COVENTRY ICE JAM FLOOD STUDY
OF THE BLACK RIVER
COVENTRY, VERMONT

Prepared for:
Town of Coventry, VT

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October 10, 2025

D&K #230817

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1.0 INTRODUCTION

This report summarizes the methods, assumptions, and results of evaluating the existing ice jam flooding conditions and flood damage reduction alternatives at specific locations in the Town of Coventry, VT. This study was completed to improve the Town's understanding of the ice jamming and hydraulic capacity on the Black River near the village center of Coventry. Originally the Scope of Work included evaluation of five different crossings over the Black River in the Town. The stream crossings included bridges on VT Route 14, Back Coventry Road, Heermanville Road and at the intersection of VT Route 105 and US Route 5 and along US Route 5 downstream of the village center. After communicating with the Town and improving our understanding of historical problem areas, it was decided to focus our efforts on the river crossing near the VT Route 105 and US Route 5 intersection. The Town of Coventry is interested in promoting flood resiliency by implementing flood resilient solutions that reduce the impacts from repeated ice jam events.

The VT Route 105 bridge over the Black River in the vicinity of the US Route 5 intersection was evaluated in detail as part of this study to help understand its influence on in-stream hydraulics and formation of ice jams. The study evaluated potential sources of flood mitigation including creation of a flood berm, installation of an ice boom, a number of potential channel modifications and improved site specific geomorphic conditions. The larger design storms of 2% and 1% Annual Exceedance Probability (AEP) (also commonly referred to as the 50-yr, 100-year storms respectively) are evaluated for existing conditions and a series of conceptual alternative scenarios. A summary of our investigation methods and findings are presented below.

The watershed area of the Black River at the study area is approximately 129 square miles (see Attached, Figure 1) and flows from west to east along the northern end of town parallel to Route 105. The river makes a 90-degree bend to the north near the intersection of Route 105 and Route 5. When the river reaches flooding stages, water and ice top the banks along the right southern portion of the channel near the VT Route 105 and US Route 5 intersection which allows water to flow into the Town of Coventry, flooding residences and businesses.

1.1 Floodplain, Flooding, and Ice Jam Definitions

There are many definitions of floodplain and flooding from a large number of authoritative groups, agencies and organizations. DuBois & King's (D&K's) basic definition for a floodplain is an area of land adjacent to a stream or river that stretches from the channel banks to the edge of the valley walls and experiences flooding during periods of high flows. Floodplains are naturally designed to convey and temporarily store excess water that has exited the channel banks.

Flooding is a natural occurrence and occurs when it rains and the volume of precipitation exceeds the capacity of the stream's watershed to absorb or attenuate the runoff. When this runoff exceeds the capacity of the channel of a stream or river the flood waters inundate the stream's floodplain. The level of flooding is dependent on the amount of excess runoff. Flood damages occur when structures intersect with the stream or river's natural floodplain capacity to convey and store excess runoff.

A river ice jam is an obstruction formed when pieces of river ice accumulate and block the water flow, often caused by rising water levels from snowmelt or heavy rain during the spring. These ice jams create a temporary dam causing water levels to rise upstream and potentially leading to significant flooding, especially in areas with narrow channels or obstructions like bridges and dams.

1.2 Purpose

The purpose of the Coventry Ice Jam Flood Study is to evaluate the hydraulic conditions in the areas known to be prone to flooding and ice jams and to develop an Alternatives Analysis to evaluate potential mitigation measures to address these issues. Flood reduction methods consist of two general groupings; 1) Non-structural and 2) Structural flood reduction methods.

Non-structural flood reduction methods:

- Land management by floodplain zoning,
- Planning and local, state and federal regulations, such as, zoning ordinances, building codes, development and redevelopment regulations, sanitary and well codes and hazard mitigation planning

Structural flood reduction methods include:

- Large flood control projects such as dams, levees, flow diversions and channel alterations
- Removal of obstructions to flow including dams, stream crossings, large debris jams, etc.
- Transportation structures such as bridges (improve bridge openings) addressing fluvial geomorphic characteristics of the stream
- Dry and Wet floodproofing
- Removing Structures from the floodplain / Elevate Structures (elevate homes)
- Stormwater Control

1.3 Flooding Overview

The historic Town of Coventry is located in northern central Vermont within Orleans County. The Black River flows from west to east along the Town's northern border and has been susceptible to ice jamming. Upstream of the Town, the Black River flows over a series of two waterfalls with a large oxbow bend between the waterfalls. A USGS gaging station, which is used to record the stage and discharge of the stream, is located just upstream of the upper waterfall and downstream of Heermanville Road on the right bank (defined facing downstream).

Ice jams in the Black River and related flooding have been well documented by a former resident (John Miller). A report Mr. Miller prepared documenting the history of the Town and flooding observations is included in Appendix D.

The US Army Corps of Engineers (USACE) Silver Jacket Team also prepared an assessment of the ice jam impacts, discussed potential mitigation options, and presented it to the Town in February 2022 (Rocks, 2022).

The Black River is not currently mapped by FEMA in the National Flood Insurance Program. Orleans County is slated for a mapping update in the NFIP at the end of 2025; however, the Black River will not be studied in detail (Ricketts, personal communication).

1.4 Scope of Work

To understand the ice jam issues in Coventry associated with the Black River, D&K completed a background review and site visit, completed a hydrologic analysis and hydraulic analysis of the Black River, developed mitigation alternatives, and prepared a benefit cost analysis of the alternatives.

In 2025, the Town secured a grant through the Vermont Department of Public Safety under the Building Resilient Infrastructure and Communities (BRIC) 2022 program. This evaluation and report is funded through the BRIC program.

2.0 BACKGROUND REVIEW & FIELD INVESTIGATION

D&K obtained, compiled, and reviewed relevant existing information, including culvert and bridge inventories, bridge hydraulic analyses, existing flood models, hazard mitigation plans, environmental studies, and geomorphic assessments. Following review of existing materials, D&K conducted a site visit which included walking the river, documenting existing conditions, and view the river crossings. A topographic survey was also conducted along the Black River from just downstream of the US Route 5 bridge near Blake Lane to approximately 1,000 feet upstream of the VT Route 14 bridge and included multiple stream cross sections and collection of critical bridge elevation data.

2.1 Background Review

A review of the background data provided a solid understanding of the issues and concerns related to the ice jam flooding in Coventry. In particular, the report by Mr. Miller was helpful regarding the locations that have been frequently flooded, the depths of the ice and water, the estimated heights of the ice jams, the estimated thickness of the ice in the channel, and dates when floods have occurred in the past. The floods noted in the report are summarized in Table 1 below.

Table 1. – Ice Jam Events in Coventry, Vermont

Event #	Date	Season	Severity	Key Impacts and Details
1	November 1927	Fall	Severe	Heerman's sawmill washed away; building detached from foundation and floated over upper falls
2	March 1936	Spring	Major	Flooding on main streets; ice chunks throughout village; ice depth 10+ feet to breach river banks
3	April 1936	Spring	Moderate	Flooding upstream at Heermanville (above upper falls), one month after March event
4	Spring 1950	Spring	Moderate	Ice jam at Miller/Cowle house and Route 14 bridge; ice notably clean (pre-corn farming era)
5	February 1993	Winter	Severe	Double ice jam (second flow hit existing jam); river rose 10 feet in minutes; ice wall 10-12 feet deep
6	February 2016	Winter	Major	Basements flooded; furnaces/tanks damaged; river 4 feet deep through garage, 1.5 feet in streets; ice 5-6 feet deep in yards
7	January 2018	Winter	Extreme (Record)	Thaw and rain event; river changed course; 3 feet deep across streets; extensive property damage; heavy silt deposits
8	February 2018	Winter	Moderate	Second jam of 2018; new ice collided with existing frozen jam
9	December 2018	Winter	Moderate	Third jam of 2018; cold period followed by thaw and heavy rain
10	January 2020	Winter	Minor	Ice jammed in oxbow upstream; froze in place without reaching town

Three separate ice jam events occurred in 2018 alone, indicating increased frequency. The document notes that double ice jams have become "much more common in recent years due to erratic weather patterns".

The Silver Jacket team presentation was also reviewed (Rocks, 2022). A summary of key takeaways from the report are summarized in Tables 2 through 5 below.

Table 2. – Recent Ice Jam Events in Coventry, VT (Rocks, 2022)

Date	Peak Flow (cfs)	Conditions
March 29, 1989	~2,000	Highest recorded flow, significant event
January 5, 1993	~800	Mid-winter thaw event
March 30, 1993	~1,200	Spring breakup conditions
February 28, 2000	~1,000	Warm period with rain events
March 9, 2012	~900	Temperature fluctuations, multiple precipitation events
January 13, 2018*	NA	Main Street inundated, numerous properties flooded, ice and silt damage
February 20, 2018	~1,000	Preceded by warm temps, rain, and flow increase
December 22, 2018*	NA	Main Street inundated, numerous properties flooded, ice and silt damage (again)

* Additional events provided by Mr. John Miller

Table 3. – General Hydraulic Conditions (Rocks, 2022)

Reach	Characteristics
General	Gently sloped river through agricultural land; shallow sections with mild riffles; aggradation and sand bars; low velocity pools and bends
Ice Formation	Surface border ice and ice cover common; some riffle sections stay open through winter
Back Coventry Rd Covered Bridge	~0.75 river miles downstream of Route 14 Bridge; site of ice jams per local accounts
Heermanville Rd Bridge	~0.70 river miles downstream of covered bridge; USGS gage 04296000 located just downstream; waterfall ~275 feet downstream (ice can pass over falls)
Route 105 Bridge Area	~0.80 river miles of shallow slope with 180-degree bends; waterfall ~0.20 miles upstream of bridge; numerous constraints to ice transport including island upstream adjacent to residential area

Table 4. – Historic Ice Jam Impacts (Rocks, 2022)

Impact Type	Description
Flooding Location	Vicinity of Route 105 and Route 5 intersection
Property Damage	Commercial properties and residential areas flooded
Infrastructure	Roadways and bridges flooded
Ice Jam Type	Most are breakup ice jams during mid-winter thaw periods
Timing Pattern	Occur during mid-winter thaws followed by sub-freezing temperatures; potential for jams to freeze in place creating prolonged flooding concerns

Table 5. – Mitigation Alternatives Discussed (Rocks, 2022)

Type	Examples	Characteristics
Advance/Early Warning	Stream gages, weather stations, web cameras, ice motion detectors, trained observers, mechanical/thermal weakening	Non-structural; 2 weeks to 6 months lead time; inexpensive; effectiveness difficult to quantify
Emergency Measures	Flood fighting, sandbags, temporary dikes, road closures, evacuation plans, ice removal	Immediate response; access may be difficult
Permanent Measures	Ice Control Structures (booms, weirs, piers); channel modifications	Structural solutions; 2-5 year lead time; high reliability; generally costly

2.2 Site Visit

The following is a summary of the information discussed during the May 28, 2025 Coventry Ice Jam Study field visit conducted by Alaina Smith, PE and Phil Marquette. The weather was calm, with clear skies and a high of 73 degrees Farenheit. Flows in the Black River were approximately 170 cubic feet per second (cfs) and observed to be below bankfull.

Ice Jams – Winter Flooding

- Mr. Marquette has observed the Black River flooding downstream towards Newport prior to any flooding occurring in Coventry; both during open flow and ice jam conditions.
- When a jam occurs at the Route 105/Route 5 Bridge, there is often ice observed upstream and downstream of the bridge.
- The stretch of the Black River from the lower falls to the Miller property generally remains open in the winter (does not freeze over).
- It appears that jams may form downstream of the Route 105 Bridge at the next tight bend located approximately 400 to 600 feet downstream.
- Mr. Marquette has observed ice backed up near the Route 5 Bridge (downstream of the Town) and open flow further downstream indicating a jam between the two points of observation. The jam likely occurs at the 90 degree bend (from east to north) that occurs approximately 600 feet downstream of the Route 105 Bridge.
- There are historic bridge abutments on each bank, at the end of Conway Court where the old bridge crossed. Mr. Marquette reported that jams do not form at this constriction.
- There have been jams seen at the apex of the large oxbow bend upstream of the Town.
- Mr. Marquette has observed that as jams break up and move downstream, the reformation (or lack of) is influenced by conditions in the river downstream (ice cover, open channel, remnants of a previous jam).
- Route 5 has overtopped between the Route 105 and Route 5 bridge, closer to Route 105 than Route 5, where Route 5 is lower in elevation.
- The Miller property (55 Conway Ct) has only flooded in the basement as has the property directly across the street at 36 Conway Ct.
- The island upstream of the Route 105 Bridge may be aggrading and impacting the channel's ability to transport ice.
- The recent jam of March 2025 did not cause extensive flooding.
- Sam (current owner of Miller property) reported water flowed over the banks and into the low-lying area of her yard, but did not get into the basement during the March 2025 ice jam.

Open Channel/Rainfall Storms

- The July 2023 storm resulted in flooding over the Route 5/Route 105 intersection. Flows also overtopped the bank at 55 Conway Court and backwater reached the lower apartment at 235 Main Street.
- Sometime after the ice jam flood in 2018, the commercial garage at 88 Main Street burned and was rebuilt 2.5 feet higher than the previous construction. It flooded during the July 2023 storm to a depth of approximately 2 feet. A high water line was observed inside the garage. A sediment line on the inside of the garage door can be seen in Appendix B.
- Water reached approximately halfway up the electric box with the meter on the power pole in the park, a height of approximately 5 feet above ground level as seen in the photos in Appendix B.

Information from the Town of Coventry

- There have been no residential complaints regarding flooding at the other four bridges in the area (Route 14, Back Coventry Road, Heermanville Road, and the Route 5 Bridge).
- The Route 14 Bridge, recently constructed after an oil tanker explosion, is an exact replacement of the previous bridge. Drawings and specs used by the contractor for the previous bridge were used for the replacement. The residence located on the right bank upstream of the bridge has not experienced any issues with flooding from the bridge. There is a sizeable open floodplain in the upstream left overbank.
- Town floodplain limits are mapped in the NMIS system.
- There are two properties that will be bought out as part of a BRIC grant; 89 Main Street, and 235 Main Street. 89 Main Street is scheduled for demolition soon.
- 36 Conway Ct. stepped through the process but did not accept the offer from FEMA.
- 117 Main Street (multi-unit building) has experienced flooding in the basement. The owner has made recent improvements and did not want to sell at this time.

2.3 Topographic Survey

Digital Elevation Model (DEM) data was obtained from the Vermont Center for Geographic Information database and used to develop the topography in the project area. The DEM was derived from a LiDAR collection effort (flown between 10/31 and 11/3/2016). Modeled existing conditions are based on this topography.

Additionally, D&K completed a limited topographic survey along the Black River within the project area. The survey consisted of collecting approximately 20 cross sections at critical locations and collecting hydraulic geometry data at three of the five bridge locations. The survey crew also collected data of critical infrastructure and first-floor and ground level elevations for select structures near the river within the project area. The survey data is incorporated into the LiDAR derived DEM to create a refined terrain for the existing conditions topography.

3.0 HYDROLOGIC ANALYSIS

The Black River watershed at the USGS gage location has a contributing drainage area of 122 square miles. An additional 7 square miles of basin contributed to the river between the gage and the Route 105 Bridge. The watershed generally drains from the south to the north through agricultural and wooded lands. A figure of the drainage area is included in Appendix A.

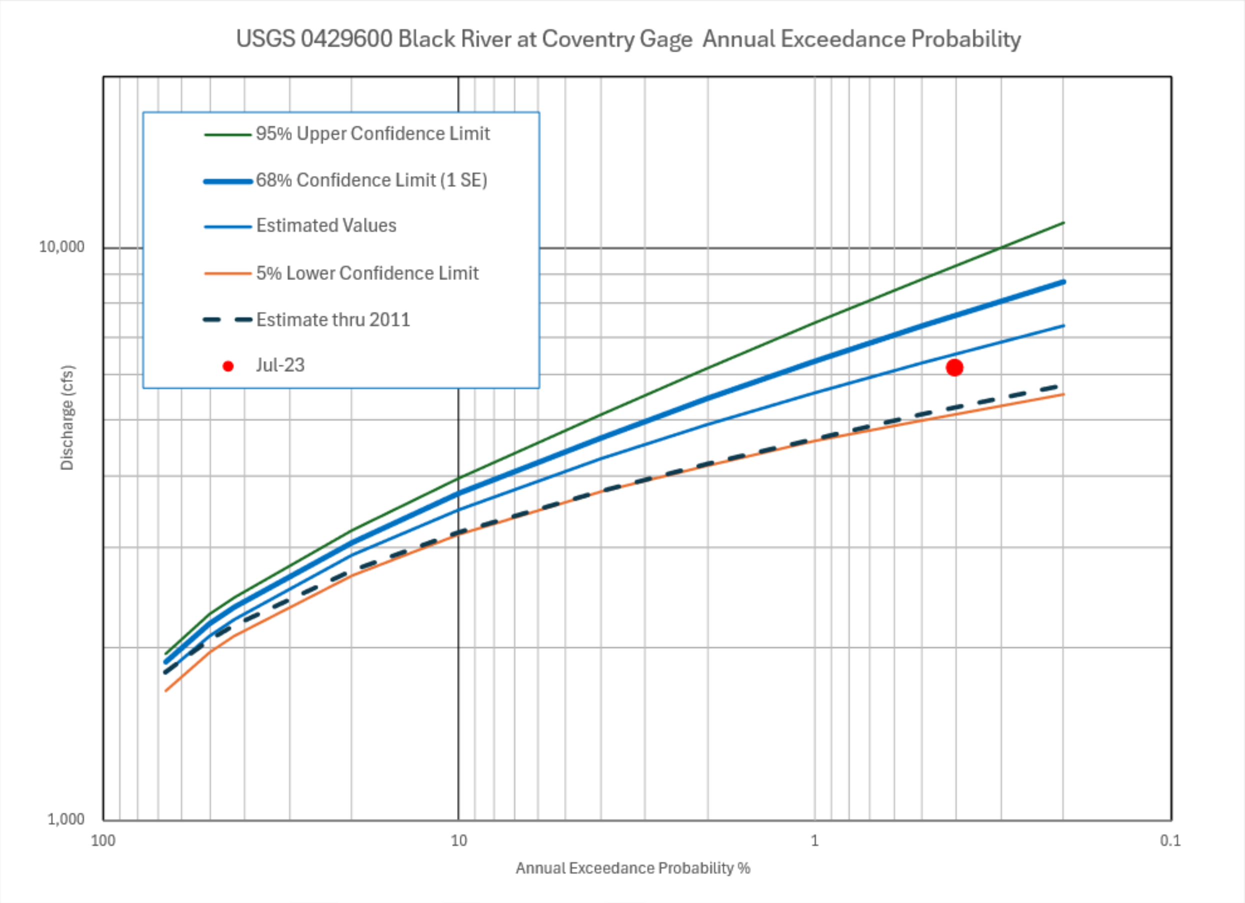
Stage and discharge on the Black River are recorded at the USGS Gage *04296000 Black River at Coventry*. The gage is located on the right bank approximately 75 feet downstream of Heermanville Road, and approximately 275 feet upstream of the upper waterfall. This gage has been in continuous operation in the same location since its installation in 1952. Annual peak flow data from the gage are used to perform a statistical analysis to estimate design flows using the

USGS program PEAK FQ. Data is presented as Figure 4 in Appendix A and results of the analysis are summarized below.

