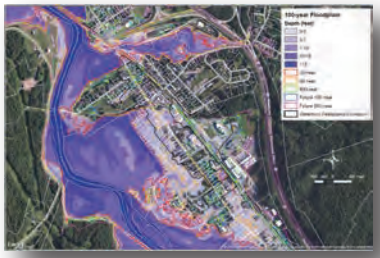
Lake Champlain Basin Program

TECHNICAL REPORT NO. 78

Evaluating the Costs and Benefits of Floodplain Protection Activities in Waterbury, Vermont and Willsboro, New York, Lake Champlain Basin, U.S.A.



April 2015

Final Report

Prepared By:

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Milone and MacBroom, Inc.; Fitzgerald Environmental Associates, Earth Economics,
and DK Carlton and Associates.

For:

The Lake Champlain Basin Program and New England Interstate Water Pollution Control Commission

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NEIWPCC Job Code: 984-003-006
Project Code: L-2013-033

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Project Code: L-2013-033
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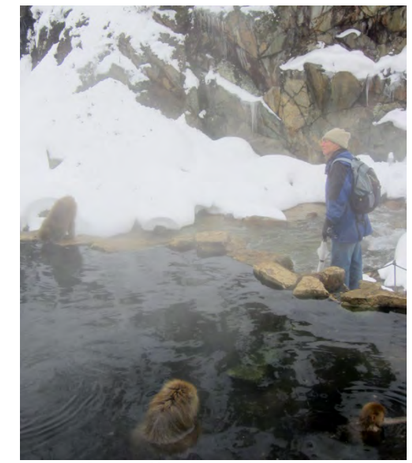

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Executive Summary

This project evaluates the costs and benefits of floodplain protection in Waterbury, Vermont and Willsboro, New York in the Lake Champlain Basin, U.S.A. The primary elements of the project are ecosystem service valuation, buildout/conservation analysis, hydrologic calculations of current existing peak flows and predicted future peak flows, hydraulic modeling of floodplains, building damage simulations due to flooding, and a cost-benefit accounting to determine what form of flood risk reduction makes sound economic sense.

The participating towns, and many others in the region, have endured damaging floods in the past few years due to their riverine and lakeshore setting. The towns are now grappling with difficult decisions to improve economic opportunities while increasing flood resiliency. Where and to what level does floodplain protection make sense? Do the benefits of floodplain protection (i.e., reduction of flood damages, lower recovery costs, increased health and safety, enhanced ecosystem services) outweigh the costs (i.e., loss of economic opportunity, reduced tax base, project implementation costs, increased building costs to flood-proof structures, and recovery of structures remaining in the floodplain)? The results of this study will provide important information to towns in the Lake Champlain region to make sensible floodplain management decisions.

The technical content of this project is a collaboration between Milone & MacBroom of Waterbury, Vermont, Fitzgerald Environmental of Colchester, Vermont, Earth Economics of Tacoma, Washington, and dkcarlton & associates of Lake Forest Park, Washington. The project was led by the Lake Champlain Basin Program, and was supported by funds awarded to the New England Interstate Water Pollution Control Commission by the U.S. Environmental Protection Agency.

The benefit transfer analysis method was used to estimate the economic value of a given ecosystem from prior studies of that ecosystem type. Research was performed to expand the Earth Economics database to cover the Lake Champlain region and the Earth Economics Ecosystem Valuation Tool Kit was used to value floodplain function. The research and analysis resulted in a range of $/acre/year for six land cover classes in the floodplain (agriculture, forest, shrubland/grassland, wetland, river, and village greenspace).

Each of the Towns in this study has a large base value of ecosystem services over a 50-year timeframe - $38.1 million to $216.3 million in Waterbury, Vermont and $4.5 million to $37.0 million in Willsboro, New York. This often unaccounted for value for services such as erosion control, flood mitigation, and recreation and tourism should be protected and expanded where possible. More services are provided when buildings are removed, while less take place upon building and land use conversion away from naturally functioning land.

Meetings were held with each Town to select floodplain management areas and scenarios for this study. The valley bottom floodplain settings and low-gradient river channels lead to flooding as the primary hazard, and thus modeled inundation-based floodplains are suitable management areas at both project sites. The management scenarios include existing conditions, building elevations, utility elevations, building removals, and buildout (full floodplain buildout following current floodplain regulations, removing all buildings in the 100-year floodplain, and removing the most floodprone buildings). Flood risk reduction alternatives were identified for each Town and inserted into the hydraulic model. A preferred alternative that lowered flood levels the most and was supported by the Town was selected for damage modeling.

A maximum total possible build-out of the largest mapped floodplain was performed where the land is cleared of all current development and rebuilt at its maximum allowable by-right density based on local zoning regulations. To calculate the residential build-out potential, each parcel was assigned a single zone that it mostly occupied. In practice, local redevelopment patterns more often consist of building expansions and subdivision of land rather than demolition and rebuild projects. The damage modeling considered this more realistic approach when considering how potential buildout would occur, taking into account local conditions, constraints due to natural features, existing buildings, and zoning. This approach resulted in a lower amount of square footage used in the damage modeling than identified in the by-right buildout analysis.

Executive Summary

A buildout by-right could yield millions of dollars of increases in residential and commercial buildings in the floodplains. However, when placing buildings on the land for damage simulation following local development patterns a lower value was realized. Although the local tax base increases, buildout in the floodplain that adheres to current regulations leads to increased damages, especially with the potential for larger future floods. Building removal and conversion back to naturally functioning floodplain is the best way to limit future building damages. Buildings need to be moved out of the floodplain to reduce future losses and residents need to be relocated within the Town or Village to avoid loss of tax revenue.

Peak flow rates were estimated for a range of recurrence intervals to use in hydraulic modeling to map floodplains. Peak flow rates for the Winooski River in Waterbury , Duxbury, and Moretown were obtained from the effective FEMA flood insurance. For the Boquet River project site in Willsboro, flow rates for existing conditions were estimated from flood frequency analysis of the USGS gauge data. The 100-year peak flow is estimated to be 42,400 cubic feet per second (cfs) in Waterbury and 13,600 cfs in Willsboro.

Future flood flows were estimated for the 100-year and 500-year recurrence intervals at each project location for the year 2065. The analysis explored gauge trends by placing data into bins to explore the change in peak flood estimates over time. A constant rate of change was assumed over 50 years and the average rate of change of flow (cfs/ years) was predicted and used for this planning study.

For Waterbury, the predicted increase in the 100-year flood by 2065 is 12,100 cfs leading to a future 100-year flow of 54,500 cfs. The predicted 2065 100-year flood flow is 29% higher than the FEMA effective flow, but only 3% higher than a simplified estimate of the peak 100-year flood in Waterbury calculated by summing up the peaks at upstream gauges just using post-1970 gauge data. The analysis suggests that could be in an era of larger floods.

For the Boquet River in Willsboro, the 100-year flow is predicted to increase by 6,300 cfs by 2065. The 2065 100-year flow would be 19,781 cfs, which is 46% higher than the current FEMA effective flow. Note that the future flood flow prediction is only 5% higher than the estimated peak 100-year flow calculated using only post-1970 gauge data.

Hydraulic modeling of floodplains was performed using HEC-RAS to create or update delineations with more current data and provide depth grids required for damage modeling. The floodplain maps show the potential for widespread damages along the Winooski River as took place during Tropical Storm Irene and the likelihood of local flooding along the Boquet River as takes place during ice-jam flooding. Modeling of the predicted future flows shows that if predicted flood flows do in fact increase, a wider floodplain and increased flood depths will take place. Floodplain restoration lowers flood depths in Waterbury, while in Willsboro creating a flood bench, dam removal, and elevating three existing buildings create lower flood levels in some locations, while elevated flood levels in the vicinity of the filling.

Building damages, content loss, and inventory losses were modeled using for the Winooski River (Waterbury, Duxbury, and Moretown, Vermont) and for the Boquet River (Willsboro, New York) using FEMA's Multi-hazard loss estimation software (HAZUS-MH). A Level 2 flood analysis was performed where the user provides manually created flood depth grids and specific facility data to be used in place of the default demographic data. Damages were determined for each of the existing (2015) and future (2065) floodplains. Annualized damages ($ of loss per year) were calculate for each community from the damage estimates for a range of floods. Damages were calculated for existing buildings in the floodplain (Waterbury, Duxbury, Moretown, and Willsboro) and the combination of existing and "reasonable" build-out condition buildings in the floodplain (Waterbury and Willsboro) for each of the floodplain management scenarios.

The damage modeling shows that the study towns "pay" thousands of annualized dollars for living in the floodplain. The modeled existing annualized building damages in Waterbury, Vermont are $51,000 and future annualized building damages are $95,000. Even with just 21 buildings in the 500-year floodplain, Willsboro, New York "pays" $1,600 dollars in annualized damages to live in the floodplain and could pay $5,800 in 2065 due to the potential for increasing floods. Simulated damages increase as more buildings are placed in the floodplain.

Executive Summary

Damages and losses decrease as mitigation strategies get more aggressive, such as from elevating to removing buildings in the most floodprone areas to removing buildings in a larger area across the floodplain. Avoidance is the best way to minimize future damages. However, the reduction of damages and increase in ecosystem function value are often outweighed by the projected maximum loss of tax revenue. For building removals to make financial sense, moving existing buildings or building new structures out of the floodplain yet in the Village and Town is needed to maintain tax revenue.

Elevating utilities was found to be beneficial at all study sites. For example, elevating utilities across the entire floodplain to the 500-year flood level and elevating the most floodprone structures to 1 foot above the 500-year flood level leads to the largest benefits in Waterbury. Elevating utilities across the entire floodplain to the 500-year flood level leads to the largest current and future benefit in Willsboro. Cost-benefit data suggest that utility elevations should be implemented following flood damages to existing buildings given the lower cost compared to other mitigation strategies and the ability to implement utility elevations as part of flood recovery.

Floodplain restoration in strategic locations reduces damages and allows flood mitigation activities such as elevations to work more effectively at reducing damages. Floodplains store flood waters, lower flood depths, and thus reduce damages. The proposed floodplain restoration in Waterbury decreases existing annual building damages from $51,000 to $41,000 (~20% damage reduction). Floodplain restoration leads to a reduction of $2.6 million dollars in simulated damages in Waterbury for a single modeled Tropical Storm Irene flood event. The current and future cost of living in the floodplain is lowered with floodplain restoration.

The costs of living in the floodplain will increase if the predicted larger floods do take place over the next 50 years so targeting higher than usual levels for mitigation activities (e.g., 1 foot over the 500-year flood) is recommended. Even with floodplain restoration and implementing mitigation strategies, future costs of living in the floodplain remain.

HYPOTHESES/CONCLUSIONS

1. The benefits of floodplain protection outweigh the costs over the long term because a complete accounting includes high-value ecosystem services.

The Towns in this study have a large base of naturally functioning land that provides ecosystem services such as flood mitigation benefits that is of high value and important to preserve and expand for future viability. A sweet spot appears to exist where benefits of floodplain protection outweigh the costs when damage reductions are high, the loss of tax revenue is low, the cost of the mitigation activity is low, and ecosystem service value is high. Removing buildings in the floodplain reduces damages the most, yet the loss of tax revenue must be offset by relocating or creating buildings in town but out of the floodplain. Costs are reduced when elevating utilities, and this activity is appealing as it can be performed during flood recovery. Building elevation makes sense when raising the most floodprone buildings to 1 foot over the 500-year flood level in Waterbury where damages are widespread. The results suggest that floodplain restoration and targeted mitigation activities of the most floodprone buildings most efficiently lower costs of living in floodplains. More work is needed to refine the number of floodprone buildings where the costs and benefits balance.

2. Floodplain protection reduces future flood damages, improves public safety, and enhances water quality because the most at risk parcels are not developed.

With the increase in the size and magnitude of flooding in the region, the size of floodplains, flood depths, and flood damages will increase. All mitigation activities reduced building damages for both today's floodplains as well as those predicted in 2065. The more naturally functioning floodplain that exists, the lower the damages to buildings in the floodplain due to the ecosystem service of flood mitigation. A partial accounting of ecosystem services indicates a high value of naturally functioning land, and this resource needs to be protected and expanded to control future damages and the predicted increase in the cost of living in floodplains. Erosion control is an important service that takes place on floodplains to reduce loss of land and to store sediment that can impact downstream receiving waters.

Primary Research Question

Do the benefits of floodplain protection outweigh the costs?

Benefits

- Reduction of flood damages
- Lower recovery costs
- Increased health and safety
- Enhanced ecosystem services
- Social benefits

Costs

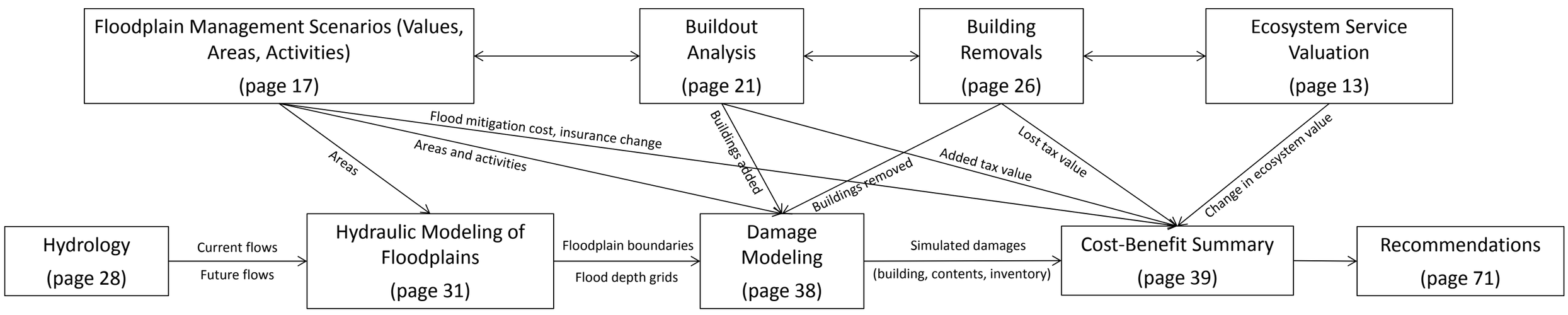
- Possible loss of economic opportunity
- Possible reduced tax base
- Floodplain restoration cost
- Increased building costs to flood-proof structures
- Recovery of structures remaining in the floodplain
- Demolitions

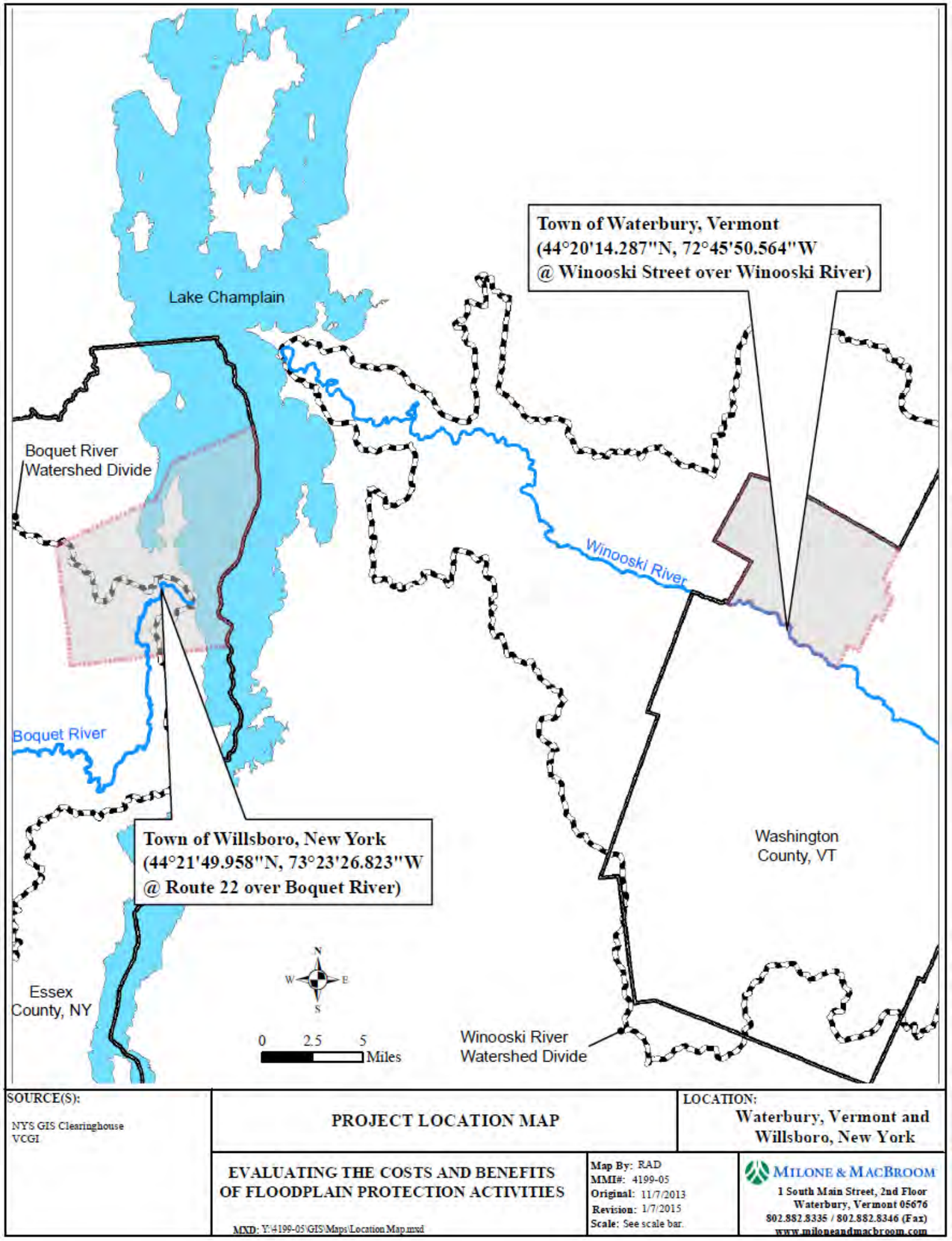
Hypotheses

1. The benefits of floodplain protection outweigh the costs over the long term because a complete accounting includes high-value ecosystem services.

2. Floodplain protection reduces future flood damages, improves public safety, and enhances water quality because the most at risk parcels are not developed.

Data Flow



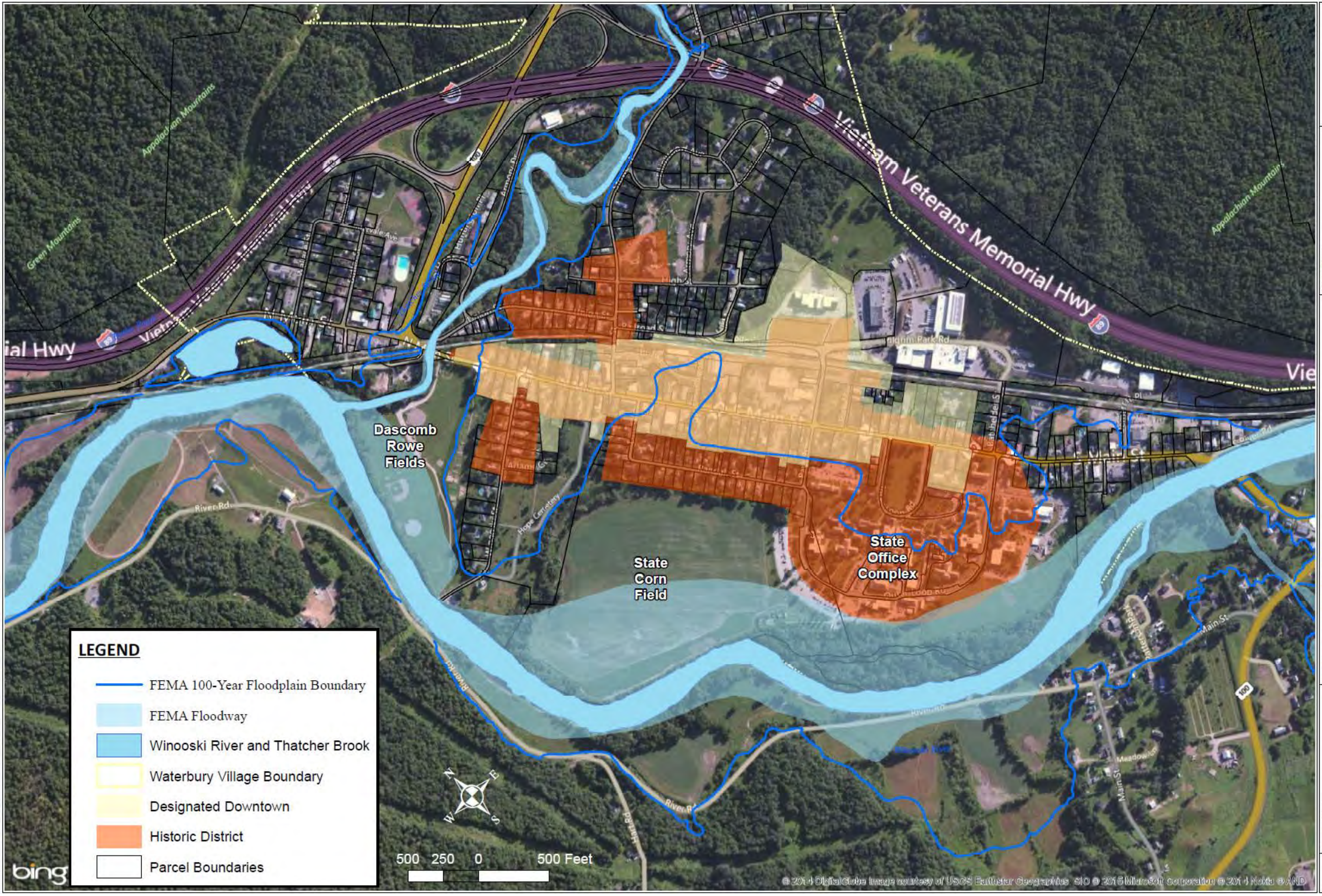


WATERBURY, VERMONT

- The source of flooding in the Village is the Winooski River during large storms that fill the broad floodplain where homes and businesses are located (see map on page 7).
- The Winooski River is one of Vermont's largest rivers with a total length of 90 miles that drains a large portion of central Vermont (drainage area ~ 1,080 square miles) (http://www.winooskiriver.org/).
- Drainage area of Winooski River at Waterbury Village is 715 square miles.
- Damaging floods took place in 2011 and 1927 leading to millions of dollars in personal, public, and unaccounted for damages (see photographs on page 9).
- Town is currently updating its flood hazard regulations.
- The primary project area is Waterbury Village, from the Ice Center to Winooski Street.

