

Prepared in cooperation with the International Joint Commission

Establishment of a Vertical Control Network Along the St. Croix River in New Brunswick and Maine

Open-File Report 2013–1236
Version 1.1, June 2019

U.S. Department of the Interior
U.S. Geological Survey



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By Pamela J. Lombard

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**U.S. Department of the Interior
U.S. Geological Survey**

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Conversion Factors

U.S. customary units to International System of Units

	Multiply	By	To obtain
inch (in.)		2.54	centimeter (cm)
inch (in.)		25.4	millimeter (mm)
foot (ft)		0.3048	meter (m)
mile (mi)		1.609	kilometer (km)

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88) processed using the Geoid 09 model unless otherwise specified.

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

Abbreviations

CBN	Cooperative Base Network
CORS	continuously operating reference station
EC	Environment Canada
FBN	Federal Base Network
GNASS	Global Navigation Satellite Systems
GNSS	global navigation satellite system
HPGPS	high-precision Global Positioning System
IJC	International Joint Commission
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration
OPUS	Online Position User Service
RMS	root mean squared
USGS	U.S. Geological Survey
VERTCON	North American Vertical Datum Conversion Tool

Establishment of a Vertical Control Network Along the St. Croix River in New Brunswick and Maine

By Pamela J. Lombard

Abstract

Consistent elevations at stable benchmarks, referenced to a common datum, are important for measuring and comparing water levels and for computing flows throughout a watershed. Elevations are presented for 38 control points within the St. Croix River watershed, mostly along the main stem of the St. Croix River. Vertical control points are located at 7 dams, 3 Environment Canada (EC) lake monitoring gages, 1 EC streamflow monitoring gage, 2 U.S. Geological Survey (USGS) lake monitoring gages, and 4 USGS streamgages. At least one point at each location was determined through High Precision Global Positioning System observation. Elevations of remaining points were determined through differential leveling. Elevations are referenced to the North American Vertical Datum of 1988, Geoid 09 and to the National Geodetic Vertical Datum of 1929.

Introduction

The International Joint Commission (IJC), dam operators and owners, and agencies monitoring streamflow and water levels in the United States and Canada struggle with inconsistent elevations, differing accuracy standards, and different reference datums for tablets, dams, lake-level monitoring gages, and streamflow monitoring gages along the St. Croix River that is the border between Maine, USA and New Brunswick, Canada. Communication among government agencies, private companies, and the public about water levels throughout the St. Croix River watershed is confusing and can lead to errors. Stakeholders, including the IJC, have recognized the benefit of establishing a consistent vertical control network for the St. Croix River.

International agreements between the United States and Canada document support for developing consistent data in the St. Croix River watershed. In 1955, the IJC was requested by the United States and Canada to investigate the development of the water resources of the St. Croix River Basin to improve the use, conservation, and regulation of the waters of the basin. The IJC continues to develop an international watersheds initiative, an effort stemming from a 1997 proposal to the United States and Canadian Federal governments to establish international watershed boards that would adopt an integrated ecosystem approach to transboundary environmental issues. As a part of this work, and to address concerns regarding inconsistent elevations, differing accuracy standards, and different reference datums for tablets, dams, lake level gages, and streamflow gages along the St. Croix River, the U.S. Geological Survey (USGS), in cooperation with the IJC, conducted a study using National Oceanic and Atmospheric Administration (NOAA) National Geodetic Survey (NGS) guidelines (National Oceanic and Atmospheric Administration, 2013) to establish a consistent vertical control network for the St. Croix River in 2011 and 2012.

Purpose and Scope

The purpose of this report is to establish and publish an internally consistent network of elevations along the St. Croix River, which flows between New Brunswick, Canada, and Maine, United States, from East Grand Lake to Calais, Maine/St. Stephen, Canada. The objective is to establish control points with high levels of accuracy through the use of survey-grade global positioning, Global Navigation Satellite System (GNSS) technology, and differential leveling. Seventeen existing control points were used in the study, and an additional 21 control points were newly established.

Description of the Study Area

The study area includes control points along the St. Croix River in both the United States and Canada. In the United States, the study area extends from Forest City township on East Grand Lake at the northeast corner of Washington County, Maine, southeast along the St. Croix River to Calais, Maine (fig. 1). In Canada, the same reach of the St. Croix River extends from west of McAdam southeast along the St. Croix River to St. Stephen, New Brunswick. In addition, a United States tributary to the St. Croix that includes Sysladobis Lake and West Grand Lake is part of the study area. Control points from seven dams, three Environment Canada (EC) lake monitoring gages, one EC streamflow monitoring gage, two USGS lake monitoring gages, and four USGS streamflow monitoring gages are included in the study.

Data Collection and Analysis

Geodetic surveys were conducted using survey-grade global positioning and GNSS technology to establish a vertical datum. A minimum of one vertical control point was established using a high-precision Global Positioning System (HPGPS) at each water monitoring gage and (or) structure. Additional data were collected at each location using HPGPS and differential leveling. All HPGPS surveying was conducted with two Leica System 1200 Type GX 1220 GPS units in static mode. One of the units was used as a base and typically was set up for at least 4 hours. The second unit was used as a rover whose observations would be linked to the base data during the post processing of the data. Data were post processed using the NGS Online Position User Service (OPUS). NGS control points were included in the network for quality control.

Elevations are reported using relevant datums for the region, including the North American Vertical Datum of 1988 (NAVD 88) processed with the Geoid 09 model and the National Geodetic Vertical Datum of 1929 (NGVD 29) (in both feet and meters). Elevations were converted by use of the NGS North American Vertical Datum Conversion Tool (VERTCON), as prescribed in Federal Register Note FRDOC#07-3377 (National Oceanic and Atmospheric Administration, 2013b, c). Latitudes and longitudes of control points are included in this report for reference and as an aid to locating the points, but an analysis of the accuracy of the latitudes and longitudes of these control points is beyond the scope of this study. Latitudes and longitudes for points established as a part of this study are referenced to the North American Datum of 1983 (NAD 83).

