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Federal Emergency Management Agency

Flood of April and May 2008 in Northern Maine

Scientific Investigations Report 2010–5003

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

Cover. Aerial view of flooding in Fort Kent, Maine, May 1, 2008. (Photograph courtesy of Maine Department of Public Safety)

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KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

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Conversion Factors, Datums and Abbreviations

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

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

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

ABBREVIATIONS

FIS	flood insurance studies
GPS	Global Positioning System
HWM	high-water mark
USGS	U.S. Geological Survey

Flood of April and May 2008 in Northern Maine

By Pamela J. Lombard

Abstract

Severe flooding occurred in Aroostook and Penobscot Counties in northern Maine between April 28 and May 1, 2008, and was most extreme in the town of Fort Kent. Peak streamflows in northern Aroostook County were the result of a persistent heavy snowpack that caused high streamflows when it quickly melted during the third week of April 2008. Snowmelt was followed by from two to four inches of rainfall over a 2-day period in northern Maine. Peak water-surface elevations resulting from the flood were obtained from 13 continuous-record streamgages and 63 surveyed high-water marks in Aroostook and Penobscot Counties. Peak streamflows were obtained from 20 sites on 15 streams through stage/discharge rating curves or hydraulic flow models. Peak water-surface elevations and streamflows were the highest ever recorded at seven continuous-record streamgages, which had between 25 and 84 years of record in northern Aroostook County. The annual exceedance probability (the percent chance of exceeding the streamflow recorded during the April/May 2008 flood during any given year) at six streamgages in northern Maine was equal to or less than 1 percent.

Data from flood-insurance studies published by the Federal Emergency Management Agency were available for five of the locations analyzed for the April/May 2008 flood and were compared to streamflows and observed peak water-surface elevations from the 2008 flood. Water-surface elevations that would be expected given the observed flow as applied to the effective flood insurance studies ranged from between 1 and 4 feet from the water-surface elevations observed during the 2008 flood. Differences were likely the result of up to 30 years of additional data for the calculation of recurrence intervals and the fact that hydraulic models used for the models had not previously been calibrated to a flood of this magnitude.

Introduction

Records and analyses of peak water-surface elevations and streamflows resulting from extreme rainfall and snowmelt events are crucial for determining the annual exceedance probabilities associated with these events. These probabilities are necessary to provide appropriate disaster-assistance funding and guide mitigation measures to minimize losses in future floods. In past flood reports, flood frequencies were expressed as recurrence intervals for selected flood quantiles such as the “100-year flood.” The use of recurrence-interval terminology is now discouraged by the U.S. Geological Survey (USGS) because it sometimes causes confusion for the general public. Recurrence-interval terminology is sometimes interpreted to imply there is a set time interval between floods of a particular magnitude, when in fact, floods are random processes that are best understood using probabilistic terms.

The use of annual exceedance probabilities is now recommended because it conveys the probability, or odds, of a flood of a given magnitude being equaled or exceeded in any given year. The exceedance probability is equivalent to the reciprocal of the recurrence interval and is expressed as a percent. For example, a flood with an annual exceedance probability of 1 percent corresponds to a 100-year flood. This does not imply that flooding will happen at regular intervals. Two streamflows with annual exceedance probabilities of 2 percent could occur in 2 consecutive years or even the same year. In contrast, a peakflow with an annual exceedance probability of 2 percent might not occur for 100 years.

Major flooding provides a unique opportunity to assess and calibrate flood water-surface elevation profiles and floodplain delineations in a region. Active streamgages with long periods of record are the single best tool for evaluating the magnitude and severity of flooding events on streams. On streams where historical data are not available, high-water marks (HWMs) and hydraulic flow models allow for the estimation of peak streamflows and exceedance probabilities.

Northern Maine experienced major floods in 1923, 1973, 1974, 1979, and 1983 (Maloney and Bartlett, 1991). All these floods occurred in late April or early May when heavy rain combined with snowmelt runoff.

Snowmelt and rainfall in northern Maine from April 28 through April 30, 2008, resulted in floods with annual exceedance probabilities of equal to or less than 1 percent at six streamgages and annual exceedance probabilities of between 2 and 1 percent at three additional gages in the region. The State of Maine declared a state of emergency in Aroostook County on April 29, 2008, as a result of the flooding (fig. 1). On May 9, 2008, Aroostook County was declared a Federal disaster area qualifying it for federal assistance, and on May 16, the federal government expanded the major disaster declaration to include Penobscot County. Fort Kent, located on the banks of the St. John River, received the most damage from the flood. More than 600 people evacuated the region and over 100 homes were flooded. Many other communities in Aroostook and Penobscot Counties were also severely affected (figs. 1, 2).

Antecedent Hydrologic Conditions

Areas of northern Maine received between 150 and 200 in. of snow throughout the 2007–08 winter season—above-average amounts for the region (River Flow Advisory Commission, State of Maine, 2008). From 40 to 70 in. of this snowpack, the equivalent of 10 to 15 in. of snow water, remained on the ground in mid-April in northern Maine. This is above-average for so late in the season (River Flow Advisory Commission, State of Maine, 2008). High temperatures caused the water content of the snow to drop more than 4 in. between April 15 and 22 in Fort Kent (fig. 3) and another 4 in. between April 22 and 29 (fig. 3), filling streams to capacity. In the week preceeding the heavy rain on April 29, the Fish River at Fort Kent (USGS streamgage 01013500) and the St. John River below the Fish River at Fort Kent (USGS streamgage 01014000) had streamflows with annual exceedance probabilities between 10 and 50 percent due to snowmelt. Snowmelt caused the St. John River below Fish River at Fort Kent to rise to 104,000 ft^3/s by April 25. It then fell to 79,000 ft^3/s by April 29 before the rain of April 29 through May 1 caused it to peak at 183,000 ft^3/s on May 1 (fig. 4). The Allagash and Penobscot Rivers also had streamflows with annual exceedance probabilities between 10 and 50 percent in the weeks leading up to the 2008 flood.

Storm Characteristics

A low-pressure system developed in the Appalachian Mountain states centered around Pennsylvania on Monday, April 27, and the resulting storm moved into southern New England by April 28 and into Maine by the morning of April 29 (Sturey and others, 2008). Heavy rain continued through April 30 and ranged from less than 2 to 4 in. in northern Maine (fig. 5). On the basis of National Weather Service precipitation records, the average rainfall received during the April/May flood of 2008 in northern Maine was roughly equivalent to a 2-day rainfall total having an annual exceedance probability of 10 percent (Wilks and Cember, 1993).

