FINAL WORKPLAN

TO INITIATE AND COMPLETE TWO SCALABLE COMPONENTS FROM THE 2013 LAKE CHAMPLAIN-RICHELIEU RIVER PLAN OF STUDY (POS):

1. **ADDRESS AND CLOSE DATA GAPS FOR THE EARLIEST POSSIBLE INITIATION OF A REAL-TIME FLOOD FORECASTING AND INUNDATION MAPPING SYSTEM**

2. **CREATE STATIC FLOOD INUNDATION MAPS**

Prepared for the

International Joint Commission

by the

International Lake Champlain - Richelieu River Technical Working Group

January 23, 2015

Table of Content

Index of Tables

Index of Figures

1. Background

On July 24 and July 31, 2014 the governments of the United States and Canada, in accordance with Article IX of the Boundary Waters Treaty, requested that the International Joint Commission (IJC) assist the two governments in the implementation of two components of the July 2013 Plan of Study (PoS) for "The Identification of Measures to Mitigate Flooding and the Impacts of Flooding of Lake Champlain and Richelieu River". The two scalable components from the PoS to be initiated and completed by the IJC are:

1. Addressing and closing data gaps through data collection and harmonization of topographic, bathymetric, aquatic vegetation, soil texture, LiDAR and observed climate and hydrometric data collection (per section 3.1, p. 34 of the July 2013 PoS) as are necessary as a basis for the earliest possible initiation of a real-time flood forecasting and inundation mapping system. This system would consist of the development of new real-time Lake Champlain and Richelieu River hydrologic and hydraulic models for predicting lake and river levels, and a precise Digital Elevation Model (DEM) of the flood plain to delineate the contours of corresponding inundated areas.
2. Creation of static flood inundation maps using a combination of existing and new data and modeling to provide practical information to communities. These maps would show which areas would be affected if Lake Champlain and Richelieu River water levels hit different heights.

The reference letters sent to the IJC by the U.S. and Canadian governments are provided in ***attachment 1***and ***attachment 2***.

In its 2013 Plan of Study (PoS) for the Identification of Measures to Mitigate Flooding and the Impacts of Flooding of Lake Champlain and Richelieu River, the IJC recommended that hydrologic and hydraulic modelling of the system be implemented. The PoS identified the basic elements that are required for the operation of a real-time flood forecasting and inundation mapping system, summarized below:

1. **Weather forecasts** with high resolution wind, precipitation and temperature estimates and a precise evaluation of the snowpack;
2. A **Digital Terrain Model** of the flood plain (horizontal resolution of 1m, vertical resolution of 0.25m) and of the watershed's geophysical characteristics (horizontal resolution of 100m and vertical resolution of 1m);
3. **Hydrological modelling** capacity for the estimation of water supplies to the watershed with a lead-time as long as possible.
4. A **Hydraulic modelling** capacity to simulate the response of Lake Champlain and the Richelieu River to predicted water supplies and winds.

Recognizing that the implementation of such an operational system on the Lake Champlain – Richelieu River basin is beyond the scope of this directive and associated timeline and resources, some gaps in specific aspects of the required elements for the operational system will be addressed by the component 1 of the IJC directive. A combination of existing and new data and models will be used to generate static maps of flood inundation under specific scenarios in

response to component 2 of the directive. Figure 1 provides the geographical extent of the Lake Champlain – Richelieu River basin.

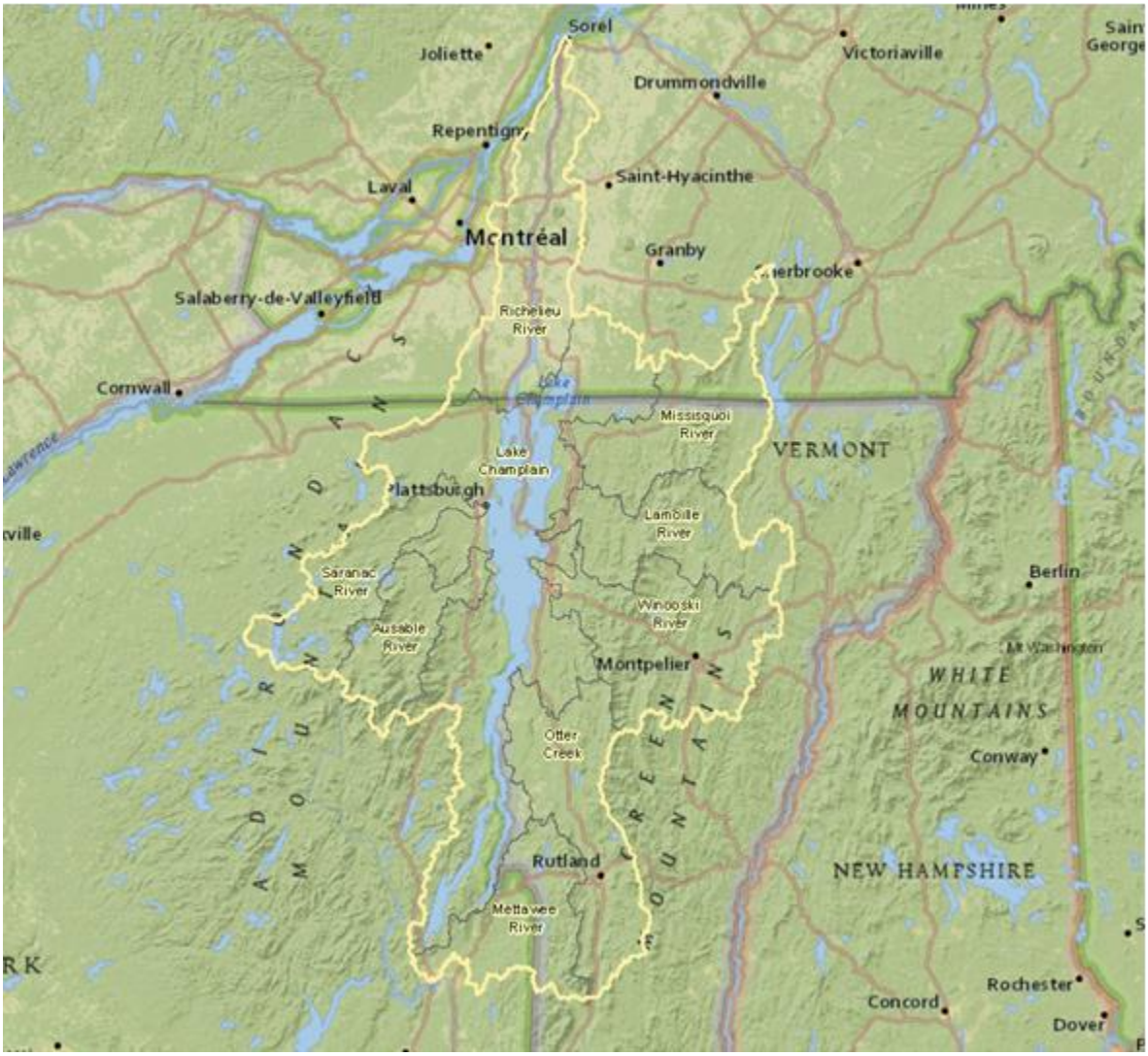

Figure 1 Lake Champlain – Richelieu River basin

2. Organization of the Study

In response to the government's joint reference, the IJC has developed a directive to establish and direct the International Lake Champlain-Richelieu River Technical Working Group (ILCRRTWG) to examine and report to the IJC on the matters identified by the governments in their July 24 and July 31, 2014 reference letters to the Commission on Lake Champlain and Richelieu River flooding. The directive is provided in ***attachment 3***.

The ILCRRTWG comprises an equal number of members from each country, with Co-Chairs appointed by the Commission to organize and execute the work of the ILCRRTWG and for

coordinating with and reporting to the Commission. The members of the ILCRRTWG are listed in ***attachment 4***.

The Commission has entered into an agreement with the U.S. Geological Survey (USGS), New England Water Science Center, to conduct the U.S. portion of the technical work associated with the Work Plan. A (USGS) Hydrologist (Engineer) will perform this technical work on the US activities of this work plan and assist the ILCRRTWG as needed. The Commission has also contracted with the Lake Champlain Basin Program through the New England Interstate Water Pollution Control Commission to provide secretariat duties as are assigned by the Co-Chairs or the ILCRRTWG as a whole, including logistical support for meetings, recording meeting minutes, assistance with presentations, communication with local and regional partners, public outreach, and facilitation of data storage and access. The ILCRRTWG is to work with the IJC, providing technical evaluations and guidance on how best to complete the reference study within the budget and time frame included in the reference from governments. An additional secretariat member as also been provided by the IJC to provide French language services for the public where necessary and to complement the ILCRRTWG's secretariat role.

The reference study will incorporate and take advantage of existing collaborations and government mechanisms already in place on both sides of the border, including work at both the state and provincial levels.

The governments have tasked the IJC with producing a final report on the above activities by September 2015. Deliverables of the two directive components will take the form of consolidated reports, maps, data, presentations, web sites and other to be determined products. Recommendations for future activities to further flood forecasting and preparedness in the Lake Champlain and Richelieu River system will be included in the final report. All the costs, and expected date of completion of each task are provided in Table 2.