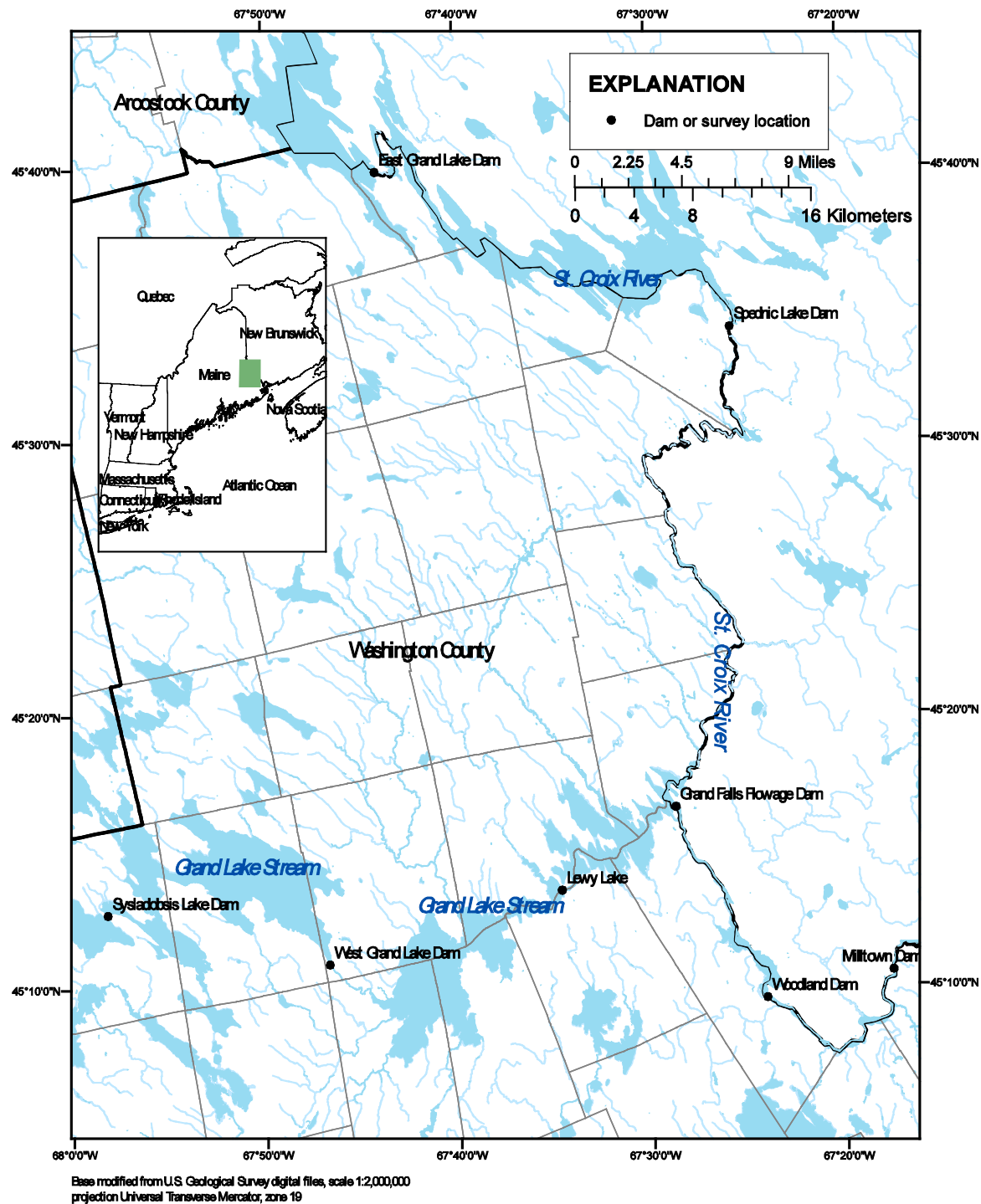


Figure 1. Site map showing the study area along the St. Croix River from East Grand Lake to Calais, Maine, and to Milltown, New Brunswick.

Control Point Locations

The following sections list the general location of control points, the sites or structures surveyed at each location along the St. Croix River, and the points surveyed, which include control points at EC monitoring stations, USGS monitoring stations, and newly established points. The sites are listed in upstream to downstream order along the St. Croix River, and the table for each site (tables 1–10, at back of report) indicates all points surveyed. New points were established if old points were not found or if old points did not have a clear path to the HPGPS satellites. Although the majority of sites are on the border between Maine and New Brunswick, three of the sites (Sysladobsis Lake Dam, West Grand Lake Dam, and Lewy Lake) are on tributaries to the St. Croix and are entirely in the United States. In-depth descriptions, photographs, and maps are presented for each location, site, and (or) structure.

Forest City, Maine

Vertical control points at Forest City, Maine, were established and (or) confirmed at East Grand Lake Dam, East Grand Lake at Forest City EC monitoring Station 01AR009 and Forest City Stream below dam at Forest City, Maine, EC monitoring Station 01AR011 (table 1). The location of these sites is at the Forest City dam at the end of Forest City Road/East Grand Lake Road. Access is from the United States, and all points are in Maine. FC_RP1 and FC_RM1 are USGS control points; FC_IBC56, FC-NB96-03, and FC-NB77-265 are EC control points. FC_BM1, FC_BM2, and FC_Dam were newly established for this network (fig. 2; table 1). The elevation of FC_BM1 was determined to be 437.74 feet (ft; 133.423 meters [m]) NAVD 88 by a 4-hour HPGPS observation on May 31, 2012. A 2-hour HPGPS observation on November 2, 2011, was used for quality control and was within 0.08 ft (0.024 m) of the first observation. All remaining points at this location were determined by differential leveling.