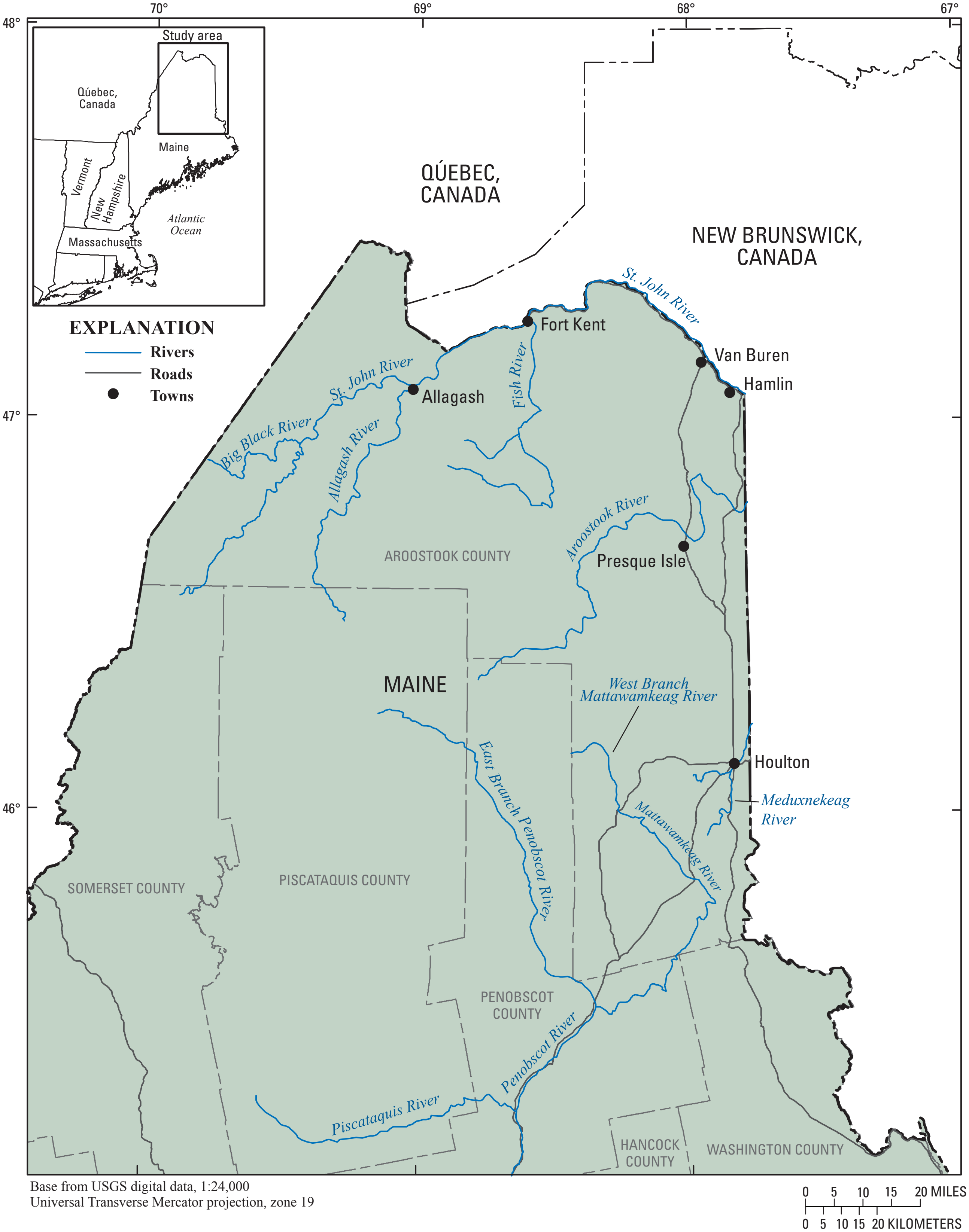

Figure 1. Location of study area.

Figure 2. Flooding from Fish River at Soldier Pond, Maine, May 3, 2008. (Photograph by Laura Flight, U.S. Geological Survey)

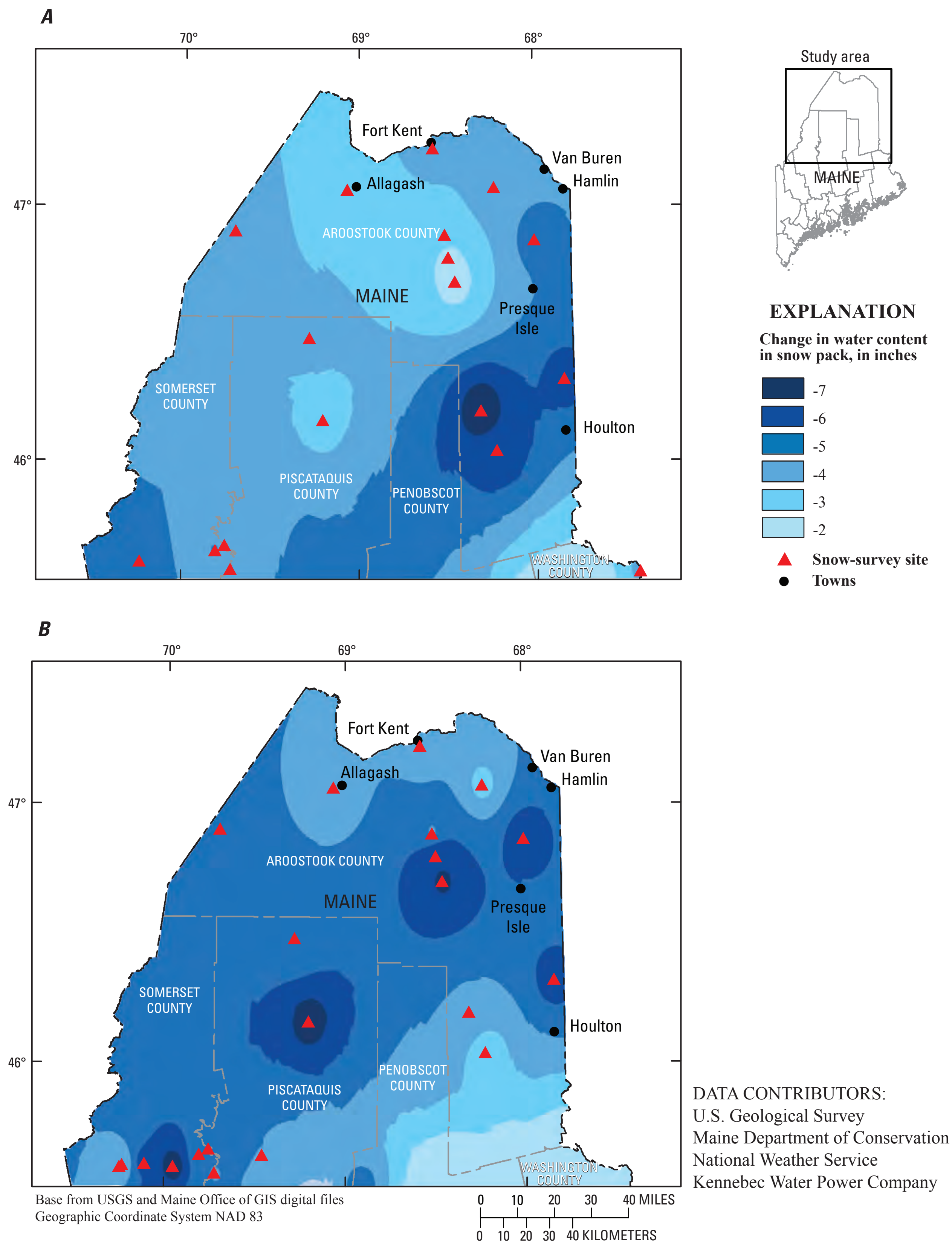

Figure 3. Change in water content in snowpack *(A)* from April 15 to 22, and *(B)* from April 22 to 29, 2008, northern Maine.

