations (KGS 2021b).

Should a change occur such that bedrock aquifer groundwater pressure decreases and the elevation of the piezometric pressure drops below the elevation of the bedrock surface, which is not anticipated anywhere along the LSMOC, the overlying till aquitard and passive reverse granular drains (which will be installed where interconnections through the aquitard might occur) would act as filters and as a reduced permeability for flow, for the infiltrating surface water. Pressure changes are considered to be transient events and not sufficient to cause any substantive change to the groundwater quality (KGS 2021b). Regular monitoring of the aquifer in the region will be conducted during, and post-construction.

13.3.5 Groundwater-Surface Water Interaction

An estimate in changes in groundwater flow and discharge rates was made for the LSMOC (Stantec 2021). Total flows are anticipated to stay the same, in the analyzed system, but will be re-allocated from one discharge area to another with construction of the LSMOC. Approximately 30% of the overall annual average discharge contributions to Lake Manitoba, Lake St. Martin, and Lake Winnipeg is planned to be redirected back to the lakes during operation via the Project depressurization system and channels. The total discharge (including the channels discharge) will be the same as during baseline conditions, equal to the average annual baseline discharge (Stantec 2021). The discharge into the Project channels (LMOC and LSMOC together) that may occur during construction or operation is also very small relative to the size of these channels. The groundwater discharge into the channels ranges from 2,000 m^3/d to 3,600 m^3/d (0.023 m^3/s to 0.045 m^3/s). These flows would be difficult to detect in the channels that have design flow values of 212 to 326 m^3/s (7,500 cfs and 11,500 cfs) (Stantec 2021). Total discharge estimated to the LSMOC during operations is approximately 0.024 m^3/s (Stantec 2021).

14.0 LSMOC MONITORING

14.1 Objectives

The objectives of the LSMOC groundwater monitoring program include:

- verify the anticipated effects to groundwater levels, quality, and quantity and based on the EA completed for the Project
- determine the effectiveness of mitigation measures
- assess the need for additional mitigation measures if initial measures are not adequate
- determine the effectiveness of any additional/adapted measure(s)
- confirm compliance with regulatory requirements relevant to ground water quality and quantity

Groundwater monitoring in the LSMOC portion of the LAA has, and will be, generally be conducted three times per ear, in the spring, summer and fall - prior to, during, and for 2 years following construction, which will be modified, if/as necessary, so that one full season of channel operations and one year post flood is captured in the data. During specific construction phases of the Project where active depressurization is required, monitoring and sampling frequency may increase to monthly, in support of adaptive management plans. In all Project phases, groundwater will be monitored for both quality and quantity (i.e., groundwater level [pressure head]). Standard field and laboratory quality assurance/quality control (QA/QC) protocols will be followed, including the use of trip blanks and collection of field blanks and blind duplicate samples. Monitoring results and analysis will be completed and communicated via written report on an annual basis. Multi-year/trend analysis may also be needed.

14.2 Baseline Monitoring

Groundwater-related investigations have been undertaken in the Project area since 2011. A total of 12 Instrumented test holes were drilled during the 2015 investigations and instrumented with a total of 24 nested standpipe piezometers (SP). Survey and monitoring of these instruments was completed as part of the 2019 field program. In 2019, as part of the Preliminary Design Phase Monitoring Program, several baseline groundwater monitoring programs were carried out, including: test hole drilling and well installation, instrumentation, hydraulic conductivity testing, pump testing, groundwater monitoring and water quality sampling. Groundwater piezometric head data for the LAA portion of the LSMOC was collected from locations shown in Figure 9 and during Project-specific monitoring programs described above and up to 2021 (KGS 2021a, KGS 2021b, KGS2022).

14.2.1 Groundwater Piezometric Head

The following groundwater monitoring locations and associated collected data were used to define the piezometric groundwater conditions in the LSMOC portion of the LAA.

There are a total of 58 SPs (24 installed in 2015 and 34 in 2019) and 32 Vibrating Wire Piezometers (VW) installed within the 46 test holes along the LSMOC alignment (see Figure 9). A high-level summary of the instrumentation is as follows:

- Peat – 19 installations
- Silty Clay / Clay Till – 8 installations
- Silt Till – 36 installations
- Sand – 2 installations (local to Sta. 5+606)
- Bedrock – 25 installations

Test Holes

In 2019 34 test holes along the LSMOC alignment were completed and surveyed. A series of nested piezometers were installed in the drilled test holes consisting of SP and VWs. A total of 34 SPs and 32 VWs were installed.

Pumping Wells

Bedrock pumping wells (125 mm diameter) were completed at 3 locations along the LSMOC alignment: near the inlet, in Reach 2 and in Reach 3. These locations are plotted on Figure 9 as follows: PW19-KGS-01 at Sta. 1+618 near the inlet, PW19-KGS-02 at Sta. 5+606 in Reach 2, and PW19-KGS-03 at Sta. 17+668, in Reach 3.

Sentinel Wells

Three sentinel wells (SW19-KGS-01 to 03) were drilled and installed within the Dauphin River First Nation community located approximately 6 km northeast of the LSMOC (Figure 9). The purpose of the sentinel wells is to collect baseline groundwater information (groundwater levels and water quality parameters) on the bedrock aquifer within the community and allow ongoing monitoring of conditions during the design and construction phases of the project, as part of the adaptive management network of groundwater monitoring sites for the LSMOC. The sentinel wells were installed as an independent system separate from intrusive monitoring of the network of existing domestic wells.

The location of the sentinel wells is shown on Figure 15. One sentinel well (SW19-KGS-01) is located on the south side of the Dauphin River near the southeastern edge of the First Nation boundary and serves as the nearest monitoring point between the community and the LSMOC site. Two wells (SW19-KGS-02 and 03) are situated on the north side of the Dauphin River within the network of existing domestic wells. Drilling and installation of the sentinel wells occurred in two stages; SW19-KGS-01 was installed in March 2019 via ice road across the Dauphin River, and SW19-KGS-02 and 03 were installed in September 2019 via road access.

14.2.2 Groundwater Quality

Groundwater quality samples are collected three times per year from the groundwater wells shown in Figure 9. Collected samples are analyzed for the suite of parameters listed in Table 5 to characterize baseline groundwater quality conditions. The analytical suite of parameters was selected to characterize the groundwater and includes:

- field monitoring to determine aquifer conditions [temperature, pH, DO and ORP
- potability testing to determine the quality and type of groundwater
- trace metal analyses
- petroleum hydrocarbon constituents and microbiological components due to the proximity of developed areas to the LMOC (to assess potability and risk of surface water- groundwater interactions)

The results of the groundwater sampling program are documented in several reports (KGS2021a, KGS2022).

Table 5:Groundwater Parameters Measured in Pre-Construction Monitoring Program

Category	Parameters
Field Monitoring	temperature, pH, electrical conductivity, DO, oxygen reduction potential, overburden groundwater elevations, bedrock aquifer piezometric pressure
Potable Water	electrical conductivity, hardness, pH, TDS, turbidity, alkalinity, bicarbonate, carbonate, fluoride, hydroxide, nitrate and nitrite (as N), nitrate (as N), nitrite (as N), sulfate
Dissolved and Total Metals	aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, calcium, cesium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, phosphorus, potassium, rubidium, selenium, silicon, silver, sodium, strontium, sulfur, tellurium, thallium, thorium, tin, titanium, tungsten, uranium, vanadium, zinc, zirconium
Environmental Stable Isotopes	deuterium, oxygen, tritium
Microbiological	*E.Coli*, total coliforms (pumping wells and sentinel wells only)

14.2.3 Groundwater-Surface Water Interactions

Groundwater/ Surface water interactions were estimated using information collected from the annual monitoring reports on groundwater and surface water quality (KGS 2021a, KGS2021b)). This information includes static water levels and piezometric pressure head (groundwater), surface water elevations, and surface water and groundwater quality.

14.3 Pre-Construction Monitoring

Groundwater monitoring activities will continue during the detailed design phase of the LSMOC to support the finalization of engineering design prior to tendering and construction. These activities include:

- continued monitoring of groundwater levels (static water levels and piezometric head) at existing instrumentation (see Figure 9)
- collection of groundwater samples for laboratory analysis of the parameters in Table 5 (above).

14.3.1 Network Expansion

Apart from the three sentinel wells, many of the current monitoring well and instrumented test hole locations located within the LSMOC portion of the LAA will be decommissioned as channel construction progresses. Additional groundwater monitoring locations (groundwater monitoring wells and/or instrumented test holes), outside of the alignment, will be installed during the pre-construction phase to provide coverage of the channel and major structures at key locations, such as the WCS and in channel excavation areas of greater potential for basal heave/hydraulic fracturing of the till. The number and location of additional groundwater monitoring locations will be determined during detailed design.

To-date, and as shown in Figure 9, the existing network of instrumentation and sites measured and sampled for groundwater are largely located to facilitate engineering design and are within the ROW of the LSMOC portion of the LAA. These existing installations will be decommissioned with the construction of the LSMOC and with channel excavations, construction of dykes, and placement of excavated spoil materials. The existing sentinel wells at Dauphin River will remain through construction and operation of the LSMOC.

It will be important to establish a network of piezometers and installed instruments that measure water levels and allow for water quality sampling, from within the upper perched peatlands, from within the till aquitard, and from the carbonate bedrock aquifer below. Nests of monitoring wells will be established in key sensitive habitat areas, to allow for measurement and monitoring of any changes that might occur during, or post-construction. Knowledge obtained from field performance will be used to modify programs as necessary as construction progresses.

The monitoring well sites would be installed prior to implementing the site clearing contract, which is envisioned to be undertaken during the winter season. It is also envisioned that there would be overlap in monitoring periods between existing, on-site instrumentation in the field (and within the LSMOC ROW), and the future adaptive management monitoring sites that are yet to be installed. The existing installations within the LSMOC ROW will be decommissioned as channel excavation contracts are executed, leaving the newly established adaptive management monitoring sites behind for the long-term (i.e., construction and operations periods for the LSMOC). It is recognized that there likely will be somewhat limited concurrent data collection overlap among future adaptive management monitoring sites and the existing LSMOC ROW instrumentation that has been collecting baseline groundwater level data since 2019.