Vanceboro, Maine, and St. Croix, New Brunswick

Vertical controls at the border of Vanceboro, Maine, and St. Croix, New Brunswick, were established and (or) confirmed at Spednic Lake Dam, Spednic Lake at St. Croix EC monitoring station 01AR010, and St. Croix River at Vanceboro, Maine, USGS monitoring station 01018500. These sites are at the international border crossing between Maine and New Brunswick, between the two customs stations. A Water Survey of Canada tablet located on the left upstream wingwall of the International Bridge, V_NB98-01, is used by both EC and the USGS as a control point (known as NB98-01 and BM2, respectively). V_NB01-03 is an EC Control point; V_RM9, V_RP15, and V_RP16 are USGS control points; and V_BM4 and V_BM3 were newly established for this network (fig. 3; table 2). The elevation of V_NB98-01 was determined to be 386.75 ft (117.881 m) NAVD 88 by a 4-hour HPGPS observation on May 31, 2012. A 2-hour HPGPS observation on November 2, 2011, was used for quality control and was within 0.03 ft (0.009 m) of the first observation. Elevations for V_BM3 and V_RP15 were determined by shorter HPGPS observations of 2 hours and 30 minutes, respectively, that were linked to the 4-hour observation of point V_NB98-01 on May 31, 2012. All remaining control points at this location were determined by differential leveling.

Sakom Township, Maine

Two vertical controls were established at Sysladobsis Dam at Sakom Township, Maine. The elevations of DOBSIS_1 and DOBSIS_2 were determined to be 307.36 ft (93.683 m) NAVD 88 and 306.18 ft (93.324 m) NAVD 88 by 4-hour HPGPS observations on August 8, 2012 (fig. 4; table 3).

Grand Lake Stream, Maine

Vertical control points at Grand Lake Stream, Maine, were established and (or) confirmed at West Grand Lake Dam and West Grand Lake at Grand Lake Stream, Maine, USGS monitoring station 01018900 (table 4). The location of the dam and the West Grand Lake monitoring station is at the outlet on the southeast corner of West Grand Lake.

WGL_BM1 and WGL_RM1 are USGS control points; WGL_BM2 and WGL_Dam are newly established for this network (fig. 5; table 4). The elevation of WGL_BM2 was determined to be 307.96 ft (93.867 m) NAVD 88, using a level II, single-base OPUS-S (static) GNSS survey conducted on February 28, 2019, in accordance with USGS [Techniques and Methods 11–D1](#) (Rydland and Densmore, 2012). All remaining points at this location were determined by differential leveling.

Princeton, Maine

Lewy Lake at Princeton, Maine, USGS monitoring station 01019300 is on the northeastern side of the US-1 overpass of Lewy Lake. A HPGPS was set up on a tablet labeled “St. Croix Paper Nov 1939, Elev 204.31” in a small field between Kennebash Street and the lake outflow on November 2, 2011, for a period of 2 hours and 50 minutes. This tablet, LL_BM1 had an elevation of 205.04 ft (62.496 m) NAVD 88 (table 5). Although the HPGPS at this location was set up for only 2 hours and 50 minutes, a second 2-hour HPGPS observation on November 1, 2011, was used for quality control and was within 0.01 ft (0.003 m) of the first observation.

Grand Falls Flowage Dam near Kellyland at Baileyville, Maine

Vertical controls at the Grand Falls Flowage Dam at Kellyland, near Baileyville, Maine, were established and (or) confirmed at the Grand Falls Flowage Dam, the canal outlet of the dam, and at St. Croix River at Grand Falls Flowage EC monitoring station 01AR013. GFF-70-B-115 and GFF-IBC-182 are EC monitoring station points. GFF_BM20 and GFF_CANAL were newly established for this network (fig. 6; table 6). The elevation GFF_BM20 was determined to be 204.92 ft (62.460 m) NAVD 88 by a 4-hour HPGPS observation on June 1, 2012. A 2-hour HPGPS observation on December 1, 2011, was used for quality control and was within 0.04 ft (0.012 m) of the first observation. Elevations for GFF-70-B-115 and GFF_CANAL were determined by shorter HPGPS observations of 30 minutes each that were linked to the longer observations of point GFF_BM20. The elevation of GFF-IBC-182 was determined by differential leveling.

Woodland Dam at Baileyville, Maine

Vertical control points at Woodland, Maine, were established and (or) confirmed at the Woodland Dam and 2,700 ft (820 m) downstream from the dam (fig. 7; table 7). WLDam_BM1, WLDam_BM2, and WLDam_BM3 are newly established points for this network (fig. 7; table 7). The elevation of WLDam_BM1 was determined to be 145.85 ft (44.455 m) NAVD 88 by a 4-hour HPGPS observation on May 30, 2012. Elevations of WLDam_2 and WLDam_BM3 were determined by differential leveling. WL_USGS_RM1 and WL_USGS_RM3 are downstream from the dam. WL_USGS_BM1 is a newly established point for this network. An elevation of 100.37 ft (30.593 m) NAVD 88 was determined at WL_USGS_BM1 with a 2-hour HPGPS observation. A 30-minute HPGPS observation on November 3, 2011, was used for quality control and was within 0.02 ft (0.006 m).

Baring Plantation, Maine

BAR_BM1 is a United States and Canadian boundary survey tablet in a ledge outcrop approximately 70 ft (21 m) southeast of the centerline of a railroad track and approximately 20 ft (6 m) southwest of the street to the old International Bridge at St. Croix River at Baring Plantation, Maine, USGS monitoring Station 01021000. A HPGPS was set up on BAR_BM1 on November 2, 2011, for 5 hours. This tablet had an elevation of 90.51 ft (27.587 m) NAVD 88 (table 8).

