HYDRO
THE POWER OF COMMITMENT

THE Lower Churchill PROJECT

April 2008

GI1190 - Dam Break Study
Volume 1

prepared by

HATCH™

in association with

RSW inc.
Statnett
TGS TransGrid Solutions

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REGISTERED PROFESSIONAL ENGINEER
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SIGNATURE
April 18/08
DATE
NEWFOUNDLAND & LABRADOR

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Executive Summary

Newfoundland and Labrador Hydro (Hydro) is undertaking preliminary engineering studies of the development of the hydroelectric potential of the lower Churchill River at Gull Island and Muskrat Falls. As part of these feasibility studies, Hatch has carried out a Dam Break Study.

The purpose of the study is to analyse various dam breach scenarios, the results of which were used to prepare inundation mapping for the potentially flooded areas. In addition, an assessment of potential incremental environmental, structural, economic and social impacts on downstream property and inhabitants was carried out. These maps and assessment have been based on the predetermined Inflow Design Flood (Probable Maximum Flood - PMF), "Fair Weather" conditions, and dam breaches in cascade, as specified by the 2007 Canadian Dam Association Dam Safety Guidelines.

These studies involved the use of GIS tools and various data sources in the setup of a HEC-GeoRAS hydrodynamic routing model. The model developed for GI1110 “Hydraulic Model of the River” and the work completed for GI1140 “PMF and Construction Design Flood Study”, also conducted by Hatch, formed inputs to this study.

A HEC-GeoRas model capable of simulating dam breach floodwaves was successfully set up and used to model hypothetical dam breaches at both Gull Island and Muskrat Falls. Although it might be of interest to the Lower Churchill Project to assess the impacts of an Upper Churchill dam breach on the planned projects at Gull Island and Muskrat Falls, this work should be coordinated and planned in cooperation with Churchill Falls (Labrador) Corporation. The results of the dam breach modeling were used to prepare inundation mapping for Emergency Preparedness Plans and to assess the overall consequences of failure for both Gull Island and Muskrat Falls.

It is recommended that:

1. The Lower Churchill Project coordinate dam breach studies with Churchill Falls (Labrador) Corporation related to Upper Churchill failure scenarios.
2. The dam break model and inundation mapping be updated prior to the preparation of Emergency Preparedness Plans. This update would take into consideration any changes to the project layouts.
3. Conduct dam breach analysis for during construction activities (cofferdams). The CDA Guidelines note that for significant cofferdams, Emergency Preparedness Plans are required.

1. Introduction

Newfoundland and Labrador Hydro (Hydro) is undertaking preliminary engineering studies for the potential hydroelectric development of the lower Churchill River at Gull Island and Muskrat Falls. These sites are located downstream 225 km and 285 km respectively from the Upper Churchill hydroelectric facility that was developed in the early 1970's. The total potential capacity at the two sites is approximately 2800 megawatts (MW), the Gull Island site being the larger at 2000 MW. In addition to the development of these sites, the overall concept includes various potential alternative power transmission arrangements involving combinations of AC and DC lines of various capacities.

In April, 2007, Hydro contracted Hatch Ltd of St. John's to undertake a program of studies to address aspects of this development relating primarily, but not exclusively, to hydrology/hydraulics and transmission components. Approximately thirty such studies have been carried out by Hatch and its associated subconsultants - RSW of Montreal, Statnett of Oslo, and Transgrid of Winnipeg. The program has been managed from Hatch's office in St. John's using the company's project management tools and a project services team that has liaised throughout with a similar group in Hydro.

This report presents the Dam Break Study for the Gull Island and Muskrat Falls Projects. The purpose of the study was to analyse various dam breach scenarios, prepare inundation mapping for the potentially flooded areas, and assess potential environmental, structural, economic and social impacts on downstream property and inhabitants. These maps and assessment have been based on the predetermined Inflow Design Flood (Probable Maximum Flood - PMF), "Fair Weather" conditions, and dam breaches in cascade, as specified by the 2007 Canadian Dam Association Dam Safety Guidelines (CDA Guidelines).

2. Model Development

The following sections present the model selected for conducting the dam breach studies and the set up of the selected model.

2.1 Model Selection

The progression of a flood along a river reach is determined by routing the computed dam outflow and local inflow hydrographs using either hydrologic or hydraulic routing techniques. As a flood progresses downstream, the hydrograph at each downstream location is modified by the effects of channel storage, frictional resistance, floodwave acceleration, channel constrictions, obstructions and downstream reservoirs and dams. Dam breach flood hydrographs, in particular, are altered rapidly in the vicinity of the originating outflow, requiring the use of hydrodynamic routing techniques to ensure local changes in acceleration are adequately captured. Hydrodynamic flood routing methods use the complete one dimensional Saint-Venant unsteady flow equations to relate flood flows to a physical description of the river, including its slope, cross section and roughness. The principal advantage of these methods, for analyzing extreme flood events, is these models provide a more accurate simulation of the unsteady floodwave. These dynamic wave methods account for the acceleration effects associated with the dam breach wave, and the influence of downstream unsteady backwater effects produced by channel constrictions, dams, bridge-road embankments, and tributary inflows.

Various hydraulic models are available for use in these types of studies. Models traditionally used for this purpose include the well-known DAMBRK and FLDWAV models, which have been developed through initiatives by the National Weather Service (NWS). However, the US Army Corps of Engineers (USACE) HEC-GeoRAS model has emerged as an equally capable tool for simulating these types of events, and offers additional advantages that can help to increase the model set up efficiency, as well as the speed with which inundation mapping can be prepared for the various dam breach scenarios. The similarities HEC-GeoRAS has with DAMBRK/ FLDWAV and the advantages over those software packages follow and are the reasons for its selection for the current studies.

- Ability to simulate unsteady flow conditions due to a dam breach using the former UNET hydrodynamic solver as well as aspects of the NWS DAMBRK/ FLDWAV model solvers. Model results have been found, by both Hatch and others, to be comparable to the results of the DAMBRK/ FLDWAV programs.
- Utilizes an empirical based methodology to define and control the development of a dam breach. Parameters entered by the user include the mode of failure (piping verses overtopping), the ultimate breach width, the breach bottom elevation, side slope, and time of formation.
- Simulates the progression and attenuation of a flood hydrograph using hydrodynamic flood routing methods.
- Supports both supercritical and subcritical flow regimes, and automatically calculates the transition between each.
- Assesses an entire river system with dams, bridges, flow control structures, and local inflows and outflows that affect the flow conditions. Internal and external boundary conditions are used to simulate a large number of prototype river system arrangements.

- Accommodates interconnected streamflow networks consisting of multiple tributaries and/or branches.
- At each dam site, the model can simulate turbine, spillway, dam overtopping and dam failure outflows. Operating policies can be represented using either time or water level dependent discharge relationships.
- Cross sectional geometry can be defined by using up to 500 data points per cross section and automatically generated from ArcGIS. This is a distinct advantage compared to the DAMBRK/ FLDWAV model, which only allows the specification of eight top widths to define a river cross section and the input is manual.
- Allows the input of both a main river channel, as well as flood plains on both banks. Off channel storage areas can also be included, as required. These areas can have a significant attenuating effect on the floodwave.
- Channel roughness parameters and other minor loss coefficients are selected to account for the effects of channel boundary roughness, meanders, debris and unanticipated obstructions. Roughness values can be varied spatially across a section.
- Results from the program can be easily imported and exported into ArcGIS. This allows model results to be developed from and input back into a GIS based topographic model of the river valley, and flood lines can then be automatically developed for the reach. This provides an increased level of efficiency and quality when producing inundation maps.

The HEC-GeoRAS model setup for this study is discussed in more detail in the following sections.

2.2 HEC-GeoRAS Model Setup

Two important pieces of work that were completed as a part of the Lower Churchill Projects studies by Hatch that form the basis of the model setup for this study follow.

- PMF and Construction Design Flood Study (GI1140)
- Hydraulic Model of the River (GI1110)

A brief summary of each is provided below; for additional detail the reader should consult the final reports related to those studies.

2.2.1 PMF and Construction Design Flood Study (GI1140)

The objective of this study was to determine the PMF inflow hydrograph for Gull Island and Muskrat Falls, route the PMF dynamically through the structures and estimate the spillway design capacity required at each site. The scope included a review of previous studies on the upper and lower Churchill basins, a meteorology study to estimate the contributors to the PMF, and detailed hydrologic modelling of the entire Churchill River basin.

A watershed model of the Churchill basin was calibrated using the following.

- Meteorological data from AES climate stations at Goose Bay, Churchill Falls, Schefferville and Wabush.
- Snow course, precipitation and lake level data from Churchill Falls (Labrador) Corporation.

- Hydrometric data from eleven Water Survey of Canada streamflow stations.

The hydrologic model was then used to test the various combinations of extreme rainfall, temperature and snowpack recommended in the CDA Guidelines to determine the governing PMF case. PMF hydrographs for Upper Churchill basin from the model were routed through the Churchill Falls Complex using a decision based operation model to implement the flood handling procedures for Smallwood and Ossokmanuan Reservoirs. The resulting upper basin outflow hydrographs and inflow hydrographs from the major tributaries in the lower Churchill basin were then routed through the lower Churchill River using a dynamic hydraulic model. This hydraulic model was calibrated using survey data and historical flood data, and then run with the critical PMF hydrographs for the pre- and post-project conditions on the river. Adding the dams resulted in PMF peaks of 20,800 m^3/s at Gull Island and 22,420 m^3/s at Muskrat Falls. The hydrographs produced from the PMF and Construction Design Flood Study were used as inputs for this study.

2.2.2 Hydraulic Model of the River (GI1110)

The objective of this study was to develop a hydrodynamic model of the lower Churchill River system to be carried forward into various other work packages, and to answer environmental and engineering questions regarding the existing and post-project hydraulic regime of the lower Churchill River.

The USACE HEC-GeoRAS program was used to develop the model of the river. This version of the model enables the model to be fully geo-referenced, with model development and post-processing of results occurring in a GIS environment. Both existing and new bathymetry (in the form of cross sections) were obtained so that sufficient detail was available to calibrate the model successfully. Over-bank portions of the sections were obtained by “cutting” sections through the LiDAR-based Digital Elevation Model, leading to a highly detailed representation of this area. Figure 2.1 and Figure 2.2 show the model extents (Digital Elevation Model) and the representative cross section locations in the model, respectively.

The model allows prediction of the velocities and water levels throughout the reach, before, during, and after construction of the Gull Island and Muskrat Falls Projects. This model setup was therefore used as the base model that could be used to start dam breach modeling. However, additional changes and updates were required to allow for dam breach simulations, as discussed in the following section.

2.2.3 HEC-GeoRAS Model Updates

The HEC-GeoRAS model was originally set up to do both steady state and dynamic routing for other studies. The modeling required for dam breach simulations is of a dynamic nature; however, it is a rapidly varied flow that can lead to numerical instabilities if the model is not accurately set up. For this reason, there were a number of changes that were required to the HEC-GeoRAS model before dam breach simulations could be conducted. The changes that were required to the model included:

- Cross section smoothing.
- Addition of interpolate cross sections.
- Model boundary extension.
- Dam characteristics representing Gull Island and Muskrat Falls.
- Upstream boundary conditions.

2.2.3.1 Cross Section Smoothing

As noted above, the cross sections from the LiDAR based Digital Elevation Model are quite detailed and can contain up to 500 separate points to define one cross section, which allows for a more accurate representation of the cross sectional geometry. However, this level of detail introduces the potential of model instability when dam breach simulations are conducted. The problem is due to the rapidly varied flow and the model having to conduct calculations for very detailed cross sections. An exercise was undertaken as a part of this study to review each cross section and “smooth” the cross sections such that each section would have the same shape, thus maintaining accuracy; however, with fewer points in the section. The sections were updated and this led to faster simulation times and a more numerically stable model.

2.2.3.2 Addition of Interpolate Cross Sections

It should be noted that only the main cross sections directly input to the model are shown in Figure 2.2. As required, the model was set up to allow the automatic addition of interpolated cross sections to enhance the numerical stability of the model. The average cross sectional spacing (primary plus interpolated sections) was 250 m, giving upwards of 2000 cross sections in the final developed model for dam breach simulations.

2.2.3.3 Model Boundary Extension

Typically for dam breach modeling it is important that the downstream model boundary extends to a location where the results of a dam breach would not induce a significant increase in water level. These locations are usually large lakes or bodies of water influenced by tidal fluctuations. For this study, the model was extended in to Lake Melville by adding cross sections in the model to represent the lake.

2.2.3.4 Dam Characteristics Representing Gull Island and Muskrat Falls

Dam breach scenarios at Gull Island and Muskrat Falls are the focus of this study. The developments are proposed to be located 225 km and 285 km, respectively, downstream from the Upper Churchill hydroelectric facility. In addition to the cross sectional information described above, the model was set up to include all pertinent data for these structures.

The Gull Island Project, as shown in Figure 2.3, is proposed to consist of three structures, as follows.

- 4 unit powerhouse capable of passing 2,548 m^3/s at full load.
- 7 bay spillway capable of passing 16,000 m^3/s at full supply level.
- A rockfill main dam with a crest elevation of 129.0 m.

A spillway rating curve for Gull Island was provided by Hydro and is shown in Figure 2.4. A speed-no-load discharge for the generating station was estimated to be approximately 245 m^3/s, using methodologies presented by Gordon [Ref 1], and was used for the dam breach modeling.

The Muskrat Falls Project (Variant 10), as shown in Figure 2.5, is proposed to consist of five structures, as follows.

- South Roller Compacted Concrete (RCC) dam (South Abutment) which is 370 m long and has a crest elevation of 45.5 m.
- 4 Unit Powerhouse capable of passing 2,667 m^3/s at full load.

- 3 Bay spillway capable of passing 10,800 m^3/s at a maximum flood level (MFL) of 44 m.
- North RCC Overflow Dam with a crest elevation of 39.2 m.
- North RCC Overflow Dam with a rubber dam on the crest, crest elevation 39.5 m inflated and 37.1 m deflated.

Spillway rating curves were provided by Hydro and are shown in Figures 2.6, 2.7, and 2.8. A speed-no-load discharge for the generating station was estimated to be approximately 405 m^3/s, using methodologies presented by Gordon [Ref 1], and was used for the dam breach modeling.

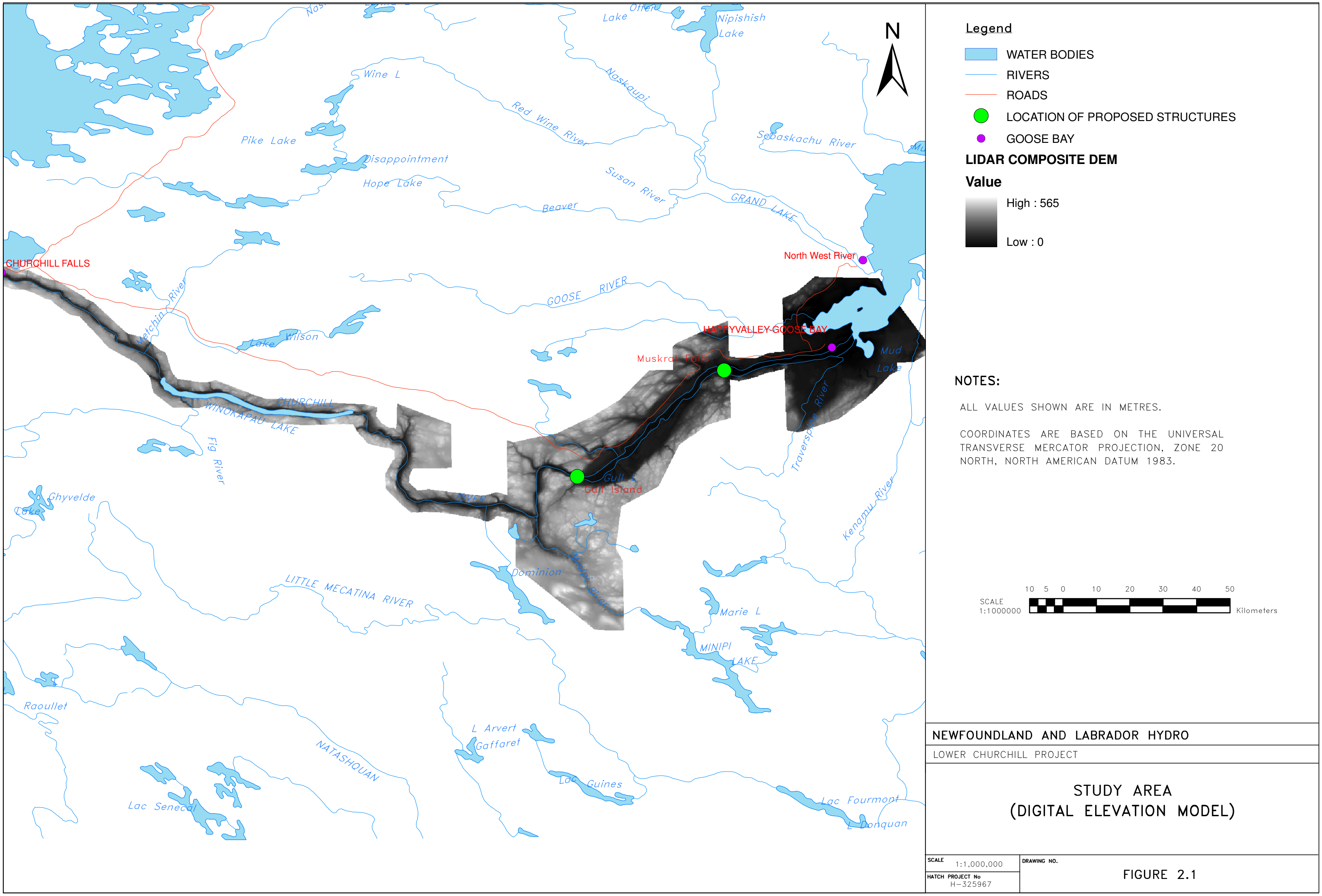
2.2.3.5 Upstream Boundary Conditions

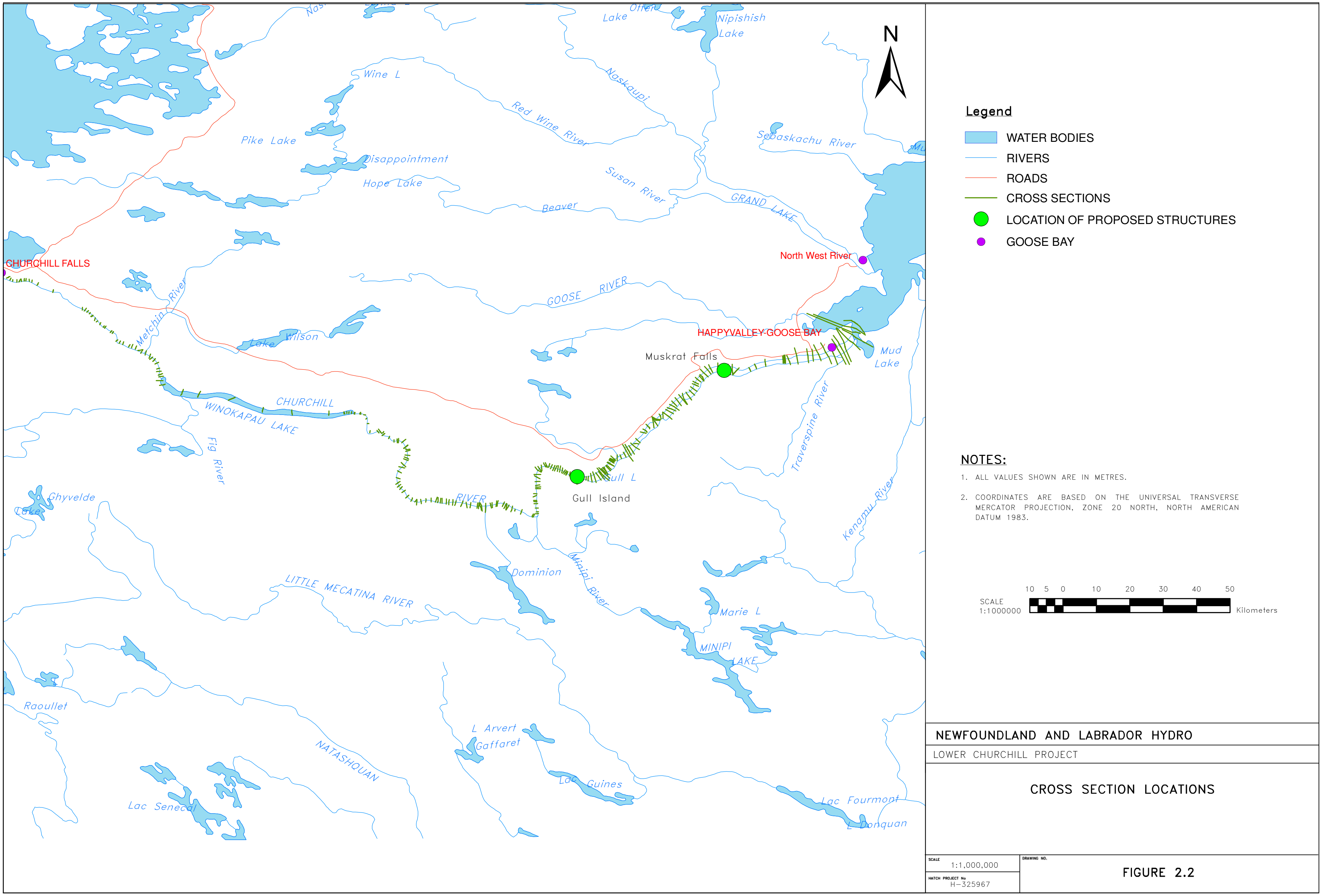
Since it is not possible or practical to model the full spatial extent of the river system, boundary conditions must be applied to represent the effect of areas not included directly within the model. The application of these boundary conditions ensures that a unique solution is achieved for each simulation. Boundary conditions associated with the dam breach model are as follows:

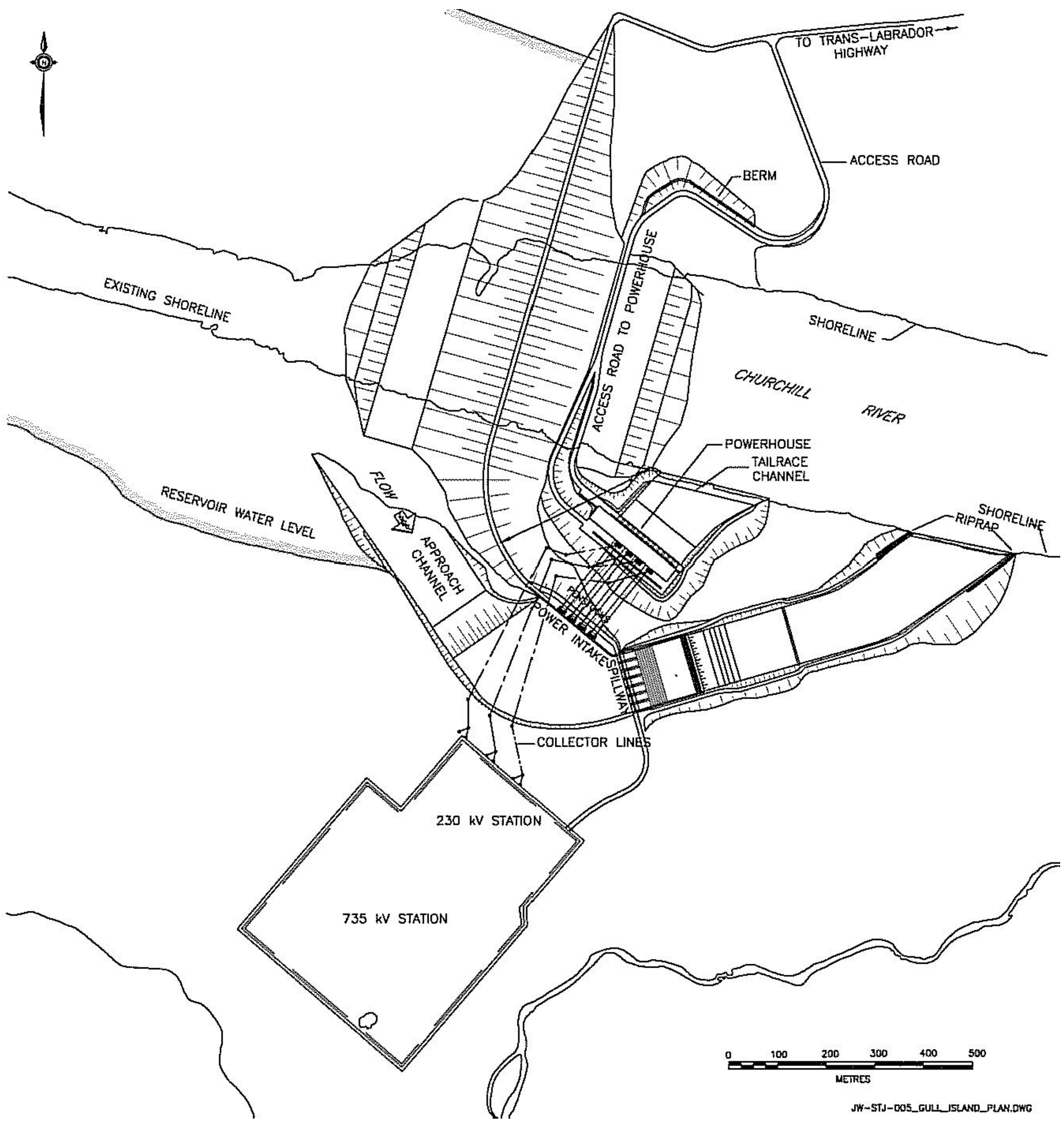
- An upstream outflow hydrograph was specified for the Upper Churchill project. This consisted of a steady discharge equal to the mean summer flow of approximately 1,412 m^3/s for "Fair Weather" conditions, and the PMF hydrograph as determined in GI1140. The PMF inflow hydrograph for the Upper Churchill and the inflow hydrographs from the main tributaries along the lower Churchill River are shown in Figure 2.9. These tributary inflow hydrographs were also taken from the results of GI1140. Table 2.1 presents the flows used for "Fair Weather" conditions.
- Rating curves for the Gull Island spillway and powerhouse as well as the Muskrat Falls spillway and powerhouse were added as inline structures in the model.
- The downstream boundary at Lake Melville was configured to represent an average condition of 0.4 m above sea level.

Table 2.1
Inflows for "Fair Weather" Conditions

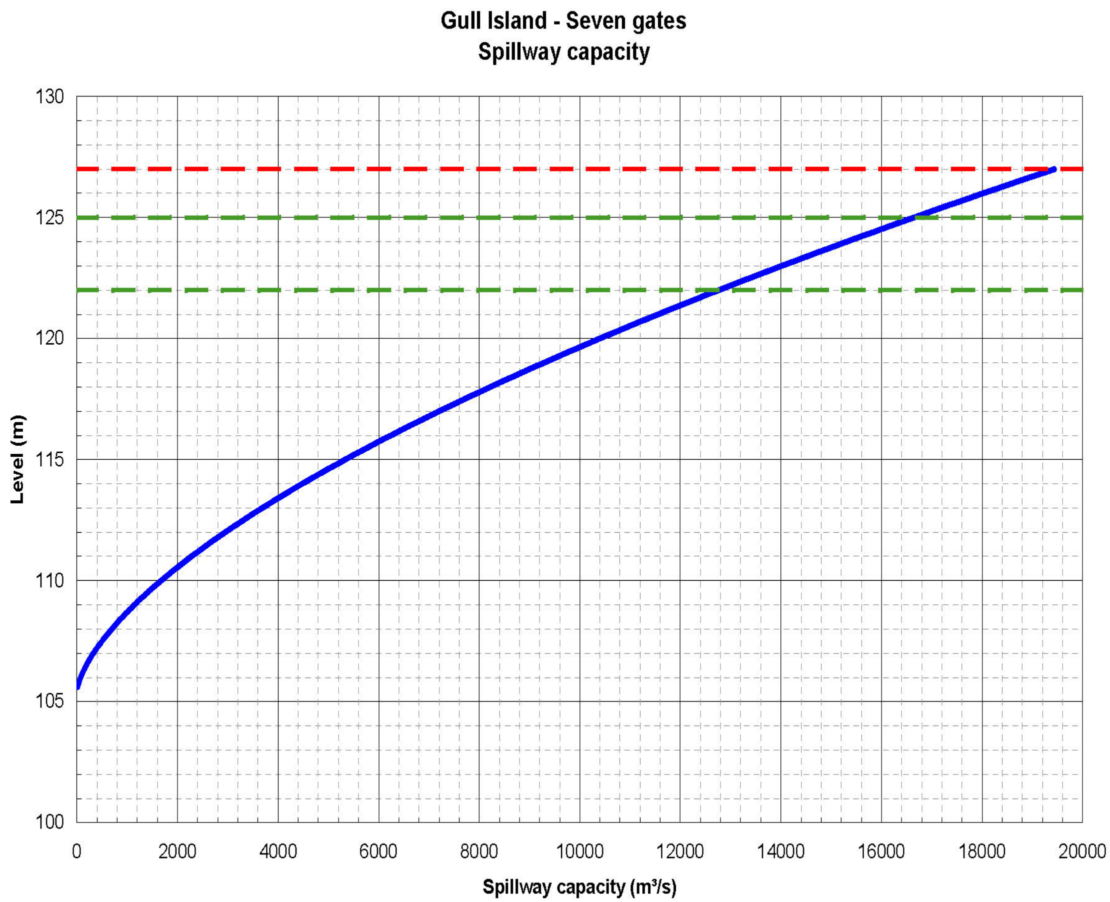
Location	Chainage from Gull Island (km)	Chainage (km)	Inflow (m^3/s)
Upper Churchill	-234.2	333.6	1412
Metchin	-184.8	284.4	90
Fig	-171.6	271.5	11
Cache	-91.9	192.4	140
Minipi	-30.1	131.1	108
Pinus	14.7	88.1	40


N
Legend
WATER BODIES
RIVERS
ROADS
LOCATION OF PROPOSED STRUCTURES
GOOSE BAY
LIDAR COMPOSITE DEM
Value
High : 565
Low : 0
NOTES:
ALL VALUES SHOWN ARE IN METRES.
COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
SCALE 1:1000000
10 5 0 10 20 30 40 50
Kilometers
CHURCHILL FALLS
North West River
HAPPYVALLEY-GOOSE BAY
Muskrat Falls
Gull Island
Nipishish Lake
Wine L
Pike Lake
Disappointment
Hope Lake
Red Wine River
Naskaupi
Sebaskachu River
Susan River
Beaver
GRAND LAKE
GOOSE RIVER
Lake Wilson
CHURCHILL
WINOKAPAU LAKE
Fig River
Ghyvelde Lake
Mud Lake
Traverspine River
Kenamu River
Dominion
LITTLE MECATINA RIVER
Marie L
MINIPI LAKE
Raoullet
NATASHQUAN
L Arvert
Gaffaret
Lac Guines
Lac Seneca
Lac Fourmont
L Donquan
NEWFOUNDLAND AND LABRADOR HYDRO
LOWER CHURCHILL PROJECT
STUDY AREA
(DIGITAL ELEVATION MODEL)
SCALE 1:1,000,000
HATCH PROJECT No H-325967
DRAWING NO.
FIGURE 2.1

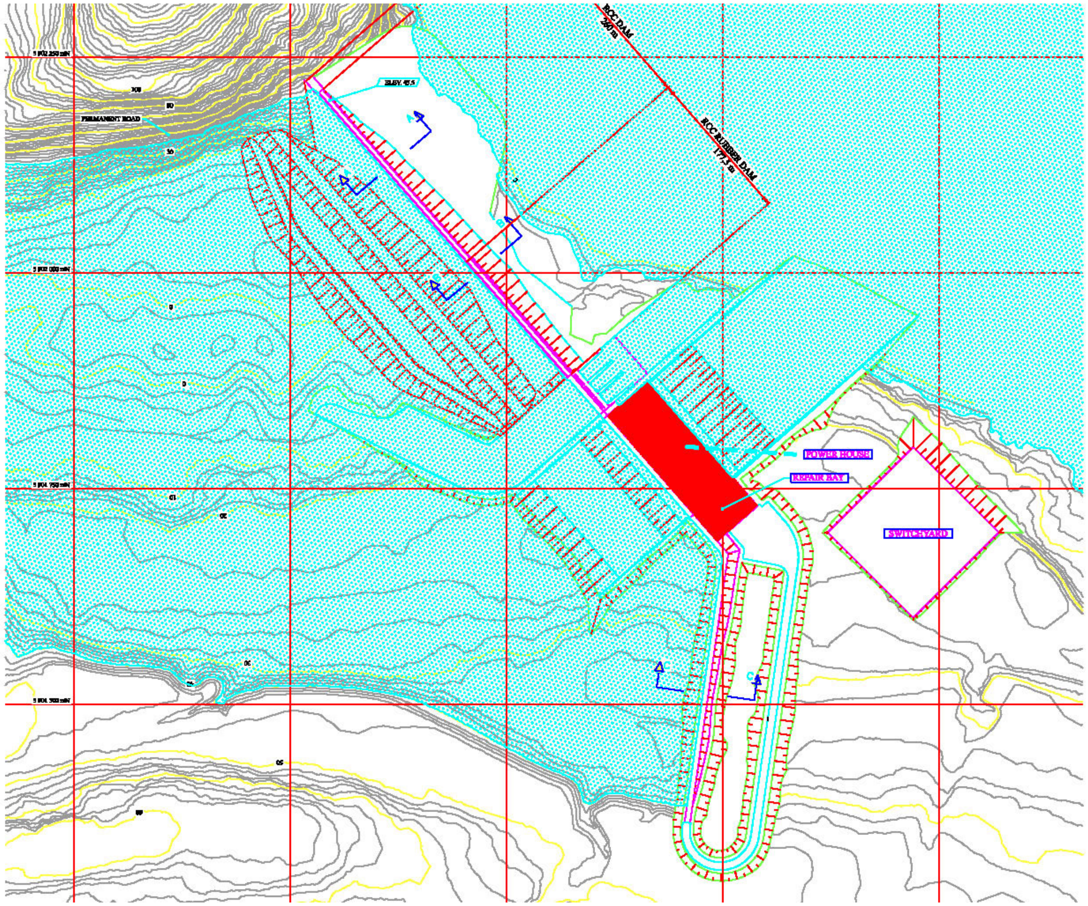

N
Legend
WATER BODIES
RIVERS
ROADS
CROSS SECTIONS
LOCATION OF PROPOSED STRUCTURES
GOOSE BAY
NOTES:
1. ALL VALUES SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
10 5 0 10 20 30 40 50
SCALE 1:1000000
Kilometers
CHURCHILL FALLS
North West River
HAPPYVALLEY-GOOSE BAY
Muskrat Falls
Gull Island
Mud Lake
Nipishish Lake
Wine L
Pike Lake
Disappointment
Hope Lake
Red Wine River
Naskaupi
Sebaskachu River
Susan River
Beaver
GRAND LAKE
GOOSE RIVER
Lake Wilson
Metchin River
CHURCHILL
WINOKAPAU LAKE
RIVER
Fig River
Traverspine River
Kenamu River
Ghyvelde Lake
Dominion
Minipi River
LITTLE MECATINA RIVER
Marie L
MINIPI LAKE
Raoullet
NATASHQUAN
L Arvert
Gaffaret
Lac Guines
Lac Seneca
Lac Fourmont
L Donquan
NEWFOUNDLAND AND LABRADOR HYDRO
LOWER CHURCHILL PROJECT
CROSS SECTION LOCATIONS
SCALE 1:1,000,000
HATCH PROJECT No H-325967
DRAWING NO.
FIGURE 2.2



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	GULL ISLAND PROJECT GENERAL ARRANGEMENT
SCALE NTS	
DATE JAN 2008	FIGURE 2.3

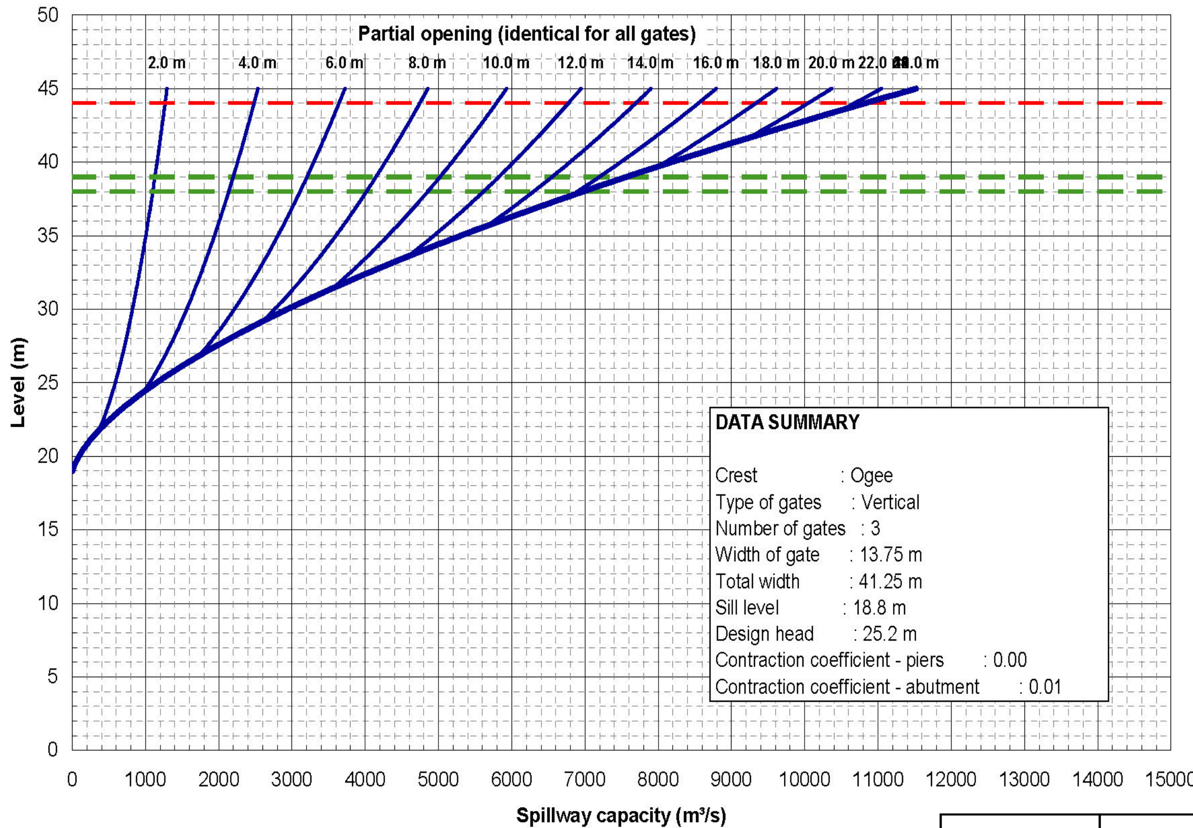


HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	GULL ISLAND PROJECT SPILLWAY RATING CURVE
SCALE NTS	
DATE JAN 2008	FIGURE 2.4

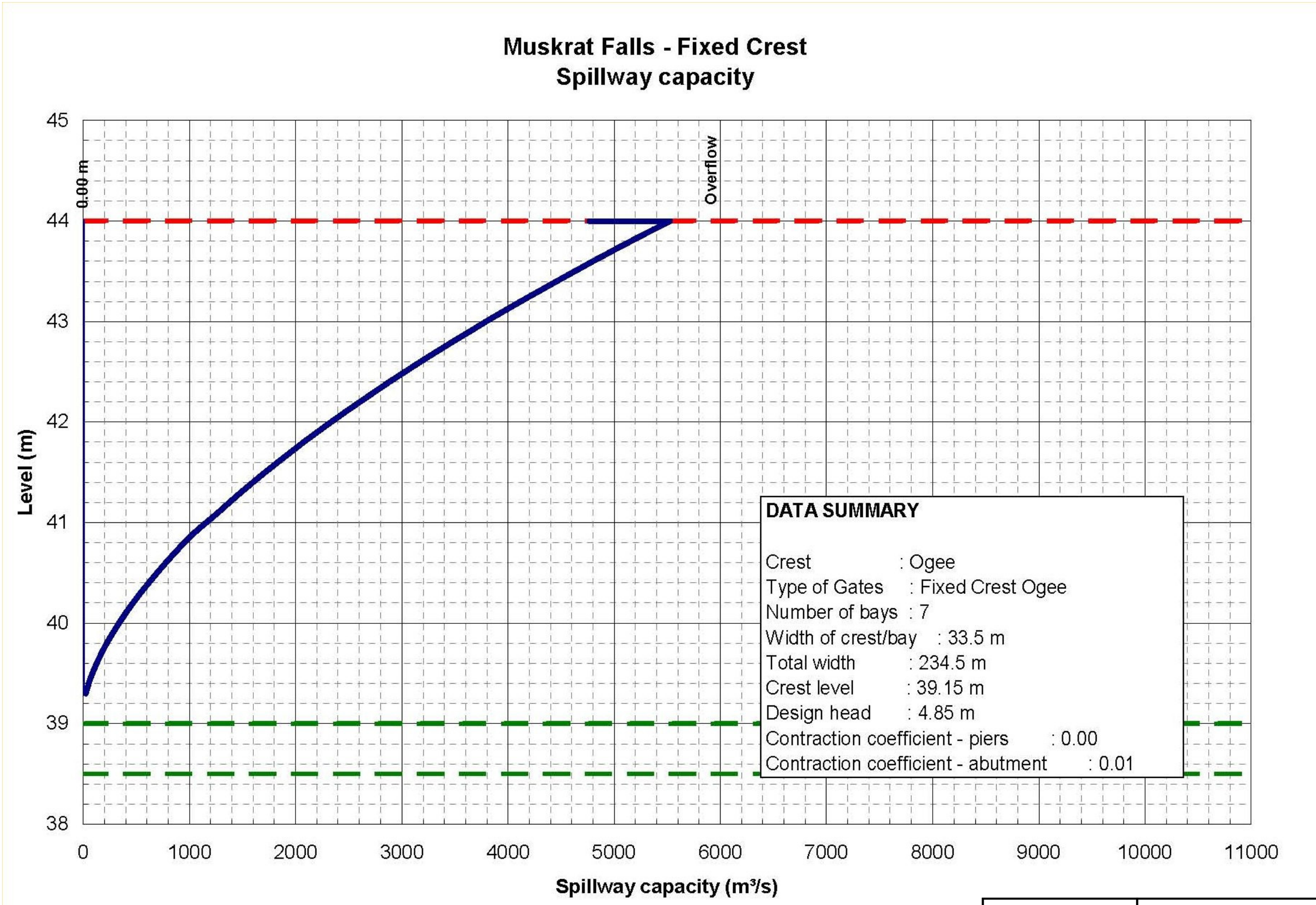


HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	MUSKRAT FALLS PROJECT GENERAL ARRANGEMENT (VARIANT 10)
SCALE NTS	
DATE JAN 2008	FIGURE 2.5

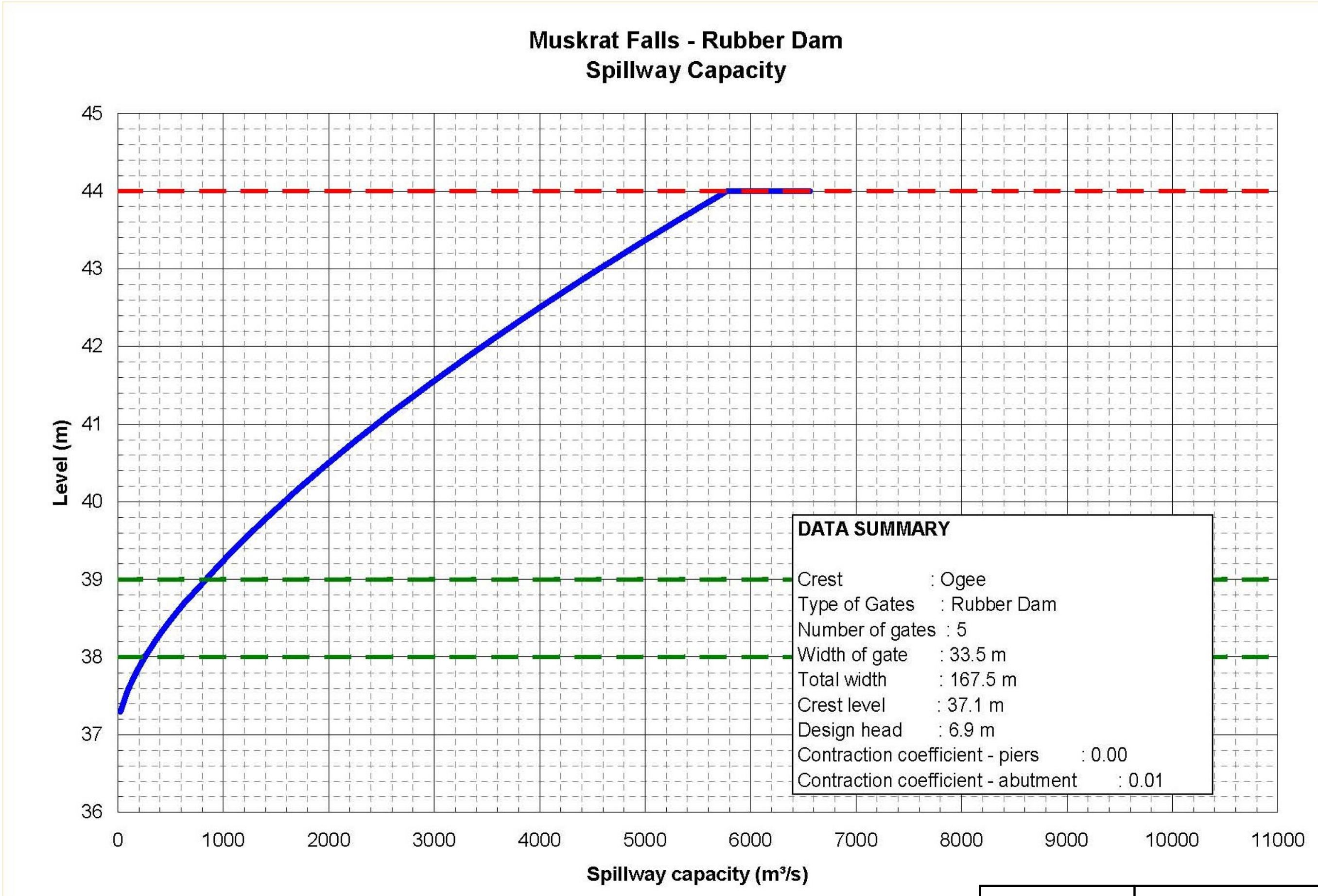
Muskrat Falls - Variant 10 - Three gates
Spillway capacity



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	MUSKRAT FALLS PROJECT SPILLWAY RATING CURVE
SCALE NTS	
DATE JAN 2008	FIGURE 2.6



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	MUSKRAT FALLS PROJECT RCC OVERFLOW RATING CURVE
SCALE NTS	
DATE JAN 2008	FIGURE 2.7



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GI1190 – DAM BREAK STUDY

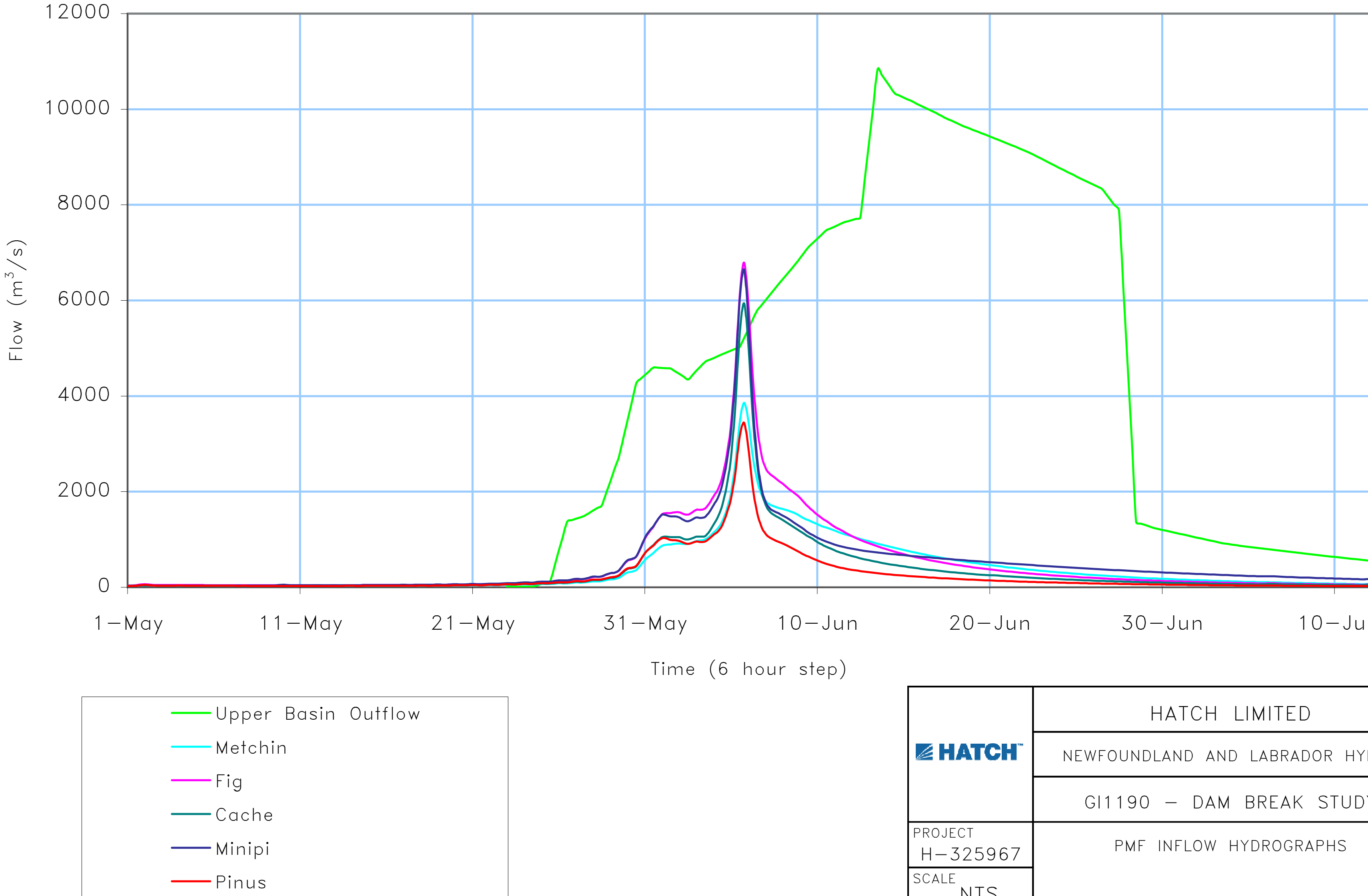
PROJECT H–325967

SCALE NTS

DATE JAN 2008

MUSKRAT FALLS PROJECT
RCC RUBBER DAM RATING CURVE

FIGURE 2.8



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	PMF INFLOW HYDROGRAPHS
SCALE NTS	
DATE MAR 2008	FIGURE 2.9

3. Dam Breach Scenarios

Several scenarios were required to adequately represent the number of potential dam breach combinations that could occur along the lower Churchill River. These scenarios were selected based on recommendations noted within the CDA Guidelines as they relate to the preparation of inundation mapping. The guidelines note that for the preparation of inundation mapping a number of separate scenarios should be investigated as follows:

- Dam breach during the Inflow Design Flood (PMF for Gull Island and Muskrat Falls).
- Dam breach during "Fair Weather" conditions.
- Dam breaches in cascade.

The first two scenarios above are defined in the CDA Guidelines as follows:

Flood-induced failure – This is a dam failure resulting from a natural flood of a magnitude that is greater than what the dam can safely pass.

Sunny-day failure – This is a sudden dam failure that occurs during normal operations. It may be caused by internal erosion, piping, earthquakes, mis-operation leading to overtopping, or another event.

During the course of the study the question was raised as to the requirements related to Upper Churchill dam breaches and potential impacts on Gull Island and Muskrat Falls, along with the development of inundation mapping for those scenarios. Since inundation maps for this study are being produced as part of the Emergency Preparedness Plans (EPP) for the Gull Island and Muskrat Falls projects (as recommended in Section 2.5.2 of the 2007 CDA Guidelines), this negates the need to review the impacts from Upper Churchill.

Section 2.5.2 of the 2007 CDA Guidelines also suggests that it is the responsibility of the Upper Churchill to update its EPP and inundation mapping to reflect the downstream developments at Gull Island and Muskrat Falls. Although for planning purposes it may be important for the Lower Churchill Project to understand the impacts on its projects due to a dam breach at Upper Churchill, this information should be provided by the Churchill Falls (Labrador) Corporation from pre-existing dam breach models or Emergency Preparedness Planning. For these reasons, dam breaches at Upper Churchill and its impacts on Gull Island and Muskrat Falls were not considered for this study.

The final scenarios selected for simulation, for both the PMF and "Fair Weather" conditions, including cascade events between Gull Island and Muskrat Falls, are as follows:

- Post Gull Island – No dam breach
- Post Gull Island – Gull Island dam breach
- Post Gull Island/ Muskrat Falls – No dam breach
- Post Gull Island/ Muskrat Falls – Gull Island dam breach
- Post Gull Island/ Muskrat Falls – Muskrat Falls dam breach
- Post Gull Island/ Muskrat Falls – Gull Island and Muskrat Falls dam breach

Simulations not including dam breaches were required to determine the natural high water level and flow conditions on the lower Churchill that could be expected under non-breach conditions. Inundation mapping of both the breach and non-breach conditions for each scenario allows for an estimate of the potential incremental damages associated with the dam breach. A description of the scenarios required for this study is provided in the following sections.

3.1 "Fair Weather" Conditions

For the "Fair Weather" conditions simulations, it was assumed that each dam would fail during a normal or typical operating condition. Inflows from the Upper Churchill project and local tributaries, as discussed previously, are held constant during the dam failure and resulting flood wave progression. Minimal powerhouse operation was assumed due to the unanticipated nature of these failures (i.e. the reservoir level was not lowered in anticipation of the breach occurring). Conditions specific to each scenario are discussed in the following sections.

3.1.1 Gull Island

Initially the failure scenario of Gull Island Dam prior to construction of Muskrat Falls Dam was considered. A steady state inflow of 1,412 m^3/s from the Upper Churchill project was simulated along with tributary inflows. The reservoir was regulated at FSL (125 m) with the total inflow of 1761 m^3/s being passed through the powerhouse and none through the spillway. Failure was assumed to occur spontaneously and powerhouse flows were cut off after the dam failure. This was deemed a reasonable assumption since when a breach is detected, operators would typically attempt to trip off the units in order to minimize the downstream flooding. It is also possible that the units might trip off on their own due to rising tailwater levels. In any case, the powerhouse flows represent a very small fraction of the peak flow and therefore this assumption is not critical. It was assumed that no other action would be taken with regards to powerhouse operation.

3.1.2 Gull Island and Muskrat Falls

Three failure scenarios were considered for post project conditions where both Gull Island and Muskrat Falls have been constructed. These included:

- Gull Island failure without a breach in Muskrat Falls
- Muskrat Falls failure without a breach in Gull Island
- Gull Island failure causing a cascade failure at Muskrat Falls

For all three scenarios, the same conditions were assumed for Gull Island as were assumed for the previous scenario.

For Muskrat Falls, the reservoir was initially regulated at the Maximum Operating Level of 39 m with the total inflow of 1,801 m^3/s being passed through the powerhouse. The spillway gates were assumed to be closed and the rubber dam fully inflated to a crest elevation of 39.5 m. For the first two scenarios failure was assumed to occur spontaneously due to piping. However, for the last case where Gull Island breaches leading to a breach at Muskrat Falls, the Muskrat Falls breach was assumed to occur due to overtopping at the peak of the floodwave hydrograph caused by Gull Island breach. For all scenarios the powerhouse flows were assumed to be cut off after the dam failure to reduce the downstream flooding caused by the breach. It was also assumed that no other action would be taken with regards to powerhouse operation.

3.2 PMF Conditions

For the PMF breach scenarios, it was assumed that each dam would fail at the peak of the passage of the development's Inflow Design Flood (IDF) – the Probable Maximum Flood (PMF). Inflow hydrographs from the Upper Churchill project and local tributaries were used as discussed in Section 2. Conditions specific to each scenario are discussed as follows.

3.2.1 Gull Island

In the case of a Gull Island breach prior to the construction of Muskrat Falls, it was assumed the Gull Island reservoir would initially be regulated at FSL (125 m) with a total discharge of 1565.6 m^3/s passing through the project. A Speed-No-Load discharge of 245 m^3/s was assumed to be available to be passed through the powerhouse with the remainder of the flow passed through the spillway gates. The reason for this is that it is reasonable to assume that at some point during the PMF event a load rejection could occur due to some factor related to the rain and flooding (i.e. damage to transmission and distribution infrastructure) thereby tripping the units off and allowing for only the Speed-No-Load discharge to be passed. In this case, the most conservative assumption is that the unit's full discharge becomes unavailable at the start of the event.

As the PMF hydrograph progresses towards its peak, the spillway gates would be opened as required to preserve the upstream water level as best as possible. At some point during the PMF the inflow will overcome the discharge capacity of the powerhouse and spillway, and the reservoir will begin to surcharge. This staging will progress until the peak of the hydrograph is reached and the discharge capacity of the dam, due to structure overtopping, equals the inflow. At this point the dam is assumed to fail due to overtopping causing the worst possible flooding condition downstream. It was assumed that no other action would be possible with regards to dam/spillway operation due to the extremely dangerous conditions associated with the dam overtopping.

3.2.2 Gull Island and Muskrat Falls

The same three failure scenarios discussed in Section 3.1.2 were also considered for the PMF flood event. The same conditions and operating procedures discussed above for a Gull Island breach prior to construction of Muskrat Falls were assumed for these scenarios.

For Muskrat Falls, the reservoir was regulated at the Maximum Operating Level of 39 m with the total inflow of 1,667 m^3/s being passed through the project. A Speed-No-Load discharge of 405 m^3/s was assumed to be available to be passed through the powerhouse with the remainder of the flow passed through the spillway gates. The rubber dam on the North RCC dam was assumed to be fully deflated, in anticipation of the flood, to crest elevation 37.1 m. As with Gull Island, the Muskrat Falls spillway gates would be opened as required to preserve the upstream water level as best as possible. The water level will stage until the peak of the hydrograph is reached and the discharge capacity of the dam, due to structure overtopping, equals the inflow.

For the first two scenarios failure was assumed to occur, due to overtopping, at the peak water level produced by the PMF inflow hydrograph. For the last case where Gull Island breaches leading to a breach at Muskrat Falls, the Muskrat Falls breach was assumed to occur due to overtopping at the peak of the floodwave hydrograph caused by the combination of the PMF and Gull Island breach. It was assumed that no other further action would be taken with regards to dam operation due to the extreme danger and accessibility difficulty resulting from a dam breach.

4. Breach Parameter Selection

HEC-GeoRAS, like its predecessors DAMBRK and FLDWAV, utilizes an empirically based methodology to define and control the development of a dam breach. Parameters specified include the mode of failure (piping vs. overtopping), the ultimate breach width, the breach bottom elevation, breach side slope, time of formation and shape.

In the case of rockfill and earthen embankment structures, similar to the proposed Gull Island Concrete Faced Rockfill Dam, various references that present statistical analysis of past dam breaches can be used to provide guidance on the selection of an appropriate set of parameters for a given structure. Unfortunately due to scatter in the data and a lack of records for large dam breaches, there is a degree of uncertainty associated with the relationships presented in these references. This is likely the greatest source of uncertainty in any dam breach analysis, and the various techniques can result in significantly different estimates of breach parameters.

In the case of concrete or RCC structures, such as those found at the Muskrat Falls development, the estimation of breach parameters is much more straightforward; however, still a great source of uncertainty. In this case, due to the fact that each structure is essentially cast as a unit, it is unlikely that the structure will fail partially and the only type of failure that can be considered is that of each structure overturning or sliding as a unit with failures occurring at expansion/construction joints. The bulk of the following discussion is therefore focussed on the development of breach parameters for Gull Island, as opposed to Muskrat Falls.

4.1 Gull Island

For Gull Island, parameter sets were initially developed and compared for two of the most highly regarded methodologies: i) an empirically based methodology developed by Froehlich [Ref. 2], and ii) standard Federal Energy and Regulatory Commission (FERC) procedures [Ref. 3]. In several previous studies it was found that these two methodologies provided results that vary dramatically. In a recent study undertaken by Hatch it was deemed necessary to undertake additional analysis to refine these parameter estimates, taking into account some of the specific characteristics of well built large dams in Canada. As a result of this study, Hatch proposed a more refined version of the Froehlich equations that provide a more practical set of breach parameters. These parameters generally provide more conservative results than those proposed by the FERC procedures, but are not normally as extreme as those determined using the original Froehlich equations.

When adopting this set of non-standard breach parameter equations the Froehlich and FERC Parameters were also reviewed to confirm that they are indeed reasonable for the specific situation and still form a conservative estimate of breach effects. The results of the review are briefly described below, along with estimated breach dimensions for Gull Island resulting from application of the various equations.

4.1.1 Froehlich Methodology

Froehlich's 1995 paper entitled "Embankment Dam Breach Parameters Revisited" [Ref. 2], analyzed the failure of 63 embankment dams to develop empirical relationships relating the breach width and the breach formation time to the embankment characteristics, reservoir volume and reservoir depth. Based on all of the measured breaches considered in the Froelich research, the average side slope ratio is nearly one. It is stated in the paper that the ultimate height of the breach can generally be pre-supposed.

In this analysis, the bottom of the breach was taken at the dam foundation which is more resistant to erosion than the embankment material. This is a conservation assumption.

As stated above, the main breach parameters established by Froehlich are the average breach width and the time of breach formation. These parameters are related to the reservoir volume at time of failure and height of the final breach as follows.

$B = 15\ k_o\ V_w^{\ 0.32}\ H^{\ 0.19}$

$t_f = 3.84\ V_w^{\ 0.53}\ H^{\ -0.90}$

Where:

B is the average breach width, meters.

K_o is 1.0 if the failure mode is piping and 1.4 for overtopping.

V_w is the reservoir volume at time of failure (millions m^3).

H is the height of water at final breach, meters.

t_f is the time of formation, hours.

For Gull Island, overall height of the dam is approximately 94 m. The volume of water in storage above the base of the dam is approximately 5300 million m^3 at the dam crest of 129 m and 4550 million m^3 at an FSL of 125 m. Based on these characteristics, Table 4.1 summarizes the breach parameters predicted for Gull Island based on the Froehlich methodology.

Table 4.1
Gull Island - Summary of Breach Parameters Based on Froehlich

Flow Scenario	Breach Parameters			
	Average Breach Width (m)	Time of Formation (hrs)	Final Breach Bottom Elevation (m)	Side Slope
"Fair Weather"	527	5.6	35	1H:1V
PMF	774	6.1	35	1H:1V

4.1.2 *FERC Methodology*

FERC [Ref. 3] also provides guidance on the selection of breach parameters. The FERC criteria for selecting breach parameters are not a function of the starting reservoir water level, but are strictly based on the overall height of the structure. Breach parameters estimated using FERC were calculated using the following guidelines:

$2H \le B \le 4H$

$0.1 \le t_f \le 1$

$0.25 \le z \le 1$

Where B and t_f are defined above, and z is the average side slope ratio (z horizontal to 1 vertical).

The average breach width was estimated at 4H and the side slope ratio was estimated at 1 for conservatism. The time to failure was estimated as 1 hour because this is the most reasonable value in the range provided for a dam the size of Gull Island. Table 4.2 lists the estimated breach parameters based on FERC criteria which apply to earthen, engineered compacted, and/or rockfill dams. It is understood; however, that these breach parameter estimates were meant to be used as rough guidelines, and were not intended to provide accurate predictions.

Table 4.2
Gull Island - Summary of Breach Parameters Based on FERC

Flow Scenario	Breach Parameters		
	Average Breach Width (m)	Time of Formation (hrs)	Side Slope
"Fair Weather" & PMF	396	1.0	1

4.1.3 *Comparison of Froehlich and FERC Parameter Sets*

As discussed above, the parameters predicted using these two different methodologies vary considerably. For example, the breach width for Gull Island using the Froehlich equation is estimated to be approximately 530 m for the "Fair Weather" scenario. Based on FERC criteria, the breach width would only be 396 m. Also, the time of failure ranges from 1 hour (based on the FERC guidelines) to up to 6 hours (based on Froehlich).

In comparing the two, one obvious criticism of the FERC criteria is that it does not take into account the volume of water in the reservoir when estimating overall parameters where the Froehlich criteria attempts to take this into account. However, the majority of the historical data set used to develop the Froehlich equations is made up of reservoirs with storage capacities of less than 100 million m^3, while the range of breach height varies considerably – from 3 m to 40 m. As can be seen, neither the height nor the storage volume of the Gull Island Dam fits within the range of this historical data set. The height is more than double the largest dam considered and the storage is an order of magnitude larger than the largest reservoir volume contained in the historical data set. Given the large weight assigned to the storage volume in the Froehlich equations, there is some concern that extrapolation of the historical data may result in exaggerated breach parameters.

Additionally, the historical data set used to develop the Froehlich equations includes dams whose breach widths are in general less than 100 m and absolutely less than 200 m. The Froehlich estimate (as well as the FERC) of average breach width for Gull Island exceeds any of the historical failure scenarios. Regarding time to failure, the historical breach formation times do appear to be correlated to the impounded reservoir volume. Larger storage volumes appear to result in longer formation times. The FERC estimate of 1 hour; however, seems to fall well outside of the historical data set which shows 1 hour failure times being restricted to reservoirs of considerably smaller volume and depth.

4.1.4 *Alternate Parameter Set Development*

Upon review of the Froehlich and FERC procedures, it was found that the Froehlich methodology represented a more logical technique for the estimation of breach parameters at this site. However, one key contention involves the overall quality of the historical data set used to derive Froehlich's equations. In particular, Froehlich included many dams that may have been poorly constructed and designed prior to having specific dam construction procedures and standards, and this may tend to exaggerate overall breach parameters. A review of the particular characteristics of the historical failures was undertaken to eliminate the effect of dams that were not constructed using relatively modern methods. Such a review was carried out, and made use of a database of information on 108 dam failures that was compiled and made available by Wahl in a 1998 paper [Ref. 4]. Starting with this information, the database was carefully reviewed, and reduced to produce a refined data set. Dams of uncertain composition or quality were discarded. Froehlich's breach coefficients were then re-estimated based on this revised data set.

The final number of dams used to derive empirical coefficients for estimating the average breach width was 65. However, only 31 dams could be used in deriving empirical coefficients for estimating time of formation due to data availability. Coefficients a, b, c, d, e, and f were fit to Froehlich's equations such that the following general relationships applied and the differences between the actual and simulated average breach width and actual time of formation were minimized.

$B = a V_w^{\,b} H^{\,c}$

$t_f = d V_w^{\,e} H^{\,f}$

Where:

B is the average breach width, meters.

V_w is the reservoir volume at time of failure (millions m^3).

H is the height of final breach, meters.

t_f is the time of formation, hours.

a, b, c, d, e, f are empirical coefficients calibrated as follows:

- a = 9.43, b = 0.12, and c = 0.64
- d = 0.91, e = 0.17, and f = 0.11.

As shown in Table 4.3, these revised equations yielded average breach width estimates that were lower than based on Froehlich's original equations, but also larger than FERC. Failure times of formation were comparable to the Froehlich equations, but still much more reasonable than the 1 hour recommended by FERC. For the reasons discussed above, the parameters shown in Table 4.3 were adopted for this study.

Table 4.3
Gull Island - Summary of Breach Parameters Based on Revised Data Set

Flow Scenario	Breach Parameters			
	Average Breach Width (m)	Time of Formation (hrs)	Final Breach Bottom Elevation (m)	Side Slope
"Fair Weather"	475	6.3	35	1H:1V
PMF	483	6.4	35	1H:1V

4.2 Muskrat Falls Dam

For Muskrat Falls, because all of the main structures are constructed using RCC, the erosion type of failure described in the previous sections is not possible. In this case it is more likely that an individual structure will fail due to overturning or sliding. For this reason it was determined that the project structures most likely to lead to worst case downstream flooding were as follows.

- South Roller Compacted Concrete (RCC) dam (South Abutment) which is 370 m long with a crest elevation of 45.5 m and an invert elevation of approximately 22 m.
- North RCC Overflow Dam which is 360 m long with a crest elevation of 39.15 m and an invert elevation of approximately 4 m.
- North RCC Overflow Dam with rubber dam which is 177.5 m long with a deflated crest elevation of 37.1 m, an inflated crest elevation of 39.5 and an invert elevation of approximately 4 m.

Due to the nature of the failure mechanism of these dams they were assumed to fail within 1 hour of the breach initiation. The breach parameters adopted for these structures are shown Table 4.4.

Table 4.4
Muskrat Falls - Summary of Breach Parameters

Structure	Breach Parameters			
	Average Breach Width (m)	Time of Formation (hrs)	Final Breach Bottom Elevation (m)	Side Slope
North RCC Overflow Dam	360	1	4	0H:1V
South RCC Dam	370	1	22	0H:1V
North RCC Overflow Dam with Rubber Dam	177.5	1	22	0H:1V

5. HEC-GeoRAS Analysis Results

As presented in Section 3, a total of four breach scenarios were proposed for both "Fair Weather" conditions and the PMF to develop inundation mapping. However, before these scenarios are presented using the breach parameters provided in Section 4 it is important to first test the sensitivity of the results to the breach parameters. The following sections discuss the breach parameter sensitivity analysis and the results of the final dam breach analysis.

5.1 Breach Parameter Sensitivity Analysis

Several series of sensitivity analysis were completed to test the breach parameters selected. The following lists the tests conducted and the purpose.

- Determining the effect of uncertainty in breach parameter estimation on the results for Gull Island. The reason for this test series is the uncertainty in the dimensions of a dam breach due to erosion. It is important to ensure that the overall results be relatively insensitive to changes in breach parameters and are conservative.
- Determining the worst case breach scenario at Muskrat Falls. Due to there being several structures it is not immediately apparent which structure will produce the worst level of downstream flooding. For this reason the three roller compacted concrete structures (the widest and deepest structures) were tested to see which failure produced the worst downstream effects.
- Determining the effect of a change in manning's roughness on the results. Although the roughness of the model was estimated using the best available information and used to calibrate to measured levels, there could still be significant effects if the degree of roughness was underestimated. This test investigates whether differences in roughness will significantly change the results of the analysis.

Each of these cases are further discussed in the following sections.

5.1.1 Gull Island Breach Parameter Sensitivities

To determine the sensitivity of the model results to changes in the breach parameters, the model was set up to represent a breach at Gull Island for the PMF prior to the construction of Muskrat Falls. Five different tests were conducted to ensure an appropriate range of side slopes, time to failure, and breach width, as shown in Table 5.1.

Table 5.1
Gull Island - Summary of Breach Parameter Sensitivities

Scenario	Breach Parameters			
	Average Breach Width (m)	Time of Formation (hrs)	Final Breach Bottom Elevation (m)	Side Slope
Base Case	483	6.4	35	1H:1V
t_f = 4	483	4	35	1H:1V
t_f = 8	483	8	35	1H:1V
t_f = 12	483	12	35	1H:1V
S/S = 1H:3V	483	6.4	35	1H:3V
B = 235	235	6.4	35	1H:1V

Figures 5.1 to 5.6 compare the effects of the various scenarios on the water level hydrographs at six downstream locations of interest. As can be seen in these figures, the sensitivity to beach parameters decreases as you move downstream. Near Happy Valley - Goose Bay and Mud Lake, the difference in water levels between scenarios is insignificant. It can therefore be concluded that the effects of differences in the breach parameters are insignificant with respect to the areas of potential impact and the base case parameters presented in Section 4 can be used for the preparation of inundation mapping.

5.1.2 Muskrat Falls Breach Parameter Sensitivities

To determine the worst case breach scenario at Muskrat Falls, the model was set up to represent a PMF cascade breach at Gull Island causing a breach at Muskrat Falls. The structures of greatest consequence are the three RCC structures shown in Figure 2.5. The South RCC non-overflow dam, North RCC overflow dam, and North RCC overflow dam with rubber dam crest as described in Section 4.2. The spillway and powerhouse do not have the same level of consequence, since they are narrower, shallower and will be providing discharge capacity during this event.

Because it is not immediately apparent which RCC structure will produce the worst downstream flooding each was breached in turn and the downstream effects were observed. Figures 5.7 to 5.12 compare the effects of the various dam breach scenarios on the water levels at six downstream locations of interest. As can be seen in these figures, there is very little difference in water level between the three failures. Of the three; however, the failure of the North RCC overflow dam produces the highest levels in the vicinity of Happy Valley - Goose Bay. For this reason, this structure was adopted as the critical failure for the remainder of this study.

5.1.3 Manning's Roughness Sensitivity

To determine the sensitivity of the model results to changes in manning's roughness, the channel roughness was increased from a Manning's "n" of 0.03 to 0.045. The overbank roughness of 0.125 was chosen at the high end of what could be expected and is therefore already conservative. Although the channel Manning's "n" was locally increased to 0.045 to calibrate the model in two locations it is still recommended that the effects of increased roughness be investigated. Figures 5.13 to 5.18 compare the effects of the increased channel roughness on water level hydrographs at six downstream locations of interest. As can be seen in these figures, the difference in water levels decrease as you move downstream and are greater than the sensitivity related to breach parameters. Although this difference is greater, it is still felt that the overall selection of breach parameters has been conservative and increasing the Manning's "n" values would not be reasonable or effect the overall development of the inundation maps.

5.2 "Fair Weather" Conditions Breach Results

5.2.1 Post Gull Island

A simulation was undertaken to estimate the impacts a breach at Gull Island would have on downstream water levels prior to the construction of Muskrat Falls. The results of the simulation are provided in Appendix A. Table 5.2 below summarizes the results for a number of key downstream locations.

Table 5.2
HEC-GeoRAS Results – "Fair Weather" Conditions, Post Gull Island, Gull Island Dam Breach

Distance Downstream of GI Dam (km)	Cross Section Description	Maximum Water Level without Breach (m)	Breach Flood Summary				
			Breach Flood Arrival Time (hr)	Peak Water Level (m)	Incremental Depth of Flooding	Maximum Discharge (m^3/s)	Time to Peak Water Level (hr)
2.3	D/S Gull Island Dam	34.5	0.0	49.7	15.2	121,600	4.6
57.5	U/S Muskrat Falls	15.9	3.3	35.1	19.2	65,900	8.7
61.0	D/S Muskrat Falls	2.6	3.9	18.8	16.2	64,500	11.4
78.2	Blackrock Bridge	1.6	4.6	15.2	13.5	56,300	11.5
93.1	Happy Valley - Goose Bay	0.7	5.9	7.9	7.1	53,300	14.2
99.5	Mud Lake	0.5	6.4	6.5	6.0	51,500	14.8

General observations from this simulation follow.

- Breach outflows from Gull Island would increase plant flows from an initial flow of approximately 1,800 m^3/s to a peak flow of approximately 121,600 m^3/s.
- Water level increases will range from approximately 19.2 m upstream of Muskrat Falls to approximately 6.0 m near Mud Lake.
- There will be approximately 6 hours of warning time available between the initiation of the breach and the flood wave reaching the populated areas of the downstream reach (Happy Valley - Goose Bay, Mud Lake).

5.2.2 Post Gull Island and Muskrat Falls

As noted in Section 3, three breach scenarios are considered for post-project conditions where both Gull Island and Muskrat falls have been constructed. The results of these scenarios are as follows.

5.2.2.1 Gull Island Dam Breach

A simulation was undertaken to estimate the impacts a breach at Gull Island would have on downstream water levels after construction of Muskrat Falls. In this scenario there was no breach at Muskrat Falls. The results of the simulation are provided in Appendix B. Table 5.3 below summarizes the results for a number of key downstream locations.

Table 5.3
HEC-GeoRAS Results – "Fair Weather" Conditions, Post Gull Island and Muskrat Falls, Gull Island Dam Breach

Distance Downstream of GI Dam (km)	Cross Section Description	Maximum Water Level without Breach (m)	Breach Flood Summary				
			Breach Flood Arrival Time (hr)	Peak Water Level (m)	Incremental Depth of Flooding	Maximum Discharge (m^3/s)	Time to Peak Water Level (hr)
2.3	D/S Gull Island Dam	39.1	0.0	53.7	14.7	121,600	8.1
57.5	U/S Muskrat Falls	39.1	1.1	53.3	14.3	48,600	8.4
61.0	D/S Muskrat Falls	2.6	1.9	16.3	13.7	48,200	11.9
78.2	Blackrock Bridge	1.6	2.7	12.8	11.2	45,000	12.1
93.1	Happy Valley - Goose Bay	0.7	3.6	7.1	6.4	43,800	15.3
99.5	Mud Lake	0.5	4.0	5.9	5.4	43,100	15.4

General observations from this simulation follow.

- Similar to the breach of Gull Island before construction of Muskrat Falls, breach outflows from Gull Island would increase flows at Gull Island from an initial plant flow of approximately 1,800 m^3/s to a peak flow of approximately 121,600 m^3/s.
- The discharge control provided by Muskrat Falls allows the breach flows to be reduced by between 8,000 m^3/s and 17,000 m^3/s in comparison to the scenario without Muskrat Falls.
- Water level increases will range from approximately 14.7 m just downstream of Gull Island to approximately 5.4 m near Mud Lake.
- There will be between 3 and 4 hours of warning time available between the initiation of the breach and the flood wave reaching the populated areas of the downstream reach (Happy Valley - Goose Bay, Mud Lake). This is a decrease in warning time of approximately 2 hours over the Gull Island only scenario. Without the Muskrat Falls reservoir in place, the flood wave travels down the river channel, inundating a large area and attenuating due to friction in the channel and along the overbanks. With the Muskrat Falls reservoir in place, the frictional effects are greatly reduced and the flood wave can travel more quickly through the reach.
- A breach at Gull Island will cause a maximum water elevation of approximately 53.3 m upstream of the Muskrat Falls project. With a maximum crest elevation of 45.5 m for the non-overflow structures, it is possible that a breach at Gull Island will cause a subsequent breach of Muskrat Falls.

5.2.2.2 Muskrat Falls Dam Breach

A simulation was undertaken to estimate the impacts a breach at Muskrat Falls would have on downstream water levels. The results of the simulation are provided in Appendix C. Table 5.4 below summarizes the results for a number of key downstream locations.

Table 5.4
HEC-GeoRAS Results – "Fair Weather" Conditions, Post Gull Island and Muskrat Falls, Muskrat Falls Dam Breach

Distance Downstream of GI Dam (km)	Cross Section Description	Maximum Water Level without Breach (m)	Breach Flood Summary				
			Breach Flood Arrival Time (hr)	Peak Water Level (m)	Incremental Depth of Flooding	Maximum Discharge (m³/s)	Time to Peak Water Level (hr)
2.3	D/S Gull Island Dam	n/a	n/a	n/a	n/a	n/a	n/a
57.5	U/S Muskrat Falls	n/a	n/a	n/a	n/a	n/a	n/a
61.0	D/S Muskrat Falls	2.6	0.0	14.2	11.6	58,400	3.4
78.2	Blackrock Bridge	1.6	0.6	10.7	9.1	37,200	3.8
93.1	Happy Valley - Goose Bay	0.7	1.4	5.9	5.1	33,500	6.8
99.5	Mud Lake	0.5	1.7	4.7	4.2	30,700	7.3

General observations from this simulation follow.

- Breach outflows from the Muskrat Falls North RCC Dam would increase flows at Muskrat Falls from an initial plant flow of approximately 1,800 m^3/s to a peak flow of approximately 58,400 m^3/s.
- Water level increases will range from approximately 11.6 m just downstream of Muskrat Falls to approximately 4.2 m near Mud Lake.
- There will be between 1 and 2 hours of warning time available between the initiation of the breach and the flood wave reaching the populated areas of the downstream reach (Happy Valley - Goose Bay, Mud Lake).

5.2.2.3 Gull Island and Muskrat Falls Dam Breach

A simulation was undertaken to estimate the impacts a breach at both Gull Island and Muskrat Falls would have on downstream water levels. The results of the simulation are provided in Appendix D. Table 5.5 below summarizes the results for a number of key downstream locations.

Table 5.5
HEC-GeoRAS Results – "Fair Weather" Conditions, Post Gull Island and Muskrat Falls, Cascade Failure

Distance Downstream of GI Dam (km)	Cross Section Description	Maximum Water Level without Breach (m)	Breach Flood Summary				
			Breach Flood Arrival Time (hr)	Peak Water Level (m)	Incremental Depth of Flooding	Maximum Discharge (m^3/s)	Time to Peak Water Level (hr)
2.3	D/S Gull Island Dam	39.1	0.0	53.7	14.7	121,600	8.1
57.5	U/S Muskrat Falls	39.1	1.1	53.3	14.2	145,900	7.3
61.0	D/S Muskrat Falls	2.6	1.9	27.2	24.6	143,700	10.6
78.2	Blackrock Bridge	1.6	2.7	22.5	20.9	103,800	10.8
93.1	Happy Valley - Goose Bay	0.7	3.6	10.4	9.7	95,700	13.0
99.5	Mud Lake	0.5	4.0	8.9	8.4	90,000	13.3

General observations from this simulation follow.

- As with the other two simulations, Gull Island outflows due to a breach would increase flows at Gull Island from an initial plant flow of approximately 1,800 m^3/s to a peak flow of approximately 121,600 m^3/s.
- The breach of Muskrat Falls North RCC Dam at the peak of the flood wave caused by the failure at Gull Island causes peak flows of over 140,000 m^3/s at Muskrat Falls, more than double the flow of the other scenarios considered.
- Water level increases will range from approximately 24.6 m just downstream of Muskrat Falls to approximately 8.4 m near Mud Lake.
- There will be between 3 and 4 hours of warning time available between the initiation of the breach and the flood wave reaching the populated areas of the downstream reach (Happy Valley - Goose Bay, Mud Lake).

A cascade breach such as this would be likely if there is a breach at Gull Island, since the Gull Island breach will cause upwards of 8 m of overtopping of the Muskrat Falls structures. Although it is unlikely that Muskrat Falls will fail at the peak of the Gull Island breach flood wave this is a conservative scenario that is intended to encompass the worst case for preparation of inundation maps.

5.3 PMF Conditions Breach Results

5.3.1 Post Gull Island

A simulation was undertaken to estimate the impacts a breach at Gull Island would have on downstream water levels prior to the construction of Muskrat Falls. The results of the simulation are provided in Appendix E. Table 5.6 below summarizes the results for a number of key downstream locations.

Table 5.6
HEC-GeoRAS Results – PMF Conditions, Post Gull Island, Gull Island Dam Breach

Distance Downstream of GI Dam (km)	Cross Section Description	Maximum Water Level without Breach (m)	Breach Flood Summary				
			Breach Flood Arrival Time (hr)	Peak Water Level (m)	Incremental Depth of Flooding	Maximum Discharge (m^3/s)	Time to Peak Water Level (hr)
2.3	D/S Gull Island Dam	38.2	0.0	51.4	13.2	133,000	4.9
57.5	U/S Muskrat Falls	27.1	1.3	38.5	11.4	88,300	7.8
61.0	D/S Muskrat Falls	11.0	1.9	23.2	12.3	86,800	10.0
78.2	Blackrock Bridge	8.0	2.1	19.1	11.1	79,100	10.1
93.1	Happy Valley - Goose Bay	5.1	3.0	9.5	4.4	76,000	12.4
99.5	Mud Lake	3.9	3.5	8.0	4.1	74,200	12.7

General observations from this simulation follow.

- Breach outflows from Gull Island would increase flows at Gull Island from a peak PMF flow of approximately 21,300 m^3/s to a peak flow of approximately 133,000 m^3/s.
- Water level increases over natural flood levels will range from approximately 13.2 m downstream of Gull Island to approximately 4.1 m near Mud Lake.
- There will be between approximately 3 hours of warning time available between the initiation of the breach and the flood wave reaching the populated areas of the downstream reach (Happy Valley - Goose Bay, Mud Lake).

5.3.2 Post Gull Island and Muskrat Falls

As noted in Section 3, three breach scenarios are considered for post-project conditions where both Gull Island and Muskrat Falls have been constructed. The results of these scenarios are as follows.

5.3.2.1 Gull Island Dam Breach

A simulation was undertaken to estimate the impacts a breach at Gull Island would have on downstream water levels after construction of Muskrat Falls. The results of the simulation are provided in Appendix F. Table 5.7 below summarizes the results for a number of key downstream locations.

Table 5.7
HEC-GeoRAS Results – PMF Conditions, Post Gull Island and Muskrat Falls, Gull Island Dam Breach

Distance Downstream of GI Dam (km)	Cross Section Description	Maximum Water Level without Breach (m)	Breach Flood Summary				
			Breach Flood Arrival Time (hr)	Peak Water Level (m)	Incremental Depth of Flooding	Maximum Discharge (m^3/s)	Time to Peak Water Level (hr)
2.3	D/S Gull Island Dam	45.2	0.0	56.8	11.6	132,900	7.7
57.5	U/S Muskrat Falls	44.8	1.0	56.1	11.3	72,700	6.8
61.0	D/S Muskrat Falls	10.8	1.2	21.0	10.2	71,500	10.1
78.2	Blackrock Bridge	7.9	1.7	17.2	9.4	66,400	10.2
93.1	Happy Valley - Goose Bay	4.9	2.5	8.8	3.8	64,700	12.8
99.5	Mud Lake	3.8	2.9	7.4	3.6	63,800	13.0

General observations from this simulation follow.

- Breach outflows from Gull Island would increase flows at Gull Island from a peak PMF flow of approximately 21,300 m^3/s to a peak flow of approximately 132,900 m^3/s.
- The discharge control provided by Muskrat Falls project allows the breach flows to be reduced by between 10,000 m^3/s and 16,000 m^3/s in comparison to the scenario without Muskrat Falls.
- Water level increases over natural flood levels will range from approximately 11.6 m just downstream of Gull Island to approximately 3.6 m near Mud Lake.
- There will be between 2 and 3 hours of warning time available between the initiation of the breach and the flood wave reaching the populated areas of the downstream reach (Happy Valley - Goose Bay, Mud Lake).
- A breach at Gull Island will result in a maximum water elevation of approximately 56.1 m upstream of Muskrat Falls. With a maximum crest elevation of 45.5 m for the non-overflow structures it is possible that a breach of Gull Island Dam will cause the subsequent failure of Muskrat Falls.

5.3.2.2 Muskrat Falls Dam Breach

A simulation was undertaken to estimate the impacts a breach at Muskrat Falls would have on downstream water levels. The results of the simulation are provided in Appendix G. Table 5.8 below summarizes the results for a number of key downstream locations.

Table 5.8
HEC-GeoRAS Results – PMF Conditions, Post Gull Island and Muskrat Falls, Muskrat Falls Dam Breach

Distance Downstream of GI Dam (km)	Cross Section Description	Maximum Water Level without Breach (m)	Breach Flood Summary				
			Breach Flood Arrival Time (hr)	Peak Water Level (m)	Incremental Depth of Flooding	Maximum Discharge (m^3/s)	Time to Peak Water Level (hr)
2.3	D/S Gull Island Dam	n/a	n/a	n/a	n/a	n/a	n/a
57.5	U/S Muskrat Falls	n/a	n/a	n/a	n/a	n/a	n/a
61.0	D/S Muskrat Falls	10.8	0.0	20.3	9.5	92,700	3.2
78.2	Blackrock Bridge	7.9	0.3	16.6	8.7	63,100	3.4
93.1	Happy Valley - Goose Bay	4.9	0.8	8.2	3.3	59,000	5.9
99.5	Mud Lake	3.8	1.2	6.9	3.1	56,500	6.3

General observations from this simulation follow.

- Breach outflows from the Muskrat Falls North RCC Dam would increase flows at Muskrat Falls from a peak PMF flow of approximately 22,800 m^3/s to a peak flow of approximately 92,700 m^3/s.
- Water level increases will range from approximately 9.5 m just downstream of Muskrat Falls to approximately 3.1 m near Mud Lake.
- There will be approximately 1 hour of warning time available between the initiation of the breach and the flood wave reaching the populated areas of the downstream reach (Happy Valley - Goose Bay, Mud Lake).

5.3.2.3 Gull Island and Muskrat Falls Dam Breach

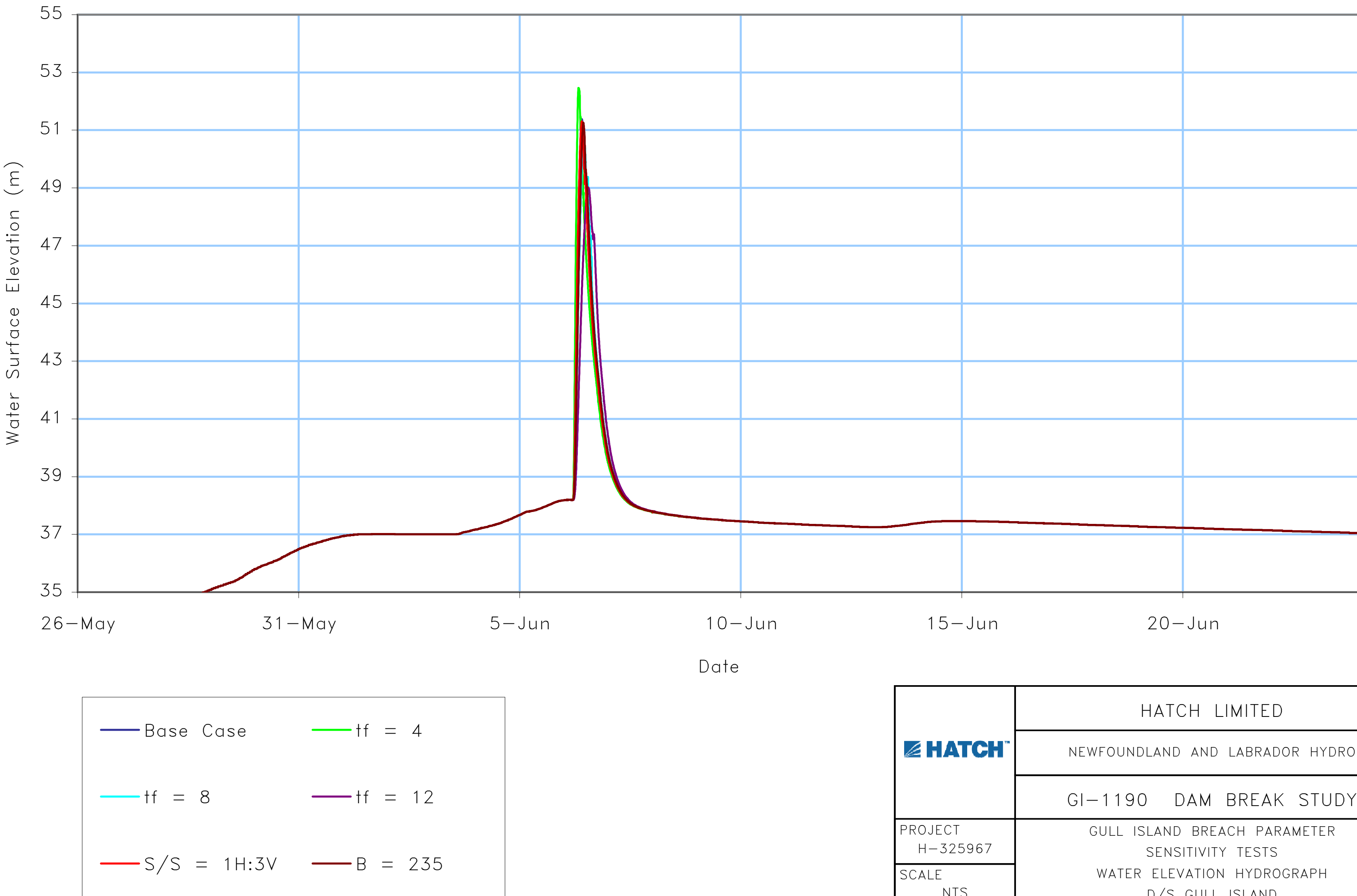
A simulation was undertaken to estimate the impacts a breach at both Gull Island and Muskrat Falls would have on downstream water levels. The results of the simulation are provided in Appendix H. Table 5.9 below summarizes the results for a number of key downstream locations.

Table 5.9
HEC-GeoRAS Results – PMF Conditions, Post Gull Island and Muskrat Falls, Cascade Failure

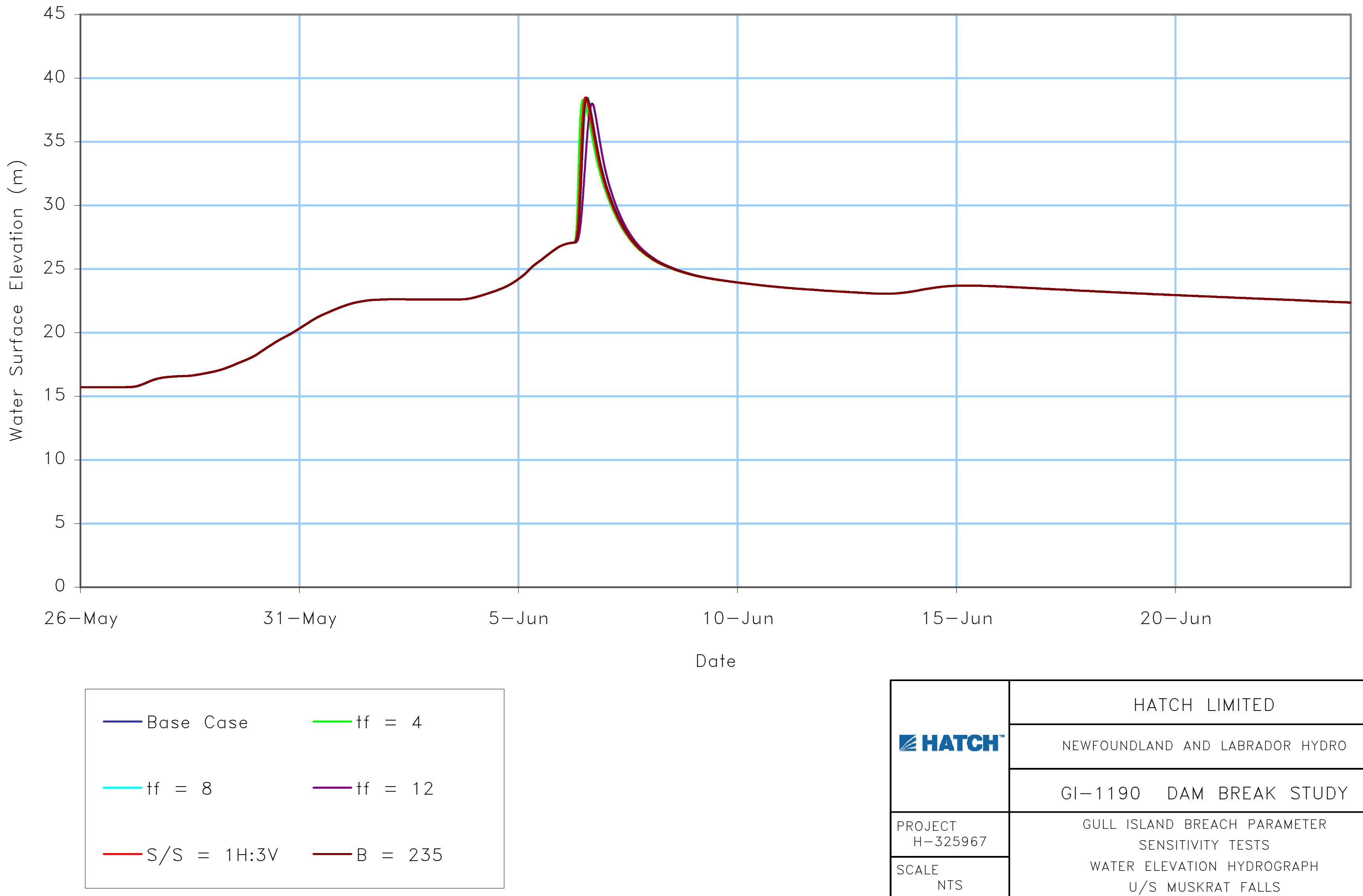
Distance Downstream of GI Dam (km)	Cross Section Description	Maximum Water Level without Breach (m)	Breach Flood Summary				
			Breach Flood Arrival Time (hr)	Peak Water Level (m)	Incremental Depth of Flooding	Maximum Discharge (m^3/s)	Time to Peak Water Level (hr)
2.3	D/S Gull Island Dam	45.2	0.0	56.8	11.6	132,800	7.7
57.5	U/S Muskrat Falls	44.8	1.0	56.0	11.2	165,200	6.7
61.0	D/S Muskrat Falls	10.8	1.2	30.5	19.7	162,900	9.7
78.2	Blackrock Bridge	7.9	1.7	25.1	17.3	125,200	9.8
93.1	Happy Valley - Goose Bay	4.9	2.5	11.6	6.7	117,600	12.0
99.5	Mud Lake	3.8	2.9	10.0	6.2	112,600	12.1

General observations from this simulation follow.

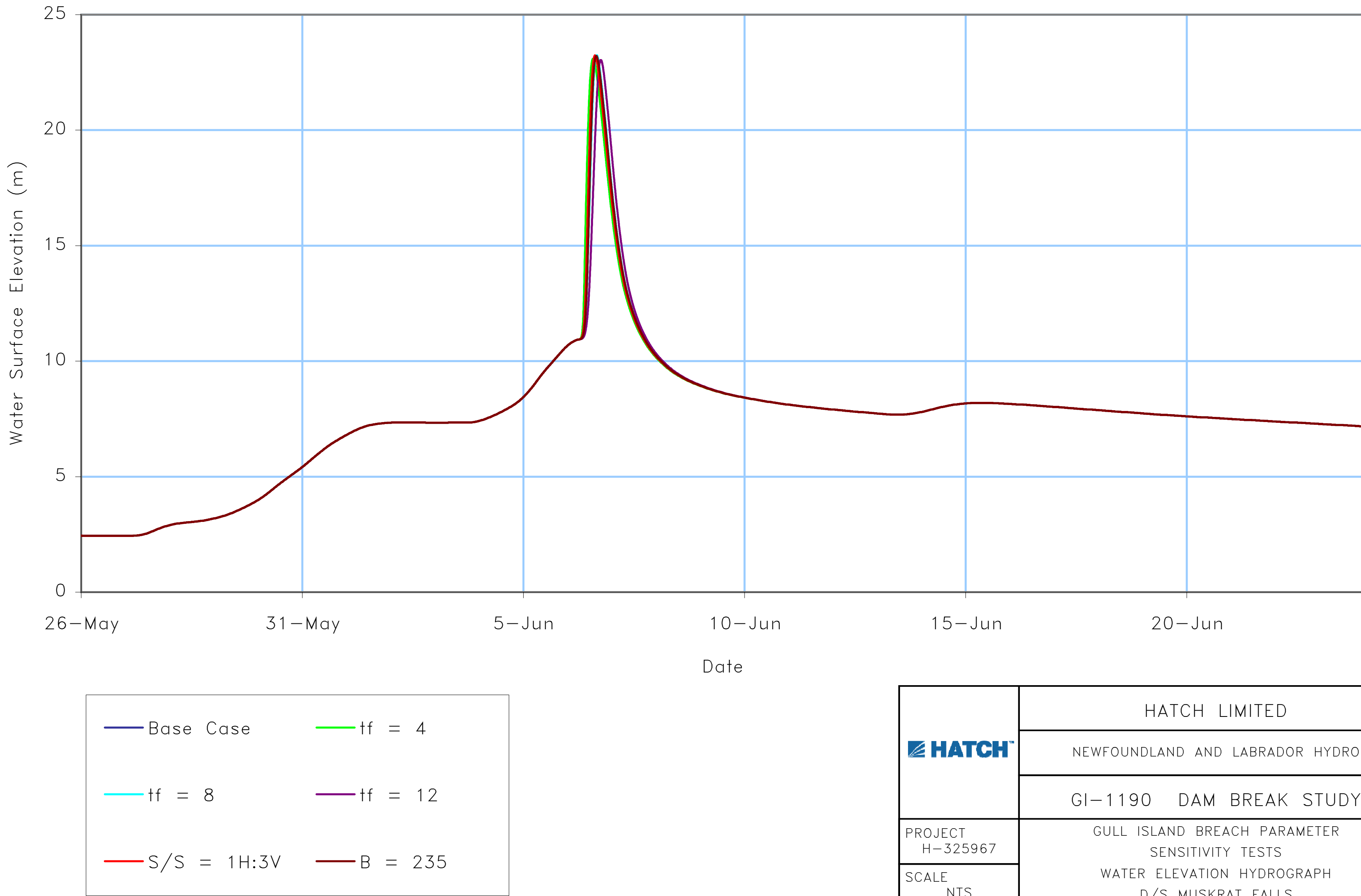
- As with the other simulations Gull Island outflows would increase flows at Gull Island from a peak PMF flow of approximately 21,300 m^3/s to a peak flow of approximately 132,800 m^3/s.
- The breach of Muskrat Falls North RCC Dam at the peak of the flood wave caused by the failure of Gull Island causes peak flows of over 165,000 m^3/s, approximately double the maximum flow of the other scenarios considered.
- Water level increases will range from 19.7 m just downstream of the Muskrat Falls Dam to approximately 6.2 m near Mud Lake.
- There will be between 2 and 3 hours of warning time available between the initiation of the breach and the flood wave reaching the populated areas of the downstream reach (Happy Valley - Goose Bay, Mud Lake).
- A cascade breach such as this is likely to occur with a breach at Gull Island because this breach will cause upwards of 10 m of overtopping of the Muskrat Falls structures. Although it is unlikely that Muskrat Falls will fail at the peak of the Gull Island breach flood wave this is a conservative scenario that is intended to encompass the worst case for the preparation of inundation maps.