3. Scope of Work

3.1 Component 1 of the directive: Addressing and closing data gaps for the earliest possible initiation of a real-time flood forecasting and inundation mapping system.

Current forecasts of Lake Champlain water levels are produced in real-time and disseminated by the U.S. National Weather Service (NWS[1]) for 3-day horizons and are based on hydrological modeling of lake's inflows, 1D-hydraulic modelling[2] of the lake, and rules-of-the-thumb appreciation of wind-induced effects. These forecasts serve, together with long-term monitoring data performed by Environment Canada (EC[3]) and hydrological modeling of the Richelieu River lateral inflow performed on the Quebec side, as input for predictions of stream flows of the

[1] http://water.weather.gov/ahps2/hydrograph.php?wfo=btv&gage=roun6

[2] A 1D model provides estimations of discharge, water levels and average velocity at discreet cross-sections, whereas a 2D model provides estimation of local discharge, water levels, intensity and direction of velocities points disseminated on a surface representing the water body.

[3] http://eau.ec.gc.ca/report/report_f.html?mode=Graph&type=realTime&stn=02OJ007&dataType=Real-Time&startDate=2015-01-14&endDate=2015-01-21&prm1=47&y1Max=&y1Min=&prm2=-1&y2Max=&y2Min=

Richelieu River produced and disseminated by the Centre d'expertise hydrique du Quebec (CEHQ[4]).

Initial discussions identified the incorporation of the wind setup (seiche effects) on the system as a critical step toward an operational flood forecasting and inundation mapping system. To achieve this, the predictions of the wind distribution in space and time must show sufficient resolution and precision, and the hydraulic component of the system must be responsive to this input, in order to simulate observations as close as possible in the main body of the lake and on its Inland Sea and Mississquoi Bay portions. The quality of precipitation estimates from weather forecast models and observations is also viewed as essential and should be assessed, including the snow-water equivalent during the winter/spring months. To conduct those assessments observations from monitoring stations and gridded datasets from predictive weather and climate products including snow pack must be compiled.

Achieving the best possible flood prediction and inundation mapping on an international, trans-boundary system such as the Lake Champlain – Richelieu River presents a governance challenge on top of the technical aspects. Multiple options are available and choices will be required. The tools (predictive models and data) covering the watershed could be developed and provided in independent U.S. and Canadian components, one feeding the other. There could be one mutually-developed common system used by only one or both countries. Or, each country could develop its own system, taking advantage of the redundancy to publish optimized flood predictions and inundation maps. Incidentally, the 2013 IJC PoS promoted redundancy and diversity to reduce model-specific bias and uncertainties in the predictions. This is not a trivial choice, with exchange mechanisms and technical, capacity and governance issues involved. Examples of existing flood prediction systems and boundary waters modelling efforts such as those in operation on the Great Lakes will serve as examples for use in the Lake Champlain – Richelieu River system.

The following tasks are therefore proposed to achieve those objectives:

3.1.1 Task 1-1: Assess the quality of surface wind predictions and precipitation analyses (EC-RPN-E[5])

Surface wind predictions, precipitation and temperature forecasts will be assessed over the entire Lake Champlain and Richelieu River basin at various resolutions and lead times, with the objective of recommending appropriate horizontal resolution and lead time for a forecasting system. In order to forecast the water level of Lake Champlain and the stream flow of the Richelieu River using numerical models, it is critical to obtain high-quality forecasts of the main atmospheric forcing variables, namely wind speed over the water (which controls storm surges and seiches), precipitation over the lake and over the watershed (which controls tributary flow and directly affects the water level of the lake), and temperature over the watershed (which controls snowmelt). The skill[6] of temperature, precipitation and wind speed forecasts decreases rapidly with increasing lead time: a one day ahead forecast will have much more skill than a five day ahead forecast. There are two main reasons for this: (1) the chaotic nature of the atmosphere, and (2) the accuracy of the Numerical Weather Prediction (NWP) system. In a watershed with

[4] https://www.cehq.gouv.qc.ca/suivihydro/graphique.asp?NoStation=030401
[5] Environnement Canada – Recherche en Prévision Numérique - Environment
[6] Forecast skill is defined as the performance of a particular forecast system in comparison to some other reference technique

significant topography such as that found in the Lake Champlain basin, significant improvements to the skill of weather forecasts can be obtained by increasing the resolution of the atmospheric model.

The quality of a selection of numerical products will be assessed. Table 1 details those specific products from EC, the National Oceanic and Atmospheric Administration's National Centers for Environmental Prediction (NOAA NCEP), European Centre for Medium-range Weather Forecasts (ECMWF) and from NOAA Burlington Weather Forecast Office (NOAA BTV WFO).

Table 1 Numerical Weather Forecast products included in Task 1-1 analysis

Model	Surface Wind	Precipitation	Temperature	Agency
High Resolution Deterministic Prediction System (HRDPS)	X	X	X	EC
Regional Deterministic Prediction System (RDPS)	X	X	X	EC
Regional Ensemble Prediction System (REPS)	X	X	X	EC
Global Deterministic Prediction System (GDPS)	X	X	X	EC
Global Ensemble Prediction System (GEPS)	X	X	X	EC
High Resolution Window - Nonhydrostatic Mesoscale Model (HRW-NMM)	X	X	X	NOAA NCEP
Weather Research & Forecasting - North American Model (WRF-NAM)	X	X	X	NOAA NCEP
High Resolution Window - Advanced Research WRF (HRW-ARW)	X	X	X	NOAA NCEP
Short Range Ensemble Forecast (SREF)	X	X	X	NOAA NCEP
Global Forecast System (GFS)	X	X	X	NOAA NCEP
Global Ensemble Forecast System (GEFS)	X	X	X	NOAA NCEP

European Centre for Medium-range Weather Forecasts (ECMWF)	X	X	X	ECMWF
Local Burlington 4-km WRF-NAM	X			NOAA BTV WFO

This task aims to document the skill of operational and experimental weather forecasting systems as a function of lead time and horizontal resolution during extreme events having affected the watershed over the last few years. The following will be carried out:

a) The skill of wind forecasts from models presenting different resolutions will be assessed for the 30 largest events of wind set-up on Lake Champlain between 2011 and 2014.
b) The skill of precipitation forecasts will be assessed for all extra-tropical storms which affected the watershed between 2011 and 2014. The NOAA / National Hurricane Center (NHC) database will be used to identify the storms. The reference for precipitation will be the NOAA/NWS Stage IV analysis in the US and the EC / Canadian Precipitation Analysis (CaPA) in Canada. The Brier skill score will also be computed as a function of lead time and daily forecasted precipitation amount for each season.
c) The skill of degree-day forecasts will be assessed for all significant snowmelt events between 2011 and 2014. The NOAA/ National Operational Hydrologic Remote Sensing Center (NOHRSC) snow analysis will be used to identify significant snowmelt events at the watershed scale.

This task will make it possible:

(a) To determine how many days ahead we should be able to forecast impacts on water levels of temperature, precipitation and wind with current NWP technology;
(b) To determine if and by how much increases in horizontal resolution improve the skill of the forecasts;
(c) To assess the added value of ensemble forecasts as a function of lead time.
A technical report will be prepared including recommendations as to the horizontal resolution and lead time of a forecasting system specifically designed for Lake Champlain and the Richelieu River. Computing cost and computing time for such a system will be assessed. Both deterministic and ensemble forecasting systems will be considered.

Task 1-1 will be conducted under EC-RPN-E leadership, will begin in early 2015, with expected completion by August 2015.

3.1.2 Task 1-2: Develop an experimental 2D hydrodynamic model of Lake Champlain, using existing bathymetric data (EC-NHS[7])

A 2D finite element (FE) model of Lake Champlain is expected to simulate the hydraulic response, more specifically the water levels, under a variety of inflowing waters and wind scenarios. The wind set-up for Lake Champlain significantly influences the flooding on the Lake itself and also on the Richelieu River. Wave set-up, run-up and over-topping are not part of this experimental model, nor are the 3D complexity of the flows in areas where it's not forced by

[7] Environment Canada – National Hydrological Services

gravity (*i.e*., winds etc.). The essential objective of this task is to assess the responsiveness of a 2D model to Lake Champlain water supplies and wind input, and its capacity to adequately simulate water levels at an appropriate spatial resolution on the Lake Champlain, while providing seamless upper limit boundary conditions to the Richelieu River hydraulic model (see task 2-3), creating a continuous hydraulic model of the Lake Champlain and Richelieu River.

The downstream limit of the Lake Champlain model will be placed below the Saint-Jean shoal (figure 2), to ensure that the shoals critical section actually serves as the hydraulic control of the entire Lake Champlain – Richelieu River system, overlapping with the upstream portion of the Richelieu River hydraulic model. This task will start in early 2015.