Milltown, New Brunswick, and Calais, Maine

Vertical controls at Milltown, New Brunswick, and Calais, Maine, were established at the Milltown Dam. MT_BM1 and MT_BM4 are existing control points (tablets) with outdated elevations. MT_BM2 and MT_BM3 were newly established for this network (fig. 8; table 9). The elevation of MT_BM2 was determined to be 48.42 ft (14.758 m) NAVD 88 by a 4-hour HPGPS observation on August 8, 2012. The elevations of all other control points were determined by differential leveling.

Errors and Quality Assurance

There are several categories of errors associated with HPGPS surveys, and thus, it is difficult to determine a single numerical representation of error for global navigation satellite systems (GNSSs) surveys establishing vertical datum. Instead, surveys can be categorized as to their level of accuracy. Levels of accuracy of a survey are based on OPUS solution quality, the number of established benchmarks included in the survey, and the distance between established benchmarks and newly established points. Points in a level I survey, as defined by the USGS (Rydland and Densmore, 2012), are typically within 0.2 ft (0.06 m) of published benchmarks with known accuracy according to class and order.

The final coordinates reported by OPUS for a point are the average of independent solutions for three independent continuously operating reference stations (CORSs). The OPUS solution quality consists of the percent of total satellites observations used in the processing, a measure of the precision of the solution (the root mean squared [RMS] error), and peak-to-peak errors. Peak-to-peak errors represent the difference between the maximum and minimum values of the coordinates obtained from the solutions to the three independent CORS points.

Two first-order NGS benchmarks were included in the survey. F200 is a first-order, class II Federal Base Network (FBN) NGS disk that is 1.1 mile (mi) southwest of Calais along U.S. Highway 1. D193 is a first-order, class II Cooperative Base Network (CBN) NGS disk that is approximately 11 miles (mi) southeast of Vanceboro, 7.5 mi northeast of Topsfield, and 6.5 mi east of U.S. Highway 1. The published orthometric elevations were determined by NGS using Geoid 09 at these stations. The difference between the published elevation at the FBN disk F200 and the elevation determined here is 0.11 ft (0.034 m). The difference between the published elevation at the CBN disk D193 and the elevation determined here is 0.01 ft (0.003 m) (table 10).

OPUS solution quality for all points surveyed as a part of this project met the criteria for a level I survey. However, the number of benchmarks included and the distance between the control points keep this study from meeting all level I standards (Rydland and Densmore, 2012).

The accuracy of the differential leveling presented here was 0.05 ft (0.015 m). All of the points determined through differential leveling were linked to a HPGPS point for their elevation as referenced to NAVD 88. Thus, errors for these points include the differential leveling error associated with the point added to the error associated with the HPGPS point it is linked to.

Data Processing

HPGPS data were post-processed through the NGS OPUS. Leica Geo Office software (Leica Geosystems AG version 2.0.0.0, build 5028, 2005) was used for postprocessing. Positions are a function of the GRS 1980 ellipsoid and the Geoid09 model. Elevations are referenced to NAVD 88, in feet and in meters. All surveyed points are converted to the National Geodetic Vertical Datum of 1929 (NGVD 29) in order to make the data more readily accessible to all users (table 11).

Summary

A vertical control network was established for the St. Croix River corridor from Forest City to Calais in Maine. In Canada, the same reach of the St. Croix River extends from west of McAdam southeast along the St. Croix River to St. Stephen, New Brunswick. Elevations for 38 control points in the St. Croix River watershed, including 17 previously existing points and 21 newly established points are presented and referenced to datums NGVD 29 and NAVD 88. OPUS solution quality for all points surveyed as a part of this project met the criteria for a Level I survey, indicating that points are typically within 0.2 ft (0.06 m) of published benchmarks with known accuracy according to class and order. However, the number of benchmarks included in this study and the distance between the control points keep this study from meeting all Level I standards.

The network will allow for more accurate communication of elevations among water-resource personnel, dam owners, and the public. In the past, challenges have stemmed from inconsistent elevations, differing accuracy standards and different reference datums for tablets, dams, lake-level monitoring gages, and streamflow monitoring gages. Horizontal coordinates are presented in this report for ease in locating the points.

References Cited

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Table 1. Latitudes, longitudes, elevations, and descriptions for control points surveyed at Forest City, Maine.

[EC, Environment Canada; deg, degree; min, minute; sec, second; NAD83, North American Datum of 1983; ft, foot; m, meter; NAVD88, North American Vertical Datum of 1988]

Point identification	Latitude (deg min sec NAD83)	Longitude (deg min sec NAD83)	Elevation (ft NAVD88)	Elevation (m NAVD88)	Description
East Grand Lake Dam and East Grand Lake at Forest City EC Monitoring Station 01AR009					
FC_BM1	45 39 52.88N	-67 44 2.46W	437.74	133.422	Top of downstream bolt next to the locked chain link fence (inside fence on Canadian side of river)
FC_IBC56	45 39 52.1N	-67 44 4.57W	438.05	133.516	Brass plug (tablet) just north of road to dam and 50 m (164 ft) southwest of dam
FC-NB77-265	45 39 52.65N	-67 44 6.41W	443.12	135.063	Nail in maple tree. 55m (180 ft) northwest of road to dam along path to lake gage
FC_BM2	45 39 52.64N	-67 44 3.06W	436.78	133.130	Timber spike on downstream bankward corner of wooden walkway of dam. Painted orange
FC_Dam	45 39 52.96N	-67 44 2.54W	432.26	131.752	Concrete that appears to be the elevation of the dam crest measured on upstream side of dam
Forest City Stream below dam at Forest City, Maine EC Monitoring Station 01AR011					
FC_RM1	45 39 50.41N	-67 44 3.15W	432.93	131.958	Bolt anchored in rock 3 m (10 ft) downstream and 1 m (3 ft) streamward of gage
FC_RP1	45 39 50.57N	-67 44 3.05W	431.26	131.449	Bolt anchored in upstream streamward side of former stilling well foundation
FC-NB96-03	45 39 49.73N	-67 44 3.41W	435.26	132.667	Lag bolt in tree 22 m (75 ft) downstream and 30 m (100 ft) bankward of gage. Inline with road from dam to gage