At each installation site (there are up to 9 installation sites described here in total), the following would be installed at each of the 9 sites:

1. Bedrock standpipe, with pressure transducer continually measuring pressure and temperature.
2. Stacked (2) grouted in VWs, installed in borehole annular space. One in deep till, second in shallow till or clay/clay till strata; complete with data logger for continuous measurement.
3. Standpipe in peat/wetlands, with pressure transducer continually measuring pressure and temperature.

The locations and rationale for the construction and operations phase monitoring well network is as follows (Table 6) and will form the basis for data collection as required during and post construction, and as needed for input to the adaptive management plan for groundwater conditions at the LSMOC.

Table 6: Proposed Locations of Monitoring Wells and Instrumentation to be Installed for Construction Phase and Post-Construction Monitoring

Locations (9 in total)	Description	Rationale
Vicinity of the WCS	2 sites; one NW of LSMOC, one SE of LSMOC	Monitor and sample groundwater conditions near the location of WCS construction phase active depressurization, and possible long term operations phase passive depressurization
Vicinity of Big Buffalo Lake Complex	2 Sites; one NW side of LSMOC; one SE of LSMOC	Monitor and sample groundwater conditions near Big Buffalo Lake Complex, and to capture region of artesian groundwater spring sites to the SE of the LSMOC
Vicinity of artesian spring sites along Big Buffalo Creek	One site, in proximity of artesian spring sites	Monitor and sample groundwater conditions in region of artesian groundwater spring sites that provide baseflow to Big Buffalo Creek
Region of bedrock exposure at existing Emergency Reach 3 Channel	2 sites, one on each side of the LSMOC	Monitor and sample groundwater conditions at the exposed bedrock portion of the existing Emergency Reach 3 channel and future LSMOC, where gradients for flow and water quality conditions require assessment as related to infiltration/exfiltration conditions that may occur along this portion of the LSMOC

Locations (9 in total)	Description	Rationale
Region of Lake Winnipeg artesian spring sites	2 sites, one on each side of the LSMOC; One in proximity to existing TH19-KGS-19 on the Lake Winnipeg side of the LSMOC; the other on opposite side of the LSMOC	Monitor and sample groundwater conditions in region of artesian groundwater spring sites that provide baseflow to wetlands in close proximity to Lake Winnipeg

14.3.2 Groundwater Piezometric Head

Continuous level monitoring using pressure transducers and VWs with dataloggers, at the locations specified above (Table 6). Ideally, the existing instrumentation sites (Figure 9), used to develop the understanding of the LSMOC portion of the LAA existing conditions (KGS 2021a, KGS 2021b) will be monitored for a period of time concurrent to the establishment of the additional sites described above (Table 6). The goal would be to establish overlap in data collection in advance of decommissioning of existing instrumentation and monitoring wells that will occur with the advance of channel construction. All active sites will be used for construction depressurization monitoring. Monitoring will be initiated before the bedrock depressurization begins.

14.3.3 Groundwater Quality

Continued monitoring of groundwater quality at existing sites (discussed in Section 14.2) and new sites (discussed in Section 14.3.1 and detailed in Table 6) will be undertaken during spring, summer and fall, with reporting completed annually. Collected samples will be analyzed for the suite of parameters listed in Table 5 to characterize baseline groundwater quality conditions. New wells discussed in Section 14.3.1 will be monitored at least once prior to the initiation of depressurization.

14.3.4 Groundwater-Surface Water Interactions

The planned instrumentation and monitoring wells (See Section 14.3.1 and Table 6) will be monitored prior to depressurization to determine the preconstruction groundwater conditions. Analyses such as those completed to establish existing groundwater piezometric pressure and quality conditions in the LAA portion of the LSMOC (KGS 2021a, KGS 2021b) will be assessed as data becomes available. Data collected during monitoring of these well and instrumentation sites will be provided at regular intervals (i.e., following each monitoring and sampling event) to the wetlands monitoring team for incorporation into their assessment and to inform recommendations made to the Project EAC and Manitoba Transportation and Infrastructure to inform recommendations made to Manitoba Transportation and Infrastructure. Any identified change (i.e., water quality) will be cause for immediate notification to the wetlands monitoring team.

14.4 Construction Monitoring

Construction groundwater aquifer monitoring events will be conducted during the LSMOC construction period. Monthly manual monitoring and groundwater sampling events are planned at the adaptive management monitoring sites during each construction year. Instrumentation installed at each of the adaptive management monitoring locations will record groundwater level and groundwater temperature data continually and will be downloaded during each monthly monitoring and sampling event that will occur during the construction period of the LSMOC.

14.4.1 Groundwater Piezometric Head

Monitoring will focus on identifying any local or regional effects of construction activities, such as active aquifer depressurization pumping, and/or channel excavation and basal heave or fracturing of the till aquitard which may have an effect on groundwater quality and levels.

Continuous level monitoring gauges will be maintained, and groundwater quality monitoring will continue annually in spring, summer and fall during construction with reporting completed annually. Additional construction monitoring of the overburden groundwater levels and bedrock aquifer piezometric pressures for geotechnical purposes will be conducted separately, as required, particularly during active depressurization for the WCS construction contract.

14.4.2 Groundwater Quality

Groundwater quality will be monitored in the established LSMOC monitoring well network and at the sentinel wells based on location and proximity to the LAA portion of the LSMOC. This data will be used to establish a baseline data set for the Project. Regular monitoring and water quality sampling of groundwater quality at the wells will continue to occur three times per year. All groundwater samples will be collected following standard procedures, will be submitted to an accredited laboratory for analysis and subject to standard laboratory quality assurance (QA)/quality control (QC) processes.

The groundwater water quality is not expected to change beyond currently observed variations (KGS 2021a) and is estimated to maintain a stable trend into the future. Monitoring of groundwater quality will continue throughout LSMOC construction, and for 2 years post-construction (i.e., one flood event and one-year post flood).

Parameters with be reviewed after each monitoring event during construction and post-construction. In some cases, groundwater concentrations of some parameters (e.g., iron, manganese, fluoride) may be present at concentrations above the water quality guidelines during the baseline period. In these instances, the threshold would be the presence of a statistically significant increasing trend. Associated actions and mitigations would be situation and site specific.

Groundwater removed during depressurization will be discharged to ground surface and /or surface water. Water quality monitoring, triggers, thresholds and management of this groundwater are discussed in Section 15. Once discharged groundwaters are part of the surface water system, the water quality management monitoring triggers and thresholds are also addressed in the SWMP.

14.4.3 Groundwater–Surface Water Interactions

The planned instrumentation and monitoring wells (See Section 14.3.1 and Table 6) will be monitored prior to depressurization to determine the preconstruction groundwater conditions. Analyses such as those completed to establish existing groundwater piezometric pressure and quality conditions in the LAA portion of the LSMOC (KGS 2021a, KGS 2021b) will be assessed as data becomes available. Data collected during monitoring of these well and instrumentation sites will be provided at regular intervals (i.e., following each monitoring and sampling event) to the wetlands monitoring team for incorporation into their assessment and decision-making. Any identified change (i.e., water quality or significant gradient changes) will be cause for notification to the wetlands monitoring team for incorporation into their assessment and to inform recommendations made to the Project EAC and Manitoba Infrastructure and Transportation for decision-making. Any identified change (i.e., water quality) will be cause for immediate notification to the wetlands monitoring team.

14.5 Operation Monitoring

Groundwater monitoring and sampling during operations will follow the same frequency of occurrence as during pre-construction and construction. Groundwater monitoring and sampling will continue for the first two years post-commissioning and including one flood event and one-year post-flood. A plan for long-term groundwater monitoring beyond two years post- commissioning will be developed based on the previous monitoring data, an assessment of any possible LSMOC effects and public engagement. The plan will include monitoring the effects of the channel on groundwater quantity (i.e., piezometric pressure head) and quality during channel operating and non-operating conditions. On-site and regional monitoring of the effects of any long-term passive aquifer depressurization will also be included in the plan.

14.5.1 Groundwater Piezometric Head

Monitoring will focus on the effect of any passive long-term aquifer depressurization, and any channel surface water/groundwater interaction during initial channel operating and non-operating conditions. Continuous water level data collection will be maintained with data downloaded at regular intervals (e.g., three times per year) for the first two years post-commissioning. Trends identified in the LSMOC portion of the LAA will be compared against other regional monitoring locations (i.e., Provincial well hydrographs) to decouple any naturally-occurring environmental variation (i.e., wet year versus dry year effects; Wang, 2011) from potential LSMOC related impacts.

After LSMOC commissioning, the regional groundwater piezometric head is estimated to stabilize at a lower elevation in some LAA areas than exists currently (pre-construction), such as at the WCS but higher than what is estimated to occur during the construction phase of the Project (KGS 2021c). There will be some natural seasonal variation in piezometric pressure as has been identified to date (KGS 2021b). Monitoring will continue for 2 years post-commissioning. If any unanticipated effects are identified, adaptive management processes will be triggered (see Section 15).

14.5.2 Groundwater Quality

Operation phase groundwater quality parameters are expected to remain consistent with those analyzed during the pre-construction and construction phases and identified in Table 5. The frequency and locations of sampling may be adjusted based on monitoring results and environmental conditions. Similarly, analytical parameters may be adjusted depending on water quality results. Groundwater quality during operations is estimated to be consistent with that measured during the pre-construction phase.

Groundwater water quality is not estimated to change beyond natural variation (KGS 2021a) and to maintain a stable trend into the future. Monitoring of groundwater quality will continue through 2 years post-construction and reported annually. The suite of analytical parameters will be reviewed each year post-construction. If an unanticipated water quality effect is identified, adaptive management processes will be triggered (see Section 15).

14.5.3 Groundwater–Surface Water Interactions

The planned instrumentation and monitoring wells (See Section 14.3.1 and Table 6) will be monitored to determine the groundwater conditions. Analyses such as those completed to establish existing piezometric pressure and quality groundwater conditions in the LSMOC portion of the LAA (KGS 2021a, KGS 2021b) will be assessed as data becomes available. Data collected during monitoring of these well and instrumentation sites will be provided at regular intervals (i.e., following each monitoring and sampling event) to the wetlands monitoring team for incorporation into their assessment and decision making. Any identified change (i.e., water quality or significant gradient changes) will be cause for notification to the wetlands monitoring team for incorporation into their assessment and to inform recommendations made to the Project EAC and Manitoba Transportation and Infrastructure and to inform recommendations made to Manitoba Transportation and Infrastructure. Any identified change (i.e., water quality) will be cause for immediate notification to the wetlands monitoring team.