The main activities are described below:

1. A scenario analysis will be carried out that will include an identification of the main tributaries that will be included into the model domain. All water inflows to the lake will be distributed among those tributaries. Collation of datasets for calibration purpose (coincident water levels and longitudinal water surface profiles for Richelieu River flows between 550m^3/s and 1500m^3/s, wind speed, inflow). Determination of the upstream boundary location between Port Henry and Whitehall. A database of all required U.S. and Canadian inflows will be developed, in collaboration with the USGS (see task 2-1).
2. Digital Elevation Model (DEM): Lake shore elevation data and the Lake Champlain bathymetry shall be collected or obtained and processed to be incorporated into the hydraulic model. Bathymetric datasets from Middlebury College and the Vermont Center for Geographic Information will begathered with the assistance of the Lake Champlain Basin Program and the USGS.. The observed difference between the vertical datums used by Canada and the U.S. will be addressed in its simplest form by use of a constant transformation, or according to a more sophisticated protocol that Task 1-6 may establish.
3. Digitization of man-made structures such as bridges, piers, causeways, etc. which can affect the hydrodynamics will be incorporated in the FE mesh.
4. Development of a finite element mesh for production of the hydrodynamic mesh for Lake Champlain respecting the criteria of the preceding tasks.
5. Calibration and validation of the hydrodynamic model simulations will be carried out, especially for wind input. Performance measures will be used to assess model performance at locations where observations are also collected. These performance measures will include (a) mean error between simulations and observations, (b) mean absolute error between simulations and observations, (c) root mean error between simulations and observations, and (d) Pearson correlation coefficient (r) of observed to simulated elevations.
6. Report: description of the hydrodynamic modeling work that was done and results of the model calibration.

Task 1-2 will be conducted under EC-NHS leadership. Preliminary activities (1 to 4) up to the FE mesh will be completed by the end of April 2015. May to August 2015 will be dedicated to calibration/validation and production of the simulations and water surface profiles. The technical report will be completed in August 2015.

3.1.3 Task 1-3: Establish a coordination mechanism to exchange data of interest (ILCRRTWG)

A basin-wide governance gap with respect to flood preparedness and coordination among jurisdictions had been identified in the 2013 plan of study for the Identification of Measures to Mitigate Flooding and the Impacts of Flooding of Lake Champlain and Richelieu River. As an initial step, a coordination mechanism to facilitate the exchange of data produced in both countries will be established at the technical level to support this study. This task will start in December 2014.

Relevant data and information such as observations of precipitation, temperatures, winds, radar data, water levels, inflows, topometric and bathymetric data, precipitation analyses including snowpack, and results from weather and hydrological and climate forecast models, and hydraulic models will be shared through the use of a combination of means, including dissemination mechanisms from relevant data providers, the Lake Champlain Basin Program (LCBP) FTP site, IJC sharepoint and internet sites. When required, an exchange of letters between the IJC and the governments will be carried out.

Task 1-3 will be conducted under the ILCRRTWG leadership in collaboration with the LCBP and IJC. ILCRRTWG were provided with login credentials to the LCBP ftp site, and the IJC has provided credentials for ILCRRTWG members to access its sharepoint site.

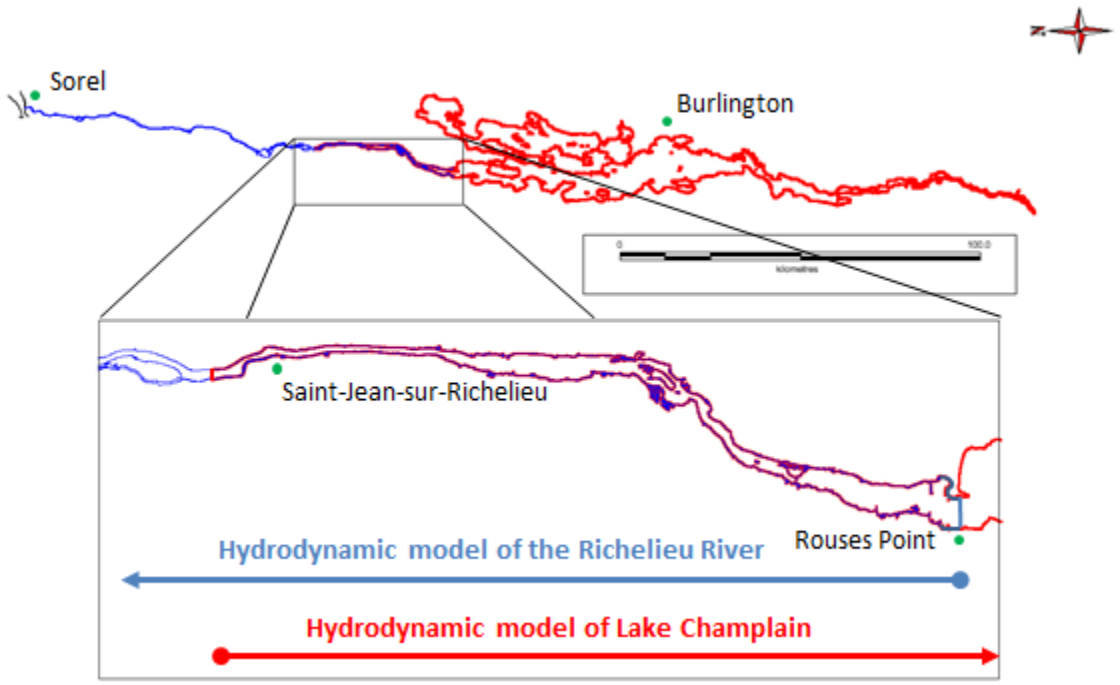

Figure 2 Spatial coverage of the Lake Champlain and Richelieu River models

3.1.4 Task 1-4: Recommend a pragmatic approach for the future operational real-time flood forecasting and inundation mapping system for the Lake Champlain and Richelieu River flood plain (ILCRRTWG).

The ILCRRTWG will work on defining the best form of the next generation lake and river forecasting models, the data needed for the models, how the models are to provide useable information on both sides of the border, and how they will be operationally administered. In recent discussions, some of the agencies involved in lake modeling expressed various opinions on what is needed for improved predictions and mapping of the flood plain. The recommended approach shall address the governance, technological, operating costs and required long-term exchange mechanisms between Canada, U.S., Vermont, New York and Quebec. At a minimum, the following aspects will be included in the recommendations to the IJC:

- Performance requirements for the system: (Spatial and temporal resolution of the system, prediction lead-time, accuracy and precision, incorporation of water inflows, wind-induced seiche and wave effects on the domain, computational requirements);
- Results from consultations with experts through a technical workshop to be held on the margins of the Conference on Great Lakes Research organized by the International Association for Great Lakes Research (IAGLR), May 25-29, 2015 in Burlington, Vermont.
- Review of governance models and operating costs considerations and,
- Recommendations addressing the technological, operating costs and governance aspects of a flood forecast and real-time flood plain mapping system.

Other potential contributions to this task will be evaluated through contacts with subject-matter experts, literature review, and studies such as the investigations undertaken by NOAA on the incorporation of wind set-up in its Lake Champlain forecasts.

Preliminary discussions of the modelling approach at the first meeting of the ILCRRTWG in December 2014 identified that approaches used for flood forecasting in the Great Lakes may be a good model for the Lake Champlain – Richelieu River system. This will be explored further by the ILCRRTWG.

Task 1-4 will be conducted under the ILCRRTWG leadership. Expected completion in August 2015.

3.1.5 Task 1-5 Collection and processing of LiDAR Data for Lake Champlain (USGS).

The USGS will supplement their current fiscal year (FY) 2014 Lake Champlain LiDAR project for New York that covers approximately 2000 square miles in Essex and Clinton counties including the Lake Champlain, Au Sable and portions of the Saranac watersheds. It is being collected at a 3D Elevation Program (3DEP) Quality Level 2 specification which includes a vertical accuracy of 9.25 cm, a DEM of 0.7M resolution, projection of Universal Transverse Mercator (UTM) Zone 18N (meters) and 1500 x 1500 meter tiling schema. The project is being flown with leaf off, snow off and acquisition preference given to the shoreline during fall traditional low water level. Funding will be provided by the USGS 3DEP, and the US Department of Agriculture, Natural Resources Conservation Service. The LiDAR data produced for this effort will become part of the National Elevation Dataset (NED).

As of December 1, 2014, LiDAR has been flown for the Vermont side of Lake Champlain. With the exception of Chittenden County, all other locations on the Vermont side of Lake Champlain

have had the LiDAR data processed and the data is ready to use. The USGS has a commitment from the contractor that processing of the Chittenden County LiDAR data along the shore of Lake Champlain will be completed by June 2015. The northern half of the NY side of Lake Champlain has been flown. The southern half has not been flown and will not be flown until the spring of 2015 and that data will be available later in 2015. Processed and quality controlled LiDAR data will be provided to the ILCRRTWG and maintained in the study data bases at IJC and the LCBP as it is provided to USGS from the contractor.

Task 1-5 will be conducted under USGS leadership. Expected completion date: September 30, 2015.