There is uncertainty in all statistical analyses. At the Black River gage, the statistical analysis provides a band of confidence between the lower 5 percent and upper 95 percent. For this effort, one standard error is applied to the estimated value to provide a 68 percent upper confidence limit. This approach is used to account for the addition uncertainty in the data predictions due to the increasing intensity of storms and variable weather patterns that are being experienced globally and locally.

Table 6. – Results of the Flood Frequency Analysis for the Black River at Coventry

Annual Exceedance Probability	Return Period (Years)	5% Lower Confidence Limit	Estimated Value	68 % Upper Confidence Limit (1 SE)	95% Upper Confidence Limit
0.667	1.5	1,678	1,805	**1,890**	1,954
0.500	2.0	1,947	2,103	**2,202**	2,287
0.429	2.3	2,073	2,246	**2,352**	2,446
0.200	5	2,654	2,905	**3,058**	3,216
0.100	10	3,154	3,485	**3,720**	3,986
0.040	25	3,768	4,275	**4,660**	5,174
0.020	50	4,195	4,906	**5,452**	6,231
0.010	100	4,601	5,574	**6,336**	7,460
0.005	200	4,991	6,286	**7,311**	8,895
0.002	500	5,490	7,301	**8,752**	11,170



4.0 HYDRAULIC ANALYSIS

The hydraulic analysis of the Black River was performed using the Hydrologic Engineering Center – River Analysis System HEC RAS v6.6 program. HEC-RAS is capable of modeling rivers with open channel flow, with ice cover, and with ice jams. For this effort, both open water and ice jam scenarios were evaluated for existing conditions and with the proposed alternatives.

4.1 Existing Conditions

Topography

Digital Elevation Model (DEM) data were obtained from the Vermont Center for Geographic Information database and used to develop the topography in the project area. A topographic survey was also performed by D&K in May 2025. The survey captured the elevation data of critical infrastructure, topography, and bathymetry of the channel. The survey data is incorporated into the LiDAR-derived DEM to create a refined terrain for the existing conditions topography.

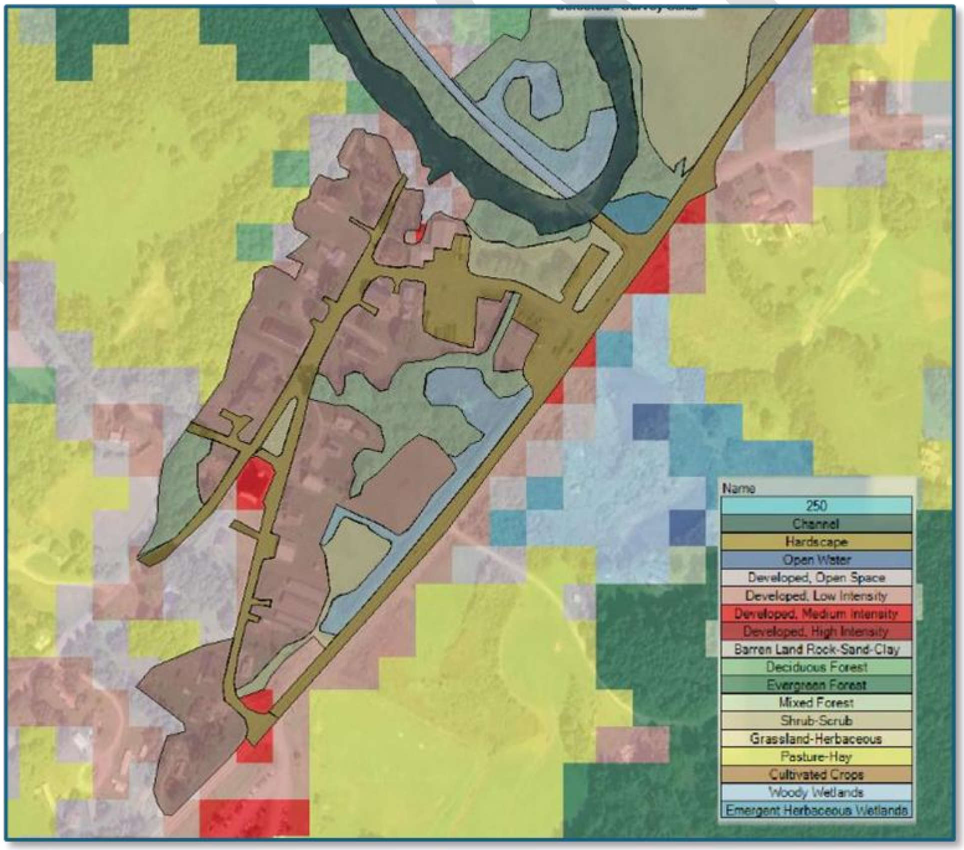
Building footprints and elevations obtained from the OpenStreetMap website were used to create blocked obstructions at the locations of the existing buildings. The final basemap titled “Terrain with Survey” was used to determine the stations and elevations of the cross sections used in the model.

Manning “N” Roughness

Overland roughness values, Manning “n”, were assigned using the National Land Cover Database, augmented with classification polygons created to represent the land use more accurately in the modeled area. Values per land cover type are shown in Table 7 below.

Table 7. – Manning “n” Roughness Values per Land Cover Type

Land Cover Type	Manning Roughness Value “n”	Land Cover Type	Manning Roughness Value “n”
Barren Land Rock-Sand-Clay	0.025	Evergreen Forest	0.160
Channel	0.035	Grassland-Herbaceous	0.035
Cultivated Crops	0.035	Hardscape	0.025
Deciduous Forest	0.130	Mixed Forest	0.140
Developed, High Intensity	0.150	Open Water	0.040
Developed, Low Intensity	0.070	Pasture-Hay	0.030
Developed, Medium Intensity	0.085	Shrub-Scrub	0.100
Developed, Open Space	0.040	Woody Wetlands	0.120
Emergent Herbaceous Wetlands	0.070		



Manning “N” Roughness Values in the Study Area

Downstream Starting Conditions
The downstream end of the study area is approximately 1,770 feet downstream of the Route 105 bridge. Starting water surface elevation conditions for the standard step backwater calculations were set by assuming a normal depth and applying a starting slope of 0.0036 ft/ft. This slope was estimated from the channel thalweg slope measured 200 feet upstream and 200 feet downstream of the starting cross section.

Structures
The Route 105 bridge is modeled based on survey data, and includes the concrete abutments and two bridge piers.

Ice Cover and Ice Jam
Hydraulic parameters of the ice cover and ice jam were selected based on guidance by the Cold Regions Research and Engineering Laboratory (CRREL) of the US Army Corps of Engineers (White, 1999). Ice thickness of 2 feet was estimated by referencing photographs and descriptions of previous ice jam flooding events (Miller, no date). The toe of the ice jam was assumed to be located at the upstream face of the bridge. The thickness of the jam at the toe and upstream was adjusted until the model results showed agreement to the observed depths and locations indicated in the Miller report.

The final thicknesses were determined to be 8 feet at the toe extending approximately 280 feet upstream, tapering to 5 feet for an additional 85 feet and upstream extents of 2 feet thick cover for an additional 185 feet. The same ice jam configuration was applied to each alternative analysis and all design storms.

5.0 ALTERNATIVES ANALYSIS

Following the review of the background information and the site visit, six mitigation alternatives were developed and evaluated for this project.

1. Installation of a permanent flood berm or wall
2. Installation and yearly deployment of an ice control structure
3. Creation of an overflow channel in the left side of the stream under the Route 105 bridge
4. Excavation and widening of the right side channel at the island upstream of the bridge
5. Clearing of vegetation and removal of the island above the bridge
6. Installation of flood proofing measures at individual residences and structures

5.1 Alternative 1 – Flood Berm

This alternative would involve the construction of a berm or wall that would act as a levee, preventing ice and flood water from accessing the right overbank. To be effective, the berm would need to extend from the grist mill foundation at the upstream end to the Route 105 bridge embankment at the downstream end. The berm would need to be constructed at a height of 701 feet based on the assumed ice jam conditions and a discharge value corresponding to the 1 percent storm. This could be an earthen berm, a wall (sheet pile, concrete, etc.), or a combination thereof. This is represented in the model with a raised berm in the terrain and applied to each affected cross section. Levee points were used to indicate the berm will act as a levee in the model calculations.

5.2 Alternative 2 – Ice Boom

This alternative would place an ice boom across the Black River upstream of the lower falls. The boom would serve to hold back ice flows, thus limiting the amount of ice available to form a jam between the bridge and the lower falls. By restricting the volume of ice available to jam in the channel, the potential for the ice decreases as does the severity of flooding caused by any smaller jams that may form. This was represented in the model by limiting the ice thickness to 2 feet from the bridge to the Miller property.

5.3 Alternative 3 – Overflow Channel near Bridge

Three in-channel modifications were also evaluated in an attempt to reduce flooding impacts due to ice jams. The three in-channel alternatives all involve making changes within the banks of the river. Such proposed activity is challenging to acquire the necessary permits for construction. These alternatives are included primarily for an understanding of the impact and less of a proposed solution.

The first in-channel modification evaluated for would entail excavating in the left overbank area from upstream of the bridge to downstream of the bridge. This “bypass channel” would allow for more water to flow beneath ice jams, which form at the bridge. This is modeled by altering the terrain to include the channel in the left portion of the stream, and the cross sections were adjusted accordingly.

5.4 Alternative 4 – Widen and Lower the Small Side Channel

This alternative would increase the flow area of the small side channel that exists to the right of the island upstream of the bridge. This side channel has likely lost conveyance over the past few decades as bed material has deposited and vegetation has matured and thickened along the channel. Increasing the flow area in this channel could potentially help with the flooding during ice jams. This is modeled by altering the terrain to include a wider and lower channel in the right portion of the stream to the right of the island, and the cross sections were adjusted accordingly.

5.5 Alternative 5 – Removal of the Island Upstream of the Bridge

The island that exists in the Black River upstream from the Route 105 bridge reduces the flow area of the river. Sands and fines were observed on the top of the island indicating it is aggrading and increasing in size. Removing the island could potentially help mitigate the impacts of flooding by creating additional flow area under the ice jam. The terrain was altered to lower the channel across the area of the current island. The cross sections were adjusted to represent the changes to the terrain.

5.6 Alternative 6 – Individual Flood Proofing Options

Residential flood proofing encompasses a range of strategies designed to protect structures from flood damage, whether from ice jam events, riverine flooding, or other sources. These methods can be broadly categorized into passive and mechanical (active) approaches, each with distinct advantages, limitations, and cost implications. These options were not modeled hydraulically.

5.6.1 Passive Flood Proofing Strategies

Passive flood proofing methods provide protection without requiring active intervention or mechanical operation during a flood event. The primary passive approaches include dry floodproofing, wet floodproofing, structural elevation, and site-based solutions.

Dry floodproofing involves making a structure watertight to prevent floodwater from entering the building. This approach typically includes applying waterproof coatings and sealants to exterior walls, installing shield systems over doors and windows, sealing all cracks and openings in the building envelope, and installing backflow valves in drains and sewer lines. The primary advantage of dry floodproofing is its ability to protect both the structure and its contents from water damage while requiring no mechanical systems to maintain or operate during an event. Additionally, dry floodproofing significantly reduces cleanup and recovery time following a flood. However, this method has important limitations. It is generally only effective for shallow flooding, typically up to two to three feet in depth, as hydrostatic pressure from deeper water can cause structural damage to foundations and walls. The method also requires a nearly perfect seal, since even small gaps can compromise the entire system's effectiveness. In some cases, walls may need to be reinforced to withstand the water pressure. Implementation costs for dry floodproofing typically range from $10,000 to $50,000 depending on the size of the home and the level of protection required.

Wet floodproofing takes a fundamentally different approach by allowing water to enter the structure in a controlled manner, thereby equalizing pressure and minimizing structural damage. This method involves installing flood vents in foundation walls to permit controlled water entry, using water-resistant materials such as ceramic tile and concrete for walls and floors, elevating critical utilities including HVAC systems, water heaters, and electrical panels, and relocating valuable contents to upper floors. Wet floodproofing is considerably less expensive than dry floodproofing, with costs typically ranging from $5,000 to $15,000 for basic implementation including vents, material changes, and utility relocation. It also reduces the risk of structural damage from hydrostatic pressure and remains effective even during deeper flooding events. The trade-offs include the need for extensive cleanup after each flood event, inevitable damage to contents stored on lower levels, increased risk of mold growth and contamination, and unsuitability for homeowners who wish to maintain finished basement spaces.

Structural elevation represents the most comprehensive passive flood protection strategy. This approach involves raising the entire structure above the Base Flood Elevation (BFE) through various methods including lifting the house onto a new or extended foundation, building on piers, posts, or columns, or constructing an elevated slab. Elevation is widely recognized as the most effective long-term solution for flood protection, as it safeguards the entire structure and its contents while significantly reducing flood insurance premiums. The approach can also increase property values in flood-prone areas. However, elevation is also the most expensive option, with costs typically ranging from $30,000 to over $150,000 depending on the foundation type, home size, and the height of elevation required. The process requires significant construction work, may necessitate special permits or variances, changes the home's aesthetics and accessibility, and usually requires temporary relocation of the residents during construction.

Site-based passive strategies focus on managing water through landscaping and drainage improvements. These methods include grading the property to direct water away from the structure, installing French drains or swales to channel water, building berms or levees for perimeter protection, and using rain gardens and permeable surfaces to reduce runoff. These approaches offer natural and aesthetically pleasing solutions that provide drainage benefits beyond flood events and may increase property value. They are also environmentally beneficial. However, site-based strategies provide only limited protection against major flooding events, require adequate space for implementation, need ongoing maintenance, and their effectiveness depends heavily on the property's topography. Costs for these improvements typically range from $3,000 to $20,000 depending on the extent of the work required.

5.6.2 Mechanical and Active Flood Proofing Systems

Mechanical flood proofing methods require active operation or deployment, either automatically or manually, to provide protection during flood events. These systems can offer significant protection but introduce dependencies on power, maintenance, and timely deployment.

Sump pump and drainage systems represent the most common mechanical flood protection approach for residential properties. These systems actively remove water that infiltrates into basements or crawl spaces through a combination of collection sumps and electric pumps. Modern installations typically include primary pumps, battery backup systems to ensure operation during power outages, and alarm systems to alert homeowners of system failures. The advantages of sump pump systems include their relatively affordable cost of $1,000 to $5,000 for installation (with battery backup systems adding $500 to $2,000), their usefulness beyond flood events for general groundwater management, and the ability to automate their operation. The limitations include dependence on electrical power, requirements for regular maintenance to ensure reliability, potential for failure during extreme flooding that overwhelms the system's capacity, and effectiveness limited to managing relatively small volumes of water infiltration.

Removable or deployable flood barriers provide temporary protection that can be installed when flooding is anticipated. These systems include aluminum or steel panels that slot into permanently installed frames around doors and other openings, inflatable barriers that can be quickly deployed, water-filled barriers that use the weight of water for stability, and traditional sandbag installations. The primary advantage of these systems is their ability to provide moderate to significant flood protection while remaining removable when not needed, thus maintaining the home's normal appearance. They can be reused across multiple events and typically deploy relatively quickly. However, these systems have significant limitations. They require advance warning of flooding to allow time for deployment, need storage space when not in use, can be physically demanding to install (particularly for elderly or disabled homeowners), may not create a perfect seal, and are completely ineffective if the homeowner is away when flooding occurs. Costs vary considerably by system type, with aluminum barrier systems ranging from $5,000 to $25,000, inflatable barriers from $2,500 to $10,000, and water-filled barriers from $500 to $3,000.

Automatic flood gates and barriers represent the premium option in mechanical flood protection. These systems deploy automatically when water reaches a predetermined level, eliminating the need for manual intervention. They can protect multiple openings simultaneously and provide reliable protection even when homeowners are absent. The primary drawbacks are high initial costs ranging from $3,000 to $15,000 per opening, requirements for regular maintenance and testing to ensure reliability, potential for mechanical failures, and typically the need for professional installation and ongoing servicing.

5.6.3 Integrated Approaches and Cost-Benefit Considerations

Flood protection experts generally recommend combining multiple strategies to create comprehensive, redundant protection systems. A typical integrated approach might include elevation or dry floodproofing as the primary defense, wet floodproofing for areas that cannot be effectively sealed, proper site grading and drainage to reduce the volume of water reaching the structure, and backup sump pumps for redundancy. The optimal combination of flood proofing methods depends on several factors including the property's flood risk level and flooding frequency, the expected depth of flooding, the home's construction type, the homeowner's available budget, and potential insurance premium reductions that can offset upfront costs over time.

For ice jam-related flooding specifically, the selection of appropriate flood proofing methods must account for the rapid onset typical of ice jam events, which may provide limited warning time for deploying removable barriers. The unpredictable nature of ice jam formation and release also argues for passive protection methods or automatic systems that do not rely on advance warning. Additionally, the potential for repeat flooding in ice jam-prone areas may justify higher upfront investments in permanent solutions such as elevation or dry floodproofing, particularly when insurance premium reductions are factored into the long-term cost-benefit analysis.

6.0 BENEFIT COST ANALYSIS

The benefit/cost ratios for the proposed structural solutions were determined by using FEMA's Benefit Cost Calculator (V6.0). This FEMA software calculates the present value of future damages estimated to occur over the useful life the proposed solutions. Based upon FEMA guidance materials, the Project Useful Life (PUL) used for each proposed solution was 50 years. These benefits are then divided by the cost of each proposed solution to determine a benefit/cost ratio. The estimated future damages are based on varying flood depth and flood flow scenarios for four different storm events.

The proposed solutions each analyzed avoided damages to 18 structures in the Town of Coventry, Vermont due to ice jam winter flooding and compares the avoided damages to the estimated cost of these three proposed solutions.

The three proposed solutions analyzed were to prevent or reduce flooding for these 18 structures.

- The first proposed solution is to install 775 liner square feet of flood wall at an average of 10 ft high
- The second proposed solution is to install and annually deploy an ice boom
- The third proposed solution is excavation and widening of the right side of the channel at the island upstream of the bridge

It is important to note that the flood wall and island lowering would reduce flooding from all sources, not just flooding due to ice jams.

The 18 structures included in these analyses calculates a present value of future damages that are estimated to occur over the useful life of the project (in our case, 50 years) and divides that figure into the cost of the project. A spreadsheet showing the square footage and other relevant building data is attached to the application. Square feet of each structure, indicated in this spreadsheet, were taken from Zillow or Xome.

Benefits

The estimated future damages are based on a depth damage function which calculates a flood depth at each structure from four flood events (10-, 50-, 100-, and 500-year) and subtracts the First Floor Elevations (FFEs) of the structure.

Social benefits not related to physical damage were also included for all residential properties, Local census data indicates there are 2.3 residents per household in Orleans County with 61.8% residents in the labor force. To be conservative, we used 2 residents per household and 1 full time worker.