15.0 LSMOC ADAPTIVE MANAGEMENT AND FOLLOW-UP

15.1 General

A follow up process is a form of adaptive management to improve practices by learning about their effects and then making changes in those practices as new information is available. The federal *Impact Assessment Act* defines a follow up program as “a program for verifying the accuracy of the impact assessment of a designated project and determining the effectiveness of any mitigation measures.” An associated Operational Policy Statement (https://www.canada.ca/content/dam/iaac-acei/documents/ops/ops-follow-up-programs-2011.pdf) indicated that “a follow-up program is used to:

- verify predictions of environmental effects identified in the EA
- determine the effectiveness of mitigation measures in order to modify or implement new measures where required
- support the implementation of adaptive management measures to address previously unanticipated adverse environmental effects
- provide information on environmental effects and mitigation that can be used to improve and/or support future EAs including cumulative environmental effects assessments, and
- support environmental management systems used to manage the environmental effects of projects.”

Follow-up is one step in the overall continuous improvement process which aims to evolve practices and processes based on feedback. Continuous improvement is generally a four-stage process: Plan, Do, Check and Act. This loop allows work to be planned, executed, reported on and then corrected as required.

In the context of groundwater management for the Project, the design will be implemented while managing risks with monitoring, as generally described in Section 14.0. As described in Section 12.4.1.1 of the Project EIS, the objective of the groundwater follow-up and monitoring program is to determine whether there are changes to the volume and accessibility or quality of the groundwater in the groundwater LAA as a result of construction or operations and update and implement mitigation measures and responses accordingly. The predicted residual effects during construction and operation of the Project include:

- a change in local groundwater flow due to depressurization operations,
- a change in local groundwater quality due to depressurization operations; and
- a change in groundwater–surface water interaction due to surficial drainage diversion and bedrock aquifer depressurization.

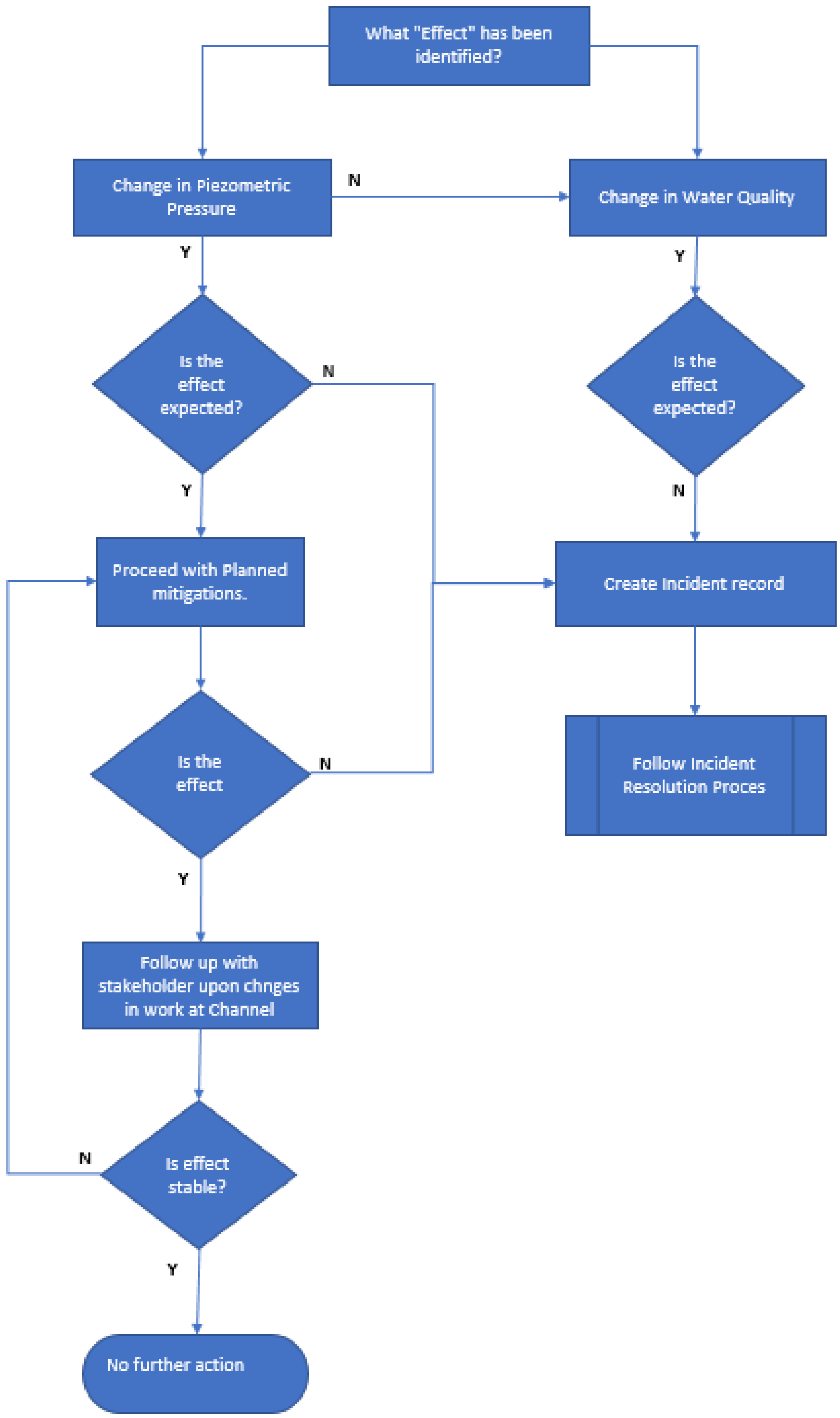

Figure 11: Adaptive Management Process

The monitoring and analysis program will provide information to better predict and quantify potential effects and confirm which locations of the groundwater LAA should be further monitored during aquifer depressurization. Existing data collection or monitoring programs will be applicable to inform development of Contractor construction phase monitoring plans, where identified, and to the extent feasible. Baseline groundwater quantity and quality will be established during the pre-construction monitoring program (in progress) which will form the basis for comparison to determine what, if any, effects are occurring. Knowledge obtained from field performance will be used to modify programs as necessary as construction progresses. It will be important to establish a network of piezometers and installed instruments that measure groundwater piezometric pressure and allow for water quality sampling, from within the upper perched peatlands, from within the till aquitard, and from the carbonate bedrock aquifer below. Nests of monitoring wells will be established in key sensitive habitat areas, to allow for measurement and monitoring of any changes that might occur during, or post-construction. Any proposed changes to the GWMP and monitoring as part of adaptive management would be discussed with Manitoba Transportation and Infrastructure and regulators, as necessary and documented.

15.2 Follow-up

The triggers and associated responses relative to groundwater conditions during construction and operations phases of the LSMOC are viewed as the same for both Project scenarios of Project construction and operation. As such, the triggers and response actions are provided below for both construction and operation phases.

15.2.1 Stakeholder Complaint Resolution Process

The Complaint Resolution Process will be implemented to allow private well owners to record any issues that they encounter with respect to their well performance or water quality. Complaints will be investigated, and mitigations determined on a case-by-case basis.

Changes in groundwater piezometric pressures (level) are expected to vary within the LAA portion of the LSMOC but are estimated to occur in areas within 3-5 km of the channel. The greatest changes will be seen at the wells most proximal to the channel alignment with an expected decrease reduction in the effect with distance from the channel. As previously stated, wells located > 5 km from the channel alignment, are expected to report variations in piezometric pressure within normal observed seasonal variation. These variations are not anticipated to impact well users. If a change is identified that is not anticipated, an incident will be created and investigated as shown in Figure 12. This investigation will determine whether the change is Project-related, the cause for the change and the parameters required to determine any required mitigations. In the short term, the effects can be mitigated by supplying a fresh water source, a pump and/or by lowering the pump intake (where applicable) until the circumstances and required actions are understood. Possible mitigation will be developed on a case-by-case basis, as required. Once the incident is resolved and stakeholder signoff is obtained, the report will be closed.

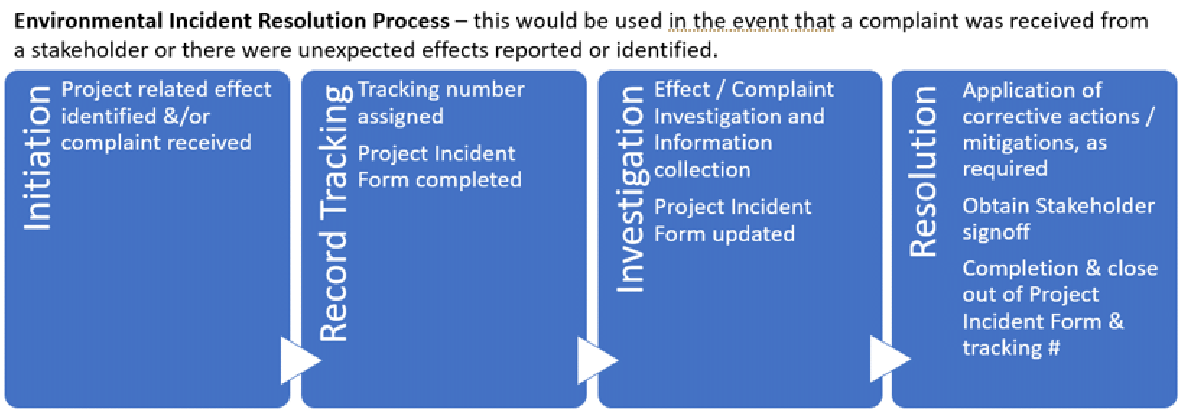

Figure 12: Incident Resolution Process

15.2.2 Groundwater Piezometric Head

The adaptive management monitoring well network for the LSMOC is envisioned to be comprised of the existing sentinel wells at Dauphin River, and the planned new monitoring sites that are to be installed outside of the LSMOC ROW and as described in Section 14.3.1. The identified groundwater piezometric pressure trigger levels for LSMOC are different than LMOC, to address fundamental differences in the LAA portion of each channel. The LAA portion for each channel has a unique response and overall range in observed seasonal and intra-seasonal (i.e., responses to high intensity, short duration rainfall events) aquifer pressure variability. Importantly, the implications for piezometric pressure variability/changes on each channel have a very different set of key receptors, where LMOC must address a large number of 3rd party domestic and agricultural well users, and LSMOC must address the sensitivity of groundwater discharge and contributions to the peatlands and fens that are pervasive in the LSMOC portion of the LAA.