WILLSBORO, NEW YORK

- The source of flooding is the Boquet River during ice jam flooding, large storms, and high water levels on Lake Champlain in the lower river that impact homes and businesses in isolated low-lying areas (see map on page 8).
- The Boquet River is the steepest river in the state with a total length of 47 miles and drainage area of 280 square miles (http://boquetriver.org/).
- Drainage area at the Saw Mill Dam (aka Boquet River Dam) in downtown Willsboro is 271 square miles.
- Damaging floods took place in 2003 (ice jam), 2011 (regional flood), and in 1912 (ice jam) that damaged homes and businesses (see photographs on page 10).
- The town is considering changes to its zoning and flood hazard regulations.
- The primary project area is where the river is parallel to NY Route 22 upstream of the dam.



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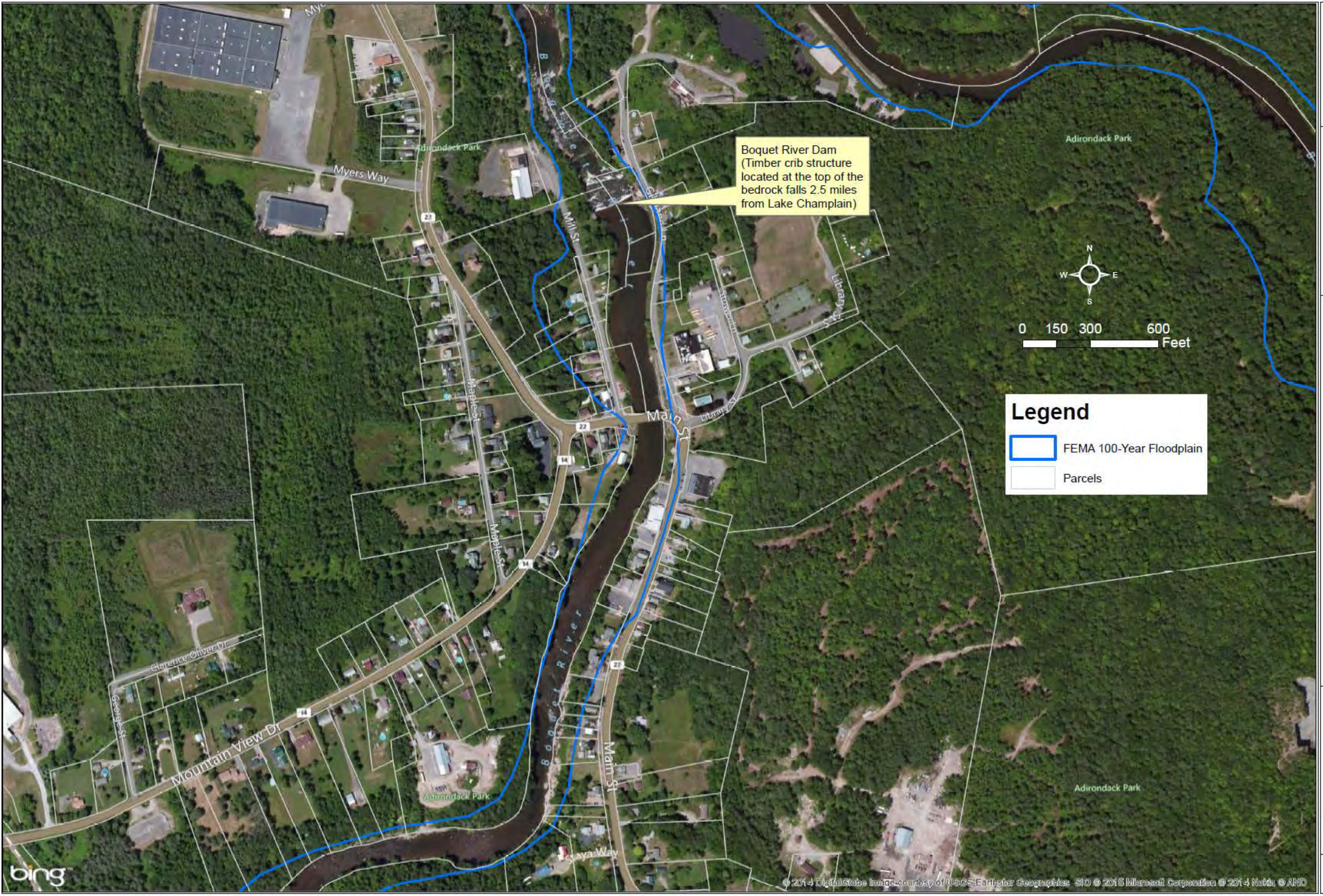
SOURCE(S):
FEMA Special Flood Hazard Area
Vermont Center for Geographic Information
Town of Waterbury
Bing Maps Aerial

PROJECT SITE MAP

EVALUATING THE COSTS AND BENEFITS OF FLOODPLAIN PROTECTION ACTIVITIES

WATERBURY, VERMONT

Map By: RKS
MMI#: 4199-05
MXD: Waterbury_overview_Roy.mxd
1st Version: February 24, 2014
Revision: January 23, 2015
Scale: See scale bar.



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SOURCE(S):
Town Parcel Data
FEMA Special Flood Hazard Area
Bing Aerial Photograph

PROJECT SITE MAP

EVALUATING THE COSTS AND BENEFITS OF FLOODPLAIN PROTECTION ACTIVITIES

WILLSBORO, NY

Map By: RKS
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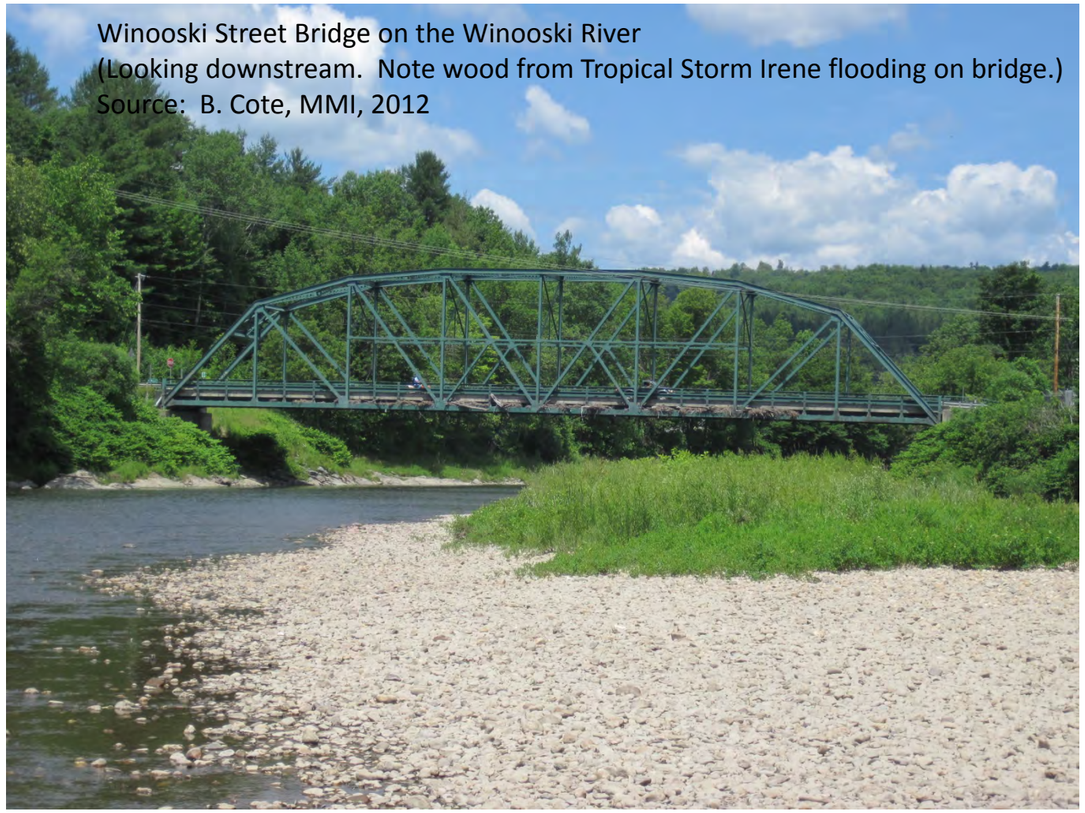
Revision: January 26, 2015
Scale: See scale bar

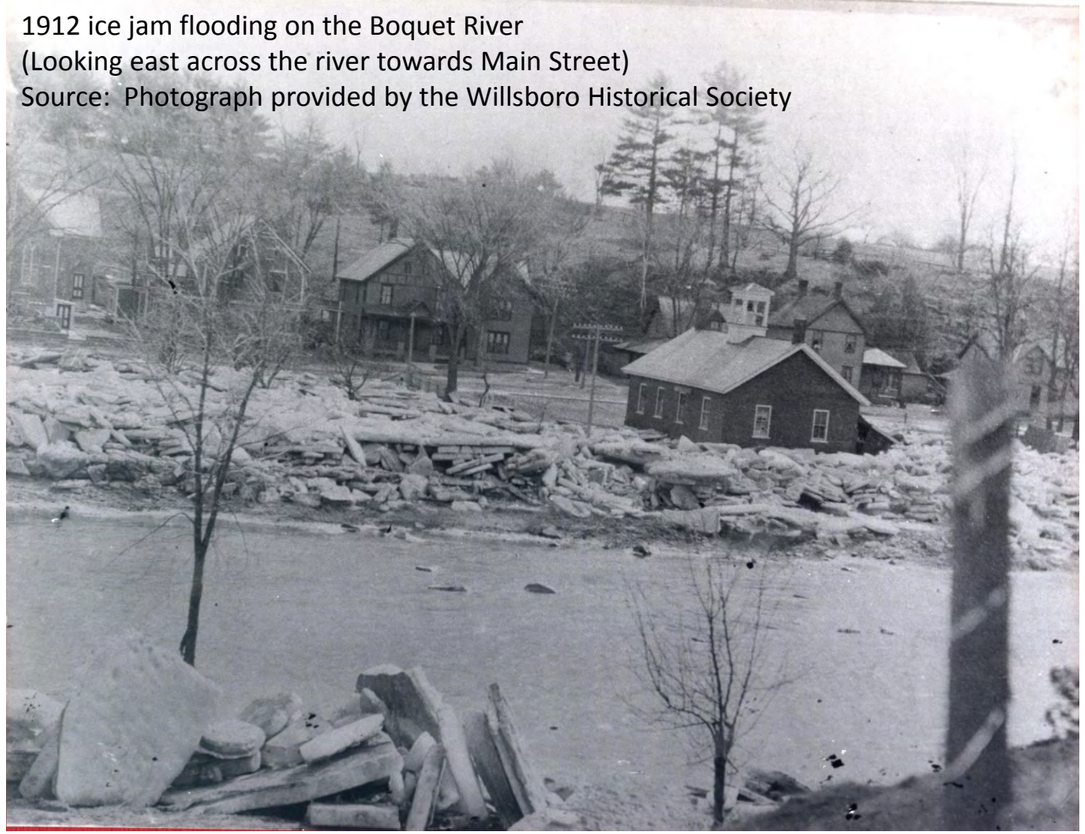


Winooski Street Bridge on the Winooski River
(Looking downstream. Note wood from Tropical Storm Irene flooding on bridge.)
Source: B. Cote, MMI, 2012

2011 flooding during Tropical Storm Irene
(Looking southeast along Main Street.)
Source: V. Starinskas, Rutland Herald

2011 and 1927 flood high water marks on Elm Street
(Looking southwest)
Source: R. Schiff, MMI, 2012

Randall Street Neighborhood that is prone to flooding
(Looking southeast)
Source: Google Maps Street View, 2015

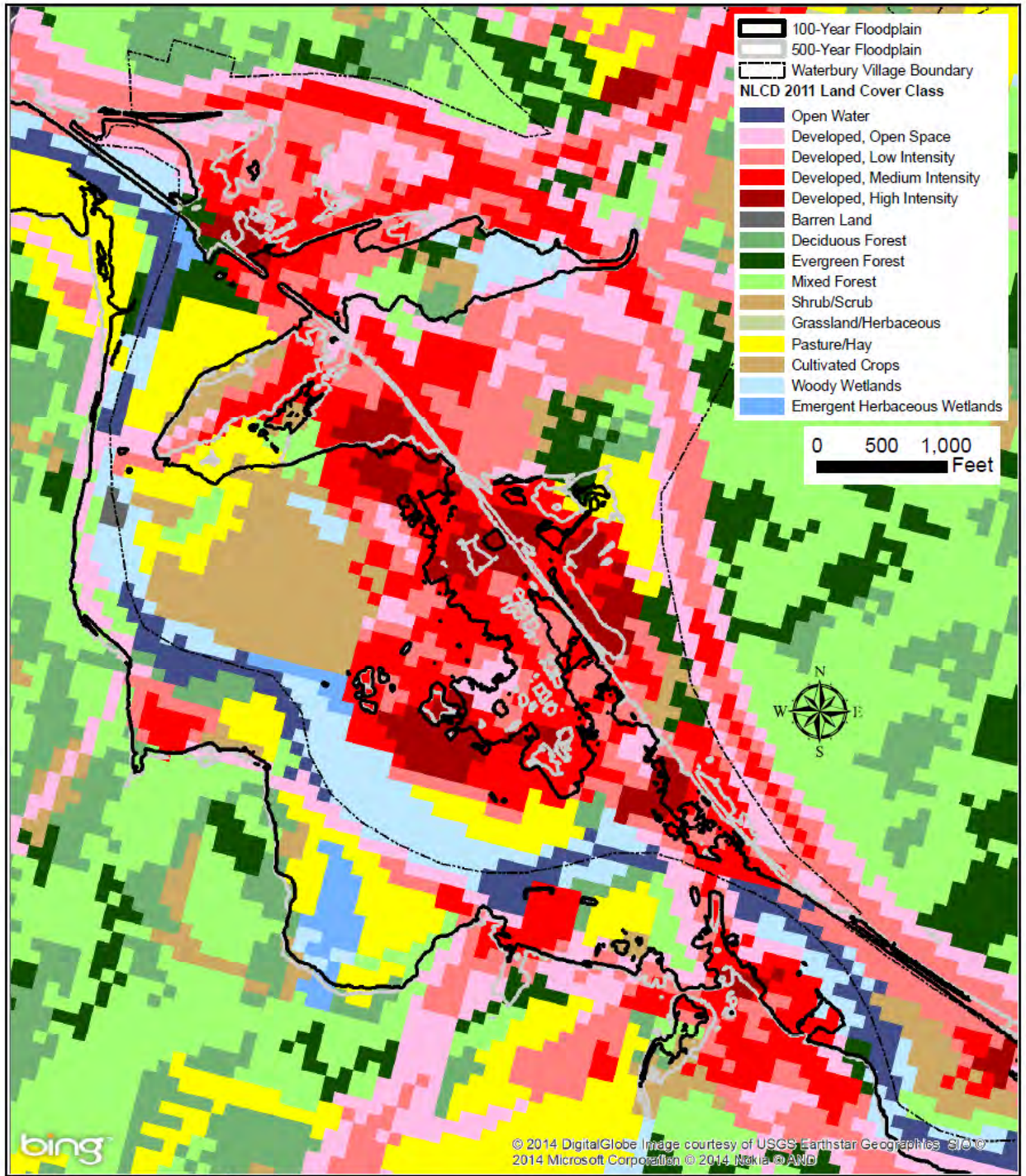


1912 ice jam flooding on the Boquet River
(Looking east across the river towards Main Street)
Source: Photograph provided by the Willsboro Historical Society

2003 ice jam flooding on the Boquet River
(Looking upstream from the Route 22 Bridge)
Source: Vic Putnam, GARC&D

2011 flooding on the Boquet River
(Looking upstream from the Route 22 Bridge)
Source: Vic Putnam, GARC&D

Boquet River Dam and Fishway
(Looking east across river towards Gilliland Lane)
Source: J. Louisos, MMI, 2013



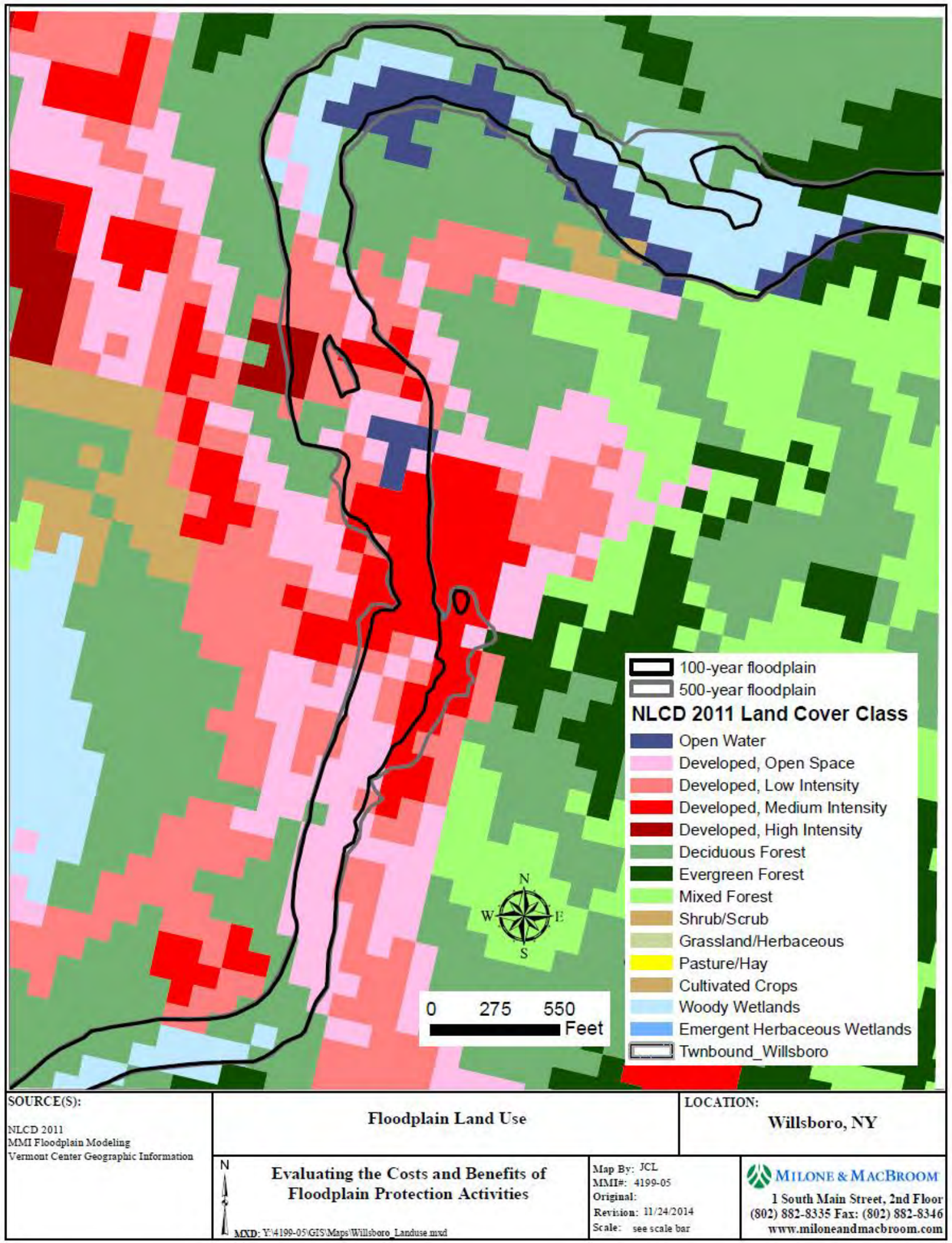
SOURCE(S):	Floodplain Land Use	LOCATION: Waterbury, VT
NLCD 2011 MMI Floodplain Modeling Vermont Center Geographic Information	Evaluating the Costs and Benefits of Floodplain Protection Activities MXD: Y:\4199-05\GIS\Maps\Waterbury_Landuse.mxd	Map By: JCL MMI#: 4199-05 Original: Revision: 11/24/2014 Scale: see scale bar MILONE & MACBROOM 1 South Main Street, 2nd Floor (802) 882-8335 Fax: (802) 882-8346 www.miloneandmacbroom.com

WATERBURY FLOODPLAIN LAND USE AREA (ACRES)
CLIPPED FROM NLCD 2011 (Jin et al., 2013)
11/24/2014

		EXISTING		
Land Use	**Q100**	**Irene**	**Q500**	**Q100_Future**
Barren Land	1.1	1.1	1.1	1.1
Cultivated Crops	42.6	42.7	42.7	42.7
Deciduous Forest	10.4	11.7	11.7	11.6
Developed, High Intensity	16.5	31.5	32.2	29.5
Developed, Low Intensity	54.4	74.8	75.9	72.3
Developed, Medium Intensity	58.0	91.0	93.0	86.3
Developed, Open Space	36.6	45.6	46.1	44.3
Emergent Herbaceous Wetlands	10.4	10.7	10.7	10.7
Evergreen Forest	7.9	9.7	9.8	9.4
Mixed Forest	22.7	27.3	27.5	26.8
Open Water	43.2	43.4	43.4	43.4
Pasture/Hay	65.0	74.5	74.8	73.4
Shrub/Scrub	13.9	18.7	19.1	17.8
Woody Wetlands	60.5	62.0	62.0	61.9
Total Area (Acres)	**443.2**	**544.6**	**550.1**	**531.2**

Floodplain Land Use in Waterbury, Vermont

- The Village is dominated by developed land uses that include residential, commercial, institutional, and recreational.
- Cropland and forestland exists near homes and businesses along river.
- The land use distribution and size of the floodplains is similar for the 500-year floodplain, 2011 Tropical Storm Irene floodplain, and the predicted future 100-year floodplain.