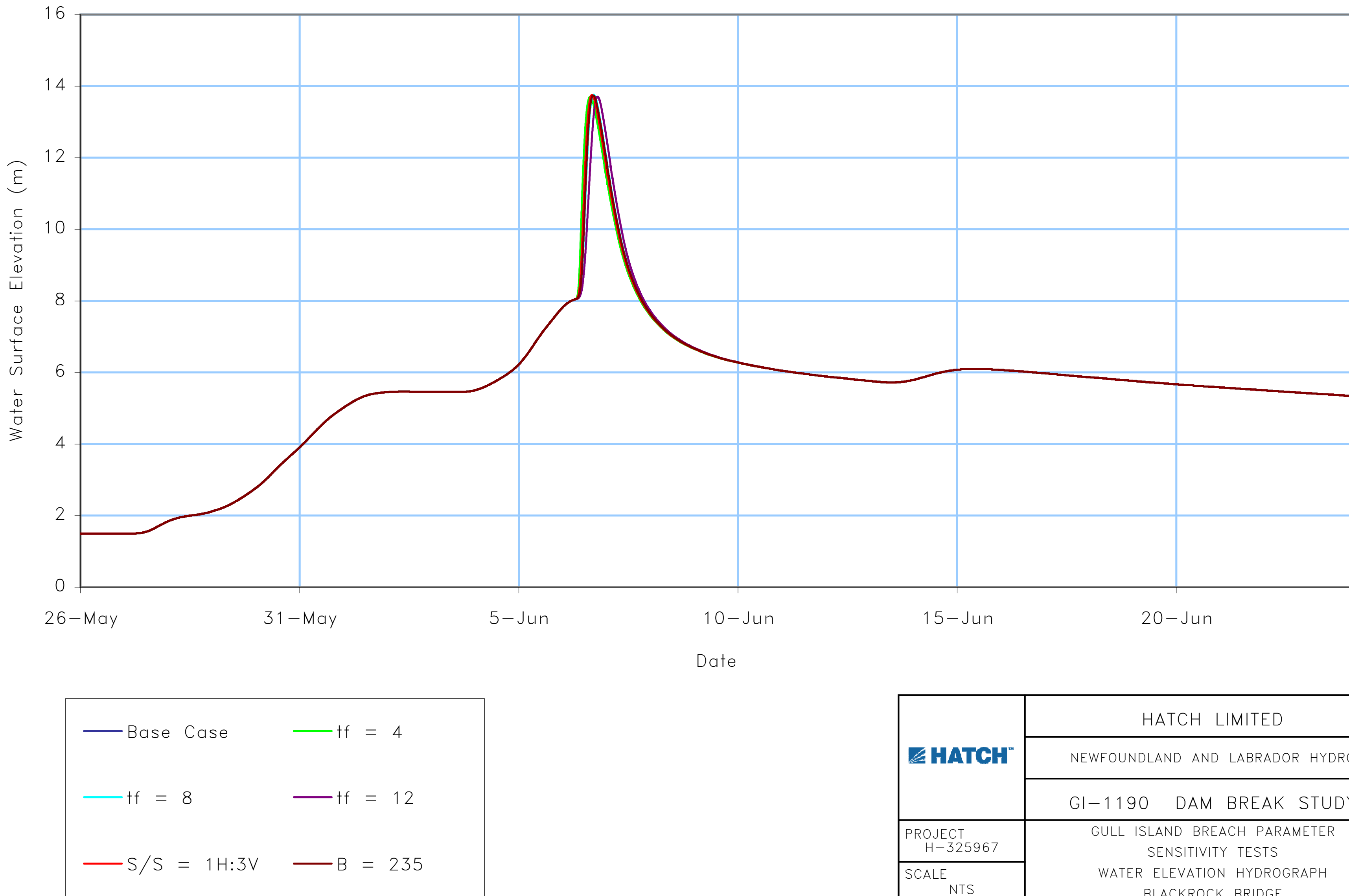
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI–1190 DAM BREAK STUDY
PROJECT H–325967	GULL ISLAND BREACH PARAMETER SENSITIVITY TESTS WATER ELEVATION HYDROGRAPH D/S GULL ISLAND
SCALE NTS	
DATE MAR 2008	FIGURE 5.1



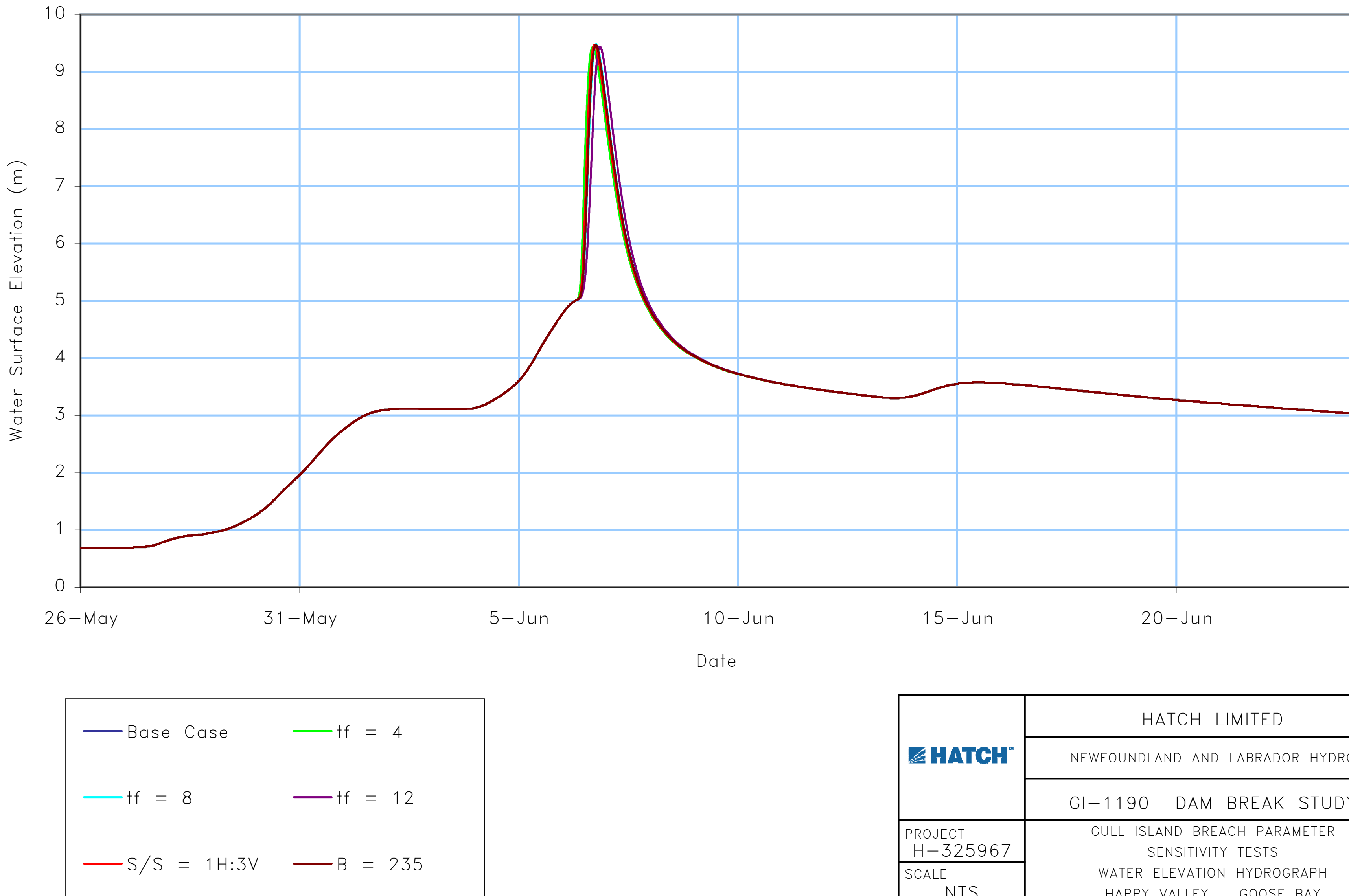
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI-1190 DAM BREAK STUDY
PROJECT H-325967	GULL ISLAND BREACH PARAMETER SENSITIVITY TESTS WATER ELEVATION HYDROGRAPH U/S MUSKRAT FALLS
SCALE NTS	
DATE MAR 2008	FIGURE 5.2



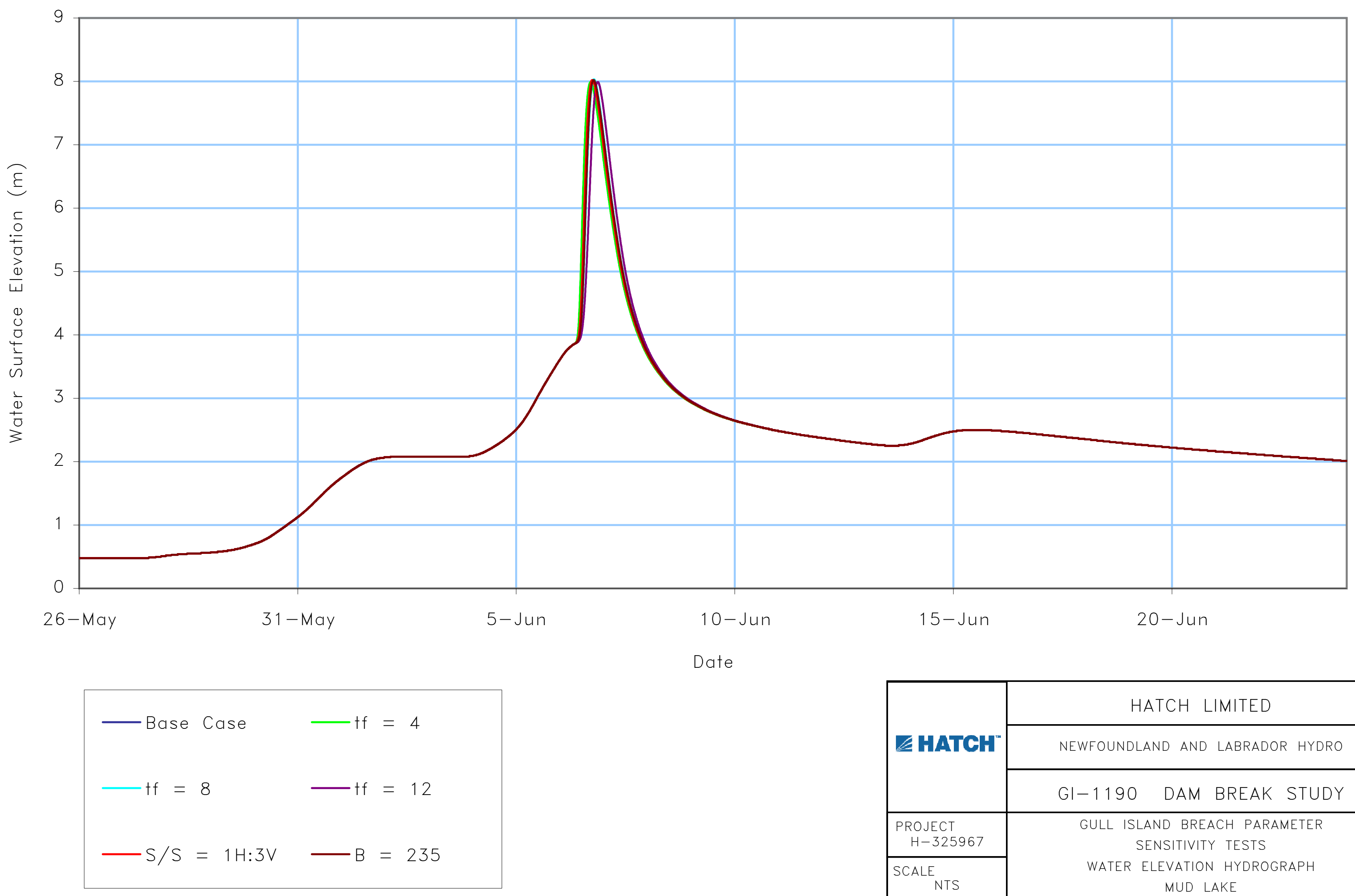
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI–1190 DAM BREAK STUDY
PROJECT H–325967	GULL ISLAND BREACH PARAMETER SENSITIVITY TESTS WATER ELEVATION HYDROGRAPH D/S MUSKRAT FALLS
SCALE NTS	
DATE MAR 2008	FIGURE 5.3



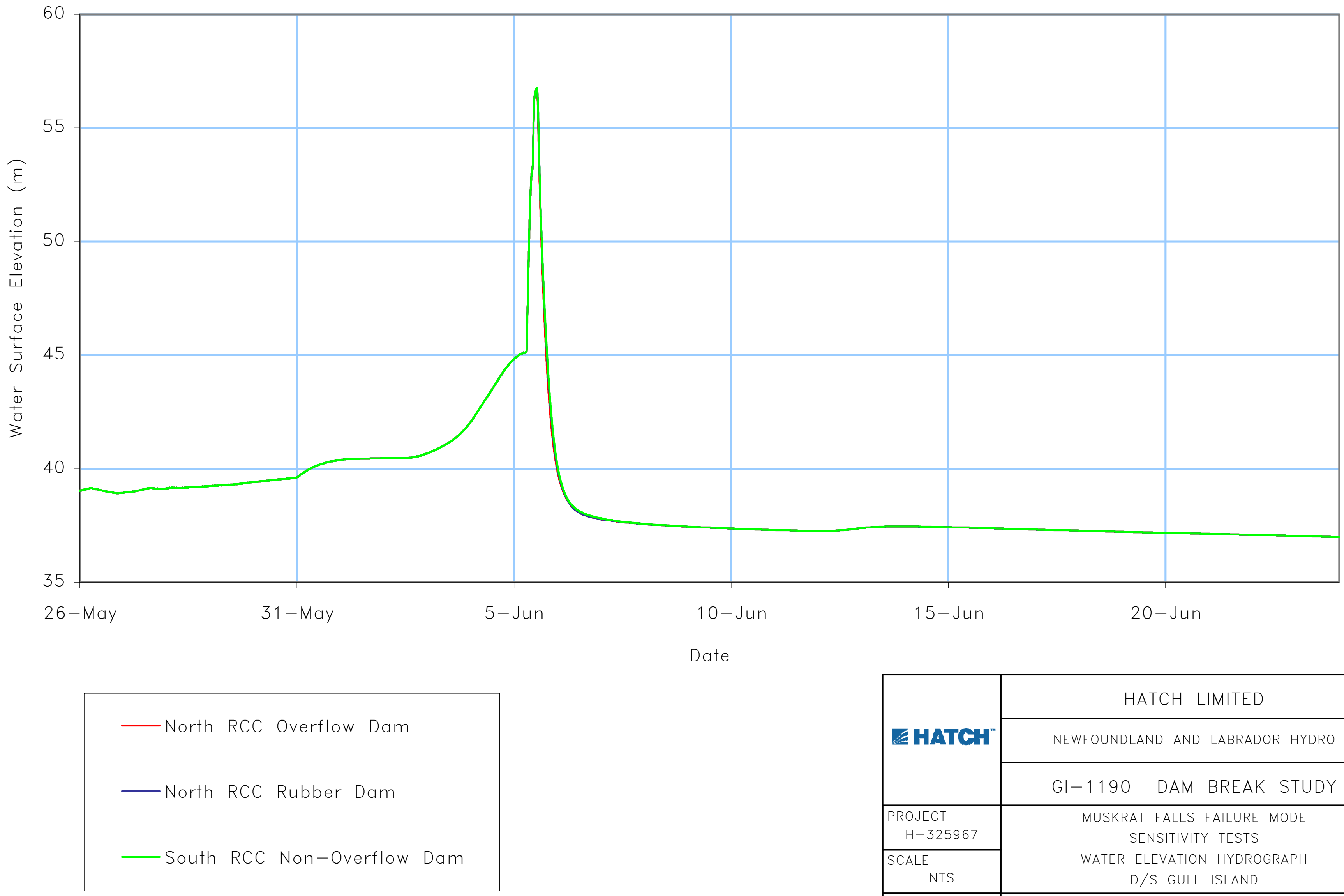
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI–1190 DAM BREAK STUDY
PROJECT H–325967	GULL ISLAND BREACH PARAMETER SENSITIVITY TESTS WATER ELEVATION HYDROGRAPH BLACKROCK BRIDGE
SCALE NTS	
DATE MAR 2008	FIGURE 5.4



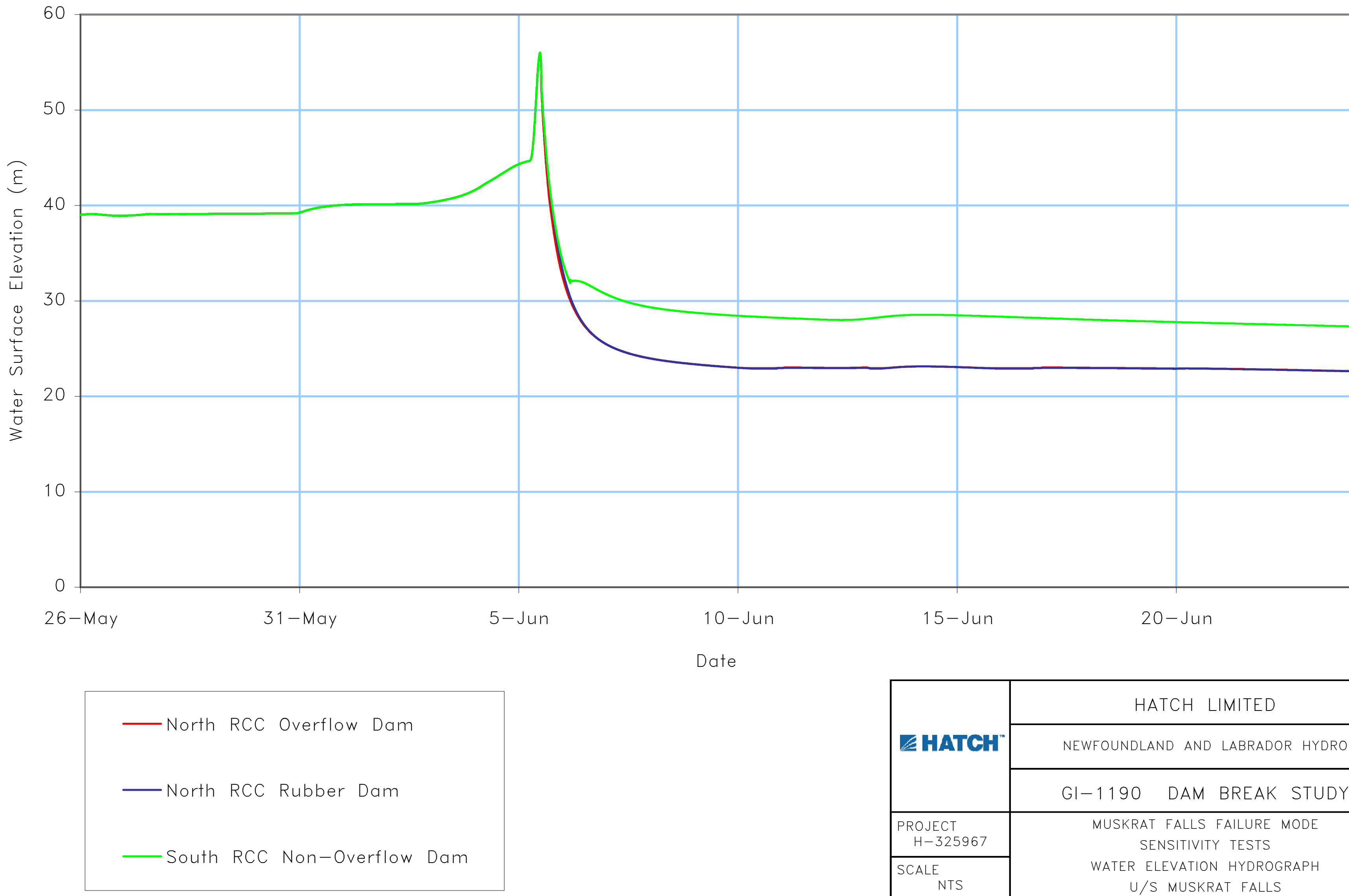
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI-1190 DAM BREAK STUDY
PROJECT H-325967	GULL ISLAND BREACH PARAMETER SENSITIVITY TESTS
SCALE NTS	WATER ELEVATION HYDROGRAPH HAPPY VALLEY - GOOSE BAY
DATE MAR 2008	FIGURE 5.5



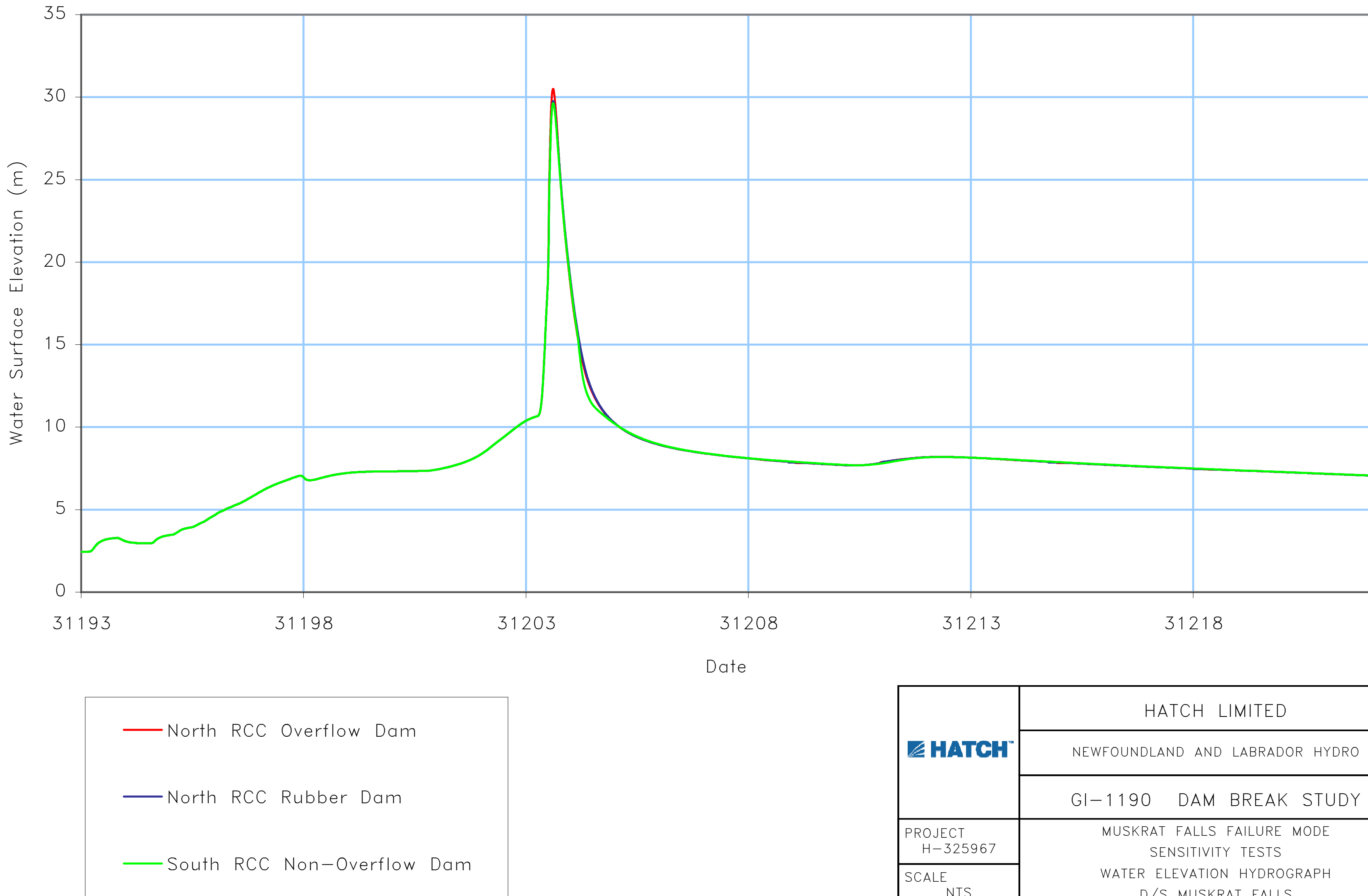
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI–1190 DAM BREAK STUDY
PROJECT H–325967	GULL ISLAND BREACH PARAMETER SENSITIVITY TESTS WATER ELEVATION HYDROGRAPH MUD LAKE
SCALE NTS	
DATE MAR 2008	FIGURE 5.6



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI–1190 DAM BREAK STUDY
PROJECT H–325967	MUSKRAT FALLS FAILURE MODE SENSITIVITY TESTS WATER ELEVATION HYDROGRAPH D/S GULL ISLAND
SCALE NTS	
DATE MAR 2008	FIGURE 5.7



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI−1190 DAM BREAK STUDY
PROJECT H−325967	MUSKRAT FALLS FAILURE MODE SENSITIVITY TESTS WATER ELEVATION HYDROGRAPH U/S MUSKRAT FALLS
SCALE NTS	
DATE MAR 2008	FIGURE 5.8



HATCH LIMITED

NEWFOUNDLAND AND LABRADOR HYDRO

GI–1190 DAM BREAK STUDY

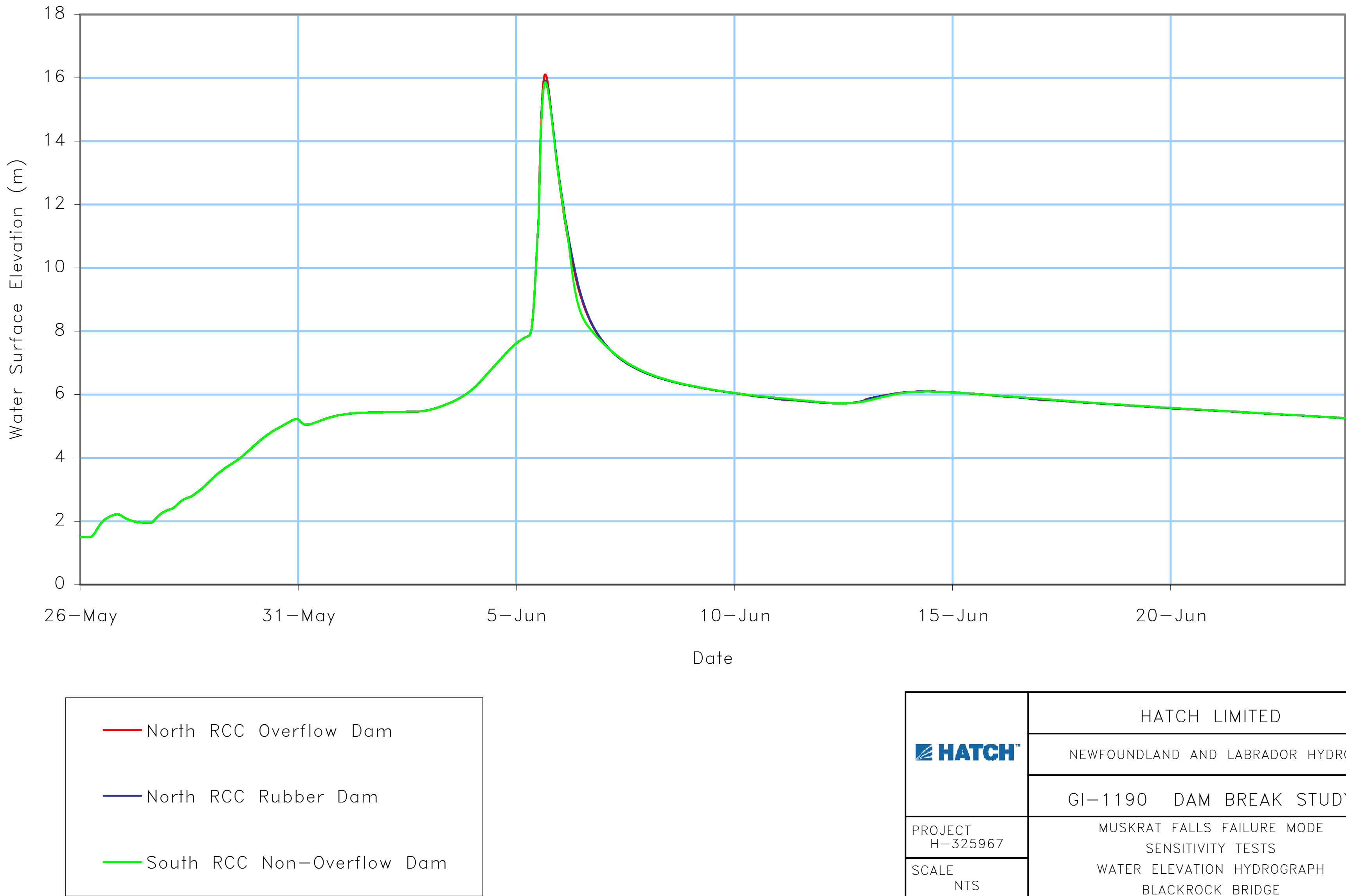
PROJECT H–325967

SCALE NTS

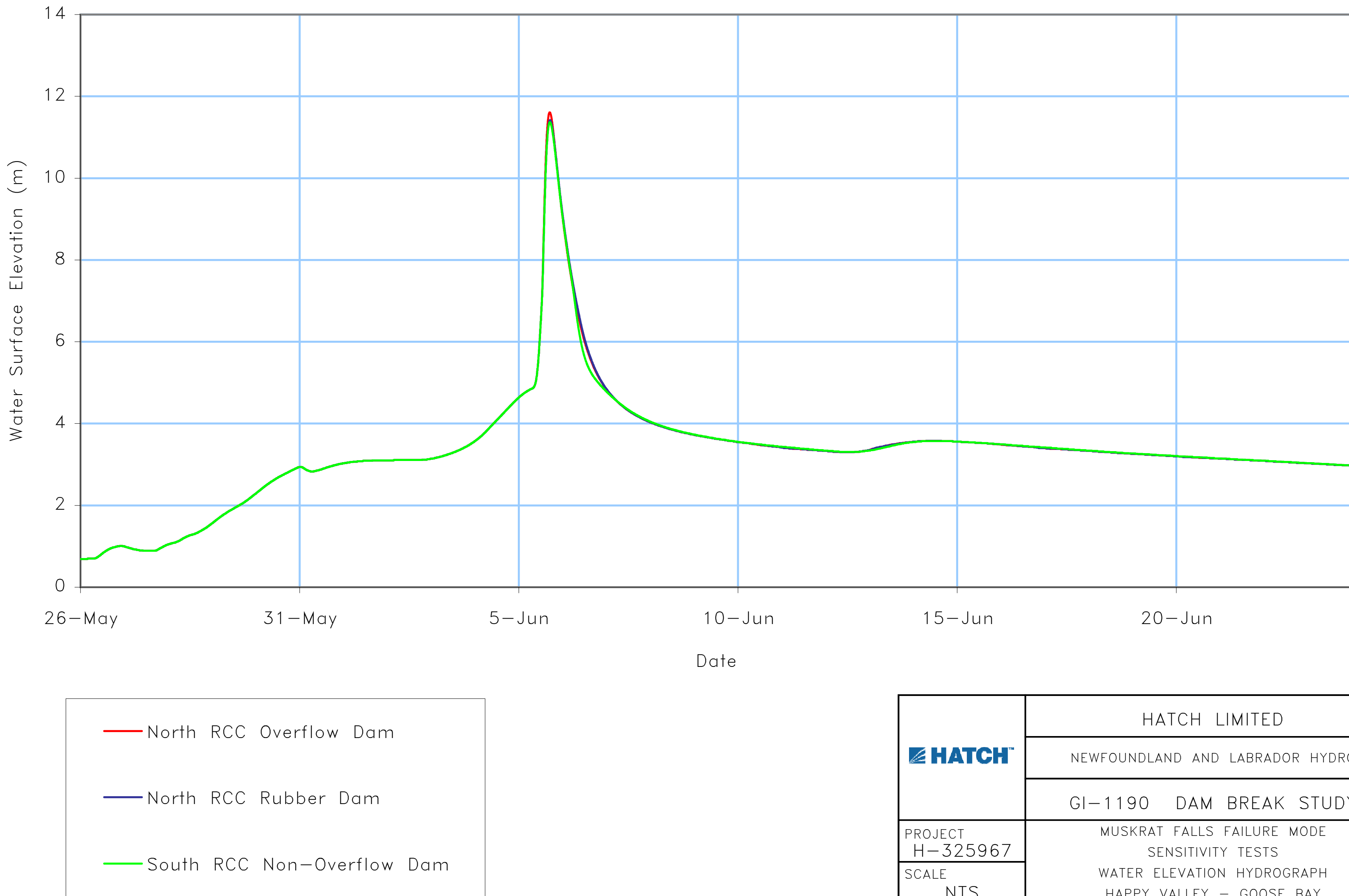
DATE MAR 2008

MUSKRAT FALLS FAILURE MODE SENSITIVITY TESTS WATER ELEVATION HYDROGRAPH D/S MUSKRAT FALLS

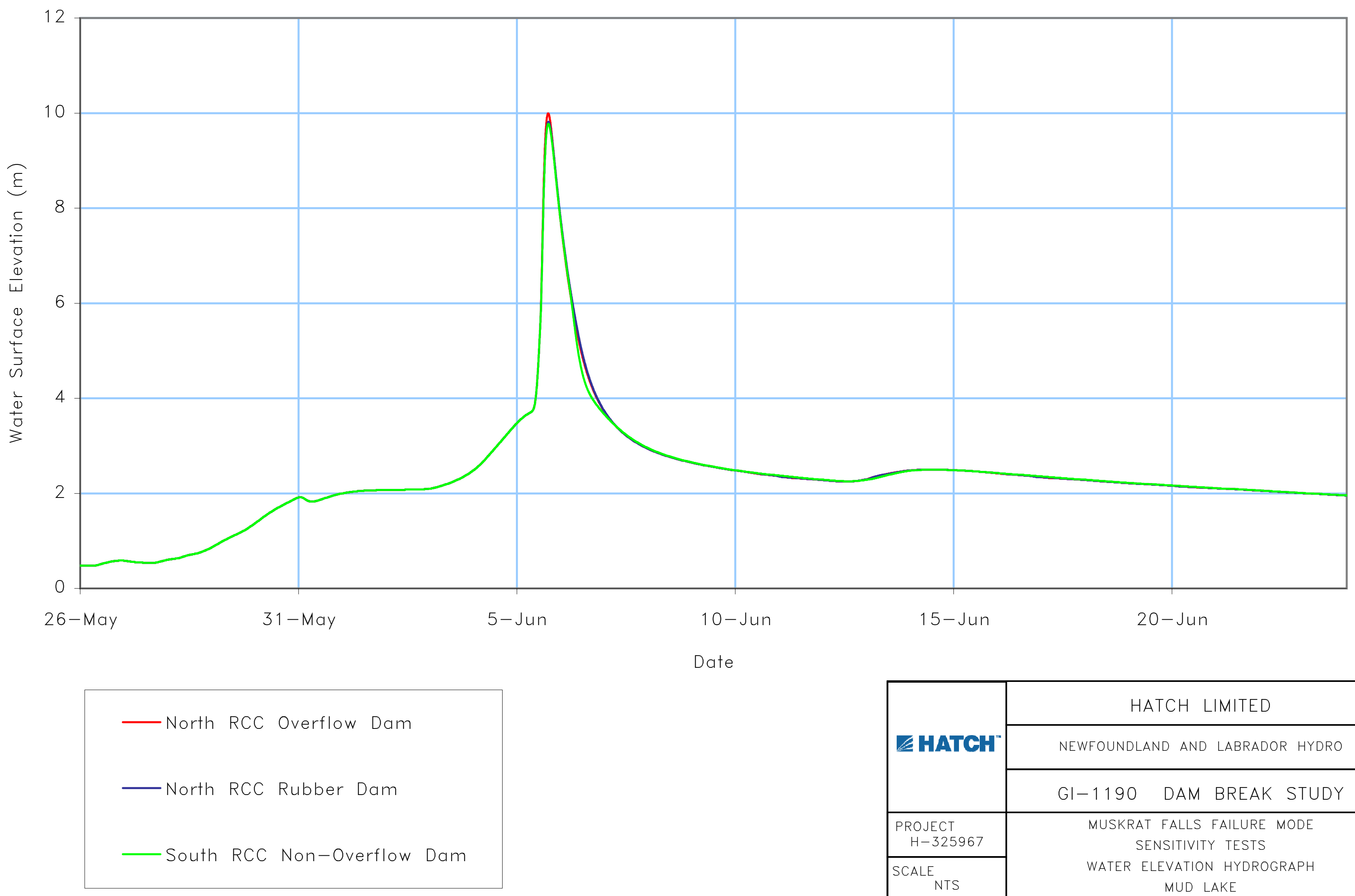
FIGURE 5.9



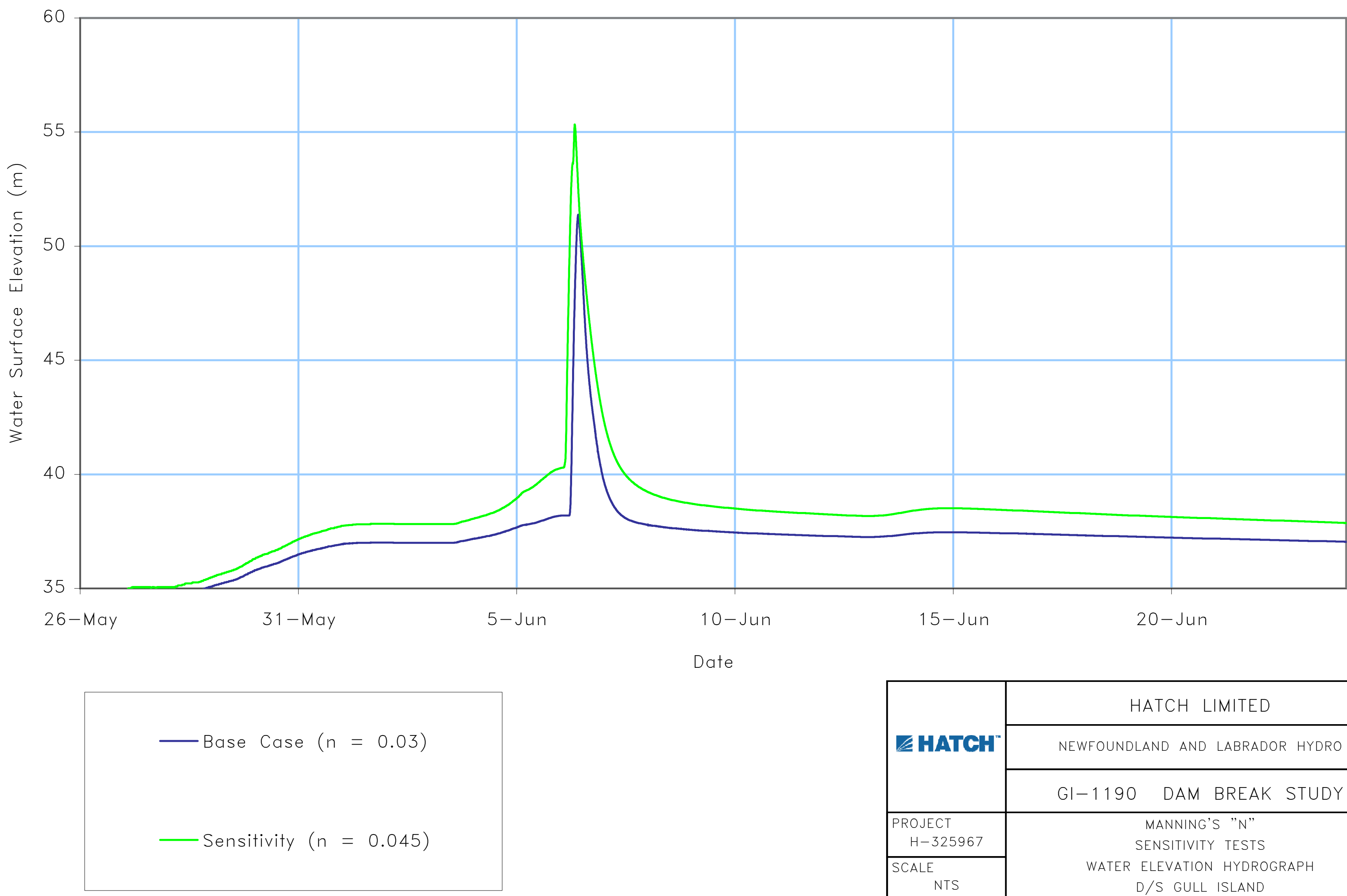
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI-1190 DAM BREAK STUDY
PROJECT H-325967	MUSKRAT FALLS FAILURE MODE SENSITIVITY TESTS WATER ELEVATION HYDROGRAPH BLACKROCK BRIDGE
SCALE NTS	
DATE MAR 2008	FIGURE 5.10



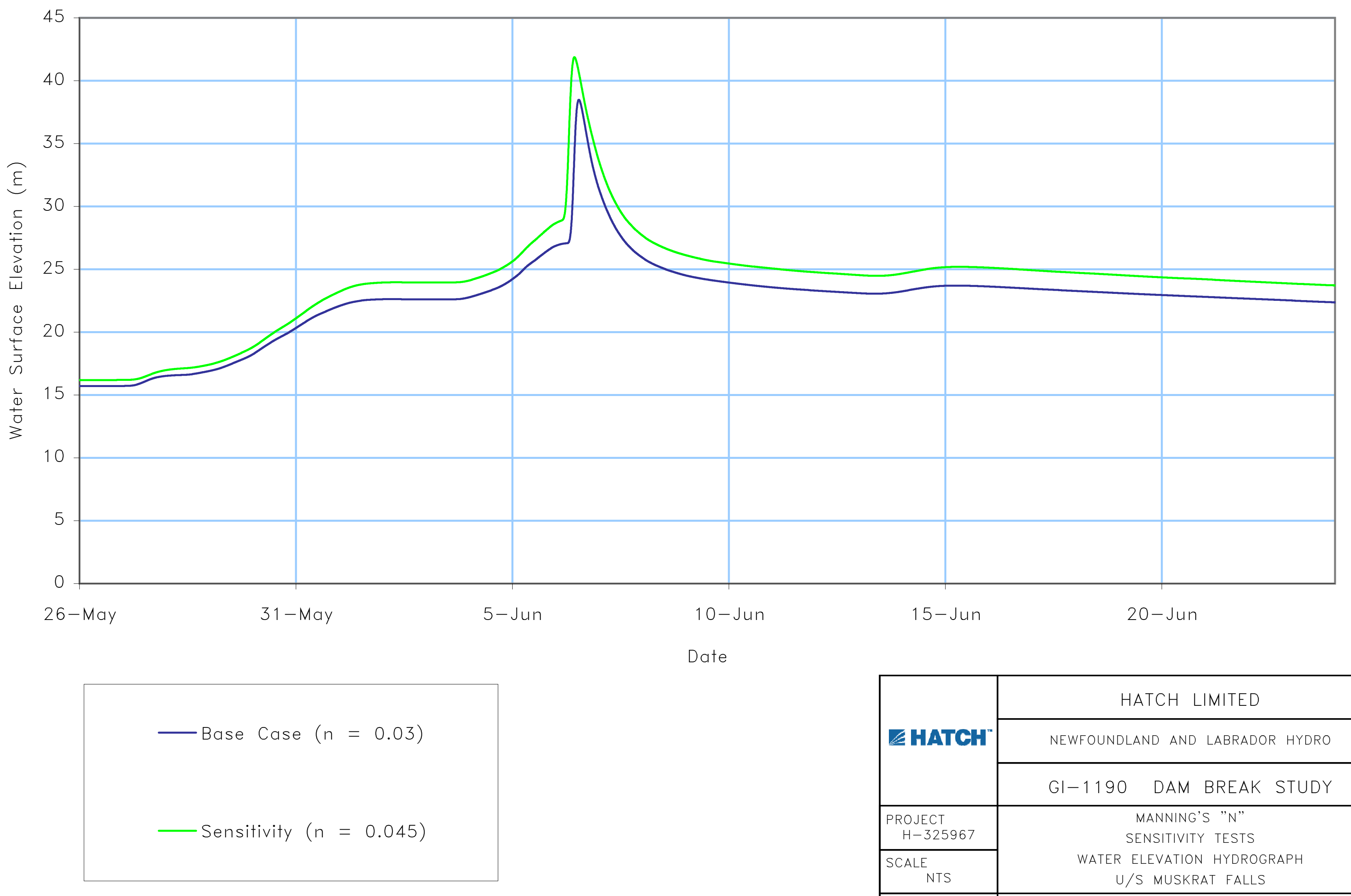
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI–1190 DAM BREAK STUDY
PROJECT H–325967	MUSKRAT FALLS FAILURE MODE SENSITIVITY TESTS
SCALE NTS	WATER ELEVATION HYDROGRAPH HAPPY VALLEY – GOOSE BAY
DATE MAR 2008	FIGURE 5.11



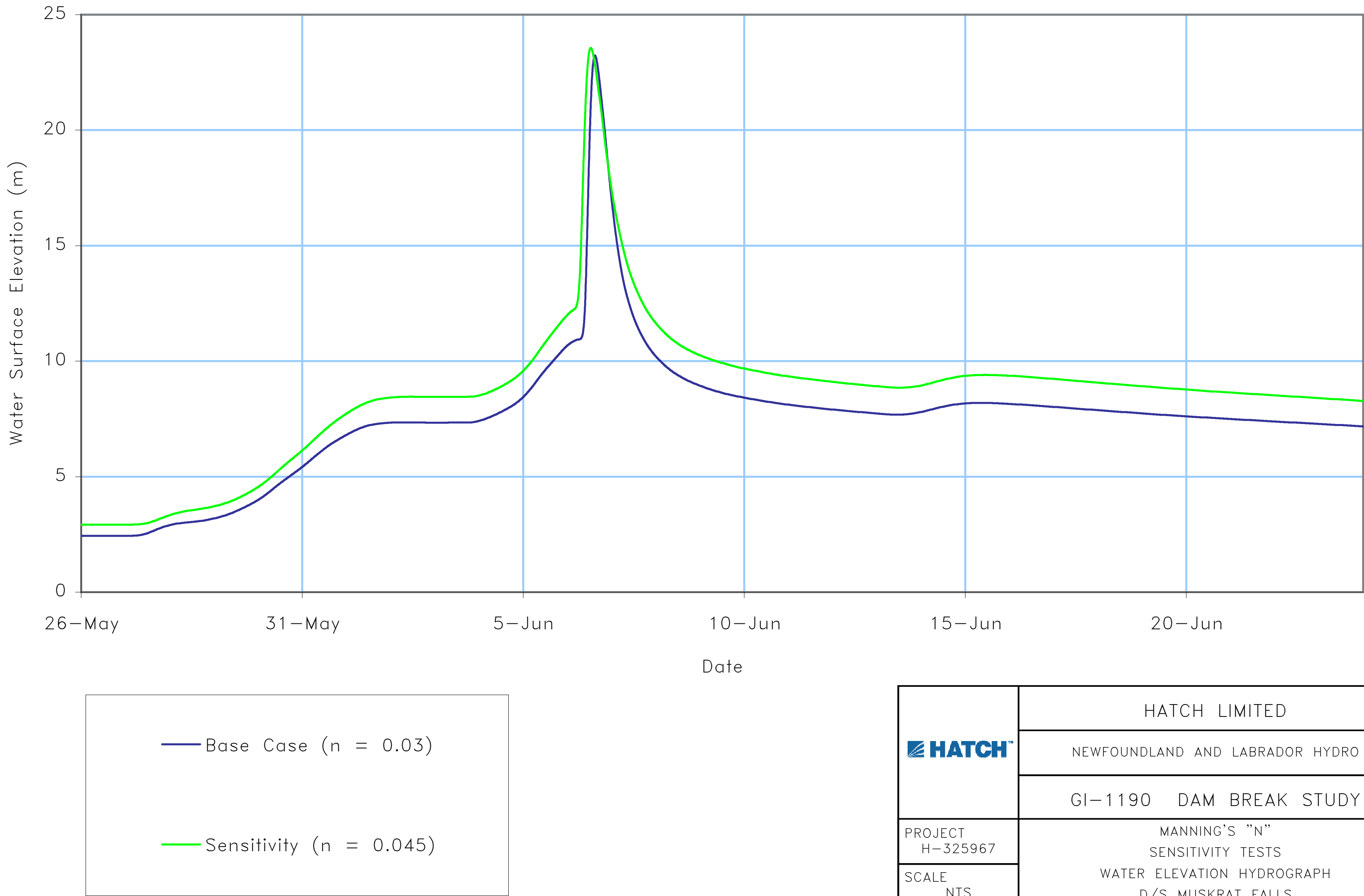
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI–1190 DAM BREAK STUDY
PROJECT H–325967	MUSKRAT FALLS FAILURE MODE SENSITIVITY TESTS WATER ELEVATION HYDROGRAPH MUD LAKE
SCALE NTS	
DATE MAR 2008	FIGURE 5.12



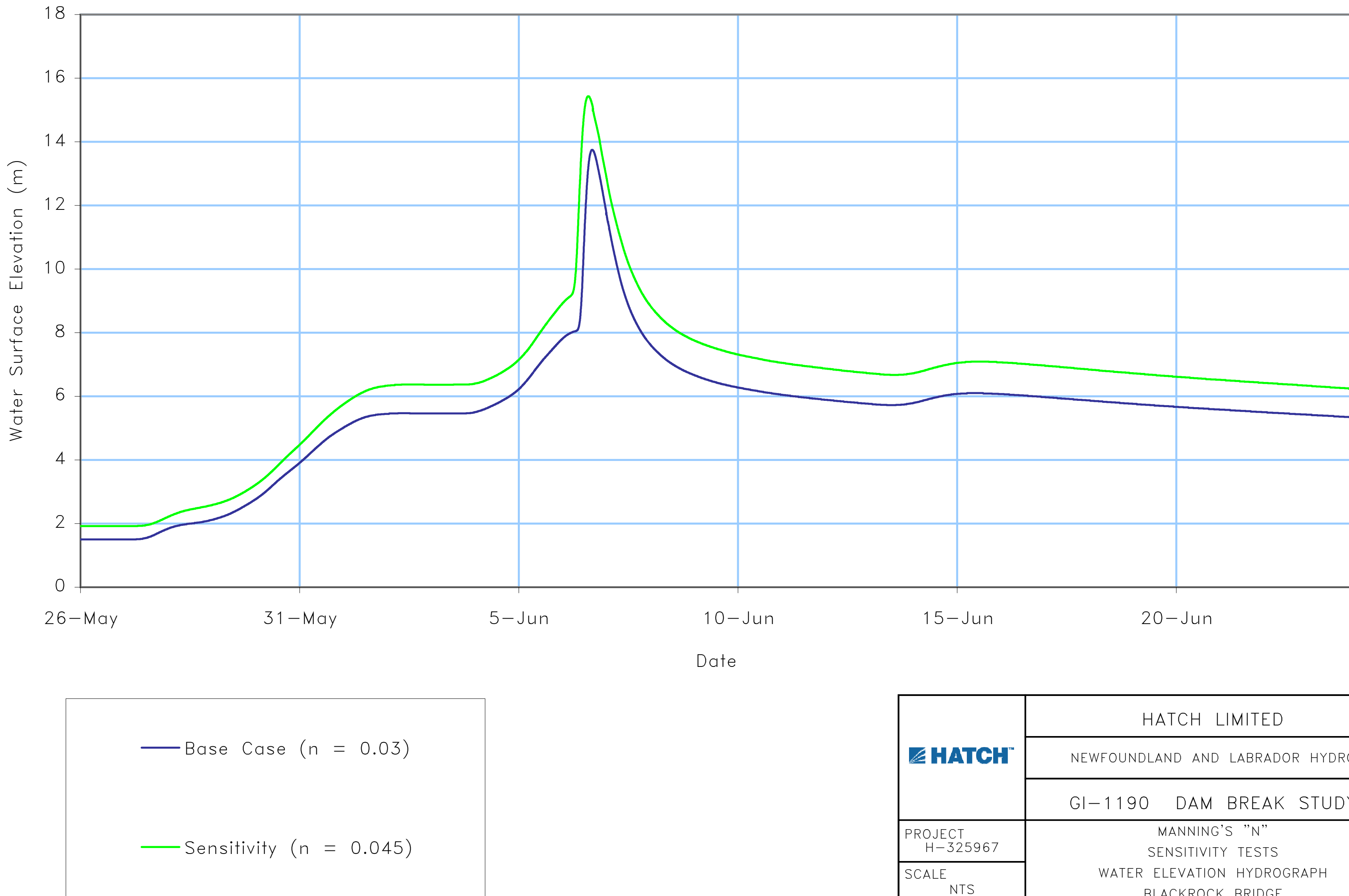
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI-1190 DAM BREAK STUDY
PROJECT H-325967	MANNING'S "N" SENSITIVITY TESTS WATER ELEVATION HYDROGRAPH D/S GULL ISLAND
SCALE NTS	
DATE MAR 2008	FIGURE 5.13



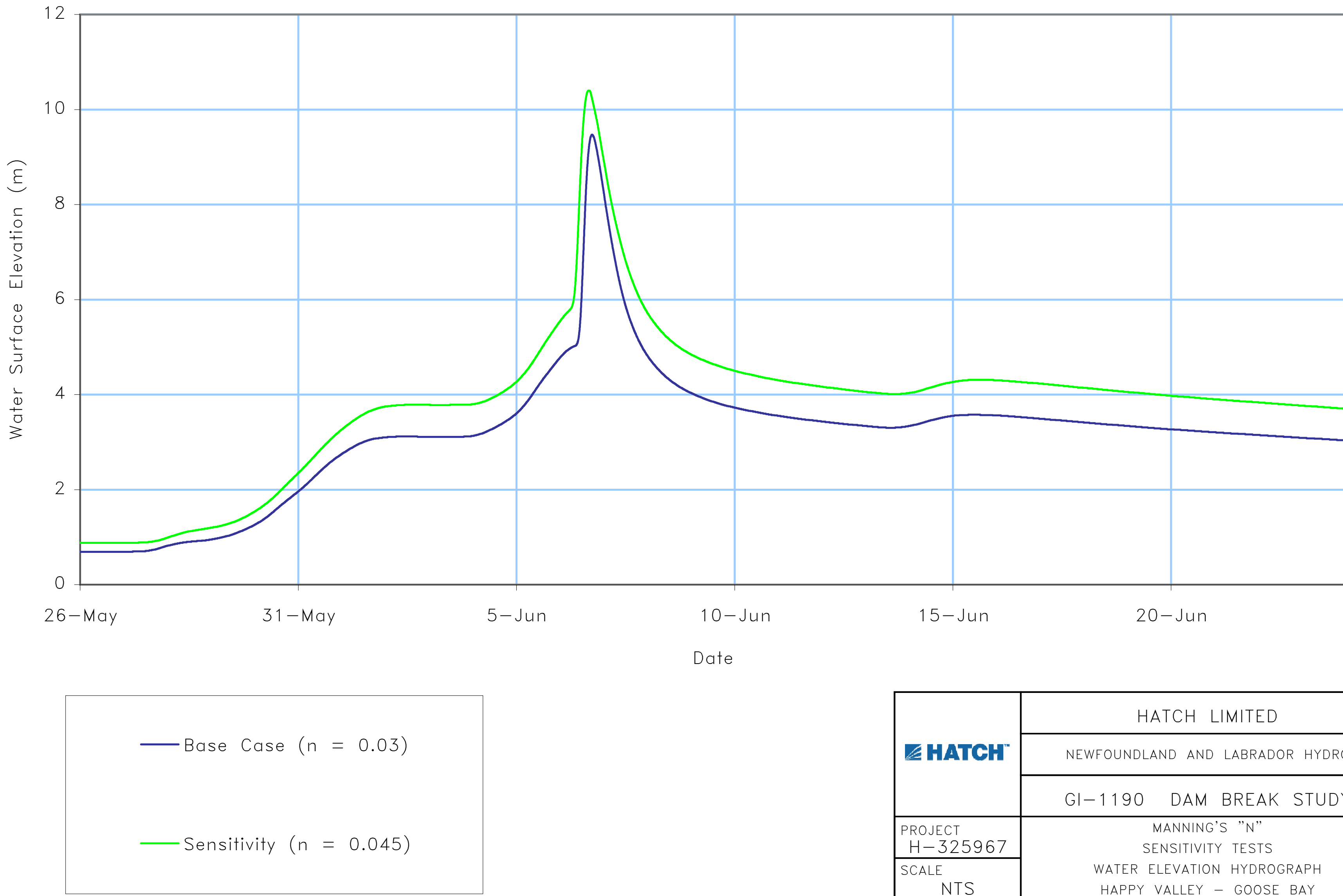
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI–1190 DAM BREAK STUDY
PROJECT H–325967	MANNING'S "N" SENSITIVITY TESTS WATER ELEVATION HYDROGRAPH U/S MUSKRAT FALLS
SCALE NTS	
DATE MAR 2008	FIGURE 5.14



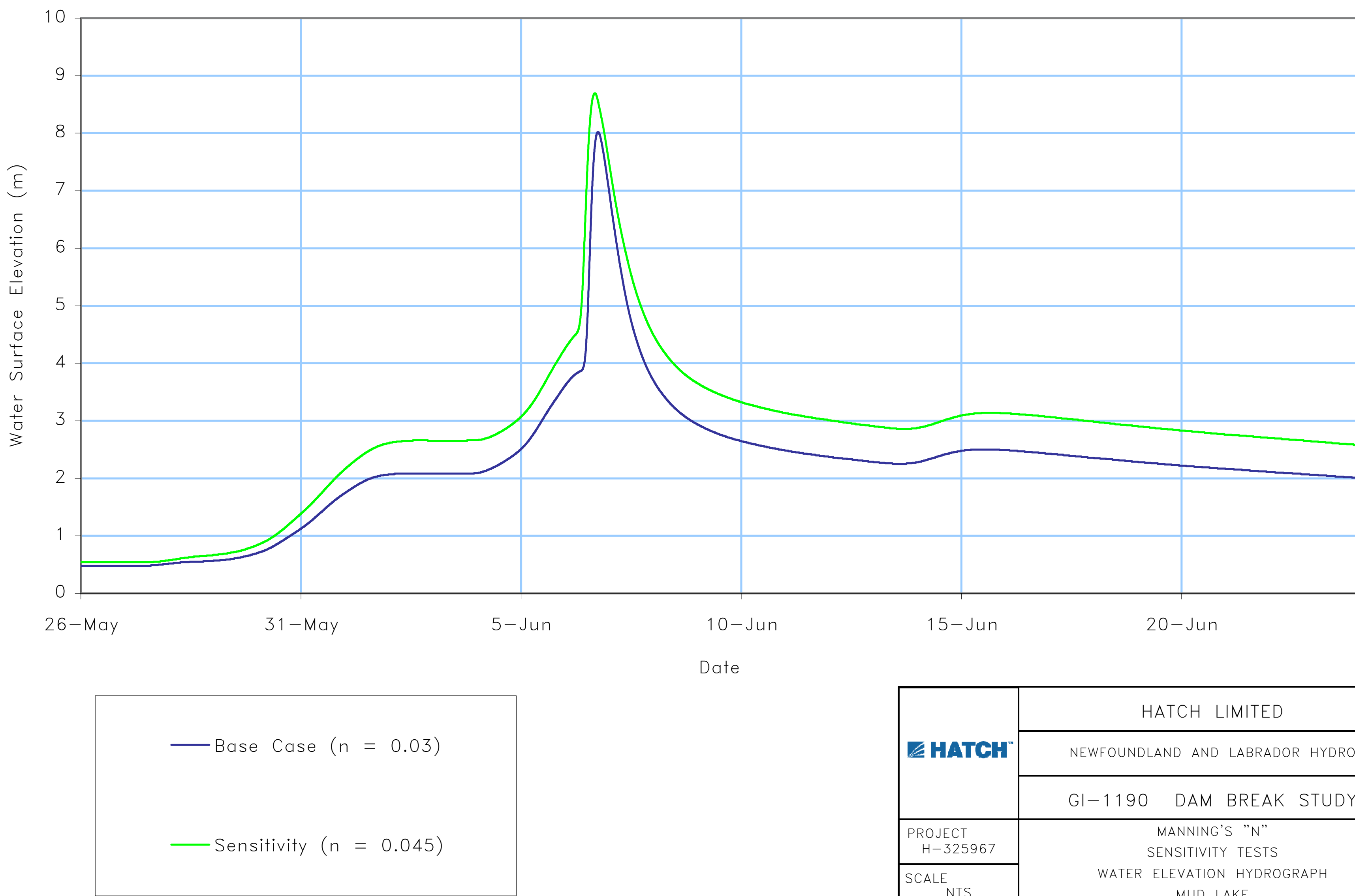
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI-1190 DAM BREAK STUDY
PROJECT H-325967	MANNING'S "N" SENSITIVITY TESTS WATER ELEVATION HYDROGRAPH D/S MUSKRAT FALLS
SCALE NTS	
DATE MAR 2008	FIGURE 5.15



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI–1190 DAM BREAK STUDY
PROJECT H–325967	MANNING'S "N" SENSITIVITY TESTS WATER ELEVATION HYDROGRAPH BLACKROCK BRIDGE
SCALE NTS	
DATE MAR 2008	FIGURE 5.16



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI–1190 DAM BREAK STUDY
PROJECT H–325967	MANNING'S "N" SENSITIVITY TESTS WATER ELEVATION HYDROGRAPH HAPPY VALLEY – GOOSE BAY
SCALE NTS	
DATE MAR 2008	FIGURE 5.17



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI–1190 DAM BREAK STUDY
PROJECT H–325967	MANNING'S "N" SENSITIVITY TESTS WATER ELEVATION HYDROGRAPH MUD LAKE
SCALE NTS	
DATE MAR 2008	FIGURE 5.18

6. Inundation Mapping

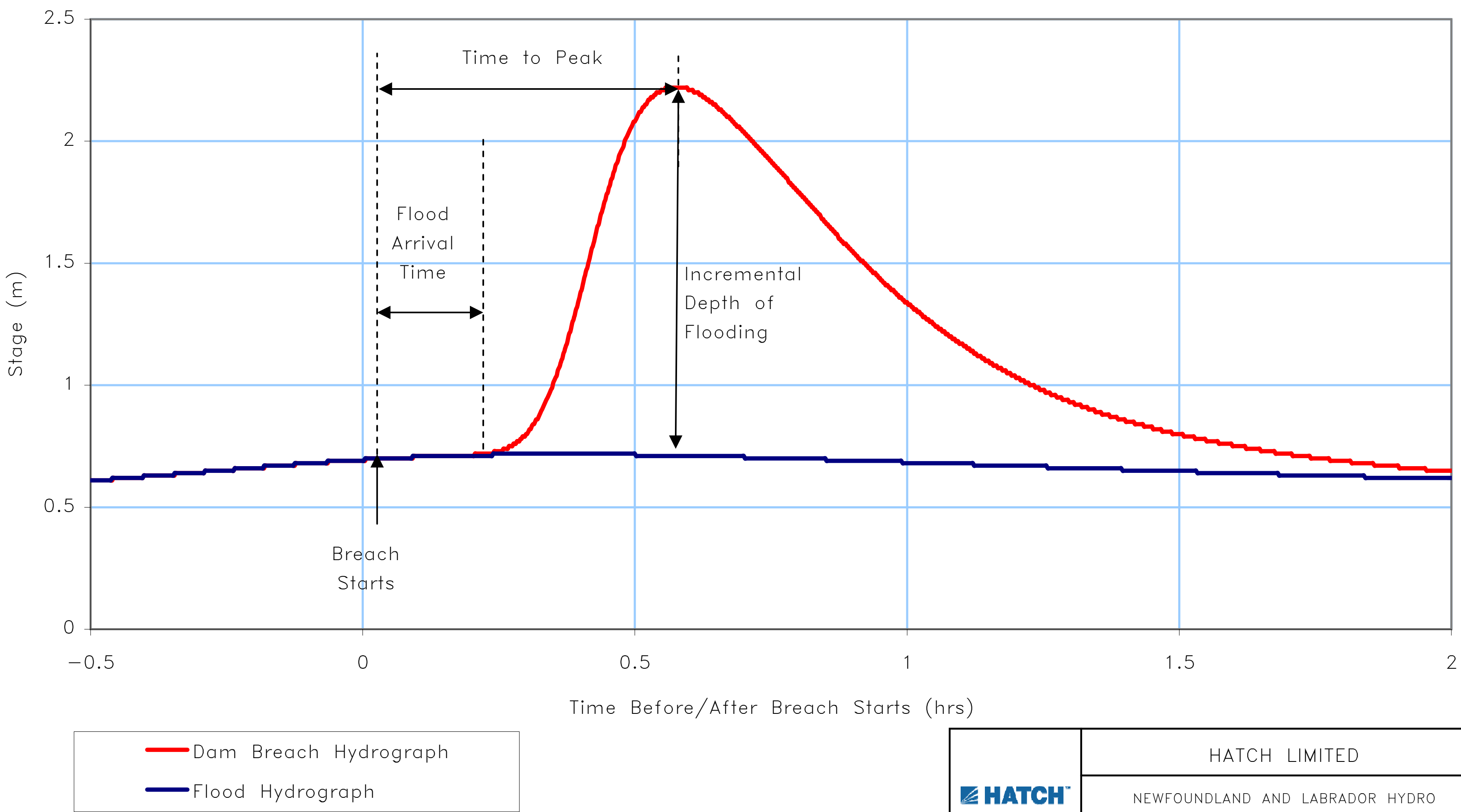
Following the completion of each dam breach simulation, the maximum water surface profile from the HEC-GeoRAS model was exported into the GIS model to prepare inundation mapping along the river valley. Inundation mapping for all dam breach simulations is included as Volume 2 of this report.

Final inundation maps were prepared using 1:50,000 scale NTS topographic maps. The contours shown on these maps have been developed based on the LiDAR topographical survey data provided by Hydro and prepared by TerraPoint. Separate map sets were prepared for both the PMF and the "Fair Weather" breach scenarios. In each case, the mapping covers the area extending from the Gull Island Dam to Lake Melville. Information boxes are provided on the maps providing specific information related to the dam breach flood wave at various locations. Information provided includes the following.

- Distance from the Gull Island Dam (km)
- Peak Flood Elevation (m)
- Peak Breach Elevation (m)
- Depth of Flooding (m)
- Time of Arrival of the Flood Wave (hrs)
- Time to Reach the Peak Stage (hrs)

Figure 6.1 illustrates typical flood and dam breach hydrographs, and the derivation of the above values.

For the communities of Happy Valley - Goose Bay and Mud Lake, additional mapping was prepared at a larger scale (1:10,000 scale) to better define flood inundation lines in these relatively more populated areas. These maps were produced using high resolution aerial photography as a back drop to better illustrate the inundated areas. This aerial photography was taken for Hydro by TerraPoint during the LiDAR survey in 2006.



HATCH

HATCH LIMITED

NEWFOUNDLAND AND LABRADOR HYDRO

GI1190 – DAM BREAK STUDY

TYPICAL DAM BREACH AND FLOOD HYDROGRAPHS

PROJECT H–325967

SCALE NTS

DATE MAR 2008

FIGURE 6.1

7. Consequences of Failure

The CDA Guidelines note that consequences of failure should be grouped into the following sections.

- Loss of life.
- Economic losses.
- Environmental losses.
- Cultural losses.

The inundation maps presented in Volume 2 were reviewed to determine the incremental consequences of failure, or the consequences of failure in the inundated area between the water level that would occur during natural conditions and the water level that would occur during a dam breach. Each of the four scenarios and two flow conditions were reviewed, and the consequences of failure for each noted, as discussed in the following sections.

7.1 Potential Loss of Life Assessment

The Population at Risk (PAR) in the incrementally inundated area provides an indication of the number of people exposed to the hazard. Consistent estimates of expected loss of life are very difficult to develop and the potential for Loss of Life (LOL) depends on many highly uncertain and variable factors, such as depth of flow, velocity, time of day, advance warning, topography, distance from the dam, transportation routes, and mobility of the population. Although no simple, reliable methodology is available, the quantitative approach for assessing the potential LOL for this study is based on the dam safety publication presented by DeKay and McClelland, "Predicting Loss of Life in Cases of Dam Failure and Flash Flood".

The DeKay/ McClelland publication derived from historical data an expression of LOL in terms of the available Warning Time (WT), the size of the PAR, and the forcefulness of the floodwaters. WT is taken as the difference in time between the first initiation of dam breach occurring to the time it takes the initial flood wave to reach the PAR. PAR, if based on inundation mapping, which would be the case for this study, would reflect the population located within the incrementally inundated zone. The forcefulness of the floodwaters assumed for this study is high force (HF), which corresponds to deep fast flowing flood waters. The equation for LOL based on high force floodwaters follows.

$$LOL_{HF} = PAR / (1 + 13.277 * (PAR^{0.44}) * e^{[2.982*(WT)-3.790]})$$

PAR was determined by counting the number of homes/ structures in the incrementally inundated area and multiplying by the average number of residents per household in Happy Valley - Gosse Bay (2.8 persons/ household based on the 2006 Statistics Canada Community Profiles). Tables 7.1 and 7.2 provide the assessment of potential LOL for both PMF and "Fair Weather" conditions, respectively.

Table 7.1
PMF Conditions – Potential Loss of Life Assessment

Scenario	# of Incrementally Inundated Buildings	PAR in Incrementally Inundated Area	WT (hours)	Incremental LOL	Incremental LOL (WT = 0 hrs)
GI – GI Breach	130	364	3.0	0	73
GI/ MF – GI Breach	130	364	2.5	0	73
GI/ MF – MF Breach	130	364	0.8	11	73
GI/ MF – GI/ MF Breach	380	1064	2.5	0	143

Table 7.2
"Fair Weather" Conditions – Potential Loss of Life Assessment

Scenario	# of Incrementally Inundated Buildings	PAR in Incrementally Inundated Area	WT (hours)	Incremental LOL	Incremental LOL (WT = 0 hrs)
GI – GI Breach	830	2324	5.9	0	230
GI/ MF – GI Breach	730	2044	3.6	0	213
GI/ MF – MF Breach	590	1652	1.4	3	187
GI/ MF – GI/ MF Breach	900	2520	3.6	0	242

The DeKay and McClelland publication note that if WT is more than an hour or two, neither population would be in great danger. This is evident in the above tables for WT greater than two hours, the potential for LOL is zero. However, this assumes that evacuation orders are provided at the point of dam breach initiation and that the PAR has coordinated emergency preparedness plans and evacuation takes place. To assess the sensitivity of LOL to WT, the potential LOL was determined in the above tables assuming the PAR had no warning time. As can be seen from the above table, LOL is highly sensitive to WT, and it would be important to evacuate the potential inundated areas prior to, or as quickly as possible after, dam breach initiation.

7.2 Potential Economic, Environmental, and Cultural Loss Assessment

For the purposes of this assessment, the inundation maps were reviewed to determine areas downstream of Gull Island and Muskrat Falls that would be within the incrementally inundated flood area and could therefore be negatively impacted by a dam breach at either dam. For the economic evaluation, a minimum assessment of economic damage was calculated by multiplying the number of buildings incrementally inundated by the average value of dwellings in Happy Valley - Goose Bay (~$100,000/ home based on the Statistics Canada 2001 Community Profiles). This represents a minimum assessment, since there would be economic damages associated with loss of energy, rebuilding generating stations, and rebuilding community infrastructure.

7.2.1 PMF Conditions Post Gull Island – Gull Island Dam Breach

- Economic damages associated with loss of homes (~130) = $13,000,000.
- Trans Labrador Highway and Transmission Line Crossing at Pinus River.
- Approximate area of incremental flooding = 90 km^2.

- Overtopping of Blackrock Bridge.
- Loss of access and transportation routes in and around Happy Valley - Goose Bay.
- Loss of transmission line infrastructure in and around Happy Valley – Goose Bay.
- Loss of Gull Island Hydroelectric Station and energy.

7.2.2 PMF Conditions Post Gull Island and Muskrat Falls – Gull Island Dam Breach

- Economic damages associated with loss of homes (~130) = $13,000,000.
- Trans Labrador Highway Crossing at Pinus River.
- Trans Labrador Highway and Transmission Line Crossing near chainage 73 km (Edwards Brook).
- Approximate area of incremental flooding = 90 km^2.
- Overtopping of Muskrat Falls Hydroelectric Stations and potential loss of energy.
- Overtopping of Blackrock Bridge.
- Loss of access and transportation routes in and around Happy Valley - Goose Bay.
- Loss of transmission line infrastructure in and around Happy Valley – Goose Bay.
- Loss of Gull Island Hydroelectric Station and energy.

7.2.3 PMF Conditions Post Gull Island and Muskrat Falls - Muskrat Falls Dam Breach

- Economic damages associated with loss of homes (~130) = $13,000,000
- Approximate area of incremental flooding = 50 km^2.
- Overtopping of Blackrock Bridge.
- Loss of access and transportation routes in and around Happy Valley - Goose Bay.
- Loss of transmission line infrastructure in and around Happy Valley – Goose Bay.
- Loss of Muskrat Falls Hydroelectric Station and energy.

7.2.4 PMF Conditions Post Gull Island and Muskrat Falls – Cascade Failure

- Economic damages associated with loss of homes (~380) = $38,000,000.
- Trans Labrador Highway Crossing at Pinus River.
- Trans Labrador Highway and Transmission Line Crossing near chainage 73 km (Edwards Brook).
- Approximate area of incremental flooding = 125 km^2.
- Overtopping of Blackrock Bridge.
- Loss of access and transportation routes in and around Happy Valley - Goose Bay.
- Loss of transmission line infrastructure in and around Happy Valley – Goose Bay.
- Loss of Gull Island and Muskrat Falls Hydroelectric Stations and energy.

7.2.5 "Fair Weather" Conditions Post Gull Island – Gull Island Dam Breach

- Economic damages associated with loss of homes (~830) = $83,000,000
- Transmission Line Crossing at Pinus River.
- Trans Labrador Highway and Transmission Line Crossing at Lower Brook.
- Approximate area of incremental flooding = 180 km^2.
- Overtopping of Blackrock Bridge.
- Loss of access and transportation routes in and around Happy Valley - Goose Bay.
- Loss of transmission line infrastructure in and around Happy Valley – Goose Bay.
- Loss of Gull Island Hydroelectric Station and energy.

7.2.6 "Fair Weather" Conditions Post Gull Island and Muskrat Falls – Gull Island Dam Breach

- Economic damages associated with loss of homes (~730) = $73,000,000
- Transmission Line Crossing at Pinus River.
- Trans Labrador Highway and Transmission Line Crossing near chainage 73 km (Edwards Brook).
- Overtopping of Muskrat Falls Hydroelectric Stations and potential loss of energy.
- Approximate area of incremental flooding = 180 km^2.
- Overtopping of Blackrock Bridge.
- Loss of access and transportation routes in and around Happy Valley - Goose Bay.
- Loss of transmission line infrastructure in and around Happy Valley – Goose Bay.
- Loss of Gull Island Hydroelectric Station and energy.

7.2.7 "Fair Weather" Conditions Post Gull Island and Muskrat Falls - Muskrat Falls Dam Breach

- Economic damages associated with loss of homes (~590) = $59,000,000.
- Approximate area of incremental flooding = 125 km^2.
- Loss of access and transportation routes in and around Happy Valley - Goose Bay.
- Loss of transmission line infrastructure in and around Happy Valley – Goose Bay.
- Loss of Muskrat Falls Hydroelectric Station and energy.

7.2.8 "Fair Weather" Conditions Post Gull Island and Muskrat Falls – Cascade Failure

- Economic damages associated with loss of homes (~900) = $90,000,000.
- Transmission Line Crossing at Pinus River.
- Trans Labrador Highway and Transmission Line Crossing near chainage 73 km (Edwards Brook).
- Approximate area of incremental flooding = 200 km^2.
- Overtopping of Blackrock Bridge.

- Loss of access and transportation routes in and around Happy Valley - Goose Bay.
- Loss of transmission line infrastructure in and around Happy Valley – Goose Bay.
- Loss of Gull Island and Muskrat Falls Hydroelectric Stations and energy.

8. Conclusions and Recommendations

A HEC-GeoRas model capable of simulating dam breach floodwaves was successfully set up and used to model hypothetical dam breaches at both Gull Island and Muskrat Falls. Although it might be of interest to the Lower Churchill Project to assess the impacts of an Upper Churchill dam breach on the planned projects at Gull Island and Muskrat Falls, this work should be coordinated and planned in cooperation with Churchill Falls (Labrador) Corporation. The results of the dam breach modeling were used to prepare inundation mapping for Emergency Preparedness Plans and to assess the overall consequences of failure for both Gull Island and Muskrat Falls.

It is recommended that:

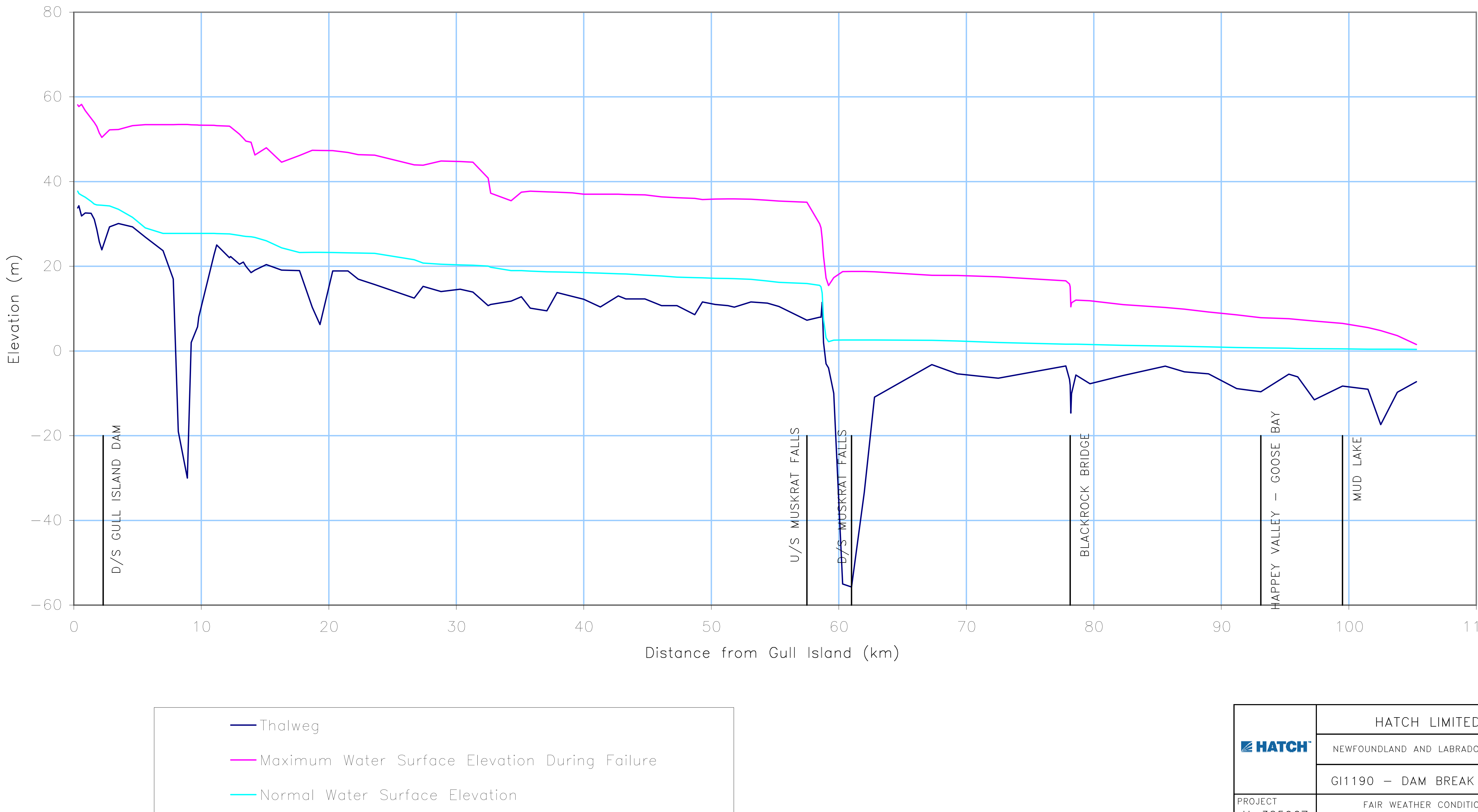
1. The Lower Churchill Project coordinate dam breach studies with Churchill Falls (Labrador) Corporation related to Upper Churchill failure scenarios.
2. The dam break model and inundation mapping be updated prior to the preparation of Emergency Preparedness Plans. This update would take into consideration any changes to the project layouts.
3. Conduct dam breach analysis for during construction activities (cofferdams). The CDA Guidelines note that for significant cofferdams, Emergency Preparedness Plans are required.

List of References

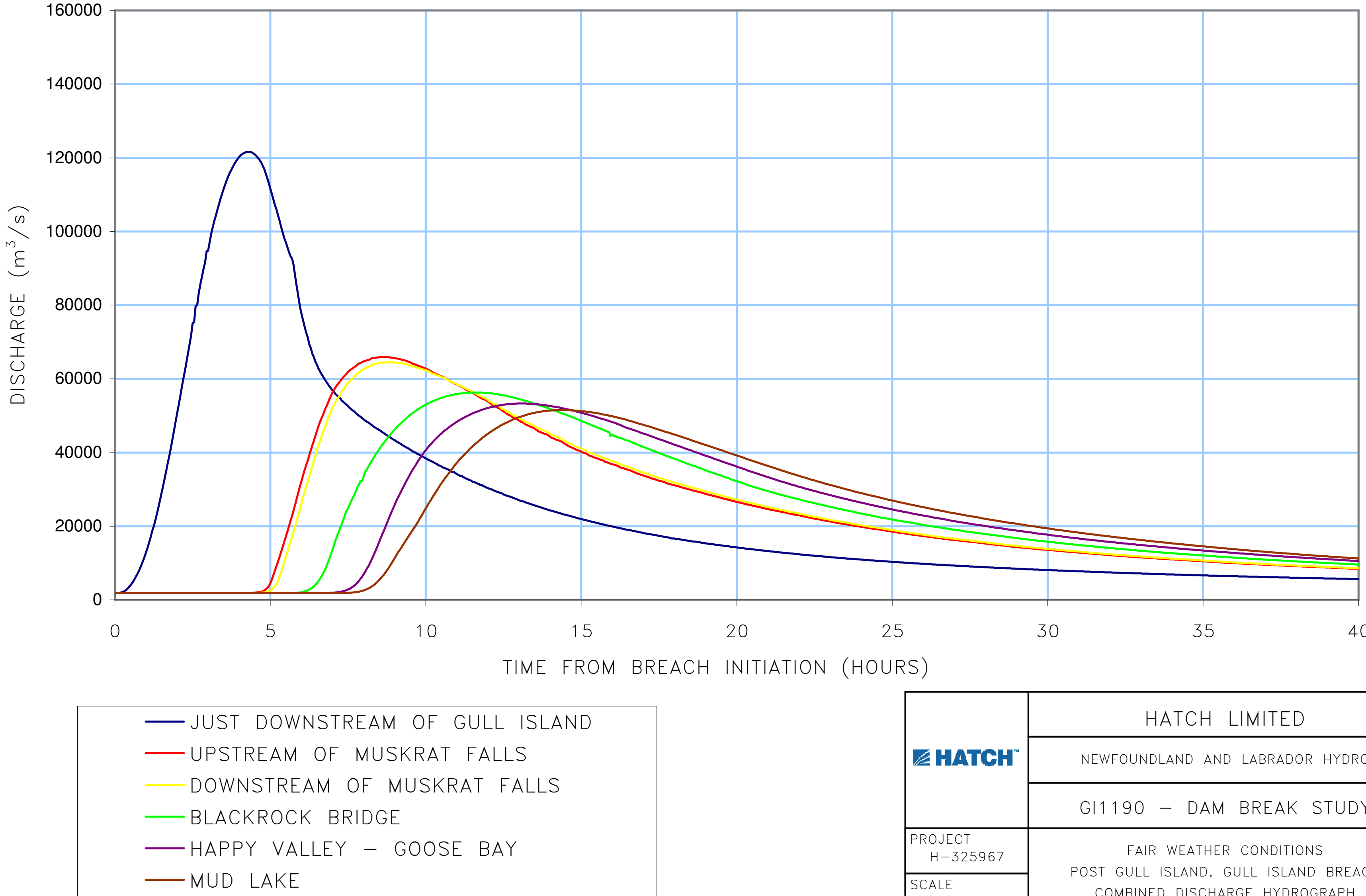
1. Gordon, J.L., “Hydraulic Turbine Efficiency,” Canadian Journal of Civil Engineering, Vol. 28, pp 238-253, 2001.
2. Froelich DC. “Embankment Dam Breach Parameters Revisited”. Proceedings of the 1995 ASCE Conference on Water Resources Engineering, San Antonio, Texas, August 14-18, 1995. pp 887-891. 1995.
3. Federal Energy Regulatory Commission (FERC). Engineering Guidelines for the Evaluation of Hydropower Projects. Chapter 4 - Embankment Dams. FERC. 1993.
4. Wahl, Tony. Prediction of Embankment Dam Breach Parameters - A Literature Review and Needs Assessment. U.S. Bureau of Reclamation Dam Safety Report DSO-98-004. July 1998.

Appendix A

"Fair Weather" Conditions – Post Gull Island – Gull Island Dam Failure



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST GULL ISLAND, GULL ISLAND BREACH MAXIMUM WATER ELEVATION PROFILES
SCALE NTS	
DATE MAR 2008	FIGURE A.1



HATCH

HATCH LIMITED

NEWFOUNDLAND AND LABRADOR HYDRO

GI1190 – DAM BREAK STUDY

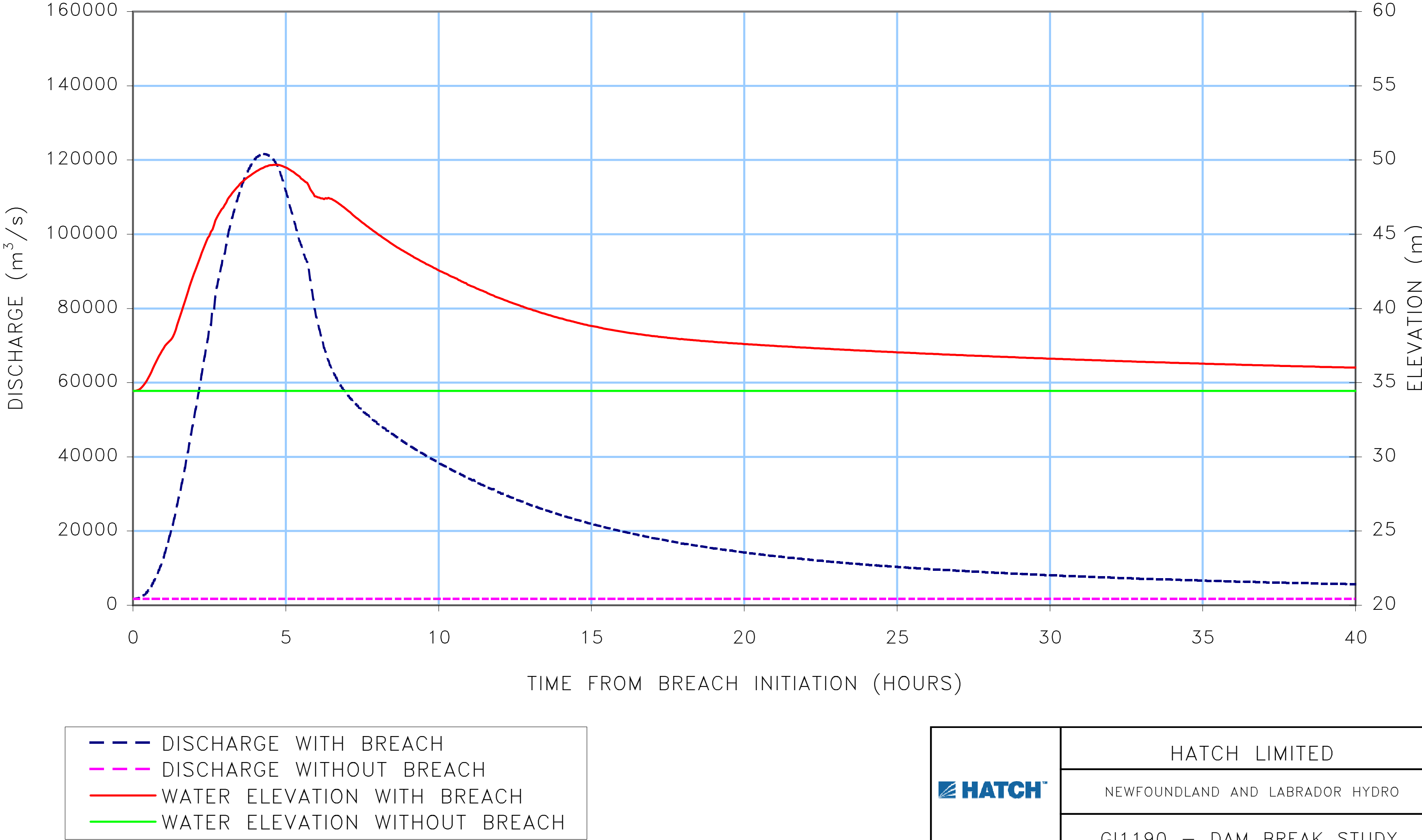
PROJECT H–325967

SCALE NTS

DATE MAR 2008

FAIR WEATHER CONDITIONS
POST GULL ISLAND, GULL ISLAND BREACH
COMBINED DISCHARGE HYDROGRAPH

FIGURE A.2



HATCH

HATCH LIMITED

NEWFOUNDLAND AND LABRADOR HYDRO

GI1190 – DAM BREAK STUDY

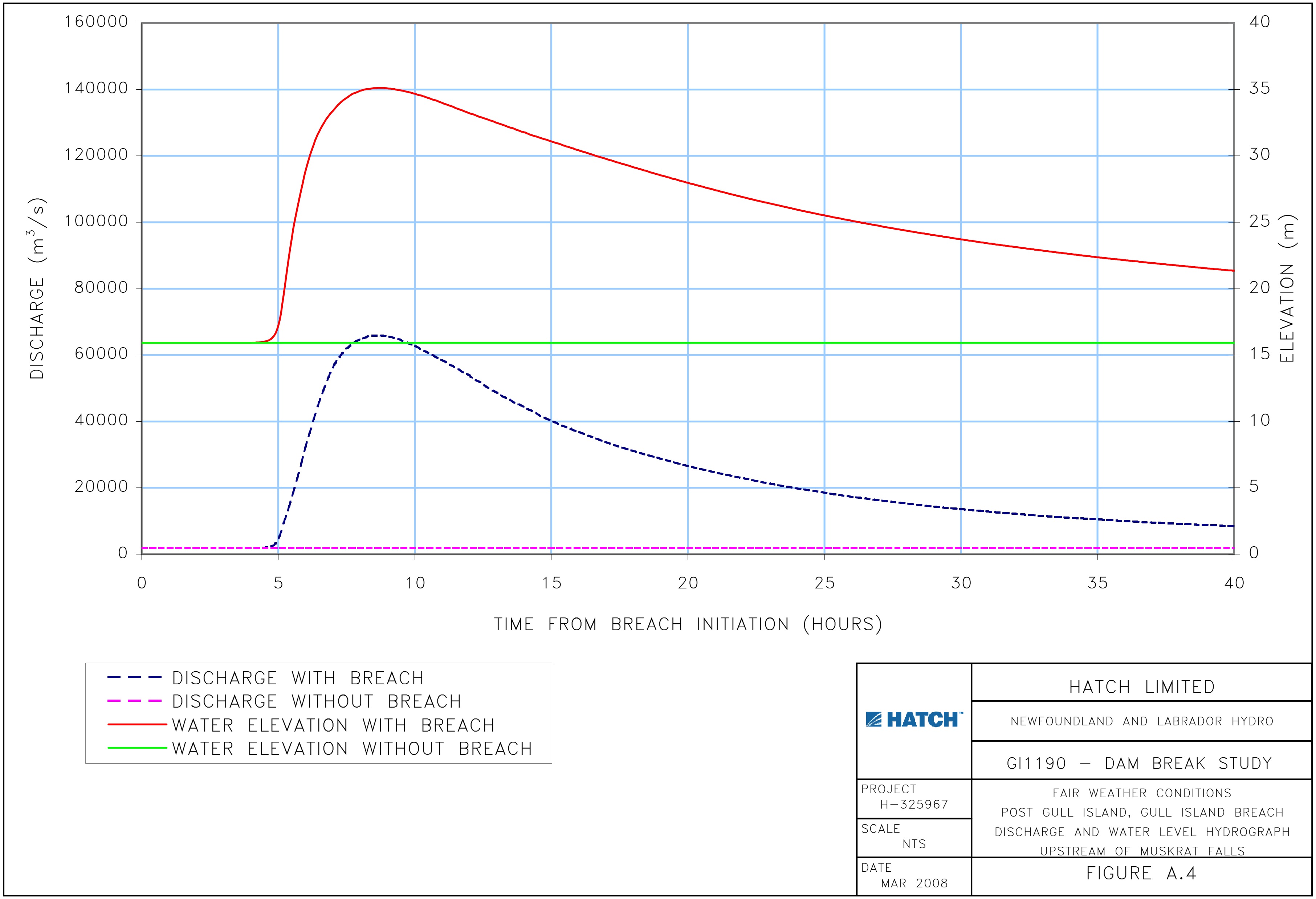
PROJECT H–325967

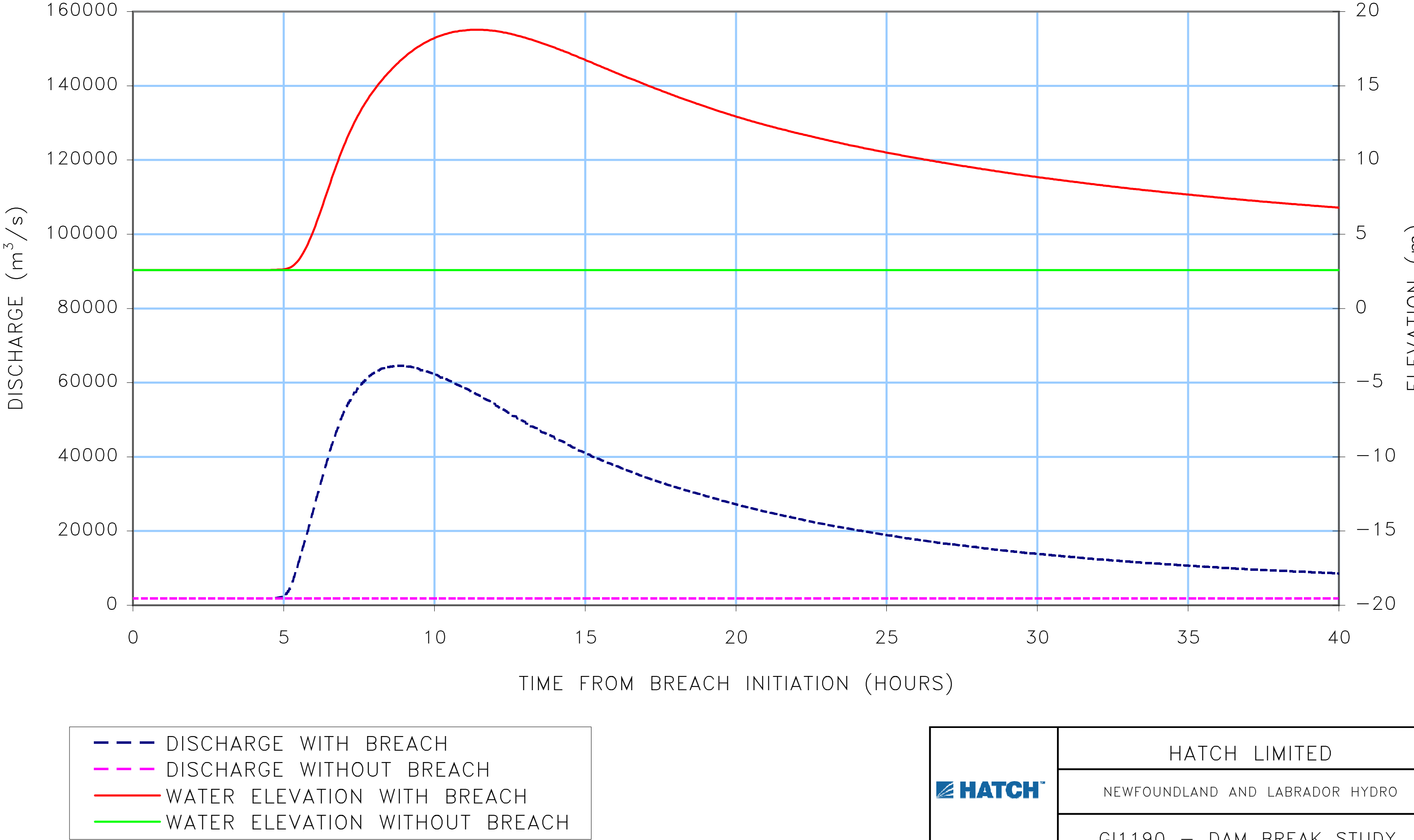
SCALE NTS

DATE MAR 2008

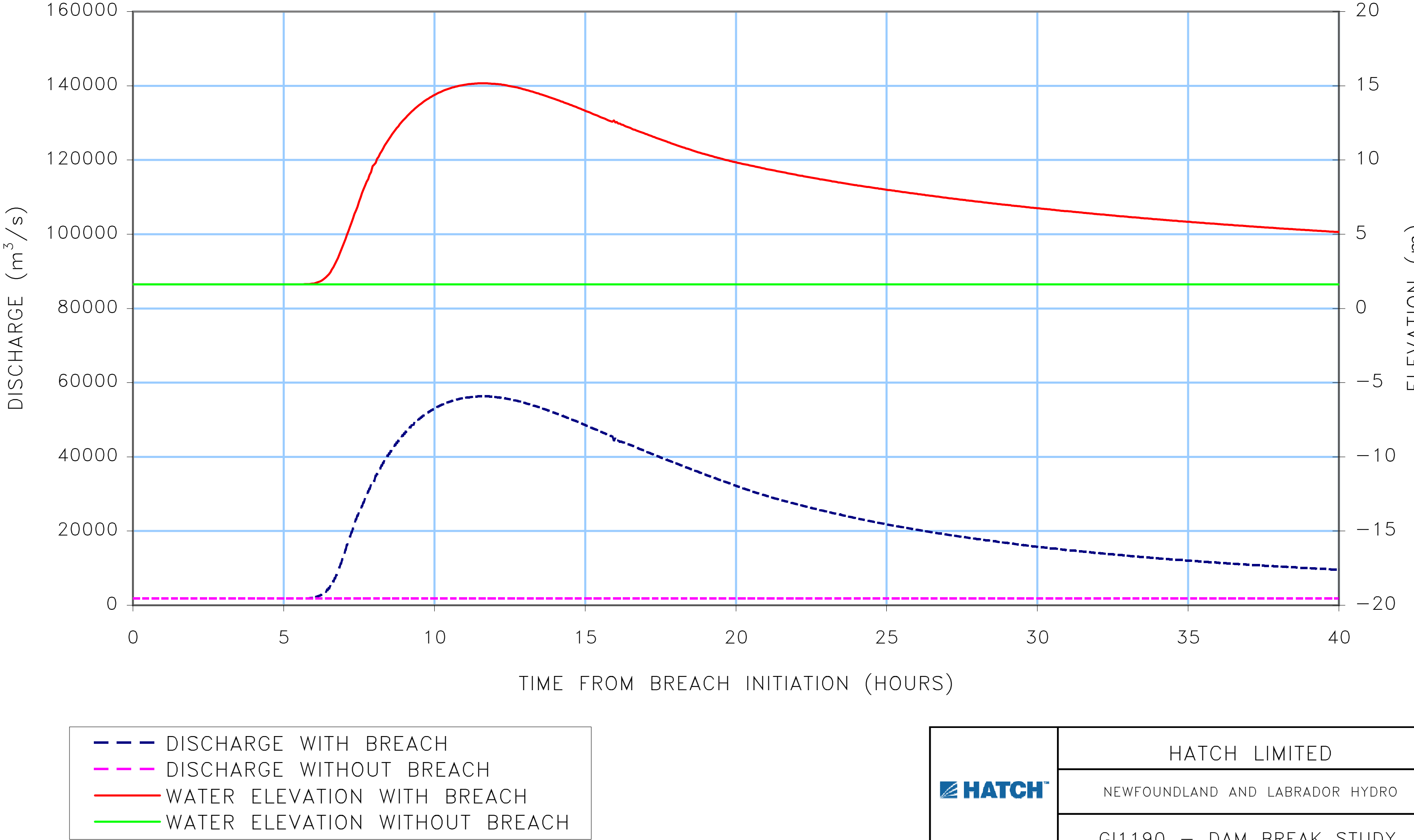
FAIR WEATHER CONDITIONS
POST GULL ISLAND, GULL ISLAND BREACH
DISCHARGE AND WATER LEVEL HYDROGRAPH
DOWNSTREAM OF GULL ISLAND DAM

FIGURE A.3

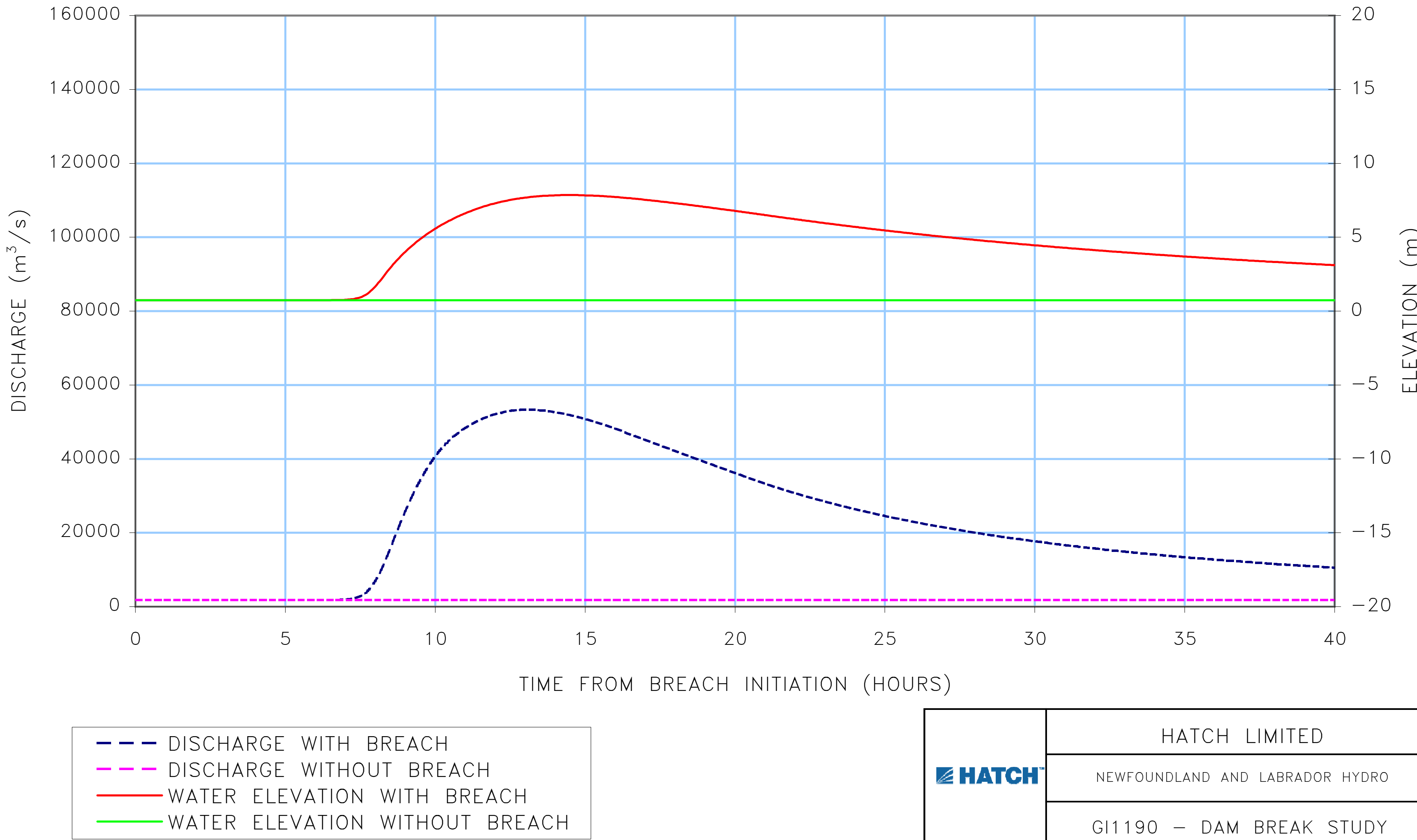

160000
140000
120000
100000
80000
60000
40000
20000
0
DISCHARGE (m³/s)
40
35
30
25
20
15
10
5
0
ELEVATION (m)
0
5
10
15
20
25
30
35
40
TIME FROM BREACH INITIATION (HOURS)
DISCHARGE WITH BREACH
DISCHARGE WITHOUT BREACH
WATER ELEVATION WITH BREACH
WATER ELEVATION WITHOUT BREACH
HATCH
HATCH LIMITED
NEWFOUNDLAND AND LABRADOR HYDRO
GI1190 – DAM BREAK STUDY
PROJECT
H–325967
SCALE
NTS
DATE
MAR 2008
FAIR WEATHER CONDITIONS
POST GULL ISLAND, GULL ISLAND BREACH
DISCHARGE AND WATER LEVEL HYDROGRAPH
UPSTREAM OF MUSKRAT FALLS
FIGURE A.4



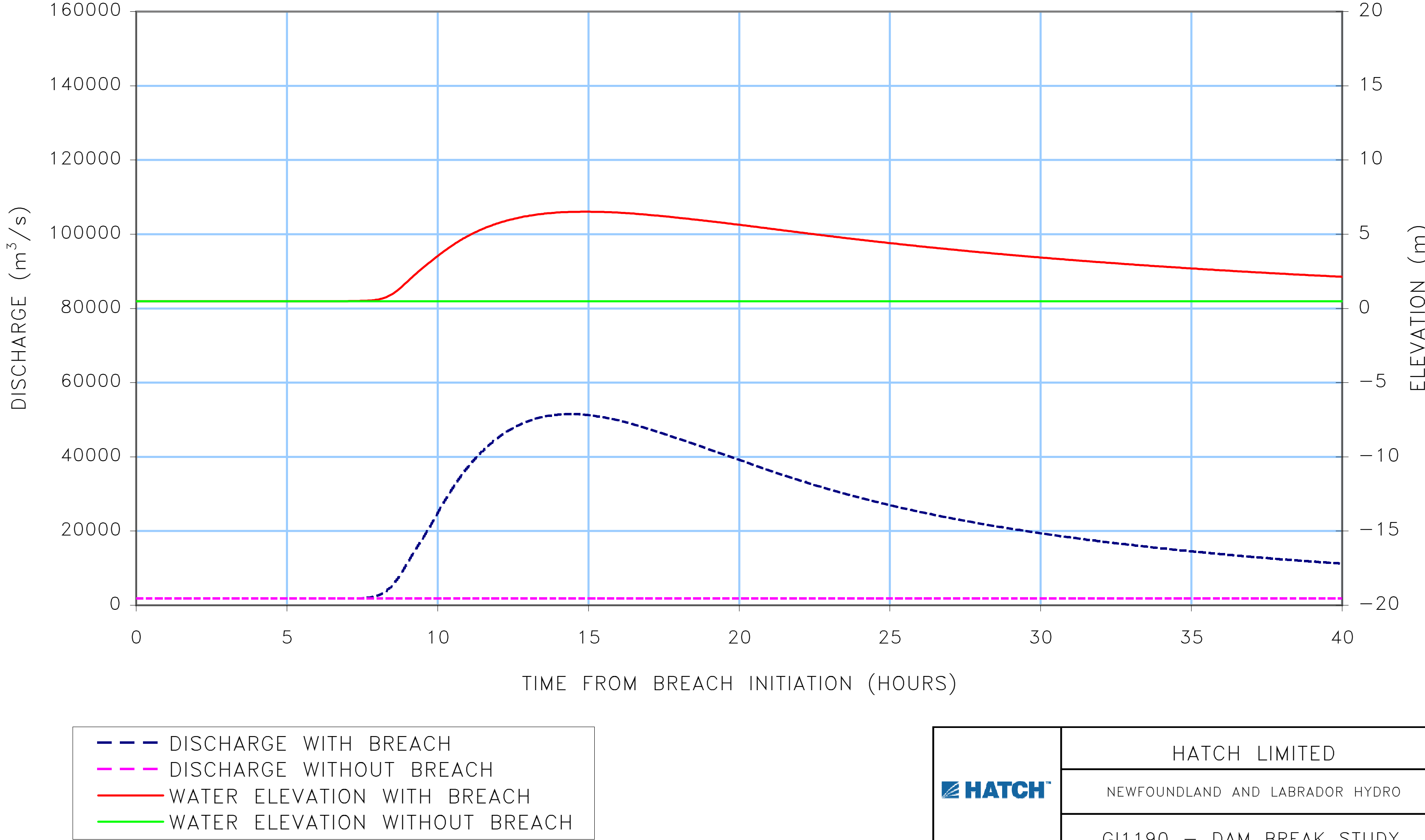
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST GULL ISLAND, GULL ISLAND BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH DOWNSTREAM OF MUSKRAT FALLS
SCALE NTS	
DATE MAR 2008	FIGURE A.5



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST GULL ISLAND, GULL ISLAND BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH BLACKROCK BRIDGE
SCALE NTS	
DATE MAR 2008	FIGURE A.6



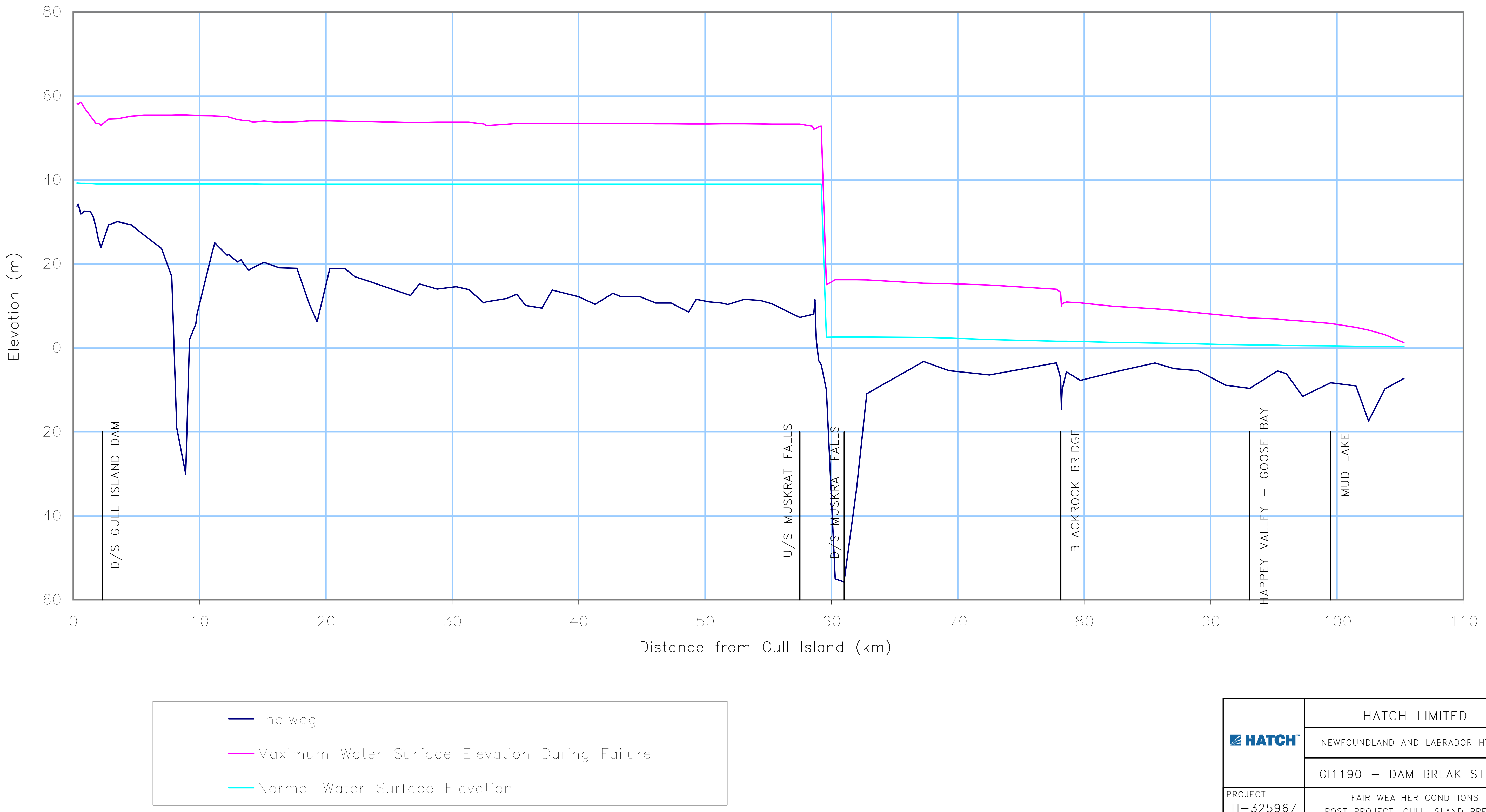
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST GULL ISLAND, GULL ISLAND BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH HAPPY VALLEY–GOOSE BAY
SCALE NTS	
DATE MAR 2008	FIGURE A.7



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST GULL ISLAND, GULL ISLAND BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH MUD LAKE
SCALE NTS	
DATE MAR 2008	FIGURE A.8

Appendix B

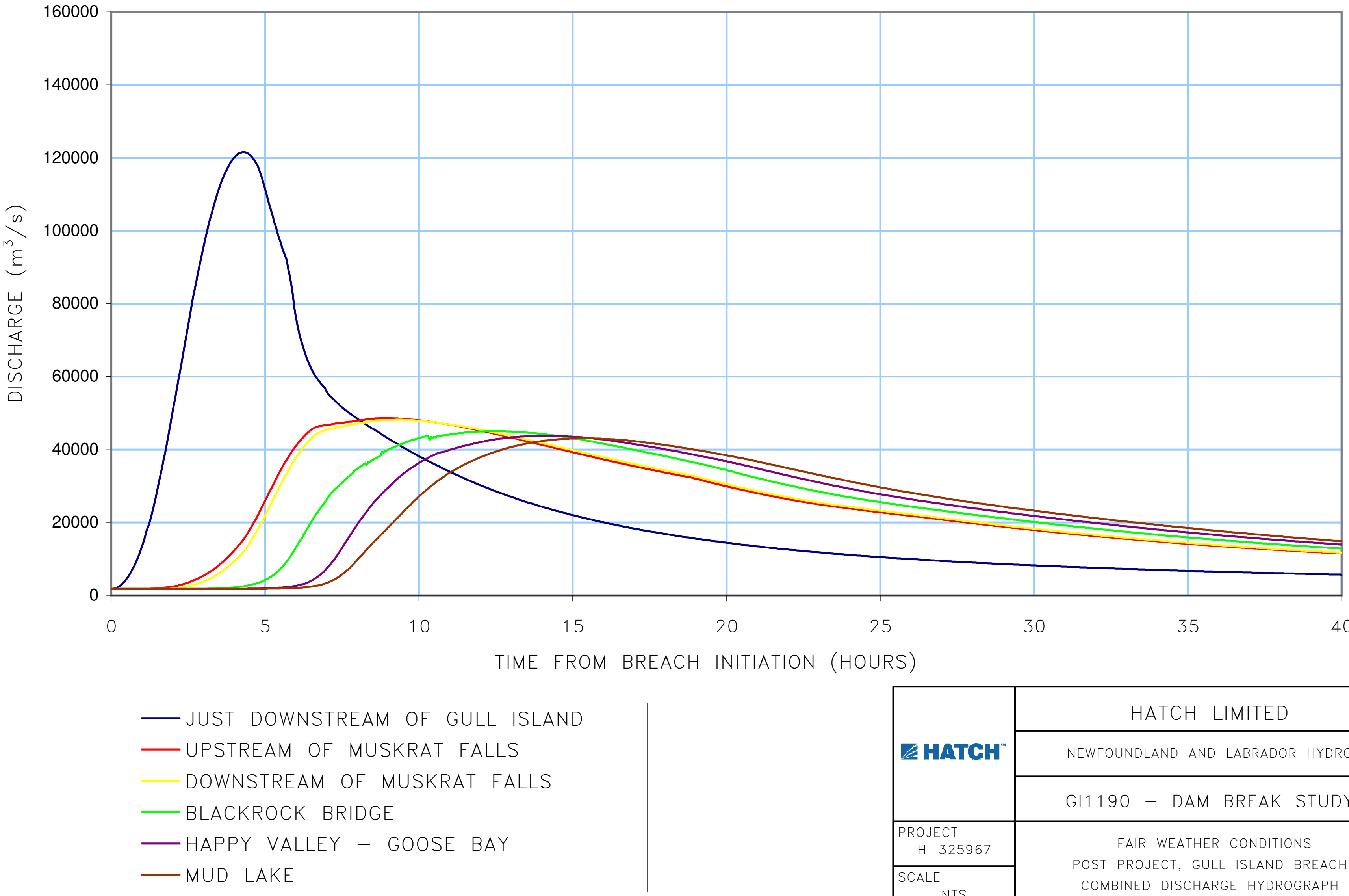
"Fair Weather" Conditions – Post Gull Island and Muskrat Falls – Gull Island Dam Failure



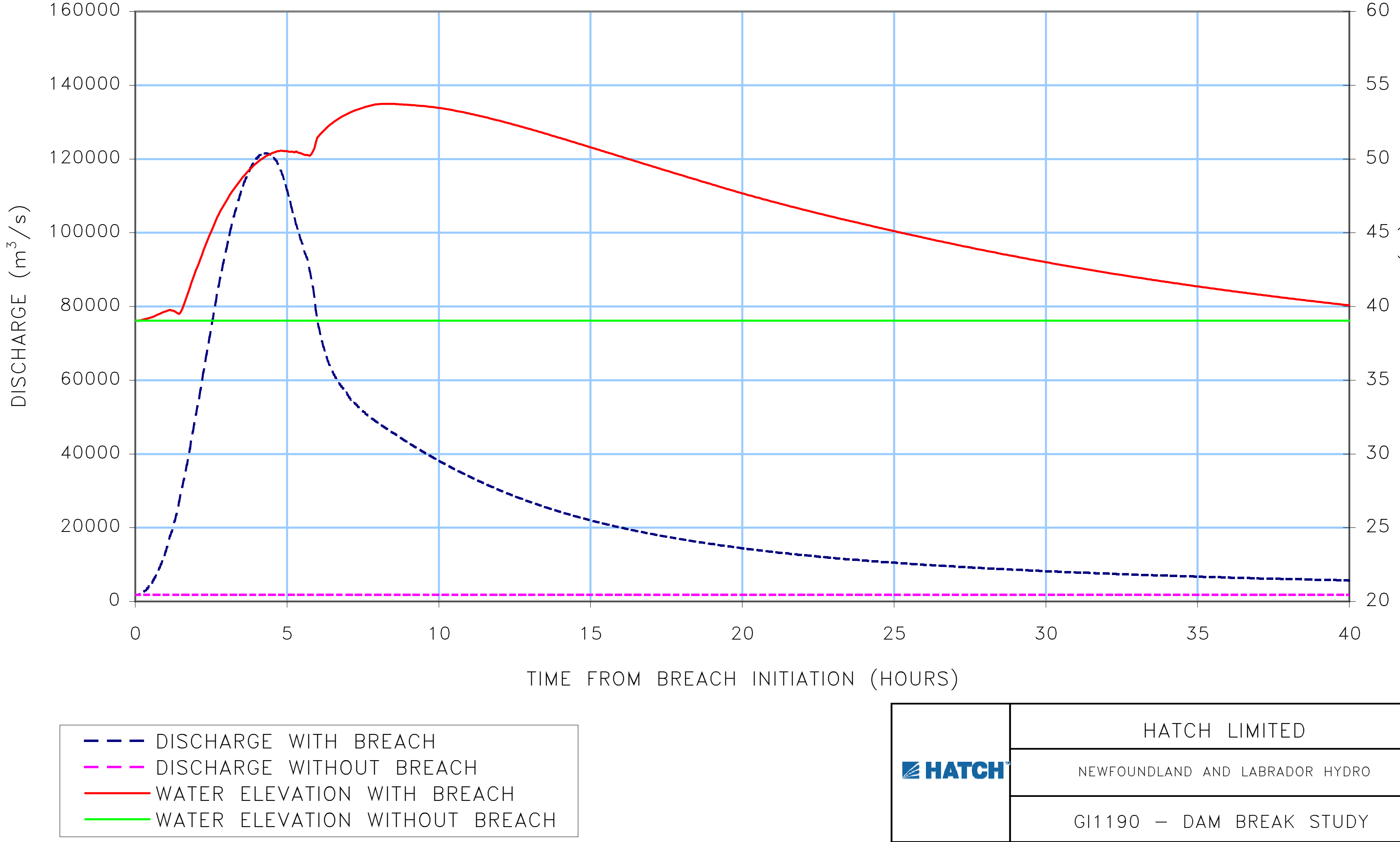
HATCH LIMITED
NEWFOUNDLAND AND LABRADOR HYDRO
GI1190 – DAM BREAK STUDY
FAIR WEATHER CONDITIONS
POST PROJECT, GULL ISLAND BREACH
MAXIMUM WATER ELEVATION PROFILES