In general, seasonal site-specific trigger water level elevations will be set at these adaptive management monitoring sites. These trigger values are determined based on the evaluation of existing condition water level data for the region of the LSMOC (KGS 2021b), and the predicted maximum extent of the cone of influence under construction and operations of the LSMOC (KGS 2021c). The reasons for these exceedances include the oversimplification of the methodology setting trigger values in a fractured rock aquifer (i.e., there often is variability in fractured confined bedrock aquifer transmissivity, and boundary conditions can occur over time that also may limit or enhance drawdown propagation with distance). More importantly, a simplified approach tends to neglect to account for the full impact of seasonality. As noted previously, it is common to observe 1.5 m +/- 0.5 m (i.e., 1.0 to 2.0 m) of aquifer piezometric pressure variability in the region of the LSMOC. Seasonal variability in groundwater levels as well as observed changes in the timing the seasons, have been observed, as have been more active aquifer pressure responses to short term high intensity seasonal rainfall events (KGS 2021b; KGS 2016).

A key objective of the adaptive management methodology is to use the concept of long-term trends from either prolonged climatic changes or those which are largely associated with aquifer dewatering. Prolonged climatic changes mean sustained periods of departure from "normal precipitation amounts" such as droughts or wet cycles. These precipitation trends result in noticeable effects on groundwater levels. Short-term trends (i.e., seasonal) should also be evaluated; however, they should not cause a concern if an exceptionally dry year results in water levels that drop below a minimum reported or predicted water level. This overall response of aquifer systems to wetter than average or dryer than average years (and particularly consecutive years of wetter than average or drier than average conditions) has been clearly demonstrated for all major aquifer systems within the province of Manitoba (Wang, 2011).

The LSMOC adaptive management plan for aquifer water levels will rely on the Seasonal Mann-Kendall Test to statistically interpret trend analysis of groundwater elevations at the adaptive management monitoring well sites. Statistically definable results can be utilized to manage groundwater resources, assess drought or wet cycle conditions, and evaluate long-term groundwater trends. The Seasonal Mann-Kendall Test considers the seasonality of the data series. This means that for monthly data with seasonality of 12 months, trends comparing month to month data will be done (i.e., comparison of one of January to another, and so forth). The Seasonal Mann-Kendall test is established on the basis that the trend is cyclically varying in relation to the seasons of the year and is used to analyze time series data for the possible existence of an upward or downward trend, at significance level, while accounting for the effect of seasonality. Data will be analyzed within the following reaches of the channel:

- Lake St. Martin to LSMOC Sta. 10+500: Typical GW El. 245.0 m - El. 242.6 m
- LSMOC Sta. 10+500 to Sta. 18+000: Typical GW El. 236.5 m - El. 230.5 m
- LSMOC Sta. 18+000 to Lake Winnipeg: GW El. 222.5 m - El. 218.3 m

As described below, appropriate triggers set for each reach, as groundwater levels vary significantly due to the naturally occurring flow system in the region of the LSMOC, specifically where the LSMOC is influenced by the proximity to the artesian spring sites near Lake Winnipeg. For any reach of the LSMOC, the minimum recorded groundwater level is considered the "0^{th} percentile" of the dataset.

Stage 1:

- Trigger: Measured seasonal groundwater levels in the bedrock aquifer fall below the 10th percentile.
- Response actions:
  - Review monitoring methods/protocols
  - Review groundwater monitoring data to determine potential origin of trigger occurrence
  - Increase monitoring frequency to weekly if current frequency is monthly

Stage 2:

- Trigger: Measured seasonal groundwater levels in the bedrock aquifer fall below the 5th percentile.
- Response actions:
  - Conduct detailed trend analysis
  - If a problematic trend is determined identify source or cause of the trigger exceedance; adjust depressurization schemes/construction staging/methodologies as practicable.

It is anticipated that the monitoring well network within the LSMOC portion of the LAA the will be installed during the clearing activity and will collect continuous water level data via planned use of pressure transducers and vibrating wire transducers with dataloggers. It should be noted that the final scheduling of routine field monitoring, data downloads, and water quality sampling of the well network will be developed prior to construction to allow for detection of water level deviations that fall within the designed trigger levels identified above.

15.2.3 Groundwater Quality

The water quality monitoring program for the LSMOC will take place at the adaptive management well installations. Water samples will be analysed for the list of parameters given within Table 5. The groundwater trigger thresholds provided below (Table 7) have the objective to provide early warning related to the potential for adverse effects to surface water/wetlands/fens in the LAA portion of the LSMOC, and to provide a method to assess the cause(s) and implications. These trigger levels for water quality are defined as a proportional percentage of the relevant guidelines, so that action is taken quickly enough to effect a mitigative change as required for the protection of the natural system, but also with sufficient allowable variance to account for expected natural variability. Triggers are set (Table 7) for scenarios where existing conditions are below the guidelines, are above guidelines, or for scenarios where there are not existing guidelines. In each scenario a 20% variance is allowed, and exceedance of this variance will initiate the trigger action, which is a reasonable reflection of natural variability within the groundwater system. In addition, because at the LSMOC the groundwater system is an important contributor to the surface wetland (i.e., fen) system, the checking of trends for specific nutrients, ions, and pH are proposed to facilitate maintenance of the groundwater discharge quality which contributes to the surface water system. These kinds of proportional thresholds, based on the guidelines, are routinely applied in groundwater adaptive management plans and are defensible and reflective of other typical groundwater quality adaptive management plans. Should the groundwater quality triggers occur as described below, it is anticipated that the SWMP and possibly the wetlands monitoring plan would come into effect, with the means and methods for monitoring and mitigating surface water conditions, and monitoring of wetlands taking an equal or possibly primary role in assessing the potential for any adverse effects to wetlands and fens in the region of the LSMOC. As indicated, threshold exceedances will be cause for notification to the wetlands monitoring team for incorporation into their assessment and to inform recommendations made to the Project EAC and Manitoba Infrastructure and Transportation for decision-making. Any identified change (i.e., water quality) will be cause for immediate notification to the wetlands monitoring team.

Table 7: Thresholds, Actions and Possible Mitigations for Unanticipated Project-Related Water Quality Effects

<table>
<tr><th>Parameter</th><th>Trigger</th><th>Response Action</th></tr>
<tr><td>Water Quality Parameters with CCME guidelines where the baseline condition is below these guidelines</td><td>Within 80% of the guideline and greater than 20% over baseline conditions</td><td rowspan="4">• Review sampling and analytical methods/protocols
• Review groundwater quality monitoring data to determine potential origin of exceedance
• Sampling frequency is monthly during construction; Increase sampling frequency to monthly if current sampling frequency is quarterly, or less
• Conduct trend analysis
• If a problematic trend is determined (e.g., increase in nutrients or salts and decrease in Ca, Mg, and/or pH); identify source or cause of the trigger exceedance; monitor wetlands as indicated within the WetMP</td></tr>
<tr><td>Water Quality Parameters with CCME guidelines where the baseline condition is currently elevated above these guidelines</td><td>Greater than 20% over baseline conditions</td></tr>
<tr><td>Water Quality Parameters with no CCME guidelines</td><td>Greater than 20% over baseline conditions</td></tr>
<tr><td>N, P, K, Ca, Mg, Na, Cl pH</td><td>Change in trend of these parameters</td></tr>
</table>

15.2.4 Groundwater-Surface Water Interactions

Based on the water quality in the region of the LSMOC, and the known groundwater/surface water interactions, which are important to the fens and wetlands in the LSMOC portion of the LAA, any changes in water quality response triggers (specifically N, P, Ca, Mg, Na, K, Cl, and pH, as noted above), will be applied to trigger a response regarding groundwater and surface water interactions. For example, an increase in nutrients and/or salts, with a decrease in key parameters such as Ca, Mg, and pH in the groundwater quality signature, could indicate a shift from groundwater baseflow contributions to the fens.

As discussed in prior sections, data collected during monitoring of the well nests (see section 14.3.1) will be provided at regular intervals (i.e., following each monitoring and sampling event) to the wetlands monitoring team for incorporation into their assessment and decision-making. As indicated, threshold exceedances will be cause for notification to the wetlands monitoring team for incorporation into their assessment and to inform recommendations made to the Project EAC and Manitoba Infrastructure and Transportation for decision-making. The data would be used to inform mitigation planning and may include mitigations or execution of adaptive management processes identified in the SWMP, the CEMP, OEMP, PERs, EPP and or others depending on the nature of the change experienced.

15.3 Contingency Measures and Emergency Response

Contingency measures and emergency response will be included for unforeseen events or circumstances related to groundwater in various planning documents for the program. These will be developed and finalized prior to construction, and include the following:

- Groundwater Depressurization Plan – The Contractor's groundwater depressurization plan will include contingency measures for loss of power during active depressurization activities and will include provisions to increase or otherwise adjust and optimize pumping rates if possible or may include longer-term measures such as additional wells to provide additional depressurization if needed in key active depressurization areas.
- Safety and Health Plan – The health and safety plan for the Project and individual contractors must address all hazards associated with channel and deeper excavations where unplanned discharge of groundwater may occur in an emergency situation.
- Construction Environmental Management Program – The CEMP provides specific measures to address the potential contamination of groundwater from hazardous materials and waste, including materials and waste management and emergency spill response and reporting procedures.
- Complaint Resolution Plan – The complaint resolution plan describes the processes and procedures for receiving and responding to private well owner complaints related to groundwater quantity and/or quality issues identified within private water wells. The plan will outline the complaint response and investigation process. Mitigations will be determined on a case-by-case basis and determined by the outcome of the investigation.