WILLSBORO FLOODPLAIN LAND USE AREA (ACRES)
CLIPPED FROM NLCD 2011 (Jin et al., 2013)
11/24/2014

		EXISTING		
Land Use	**Q100**	**Irene**	**Q500**	**Q100_Future**
Barren Land	0.0	0.0	0.0	0.0
Cultivated Crops	0.0	0.0	0.0	0.0
Deciduous Forest	9.0	10.8	11.7	13.6
Developed, High Intensity	0.6	0.7	0.8	0.8
Developed, Low Intensity	5.9	6.4	6.7	7.2
Developed, Medium Intensity	5.3	7.1	7.7	8.9
Developed, Open Space	9.2	9.6	9.8	10.2
Emergent Herbaceous Wetlands	0.0	0.0	0.0	0.0
Evergreen Forest	1.7	1.9	2.1	2.2
Mixed Forest	0.1	0.2	0.2	0.3
Open Water	6.3	6.7	7.0	7.4
Pasture/Hay	0.0	0.0	0.0	0.0
Shrub/Scrub	0.1	0.1	0.1	0.2
Woody Wetlands	13.5	15.3	15.5	15.7
Total Area (Acres)	**51.8**	**58.8**	**61.7**	**66.4**

Floodplain Land Use in Willsboro, New York

- The area along the river is dominated by developed land uses that include residential, commercial, and small recreational areas.
- Forestland surrounds the developed areas and is located in some parts of the riparian buffer.
- The land use distribution of floodplain inundated during a range of large floods is similar.

EARTH ECONOMICS

What Are Ecosystem Services?

Ecosystem services are benefits that people receive from natural systems.

Ecosystem services require *natural capital*, such as a forest or marine ecosystem, with physical and/or nonphysical processes to support human activities and sustain life. For example, forest and soils are natural capital assets that provide the ecosystem service of filtering water naturally without need of a costly man-made filtration plant.

Four categories of ecosystem services:

PROVISIONING SERVICES produce food, water, oxygen, raw materials, fuel, clothing, medicine, etc. Everything in our economy is made from natural capital such as minerals, liquids, gases and living things.

REGULATING SERVICES create and maintain healthy environmental conditions. Examples are carbon sequestration, aquifer recharge, soil erosion control, and pest and disease control. These contribute to healthy ecosystem functions.

INFORMATION SERVICES provide humans with meaningful interactions with nature. These services include spiritually significant species and natural areas, places for recreation, and educational opportunities through science.

SUPPORTING SERVICES provide refuge and reproduction habitat to wild plants and animals and thereby contribute to the (in situ) conservation of biological and genetic diversity and evolutionary processes.

Provisioning

ENERGY AND RAW MATERIALS
Providing fuel, fiber, fertilizer, minerals and energy

FOOD
Producing crops, fish, game and fruits

MEDICINAL RESOURCES
Providing traditional medicines, pharmaceuticals, and assay organisms

ORNAMENTAL RESOURCES
Providing resources for clothing, jewelry, handicraft, worship, and decoration

WATER SUPPLY
Provisioning of surface and ground water for drinking water, irrigation, and industrial use

Regulating

AIR QUALITY
Providing clean, breathable air

BIOLOGICAL CONTROL
Providing pest and disease control

CLIMATE STABILITY
Supporting a stable climate at global and local levels through carbon sequestration and other processes

MODERATION OF EXTREME EVENTS
Preventing and mitigating natural hazards such as floods, hurricanes, fires, and droughts

POLLINATION
Providing pollination of wild and domestic plan species

SOIL FORMATION
Creating soils for agricultural and ecosystem integrity; maintenance of soil fertility

SOIL RETENTION
Retaining arable land, slope stability and coastal integrity

WASTE TREATMENT
Improving soil, water and air quality by decomposing human and animal waste, and removing pollutants

WATER REGULATION
Providing natural irrigation, drainage, ground water recharge, river flows, and navigation

Information

AESTHETIC
Enjoying and appreciating the presence, scenery, sounds and smells of nature

CULTURAL AND ARTISTIC
Using nature as motifs in art, film, folklore, books, cultural symbols, architecture and media

RECREATION AND TOURISM
Experiencing natural ecosystems and enjoying outdoor activities

SCIENCE AND EDUCATION
Using natural systems for education and scientific research

SPIRITUAL AND HISTORICAL
Using nature for religious and spiritual purposes

Supporting

GENETIC RESOURCES
Improve crop resistance to pathogens and pests

HABITAT AND NURSERY
Maintaining genetic and biological diversity, the basis for most other functions; promoting growth of commercially harvested species

Range of Annual Values for Ecosystem Services in the Lake Champlain Basin

ECOSYSTEM SERVICE VALUATION METHODS (SEE APPENDIX 2 AND 3)

The benefit transfer analysis method was used to estimate the economic value of a given ecosystem (e.g., wetlands) from prior studies of that ecosystem type. While every wetland, forest, or other ecosystem is unique in some way, ecosystems of a given type, by their definition, have many things in common that allows for the use of average values in ecosystem valuation. This study's estimate of the aggregate value of the ecosystem service values for Waterbury, Vermont and Willsboro, New York is a valid and useful basis for assessing and comparing these services with conventional economic goods and services (See Costanza et al., 1997 and Howarth and Farber, 2002).

Research was performed to expand the Earth Economics database for the Lake Champlain region and the Earth Economics Ecosystem Valuation Tool Kit (EE, 2012, 2013) was used to value floodplain function in Waterbury, Vermont and Willsboro, New York. The research and analysis resulted in a range of $/acre/year for six land cover classes in the floodplain (agriculture, forest, shrubland/grassland, wetland, river, and village greenspace) (see tables below). Blank spaces in the tables above do not reflect a value of 0 $/acre/year, yet they reflect a research gap in the literature entered in the Earth Economics database. The ecosystem service values provided by this analysis for the Lake Champlain Basin are likely underestimated given the numerous gaps in the data (see gaps analysis table on page 15).

Limitations of this approach to approximate the value of ecosystem services include incomplete coverage in the benefit transfer database, the lack of inclusion of a value for just the existence of the ecosystem even if the service is not used, the analysis is static, and the analysis hinges on coarse land use data. The low and high values and the data gaps provide some indication of the range of possible values developed here. Even with these and other limitations, this project has resulted in a conservative estimate of ecosystem services in the Lake Champlain Basin that can be used for research and planning.

Ecosystem Service	Agriculture		Forest	
	Low Value ($/acre/year)	High Value ($/acre/year)	Low Value ($/acre/year)	High Value ($/acre/year)
Aesthetic	0	6134	5497	5497
Air Quality			195	195
Biological Control			14	14
Climate Stability	2	125	1	166
Cultural and Artistic	55	2091		
Energy and Raw Materials			48	48
Erosion Control	5	122	1	4
Flood Mitigation				
Food Production	150	150		
Genetic Resources				
Habitat and Nursery				
Medicinal Resources				
Ornamental Resources				
Pollination	46	1903		
Recreation and Tourism	67	67	14	68
Science and Education				
Soil Formation	1	166		
Spiritual and Historic				
Waste Treatment			48	465
Water Regulation	26	50		
Water Supply			3	3
TOTAL	**$ 352**	**$ 10,808**	**$ 5,823**	**$ 6,461**

Ecosystem Service	Shrubland / Grassland		Wetland	
	Low Value ($/acre/year)	High Value ($/acre/year)	Low Value ($/acre/year)	High Value ($/acre/year)
Aesthetic			37	10096
Air Quality				
Biological Control	316	316		
Climate Stability	6	107	9	41
Cultural and Artistic				
Energy and Raw Materials	20	20		
Erosion Control	4844	4844		
Flood Mitigation	3867	3867	166	7509
Food Production			50	50
Genetic Resources				
Habitat and Nursery	93	93	2838	4675
Medicinal Resources				
Ornamental Resources				
Pollination				
Recreation and Tourism			577	10354
Science and Education				
Soil Formation				
Spiritual and Historic				
Waste Treatment			399	4555
Water Regulation				
Water Supply			1731	18591
TOTAL	**$ 9,147**	**$ 9,247**	**$ 5,807**	**$ 55,870**

Ecosystem Service	River		Village Greenspace	
	Low Value ($/acre/year)	High Value ($/acre/year)	Low Value ($/acre/year)	High Value ($/acre/year)
Aesthetic	515	53845	1693	10809
Air Quality				
Biological Control				
Climate Stability				
Cultural and Artistic				
Energy and Raw Materials				
Erosion Control				
Flood Mitigation				
Food Production				
Habitat and Biodiversity				
Genetic Resources				
Habitat and Nursery				
Medicinal Resources				
Ornamental Resources				
Pollination				
Recreation and Tourism	1604	23245	567	6667
Science and Education				
Soil Formation				
Spiritual and Historic				
Waste Treatment				
Water Regulation			143	444
Water Supply				
TOTAL	**$ 2,119**	**$ 77,089**	**$ 2,404**	**$ 17,919**

Range of Annual Values for Ecosystem Services

ECOSYSTEM SERVICE VALUATION METHODS (SEE APPENDIX 2 AND 3)

The value of ecosystem services was aggregated for each floodplain land cover class to create low and high annualized values ($/acre/year) (see table below). The values were then projected to a 50-year timespan ($/acre) using a discount rate of 4.125%. This rate was selected as a common discount rate applied for public infrastructure investments, yet it is not necessarily reflective of the specific characteristics of natural capital that distinguish it from built capital.

Over 50 years, the floodplain asset value, or stock of ecosystem service benefits, in Waterbury, Vermont ranges between $38,183,000 to $216,334,000. The annual ecosystem service value (in the current land cover in the 500-year floodplain) ranges between $1,795,470 and 9,894,061 per year. The average of these values ($5,844,765) was used to consider annual change in ecosystem service value with conversion to or from naturally functioning land associated with adding or removing buildings (see cost-benefit summary tables for Waterbury).

Over 50 years, the stock of ecosystem service benefits, in Willsboro, New York ranges between $4,528,000 and $36,962,000. The annual ecosystem service value (in the current land cover in the 500-year floodplain) ranges between $211,000 and $1,672,000 per year. The average of these values ($941,774) was used to consider annual change in ecosystem service value with conversion to or from naturally functioning land associated with adding or removing buildings (see cost-benefit summary tables for Willsboro).

Data Gaps Analysis Summary		Agriculture	Forest	Shrubland/Grassland	River	Village Greenspace	Wetland
	Air Quality		x				
	Biological Control		x	x			
	Climate Stability	x	x	x			x
	Erosion Control	x	x	x			
	Flood Mitigation			x			x
	Pollination	x					
	Soil Formation	x					
	Waste Treatment		x				x
	Water Regulation	x				x	
	Water Supply		x				x
	Energy & Raw Materials		x	x			
	Food Production	x					x
	Genetic Resources						
	Medicinal Resources						
	Ornamental Resources						
	Habitat & Nursery			x			x
	Aesthetic Information	x	x		x	x	x
	Cultural & Artistic	x					
	Recreation & Tourism	x	x		x	x	
	Science & Education						
	Spiritual & Historic						

Key:

	Ecosystem service exists with the land cover but is not valued in this report
X	Ecosystem service produced by land cover and valued in this report
	Ecosystem service not produced by land cover

50 yr timespan (Rounded to the nearest $100)						
Floodplain Land Cover Class	Low Value ($/acre/year)	High Value ($/acre/year)	Carbon Storage Low	Carbon Storage High	NPV per Acre Low (4.125%)	NPV per Acre High (4.125%)
Agriculture	400	10,800	500	3,600	7,700	224,100
Forest	5,800	6,500	300	19,800	119,200	151,500
Shrubland / Grassland	9,100	9,200	200	300	186,800	189,000
Wetland	5,800	55,900	4,900	84,100	123,400	1,224,400
River	2,100	77,100	-	-	43,300	1,573,000
Village Greenspace	2,400	17,900	100	16,100	50,600	393,000
Developed Land	Not Valued	Not Valued	Not Valued	Not Valued	Not Valued	Not Valued

Ecosystem Service Values for the Lake Champlain Basin Region

Use this table by multiplying values by land cover class acreage to estimate annual ecosystem service value ($/year) (see tables on page 16) or to estimate the range of ecosystem service value over 50-years ($).

Range of Annual Values for Ecosystem Services

WATERBURY, VERMONT

100-Year Floodplain

Floodplain Land Cover Class	Acres	Low Value ($/acre/year)	High Value ($/acre/year)	Annual Low ($/year)	Annual High ($/year)
Agriculture	43	352	10,808	15,002.66	460,125
Forest	41	5,823	6,461	238,135	264,223
Shrubland / Grassland	80	9,147	9,247	732,250	740,275
Wetland	71	5,807	55,870	411,952	3,963,203
River	43	2,119	77,089	91,589	3,331,725
Village Greenspace	37	2,404	17,919	87,999	655,966
Developed Land	129	Not Valued	Not Valued	Not Valued	Not Valued
Total	**443**			**$ 1,576,928**	**$ 9,415,519**

500-Year Floodplain

Floodplain Land Cover Class	Acres	Low Value ($/acre/year)	High Value ($/acre/year)	Annual Low ($/year)	Annual High ($/year)
Agriculture	43	352	10,808	15,035.94	461,146
Forest	49	5,823	6,461	285,630	316,921
Shrubland / Grassland	95	9,147	9,247	869,427	878,956
Wetland	73	5,807	55,870	422,514	4,064,821
River	43	2,119	77,089	91,971	3,345,601
Village Greenspace	46	2,404	17,919	110,891	826,615
Developed Land	201	Not Valued	Not Valued	Not Valued	Not Valued
Total	**550**			**$ 1,795,470**	**$ 9,894,061**

Irene Floodplain

Floodplain Land Cover Class	Acres	Low Value ($/acre/year)	High Value ($/acre/year)	Annual Low ($/year)	Annual High ($/year)
Agriculture	43	352	10,808	15,035.14	461,122
Forest	49	5,823	6,461	283,532	314,593
Shrubland / Grassland	94	9,147	9,247	862,809	872,265
Wetland	73	5,807	55,870	422,201	4,061,802
River	43	2,119	77,089	91,964	3,345,376
Village Greenspace	46	2,404	17,919	109,518	816,379
Developed Land	197	Not Valued	Not Valued	Not Valued	Not Valued
Total	**545**			**$ 1,785,059**	**$ 9,871,537**

Future 100-Year Floodplain

Floodplain Land Cover Class	Acres	Low Value ($/acre/year)	High Value ($/acre/year)	Annual Low ($/year)	Annual High ($/year)
Agriculture	43	352	10,808	15,015.95	461,058
Forest	48	5,823	6,461	278,513	309,029
Shrubland / Grassland	92	9,147	9,247	844,755	853,991
Wetland	73	5,807	55,870	421,304	4,053,432
River	43	2,119	77,089	91,943	3,344,871
Village Greenspace	44	2,404	17,919	106,496	793,803
Developed Land	188	Not Valued	Not Valued	Not Valued	Not Valued
Total	**531**			**$ 1,758,028**	**$ 9,816,183**

WILLSBORO, NEW YORK

100-Year Floodplain

Floodplain Land Cover Class	Acres	Low Value ($/acre/year)	High Value ($/acre/year)	Annual Low ($/year)	Annual High ($/year)
Agriculture	0	352	10,808	-	-
Forest	11	5,823	6,461	62,989	69,889
Shrubland / Grassland	0	9,147	9,247	1,028	1,039
Wetland	14	5,807	55,870	78,585	756,029
River	6	2,119	77,089	13,395	487,265
Village Greenspace	9	2,404	17,919	22,025	164,180
Developed Land	12	Not Valued	Not Valued	Not Valued	Not Valued
Total	**52**			**$ 178,021**	**$ 1,478,402**

500-Year Floodplain

Floodplain Land Cover Class	Acres	Low Value ($/acre/year)	High Value ($/acre/year)	Annual Low ($/year)	Annual High ($/year)
Agriculture	0	352	10,808	-	-
Forest	14	5,823	6,461	81,530	90,461
Shrubland / Grassland	0	9,147	9,247	1,242	1,255
Wetland	16	5,807	55,870	90,237	868,125
River	7	2,119	77,089	14,755	536,736
Village Greenspace	10	2,404	17,919	23,563	175,645
Developed Land	15	Not Valued	Not Valued	Not Valued	Not Valued
Total	**62**			**$ 211,326**	**$ 1,672,223**

Irene Floodplain

Floodplain Land Cover Class	Acres	Low Value ($/acre/year)	High Value ($/acre/year)	Annual Low ($/year)	Annual High ($/year)
Agriculture	0	352	10,808	-	-
Forest	13	5,823	6,461	75,394	83,654
Shrubland / Grassland	0	9,147	9,247	1,175	1,188
Wetland	15	5,807	55,870	88,877	855,043
River	7	2,119	77,089	14,288	519,763
Village Greenspace	10	2,404	17,919	23,065	171,934
Developed Land	14	Not Valued	Not Valued	Not Valued	Not Valued
Total	**59**			**$ 202,800**	**$ 1,631,582**

Future 100-Year Floodplain

Floodplain Land Cover Class	Acres	Low Value ($/acre/year)	High Value ($/acre/year)	Annual Low ($/year)	Annual High ($/year)
Agriculture	0	352	10,808	-	-
Forest	16	5,823	6,461	93,847	104,129
Shrubland / Grassland	0	9,147	9,247	1,377	1,392
Wetland	16	5,807	55,870	91,327	878,673
River	7	2,119	77,089	15,611	567,915
Village Greenspace	10	2,404	17,919	24,416	181,994
Developed Land	17	Not Valued	Not Valued	Not Valued	Not Valued
Total	**66**			**$ 226,578**	**$ 1,734,103**

FLOODPLAIN MANAGEMENT SCENARIOS (VALUES, AREAS, AND ALTERNATIVES)

Floodplain Values – Waterbury, Vermont

Social

- Maintain vibrant village
- Help establish housing and businesses
- Grow tax base
- Create flood-safe community
- Support state government presence
- Maintain historic downtown
- Create tourism hub
- Support local arts

Environmental

- Establish connections between Village and recreation / natural areas
- Highlight river setting
- Maintain open space for recreation
- Create outdoor recreation tourism economy
- Support local agriculture

Floodplain Values – Willsboro, New York

Social

- Create a flood-safe community
- Protect public infrastructure
- Help establish housing and businesses in the Village
- Grow tax base
- Maintain historic Lake Champlain aesthetics and traditions
- Create tourism hub
- Support local arts