PROJECT H–325967
SCALE NTS
DATE MAR 2008

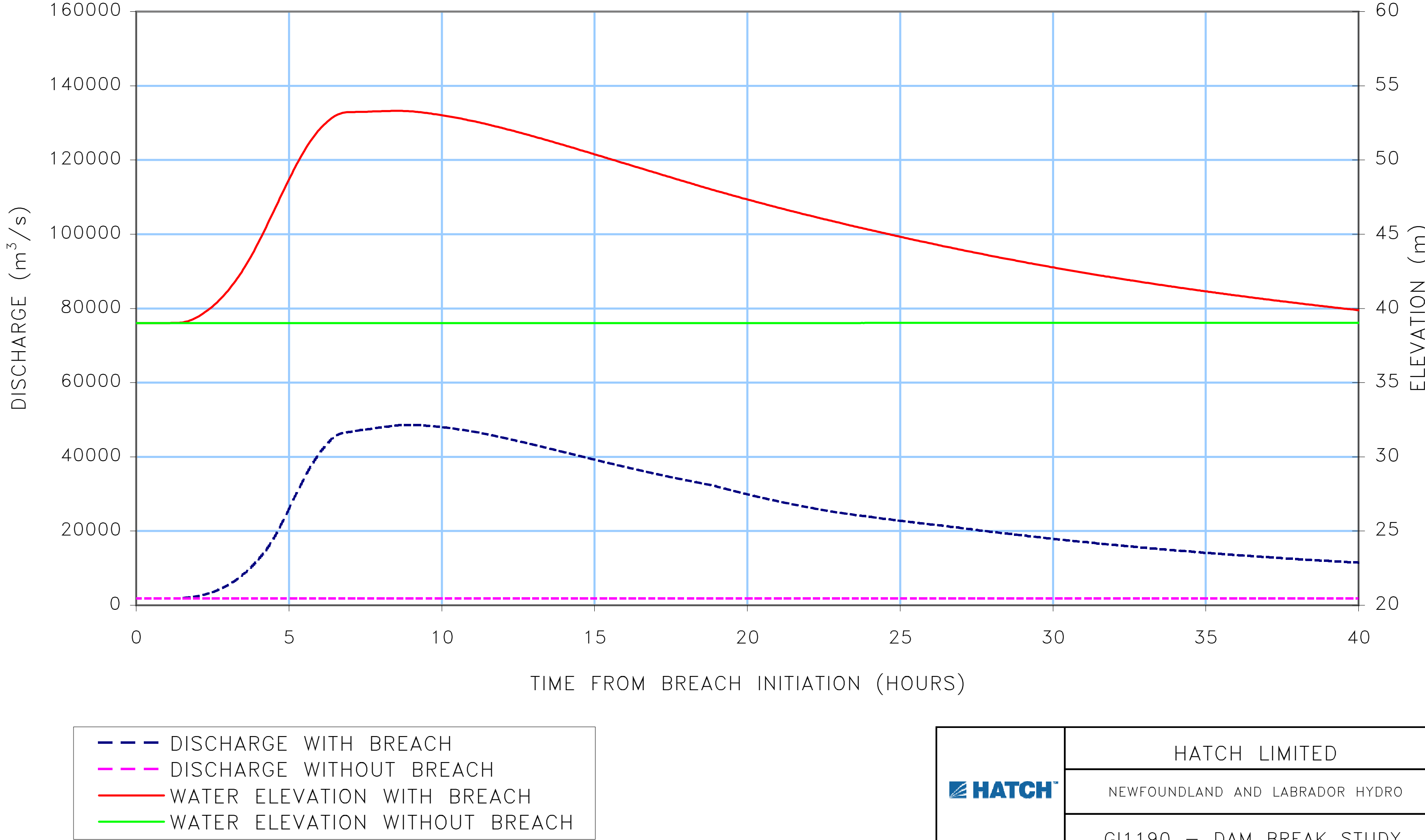
FIGURE B.1



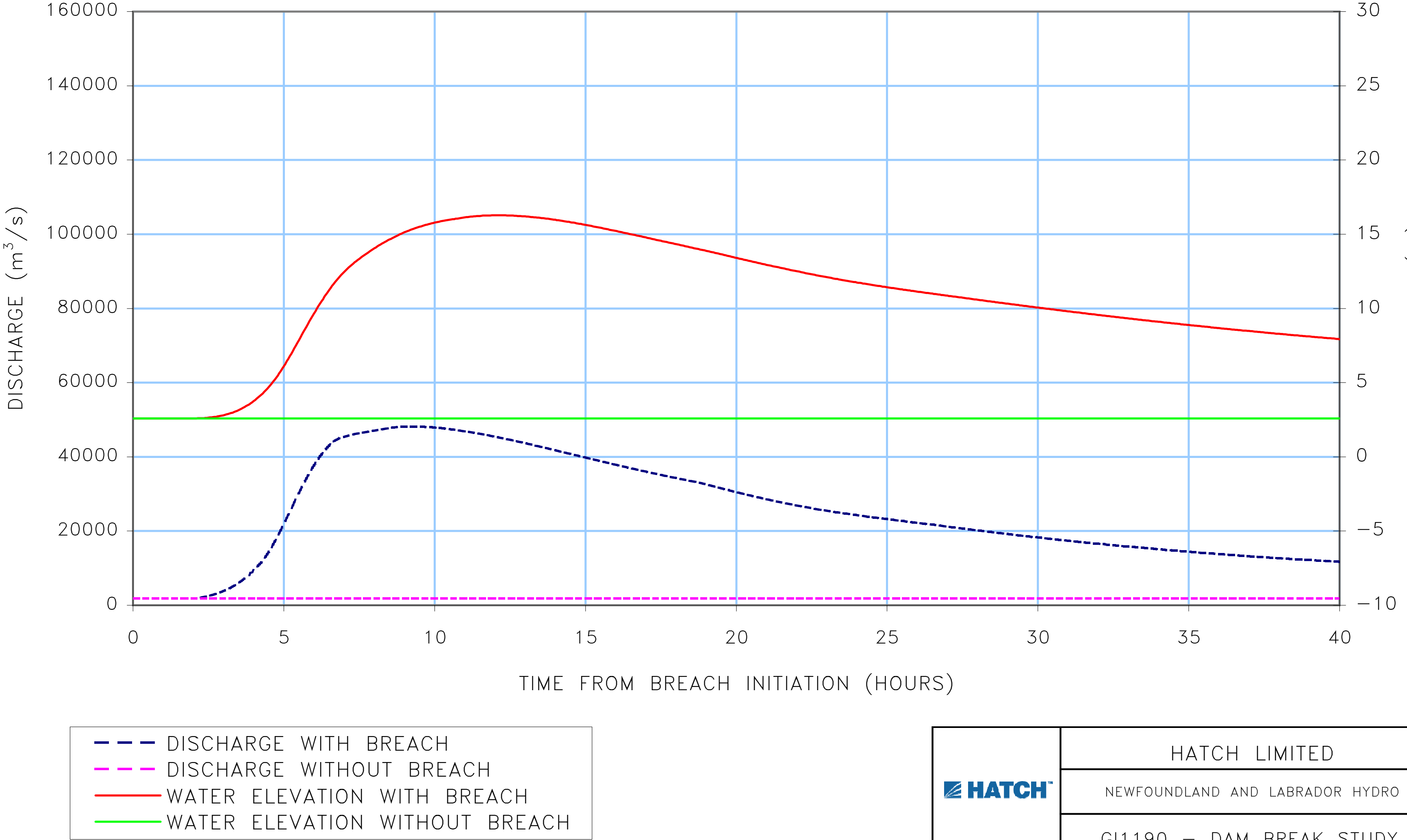
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST PROJECT, GULL ISLAND BREACH COMBINED DISCHARGE HYDROGRAPH
SCALE NTS	
DATE MAR 2008	FIGURE B.2



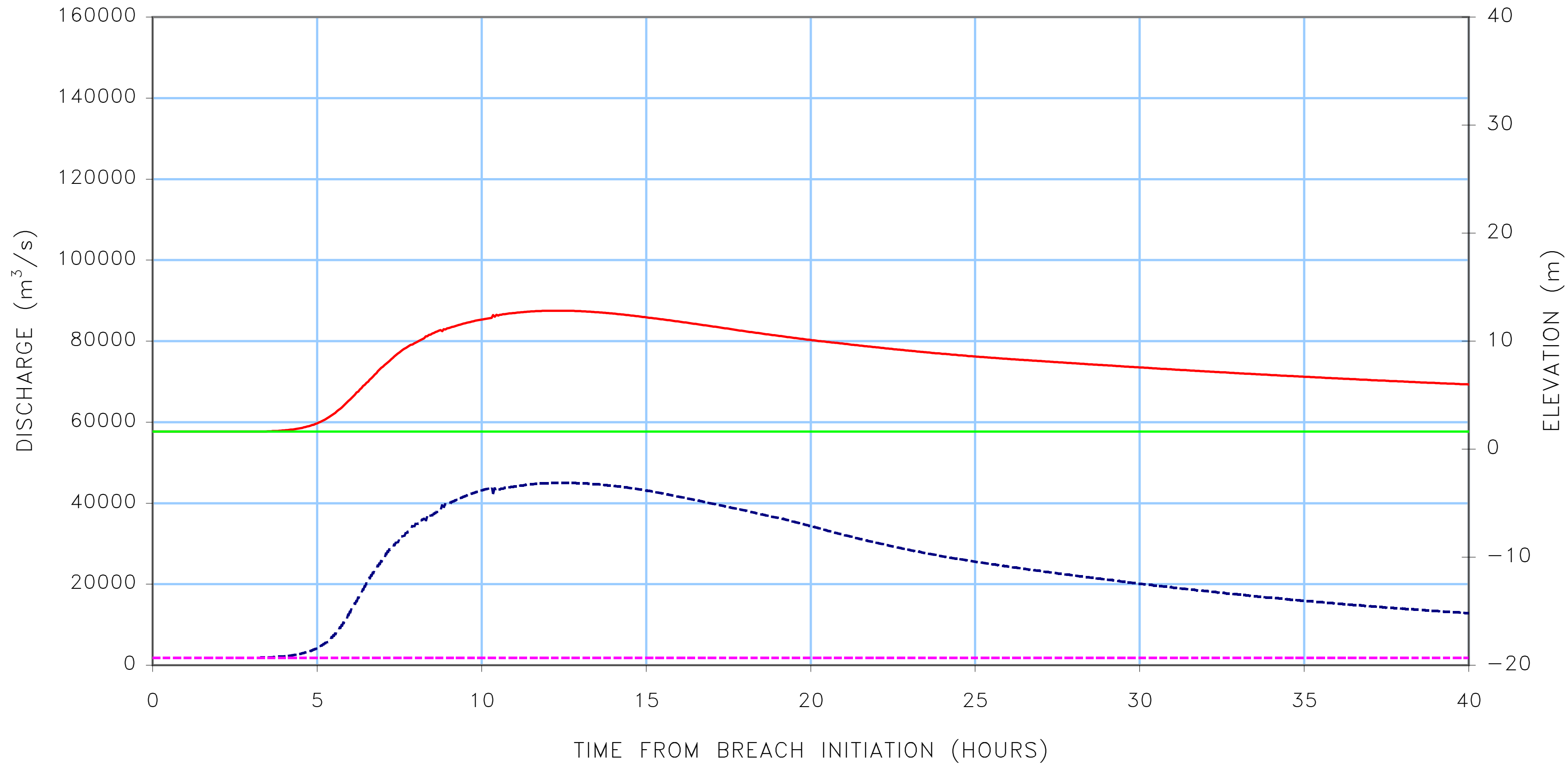
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST PROJECT, GULL ISLAND BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH DOWNSTREAM OF GULL ISLAND DAM
SCALE NTS	
DATE MAR 2008	FIGURE B.3



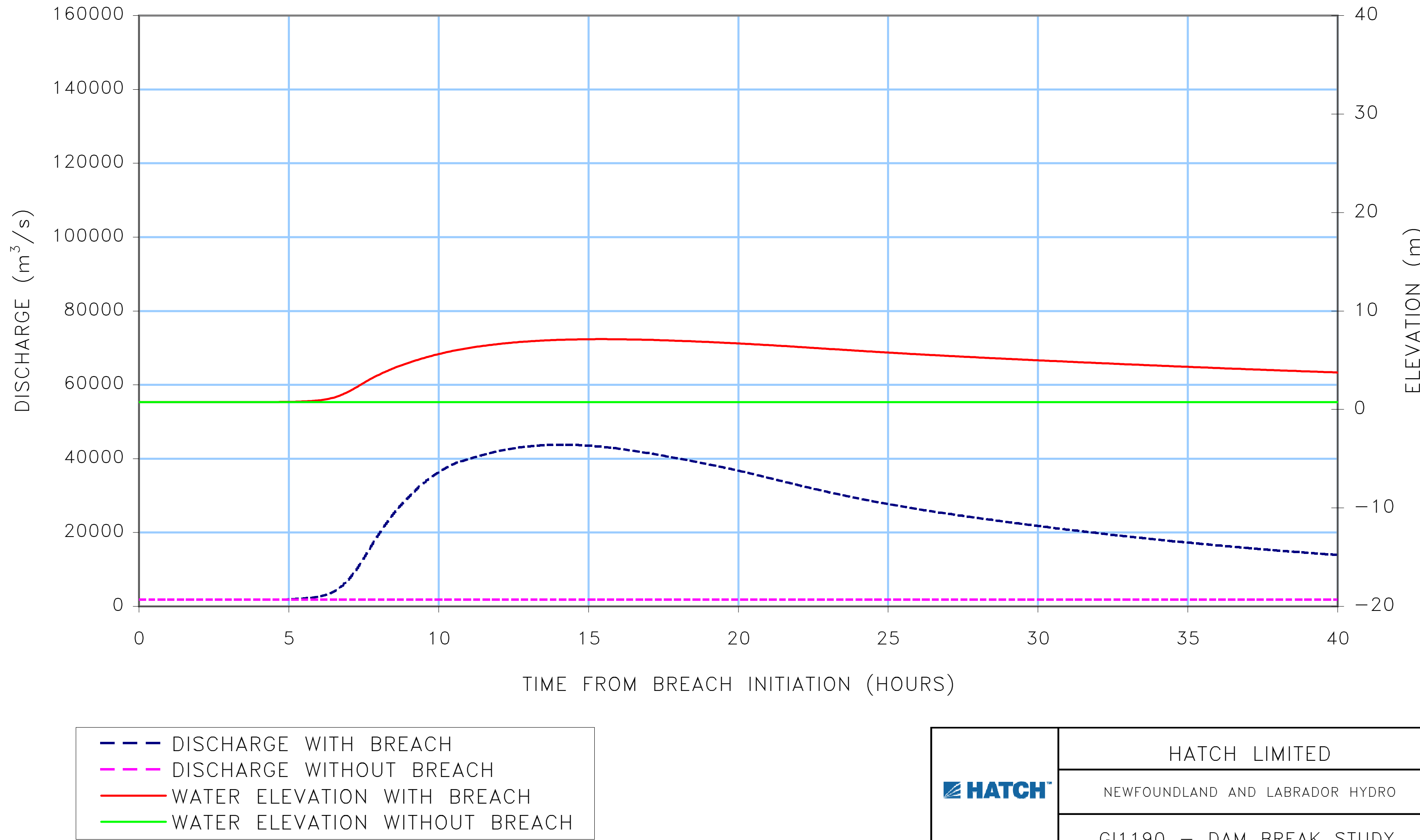
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST PROJECT, GULL ISLAND BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH UPSTREAM OF MUSKRAT FALLS
SCALE NTS	
DATE MAR 2008	FIGURE B.4



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H-325967	FAIR WEATHER CONDITIONS POST PROJECT, GULL ISLAND BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH DOWNSTREAM OF MUSKRAT FALLS
SCALE NTS	
DATE MAR 2008	FIGURE B.5



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST PROJECT, GULL ISLAND BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH BLACKROCK BRIDGE
SCALE NTS	
DATE MAR 2008	FIGURE B.6



HATCH

HATCH LIMITED

NEWFOUNDLAND AND LABRADOR HYDRO

GI1190 – DAM BREAK STUDY

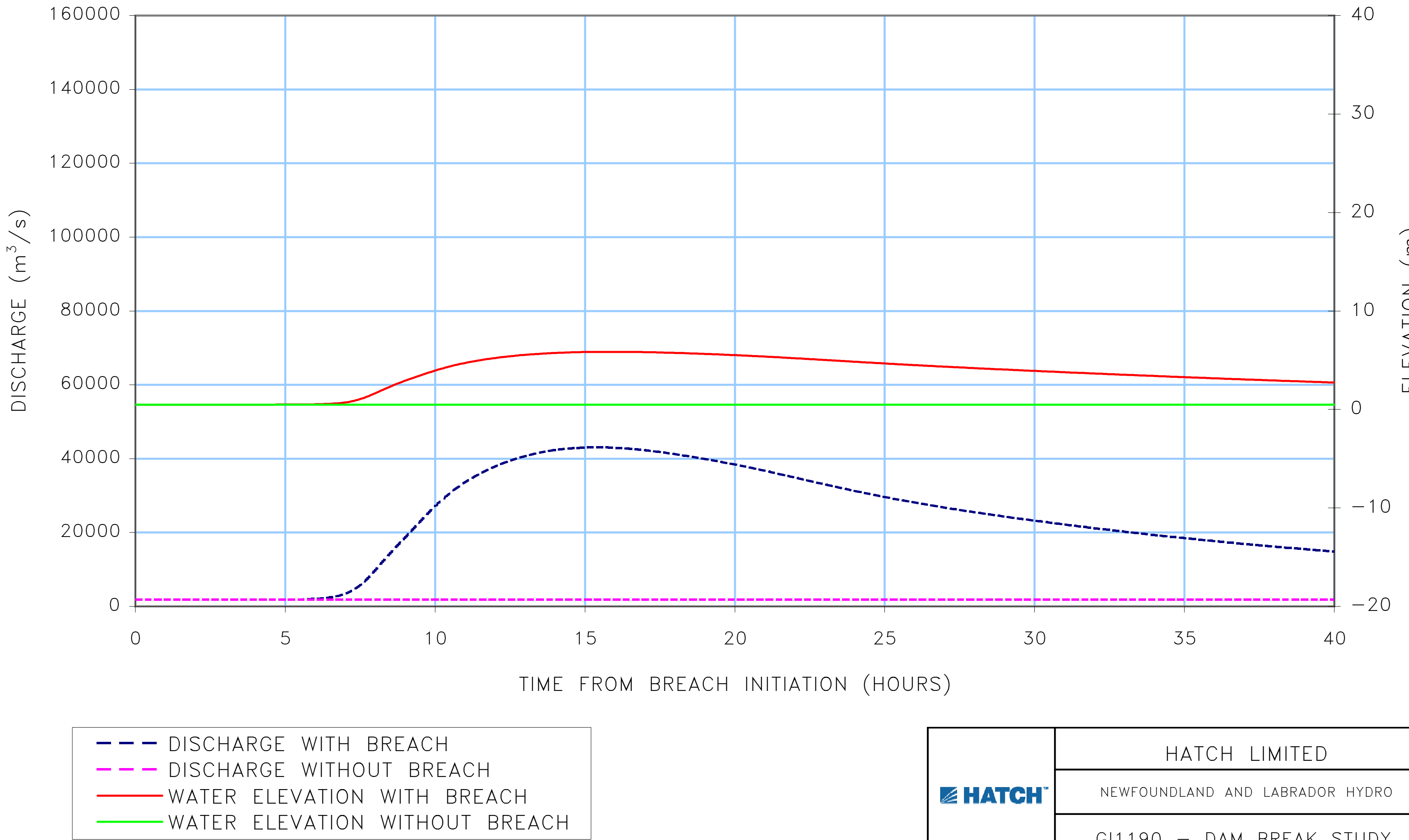
PROJECT H–325967

SCALE NTS

DATE MAR 2008

FAIR WEATHER CONDITIONS
POST PROJECT, GULL ISLAND BREACH
DISCHARGE AND WATER LEVEL HYDROGRAPH
HAPPY VALLEY–GOOSE BAY

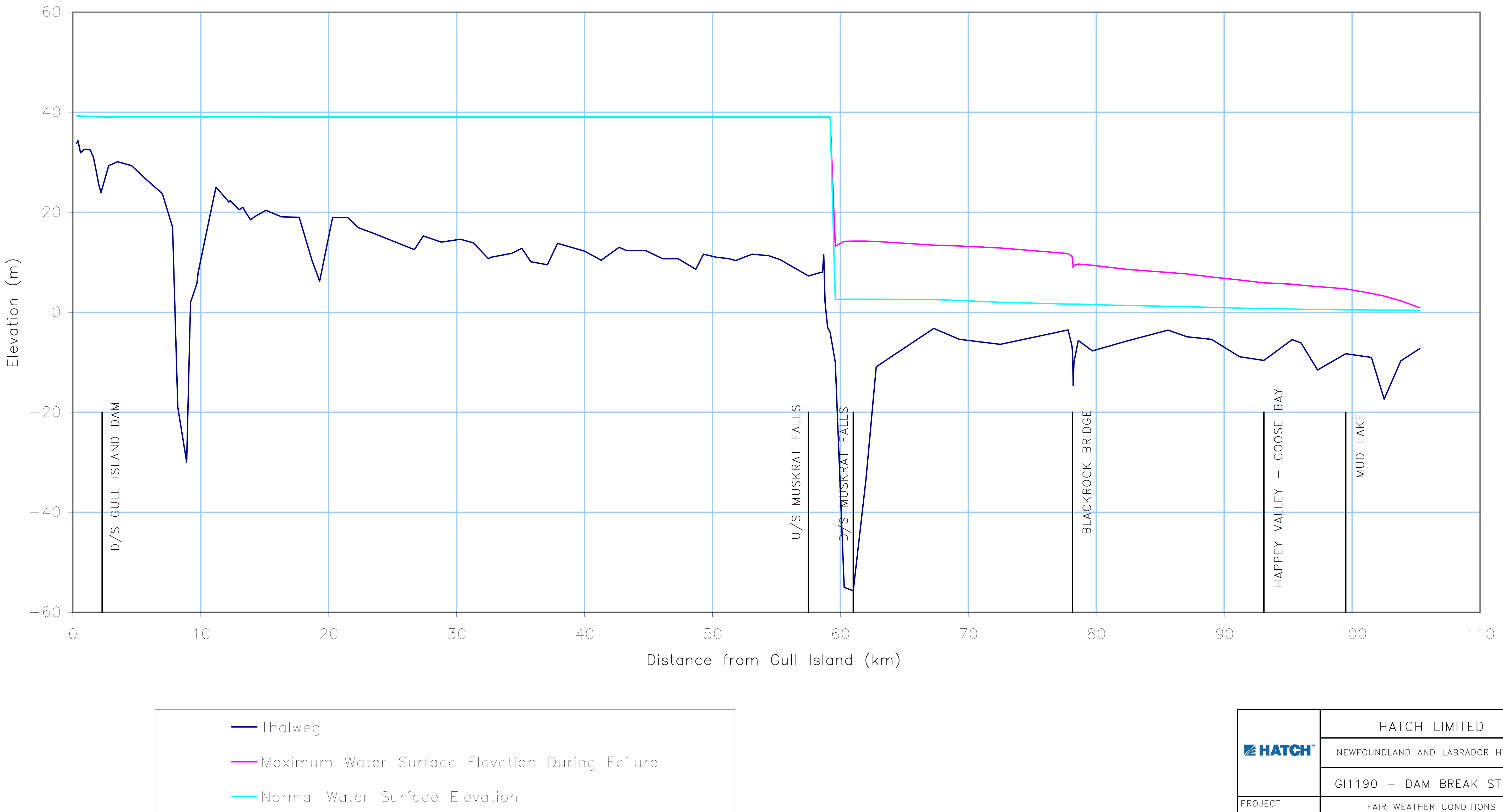
FIGURE B.7



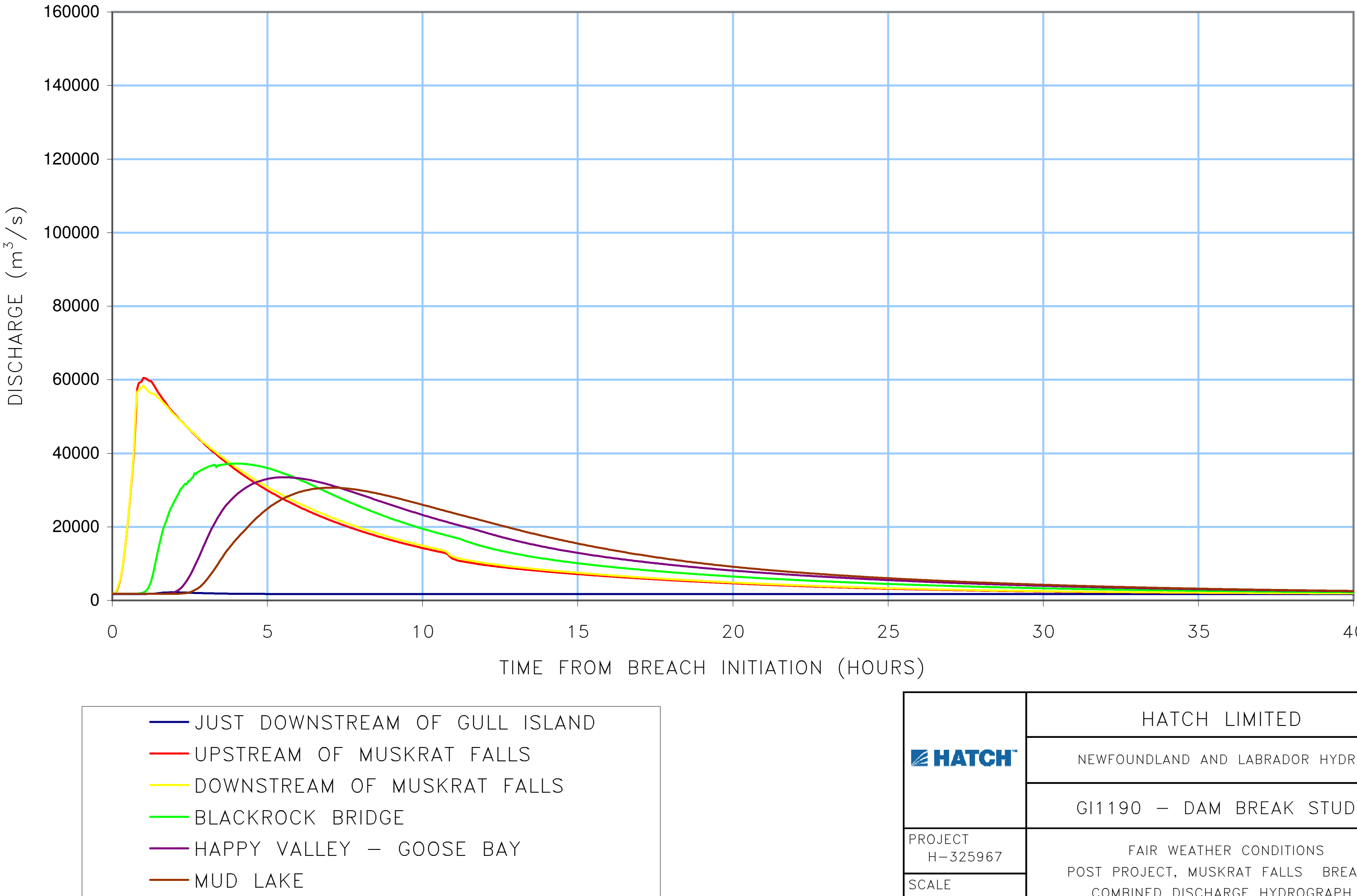
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST PROJECT, GULL ISLAND BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH MUD LAKE
SCALE NTS	
DATE MAR 2008	FIGURE B.8

Appendix C

"Fair Weather" Conditions – Post Gull Island and Muskrat Falls – Muskrat Falls Dam Failure

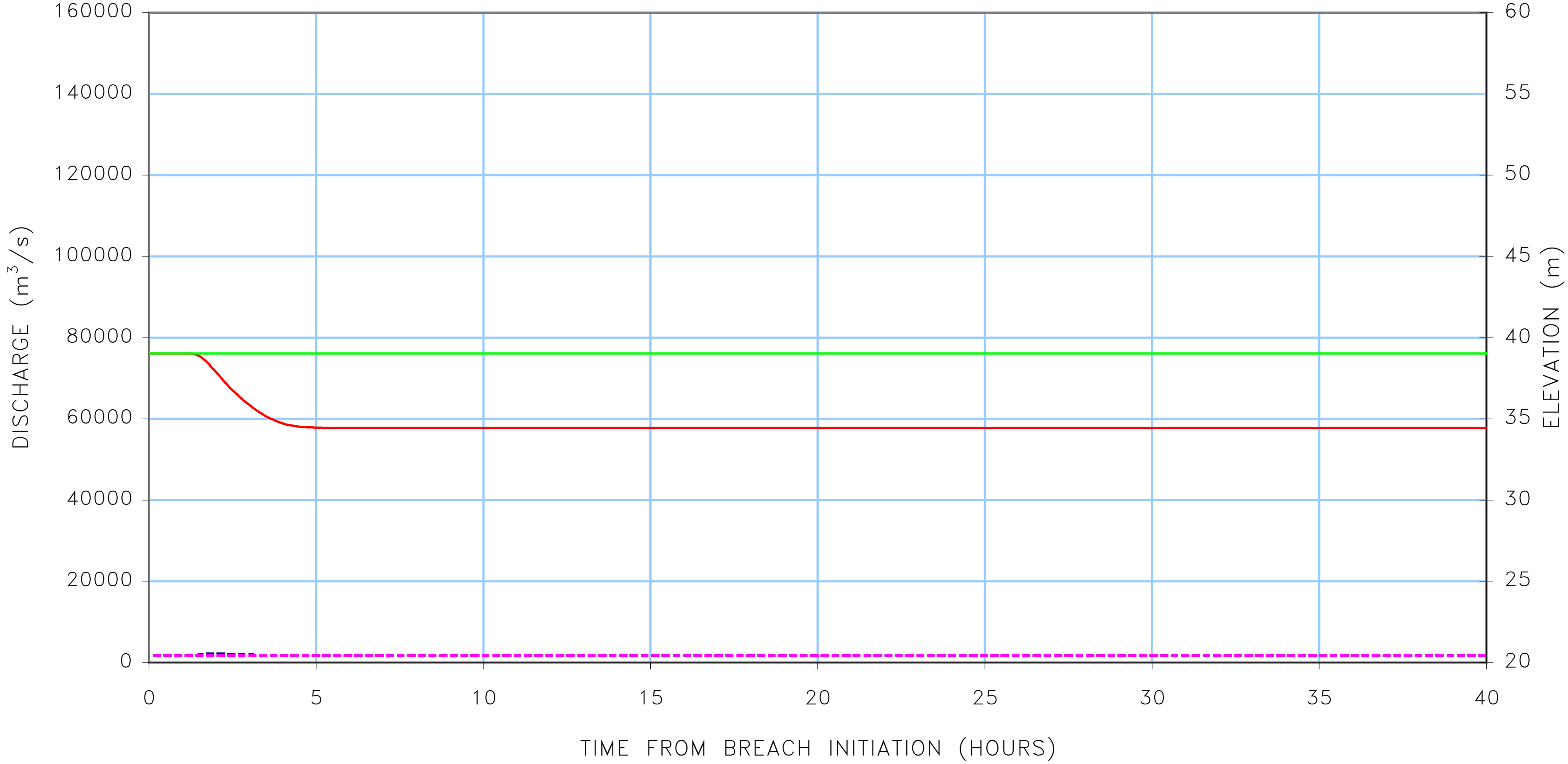


HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H-325967	FAIR WEATHER CONDITIONS POST PROJECT, MUSKRAT FALLS BREACH MAXIMUM WATER ELEVATION PROFILES
SCALE NTS	
DATE MAR 2008	FIGURE C.1

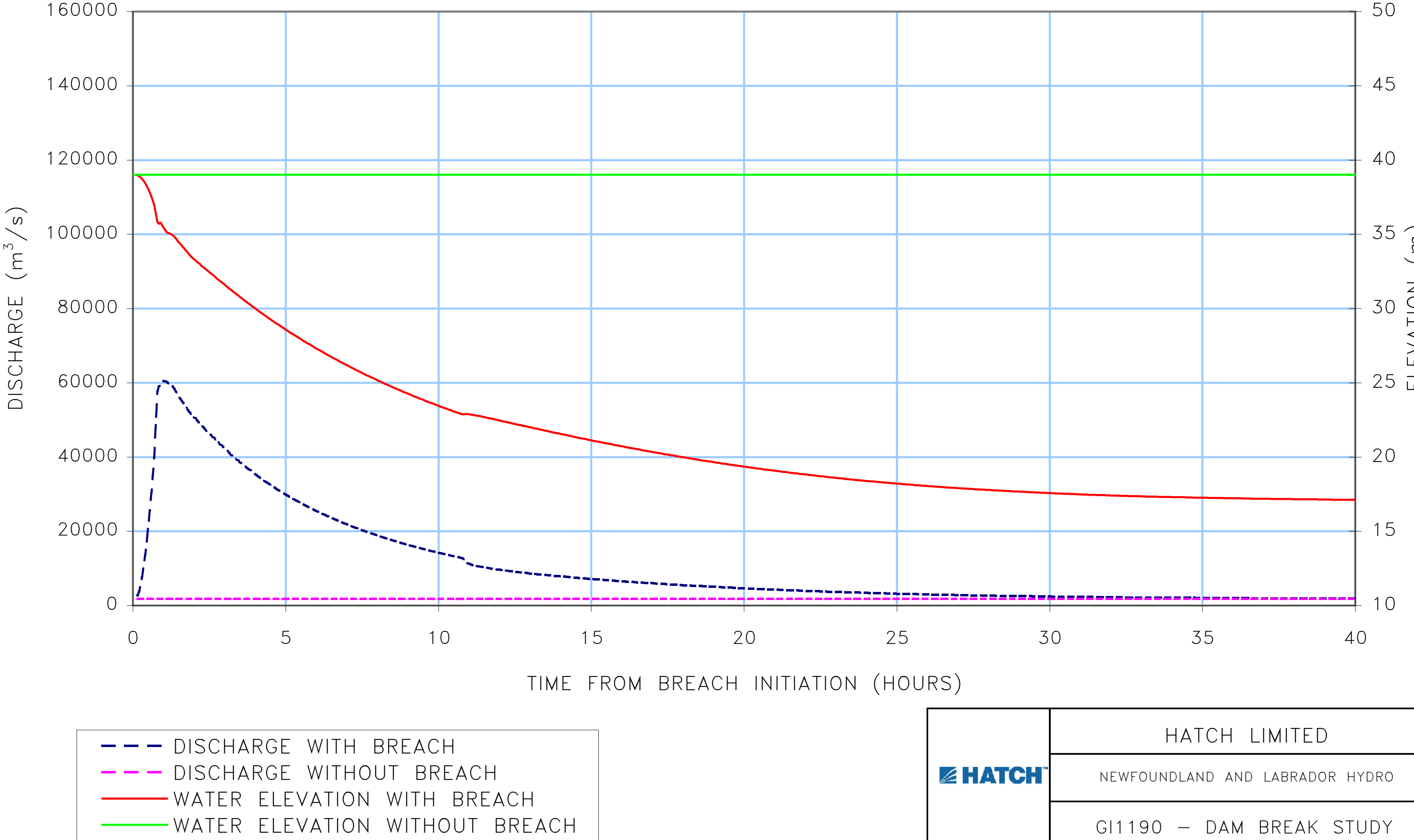


Note: Discharge upstream of Muskrat Falls is high due to downstream breach.

HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST PROJECT, MUSKRAT FALLS BREACH COMBINED DISCHARGE HYDROGRAPH
SCALE NTS	
DATE MAR 2008	FIGURE C.2

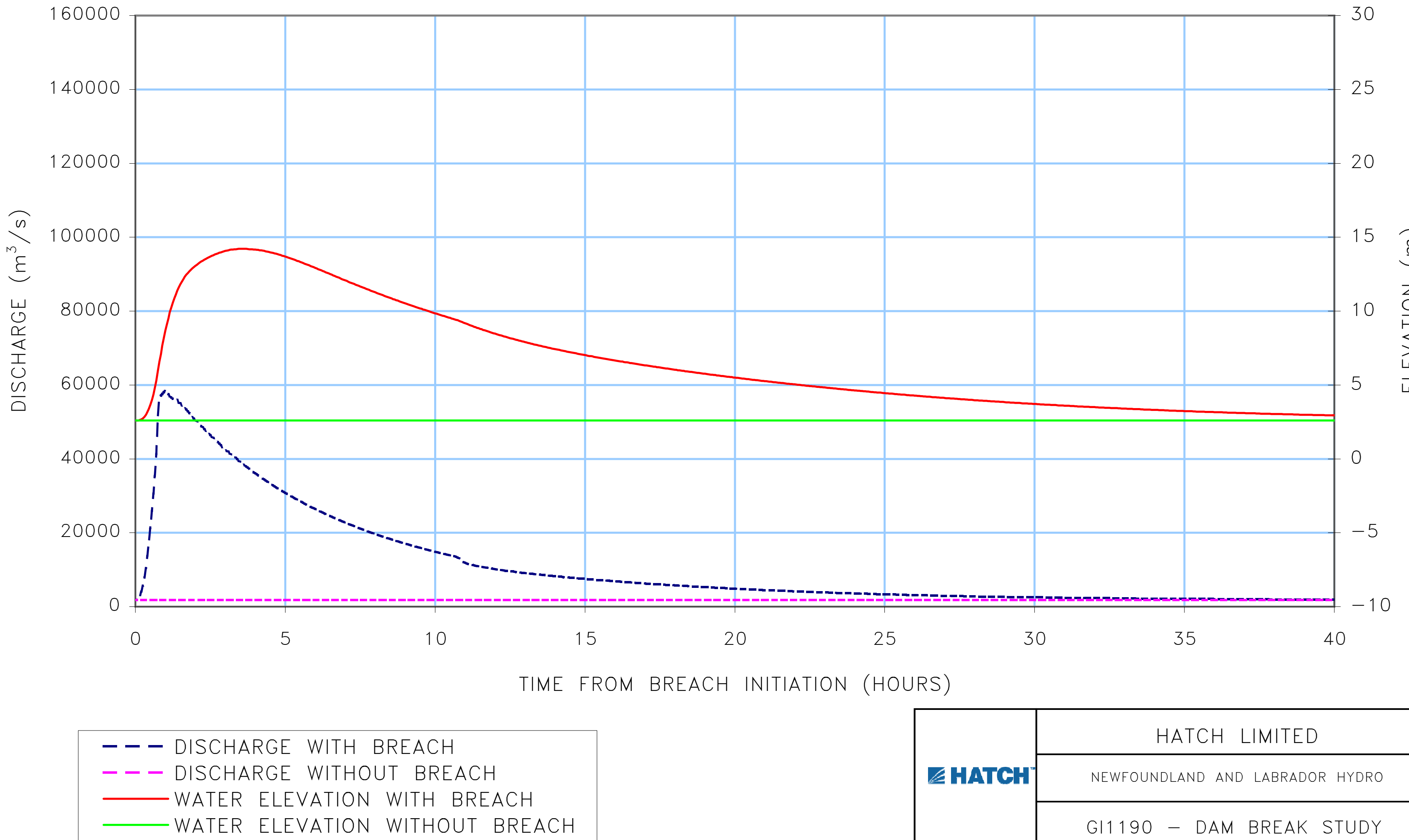


HATCH	HATCH LIMITED	
	NEWFOUNDLAND AND LABRADOR HYDRO	
	GI1190 – DAM BREAK STUDY	
PROJECT H–325967	FAIR WEATHER CONDITIONS POST PROJECT, MUSKRAT FALLS BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH DOWNSTREAM OF GULL ISLAND DAM	
SCALE NTS		
JAN 2008 MAR 2008	FIGURE C.3	

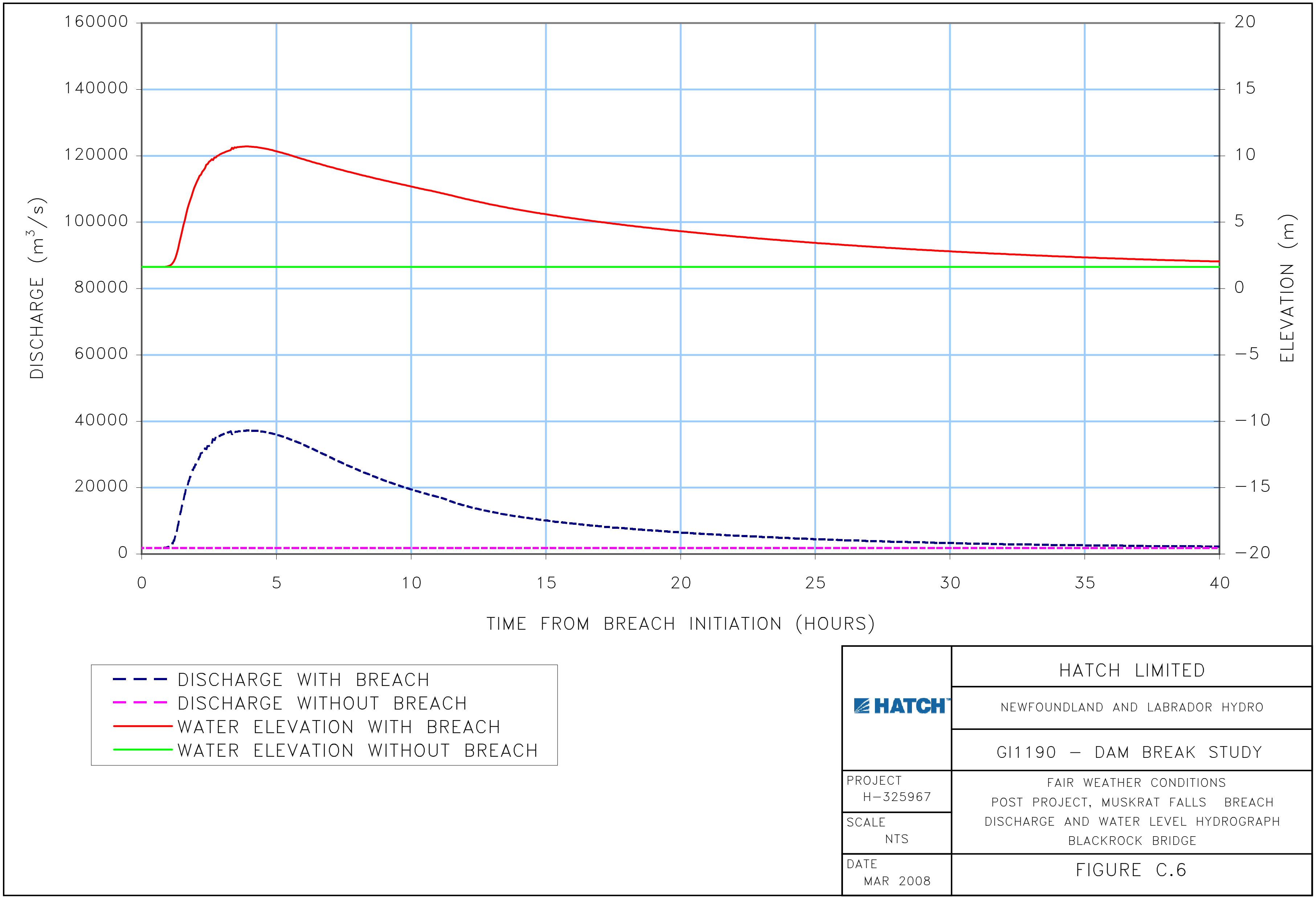


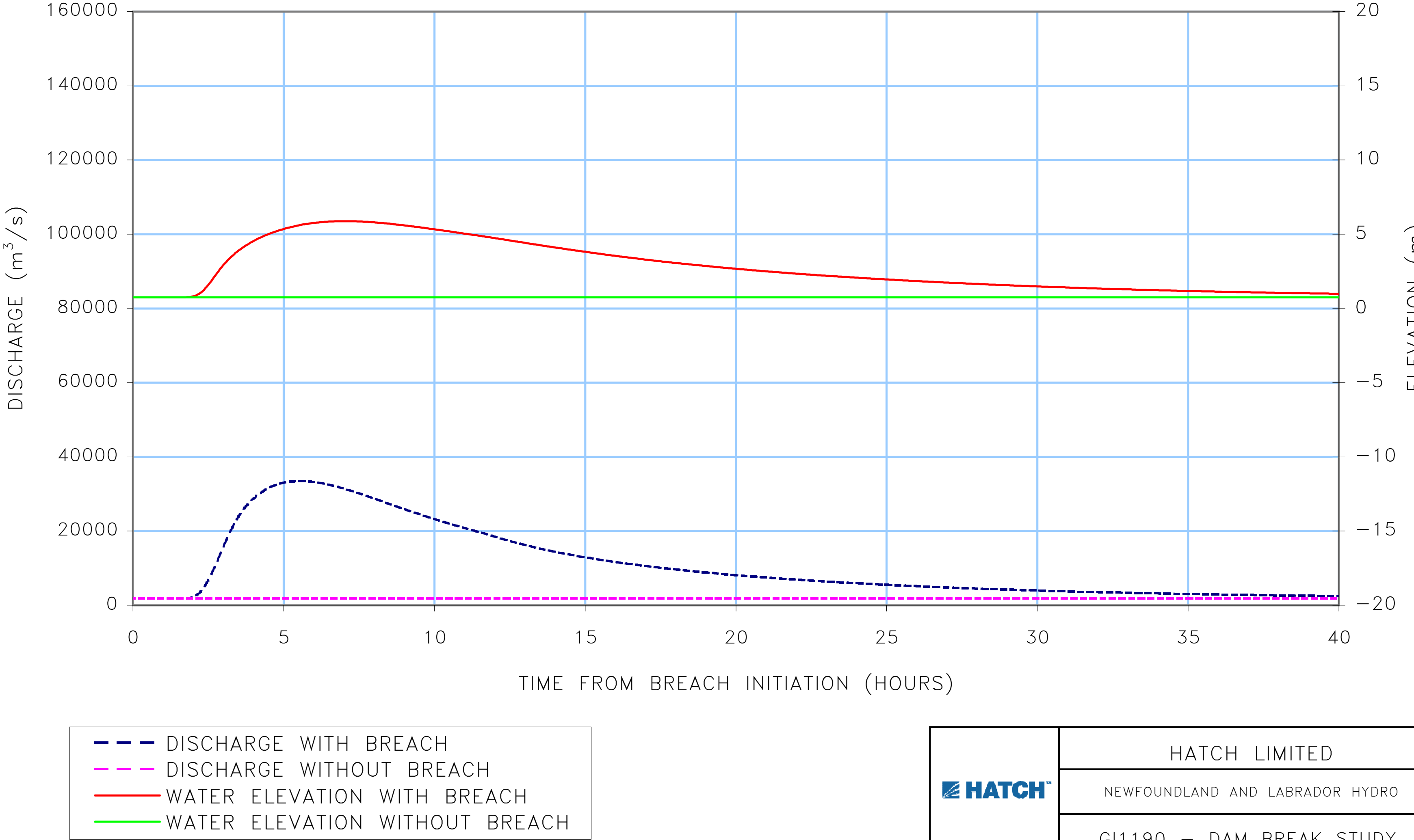
Note: Discharge upstream of Muskrat Falls is high due to downstream breach.

HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST PROJECT, MUSKRAT FALLS BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH UPSTREAM OF MUSKRAT FALLS
SCALE NTS	
DATE MAR 2008	FIGURE C.4

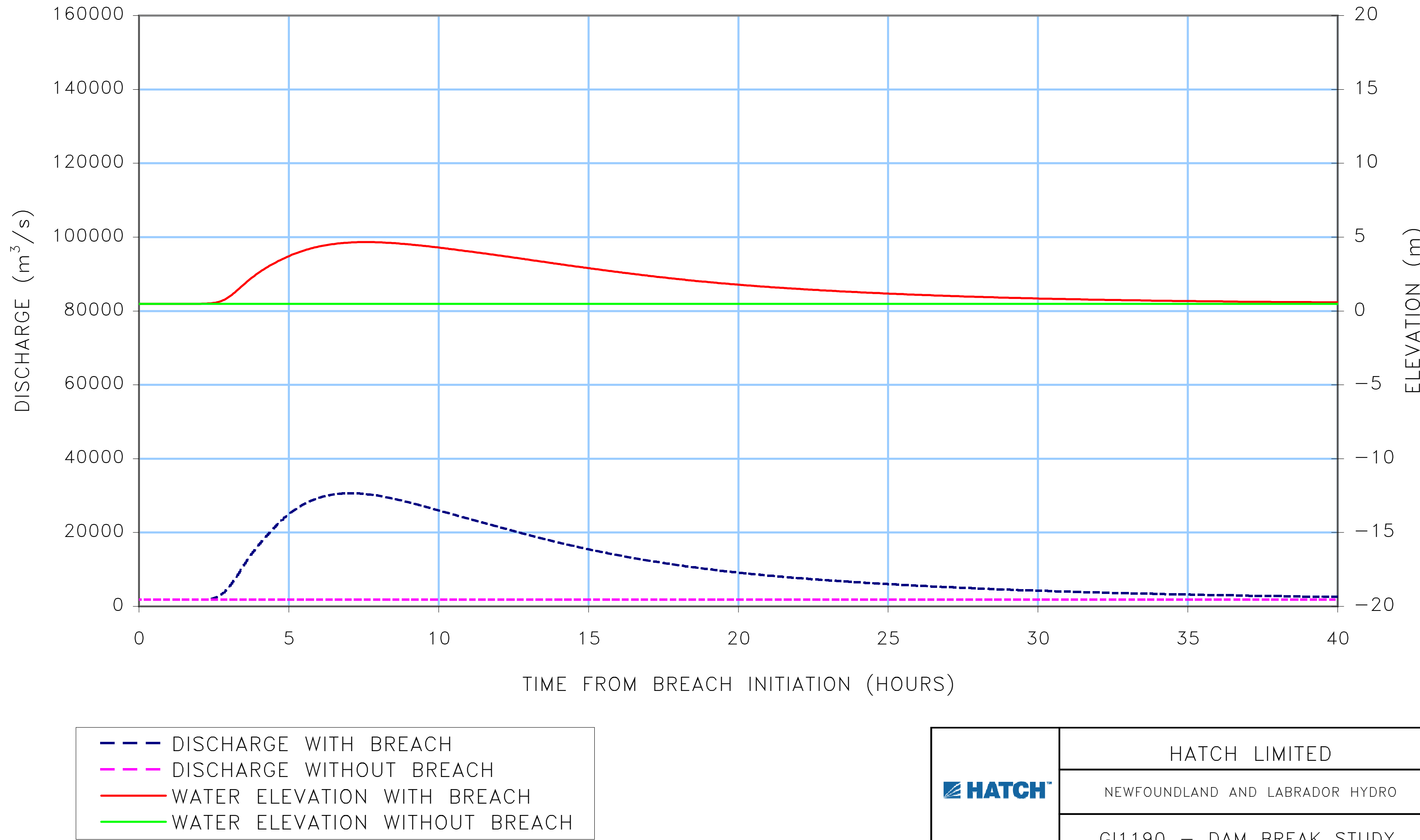


HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST PROJECT, MUSKRAT FALLS BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH DOWNSTREAM OF MUSKRAT FALLS
SCALE NTS	
DATE MAR 2008	FIGURE C.5


160000
140000
120000
100000
80000
60000
40000
20000
0
DISCHARGE (m³/s)
20
15
10
5
0
−5
−10
−15
−20
ELEVATION (m)
0
5
10
15
20
25
30
35
40
TIME FROM BREACH INITIATION (HOURS)
DISCHARGE WITH BREACH
DISCHARGE WITHOUT BREACH
WATER ELEVATION WITH BREACH
WATER ELEVATION WITHOUT BREACH
HATCH LIMITED
HATCH
NEWFOUNDLAND AND LABRADOR HYDRO
GI1190 – DAM BREAK STUDY
PROJECT H–325967
SCALE NTS
DATE MAR 2008
FAIR WEATHER CONDITIONS
POST PROJECT, MUSKRAT FALLS BREACH
DISCHARGE AND WATER LEVEL HYDROGRAPH
BLACKROCK BRIDGE
FIGURE C.6



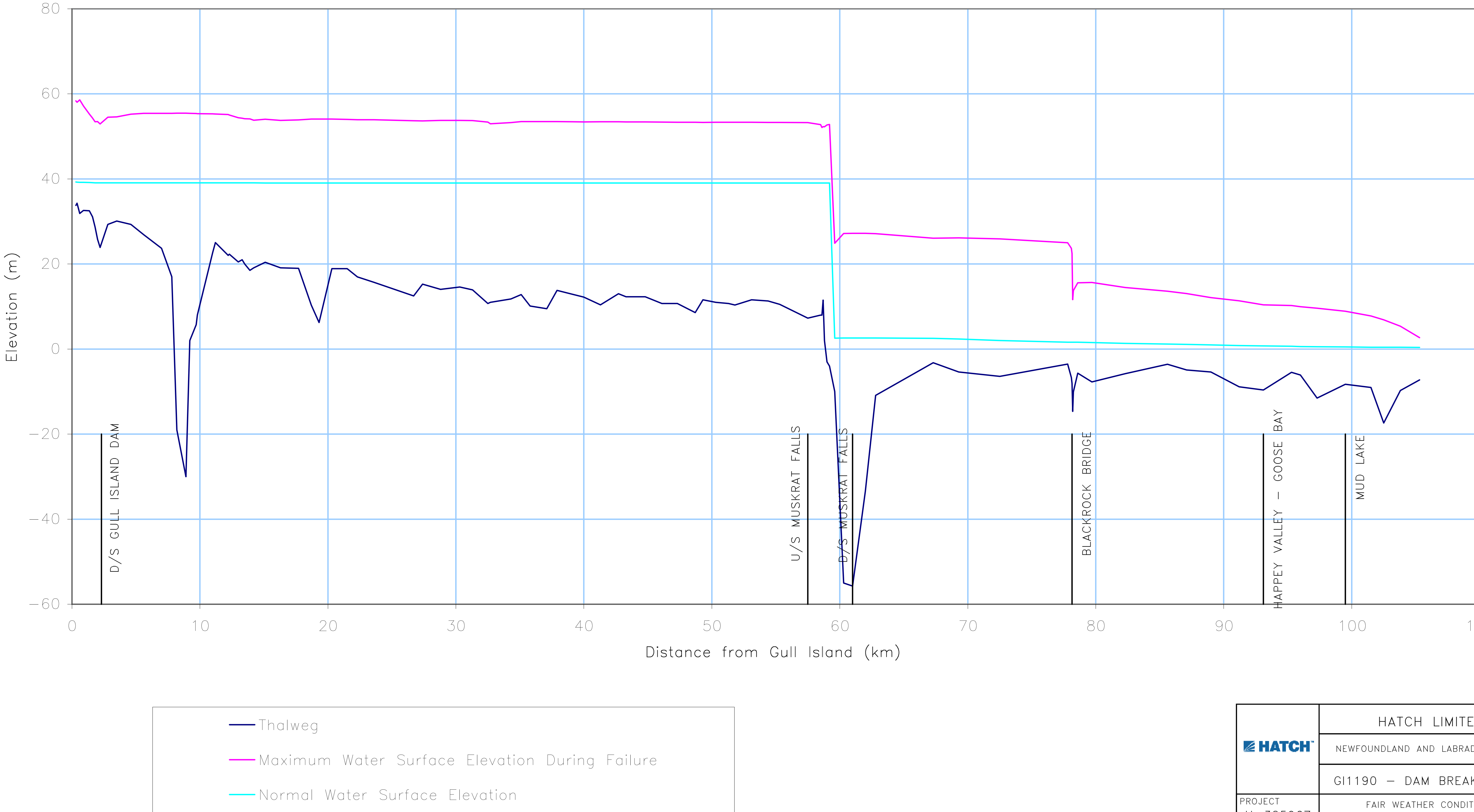
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST PROJECT, MUSKRAT FALLS BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH HAPPY VALLEY–GOOSE BAY
SCALE NTS	
DATE MAR 2008	FIGURE C.7



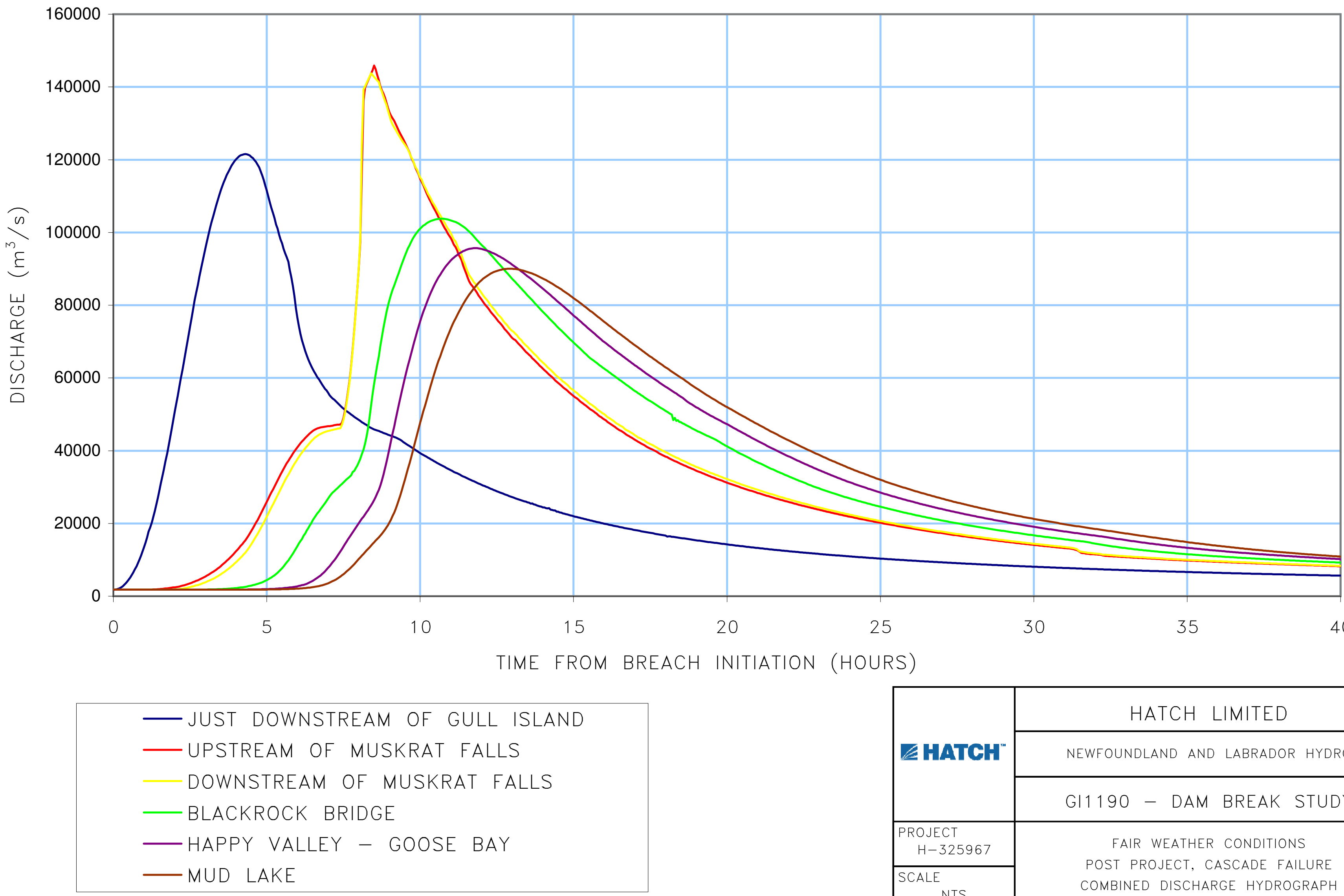
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST PROJECT, MUSKRAT FALLS BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH MUD LAKE
SCALE NTS	
DATE MAR 2008	FIGURE C.8

Appendix D

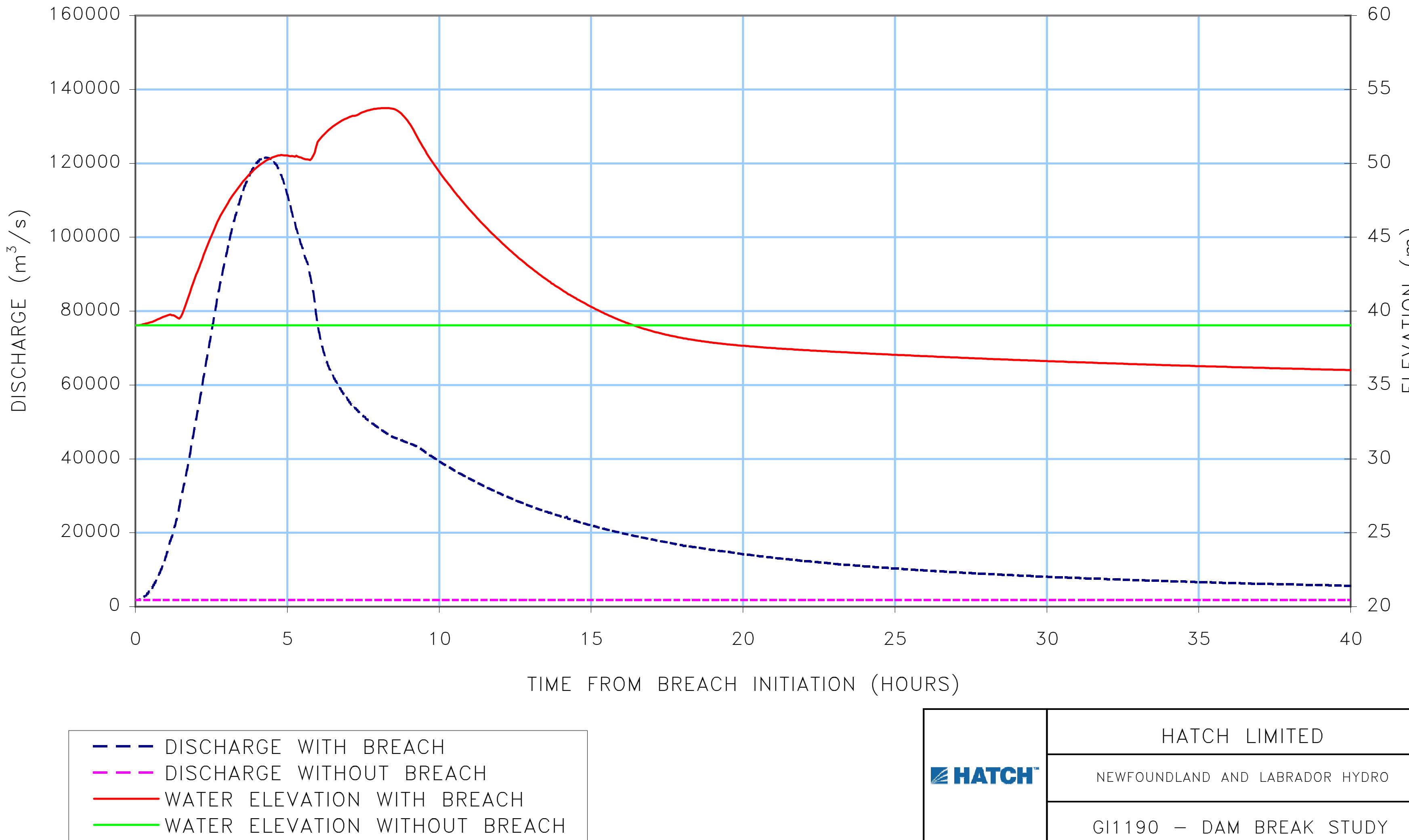
"Fair Weather" Conditions – Post Gull Island and Muskrat Falls – Cascade Failure



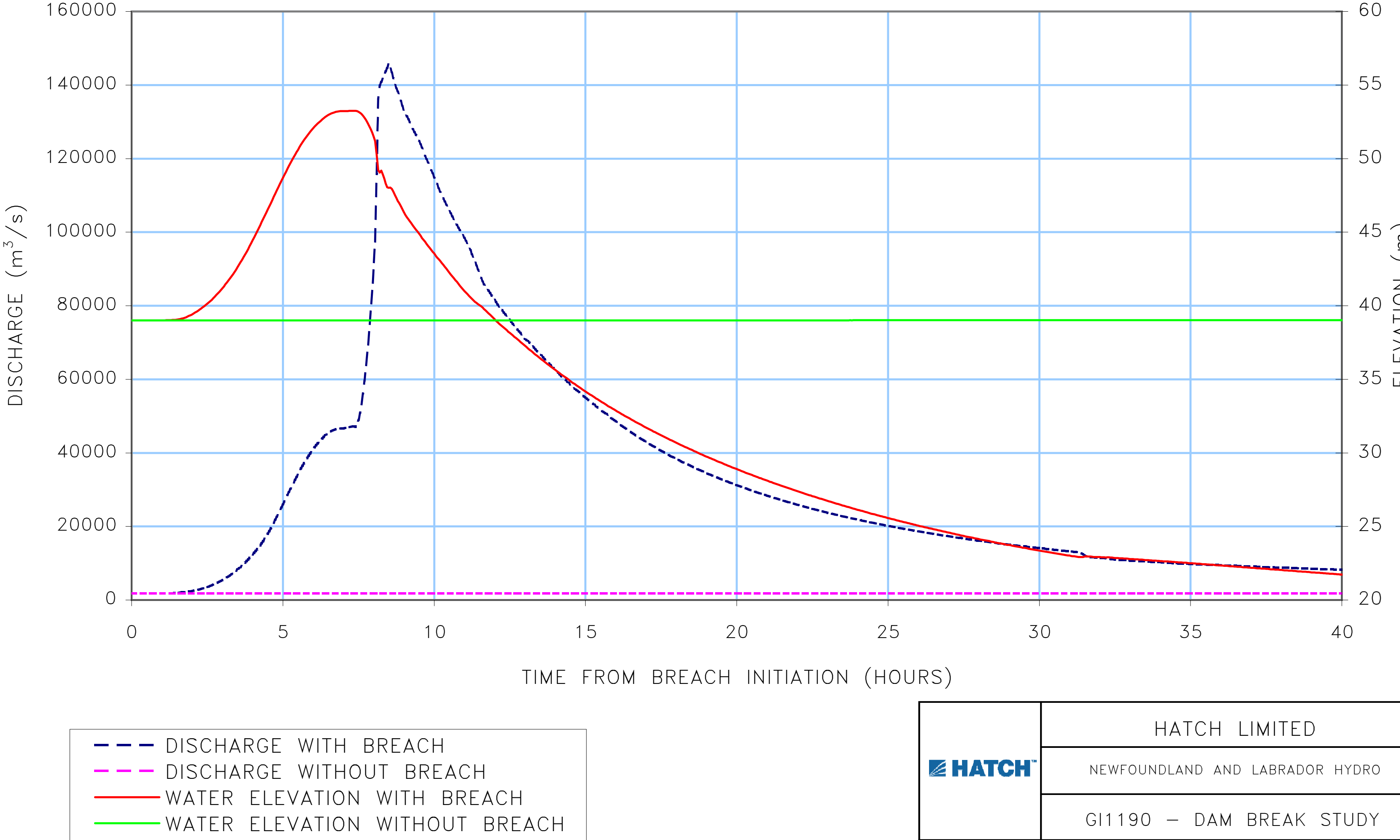
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST PROJECT, CASCADE FAILURE MAXIMUM WATER ELEVATION PROFILES
SCALE NTS	
DATE MAR 2008	FIGURE D.1



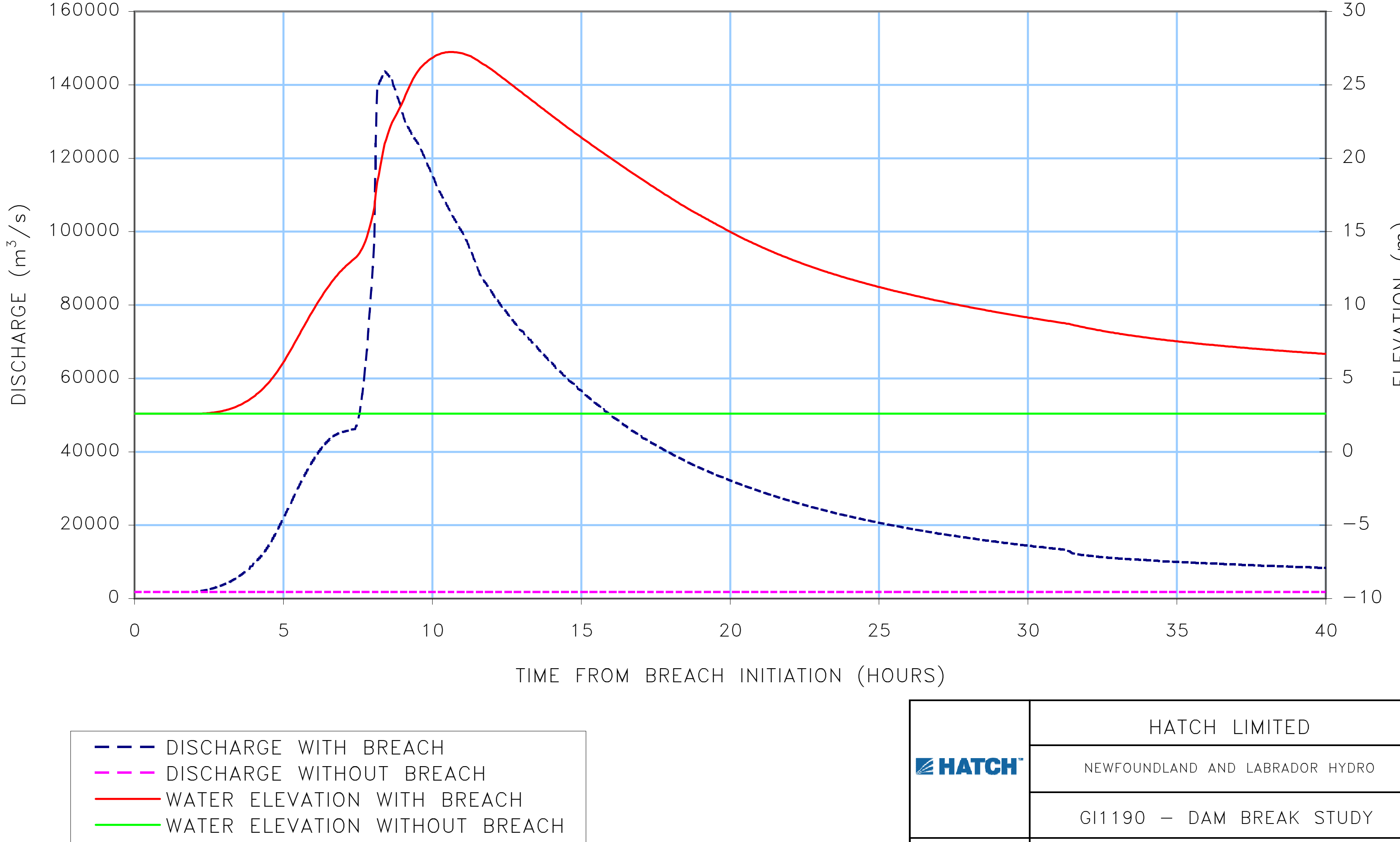
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST PROJECT, CASCADE FAILURE COMBINED DISCHARGE HYDROGRAPH
SCALE NTS	
DATE MAR 2008	FIGURE D.2



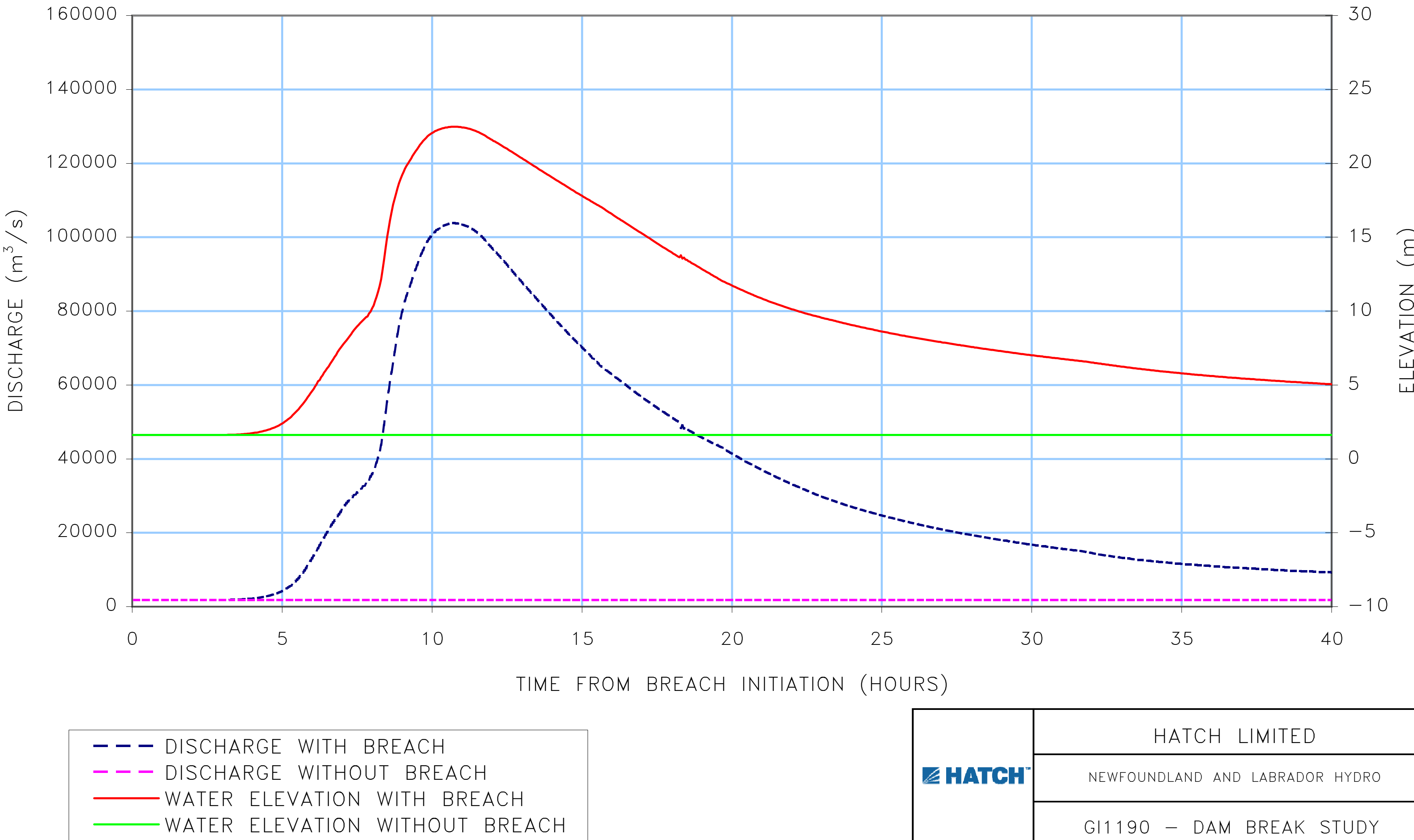
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST PROJECT, CASCADE FAILURE DISCHARGE AND WATER LEVEL HYDROGRAPH DOWNSTREAM OF GULL ISLAND DAM
SCALE NTS	
DATE MAR 2008	FIGURE D.3



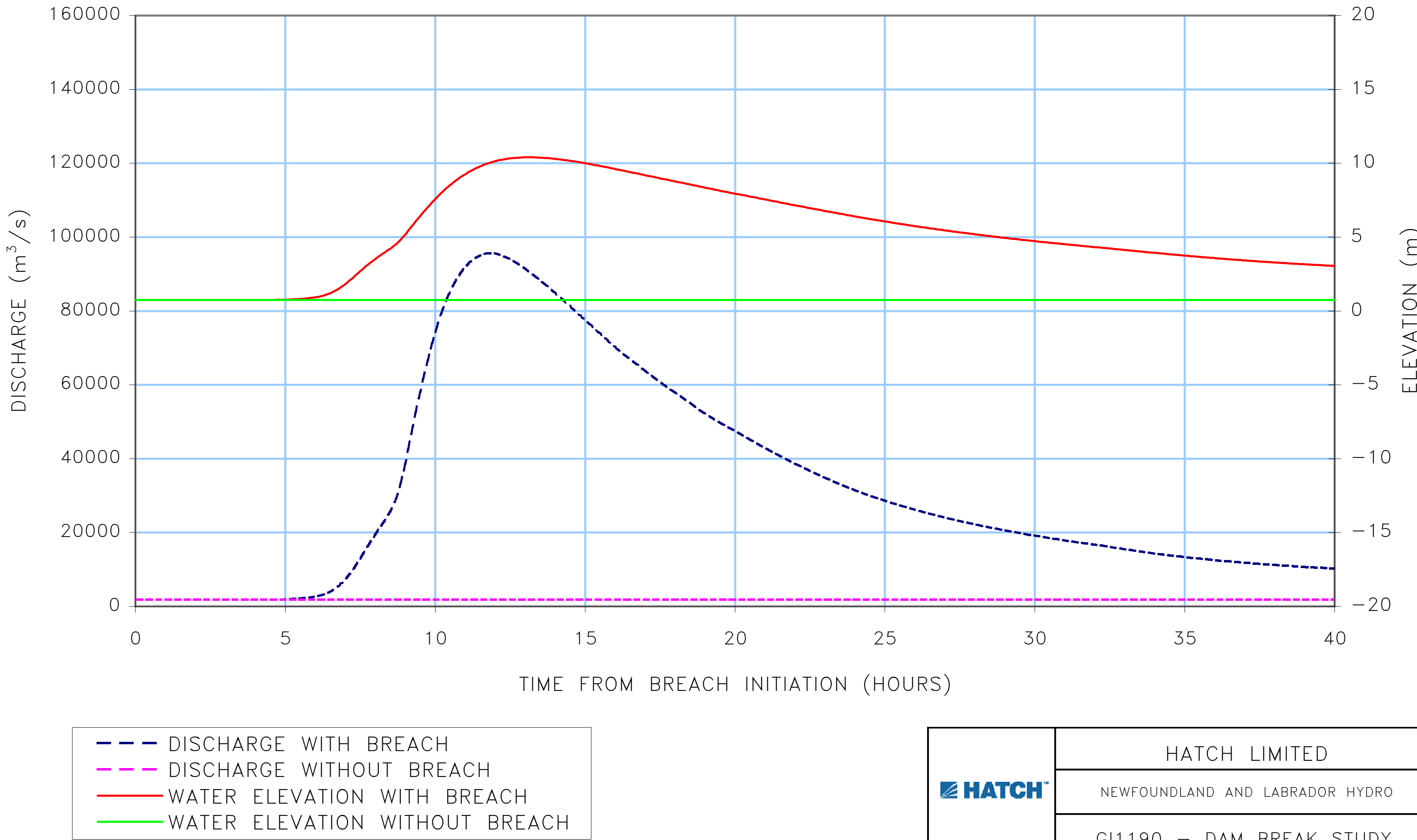
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST PROJECT, CASCADE FAILURE DISCHARGE AND WATER LEVEL HYDROGRAPH UPSTREAM OF MUSKRAT FALLS
SCALE NTS	
DATE MAR 2008	FIGURE D.4



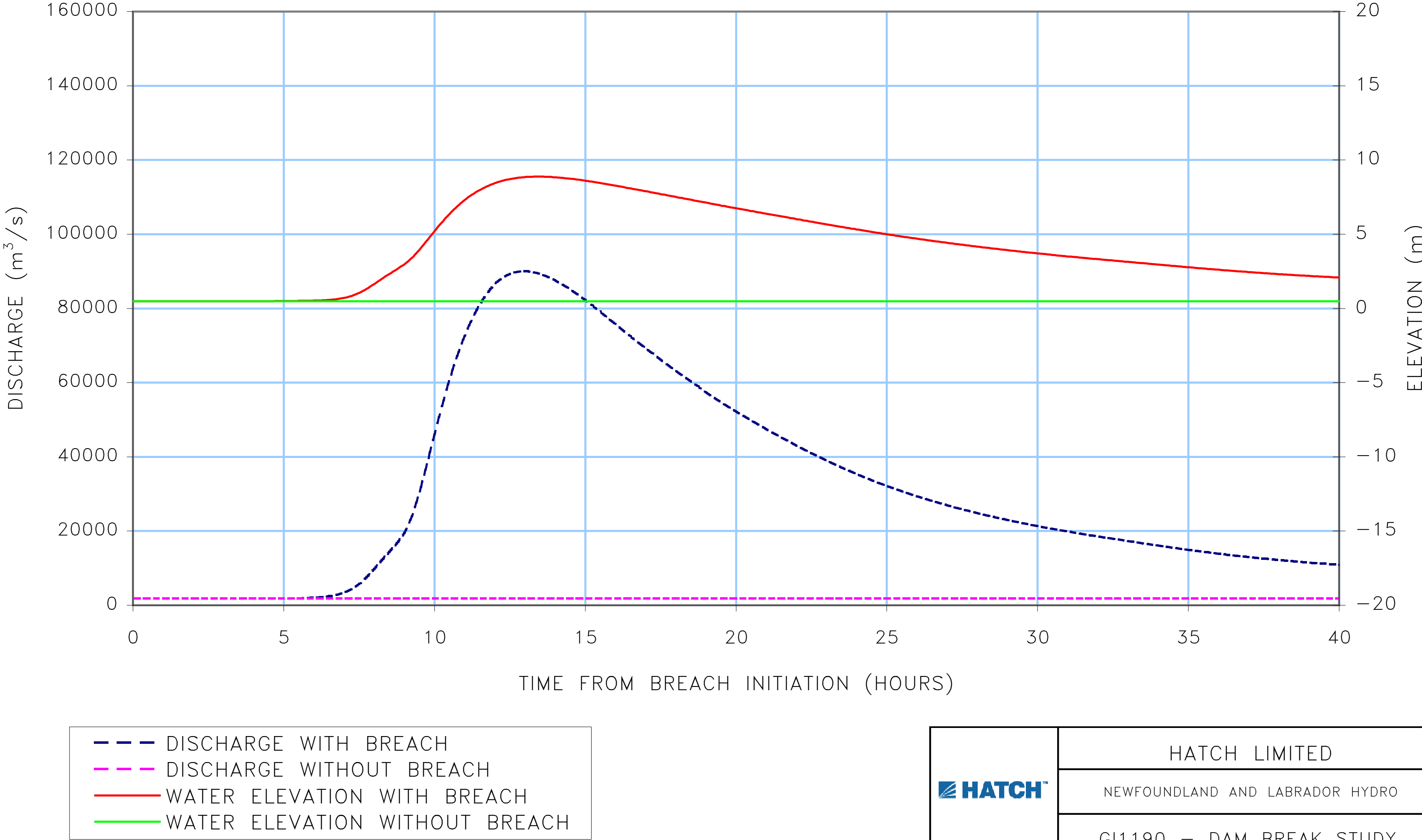
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST PROJECT, CASCADE FAILURE DISCHARGE AND WATER LEVEL HYDROGRAPH DOWNSTREAM OF MUSKRAT FALLS
SCALE NTS	
DATE MAR 2008	FIGURE D.5



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST PROJECT, CASCADE FAILURE DISCHARGE AND WATER LEVEL HYDROGRAPH BLACKROCK BRIDGE
SCALE NTS	
DATE MAR 2008	FIGURE D.6



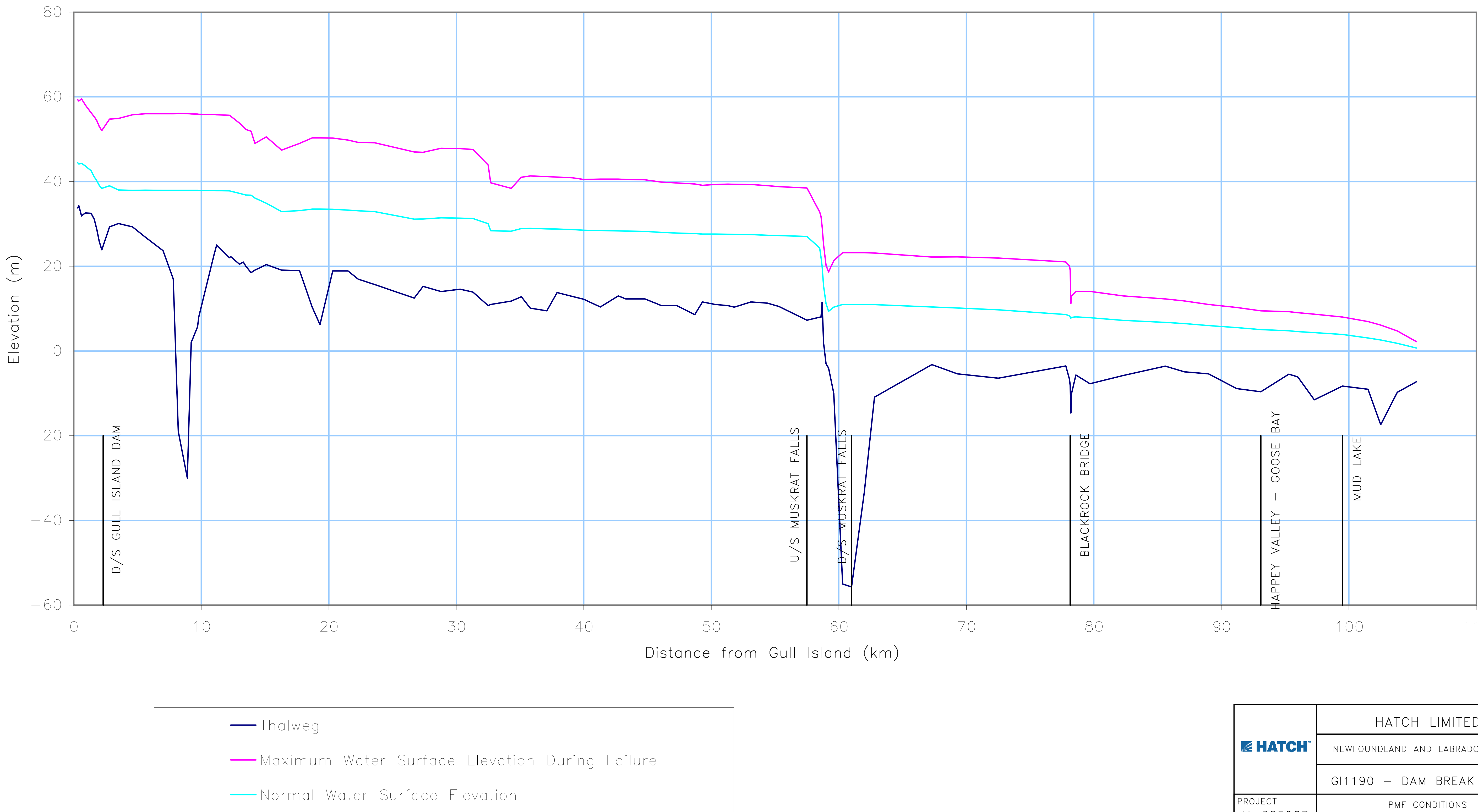
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST PROJECT, CASCADE FAILURE DISCHARGE AND WATER LEVEL HYDROGRAPH HAPPY VALLEY–GOOSE BAY
SCALE NTS	
DATE MAR 2008	FIGURE D.7



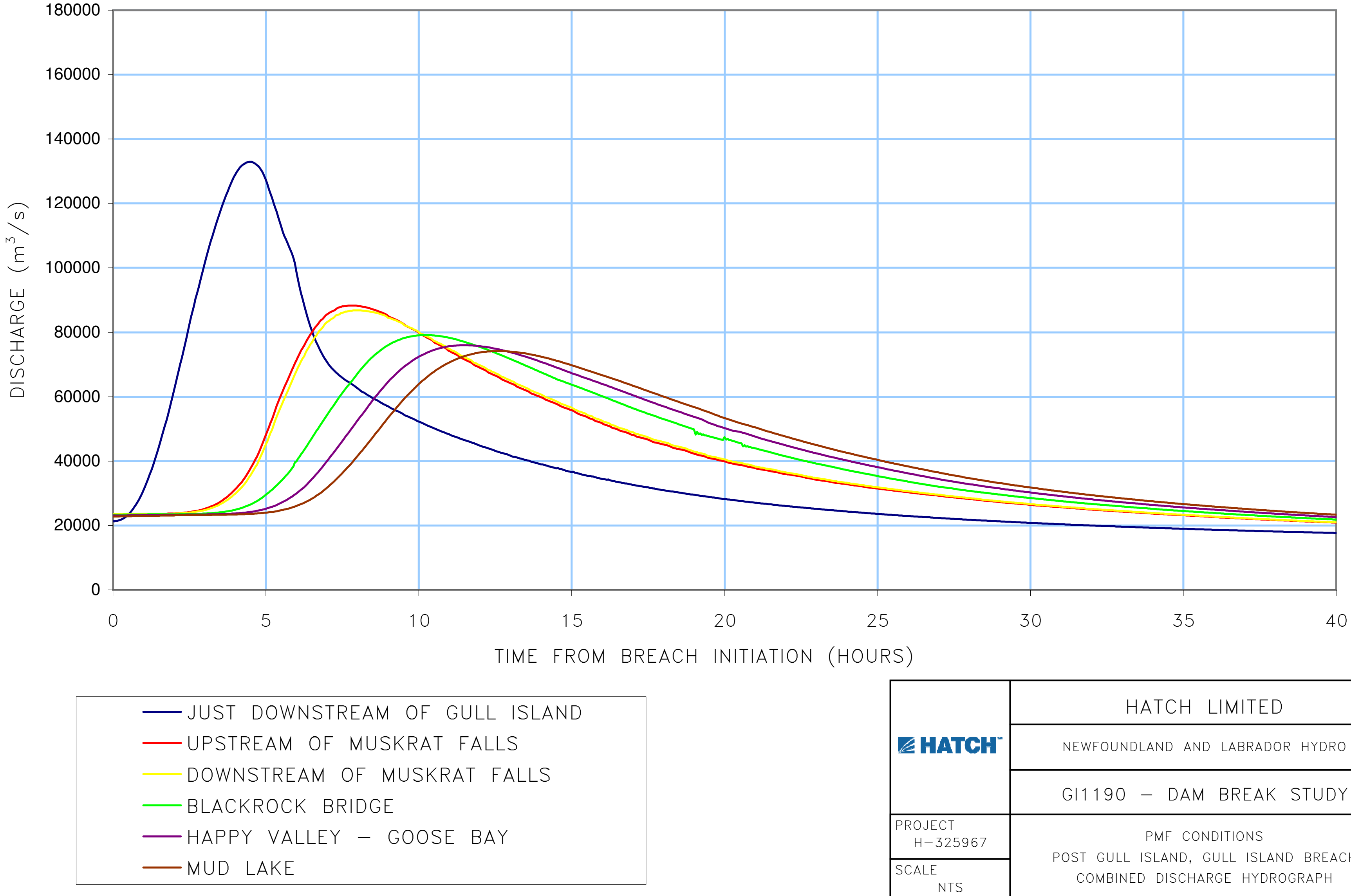
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	FAIR WEATHER CONDITIONS POST PROJECT, CASCADE FAILURE DISCHARGE AND WATER LEVEL HYDROGRAPH MUD LAKE
SCALE NTS	
DATE MAR 2008	FIGURE D.8

Appendix E

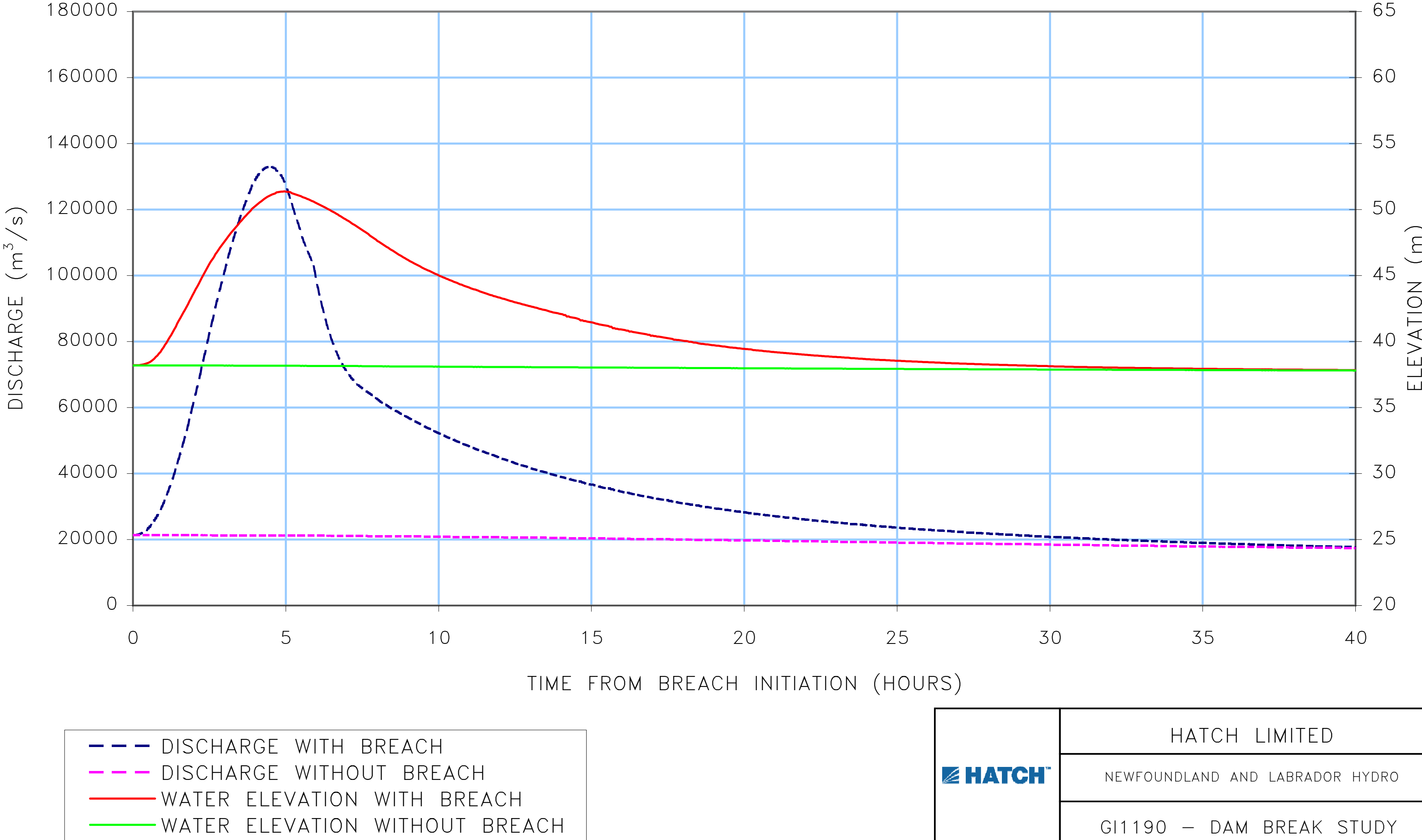
PMF Conditions – Post Gull Island – Gull Island Dam Failure



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H−325967	PMF CONDITIONS POST GULL ISLAND, GULL ISLAND BREACH MAXIMUM WATER ELEVATION PROFILES
SCALE NTS	
DATE MAR 2008	FIGURE E.1



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	PMF CONDITIONS POST GULL ISLAND, GULL ISLAND BREACH COMBINED DISCHARGE HYDROGRAPH
SCALE NTS	
DATE MAR 2008	FIGURE E.2



HATCH

HATCH LIMITED

NEWFOUNDLAND AND LABRADOR HYDRO

GI1190 – DAM BREAK STUDY

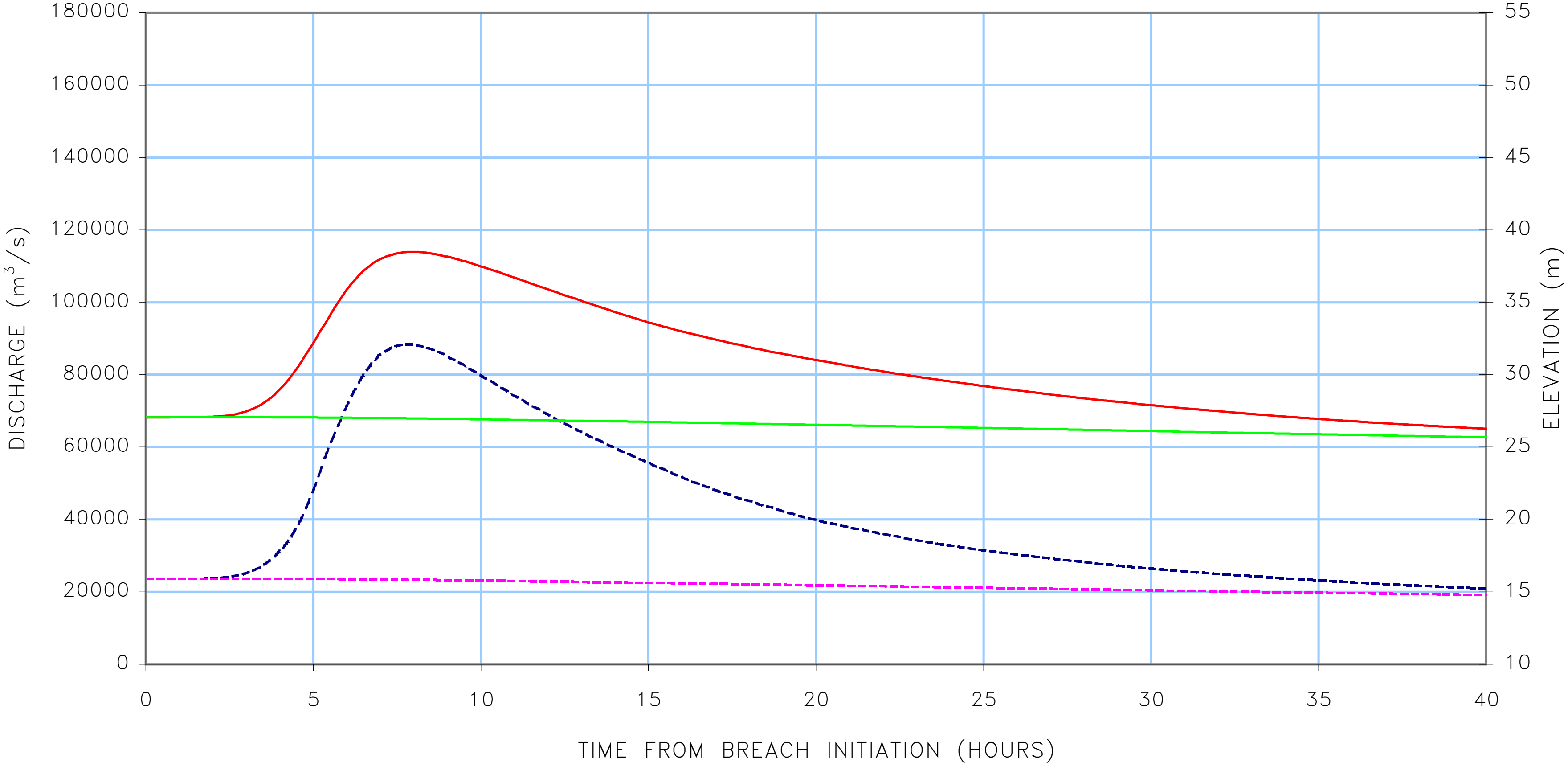
PROJECT H–325967

SCALE NTS

DATE MAR 2008

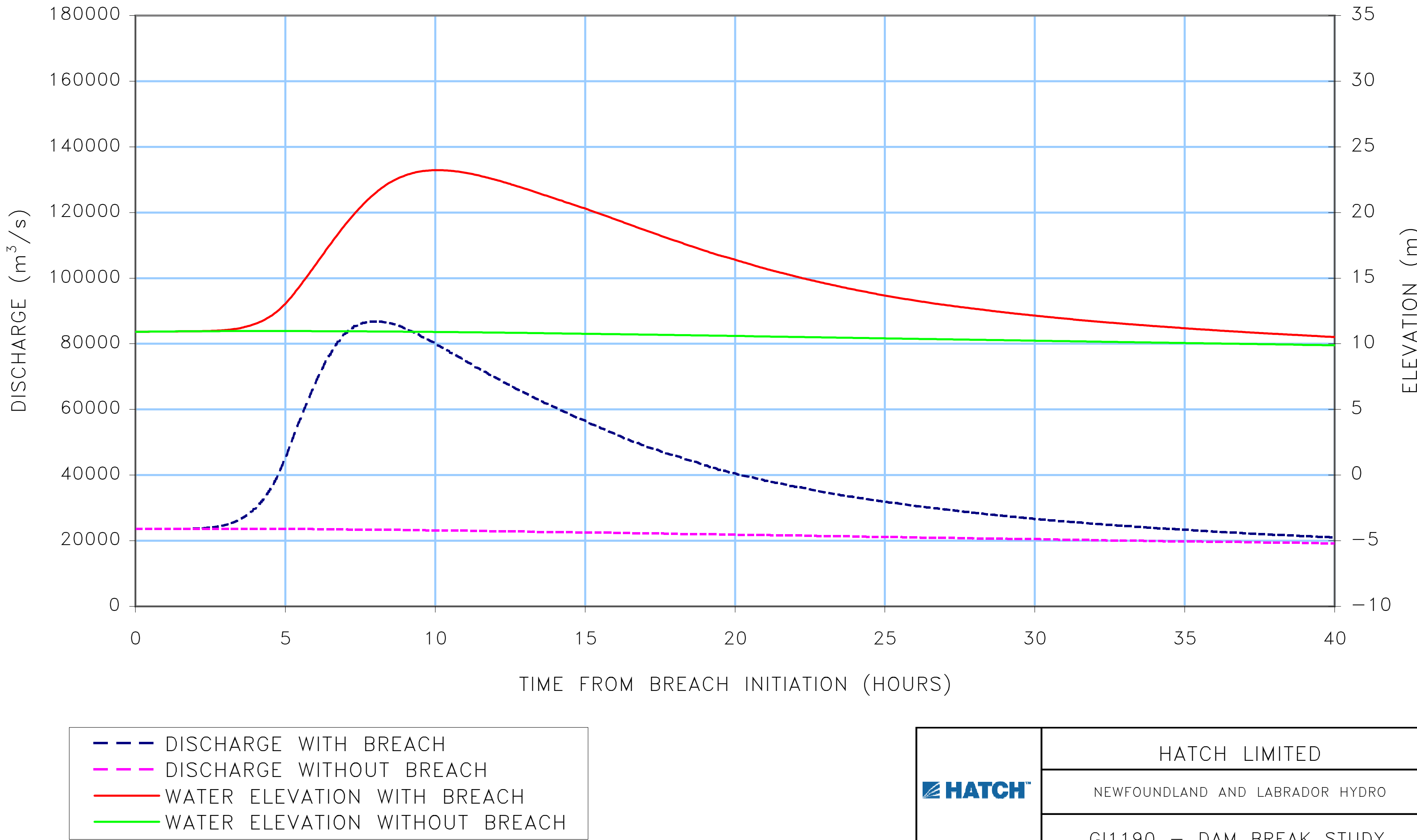
PMF CONDITIONS
POST GULL ISLAND, GULL ISLAND BREACH
DISCHARGE AND WATER LEVEL HYDROGRAPH
DOWNSTREAM OF GULL ISLAND DAM

FIGURE E.3



DISCHARGE WITH BREACH
DISCHARGE WITHOUT BREACH
WATER ELEVATION WITH BREACH
WATER ELEVATION WITHOUT BREACH

HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H-325967	PMF CONDITIONS POST GULL ISLAND, GULL ISLAND BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH UPSTREAM OF MUSKRAT FALLS
SCALE NTS	
DATE MAR 2008	FIGURE E.4



HATCH LIMITED

NEWFOUNDLAND AND LABRADOR HYDRO

GI1190 – DAM BREAK STUDY

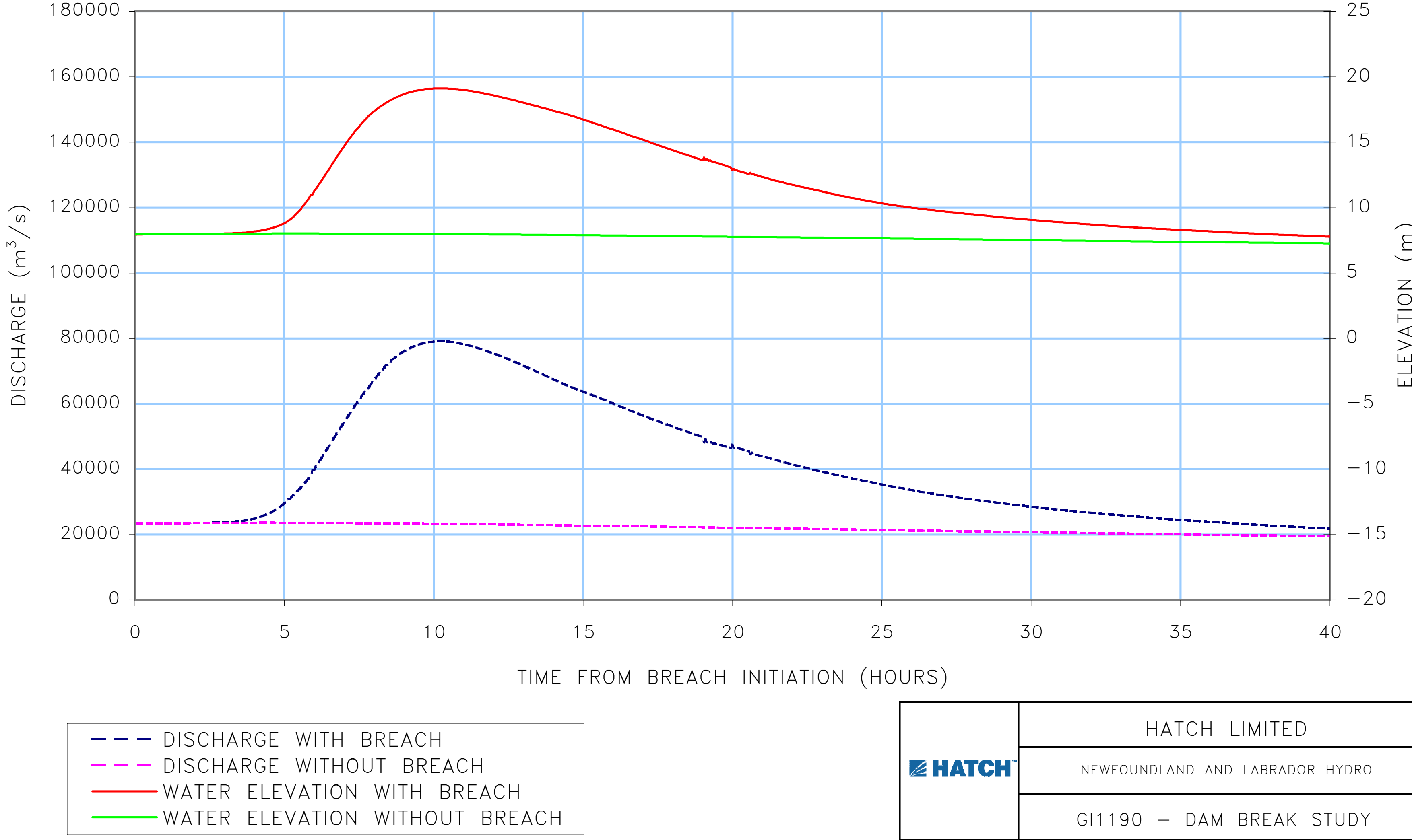
PROJECT H-325967

SCALE NTS

DATE MAR 2008

PMF CONDITIONS
POST GULL ISLAND, GULL ISLAND BREACH
DISCHARGE AND WATER LEVEL HYDROGRAPH
DOWNSTREAM OF MUSKRAT FALLS

FIGURE E.5



HATCH LIMITED

NEWFOUNDLAND AND LABRADOR HYDRO

GI1190 – DAM BREAK STUDY

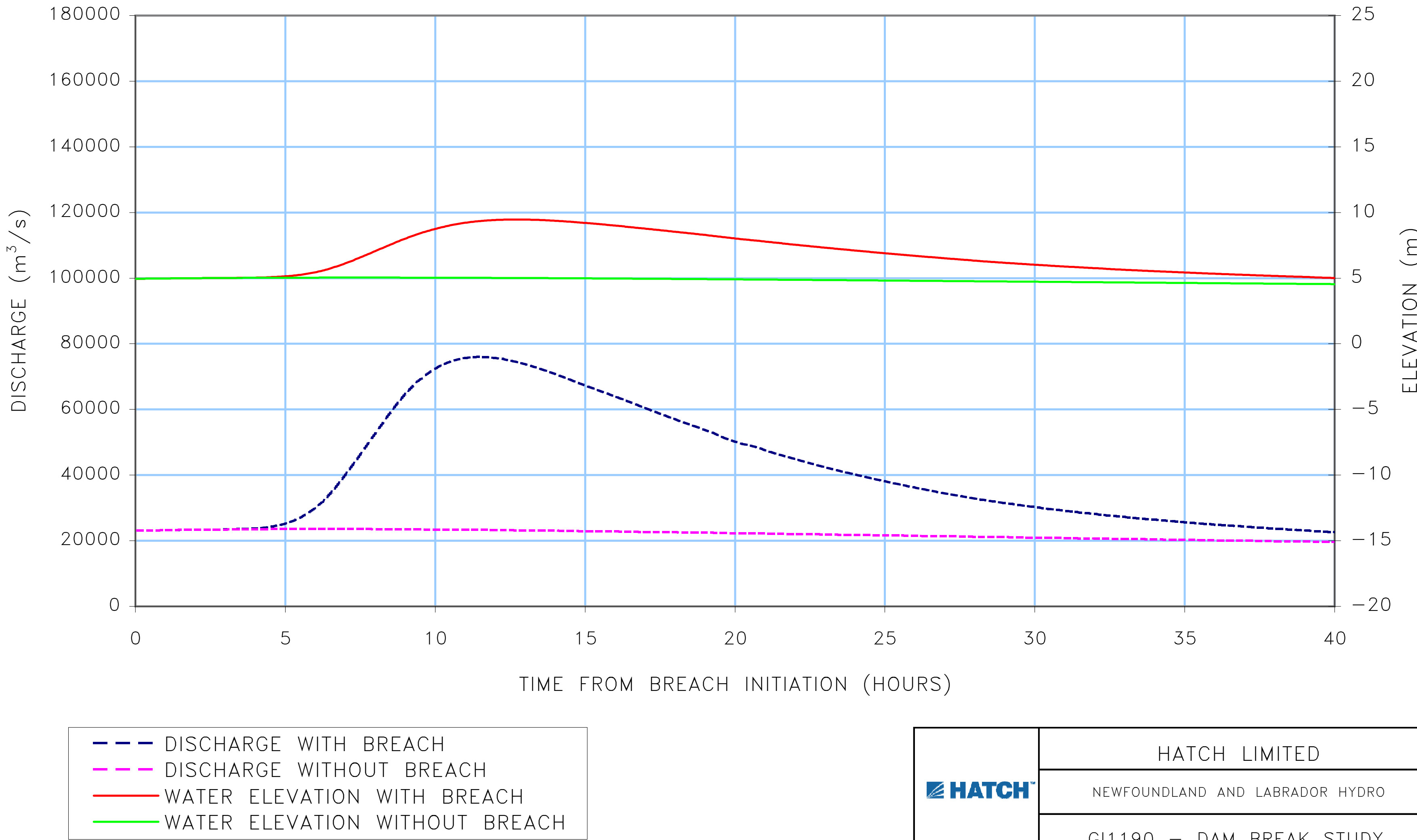
PROJECT H–325967

SCALE NTS

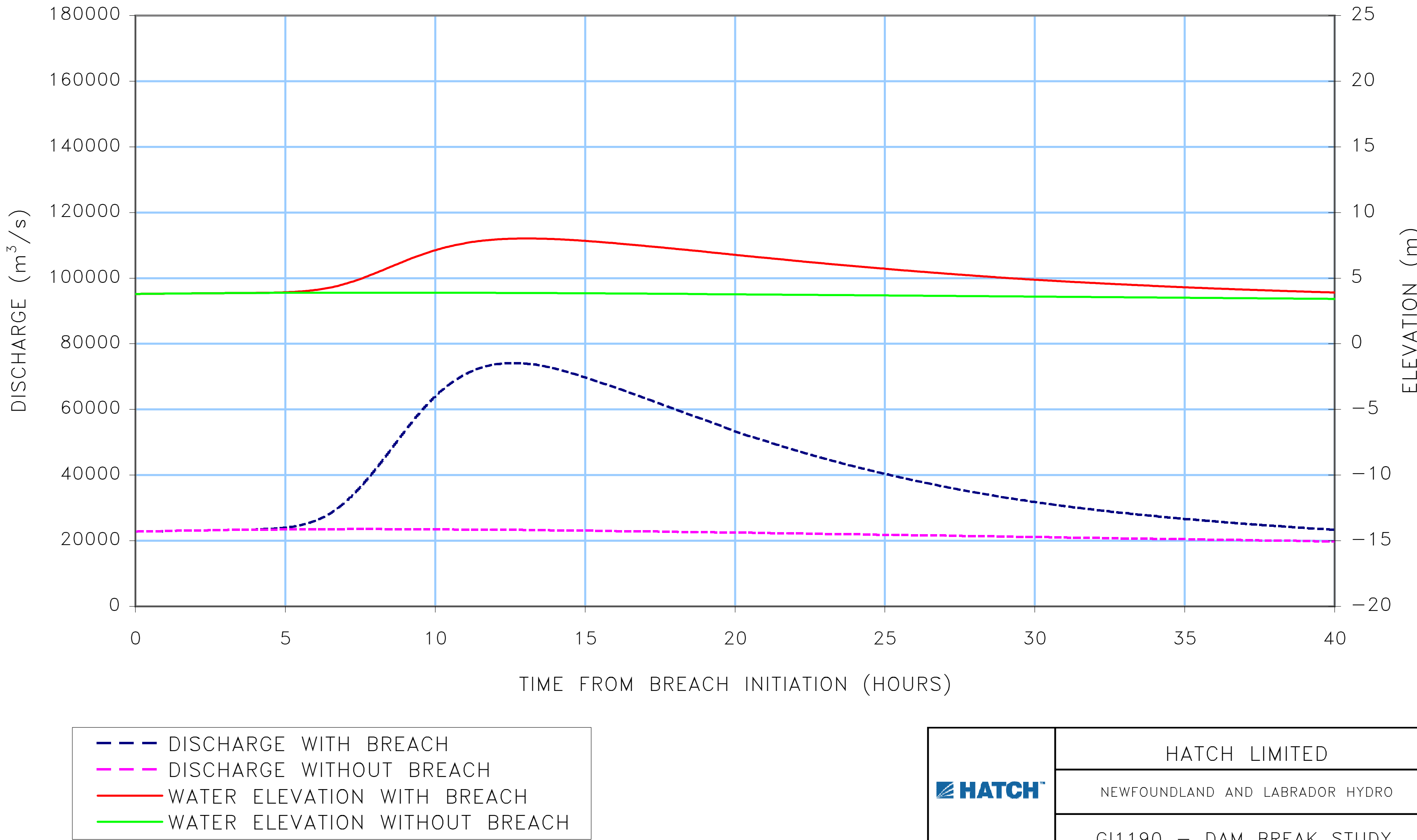
DATE MAR 2008

PMF CONDITIONS
POST GULL ISLAND, GULL ISLAND BREACH
DISCHARGE AND WATER LEVEL HYDROGRAPH
BLACKROCK BRIDGE

FIGURE E.6



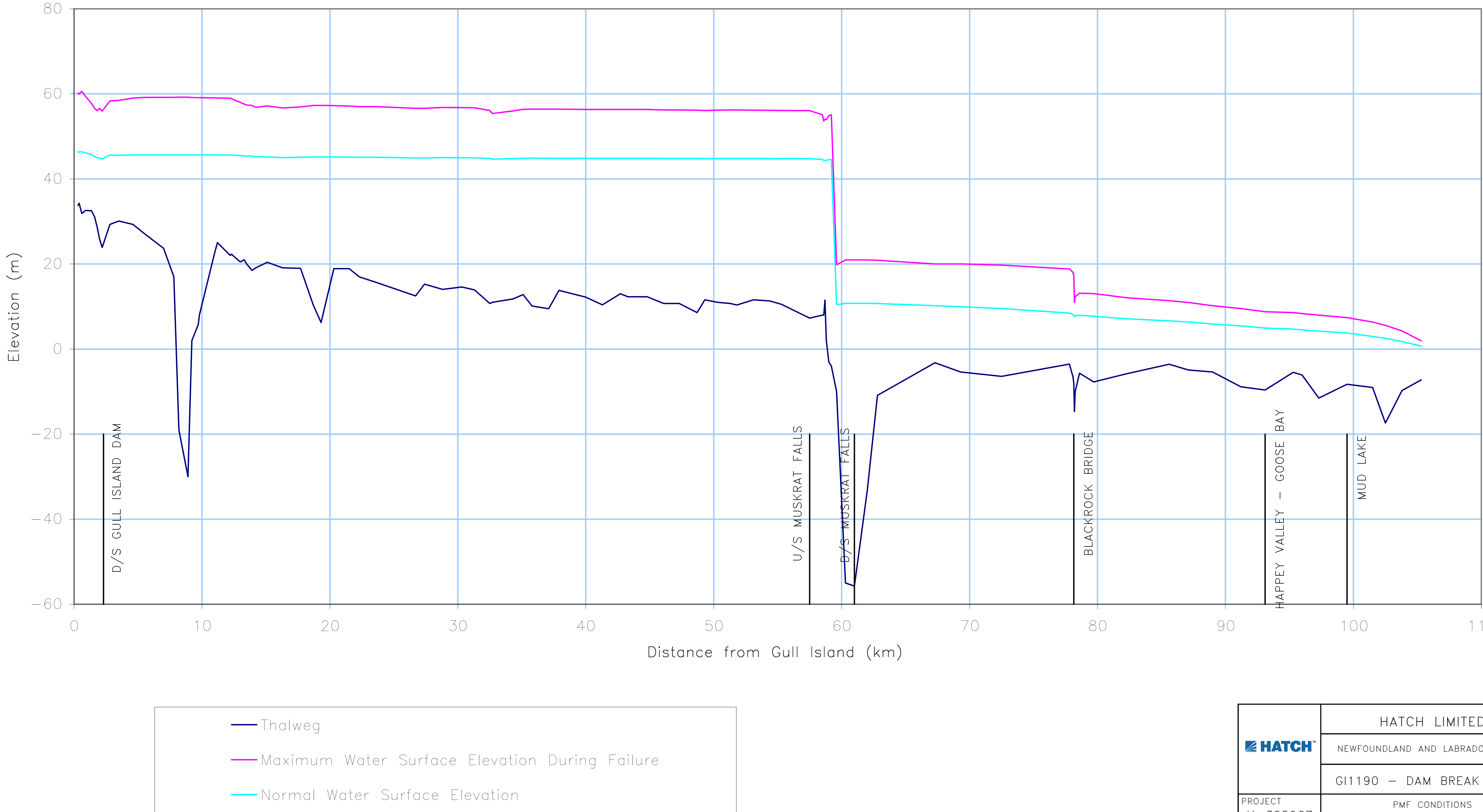
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	PMF CONDITIONS POST GULL ISLAND, GULL ISLAND BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH HAPPY VALLEY–GOOSE BAY
SCALE NTS	
DATE MAR 2008	FIGURE E.7