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APPENDIX 1A

Lake Manitoba Hydrogeologic Conditions

1A.1 Site Characterization

Site geological and hydrogeological information from previous and ongoing studies, was used to develop an understanding of the existing groundwater regime. The data is contributing to the preliminary and detailed design of the LMOC construction and operation depressurization systems and will assist in informing and refining mitigation and monitoring programs.

The proposed LMOC is located within the Interlake area of the Manitoba lowland physiographic region. Paleozoic and Mesozoic carbonate bedrock, with minor clastic and argillaceous units dip gently to the southwest and are overlain by tills, proglacial lacustrine sediments and more recent organic deposits found in low-lying areas (Figure A-1).

The upper till layer thins in some places allowing bedrock to be present near or at the surface, particularly in proximity to Reed Lake just east of the LMOC alignment. The areas with near surface bedrock are shown on Figure A-1. Topography in the area is relatively flat, and the terrestrial environment is diverse, including agricultural areas, grasslands, forested areas, small lakes and larger regions of wetlands. Regional and local geology of the LMOC region has been described in Section 3.0 of this GWMP.

The Interlake region features one main aquifer that is associated with the extensive Paleozoic Carbonate Evaporite Unit (Betcher et. al.,1995). The upper carbonate aquifer has an effective depth of 15-30 m and is described as the most active zone of groundwater movement and storage of the carbonate aquifer (Simpson 1987). Recorded transmissivities in the Interlake area display considerable variation, ranging between less than 10 m^2/day to 10,000 m^2/day (Rutulis 1987; Render 1988). The primary recharge area for the aquifer lies in the central part of the Interlake, with flow occurring outwards towards Lake Manitoba on the west and Lake Winnipeg on the east (Betcher 1997). Although the aquifer is confined by till along the LMOC alignment, there are recharge areas to the east and west of the Project typically associated with areas of near surface bedrock (Figure 3).

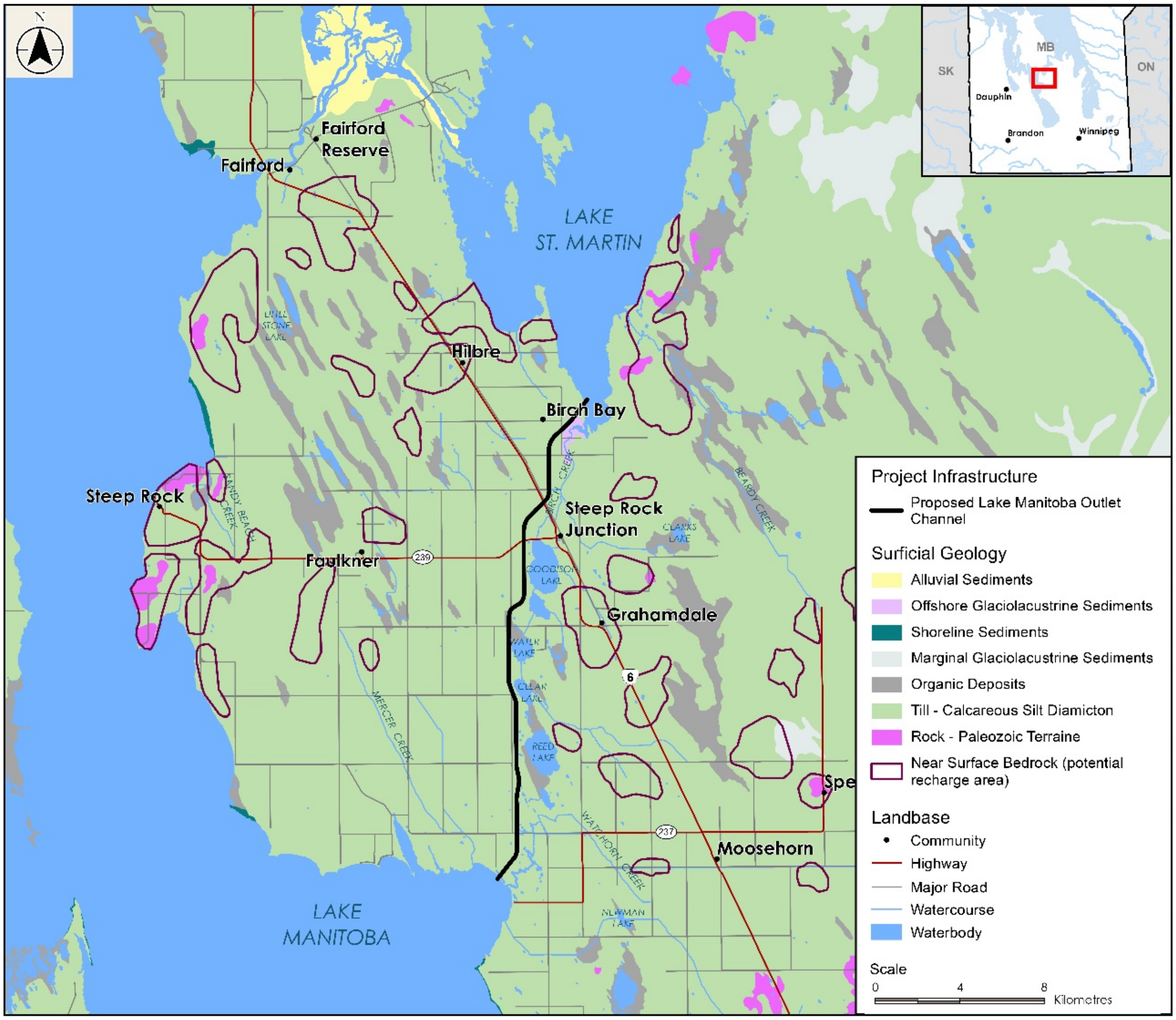

Figure A-1: Surficial Geology Within the LMOC Region

1A.2 Geologic Units and Aquifers

1A.2.1 Site Geological Stratigraphy

A geological model was developed based on subsurface, topography and geographic information system data. The geological units of the overburden were based on data from more than 1,600 borehole logs (Table A-1). Borehole logs were sourced from:

- publicly accessible well data from the Provincial Well Record Database (GWDrill), which includes data from the Groundwater Information Network between 1903 and 2017 (GWDrill 2018)
- previous reports (i.e., KGS 2017b)
- previous investigations by Manitoba Transportation and Infrastructure (Tetra Tech EBA, 2016)
- the 2019 field drilling program and hydrogeological field program

Table A-1: Sources of Borehole Data used in Geological Model

Borehole Data Source	Number of Boreholes
GWDrill[a]	1508
Existing Project Related Data[b]	28
2016 Lake Bottom Stratigraphy [c]	9
2019 Team Drilling Program [d]	57

Notes:
[a] GWDrill 2018
[b] KGS 2017
[c] TetraTech 2016
[d] TREK 2020

A generalized view of the LMOC stratigraphy along the LMOC is provided in Appendix 1A- Plate 1. In general, site stratigraphy consists of five Quaternary overburden units underlain by carbonate bedrock. The overburden stratigraphy from youngest to oldest is peat-topsoil at the surface, followed by clay, upper sand and gravel, till, lower sand and gravel and bedrock.

Peat-Topsoil

Peat-topsoil was observed at surface over the majority of the LMOC. The peat-topsoil is relatively evenly distributed in areas with very low relief as it accumulates in fen, bog, swamp, and marsh settings (Matile, 2004). It is composed of peat and muck deposits in wetland areas and topsoil on fields and ranges in thickness between <0.1 m and 3 m, with an average thickness of 0.5 m.

Clay

Clay deposits in the LMOC area are observed at surface in some areas or below the peat-topsoil deposits. Matile (2004) describes the deposits as clay, silt and minor sand, very low relief massive and laminated deposits. These sediments were likely deposited from suspension in the offshore, deep water of glacial Lake Agassiz and commonly sourced and homogenized by icebergs. The thickness of the clay generally ranges between 1 m and 5 m, with an average thickness of 2.7 m.

Till

The Quaternary till / glacial diamicton deposits are composed of calcareous silt diamicton and are predominately derived from Paleozoic dolomite and limestone (Matile 2004). Till is observed at surface in some areas or below the peat-topsoil, clay and/or upper sand and gravel deposits and ranges in thickness between 1 m and 15 m, with an average thickness of 8.6 m.

Till was encountered in every historical and recent investigation program. Sand and gravel lenses are present below, within and above the till unit. Parts of the till are overlain by sand and gravel deposits, clay and organic material such as peat and topsoil.

Upper and Lower Sand and Gravel

The upper and lower sand and gravel deposits represent preglacial, marginal glaciolacustrine and postglacial shoreline sediments. The glaciolacustrine deposits are composed of sand and gravel deposited by waves at the margin of glacial Lake Agassiz and are found as beach ridges, spits, bars or littoral sand and gravel. The shoreline sediments were formed by waves at the margins of modern Lake St. Martin and Lake Manitoba (Matile 2004). These deposits are observed at surface in some areas or below peat-topsoil and/or the clay deposits in other areas. The lower Sand and Gravel unit represents unconsolidated preglacial sediments lying within or underlying the less permeable till unit and show limited areal distribution (Betcher 1995). These deposits have the potential to host a sand and gravel aquifer at the bedrock-till interface (Betcher 1995).

Sand and gravel deposits were identified within the till unit in a few boreholes, but they had limited thickness and lateral extent. The deposits vary in thickness between 1 m and 8 m, with an average thickness of 2.5 m and 5.5 m for the upper sand and gravel and lower sand and gravel deposits, respectively.

Bedrock

The bedrock in the region consists of sedimentary rocks of Paleozoic age which are primarily carbonates with minor clastics and evaporite sequences. The Project area is underlain by fossiliferous dolomite of the Silurian Interlake Group in the northeast and Devonian rocks in the southwest. The Devonian rocks are subdivided into argillaceous dolomite and dolomitic shales of the Ashern Formation in the northeast and mottled limestones of the Elm Point Formation in the southwest. The Devonian Ashern and Elm Point Formations and Silurian Interlake Group underlie all of the above-mentioned units and is considered the principal aquifer in the region (the upper carbonate aquifer).