The residential building replacement values (BRVs) used was the FEMA default value of $100/sqft.

In the post project H&H where floodwater did not inundate structures, water surface elevations were scaled by -0.5 feet for each event so the model could generate a curve without inflating benefits.

Benefits are as follows:

All three proposed solutions would protect any remaining properties in the benefit area not included in this analysis and will likely only serve to increase the BCA further.

Flood Wall:
$2,926,884

Ice Boom
$2,466,702

Lowered Island
$1,106,217

Project Costs

The project costs shown below are estimates that will need to be finalized when an application is submitted for funding consideration. Below are preliminary estimates based on the best available data at this point.

The flood wall is estimated between $3,000 and $3,500 per liner foot at 775 feet (between $2,325,000 and $2,712,500). This project will also require engineering, permitting and grant management. This project will likely be cost effective but will depend on final cost estimates.

The Ice Boom is estimated at $2,000,000 with $25,000 annual maintenance and installation cost. This project will also require permitting and grant management. This project will likely be cost effective but will depend on final cost estimates.

The lowered island is estimated at $750,000. This project will also require permitting, engineering and grant management. This project will likely be cost effective but will depend on final cost estimates.

This Benefit Cost Analysis estimates future flooding based on Depth Damage Functions. The analysis generates a Depth Damage Curve that predicts how much damage each structure will experience based on the depth of flooding without improvements and the depth of flooding after improvements and the probability of each flood taking place. In this case, the damages that would be avoided by implementing the improvements are more than the cost to implement these drainage improvements.

7.0 CONCLUSIONS/RECOMMENDATIONS

The existing conditions model results show good agreement with observations of flood depths and locations noted in the Miller report.

Six different alternatives were evaluated for this effort, with the goal of reducing the impacts of flooding primarily caused by ice jams. Each alternative has pros and cons. The alternatives that involve changes in the channel will be the most challenging to permit. Those include overflow channel under the bridge, a channel near the island, and removing the island entirely. Each of those is also estimated to have minimal reductions in the flooding caused by the ice jams.

The ice boom alternative would limit the amount of ice that can flow into the reach of the channel most impacted by ice jams. Limiting the ice volume will limit the ice jam thickness and extents, and therefore the ability of the ice to form a jam significant enough to result in significant flooding. The flood berm would be the most effective solution; however, it would be costly to construct and could impact the aesthetics of the town along the riverbank.

Individual flood proofing measures may provide the most cost effective solutions for the businesses and residences impacted by flooding in the past.

The results of the modeling efforts are shown in Appendix C. Each alternative is shown representing the ice jam in the model with the existing condition water surface elevations. The profiles provide a comparison of the existing conditions to the proposed alternative for each design storm. The profile begins with the bridge on the downstream end of the reach and proceeds upstream, as if the viewer were standing on Route 105 looking at the channel from the bridge and proceeding upstream to the Miller property.

Also included in Appendix C are aerial comparisons of the extent of flood and depth of water for each alternative. Each set of six figures represents a different flow level and the resulting depths for the existing condition and each alternative.

Table 8. – Comparison of Alternatives

Alternative	Effectiveness in Flood Reduction	Protects Street	Costs	Permitting	Access	Maintenance
0-Existing Conditions	None	No	Variable due to repairs needed after future flooding events	None	None	As needed
1-Flood Wall	Provides total protection during open water and ice jam floods	Yes	Very High	Moderate	Private Land	Yes
2-Ice Boom	Significant reduction during ice jam floods,	Only from ice jam-induced	Initial land acquisition and construction.	Moderate	Private Land	Annual

	no protection during open water floods	flooding	Yearly maintenance, installation, and removal			
3-Overflow Channel at Bridge	Minor reduction in flood depth	Minor reduction in flood depth	Moderate, heavy machinery to remove vegetation and bed material	Challenging	In stream	2-5 years
4-Side Channel at Island	Minor reduction in flood depth	Minor reduction in flood depth	Moderate, heavy machinery to remove vegetation and bed material	Challenging	In stream	2-5 years
5-Remove Island	Minor reduction in flood depth	Minor reduction in flood depth	Moderate, heavy machinery to remove vegetation and bed material	Challenging	In stream	2-5 years
6-Individual Flood Proofing	100% at each structure only	No	Low to moderate, varying by structure	None	None	Annual inspection

Based on the results of the Hydrologic & Hydraulic model and Benefit Cost Analysis, DuBois & King recommends that the Town of Coventry implement a multipronged approach to mitigate impacts from ice jam flooding including installation of an ice boom, construction of an earthen berm or floodwall along the southern bank of the Black River and implementation of floodproofing strategies at the most vulnerable structures within the village center.

8.0 REFERENCES

American Society of Civil Engineers (ASCE), 2015. Flood Resistant Design and Construction, ASCE Standard 24-14. Reston, VA.

Federal Emergency Management Agency (FEMA), Flood Insurance Study, Volume 1 of 4, Windsor County, Vermont. FIS Study Number 50027CV001A. September 28, 2007.

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Rocks, J. (2022, February 25). *Ice jam assessment Coventry, VT* [PowerPoint presentation]. US Army Corps of Engineers, Cold Regions Research and Engineering Laboratory (CRREL). Vermont Silver Jackets Team.

White, Kathleen D. 1999. Hydraulic and Physical Properties Affecting Ice Jams. December 1999. U.S. Army Corps of Engineers, Cold Regions Research & Engineering Laboratory, CRREL Report 99-11