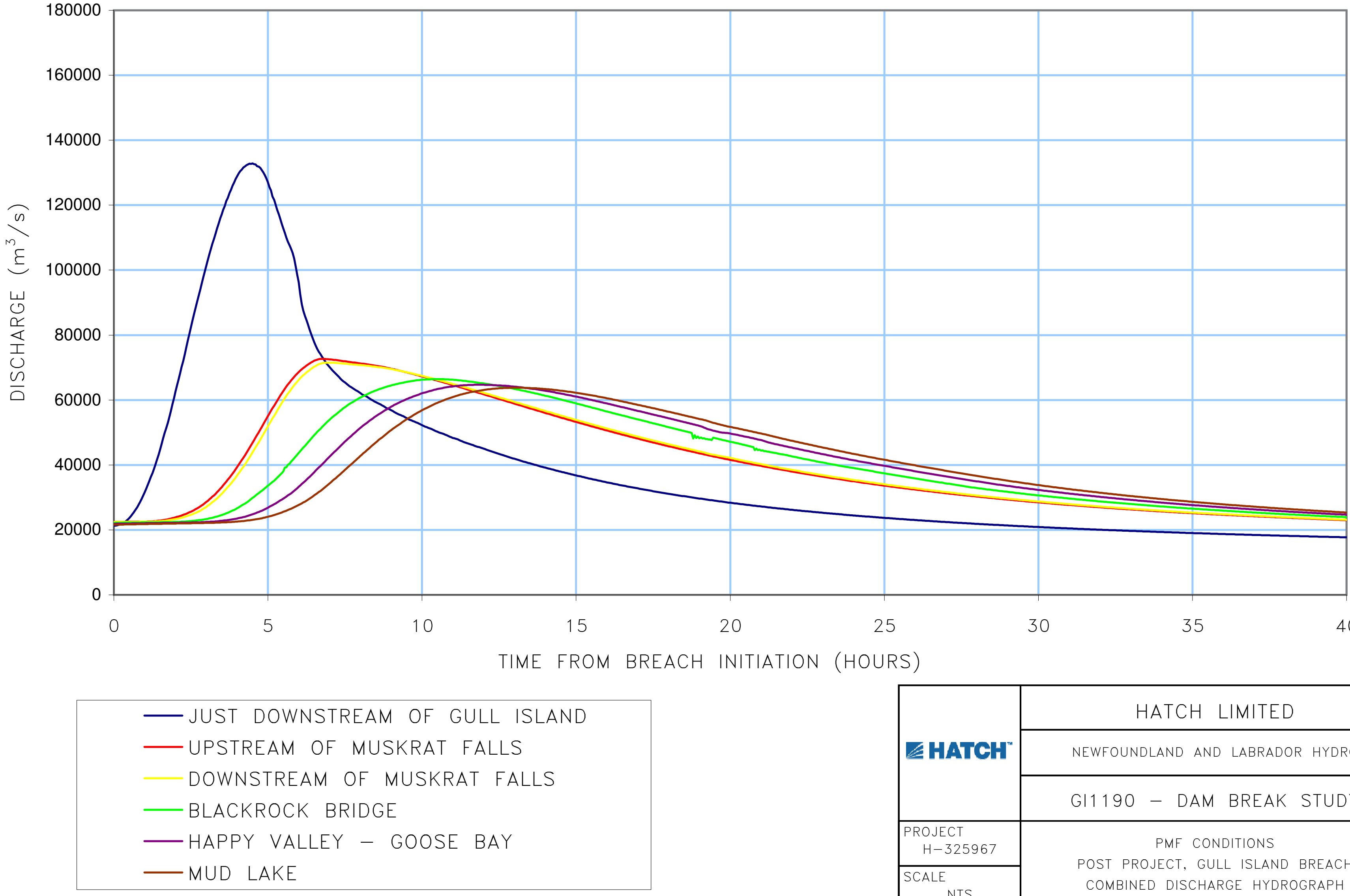
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	PMF CONDITIONS POST GULL ISLAND, GULL ISLAND BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH MUD LAKE
SCALE NTS	
DATE MAR 2008	FIGURE E.8

Appendix F

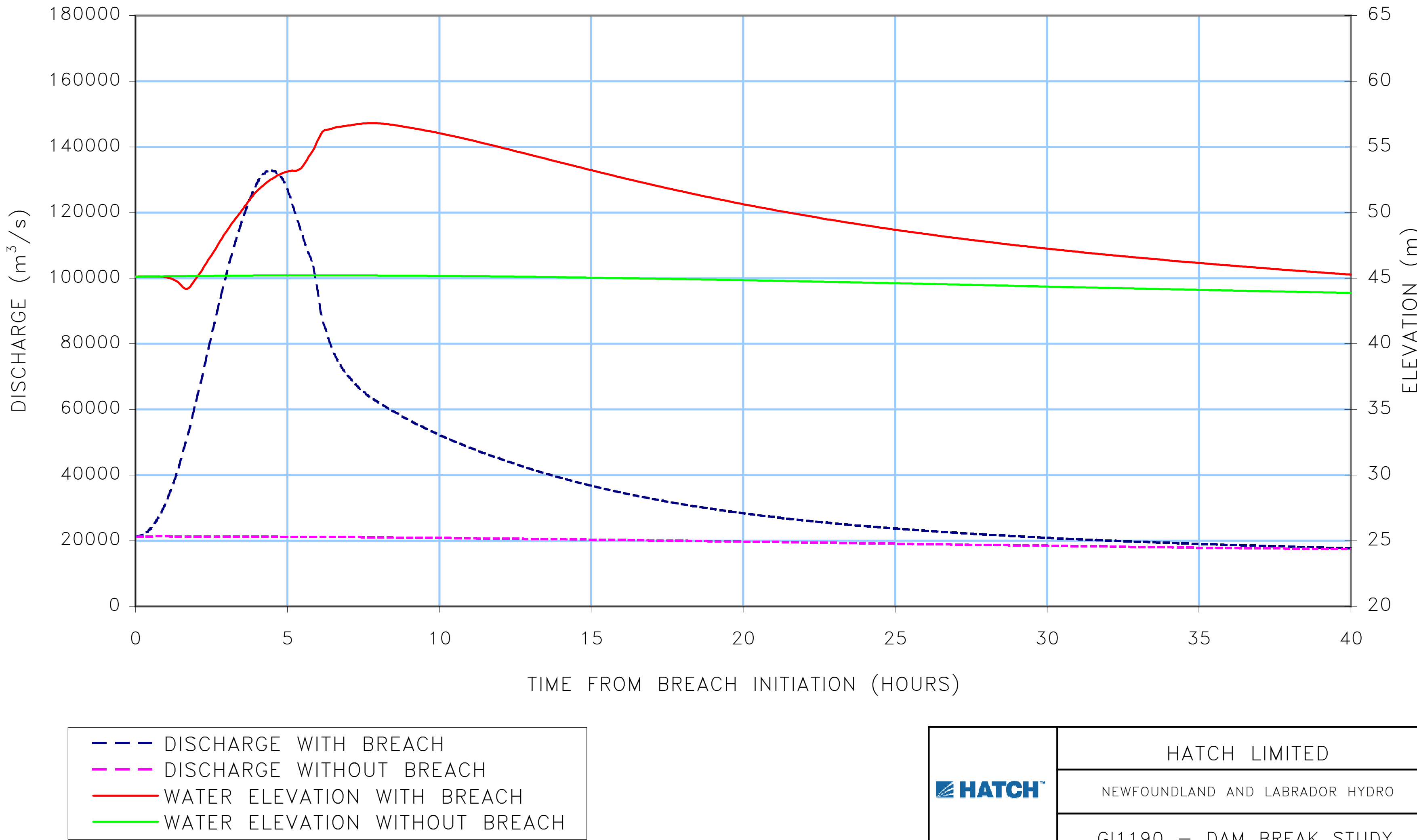
PMF Conditions – Post Gull Island and Muskrat Falls – Gull Island Dam Failure



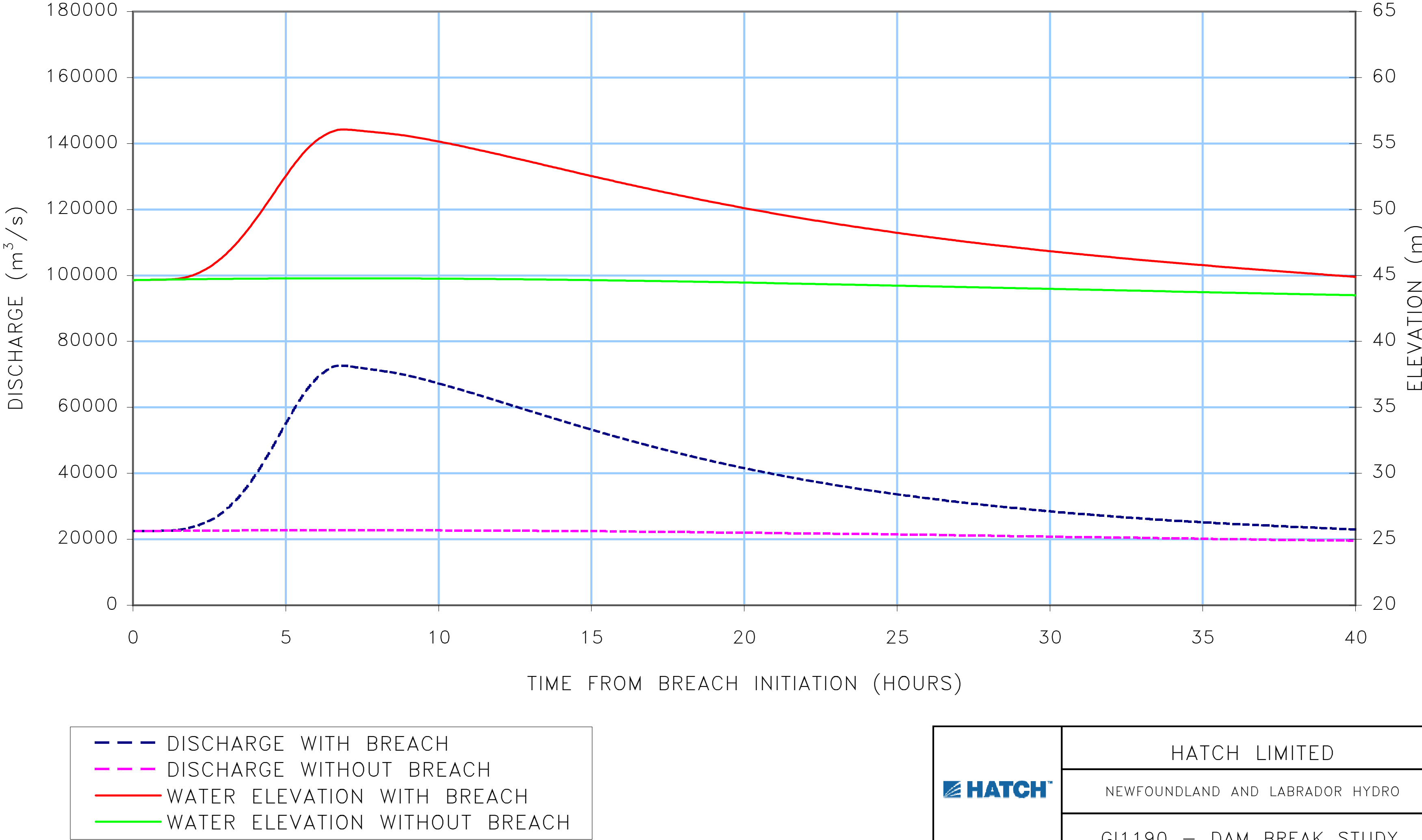
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	PMF CONDITIONS POST PROJECT, GULL ISLAND BREACH MAXIMUM WATER ELEVATION PROFILES
SCALE NTS	
DATE MAR 2008	FIGURE F.1



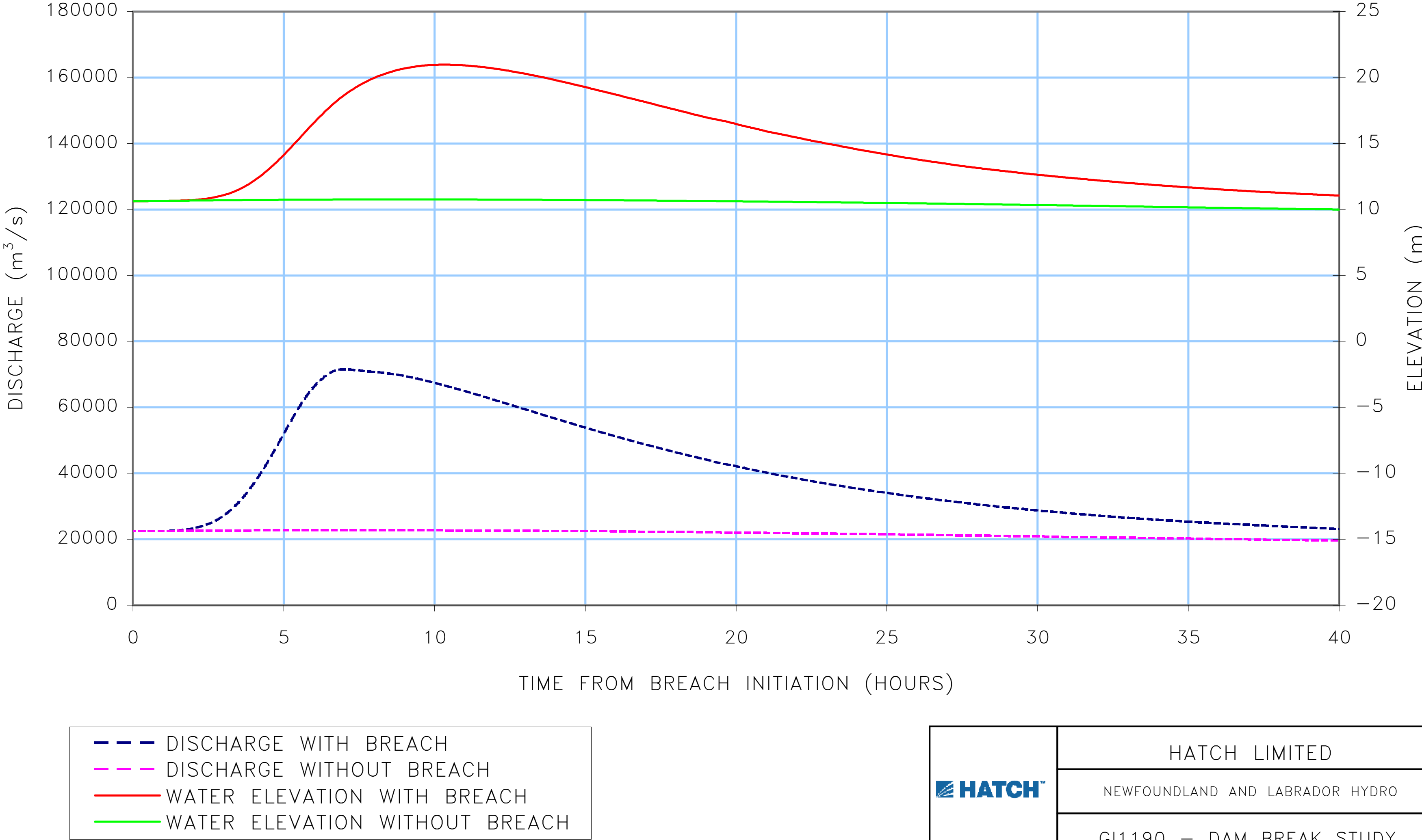
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	PMF CONDITIONS POST PROJECT, GULL ISLAND BREACH COMBINED DISCHARGE HYDROGRAPH
SCALE NTS	
DATE MAR 2008	FIGURE F.2



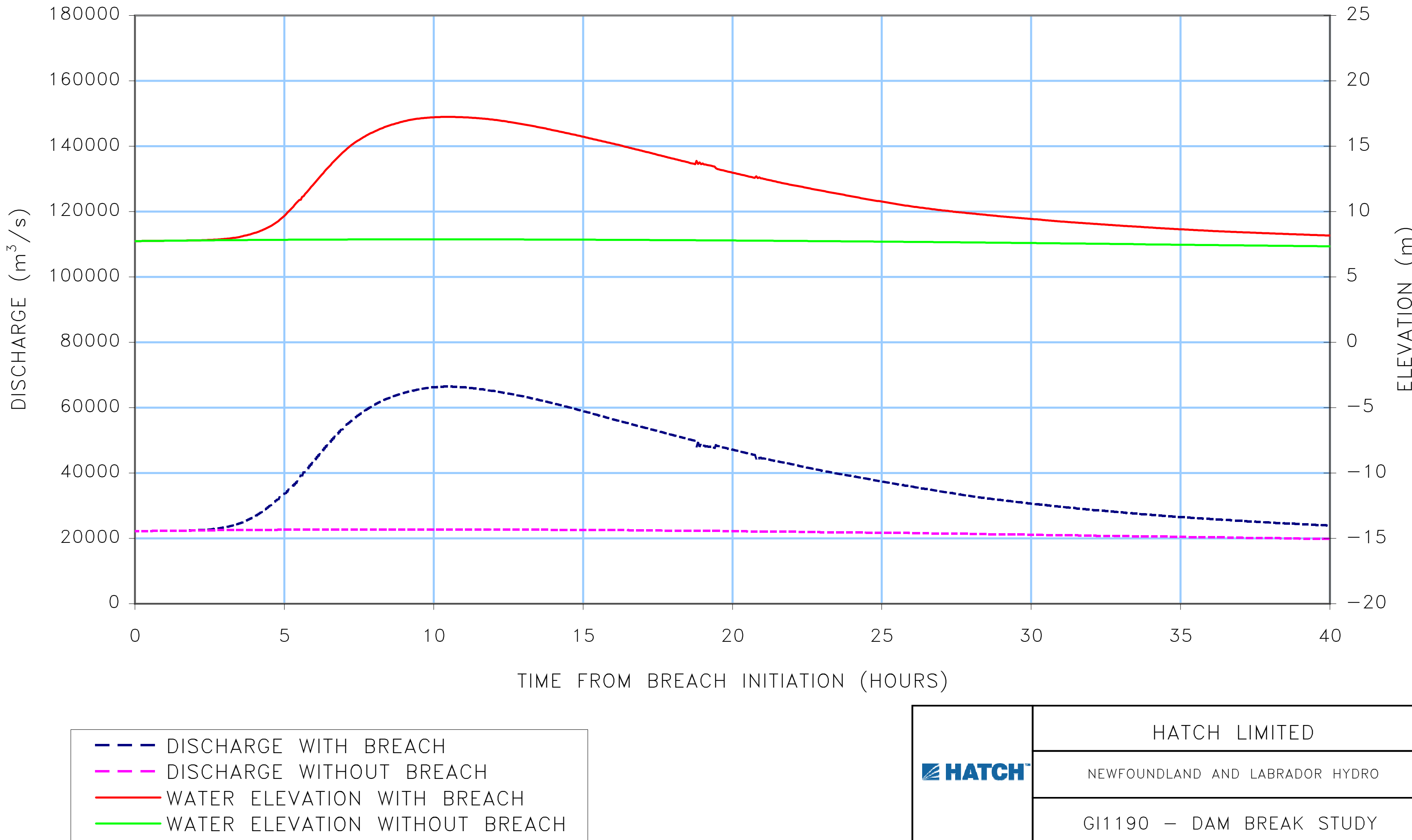
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H-325967	PMF CONDITIONS POST PROJECT, GULL ISLAND BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH DOWNSTREAM OF GULL ISLAND DAM
SCALE NTS	
DATE MAR 2008	FIGURE F.3



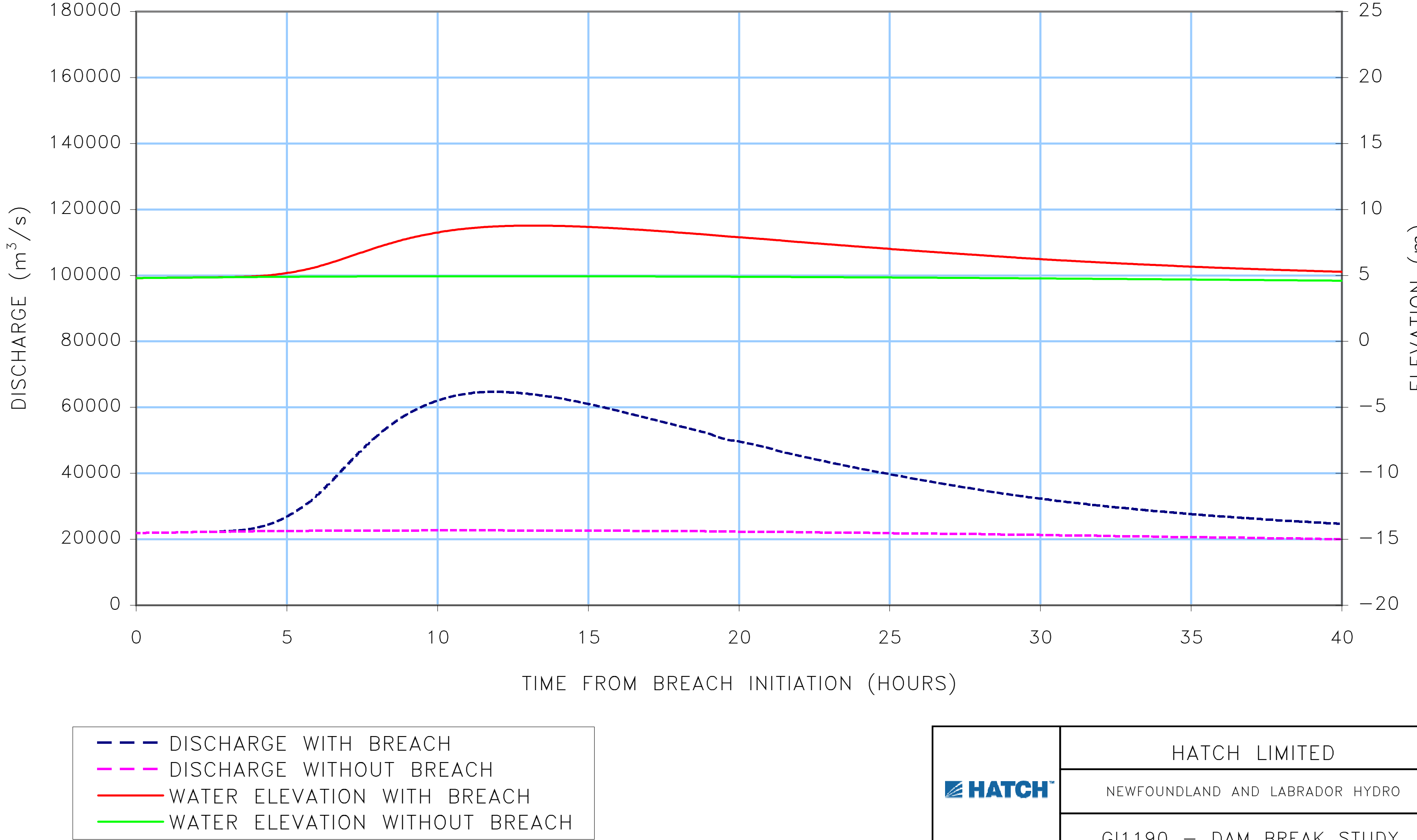
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H-325967	PMF CONDITIONS POST PROJECT, GULL ISLAND BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH UPSTREAM OF MUSKRAT FALLS
SCALE NTS	
DATE MAR 2008	FIGURE F.4



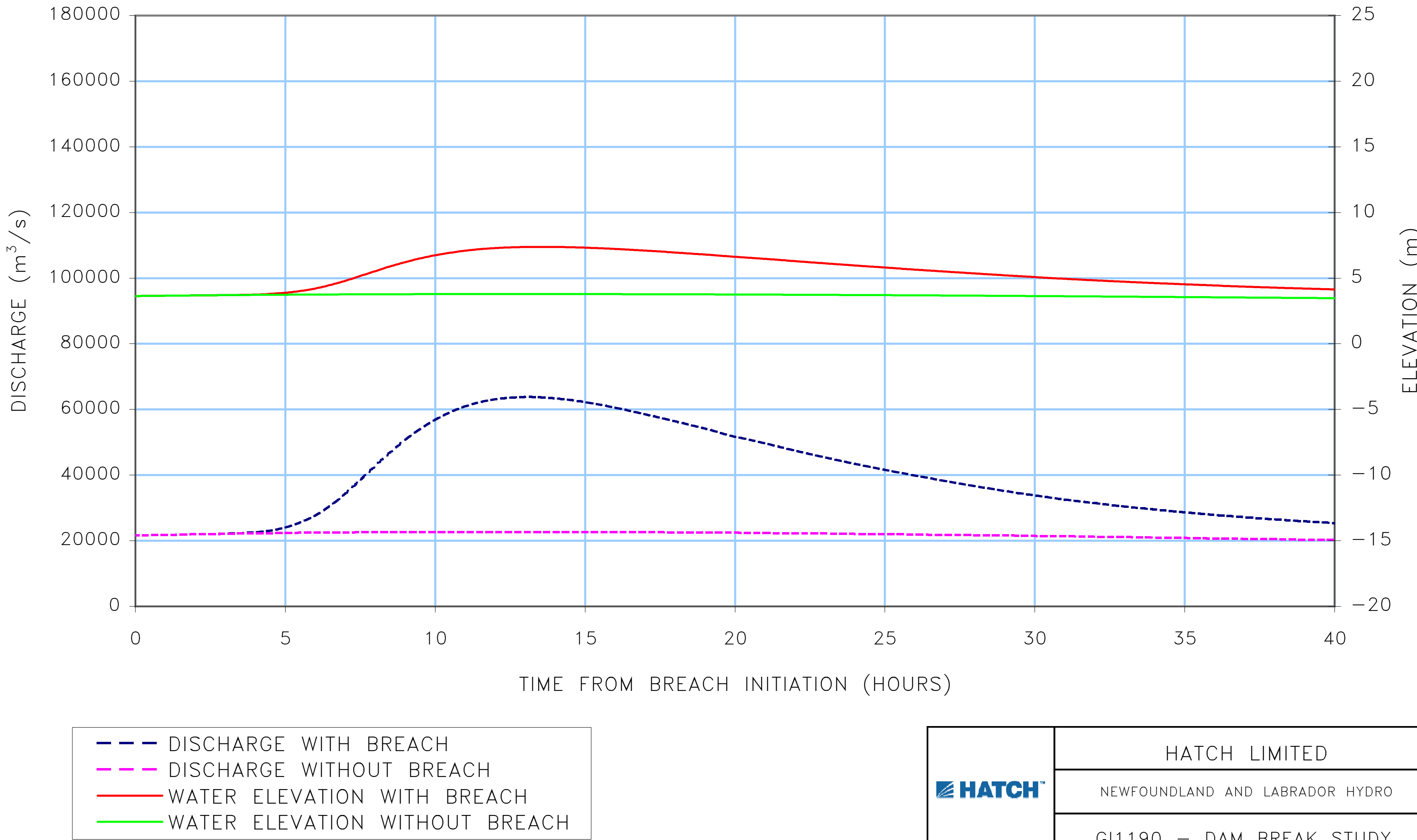
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H−325967	PMF CONDITIONS POST PROJECT, GULL ISLAND BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH DOWNSTREAM OF MUSKRAT FALLS
SCALE NTS	
DATE MAR 2008	FIGURE F.5



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	PMF CONDITIONS POST PROJECT, GULL ISLAND BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH BLACKROCK BRIDGE
SCALE NTS	
DATE MAR 2008	FIGURE F.6



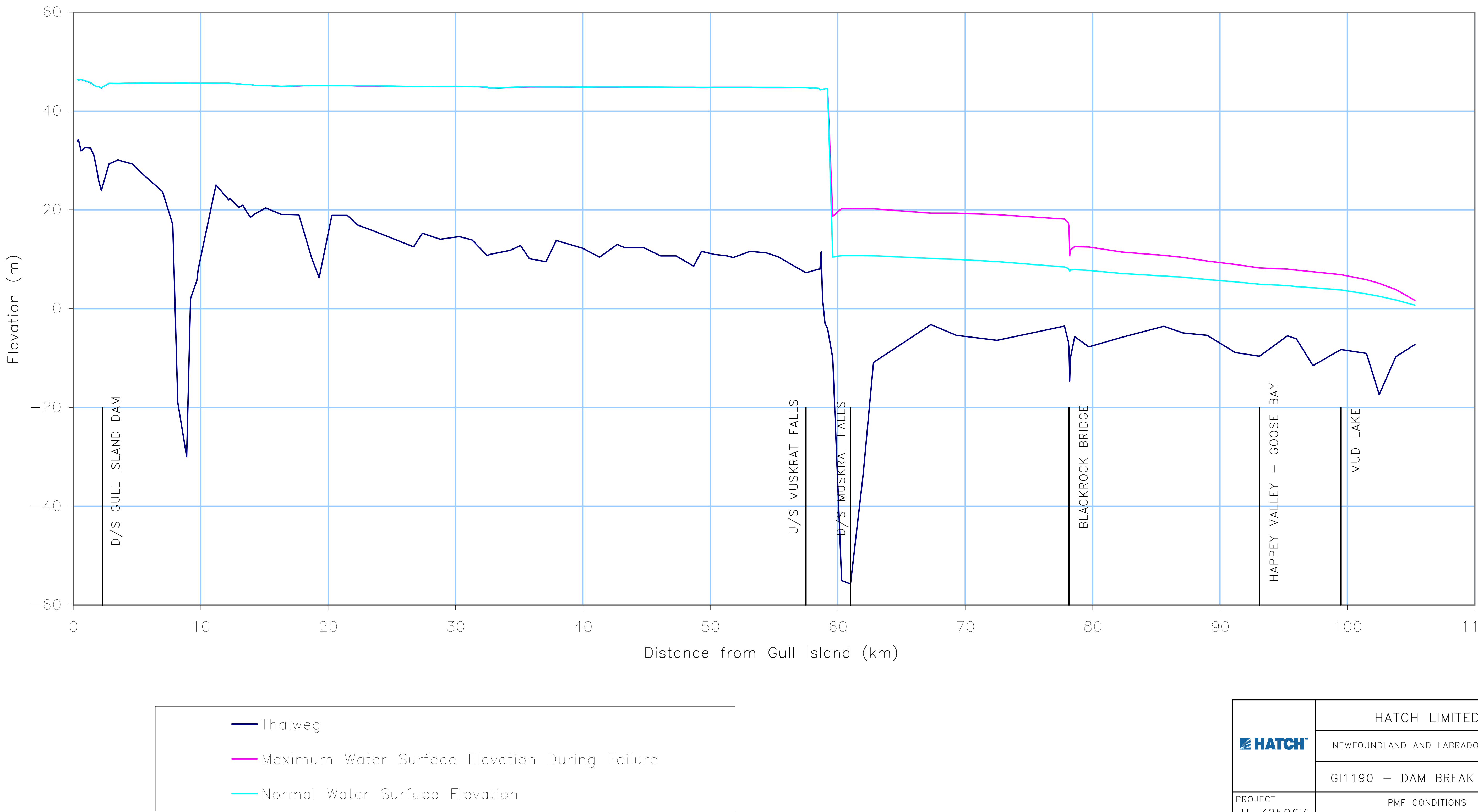
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	PMF CONDITIONS POST PROJECT, GULL ISLAND BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH HAPPY VALLEY–GOOSE BAY
SCALE NTS	
DATE MAR 2008	FIGURE F.7



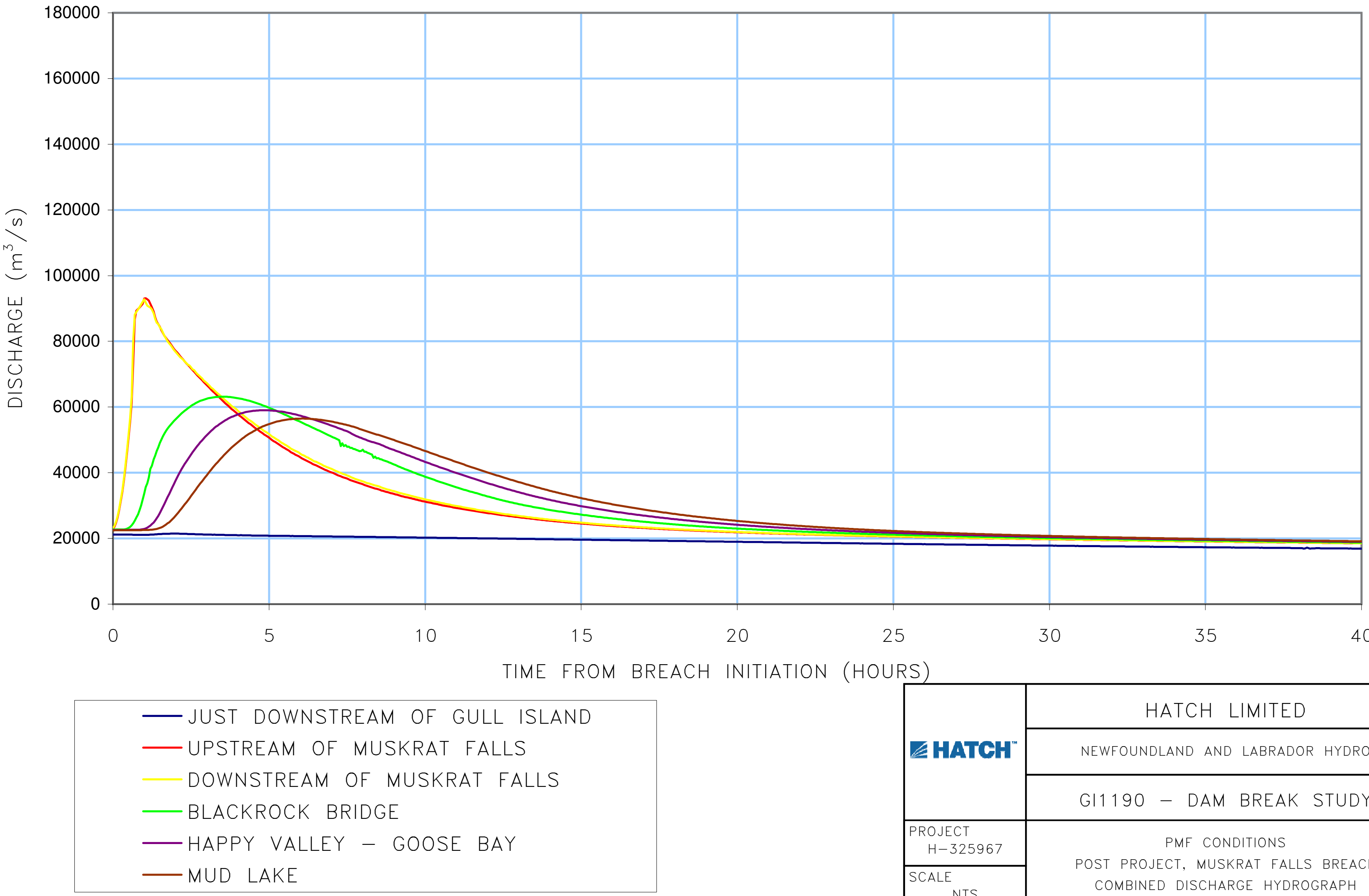
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	PMF CONDITIONS POST PROJECT, GULL ISLAND BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH MUD LAKE
SCALE NTS	
DATE MAR 2008	FIGURE F.8

Appendix G

PMF Conditions – Post Gull Island and Muskrat Falls – Muskrat Falls Dam Failure

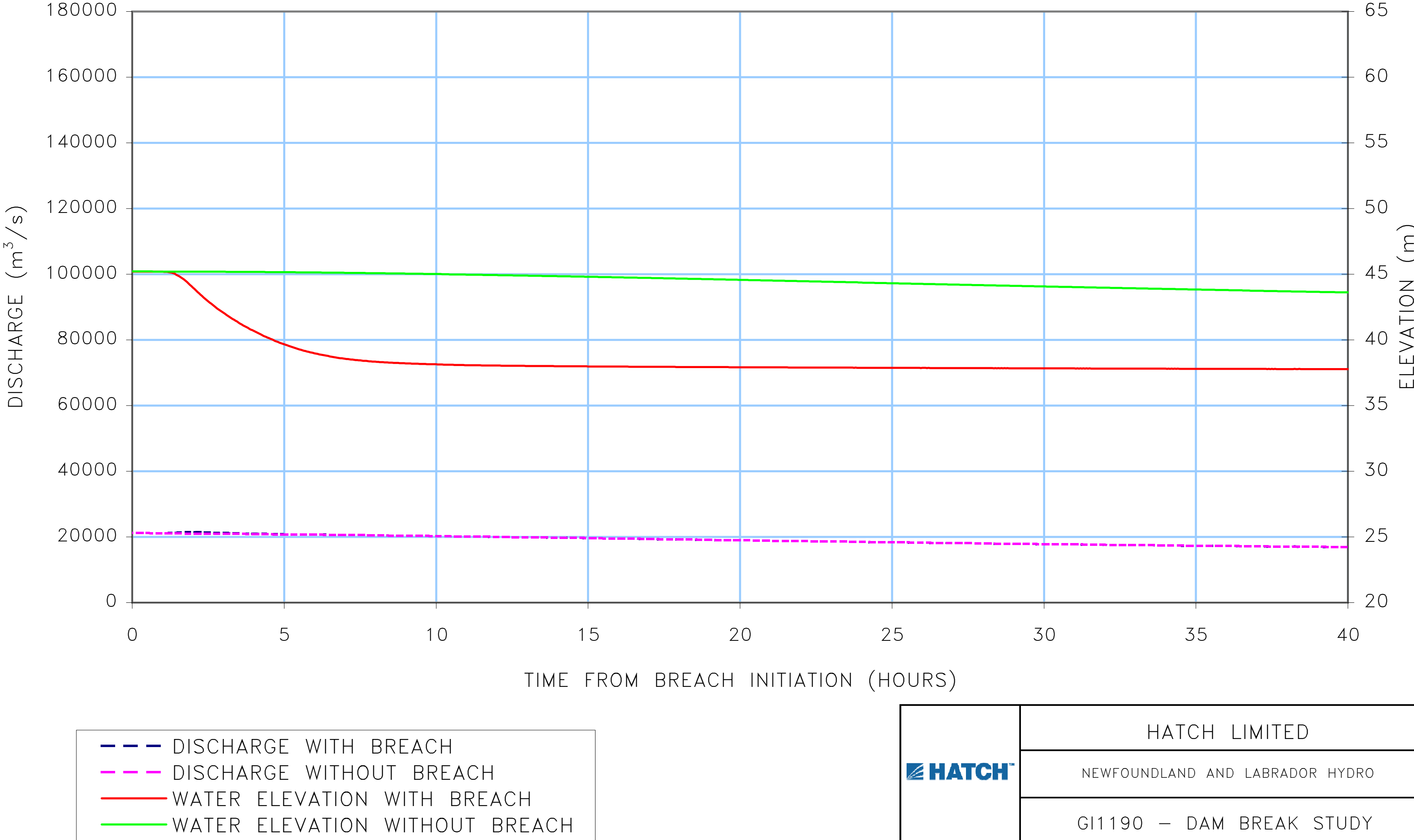


HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H-325967	PMF CONDITIONS POST PROJECT, MUSKRAT FALLS BREACH MAXIMUM WATER ELEVATION PROFILES
SCALE NTS	
DATE MAR 2008	FIGURE G.1



Note: Discharge upstream of Muskrat Falls is high due to downstream breach.

HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	PMF CONDITIONS POST PROJECT, MUSKRAT FALLS BREACH COMBINED DISCHARGE HYDROGRAPH
SCALE NTS	
DATE MAR 2008	FIGURE G.2



HATCH

HATCH LIMITED

NEWFOUNDLAND AND LABRADOR HYDRO

GI1190 – DAM BREAK STUDY

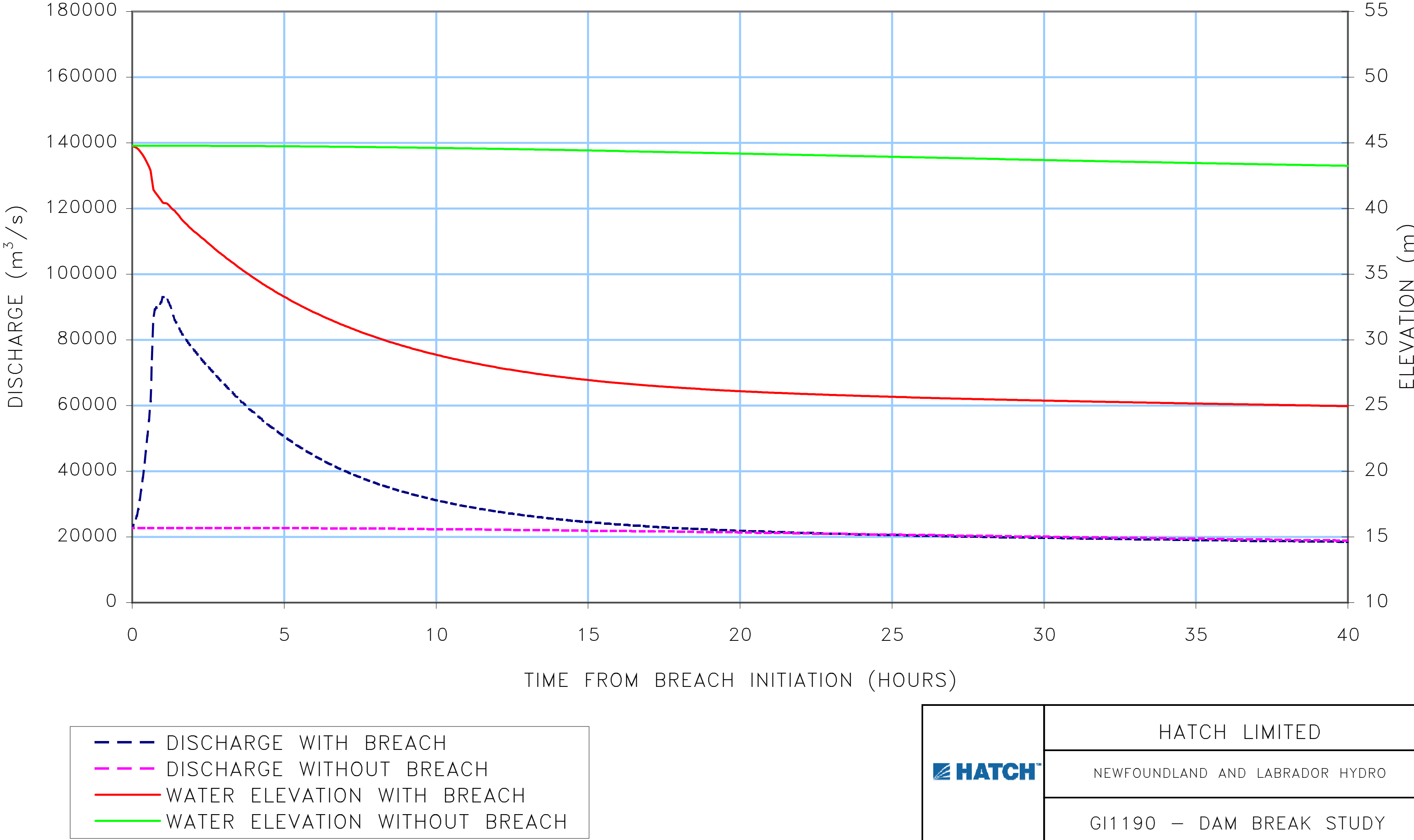
PROJECT H–325967

SCALE NTS

DATE MAR 2008

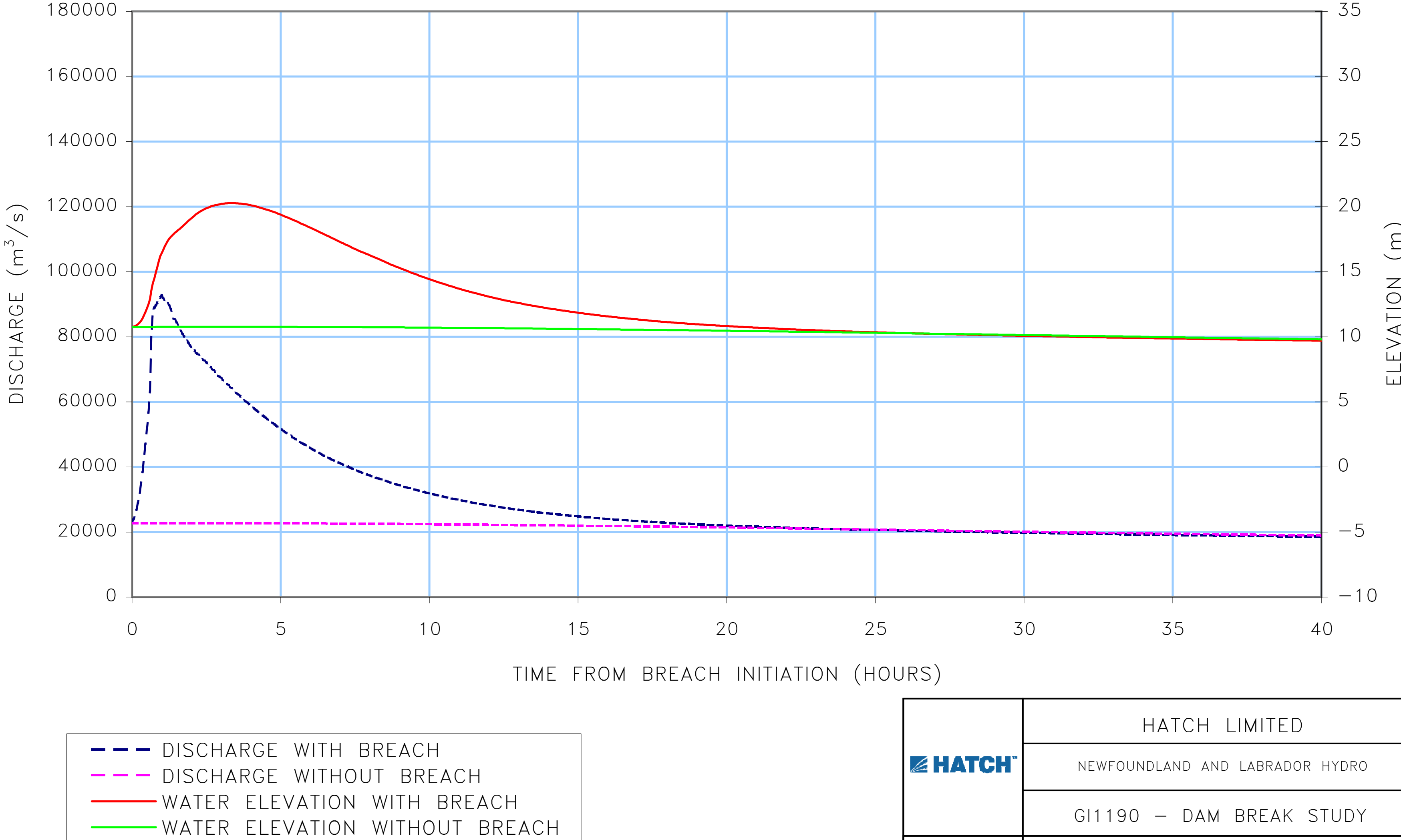
PMF CONDITIONS
POST PROJECT, MUSKRAT FALLS BREACH
DISCHARGE AND WATER LEVEL HYDROGRAPH
DOWNSTREAM OF GULL ISLAND DAM

FIGURE G.3

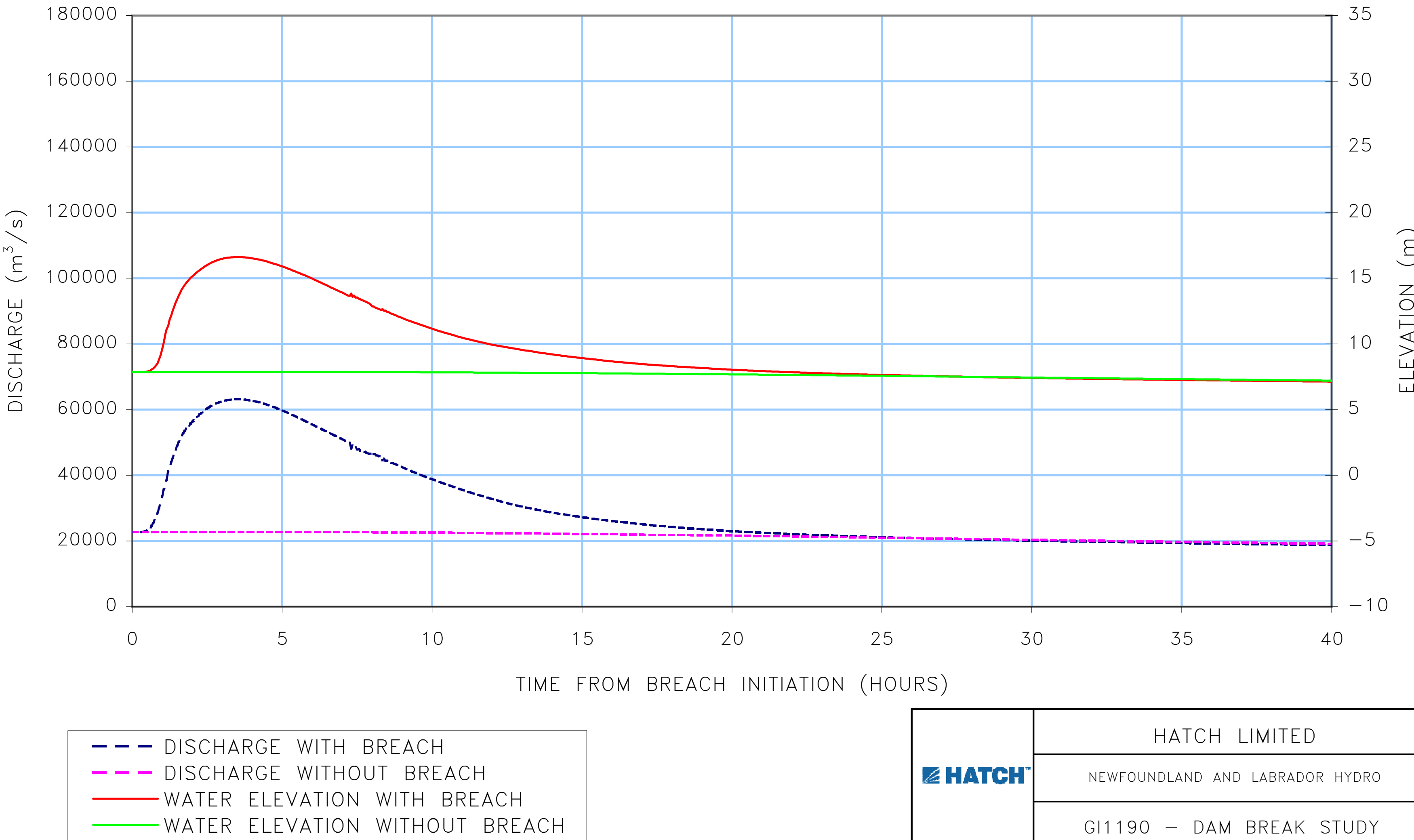


Note: Discharge upstream of Muskrat Falls is high due to downstream breach.

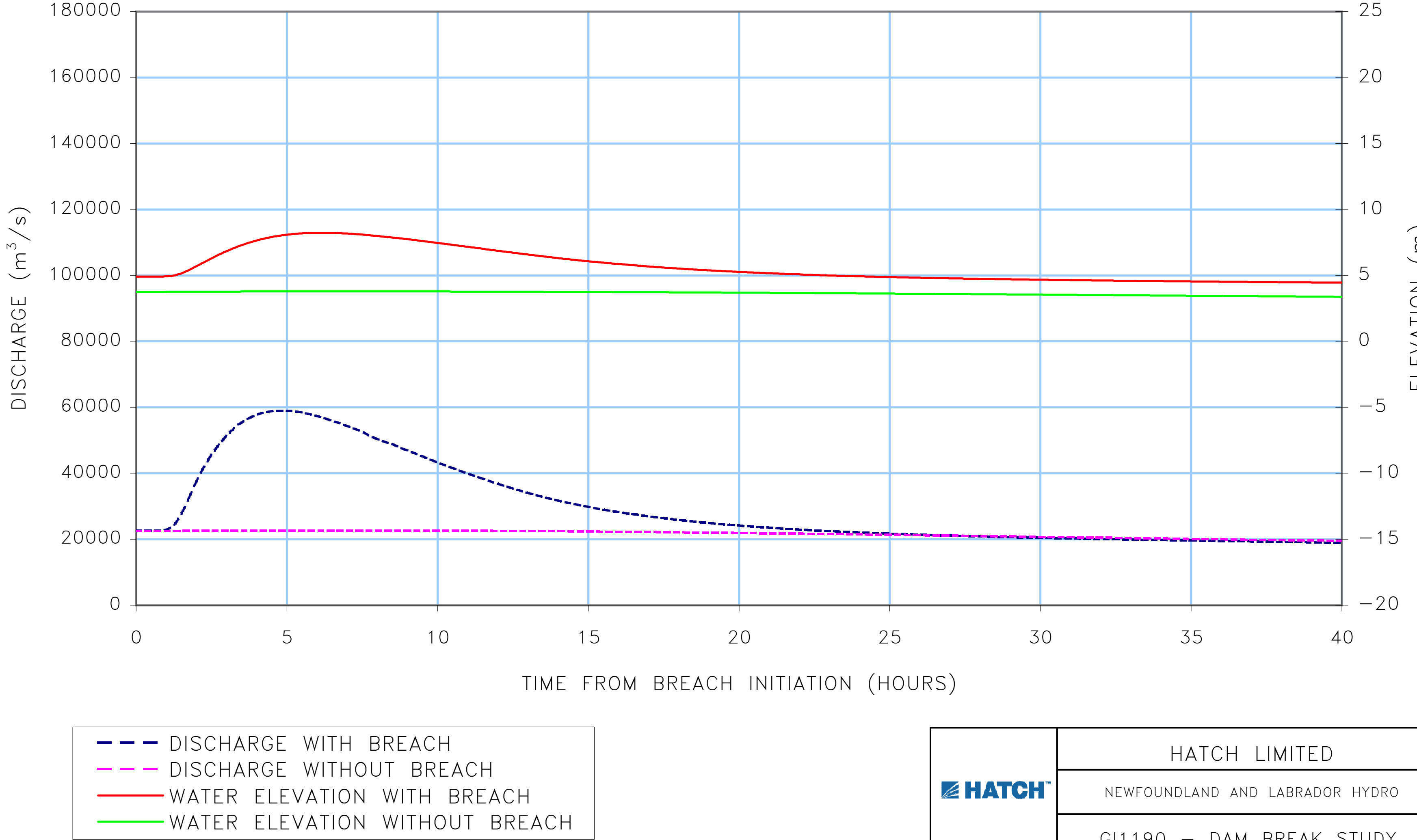
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	PMF CONDITIONS POST PROJECT, MUSKRAT FALLS BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH UPSTREAM OF MUSKRAT FALLS
SCALE NTS	
DATE MAR 2008	FIGURE G.4



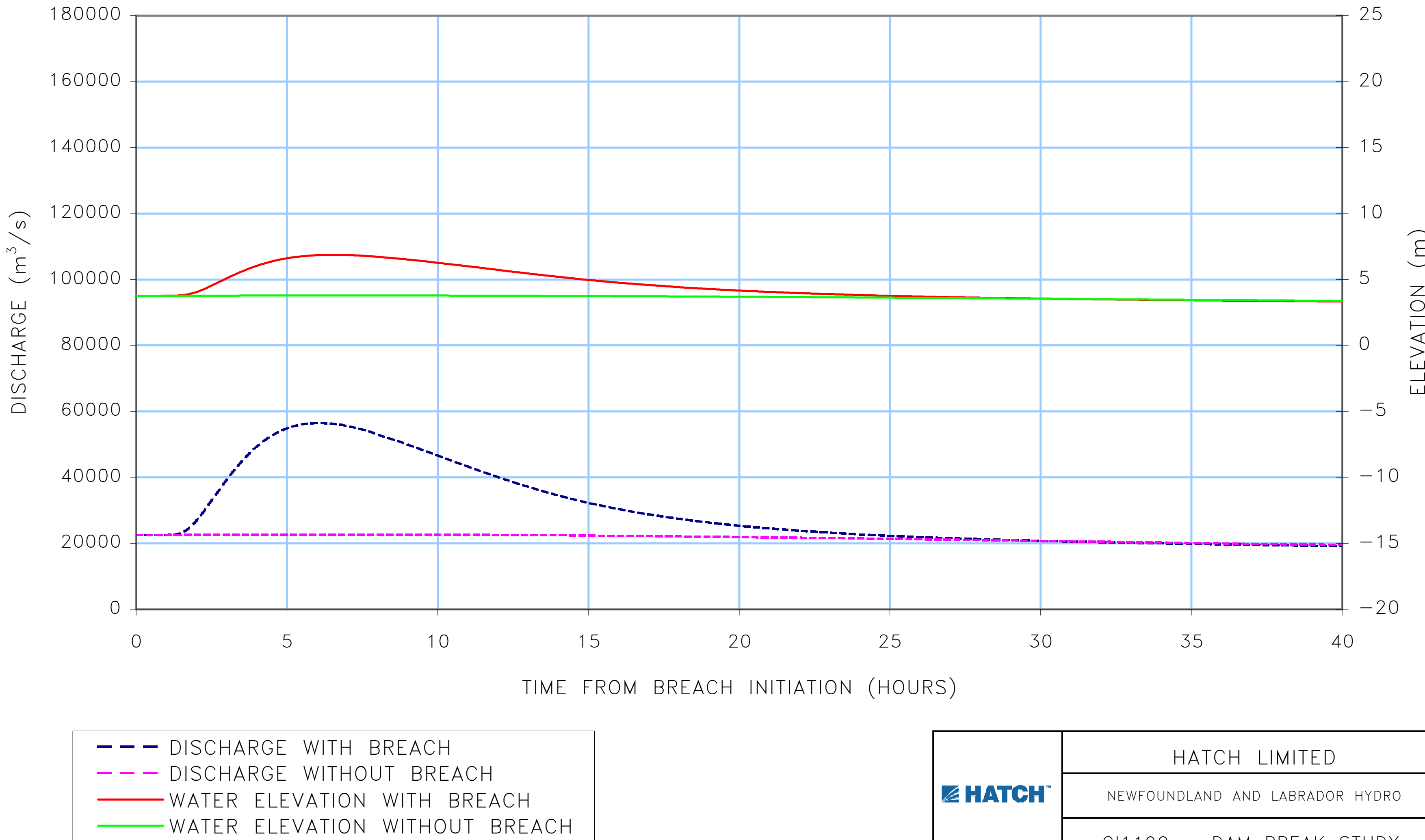
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 — DAM BREAK STUDY
PROJECT H-325967	PMF CONDITIONS POST PROJECT, MUSKRAT FALLS BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH DOWNSTREAM OF MUSKRAT FALLS
SCALE NTS	
DATE MAR 2008	FIGURE G.5



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	PMF CONDITIONS POST PROJECT, MUSKRAT FALLS BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH BLACKROCK BRIDGE
SCALE NTS	
DATE MAR 2008	FIGURE G.6



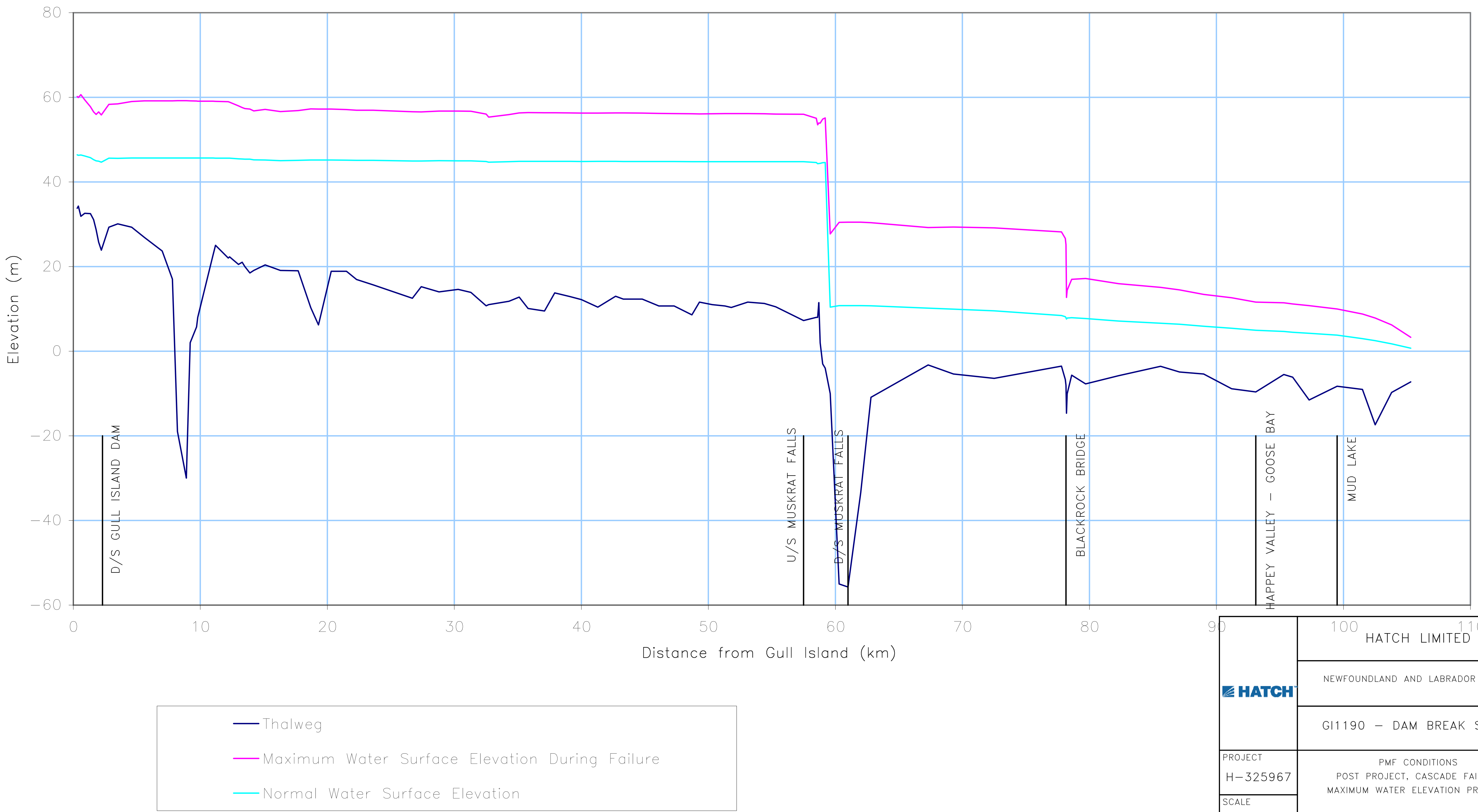
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	PMF CONDITIONS POST PROJECT, MUSKRAT FALLS BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH HAPPY VALLEY–GOOSE BAY
SCALE NTS	
DATE MAR 2008	FIGURE G.7



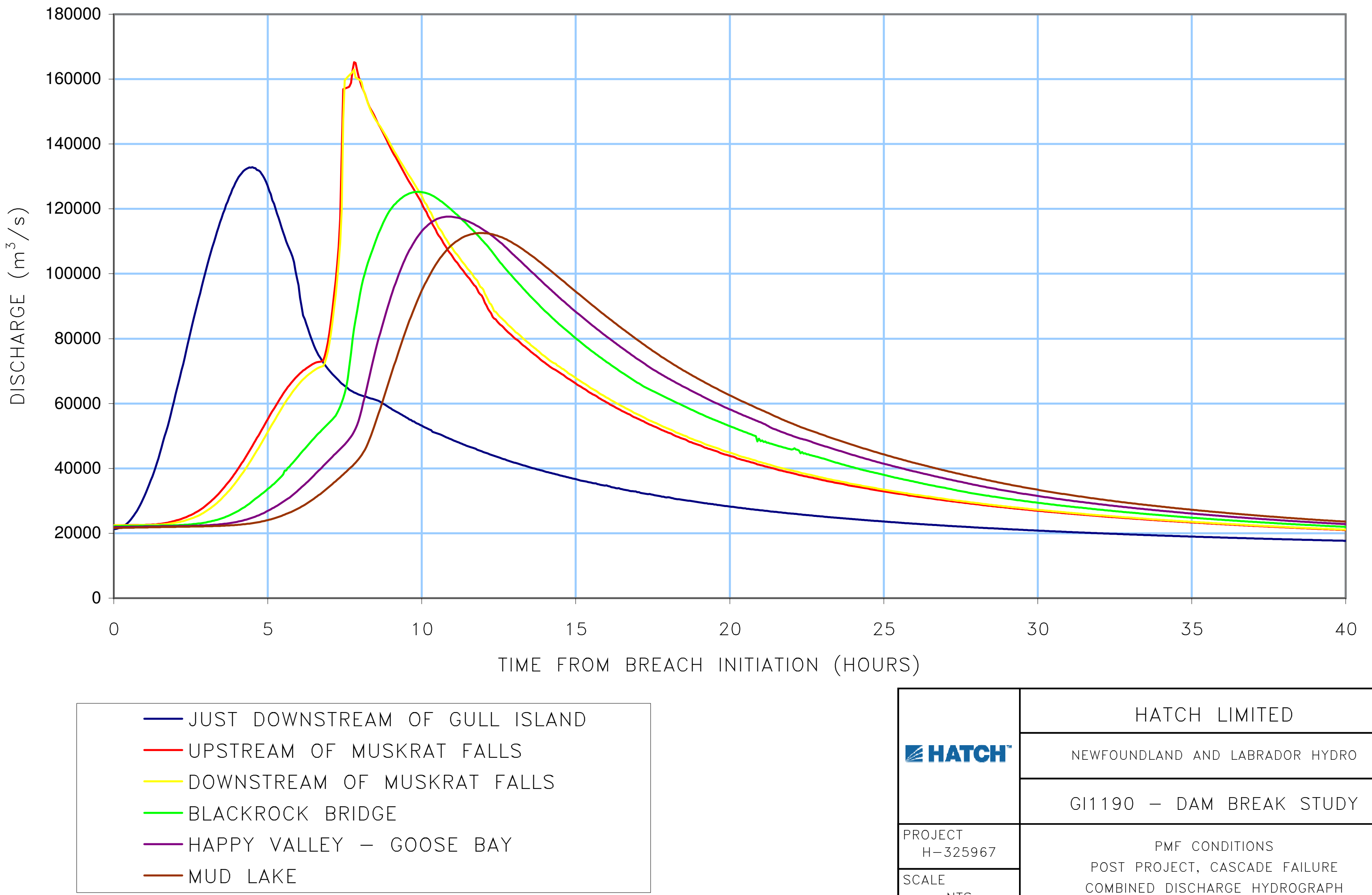
HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	PMF CONDITIONS POST PROJECT, MUSKRAT FALLS BREACH DISCHARGE AND WATER LEVEL HYDROGRAPH MUD LAKE
SCALE NTS	
DATE MAR 2008	FIGURE G.8

Appendix H

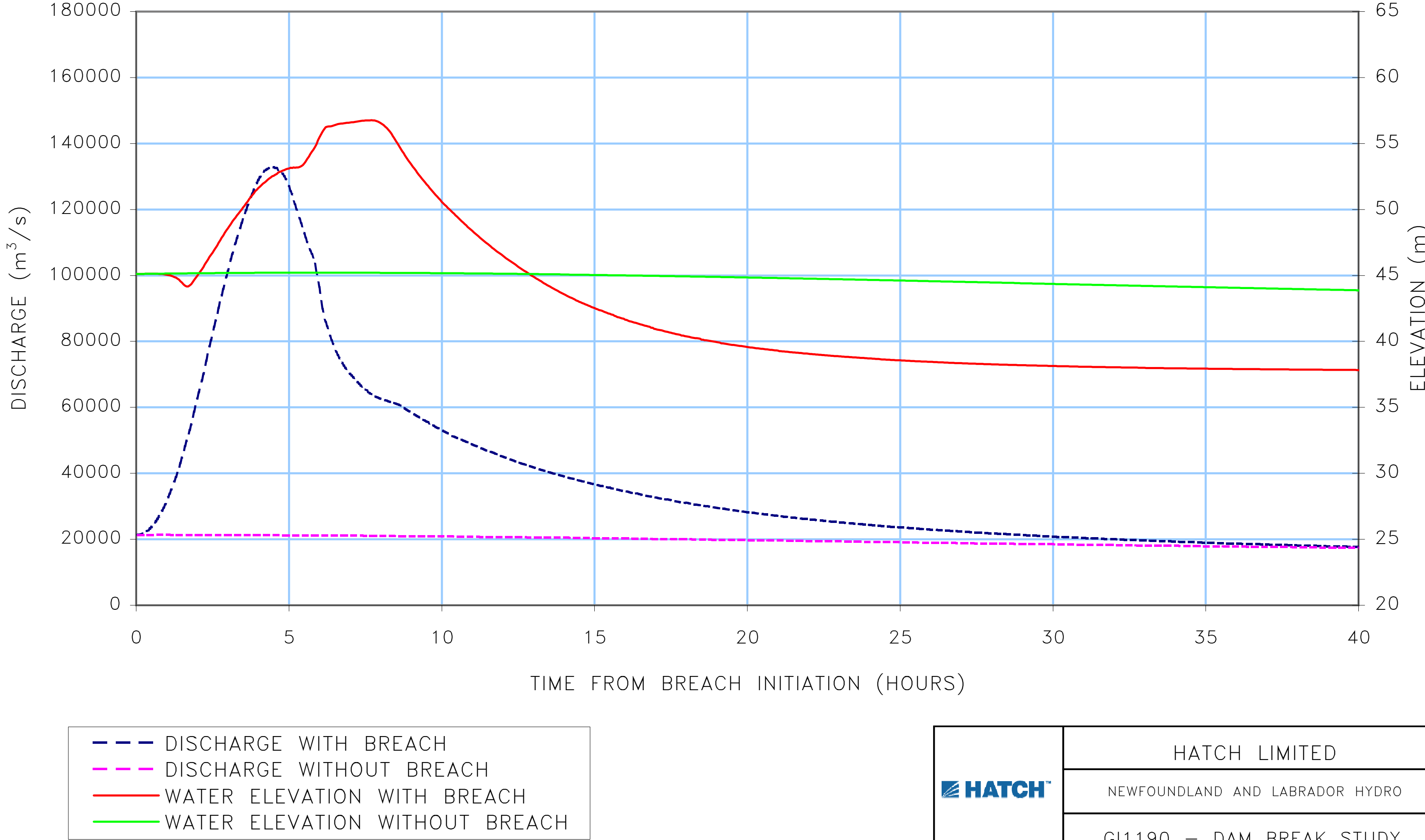
PMF Conditions – Post Gull Island and Muskrat Falls – Cascade Failure



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	PMF CONDITIONS POST PROJECT, CASCADE FAILURE MAXIMUM WATER ELEVATION PROFILES
SCALE NTS	
DATE MAR 2008	FIGURE H.1



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	PMF CONDITIONS POST PROJECT, CASCADE FAILURE COMBINED DISCHARGE HYDROGRAPH
SCALE NTS	
DATE MAR 2008	FIGURE H.2



HATCH

HATCH LIMITED

NEWFOUNDLAND AND LABRADOR HYDRO

GI1190 – DAM BREAK STUDY

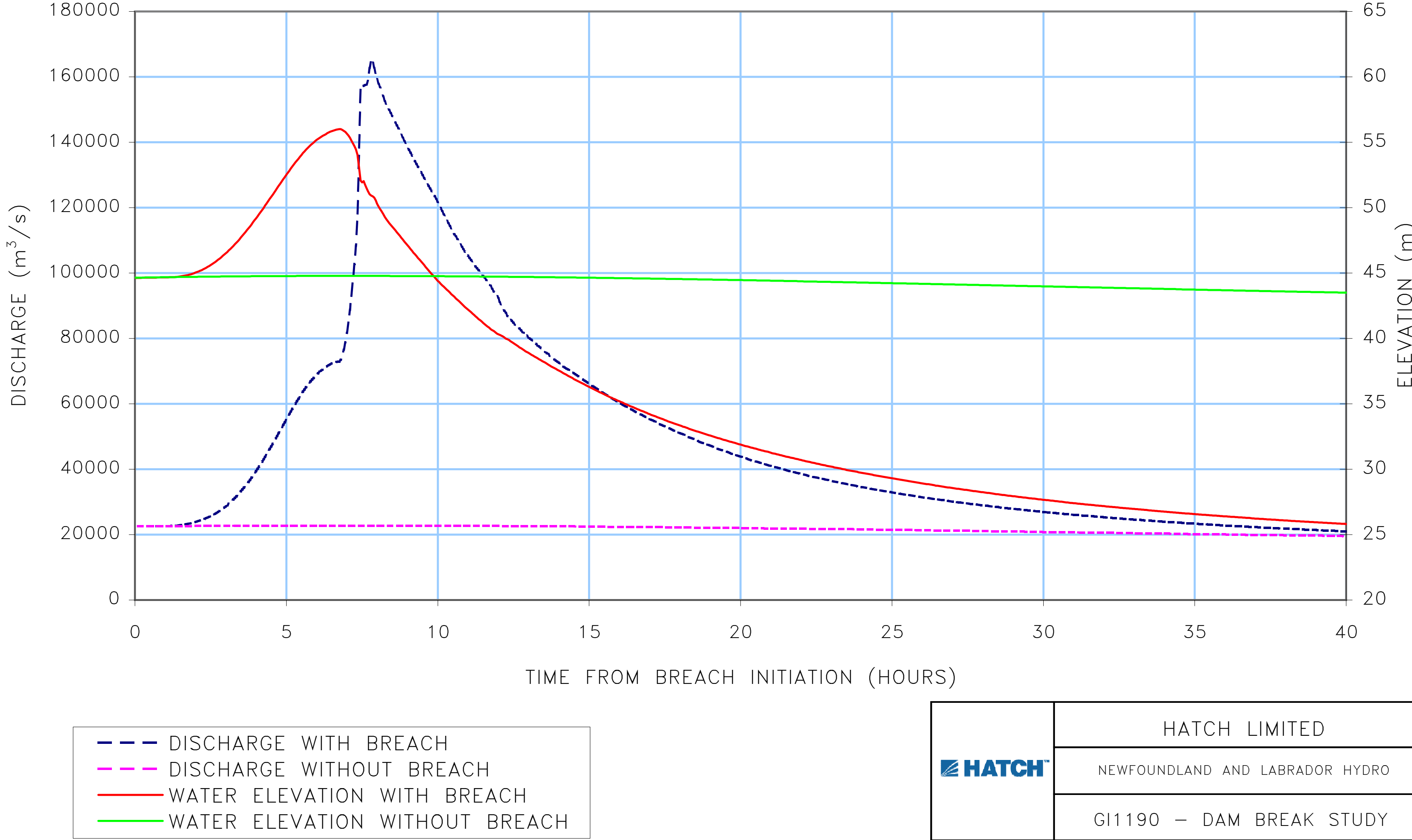
PROJECT H–325967

SCALE NTS

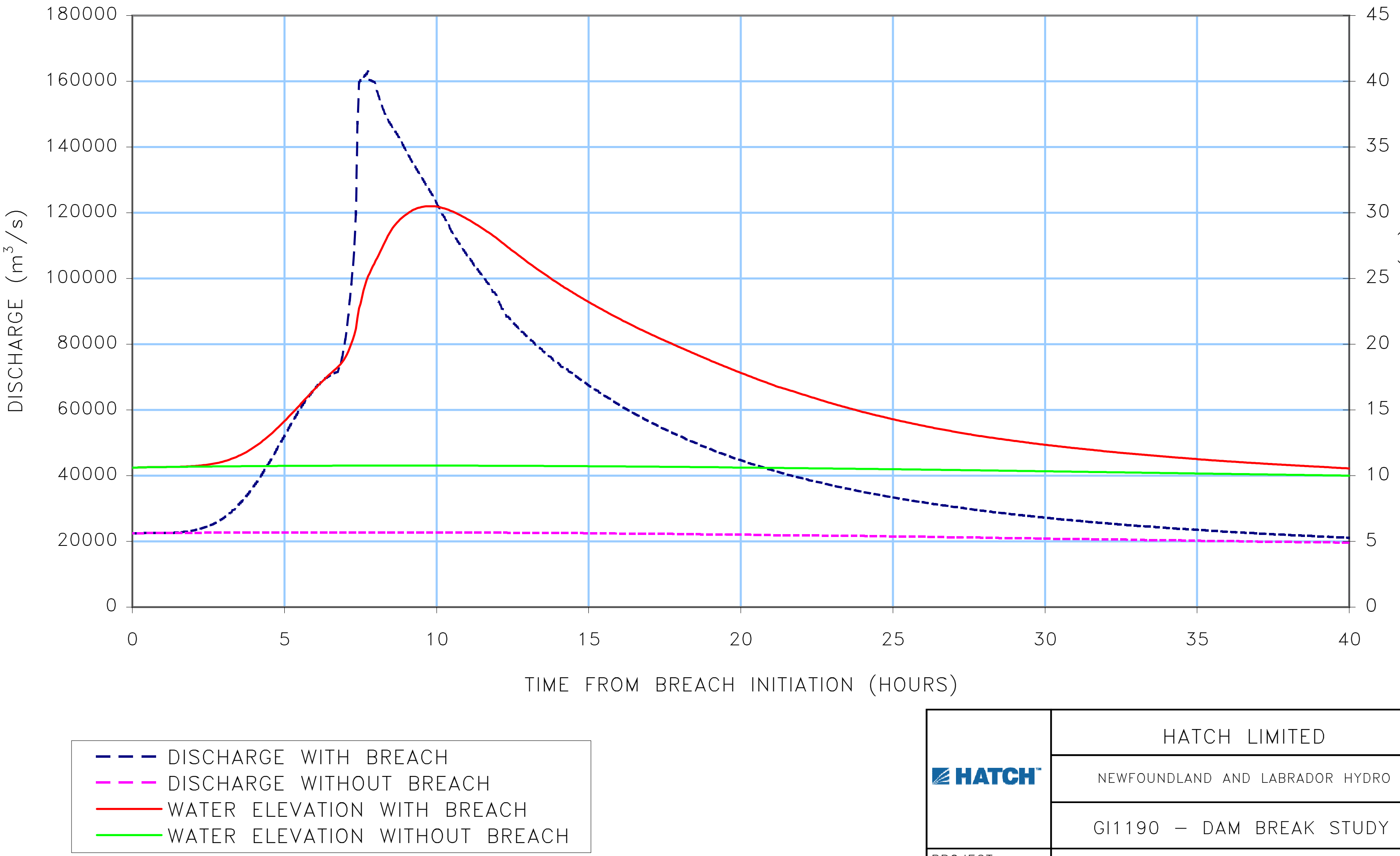
DATE MAR 2008

PMF CONDITIONS
POST PROJECT, CASCADE FAILURE
DISCHARGE AND WATER LEVEL HYDROGRAPH
DOWNSTREAM OF GULL ISLAND DAM

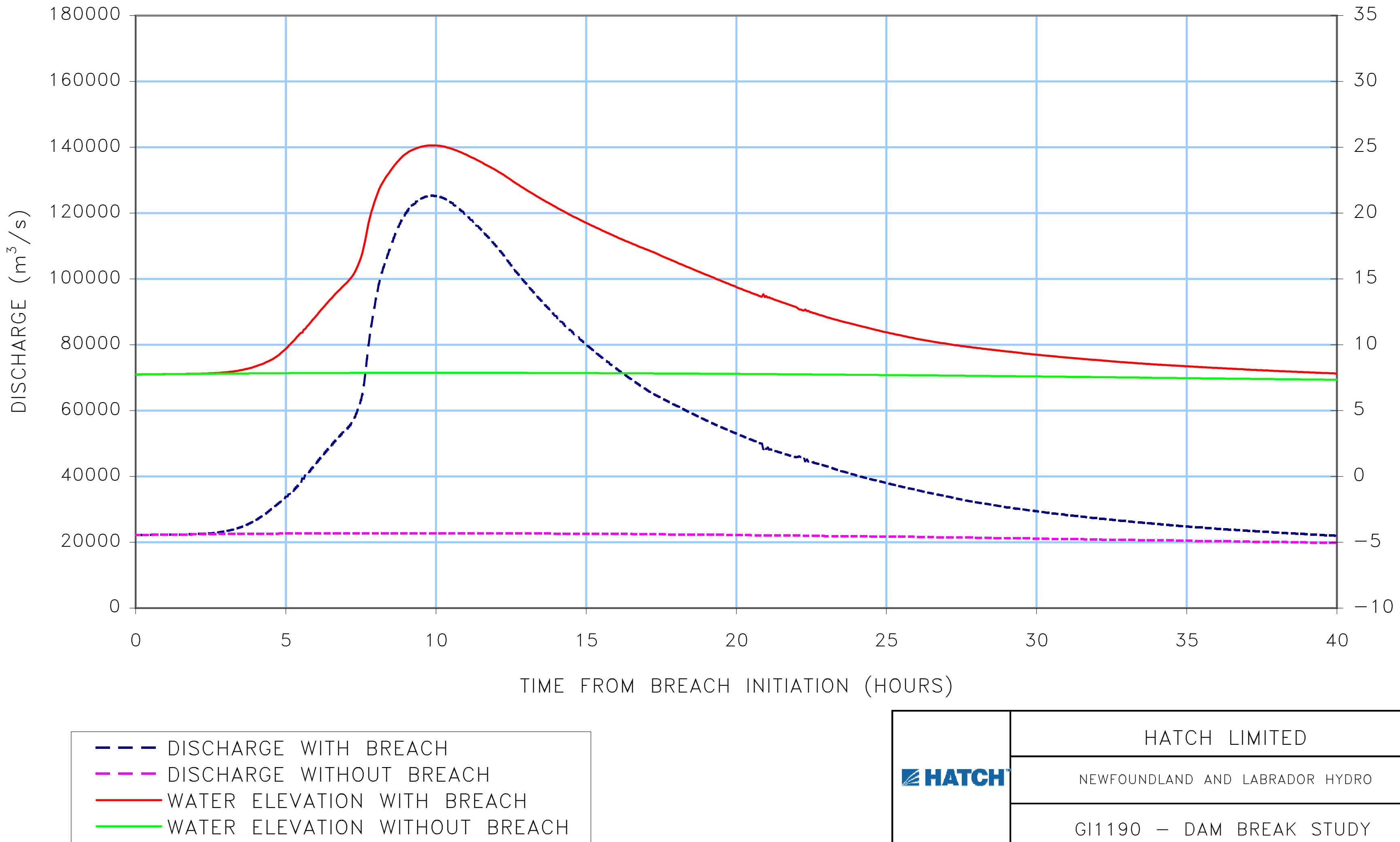
FIGURE H.3



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	PMF CONDITIONS POST PROJECT, CASCADE FAILURE DISCHARGE AND WATER LEVEL HYDROGRAPH UPSTREAM OF MUSKRAT FALLS
SCALE NTS	
DATE MAR 2008	FIGURE H.4



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H–325967	PMF CONDITIONS POST PROJECT, CASCADE FAILURE DISCHARGE AND WATER LEVEL HYDROGRAPH DOWNSTREAM OF MUSKRAT FALLS
SCALE NTS	
DATE MAR 2008	FIGURE H.5



HATCH

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NEWFOUNDLAND AND LABRADOR HYDRO

GI1190 – DAM BREAK STUDY

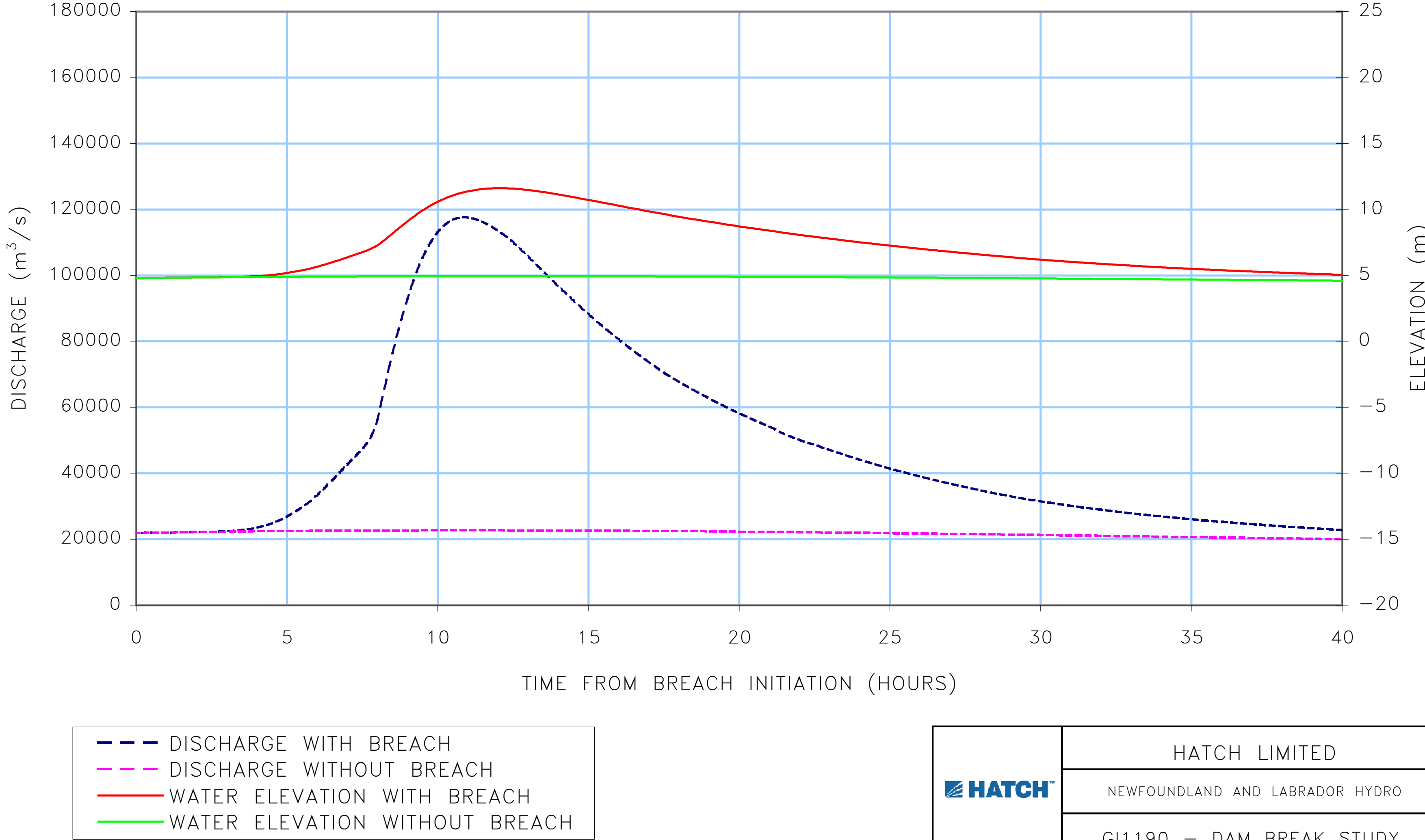
PROJECT H–325967

SCALE NTS

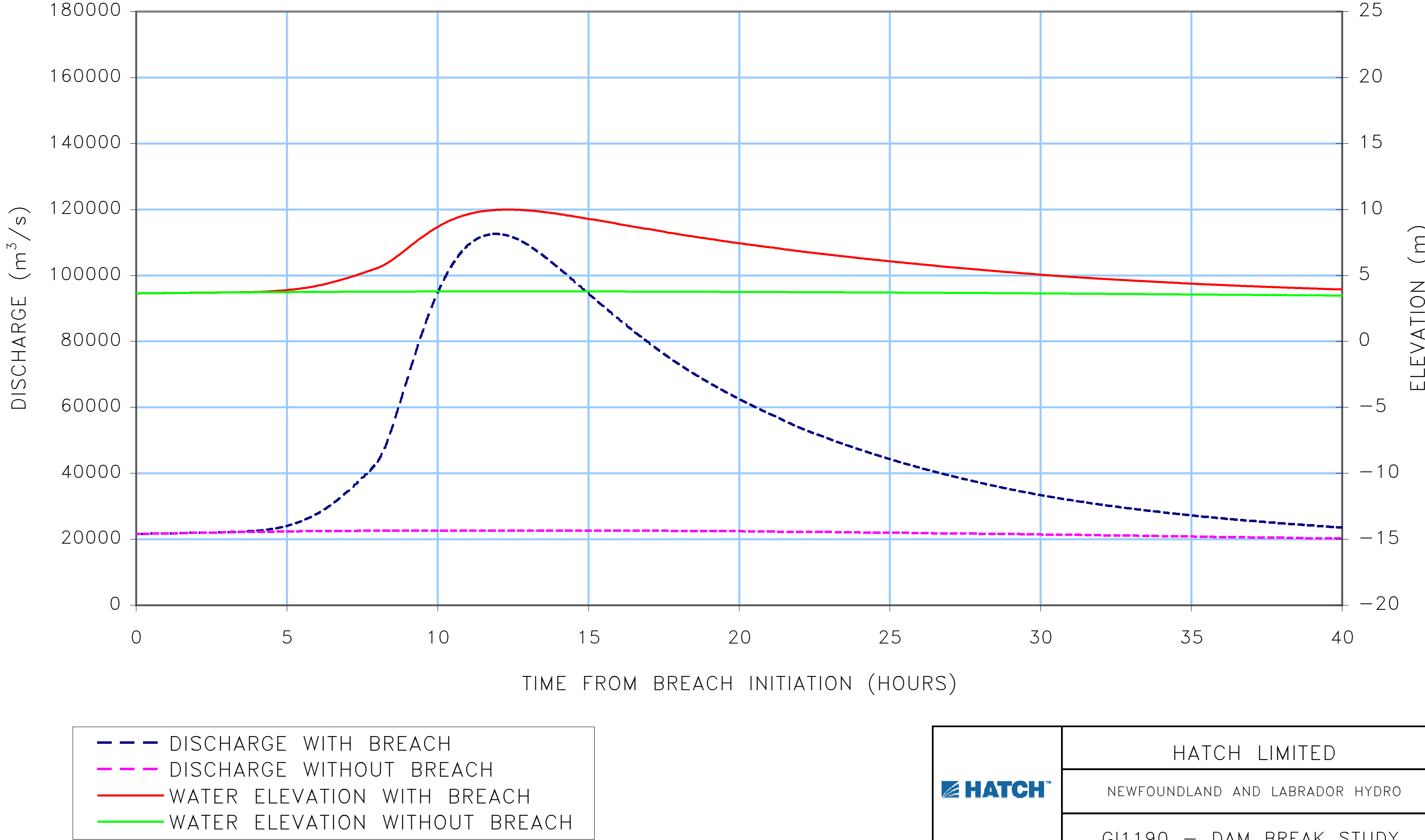
DATE MAR 2008

PMF CONDITIONS
POST PROJECT, CASCADE FAILURE
DISCHARGE AND WATER LEVEL HYDROGRAPH
BLACKROCK BRIDGE

FIGURE H.6



HATCH	HATCH LIMITED
	NEWFOUNDLAND AND LABRADOR HYDRO
	GI1190 – DAM BREAK STUDY
PROJECT H-325967	PMF CONDITIONS POST PROJECT, CASCADE FAILURE DISCHARGE AND WATER LEVEL HYDROGRAPH HAPPY VALLEY-GOOSE BAY
SCALE NTS	
DATE MAR 2008	FIGURE H.7



HATCH

HATCH LIMITED

NEWFOUNDLAND AND LABRADOR HYDRO

GI1190 – DAM BREAK STUDY

PROJECT H–325967

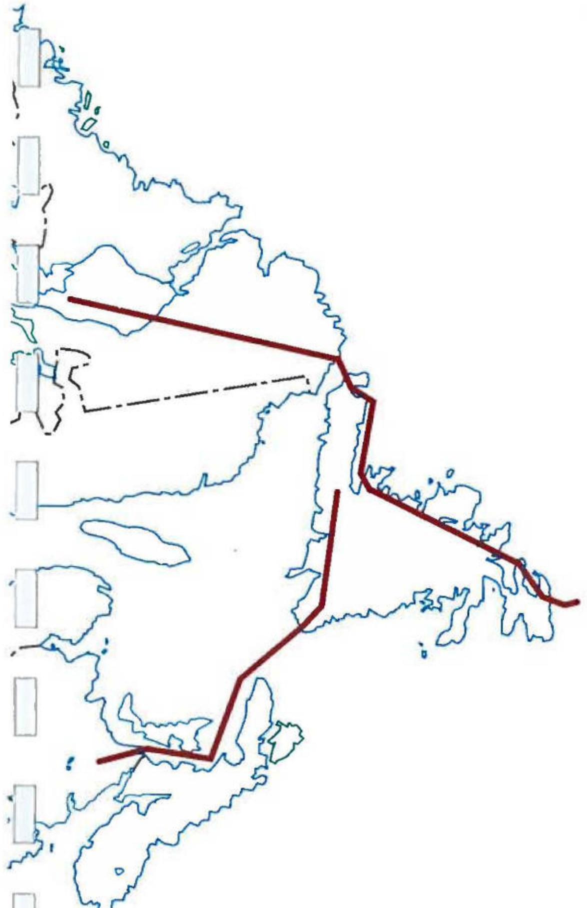
SCALE NTS

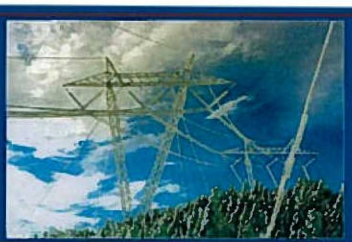
DATE MAR 2008

PMF CONDITIONS
POST PROJECT, CASCADE FAILURE
DISCHARGE AND WATER LEVEL HYDROGRAPH
MUD LAKE

FIGURE H.8

HYDRO
THE POWER OF COMMITMENT





THE Lower Churchill PROJECT

April 2008

GI1190 - Dam Break Study
Volume 2

prepared by

HATCH™

in association with

RSW inc.

Statnett

TGS TransGrid Solutions

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THE POWER OF COMMITMENT

THE Lower Churchill PROJECT

April 2008

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Volume 2

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in association with

RSW inc.

Statnett

TGS

Appendix A

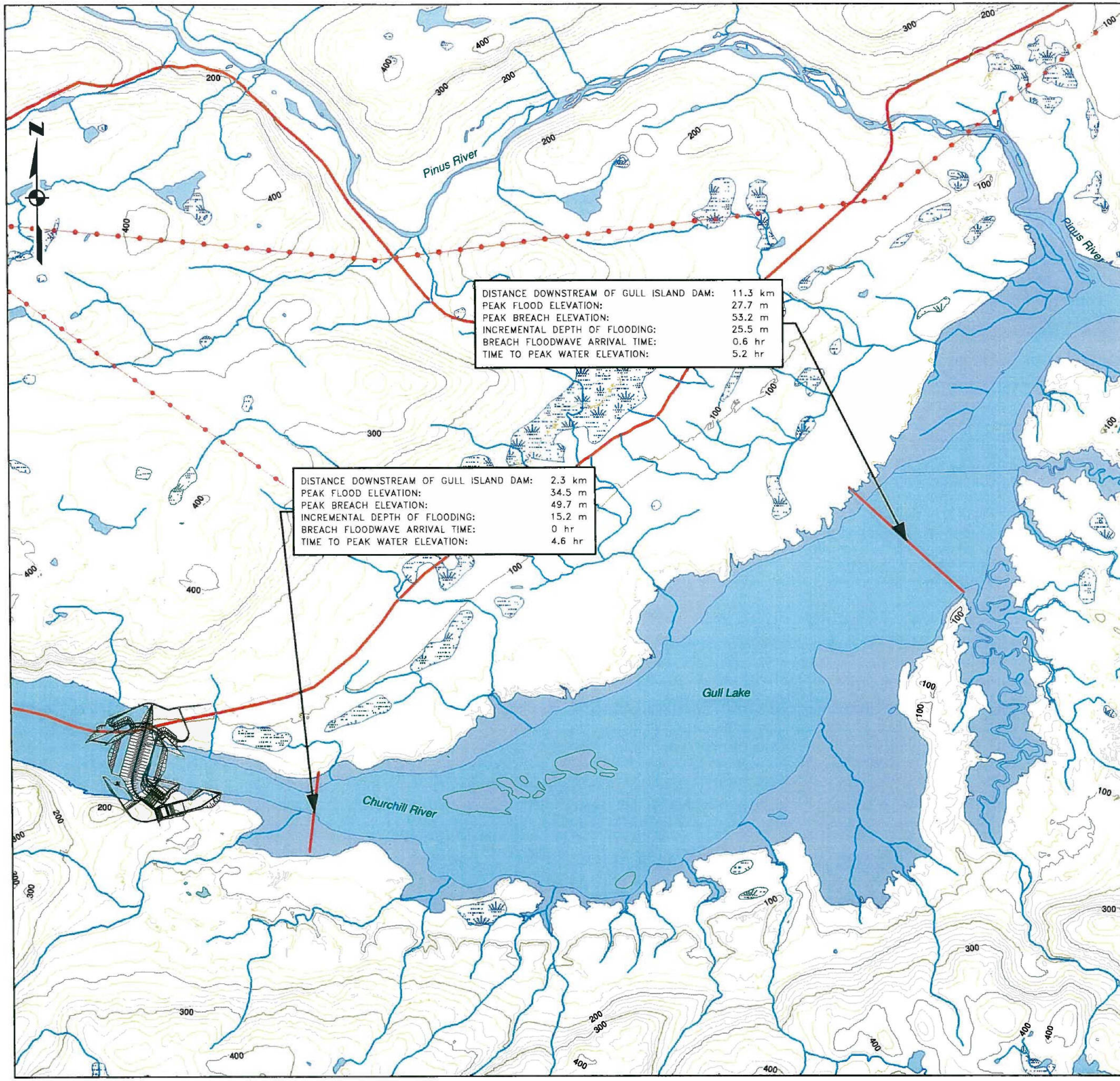
"Fair Weather" Inundation Mapping Series

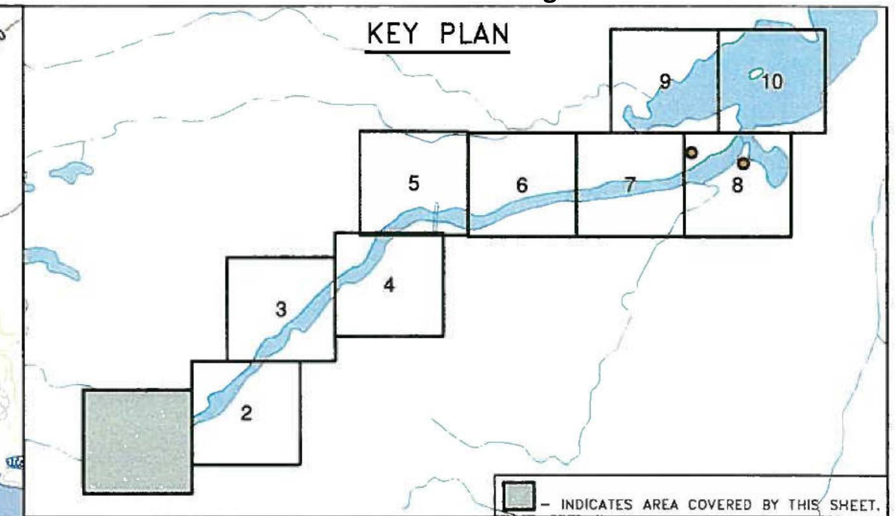
(1:50,000 Scale)

Appendix A

"Fair Weather" Inundation Mapping Series

(1:50,000 Scale)





LEGEND

■	BUILDING	———	RIVER
○	TANK	———	ROAD
	TOWER	—●—	TRANSMISSION LINE
	WATER BODY	CONTOURS	
	WETLAND		CONTOUR (20 m)
	BREACH INUNDATION		INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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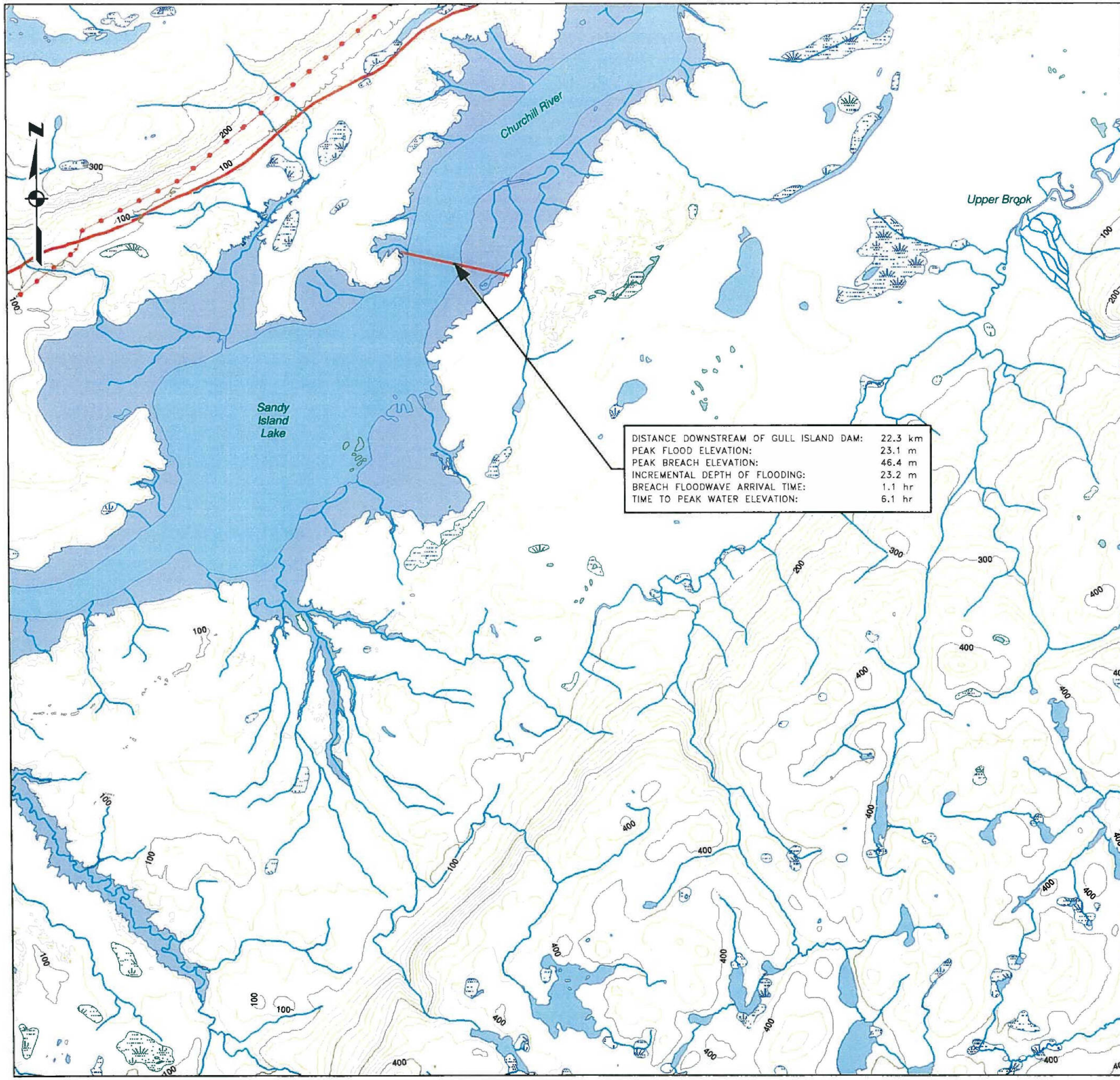
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000	DRAWING NO. FIGURE A1–1
HATCH PROJECT No. H–325967	



LEGEND

BUILDING	RIVER
TANK	ROAD
TOWER	TRANSMISSION LINE
WATER BODY	CONTOURS
WETLAND	CONTOUR (20 m)
BREACH INUNDATION	INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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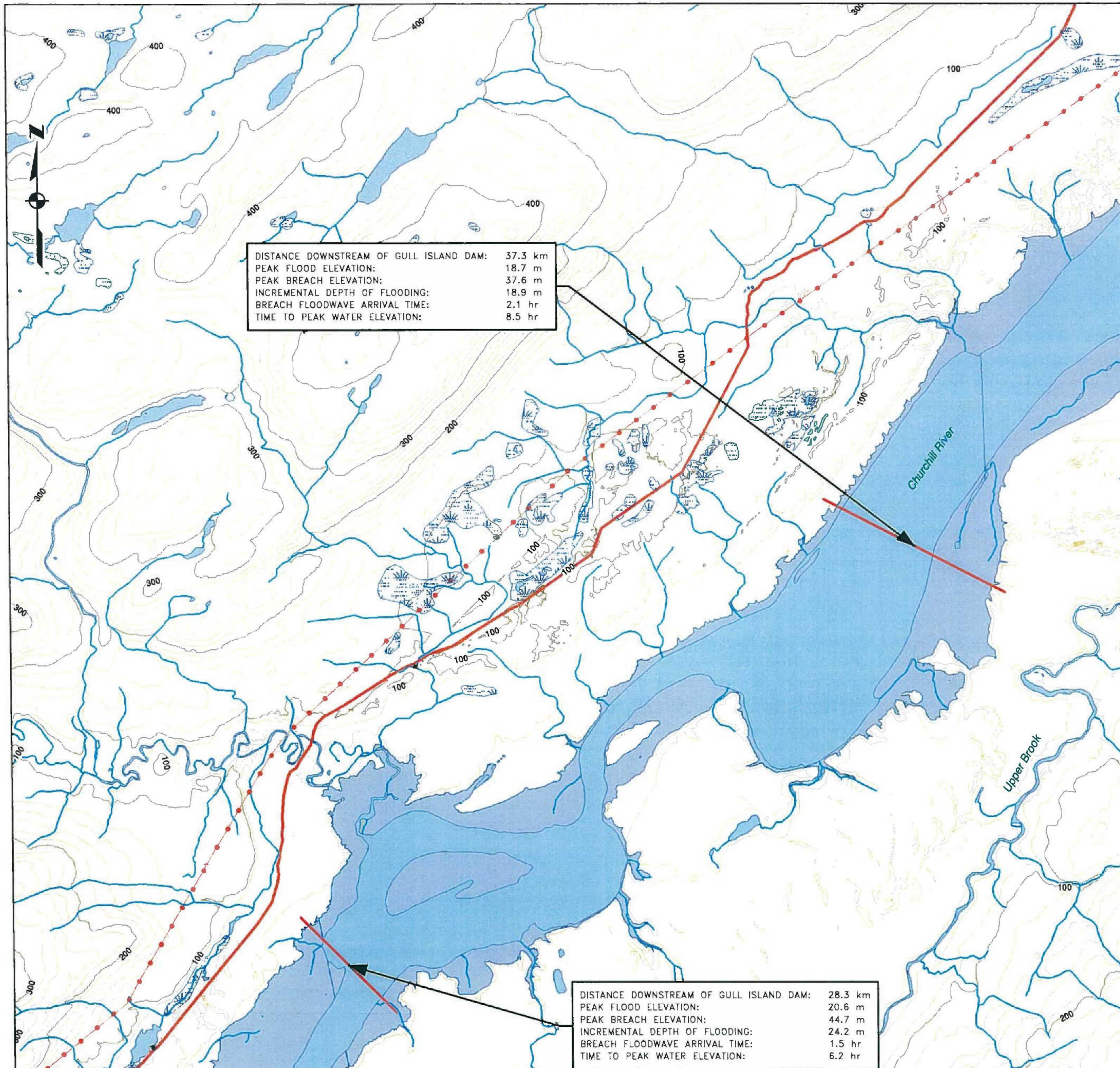
NEWFOUNDLAND AND LABRADOR HYDRO

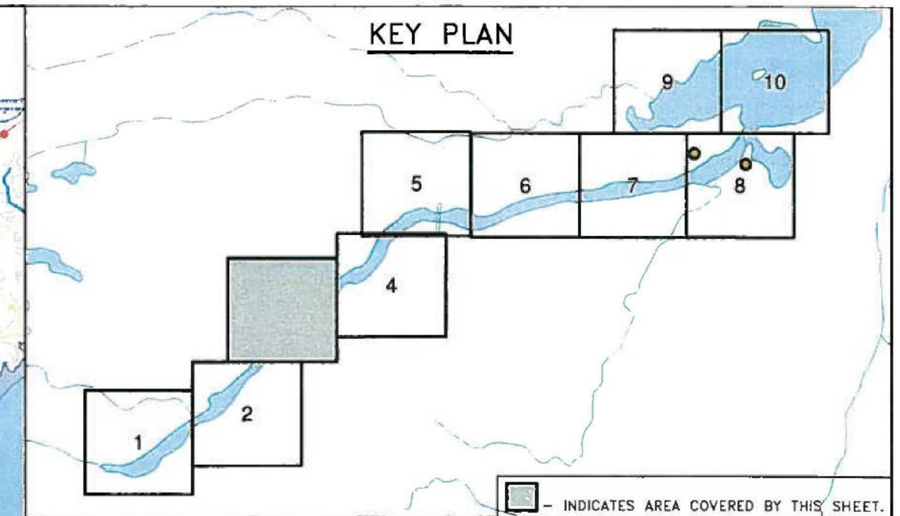
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000
HATCH PROJECT No. H-325967
DRAWING NO. FIGURE A1-2



KEY PLAN



- INDICATES AREA COVERED BY THIS SHEET.

LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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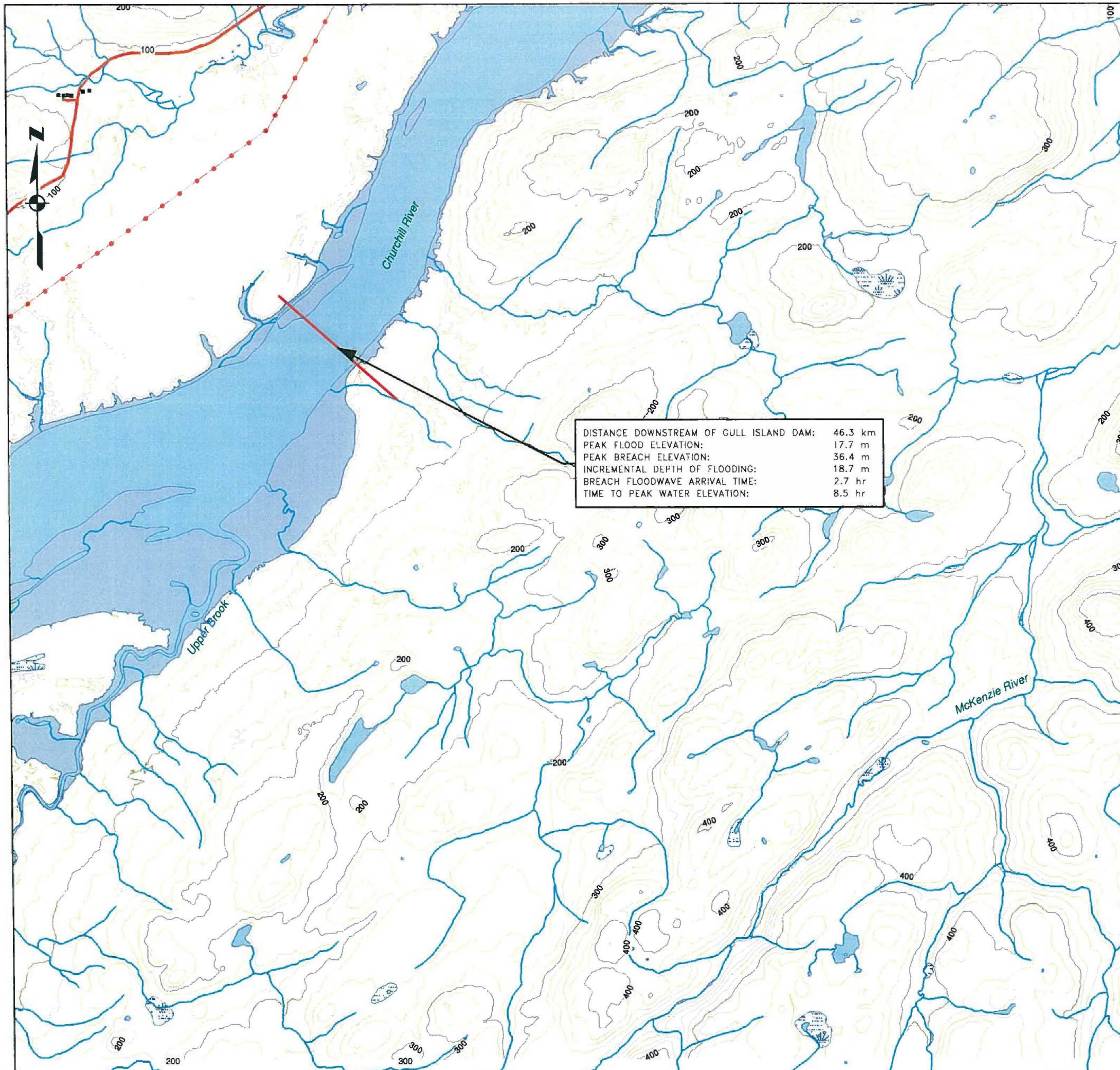
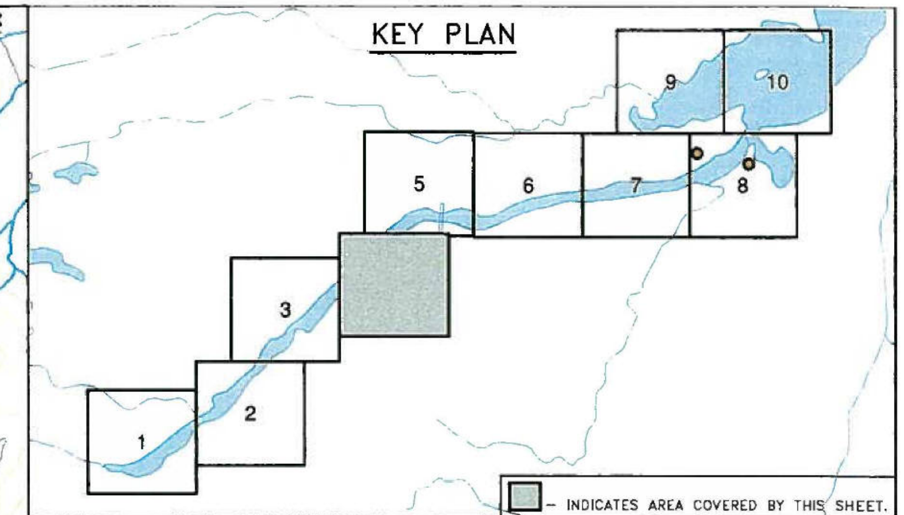
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000	DRAWING NO. FIGURE A1-3
HATCH PROJECT No. H-325967	





LEGEND

▪	BUILDING		RIVER
○	TANK		ROAD
	TOWER		TRANSMISSION LINE
	WATER BODY	CONTOURS	
	WETLAND		CONTOUR (20 m)
	BREACH INUNDATION		INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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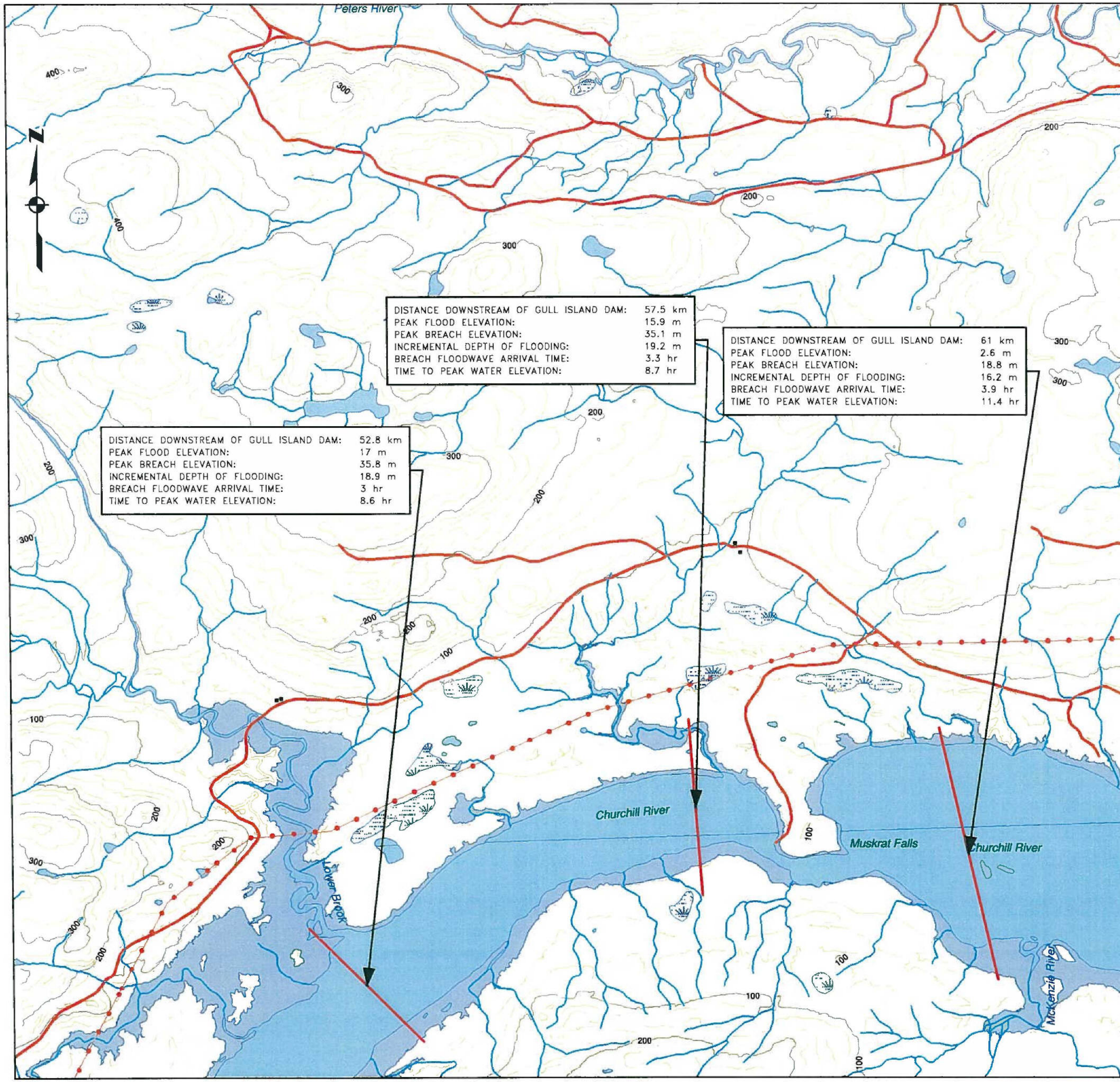
NEWFOUNDLAND AND LABRADOR HYDRO

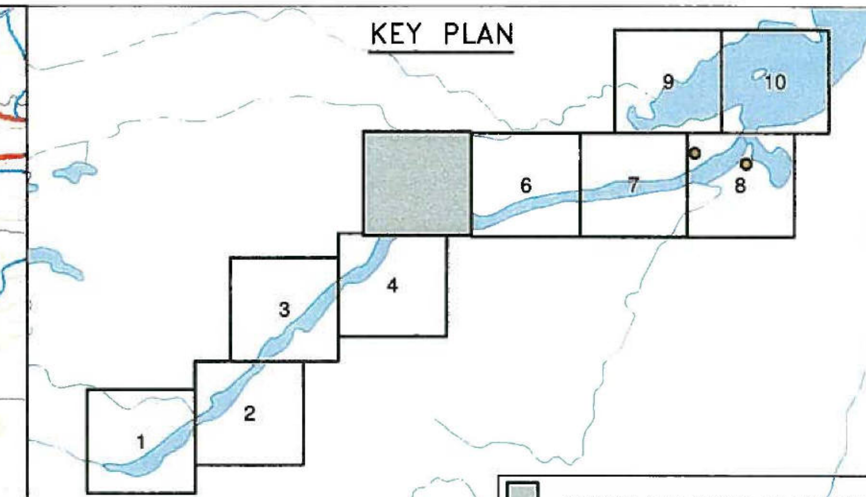
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000
HATCH PROJECT No. H-325967
DRAWING NO. FIGURE A1-4



KEY PLAN



– INDICATES AREA COVERED BY THIS SHEET.

LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

NOTES:

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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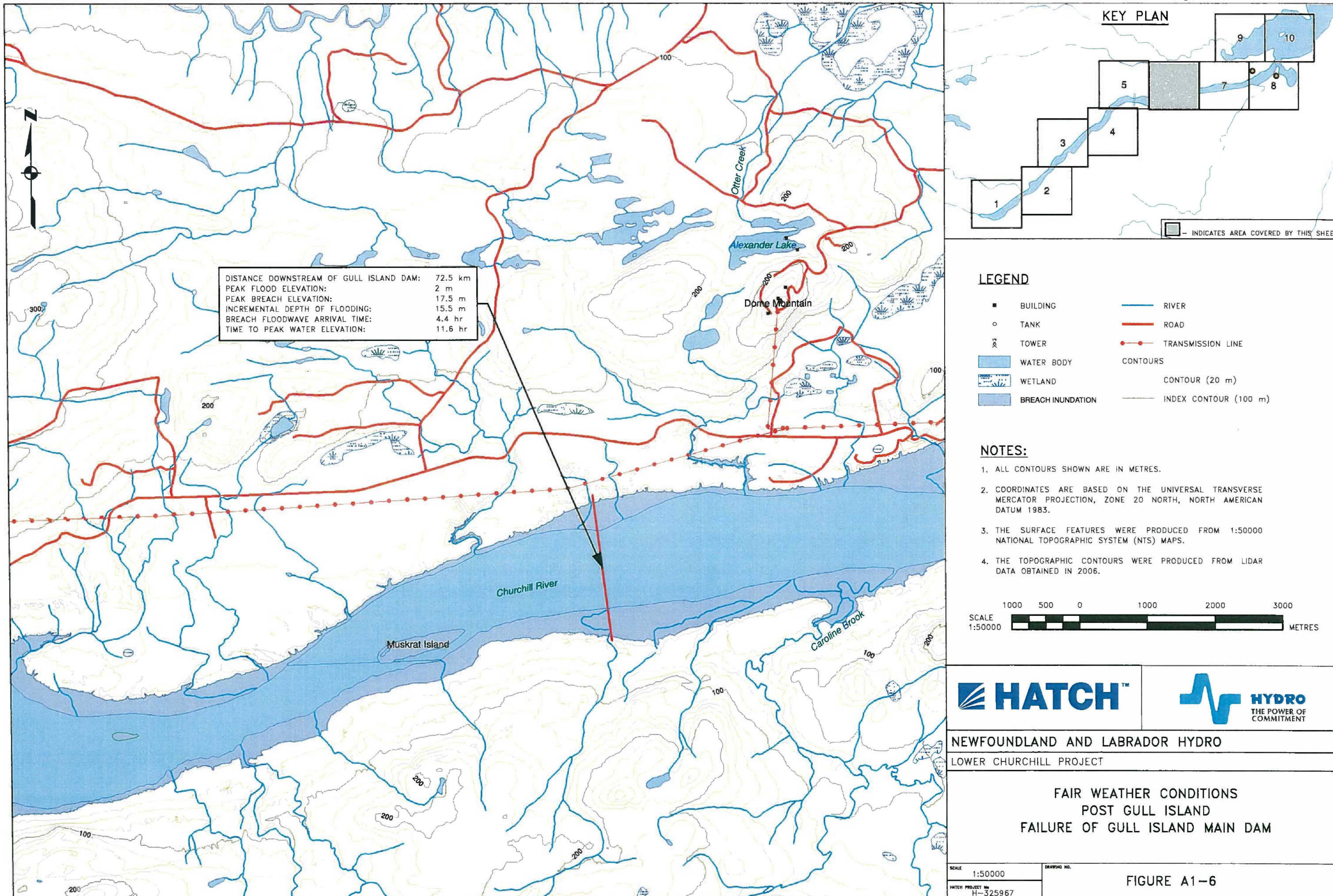
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE	DRAWING NO.
1:50000	FIGURE A1–5
HATCH PROJECT No. H-325967	



LEGEND

BUILDING	RIVER
TANK	ROAD
TOWER	TRANSMISSION LINE
WATER BODY	CONTOURS
WETLAND	CONTOUR (20 m)
BREACH INUNDATION	INDEX CONTOUR (100 m)

NOTES:

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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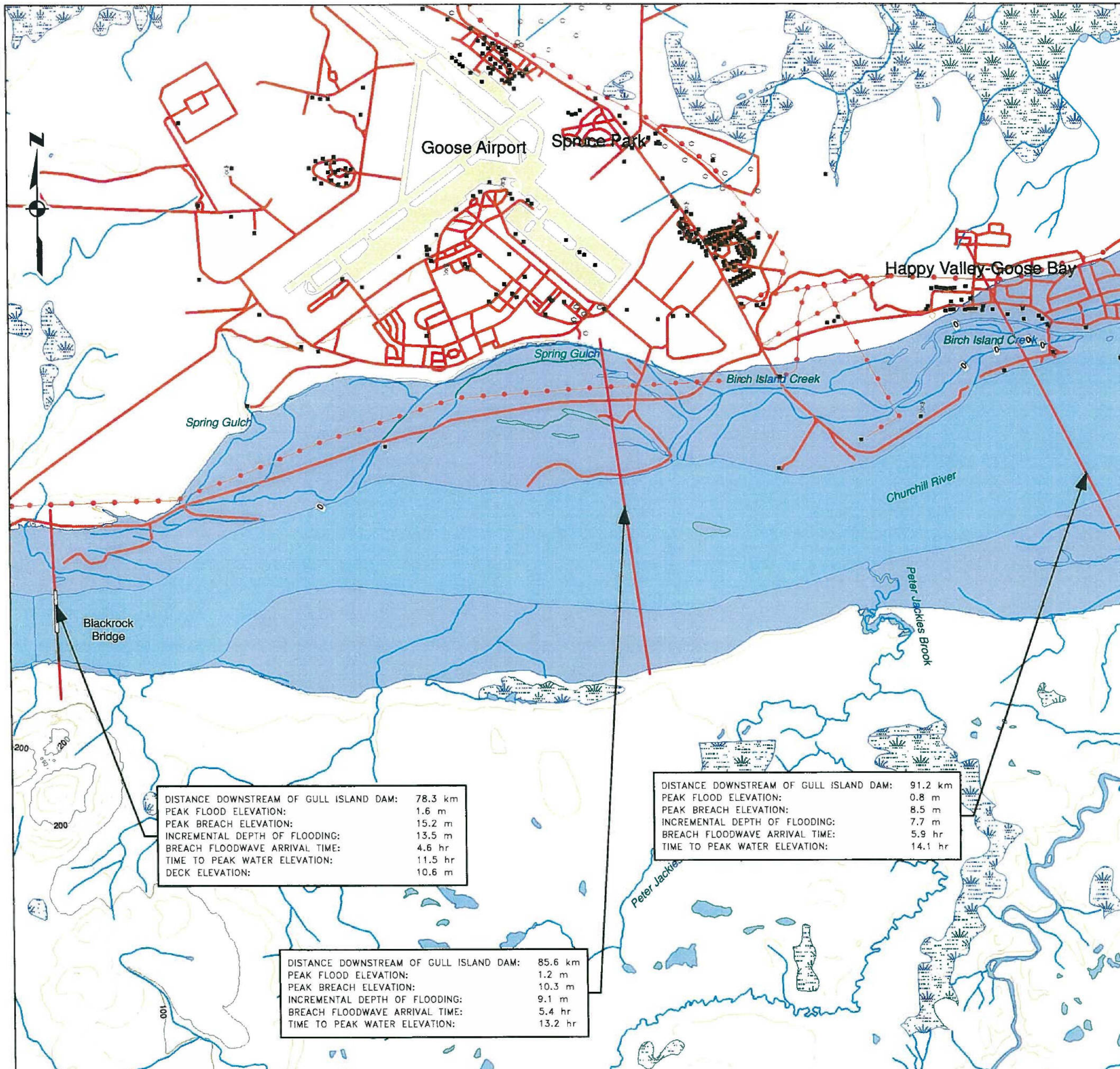
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

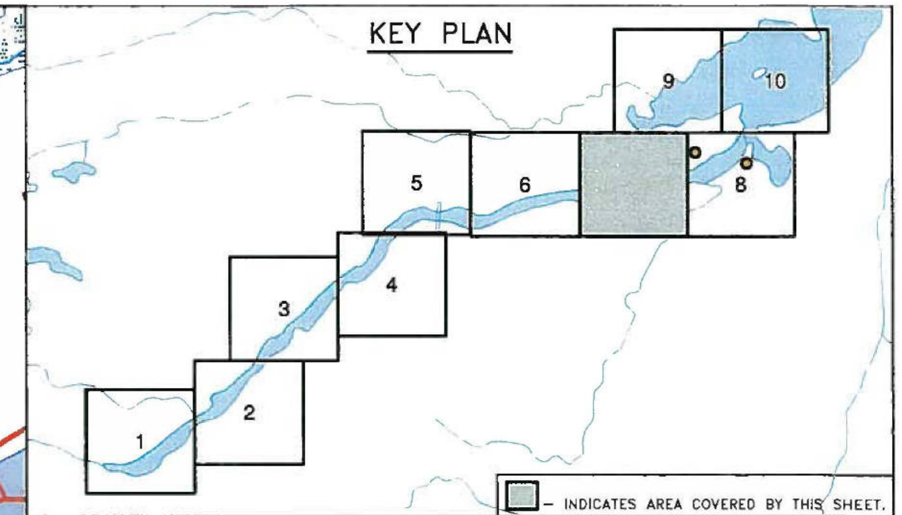
SCALE 1:50000

HATCH PROJECT No. H-325967

DRAWING NO. FIGURE A1-6



KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

NOTES:

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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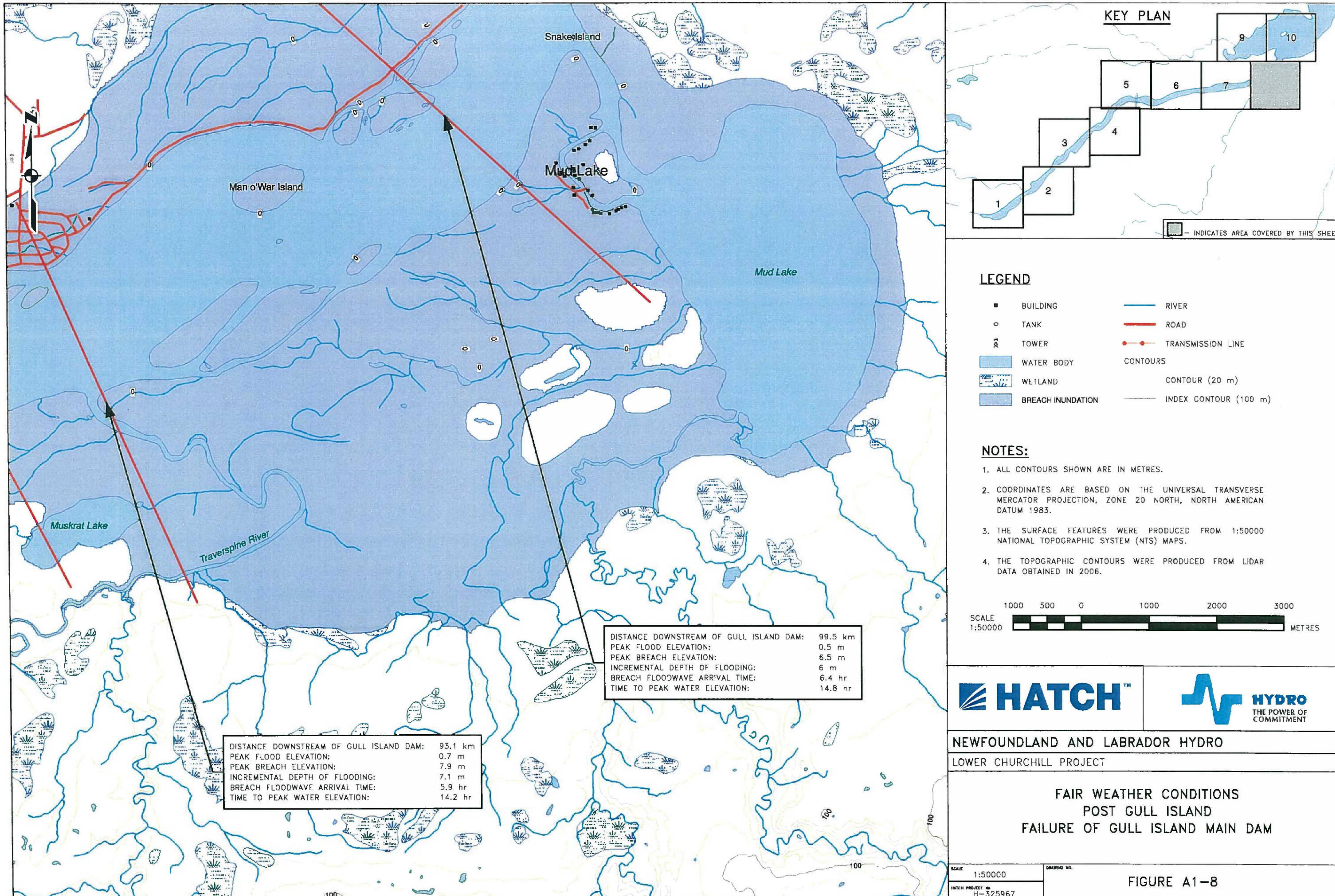
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000
HATCH PROJECT No H-325967
DRAWING NO. FIGURE A1-7



LEGEND

▪	BUILDING		RIVER
○	TANK		ROAD
	TOWER		TRANSMISSION LINE
	WATER BODY	CONTOURS	
	WETLAND		CONTOUR (20 m)
	BREACH INUNDATION		INDEX CONTOUR (100 m)

NOTES:

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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NEWFOUNDLAND AND LABRADOR HYDRO

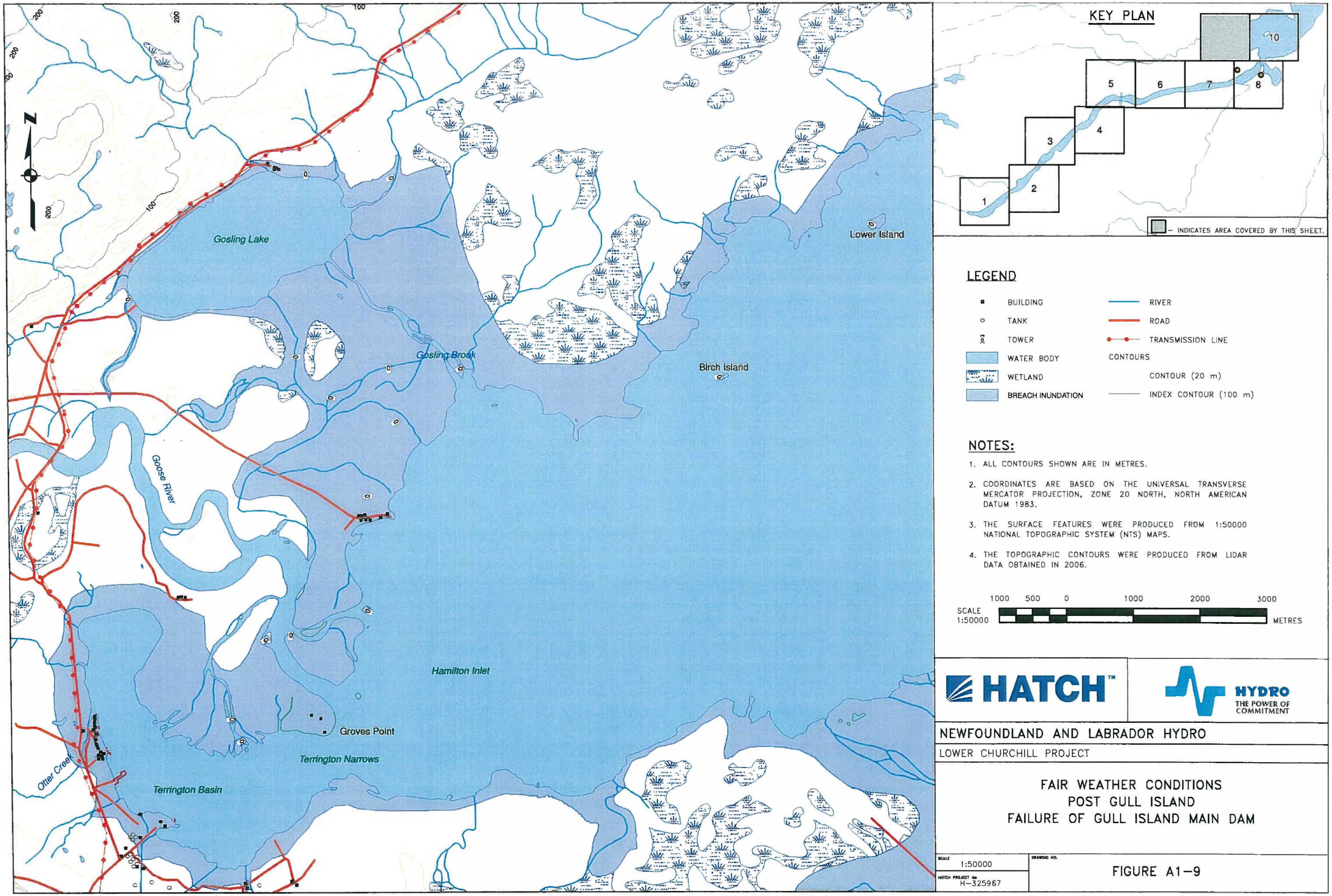
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000

HATCH PROJECT No. H-325967

DRAWING NO. FIGURE A1-8


KEY PLAN
1
2
3
4
5
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8
10
INDICATES AREA COVERED BY THIS SHEET.
Gosling Lake
Gosling Brook
Goose River
Lower Island
Birch Island
Hamilton Inlet
Groves Point
Terrington Narrows
Terrington Basin
Otter Creek
LEGEND
BUILDING
TANK
TOWER
WATER BODY
WETLAND
BREACH INUNDATION
RIVER
ROAD
TRANSMISSION LINE
CONTOURS
CONTOUR (20 m)
INDEX CONTOUR (100 m)
NOTES:
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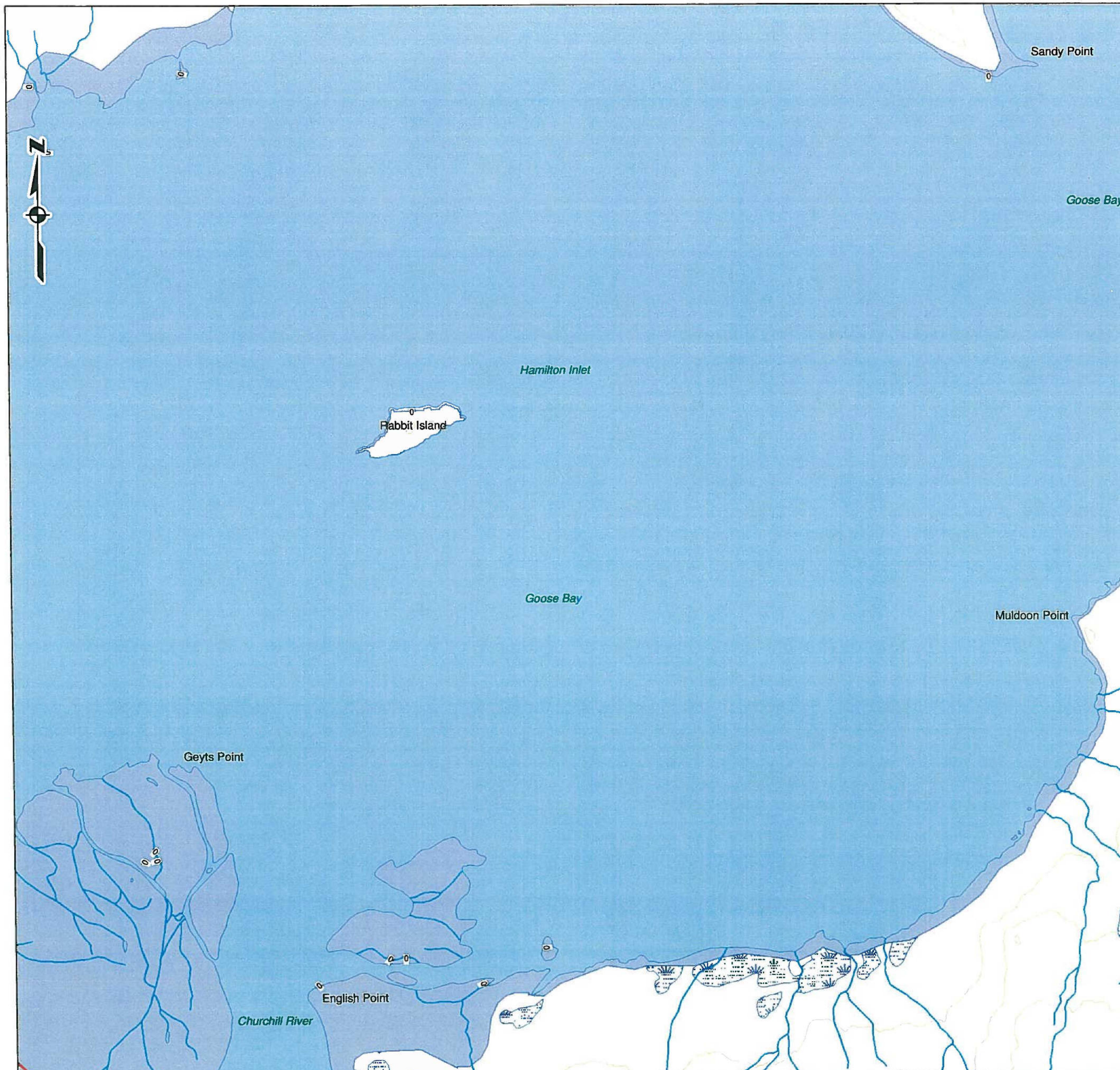
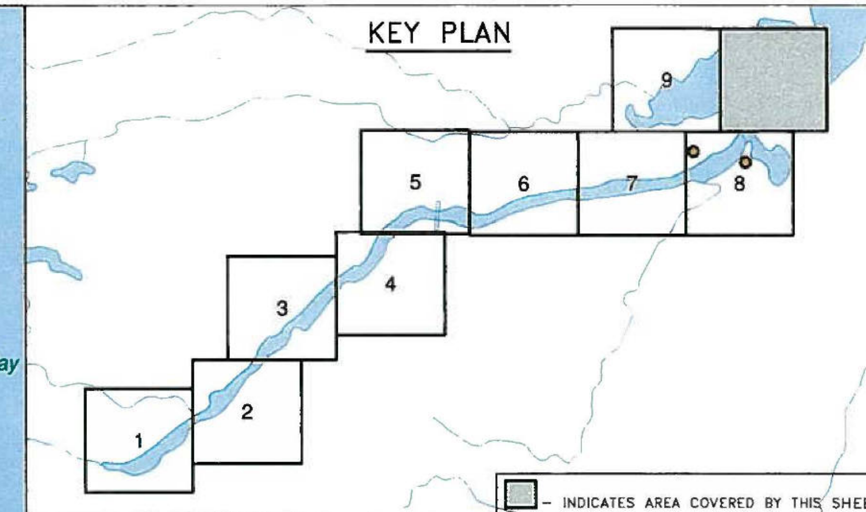
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.
SCALE 1:50000
1000 500 0 1000 2000 3000
METRES
HATCH
HYDRO
THE POWER OF COMMITMENT
NEWFOUNDLAND AND LABRADOR HYDRO
LOWER CHURCHILL PROJECT
FAIR WEATHER CONDITIONS
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM
SCALE 1:50000
HATCH PROJECT No. H-325967
DRAWING NO.
FIGURE A1-9





LEGEND

■	BUILDING		RIVER
○	TANK		ROAD
	TOWER		TRANSMISSION LINE
	WATER BODY	CONTOURS	
	WETLAND		CONTOUR (20 m)
	BREACH INUNDATION		INDEX CONTOUR (100 m)

NOTES:

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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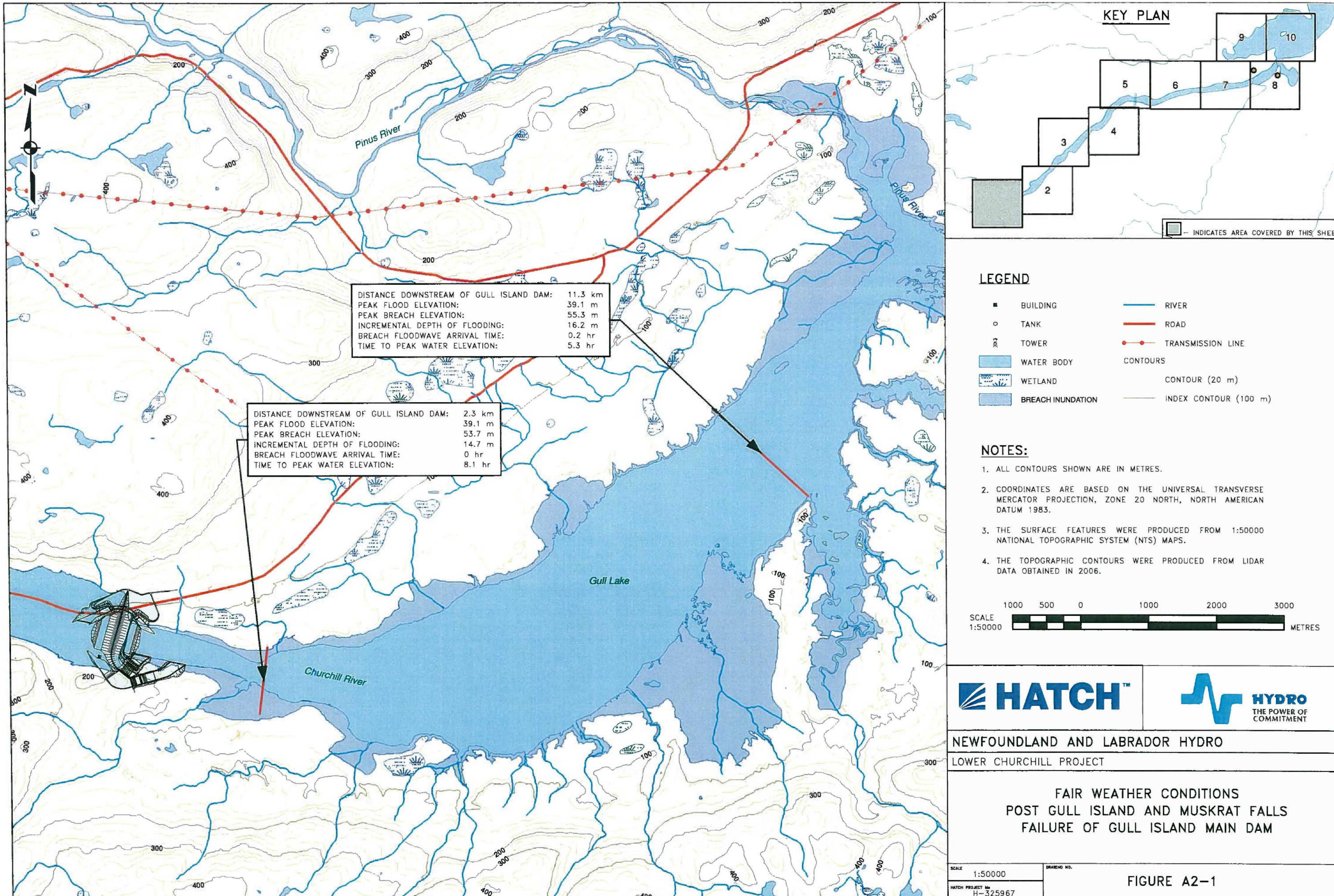
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000	DRAWING NO. FIGURE A1–10
HATCH PROJECT No H-325967	



HATCH

HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

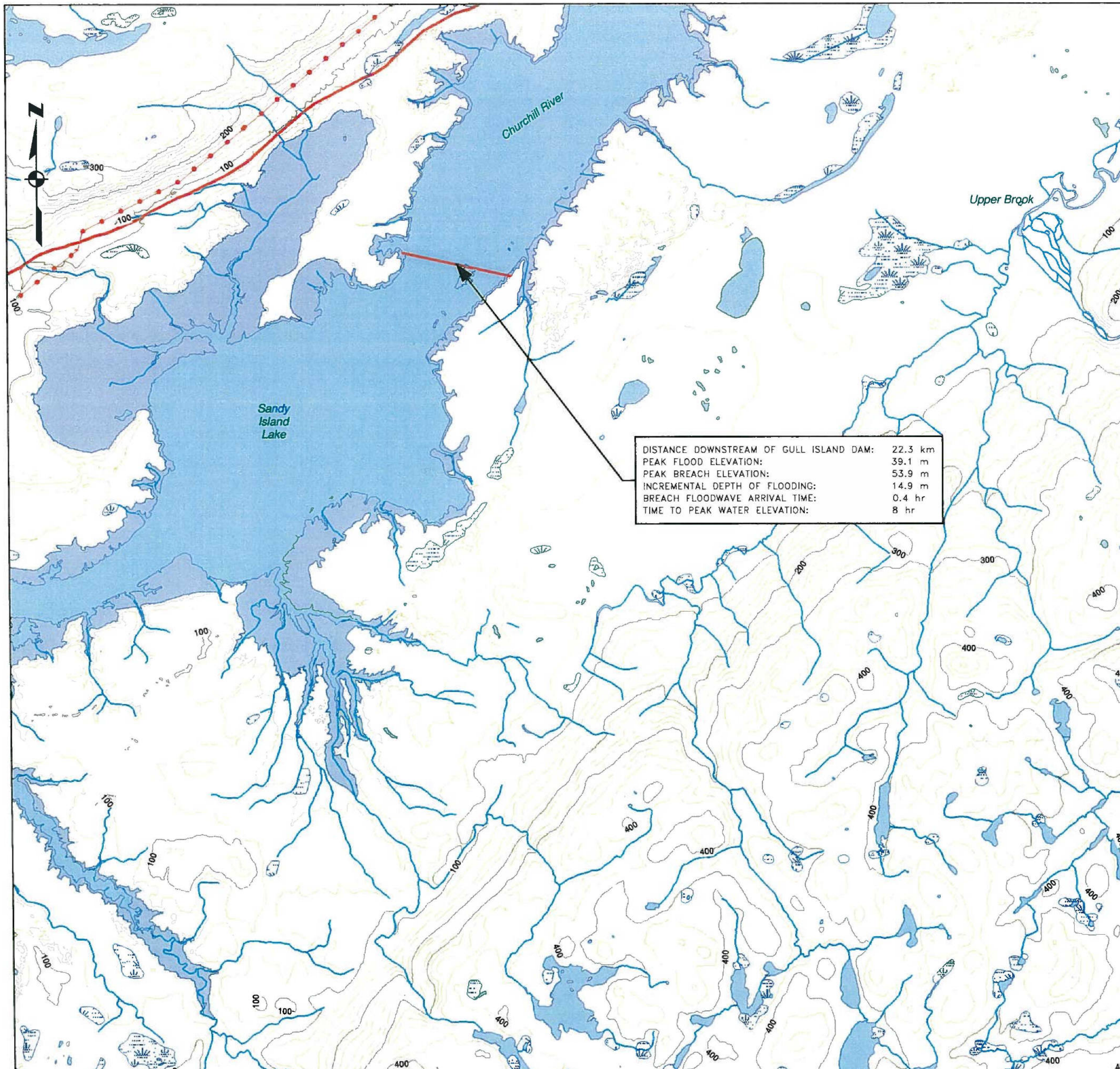
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

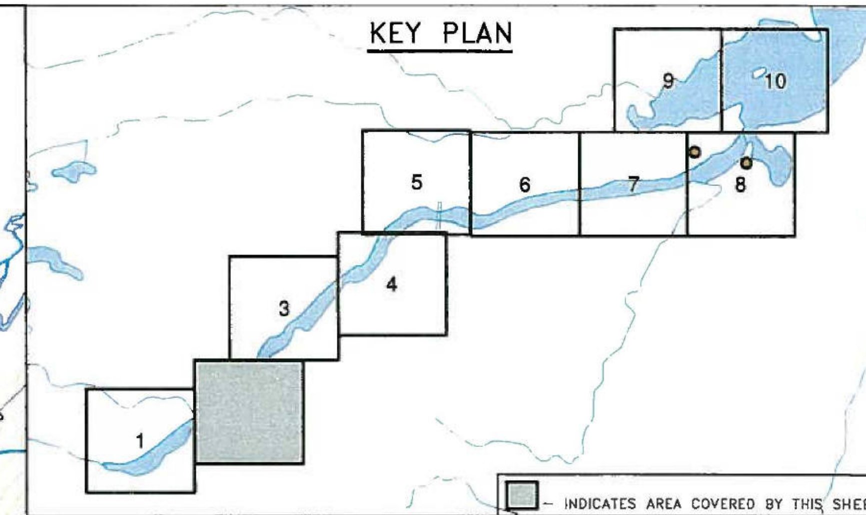
SCALE 1:50000

HATCH PROJECT No H-325967

DRAWING NO. FIGURE A2-1



KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

NOTES:

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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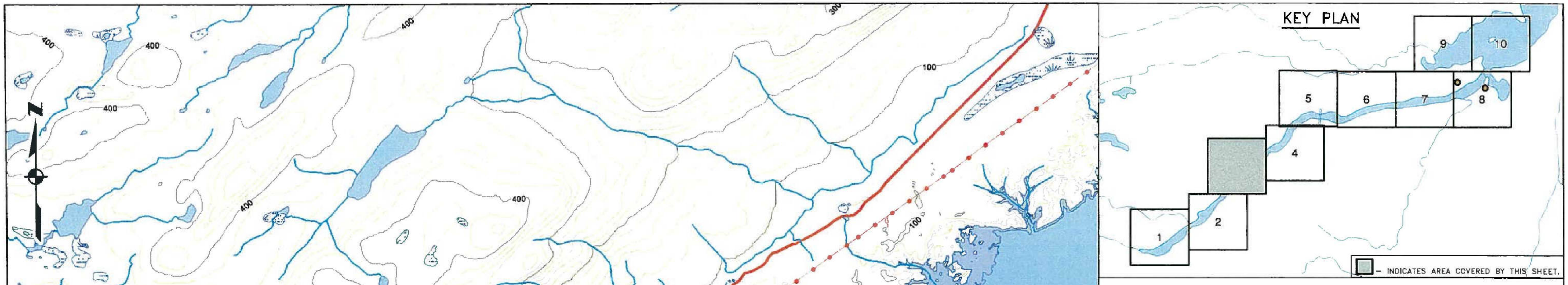
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE: 1:50000
HATCH PROJECT No: H-325967
DRAWING NO.: FIGURE A2-2



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

NOTES:

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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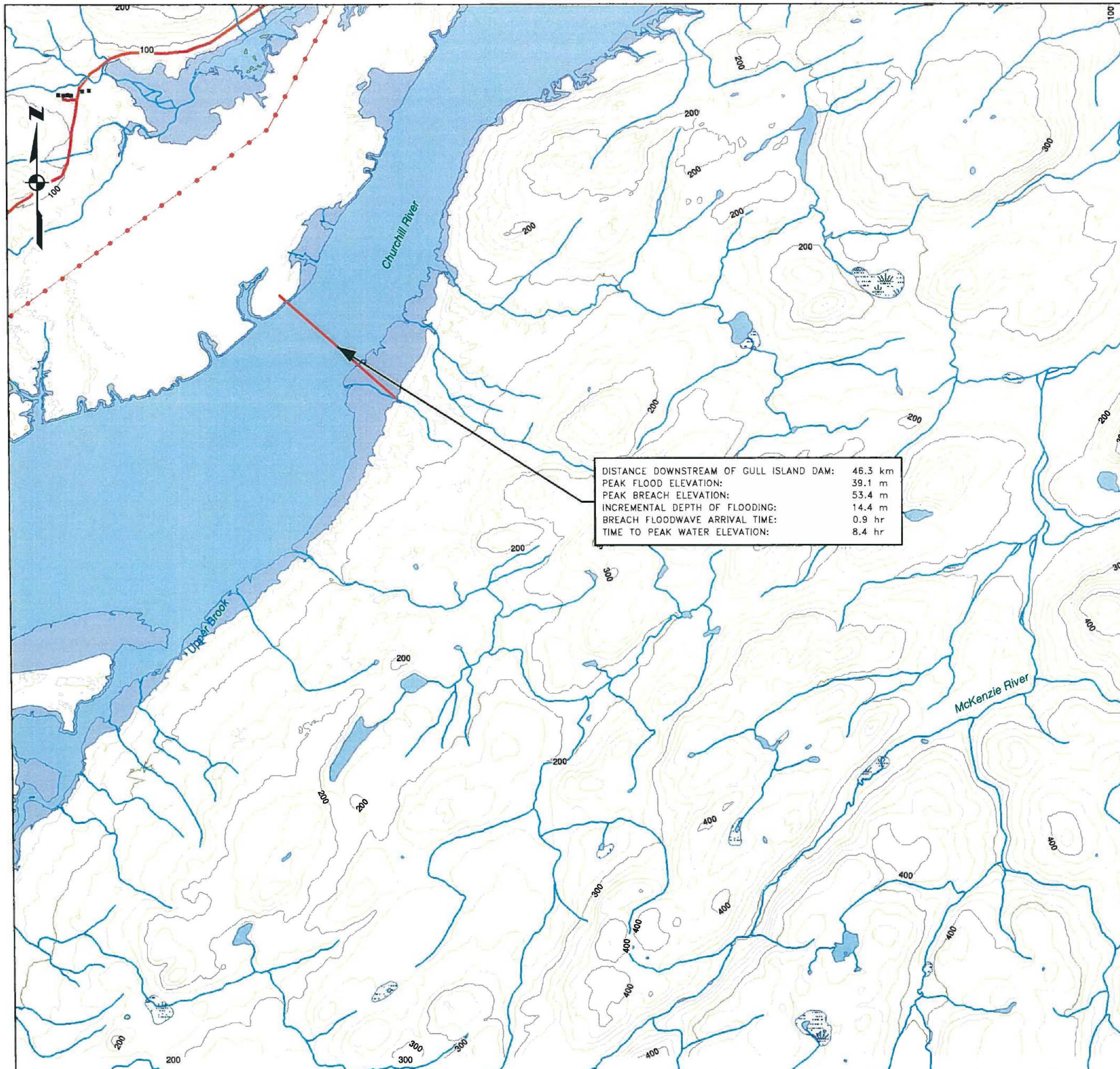
NEWFOUNDLAND AND LABRADOR HYDRO

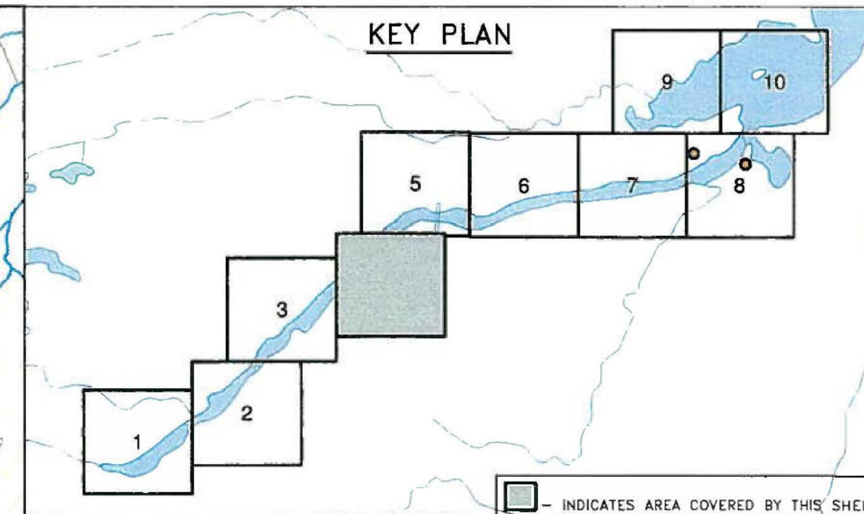
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000
HATCH PROJECT No. H-325967
DRAWING NO. FIGURE A2-3



KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE

CONTOURS

- CONTOUR (20 m)
- INDEX CONTOUR (100 m)

NOTES:

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

HATCH™

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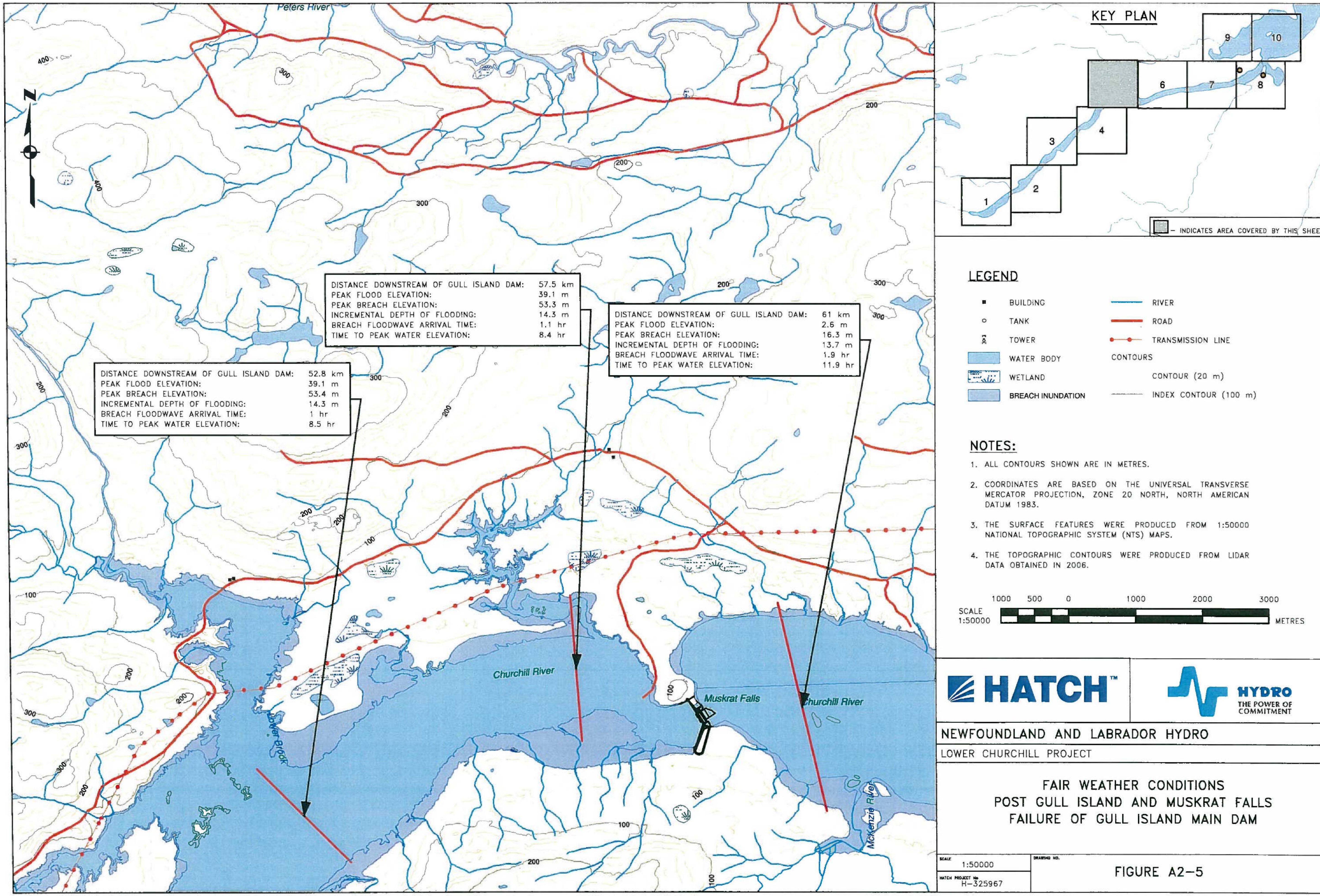
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE	DRAWING NO.
1:50000	FIGURE A2-4
HATCH PROJECT No. H-325967	


DISTANCE DOWNSTREAM OF GULL ISLAND DAM: 52.8 km
PEAK FLOOD ELEVATION: 39.1 m
PEAK BREACH ELEVATION: 53.4 m
INCREMENTAL DEPTH OF FLOODING: 14.3 m
BREACH FLOODWAVE ARRIVAL TIME: 1 hr
TIME TO PEAK WATER ELEVATION: 8.5 hr
DISTANCE DOWNSTREAM OF GULL ISLAND DAM: 57.5 km
PEAK FLOOD ELEVATION: 39.1 m
PEAK BREACH ELEVATION: 53.3 m
INCREMENTAL DEPTH OF FLOODING: 14.3 m
BREACH FLOODWAVE ARRIVAL TIME: 1.1 hr
TIME TO PEAK WATER ELEVATION: 8.4 hr
DISTANCE DOWNSTREAM OF GULL ISLAND DAM: 61 km
PEAK FLOOD ELEVATION: 2.6 m
PEAK BREACH ELEVATION: 16.3 m
INCREMENTAL DEPTH OF FLOODING: 13.7 m
BREACH FLOODWAVE ARRIVAL TIME: 1.9 hr
TIME TO PEAK WATER ELEVATION: 11.9 hr
Peters River
Churchill River
Muskrat Falls
Churchill River
Lower Brook
McKenzie River
KEY PLAN
1
2
3
4
6
7
8
9
10
- INDICATES AREA COVERED BY THIS SHEET.
LEGEND
BUILDING
TANK
TOWER
WATER BODY
WETLAND
BREACH INUNDATION
RIVER
ROAD
TRANSMISSION LINE
CONTOURS
CONTOUR (20 m)
INDEX CONTOUR (100 m)
NOTES:
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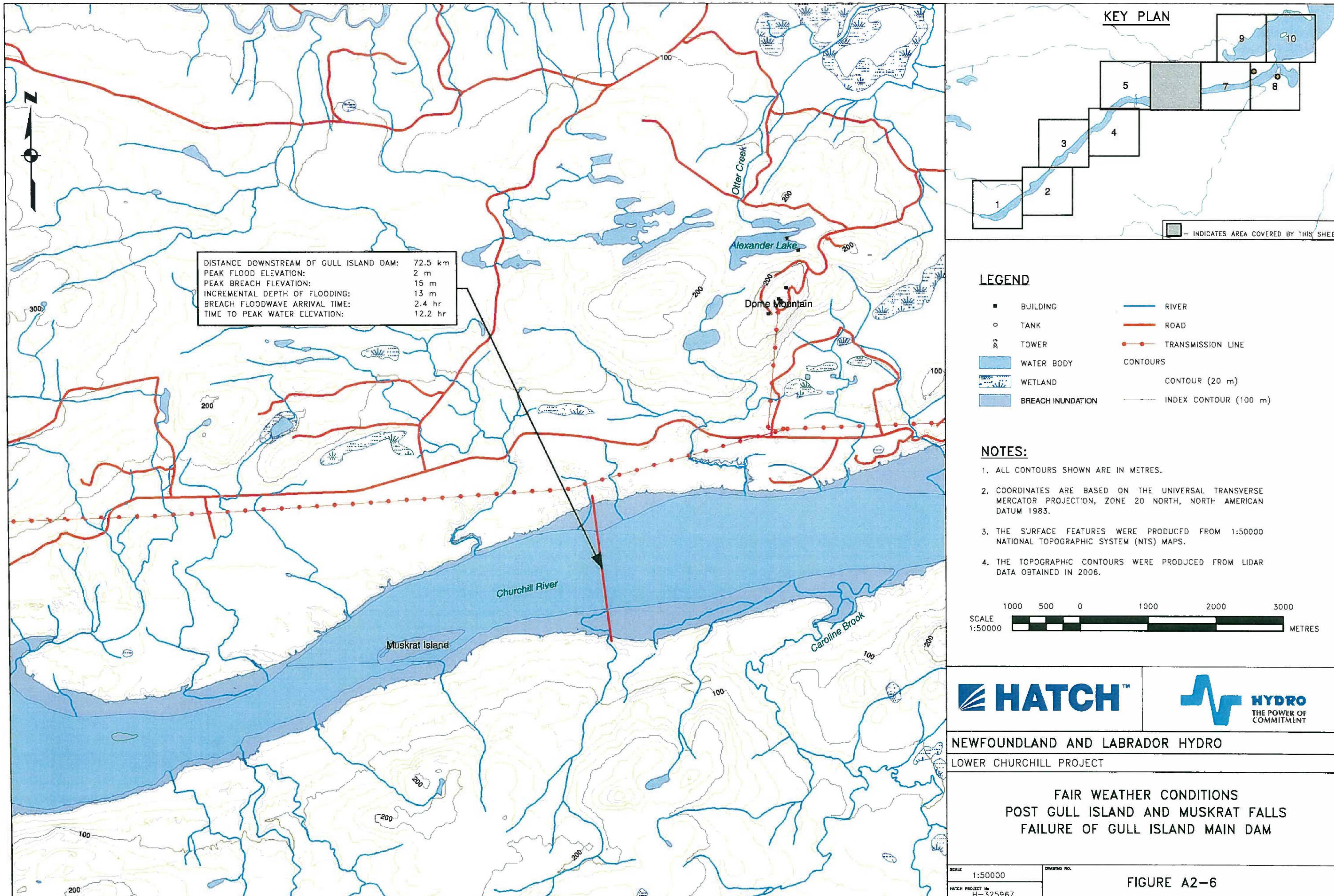
SCALE 1:50000
1000 500 0 1000 2000 3000
METRES
HATCH
HYDRO
THE POWER OF COMMITMENT
NEWFOUNDLAND AND LABRADOR HYDRO
LOWER CHURCHILL PROJECT
FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM
SCALE 1:50000
HATCH PROJECT No. H-325967
DRAWING NO.
FIGURE A2-5



LEGEND

▪	BUILDING		RIVER
○	TANK		ROAD
	TOWER		TRANSMISSION LINE
	WATER BODY	CONTOURS	
	WETLAND		CONTOUR (20 m)
	BREACH INUNDATION		INDEX CONTOUR (100 m)

NOTES:

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

HATCH™

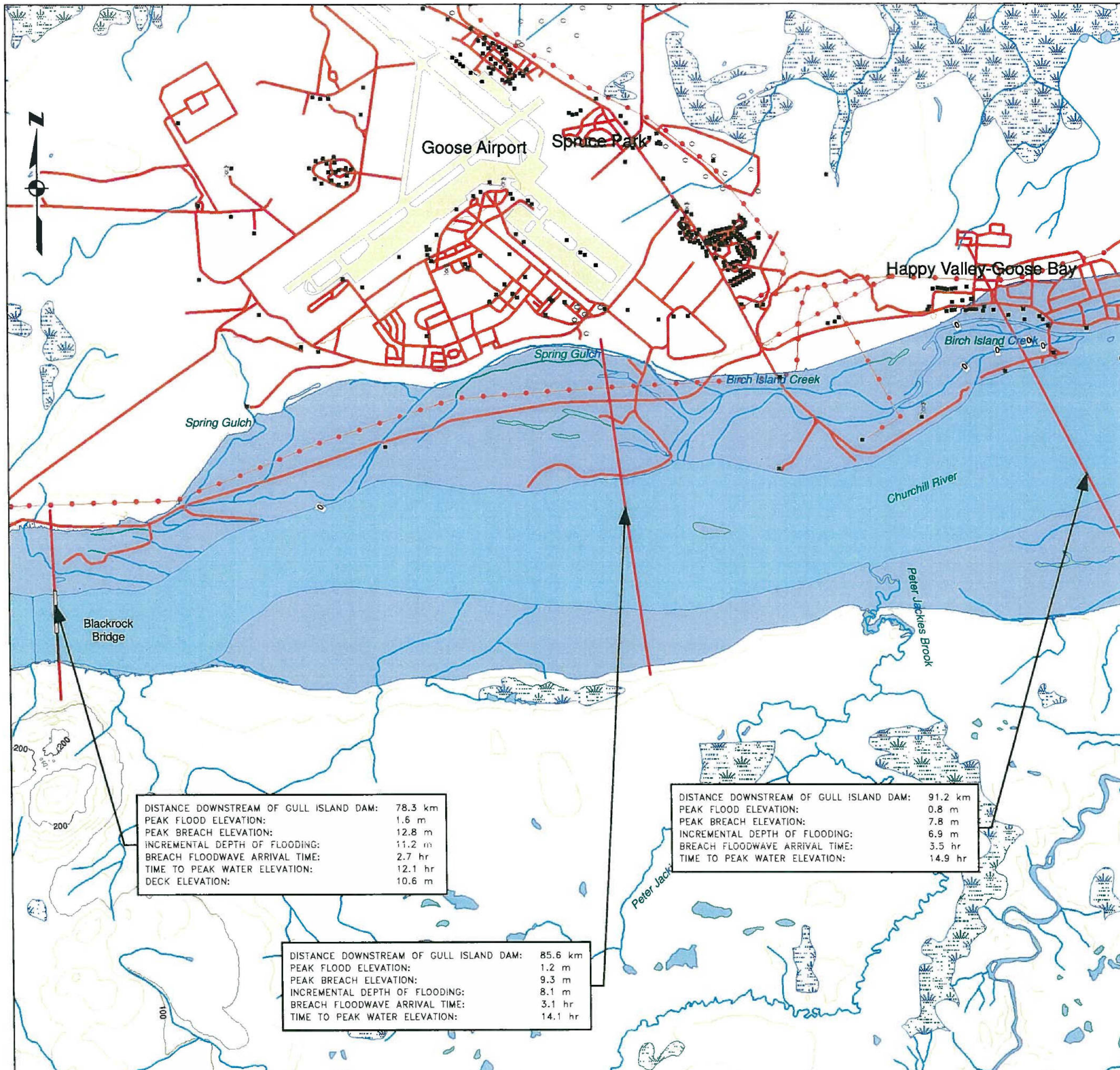
HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000
HATCH PROJECT No. H-325967
DRAWING NO. FIGURE A2-6

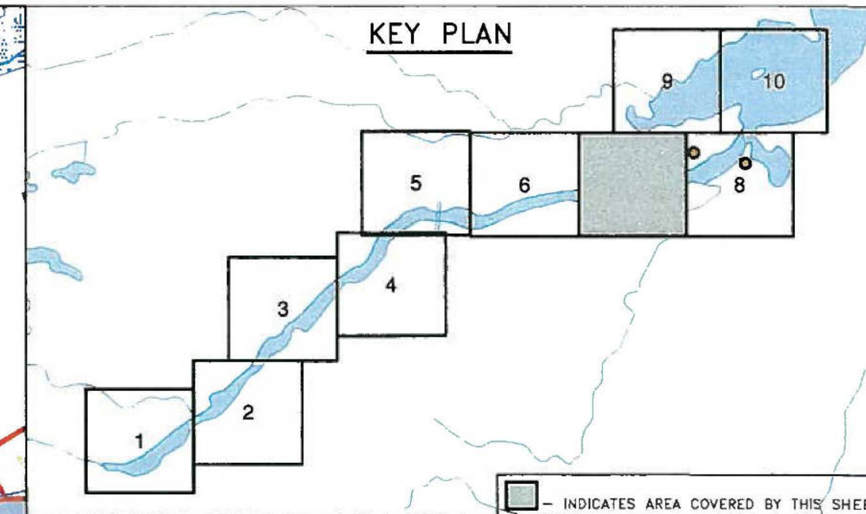


DISTANCE DOWNSTREAM OF GULL ISLAND DAM:	78.3 km
PEAK FLOOD ELEVATION:	1.6 m
PEAK BREACH ELEVATION:	12.8 m
INCREMENTAL DEPTH OF FLOODING:	11.2 m
BREACH FLOODWAVE ARRIVAL TIME:	2.7 hr
TIME TO PEAK WATER ELEVATION:	12.1 hr
DECK ELEVATION:	10.6 m

DISTANCE DOWNSTREAM OF GULL ISLAND DAM:	85.6 km
PEAK FLOOD ELEVATION:	1.2 m
PEAK BREACH ELEVATION:	9.3 m
INCREMENTAL DEPTH OF FLOODING:	8.1 m
BREACH FLOODWAVE ARRIVAL TIME:	3.1 hr
TIME TO PEAK WATER ELEVATION:	14.1 hr

DISTANCE DOWNSTREAM OF GULL ISLAND DAM:	91.2 km
PEAK FLOOD ELEVATION:	0.8 m
PEAK BREACH ELEVATION:	7.8 m
INCREMENTAL DEPTH OF FLOODING:	6.9 m
BREACH FLOODWAVE ARRIVAL TIME:	3.5 hr
TIME TO PEAK WATER ELEVATION:	14.9 hr

KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

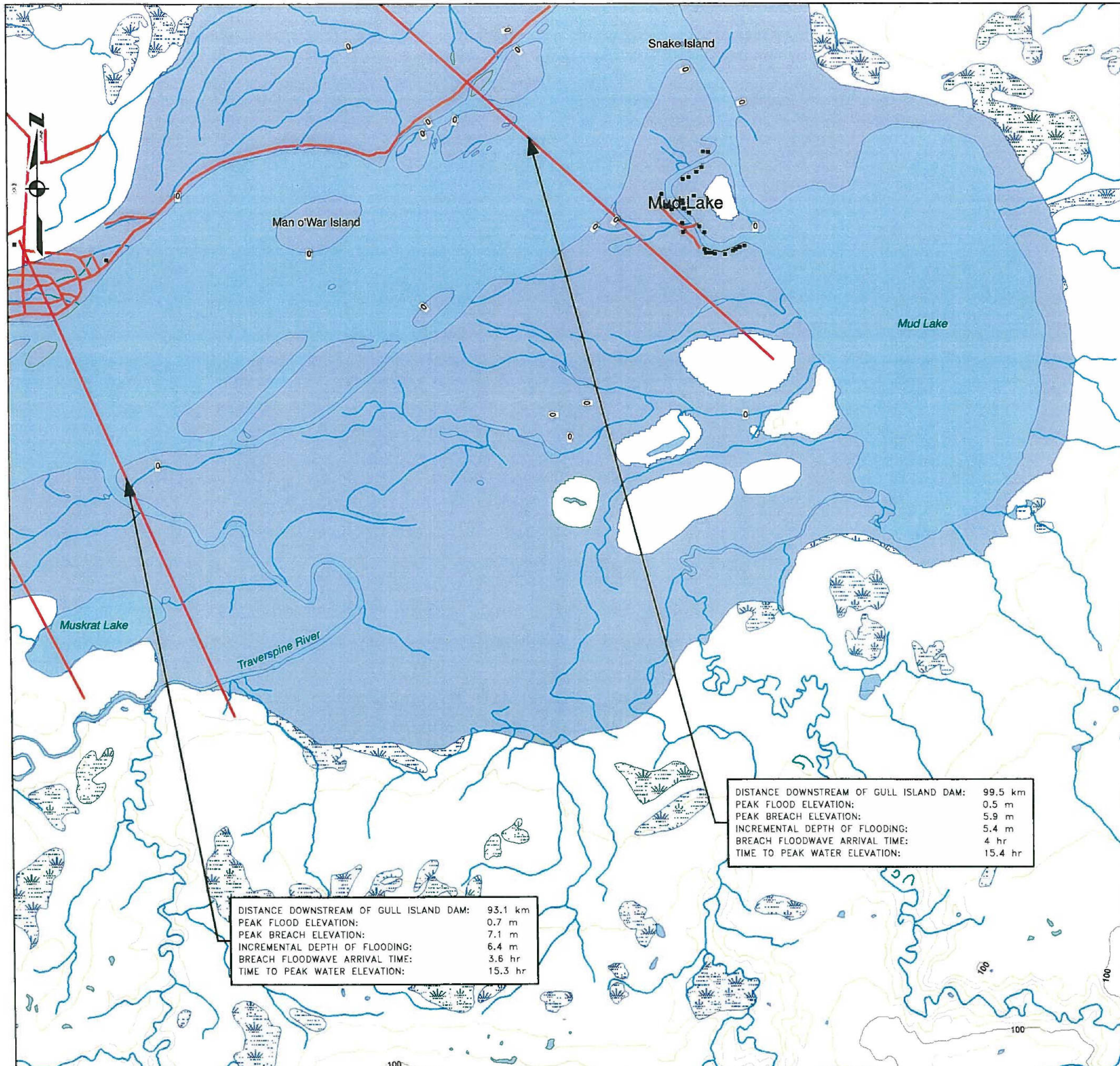
HATCH™ — HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

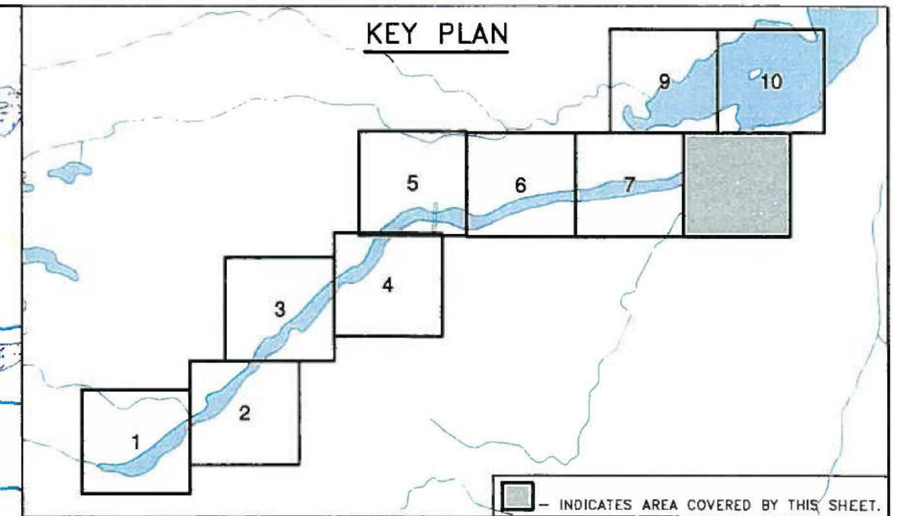
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000
HATCH PROJECT No. H-325967
DRAWING NO. FIGURE A2-7



KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

HATCH™

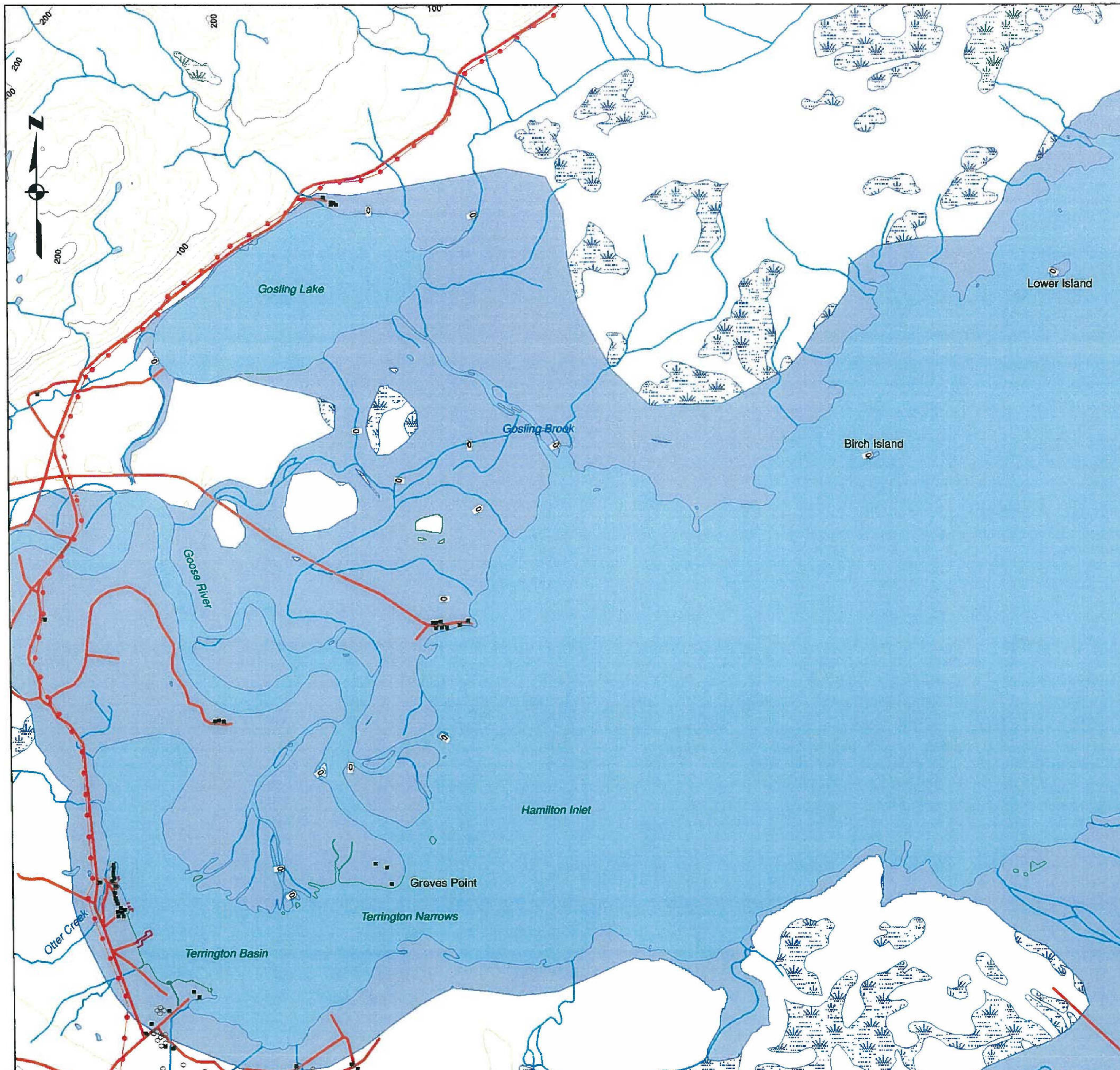
HYDRO THE POWER OF COMMITMENT

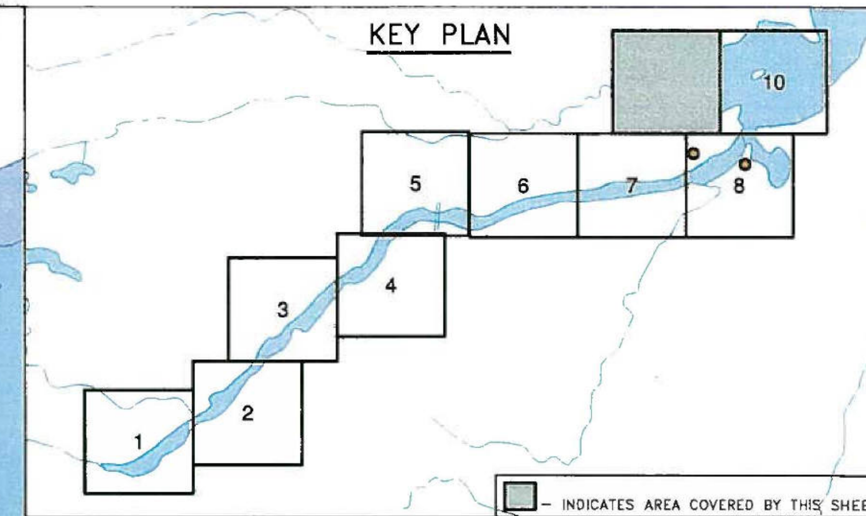
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000	DRAWING NO. FIGURE A2-8
HATCH PROJECT No. H-325967	





LEGEND

■	BUILDING		RIVER
○	TANK		ROAD
	TOWER		TRANSMISSION LINE
	WATER BODY	CONTOURS	
	WETLAND		CONTOUR (20 m)
	BREACH INUNDATION		INDEX CONTOUR (100 m)

NOTES:

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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

HATCH™

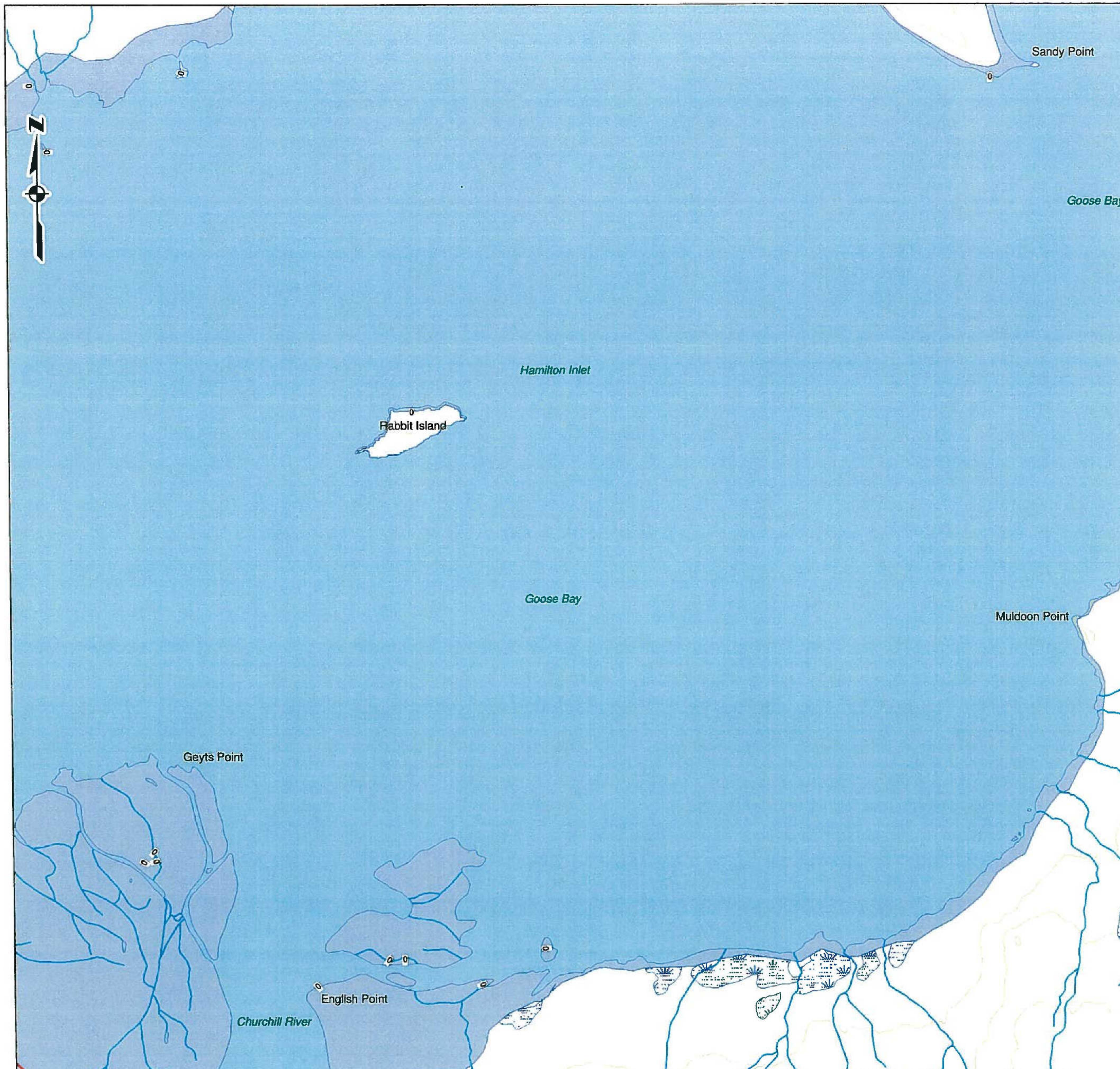
HYDRO
THE POWER OF COMMITMENT

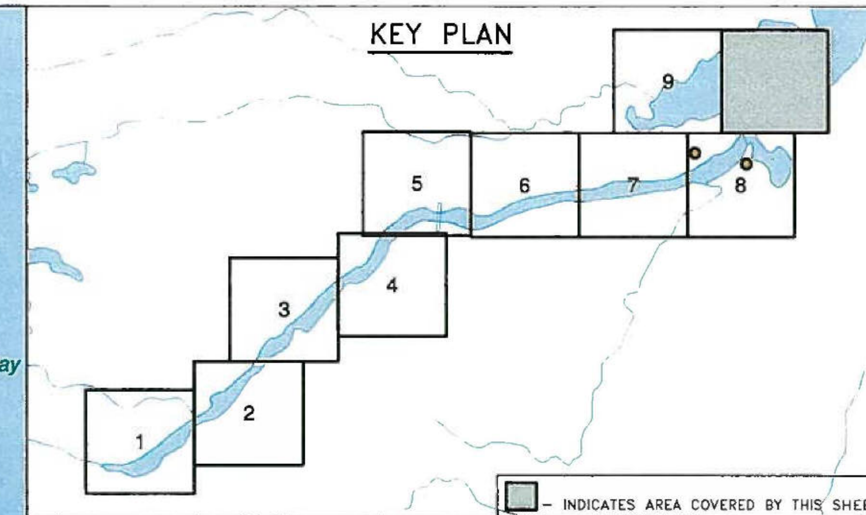
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000
HATCH PROJECT No. H-325967
DRAWING NO. FIGURE A2-9





LEGEND

▪	BUILDING		RIVER
○	TANK		ROAD
	TOWER		TRANSMISSION LINE
	WATER BODY		CONTOURS
	WETLAND		CONTOUR (20 m)
	BREACH INUNDATION		INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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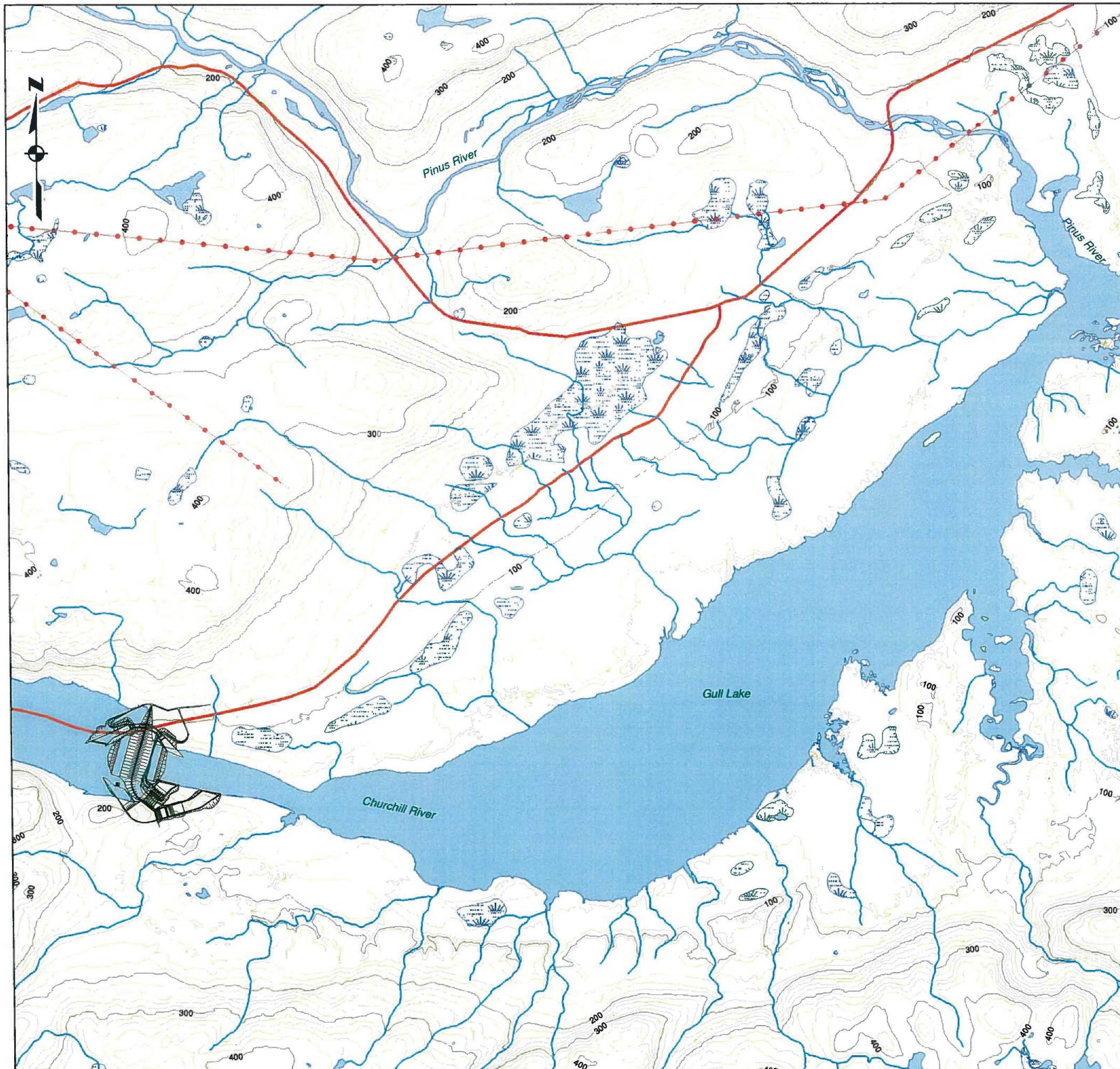
LOWER CHURCHILL PROJECT

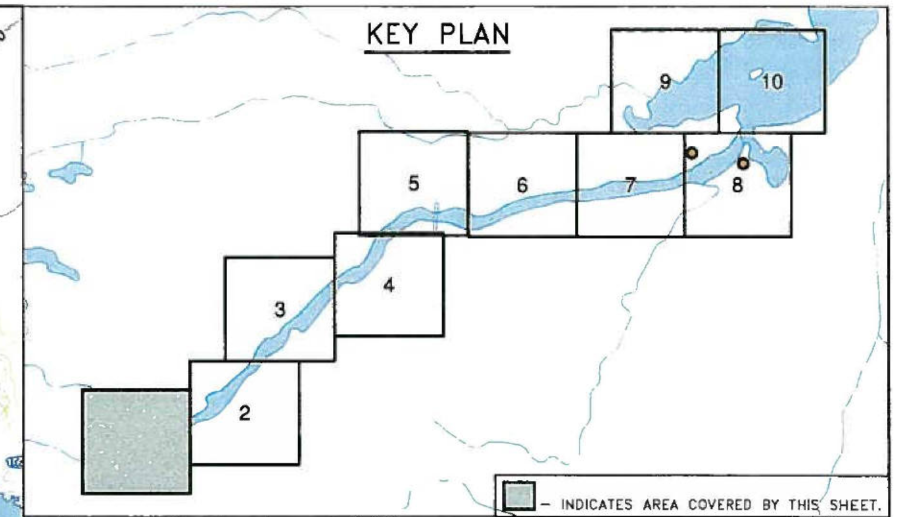
FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000

HATCH PROJECT No. H-325967

DRAWING NO. FIGURE A2-10





LEGEND

▪	BUILDING		RIVER
○	TANK		ROAD
	TOWER		TRANSMISSION LINE
	WATER BODY	CONTOURS	
	WETLAND		CONTOUR (20 m)
	BREACH INUNDATION		INDEX CONTOUR (100 m)

NOTES:

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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

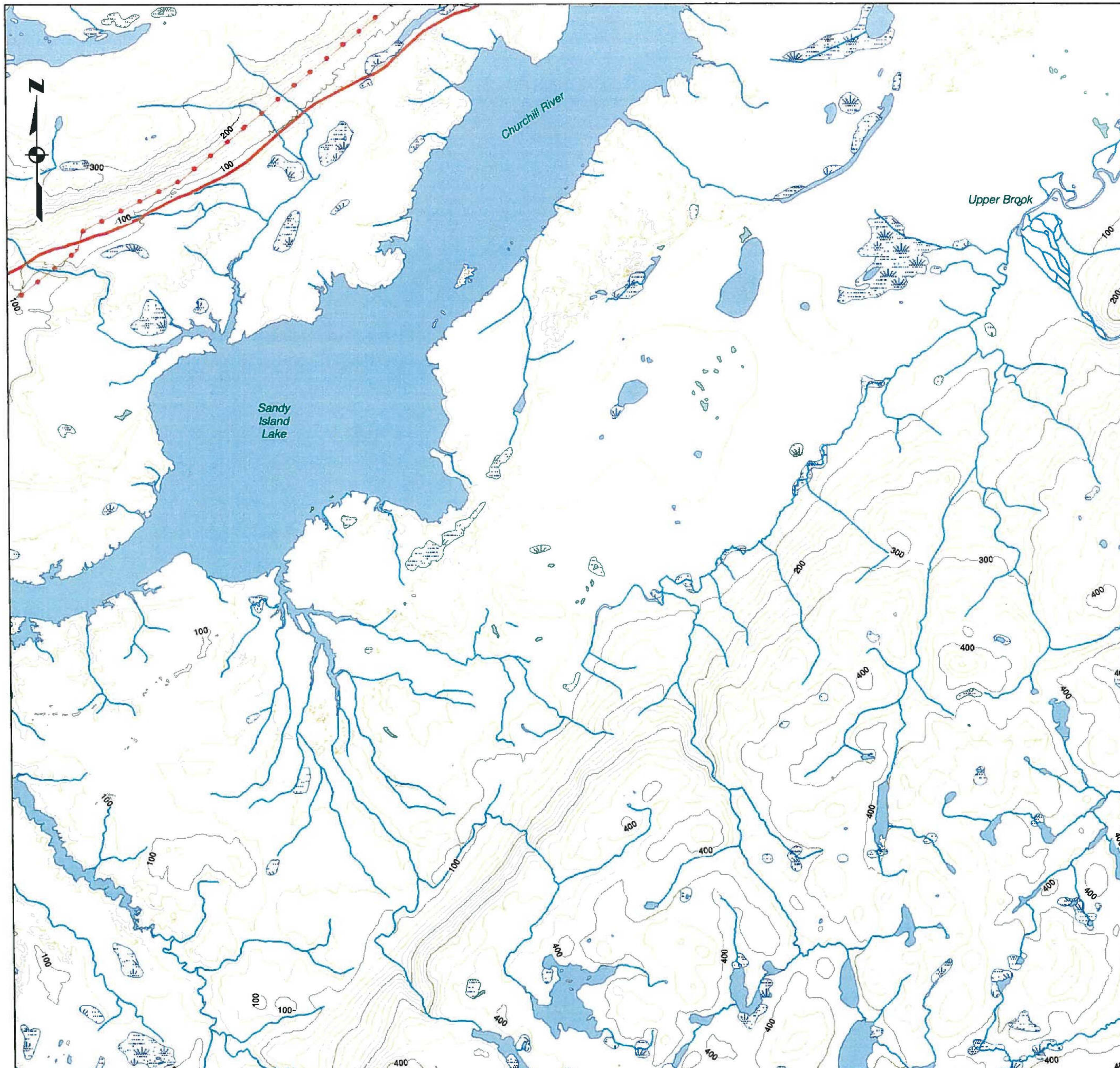
HATCH™ — HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

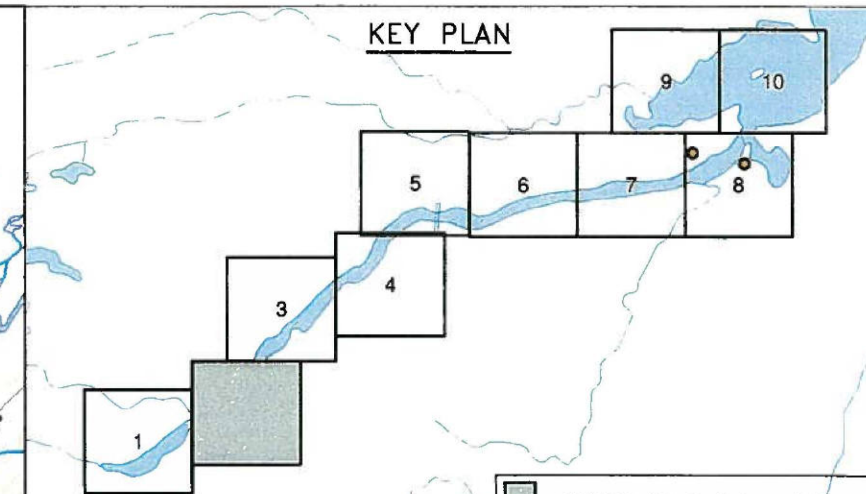
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000
HATCH PROJECT No. H-325967
DRAWING NO. FIGURE A3-1



KEY PLAN



▭ – INDICATES AREA COVERED BY THIS SHEET.

LEGEND

■	BUILDING	——	RIVER
○	TANK	——	ROAD
	TOWER	•—•	TRANSMISSION LINE
	WATER BODY	CONTOURS	
	WETLAND		CONTOUR (20 m)
	BREACH INUNDATION		INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

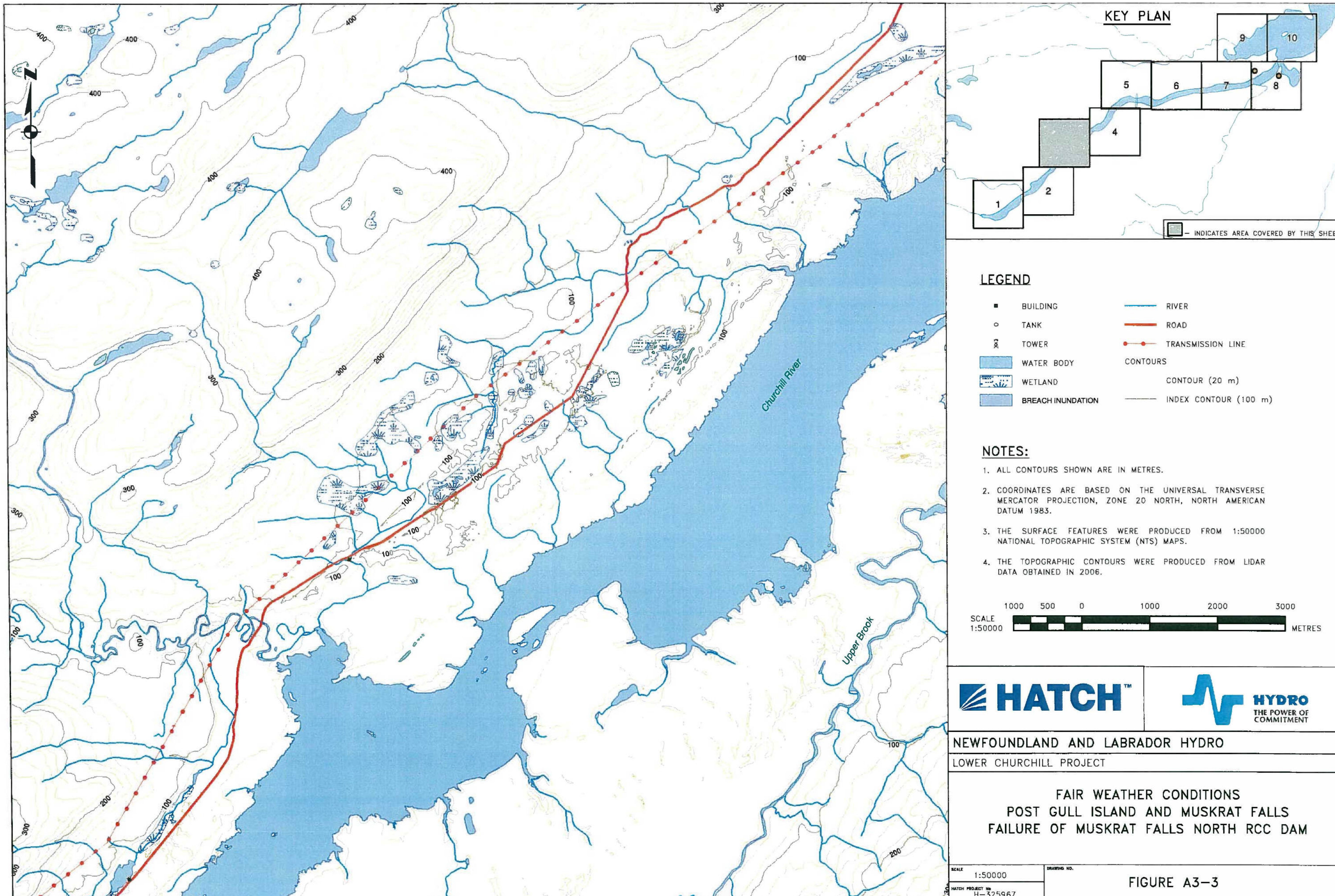
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000

HATCH PROJECT No. H-325967

DRAWING NO. FIGURE A3-2



LEGEND

▪	BUILDING		RIVER
○	TANK		ROAD
	TOWER		TRANSMISSION LINE
	WATER BODY		CONTOURS
	WETLAND		CONTOUR (20 m)
	BREACH INUNDATION		INDEX CONTOUR (100 m)

NOTES:

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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NEWFOUNDLAND AND LABRADOR HYDRO

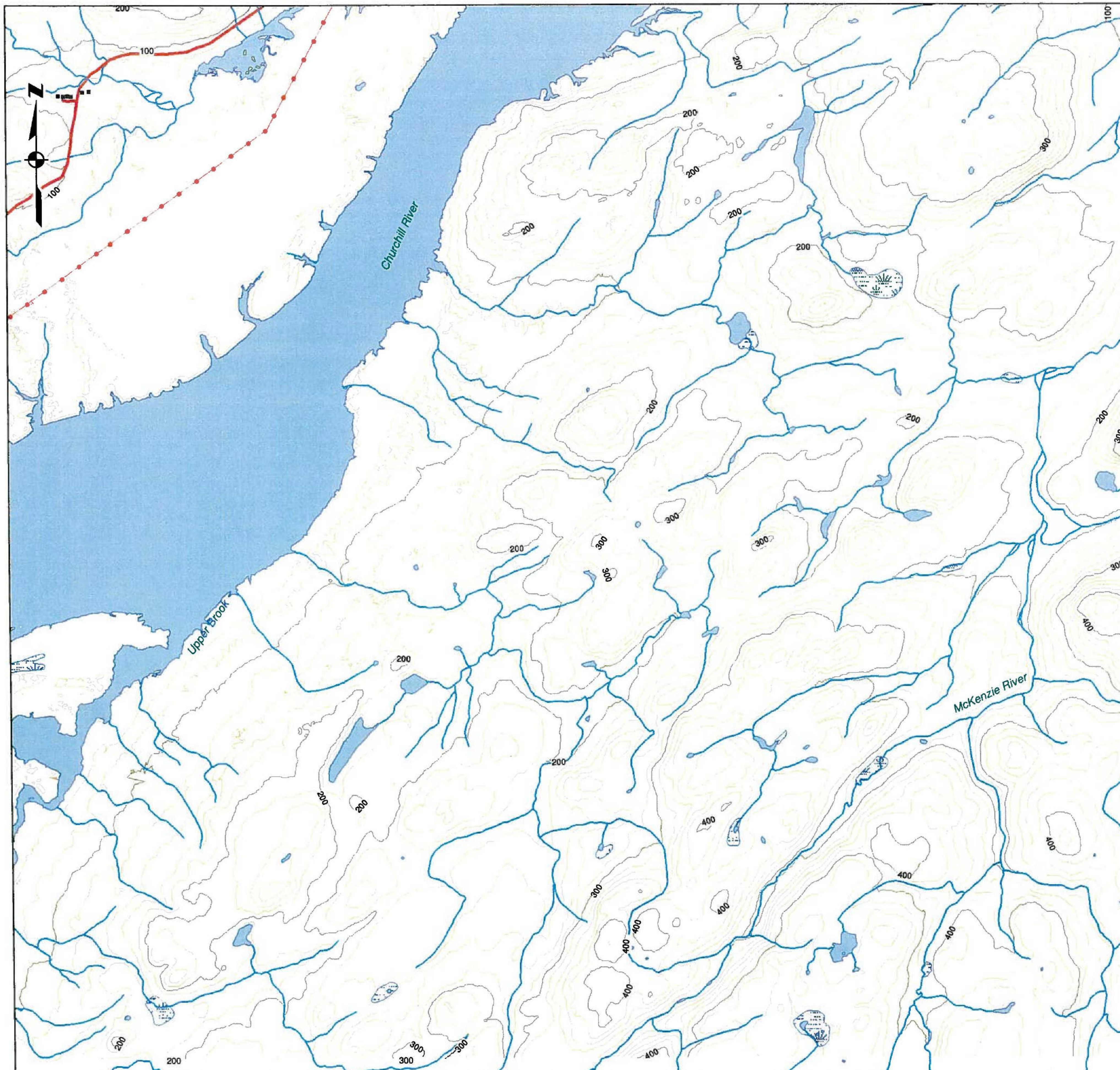
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

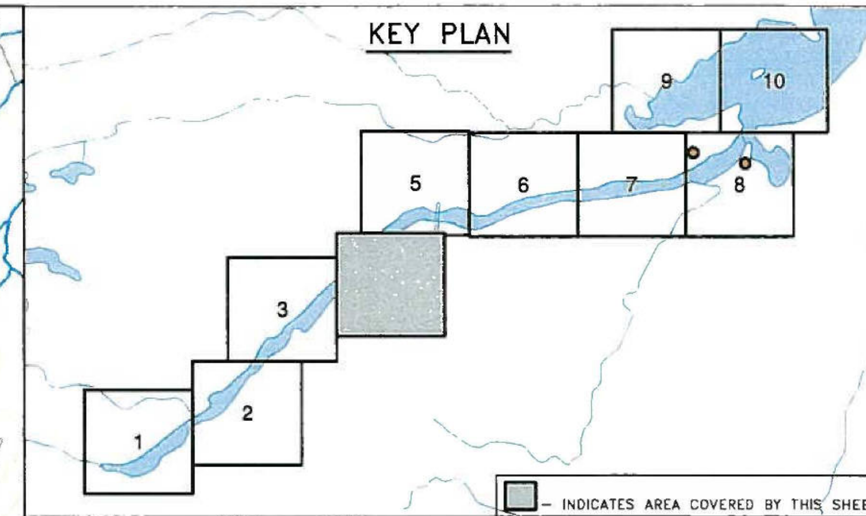
SCALE 1:50000

HATCH PROJECT No H-325967

DRAWING NO. FIGURE A3-3



KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE

CONTOURS

- CONTOUR (20 m)
- INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

HATCH™

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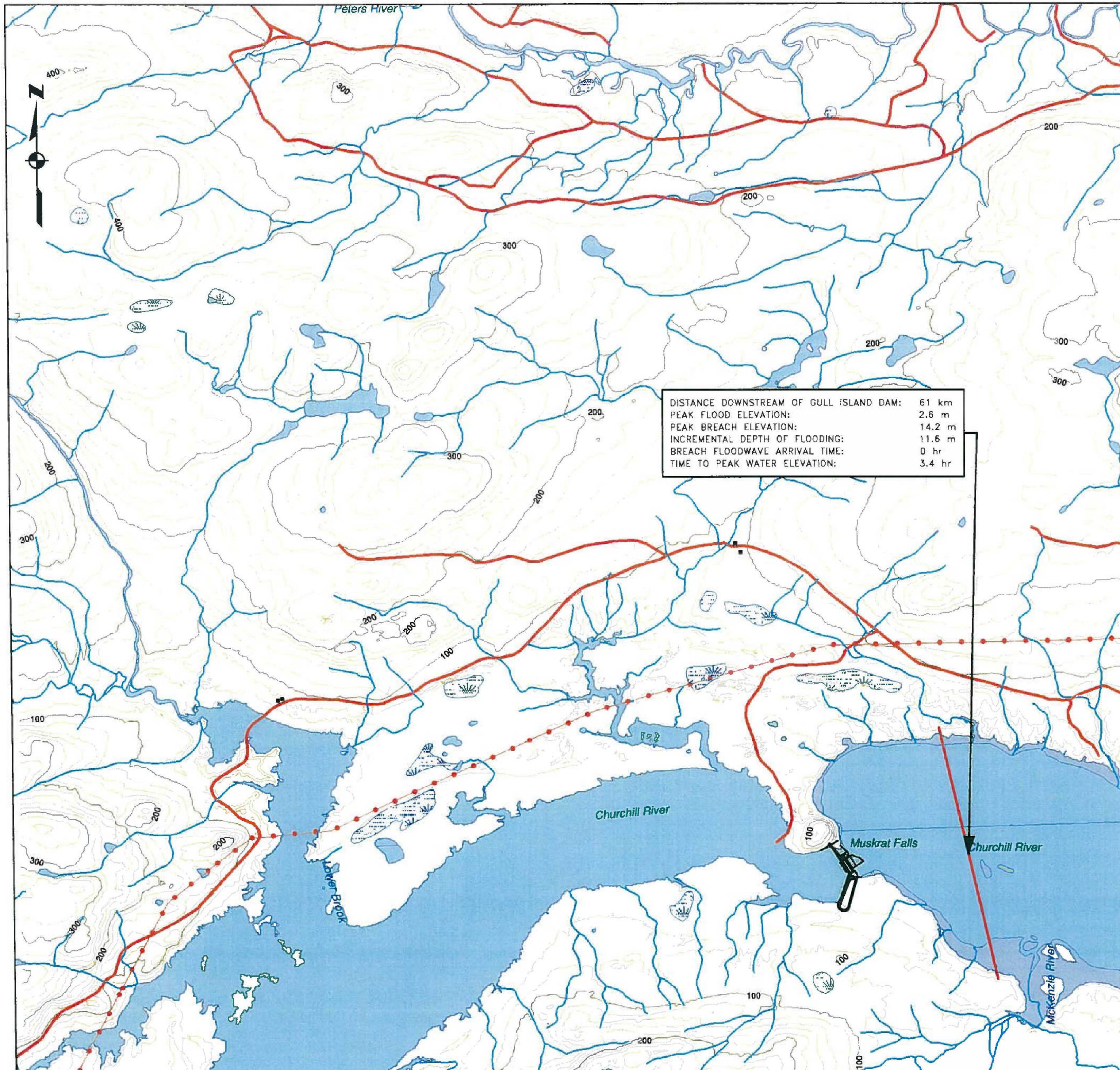
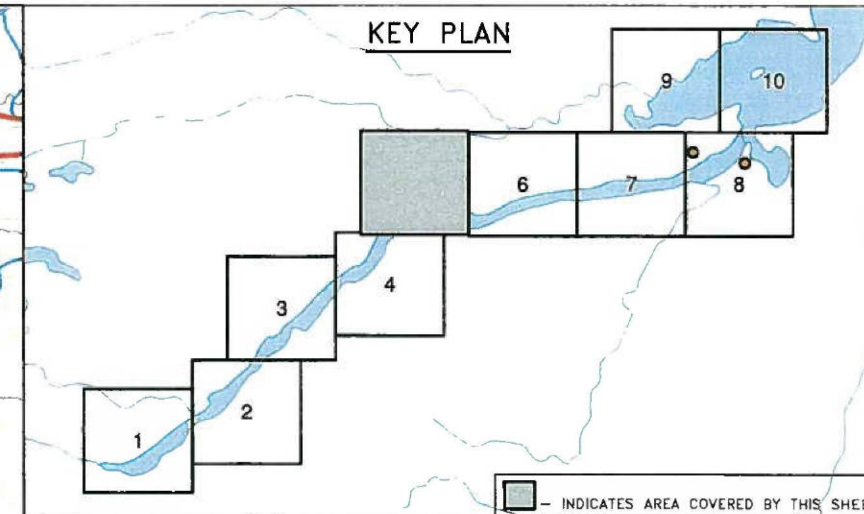
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000	DRAWING NO. FIGURE A3-4
HATCH PROJECT No H-325967	





LEGEND

■	BUILDING		RIVER
○	TANK		ROAD
	TOWER		TRANSMISSION LINE
	WATER BODY		CONTOURS
	WETLAND		CONTOUR (20 m)
	BREACH INUNDATION		INDEX CONTOUR (100 m)

NOTES:

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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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NEWFOUNDLAND AND LABRADOR HYDRO

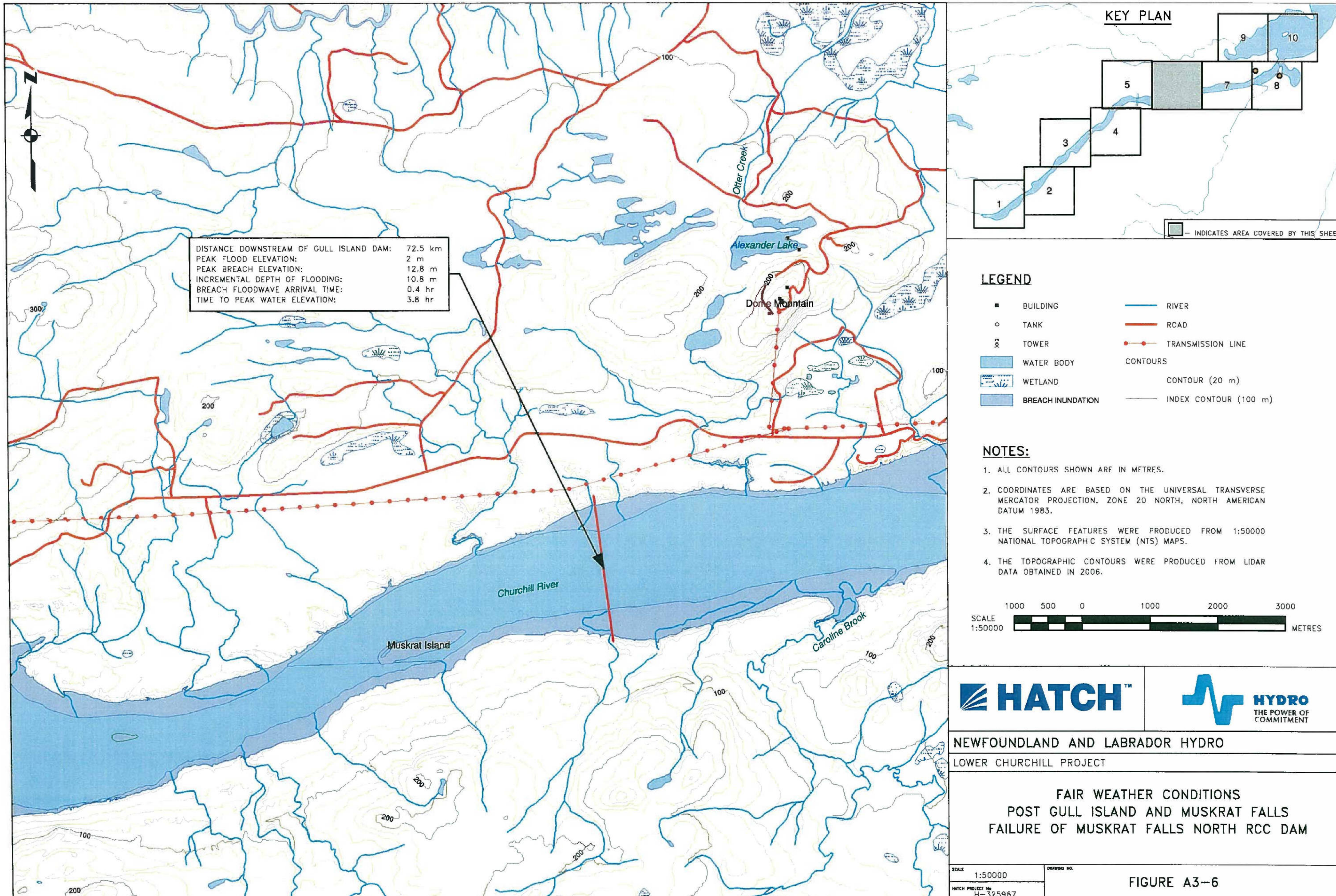
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000

HATCH PROJECT No. H-325967

DRAWING NO. FIGURE A3-5



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

NOTES:

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

HATCH

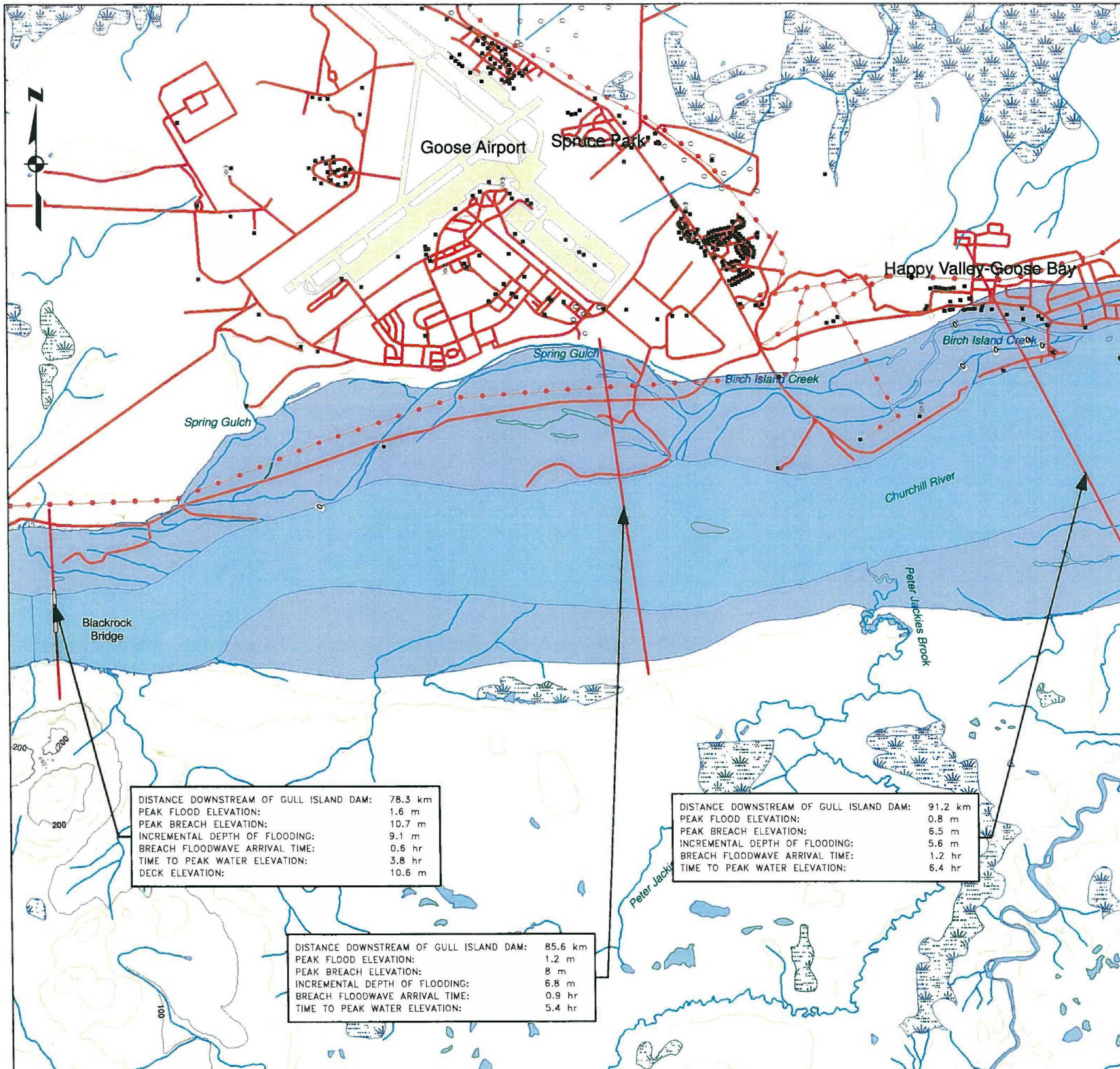
HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

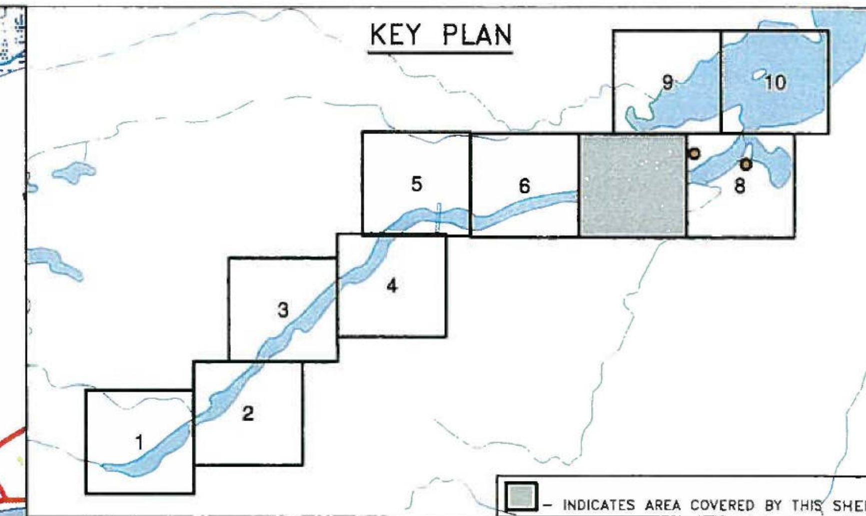
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000	DRAWING NO.
HATCH PROJECT No H-325967	FIGURE A3-6



KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

NOTES:

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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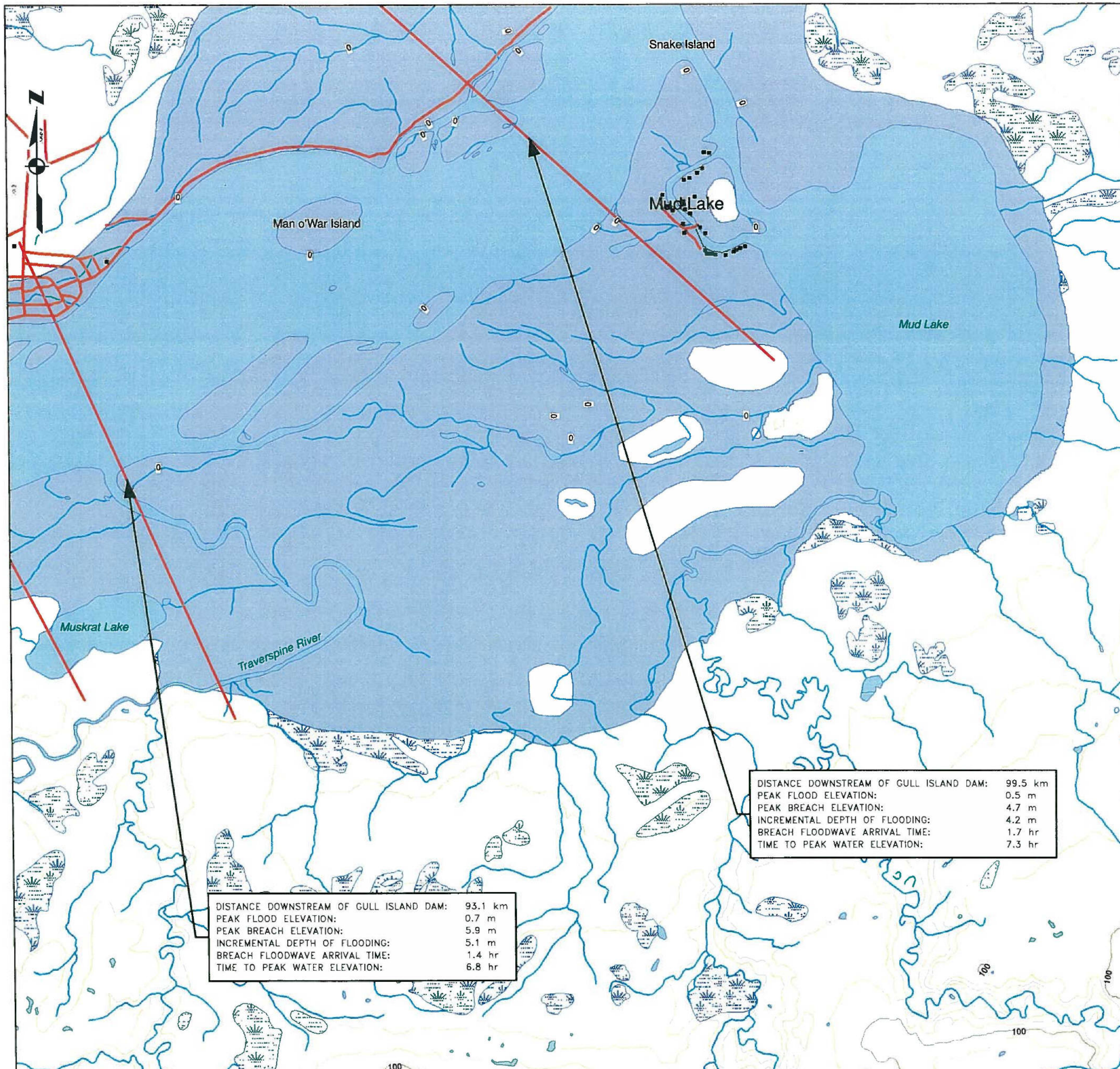
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

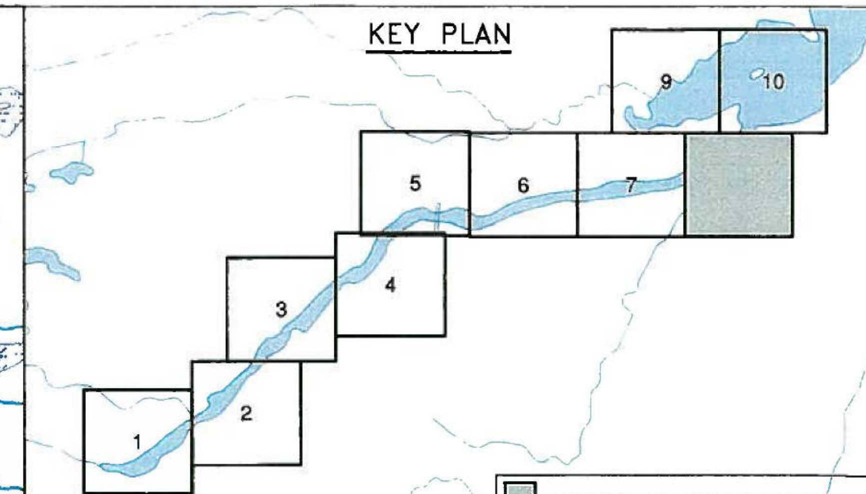
SCALE 1:50000
HATCH PROJECT No H-325967
DRAWING NO. FIGURE A3-7



DISTANCE DOWNSTREAM OF GULL ISLAND DAM:	93.1 km
PEAK FLOOD ELEVATION:	0.7 m
PEAK BREACH ELEVATION:	5.9 m
INCREMENTAL DEPTH OF FLOODING:	5.1 m
BREACH FLOODWAVE ARRIVAL TIME:	1.4 hr
TIME TO PEAK WATER ELEVATION:	6.8 hr

DISTANCE DOWNSTREAM OF GULL ISLAND DAM:	99.5 km
PEAK FLOOD ELEVATION:	0.5 m
PEAK BREACH ELEVATION:	4.7 m
INCREMENTAL DEPTH OF FLOODING:	4.2 m
BREACH FLOODWAVE ARRIVAL TIME:	1.7 hr
TIME TO PEAK WATER ELEVATION:	7.3 hr

KEY PLAN



- INDICATES AREA COVERED BY THIS SHEET.