1A.2.2 Groundwater Systems – Aquifers and Aquitard

Groundwater flow and quality are closely dependent on geology. There are three main hydrogeological components, which correspond to lithologic formations in the LMOC area with the following characteristics:

- surficial aquifer - relatively thin, discontinuous, composed of soils, peat and isolated thin sand layers; related to wetlands.
- aquitard - undifferentiated till; this is the principal geological component in which the Project will be embedded. Intertill lenses composed of till occur with greater proportions of coarse sediments (water bearing) and major lakes intercept this horizon.
- bedrock aquifer - confined carbonate aquifer; it has a regional extent and is connected with major lakes.

The carbonate (bedrock) aquifer is overlain by a till aquitard at the LMOC. The fluted morphology of the till surface is particularly apparent with the distribution of low-lying organic deposits (wetlands) within till troughs. Those wetlands are believed to be fed with water from precipitation trapped within these low-lying depressions. Recent groundwater-surface water interaction investigations (Stantec 2021) suggest that groundwater discharge occur to the wetlands but represents a very small portion of their overall water budget, supporting the assertion that the wetlands are predominantly surface water/precipitation fed.

Domestic and livestock wells are generally fed by the carbonate aquifer in the LMOC area. Livestock wells are often flowing or artesian wells.

A generalized view of groundwater flow and piezometric head conditions in the LMOC area, based on pre-2019 data, is provided in Figure A-2. The regional carbonate bedrock aquifer is confined and underlies the LMOC. The carbonate aquifer recharge occurs in the upland areas (Figure A-2) under unconfined conditions where bedrock elevations are relatively high, above 280 masl, and sediment cover is thin to non-existent.

The groundwater flow radiates out from the uplands in all directions towards the major lakes (St. Martin, Manitoba and Winnipeg). In general, the uppermost 10 m of the carbonate bedrock aquifer exhibits some karsticity; this is the most productive horizon of the aquifer. The aquifer likely discharges into bogs, streams, and lakes; namely, Lake Manitoba, Lake St. Martin and Lake Winnipeg. Discharge to lakes could be widely distributed, but most likely near where bedrock outcrops occur. Discharge occurs under flowing artesian conditions in some places.

The aquifer pressure head varies seasonally as shown at two Province of Manitoba Water Resources Branch (long term monitoring wells (WRB 122050 and WRB-116766). The upland well (WRB 116766) piezometric head varies between 272 masl and 277 masl (Figure A-3), rising after spring snow melt and dropping over the winter, indicating that recharge locally occurs in the uplands at elevations above 277 masl.

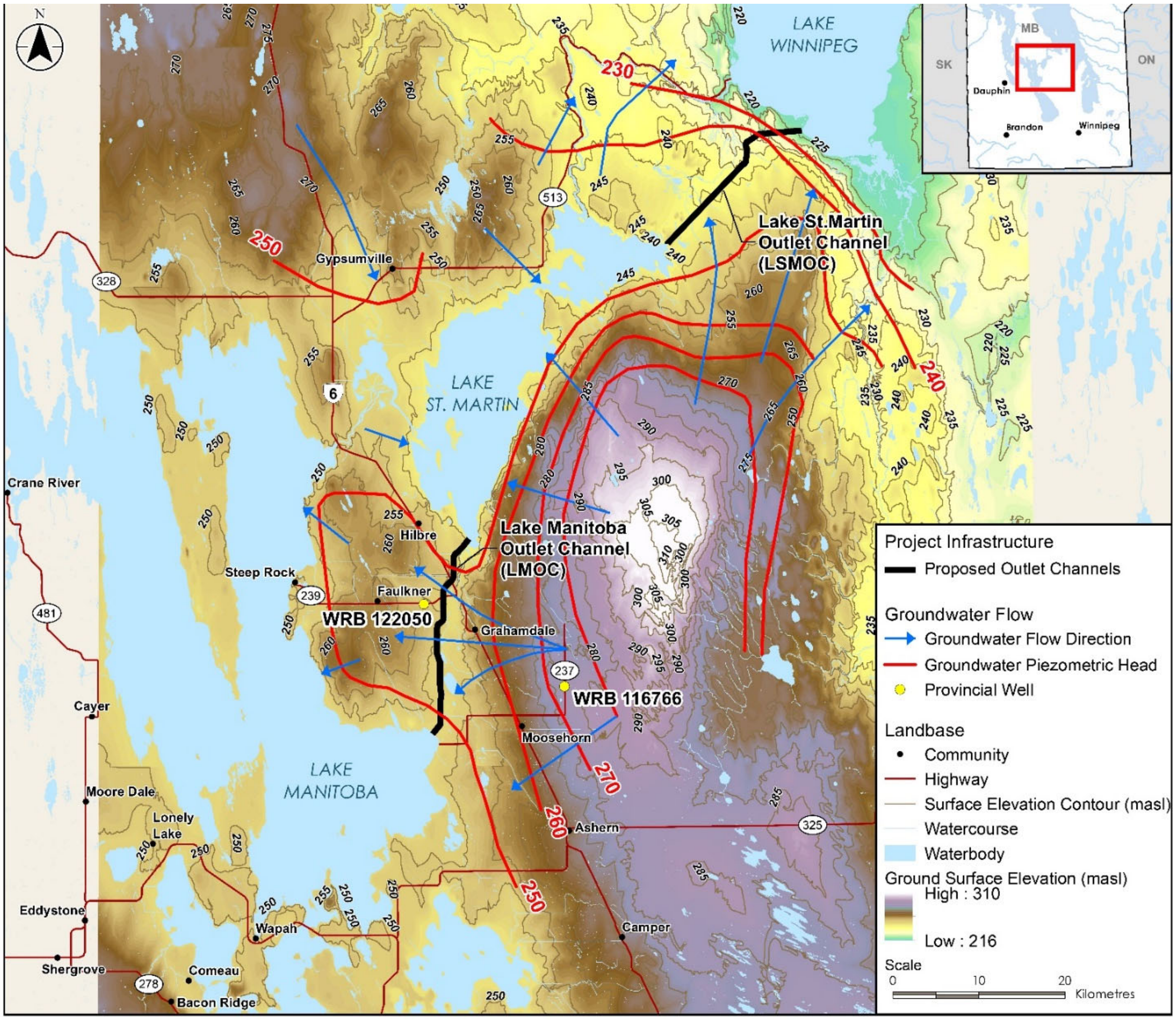

Figure A-2: Regional Groundwater Flow and Piezometric Head Conditions

The upper carbonate aquifer in the Project area is overlain by 5 m to 18 m of till. The LMOC is located in the Birch Creek valley, which has a ground surface elevation between 246 masl and 250 masl. The piezometric head in this area ranges from 249 masl to 255 masl and is therefore up to 5 m higher than the elevation of the ground surface. Seasonal variation, as measured by the provincial monitoring well (WRB 122050) has recorded piezometric head variations between a minimum of 252 masl and a maximum of 256 masl (Figure A-3) with typical seasonal piezometric head variations between 2.5 m and 3 m per year in the LMOC area.

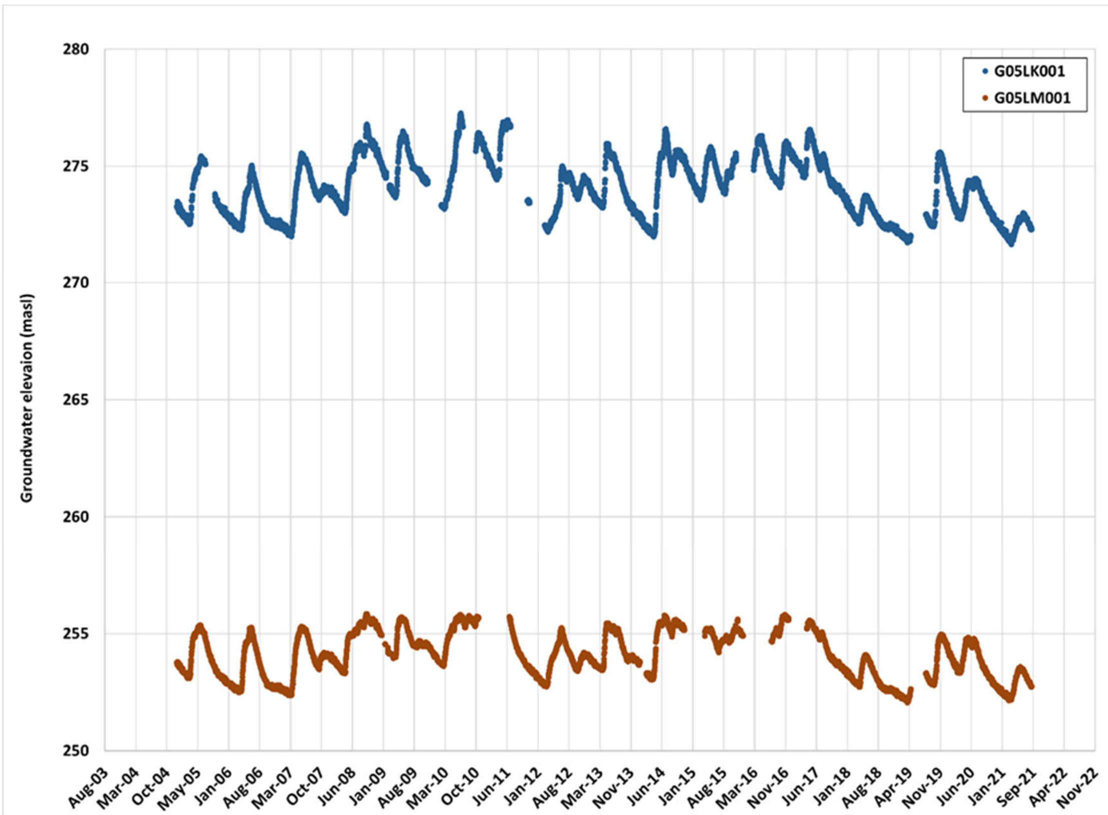

Figure A-3: Piezometric Water Elevations in the Carbonate Aquifer (2005-2021)