APPENDIX A

Figures

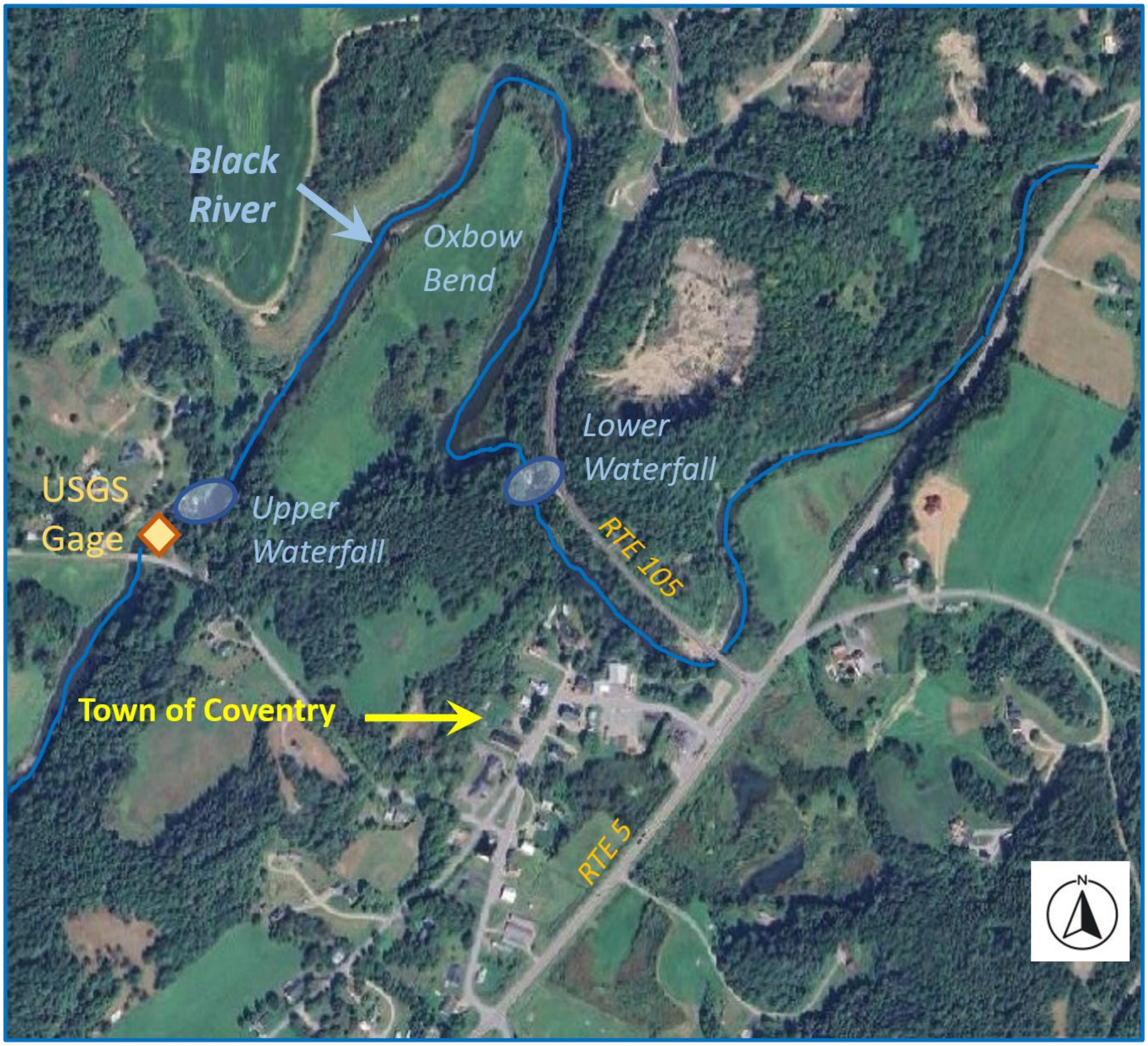


Figure 1. Site Map of Coventry and the Black River, Vermont

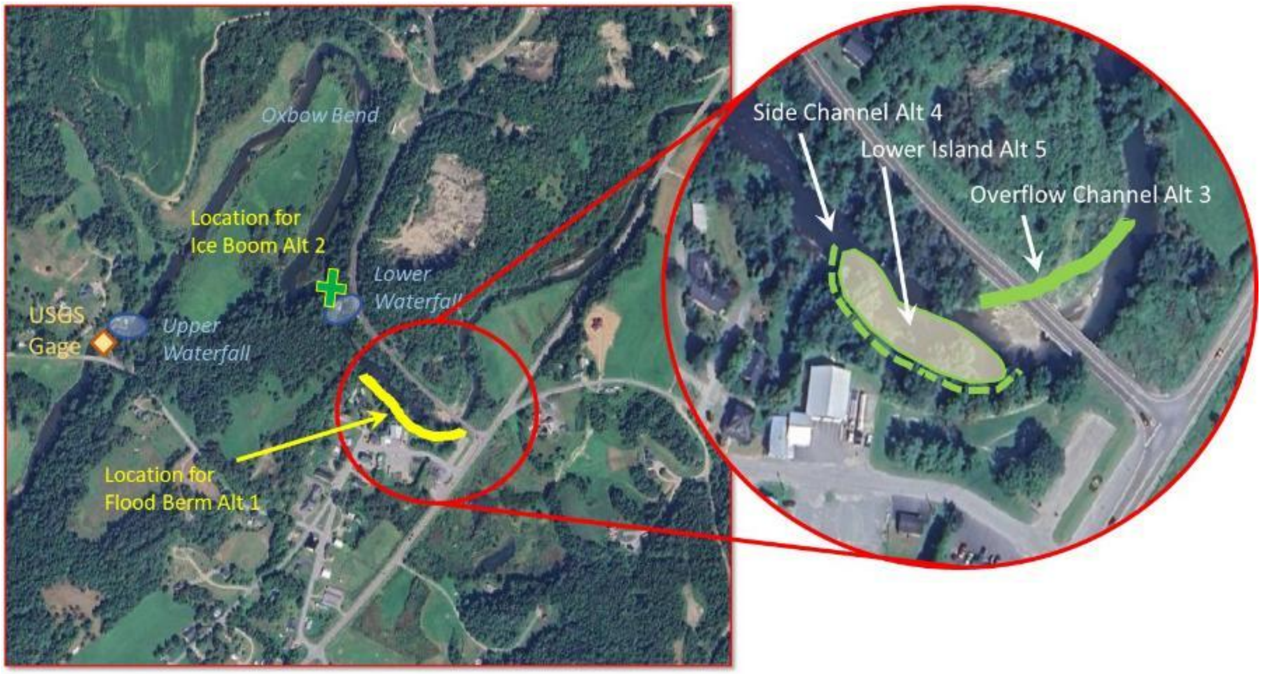


Figure 2. Locations of Mitigation Alternatives

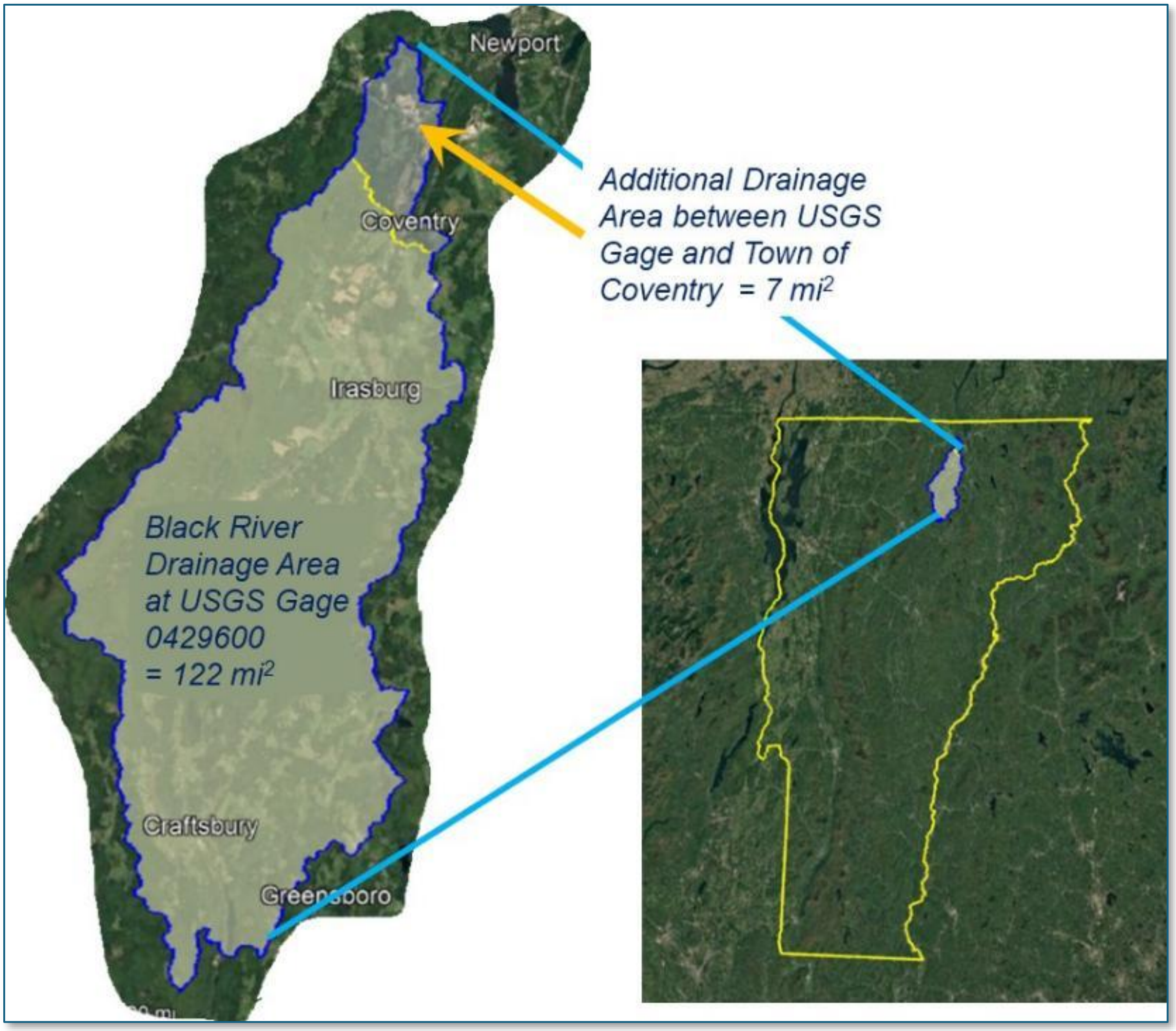


Figure 3. Black River Watershed Basin

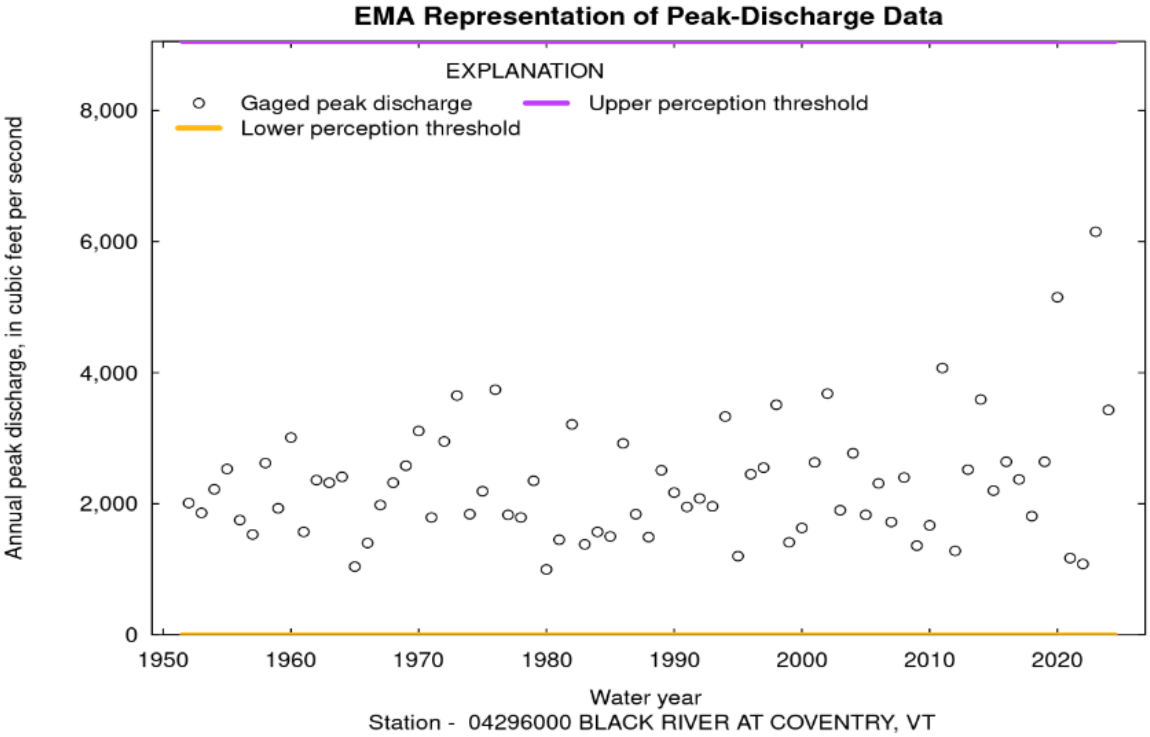


Figure 4. Annual peak flow data – Black River Coventry

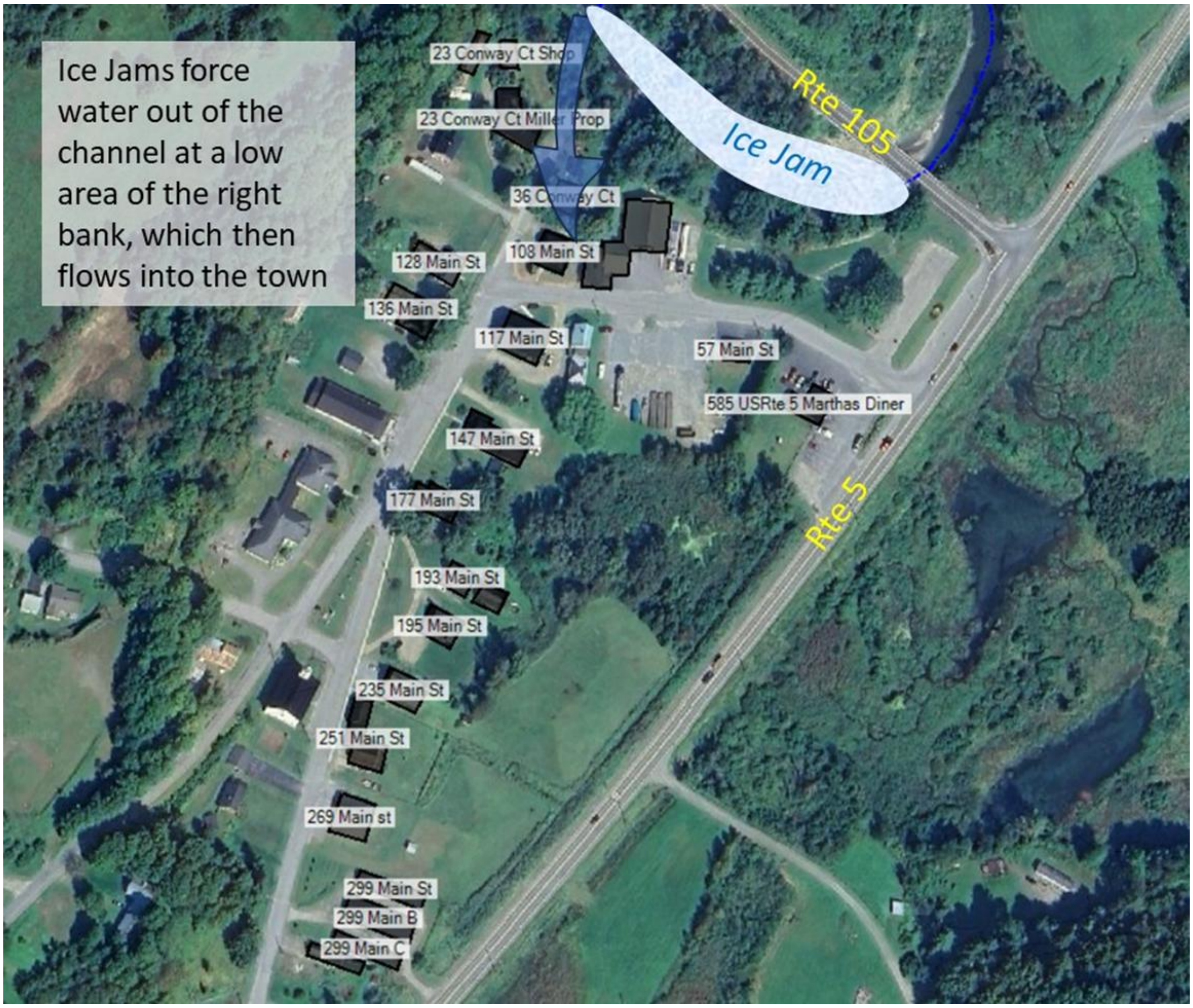


Figure 5. General Path of Flooding from Ice Jam in Coventry, VT

APPENDIX B

Photographic Log

Photo 1. Overview looking south of the Town of Coventry and the intersection of Rte 5 (N-S) and Rte 105 (E-W)

Photo 2a and 2b. Aerial view of the town in 1963 (left) and 2024 (right). The Rte 105 bridge had recently been built in 1963, however, Rte 5 had not yet been realigned.

Photo 3. Looking at the Rte 105 Bridge from upstream to downstream

Photo 4. Looking at the Rte 105 Bridge from the right bank towards the left bank

Photo 5. Large riprap along the right bank just upstream of the Rte 105 bridge. The riprap was placed along the right bank when the bridge was constructed (see Photo 2a.)

Photo 6. The home at 23 Conway Court, previously owned by John Miller. Flood waters have filled the basement of this home but not reached the first floor. The river typically overtops the right bank in the side yard of this property before flowing toward town.

Photo 7a and 7b. The remnants of a foundation on the property of 23 Conway Court (May 2025 – left) and during the ice jam storm (Dec 22, 2018) (Miller, n.d.).

Photo 8a and 8b. The front of the home at 36 Conway Court. The owner noted that ice and water have reached the sill of the doorway (approximately 2 ft above the adjacent ground) but haven't overtopped into the home.

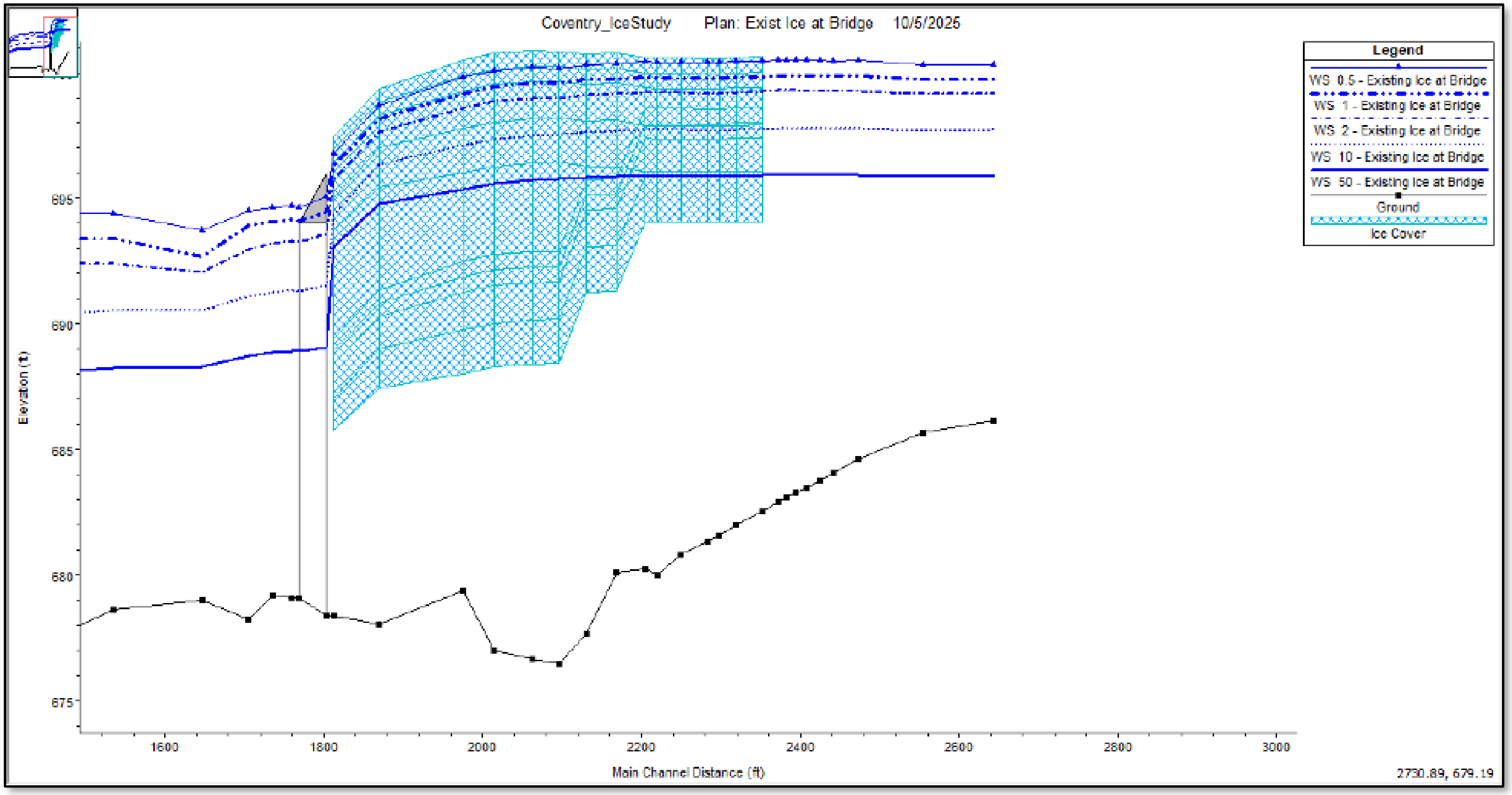
Photo 9a and 9b. The recently raised garage at 88 Main St (left). Sediment line inside the garage door (right). This is a remnant from the July 2023 open-water flood event.

Photo 10a and 10b. Back entrance (left) and front entrance (right) of 117 Main Street. This building has been impacted by the ice jam floods.

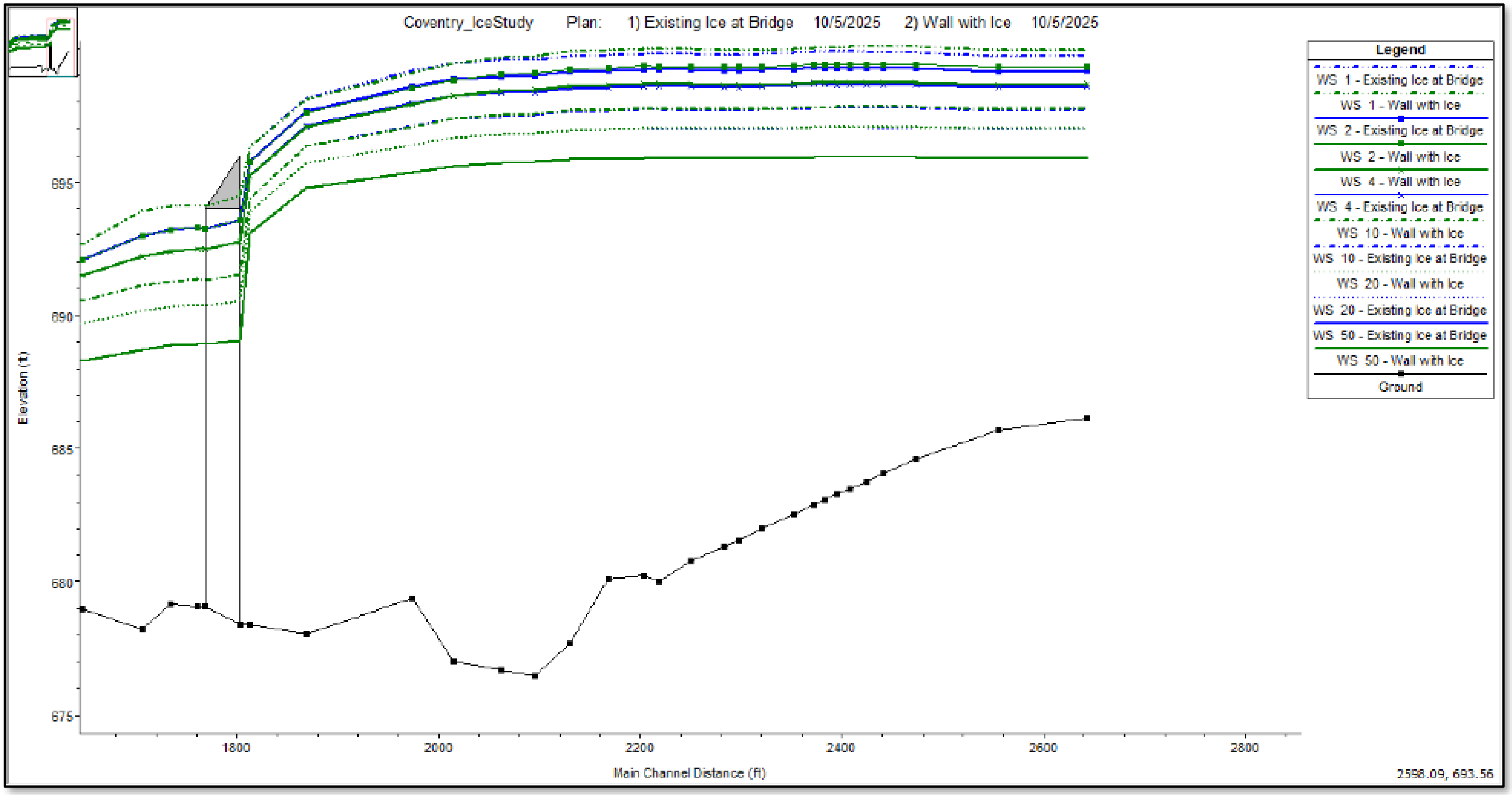
Photo 11a and 11b. The entrance to the lower apartment at 235 Main Street (left). Sediment and damage to siding from the July 2023 flood were observed on the south side of 235 Main Street (right).

APPENDIX C

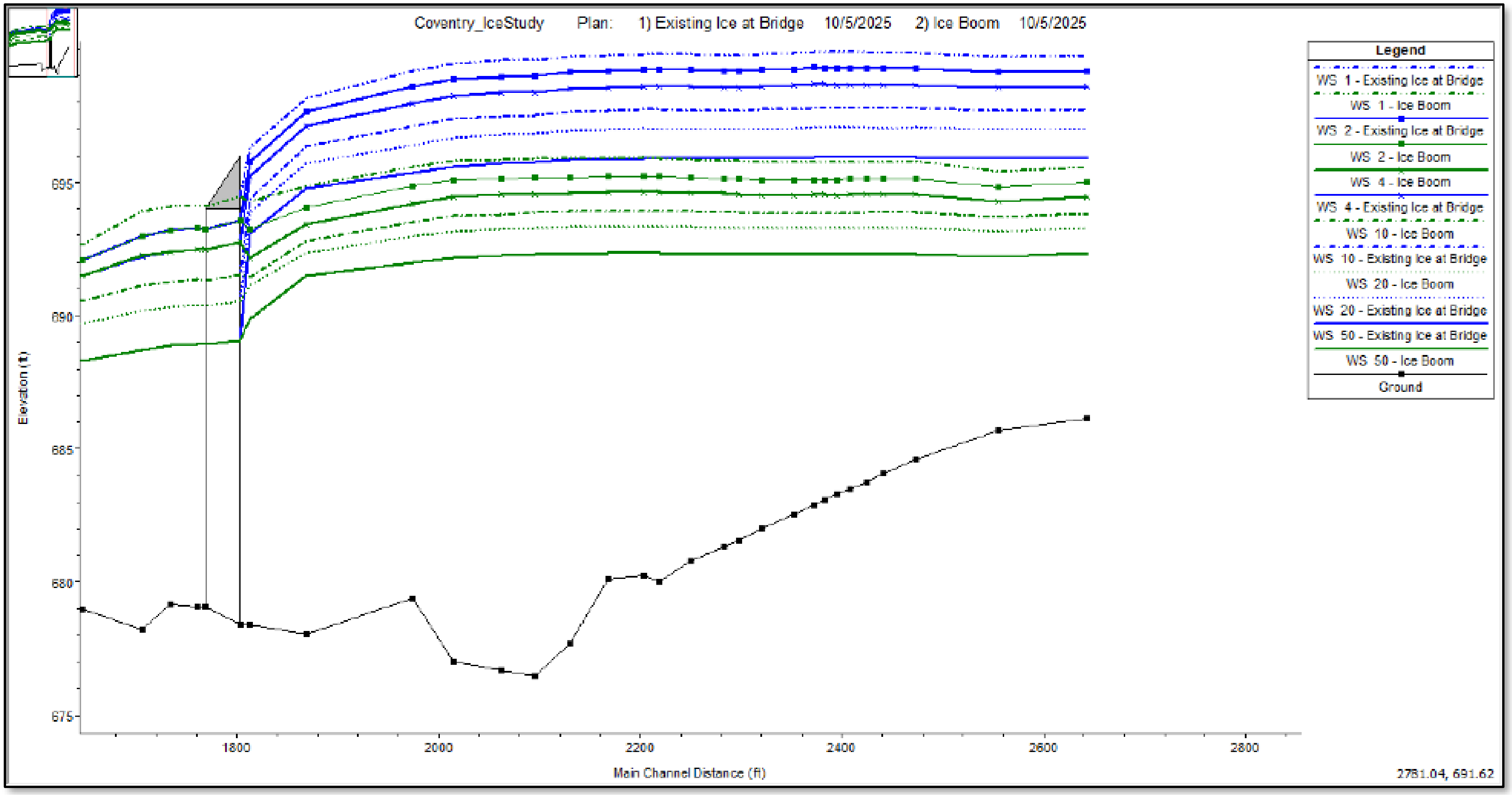
HEC RAS Output



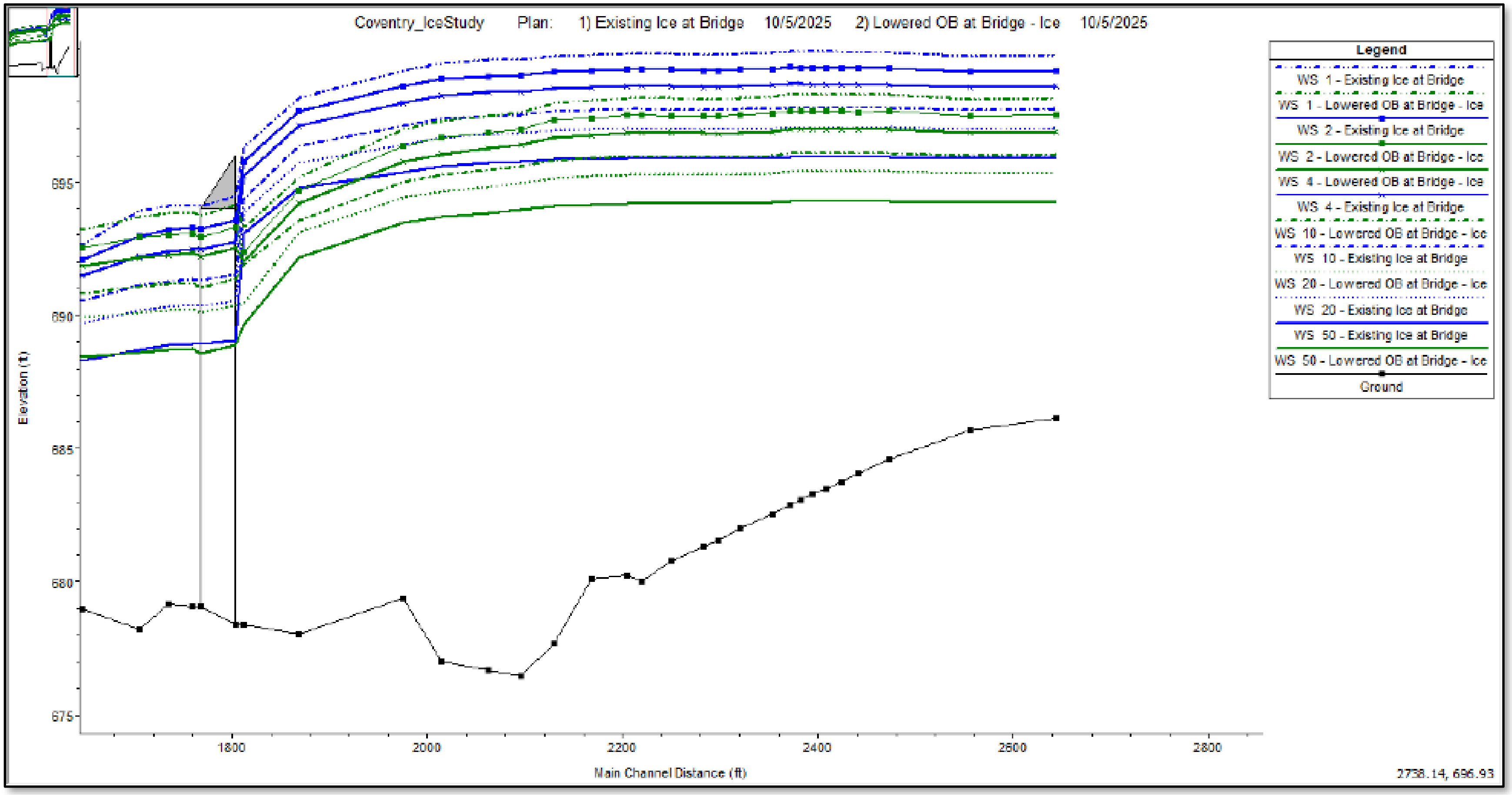
Ice jam and water surface profiles for existing conditions on the Black River.