LEGEND

- ■ BUILDING
- ○ TANK
- TOWER
- WATER BODY
- WETLAND
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

NOTES:

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

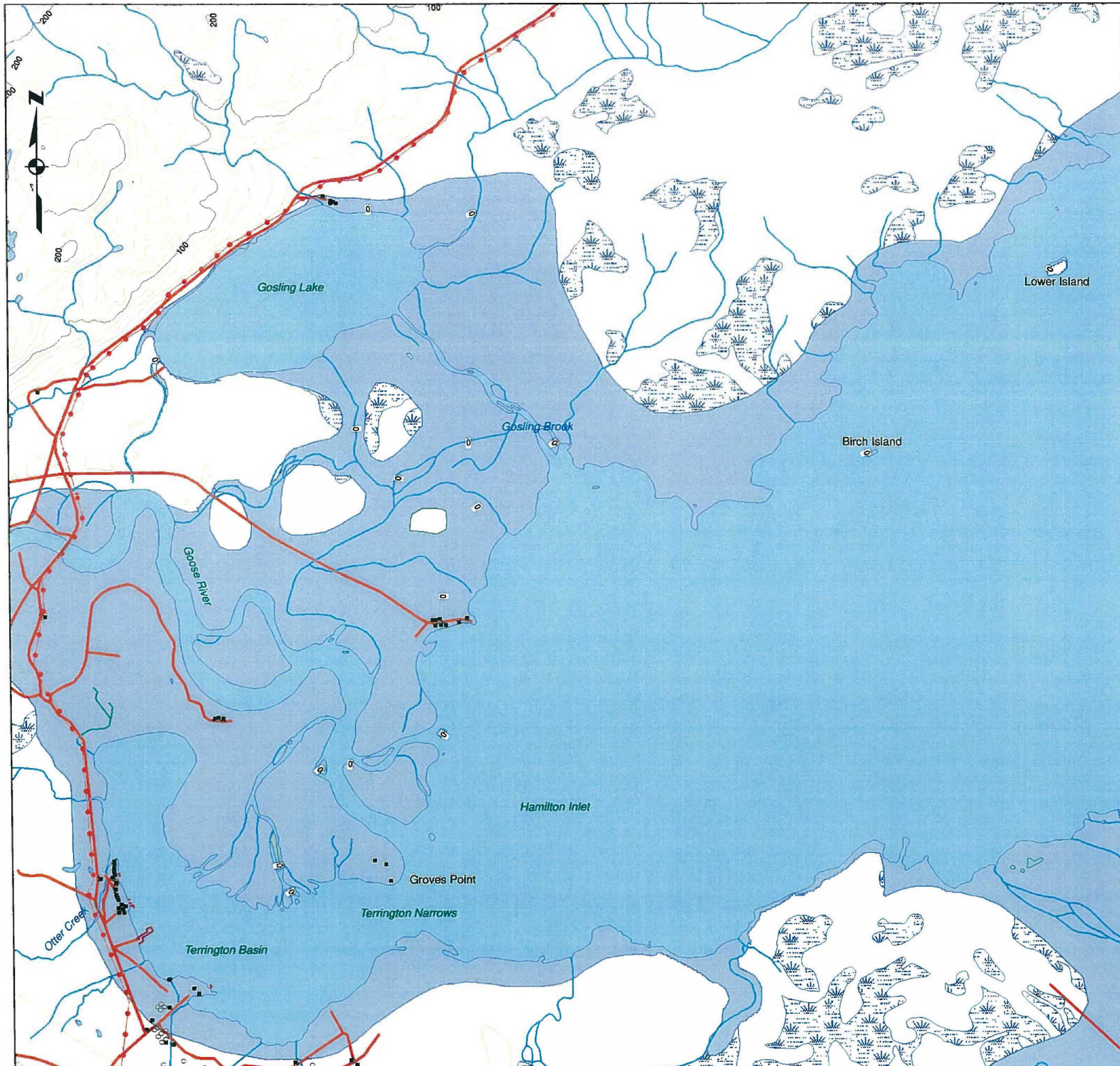
FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000

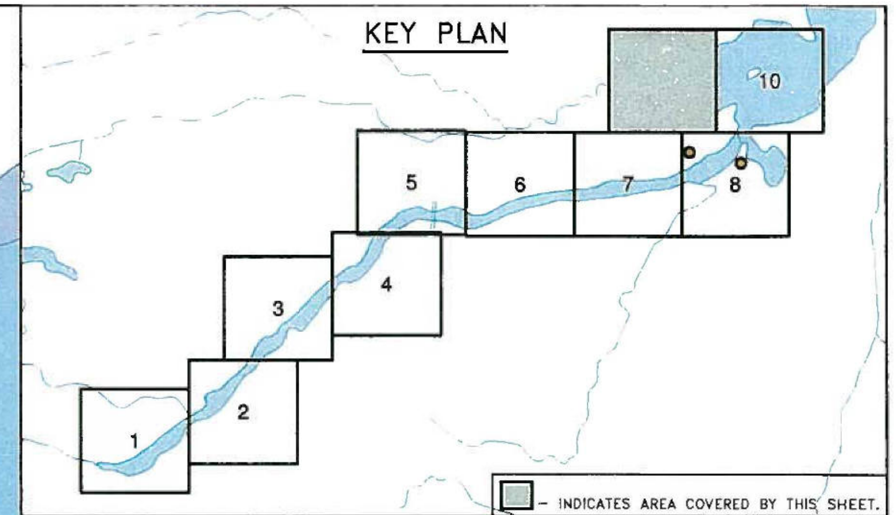
HATCH PROJECT No. H-325967

DRAWING NO.

FIGURE A3-8



KEY PLAN



- INDICATES AREA COVERED BY THIS SHEET.

LEGEND

■	BUILDING	——	RIVER
○	TANK	——	ROAD
	TOWER	—●—	TRANSMISSION LINE
	WATER BODY		CONTOURS
	WETLAND		CONTOUR (20 m)
	BREACH INUNDATION	——	INDEX CONTOUR (100 m)

NOTES:

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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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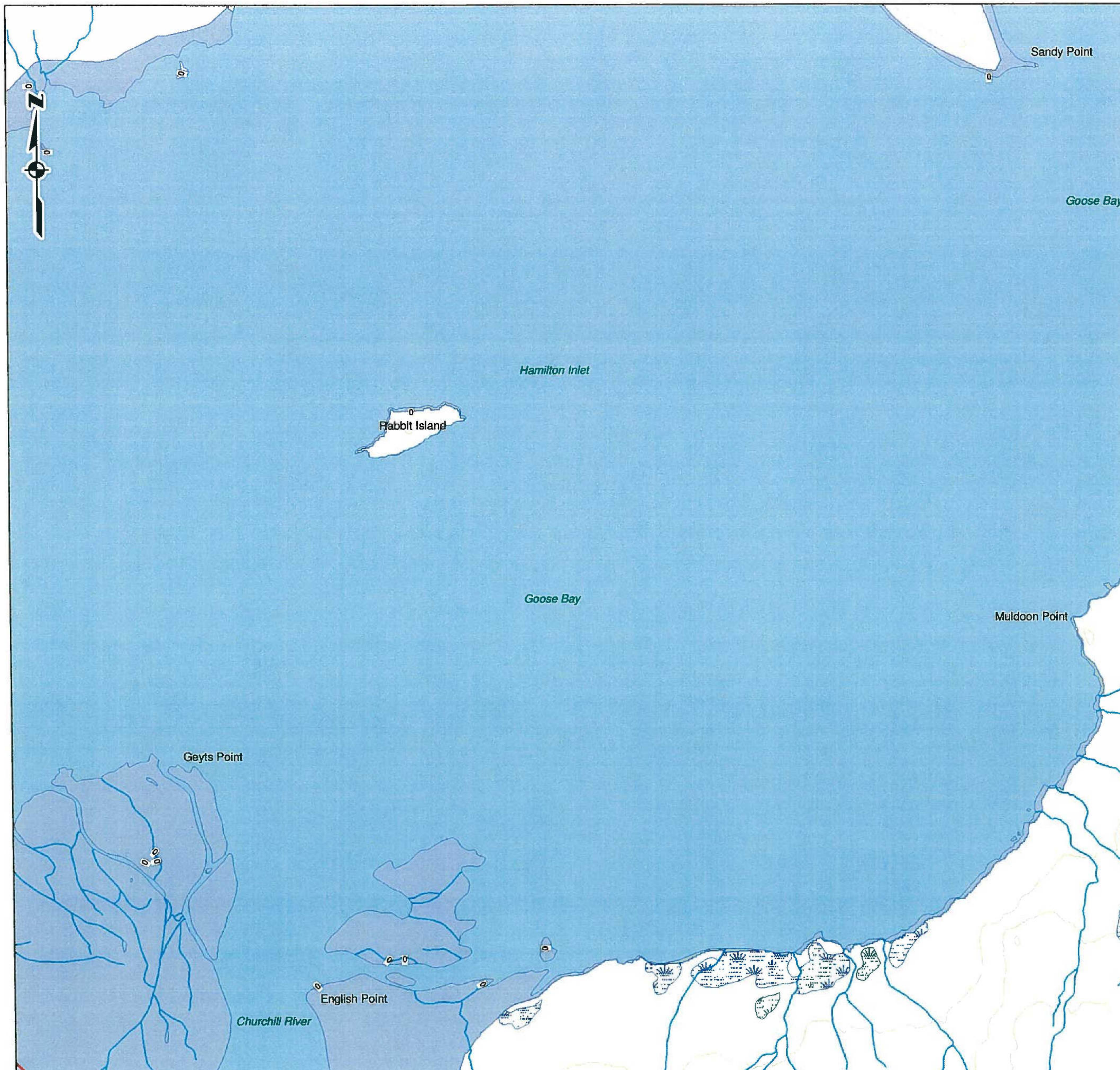
NEWFOUNDLAND AND LABRADOR HYDRO

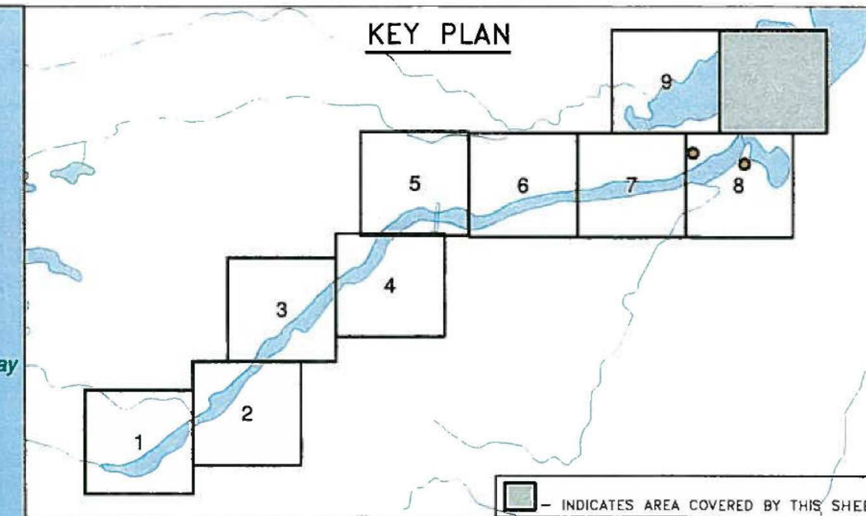
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE	DRAWING NO.
1:50000	FIGURE A3-9
HATCH PROJECT No. H-325967	



KEY PLAN



LEGEND

▪	BUILDING		RIVER
o	TANK		ROAD
	TOWER		TRANSMISSION LINE
	WATER BODY	CONTOURS	
	WETLAND		CONTOUR (20 m)
	BREACH INUNDATION		INDEX CONTOUR (100 m)

NOTES:

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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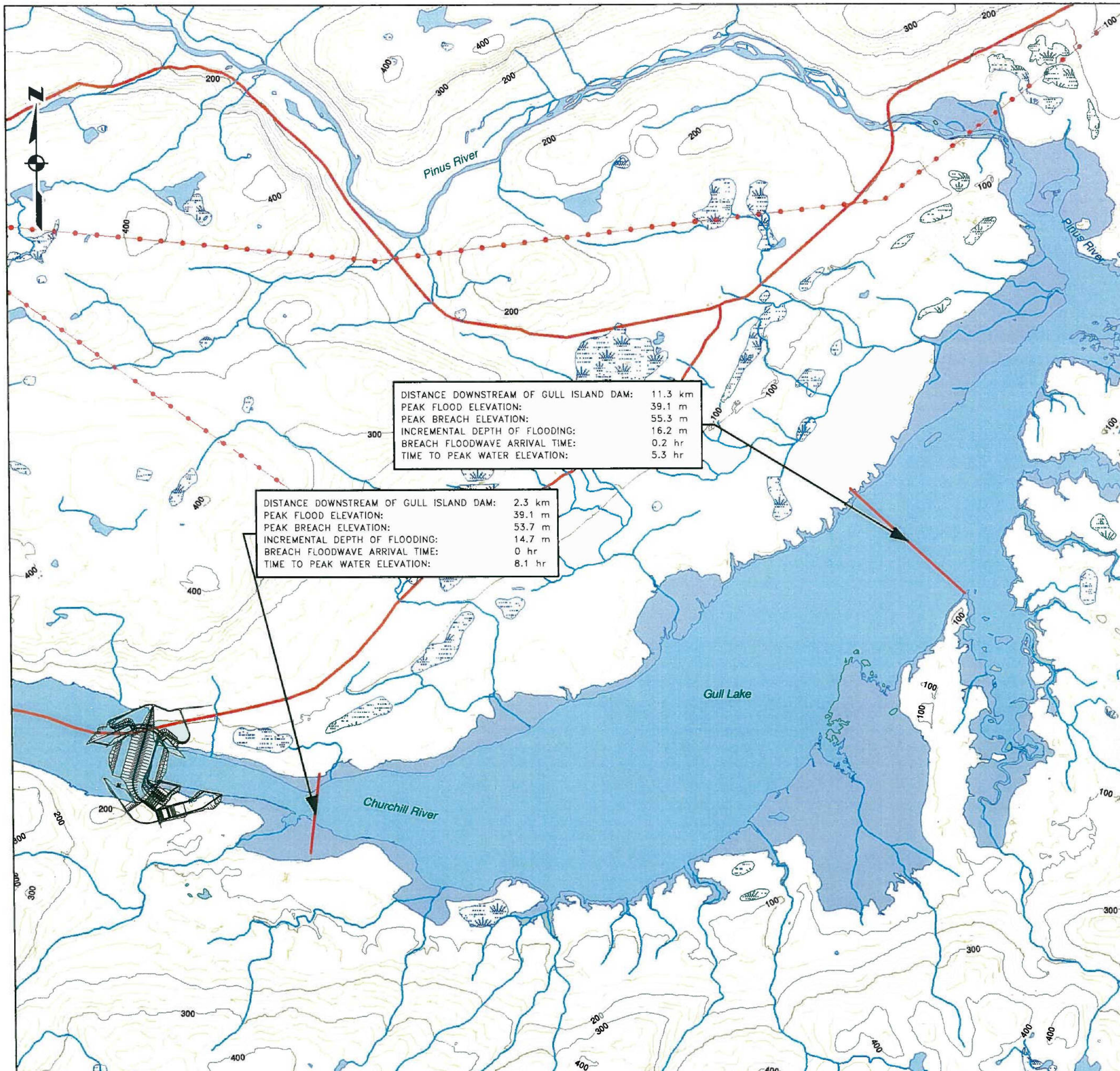
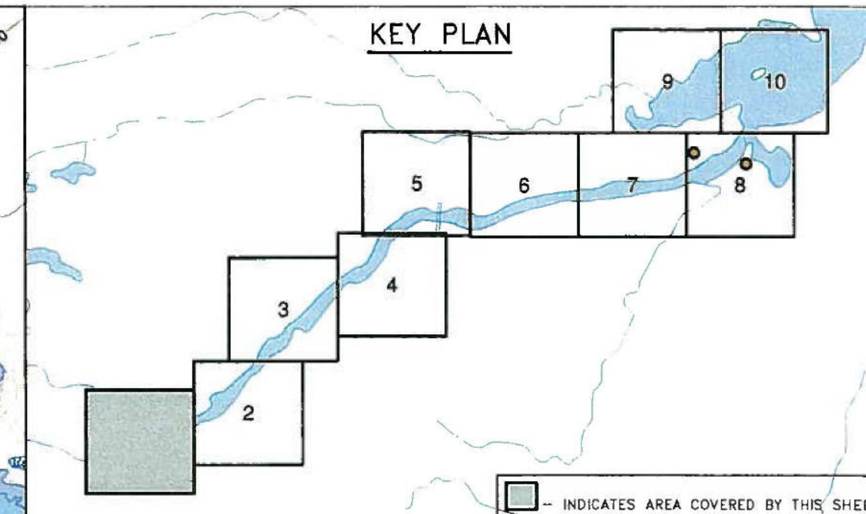
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE	DRAWING NO.
1:50000	FIGURE A3–10
HATCH PROJECT No H–325967	



KEY PLAN



LEGEND

BUILDING		RIVER	
TANK		ROAD	
TOWER		TRANSMISSION LINE	
WATER BODY		CONTOURS	
WETLAND		CONTOUR (20 m)	
BREACH INUNDATION		INDEX CONTOUR (100 m)	

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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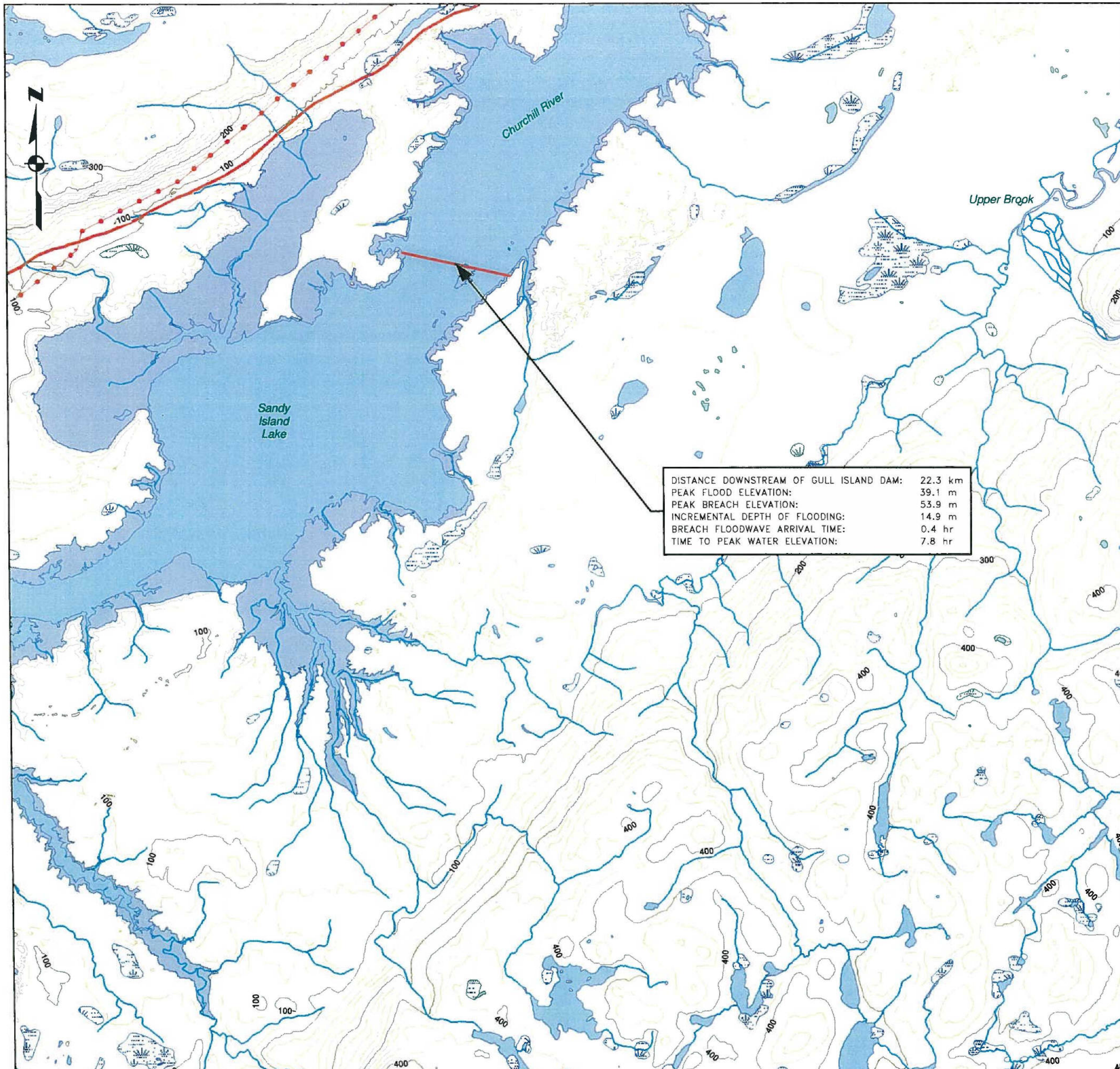
FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND
MUSKRAT FALLS NORTH RCC DAM

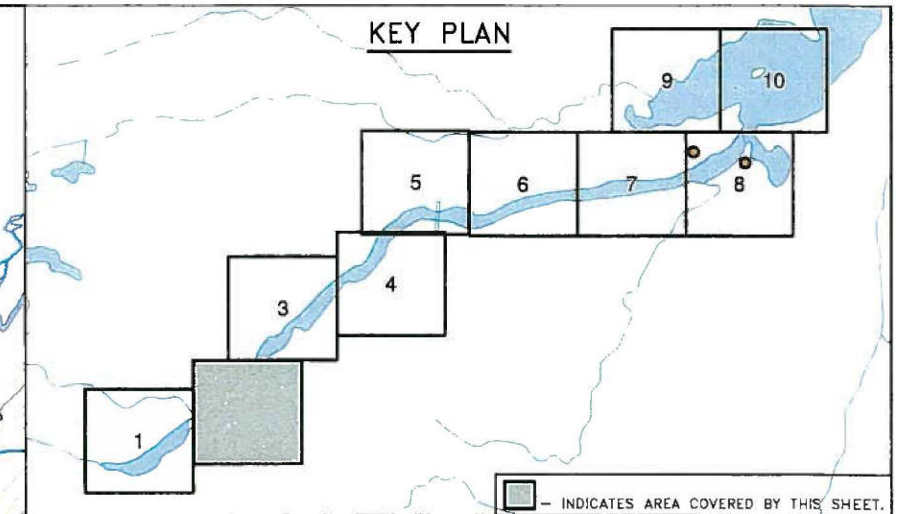
SCALE 1:50000

HATCH PROJECT No. H-325967

DRAWING NO. FIGURE A4-1



KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

NOTES:

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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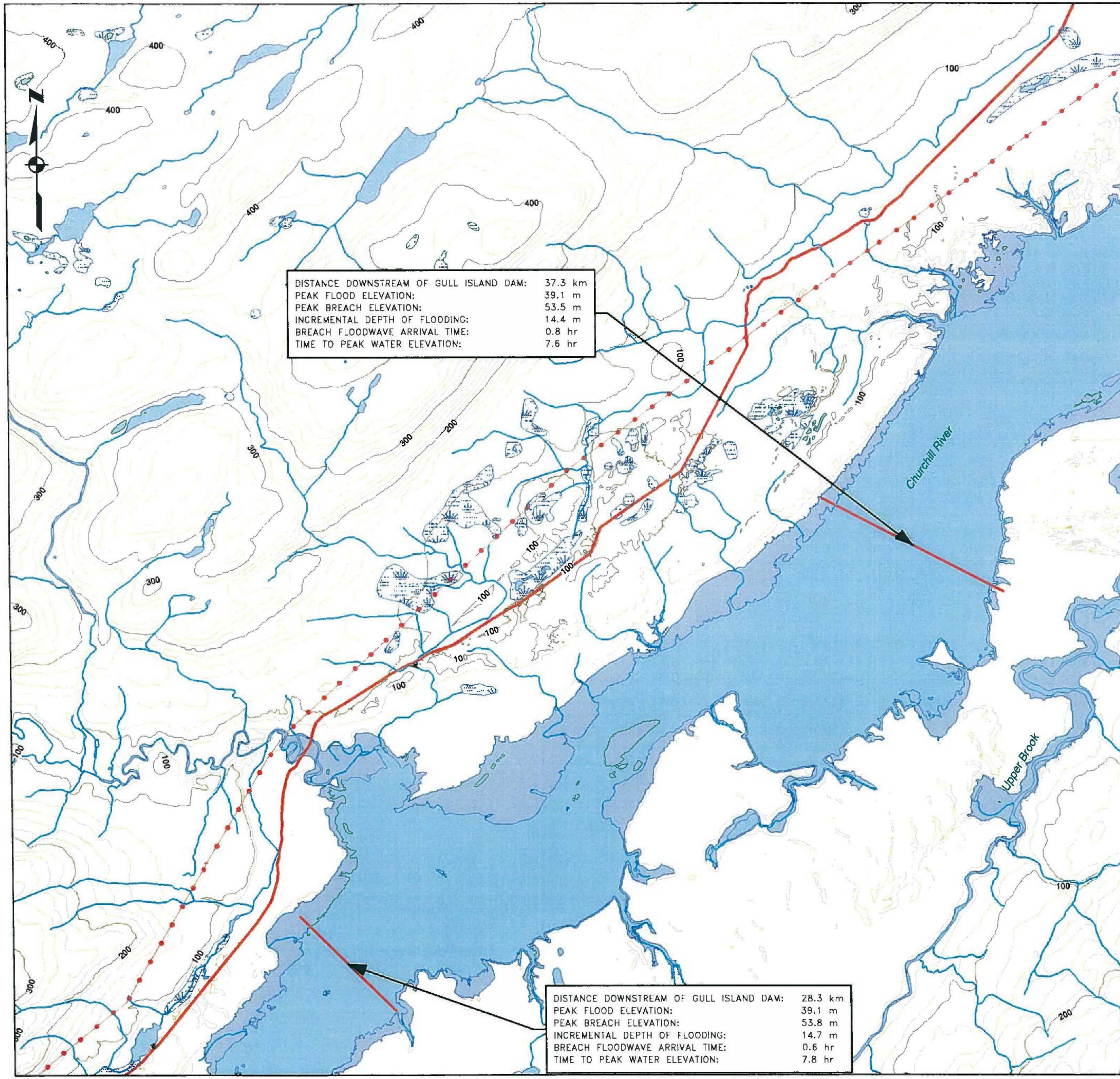
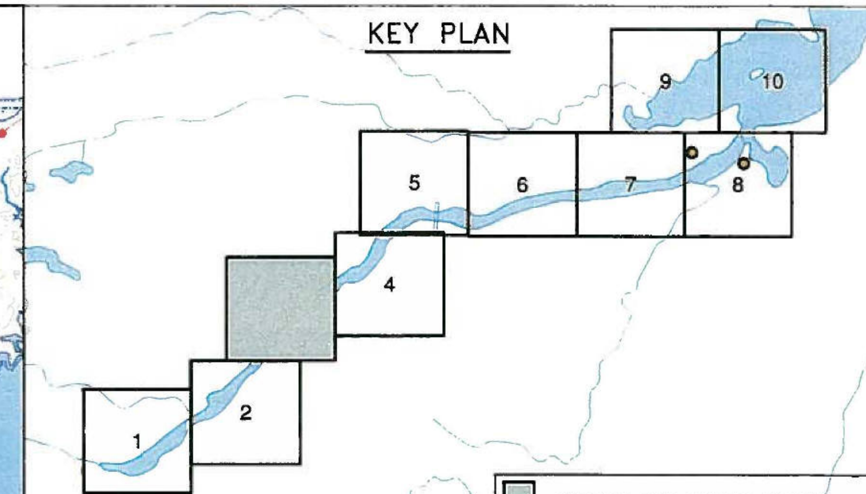
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND
MUSKRAT FALLS NORTH RCC DAM

SCALE	DRAWING NO.
1:50000	FIGURE A4-2
HATCH PROJECT No H-325967	



KEY PLAN



– INDICATES AREA COVERED BY THIS SHEET.

LEGEND

■	BUILDING		RIVER
o	TANK		ROAD
	TOWER		TRANSMISSION LINE
	WATER BODY		CONTOURS
	WETLAND		CONTOUR (20 m)
	BREACH INUNDATION		INDEX CONTOUR (100 m)

NOTES:

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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

HATCH™

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NEWFOUNDLAND AND LABRADOR HYDRO

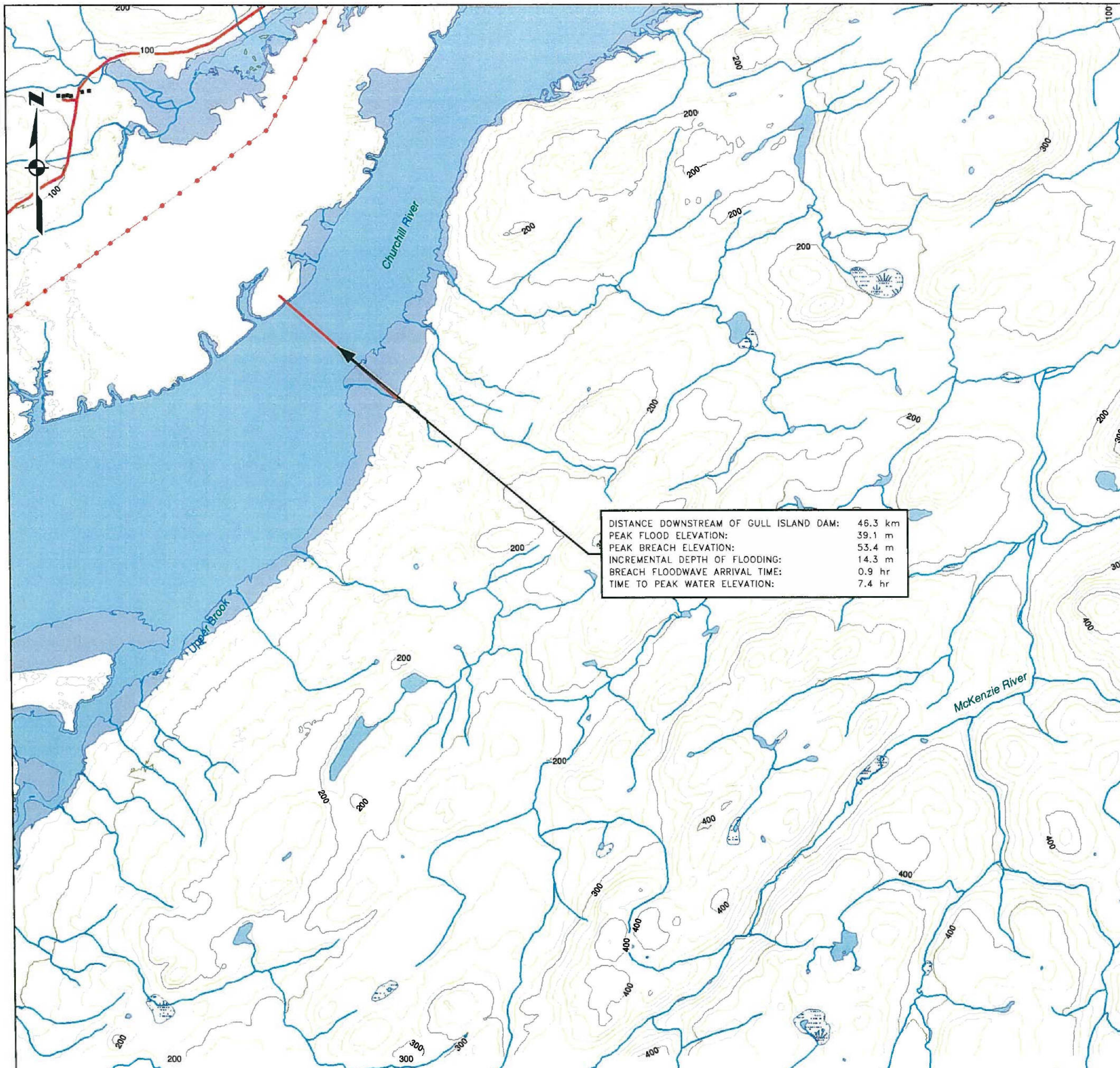
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND
MUSKRAT FALLS NORTH RCC DAM

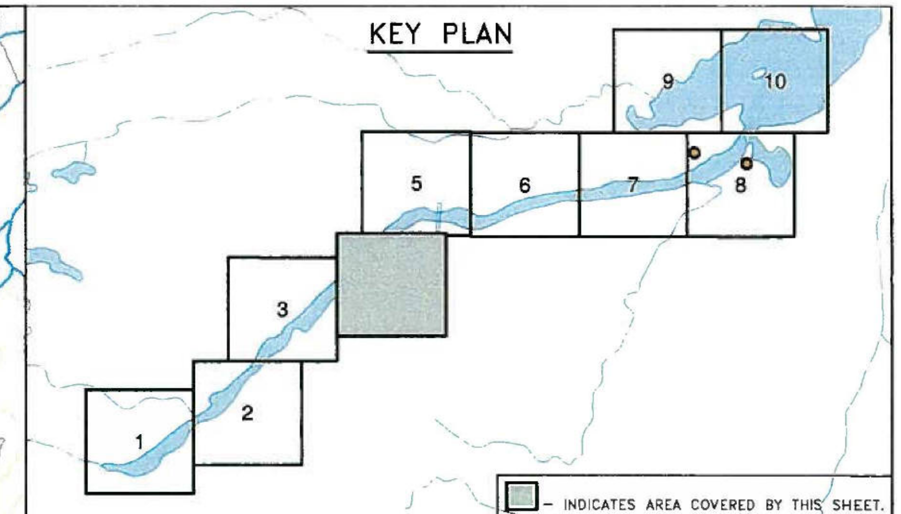
SCALE 1:50000

HATCH PROJECT No H-325967

DRAWING NO. FIGURE A4-3



KEY PLAN



LEGEND

■	BUILDING	—	RIVER
○	TANK	—	ROAD
	TOWER	•—•	TRANSMISSION LINE
	WATER BODY		CONTOURS
	WETLAND		CONTOUR (20 m)
	BREACH INUNDATION		INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

HATCH™

HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

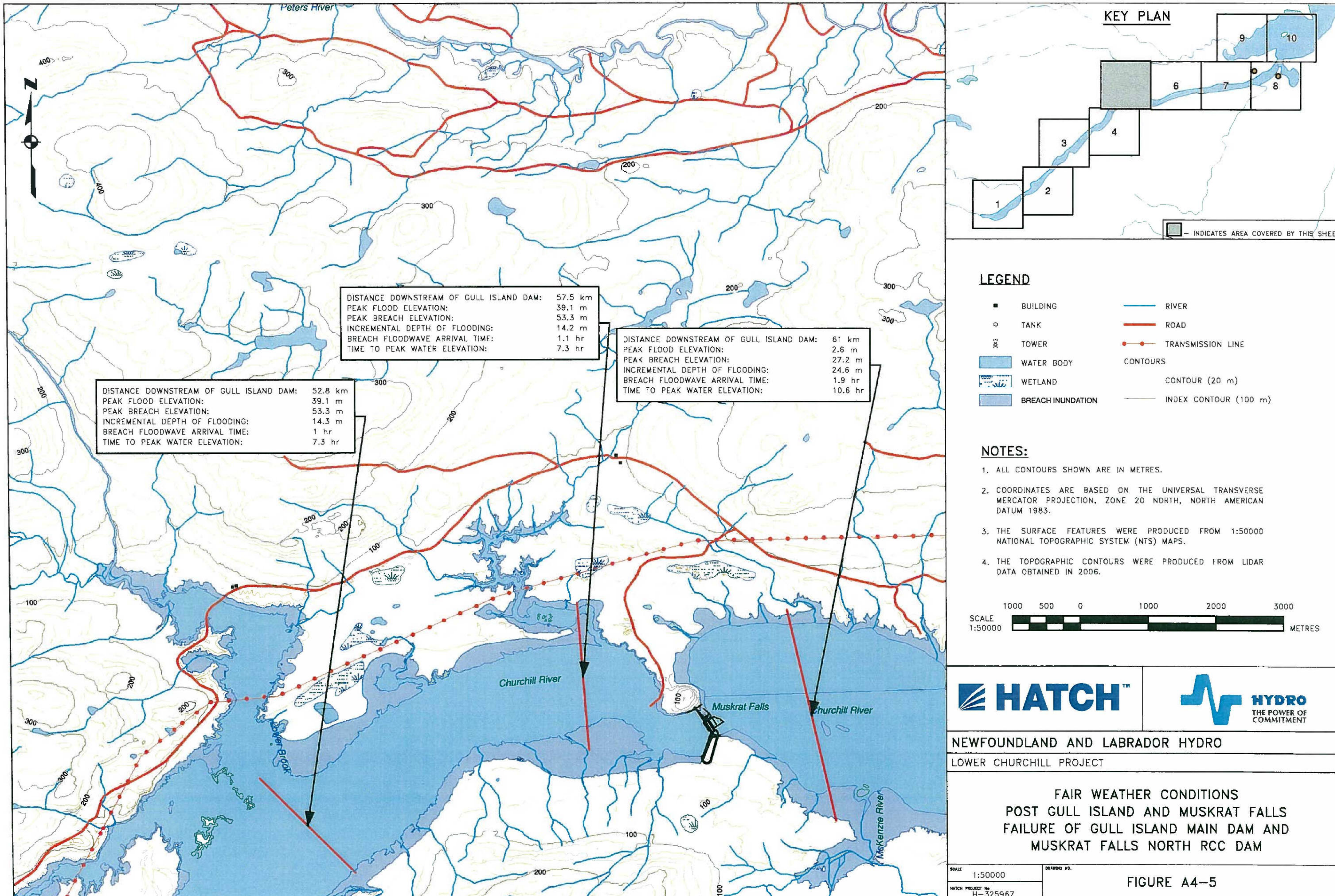
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND
MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000

HATCH PROJECT No H-325967

DRAWING NO. FIGURE A4-4



LEGEND

BUILDING	RIVER
TANK	ROAD
TOWER	TRANSMISSION LINE
WATER BODY	CONTOURS
WETLAND	CONTOUR (20 m)
BREACH INUNDATION	INDEX CONTOUR (100 m)

NOTES:

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2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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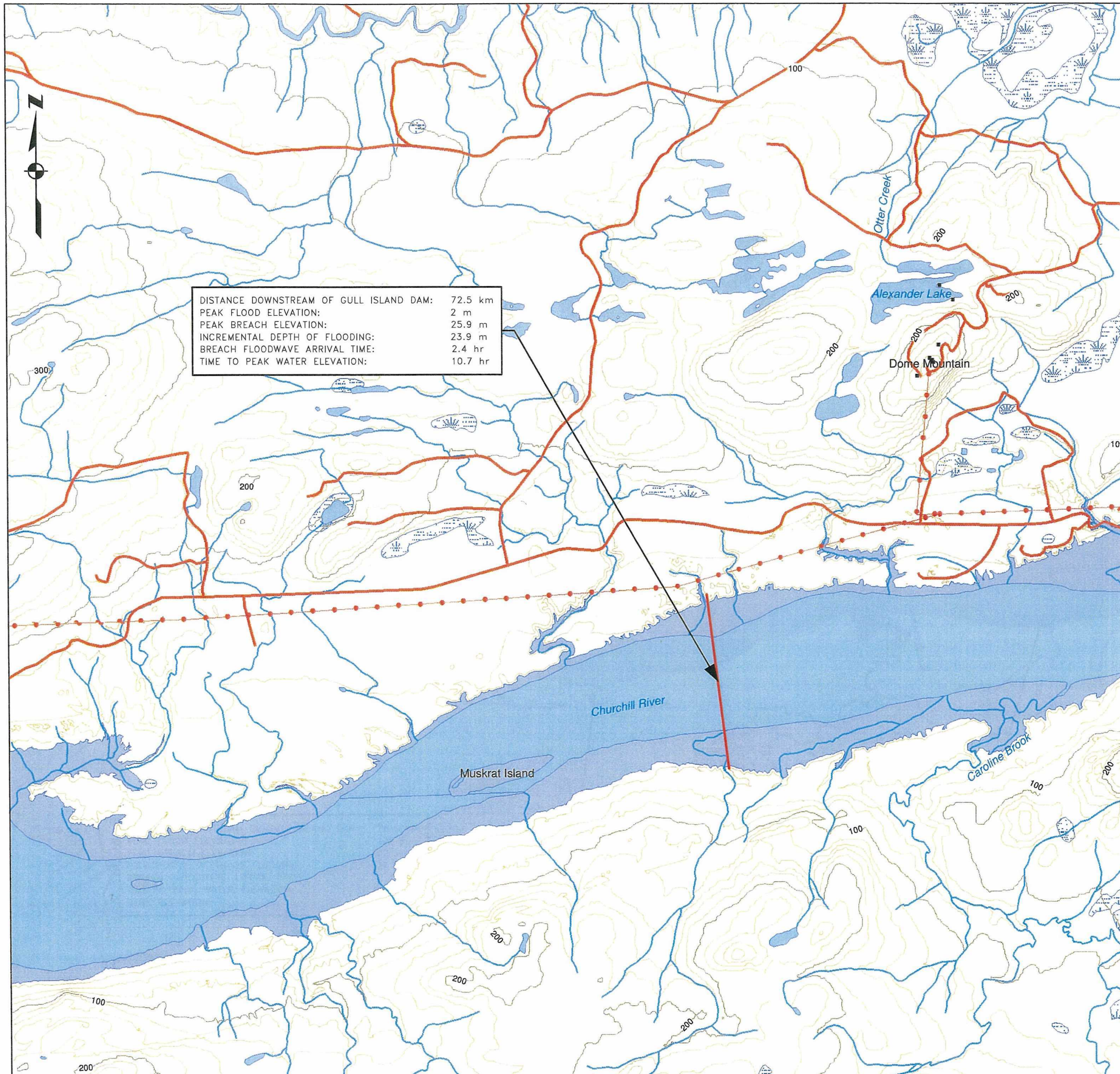
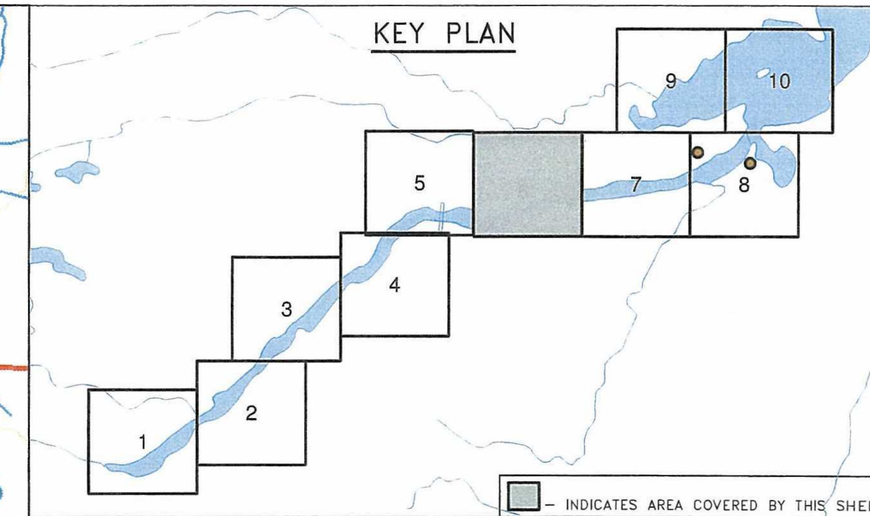
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND
MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000
HATCH PROJECT No. H-325967
DRAWING NO. FIGURE A4-5





LEGEND

▪	BUILDING	——	RIVER
○	TANK	——	ROAD
	TOWER	•—•	TRANSMISSION LINE
	WATER BODY		CONTOURS
	WETLAND		CONTOUR (20 m)
	BREACH INUNDATION		INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

HATCH

HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

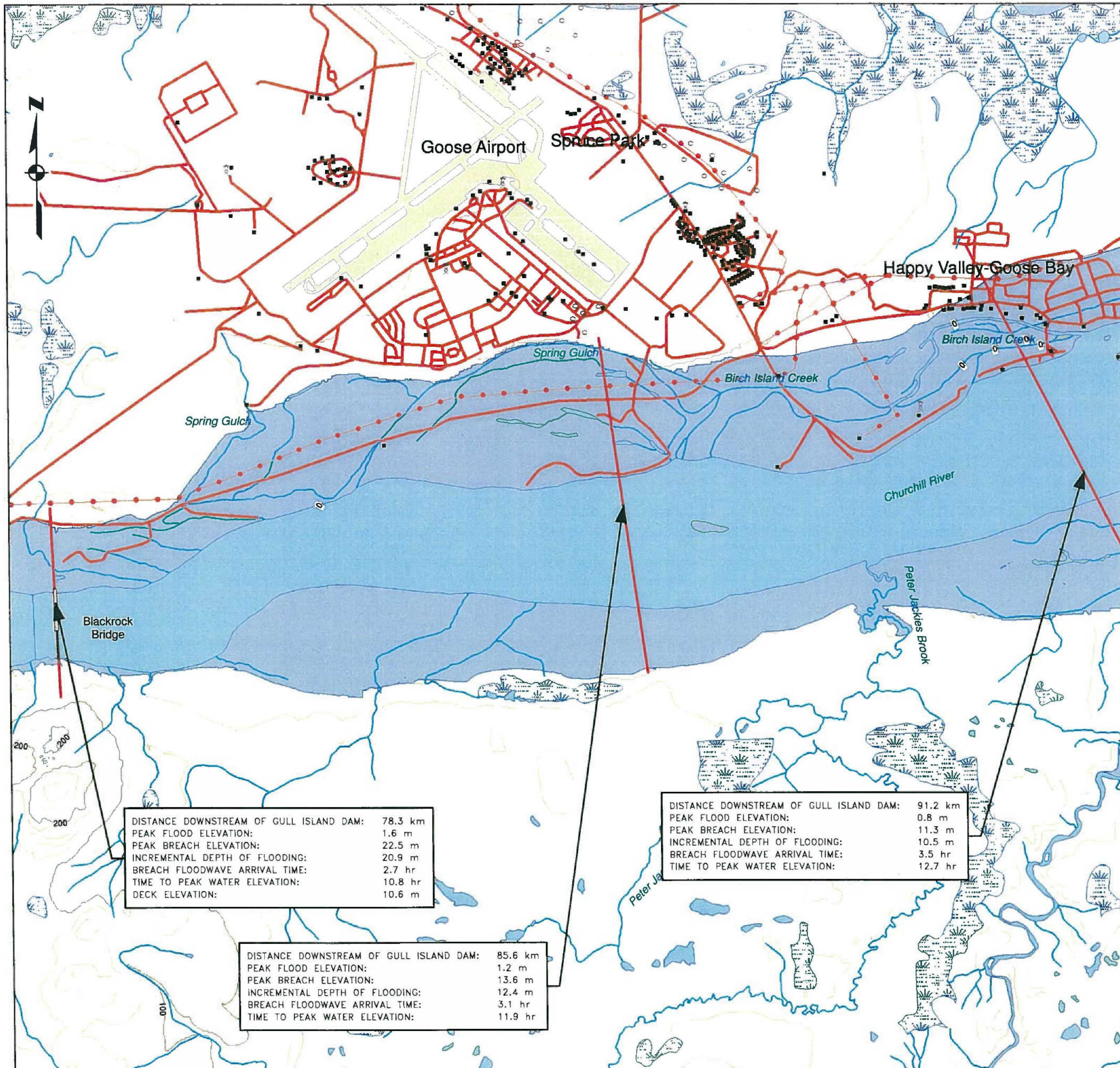
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND
MUSKRAT FALLS NORTH RCC DAM

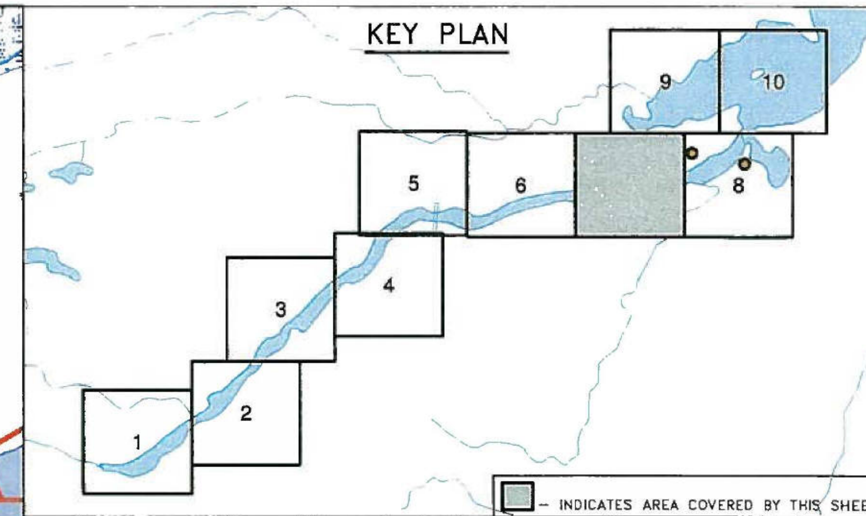
SCALE 1:50000

HATCH PROJECT No H-325967

DRAWING NO. FIGURE A4-6



KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

NOTES:

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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

HATCH™

HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

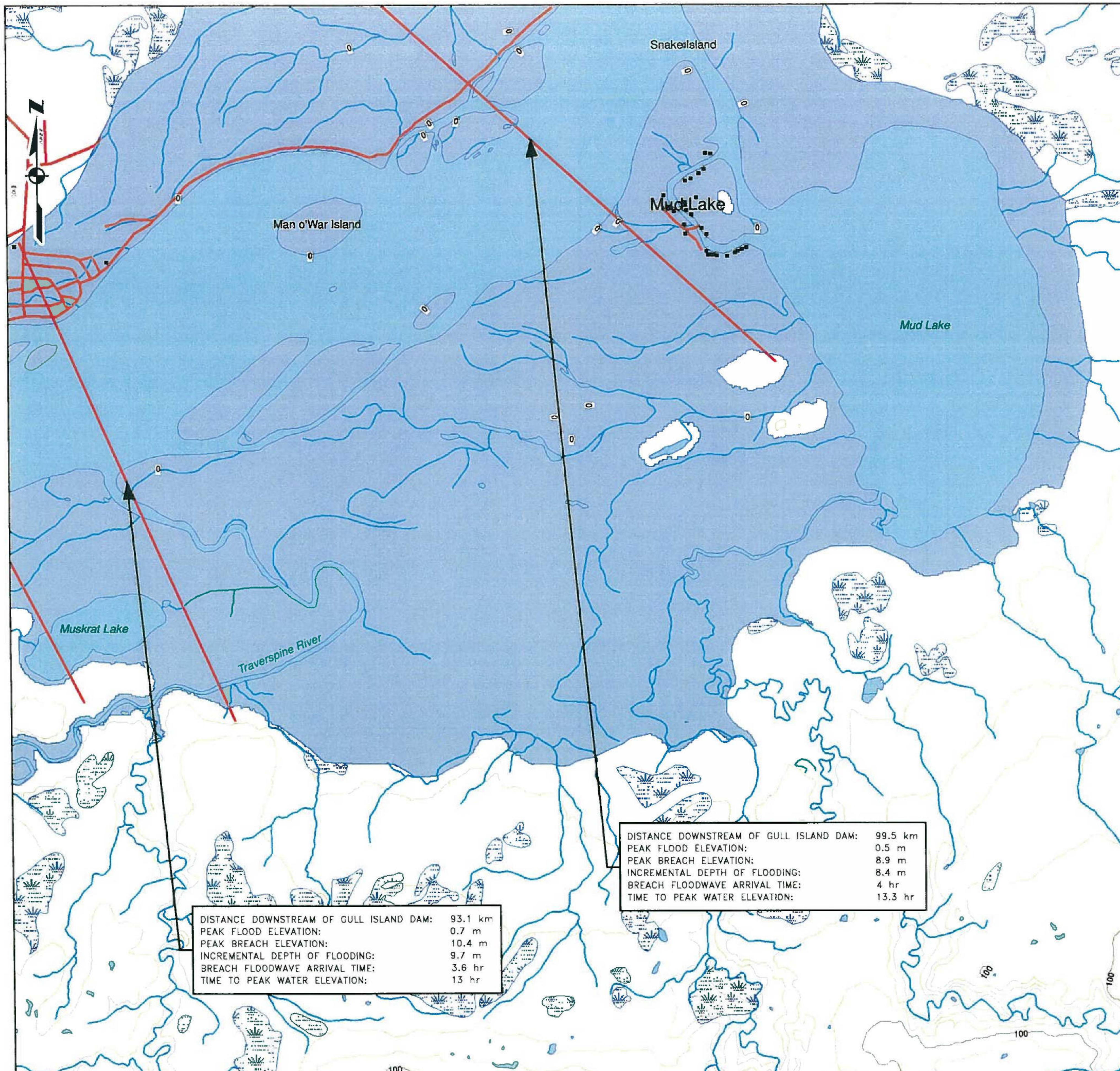
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND
MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000

HATCH PROJECT No. H-325967

DRAWING NO. FIGURE A4-7



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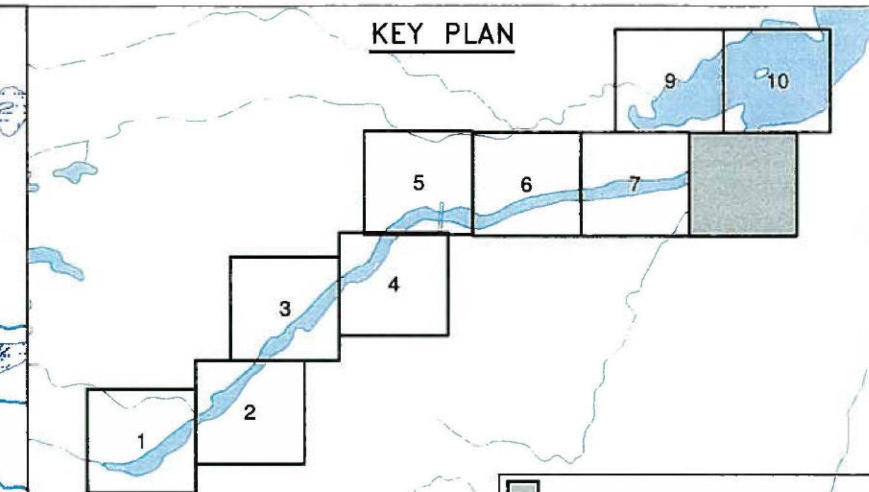

– INDICATES AREA COVERED BY THIS SHEET.

LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE

CONTOURS

- CONTOUR (20 m)
- INDEX CONTOUR (100 m)

NOTES:

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2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

HATCH™

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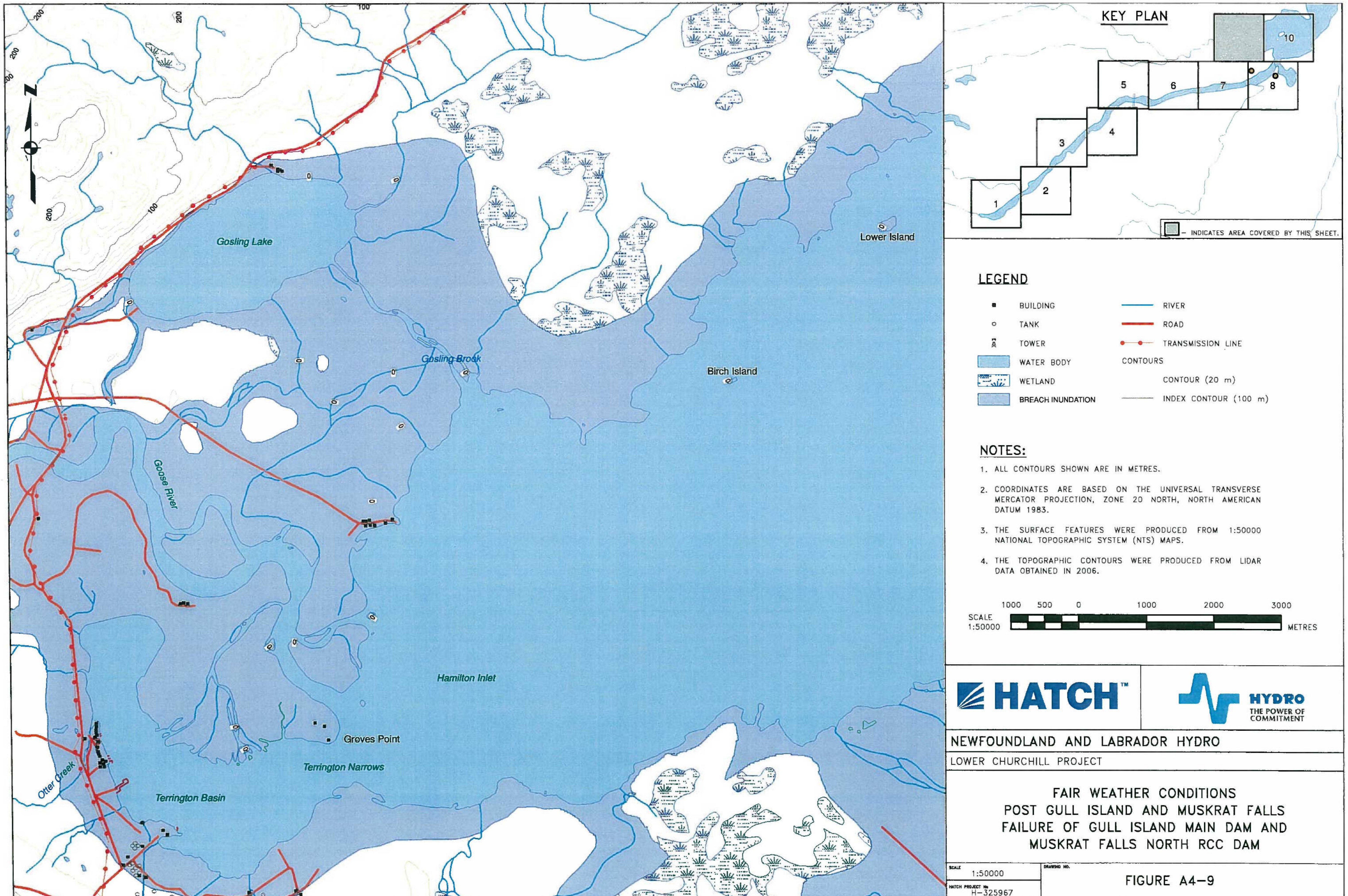
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND
MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000	DRAWING NO.	FIGURE A4–8
HATCH PROJECT No H–325967		


KEY PLAN
1
2
3
4
5
6
7
8
10
- INDICATES AREA COVERED BY THIS SHEET.
Gosling Lake
Gosling Brook
Lower Island
Birch Island
Goose River
Hamilton Inlet
Groves Point
Terrington Narrows
Terrington Basin
Otter Creek
LEGEND
BUILDING
TANK
TOWER
WATER BODY
WETLAND
BREACH INUNDATION
RIVER
ROAD
TRANSMISSION LINE
CONTOURS
CONTOUR (20 m)
INDEX CONTOUR (100 m)
NOTES:
1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
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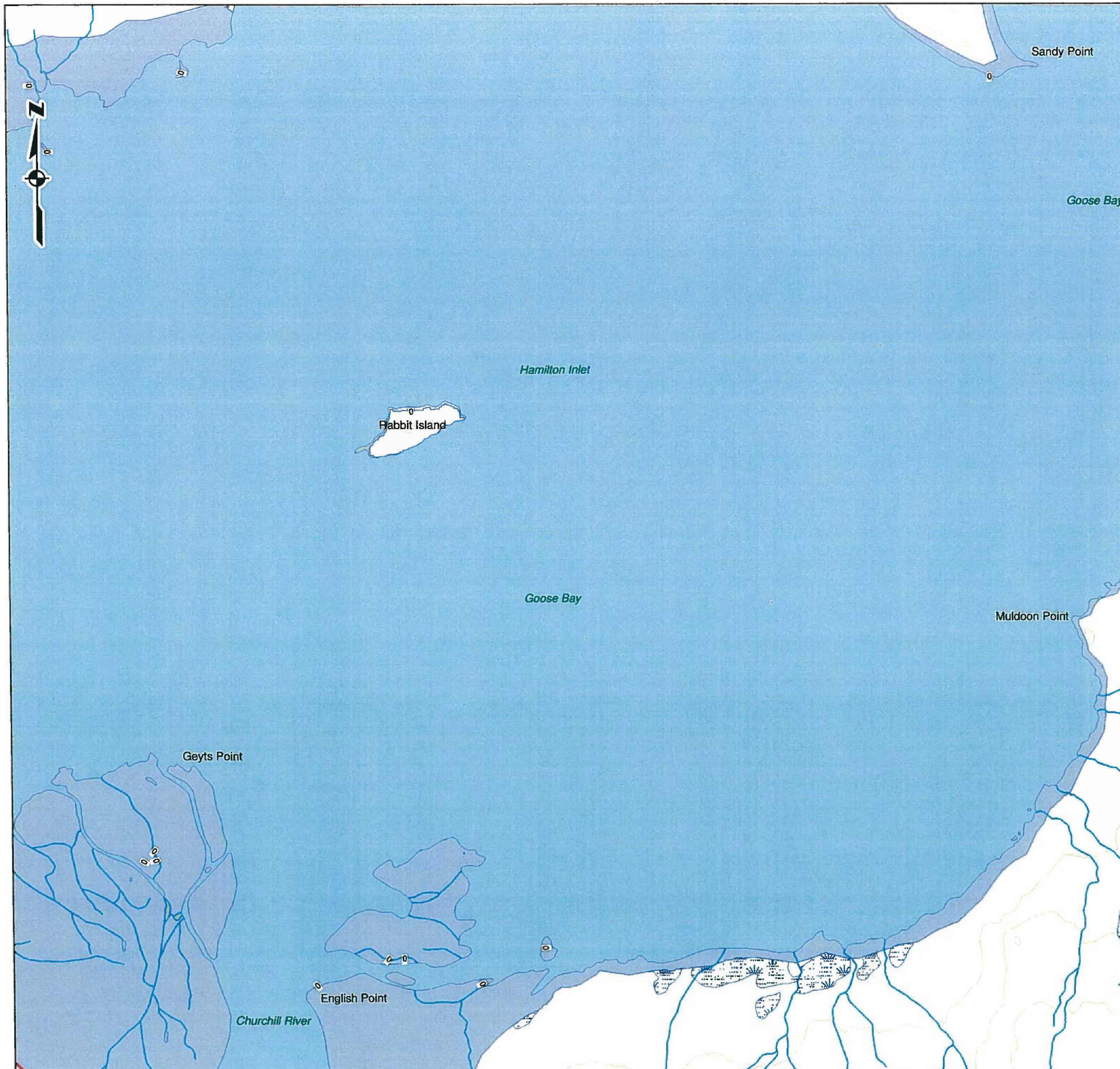
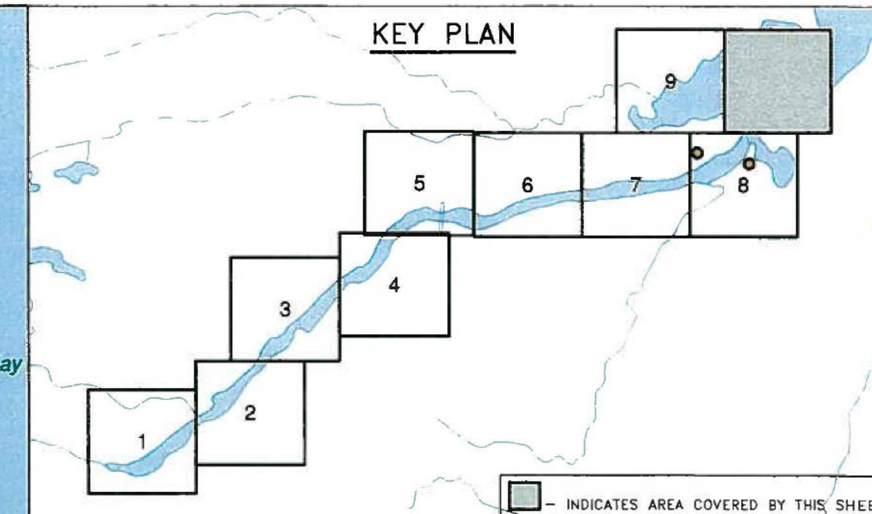
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.
SCALE 1:50000
1000 500 0 1000 2000 3000
METRES
HATCH
HYDRO THE POWER OF COMMITMENT
NEWFOUNDLAND AND LABRADOR HYDRO
LOWER CHURCHILL PROJECT
FAIR WEATHER CONDITIONS POST GULL ISLAND AND MUSKRAT FALLS FAILURE OF GULL ISLAND MAIN DAM AND MUSKRAT FALLS NORTH RCC DAM
SCALE 1:50000
HATCH PROJECT No H-325967
DRAWING NO.
FIGURE A4-9





LEGEND

▪	BUILDING		RIVER
○	TANK		ROAD
	TOWER		TRANSMISSION LINE
	WATER BODY	CONTOURS	
	WETLAND		CONTOUR (20 m)
	BREACH INUNDATION		INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

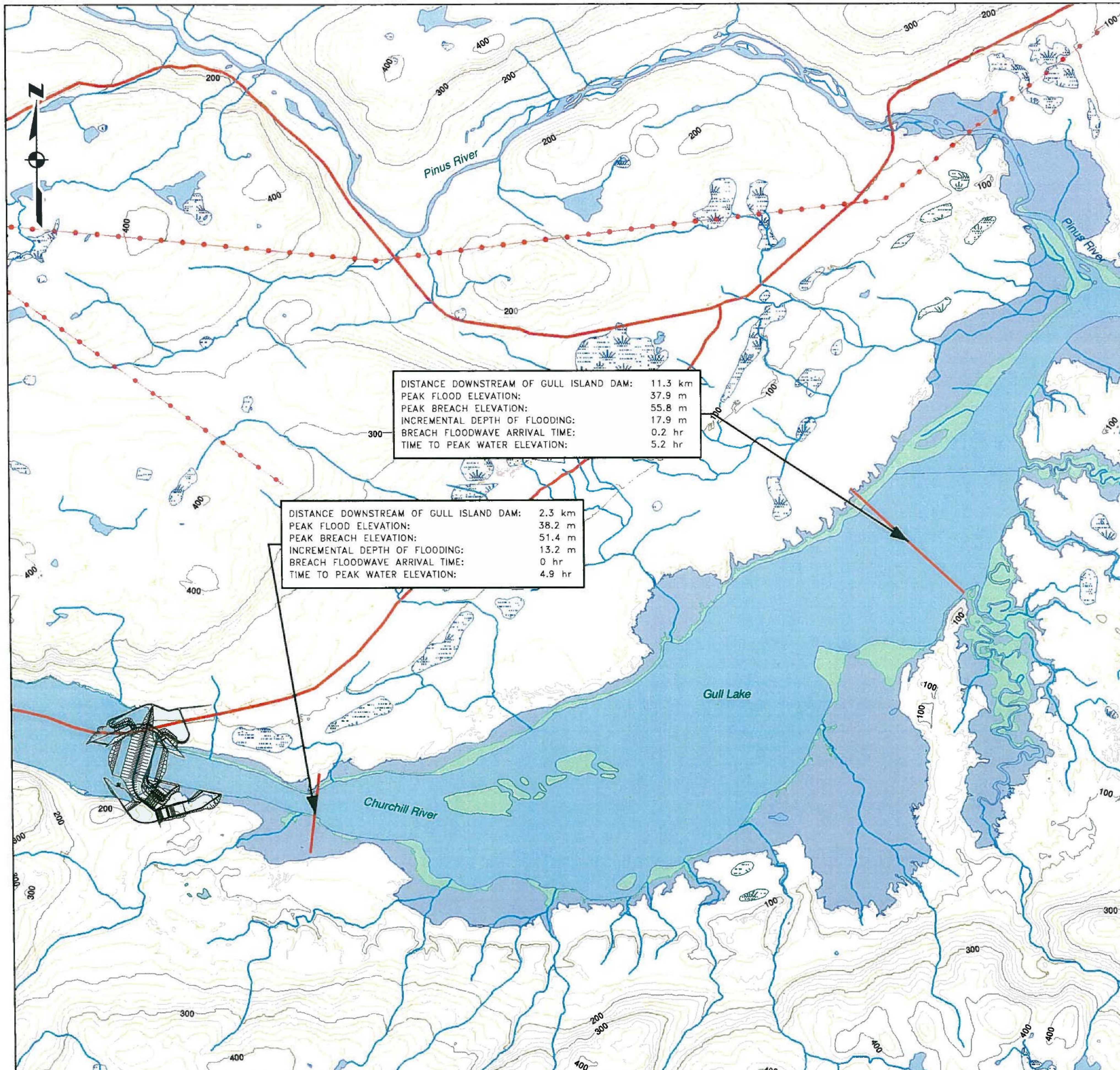
FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND
MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000	DRAWING NO. FIGURE A4–10
HATCH PROJECT No. H–325967	

Appendix B

PMF Inundation Mapping Series

(1:50,000 Scale)



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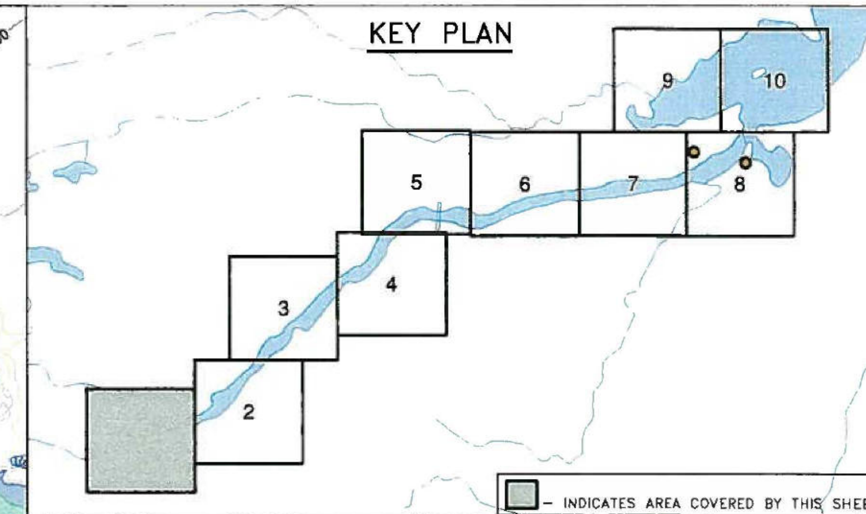

LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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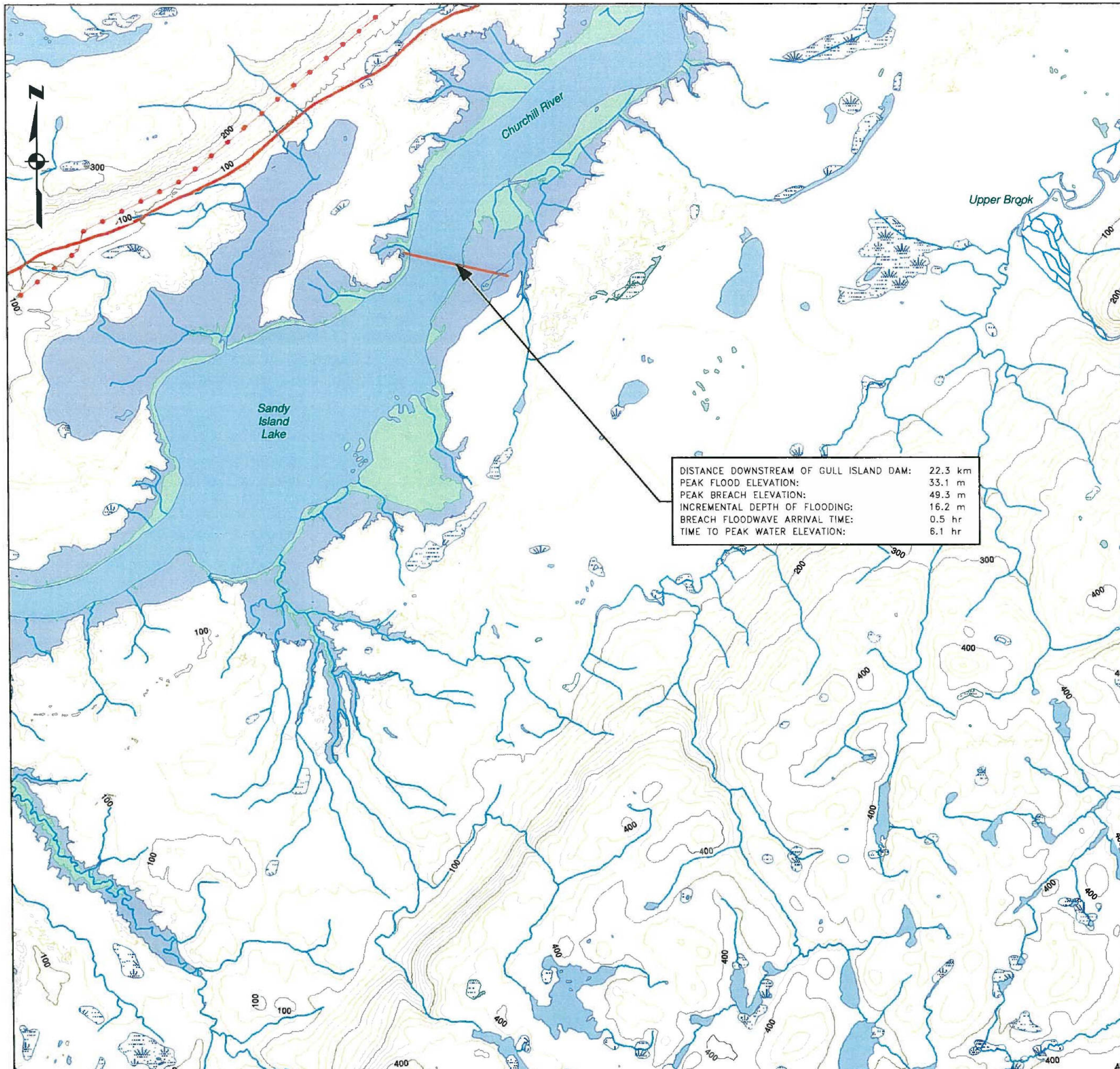
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000
HATCH PROJECT No H-325967
DRAWING NO. FIGURE B1-1



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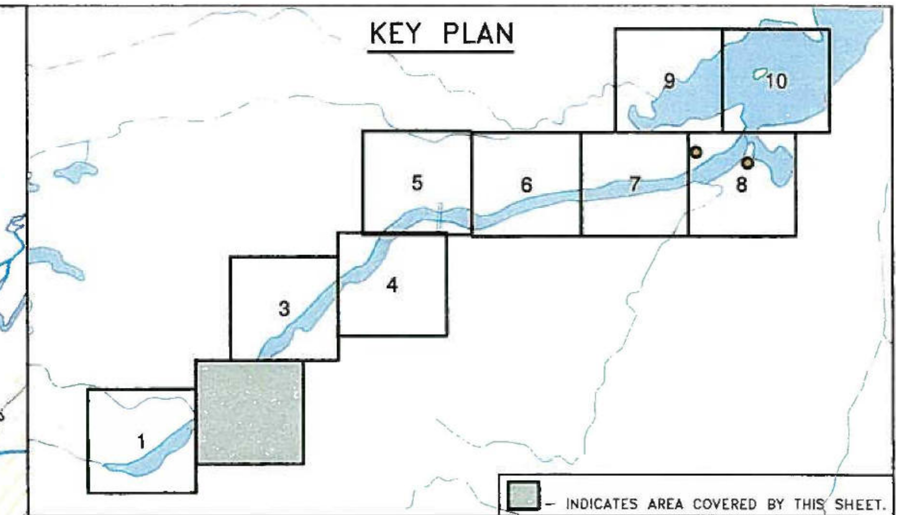

LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

NOTES:

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3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

HATCH™

HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

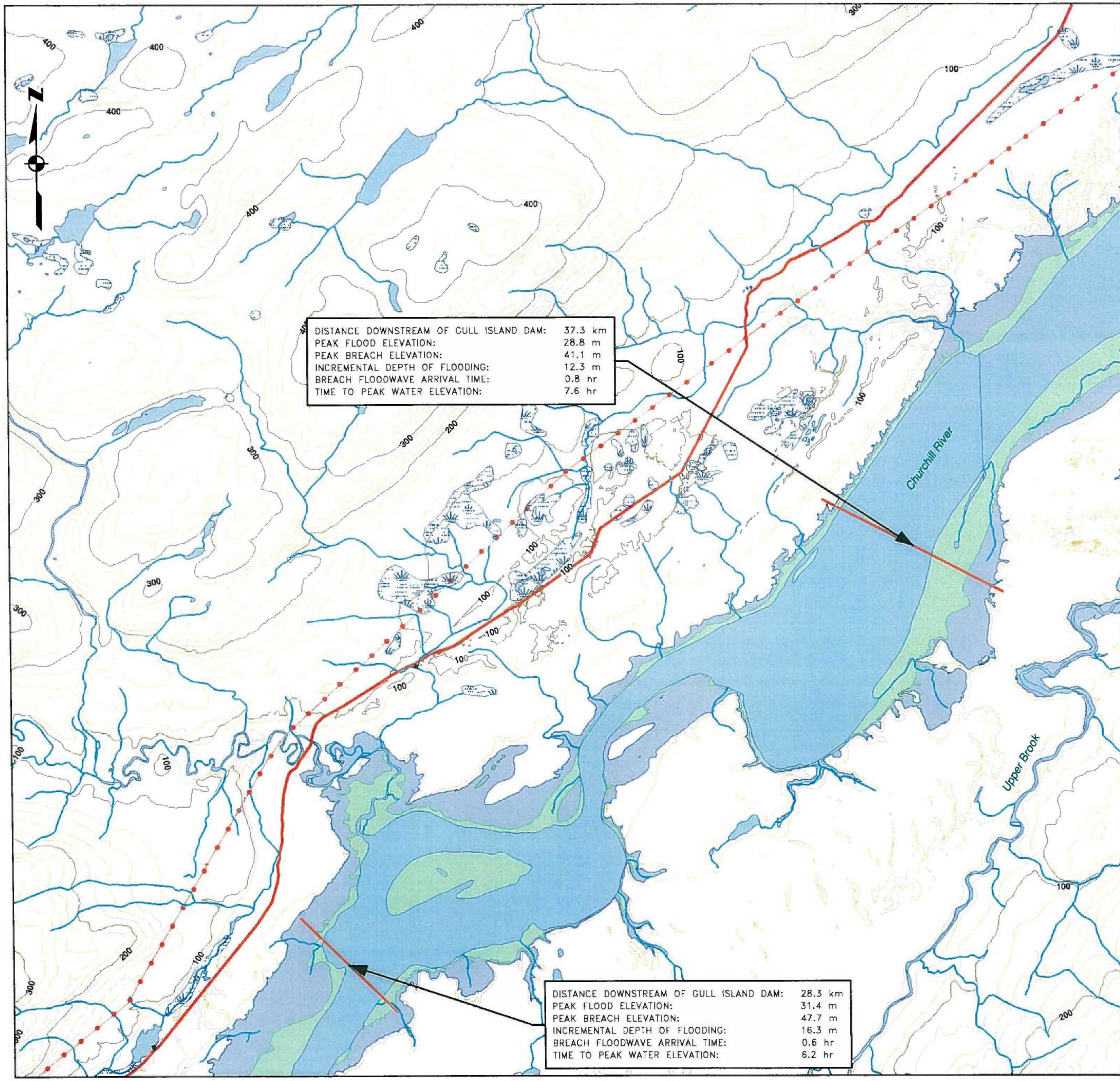
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

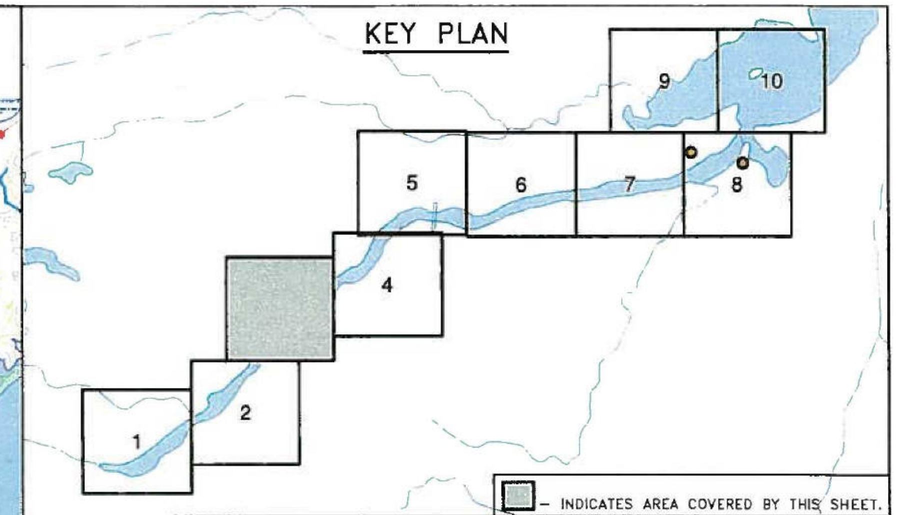
SCALE 1:50000

HATCH PROJECT No. H-325967

DRAWING NO. FIGURE B1-2



KEY PLAN



LEGEND

▪	BUILDING	—	RIVER
○	TANK	—	ROAD
	TOWER	•—•—	TRANSMISSION LINE
	WATER BODY	CONTOURS	
	WETLAND		CONTOUR (20 m)
	FLOOD INUNDATION		INDEX CONTOUR (100 m)
	BREACH INUNDATION		

NOTES:

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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

HATCH™

HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

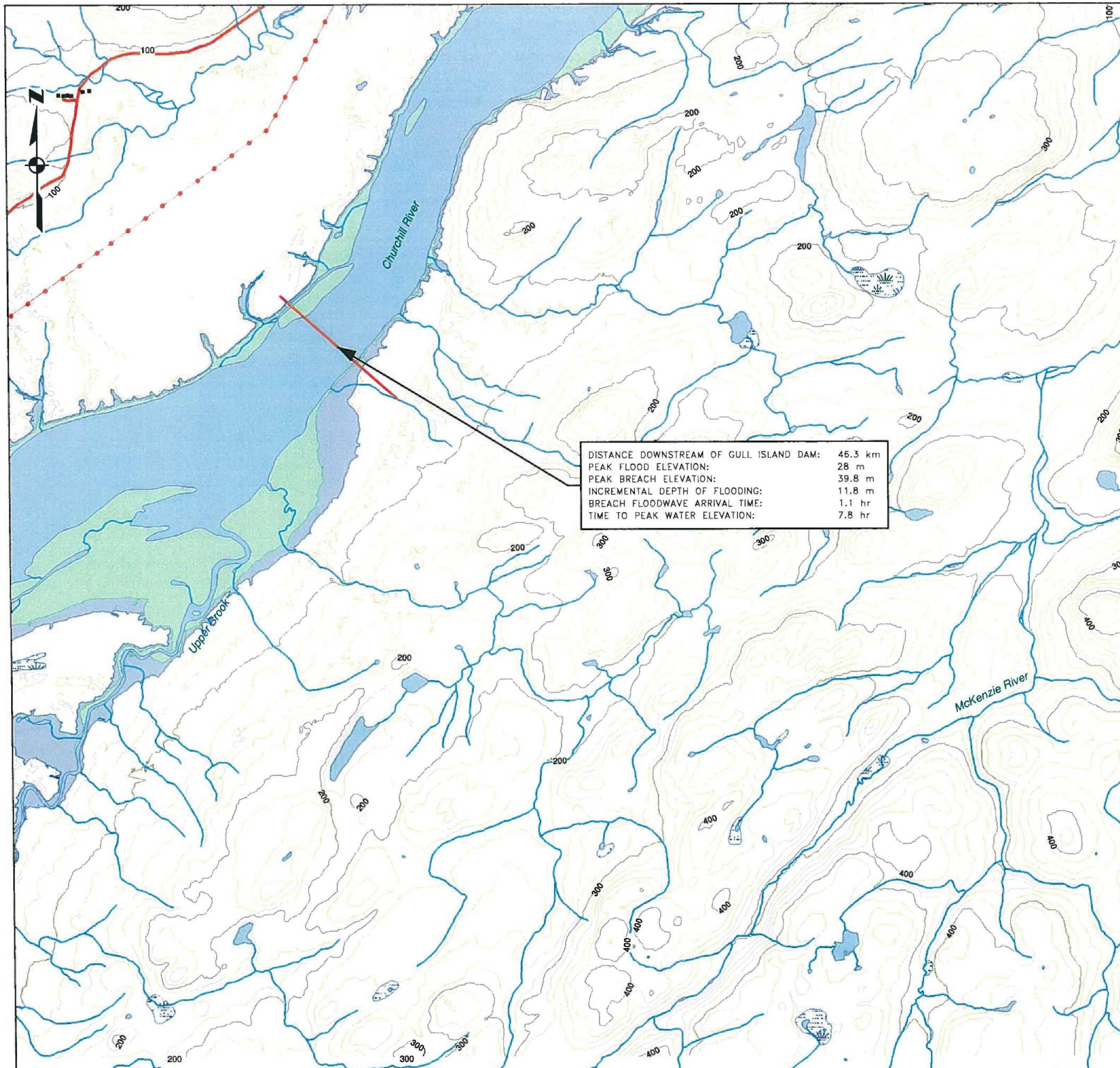
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

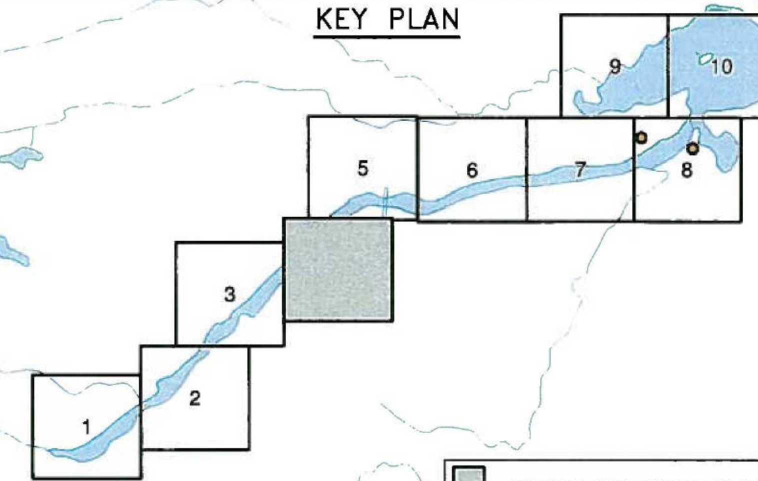
SCALE 1:50000

HATCH PROJECT No H-325967

DRAWING NO. FIGURE B1-3



KEY PLAN



– INDICATES AREA COVERED BY THIS SHEET.

LEGEND

▪	BUILDING		RIVER
▫	TANK		ROAD
	TOWER		TRANSMISSION LINE
	WATER BODY	CONTOURS	
	WETLAND		CONTOUR (20 m)
	FLOOD INUNDATION		INDEX CONTOUR (100 m)
	BREACH INUNDATION		

NOTES:

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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

HATCH™

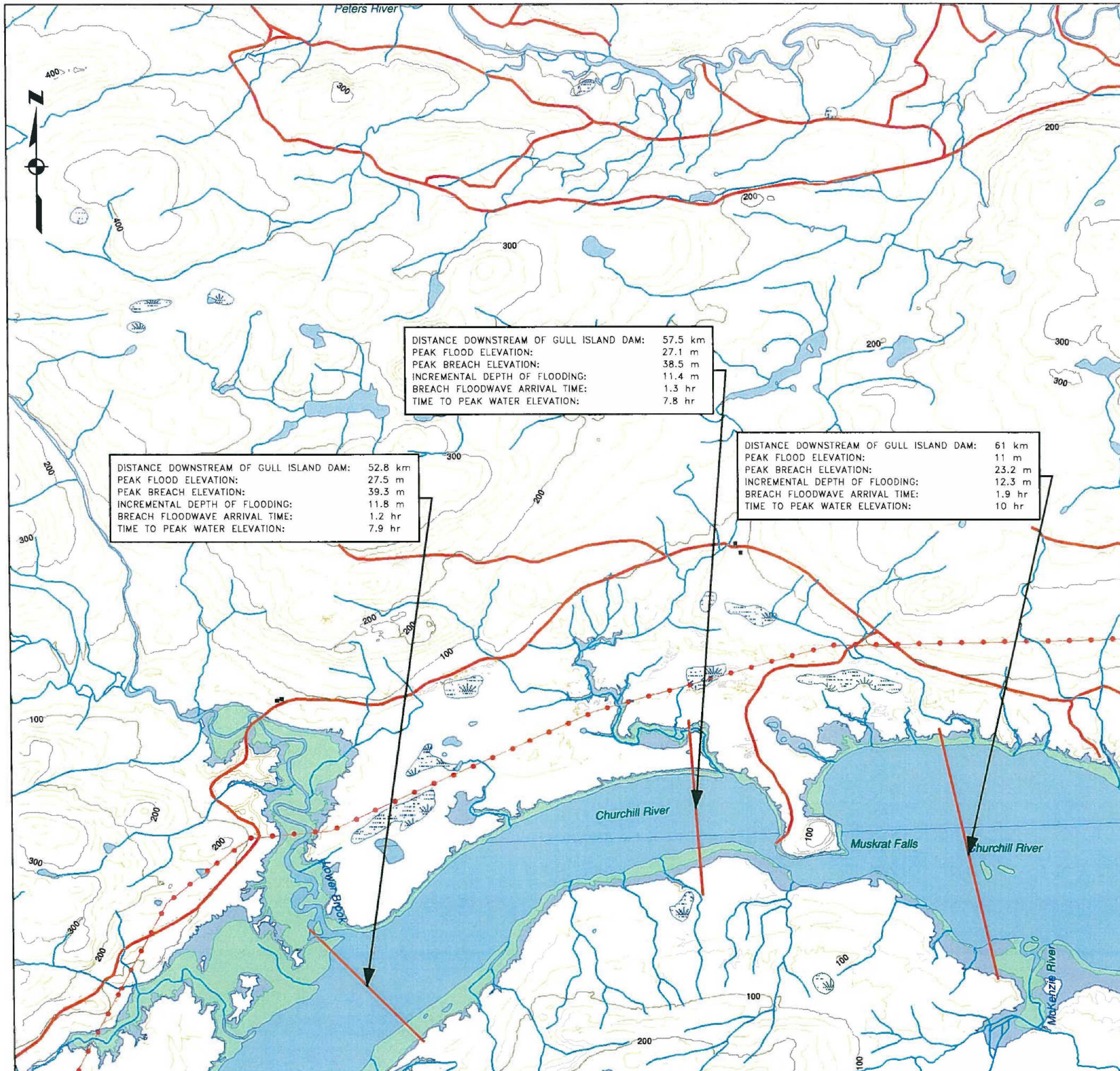
HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE	DRAWING NO.
1:50000	FIGURE B1–4
HATCH PROJECT No H–325967	



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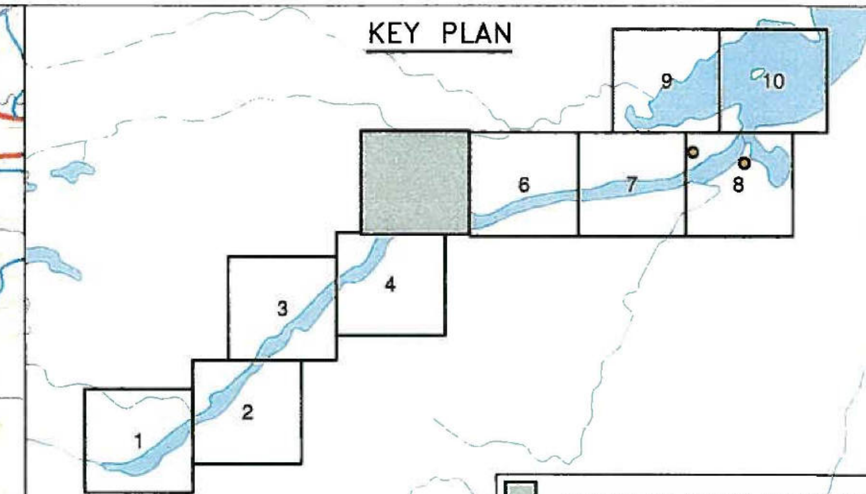

← INDICATES AREA COVERED BY THIS SHEET.

LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

HATCH™

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NEWFOUNDLAND AND LABRADOR HYDRO

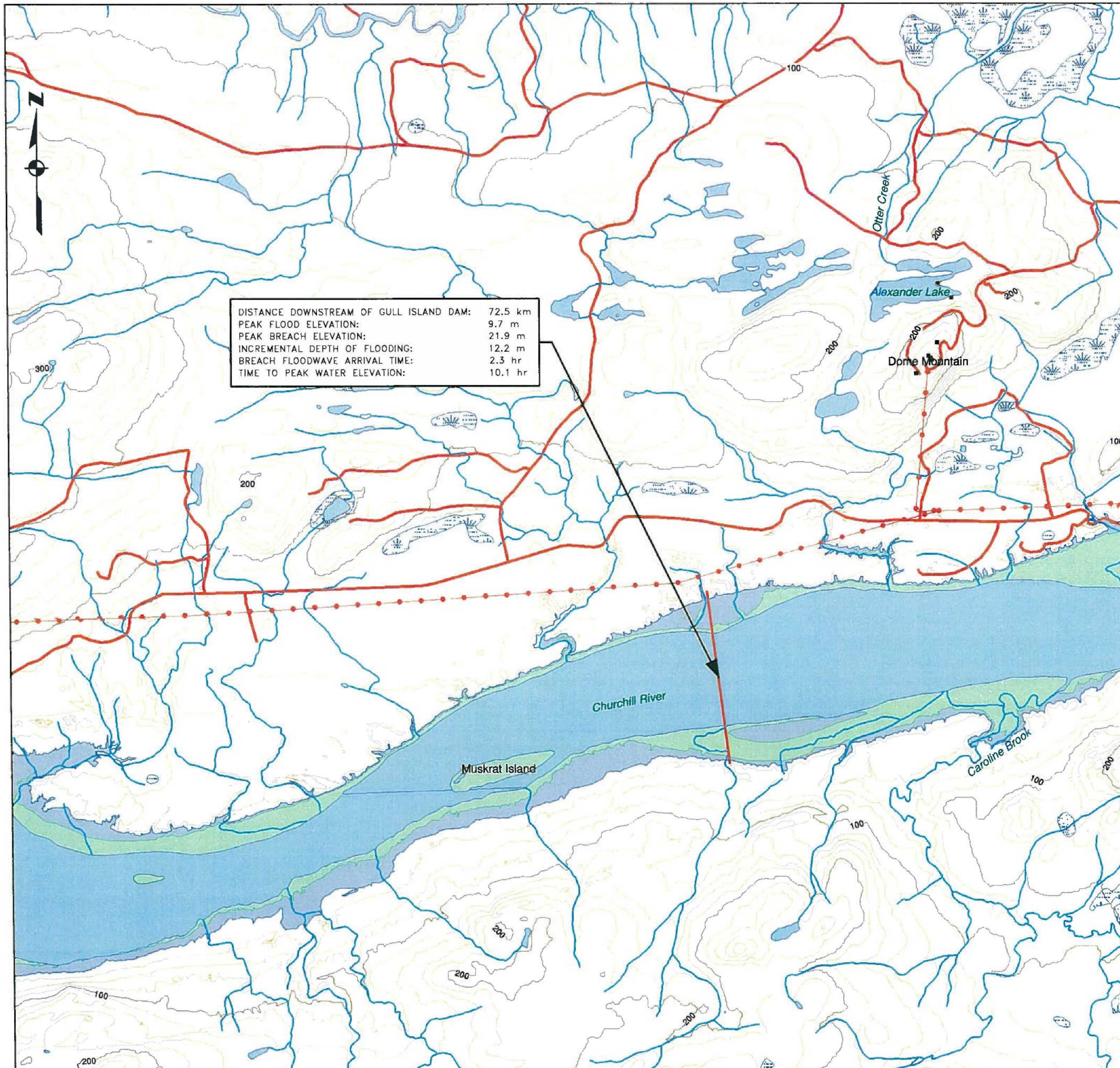
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000

HATCH PROJECT No. H-325967

DRAWING NO. FIGURE B1-5



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

NOTES:

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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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NEWFOUNDLAND AND LABRADOR HYDRO

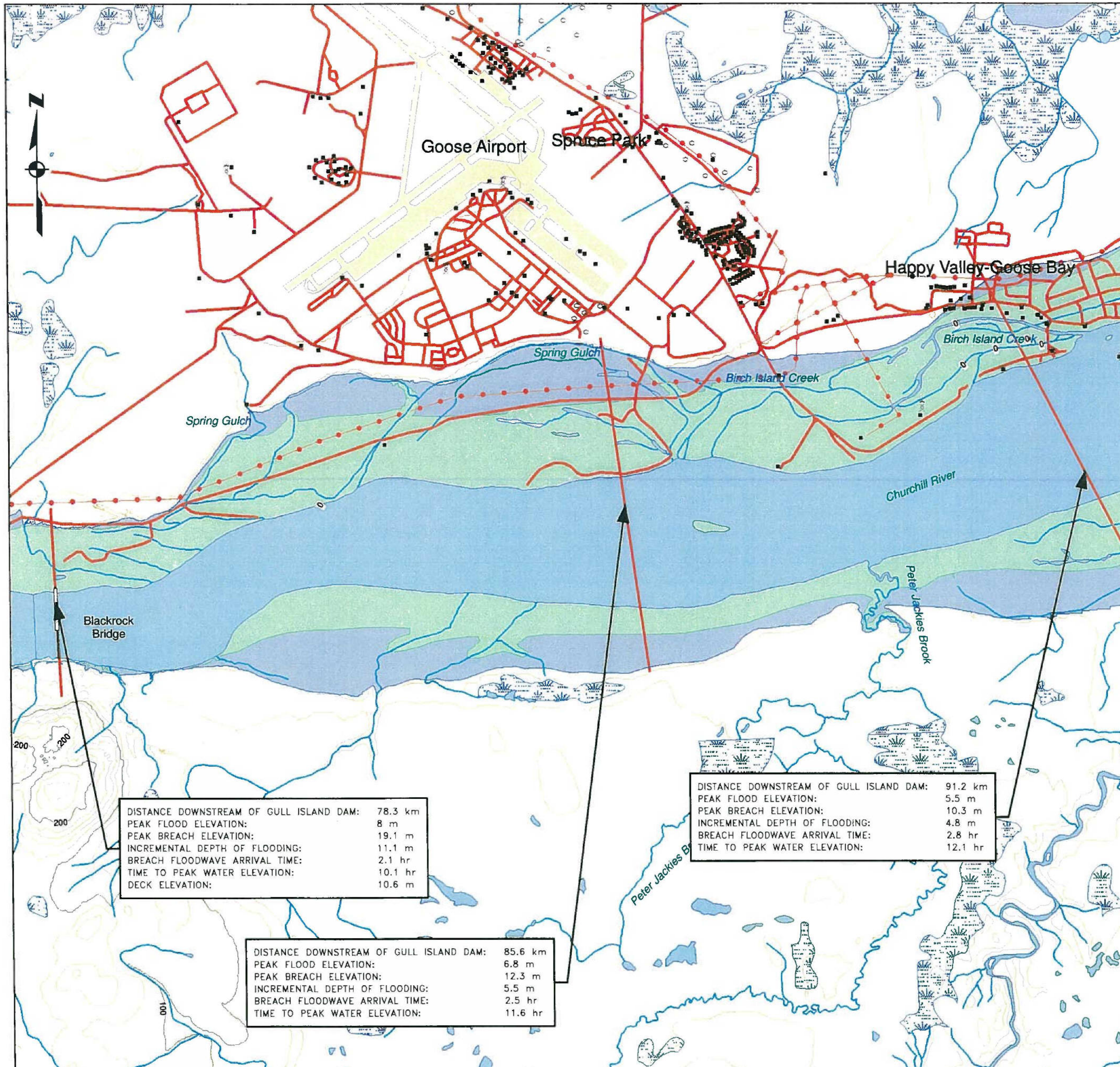
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

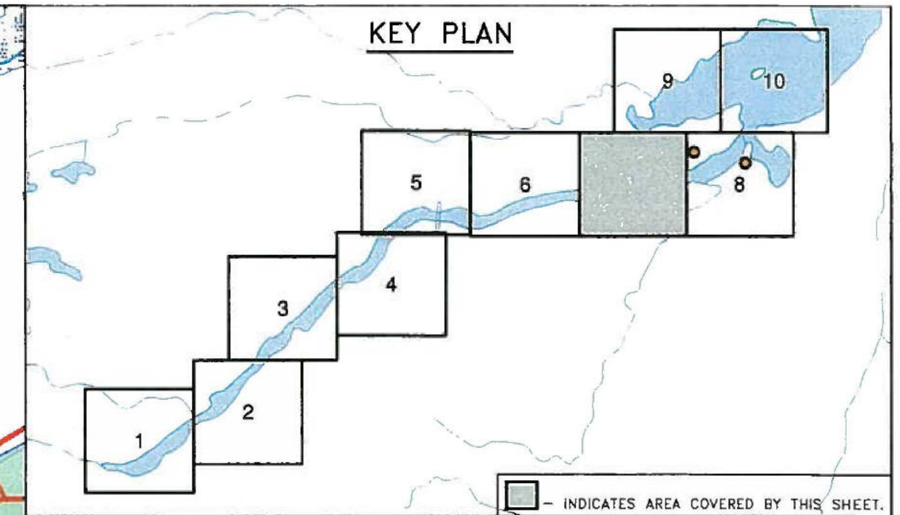
SCALE 1:50000

HATCH PROJECT No H-325967

DRAWING NO. FIGURE B1–6



KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE

CONTOURS

- CONTOUR (20 m)
- INDEX CONTOUR (100 m)

NOTES:

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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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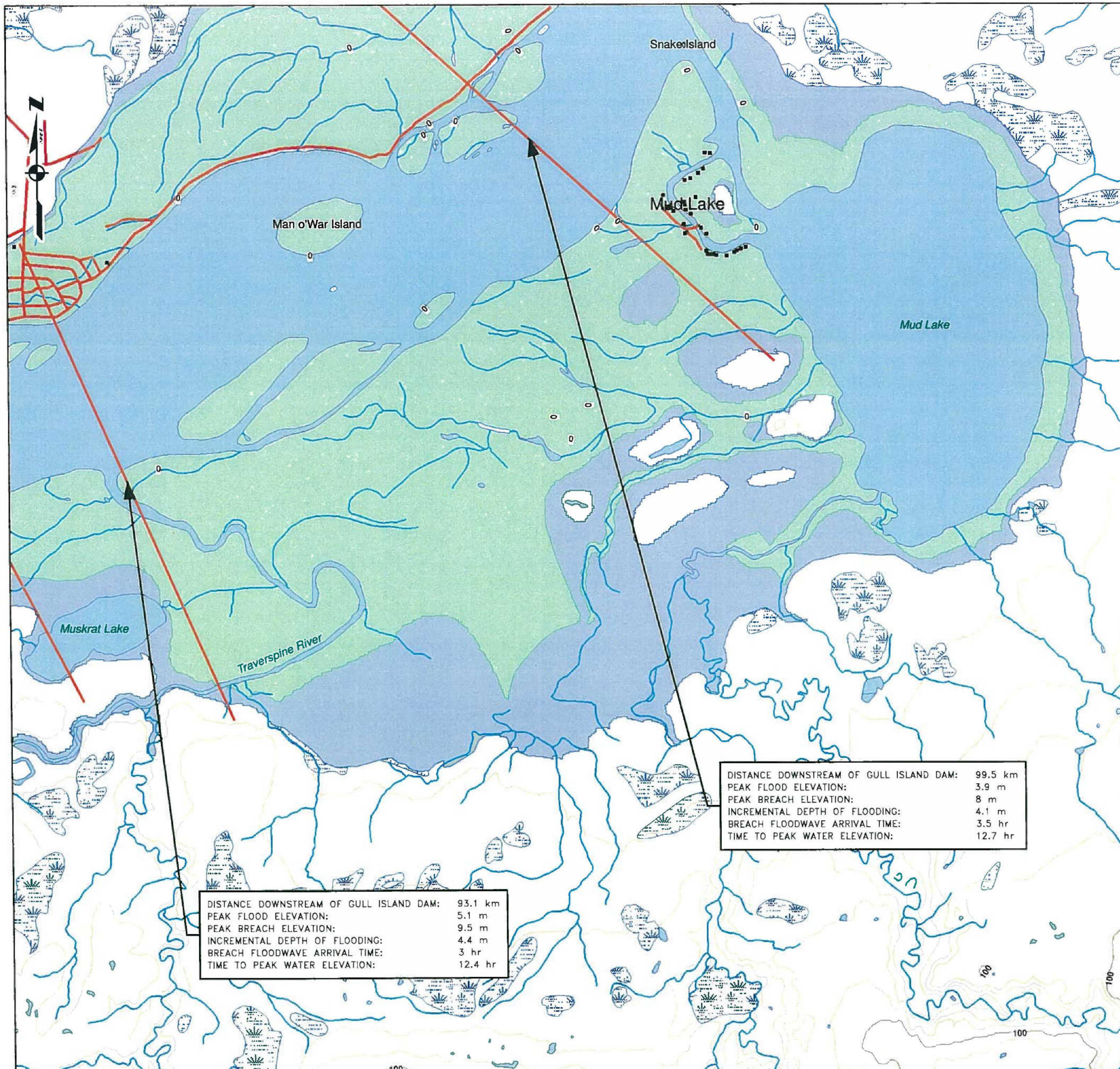
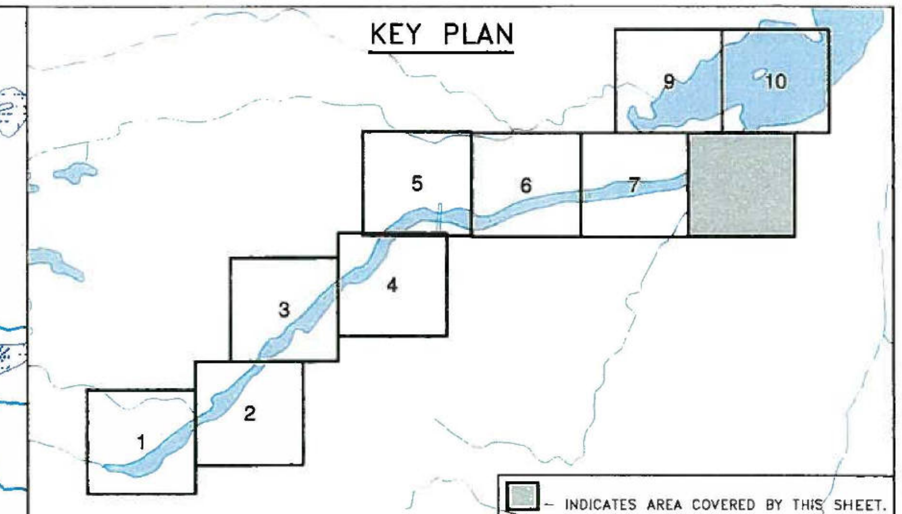
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000
HATCH PROJECT No. H-325967
DRAWING NO. FIGURE B1-7



KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE

CONTOURS

- CONTOUR (20 m)
- INDEX CONTOUR (100 m)

NOTES:

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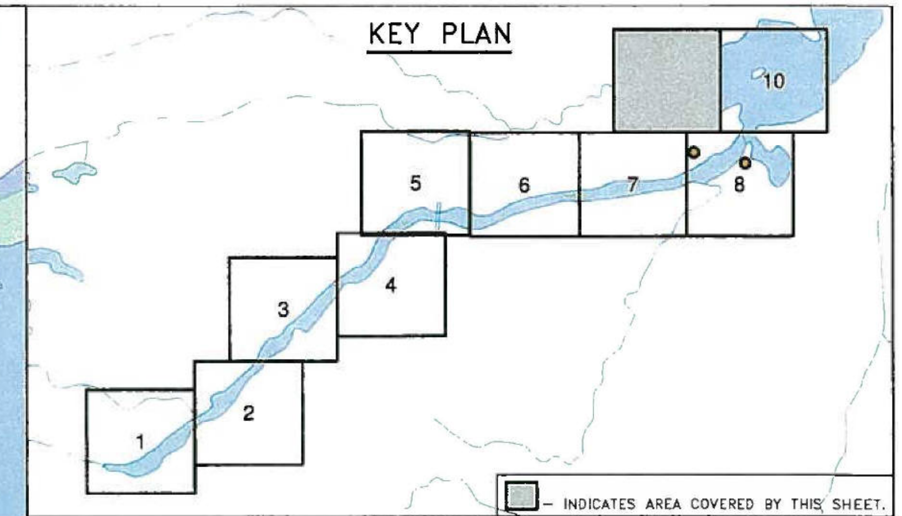
SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000
HATCH PROJECT No. H-325967
DRAWING NO. FIGURE B1-8



LEGEND

■	BUILDING		RIVER
○	TANK		ROAD
	TOWER		TRANSMISSION LINE
	WATER BODY		CONTOURS
	WETLAND		CONTOUR (20 m)
	FLOOD INUNDATION		INDEX CONTOUR (100 m)
	BREACH INUNDATION		

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

HATCH™

HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

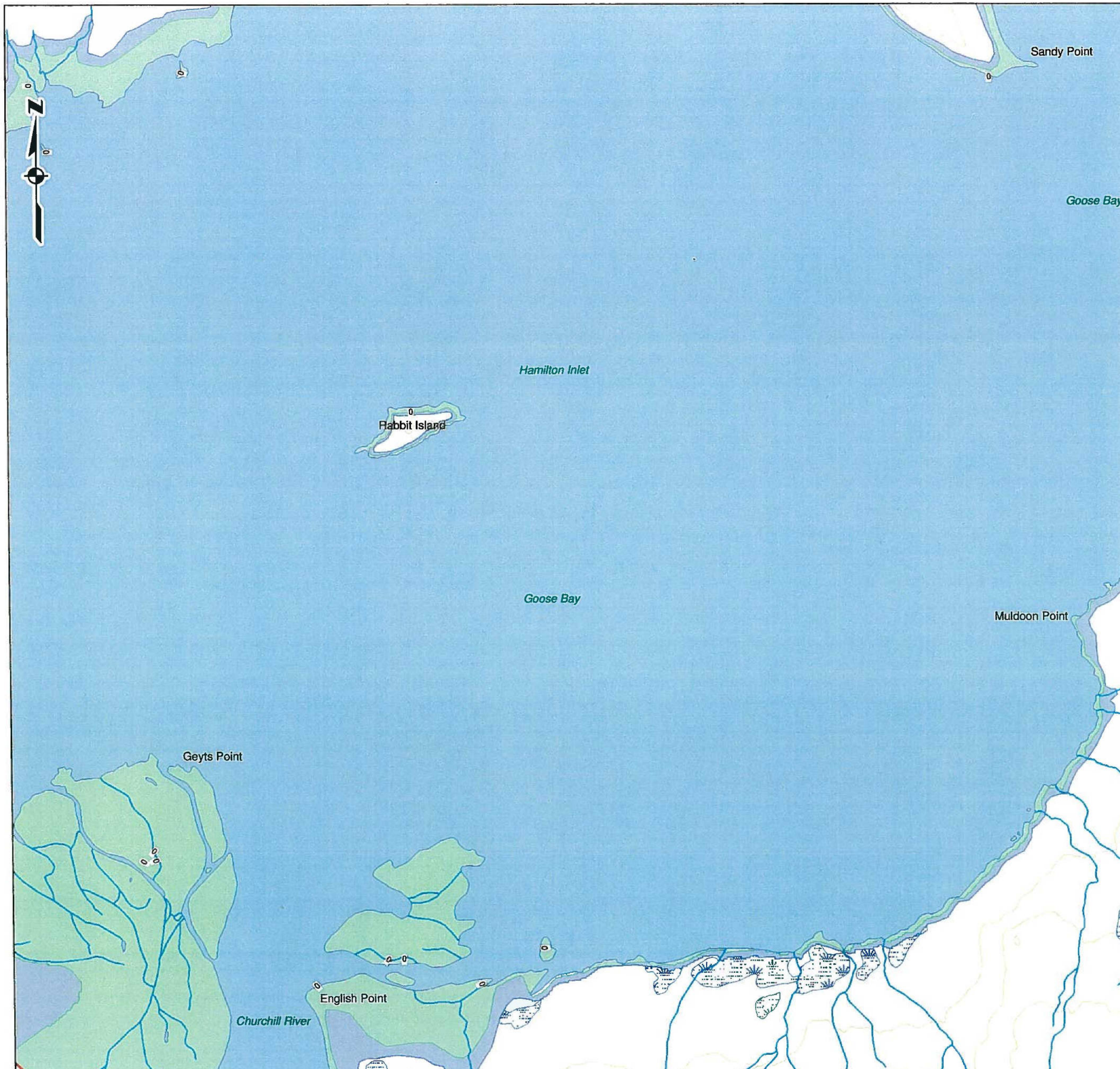
PROBABLE MAXIMUM FLOOD
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000

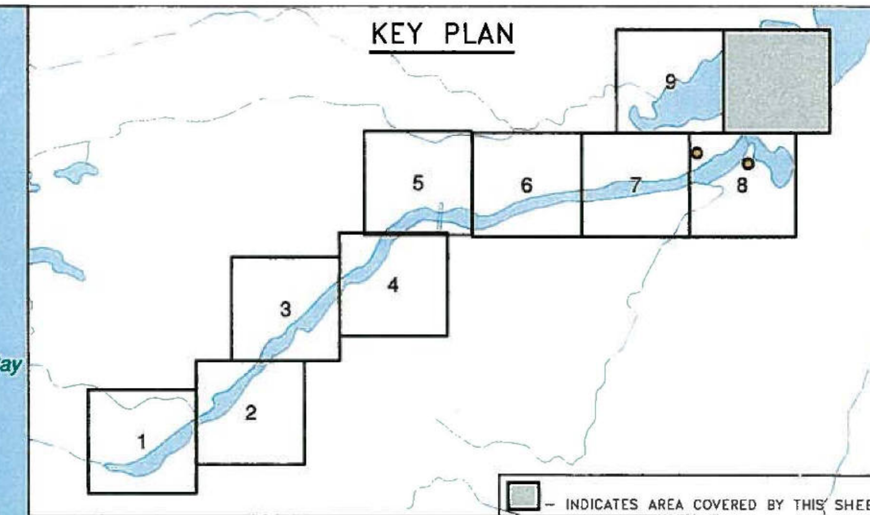
HATCH PROJECT No. H-325967

DRAWING NO.

FIGURE B1-9



KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE

CONTOURS

- CONTOUR (20 m)
- INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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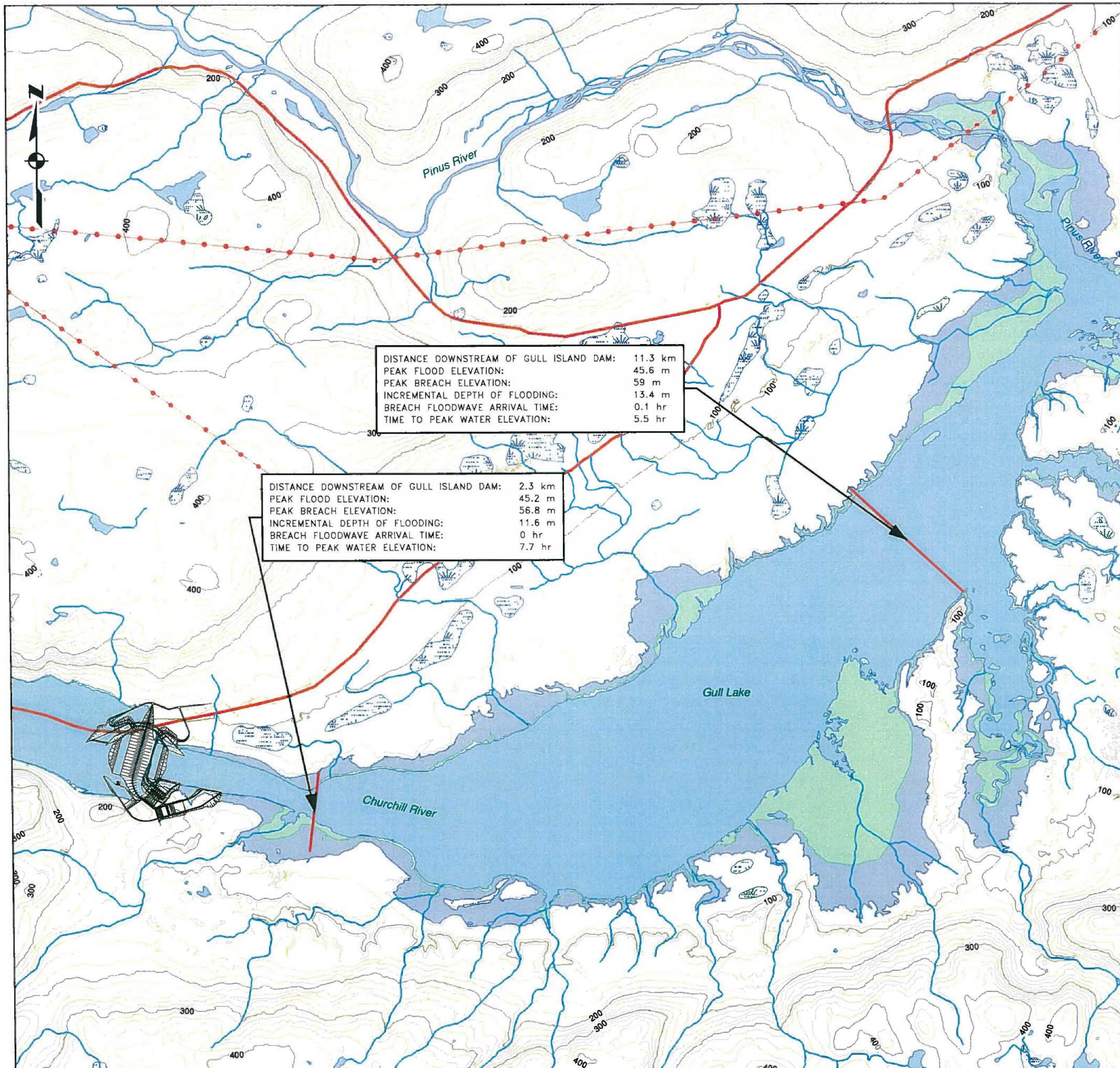
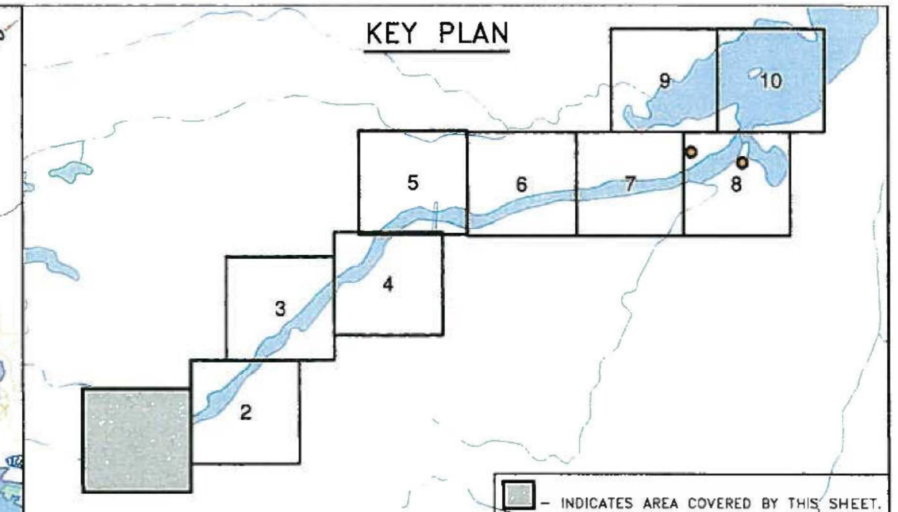
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000
HATCH PROJECT No H-325967
DRAWING NO. FIGURE B1-10



KEY PLAN



LEGEND

▪	BUILDING		RIVER
○	TANK		ROAD
	TOWER		TRANSMISSION LINE
	WATER BODY	CONTOURS	
	WETLAND		CONTOUR (20 m)
	FLOOD INUNDATION		INDEX CONTOUR (100 m)
	BREACH INUNDATION		

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

HATCH™

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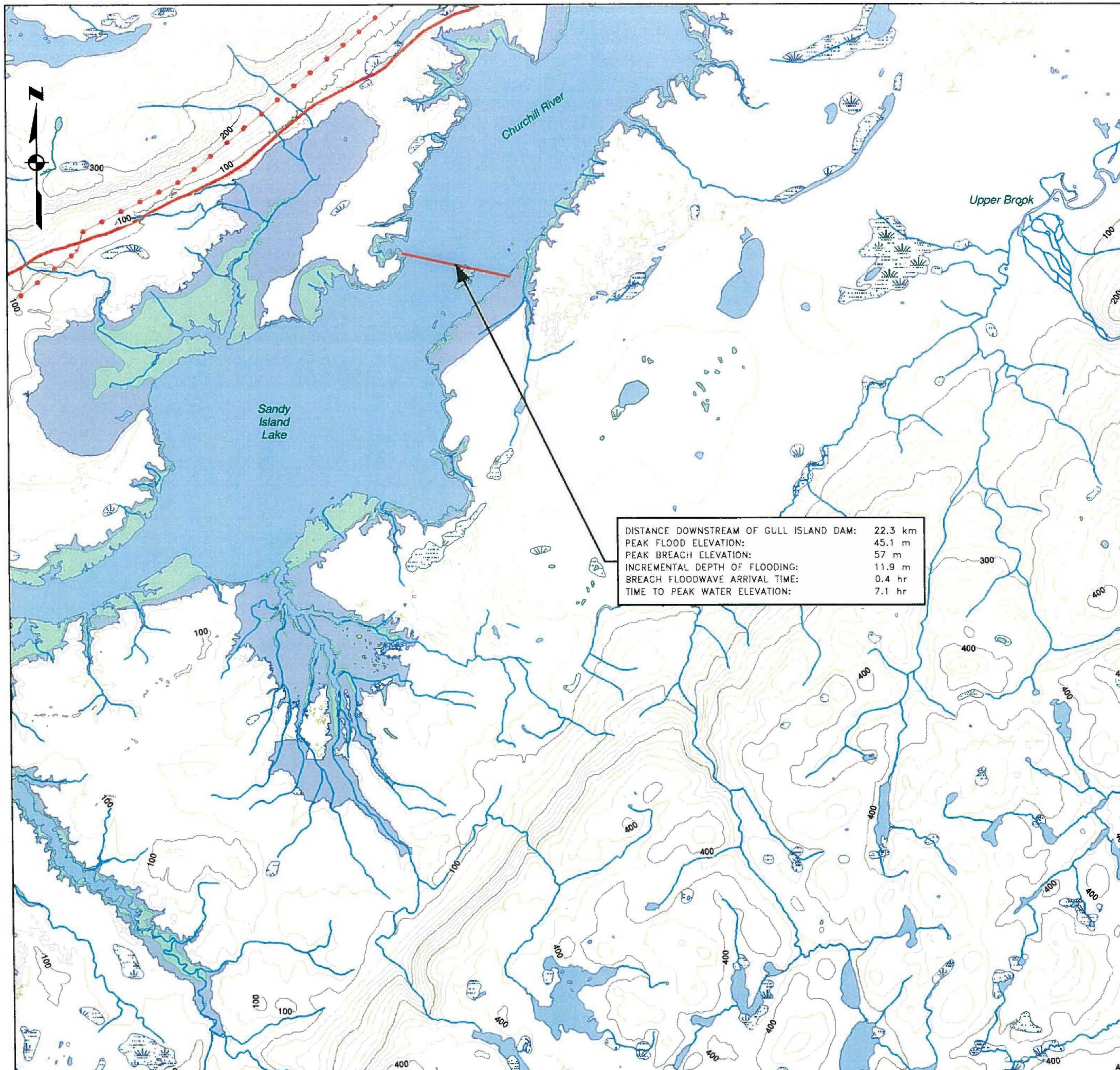
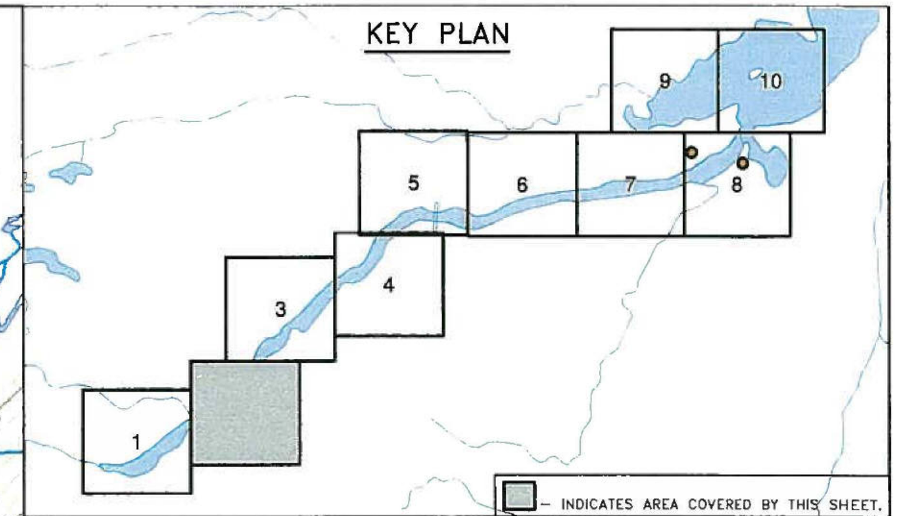
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000	DRAWING NO. FIGURE B2–1
HATCH PROJECT No. H–325967	



KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE

CONTOURS

- CONTOUR (20 m)
- INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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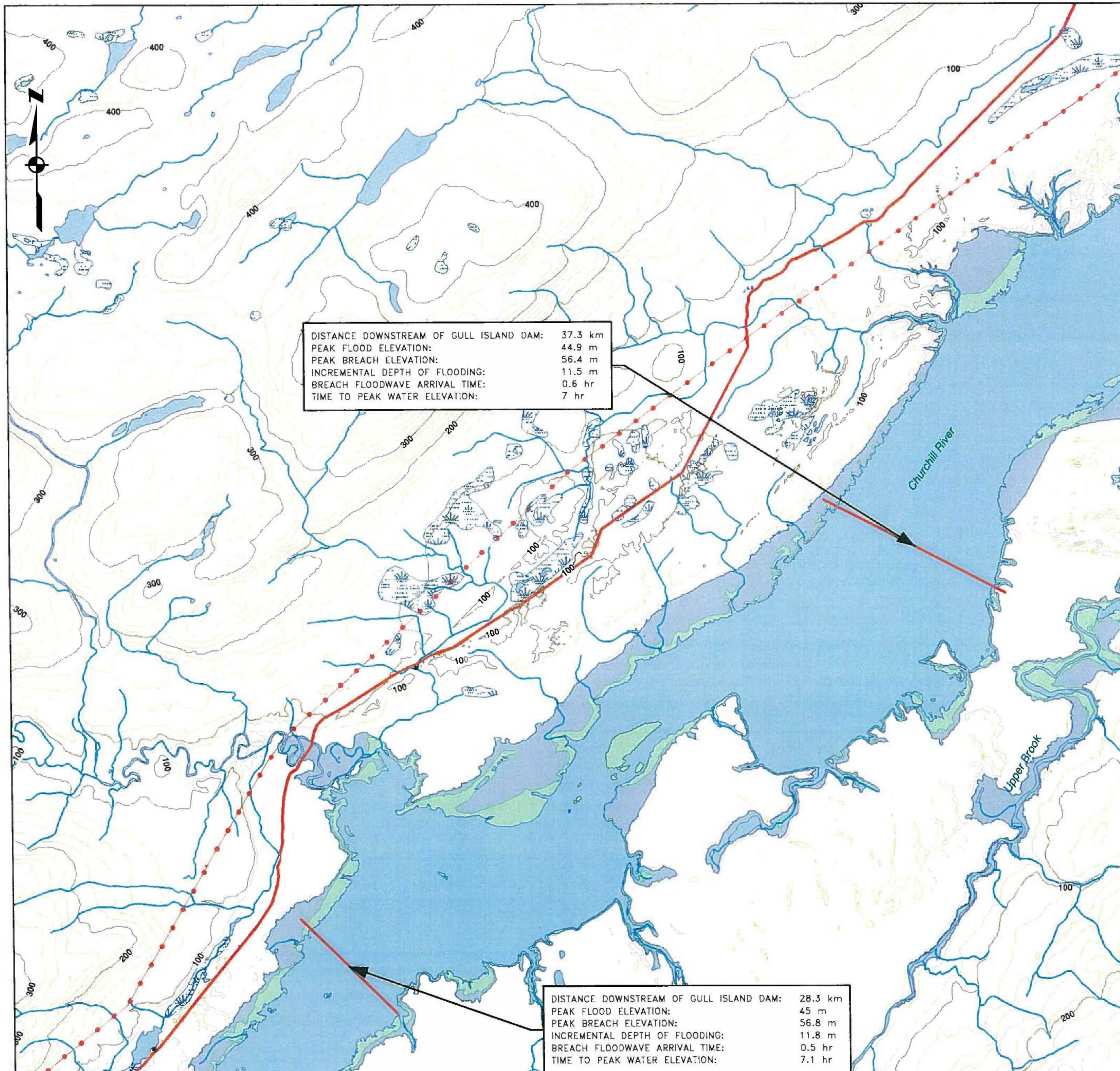
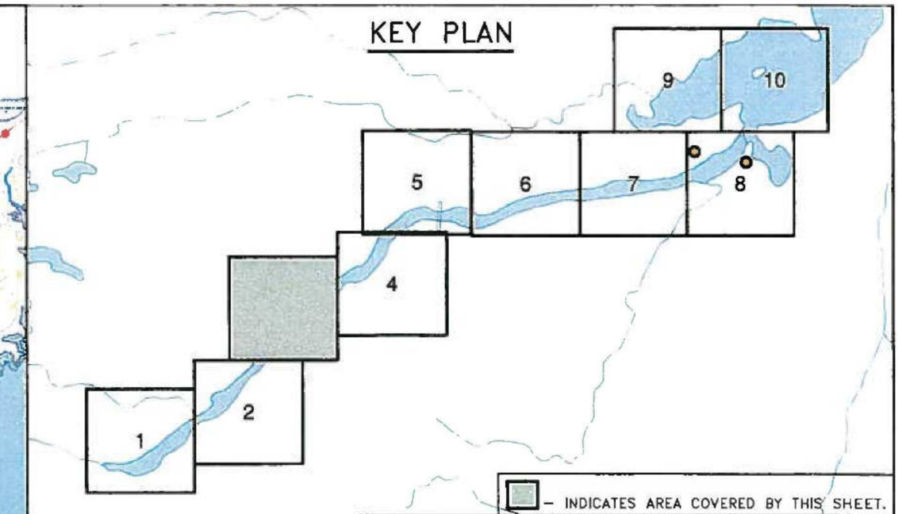
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000
HATCH PROJECT No H-325967
DRAWING NO. FIGURE B2-2



KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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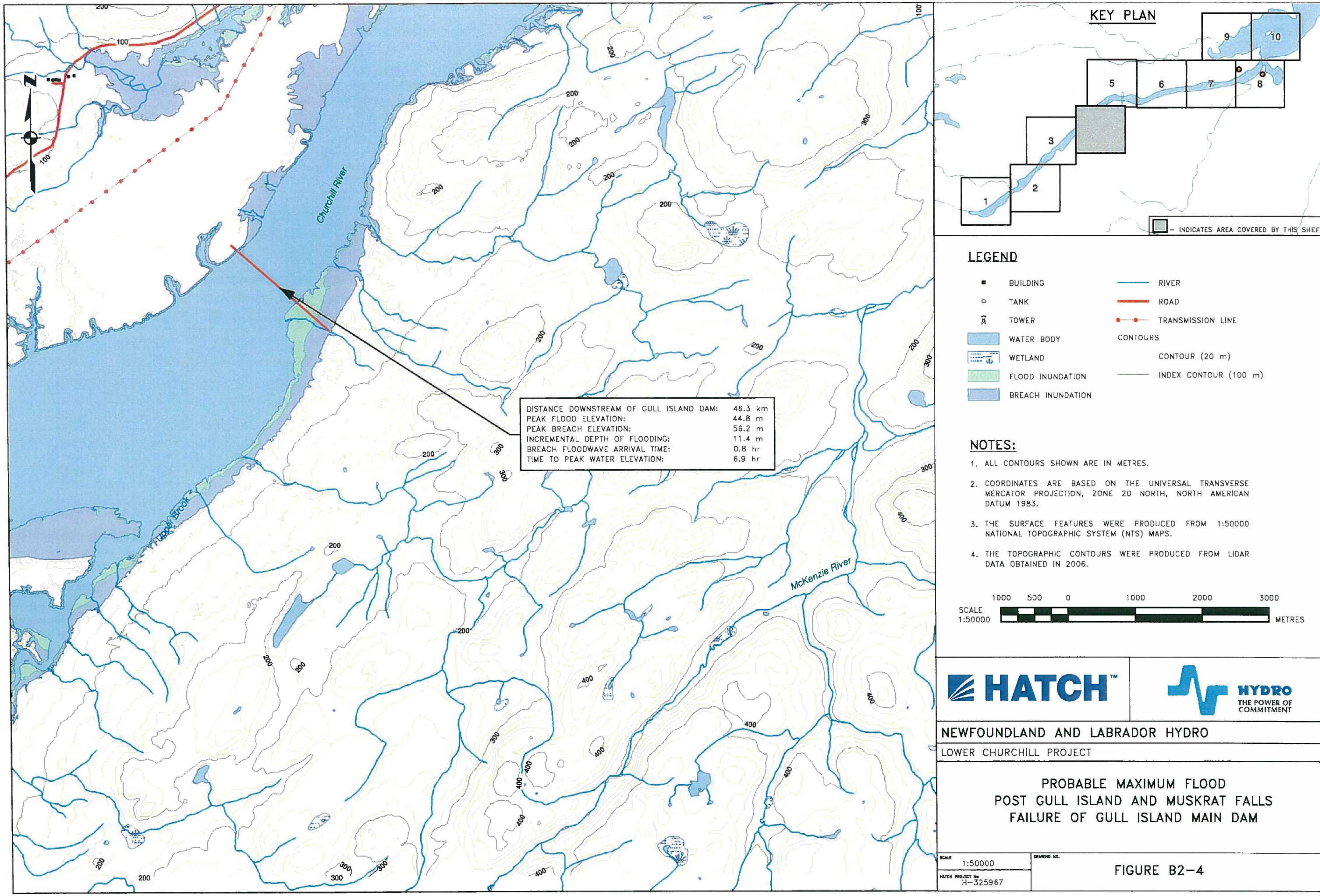
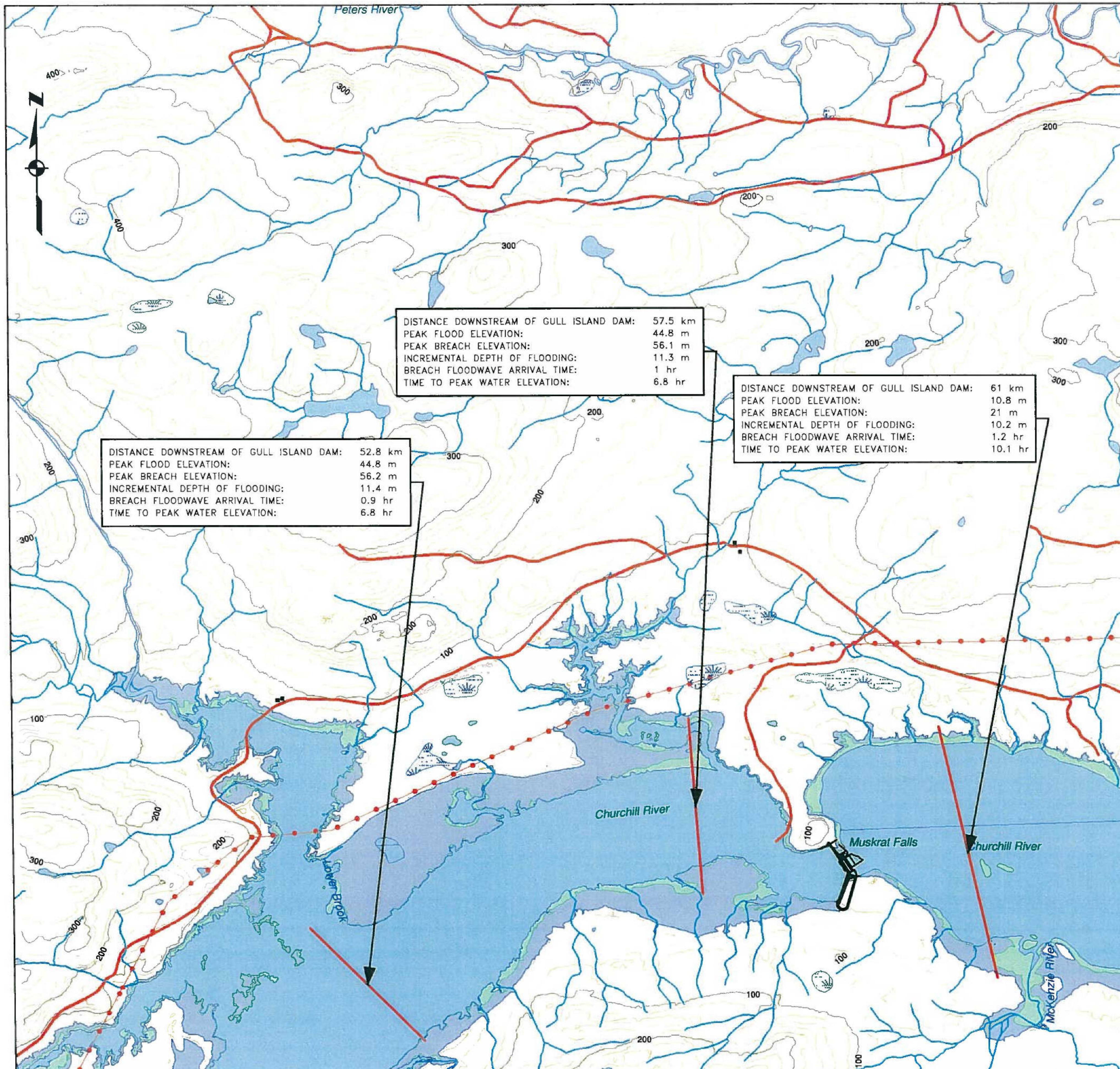
NEWFOUNDLAND AND LABRADOR HYDRO

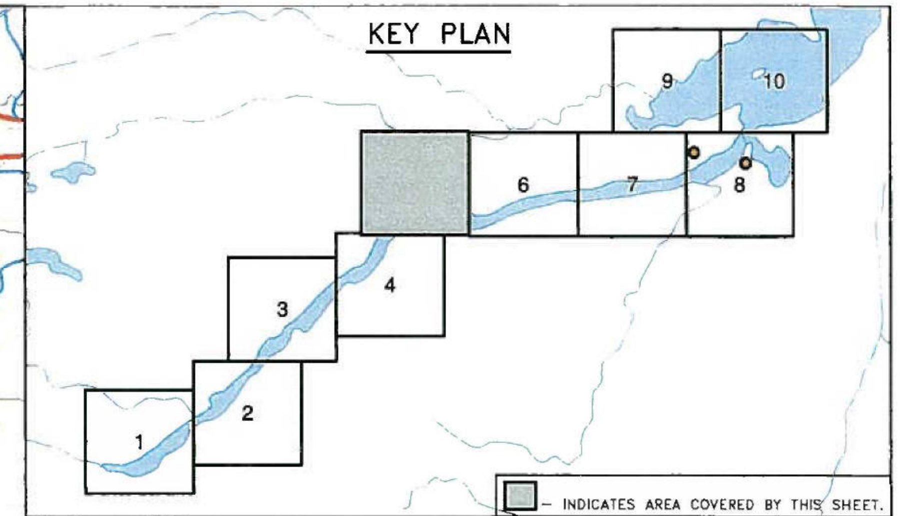
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000
HATCH PROJECT No H-325967
DRAWING NO. FIGURE B2-3


Churchill River
McKenzie River
DISTANCE DOWNSTREAM OF GULL ISLAND DAM: 45.3 km
PEAK FLOOD ELEVATION: 44.8 m
PEAK BREACH ELEVATION: 56.2 m
INCREMENTAL DEPTH OF FLOODING: 11.4 m
BREACH FLOODWAVE ARRIVAL TIME: 0.8 hr
TIME TO PEAK WATER ELEVATION: 6.9 hr
KEY PLAN
1
2
3
5
6
7
8
9
10
- INDICATES AREA COVERED BY THIS SHEET.
LEGEND
BUILDING
TANK
TOWER
WATER BODY
WETLAND
FLOOD INUNDATION
BREACH INUNDATION
RIVER
ROAD
TRANSMISSION LINE
CONTOURS
CONTOUR (20 m)
INDEX CONTOUR (100 m)
NOTES:
1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.
1000 500 0 1000 2000 3000
SCALE 1:50000
METRES
HATCH
HYDRO
THE POWER OF COMMITMENT
NEWFOUNDLAND AND LABRADOR HYDRO
LOWER CHURCHILL PROJECT
PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM
SCALE 1:50000
HATCH PROJECT No H-325967
DRAWING NO.
FIGURE B2-4





LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE

CONTOURS

- CONTOUR (20 m)
- INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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LOWER CHURCHILL PROJECT

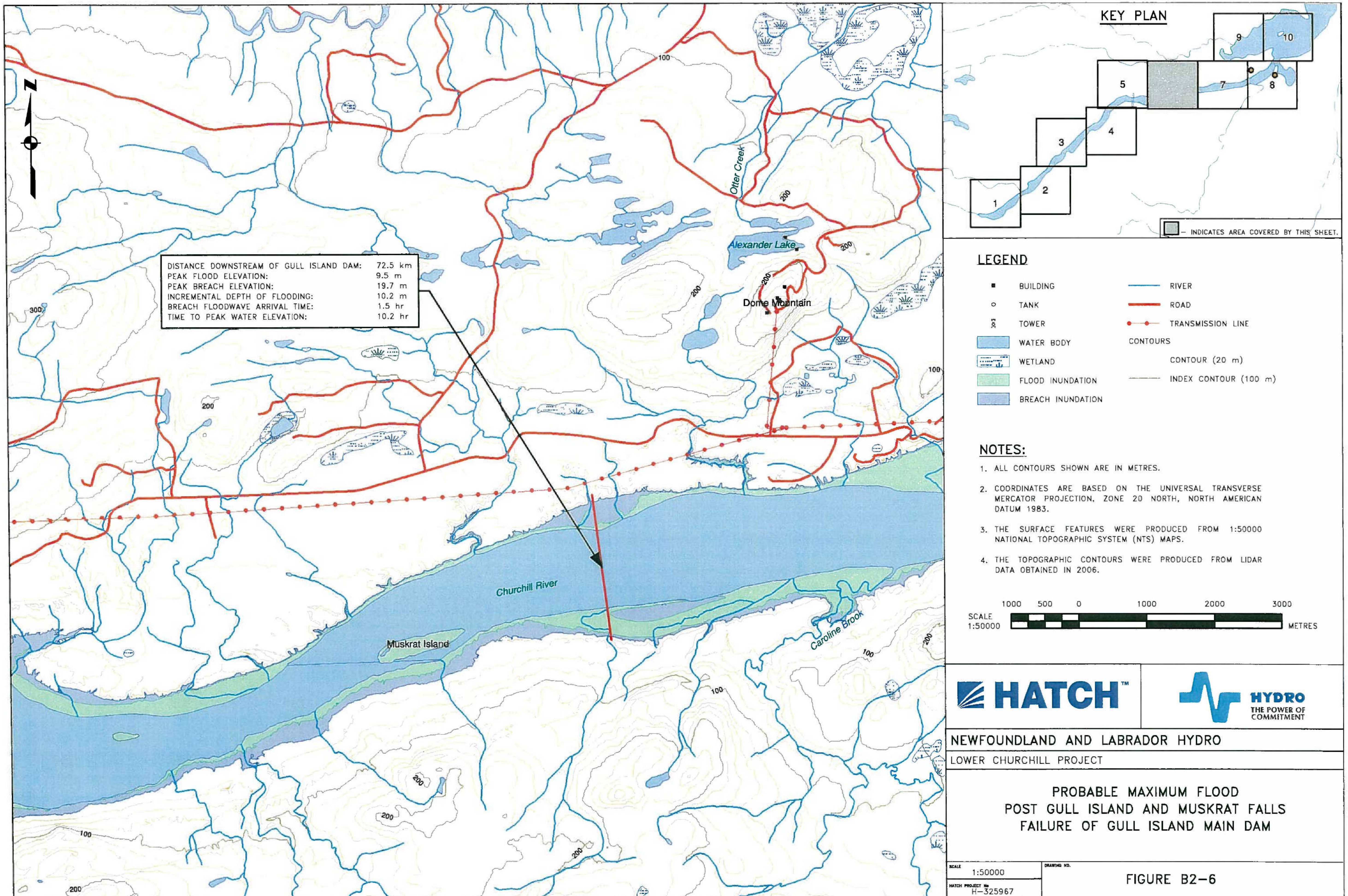
PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

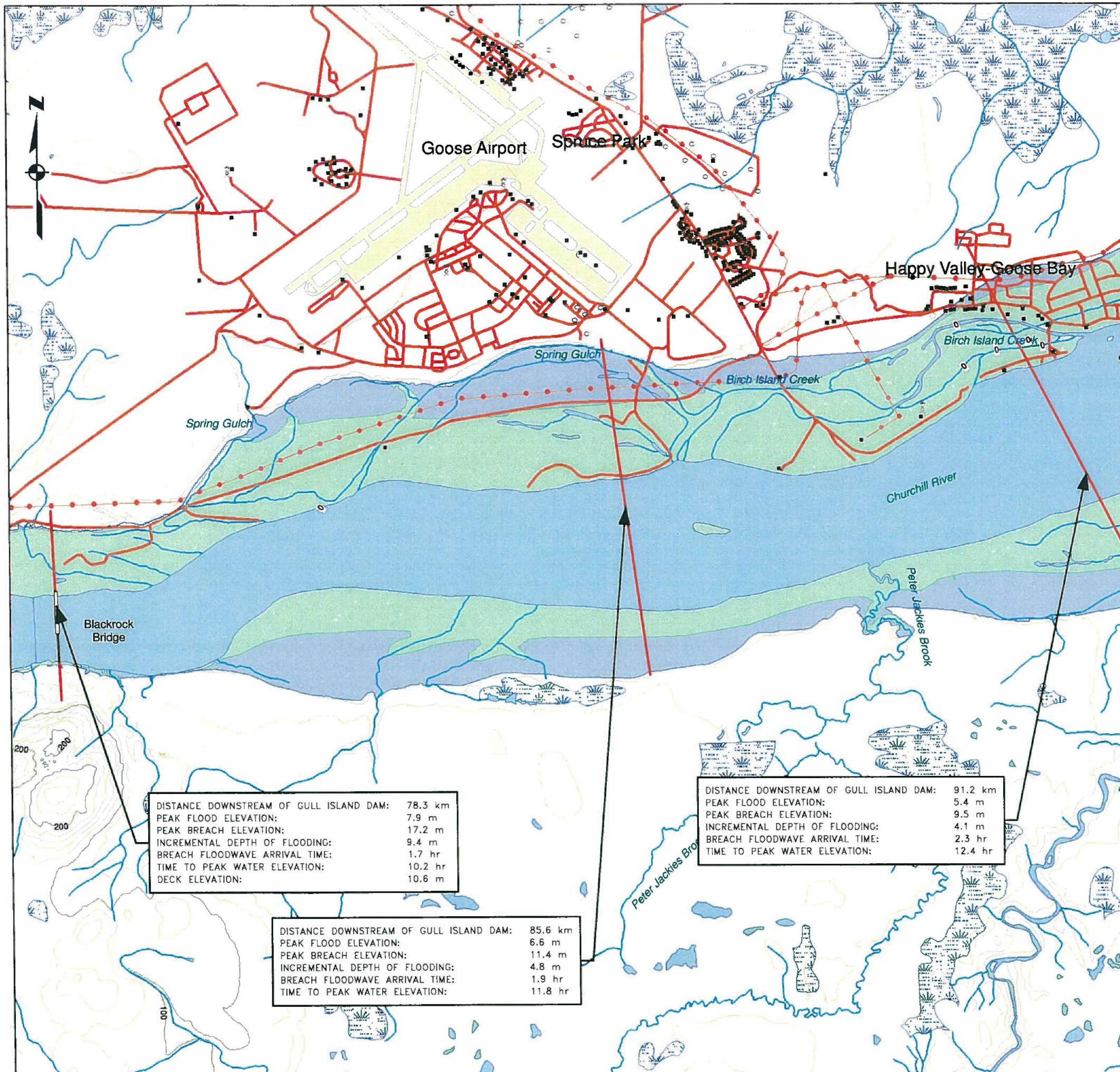
SCALE 1:50000

HATCH PROJECT No H-325967

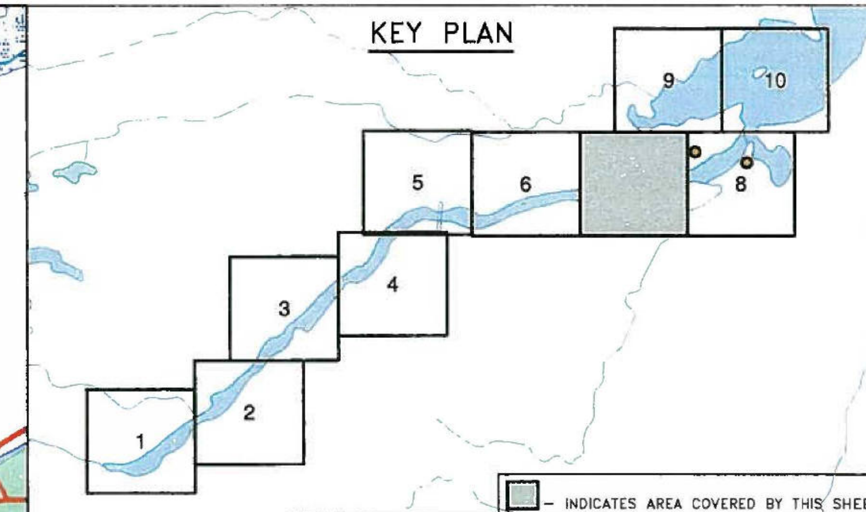
DRAWING NO.

FIGURE B2-5


DISTANCE DOWNSTREAM OF GULL ISLAND DAM: 72.5 km
PEAK FLOOD ELEVATION: 9.5 m
PEAK BREACH ELEVATION: 19.7 m
INCREMENTAL DEPTH OF FLOODING: 10.2 m
BREACH FLOODWAVE ARRIVAL TIME: 1.5 hr
TIME TO PEAK WATER ELEVATION: 10.2 hr
N
Otter Creek
Alexander Lake
Dome Mountain
Churchill River
Muskrat Island
Caroline Brook
100
200
300
KEY PLAN
1
2
3
4
5
7
8
9
10
INDICATES AREA COVERED BY THIS SHEET.
LEGEND
BUILDING
TANK
TOWER
WATER BODY
WETLAND
FLOOD INUNDATION
BREACH INUNDATION
RIVER
ROAD
TRANSMISSION LINE
CONTOURS
CONTOUR (20 m)
INDEX CONTOUR (100 m)
NOTES:
1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.
SCALE 1:50000
1000 500 0 1000 2000 3000
METRES
HATCH
HYDRO
THE POWER OF COMMITMENT
NEWFOUNDLAND AND LABRADOR HYDRO
LOWER CHURCHILL PROJECT
PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM
SCALE 1:50000
HATCH PROJECT No H-325967
DRAWING NO.
FIGURE B2-6



KEY PLAN



– INDICATES AREA COVERED BY THIS SHEET.

LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE

CONTOURS

- CONTOUR (20 m)
- INDEX CONTOUR (100 m)

NOTES:

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2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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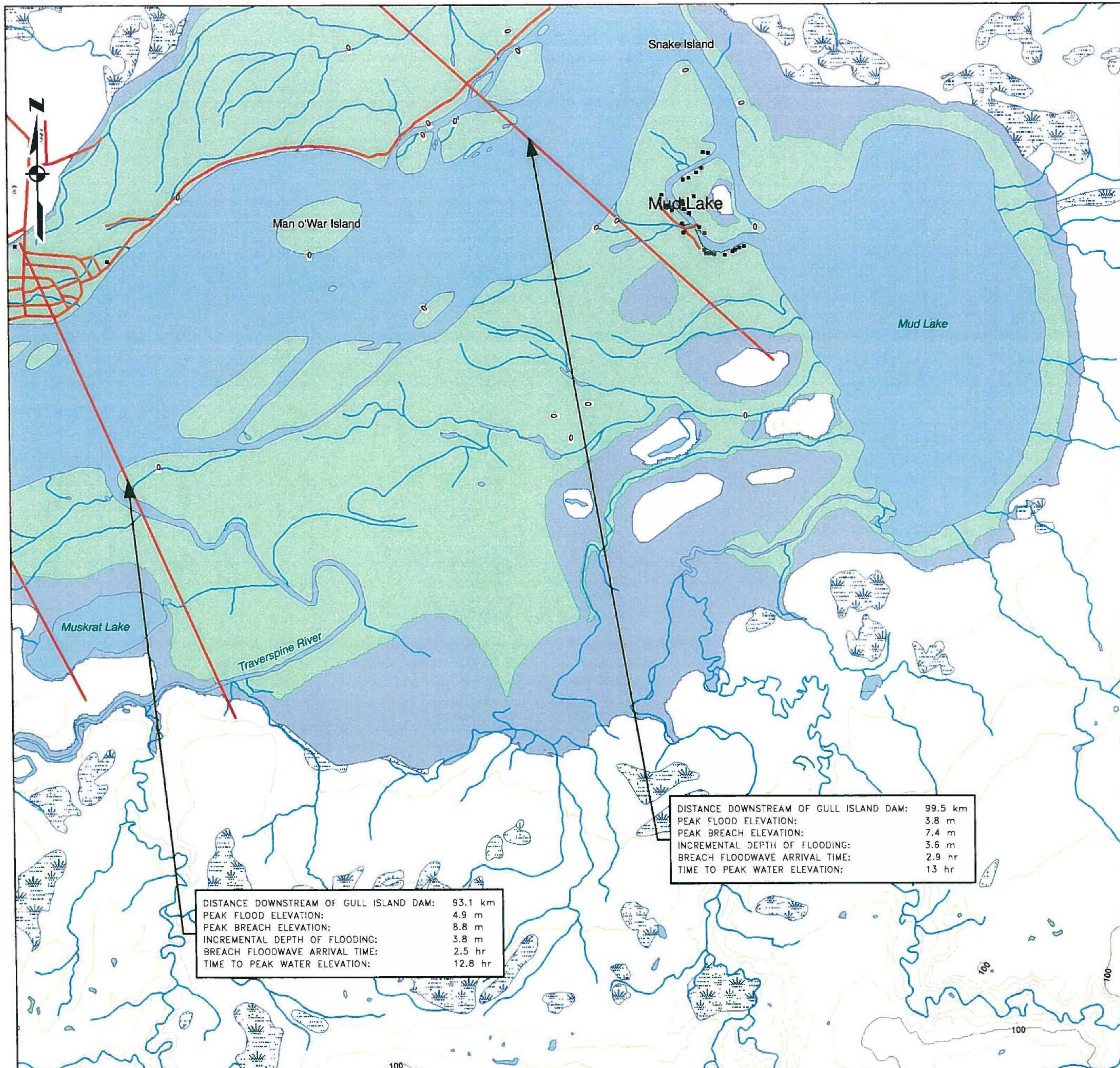
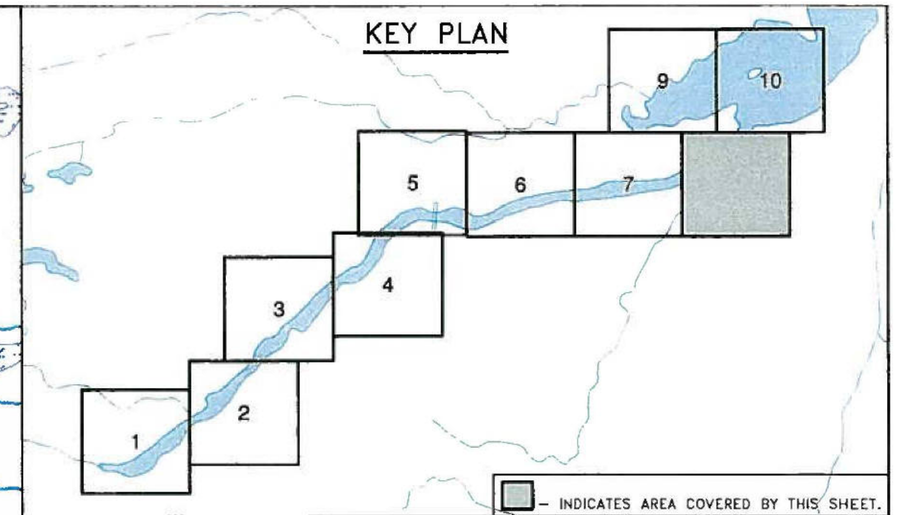
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000
HATCH PROJECT No H-325967
DRAWING NO. FIGURE B2-7





LEGEND

▪	BUILDING		RIVER
○	TANK		ROAD
	TOWER		TRANSMISSION LINE
	WATER BODY	CONTOURS	
	WETLAND		CONTOUR (20 m)
	FLOOD INUNDATION		INDEX CONTOUR (100 m)
	BREACH INUNDATION		

NOTES:

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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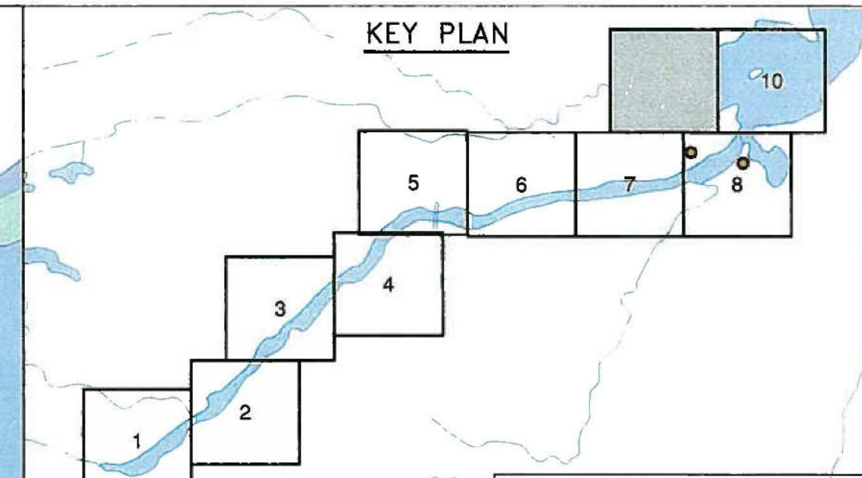
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000
HATCH PROJECT No H-325967
DRAWING NO. FIGURE B2-8

KEY PLAN



– INDICATES AREA COVERED BY THIS SHEET.

LEGEND

■	BUILDING	——	RIVER
○	TANK	——	ROAD
	TOWER	●—●	TRANSMISSION LINE
	WATER BODY	CONTOURS	
	WETLAND		CONTOUR (20 m)
	FLOOD INUNDATION	——	INDEX CONTOUR (100 m)
	BREACH INUNDATION		

NOTES:

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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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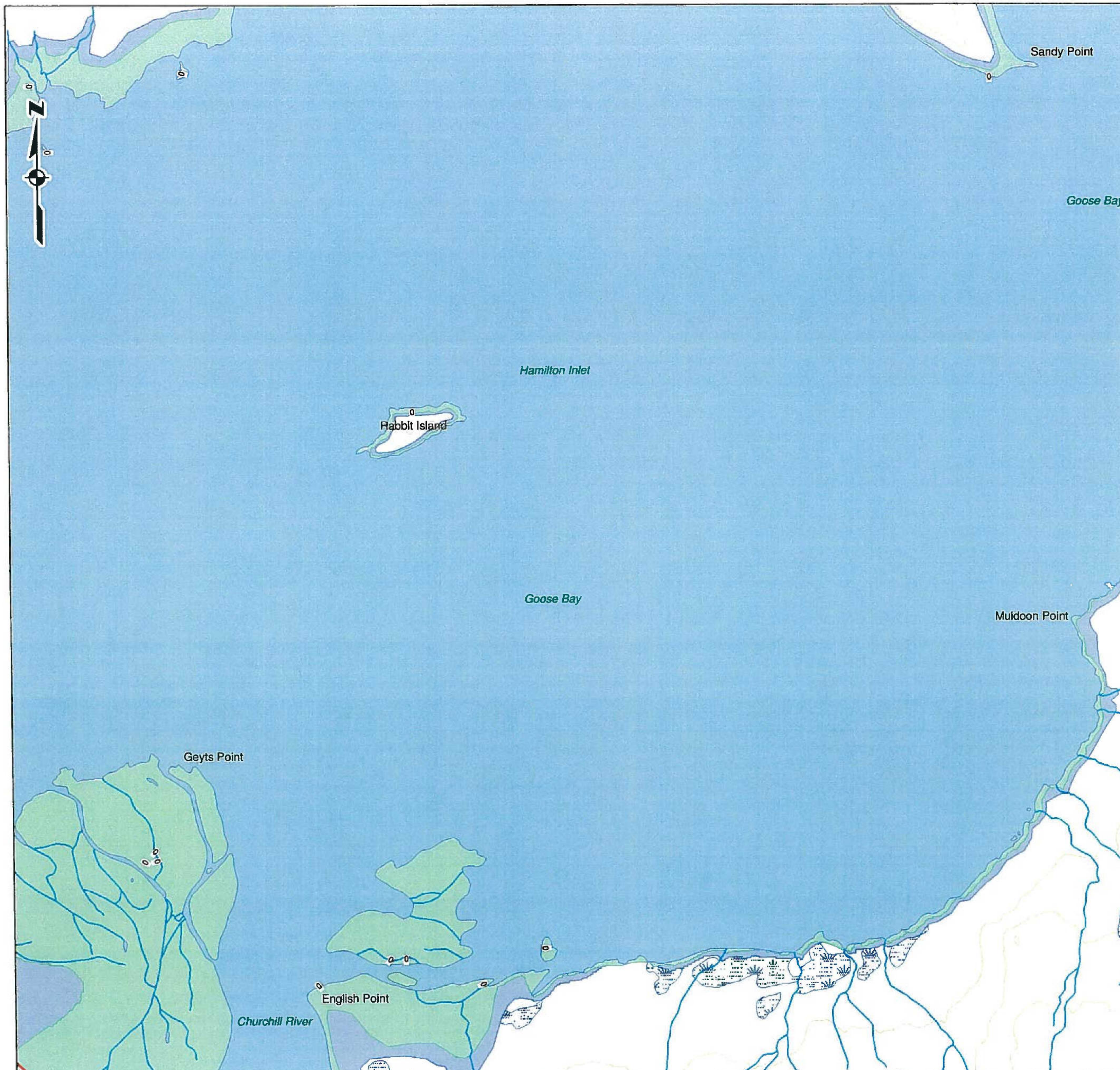
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000	DRAWING NO.
HATCH PROJECT No H–325967	FIGURE B2–9



KEY PLAN

■ - INDICATES AREA COVERED BY THIS SHEET.

LEGEND

BUILDING
TANK
TOWER
WATER BODY
WETLAND
FLOOD INUNDATION
BREACH INUNDATION
RIVER
ROAD
TRANSMISSION LINE
CONTOURS
CONTOUR (20 m)
INDEX CONTOUR (100 m)

NOTES:

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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000
1000 500 0 1000 2000 3000 METRES

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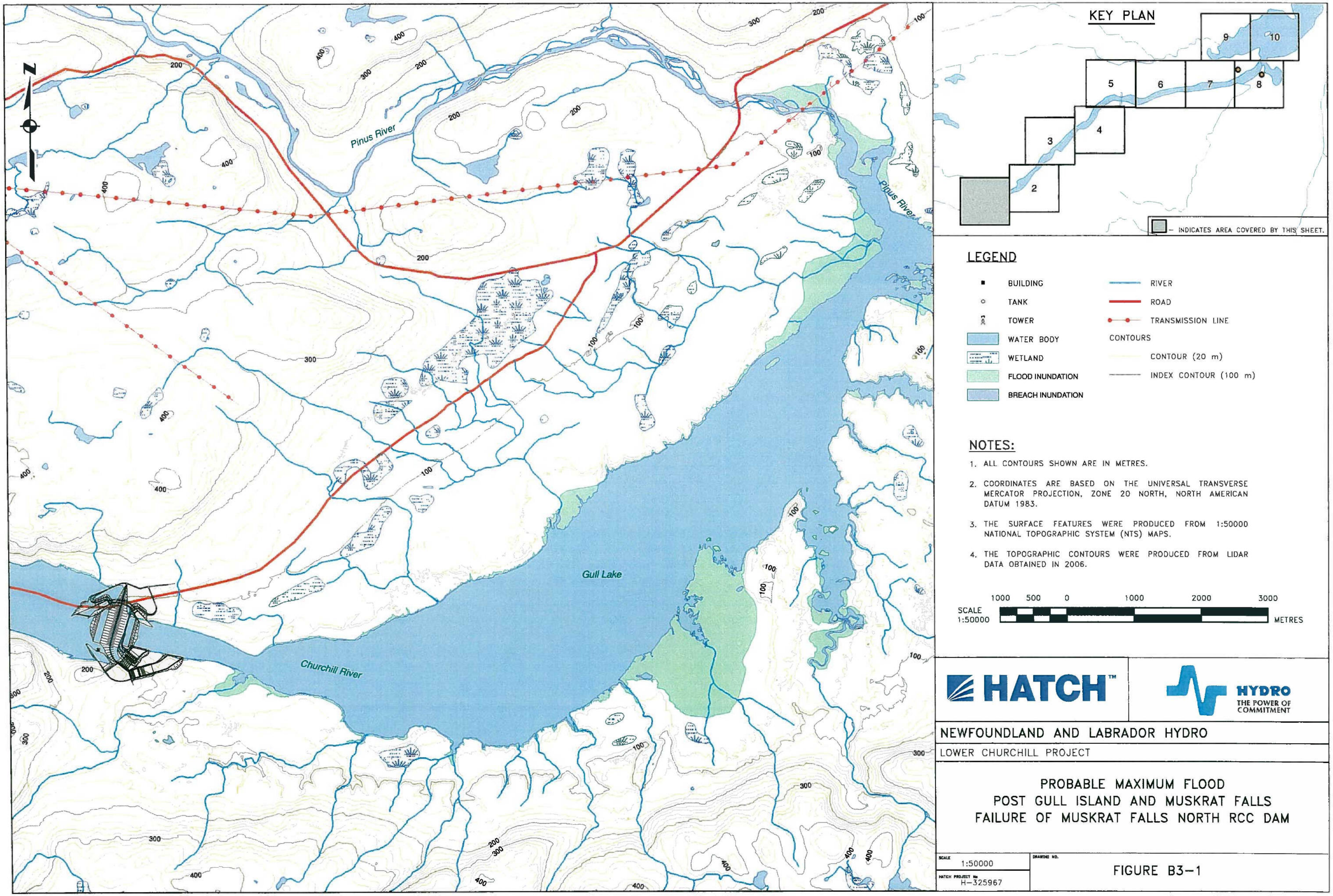
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:50000
HATCH PROJECT No H-325967
DRAWING NO.
FIGURE B2-10


KEY PLAN
2
3
4
5
6
7
8
9
10
INDICATES AREA COVERED BY THIS SHEET.
LEGEND
BUILDING
TANK
TOWER
WATER BODY
WETLAND
FLOOD INUNDATION
BREACH INUNDATION
RIVER
ROAD
TRANSMISSION LINE
CONTOURS
CONTOUR (20 m)
INDEX CONTOUR (100 m)
NOTES:
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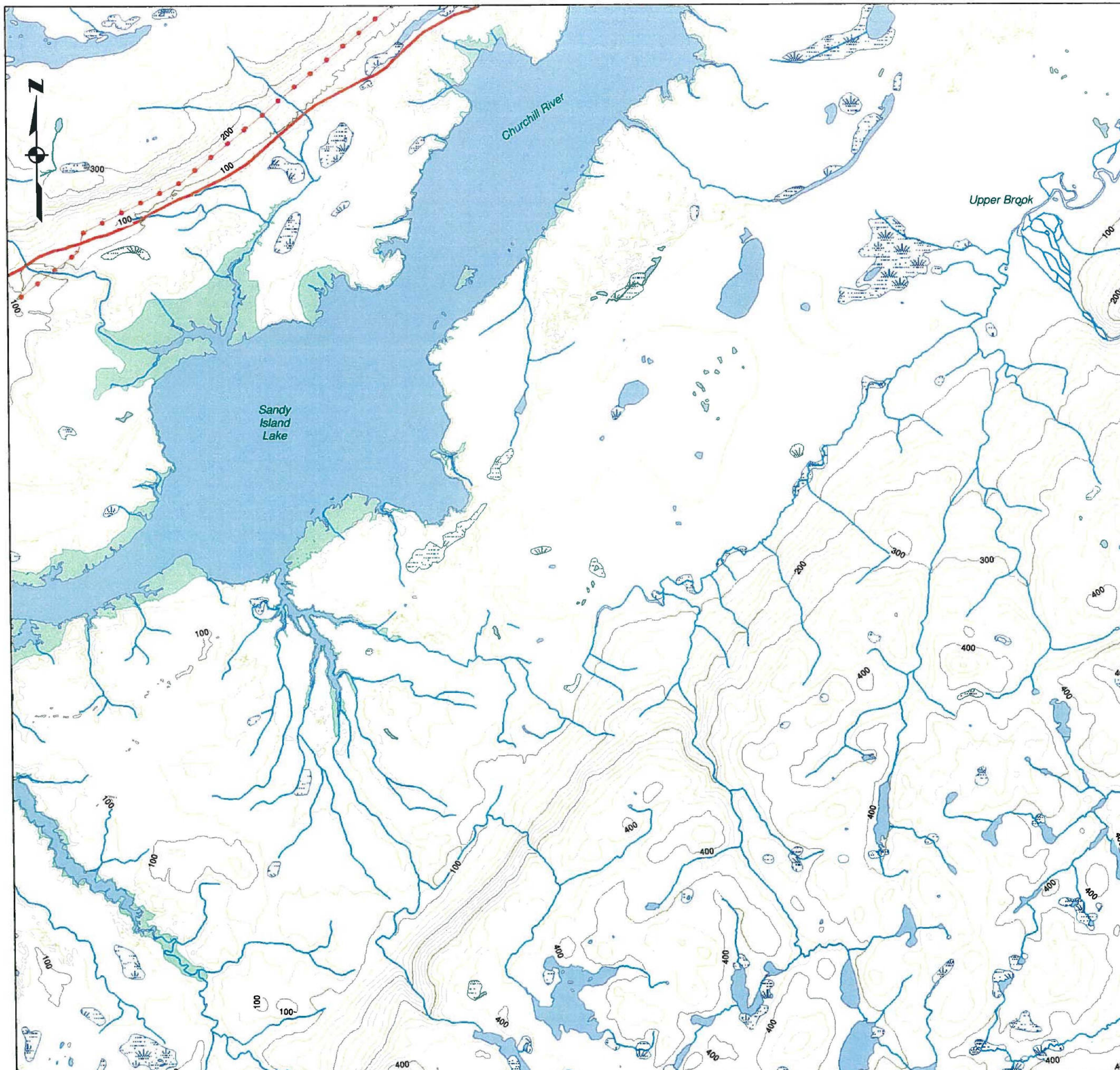
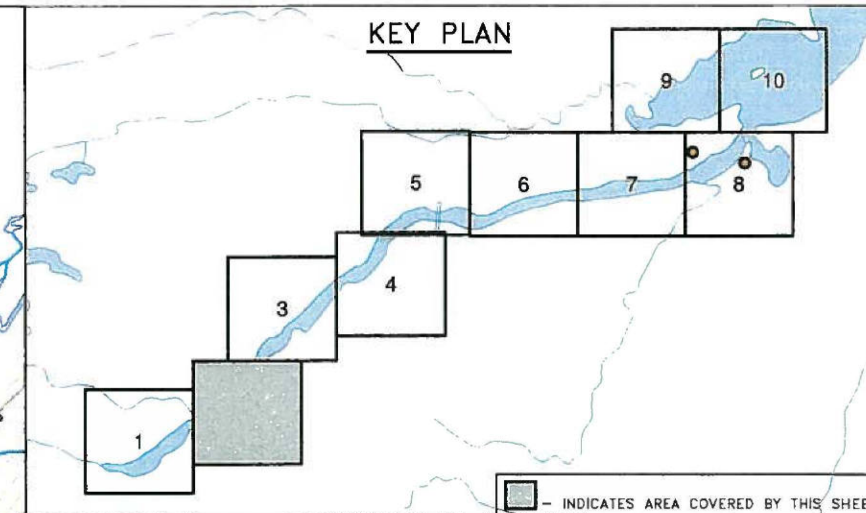
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.
SCALE 1:50000
1000 500 0 1000 2000 3000
METRES
Pinus River
Gull Lake
Churchill River
HATCH™
HYDRO
THE POWER OF COMMITMENT
NEWFOUNDLAND AND LABRADOR HYDRO
LOWER CHURCHILL PROJECT
PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM
SCALE 1:50000
HATCH PROJECT No H-325967
DRAWING NO.
FIGURE B3-1



KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE

CONTOURS

- CONTOUR (20 m)
- INDEX CONTOUR (100 m)

NOTES:

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2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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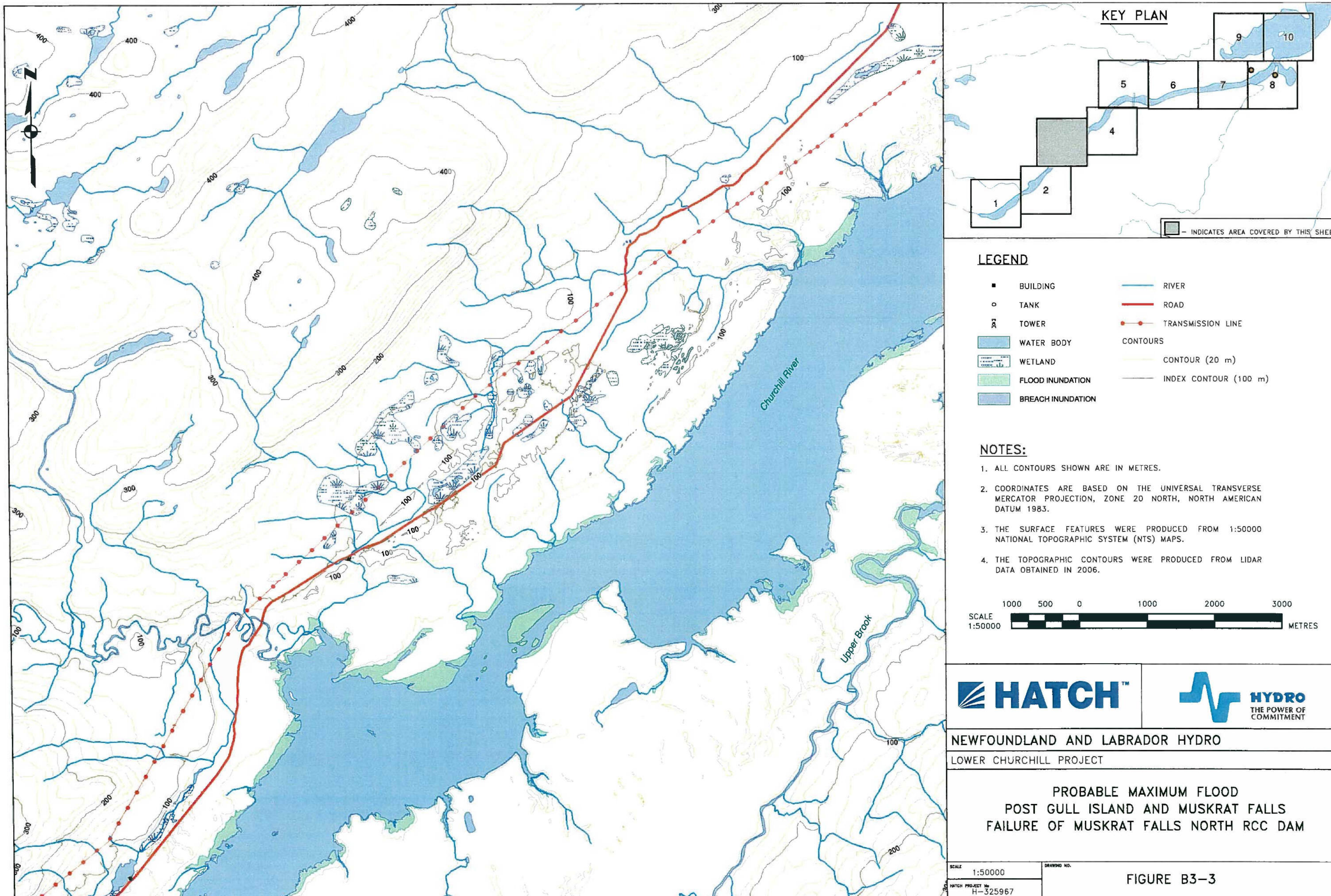
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000	DRAWING NO. FIGURE B3-2
HATCH PROJECT No H-325967	



LEGEND

■	BUILDING	—	RIVER
o	TANK	—	ROAD
	TOWER	—•—	TRANSMISSION LINE
	WATER BODY		CONTOURS
	WETLAND		CONTOUR (20 m)
	FLOOD INUNDATION		INDEX CONTOUR (100 m)
	BREACH INUNDATION		

NOTES:

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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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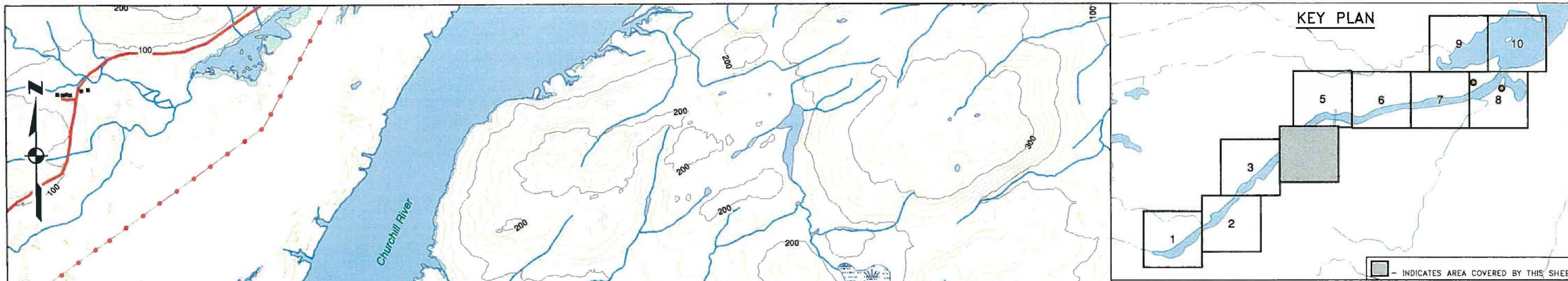
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000	DRAWING NO.
HATCH PROJECT No. H-325967	FIGURE B3-3



LEGEND

■	BUILDING		RIVER
○	TANK		ROAD
	TOWER		TRANSMISSION LINE
	WATER BODY	CONTOURS	
	WETLAND		CONTOUR (20 m)
	FLOOD INUNDATION		INDEX CONTOUR (100 m)
	BREACH INUNDATION		

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

HATCH™

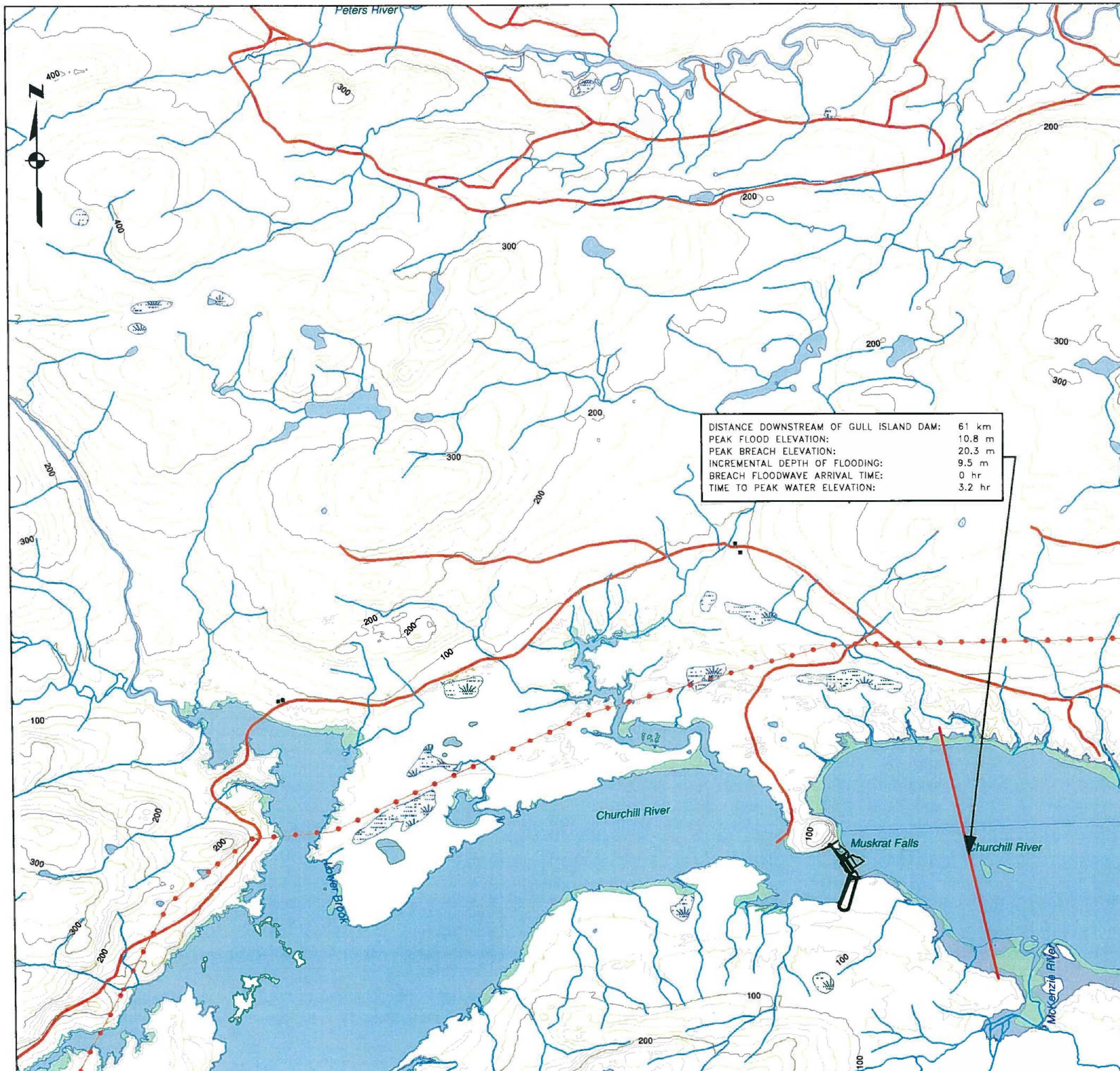
HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

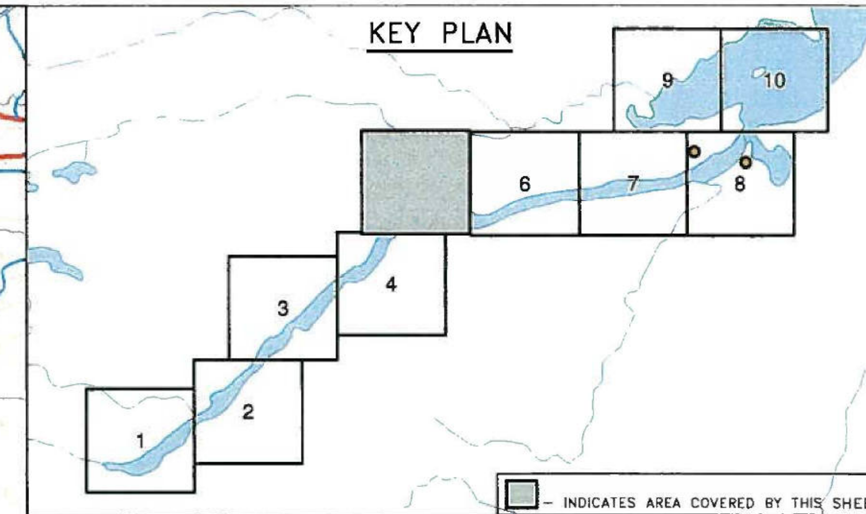
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE	DRAWING NO.
1:50000	FIGURE B3-4
HATCH PROJECT No H-325967	



KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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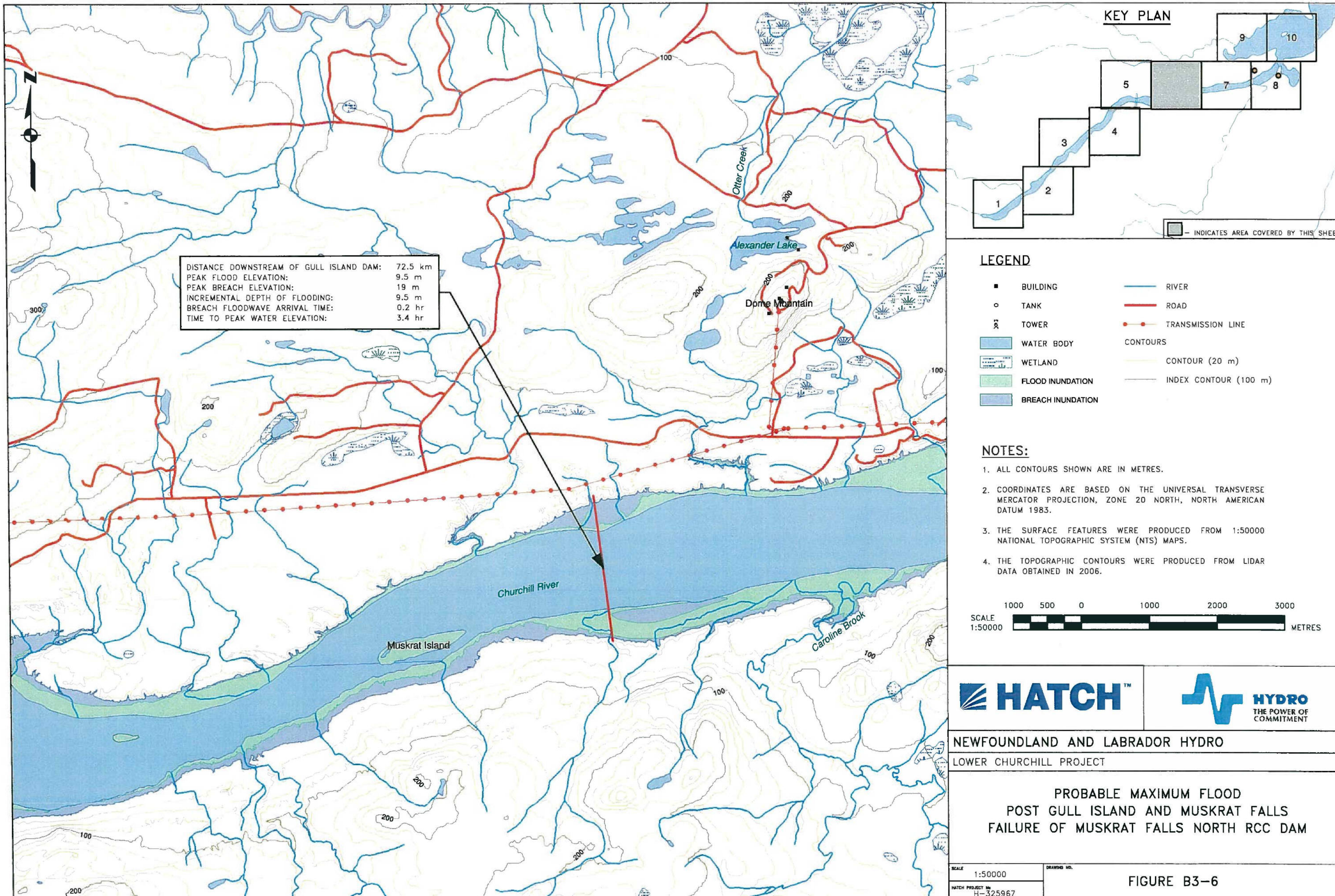
HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000	DRAWING NO.
HATCH PROJECT No H-325967	FIGURE B3-5



LEGEND

▪	BUILDING		RIVER
○	TANK		ROAD
	TOWER		TRANSMISSION LINE
	WATER BODY	CONTOURS	
	WETLAND		CONTOUR (20 m)
	FLOOD INUNDATION		INDEX CONTOUR (100 m)
	BREACH INUNDATION		

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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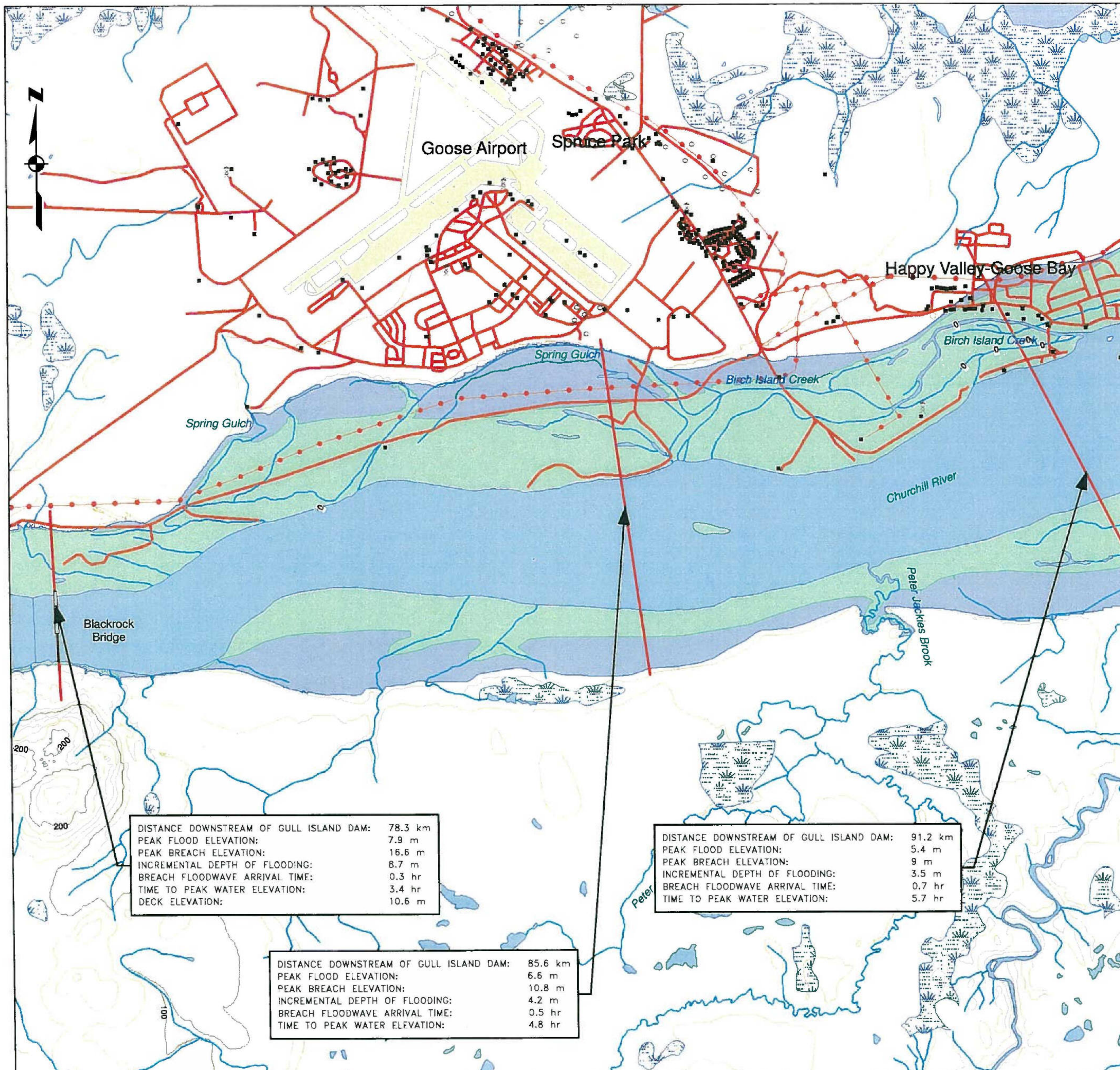
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

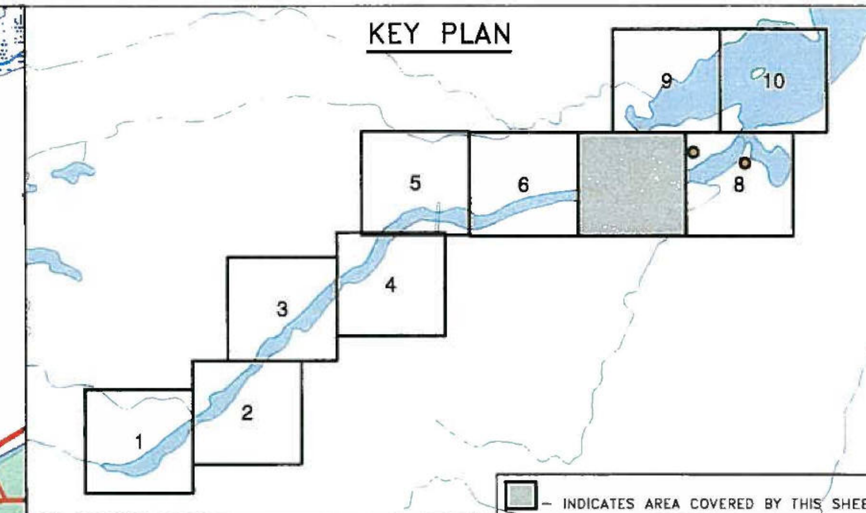
SCALE 1:50000

HATCH PROJECT No. H-325967

DRAWING NO. FIGURE B3-6



KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE

CONTOURS

- CONTOUR (20 m)
- INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000

1000 500 0 1000 2000 3000 METRES

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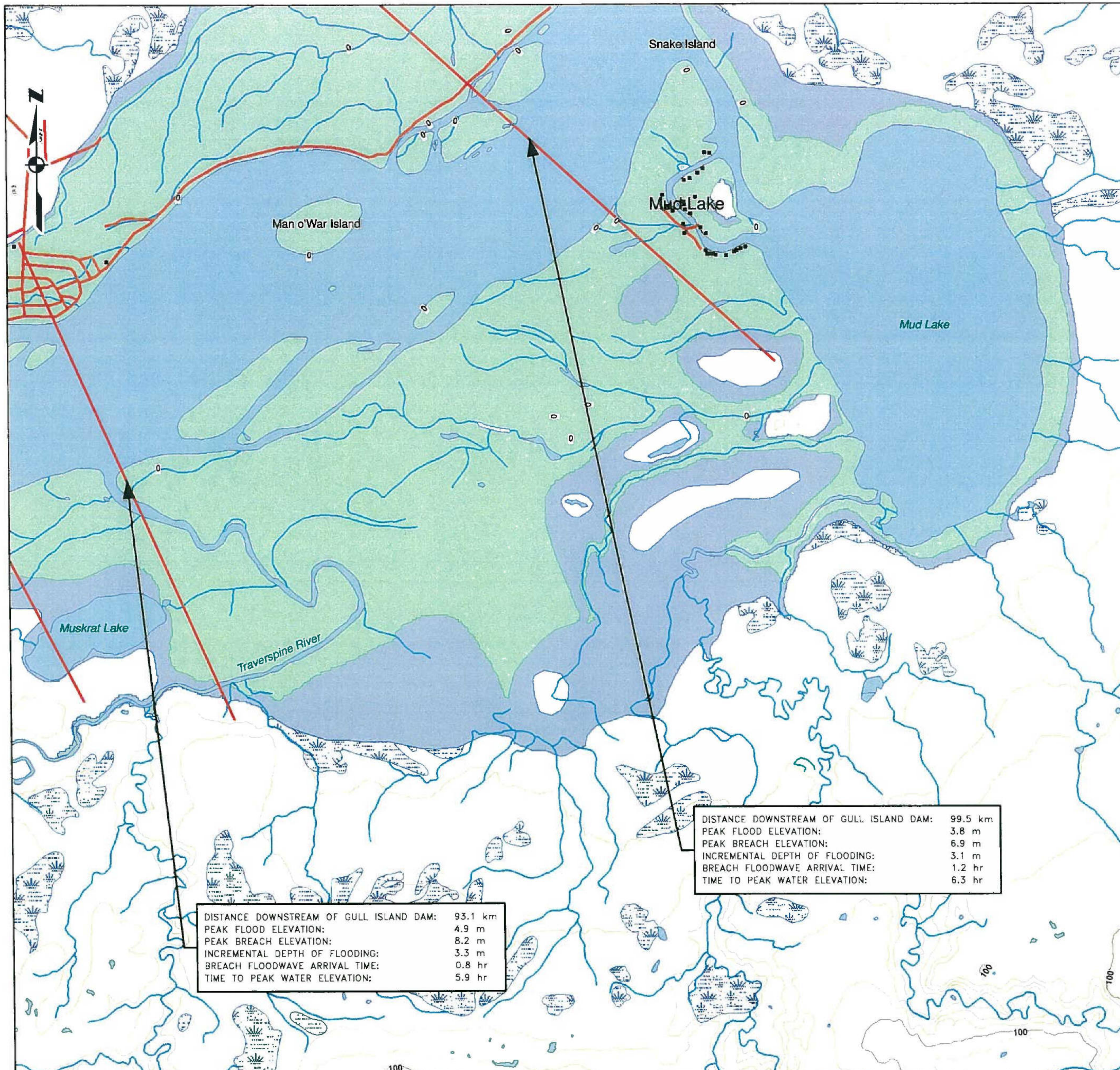
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000

HATCH PROJECT No H-325967

DRAWING NO. FIGURE B3-7



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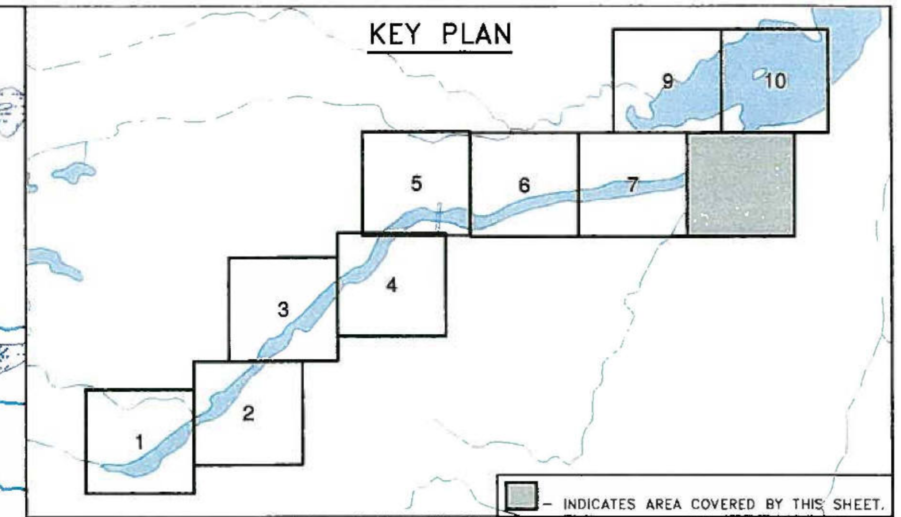

LEGEND

■	BUILDING	——	RIVER
○	TANK	——	ROAD
	TOWER	●—●	TRANSMISSION LINE
	WATER BODY		CONTOURS
	WETLAND		CONTOUR (20 m)
	FLOOD INUNDATION	——	INDEX CONTOUR (100 m)
	BREACH INUNDATION		

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

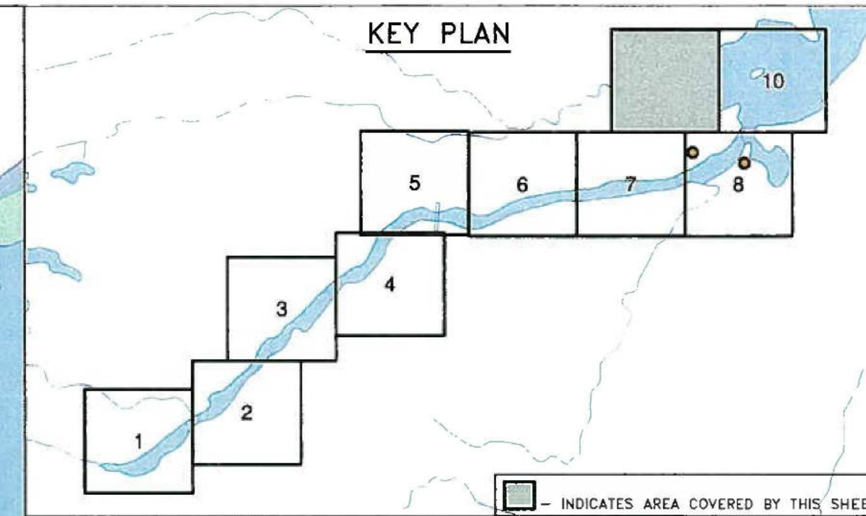
SCALE 1:50000

HATCH PROJECT No. H-325967

DRAWING NO.