3.1.6 Task 1-6 Address Border Datum Issue (USGS, NOAA, NRCan, Environment Canada)

A difference of some 11cm is observed in the upper Richelieu area between the commonly used U.S. and Canadian vertical datums (NAVD1929 and CGVD1928). Such a difference must be addressed, as it may induce a considerable discrepancy in the delineation of flood plains in such a flat area. The vertical datum correction is not simply a matter of applying a single offset value (e.g., it is not a shift and, as such, the correction for Richelieu River is different than for a location on Lake Champlain).

The objective of this effort is the creation of a vertical datum transformation so that all of the data in the study area (comprised of the Lake Champlain, Richelieu River, and their flood plains) will be usable in either NAVD 88 or CGVD2013 geoid based datums.

A Global Navigation Satellite System (GNSS) survey will be performed to achieve centimetre precision level ellipsoid heights referenced to the latest US realization of the North American Datum of 1983 (NAD 83), currently NAD 83(2011) epoch 2010.00 (this geometric reference frame is equivalent to the Canadian NAD83(CSRS) epoch 2010.0). NAVD 88 or CGVD2013 orthometric heights will be determined by applying either GEOID12A or CGG2013 geoid heights, respectively.

The following steps will be taken for a harmonized datum in the Lake Champlain-Richelieu River basin:

- acquire centimetric precision GNSS observations at 7 water level lake gage and streamgage benchmarks (Whitehall, Burlington, Rouses Point, Phillipsburgh, Saint-Paul de l'Ile aux Noix, Saint-Jean-sur-Richelieu, and Sorel St. Lawrence) and 2 hydro-sensitive locations (Chambly and Saint-Ours dams) to allow determination of their ellipsoidal heights and allow the application of modern geoid models (currently Geoid12A and CCG2013.
- GNSS survey of the water level gages will consist of simultaneous 12-hour observations, followed by simultaneous 6-hour observations on a different day for redundancy. The survey will be conducted using dual-frequency geodetic grade receivers.
- In locations where existing reference marks cannot be surveyed directly, new reference marks will be set and observed. Geodetic leveling observations will be conducted between the new reference mark and the existing reference marks in the immediate area, as well as to the water level gauge itself.

- Produce the vertical datum transformation for water levels water level stations on the Lake and upper Richelieu River.

The GNSS data and metadata collected will be made available to USGS, EC, National Geodetic Survey (NGS) and NRCan. The data will be processed using NGS's OPUS (Online Positioning User Service) and NRCan's CSRS-PPP (Precise Point Processing) applications. Each of the OPUS solutions will be "shared" to the OPUS database, where their ellipsoid height can be further used to help refine the US hybrid geoid model if and where necessary. A USGS Open-File Report will present results.

Task 1-6 will be conducted under USGS leadership with the support of staff from the US National Geodetic Survey, EC and NRCan. Expected completion of the field work is April 2015, and the USGS report by September 30, 2015.

3.1.7Task 1-7 Collection of new in-lake and watershed data to assist with flood forecasting and inundation mapping system (USGS)

The USGS will establish two USGS Lake Water Level and Meteorological Gages: These gages will be located on Lake Champlain at Port Henry New York and on the east side of Grand Isle (or South Hero Island), Vermont. These locations were endorsed by the ILCRRTWG as the 2 most desirable for new lake level gages. The Port Henry gage would fill a spatial gap in data for the southern portion of the Lake and is anticipated to be a long-term gage (beyond the dates of this agreement) as part of the annual IJC-USGS stream gaging agreement. The Grand Isle (or South Hero Island) lake level gage is designed to better quantify the seiche effects in the Inland Sea / Mississquoi Bay area and would be installed/operated for a period of 6 months. Both gages would be operational by April 1, 2015. Fifteen minute lake level data would be collected by the gages, transmitted in near real-time (one hour delay) and posted on the USGS National Water Information System public web page. Meteorological data collected will include wind speed/direction and air temperature (precipitation would be collected at the Port Henry site only as a local weather monitoring site already exists on Grand Isle).

Task 1-7 will be conducted under USGS leadership. Gage installation and operation initiated by April 1, 2015 and data collection completed by September 30, 2015.

3.1.8 Task 1-8 Collection of new substratum, aquatic plant assemblages and distribution in the Richelieu River between Saint-Jean-sur-Richelieu and Rouses Point on the Lake Champlain (EC-NHS)

Assessment of the aquatic plant assemblages and distribution in the upper reach of the Richelieu River and sampling of substratum characteristics, essentially between the municipality of Saint-Jean-sur-Richelieu and the Lake Champlain at Rouses Point will allow for a finer calibration of the hydraulic models. Data will be processed to develop maps of the river bed substratum and aquatic plants characteristics, allowing a more precise definition of the associated friction coefficients in the hydraulic model.

Task 1-8 is under EC-NHS leadership. This task would be completed by September 30, 2015.

3.2 Component 2 of the directive: Creation of static flood inundation maps

The objective is to create flood inundation maps for the entire shoreline of Lake Champlain and the Richelieu River. A set of flood inundation maps of the transboundary waters will be created

for those shoreline areas of Lake Champlain where LiDAR exists and for the Richelieu River and Mississquoi Bay to document the extent of the flood plains under a finite number of hydraulic scenarios corresponding to lake elevations and river discharges.

The following are available in Canada: Bathymetric data, descriptions of anthropogenic features and LiDAR coverage of the Richelieu River and Canadian portion of Lake Champlain, measured longitudinal profiles of surface elevation for 5-6 events, data collected during the 2011 and Hurricane Irene flood events, inundation mapping expertise. The gaps that have been identified in Canada are: availability of longitudinal surface elevations of the Richelieu River for specific hydraulic scenarios, harmonization of the discrepancy between vertical datums used by Canada and the U.S.

The following data are available in the U.S.: Bathymetric data, anthropogenic features and LiDAR coverage of Franklin and Addison Counties VT, Lake levels at 3 locations and estimated maximum lake inundation locations during 2011. The gaps that have been identified in the U.S. are: LiDAR for many areas of the Lake Champlain shoreline, prediction of shoreline water levels due to wind setup and lake seiche. For the creation of the static inundation maps for Lake Champlain, LiDAR for the Lake shoreline will be available for all of Vermont, the islands, and a corner of Northeastern New York, as shown in figure 3.