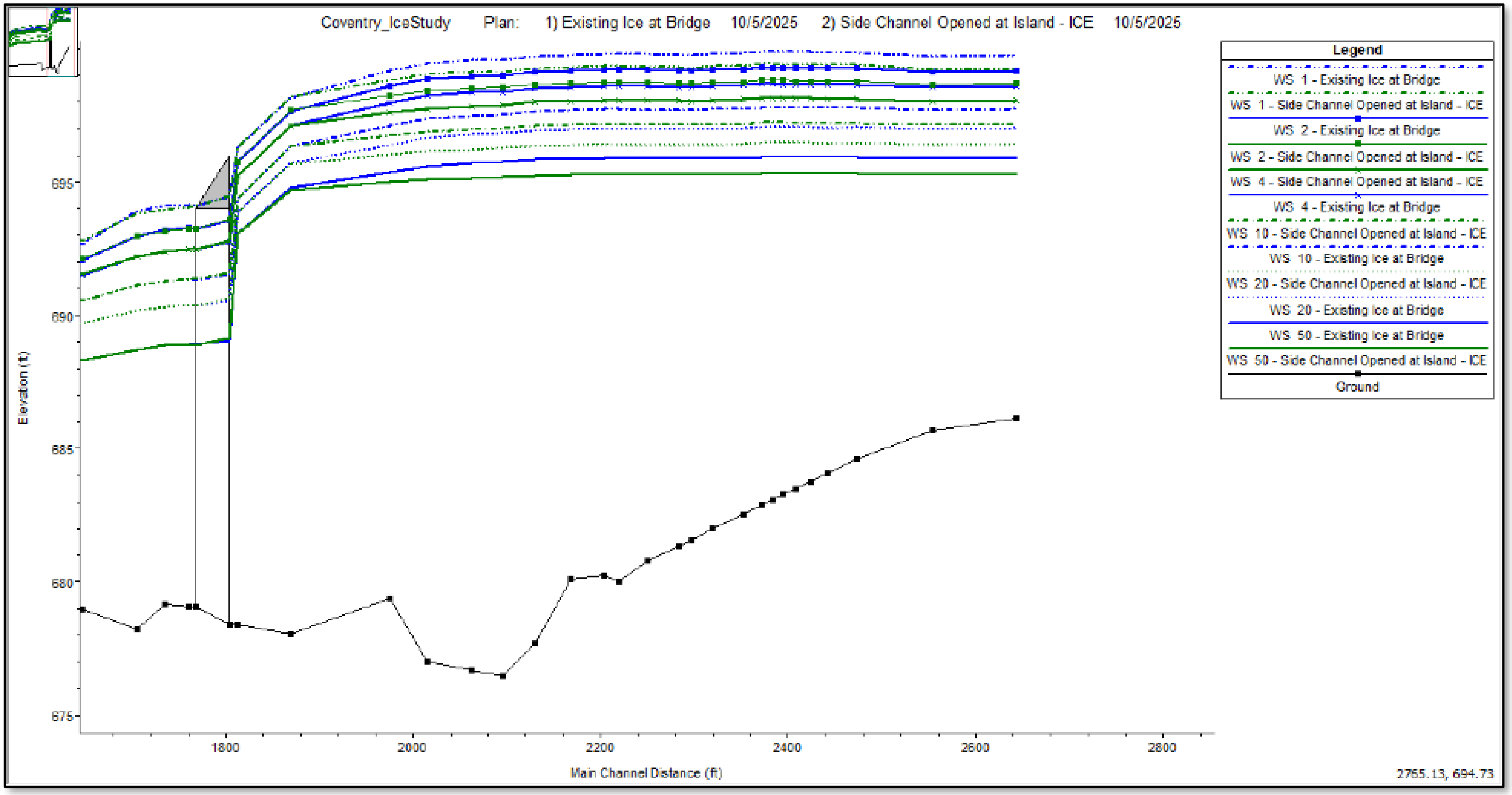
Water surface profiles for Existing Conditions and Alternative 1 – Flood Wall.



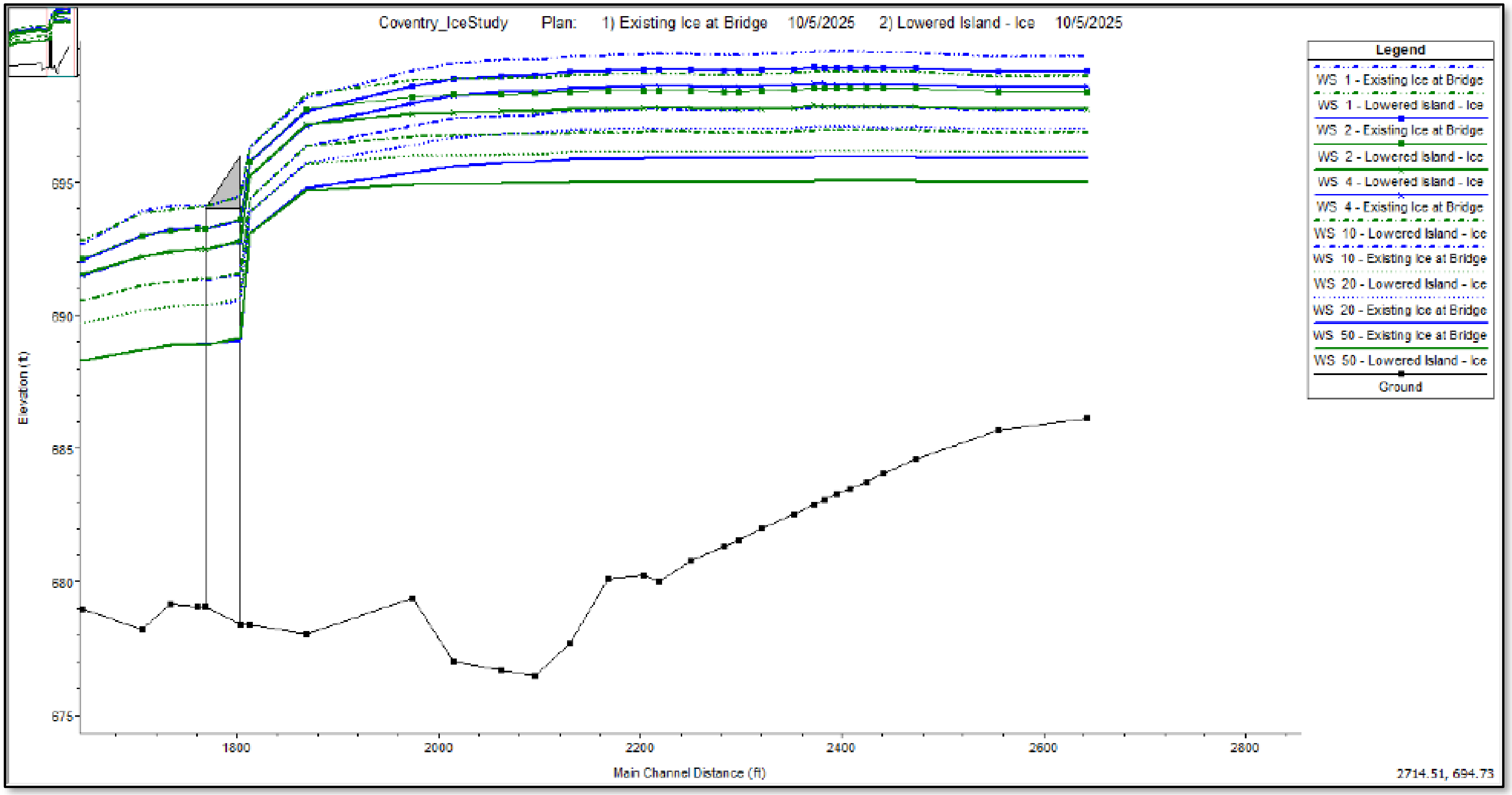
Water surface profiles for Existing Conditions and Alternative 2 – Ice Boom



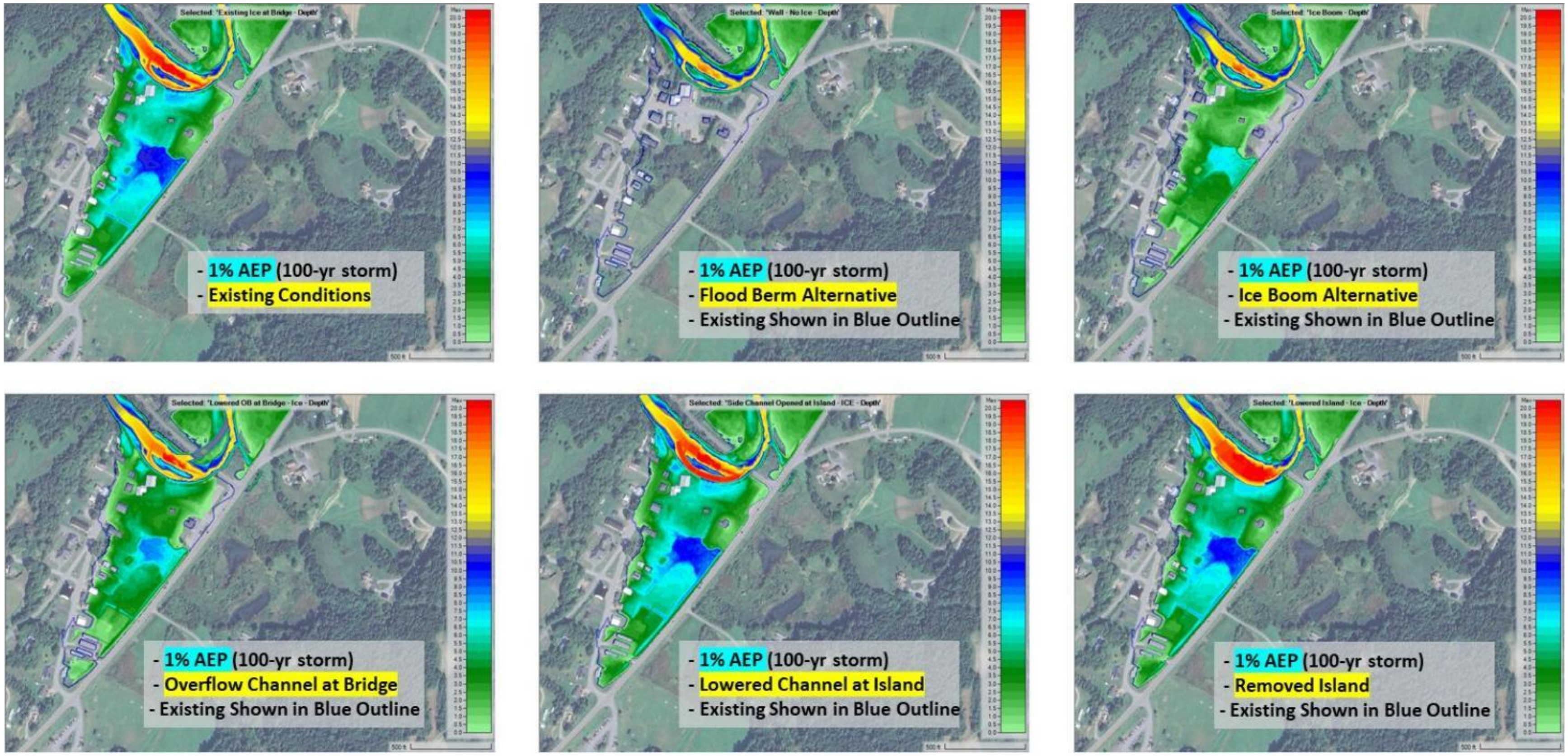
Water surface profiles for Existing Conditions and Alternative 3 Overflow Channel.



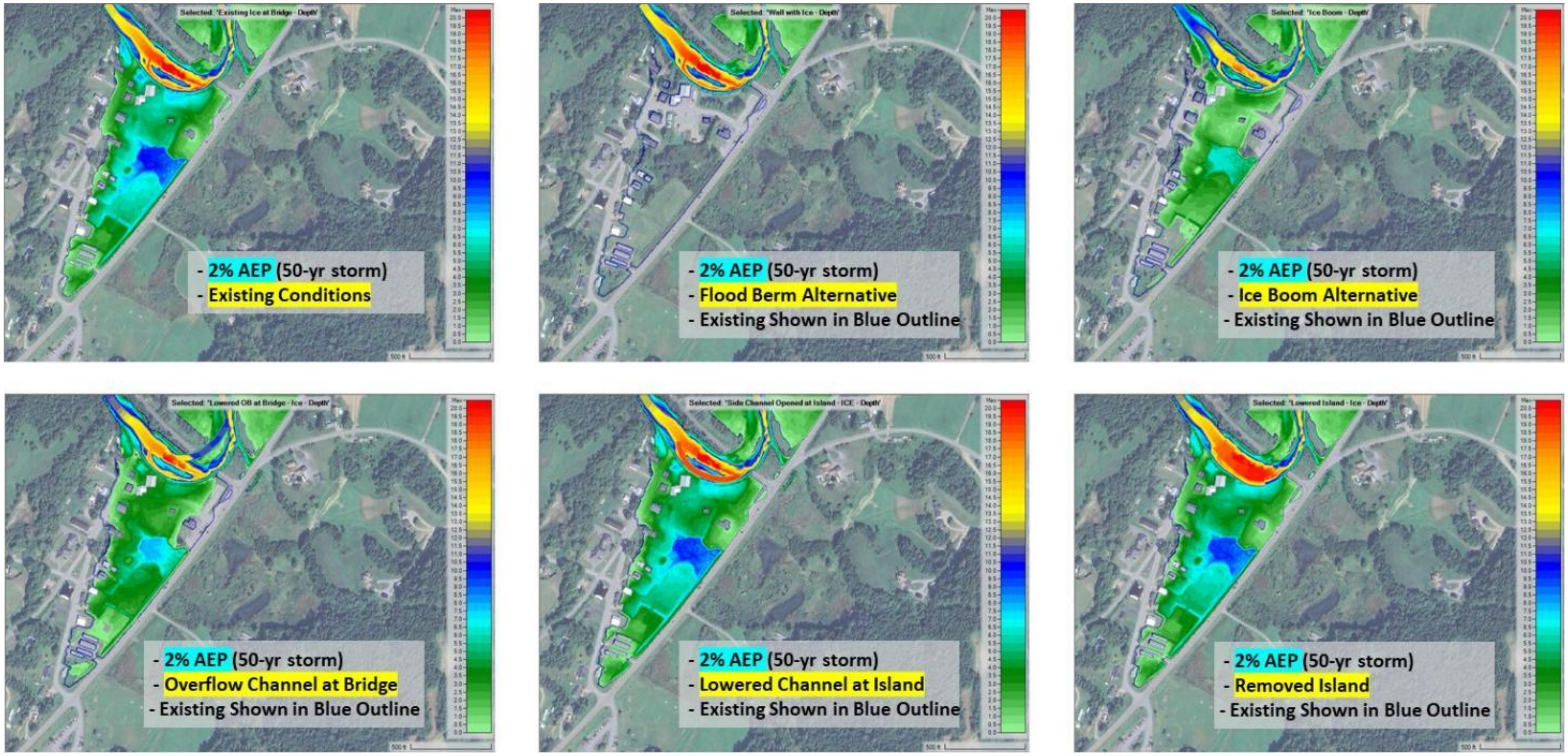
Water surface profiles for Existing Conditions and Alternative 4 – Widen Side Channel.



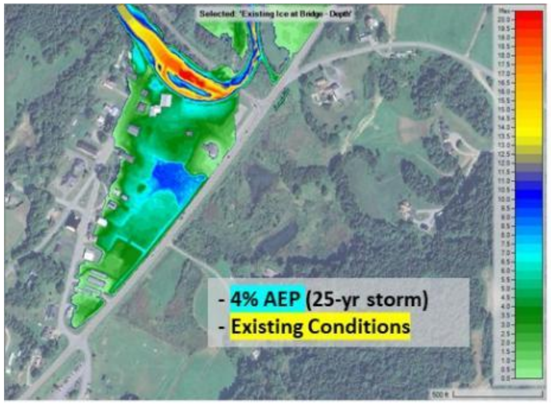
Water surface profiles for Existing Conditions and Alternative 5 – Remove Island.

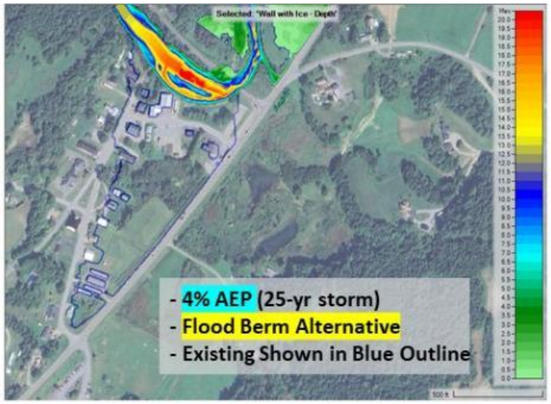


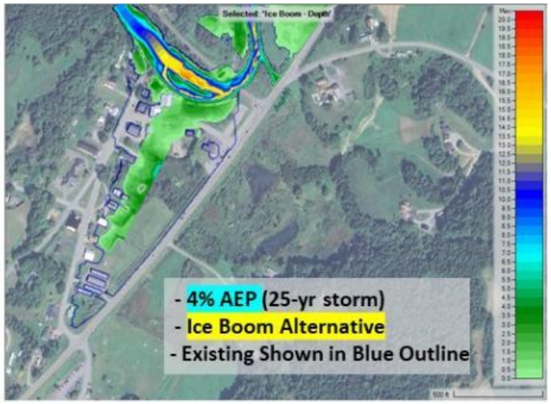
Comparison of Maximum Estimated Flood Depths for the 1% AEP with Each Alternative.