Environmental

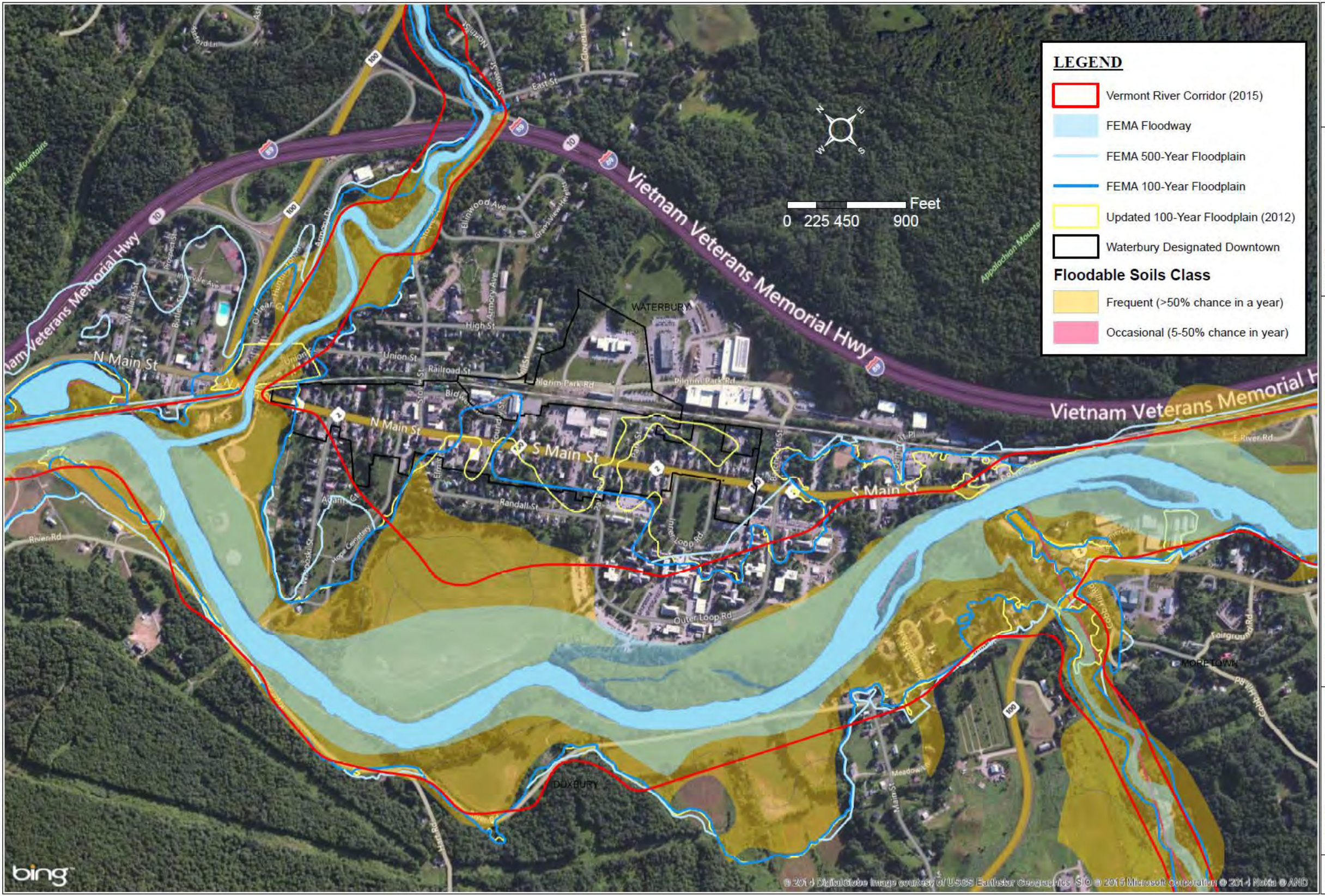
- Grow outdoor recreation tourism economy focused on river and fishing
- Establish connections between Village and recreation / natural areas
- Preserve floodplain forest along Lake Champlain and northern population of sycamore trees
- Highlight natural river setting as focus of Village
- Support local agriculture

Management Areas – Waterbury, Vermont

- Considered the FEMA 100-year and 500-year floodplains (FEMA, 2013), revised floodplains, the approximate state-mapped river corridor (Kline and Cahoon, 2010; VTANR, 2014), frequently flooded soils (NRCS, 2013; Coulton, 2014), the Village Designated Downtown, Main Street, the Historic District, and neighborhoods (see map on page 18).
- Due to the dominance of inundation-based hazards, the revised floodplains from the hydraulic modeling were selected as the primary management areas, with select removals from floodprone areas with highest flood depths.

Management Areas – Willsboro, New York

- Considered the FEMA 100-year and 500-year floodplains (FEMA, 1992), revised floodplains, an approximate river corridor (VTANR, 2014), frequently flooded soils (NRCS, 2013; Coulton, 2014), the 150-foot buffer, and the Willsboro land conservation river zone (LCR) (Willsboro, 2002) (see map on page 19).
- The revised floodplains from the hydraulic modeling were selected as the primary management areas as they appeared to be the best local representation of the area of primary risk. Selected structure removals from the most floodprone areas were based on the modeling.



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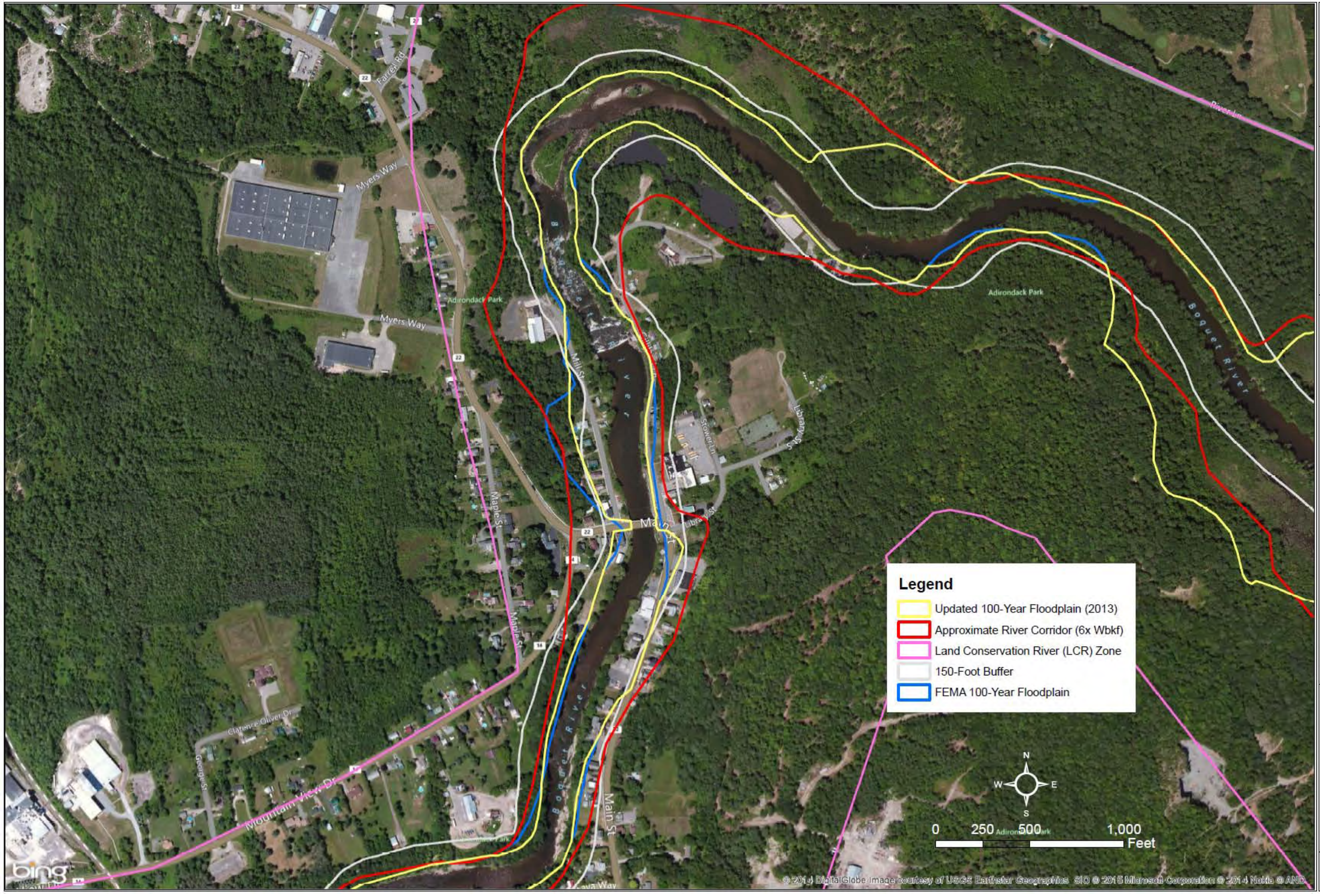
SOURCE(S):
Floodway (FEMA / VCGI)
Q100 Floodplain (FEMA / MMD)
DRAFT FEH - DO NOT DISTRIBUTE (ANR)
VHD (VCGI)
Bing Aerial Map Service

FLOODPLAIN MANAGEMENT AREAS

EVALUATING THE COSTS AND BENEFITS OF FLOODPLAIN PROTECTION ACTIVITIES

WATERBURY, VT

Map By: RKS
MMI#: 4419-05
MXD: Waterbury_management_areas.mxd
1st Version: June 27, 2014
Revision: 1/23/2015
Scale: See scale bar.



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SOURCE(S):
BING MAP
MMI SECTION LOCATIONS
FEA FLOODPLAIN AREAS

WILLSBORO FLOODPLAIN MANAGEMENT AREAS

EVALUATING THE COSTS AND BENEFITS
OF FLOODPLAIN PROTECTION ACTIVITIES

WILLSBORO, NY

Map By: RKS
MMI#: 4199-05
MXD: Willsboro_Floodplain Areas_ZOOM.mxd
1st Version: 1/16/2015
Revision: 1/23/2015
Scale: See scale bar

Floodplain Management Scenarios

1. Business as usual
   - 1A. Existing floodplain development
   - 1B. Full floodplain buildout to following current zoning and floodplain regulations.
2. Elevate
   - 2A. All buildings in the 500-year floodplain to be elevated 2 feet above the revised 100-year flood level.
   - 2B. All buildings that are most prone to flooding and new buildout buildings to be elevated 2 feet above the revised 100-year flood level.
   - 2C. All utilities in the 500-year floodplain to be elevated to the revised 500-year flood level.
3. Avoidance and no fill
   - 3A. Remove buildings in the most floodprone areas that have the deepest flood levels.
   - 3B. No additional fill in the floodplain. (policy)
   - 3C. All buildings that are most prone to flooding and new buildout buildings to be elevated to 1 foot above the revised 500-year flood level.
4. Extreme flood risk avoidance
   - 4A. Remove the majority of structures that are prone to flooding following substantial damages.
   - 4B. Remove the majority of structures that are prone to flooding following substantial damages and elevate essential buildings following damages selected to remain.
   - 4C. Floodplain development restrictions. (policy)

Waterbury, Vermont

- Modeled flows – 10-year, 50-year, 100-year, Irene, 500-year, predicted future 100-year
- Scenarios – Existing conditions (1A), full buildout (1B), widespread elevations (2), select removals or elevations (3), widespread removals and specific elevations (4)
- Flood risk reduction alternatives
  - Alternative 1 – Restore all 3 floodplain areas (selected).
  - Alternative 2 – Restore 2 of 3 floodplain areas.

Willsboro, New York

- Modeled flows – 10-year, 25-year, 50-year, 100-year, Irene, 500-year, predicted future 100-year
- Scenarios – Existing conditions (1A), full buildout (1B), widespread elevations (2), select removals or elevations (3), widespread removals (4A)
- Flood risk reduction alternatives
  - Alternative 1 – Remove dam.
  - Alternative 2 – Restore floodplain and elevate floodprone commercial buildings, and remove dam (selected).

SELECTING FLOODPLAIN MANAGEMENT SCENARIOS

Meetings were held with each Town to review floodplain management areas and scenarios. The valley bottom floodplain settings and low-gradient river channels lead to flooding as the primary hazard, and thus modeled inundation-based floodplains are suitable management areas at both project sites. The management scenarios include existing conditions, building elevations, utility elevations, building removals, and buildout. Common flood mitigation activities were reviewed in conjunction with local and state regulations, and then the Towns selected several management scenarios to explore. For example, Waterbury was interested in utility elevation as a possible low-cost flood recovery option compared to building elevation to build back stronger. Given the recent large floods, elevations such as 2 feet above the 100-year flood, the 500-year flood level, and 1 foot above the 500-year flood were investigated as possible future management elevations for keeping property safe in these floodprone areas. The management scenarios included existing conditions, full floodplain buildout following current floodplain regulations, removing all buildings in the 100-year floodplain, and removing the most floodprone buildings. Flood risk reduction alternatives were identified for each Town and inserted into the hydraulic model. A preferred alternative that lowered flood levels the most and was supported by the Town was selected for damage modeling.

Buildout / Removals Analysis

Waterbury, Vermont

- There are 555 parcels in Waterbury Village with a total value of $399 million. 59% of the town's value is in the current 100-year floodplain and 64% is in the future 100-year floodplain (see page 22).
- Currently over half of the assessed value in the Village is associated with the State office complex. It is valued at $200 million, while the assessment of the remaining property in the Village is valued at $199 million. Following the completion of the reconstruction and redevelopment of the site, the estimated complex value is $135 million.
- There are 156 parcels that are at least 50% in the existing 100-year floodplain. Their assessed value is $233.7 million.
- The by-right full redevelopment of the parcels in the 100-year floodplain could net 259 dwelling units by right, and 3.9 million square feet of commercial or industrial space. This is $536.7 million in potential assessed value, or an increase of $303 million. The incremental buildout in this area would have a lower value.
- There are 211 parcels that are at least 50% in the predicted future 100-year floodplain. Their assessed value is $254.1 million.
- The full redevelopment of the parcels in the 500-year floodplain could net 586 dwelling units by right, and 4.8 million square feet of commercial or industrial space. This is $672.1 million in potential assessed value, or an increase of $418 million. The incremental buildout in this area would have a lower value.
- There are 53 parcels that are most prone to flooding (i.e., they are in the deepest portions of the 50-year floodplain) with an existing value of $11.3 million. By right these parcels could yield 103 dwelling units and 87,058 square feet of commercial with a potential value of $25.7 million (see maps on pages 23, 24, and 26).
- There are 119 parcels that are prone to flooding (i.e., they are in the deepest portions of the 100-year floodplain) with an existing value of $26.3 million. By right these parcels could yield 354 dwelling units and 2.0 million square feet of commercial with a potential value of $286.4 million. Most of this value is in commercial square feet.

Willsboro, New York

- There are 11 parcels that are at least 50% in the existing 100-year floodplain with an assessed value of $830,800, or 0.2% of the total Town Grand List (see page 22).
- The full redevelopment of these parcels could net 144 dwelling units by right, and 66,935 square feet of commercial space. This is worth $24.7 million in potential assessed value, or an increase of $23.9 million.
- There are 16 parcels that are at least 50% in the future 100 year floodplain. Their assessed value is $1.5 million that is 0.4% of the total Town Grand List.
- The full redevelopment of these parcels could net 170 dwelling units by right, and 99,924 square feet of commercial space. This is $31.3 million in potential assessed value, or an increase of $29.8 million.
- There are 11 parcels that are most prone to flooding (i.e., they are in the deepest portions of the 50-year floodplain) with an existing value of $830,000. By right these parcels could yield 70 dwelling units and 57,855 square feet of commercial with a potential value of $14.6 million (see maps on pages 25 and 27).
- There are 16 parcels that are prone to flooding (i.e., they are in the deepest portions of the Irene floodplain) with an existing value of $1.5 million. By right these parcels could yield 118 dwelling units and 99,924 square feet of commercial with a potential value of $24.8 million.

BUILDOUT METHODS (SEE APPENDIX 4)

This build-out consisted of a maximum total possible build-out of the largest mapped floodplain area meaning that the land is cleared of all current development and rebuilt at its maximum allowable by-right density based on local zoning regulations. To calculate the residential build-out potential, each parcel was assigned a single zone that it mostly occupied. In practice, redevelopment more often consists of building expansions and subdivision of land rather than demolition and rebuild projects. The damage modeling (see page 38) considered this more realistic approach when considering how potential buildout would occur, taking into account local development patterns, constraints due to natural features, existing buildings, and zoning. This resulted in a lower amount of square footage in the buildout condition than would have been expected as presented in the by-right analysis above. The buildout information was used to understand increased damage levels due to flooding and increased benefits of floodplain management scenarios to protect additional buildings. The analysis also provided information for building removal and floodplain conservation scenarios (see pages 26-27).

Buildout Analysis

(See Appendix 4)

Waterbury, Vermont

Waterbury Village Grand List

Existing Land Use	# of Parcels	Assessed Value	Amount in Current Floodplain	Amount in Future Floodplain
Commercial/ Industrial	69	$59,658,700	10%	29%
Residential	421	$100,185,800	20%	28%
Mixed Use	16	$5,764,100	26%	48%
Municipal/ Institutional**	28	$219,788,700	93%	94%
Vacant/ Unclassified	19	$11,704,100	5%	6%
TOTAL	**555**	**$399,095,200**	**59%**	**64%**

*Parcels are land based parcels and may not correspond to the total tax records.

**Church, State, Town, Park, Utility, Public Institutional. The State complex is valued at $94,700 Land/ $200,000,000 Buildings. Future value is estimated at $135,000,000.

***Total includes 2 ROW parcels not listed in the buildout.

Source: 2014 Waterbury Tax Assessor Records

Current 100-Year Floodplain

	Existing Conditions		Full Buildout		
Existing Land Use	# of Parcels	Assessed Value	Potential Dwelling Units allowed by Right	Potential Commercial / Industrial Square Footage	Potential Value
Commercial/ Industrial	20	$6,056,600	86	244,813	$35,473,690
Residential	112	$20,256,700	118	109,344	$28,361,720
Mixed Use	5	$1,470,500	24	22,879	$5,681,270
Municipal/ Institutional**	13	$205,283,000	n/a	3542927	$460,580,510
Vacant/ Unclassified	6	$596,300	31	0	$6,603,000
TOTAL	**156**	**$233,663,100**	**259**	**3,919,963**	**$536,700,190**

Future (2065) 100-Year Floodplain

	Existing Conditions		Full Buildout		
Exisiting Land Use	# of Parcels	Assessed Value	Potential Dwelling Units allowed by Right	Potential Commercial / Industrial Square Footage	Potential Value
Commercial/ Industrial	38	$17,035,700	293	924,404	$130,574,520
Residential	142	$27,825,600	219	228,082	$53,897,660
Mixed Use	9	$2,794,400	43	54,320	$12,324,600
Municipal/ Institutional**	15	$205,720,100	n/a	3,542,927	$460,580,510
Vacant/ Unclassified	7	$758,900	31	62,778	$14,764,140
TOTAL	**211**	**$254,134,700**	**586**	**4,812,511**	**$672,141,430**

Willsboro, New York

Willsboro Grand List

Existing Land Use	# of Parcels	Assessed Value	Amount in Current Floodplain	Amount in Future Floodplain
TOTAL	**2133**	**$343,703,785**	**0.2%**	**0.4%**

*Parcels are land based parcels and may not correspond to the total tax records.