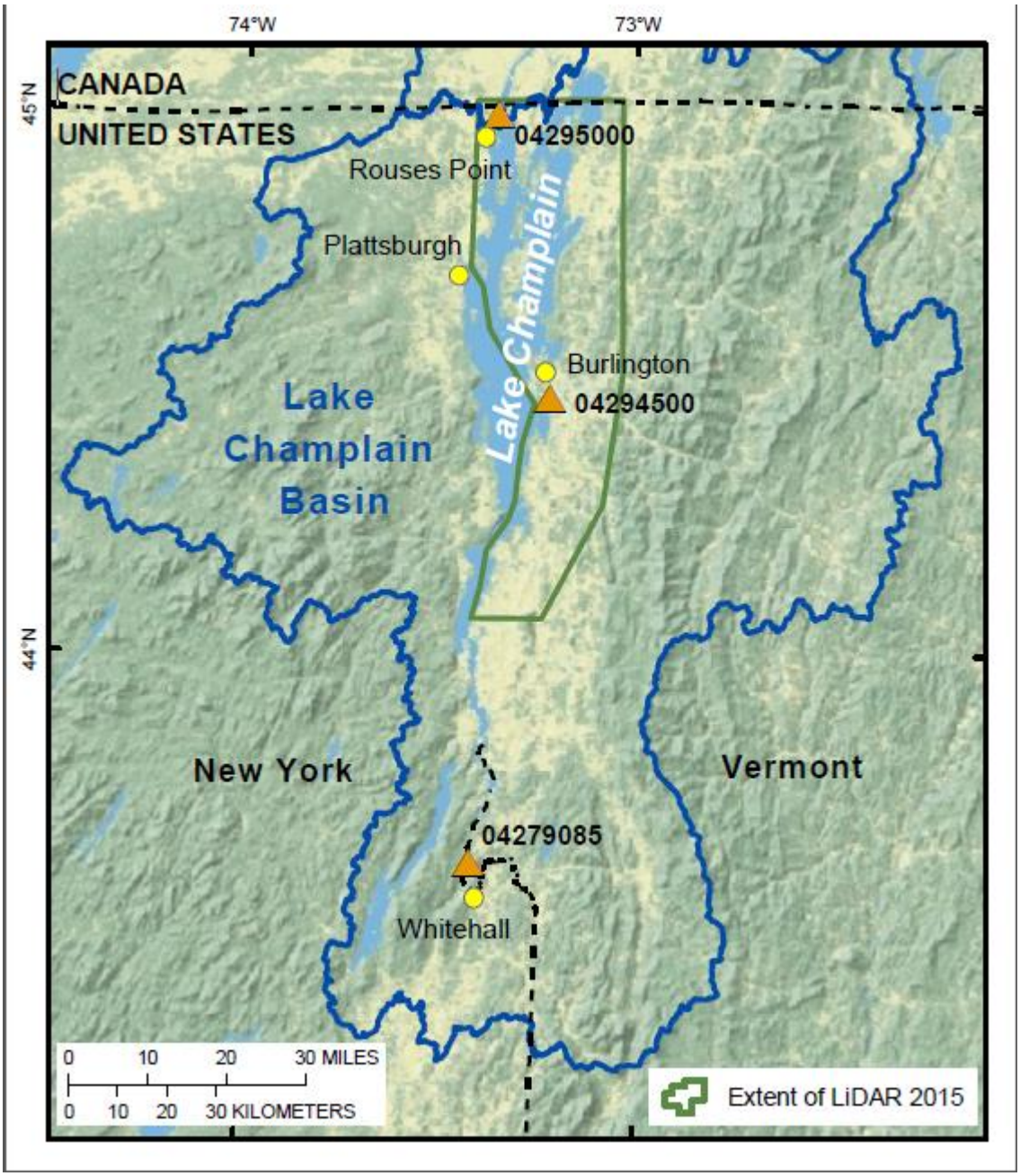

Figure 3 U.S. LiDAR acquisition planned for 2015

3.2.1 Task 2-1 Consolidation and Harmonization of U.S. Data (U.S. Technical Lead)

USGS and the LCBP will inventory, compile and assess Lake Champlain watershed data in the United States that will be useful for lake modeling being done in Tasks 1-1 and 1-2. This will include data on stream inflows, bathymetry, wind, waves, snowpack, lake evaporation, structures influencing lake levels and flows, trends in tributary inflows, and other data recommended by the ILCRRTWG and others. LCBP staff will work with the TWG to identify and acquire data from federal, state, provincial or other sources to resolve data gaps in the areas of topography, bathymetry, aquatic vegetation, LiDAR, other data types identified with input from the IJC and TWG. Identification and acquisition of data will include the migration of existing static map

products into dynamic map services and consumable data layers. These dynamic map services will be made available to the ILCRRTWG and the public through standard File Transfer Protocol (FTP) and hosted web map services in coordination with the IJC. USGS and the LCBP will describe the data, sources and limitations. An inventory of the data will be provided in the final report to IJC. The LCBP will assist with data collection and documentation where is makes sense based on their experience and knowledge of certain data sets. USGS and the LCBP will describe the data, sources and limitations. An inventory of the data will be provided in the final report to IJC.
Data necessary for the development of the flood inundation mapping of Lake Champlain will also be gathered and harmonized so that seamless and integrated data sets are created for use in the mapping product.

Task 2-1 will be conducted in early 2015 and will be completed by June 30, 2015, under USGS and LCBP leadership.

3.2.2 Task 2-2 Creation of a quality-controlled Digital Elevation Model (DEM) from available LiDAR datasets along the Richelieu River and Missisquoi Bay of Lake Champlain (CEHQ).

The CEHQ will produce a digital elevation model (DEM) of the Mississquoi Bay and Richelieu River flood plain between the average high water shoreline delineation and an upper limit compatible with the U.S. DEM of 106 ft in first approximation, for Lake Champlain. This DEM will be developed from various existing LiDAR datasets that are already controlled for quality and have an average density of one point per square meter on the ground. This initial resolution may be reduced to limit computational costs if needed. As a final deliverable, the DEM will be exported for hydrodynamic simulation in a suitable format. The current cost estimation includes the purchase of the existing lower Richelieu LiDAR dataset at an estimated cost of $7.5k; however, the possibility of obtaining the data at no cost has not yet been confirmed. The Plan d'Action Saint-Laurent signed between the governments of Canada and Québec is expected to facilitate the transfer of funds to CEHQ.

Task 2-2 will be conducted under CEHQ leadership. The DEM completion is expected by March 2015.

3.2.3 Task 2-3 Set-up of a 2D hydraulic model of the Richelieu River between Rouses Point and Sorel (EC-NHS).

The 2-D hydraulic model is viewed as an effective means to generate longitudinal profiles of the water surface in continuity with the surface elevation of Lake Champlain selected for the static inundation maps. An experimental model that has been developed under the Canada-Quebec Plan d'Action Saint-Laurent's Environmental Numerical Prediction Working Group (PASL/NPWG) will be refined and calibrated. The application is based on H2D2[8], a finite element hydrodynamic model, modular and extensible, solving the shallow water equations, also known as St. Venant equations.

The main activities to implement this model on the Richelieu River are described below.

1. A scenario analysis will be carried out that includes the identification of the main tributaries that will be included into the model domain. All water inflows to the river will

[8] http://www.gre-ehn.ete.inrs.ca/H2D2

be distributed among those tributaries. Reference events for calibration purpose will be identified (water levels, inflows) and included.
2. Available calibration data from the 2011 flood event will be collected from various sources such as Ministère de la Sécurité Publique, Centre d'Expertise Hydrique du Québec, Parks Canada, Natural Resources Canada, etc.
3. Digital Elevation Model (DEM): River shore elevation data, the Richelieu River bathymetry and available substratum observations will be consolidated and incorporated in the finite element mesh of the hydraulic model.
4. Significant man-made structures such as bridges piers, dams, locks etc. which can affect the water level simulations will be digitized and incorporated in the FE mesh.
5. FE Mesh: Production of the hydrodynamic mesh for the Richelieu River respecting criteria from the preceding tasks.
6. Calibration and validation of the hydraulic model simulations: Calibration and validation of the hydrodynamic model. Performance measures will be used to assess model performance at locations where observations are also collected. These performance measures will include (a) mean error between simulations and observations, (b) mean absolute error between simulations and observations, (c) root mean error between simulations and observations, and (d) Pearson correlation coefficient (r) of observed to simulated elevations.
7. Simulation of the hydrodynamic scenarios corresponding to the surface elevation of Lake Champlain selected for the static inundation maps, to generate longitudinal profiles of the water surface of the Richelieu River.
8. A technical report describing the hydrodynamic modeling development work and results of the model application will be written.

Task 2-3 will be conducted under EC-NHS leadership. Information for activity 4 is almost complete; further digitization has to be done. The digitization and FE mesh activities should be completed by the end of February 2015. The calibration/validation of the model will begin in March. The final calibration and production simulations will be done during the summer of 2015. The report will be finalized in August 2015.

Note on the mapping of the substrate and aquatic plants for Richelieu River. The presence of aquatic plants in the Richelieu River between Saint-Jean-sur-Richelieu and Rouses Point, and to a lesser degree, downstream of Saint-Jean-sur-Richelieu can affect the flow as those plants grow progressively during summer and die, in the fall. Substrate observations are needed to assess the friction coefficients for the hydraulic model.New aquatic plant observations will not be included in this first iteration describing spring freshet flood events; however, the collection of new substratum observations along the Richelieu River and aquatic plant assemblages and distribution in the Richelieu River will be completed under task 1.8.

3.2.4 Task 2-4 Creation of static inundation maps (CEHQ and USGS)

In Canada, a finite number of discrete maps (~10) are envisioned to represent a range of hydraulic scenarios comprised between the average spring flood and beyond the extreme high water observed in 2011. The flood inundation maps will cover the entire shoreline of the Richelieu River and of the Canadian portion of Lake Champlain to document the extent of the flooding under a finite number of hydraulic scenarios corresponding to lake elevations. Results of hydraulic simulations from task 2-3 will be imported in Arc/GIS to produce flood zone models by intersecting the profiles of the water surface with the DEM of the Richelieu River and

Mississquoi Bay. These models will then be cross-referenced with the DEM to identify flood limits. Conventional maps (in pdf format) or digital maps would be produced as deliverable. The Plan d'Action Saint-Laurent signed between the governments of Canada and Québec is expected to facilitate the transfer of funds to CEHQ.

In the U.S., the USGS will produce flood inundation maps for selected communities along the shoreline of the Lake Champlain basin, by the production of a USGS Open File Report and presentation on IJC and LCBP webpages. These maps are only the start in what is planned to be flood inundation maps for the entire shoreline once the LiDAR is available for the entire Lake basin. The static inundation maps will be produced for 1 foot intervals from 100' to 106'above Mean Sea Level (MSL). The lower level (100') is the stage for minor flooding as defined by the NWS. The 106' lake level is about 2 feet above the historical highest flood stage and can be used to help determine the impacts of lake seiche and wind on areas to be inundated.

The USGS report will describe methods and data used and results of the flood inundation mapping effort. The report will be made available to the public on the USGS publications web pages. On the US side of the border, the USGS will prepare static flood inundation maps that will be posted on the USGS web site[9].

Flood inundation maps from the U.S. and Canada will be consolidated by the CEHQ and USGS so that the final products are produced in as consistent a manner as possible for use by other agencies and communities on both side of the border. Static maps will refer to the historical observed context rather than through frequency analysis performed on lake levels and river discharges that could prove difficult to resolve under this directive. The IJC will publish the Canada – U.S. consolidated static maps.

Task 2-4 will be conducted under leadership of CEHQ and USGS. Expected completion of static maps by September 30, 2015.