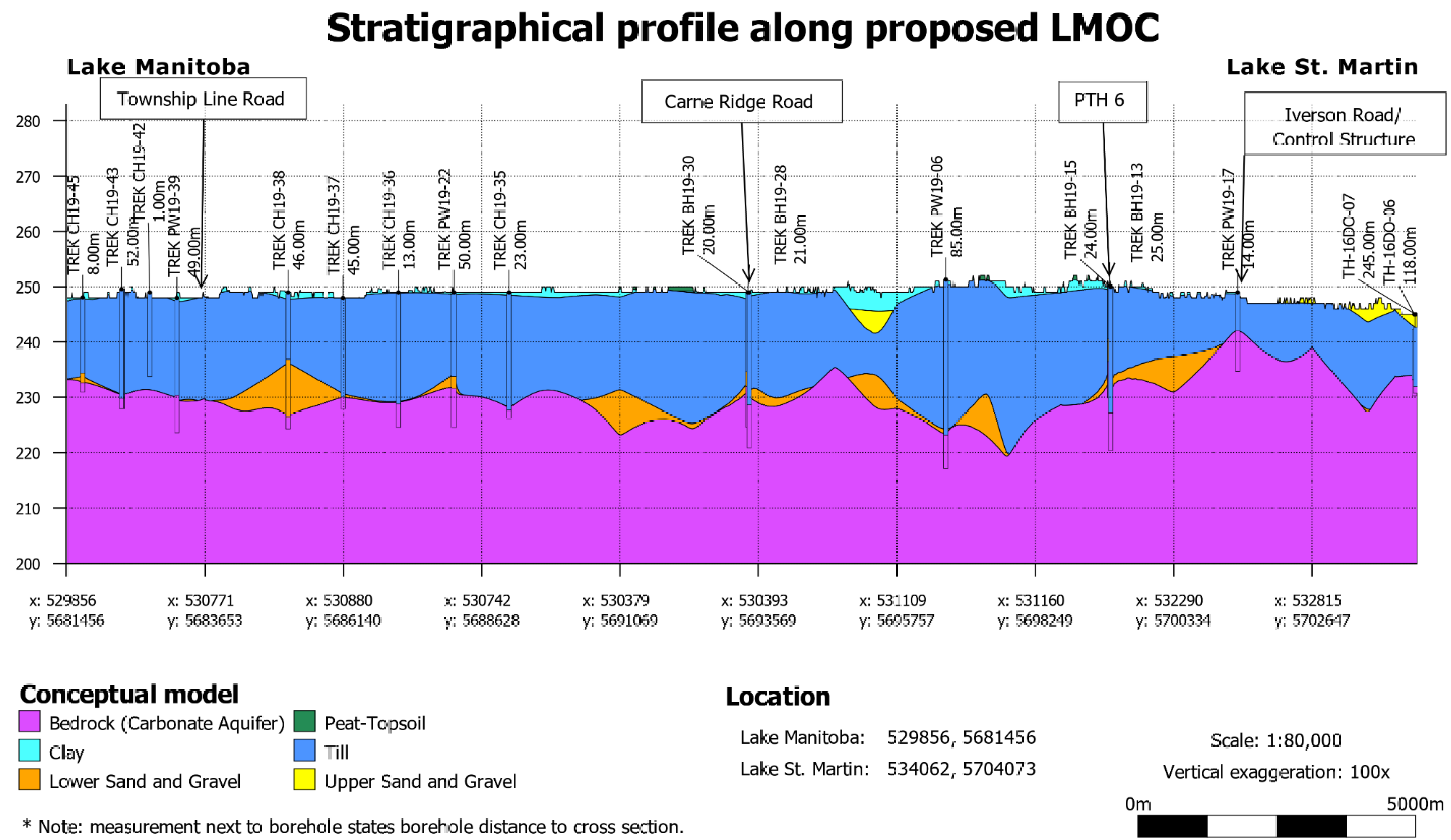

Plate 1: Cross section of the geological model along the proposed LMOC. Selected boreholes and structures are indicated. Vertical exaggeration is 100x.

APPENDIX 1B

Lake St. Martín Outlet Channel Hydrogeologic Conditions

1B.1 Site Characterization

Hydrogeologic conditions in the vicinity of the LSMOC are interpreted from available information, previous field studies and the groundwater field programs conducted as part of the Preliminary Design for the LSMOC (KGS 2021a, KGS 2021b, KGS 2022).

The proposed LSMOC is located within the Interlake area of the Manitoba lowland physiographic region. The Manitoba lowland is a region of gentle relief situated east of the Manitoba Escarpment. The lowland is underlain by gently southwestward dipping Paleozoic and Mesozoic sediments consisting of carbonate rocks, with minor clastic and argillaceous units. The bedrock is predominantly overlain by tills, proglacial lacustrine sediments, and more recent organic deposits found in low-lying areas. An overview of the regional and local surficial geology modified from Matile and Keller (2006) is provided in Figure B-1 below.

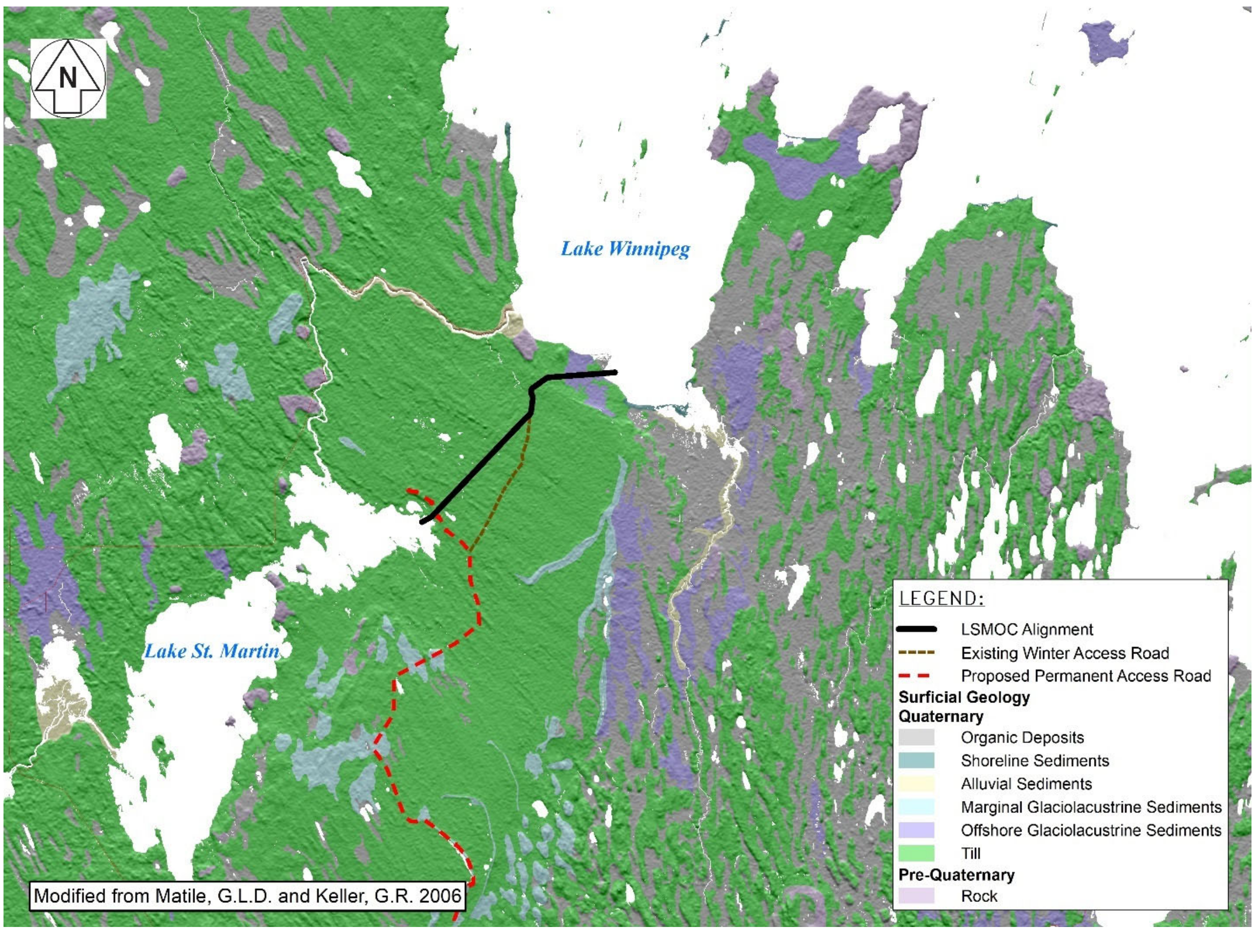

Figure B-1: Surficial Geology Within the Region of the LSMOC

Two distinct groundwater systems are known to be present within the region of the LSMOC - an upper saturated peat, and an underlying confined carbonate bedrock aquifer. Glaciolacustrine clays/clay tills, and silt tills form a low permeability aquitard between the perched peat groundwater flow system, and the underlying confined carbonate bedrock aquifer system.

Lake Winnipeg and Lake St. Martin are key discharge areas for the bedrock aquifer and flowing artesian conditions have been observed in the area due to confined piezometric pressure within the bedrock aquifer. The lakes within the Manitoba lowland collect drainage from the southern portion of the Province, which is directed through Lake Winnipeg into the Nelson River system. Discharge of the drainage system ultimately occurs at Hudson Bay.

1B.2 Geologic Units and Aquifers

1B.2.1 Site Geological Stratigraphy

Stratigraphy in the LSMOC portion of the LAA was interpreted based on the results of recent field investigations and from previous studies in the area. It was also interpreted based on stratigraphy observed along the Reach 3 of the Emergency Outlet Channel (EOC) during construction in 2011/2012.

A generalized view of the LSMOC stratigraphy along the LSMOC is provided in Appendix 1B- Plate 1. In general, the overburden layer in the LSMOC portion of the LAA varies in thickness along the channel alignment from 1 m to 24 m. As described below, the stratigraphy encountered in the test holes drilled generally consists of peat over silty clay, glacial till (consisting of clay till and silt till) and isolated sand, gravel, and cobble lenses, underlain by bedrock.

Peat

Peat was observed at surface along the majority of the LSMOC portion of the LAA. The peat is generally described as black to dark brown in colour, moist to wet, and is fibrous to amorphous and ranges in thickness between about 0 m to 3.0 m (however, it is typically about 1.0 m to 2.0 m in thickness).

Silty Clay

A silty clay unit was observed below the peat surface and is most apparent downstream of the existing Reach 3 of the EOC towards Lake Winnipeg. The silty clay is brown to grey in colour, moist, soft to stiff, intermediate to high plasticity (low plasticity in some instances), containing trace silt pockets, trace fine- to coarse-grained sand, trace gravel, and ranges in thickness between approximately 0.5 m to 4.0 m.