Figure 2. Some of the control points surveyed at Forest City, Maine, including A, FC_BM1, B, FC_BM2, and C, FC_IBC56 at East Grand Lake Dam and D, FC_RM1 at Environment Canada streamflow monitoring station, Forest City Stream below dam.

Table 2. Latitudes, longitudes, elevations, and descriptions for all control points surveyed at Vanceboro, Maine, and St. Croix, New Brunswick, Canada.

[EC, Environment Canada; USGS, U.S. Geological Survey; deg, degree; min, minute; sec, second; NAD83, North American Datum of 1983; ft, foot; m, meter; NAVD88, North American Vertical Datum of 1988]

Point identification	Latitude (deg min sec NAD83)	Longitude (deg min sec NAD83)	Elevation (ft NAVD88)	Elevation (m NAVD88)	Description
Spednic Lake Dam and Spednic Lake at St. Croix EC Monitoring Station 01AR010					
V_NB98-01	45 34 7.63N	-67 25 41.56W	386.75	117.882	Water Survey of Canada tablet set on left upstream wingwall of International Bridge
V_NB01-03	45 34 7.46N	-67 25 37.4W	384.47	117.187	Spike in base of cedar tree located at edge of parking lot 35 m from house and 24 m from top of dam
V_BM3	45 34 9.96N	-67 25 39.08W	390.26	118.951	Most upstream leftward bolt at base of lamp post in center of dam (new point)
V_BM4	45 34 9.6N	-67 25 38.85W	390.10	118.903	Most bankward of 2 bolts located just outside of locked fence on Canadian side of dam and on most downstream portion of dam (new point)
St. Croix River at Vanceboro, Maine USGS Monitoring Station 01018500					
V_RM9	45 34 6.7N	-67 25 44.86W	386.74	117.879	Top of threaded bolt end on streamward side of wooden guard rail post; post is 2d one from downstream end
V_RP16	45 34 6.18N	-67 25 44.61W	378.54	115.378	Painted part on cap of pipe coming out from cribbing/under road, 20 ft downstream from USGS orifice line on right bank
V_RP15	45 34 6.39N	-67 25 44.46W	374.35	114.100	Lag bolt in top of rock to which orifice line is attached



Figure 3. Some of the control points surveyed at Vanceboro, Maine, and St. Croix, New Brunswick, Canada, including A, V_NB98-01, Water Survey of Canada tablet set on left upstream wingwall of International Bridge, B, V_USGS_RP15 at St. Croix River at Vanceboro, Maine, U.S. Geological Survey monitoring station, C, V_BM3, most upstream leftward bolt at base of lamppost in center of dam, and D, Spednic Lake Dam with arrow pointing to location of V_BM3 point.

Table 3. Latitudes, longitudes, elevations, and descriptions for control points surveyed at Sysladobsis Dam at Sakom Township, Maine.
 [deg, degree; min, minute; sec, second; NAD83, North American Datum of 1983; ft, foot; m, meter; in., inch; NAVD88, North American Vertical Datum of 1988]

Point identification	Latitude (deg min sec NAD83)	Longitude (deg min sec NAD83)	Elevation (ft NAVD88)	Elevation (m NAVD88)	Description
Sysladobsis Dam					
DOBSIS_1	45 12 42.11N	-67 58 11.63W	307.36	93.683	Top of 0.5 in threaded upper left most northwest bolt facing north on eastern end of northern most railing on dam. Railing is set in concrete
DOBSIS_2	45 12 41.65N	-67 58 10.82W	306.18	93.322	2 in. by 2 in. chiseled square on top of newest concrete pier of the fish ladder. Western side of ladder and upstream from top of pier. It is the southeast corner



Figure 4. Control points surveyed at Sysladobsis Dam at Sakom Township, Maine, including *A* and *B*, DOBSIS_1 and *C* and *D*, DOBSIS_2.

Table 4. Latitudes, longitudes, elevations, and descriptions for control points surveyed at Grand Lake Stream, Maine.

[USGS, U.S. Geological Survey; deg, degree; min, minute; sec, second; NAD83, North American Datum of 1983; ft, foot; m, meter; in., inch; NAVD88, North American Vertical Datum of 1988]

Point identification	Latitude (deg min sec NAD83)	Longitude (deg min sec NAD83)	Elevation (ft NAVD88)	Elevation (m NAVD88)	Description
West Grand Lake Dam and West Grand Lake at Grand Lake Stream, Maine USGS Monitoring station 01018900					
WGL_BM1	45 10 51.08N	-67 46 43.32W	301.75	91.974	Tablet 10 ft north of northwest corner of public outhouse and approximately 180 ft southwest of gage labeled C-31-1931
WGL_RM1	45 10 51.96N	-67 46 42.46W	305.74	93.191	Lag bolt set in power pole next to pole 194B on the downstream right edge of water of West Grand Lake dam
WGL_BM2	45 10 52.56N	-67 46 42.04W	307.96	93.867	Top of 5/8-in. hex bolt securing northwest end of chain link fence on right edge of water near parking lot. Accessible without key (U.S.). Fence is southeast of boat ramp on first wood walk from ramp parking lot
WGL_Dam	45 10 52.37N	-67 46 40.59W	290.25	88.470	Concrete at dam outfall

Table 5. Latitude, longitude, elevation, and description for control point surveyed at Princeton, Maine.