Note on the publication of flood plain maps: As part of its mandated work, the ILCRRTWG will produce maps that will show areas identified as being flooded along the Richelieu River and Mississquoi Bay at various Richelieu River discharges corresponding to the selected levels of Lake Champlain. These maps will not replace the official Québec maps or flood markers that have been identified in land management and development plans in Regional County Municipalities (RCM) and in municipal land management regulations, nor replace the Federal Emergency Management Agency (FEMA) floodway maps in the U.S.

4. Public Information Strategy

This section describes what the technical working group sees as outreach activities, including public meetings, dissemination of reports and other material produced by the ILCRRTWG.

4.1 Informal consultations with targeted stakeholders:

- ILCRRTWG members from Québec, Vermont and New York will contact appropriate first-responders and emergency measures managers to inform them of the production of the static flood maps and will obtain their views on the desired characteristics of an

[9] http://water.usgs.gov/osw/flood_inundation/

operational flood forecasting and flood plain mapping system.(December 2014 – February 2015)

- The ILCRRTWG will perform ad-hoc outreach to subject-matter experts in fields related to the two directive's components as required. An example of this is to consult TETRA TECH which has developed a Lake Champlain water quality model to assist with nutrient control strategies. There could be linkages between this Lake model and models used for flood forecasting. (January – June 2015)
- The LCBP will coordinate, upon future direction by the TWG and IJC, public meetings. LCBP's education and outreach staff will contact key stakeholders to bolster participation in any public meetings. Meetings would also be prefaced by a presentation of the technical products to the LCBP Citizens Advisory Committee.

4.2 Internal Communication/Documentation

The following means will be used for communication and gathering and sharing of information:

- IJC ILCRRTWG website[10]
- Access for team members to the PoS IJC sharepoint site that contains several key documents gathered during the work group's mandate.
- LCBP FTP site to post ILCRRTWG documents, databases, etc (presently up, databases being added by LCBP)
- The IJC and the ILCRRTWG have agreed to explore potential solutions for the needs of this working group (through access to IJC's sharepoint site) and for future real time flood models. At this time the following communication strategy among the ILCRRTWG will be used:
    - Monthly ILCRRTWG calls will be held to check on progress.
    - A possible face to face meeting to be held in March is being considered (if required, date and location to be determined)
    - Meeting in May that will be held concurrently with the International annual IAGLR conference, May 25-29, 2015 in Burlington, Vermont
    - Meeting in late July/Early August will be required to go over the draft report and to determine recommendations, etc. (date and location to be determined)
- LCBP staff will work with the IJC and the TWG to host and facilitate two technical workshops. One workshop will be located in the U.S. and one will be located in Canada, and each selected venue will be equipped with tele- and video-conference technology. Dates for these events will be selected in cooperation with the IJC and TWG with the understanding that the workshops and all follow-up work will be completed by September 30, 2015.

4.3 Communication Plan:

- The IJC will issue a new press release when the work plan (EN/FR) is available on the IJC website to correct the impression in Québec that we are working on the whole PoS not only two components. "What it is and What it is not". (January 2015)
- ILCRRTWG co-chairs presentation of Progress at IJC Semi-annual meeting (Washington, April 2015)

[10] http://ijc.org/en_/LCRRTWG

- A presentation will be given at IAGLR during a technical session on "Flood forecasting and preparedness across International borders using Lake Champlain and the Richelieu River as an example" and a possible technical workshop will be hosted (Burlington, May 25-29 2015). The aim of the workshop is to present experts with the envisioned operational flood forecasting and inundation mapping system, static flood plain maps and seek their input.
- Public meeting or Webinar to present products that are being planned (Here is what we have generated and how you can use it). If in person, there should be at least one meeting on each side of the border. We may wish to have two in the US (NY and VT). In Québec, we will have to keep in mind that we will have to manage expectations that actual structural and non-structural solutions are being looked at. The ILCRRTWG may request the presence of a Commissioner in Québec. (dates and or locations - tbc)
- ILCRRTWG co-chairs' presentation of draft final report of the TWG at IJC Semi-annual meeting (Ottawa, October 2015)
- The flood maps will be posted on the IJC web site and the USGS Flood Inundation Mapping public websites by September 30, 2015.
- The final IJC approved ILCRRTWG report (EN/FR) will be posted on the IJC website (date to be determined). The final report will be posted for the public so they can make suggestions for future studies and advanced modeling, etc. This will be a public communication and if the public has a lot of suggestions, this should be documented. Could be held either face to face or via webinar.
- LCBP staff will assist in the coordination of all public outreach activities with the TWG and the IJC's public affairs officers. Upon approval from the IJC, LCBP staff will post all pertinent materials on www.lcbp. org and maintain all information intended for public consumption. All approved content will be web-available by September 30, 2015.

4.4 Secretariat support from LCBP

The LCBP will provide logistic and secretariat support for a number of activities associated with this work plan and the work of the TWG. These will include:

- LCBP staff will generate electronic monthly progress updates to be posted on the LCBP website (www.lcbp. org) after receipt of approval by the IJC and the technical work group (TWG). Content and length of these reports will reflect the volume of work completed for that reporting period. Each report also will include a statement of anticipated work in coming month(s) and an assessment of the overall completion of the project at the time of closing of the reporting period. Each monthly report also shall include any challenges or anticipated delays in the completion of deliverables, with a proposed solution to overcome these challenges or delays.
- The first monthly report will be delivered October 31,2014; the final report will be delivered September 30,2015 for a total of 12 monthly status reports.
- LCBP staff will work with the IJC and the TWG co-chairs to develop draft agendas for each TWG meeting and two technical workshops. Draft agendas will be circulated a minimum of 14 calendar days prior to the proposed meeting or workshop date, each of which willfall before September 30, 2015. Each draft agenda will detail times, locations, anticipated subject matter, and expected attendees for each meeting or workshop

- LCBP staff will work with vendors provided by IJC for real-time French-English translation and bilingual translation of documents generated from these meetings. Draft meeting summaries will be provided, in English,to the IJC and TWG within seven calendar days following the conclusion of each workshop. LCBP staff will work with the IJC-provided translator to provide the meeting summaries documents in French once the English versions are approved. Upon approval of English and French-translated documents, all meeting documentation, including presentations, will be posted on www.lcbp.org and also will be noted in the relevant monthly report

4.5 Additional secretariat support for French language services

The Canadian secretary is to provide French language services for the public where necessary to complement the TWG's primary secretariat (provided by the Lake Champlain Basin Program under agreement with the US section of the IJC), at an estimated cost of $20k. Activities by the Canadian Secretary would include:

- Coordination of French language outreach with the TWG and the secretariat of the LCBP
- Participating in the meetings and teleconferences of the TWG to be familiar with the group's activities,
- Arranging a public outreach meeting(s) in Quebec in coordination with LCBP,
- Working with the IJC to arrange French translation services at public meetings and translation of English products, and
- Reviewing and editing French translations of public information and final products of the TWG and coordinating with the IJC the posting of those French language products on the TWG's IJC website.

Table 2: Cost Breakdown

Task	Brief description	Costs ($)				Expected Completion
		FY 2014		FY 2015		
		U.S.	Can.	U.S.	Can.	
1-1	Assess the quality of surface wind predictions and precipitation analyses (EC-RPN-E)				30 000	2015-08-31
1-2	Implement an experimental 2D hydrodynamic model of Lake Champlain, using existing bathymetric data (EC-NHS)		20 000		15 000	2015-08-31
1-3	Establish a coordination mechanism to exchange data of interest (ILCRRTWG)					2015-09-15
1-4	Recommend a pragmatic approach for the future operational real-time flood forecasting and inundation mapping system for the Lake Champlain and Richelieu River flood plain (ILCRRTWG)			10 000	10 000	2015-08-31
1-5	Collection and processing of LiDAR Data for Lake Champlain (USGS)			50 000		2015-09-30
1-6	Address Border Datum Issue (USGS)			118 000		2015-09-30
1-7	Collection of new in-lake and watershed data to assist with flood forecasting and inundation mapping system (USGS)			67 000		2015-09-30
1-8	Collection of new substratum, aquatic plant assemblages and distribution in the Richelieu River between Saint-Jean-sur-Richelieu and Rouses Point on the Lake Champlain (EC-NHS)				35 000	2015-09-30
2-1	Consolidation and Harmonization of U.S. Data (USGS and LCBP)			87 000		2015-06-30
2-2	Creation of a quality-controlled Digital Elevation Model (DEM) from available LiDAR datasets along the Richelieu River and Missisquoi Bay of Lake Champlain (CEHQ).		20 000			2015-03-30
2-3	Set-up of a 2D hydraulic model of the Richelieu River between Rouses Point and Sorel (EC-NHS).				35 000	2015-08-31
2-4	Creation of static inundation maps (CEHQ and USGS)			120 000	25 000	2015-09-30
	Public Information Strategy (LCBP/ILCRRTWG)			20 000		2015-09-30
	Secretariat support from LCBP			15 000		2015-09-30
	Additional secretariat support for French language services				20000	2015-09-30
	Translation (of documents, public meetings, web material, etc.)				40000	2015-09-30
	In-kind contribution from Environment Canada				85000	
	In-kind contribution from CEHQ				82000	
	TOTALS	0	40 000	487 000	377 000	

Attachment 1–Reference letter provided to the IJC by the U.S. government

United States Department of State

Bureau of Western Hemisphere Affairs
Washington, D.C. 20520-6258

July 24, 2014

Mr. Chuck Lawson
Secretary, U.S. Section
International Joint Commission
2000 L St. NW, Suite 615
Washington, D.C. 20440

Lake Champlain and Richelieu River Reference

Dear Mr. Lawson:

The Governments of Canada and the United States thank the International Joint Commission (IJC) for its July 2013 Plan of Study: "The Identification of Measures to Mitigate Flooding and the Impacts of Flooding of Lake Champlain and Richelieu River" which the IJC undertook in response to our governments' request in a March 19, 2012, letter to investigate flood mitigation solutions following devastating floods in that region in the spring of 2011.