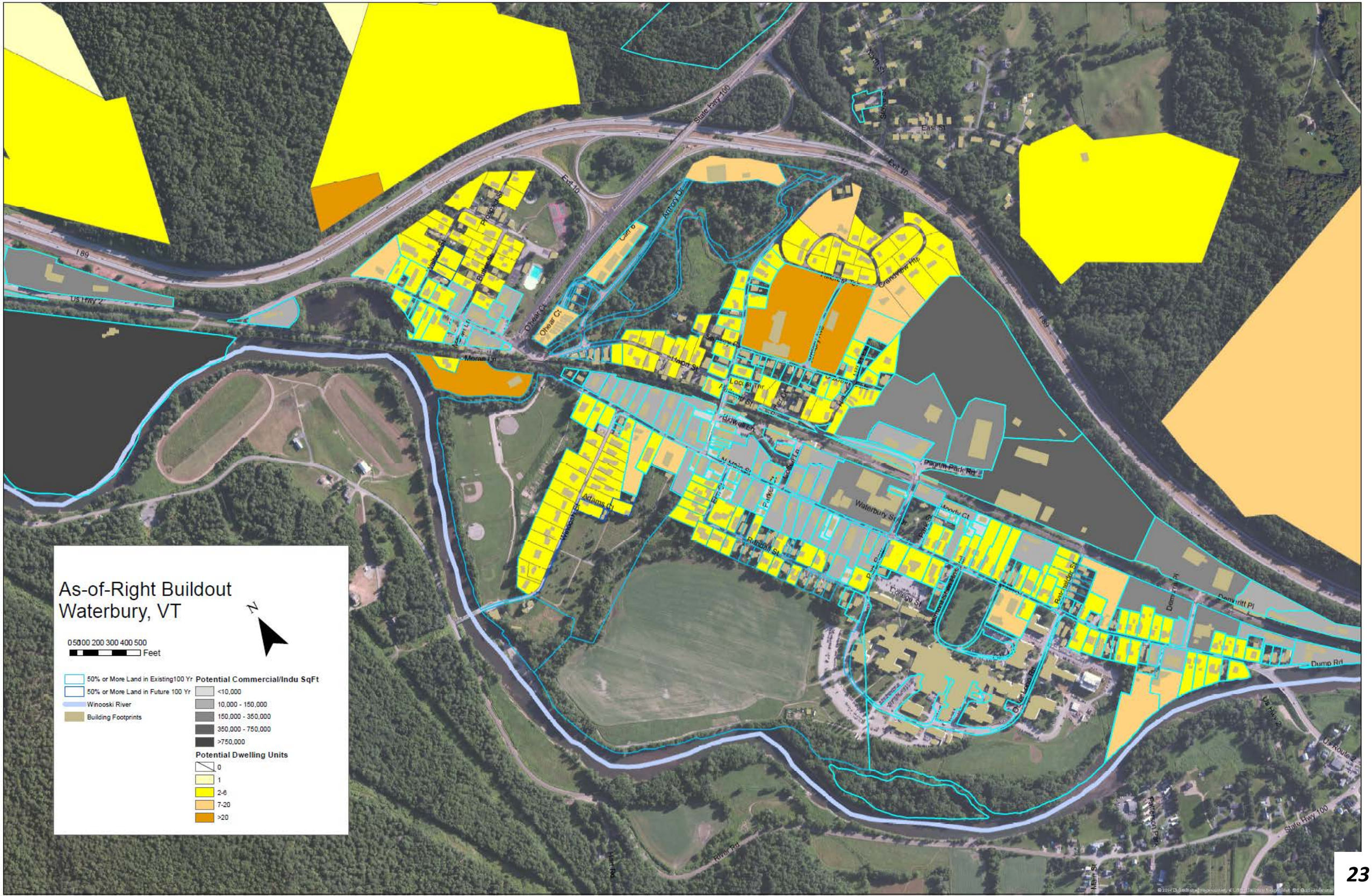
Source: 2014 Willsboro Tax Assessor Records

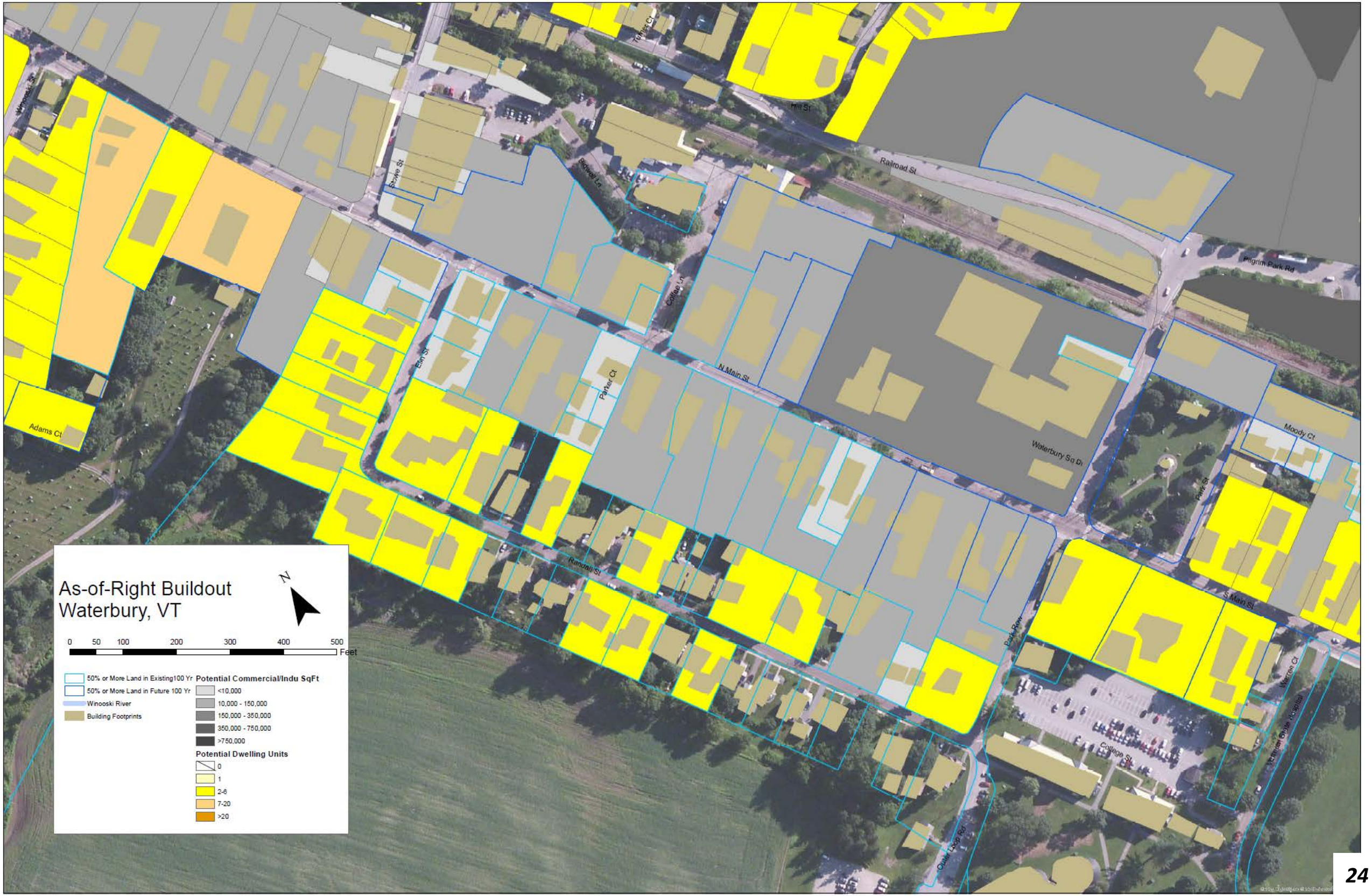
Current 100-Year Floodplain

	Existing Conditions		Full Buildout		
Existing Land Use	# of Parcels	Assessed Value	Potential Dwelling Units allowed by Right	Potential Commercial / Industrial Square Footage	Potential Value
Commercial	2	$214,500	0	66,935	$6,693,530
Residential	4	$467,500	30	0	$3,750,000
Municipal/ Institutional	2	$50,900	16	0	$2,050,000
Vacant/ Unclassified	3	$97,900	98	0	$12,250,000
TOTAL	**11**	**$830,800**	**144**	**66,935**	**$24,743,530**

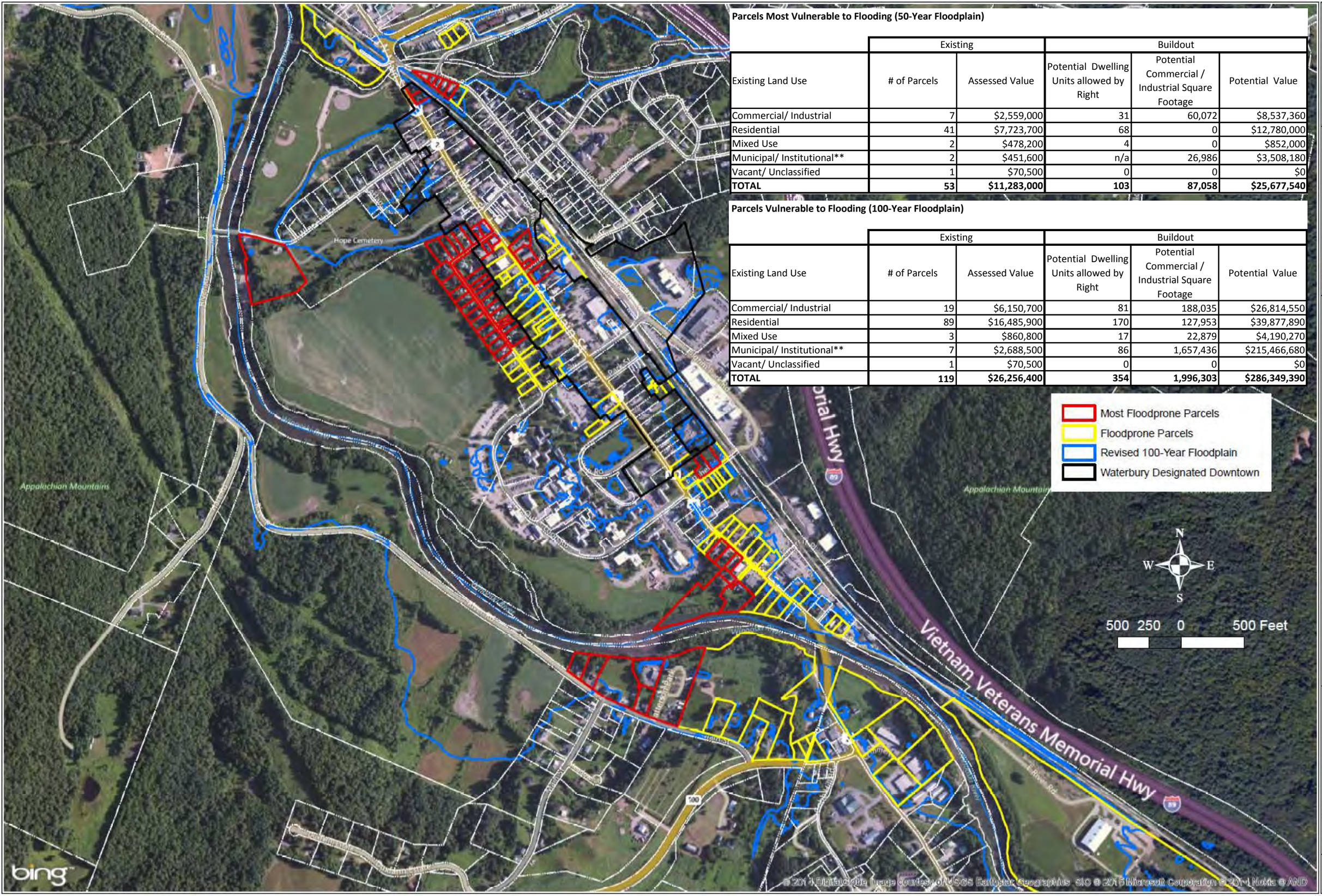
Future (2065) 100-Year Floodplain

	Existing Conditions		Full Buildout		
Exisiting Land Use	# of Parcels	Assessed Value	Potential Dwelling Units allowed by Right	Potential Commercial / Industrial Square Footage	Potential Value
Commercial	3	$289,500	0	99,924	$9,992,370
Residential	7	$888,500	52	0	$6,500,000
Municipal/ Institutional	3	$175,500	20	0	$2,550,000
Vacant/ Unclassified	3	$97,900	98	0	$12,250,000
TOTAL	**16**	**$1,451,400**	**170**	**99,924**	**$31,292,370**


As-of-Right Buildout
Waterbury, VT
N
0 50 100 200 300 400 500
Feet
50% or More Land in Existing100 Yr
50% or More Land in Future 100 Yr
Winooski River
Building Footprints
Potential Commercial/Indu SqFt
<10,000
10,000 - 150,000
150,000 - 350,000
350,000 - 750,000
>750,000
Potential Dwelling Units
0
1
2-6
7-20
>20
I 89
Us Hwy 2
State Hwy 100
Exit 10
Ohear Ct
Moran Ln
Hilton St
Locust Ln
Grandview Trlr
Pilgrim Park Rd
Waterbury St
Adams Ct
Winooski Pl
Randall St
Park St
Moody Ct
College St
Dump Rd
Demmitt Pl
Rutledge St
Rural Rd
Hill Rd
East St
Main St


As-of-Right Buildout
Waterbury, VT
N
0 50 100 200 300 400 500
Feet
50% or More Land in Existing100 Yr
50% or More Land in Future 100 Yr
Winooski River
Building Footprints
Potential Commercial/Indu SqFt
<10,000
10,000 - 150,000
150,000 - 350,000
350,000 - 750,000
>750,000
Potential Dwelling Units
0
1
2-6
7-20
>20
Tillotsy Ct
Hill St
Railroad St
Pilgrim Park Rd
Howard St
Stowe St
Berwell Ln
College Ln
Elm St
Parker Ct
N Main St
Adams Ct
Waterbury Sq Dr
Moody Ct
Park St
Randall St
S Main St
Park Row
Warren Ct
College St
Outer Loop Rd

As-of-Right Buildout
100 Year Floodplain
Willsboro, NY
0 37.5 75 150 225 300
Feet
Existing 100-yr Floodplain
Future 100-yr Foodplain
50% of More Land in Existing 100 Yr
50% of More Land in Future 100 Yr
Potential Dwelling Units, Full Build-Out
0
1
2 - 5
6 - 25
26 - 296
N
Parcel in Floodplain
Location Map
bing



Parcels Most Vulnerable to Flooding (50-Year Floodplain)

	Existing		Buildout		
Existing Land Use	# of Parcels	Assessed Value	Potential Dwelling Units allowed by Right	Potential Commercial / Industrial Square Footage	Potential Value
Commercial/ Industrial	7	$2,559,000	31	60,072	$8,537,360
Residential	41	$7,723,700	68	0	$12,780,000
Mixed Use	2	$478,200	4	0	$852,000
Municipal/ Institutional**	2	$451,600	n/a	26,986	$3,508,180
Vacant/ Unclassified	1	$70,500	0	0	$0
TOTAL	**53**	**$11,283,000**	**103**	**87,058**	**$25,677,540**

Parcels Vulnerable to Flooding (100-Year Floodplain)

	Existing		Buildout		
Existing Land Use	# of Parcels	Assessed Value	Potential Dwelling Units allowed by Right	Potential Commercial / Industrial Square Footage	Potential Value
Commercial/ Industrial	19	$6,150,700	81	188,035	$26,814,550
Residential	89	$16,485,900	170	127,953	$39,877,890
Mixed Use	3	$860,800	17	22,879	$4,190,270
Municipal/ Institutional**	7	$2,688,500	86	1,657,436	$215,466,680
Vacant/ Unclassified	1	$70,500	0	0	$0
TOTAL	**119**	**$26,256,400**	**354**	**1,996,303**	**$286,349,390**

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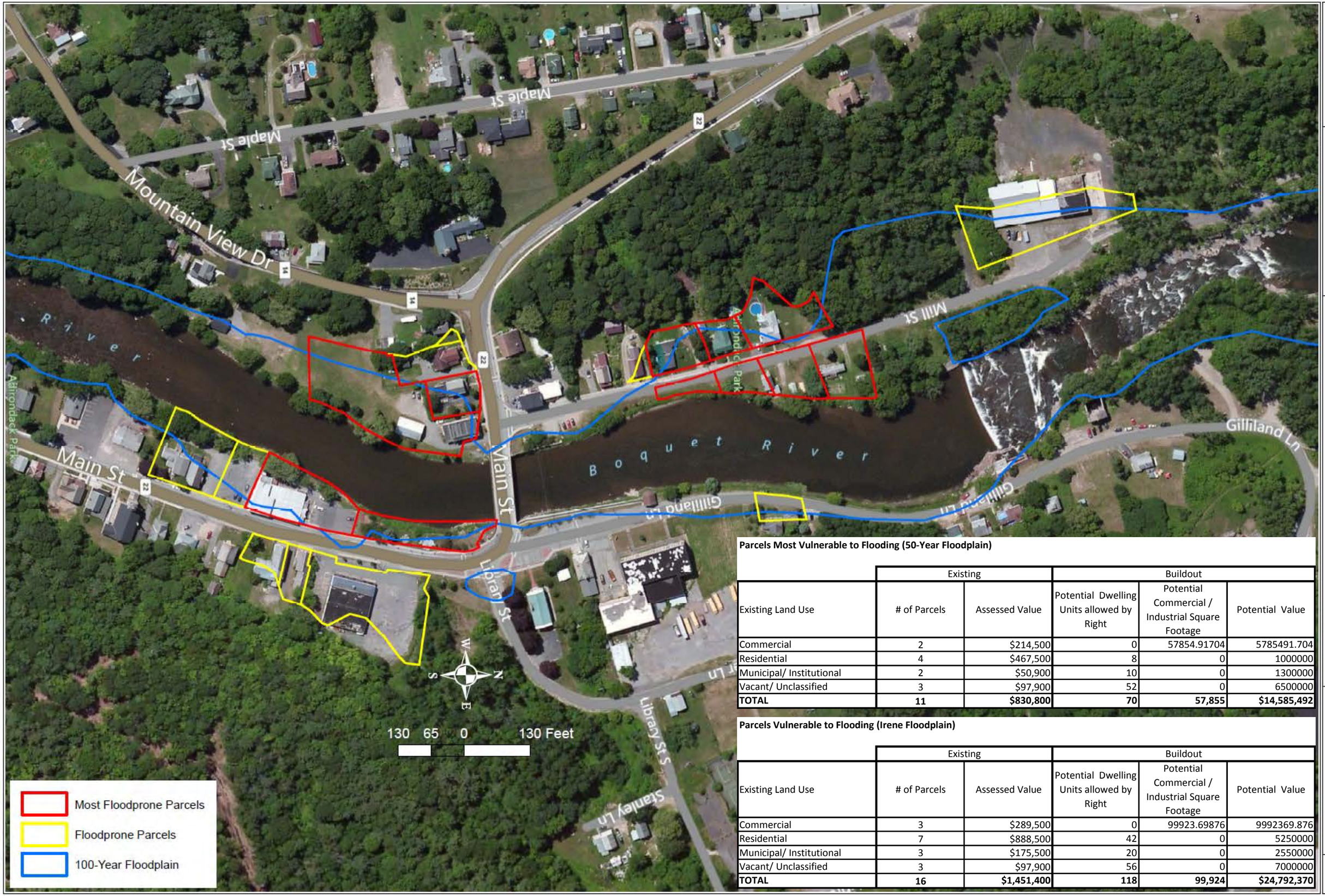
SOURCE(S):
At-risk parcels - MMI hydraulic modeling
Parcel data - VCGI
Aerials - Bing
Designated downtown - CVRPC

FLOODPRONE PARCELS TO CONSIDER REMOVALS

EVALUATING THE COSTS AND BENEFITS OF FLOODPLAIN PROTECTION ACTIVITES

WATERBURY, VERMONT

Map By: RKS
MMI#: 4199-05
MXD: Y:\4199-05\GIS\Maps\Waterbury_FP_Removals.mxd
1st Version: 10/14/2014
Revision: January 26, 2015
Scale: See scale bar



Parcels Most Vulnerable to Flooding (50-Year Floodplain)

	Existing		Buildout		
Existing Land Use	# of Parcels	Assessed Value	Potential Dwelling Units allowed by Right	Potential Commercial / Industrial Square Footage	Potential Value
Commercial	2	$214,500	0	57854.91704	5785491.704
Residential	4	$467,500	8	0	1000000
Municipal/ Institutional	2	$50,900	10	0	1300000
Vacant/ Unclassified	3	$97,900	52	0	6500000
TOTAL	**11**	**$830,800**	**70**	**57,855**	**$14,585,492**

Parcels Vulnerable to Flooding (Irene Floodplain)

	Existing		Buildout		
Existing Land Use	# of Parcels	Assessed Value	Potential Dwelling Units allowed by Right	Potential Commercial / Industrial Square Footage	Potential Value
Commercial	3	$289,500	0	99923.69876	9992369.876
Residential	7	$888,500	42	0	5250000
Municipal/ Institutional	3	$175,500	20	0	2550000
Vacant/ Unclassified	3	$97,900	56	0	7000000
TOTAL	**16**	**$1,451,400**	**118**	**99,924**	**$24,792,370**

SOURCE(S):
Floodplains - FEA/MM hydraulic modeling
Parcel data - Town of Willsboro
Aerial Photograph - Bing

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FLOODPRONE PARCELS TO CONSIDER REMOVALS

EVALUATING THE COSTS AND BENEFITS OF FLOODPLAIN PROTECTION ACTIVITES

WILLSBORO, NEW YORK

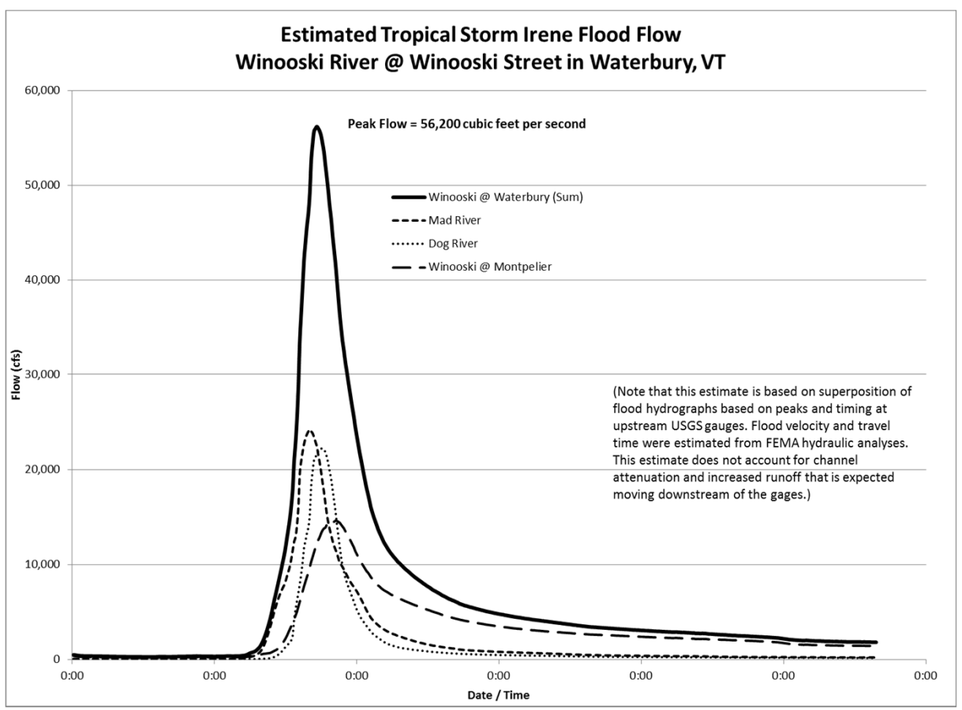
Map By: BKS
MMI#: 4199-05
MXD: Willsboro FP_Removals.mxd
1st Version: 12/7/2014
Revision: January 26, 2015
Scale: See scale bar

Hydrology – Existing Design Flow Estimates

Waterbury, Vermont (See Appendix 5)

EXISTING	Waterbury	
Flood	**Existing Flow (cfs)**	**Notes**
10-year	25,800	From 2013 FEMA RAS model @ Little River.
50-year	36,800	From 2013 FEMA RAS model @ Little River.
100-year	42,400	From 2013 FEMA RAS model @ Little River.
Irene (444-year)	56,200	Superposition of flood waves from Dog, Mad, and upper Winooski Rivers. Recurrence interval interpolated from flow exceedance curve.
500-year	57,100	From 2013 FEMA RAS model @ Little River.