An additional zone of inter-till clay soil was described in one borehole advanced along the LSMOC. A 5.1 m thick zone of soft (putty-like) clay was encountered below the silt till and above the bedrock surface in TH19-KGS-04 (Station [Sta.] 3+500).

Clay Till

A clay till unit is located either immediately below the peat, or below the silty clay, and above the silt till. The predominant grain size within the clay till varied spatially and with depth. The clay till is generally described as silty, brown to dark grey in colour, moist to wet, firm to stiff, intermediate to high plasticity (low plasticity in some instances), containing trace to some silt pockets, trace to some sand, trace gravel, trace cobbles, trace boulders, and ranges in thickness between about 0 m to 5.0 m.

Silt Till

A silt till unit is present below either the silty clay or clay till units and overlying the bedrock. The predominant grain size within the till varied spatially and with depth. The silt till is described as tan to grey in colour, dry to moist, dense to very dense, low plasticity, containing some to with clay, trace to some sand, trace to some gravel, trace to some cobbles and boulders, and ranges in thickness between about 1.5 m to 21.0 m. The silt till is generally thickest upstream of the existing Reach 3 EOC between Sta. 0+000 and 13+800, ranging from approximately 7.0 m to 21.0 m along this reach of the LSMOC. In the upstream section of the EOC Reach 3 itself (between approximately Sta. 13+800 to 17+000) the till thickness ranges between approximately 1.5 m and 12.0 m. The downstream section of the Reach 3 emergency channel (between approximately Sta. 17+000 to 18+300) is characterized by a bedrock high, and has a limited thickness of silt till ranging from approximately 0 m to 1.5 m. Downstream of the Reach 3 emergency channel (i.e., between approximately Sta. 18+300 to 24+000), the silt till thickness ranges from approximately 2 m to 9 m.

Sand / Gravel / Cobbles

Isolated sand, gravel, and cobble layers were encountered at various locations and depths along the channel alignment. Sandy gravel and sand layers were observed on the lake bottom surface within Lake St. Martin in TH-17-LSMI-10 and -11, with thicknesses of 1.1 and 0.7 m, respectively. A near surface sand layer approximately 0.2m thick was observed beneath the peat in TP19-KGS-07 (Sta. 1+614).

A discontinuous inter-till sand unit was observed within the silt till, from 6.2 m to 7.4 m below grade, and also from 8.7 to at least 12.0 m below grade (end of test hole), in test hole TH19-KGS-07 (Sta. 5+606). Inter-till sand layers ranging in thickness from at least 0.6 m to 1.2 m were also encountered near Lake St. Martin in test holes TH-17LSMI-10 and -11 at depths of 10.7 m and 7.7 m, respectively. A cobble and gravel layer ranging in thickness from 0.5 m to 1.7 m was observed at the base of the silt till unit immediately above bedrock within Lake St. Martin and Lake Winnipeg in test holes TH-17LSMI-13, -14, and TH17-LWGO-16.

Bedrock

The bedrock encountered along the channel alignment was intersected at depths ranging from approximately 1.0 m to 24.0 m below grade based on drilled test holes. The bedrock is generally described as dolomite to dolomitic limestone. Layers of carbonaceous shale were observed at several test hole locations, generally downstream of approximate station 13+200.

1B.2.2 Groundwater Systems – Aquifers and Aquitard

Two distinct groundwater systems are known to be present within the region of the LSMOC, within the upper saturated peat and the lower confined carbonate bedrock aquifer.

Perched Peat Flow System

The upper, saturated peat unit is perched above the clays (where present) and underlying till units. The peat is recharged directly from surface rainfall and snowmelt, and from groundwater discharge of the carbonate aquifer at artesian spring sites. Groundwater flows within the peat will be locally controlled, though some other areas of seepage from the bedrock may be more diffuse and harder to identify when a distinct spring site is not visible at surface. Small-scale spring site flow systems develop from raised bog/peat mound areas, flowing radially outward toward relatively lower-lying depressions and other associated open water areas.

The water table within the peat is at or near ground surface, with an overall hydraulic gradient, including surficial flow, to the east. The water quality within the upper perched peatlands has a signature associated with the confined carbonate bedrock in the region of the LSMOC.

Aquitard

Glaciolacustrine clays/clay tills, and silt tills form a low permeability aquitard between the perched peat groundwater flow system, and the underlying confined carbonate bedrock aquifer system. Aside from regional surface water drainage patterns, the low permeability nature of the aquitard is a key element in maintaining perched water levels in the surficial peat and confined head in the bedrock aquifer and overlying silt till. It is likely that only negligible recharge occurs through the aquitard to the bedrock, as recharge to the bedrock occurs regionally within bedrock outcrop areas, and/or where the bedrock topography is high, and the overlying till cover is thin. The water quality within the till aquitard is unique from the carbonate bedrock, and perched peatland water qualities (KGS 2021a).

Carbonate Bedrock Aquifer

The underlying, confined bedrock aquifer is comprised of a Paleozoic rock sequence commonly referred to in Manitoba as the "Carbonate Aquifer System." This aquifer system is isolated from the peat unit by the upper clay and till aquitard zone. The confined bedrock aquifer is recharged via rainfall and snowmelt regionally, with recharge areas occurring at locations of bedrock outcrop or in areas where the bedrock is covered by a thin overburden layer.

Well yields are highly variable in the region, a direct result of the fractured rock conditions. Water yields depend on the number of fractures intersected by a well, their size (aperture), extent, and interconnection to other fractures. East of Lake Manitoba the water quality is generally fresh, with TDS <1,000 mg/L. Water quality is generally Mg Ca-HCO3 type, with TDS in the order of 400 mg/L to 650 mg/L (Betcher, 1987). This water quality reflects the substantial contribution of atmospheric precipitation to the aquifer recharge zone noted within the Interlake area (Betcher, 1987). Due to more complex geology and evaporate mineralogy in the Gypsumville area, water quality varies and is locally poorer with TDS concentrations up to 4,550 mg/L (Betcher, 1987). Typical bedrock piezometric pressure variability in the region of the LSMOC is measured at 1.5 m +/- 0.5 m (KGS 2021b). The water quality within the carbonate bedrock aquifer in the region of the LSMOC is distinct from surface water (e.g., Lake St. Martin and Lake Winnipeg), is distinct from the water quality within the till aquitard and is similar to the water quality observed within the perched peatland system, to which it discharges at artesian spring sites (KGS 2021a).

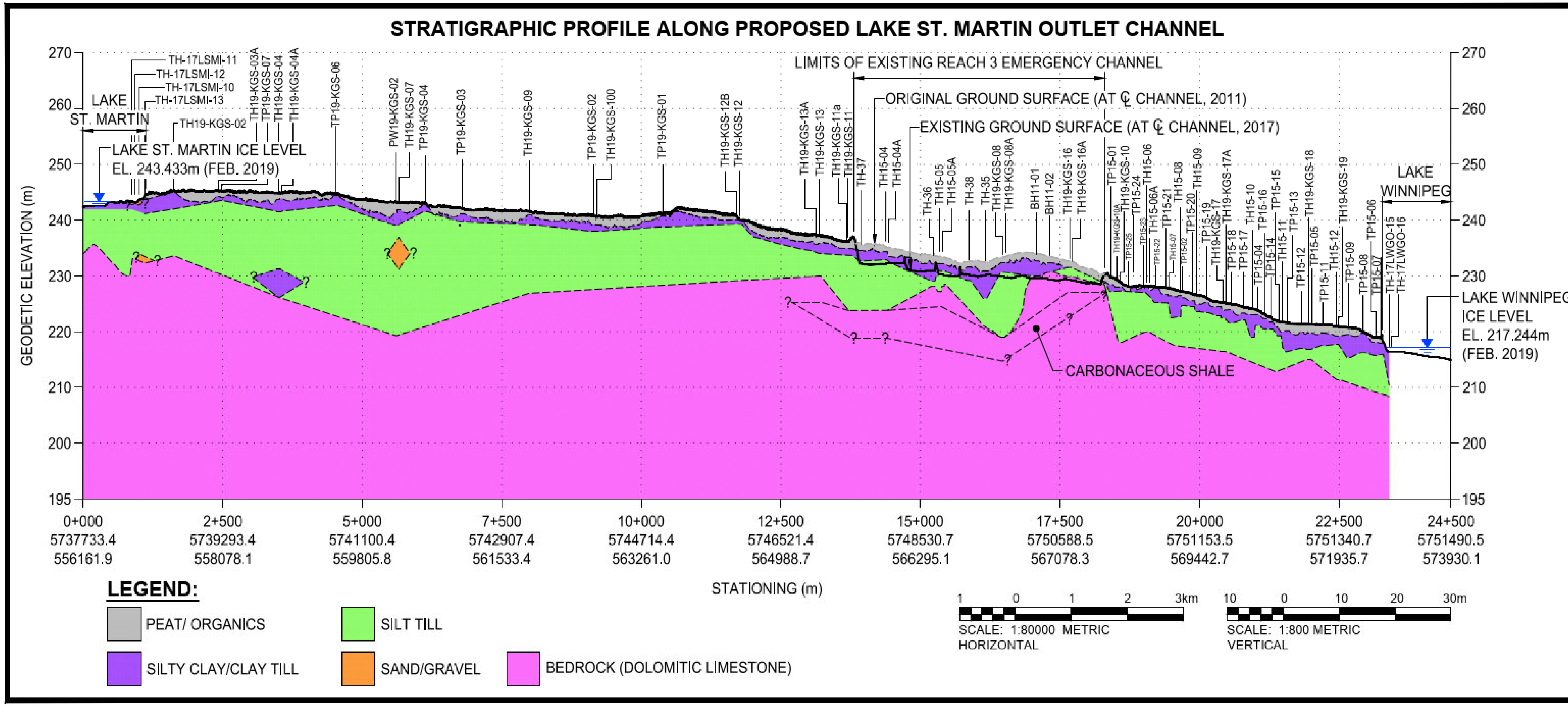

Figure B-2: Stratigraphic Profile of Proposed LSMOC as Interpreted from Borehole Logs