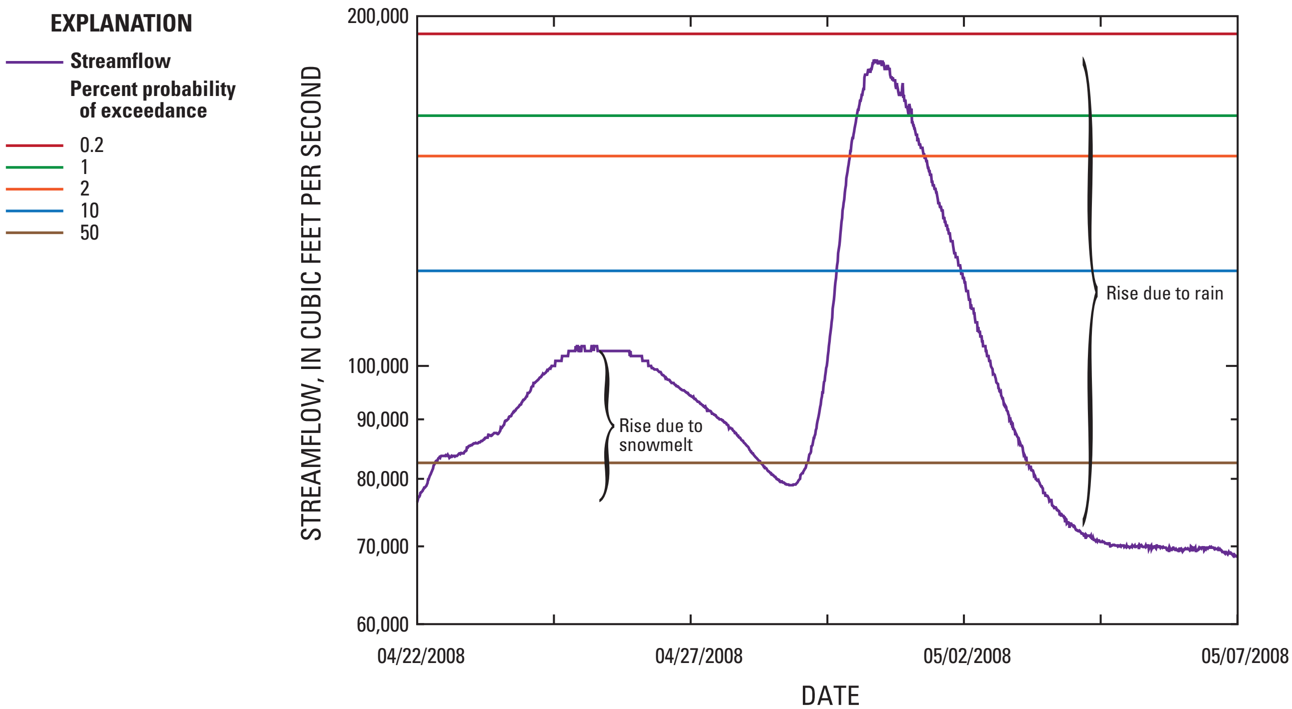

Figure 4. Hydrograph of St. John River below Fish River at Fort Kent, Maine (U.S. Geological Survey streamgage 01014000), from April 22 through May 7, 2008, and streamflows of selected exceedance probabilities at this location.

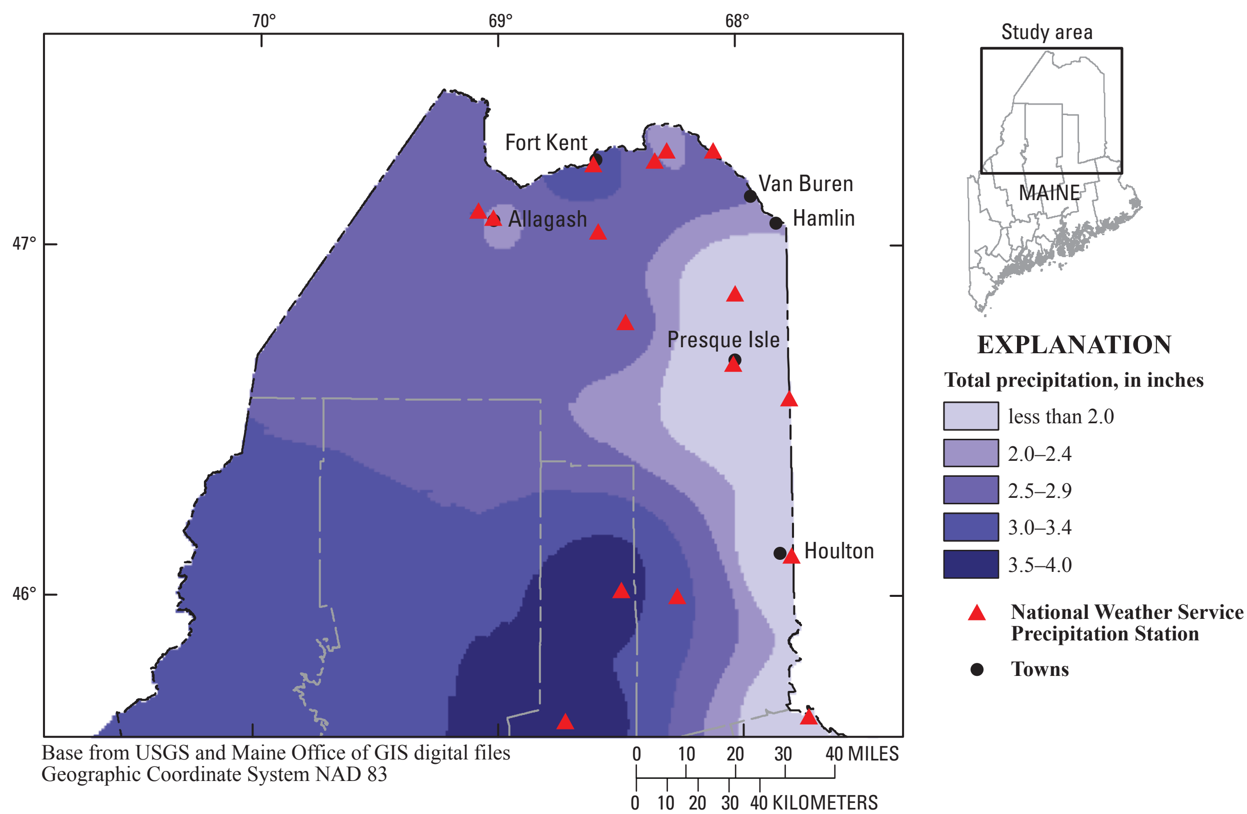

Figure 5. Total storm precipitation from April 29 through 30, 2008, northern Maine. (Precipitation data courtesy of the National Weather Service)

Description of Flood

Floods are typically characterized by peak water-surface elevations, peak streamflows, and peak streamflow exceedance probabilities. Peak water-surface elevations are recorded at streamgages and (or) estimated from HWMs at other locations along streams. Methods to calculate peak streamflows include the use of a relation between streamflow and water-surface elevation (a rating curve) at a streamgage or through use of hydraulic models at ungaged locations.

Peak Water-Surface Elevations

Most of the streams in Aroostook and Penobscot Counties peaked on April 30 or May 1, 2008. Water from the St. John River at Fort Kent peaked at 30.17 ft (5 ft above flood stage) and closed international bridges in Fort Kent, Van Buren, and Hamlin. It also came within inches of the top of a 30-ft high earthen dike constructed to protect the downtown area of Fort Kent and hit the low steel of the International Bridge connecting Fort Kent to New Brunswick (fig. 6).

Thirteen peak water-surface elevations from active USGS continuous-record streamgages in Aroostook and Penobscot Counties are included in this report (table 1). Peak stage data from streamgages typically have an accuracy of plus or minus 0.01 ft. In addition, a peak water-surface elevation was obtained from a HWM at the location of a streamgage discontinued in 1983, Machias River near Ashland (USGS streamgage 01016500). Peak water-surface elevations were obtained from two crest-stage streamgages at Clark Brook (table 1). Crest-stage streamgages are used to obtain only the elevation of the flood crest on a river or stream, and often are located both upstream and downstream of a structure.

In addition, 63 HWMs were located and surveyed for elevations on streams in Aroostook and Penobscot Counties using the techniques of Benson and Dalrymple (1967) (table 1, fig. 7). HWMs typically consist of debris lines or wash lines caused by the flooding event and indicate the highest elevation point that water reached during the event (fig. 8). Debris lines usually consist of a line of fine material such as silt, hemlock needles, or seeds on a tree, bridge abutment, or bank; wash lines are defined by the absence of debris and leaves below them. It is important to locate, mark, and rate these points as soon as possible after the flooding event because they can quickly fade or wash away with subsequent rain.