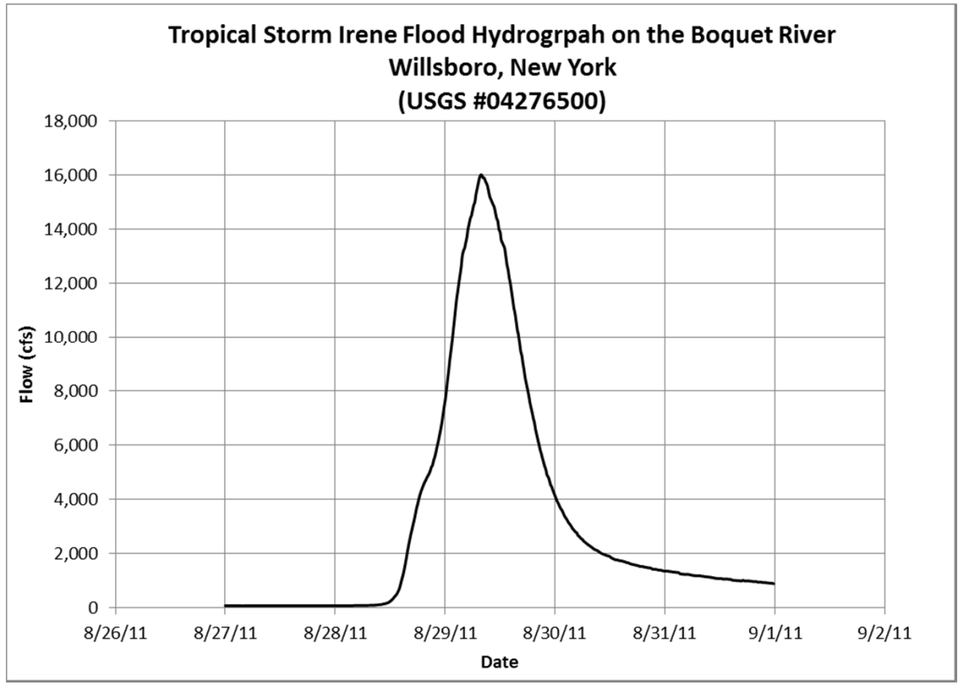
- Peak flow rates used for the Winooski River in Waterbury were obtained from the FEMA flood insurance study updated in 2013 and used in previous version of the hydraulic model.
- Tropical Storm Irene was determined from the superposition of flood hydrographs from upstream gauges assuming the 70 square miles of additional watershed area (10% of the total drainage area) is offset by floodplain attenuation.



Willsboro, New York

EXISTING	Willsboro	
Flood	**Existing Flow (cfs)**	**Notes**
10-year	8,437	From gauge analysis.
50-year	12,030	From gauge analysis.
100-year	13,600	From gauge analysis.
Irene (285-year)	16,000	Interpolated from flow exceedance curve.
500-year	17,367	From gauge analysis.

- Flow rates for existing conditions were calculated using flood frequency analysis of the full data record for USGS gauge #04276500 located on the Boquet River upstream of the NY Route 22 Bridge. This analysis updated an earlier similar calculation to develop an initial hydraulic model on the Boquet River in 2012.
- Flow values for Tropical Storm Irene were defined from peak flow rates recorded at the nearby.



Hydrology – Predicting Future Flows

Waterbury, Vermont (See Appendix 5)

FUTURE	Waterbury	
Flood	**Future Flow (cfs)**	**Notes**
6-year	25,800	EX 10*
23-year	36,800	EX 50*
38-year	42,400	EX 100*
100-year	54,500	From gauge trends.
118-year	56,200	EX Irene*
128-year	57,100	EX 500*
500-year	85,500	From gauge trends.

- The estimated increase in the 100-year flood flow using a simple addition of upstream peak flows calculated using just the post-1970 record is 9%. The validity of this approximation method arises from the fact that the three USGS gauge locations cover 90% of the drainage area where the prediction is being made for the Winooski River at Winooski Street in Waterbury (see appendix 5). This approximation assumes that additional flow from the watershed is offset by storage.
- Future flood flows were estimated for the 100-year and 500-year recurrence intervals for the year 2065 by exploring possible gauge data trends (see appendix 5). Flood frequency analysis was performed for data that were split into two, three, or four bins to see if a trend existed over time.
- The predicted increase in the 100-year flood by 2065 is 12,100 cfs leading to a future 100-year flow of 54,500 cfs (see page 30). This value was approximated by adding the future predictions at each upstream gauge. The predicted 2065 100-year flood flow is 29% higher than the FEMA effective flow, but only 3% higher than a simplified estimate of the peak 100-year flood in Waterbury calculated by summing up the peaks at upstream gauges just using post-1970 gauge data (without binning).
- The existing flow values for the 10-, 50-, 100-, 500-year, and Irene floods were evaluated on a future flow exceedance curve generated from post-1970 gauge data to approximate a future recurrence interval for each flow value (see table above and appendix 5). This information is required for damage modeling of future conditions.
- Gauge trends show that over the past 70 years the flood that had a 1% chance of occurring in a given year (i.e., the 100-year flood) will have a 2.6 % chance of occurring in the future (i.e., 38-year future flood) – 2.6 times more likely.

Willsboro, New York

FUTURE	Willsboro	
Flood	**Future Flow (cfs)**	**Notes**
6-year	8,437	EX 10*
11-year	~10,500	EX 25*
18-year	12,030	EX 50*
25-year	13,600	EX 100*
50-year	16,000	EX Irene*
67-year	17,367	EX 500*
100-year	19,781	From gauge trends.
500-year	27,111	From gauge trends.

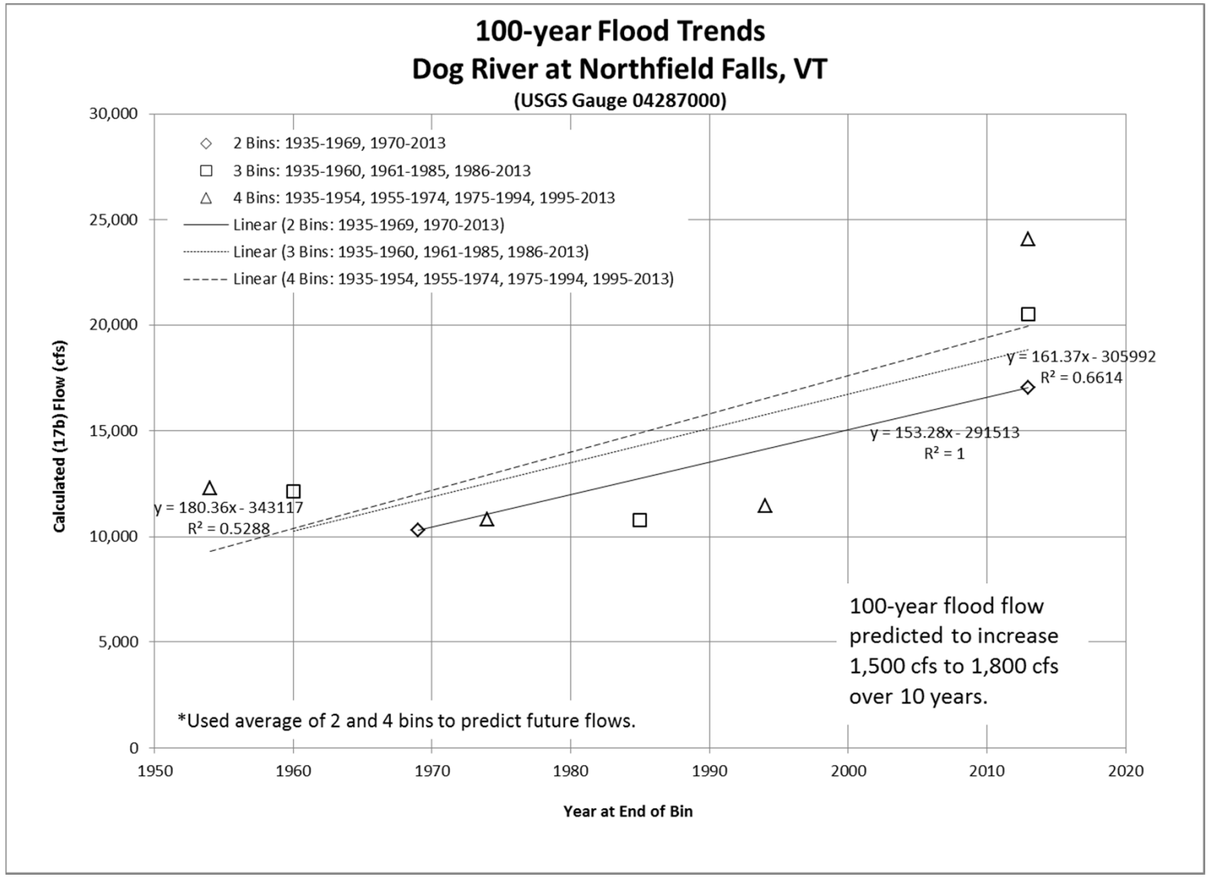
- Flood frequency analysis at the Boquet River gauge site indicates that the 100-year flood calculated from the post-1970 record is 38% higher than a flood frequency analysis using the entire gauge record.
- For the Boquet River in Willsboro, the 100-year flow is predicted to increase by 6,300 cfs by 2065. The 2065 100-year flow would be 19,781 cfs, which is 46% higher than the current FEMA effective flow (see page 30). Note that the effective FEMA flow is calculated from historic gauge records dating as far back as 1924. Note that the future flood flow prediction is only 5% higher than the estimated peak 100-year flow calculated using only post-1970 gauge data (without binning) suggesting that an era of higher floods may now exist, and stationarity may not exist (Milly et al., 2008).
- The existing flow values for the 10-, 25-, 50-, 100-, 500-year, and Irene floods were evaluated on the future flow exceedance curve to predict a future recurrence interval generated from just the post-1970 gauge data (see table above and appendix 5).
- Gauge trends show that over the past 70 years the flood that had a 1% chance of occurring in a given year (i.e., the 100-year flood) will have a 4 % chance of occurring in the future (i.e., 25-year future flood) – 4 times more likely.

- **The projected increase in future flows agrees with recent studies indicating 11-20% increase in flow by 2060 and 21-30% by 2080 (AECOM, 2013). The 100-year floodplain is expected to increase in size 31-40% by 2060 and 41-50% by 2080.**
- **Although this non-traditional approach is not suitable for design-level floodplain management, it is a useful planning tool given that the findings do agree with estimates from several studies on predicted increased future flows**

Hydrology – Predicting Future Flows Using Trends in Gauge Data

Waterbury, Vermont

(See Appendix 5)

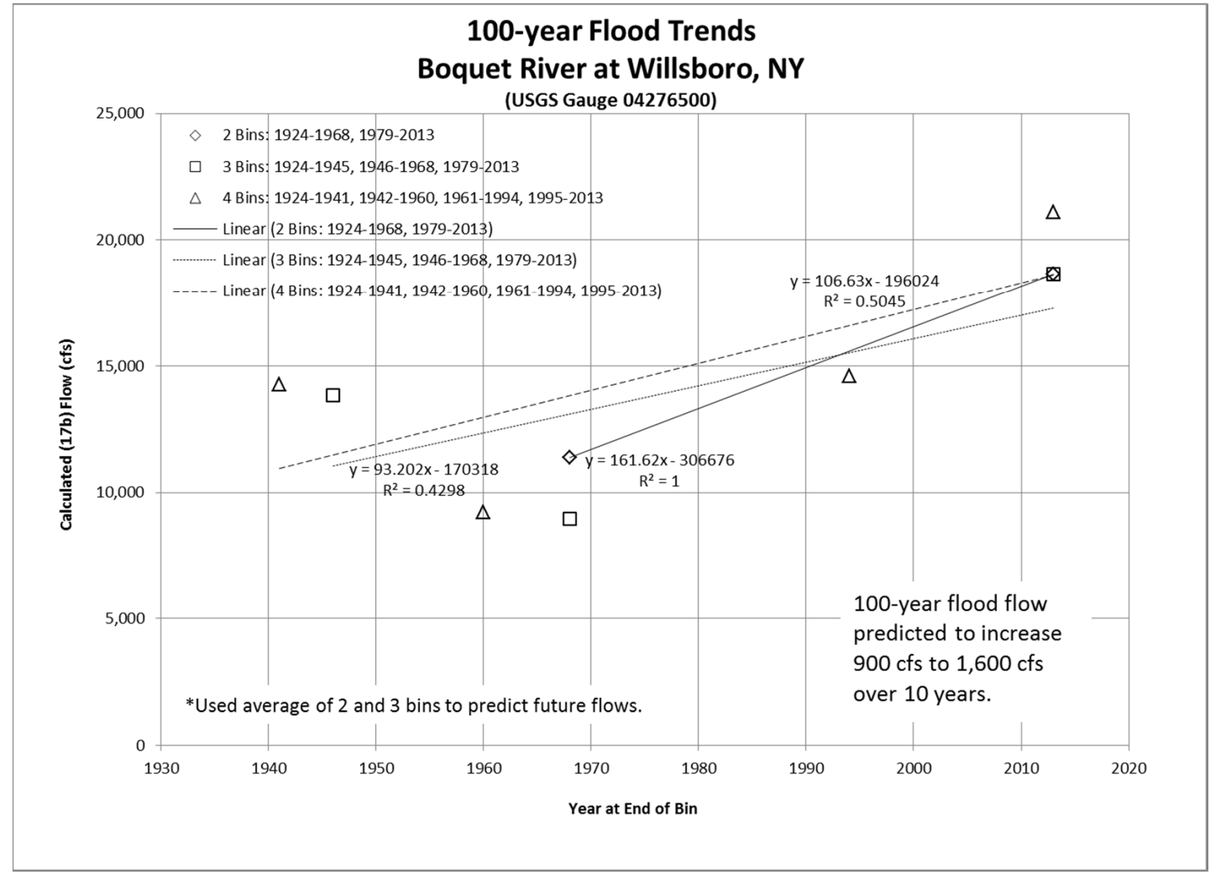


Winooski River Predicted Future Flood Flows
4/15/2015

USGS Gauge	100-year Flood - 1% Annual Chance			
	10-year Projected Increase (cfs)		50-year Projected Increase (cfs)	
	Low	High	Low	High
Dog River at Northfield Falls, VT (# 04287000)	1,500	1,800	7,500	9,000
Mad River near Moretown, VT (# 04288000)	100	950	500	4,750
Winooski River at Montpelier, VT (# 04286000)	75	400	375	2,000
TOTAL	*1,675*	*3,150*	*8,375*	*15,750*

50-year Projected Increase (cfs):	12,100	
FEMA Effective 100-year Peak Discharge used in Model (cfs):	42,400	
Current 100-year Peak Discharge - 17b Analysis of **Full** Gauge Record (cfs):	49,109	
Current 100-year Peak Discharge - 17b Analysis of **Post-1970** Gauge Record (cfs):	53,413	(+9%)
2065 Predicted 100-year Peak Discharge (cfs):	***54,500***	
Percent Increase from FEMA Effective Flow (%):	29	
Percent Increase from Current using **post-1970** Gauge Record (%):	3	

Willsboro, New York



Boquet River Projected Flood Flows
4/15/2015

U.S.G.S. Gauge	100-year Flood - 1% Annual Chance			
	10-year Projected Increase (cfs)		50-year Projected Increase (cfs)	
	Low	High	Low	High
Boquet River at Willsboro, NY (#04276500)	900	1,600	4,500	8,000

Average Predicted 50-year Flow Increase (cfs):	6,300	
FEMA Effective 100-year Peak Discharge used in Model (cfs):	13,600	
Current 100-year Peak Discharge - 17b Analysis of **Full** Gauge Record (cfs):	13,481	
Current 100-year Peak Discharge - 17b Analysis of **Post-1970** Gauge Record (cfs):	18,661	(+38%)
2065 Projected 100-year Peak Discharge (cfs):	***19,781***	
Percent Increase from Current 100-Year Peak Discharge (%):	46	
Percent Increase from Current using **post-1970** Gauge Record (%):	8	

Hydraulic Modeling of Floodplains

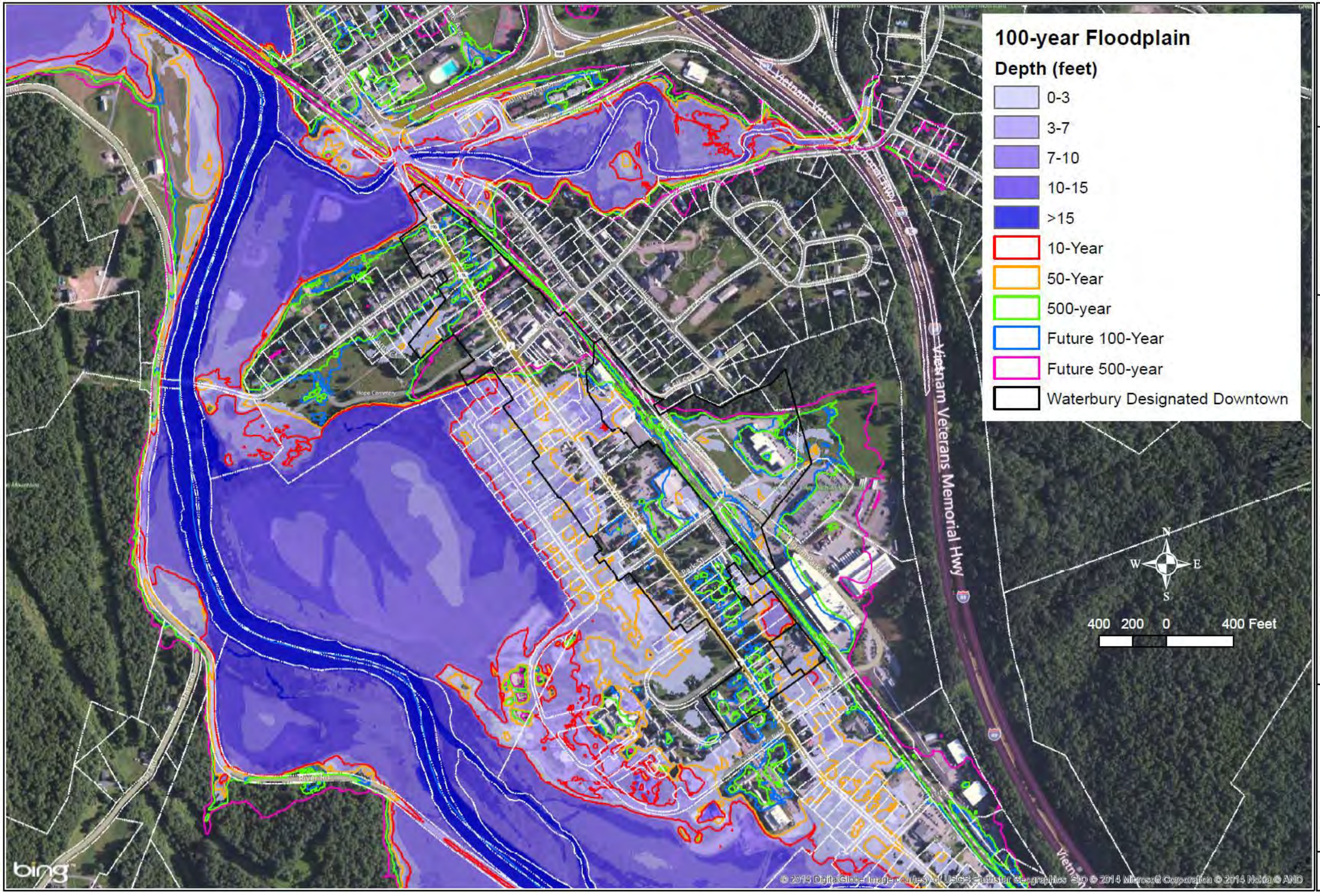
Waterbury, Vermont

(See Appendix 5)

- Floodplain delineation was created with an updated version of a hydraulic model for the Winooski River that was originally the FEMA HEC-RAS model (USACE, 2010a; FEMA, 2013), updated as part of the Waterbury Flood Study (MMI, 2013b, a), and revised in 2014 as part of this project. Floodplains were mapped using the HEC-GeoRAS extension (USACE, 2010).
- Data sources include FEMA data (FEMA, 2013), 2013 survey (MMI, 2013b, a), and 2014 LiDAR (provided by Central Vermont Regional Planning Commission) to fill the known data gap in the Village.
- The model revisions resulted in a larger 100-year floodplain than the effective FEMA 100-year floodplain.
- Village flooding occurs along South Main Street, Elm Street, Randall Street, Foundry Street, Park Row, Batchelder Street, and at the State Office Complex.
- The 100-year flood depths around homes and businesses typically range between 1 and 4 feet. The maximum floodplain width is approximately 3,000 feet at the Village Center (see maps on pages 32 and 33).
- Model validation indicates that HEC-RAS flood depths are within 0.5 to 1.5 feet of known high water marks recorded during Tropical Storm Irene with the area of inundation replicating known damage areas.
- Many developed areas in the Village get shallow flooding during the 100-year flood that appear to have been built near the edge of the floodplain on fill.
- Modeling of the preferred floodplain restoration alternative (MMI, 2013b) indicates that flood depths would decrease by 0.5 to 1.0 feet in the Village (see maps on pages 34 and 35).
- Future floodplain mapping shows larger floodplains with more anticipated damage potential and management needs.
- The most floodprone properties were identified by those that are located in the 50-year floodplain, while floodprone properties are those that are located in the 100-year floodplain (see map on page 26).