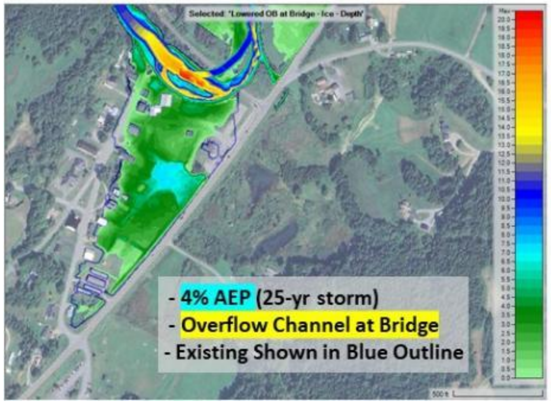


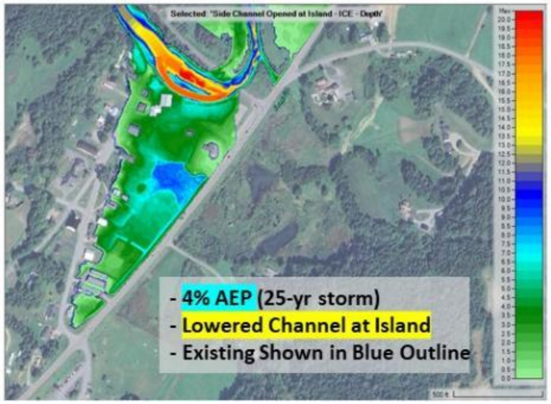
Comparison of Maximum Estimated Flood Depths for the 2% AEP with Each Alternative.

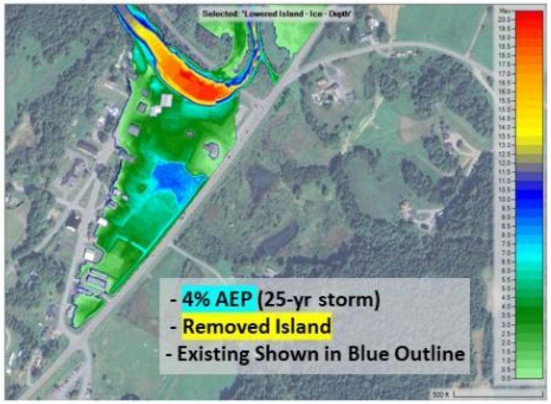

Selected: 'Existing Ice at Bridge - Depth'
- 4% AEP (25-yr storm)
- Existing Conditions
500 ft

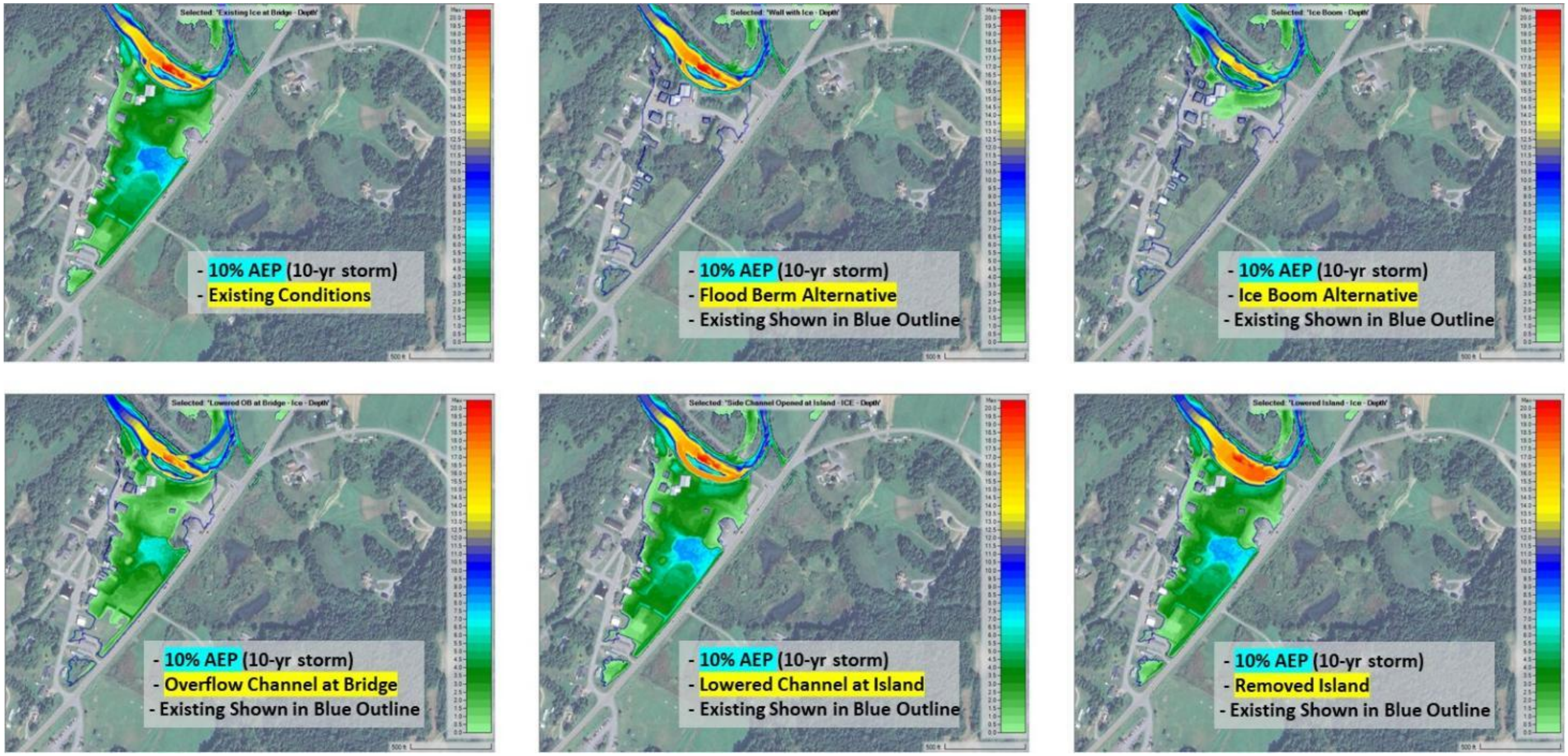

Selected: 'Wall with Ice - Depth'
- 4% AEP (25-yr storm)
- Flood Berm Alternative
- Existing Shown in Blue Outline
500 ft


Selected: 'Ice Boom - Depth'
- 4% AEP (25-yr storm)
- Ice Boom Alternative
- Existing Shown in Blue Outline
500 ft

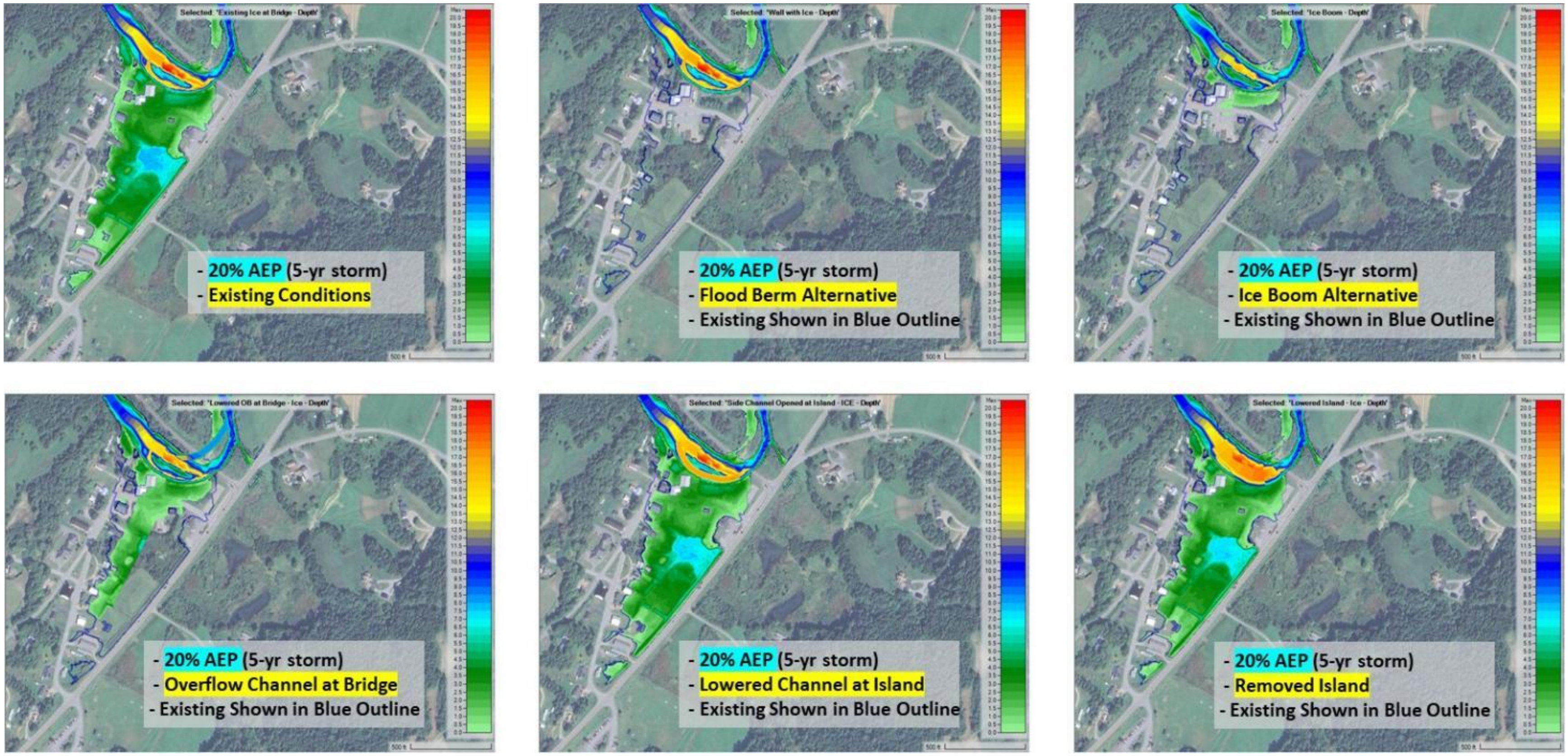

Selected: 'Lowered OB at Bridge - Ice - Depth'
- 4% AEP (25-yr storm)
- Overflow Channel at Bridge
- Existing Shown in Blue Outline
500 ft


Selected: 'Side Channel Opened at Island - ICE - Depth'
- 4% AEP (25-yr storm)
- Lowered Channel at Island
- Existing Shown in Blue Outline
500 ft

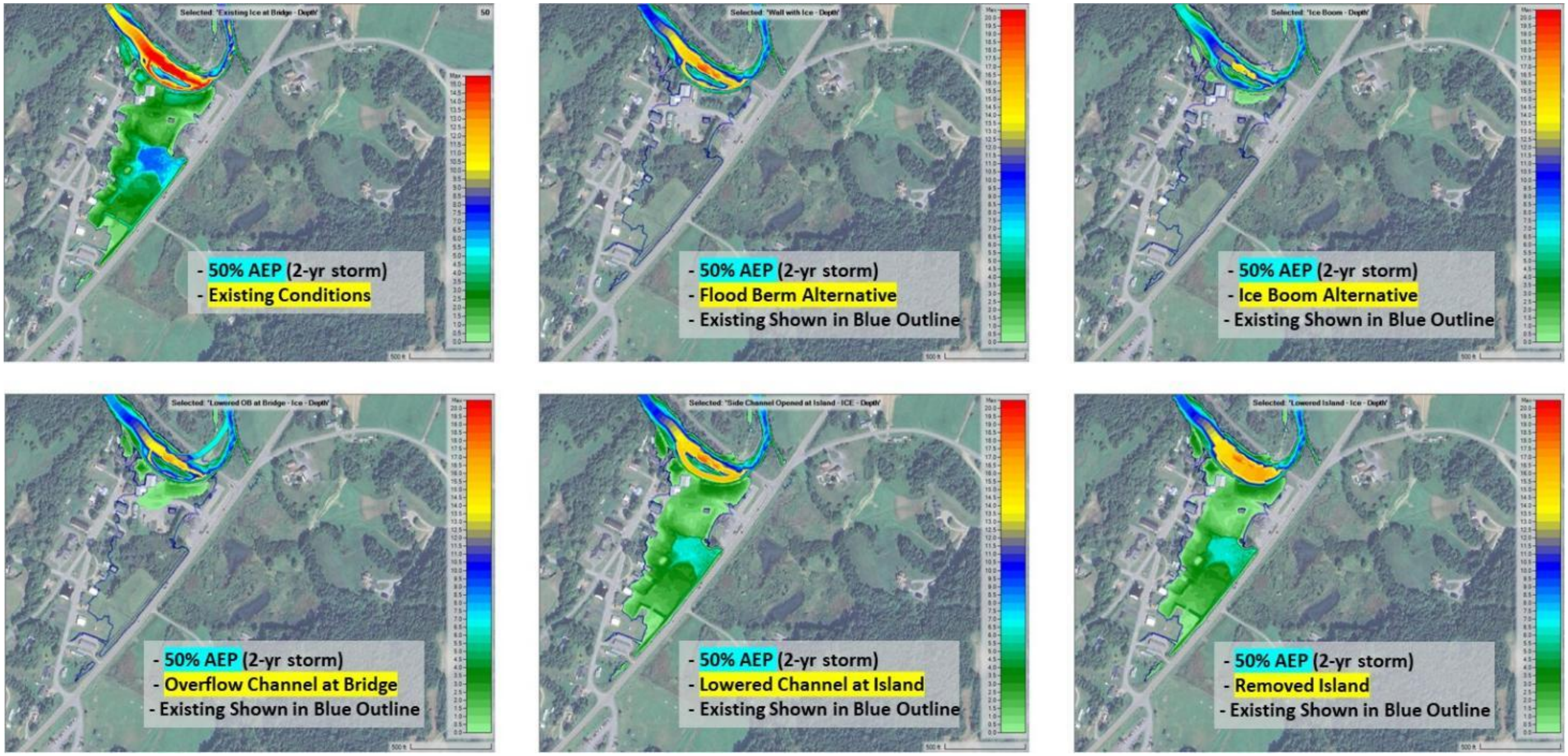

Selected: 'Lowered Island - Ice - Depth'
- 4% AEP (25-yr storm)
- Removed Island
- Existing Shown in Blue Outline
500 ft



Comparison of Maximum Estimated Flood Depths for the 10% AEP with Each Alternative.



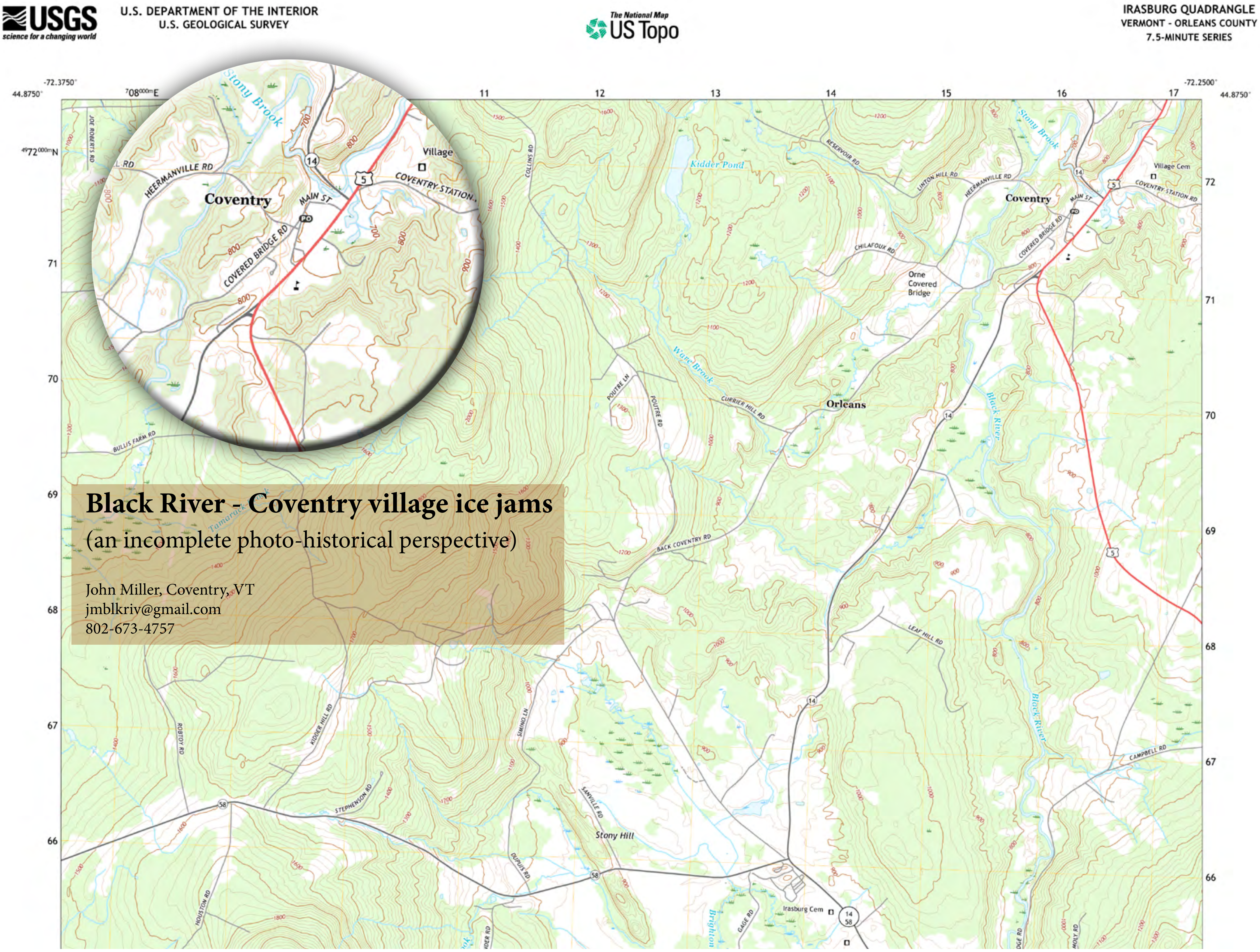
Comparison of Maximum Estimated Flood Depths for the 20% AEP with Each Alternative.



Comparison of Maximum Estimated Flood Depths for the 50% AEP with Each Alternative.