Figure 6. Flooding at International Bridge connecting Fort Kent, Maine, to New Brunswick, Canada, on April 30, 2008. (Photograph by Andrew Cloutier, U.S. Geological Survey)

Table 1. Identification numbers and locations for high-water marks in northern Maine from flood of April and May 2008.

[HWM, high-water mark; Northings and Eastings referenced to Maine State Plane East; Datum, North American Datum of 1983; Elevations referenced to North American Vertical Datum of 1988; ft, feet; US, upstream; DS, downstream; LEW, left edge of water (when facing downstream); REW, right edge of water; USGS, U.S. Geological Survey; R., river; Rd., road; RR, railroad; Rte., route; St., street; CSG, crest-stage streamgage; WBr, West Branch; EBr, East Branch; all HWMs listed are approximately one structure width upstream or downstream of the listed location; eight digit site numbers refer to USGS streamgage numbers]

Site number	HWM number	Northing (ft)	Easting (ft)	Elevation (ft)	Water body, town	Location and description
01010000		1108450.3	679277.4	942.80	St. John R. at Ninemile Bridge	At streamgage
01010070		1179096.7	671340.4	898.28	Big Black R. near Depot Mountain	At streamgage
1	1	1258252.9	837020.1	610.71	St. John R., Dickey	Rte. 161, US LEW
1	2	1256320.2	837894.3	610.05	St. John R., Dickey	Rte. 161, DS REW
01010500		1257081.1	837838.9	610.09	St. John R. at Dickey	At streamgage
2	3	1246082.5	847648.3	600.47	Allagash R., Allagash	Rte. 161, US LEW
2	4	1246195.6	848675.8	600.41	Allagash R., Allagash	Rte. 161, DS REW
01011000		1241261.3	839865.7	619.01	Allagash R. near Allagash	At streamgage
3	9	1305315.7	958127.9	520.53	St. John R., Fort Kent	International Bridge, US REW
3	10	1306369.6	959120.2	520.18	St. John R., Fort Kent	International Bridge, DS1 REW
3	11	1306933.4	959744.3	520.15	St. John R., Fort Kent	International Bridge, DS2 REW
01014000		1309427.9	960454.8	517.64	St. John R. below Fish R. at Fort Kent	At streamgage
4	5	1271761.3	966087.9	573.20	Fish R., Soldier Pond	Bridge Rd., US REW
4	6	1272193.1	966073.0	572.88	Fish R., Soldier Pond	Bridge Rd., DS REW
5	7	1276304.0	959945.4	582.59	Wallagrass Stream, Wallagrass	Rte. 11, US REW
5	8	1276290.6	960052.2	579.81	Wallagrass Stream, Wallagrass	Rte. 11, DS REW
6	12	1307286.7	960945.2	519.87	Fish R., Fort Kent	Blockhouse Rd., DS1 LEW
6	13	1307327.3	960760.9	516.63	Fish R., Fort Kent	Blockhouse Rd., DS2 LEW
6	14	1307577.0	960684.0	519.46	Fish R., Fort Kent	Blockhouse Rd., DS3 LEW
6	15	1306963.5	961089.6	520.04	Fish R., Fort Kent	Rte. 1, US LEW
7	16	1303766.3	964324.6	521.67	Fish R., Fort Kent	Jalbert Park, US REW
7	17	1304409.5	964242.6	521.72	Fish R., Fort Kent	Jalbert Park, DS LEW
01013500		1301927.3	963688.5	524.60	Fish R. near Fort Kent	At streamgage
8	18	1346149.0	1027437.7	468.89	St. John R., Madawaska	International Bridge, DS REW
9	19	1343925.3	1034418.7	489.45	Factory Brook, Madawaska	Rte. 1, US LEW
10	20	1273891.2	1125227.4	450.23	St. John R., Van Buren	International Bridge, US REW
10	21	1273555.6	1125392.9	449.92	St. John R., Van Buren	International Bridge, DS REW
11	22	1010439.6	1008291.8	640.51	Houlton Brook, T9R5 WELS	Oxbow Rd., US LEW
11	23	1010429.5	1008246.3	640.33	Houlton Brook, T9R5 WELS	Oxbow Rd., US REW
11	24	1010317.0	1008215.7	637.33	Houlton Brook, T9R5 WELS	Oxbow Rd., DS REW
12	25	1041326.2	1016334.3	548.09	Aroostook R., Masardis	Garfield Rd., US LEW
12	26	1041668.6	1016057.8	552.94	Aroostook R., Masardis	Garfield Rd., DS LEW
01015800		1041392.7	1016553.2	548.13	Aroostook R. near Masardis	At streamgage
13	27	1079558.9	1000670.4	542.67	Machias R., Ashland	Garfield Rd., US discontinued streamgage, REW
13	28	1079542.5	1000706.9	542.65	Machias R., Ashland	Garfield Rd., DS discontinued streamgage, REW
01016500		1079756.7	1000632.1	542.48	Machias R. near Ashland	At streamgage
14	29	1081006.1	1004286.7	537.03	Aroostook R., Ashland	Rte. 11, US LEW
14	30	1081205.7	1004860.1	536.26	Aroostook R., Ashland	Rte. 11, DS REW
15	31	1139272.7	1069872.9	469.95	Salmon Brook, Washburn	Bridge St./Hines St., US LEW
15	32	1139167.5	1069783.0	468.85	Salmon Brook, Washburn	Bridge St./Hines St., DS LEW
16	33	1133107.7	1070010.0	451.07	Aroostook R., Washburn	RR Bridge, US REW
16	34	1133952.0	1070438.8	448.96	Aroostook R., Washburn	Castle Hill Rd., US REW (DS of RR)

Table 1. Identification numbers and locations for high-water marks in northern Maine from flood of April and May 2008.—Continued

[HWM, high-water mark; Northings and Eastings referenced to Maine State Plane East; Datum, North American Datum of 1983; Elevations referenced to North American Vertical Datum of 1988; ft, feet; US, upstream; DS, downstream; LEW, left edge of water (when facing downstream); REW, right edge of water; USGS, U.S. Geological Survey; R., river; Rd., road; RR, railroad; Rte., route; St., street; CSG, crest-stage streamgage; WBr, West Branch; EBr, East Branch; all HWMs listed are approximately one structure width upstream or downstream of the listed location; eight digit site numbers refer to USGS streamgage numbers]