FIGURE B3-8

KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE

CONTOURS
- CONTOUR (20 m)
- INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000
1000 500 0 1000 2000 3000 METRES

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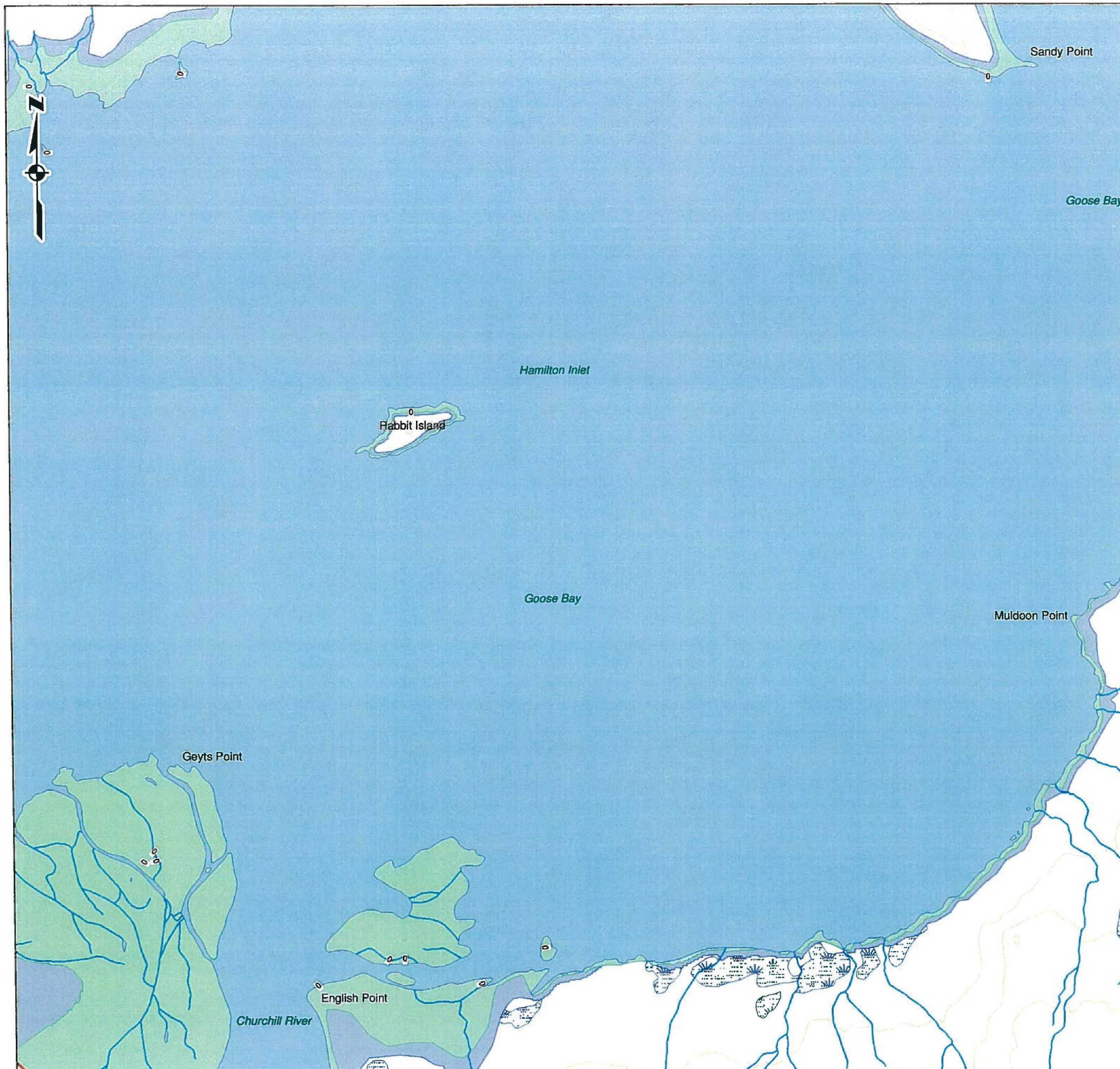
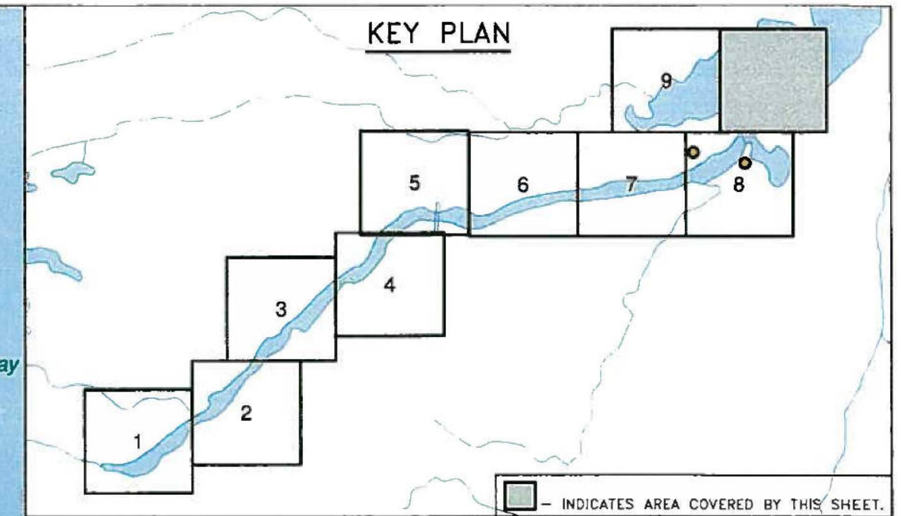
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000	DRAWING NO.	FIGURE B3-9
HATCH PROJECT No. H-325967		





LEGEND

▪	BUILDING	——	RIVER
○	TANK	——	ROAD
	TOWER	●—●	TRANSMISSION LINE
	WATER BODY		CONTOURS
	WETLAND		CONTOUR (20 m)
	FLOOD INUNDATION		INDEX CONTOUR (100 m)
	BREACH INUNDATION		

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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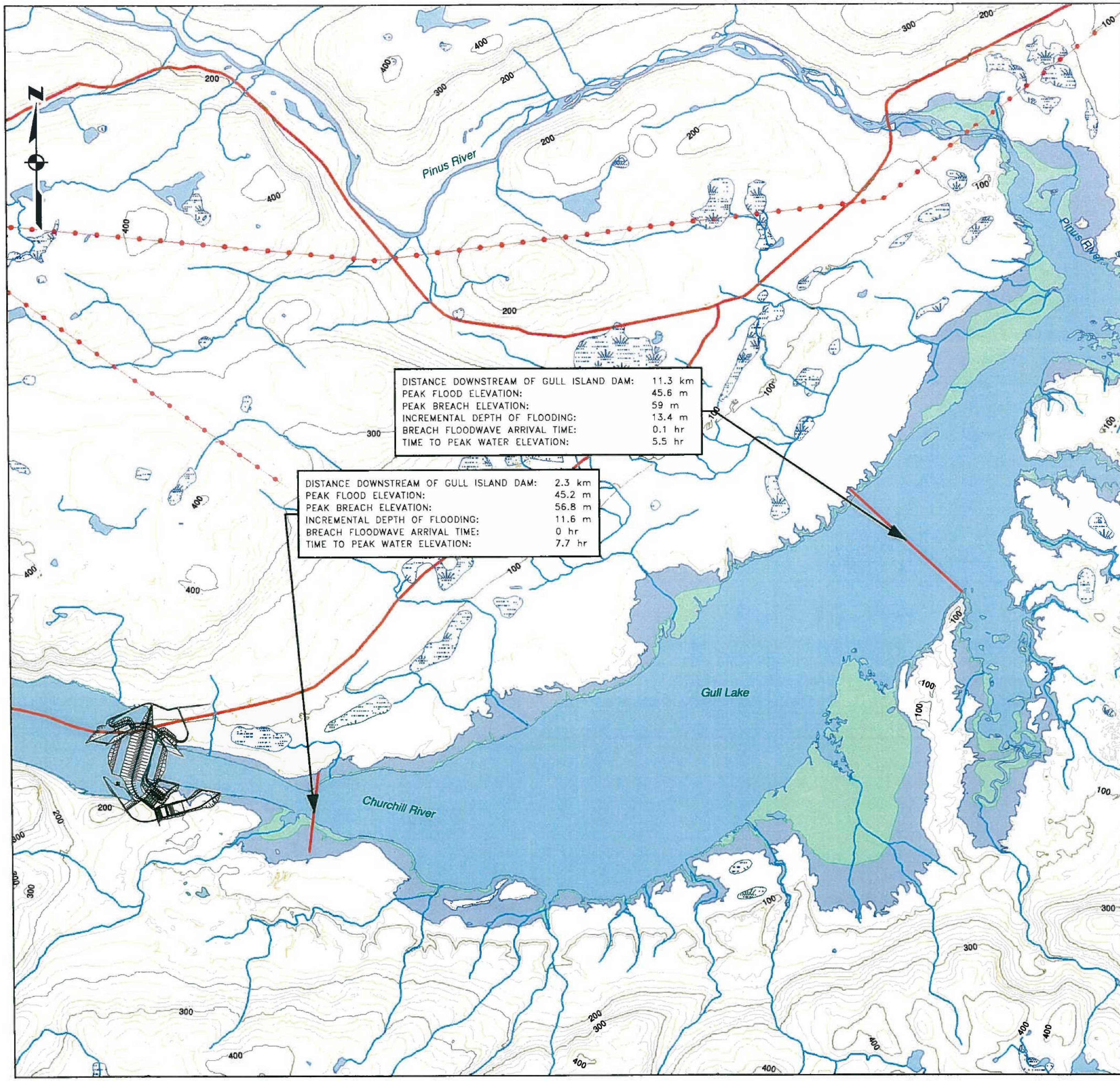
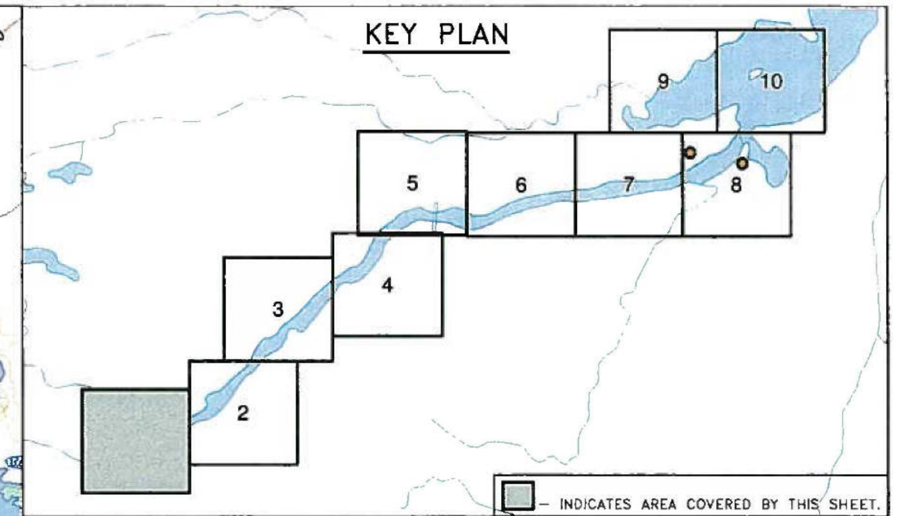
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000	DRAWING NO. FIGURE B3-10
HATCH PROJECT No H-325967	





LEGEND

▪	BUILDING		RIVER
○	TANK		ROAD
	TOWER		TRANSMISSION LINE
	WATER BODY	CONTOURS	
	WETLAND		CONTOUR (20 m)
	FLOOD INUNDATION		INDEX CONTOUR (100 m)
	BREACH INUNDATION		

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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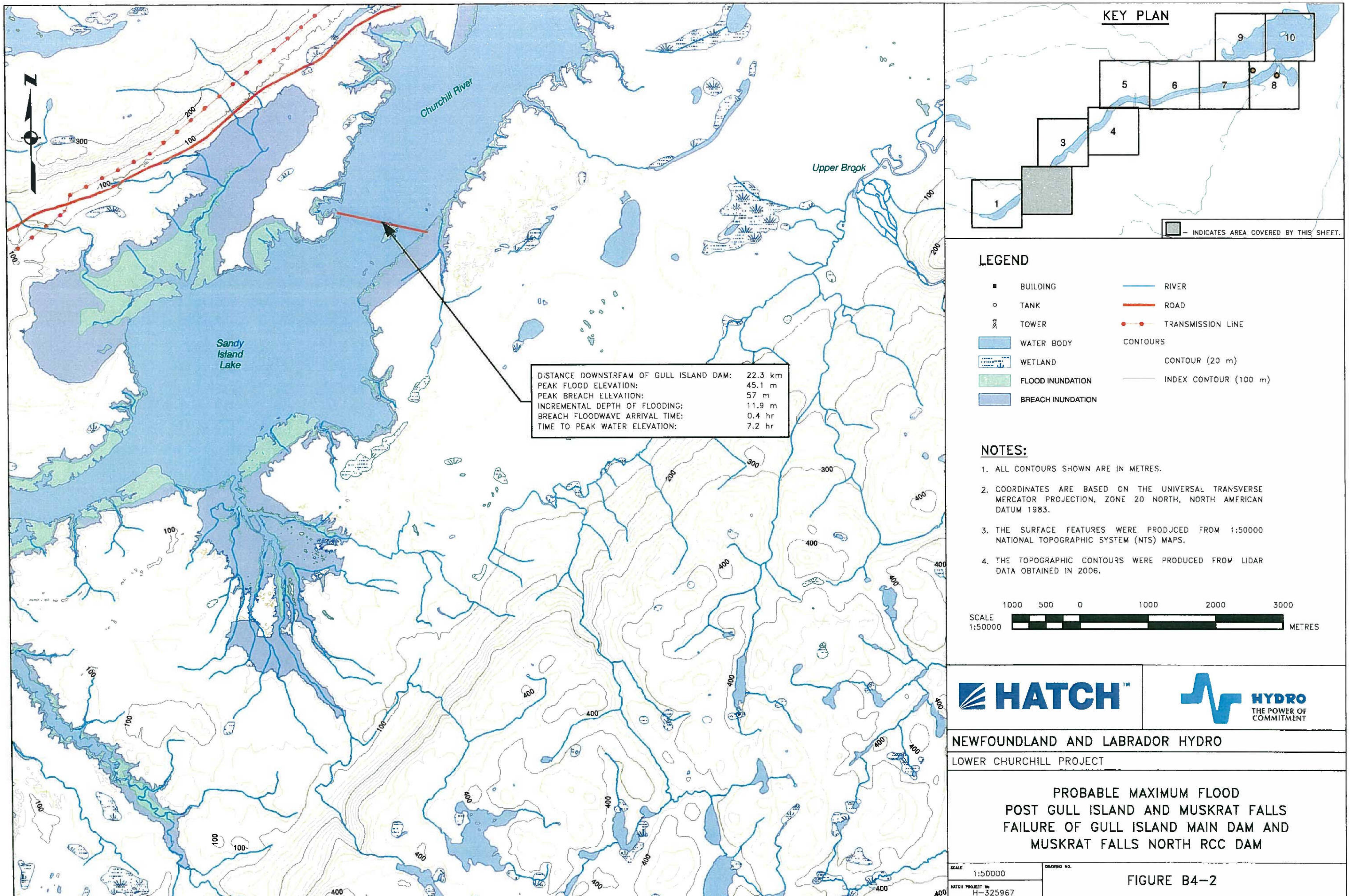
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND
MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000
HATCH PROJECT No. H-325967
DRAWING NO. FIGURE B4-1



LEGEND

BUILDING	RIVER
TANK	ROAD
TOWER	TRANSMISSION LINE
WATER BODY	CONTOURS
WETLAND	CONTOUR (20 m)
FLOOD INUNDATION	INDEX CONTOUR (100 m)
BREACH INUNDATION	

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

HATCH

HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

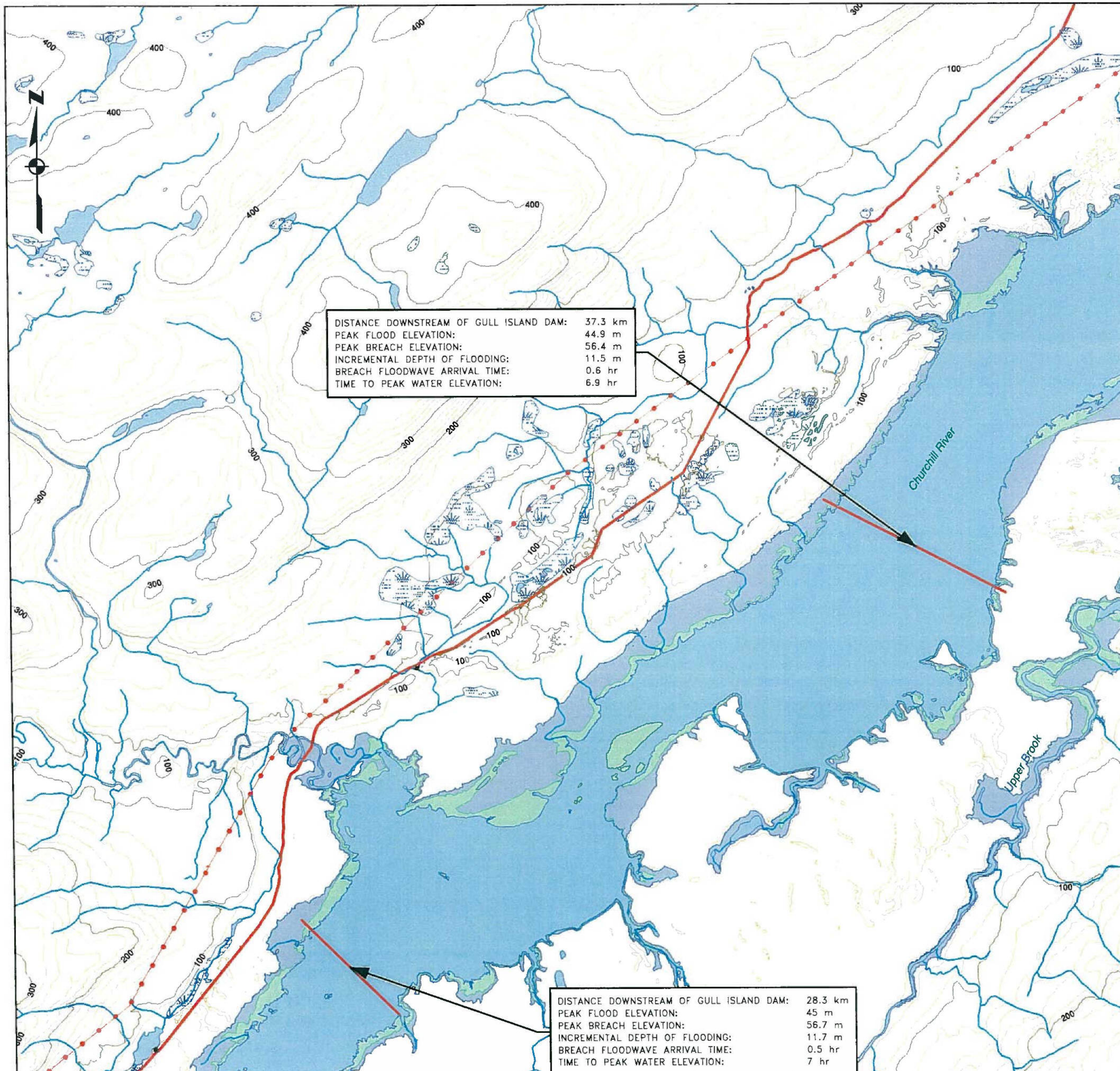
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND
MUSKRAT FALLS NORTH RCC DAM

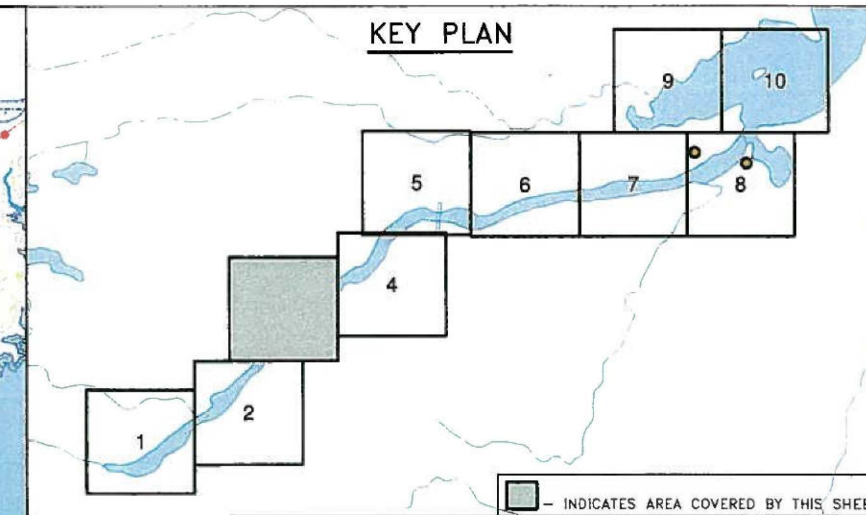
SCALE: 1:50000

HATCH PROJECT No: H-325967

DRAWING NO.: FIGURE B4-2



KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE

CONTOURS

- CONTOUR (20 m)
- INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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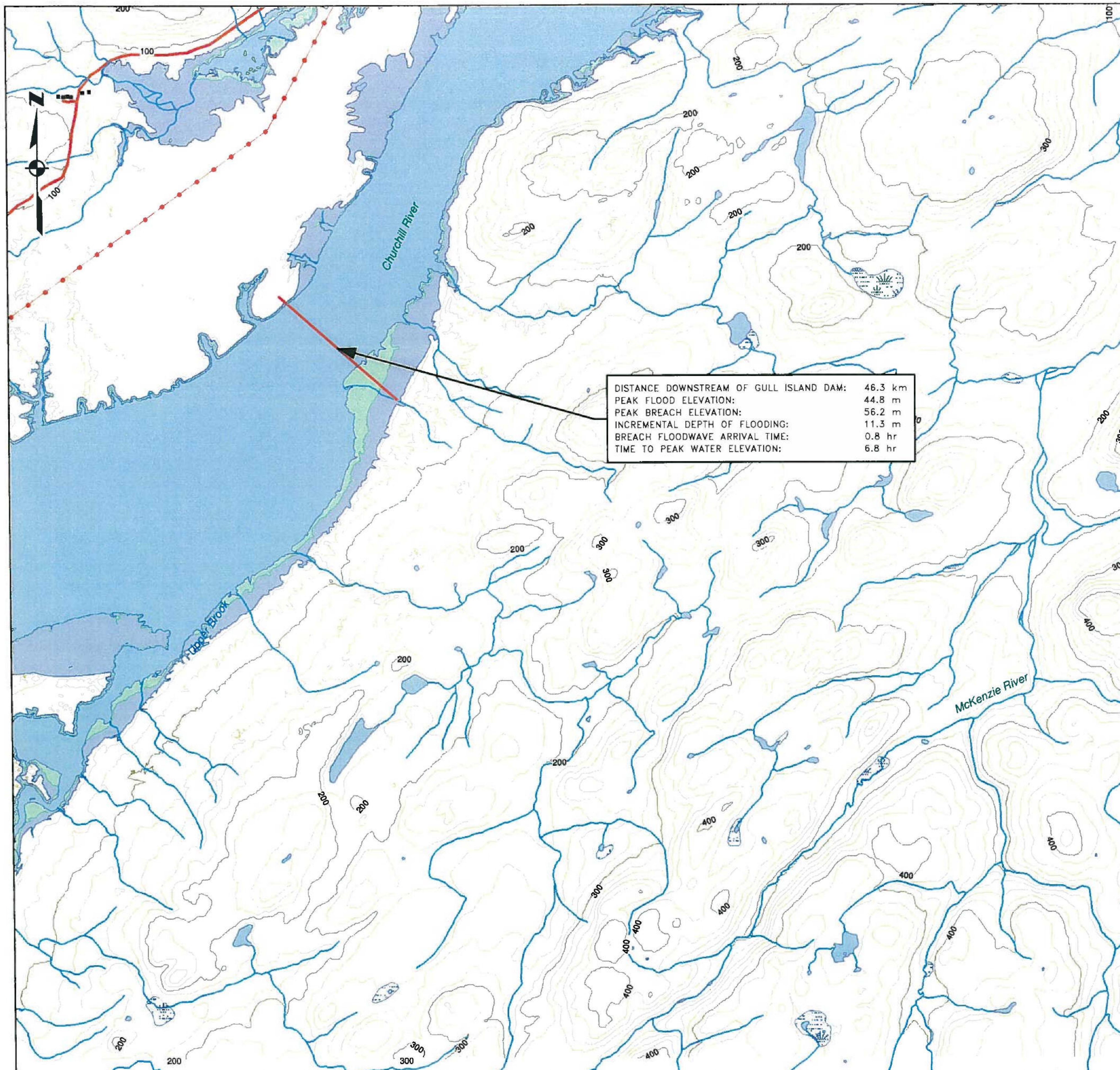
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND
MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000	DRAWING NO. FIGURE B4-3
HATCH PROJECT No H-325967	



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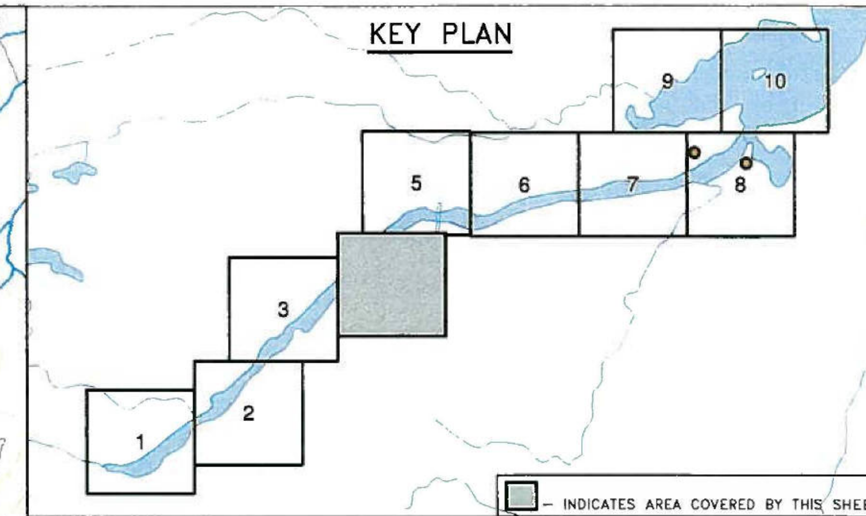

LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE

CONTOURS

- CONTOUR (20 m)
- INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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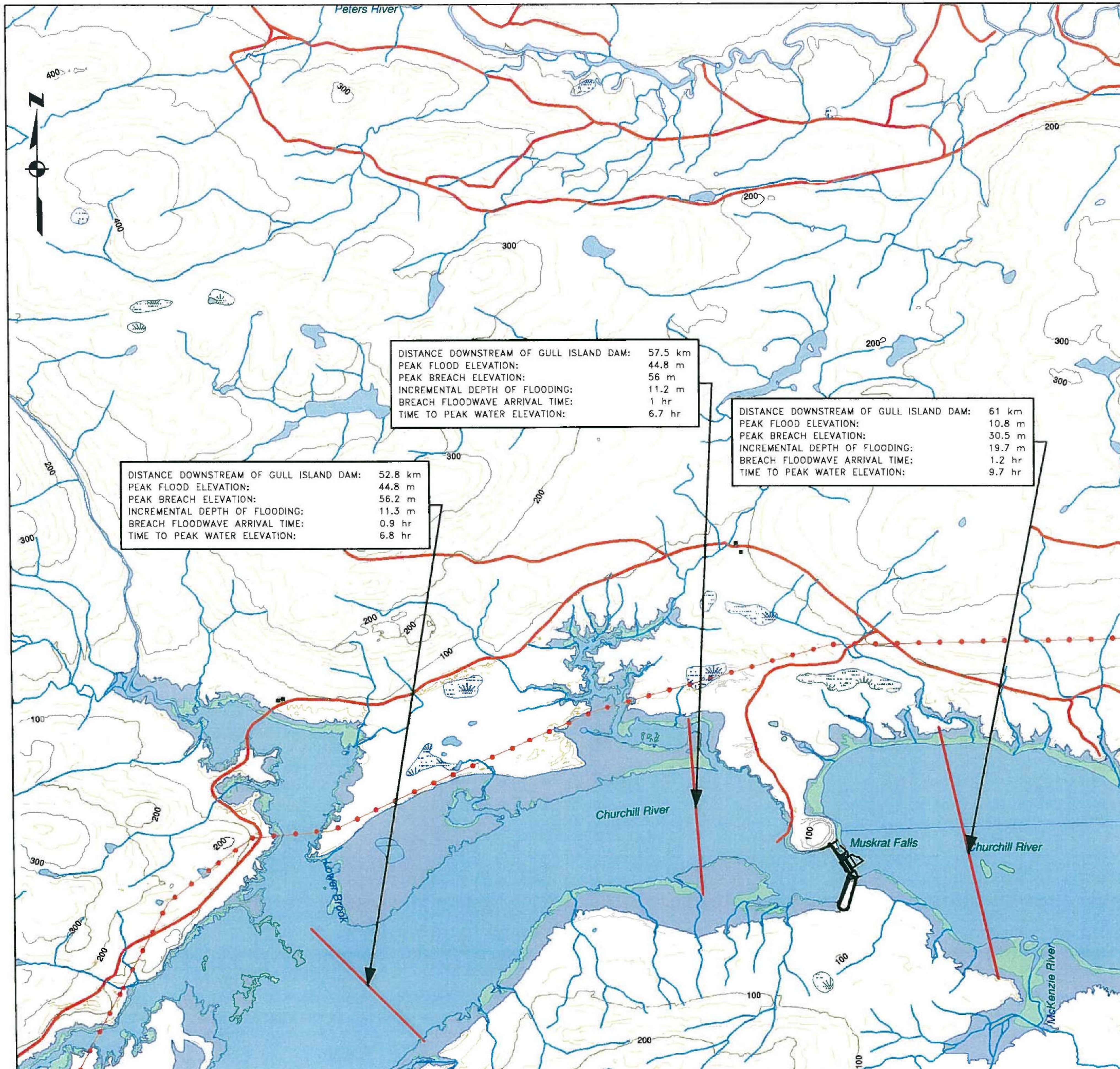
NEWFOUNDLAND AND LABRADOR HYDRO

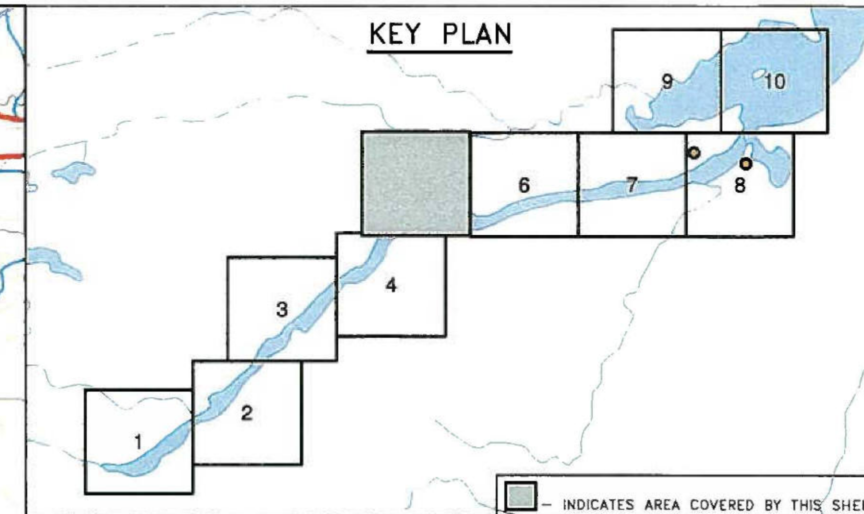
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND
MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000	DRAWING NO.
HATCH PROJECT No H-325967	FIGURE B4–4



KEY PLAN



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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NEWFOUNDLAND AND LABRADOR HYDRO

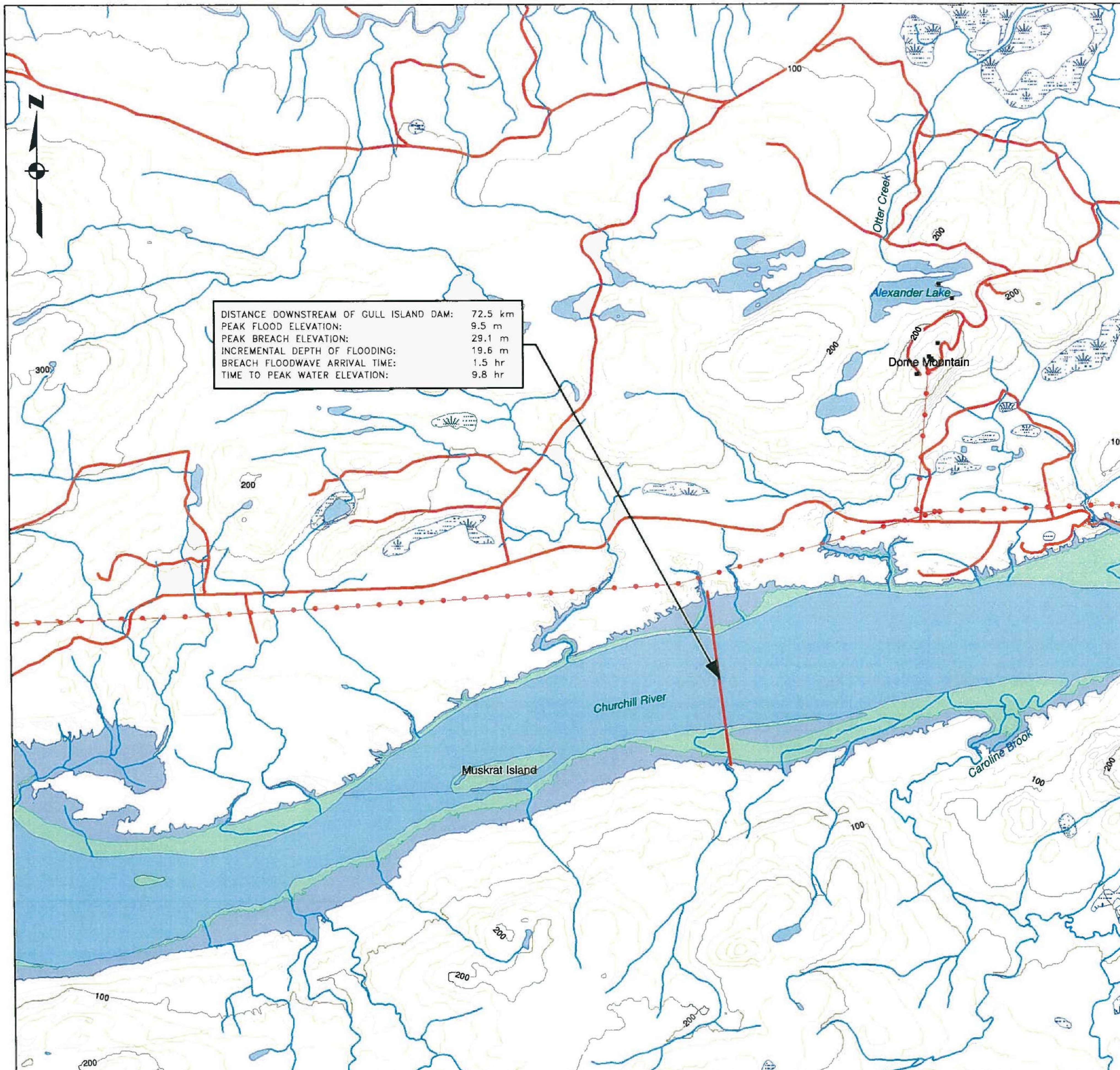
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND
MUSKRAT FALLS NORTH RCC DAM

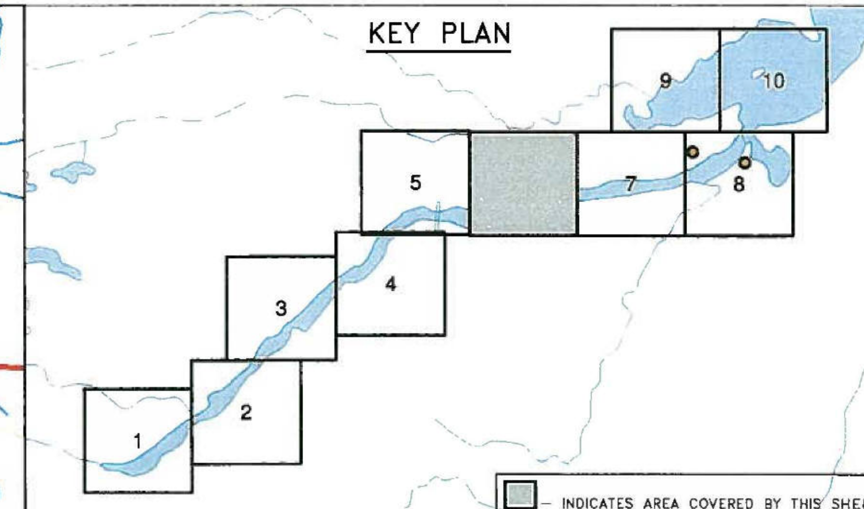
SCALE 1:50000

HATCH PROJECT No. H-325967

DRAWING NO. FIGURE B4-5



KEY PLAN



– INDICATES AREA COVERED BY THIS SHEET.

LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE

CONTOURS

- CONTOUR (20 m)
- INDEX CONTOUR (100 m)

NOTES:

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SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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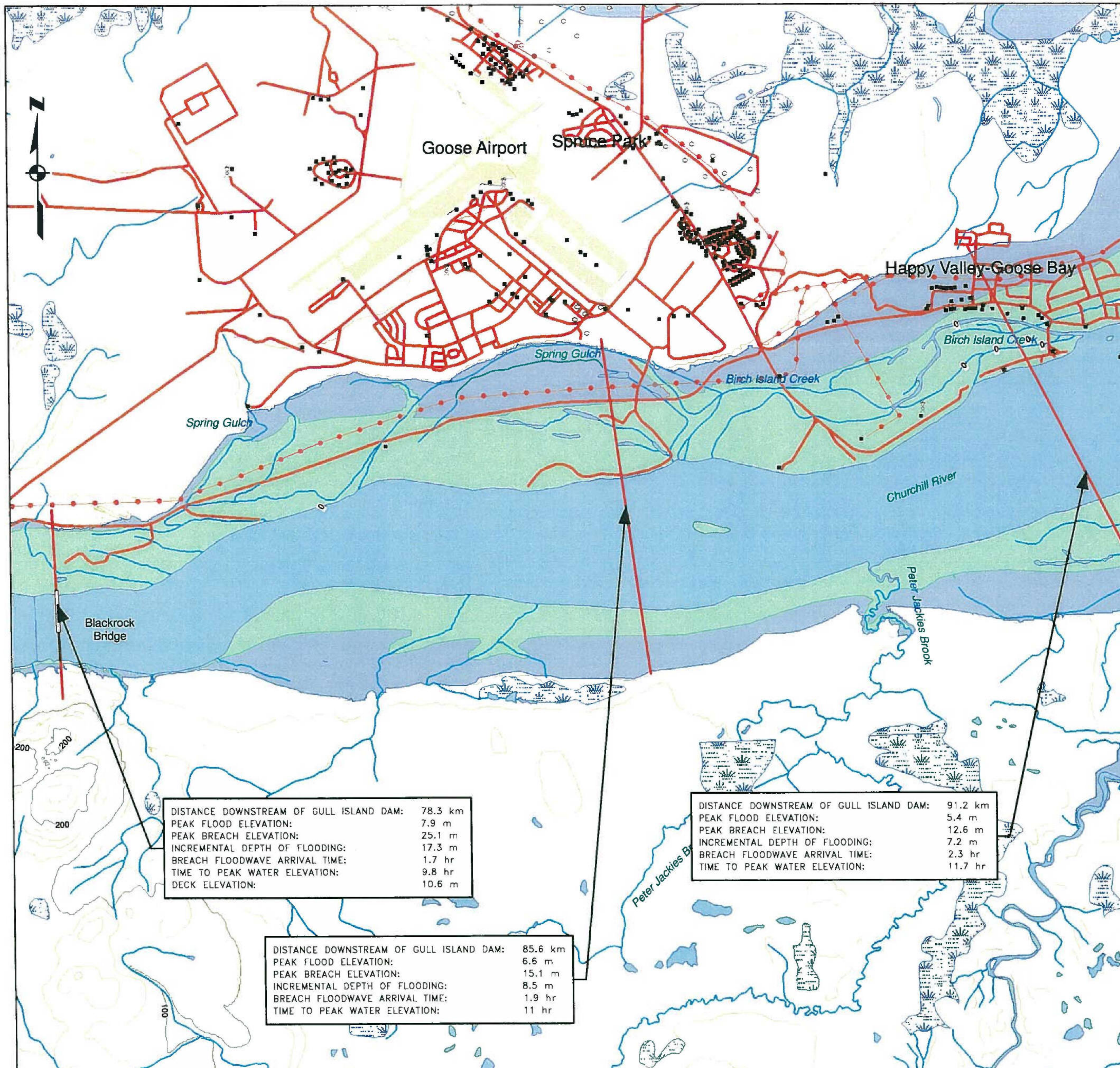
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND
MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000	DRAWING NO. FIGURE B4-6
HATCH PROJECT No H-325967	



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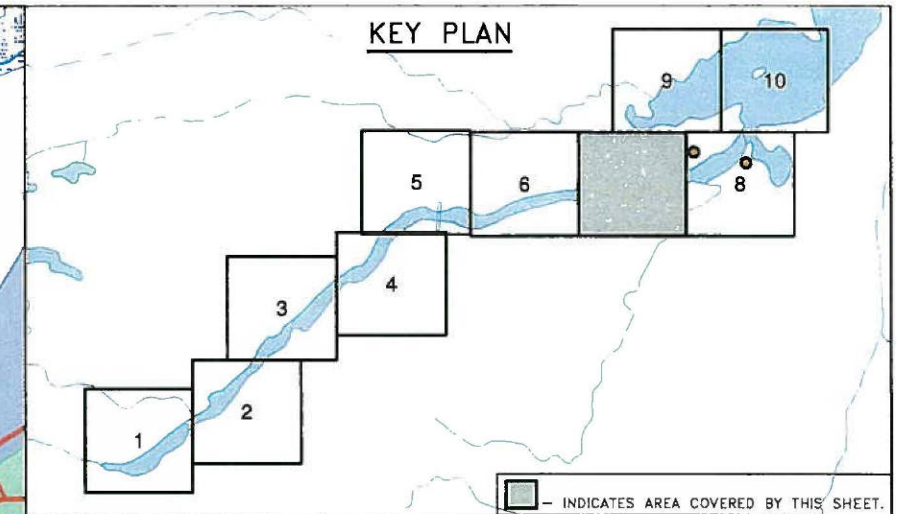

LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

NOTES:

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2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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NEWFOUNDLAND AND LABRADOR HYDRO

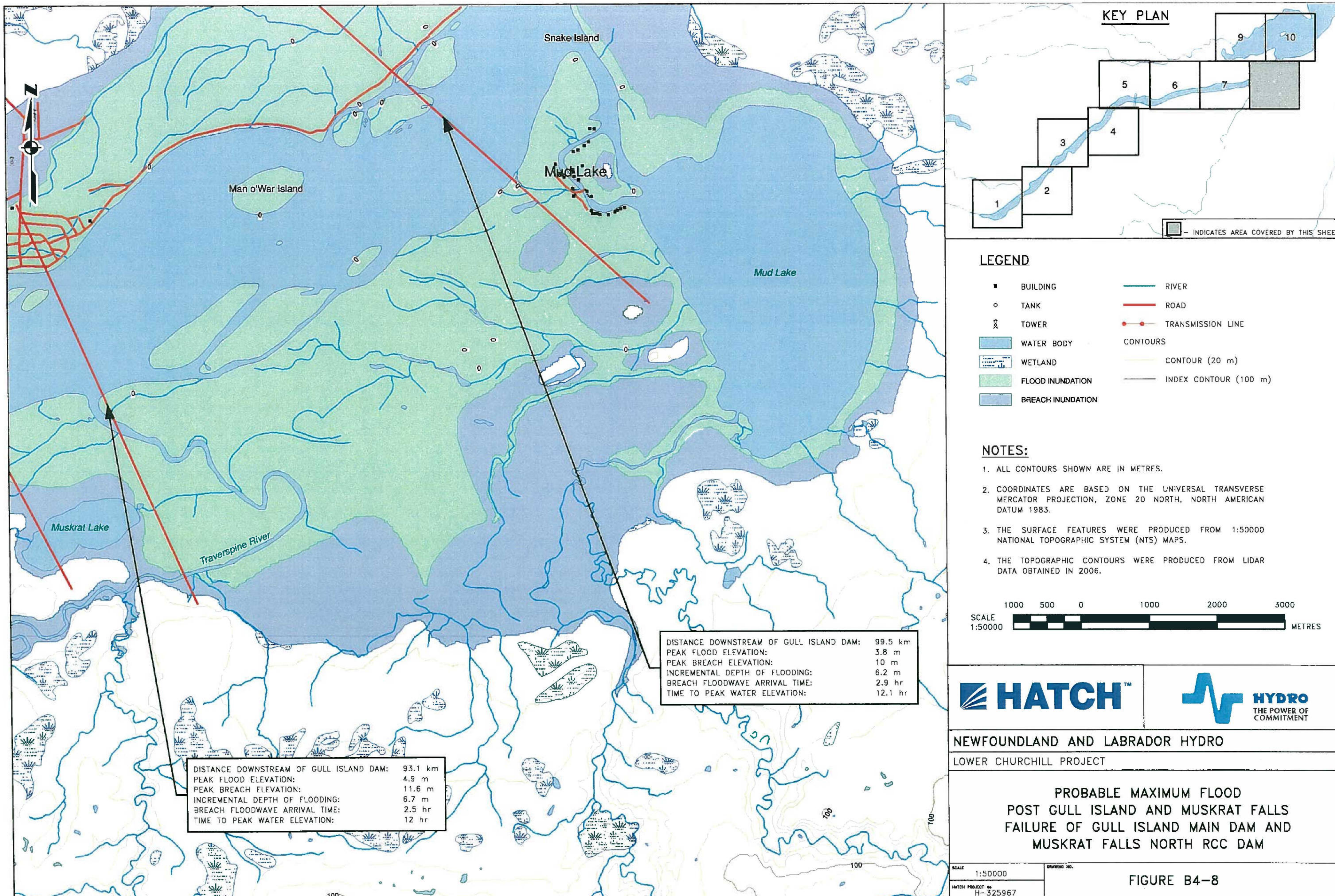
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND
MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000

HATCH PROJECT No. H-325967

DRAWING NO. FIGURE B4-7



DISTANCE DOWNSTREAM OF GULL ISLAND DAM:	99.5 km
PEAK FLOOD ELEVATION:	3.8 m
PEAK BREACH ELEVATION:	10 m
INCREMENTAL DEPTH OF FLOODING:	6.2 m
BREACH FLOODWAVE ARRIVAL TIME:	2.9 hr
TIME TO PEAK WATER ELEVATION:	12.1 hr

DISTANCE DOWNSTREAM OF GULL ISLAND DAM:	93.1 km
PEAK FLOOD ELEVATION:	4.9 m
PEAK BREACH ELEVATION:	11.6 m
INCREMENTAL DEPTH OF FLOODING:	6.7 m
BREACH FLOODWAVE ARRIVAL TIME:	2.5 hr
TIME TO PEAK WATER ELEVATION:	12 hr

NOTES:

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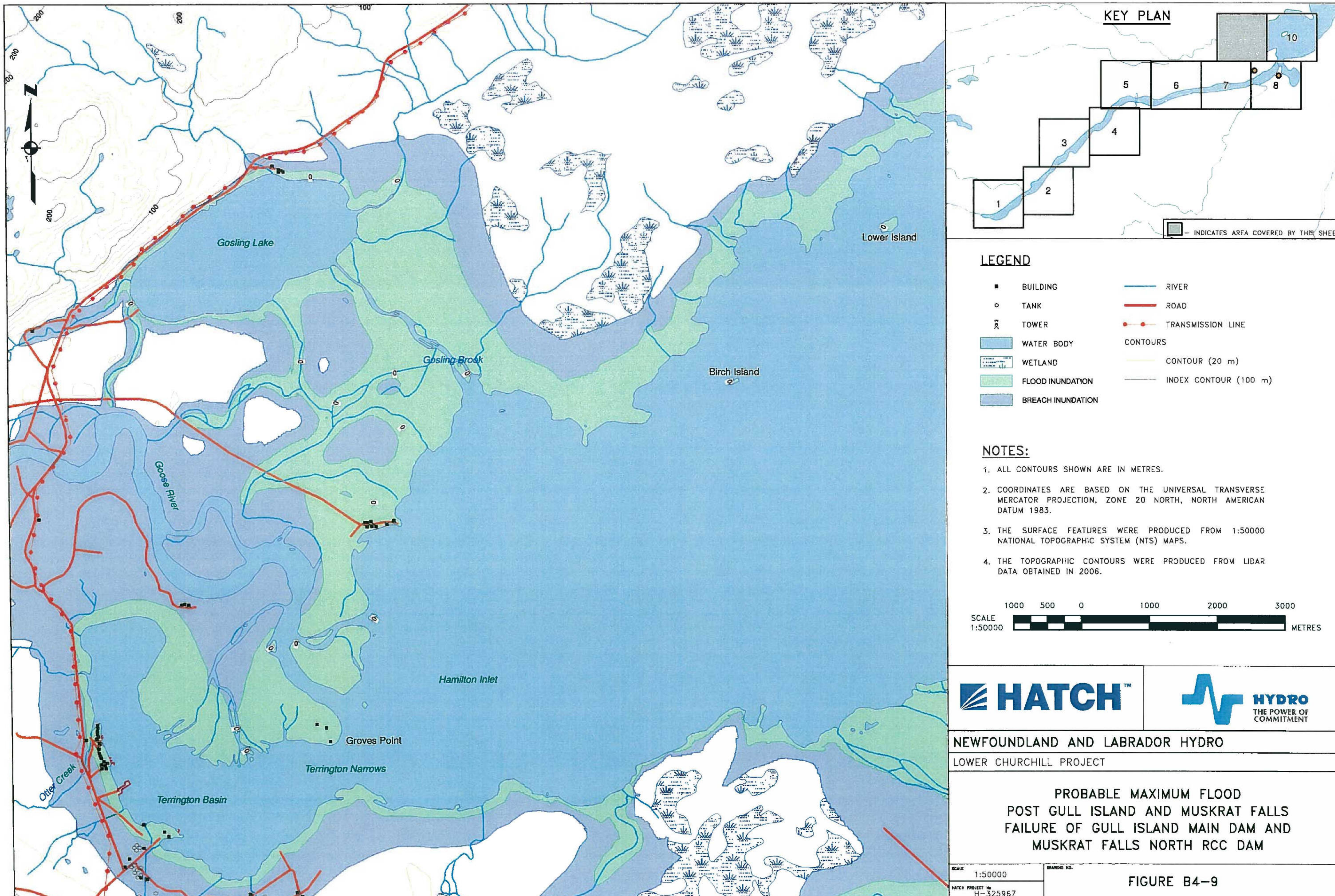
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD POST GULL ISLAND AND MUSKRAT FALLS FAILURE OF GULL ISLAND MAIN DAM AND MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000

HATCH PROJECT No H-325967

DRAWING NO. FIGURE B4-8



LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE
- CONTOURS
  - CONTOUR (20 m)
  - INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.
3. THE SURFACE FEATURES WERE PRODUCED FROM 1:50000 NATIONAL TOPOGRAPHIC SYSTEM (NTS) MAPS.
4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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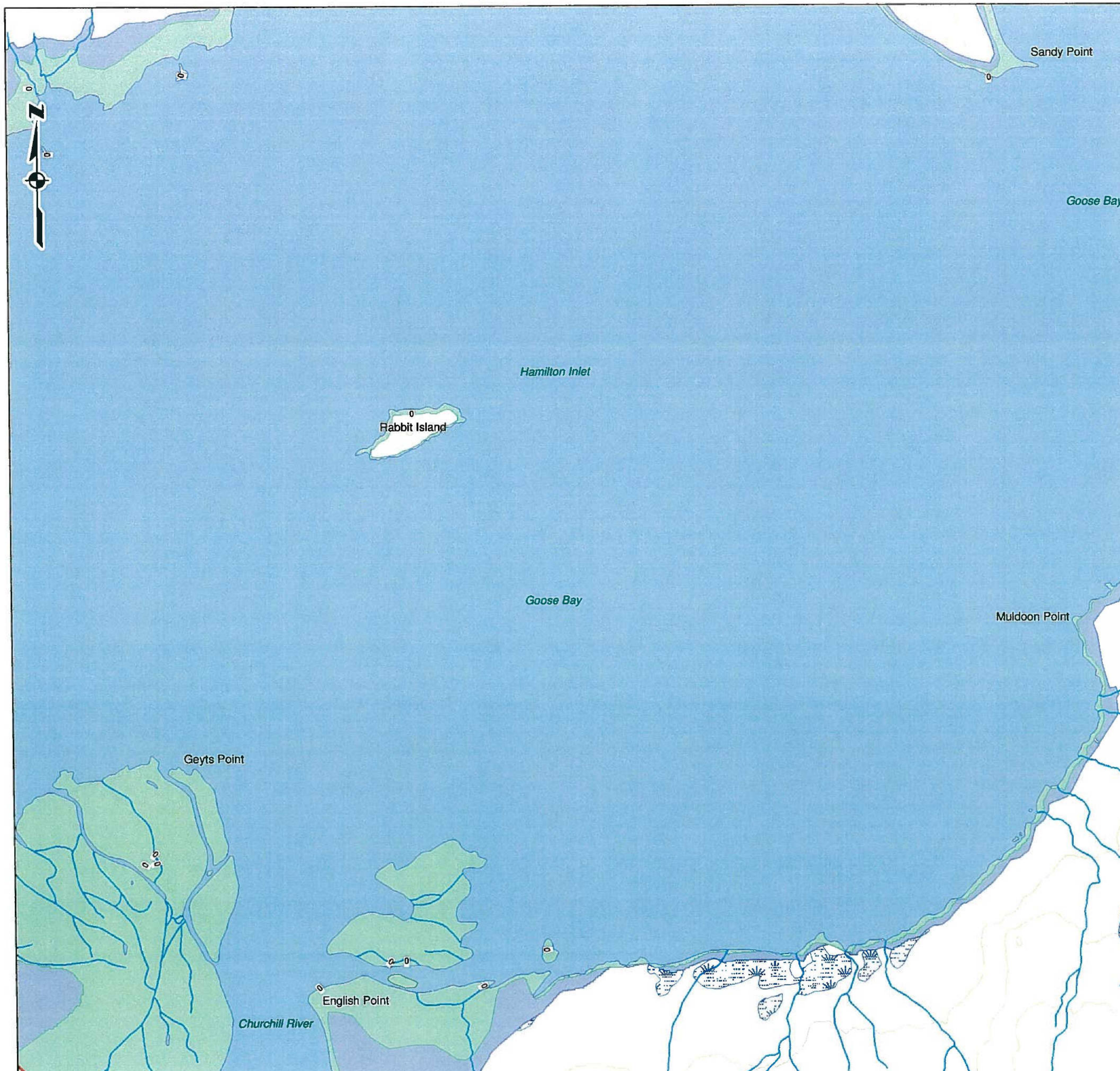
NEWFOUNDLAND AND LABRADOR HYDRO

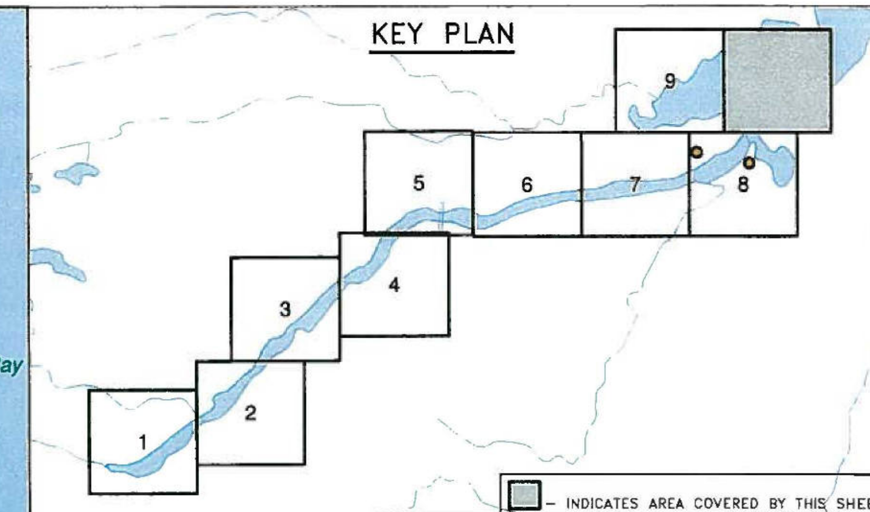
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND
MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000
HATCH PROJECT No H-325967
DRAWING NO. FIGURE B4-9



KEY PLAN



– INDICATES AREA COVERED BY THIS SHEET.

LEGEND

- BUILDING
- TANK
- TOWER
- WATER BODY
- WETLAND
- FLOOD INUNDATION
- BREACH INUNDATION
- RIVER
- ROAD
- TRANSMISSION LINE

CONTOURS

- CONTOUR (20 m)
- INDEX CONTOUR (100 m)

NOTES:

1. ALL CONTOURS SHOWN ARE IN METRES.
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4. THE TOPOGRAPHIC CONTOURS WERE PRODUCED FROM LIDAR DATA OBTAINED IN 2006.

SCALE 1:50000 — 1000 500 0 1000 2000 3000 METRES

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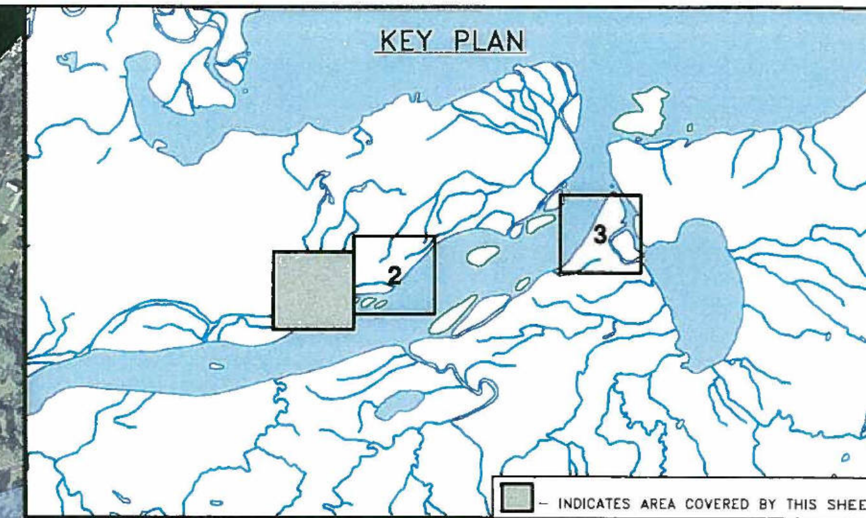
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND
MUSKRAT FALLS NORTH RCC DAM

SCALE 1:50000	DRAWING NO. FIGURE B4–10
HATCH PROJECT No. H–325967	

Appendix C

"Fair Weather" Inundation Mapping Series – Happy Valley-Goose Bay and Mud Lake

(1:10,000 Scale)



LEGEND

BREACH INUNDATION

NOTES:

1. ORTHOPHOTOS WERE OBTAINED BY NL HYDRO DURING THE 2006 LIDAR SURVEY
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.

SCALE 1:10000 — 200 100 0 200 400 600 METRES

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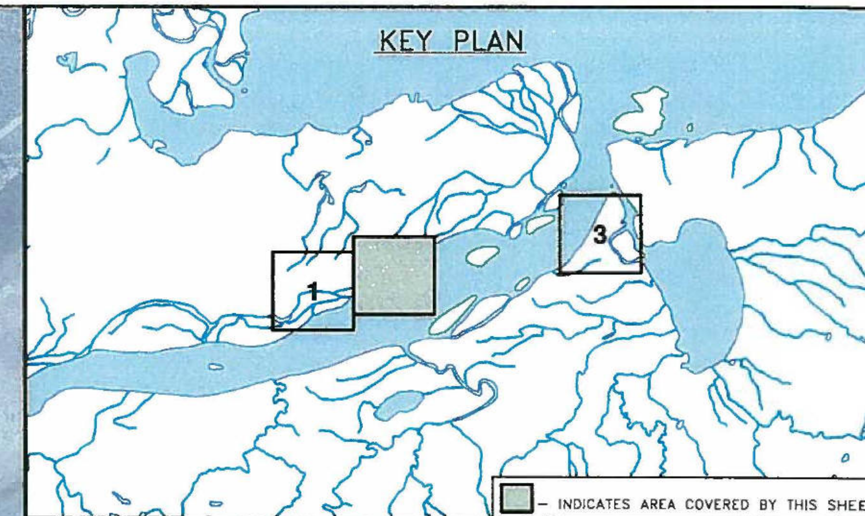
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:10000

HATCH PROJECT No H-325967

DRAWING NO. FIGURE C1-1



LEGEND

BREACH INUNDATION

NOTES:

1. ORTHOPHOTOS WERE OBTAINED BY NL HYDRO DURING THE 2006 LIDAR SURVEY
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.

SCALE 1:10000

200 100 0 200 400 600 METRES

HATCH™

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NEWFOUNDLAND AND LABRADOR HYDRO

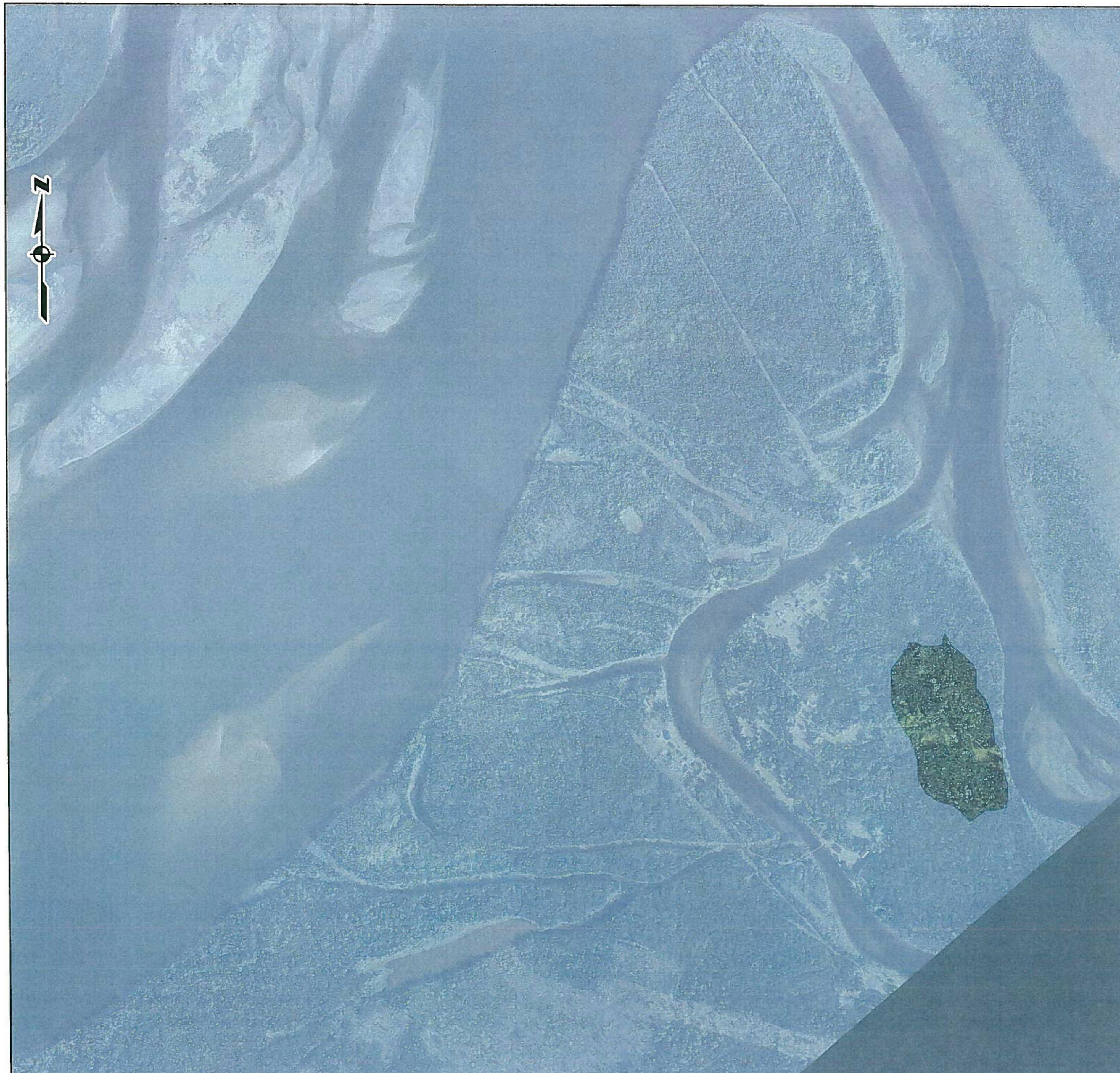
LOWER CHURCHILL PROJECT

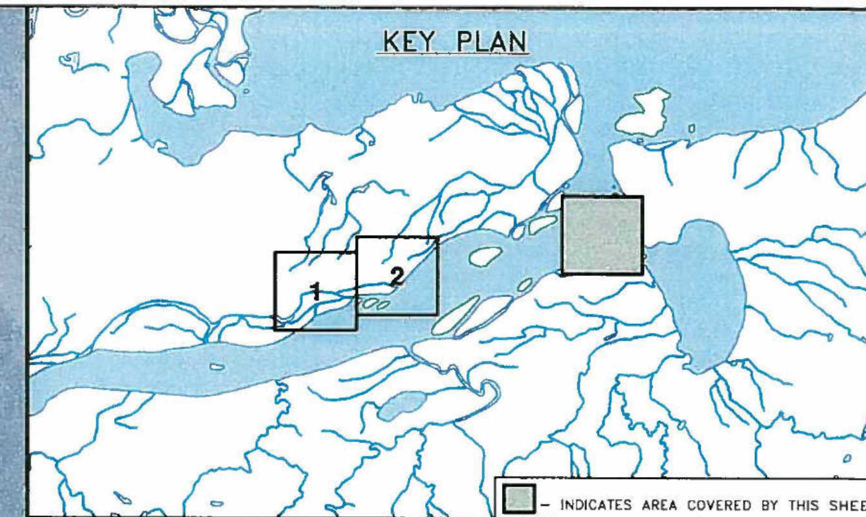
FAIR WEATHER CONDITIONS
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:10000

HATCH PROJECT No H-325967

DRAWING NO. FIGURE C1-2





LEGEND

BREACH INUNDATION

NOTES:

1. ORTHOPHOTOS WERE OBTAINED BY NL HYDRO DURING THE 2006 LIDAR SURVEY
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SCALE 1:10000 — 200 100 0 200 400 600 METRES

HATCH™

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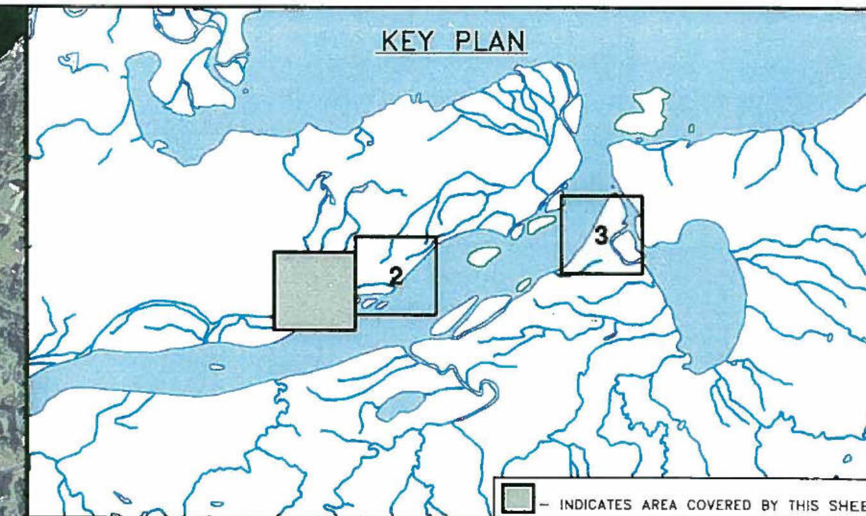
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE	DRAWING NO.
1:10000	FIGURE C1–3
HATCH PROJECT No H–325967	



LEGEND

BREACH INUNDATION

NOTES:

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SCALE 1:10000 — 200 100 0 200 400 600 METRES

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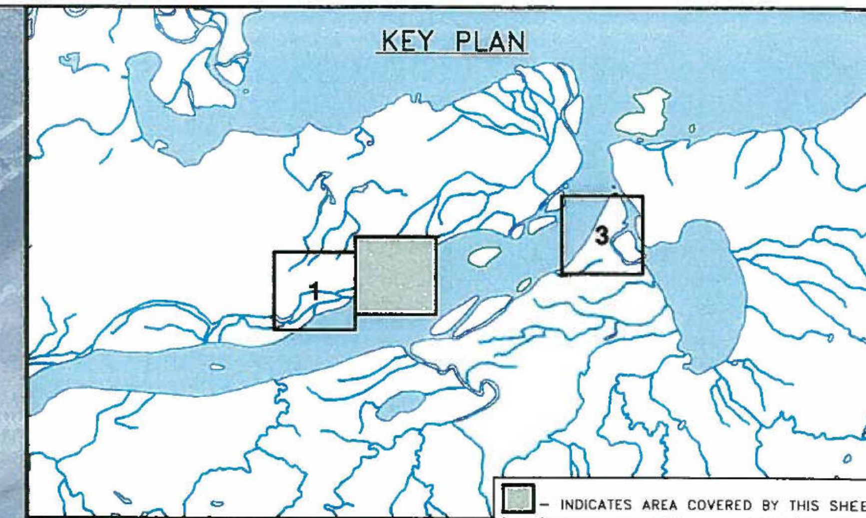
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:10000	DRAWING NO. FIGURE C2-1
HATCH PROJECT No. H-325967	



LEGEND

BREACH INUNDATION

NOTES:

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SCALE 1:10000 — 200 100 0 200 400 600 METRES

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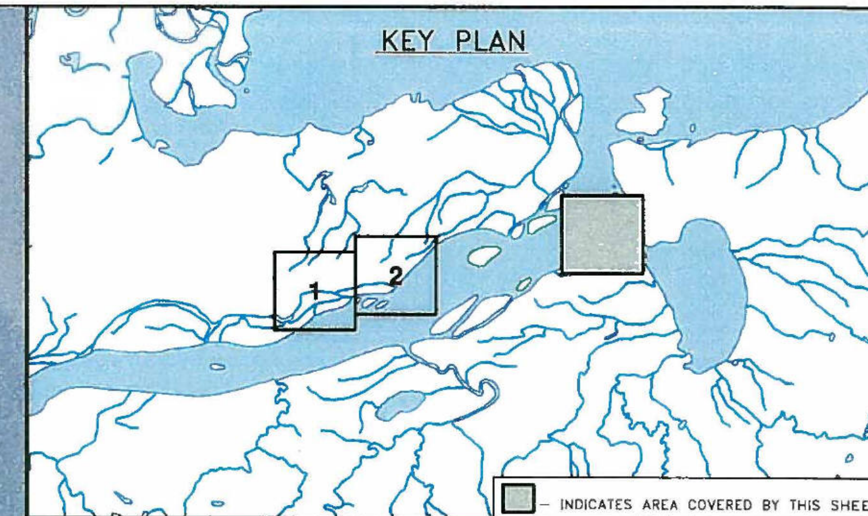
FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:10000	DRAWING NO. FIGURE C2-2
HATCH PROJECT No H-325967	



LEGEND

BREACH INUNDATION

NOTES:

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SCALE 1:10000 — 200 100 0 200 400 600 METRES

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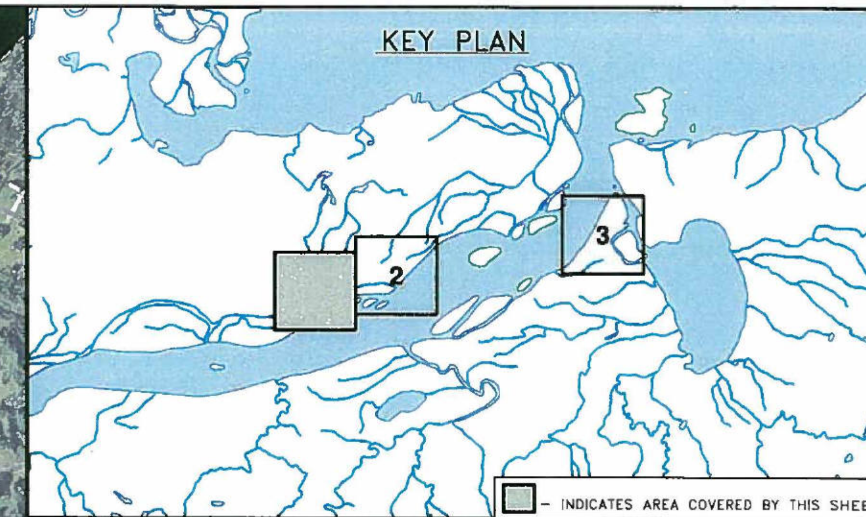
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:10000	DRAWING NO. FIGURE C2–3
HATCH PROJECT No. H–325967	



LEGEND

BREACH INUNDATION

NOTES:

1. ORTHOPHOTOS WERE OBTAINED BY NL HYDRO DURING THE 2006 LIDAR SURVEY
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SCALE 1:10000 — 200 100 0 200 400 600 METRES

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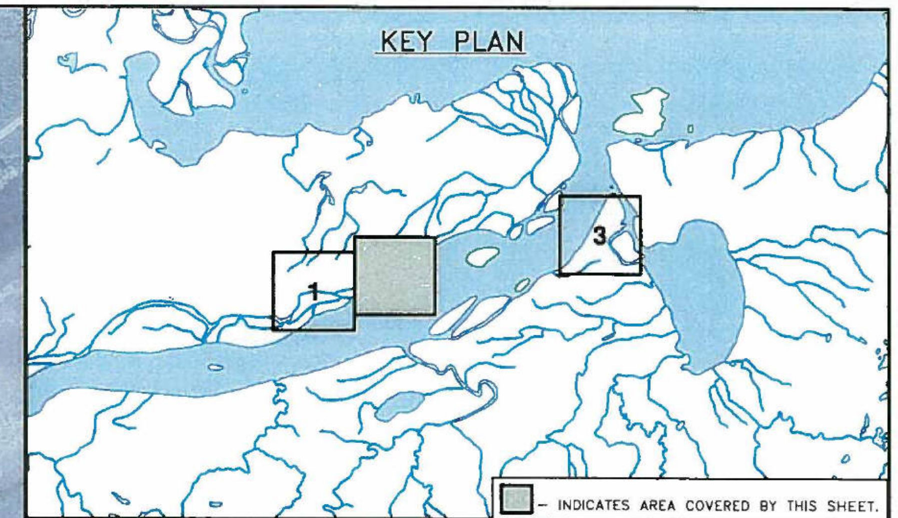
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE 1:10000

HATCH PROJECT No. H-325967

DRAWING NO. FIGURE C3-1



LEGEND

BREACH INUNDATION

NOTES:

1. ORTHOPHOTOS WERE OBTAINED BY NL HYDRO DURING THE 2006 LIDAR SURVEY
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SCALE 1:10000 — 200 100 0 200 400 600 METRES

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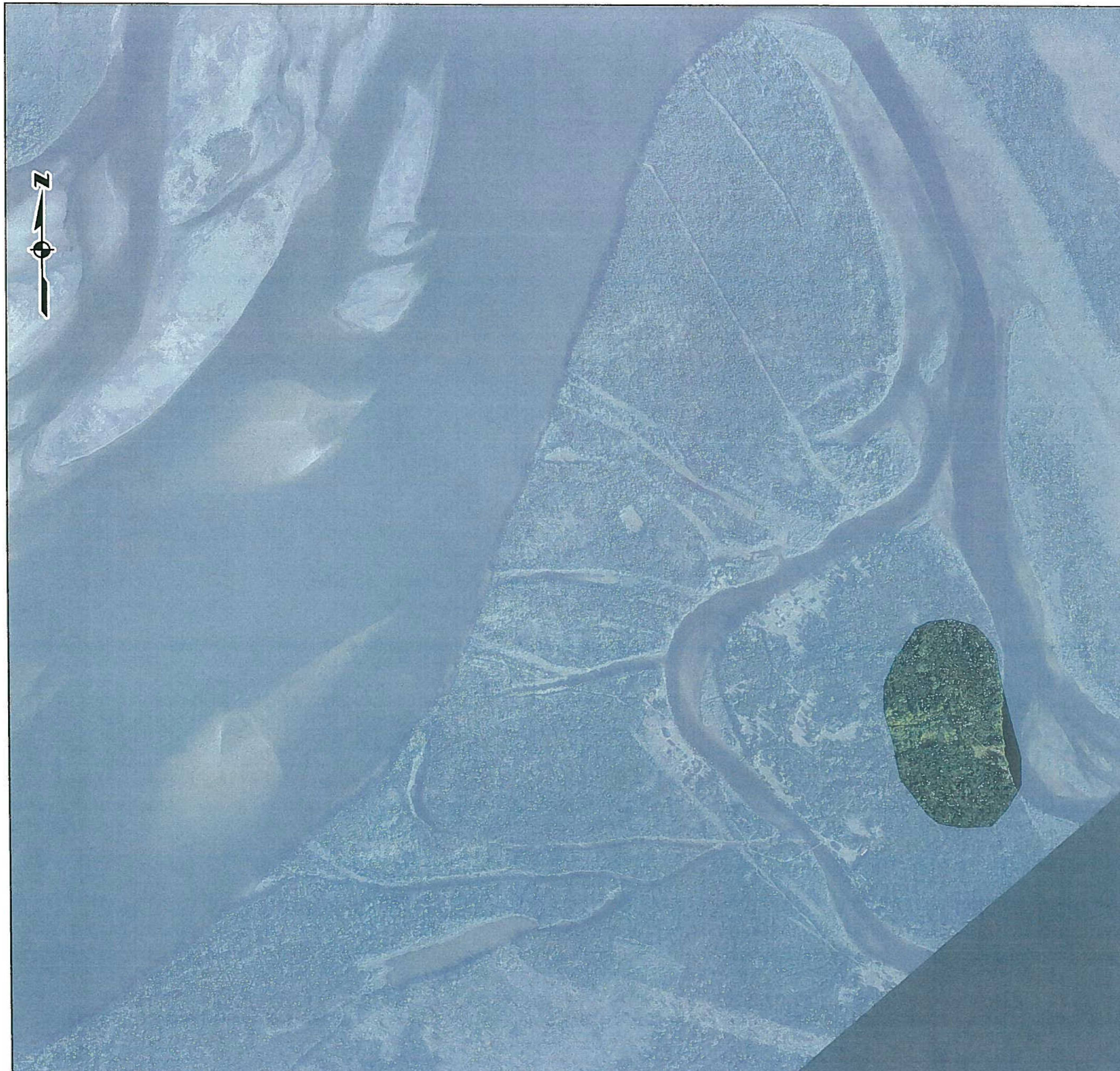
LOWER CHURCHILL PROJECT

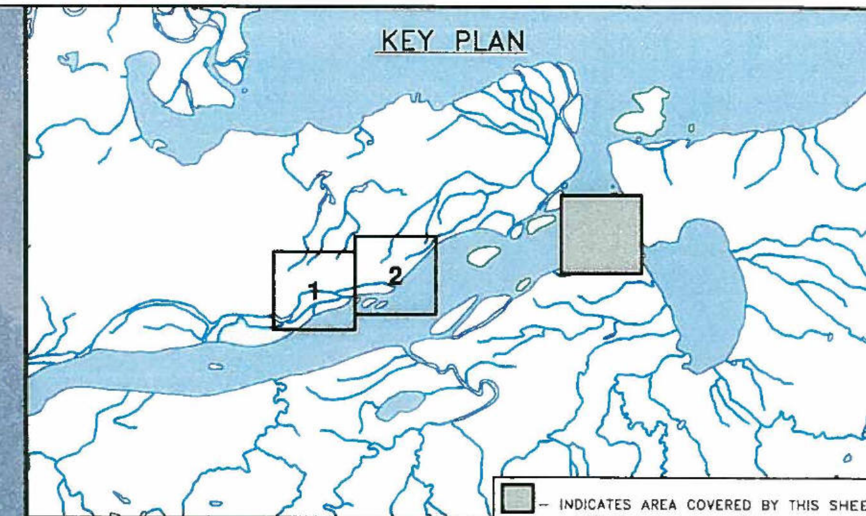
FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE 1:10000

HATCH PROJECT No. H-325967

DRAWING NO. FIGURE C3-2





LEGEND

BREACH INUNDATION

NOTES:

1. ORTHOPHOTOS WERE OBTAINED BY NL HYDRO DURING THE 2006 LIDAR SURVEY
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SCALE 1:10000 — 200 100 0 200 400 600 METRES

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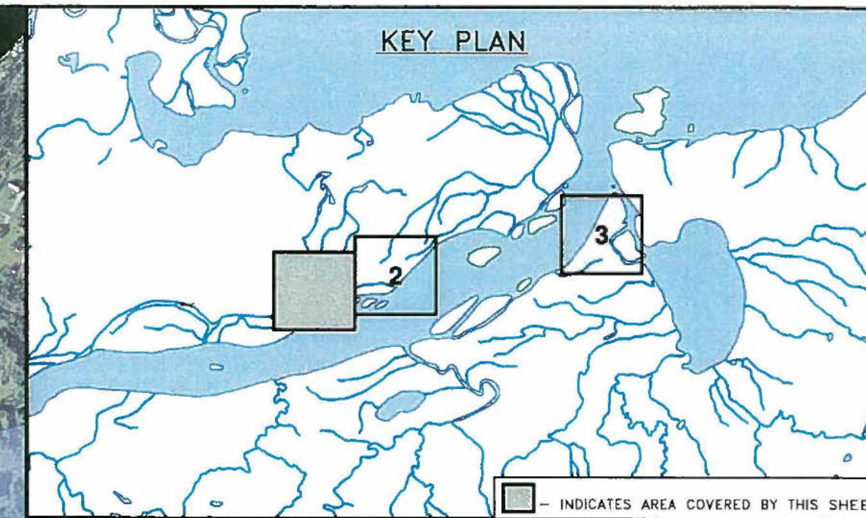
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE 1:10000	DRAWING NO. FIGURE C3-3
HATCH PROJECT No. H-325967	



LEGEND

BREACH INUNDATION

NOTES:

1. ORTHOPHOTOS WERE OBTAINED BY NL HYDRO DURING THE 2006 LIDAR SURVEY
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SCALE 1:10000

200 100 0 200 400 600 METRES

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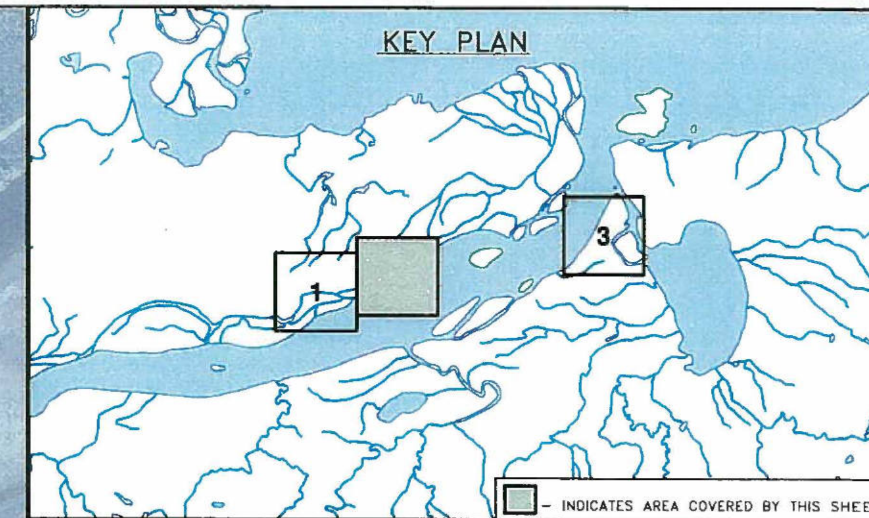
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND MUSKRAT FALLS NORTH RCC DAM

SCALE 1:10000

HATCH PROJECT No H-325967

DRAWING NO. FIGURE C4-1



LEGEND

BREACH INUNDATION

NOTES:

1. ORTHOPHOTOS WERE OBTAINED BY NL HYDRO DURING THE 2006 LIDAR SURVEY
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SCALE 1:10000 — 200 100 0 200 400 600 METRES

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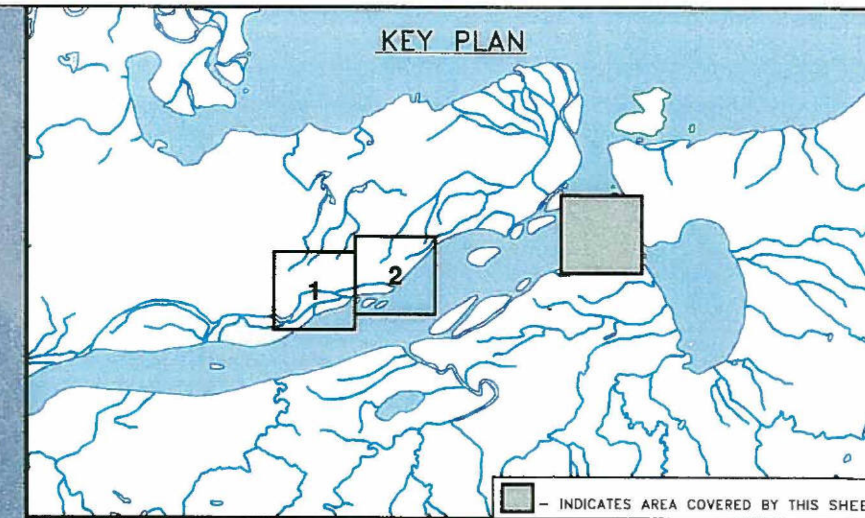
LOWER CHURCHILL PROJECT

FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND MUSKRAT FALLS NORTH RCC DAM

SCALE	DRAWING NO.
1:10000	FIGURE C4-2
HATCH PROJECT No H-325967	



LEGEND

BREACH INUNDATION

NOTES:

1. ORTHOPHOTOS WERE OBTAINED BY NL HYDRO DURING THE 2006 LIDAR SURVEY
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SCALE 1:10000 — 200 100 0 200 400 600 METRES

HATCH

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NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

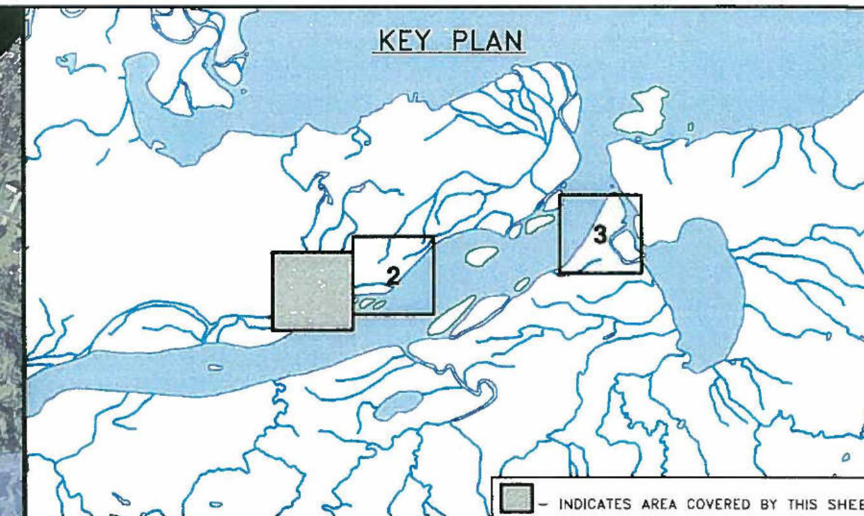
FAIR WEATHER CONDITIONS
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND MUSKRAT FALLS NORTH RCC DAM

SCALE 1:10000	DRAWING NO. FIGURE C4-3
HATCH PROJECT No H-325967	

Appendix D

PMF Inundation Mapping Series – Happy Valley-Goose Bay and Mud Lake

(1:10,000 Scale)



LEGEND

- FLOOD INUNDATION
- BREACH INUNDATION

NOTES:

1. ORTHOPHOTOS WERE OBTAINED BY NL HYDRO DURING THE 2006 LIDAR SURVEY
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.

SCALE 1:10000 — 200 100 0 200 400 600 METRES

HATCH™

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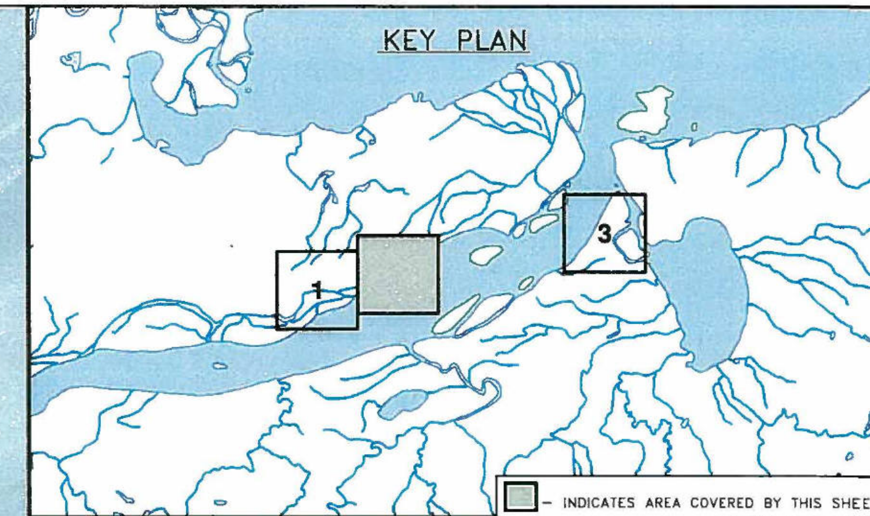
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE	DRAWING NO.
1:10000	FIGURE D1-1
HATCH PROJECT No. H-325967	



LEGEND

FLOOD INUNDATION

BREACH INUNDATION

NOTES:

1. ORTHOPHOTOS WERE OBTAINED BY NL HYDRO DURING THE 2006 LIDAR SURVEY

2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.

SCALE 1:10000 — 200 100 0 200 400 600 METRES

HATCH™

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NEWFOUNDLAND AND LABRADOR HYDRO

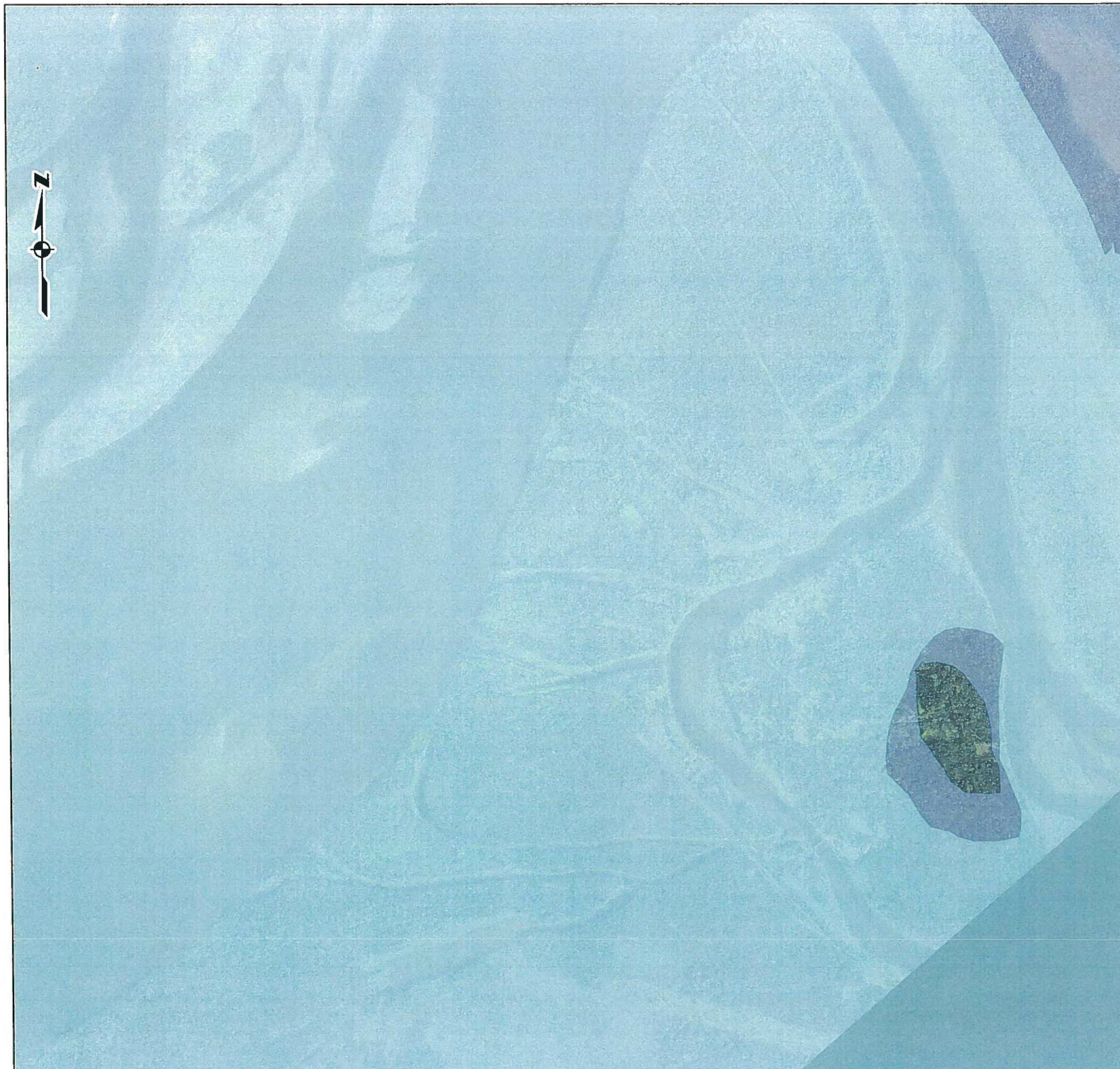
LOWER CHURCHILL PROJECT

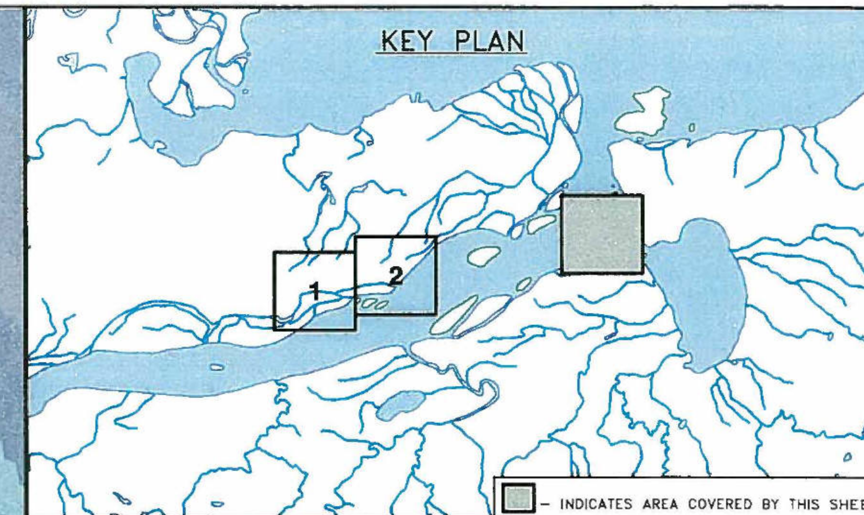
PROBABLE MAXIMUM FLOOD
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:10000

HATCH PROJECT No H-325967

DRAWING NO. FIGURE D1-2





LEGEND

FLOOD INUNDATION

BREACH INUNDATION

NOTES:

1. ORTHOPHOTOS WERE OBTAINED BY NL HYDRO DURING THE 2006 LIDAR SURVEY
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.

SCALE 1:10000 — 200 100 0 200 400 600 METRES

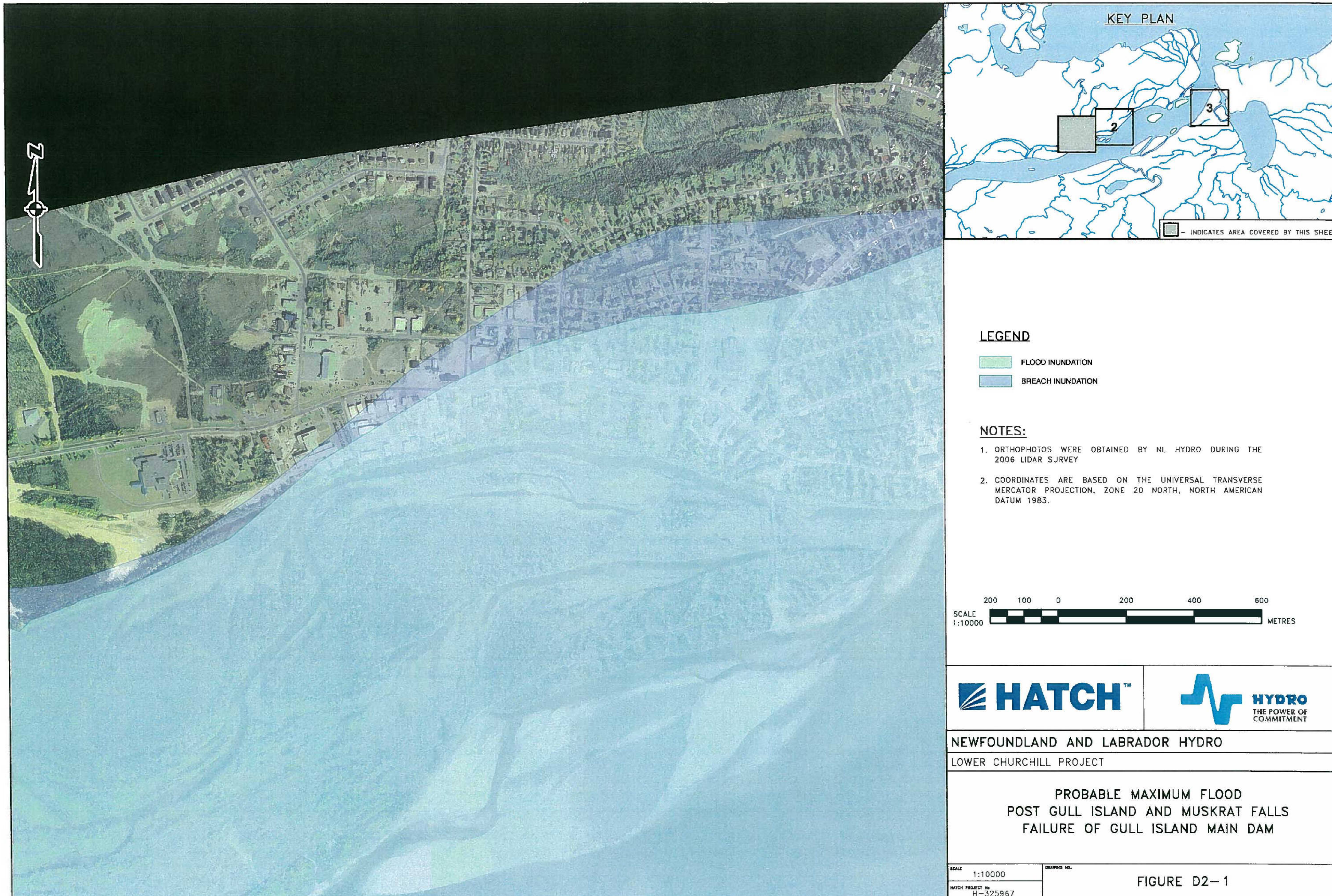
HATCH™ | HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:10000
HATCH PROJECT No H-325967
DRAWING NO. FIGURE D1-3



LEGEND

FLOOD INUNDATION
BREACH INUNDATION

NOTES:

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SCALE 1:10000 — 200 100 0 200 400 600 METRES

HATCH™

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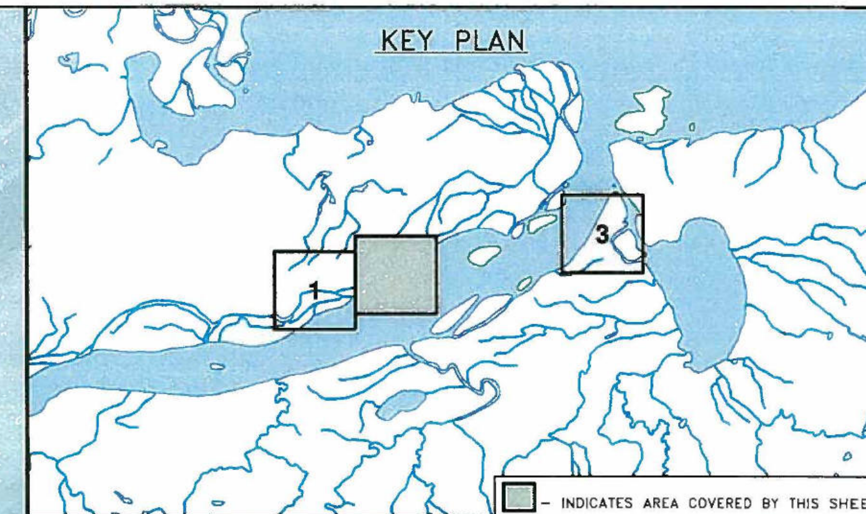
LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:10000
HATCH PROJECT No H-325967
DRAWING NO. FIGURE D2-1



LEGEND

- FLOOD INUNDATION
- BREACH INUNDATION

NOTES:

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2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.

SCALE 1:10000 — 200 100 0 200 400 600 METRES

HATCH™

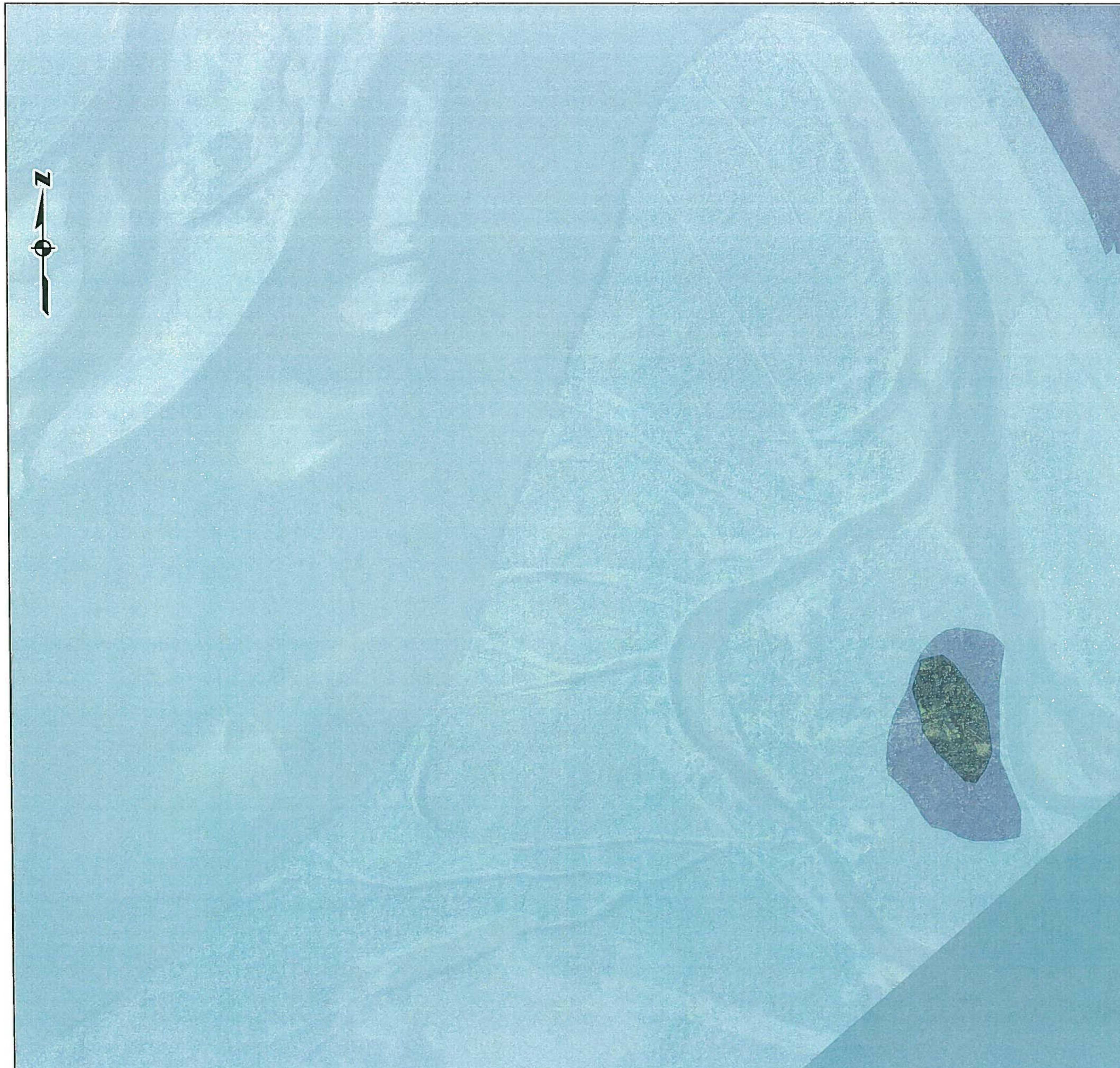
HYDRO THE POWER OF COMMITMENT

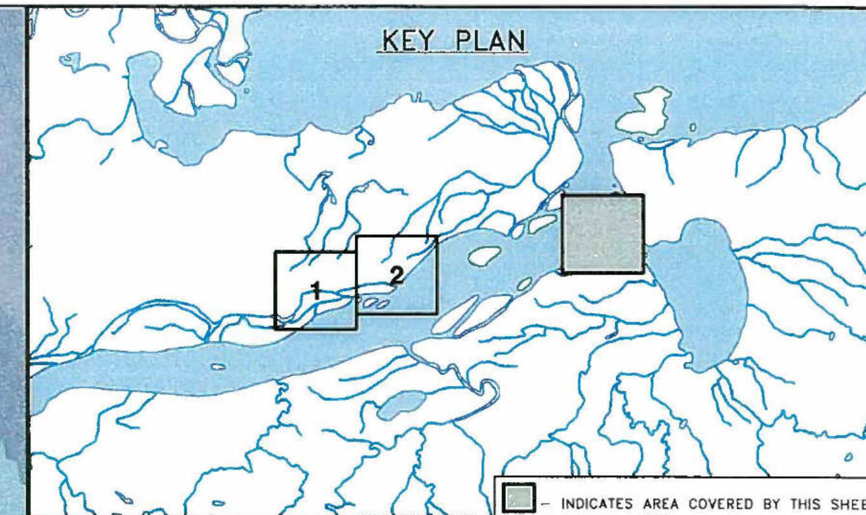
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:10000	DRAWING NO. FIGURE D2–2
HATCH PROJECT No. H–325967	





LEGEND

- FLOOD INUNDATION
- BREACH INUNDATION

NOTES:

1. ORTHOPHOTOS WERE OBTAINED BY NL HYDRO DURING THE 2006 LIDAR SURVEY
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.

SCALE 1:10000 — 200 100 0 200 400 600 METRES

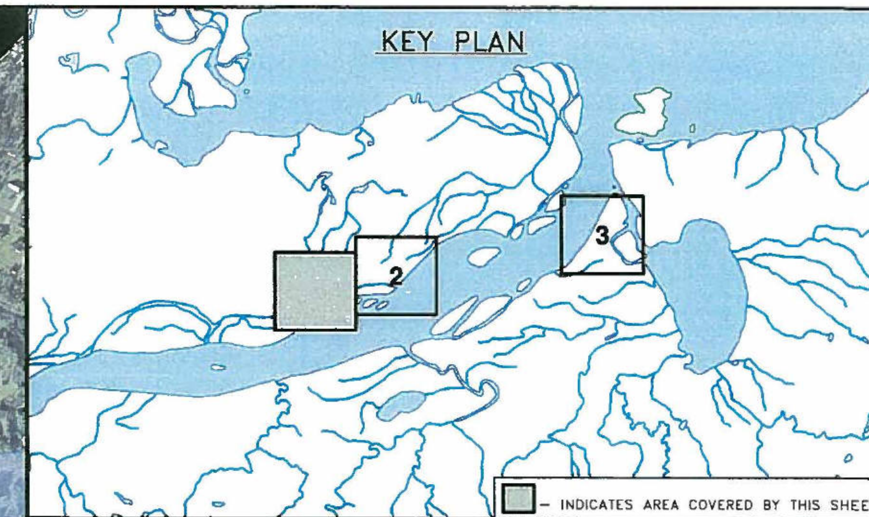
HATCH™ | HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM

SCALE 1:10000	DRAWING NO. FIGURE D2–3
HATCH PROJECT No. H–325967	



LEGEND

- FLOOD INUNDATION
- BREACH INUNDATION

NOTES:

1. ORTHOPHOTOS WERE OBTAINED BY NL HYDRO DURING THE 2006 LIDAR SURVEY
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.

SCALE 1:10000 — 200 100 0 200 400 600 METRES

HATCH™

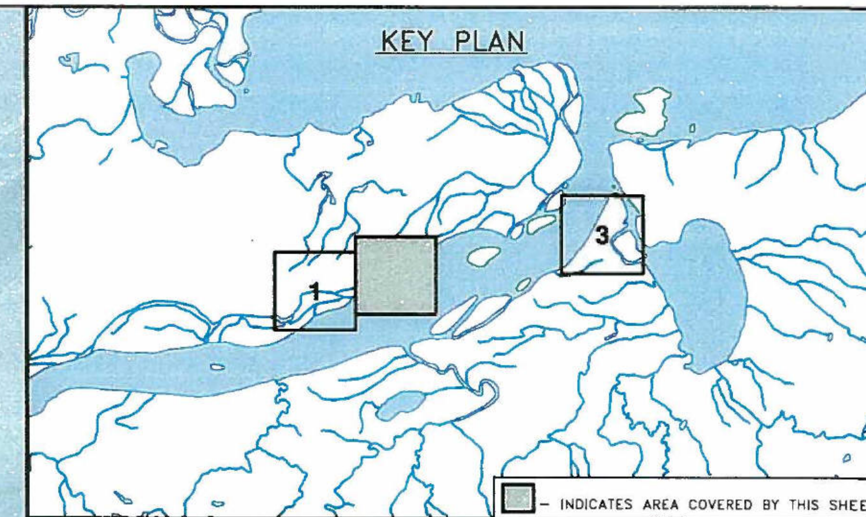
HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE 1:10000	DRAWING NO. FIGURE D3-1
HATCH PROJECT No. H-325967	



LEGEND

- FLOOD INUNDATION
- BREACH INUNDATION

NOTES:

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SCALE 1:10000 — 200 100 0 200 400 600 METRES

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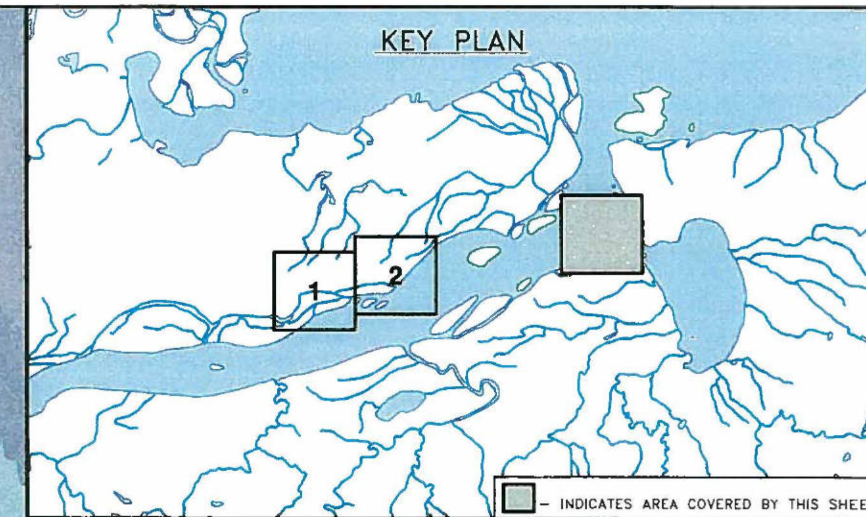
NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE	DRAWING NO.
1:10000	FIGURE D3-2
HATCH PROJECT No. H-325967	



LEGEND

FLOOD INUNDATION

BREACH INUNDATION

NOTES:

1. ORTHOPHOTOS WERE OBTAINED BY NL HYDRO DURING THE 2006 LIDAR SURVEY
2. COORDINATES ARE BASED ON THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 20 NORTH, NORTH AMERICAN DATUM 1983.

SCALE 1:10000 — 200 100 0 200 400 600 METRES

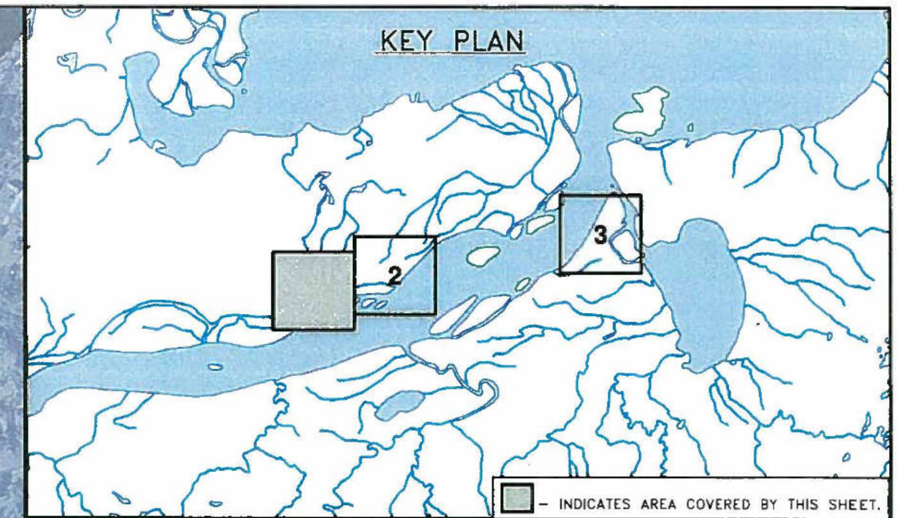
HATCH™ | HYDRO THE POWER OF COMMITMENT

NEWFOUNDLAND AND LABRADOR HYDRO

LOWER CHURCHILL PROJECT

PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF MUSKRAT FALLS NORTH RCC DAM

SCALE 1:10000	DRAWING NO. FIGURE D3-3
HATCH PROJECT No. H-325967	



LEGEND

FLOOD INUNDATION

BREACH INUNDATION

NOTES:

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SCALE 1:10000 — 200 100 0 200 400 600 METRES

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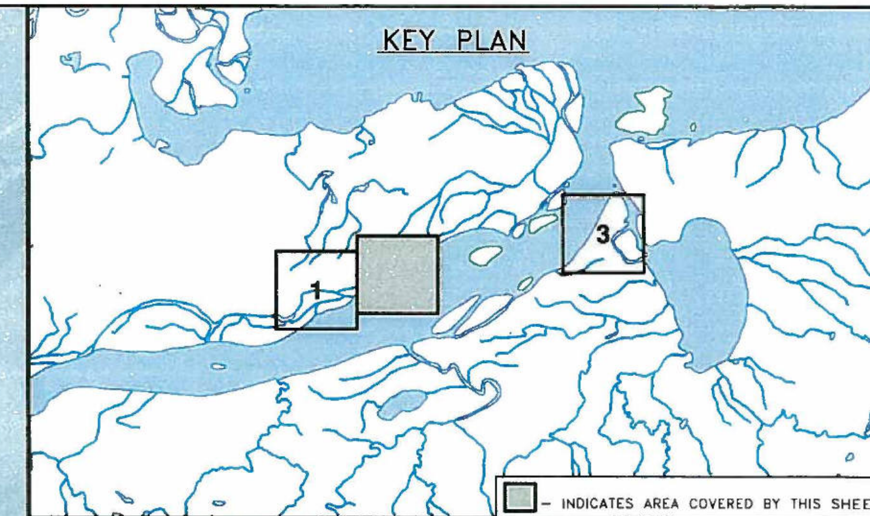
PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND MUSKRAT FALLS NORTH RCC DAM

SCALE 1:10000
HATCH PROJECT No. H-325967
DRAWING NO. FIGURE D4-1



LEGEND

- FLOOD INUNDATION
- BREACH INUNDATION

NOTES:

1. ORTHOPHOTOS WERE OBTAINED BY NL HYDRO DURING THE 2006 LIDAR SURVEY
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SCALE 1:10000

200 100 0 200 400 600 METRES

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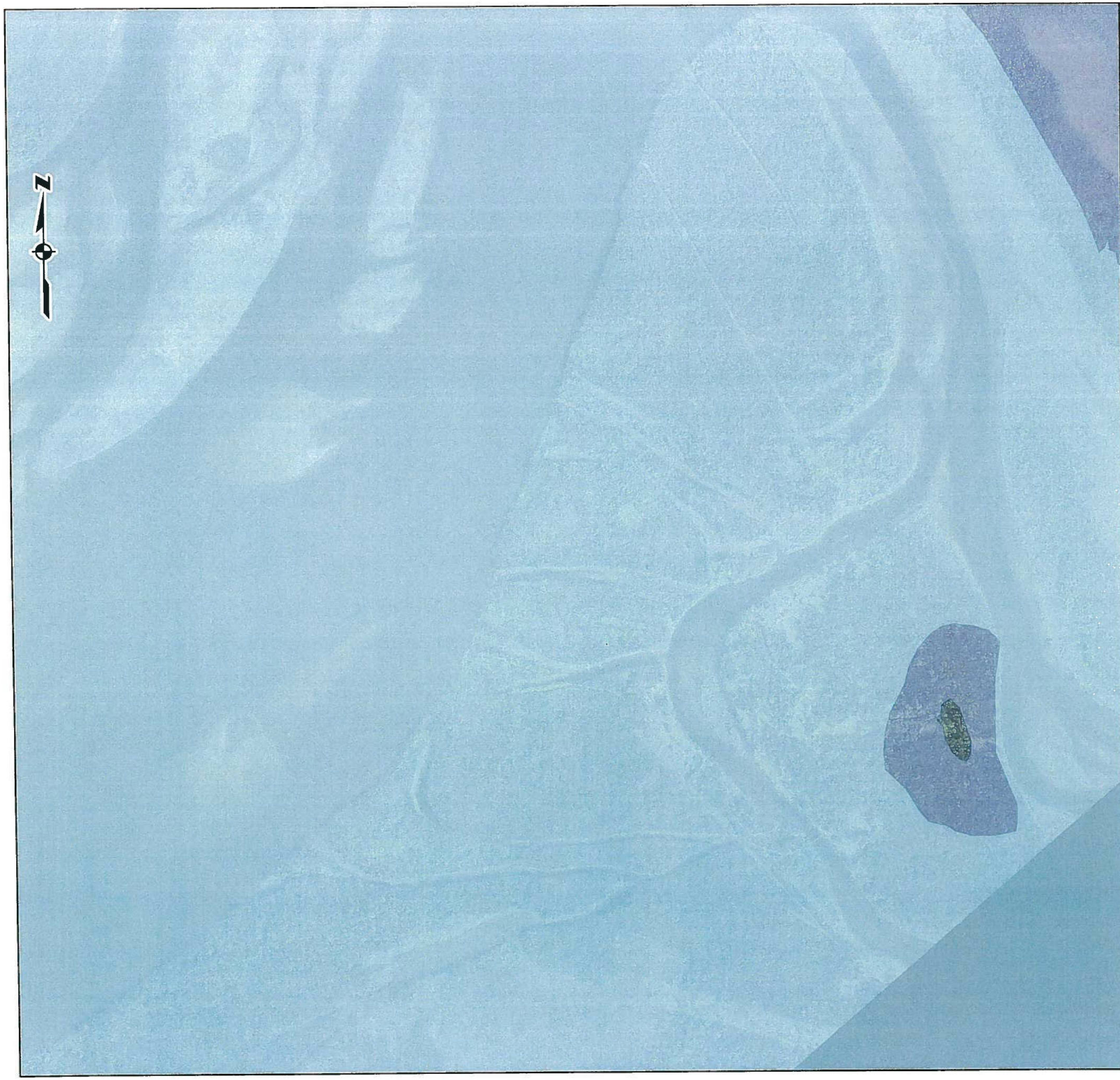
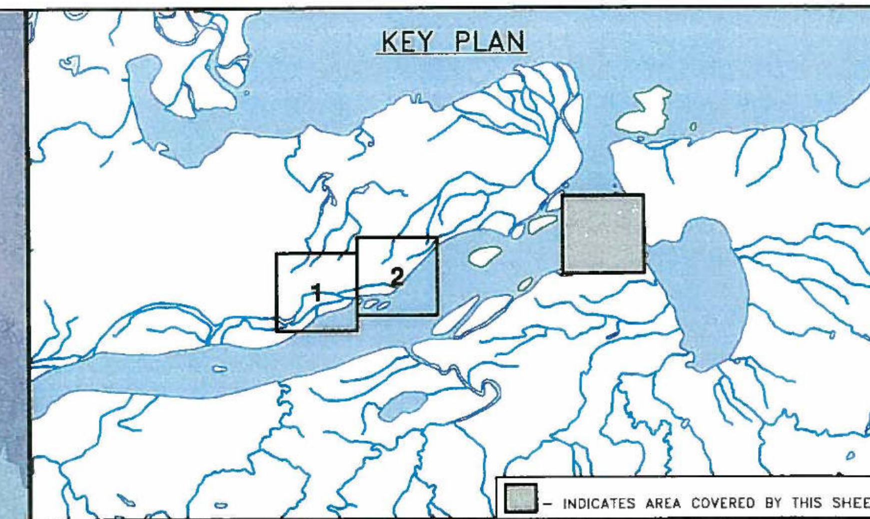
PROBABLE MAXIMUM FLOOD
POST GULL ISLAND AND MUSKRAT FALLS
FAILURE OF GULL ISLAND MAIN DAM AND MUSKRAT FALLS NORTH RCC DAM

SCALE 1:10000	DRAWING NO. FIGURE D4–2
HATCH PROJECT No. H–325967	





LEGEND

FLOOD INUNDATION

BREACH INUNDATION

NOTES:

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SCALE 1:10000

HATCH PROJECT No H-325967

DRAWING NO. FIGURE D4-3