APPENDIX D

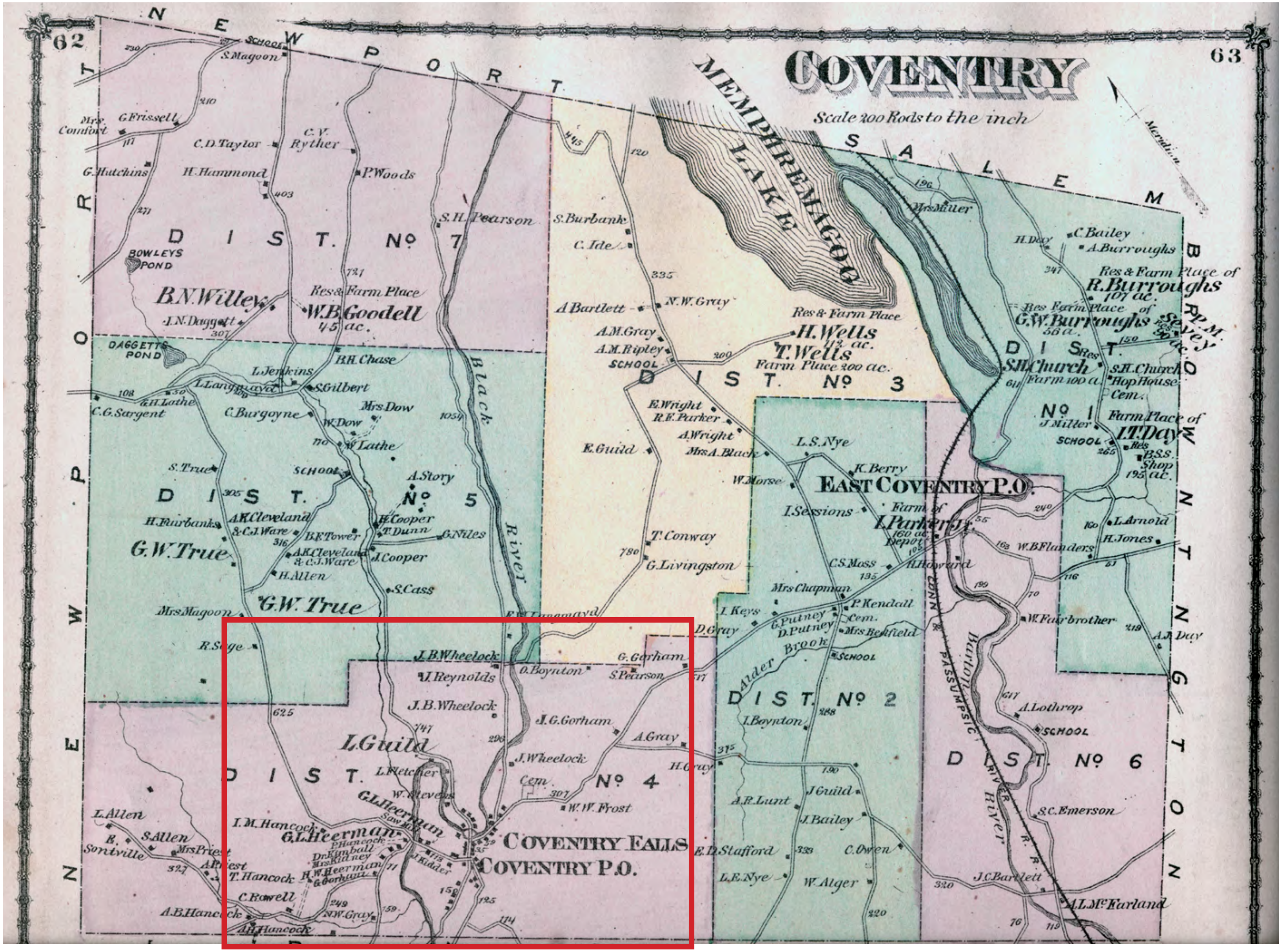
Miller Report



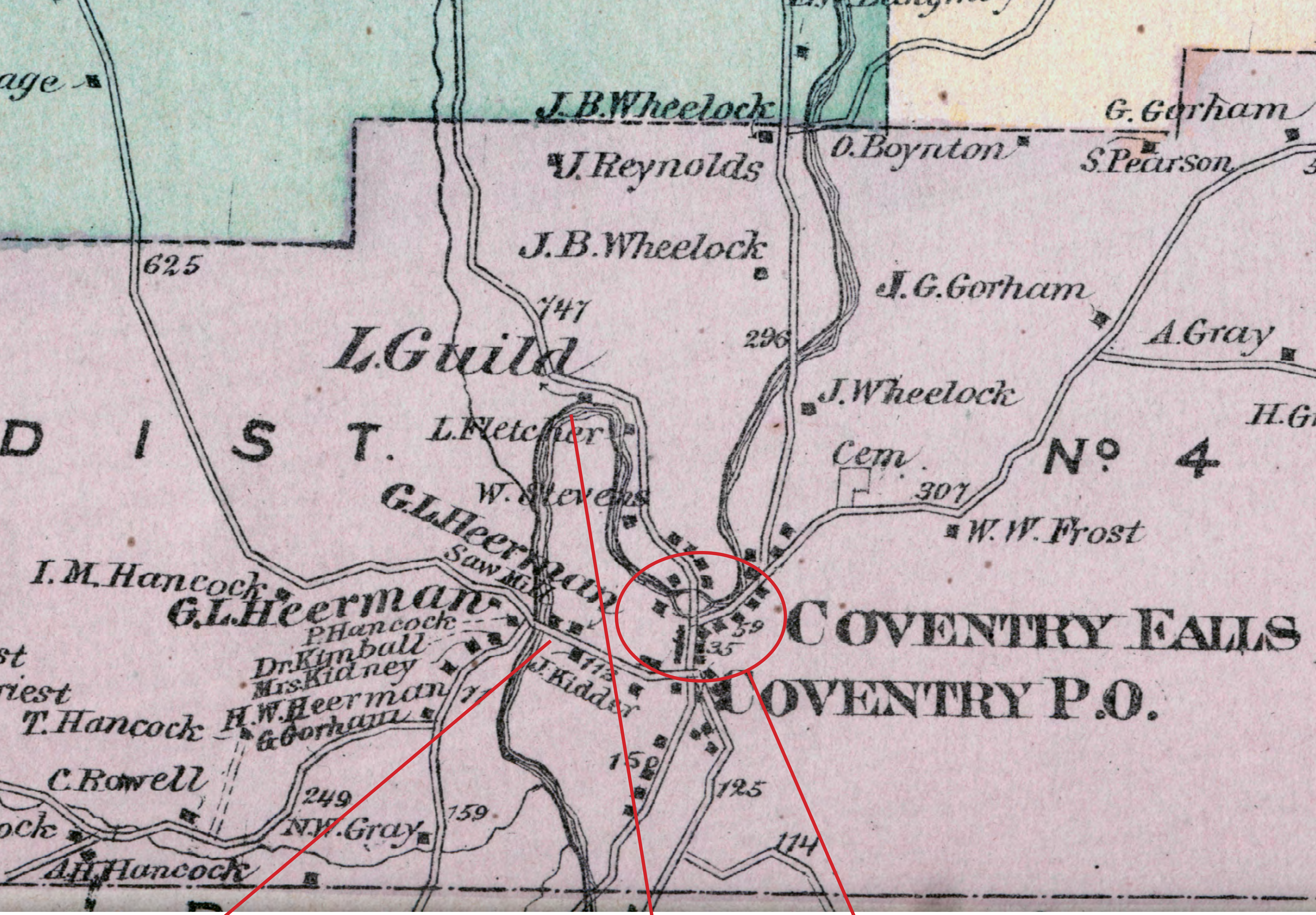
Black River - Coventry village ice jams

(an incomplete photo-historical perspective)

John Miller, Coventry, VT
jmblkriv@gmail.com
802-673-4757



Beers Atlas map of Coventry, Vermont, 1878



Upper Falls - Heerman sawmill
USGS gauging station also here

River oxbow upstream from village

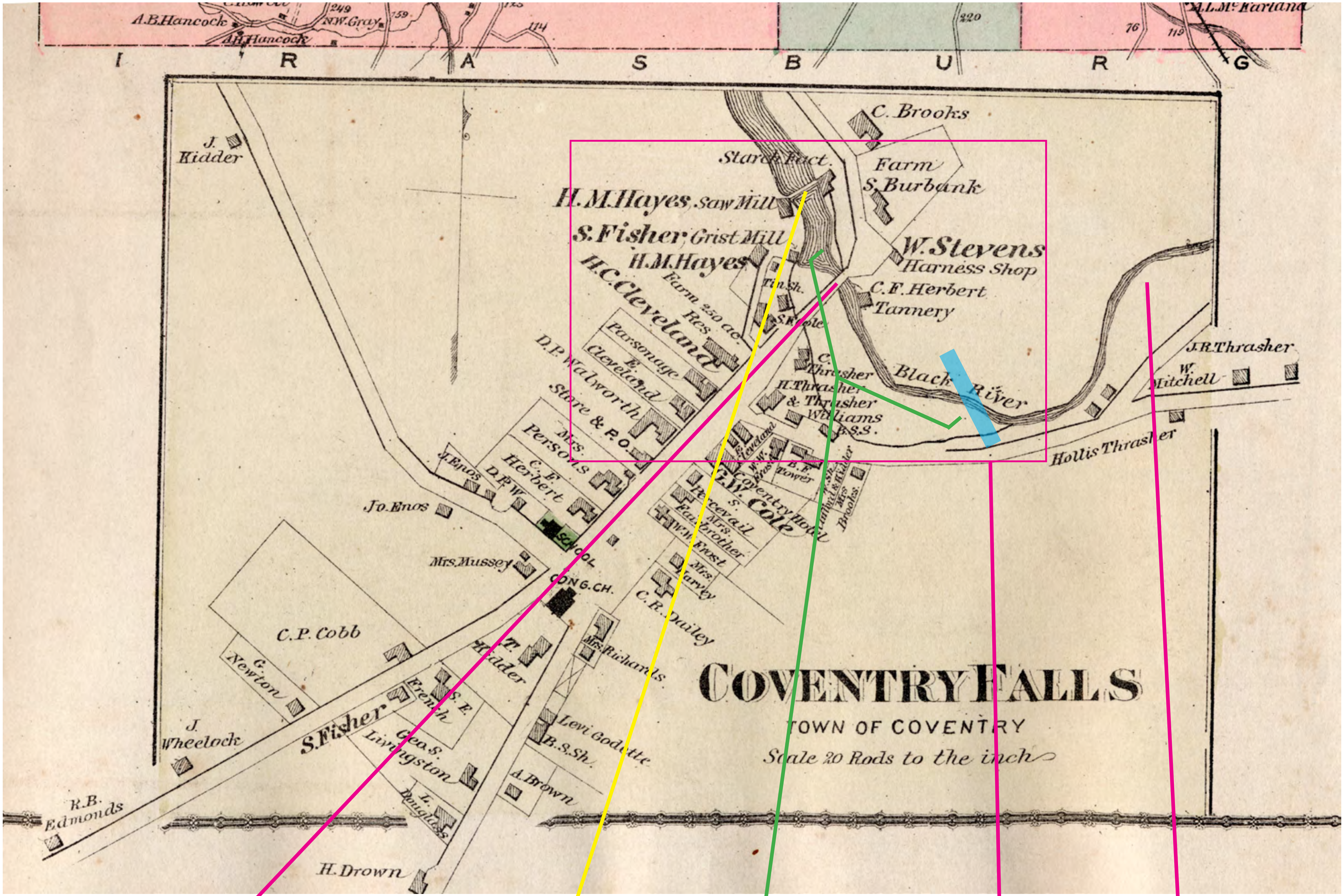
Lower Falls, Coventry village - location of primary
ice jam/flooding/property damage

Upper water falls
USGS monitoring station

Lower water falls

Ice pack slows in this section of river before descending to village at upper left

Black river oxbow north of Coventry village June 2020   Reverse of Beers map rendering on prior page



Old Rte 14 and bridge

River channel in this section widened substantially in 1959

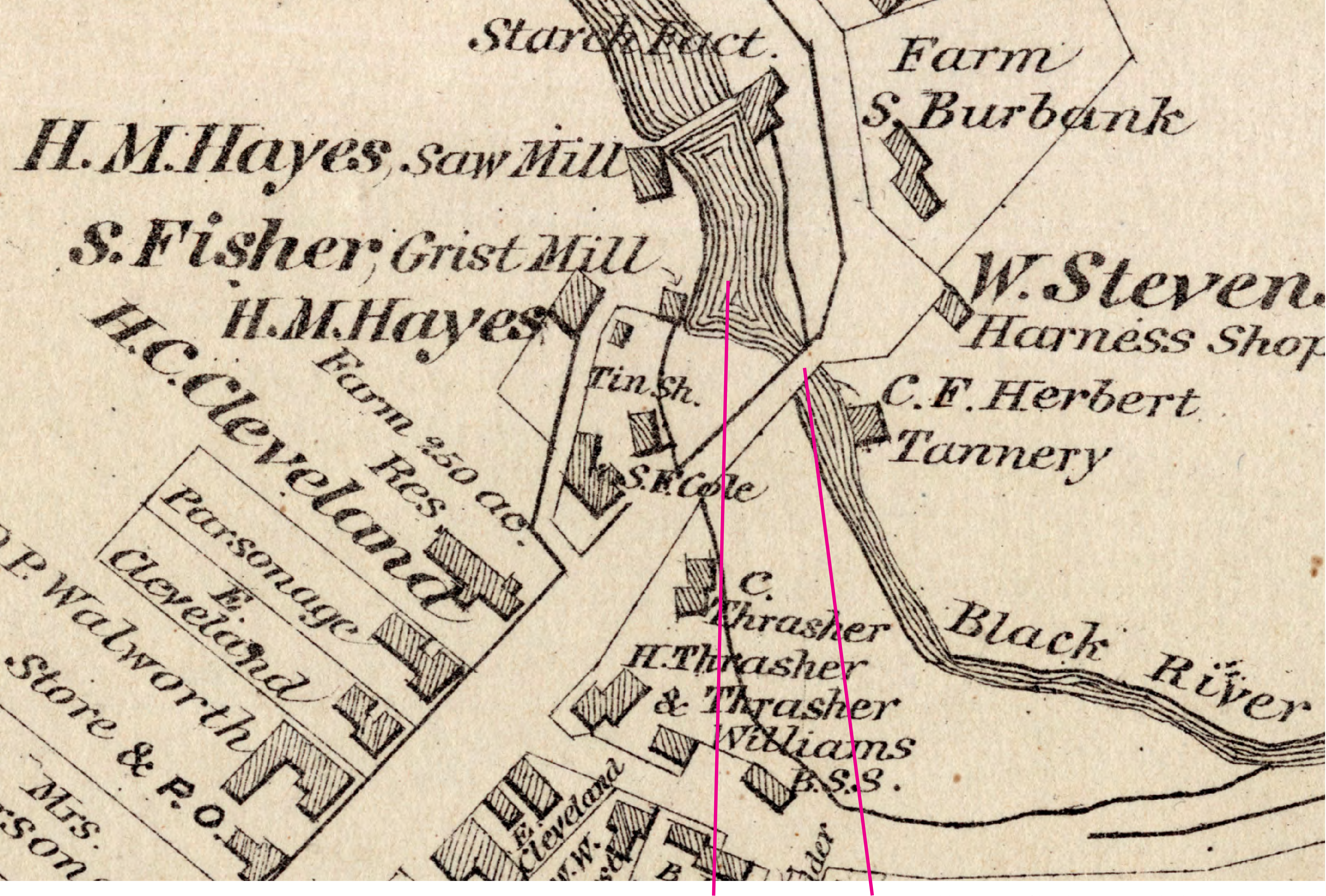
Approx location of new Rte 14 bridge built in 1959

River channel in this area in 1878 similar to 2018

Beers Atlas map of Coventry Falls, 1878
Most of Coventry's water-powered industry was located in area below mill dam and lower falls

Coventry village Spring 2020

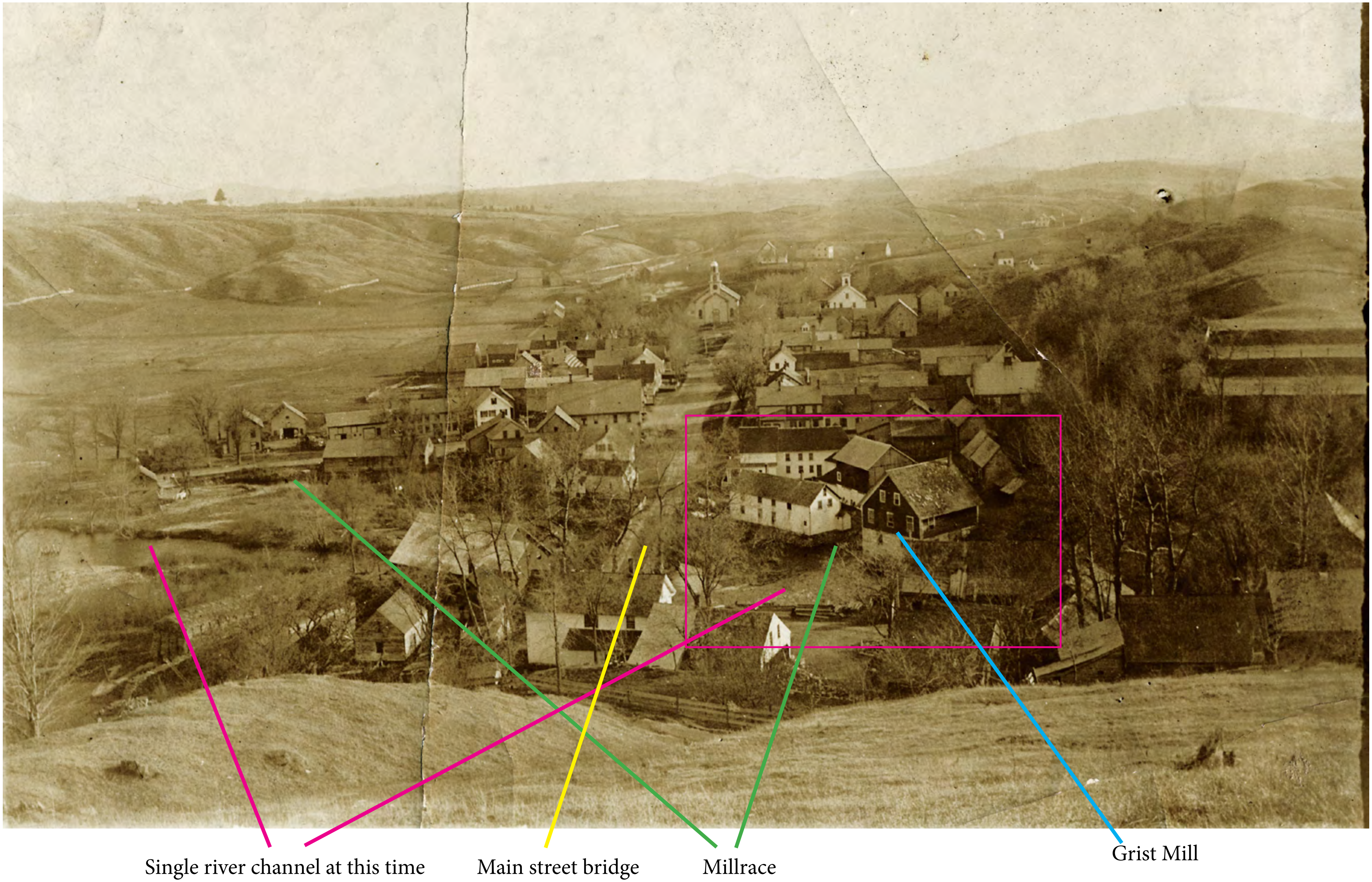
New location of Rte 14 bridge across Black river