Site number	HWM number	Northing (ft)	Easting (ft)	Elevation (ft)	Water body, town	Location and description
16	35	1133322.7	1070797.4	448.25	Aroostook R., Washburn	Castle Hill Rd., DS REW
01017000		1134241.7	1070128.6	449.70	Aroostook R. at Washburn	At streamgage
17	36	1108426.3	1106971.0	426.42	Aroostook R., Presque Isle	Rte. 1, US LEW
17	37	1107575.7	1108104.2	425.71	Aroostook R., Presque Isle	Rte. 1, DS LEW
18	38	1159623.3	1108949.2	398.48	Aroostook R., Caribou	Above Dam LEW
18	39	1161929.8	1108430.2	392.06	Aroostook R., Caribou	Rte. 161 US LEW
18	40	1163048.2	1108496.2	389.27	Aroostook R., Caribou	Rte. 161 DS LEW
19	41	1175374.1	1121968.8	415.96	Little Madawaska R., Caribou	Rte. 89 US REW
20	42	1164034.0	1124958.9	390.99	Nichols Brook, Caribou	Grimes Mill Rd., US LEW
20	43	1164118.9	1124801.7	383.43	Nichols Brook, Caribou	Grimes Mill Rd., DS REW
21	44	1133963.5	1151269.6	361.43	Aroostook R., Fort Fairfield	Rte. 1A, US LEW
21	45	1133425.7	1152065.6	360.28	Aroostook R., Fort Fairfield	Rte. 1A, DS LEW
22	46	913292.3	1024534.8	636.06	WBr Mattawamkeag R., Moro Plantation	Rte. 11, US REW
22	47	913148.7	1024659.4	634.02	WBr Mattawamkeag R., Moro Plantation	Rte. 11, DS REW
23	48	856246.7	1039509.8	454.81	WBr Mattawamkeag R., Island Falls	RR Bridge, DS1 REW
23	49	856255.2	1039503.0	455.15	WBr Mattawamkeag R., Island Falls	RR Bridge, DS2 REW
23	50	856300.5	1039525.9	455.73	WBr Mattawamkeag R., Island Falls	RR Bridge, DS3 REW
23	51	856296.6	1039524.0	455.90	WBr Mattawamkeag R., Island Falls	RR Bridge, DS4 REW
23	52	856497.0	1039249.8	457.26	WBr Mattawamkeag R., Island Falls	RR Bridge, US1 REW
23	53	856495.0	1039253.1	457.20	WBr Mattawamkeag R., Island Falls	RR Bridge, US2 REW
23	54	856617.2	1039213.0	457.15	WBr Mattawamkeag R., Island Falls	RR Bridge, US3 REW
24	55	855030.9	1041258.5	456.70	WBr Mattawamkeag R., Island Falls	Bog Bk Rd., US LEW
24	56	855099.4	1041105.2	454.27	WBr Mattawamkeag R., Island Falls	Bog Bk Rd., DS1 LEW
24	57	855106.9	1041098.0	454.85	WBr Mattawamkeag R., Island Falls	Bog Bk Rd., DS2 LEW
25	58	903925.9	1095238.7	608.55	Marley Brook, Smyrna	Rte. 2, US1 REW
25	59	903906.5	1095246.5	607.73	Marley Brook, Smyrna	Rte. 2, US2 REW
27	60	710278.7	974185.1	247.56	EBr Penobscot R., Medway	Rte. 157/11 US REW
27	61	709304.5	974616.6	246.88	EBr Penobscot R., Medway	Rte. 157/11 DS REW
26	62	753105.1	961631.3	310.21	EBr Penobscot R., Grindstone	Rte. 11, US of RR (US of USGS gage) LEW
26	63	751852.2	961678.4	309.12	EBr Penobscot R., Grindstone	Rte. 11, DS of RR (at USGS gage) LEW
01029500		752300.3	961410.3	309.41	EBr Penobscot R. at Grindstone	At streamgage
01018000		889561.2	1144887.1	341.11	Meduxnekeag R. near Houlton	At streamgage
01031500		550894.1	774158.5	371.41	Piscataquis R. near Dover-Foxcroft	At streamgage
01034000		581243.6	889339.1	261.39	Piscataquis R. at Medford	At streamgage
01034500		572151.2	945253.3	146.89	Penobscot R. at West Enfield	At streamgage
01012895		1253301.8	961700.1	637.20	Clark Brook	At US CSG
01012895		1253301.8	961700.1	632.77	Clark Brook	At DS CSG

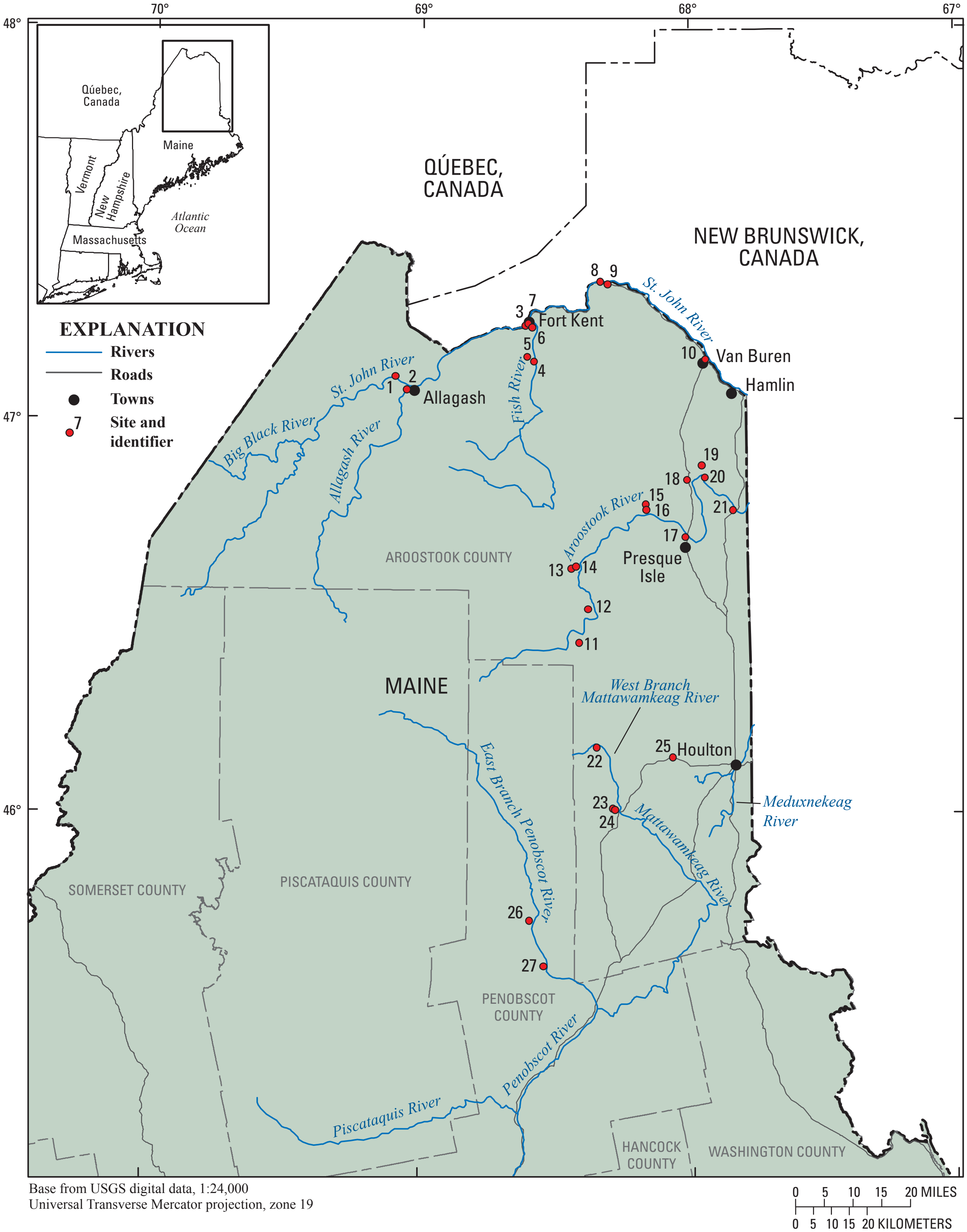

Figure 7. Site numbers of surveyed high-water marks following the April and May 2008 flood in northern Maine. (See table 1 for high-water mark numbers)

Figure 8. High-water mark identification and marking after the April/May 2008 flood in northern Maine: *(A)* debris line, *(B)* debris line along St. John River dike in Fort Kent looking downstream at International Bridge, *(C)* debris line on tree, *(D)* U.S. Geological Survey high-water marker, *(E)* setting high-water mark along St. John River in Allagash, and *(F)* debris line on fence in Fort Kent. (Photographs by Laura Flight and Andrew Cloutier, U.S. Geological Survey)

HWMs are rated on the basis of the type and quality of the debris line or wash line and corroborating evidence in the area. All HWMs used in this analysis were marks with an estimated accuracy of within 0.2 ft of the true peak water-surface elevation during the event. The dates that the peak water-surface elevations occurred at the 63 HWM locations are unknown.

All HWMs included in this report were surveyed relative to local reference points. The elevations of the local reference points were established with high precision Global Positioning System (GPS) instrumentation and referenced to NAVD 88.