Willsboro, New York

- Floodplain delineations were created using HEC-GeoRAS (USACE, 2010) and then corrected with field observations and known flood patterns.
- The HEC-RAS model was created by updating the existing FEMA hydraulic model (HEC-2, 1989) with limited field survey in the vicinity of the dam collected by Dean Lashway September 2013, supplemental field survey collected by Fitzgerald Environmental and Milone & MacBroom, plans for the NY Route 22 Bridge, and the National Elevation Dataset. The resulting coarse topography information was used for plotting the floodplain boundary and depths.
- Model validation indicates that HEC-RAS flood depths are within 1.0 to 1.5 feet of known high water marks recorded during Tropical Storm Irene with the area of inundation replicating known damage areas.
- The existing conditions floodplain update reduced the number of homes and businesses in the 100-year floodplain along Main Street and Mill Lane compared to the effective FEMA 100-year floodplain.
- The updated existing conditions floodplain replicates the patterns of flooding observed during Tropical Storm Irene.
- The predicted future 100-year floodplain is larger than the existing 500-year floodplain with more anticipated building damage potential and management needs (see map on page 36).
- The proposed floodplains for Alternative 1 (dam removal) show that the flood water would not leave the channel and travel down Mill Lane for any flood. Flood reduction benefits do not extend upstream of the NY Route 22 Bridge.
- The proposed floodplains for Alternative 2 (dam removal, flood bench restoration upstream of the NY Route 22 Bridge, and elevate three properties on fill) show the same benefits from dam removal alone. Upstream of Route 22 the existing and proposed floodplains have similar flood depth, with local decreases and increases of less than 0.2 feet along Main Street (see map on page 37).
- The most floodprone properties were identified by those that are located in the 50-year floodplain, while floodprone properties are those that are located in the Irene (285-year) floodplain (see map on page 27).



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1 South Main Street
Waterbury, Vermont 05676
802-882-8335 Fax 802-882-8346
www.milboneandmacbroom.com

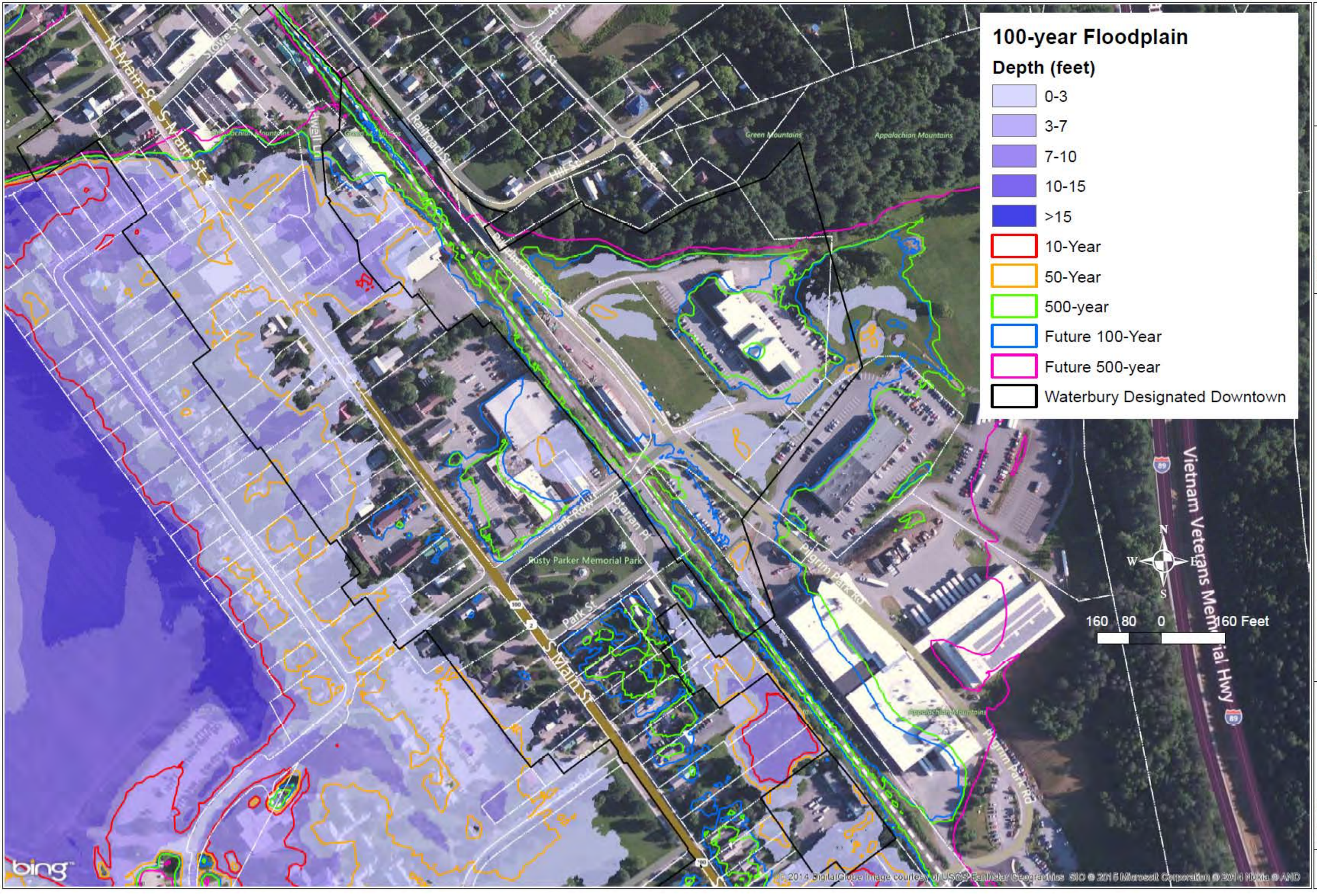
SOURCE(S):
At-risk parcels - MMI hydraulic modeling
Parcel data - VCGI
Aerials - Bing
Designated downtown - CVRPC

UPDATED EXISTING FLOODPLAINS

EVALUATING THE COSTS AND BENEFITS OF FLOODPLAIN PROTECTION ACTIVITES

WATERBURY, VERMONT

Map By: RKS
MM#: 4199-05
MXD: Y:\4199\5038\Map\Waterbury_floodplains.mxd
1st Version: 12/7/2014
Revision: 1/16/2015
Scale: See scale bar



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Waterbury, Vermont 05676
802-882-8335 Fax 802-882-8346
www.miloneandmacbroom.com

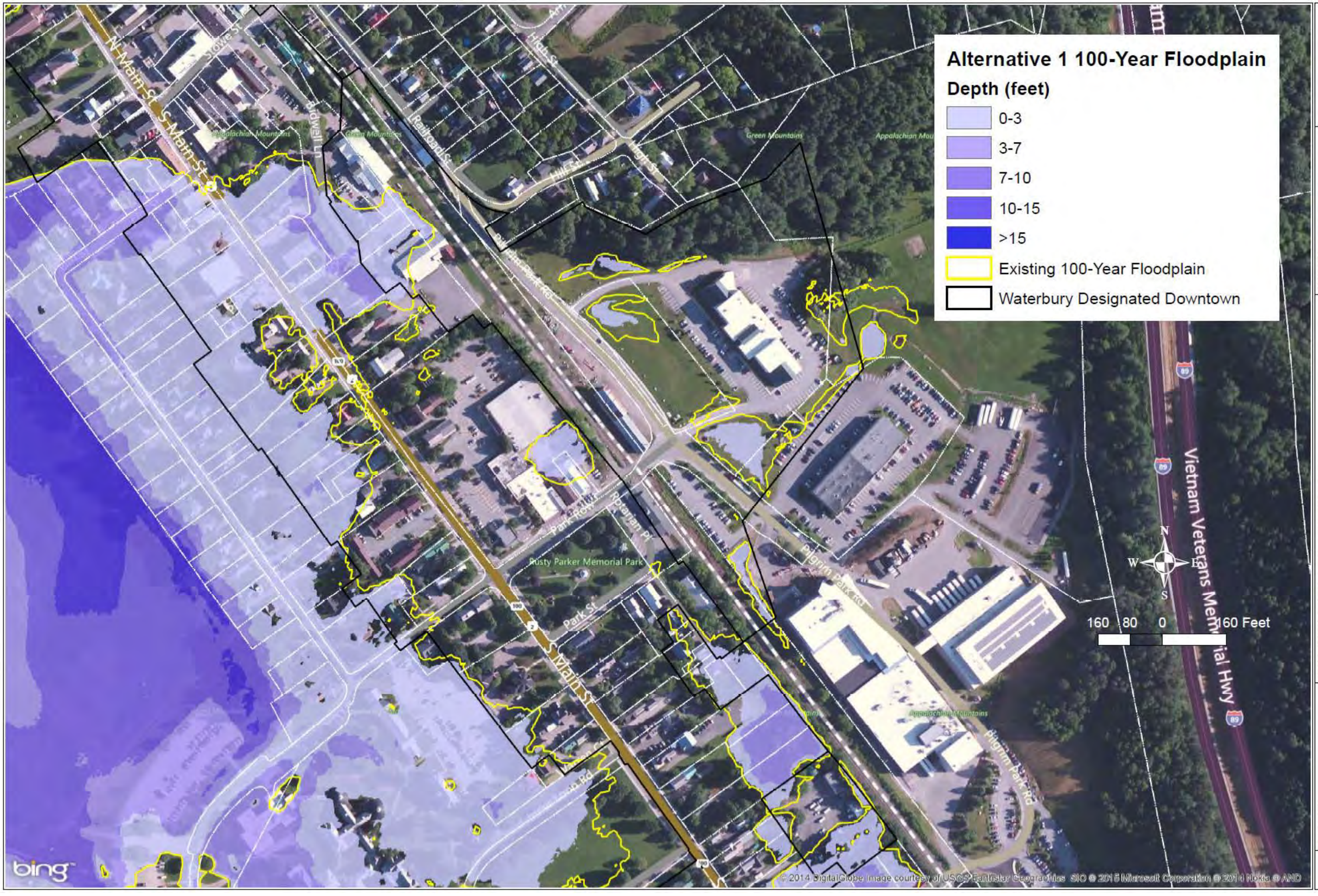
SOURCE(S):
At-risk parcels - MMI hydraulic modeling
Parcel data - VCGI
Aerials - Bing
Designated downtown - CVRPC

UPDATED EXISTING FLOODPLAINS (ZOOM)

EVALUATING THE COSTS AND BENEFITS OF FLOODPLAIN PROTECTION ACTIVITES

WATERBURY, VERMONT

Map By: RKS
MMI#: 4199-05
MXD: Y:\4199-05\GIS\Maps\Waterbury_floodplains.mxd
1st Version: 12/7/2014
Revision: 1/16/2015
Scale: See scale bar.



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SOURCE(S):
At-risk parcels - MMI hydraulic modeling
Parcel data - VCGI
Aerials - Bing
Designated downtown - CVRPC

PROPOSED FLOODPLAINS (ZOOM)

EVALUATING THE COSTS AND BENEFITS OF FLOODPLAIN PROTECTION ACTIVITES

WATERBURY, VERMONT

Map By: RKS
MMI#: 4199-05
MXD: Y:\4199-05\GIS\Maps\Waterbury_Floodplains.mxd
1st Version: 12/7/2014
Revision: 1/16/2015
Scale: See scale bar.

Floodplain Reconnection
Area at the Duxbury Field
Total Area = 13.2 ac
Max Cut Depth = 12.0 ft
Avg Cut Depth = 7.5 ft

Protect or Relocate
Exisitng Utility Poles

Approximate Location of
Proposed Improvements
at the State Office Complex
Designed by Others

Floodplain Reconnection
Area at the State Complex
Total Area = 8.0 ac
Max Cut Depth = 5.0 ft
Avg Cut Depth = 2.5 ft

Dascomb
Rowe
Fields

State
Office
Complex

State
Corn
Field

n/f
Harvey,
James A.

n/f
Green Mountain
Power

n/f
Vermont,
State of

n/f
Hodge, Wade J. &
Aldrich, Whitney L.

Apply Stone Armoring
along Cut Slope at the
Edge of the Newly
Created Floodplain

Avoid Conflicts with
Existing Transmission Line

Floodplain Reconnection
Area at the State Corn Field
Total Area = 15.6 ac
Max Cut Depth = 6.0 ft
Avg Cut Depth = 2.0 ft

Connect New Floodplain to
Existing Wetland / Flood Chute

LEGEND

- Floodplain Creation
- State Complex Improvements
- Parcel Boundary
- VT Wetland Inventory
- Cross Section Location

Engineering, Environmental Services and Environmental Science
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SOURCE(S):
Vermont River Management Program
Vermont Center for Geographic Information
Bing Maps Aerial

0 125 250 500 Feet

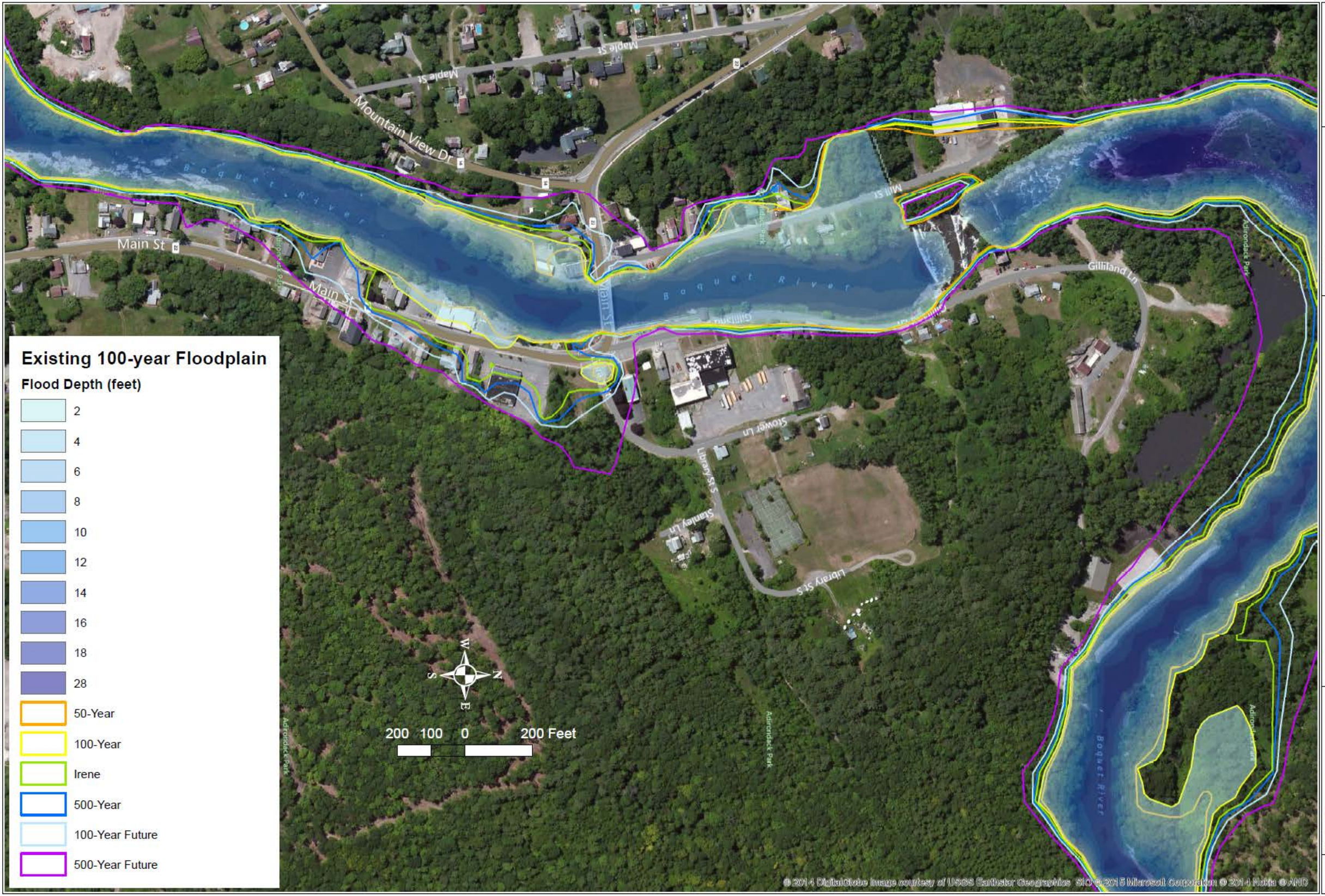
CONCEPT PLAN - PREFERRED ALTERNATE

WATERBURY FLOOD STUDY

WATERBURY, VERMONT

Map By: BMC
MM#: 4942-01-3
MXD: WaterburyStudy_Fig3.mdx
1st Version: July 10, 2013
Revision: October 8, 2013
Scale: 1" = 500'

Figu



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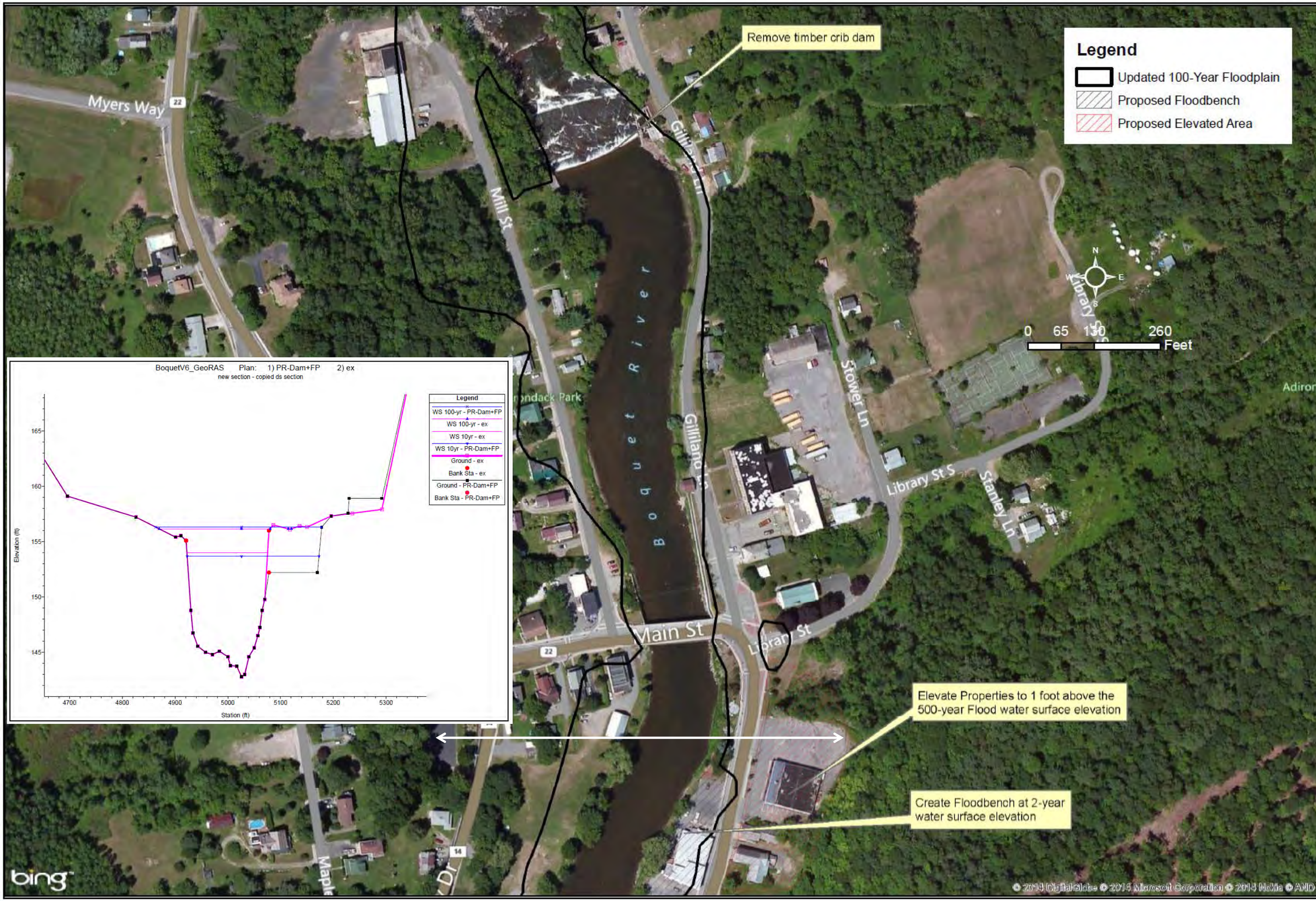
SOURCE(S):
Floodplains - FEA/MMI hydraulic modeling
Parcel data - Town of Willsboro
Aerial Photograph - Bing