[USGS, U.S. Geological Survey; deg, degrees; min, minutes; sec, seconds; NAD83, North American Datum of 1983; ft, feet; m, meters; NAVD88, North American Vertical Datum of 1988]

Point identification	Latitude (deg min sec NAD83)	Longitude (deg min sec NAD83)	Elevation (ft NAVD88)	Elevation (m NAVD88)	Description
Lewy Lake at Princeton, Maine USGS Monitoring Station 01019300					
LL_BM1	45 13 34.0N	-67 34 37.0W	205.04	62.496	Tablet labeled "St. Croix Paper Co Elev 204.31 Nov 1939" located on 1 ft tall concrete post between foot of northeast wingwall of bridge and along north side of water



Figure 5. Control point WGL_BM2 surveyed at West Grand Lake Dam at Grand Lake Stream, Maine.

Table 6. Latitudes, longitudes, elevations, and descriptions for control points surveyed at the Grand Falls Flowage Dam near Kellyland at Baileyville, Maine.

[EC, Environment Canada; deg, degree; min, minute; sec, second; NAD83, North American Datum of 1983; ft, foot; m, meter; NAVD88, North American Vertical Datum of 1988]

Point identification	Latitude (deg min sec NAD83)	Longitude (deg min sec NAD83)	Elevation (ft NAVD88)	Elevation (m NAVD88)	Description
Grand Falls Flowage Dam and St. Croix River at Grand Falls Flowage EC Monitoring Station 01AR013					
GFF_BM20	45 16 28.13N	-67 28 45.18W	204.92	62.461	Center of pipe filled with concrete on most downstream point of concrete walkway on U.S. side of river next to parking lot
GFF- 70-B-115	45 16 32.96N	-67 28 44.09W	206.09	62.816	Tablet in concrete pier at center of dam. 700 ft from south end of dam
GFF-IBC-182	45 16 27.62N	-67 28 47.34W	207.11	63.126	Top of square bronze pin in rock outcrop behind gage house near South end of dam (U.S. side). 12 m south of water's edge. 3 m west of west side of gage house
GFF_CANAL	45 16 1.47N	-67 28 40.14W	205.25	62.560	Chiseled square under yellow railing in concrete above metal plate sticking out from southern end of southernmost inlet canal. In line with southern crank wheel on canal dam 0.7 miles south of Grand Falls Flowage dam

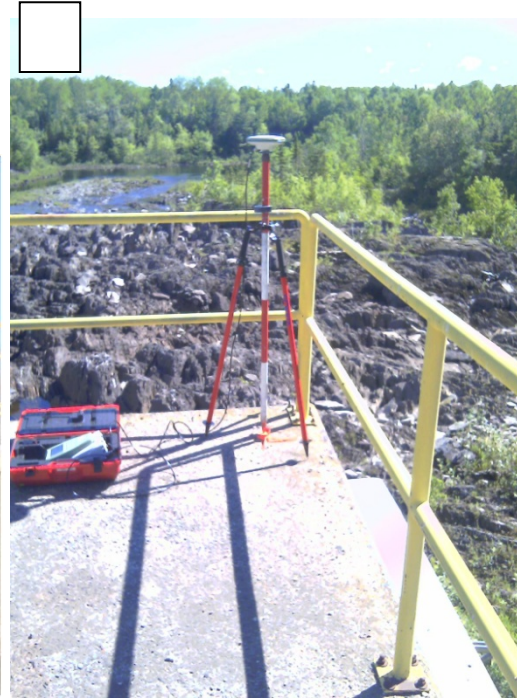


Figure 6. Some of the control points surveyed at Grand Falls Flowage Dam near Kellyland at Baileyville, Maine, including *A*, GFF-70-B-115, tablet in concrete pier at center of dam, *B*, GFF_BM20, pipe filled with concrete on most downstream point of concrete walkway on U.S. side of river next to parking lot, and *C* and *D*, GFF_CANAL, chiseled square on upstream side of bridge over southern most inlet canal of Grand Falls Flowage Dam.

Table 7. Latitudes, longitudes, elevations, and descriptions for all control points surveyed on Woodland Dam at Baileyville, Maine.

[deg, degree; min, minute; sec, second; NAD83, North American Datum of 1983; ft, foot; m, meter; in., inch; NAVD88, North American Vertical Datum of 1988]

Point identification	Latitude (deg min sec NAD83)	Longitude (deg min sec NAD83)	Elevation (ft NAVD88)	Elevation (m NAVD88)	Description
Woodland Dam					
WLDam_BM1	45 9 30.79N	-67 24 11.4W	145.85	44.455	1 in. by 1 in. chiseled square in concrete at corner of iron rail 15 ft south of staff gage near gage wheel number 6
WLDam_BM2	45 9 33.15N	-67 24 9.84W	150.15	45.766	1 in. by 1 in. chiseled square in concrete at midpoint of dam on walkway where yellow and blue fences come together
WLDam_BM3	45 9 30.92N	-67 24 11.42W	145.83	44.450	Bolt in the base of the number 6 beam between water wheel and staff gage, closest to staff gage (see figure 7C)
Downstream of Woodland Dam 2700 ft (820 m)					
WL_USGS_BM1	45 9 15.21N	-67 23 37.83W	100.37	30.593	1 in. by 1 in. chiseled square in ledge between road and pump house at end of Palm St. 10 ft streamward of paved road and 13 ft downstream from telephone pole
WL_USGS_RM3	45 9 15.57N	-67 23 36.98W	99.71	30.391	Lag bolt in U.S. side of telephone pole approximately 15 ft downstream from downstream corner of pumphouse
WL_USGS_RM1	45 9 15.7N	-67 23 37.1W	98.62	30.059	On bolt head of bolt in concrete foundation on U.S. side of door to pump house

Table 8. Latitude, longitude, elevation, and description for control point surveyed at Baring Plantation, Maine.