Peak Streamflows

Peak streamflows associated with the April/May 2008 flood were obtained at 20 sites on 15 streams (table 2, fig. 9). Peak streamflows were determined through rating curves (the relation between streamflow and water-surface elevations) at 14 long-term continuous-record streamgages (1 of which is currently no longer in operation) and through indirect hydraulic models at 6 sites including 1 active crest-stage gage, 4 discontinued crest-stage gages, and 1 ungaged site on Route 11 in Moro Plantation that was the location of a bridge failure during the 2008 flood. The April/May 2008 peak streamflow was the highest recorded peak streamflow at seven streamgages on five streams. These included Big Black River near Depot Mountain; St. John River at Dickey and below Fish River at Fort Kent; Allagash River near Allagash; Fish River near Fort Kent; and Aroostook River at Masardis and at Washburn—streamgages having periods of record from 25 to 84 years (table 2, fig. 9).

The most reliable method with which to calculate peak streamflows is a calibrated and recently confirmed rating curve at a streamgage. To compute the peak streamflow with a rating curve, available streamflow measurements and corresponding stream water-surface elevations at a site are analyzed, plotted, graphically represented as a line, and extrapolated beyond the calibrated range of measured streamflows when plotted in logarithmic space (Rantz and others, 1982). Rating-curve development and extension depend on the type and stability of the river control at high flows. Historic rating curves can be used at sites that are no longer gaged if the site is presumed to have a stable rating curve.

If a rating curve is not available or is unreliable for extremely high flows, the peak flow can be calculated using indirect methods. Indirect methods of determining peak flow are based on hydraulic relations between flow and the geometry of the channel (Benson and Dalrymple, 1967; Matthai, 1967). For this study, the geometry of the channel and bridge and estimates of downstream slope and roughness values were defined through field surveys and entered into the one-dimensional steady-flow water-surface profile computation component of the U.S. Army Corps of Engineers step-backwater computer model HEC-RAS (U.S. Army Corps of Engineers, 2004). Flows were selected and input into the models, and the models were calibrated so that the resulting locations and water-surface elevation output from HEC-RAS matched the locations and elevations of HWMs observed in the field (table 1).

Exceedance Probabilities of Peak Streamflows

Peak streamflows from the April/May 2008 flood were compared to statistical peak streamflows with standard annual exceedance probabilities at the same locations in northern Maine to determine the exceedance probabilities of the April/May 2008 peak streamflows (table 2, fig. 10). All estimates of exceedance probability have uncertainty associated with them, and the uncertainty generally increases as the exceedance probability decreases, especially at sites where the period of record is short.

Peak flows with exceedance probabilities of 10-, 2-, 1-, and 0.2-percent for streamgages with at least 10 years of peak-flow data were calculated using the guidelines (Bulletin 17B) of the Interagency Advisory Committee on Water Data (1982) as applied for Maine in Hodgkins (1999). Although Hodgkins (1999) provides equations for calculating recurrence intervals, the annual exceedance probability is the reciprocal of the recurrence interval. For the 14 streamgages with sufficient annual peak data, a Pearson Type III probability distribution was fitted to the logarithms (base 10) of the observed annual peak flows at a given streamgage. Weighted estimates of 10-, 50-, 100-, and 500-year peak flows from Hodgkins (1999) were updated with an additional 9 years of data where available for streamgages in northern Maine and then converted to 10-, 2-, 1-, and 0.2-percent exceedance probabilities for this report (table 2).

For the six locations where flows were determined by indirect methods, historical streamflow records were not available. Annual exceedance probabilities for peak flows at sites without historical peak-flow data were calculated using the regression equations presented in Hodgkins (1999). Regression equations were developed using generalized least squares regression procedures that were based on data from 70 USGS streamgages in Maine and eastern New Hampshire. The explanatory variables used in the equations were drainage area and percentage of wetlands in the basin.

Streamflows observed during the April/May 2008 flood had the lowest probabilities of exceedance from Allagash to Fort Kent on the border with Canada (fig. 10). The Allagash River near Allagash, St. John River in Fort Kent, and Fish River at Fort Kent all had flows with annual exceedance probabilities less than 1 percent. Although the East Branch of the Penobscot River at Grindstone (USGS station number 01029500, fig. 9) had a streamflow with an annual probability of exceedance of less than 1 percent, this site is regulated.

Table 2. Peak flows for selected exceedance probabilities and actual peak flows calculated for the April and May 2008 flood in northern Maine.

[USGS, U.S. Geological Survey; mi^2, square miles; ft^3/s, cubic feet per second; Annual exceedance probability is the chance of a flood of a given magnitude being equaled or exceeded in any given year, and is equivalent to the reciprocal of the recurrence interval. R., river; EBr, East Branch; WBr, West Branch; NA, not applicable; ft, feet; Rd., road; Rte., route; <, less than; >, greater than]

USGS station number	Stream and location	Road crossing	Drainage area (mi^2)	Percentage of wetlands in basin	Peak flows (ft^3/s) Annual exceedance probability (percent)				Peak stage NAVD 88 (ft)	April–May 2008 Peak flow (ft^3/s)	Annual exceedance probability (percent)	Period of record (yrs)
					10	2	1	0.20				
					Calculated with flood-frequency analyses					Computed with rating curves		
01010000	St. John R. at Ninemile Bridge		1,341	NA	36,400	45,400	48,900	56,800	942.80	43,600	10–2	[1]58
01010070	Big Black R. near Depot Mountain		171	NA	7,550	10,000	11,000	13,400	898.28	7,420	>10	25
01010500	St. John R. at Dickey		2,680	NA	77,700	99,800	109,000	130,000	610.09	104,000	2–1	[1]62
01011000	Allagash R. near Allagash		1,478	NA	24,700	33,300	36,900	45,600	619.01	40,900	1–0.2	77
01013500	Fish R. near Fort Kent		873	NA	12,000	15,000	16,300	19,300	524.60	18,300	1–0.2	84
01014000	St. John R. below Fish R. at Fort Kent		5,914	NA	121,000	152,000	164,000	193,000	517.64	183,000	1–0.2	[1]82
01015800	Aroostook R. near Masardis		892	NA	21,000	26,800	29,100	34,500	548.13	29,500	1	51
01016500	Machias R. near Ashland[2]		330	NA	10,500	14,700	16,500	21,100	542.48	9,730	>10	32
01017000	Aroostook R. at Washburn		1,654	NA	36,100	46,200	50,400	59,900	449.70	49,500	2–1	78
01018000	Meduxnekeag R. near Houlton		175	NA	5,620	7,620	8,480	10,500	341.11	4,370	>10	47
01029500	EBr Penobscot R. at Grindstone[3]		837	NA	23,000	31,200	34,800	43,200	309.41	35,200	1–0.2	89
01031500	Piscataquis R. near Dover-Foxcroft		298	NA	15,600	22,700	25,800	33,700	371.41	15,200	>10	106
01034000	Piscataquis R. at Medford		1,162	NA	39,100	56,000	63,700	82,600	261.39	43,200	10–2	[1]78
01034500	Penobscot R. at West Enfield[3]		6,422	NA	100,000	133,000	147,000	180,000	146.89	126,000	10–2	[1]107
					Calculated with regression equations					Computed with indirect methods		
[4]22	WBr Mattawamkeag R., Island Falls	Bog Brook Rd.	44.6	4.44	2,183	3,196	3,667	4,820	636.06	3,680	1	None
[5]01015700	Houlton Brook, T9R5 WELS	Oxbow Rd.	6.09	1.35	189	275	316	413	640.42	302	2–1	10
[5]01014700	Factory Brook, Madawaska	Rte. 1	6.01	0.12	752	1,203	1,420	1,982	489.45	332	>10	10
[5]01017300	Nichols Brook, Caribou	Grimes Mill	3.81	0.27	365	577	680	940	391.00	193	>10	10
[5]01017900	Marley Brook, Smyrna	Rte. 2	1.49	0.02	261	434	520	745	608.56	203	>10	18
01012895	Clark Brook, Wallagrass	Rte. 11	1.12	0.11	114	183	218	305	637.20	[6]69	>10	8

[1] Does not include additional historical period that is outside period of continuous record.