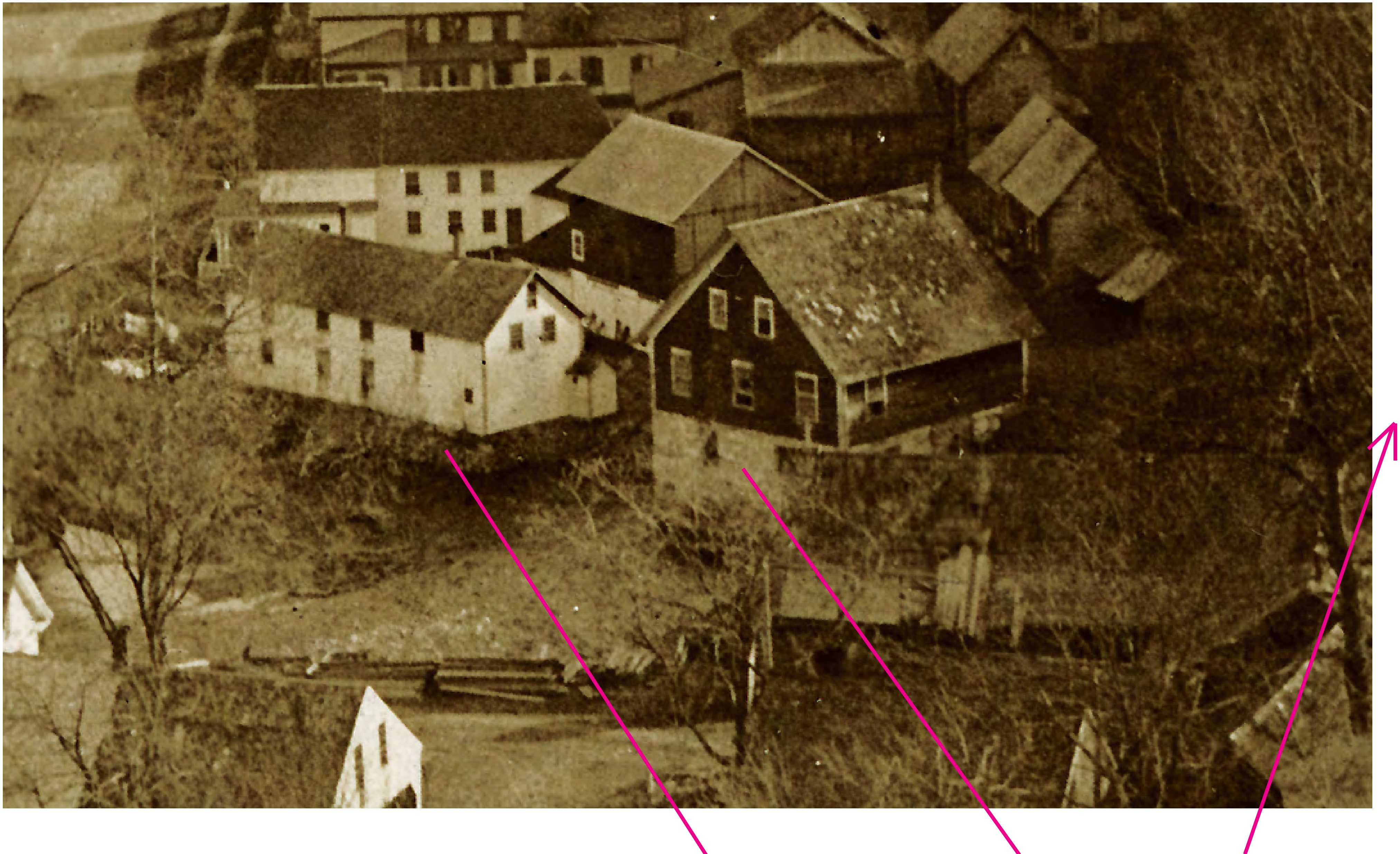
Note width of river around mills before coursing below bridge and around bend

Original location of bridge across Black river, the extension of village Main street

Birds-eye view (Beers Atlas) of village (Coventry Falls) mill district (dam and pond, saw mill and starch factory, grist mill, tin shop, tannery



View of Coventry from hill north north of village, circa 1890. **Note - Black river as it passes grist mill and tin shop**



Tinsmith shop

Grist mill - Only a portion of this foundation still exists and continues to be a partial protective barrier for house and sheds, above and to left

Mill dam and pond and saw mill to right - upstream and right of photo

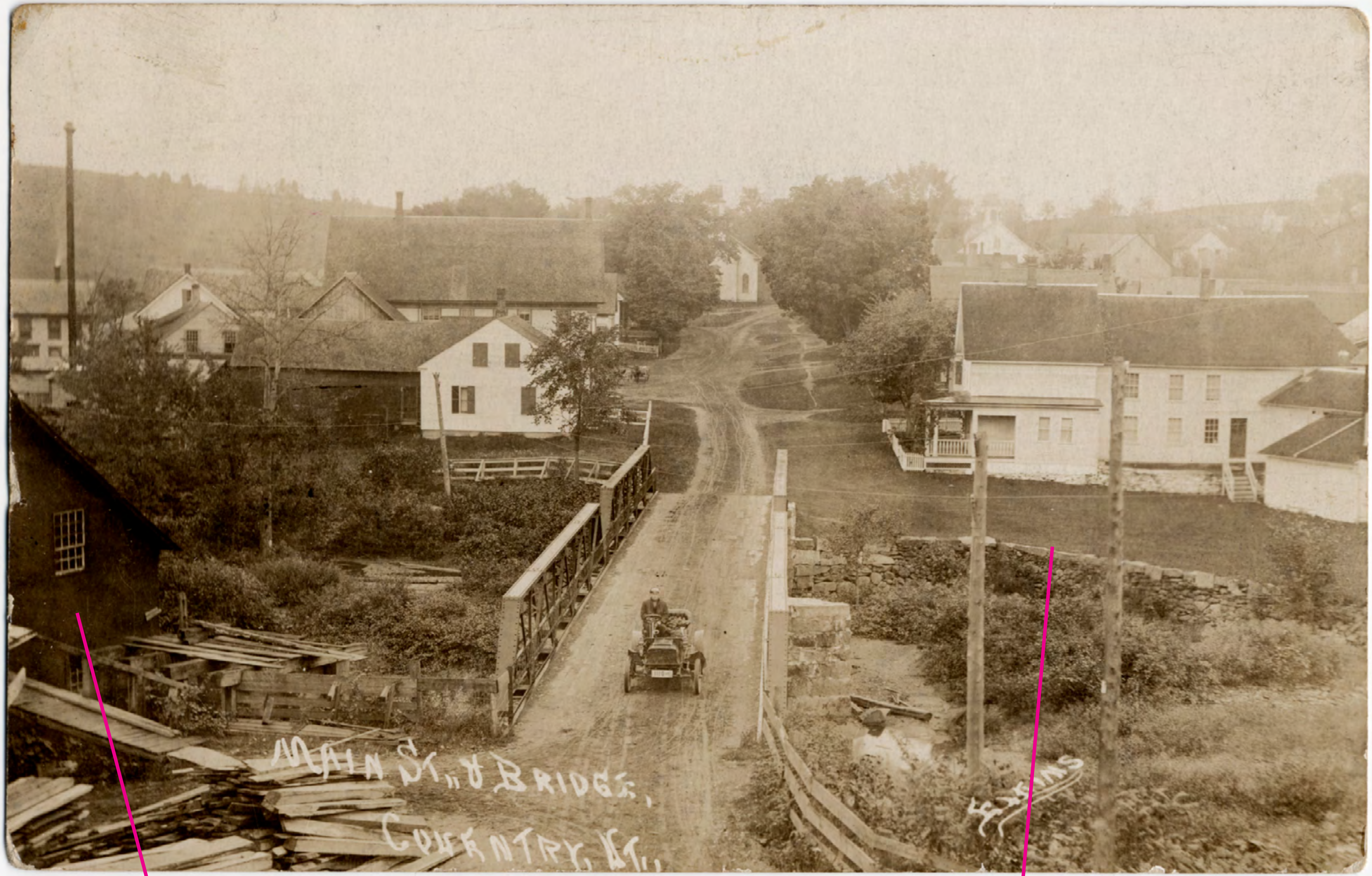
Mill district - Black River, circa 1890, starch factory on right.
Penstock provided water to power bobbin mill downstream
Grist mill in picture below to left of this picture.

Old origanal Mill Dam
Coventry Falls
Vt.

Grist mill, mill dam and penstock, Black river, Coventry village, circa 1900. There were mill dams like this upstream - in Irasburg, Albany, Craftsbury - all helped to deter ice jams by trapping ice during thaws at varying points along the river.

Seth Cowle house - tinsmith shop on right - grist mill roof beyond left and starch factory beyond right (across river)

As with many villages near water and water falls in Vermont, not only were the affiliated industrial buldings placed near water for power but often houses were built in close proximity. Question - How familiar were these homeowners and mill proprietors with prior history of flooding and ice jams? **Because of mill dams upstream to Craftsbury (Albany and Irasburg), ice jams may not have posed as significant a problem because of their ability to serve as catch/stop basins for ice along sections of the river. Also, flooding frequency may have been such that there was little cause for concern?**



Early Rte 14 steel bridge across Black River, Coventry, circa 1910

Black River Bobbin Mill Co

See picture on previous page
Note: Tinsmith shop has been removed. Why?
Closed business, ice jam, flood?
Only the slate and granite foundation remains

Ice Jams and flooding in Coventry village and upstream above upper falls - An incomplete record...

Spring flooding with ice jams on main streets March 19th 1936

Ice chunks along main street and Newport street. Water has subsided some in this photo for rowboat is no longer next to garage on right of photo.

Spring flooding with ice jams on main streets March 19th 1936 - the Black river is beyond far fence - river level is same or above that of the street in these images. Street in foreground with water is old Rte 14. In far background is Rte 5. Both roads intersected in the center of the village until 1960.

In terms of ice jam and related flood water height, ice would have had to be 10 + feet or so in depth to push water over river banks in village

This hand-colored photo was made in April 1936, upstream from the village, and just above the upper falls at Heermanville. Photo was made only a month after the ice jam flooding in Coventry village downstream (prior photographs).
Heerman's sawmill, next to the upper falls and just downstream from this photo, had been washed away during the flood of 1927 - see next page

Mill yard lumber piles, much of which has already washed downstream.

Heerman sawmill inundated and detached from its foundation begins to float over the upper falls in November 1927.

Ice Jam approx. Spring 1950 Miller/Cowle house and Rte 14 bridge

Ice Jam approx. 1950 Miller/Cowle property

Note how clean the ice is. Ice jams did not bring in as much silt/mud before the planting of corn in much of the Black river bottom land upstream from Coventry village. Ice flow in this photo is on the lawn, river channel is beyond and to right

Ice Jam Feb 1993 - Coventry village experienced severe flooding --- This photo taken in late March/early April soon after a second ice jam caused by warm weather and rain came downstream to the village and ran into the first ice jam; thus causing the Black river to rise very quickly (10 or so feet within a couple of minutes) . (note same shed in previous photo) **Ice wall depth in river channel varied at least 10-12 feet in places**

Ice jam and subsequent flooding, Coventry village, Feb 2016 - many basements in village near river filled with water - furnaces, ductwork and oil tanks inundated. Blue garage building to left of house had river flowing through it, approx, 4 feet deep
River in this photo approximately1.5 feet deep running across street and into lawn next.

Remaining grist mill foundation wall serves to hold some of the more intense ice flow from hitting sheds and house with direct force
Ice in river channel in background 10-12 feet deep

Water and ice depth on back yard approximately 5- 6 feet deep

Ice jam and subsequent flooding, Coventry village, Feb 2016 a day or so after initial flood when weather has cleared and MUCH COLDER - very common sequence; thus potential of second ice jam with Spring melt/rain combination making for second flood within a few months
Note: this scenario has been much more common in recent years - double ice jams and flooding - because of erratic weather patterns

Feb 2016 ice jam and flood aftermath in late March -early April

Note much more silt and debris in 2016 vs 1950s

There were three ice jam related flood events in 2018 in Coventry village.

- **January 13** Extreme thaw and rain event produces record ice jam and flood
- **February thaw**, a second ice jam at village where a new ice flow runs into ice jam already frozen in place to produce more ice and flooding
- **December**, weekend before Christmas, significant cold weather in November/early December produces ice in river which breaks up and flows downstream to village because of unusual thaw combined with heavy rain event

All produced damage/or in some cases, total destruction) to buildings, basements (furnaces, water tanks, oil tanks, pressure tanks, duct

January 13, 2018 Coventry village - Ice jam occurred early morning, Jan 13 - river changed course and flowed through yard and property, across street into another yard and then into much of low-lying village. River flowed at a depth of approx 3 feet across this street through garage in background

Following photos of damage all from January 2018 ice jam and flooding

January 13, 2018 - morning - Main Street, Coventry village inundated from ice jam

- Carpeting, insulation, drywall, furnace, furniture damaged or destroyed

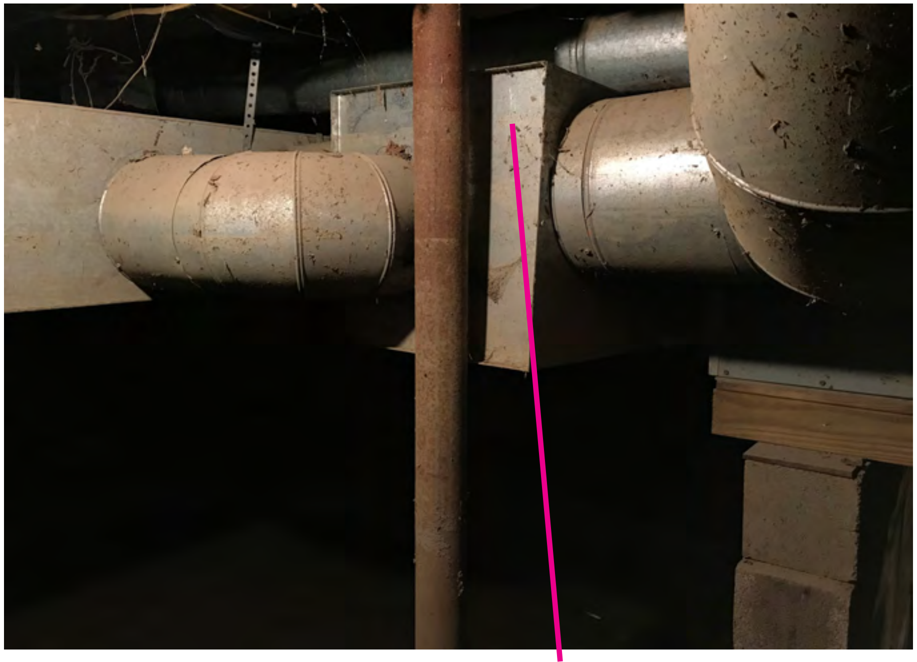
Main street Coventry village

When ice jam occurred, flood water crests very quickly in the middle of the night so no time to remove valuable items! And in January water freezes quickly

Main street - moving trucks in flood water
after it has partially subided

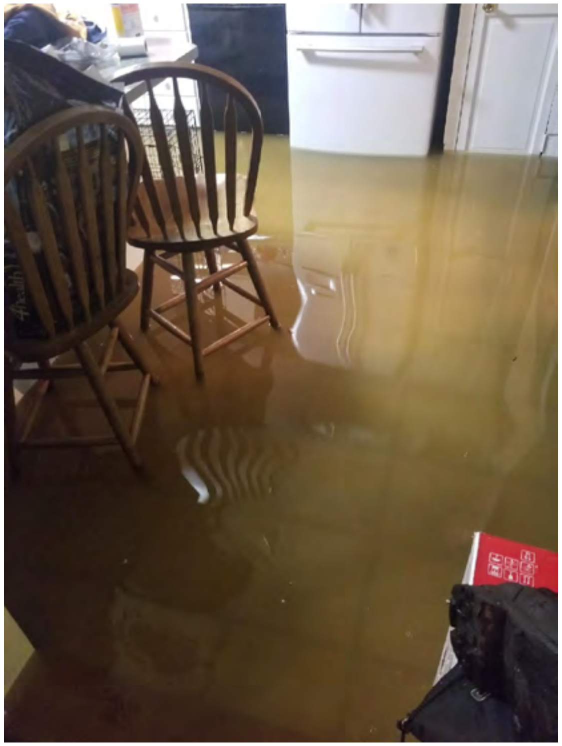
Note high water cresting mark during January 13, 2018
Inside garage bay after most of water has subsided January 2018

Trucking and excavating business inundated inside garage and outside in parking lot - machinery, furnace, smaller heavy equipment damaged



basement flood water level mark on furnace duct work

furnace, water heater, pressure tank destroyed, oil tank must be replaced



Hardwood kitchen floor, dry wall, insulation, furniture, personal items destroyed

Note wet drywall to water depth

Soon after removal of carpeting

Amanda Carlson photo

ice jam below Rte 14 bridge Coventry January 17 2018

Late March 2018 Lawn and shrubbery damage, extensieve silt deposits and clean-up

April 2018 Silting on lawn (3-4 inches deep in places) and also grist mill foundation with **flood level mark** - extensive silt in water up to this depth

This grist mill granite wall served to hold back river ice
(many chunks 10x10x2 feet thick) from directly impacting house and sheds

Ice and silt damage on another property in village, April 2018

mid-April 2018 **Grist mill foundation in foreground** Note height of ice jam to right of bridge abuttment (approx 15 feet) <u>3 months after ice jam</u>

Late April 2018, lower fall - note fisherman near ice pack - **note also broken tree limbs and scuff marks on tree bark from ice 6-8 feet above ice pack suggesting the initial ice jamb was substantially higher on Jan 13th, 2018**

Lower falls, Coventry village

Thoughts - Islands in river next to village do serve to inhibit flow of ice and are one cause of ice jamming?
- Two channels serve to reduce river intensity; thus slowing movement of ice through main channel to left
- Narrowing and deepening channel would reduce ice jam?

Ice Jam December 22, 2018

Ice Jam December 22, 2018

Black River, remains of late December 2018 ice jam (3rd ice jam in 2018) This photo taken in mid-March 2019. River channel opening with thawing. Ice jam under this snow pack is 8-10 feet deep in places

Black River, late-March 2019. River channel opening with more thawing.

Coventry village - Ice jam and high water Jan 12, 2020

Ice jam and high water Jan 12, 2020 - At bridge above Upper Falls

Phil Marquette photo

Note: River channel now open with very little remaining ice at this point for it has travelled downstream into oxbow area

Coventry ice jam January 12, 2020 Ice jammed in oxbow upstream from village. Fortunately, this jam froze and did not inundate the village below

Ice pack viewed from level of Black River

Phil Marquette photos

Jan 12, 2020 ice jam at village and above Rte 14 village.

Note: ice pack almost at height of right bridge support girder

Phil Marquette photos

Phil Marquette photo

View downstream toward Newport from Rte 14 bridge Jan 12, 2020