We particularly appreciate the IJC's presentation of individually scalable options for study implementation. We understand that the IJC recommends Option C at $14 million (to be funded jointly by Canada and the United States) as the best option for a thorough understanding of the causes and solutions for flood mitigation through a long-term study. Our governments are not at this time, however, able to commit to such a large scale, long-term undertaking, and thus cannot make a reference including that option now.

Instead, in accordance with Article IX of the Boundary Waters Treaty, the Governments of Canada and the United States request that the International Joint Commission assist our governments in the implementation, with existing 2014 funding, of two scalable components in the study. These components will provide valuable information to assist affected communities in floodplains in a practical and immediate fashion and also provide a basis for a future real-time flood forecasting and inundation mapping system.

This reference is limited to initiating and completing work on the following, which will be organized and implemented by a small technical working group, to be convened by the IJC:

1. Addressing and closing data gaps through data collection and harmonization of topographic, bathymetric, aquatic vegetation, soil texture, Light Detection and Ranging (LiDAR) and observed climate and hydrometric data collection (per section 3.1, page 34 of the July 2013 Plan of Study) as are necessary as a basis for the earliest possible initiation of a real-time flood forecasting and inundation mapping system. This system would consist of the development of new real-time Lake Champlain and Richelieu River hydrologic and hydraulic models for predicting lake and river levels, and a precise Digital Elevation Model of the flood plain to delineate the contours of corresponding inundated areas.

2. Creation of static flood inundation maps using a combination of existing and new data and modeling to provide practical information to communities. These maps would show which areas would be affected if Lake Champlain and Richelieu River water levels hit different heights.

Subject to each government's national appropriations process, Canada and the United States may consider a subsequent reference on other components of the 2013 Plan of Study, including using data from this work to produce a real time flood forecasting and inundation mapping system.

In examining and collecting data, the IJC–assembled working group should build on the technical data gap analysis outlined in the IJC July 2013 plan of study and decide early on which government agency will take leadership on the different elements. The study should incorporate and take advantage of existing systems and government mechanisms already in place on both sides of the border. These include the bilateral agreement that the NOAA has with Environment Canada, the Canada-Quebec St. Lawrence Action Plan, and a Vermont river management/river easement program that deals with river stability and other elements. The group should also assess and use data from the U.S. national initiative to promote better soil health through management to increase water infiltration and water holding capacity on a landscape basis and wetland restoration, among other things. The working group should also take into account and build on work done at the state and provincial levels.

Although the political-social study component identified in the 2013 Plan of Study cannot be undertaken at this time, the workgroup should be sensitive throughout this process to local stakeholders' concerns as expressed during the previous plan of study.

The Commission is requested to pursue its activities expeditiously and to report periodically to the Governments. This should include an initial work plan by August 2014 and interim briefings at the October 2014 and April 2015 semi-annual meetings. The final report should be completed by September 2015.

The United States and Canada underscore their joint commitment to the principle of parity, including funding, under the Boundary Waters Treaty. To undertake the work described above, the United States Government commits $487,000 of appropriated 2014 fiscal year funds. The Government of Canada commits a minimum of $150,000 of existing Canadian Section IJC funds and in-kind contributions (the dollar value of which shall be mutually agreed by the Governments), with the understanding that ultimate funding of all references relating to this matter will, in cumulative total, be funded by the two Governments on a basis of parity.

Canada's total contribution of resources over the course of this and any future references will equal those of the United States, subject to national appropriations.

The governments of Canada and the United States welcome the opportunity to collaborate and assist the Commission in its work. An identical letter is being sent to the Secretary of the Canadian Section of the Commission by the Canadian Department of Foreign Affairs, Trade and Development.

Sincerely,

Sue Saarnio
Acting Deputy Assistant Secretary
Bureau of Western Hemisphere Affairs
United States Department of State

Attachment 2–Reference letter provided to the IJC by the government of Canada

Foreign Affairs, Trade and Development Canada | Affaires étrangères, Commerce et Développement Canada

July 31, 2014

125 Sussex Drive
Ottawa, Ontario
K1A 0G2

Ms. Camille Mageau
Secretary, Canadian Section
International Joint Commission
234 Laurier Avenue West, 22nd Floor
Ottawa, Ontario
K1P 6K6

Lake Champlain and Richelieu River Reference

Dear Ms. Mageau:

The Governments of Canada and the United States thank the International Joint Commission (IJC) for its July 2013 Plan of Study: "The Identification of Measures to Mitigate Flooding and the Impacts of Flooding of Lake Champlain and Richelieu River" which the IJC undertook in response to our governments' request in a March 19, 2012, letter to investigate flood mitigation solutions following devastating floods in that region in the spring of 2011.

We particularly appreciate the IJC's presentation of individually scalable options for study implementation. We understand that the IJC recommends Option C at $14 million (to be funded jointly by Canada and the United States) as the best option for a thorough understanding of the causes and solutions for flood mitigation through a long-term study. Our governments are not at this time, however, able to commit to such a large scale, long-term undertaking, and thus cannot make a reference including that option now.

Instead, in accordance with Article IX of the Boundary Waters Treaty, the Governments of Canada and the United States request that the International Joint Commission assist our governments in the implementation, with existing 2014 funding, of two scalable components in the study. These components will provide valuable information to assist affected communities in floodplains in a practical and immediate fashion and also provide a basis for a future real-time flood forecasting and inundation mapping system.

…/2

Canada

This reference is limited to initiating and completing work on the following, which will be organized and implemented by a small technical working group, to be convened by the IJC:

1. Addressing and closing data gaps through data collection and harmonization of topographic, bathymetric, aquatic vegetation, soil texture, Light Detection and Ranging (LiDAR) and observed climate and hydrometric data collection (per Section 3.1, page 34 of the July 2013 Plan of Study) as are necessary as a basis for the earliest possible initiation of a real-time flood forecasting and inundation mapping system. This system would consist of the development of new real-time Lake Champlain and Richelieu River hydrologic and hydraulic models for predicting lake and river levels, and a precise Digital Elevation Model of the flood plain to delineate the contours of corresponding inundated areas.

2. Creation of static flood inundation maps using a combination of existing and new data and modeling to provide practical information to communities. These maps would show which areas would be affected if Lake Champlain and Richelieu River water levels hit different heights.

Subject to each government's national appropriations process, Canada and the United States may consider a subsequent reference on other components of the 2013 Plan of Study, including using data from this work to produce a real time flood forecasting and inundation mapping system.

In examining and collecting data, the IJC–assembled working group should build on the technical data gap analysis outlined in the IJC July 2013 plan of study and decide early on which government agency will take leadership on the different elements. The study should incorporate and take advantage of existing systems and government mechanisms already in place on both sides of the border. These include the bilateral agreement that the NOAA has with Environment Canada, the Canada-Quebec St. Lawrence Action Plan, and a Vermont river management/river easement program that deals with river stability and other elements. The group should also assess and use data from the U.S. national initiative to promote better soil health through management to increase water infiltration and water holding capacity on a landscape basis and wetland restoration, among other things. The working group should also take into account and build on work done at the state and provincial levels.

Although the political-social study component identified in the 2013 Plan of Study cannot be undertaken at this time, the workgroup should be sensitive throughout this process to

…/3

local stakeholders' concerns as expressed during the previous plan of study.

The Commission is requested to pursue its activities expeditiously and to report periodically to the Governments. This should include an initial work plan by August 2014 and interim briefings at the October 2014 and April 2015 semi-annual meetings. The final report should be completed by September 2015.

The United States and Canada underscore their joint commitment to the principle of parity, including funding, under the Boundary Waters Treaty. To undertake the word described above, the United States Government commits $487,000 of appropriated 2014 fiscal year funds. The Government of Canada commits a minimum of $150,000 of existing Canadian Section IJC funds and in-kind contributions (the dollar value of which shall be mutually agreed by the Governments), with the understanding that ultimate funding of all references relating to this matter will, in cumulative total, be funded by the two Governments on a basis of parity.

Canada's total contribution of resources over the course of this and any future references will equal those of the United States, subject to national appropriations.

The governments of Canada and the United States welcome the opportunity to collaborate and assist the Commission in its work. An identical letter is being sent to the Secretary of the United States Section of the Commission by the U.S. Department of State.