[USGS, US Geological Survey; deg, degree; min, minute; sec, second; NAD83, North American Datum of 1983; ft, foot; m, meter; NAVD88, North American Vertical Datum of 1988]

Point identification	Latitude (deg min sec NAD83)	Longitude (deg min sec NAD83)	Elevation (ft NAVD88)	Elevation (m NAVD88)	Description
St Croix River at Baring, Maine USGS Monitoring Station 01021000					
BAR_BM1	45 8 10.44N	-67 19 00.93W	90.51	27.588	United States and Canadian boundary survey tablet in ledge outcrop approximately 70 ft southeast of centerline of railroad track and approximately 20 ft southwest of street to old International Bridge

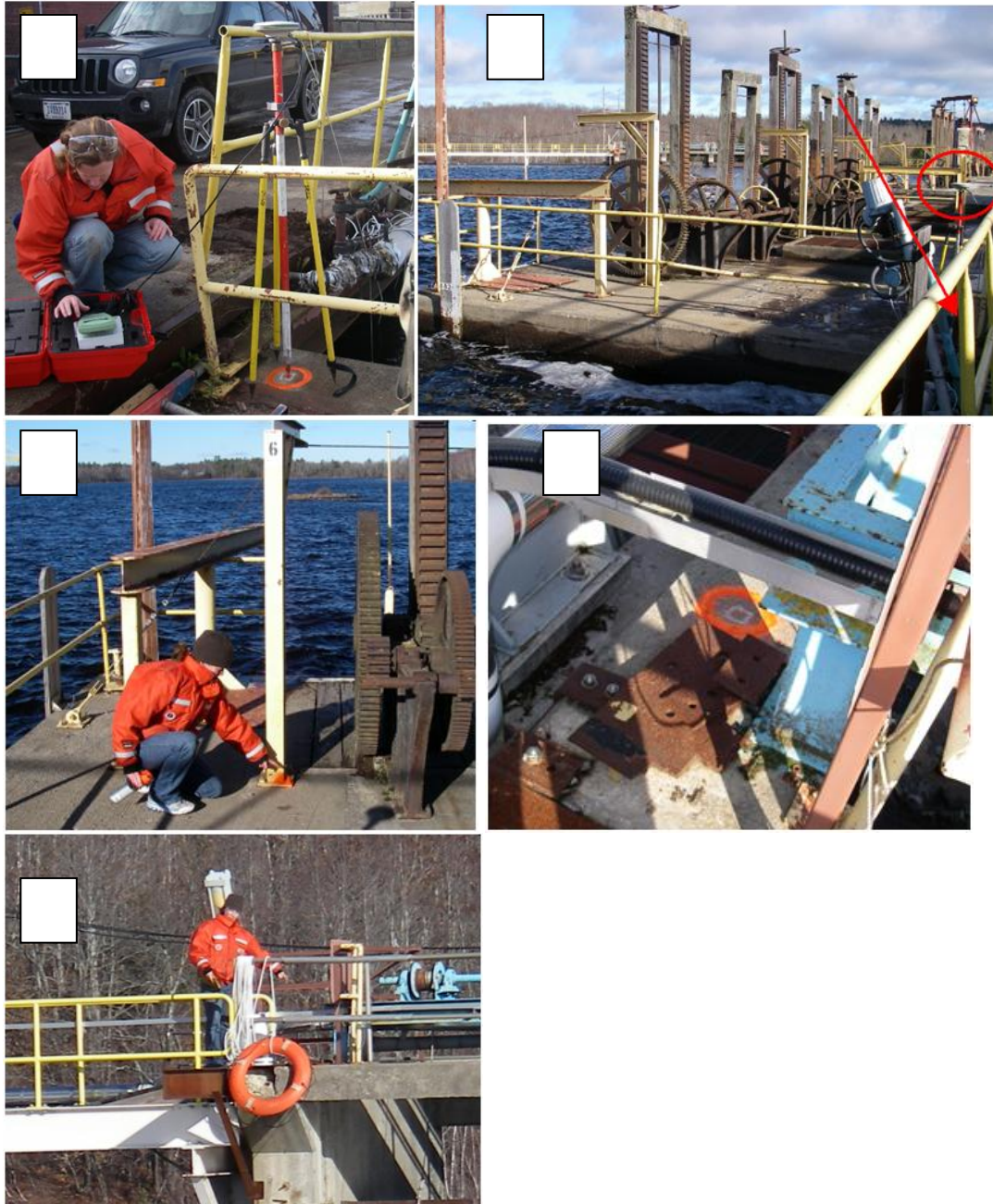


Figure 7. Control points surveyed on Woodland Dam at Baileyville, Maine, including A and B, WLDam_BM1, chiseled square in concrete at corner of iron rail 15 feet south of a staff gage near gage wheel number 6, C, WLDam_BM3, bolt in the base of the #6 beam between water wheel and staff gage, and D and E, WLDam_BM2, chiseled square in concrete at midpoint of the dam on the walkway where yellow and blue fences come together.