[2] This station was discontinued; thus rating is from 1983. No evidence that 2008 flow was not exceeded between 1984–2007.

[3] These stations affected by regulation, and thus exceedance probability estimates only apply if regulation continues as was done historically.

[4] This location was never a U.S. Geological Survey streamgage, but peak streamflow elevations and flows were calculated because this was the location of a bridge failure. Station number refers to location on figure 9.

[5] Although these stations were run as crest-stage gages from 1964–1974, these records were not used in computing the flow frequencies due to altered conditions of structures.

[6] This peak flow computed with rating curve from crest-stage streamgage run from 2000 to 2009.

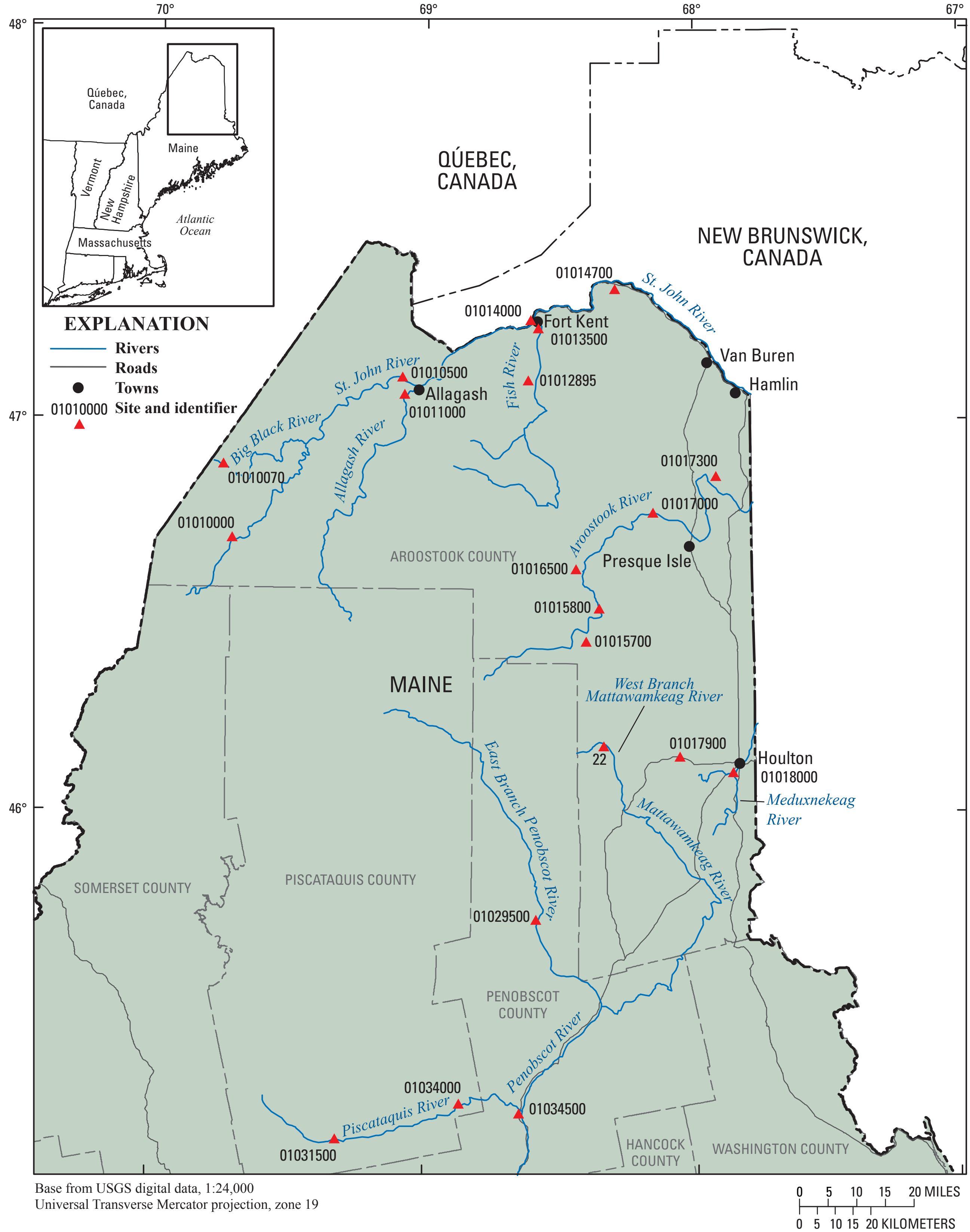

Figure 9. Sites where peak streamflows were calculated for the April and May 2008 flood in northern Maine.

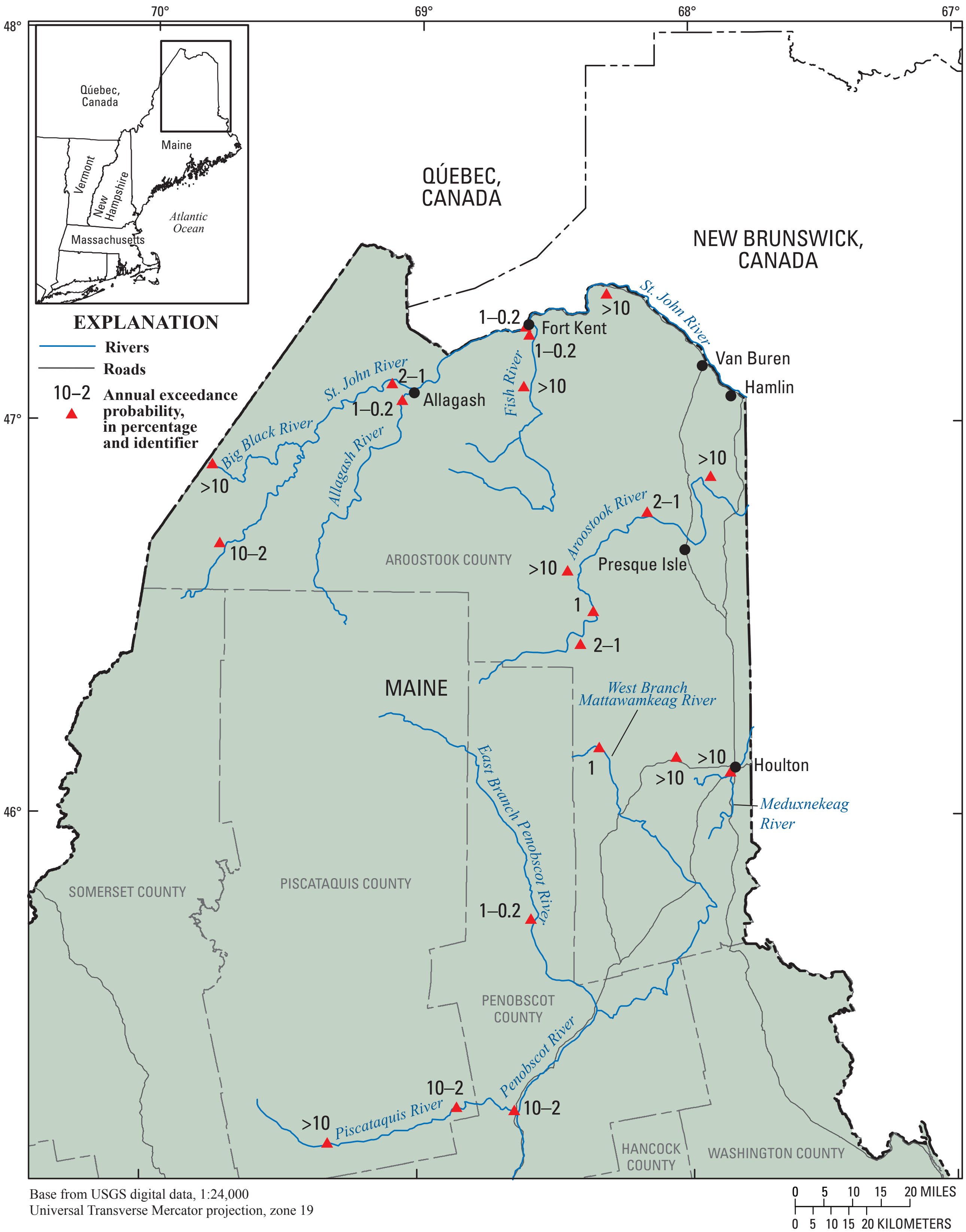

Figure 10. Annual probability of exceedance for peak streamflows observed during the April and May 2008 flood at selected sites in northern Maine.