Sincerely,

Christopher Wilkie
Director
U.S. Transboundary Affairs Division

Attachment 3–Directive to the International Lake Champlain – Richelieu River Technical Working Group

DIRECTIVE TO THE INTERNATIONAL LAKE CHAMPLAIN-RICHELIEU RIVER TECHNICAL WORKING GROUP

The purpose of this directive is to establish and direct the International Lake Champlain-Richelieu River Technical Working Group (TWG) to examine and report to the International Joint Commission on the matters identified by the governments in their July 24 and July 31, 2014 reference letters to the Commission on Lake Champlain and Richelieu River flooding. (copies attached) As stated in these letters, the governments requested that the Commission initiate and complete two scalable components from the 2013 Lake Champlain-Richelieu River Plan of Study (PoS). The 2013 PoS was prepared in response to the floods of 2011 in the Richelieu River and the Lake Champlain basin and built upon IJC's long history investigating water management in this system including the 1937 order of approval and the 1973 reference by the US and Canadian governments to "investigate and report on the feasibility and desirability of regulation of the Richelieu River …for the purpose of alleviating extreme water conditions in the Richelieu River and in Lake Champlain…" (see Dockets 38A, 98R). The PoS recommended a comprehensive study of measures to mitigate flooding and the impacts of flooding in the basin. Work on two scalable components identified in the PoS is to be completed by the IJC within existing funding limits.

These components are:

1. Addressing and closing data gaps through data collection and harmonization of topographic, bathymetric, aquatic vegetation, soil texture, Light Detection and Ranging (LiDAR) and observed climate and hydrometric data (per section 3.1, page 34 of the July 2013 Plan of Study) as are necessary as a basis for the earliest possible initiation of a real-time flood forecasting and inundation mapping system. This system would consist of the development of new real-time Lake Champlain and Richelieu River hydrologic and hydraulic models for predicting lake and river levels, and a precise Digital Elevation Model of the flood plain to delineate the contours of corresponding inundated areas.
2. Creation of static flood inundation maps using a combination of existing and new data and modeling to provide practical information to communities. These maps would show which areas would be affected if Lake Champlain and Richelieu River water levels hit different heights.

To assist the Commission in the organization and implementation of the work outlined in the July reference letters, the Commission will appoint members to a Technical Working Group and Co-Chairs to lead the Technical Working Group's efforts. The co-chairs shall convene and preside at meetings of the Technical Working Group and shall jointly take a leadership role in planning and implementing the Group's work. The Technical Working Group will be binational,

2

with an equal number of members from each country. The Commission shall arrange for provision of secretariat support to carry out such duties as are assigned by the Co-Chairs or the Technical Working Group as a whole. The Commission will provide guidance to the TWG and will pursue technical assistance from the two governments, as identified by the TWG. Members

of the TWG and any committees or work groups created by it will be responsible for their own expenses unless otherwise arranged with the Commission.

The Technical Working Group is to work with the IJC, and the agencies that are identified by the IJC to perform work tasks, providing those agencies and IJC staff with technical determinations, evaluations and guidance on how best to complete IJC-designated tasks within the budget and time frame included in the reference from governments. Given that the envisioned work tasks contain unknown factors related to the extent and resolution of existing data, the scope of data collection needed to close data gaps, and the nature of computer modeling and graphical products or interfaces needed to make the data useful to the public and government, the Technical Working Group may suggest to the IJC modifications to the work tasks.

To facilitate public outreach, the Technical Working Group shall make information related to its work plan as widely available as practicable, including data, its reports and other materials, as appropriate. The Technical Working Group in collaboration with the IJC shall develop and maintain a web-site hosted by the IJC as a means for disseminating information related to implementation of its tasks. To the extent practicable, the Technical Working Group shall make available on the web-site all documents that are available for public information under the Commission's Rules of Procedure.

The Technical Working Group shall keep the Commission fully informed of its progress and direction. The Technical Working Group shall also maintain an awareness of basin-wide activities and conditions and shall inform the Commission about any such activities or conditions that might affect its work. In addition to regular contact with designated Commission personnel, the Technical Working Group shall be prepared to meet with the Commission at least semi-annually if requested by Commissioners, and if so requested, it shall submit written progress reports to the Commission at least three weeks in advance of those meetings.

The Technical Working Group shall act as a unitary body. The members of the work group shall serve the Commission in their professional capacity, in an impartial manner for the common good of both countries, and not as representatives of their countries, agencies, organizations, or other affiliations. The Technical Working Group will strive to reach decisions by consensus and will immediately notify the Commission of any irreconcilable differences. Any lack of clarity or precision in instructions or directions received from the Commission shall be promptly referred to the Commission for clarification.

3

The Technical Working Group shall within one month of its creation submit for the Commission's approval an initial work plan with a schedule of tasks, products and budget based on this directive. The work plan shall include a proposal that will describe how public consultation will be undertaken. The consultation plan shall discuss how the TWG will collaborate with federal governments, provinces, states as well as the wider body of stakeholders and the public. The TWG will compile the data necessary as a basis for initiation of a real-time flood forecasting and inundation mapping system, complete the static flood inundation maps and submit its final report no later than September 15, 2015. The final report should contain the TWG’s findings, conclusions and recommendations regarding the matters raised by the governments.

Documents, letters, memoranda and communications of every kind in the official records of the Commission are privileged and become available for public information only after their release by the Commission. The Commission considers all documents in the official records of the TWG

or any of its committees to be similarly privileged. Accordingly, all such documents shall be so identified and maintained as separate files.

September 12, 2014

Attachment 4 – Composition of the International Lake Champlain Richelieu River Technical Working Group and its secretariat support

International Lake Champlain Richelieu River Technical Working Group

Jean-François Cantin, ing., M.Sc. Canadian co-chair Manager, Hydrology and Ecohydraulics Section National Hydrologic Services Meteorological Service of Canada Environment Canada 1550, avenue d'Estimauville Québec (Québec), G1J 0C3 Telephone 418-649-6565 Cellular phone 418-564-0521 Facsimile 418-648-5643 E-mail jean-francois.cantin@ec.gc.ca Government of Canada	**Keith Robinson** United States co-chair Director, New England Water Science Center US Geological Survey 331 Commerce Way, Suite 2 Pembroke NH 03244 Telephone 603-226-7807 Cellular phone 603-986-2327 Facsimile 603-226-7894 E-mail kwrobins@usgs.gov United States Government
Vincent Fortin Federal member Chercheur en prévision numérique environnementale 2121, route Transcanadienne Dorval, Québec H9P 1J3 Canada Telephone : 514-421-4630 E-mail : vincent.fortin@ec.gc.ca	**William (Bill) Saunders** Federal Member Senior Hydrologist National Weather Service Northeast River Forecast Center 445 MylesStandishBlvd Taunton, MA 02780 Telephone: 508-824-5116 x260 Email: william.saunders@noaa.gov
Daniel Leblanc, ing. M.Sc.A. Quebecmember Directeur adjoint Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques Direction régionale de l'analyse et de l'expertise de l'Estrie et de la Montérégie Service agricole, hydrique, municipal et naturel	**Blaine Hastings** Vermont member Hydrologist Vermont Department of Environmental Conservation Watershed Management Division 1 National Life Drive, Main 2 Montpelier, VT 05620-3522 Telephone: 802-490-6156

201, place Charles-Le Moyne, 2ième étage Longueuil (Québec) J4K 2T5 tél.:450-928-7607 poste 305 téléc.: 450-928-7625	Email: Blaine.Hastings@state.vt.us
Richard Turcotte, ing, Ph.D. Quebec member Conseiller scientifique Direction de l'expertise hydrique Centre d'expertise hydrique du Québec et Coordonnateur du programme "Gestion de l'eau" Consortium Ouranos en climatologie régionale et adaptation à l'impact des changements climatiques Développement durable, Environnement et Lutte contre les changements climatiques Aile Taschereau, 4e étage, boîte postale 28 675, boulevard René Lévesque Est Québec (Québec) G1R 5V7 Tél: 418 521-3993 poste 7145 Fax: 418 643-6900 Courriel: www.cehq.gouv.qc.ca	**Fred Dunlap** New York member NY Lake Champlain Basin Coordinator New York State Dept of Environmental Conservation 1115 NYS Rte 86 - Box 296 Ray Brook, NY 12977 Telephone: 518-897-1241 Email: fred.dunlap@dec.ny.gov

Technical support

Robert Flynn

(USGS) Hydrologist-Engineer USGS, New England Water Science Center 331 Commerce Way, Suite 2
Pembroke NH 03244
Telephone 603-226-7824
Facsimile 603-226-7894

E-mail rflynn@usgs.gov

Secretariat support

Secretariat support from LCBP

Stephanie Castle

Lake Champlain Basin Program
NEIWPCC Environmental Analyst
Lake Champlain Basin Program Technical Associate
Champlain Valley International Wine Trail Coordinator
54 West Shore Rd., Grand Isle, VT 05458
p: 802-372-3213; f: 802-372-3233
scastle@lcbp.org
www.neiwpcc.org
www.lcbp.org

Additional secretariat support for French language services

Madeleine Papineau

E-mail: gfalardeau@sympatico.ca