Table 9. Latitudes, longitudes, elevations, and descriptions for all control points surveyed at Milltown, New Brunswick, and Calais, Maine.
[deg, degree; min, minute; sec, second; NAD83, North American Datum of 1983; ft, foot; m, meter; in., inch; NAVD88, North American Vertical Datum of 1988]

Point identification	Latitude (deg min sec NAD83)	Longitude (deg min sec NAD83)	Elevation (ft NAVD88)	Elevation (m NAVD88)	Description
Milltown Dam					
MT_BM1	45 10 30.81N	-67 17 34.02W	48.63	14.823	Tablet at base of metal gage house at mill
MT_BM2	45 10 30.72N	-67 17 34.2W	48.42	14.758	Top of northwest most 1-in. green threaded bolt on bankward of two green crank wheels near metal gage house
MT_BM3	45 10 32.42N	-67 17 33.99W	52.52	16.010	Chiseled square at center of dam walkway. Southern end of metal tracks on top of dam (downstream side of metal tracks)
MT_BM4	45 10 32.22N	-67 17 32.07W	53.67	16.359	Tablet at base of disconnected electrical tower that holds cable across river. Maine side of river



Figure 8. Control points surveyed at Milltown Dam at Milltown, New Brunswick, and Calais, Maine, including A, MT_BM2, top of northwesternmost 1 inch green thread bolt on bankward of two green crank wheels near metal gage house, B, MT_BM4, tablet at base of disconnected electrical tower that holds cable across river on Maine side of river, C and D, MT_BM3, chiseled square at center of dam walkway, and E and F, MT_BM1, tablet at base of metal gage house at mill.

Table 10. Latitudes, longitudes, elevations, and descriptions for National Geodetic Survey control points used for quality control.

[PID, permanent identifiers; deg, degree; min, minute; sec, second; NAD83, North American Datum of 1983; ft, foot; m, meter; mi, mile; km, kilometer; in., inch; NAVD88, North American Vertical Datum of 1988]

Point identification	Latitude (deg min sec NAD83)	Longitude (deg min sec NAD83)	Published elevation (ft NAVD88)	Found elevation (ft NAVD88)	Difference (ft)	Description
F200 (PID QF0233)	45 10 22.36109N	67 17 20.77753W	122.64	122.53	0.11	Federal Base Network Control (FBN) station in Calais at the junction of U.S. Highway (Route) 1 and Harrison Road. Approximately 1.3 mi (2.1 km) southwest of the junction of Route 1 and Canada Highway 9 in the top of a massive rock outcrop projecting about 7 ft (2.14 m) above the highway. 56.4 ft (17.2 m) south/southwest of Harrison Road center. 43.8 ft (13.35m) east of the center of Route 1, 29.4 ft (8.96 m) northeast of power pole number 47
D193 (PID QF0195)	45 27 32.27200N	067 38 12.09291W	294.79	294.80	.01	Cooperative Base Network (CBN) Control Station about 11 mi (17.7km) southeast of Vanceboro, 7.5 mi (12.1 km) northeast of Topsfield, and 6.5 mi (10.5 km) east of Route 1. Set in flat ledge outcrop 538 ft (164 m) west of center of multiplate culvert at Tomah Stream and 90.5 ft (27.6 m) southeast of a 16-in. hemlock. 90.1 ft (27.5 m) north-northeast of Bell Atlantic pole number 114. 22.3 ft (6.8 m) north of the centerline of Highway 6

Table 11. Elevations for all surveyed points in St. Croix River watershed, Maine, as referenced to vertical datums NAVD88 and NGVD29.

[ft, foot; m, meter; NAVD88, North American Vertical Datum of 1988; NGVD29, National Geodetic Vertical Datum of 1929]

Point identification	Elevation (ft NAVD88)	Elevation (m NAVD88)	Elevation (ft NGVD29)	Elevation (m NGVD29)
FC_BM1	437.74	133.422	438.28	133.586
FC_IBC56	438.05	133.516	438.59	133.681
FC-NB77-265	443.12	135.063	443.66	135.228
FC_BM2	436.78	133.130	437.32	133.295
FC_Dam	432.26	131.752	432.80	131.916
FC_RM1	432.93	131.958	433.47	132.122
FC_RP1	431.26	131.449	431.80	131.614
FC-NB96-03	435.26	132.667	435.80	132.831
V_NB98-01	386.75	117.882	387.35	118.065
V_NB01-03	384.47	117.187	385.07	117.370
V_BM3	390.26	118.951	390.86	119.134
V_BM4	390.10	118.903	390.70	119.086
V_RM9	386.74	117.879	387.34	118.062
V_RP16	378.54	115.378	379.14	115.561
V_RP15	374.35	114.100	374.95	114.283
DOBSIS_1	307.36	93.683	308.00	93.878
DOBSIS_2	306.18	93.322	306.82	93.518
WGL_BM1	301.75	91.974	302.38	92.167
WGL_RM1	305.74	93.191	306.37	93.384
WGL_BM2	307.96	93.867	308.59	94.060
WGL_Dam	290.25	88.470	290.88	88.663
LL_BM1	205.04	62.496	205.67	62.688
GFF_BM20	204.92	62.461	205.55	62.653
GFF-70-B-115	206.09	62.816	206.72	63.008
GFF-IBC-182	207.11	63.126	207.74	63.318
GFF_CANAL	205.25	62.560	205.88	62.752
WLDam_BM1	145.85	44.455	146.51	44.656
WLDam_BM2	150.15	45.766	150.81	45.967
WLDam_BM3	145.83	44.450	146.49	44.651
WL_USGS_BM1	100.37	30.593	101.03	30.794
WL_USGS_RM3	99.71	30.391	100.37	30.592
WL_USGS_RM1	98.62	30.059	99.28	30.260
BAR_BM1	90.51	27.588	91.17	27.789
MT_BM1	48.63	14.823	49.31	15.030
MT_BM2	48.42	14.758	49.10	14.965
MT_BM3	52.52	16.010	53.20	16.217
MT_BM4	53.67	16.359	54.35	16.566

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