Comparison of 2008 Flood Data to Published Flood Insurance Studies

Standard exceedance probabilities for streamflows calculated in this report (table 2) were compared to the peak streamflow recurrence intervals published in the effective flood insurance studies (FIS) for each of the five sites where information from a detailed FIS is available (table 3). Applicable FISs were published from 1979 to 2003 (Federal Emergency Management Agency, various dates). Differences between exceedance probabilities in this flood report and the reciprocals of the recurrence intervals in the effective FISs resulted in different estimates of the exceedance probability for the 2008 flood only at the two sites on the Aroostook River. Aroostook River at Washburn had a 2008 peak flow of 49,500 ft^3/s, giving it an annual exceedance probability between 2 and 1 percent (table 2)—equivalent to a recurrence interval between 50 and 100 years. A peak flow of 49,500 ft^3/s would have had a recurrence interval between 10 and 50 years in the Washburn FIS (Federal Emergency Management Agency, 1980) (table 3). Aroostook River near Masardis had a 2008 peak flow of 29,500 ft^3/s, giving it an annual exceedance probability of 1 percent (table 2)—equivalent to a recurrence interval of 100 years. A peak flow of 29,500 ft^3/s would have had a recurrence interval less than 100 years in the Masardis FIS (Federal Emergency Management Agency, 1988) (table 3). Exceedance probabilities for this report and the recurrence intervals in the effective FISs were calculated using Log Pearson type III frequency analyses at continuous-record streamgages. Thus, differences show where 30 years of additional data can change statistical flows over time.

In a separate analysis, the peak water-surface elevations observed in the April/May 2008 flood were compared to the peak water-surface elevations that would have been expected if the April/May 2008 peak streamflows were applied to the recurrence-interval data and the elevation profiles from the effective FIS for the given location. Discrepancies were found at two sites. A peak water-surface elevation of 524.60 ft was observed at Fish River near Fort Kent in 2008. The 2008 peak flow of 18,300 ft^3/s would have had a peak water-surface elevation of 520.8 ft if applied to the Fort Kent FIS (Federal Emergency Management Agency, 1979) (table 3). A peak water-surface elevation of 517.64 ft was observed at St. John River at Fort Kent in 2008. The 2008 peak flow of 183,000 ft^3/s would have had a peak water-surface elevation of 519.0 ft if applied to the Fort Kent FIS (table 3). The discrepancies are likely because hydraulic models from which FIS elevations were obtained were not calibrated to a flood the magnitude of which was observed in 2008 (table 3). In addition, there are differences in the hydraulic models (i.e., improved bridge routines in HEC-RAS compared to HEC-2) and (or) differences in modeler input parameters (roughness coefficients, etc.). At both streamgages with discrepancies, the 2008 flood was the flood of record. Additional years of data, including the April/May 2008 flood, will allow for more accurate calibration of future hydraulic models in this region. FIS profiles were adjusted from NGVD 29 to NAVD 88 in order to make the comparison with 2008 peak water-surface elevations surveyed in NAVD 88.

Table 3. Relation of computed April and May 2008 peak streamflows and high-water mark elevations to flood-insurance study data at selected streamgages in northern Maine.

[All streamflow recurrence intervals from flood insurance studies (FIS) computed with Log-Pearson type-3 frequency analyses; all elevations are in NAVD 88; FIS profile elevations were originally in NGVD 29, but were adjusted to NAVD 88 for this report; USGS, U.S. Geological Survey; ft^3/s, cubic feet per second; yr, year; ft, feet; R., river; --, data not available; 10-, 50-, 100-, and 500-yr recurrence intervals correspond to 10-, 2-, 1-, and 0.2 percent annual exceedance probabilities]

USGS station number	Water body and location	2008 Peak flow (ft^3/s)	Streamflow recurrence intervals from flood insurance studies (ft^3/s)				2008 Elevation (ft)	Elevations from FIS profiles (ft)			
			10-yr	50-yr	100-yr	500-yr		10-yr	50-yr	100-yr	500-yr
01010500	St. John R. at Dickey	104,000	--	--	107,900	--	610.09	--	--	624.508	--
01013500	Fish R. near Fort Kent	18,300	12,300	16,300	18,000	22,200	524.60	518.626	520.026	520.826	522.226
01014000	St. John R. below Fish R. at Fort Kent	183,000	121,000	158,000	175,000	210,000	517.64	513.506	517.306	518.406	521.006
01015800	Aroostook R. near Masardis	29,500	--	--	29,600	--	548.13	--	--	549.059	--
01017000	Aroostook R. at Washburn	49,500	37,675	49,885	55,000	68,200	449.70	447.596	449.996	450.596	452.796

Summary and Conclusions

Above average snowpacks late into the second week in April 2008, rapid snowmelt during the third week in April, and a low-pressure system dropping from two to four in. of rain in northern Maine from April 29–30, 2008, resulted in record-high peak water-surface elevations and peak streamflows in northern Aroostook County on April 30 and May 1, 2008. The most severe flooding was in Fort Kent. Peak water-surface elevations resulting from the flood were obtained at 13 continuous-record streamgages and 63 surveyed high-water marks on streams in Aroostook and Penobscot Counties.

Peak streamflows for the April/May 2008 flood were computed at 20 sites on 15 streams through water-surface elevation/streamflow rating curves or hydraulic flow models. Seven long-term streamgages having 25 to 84 years of record on the Big Black, St. John, Allagash, Fish, and Aroostook Rivers recorded maximum streamflows for their respective periods of record. Streamflows with exceedance probabilities equal to or less than 1 percent were recorded on the St. John and Fish Rivers in Fort Kent, the Allagash River in Allagash, the Aroostook River near Masardis, and the West Branch Mattawamkeag River at Moro Plantation. The St. John River at Dickey, the Aroostook River at Washburn, and Houlton Brook at T9R5WELS all had streamflows with exceedance probabilities between 1 and 2 percent.

Minimal differences between peak flows of standard annual exceedance probabilities in this flood report and peak flows of equivalent recurrence intervals at the same locations in the effective Federal Emergency Management Agency flood insurance studies at five locations in Aroostook County were likely because of Log Pearson type III frequency analyses being used in both cases at the same long-term continuous-record streamgages. Differences on the Aroostook River at Washburn and at Masardis show that 30 years of additional data can result in improvements to statistical flows over time. Discrepancies between peak water-surface elevations in the flood insurance studies and peak water-surface elevations observed in 2008, given the flow observed in the April/May 2008 flood at Fish River near Fort Kent and St. John River below Fish River at Fort Kent, are likely due to differences in hydraulic models; in addition, flood insurance studies-derived elevations had not previously been calibrated to a flood of the magnitude observed in 2008.

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