EXISTING FLOODPLAINS

EVALUATING THE COSTS AND BENEFITS OF FLOODPLAIN PROTECTION ACTIVITIES

WILLSBORO, NEW YORK

Map By: JCL
MM#: 4199-05
MXD: Willsboro_GeoRAS_FP_Existing.mxd
1st Version: 12/7/2014
Revision: 1/16/2015
Scale: See scale bar



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SOURCE(S):
MMI Floodplain Restoration Area
FEMA Special Flood Hazard Area
Bing Aerial Photograph

FLOODPLAIN RESTORATION ALTERNATIVE

EVALUATING THE COSTS AND BENEFITS OF FLOODPLAIN PROTECTION ACTIVITIES

WILLSBORO, NY

Map By: RKS
MMI#: 4199-05
MXD: Willsboro_Alternative_PP_PR2.mxd
1st Version: January 15, 2015
Revision: n/a
Scale: See scale bar

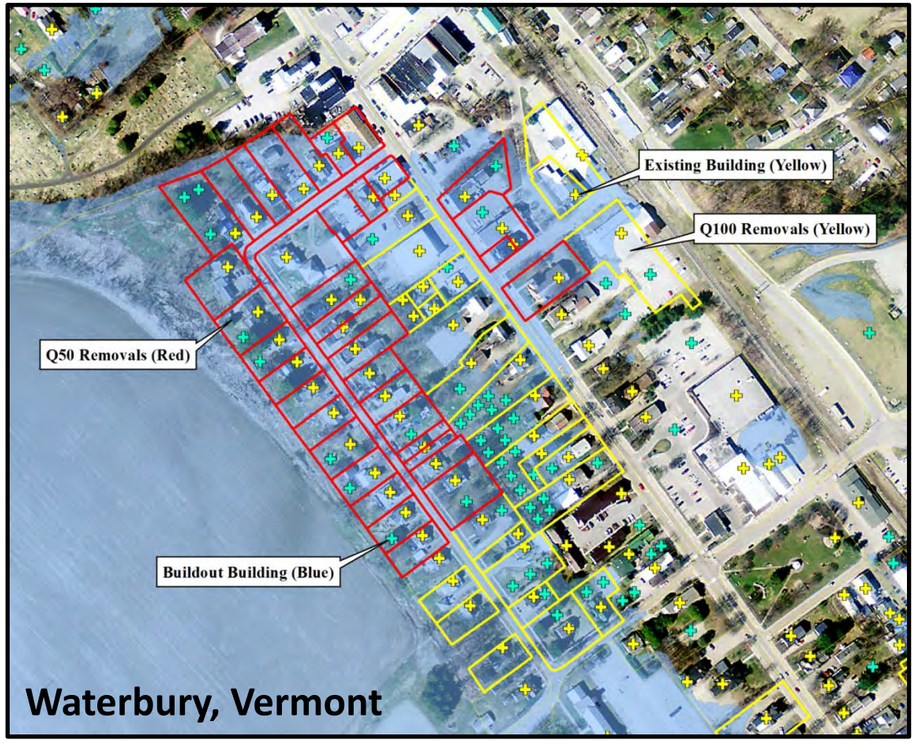
Damage Modeling

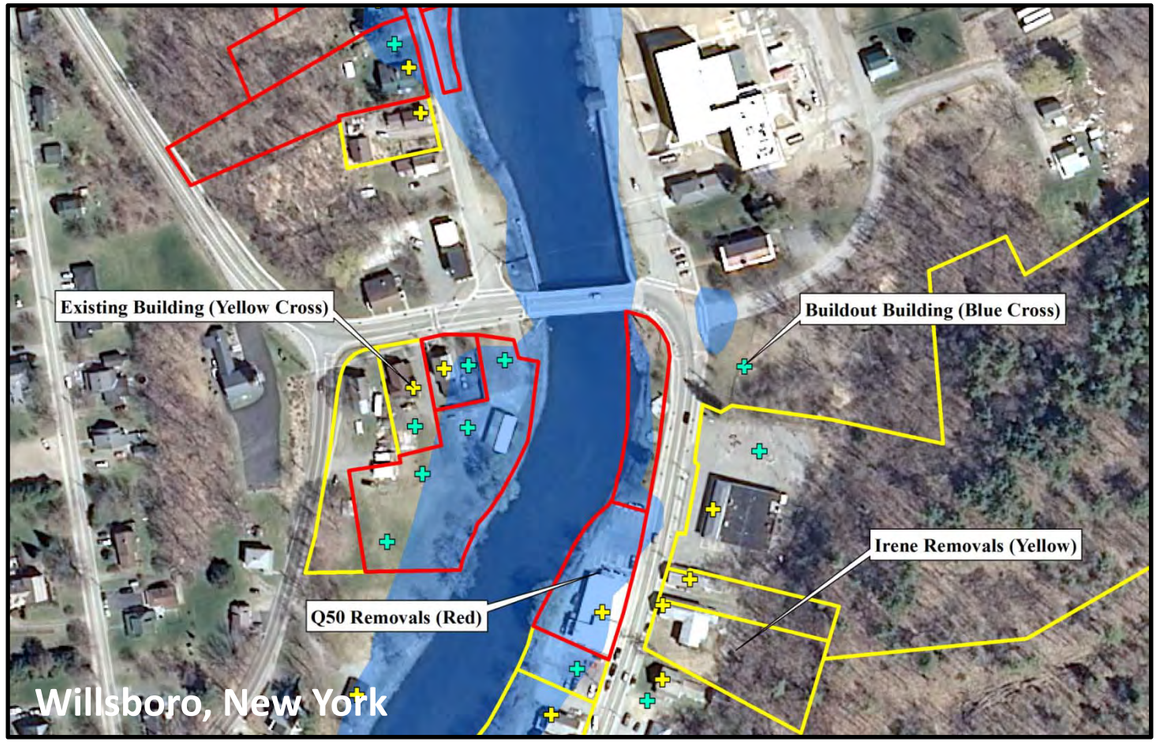
DAMAGE MODELING METHODS (SEE APPENDIX 6)

Building damages, content loss, and inventory losses were modeled using for the Winooski River (Waterbury, Duxbury, and Moretown, Vermont) and for the Boquet River floodplain (Willsboro, New York) using FEMA's Multi-hazard loss estimation software (HAZUS-MH) (FEMA, 2013b). A Level 2 flood analysis was performed where the user provides manually created flood depth grids and specific facility data to be used in place of the default demographic data (ASFPM, 2010; FEMA, 2012). The primary data inputs are flood depths from the hydraulic modeling and local building data from local records, town officials, and field work. HAZUS-MH utilizes a single point location to estimate damages based on the building stock information. Building center points were manually generated in ArcGIS based on parcel data and recent aerial photography and assigned latitude and longitude values.

The stated range of uncertainty of the level 2 HAZUS MH simulation is a factor of 2 with good inventories of built environment , demographics, and economics such as used for this study. The methodology has been tested against actual events and provided a credible estimate of aggregated losses, but less accurate estimates of local partial damages.

Damages were determined for each of the existing (2015) and future (2065) floodplains as delineated with the hydraulic model using the estimated flood flows. Annualized damages ($ of loss per year) were calculate for each community from the damage estimates. Damages were calculated for existing buildings in the floodplain (Waterbury, Duxbury, Moretown, and Willsboro) and the combination of existing and "reasonable" build-out condition buildings in the floodplain (Waterbury and Willsboro) (see page 21) for each of the floodplain management scenarios (see page 20 and appendix 6). Buildout included typical residential and commercial sizes and values as provided by the Towns (Appendix 6).





Cost-Benefit Summary – LEGEND

A cost-benefit summary showing annualized losses (in parentheses) and gains (no parentheses) was prepared for each damage simulation. Each table includes both current and future damages. Two versions of the table exist – one that shows the cost-benefit for the existing conditions and predicted future floodplain for the existing buildings (EX) and buildout buildings (BO); and a second table that shows the cost-benefit for the preferred flood mitigation alternative or predicted future floodplain with the alternative in place for the existing buildings (REX) and buildout buildings (RBO). The cost-benefit summary accounts for the following items:

1. Changes to the value of ecosystem service with increases or decreases in naturally functioning land with buildout or building removals;
2. Changes in tax revenue based on increases or decreases in building stock;
3. Costs of flood mitigation activities;
4. Modeled damages of buildings, contents, and inventory; and
5. Changes to flood insurance premiums.

Table ID
EX=existing floodplain, existing buildings
BO=existing floodplain, buildout buildings
REX=restoration alternative floodplain, existing buildings
RBO=restoration alternative floodplain, buildout buildings

Changes to buildings and management elevations for each scenario.

Value gained or lost due to changes in naturally functioning land.

Tax value gained due to additional buildings or lost due to building removal assuming residents leaving Town or Village. Average tax rate includes school, Town, Village, and local agreement.

Approximate annual cost for flood mitigation activities based on ballpark engineer's opinion of probable construction cost and implementation services.

Modeled 2015 current flood damages due to losses associated with buildings, contents, and inventory. See building damage plots.

Change in FEMA flood insurance premiums based on increased or decreased flood risk and average values for policies taken from current municipal flood insurance summary reports.

Cost-benefit balance showing annualized gains or (losses) for the 2015 floodplains. See cost-benefit summary plots.

Difference between the existing cost-benefit summary on the first line and each floodplain management scenario (line).

Modeled 2065 flood damages due to losses associated with buildings, contents, and inventory in a predicted future floodplain. See building damage plots.

Cost-benefit balance showing annualized gains or (losses) for the predicted 2065 floodplains. See cost-benefit summary plots.

	Floodplain Management Scenario		Ecosystem Services		Buildout/Conservation		Flood Mitigation		Current Flood Damages (2015)			Flood Insurance	Balance	Δ	Future Flood Damages (2065)			Balance	Δ
	ID	Description	Δ Value ($/yr)	Description	Δ Value ($)	Δ Tax Value ($/yr)	Description	Cost ($/yr)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	Δ Premium ($/yr)	($ 2015)	($ 2015)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	($ 2065)	($ 2065)
EX	1A	Existing condition with updated floodplain. (282 buildings damaged in the 500-year floodplain)	$ -	Base value of naturally functioning land in 500-year floodplain = $5,844,765	$ -	$ -	None	$ -	$ (50,881)	$ (40,737)	$ (4,940)	$ -	$ (96,558)	$ -	$ (94,909)	$ (76,837)	$ (9,486)	$ (181,232)	$ -
ELEVATE	2A	Elevate (103) existing buildings in the 500-year floodplain to 2 feet above the 100-year flood level.	$ -	No change from base value upon building elevation.	$ 14,524,380	$ 298,970	Elevate 103 buildings.	$ (309,000)	$ (25,562)	$ (24,633)	$ (2,431)	$ 54,075	$ (8,581)	$ 87,977	$ (48,534)	$ (46,402)	$ (4,501)	$ (55,393)	$ 125,839
ELEVATE	2B	Elevate (49) existing buildings that are most prone to flooding (see map) to 2 feet above the 100-year flood level.	$ -	No change from base value upon building elevation.	$ 6,909,657	$ 142,228	Elevate 49 buildings.	$ (147,000)	$ (31,087)	$ (30,835)	$ (4,086)	$ 71,400	$ 621	$ 97,179	$ (59,429)	$ (58,740)	$ (7,751)	$ (59,291)	$ 121,940
ELEVATE	2C	Elevate utilities in all (282) existing buildings in the 500-year floodplain to the 500-year flood elevation.	$ -	No change from base value upon building elevation.	$ 7,262,190	$ 149,485	Elevate utilities in 282 buildings.	$ (112,800)	$ (26,621)	$ (40,763)	$ (4,940)	$ 25,380	$ (10,259)	$ 86,299	$ (50,173)	$ (76,851)	$ (9,486)	$ (74,445)	$ 106,786
AVOIDANCE AND NO FILL	3A	Remove (50) existing buildings that are most prone to flooding.	$ 34,000	Increase of ecosystem services on naturally vegetated land with removals.	$ (14,601,560)	$ (300,559)	Remove 50 buildings.	$ (30,000)	$ (24,924)	$ (25,384)	$ (3,699)	$ 75,000	$ (275,565)	$ (179,007)	$ (47,799)	$ (48,542)	$ (7,031)	$ (324,931)	$ (143,699)
AVOIDANCE AND NO FILL	3C	Elevate (50) existing buildings to 1 foot above the 500-year flood elevation upon rebuild of the most floodprone buildings	$ -	No change from base value upon building elevation.	$ 7,050,670	$ 145,131	Elevate 50 buildings.	$ (150,000)	$ (25,117)	$ (25,520)	$ (3,702)	$ 26,250	$ (32,959)	$ 63,599	$ (48,156)	$ (48,754)	$ (7,039)	$ (82,567)	$ 98,664
EXTREME AVOIDANCE	4A	Remove (116) existing buildings that are prone to flooding (see map).	$ 82,450	Increase of ecosystem services on naturally vegetated land with removals.	$ (38,090,160)	$ (784,048)	Remove 116 buildings.	$ (69,600)	$ (11,133)	$ (11,224)	$ (1,291)	$ 174,000	$ (620,846)	$ (524,288)	$ (21,145)	$ (20,993)	$ (2,387)	$ (641,723)	$ (460,491)
EXTREME AVOIDANCE	4B	Remove (116) existing buildings that are prone to flooding. Elevate sewer pump station and medical center, elevate utilities in police station and fire station.	$ 82,450	Increase of ecosystem services on naturally vegetated land with removals.	$ (38,090,160)	$ (784,048)	Remove 116 buildings. Elevate 2 buildings. Elevate utilities in 2 buildings.	$ (76,400)	$ (11,720)	$ (11,888)	$ (1,291)	$ 175,230	$ (627,667)	$ (531,109)	$ (22,198)	$ (22,377)	$ (2,387)	$ (649,730)	$ (468,498)

Ecosystem Value Notes
Assume naturally functioning land loss (gain) per added (removed) building is equal to average building footprint + 25% for residential (0.05 acres) and commercial (0.2 acres).
Assume land conversion between developed and combination of forest and village greenspace for average ecosystem service value of $8,500/acre/yr.

Buildout/Conservation Notes
EX = existing building stock and BO = maximum buildout building stock.
Waterbury Village grand list taxable properties = $192,808,100.
The portion of the taxable properties in the current 100-year floodplain is $28,380,100 (12%). Use as approximate base value for 10-year and 50-year floodplains.
The portion of the taxable properties in the future 100-year floodplain is $48,414,600 (19%). Use as approximate base value for Irene and 500-year floodplains.
Tax rate taken as 2.0584% that is the average of residential and non-residential rates (including school, Town, Village, and local agreement).
Pilot payment in lieu of taxes made to Village for State Complex of $44,155 in 2014 included in tax value.
Costs for building construction for buildout not included.
Assume 15% increase in value and tax revenue for elevated utilities and a 30% increase for elevated buildings.

Mitigation Notes
Assume $20,000 to elevate utilities and $150,000 to elevate building.
Assume $30,000 to remove building and restore natural vegetation.
Mitigation cost divided by 50 to estimate per year value over a 50-year time period.
Costs for building acquisition for removals not included.

Notes under each table summarize the assumptions and calculation methods for each cost or benefit entry.

Flood Insurance Notes
Current total premium for the Village = $360,089 per year that includes mandatory and non-mandatory policies most of which are pre-firm, flat rate policies.
Typical premium taken as $1,500 per year that is the average post-firm premium of the 9 policies in the Village.
Assume flood insurance carried (eliminated) for new (removed) buildings ($1,500/yr) and reduced for elevated buildings (-35% or -$525/yr) or utilities (-6% or -$90/yr).

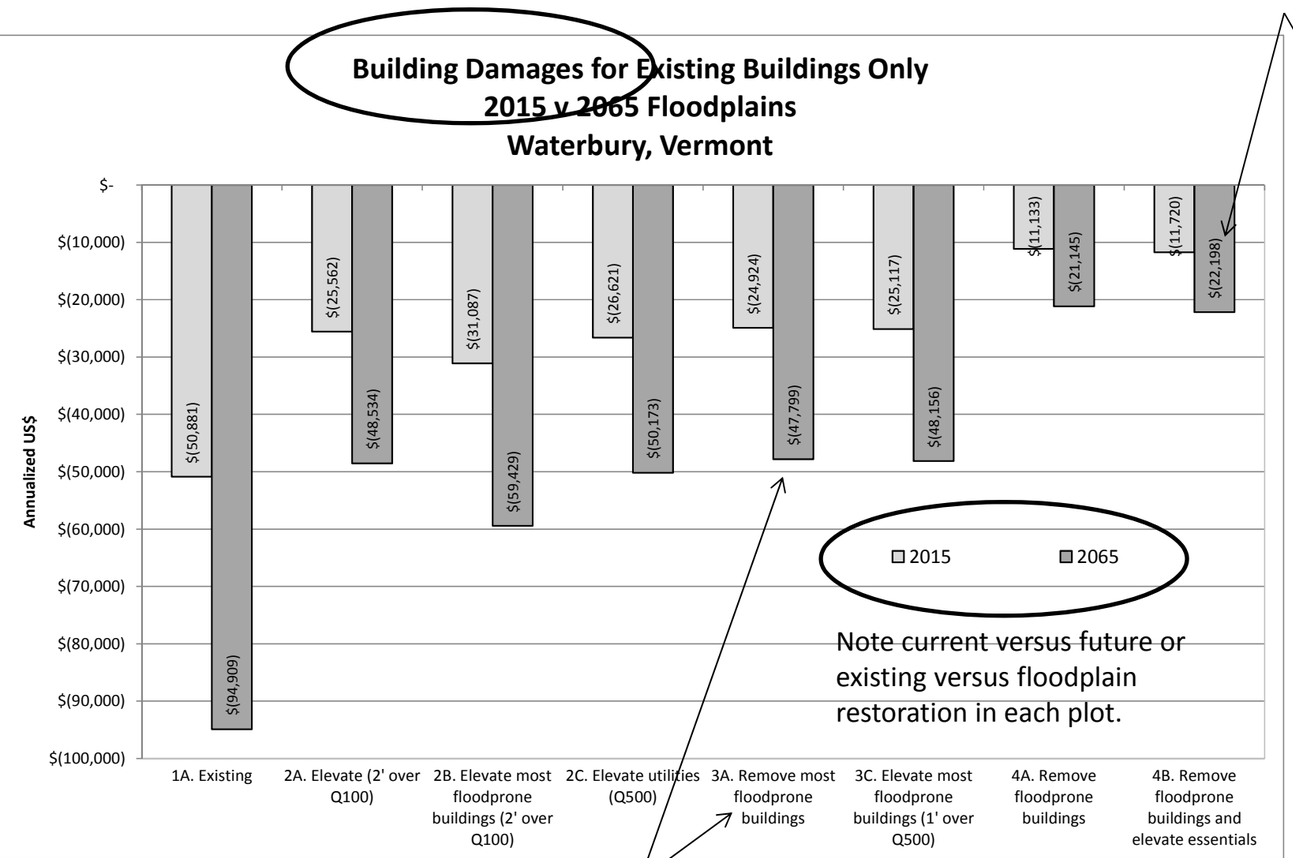
Future Damages
The 2065 balance considers future flood damages while other values remain in today's currency.

Building Damage and Cost-Benefit Summary Plots – LEGEND

This plot shows annualized building damages (all losses).

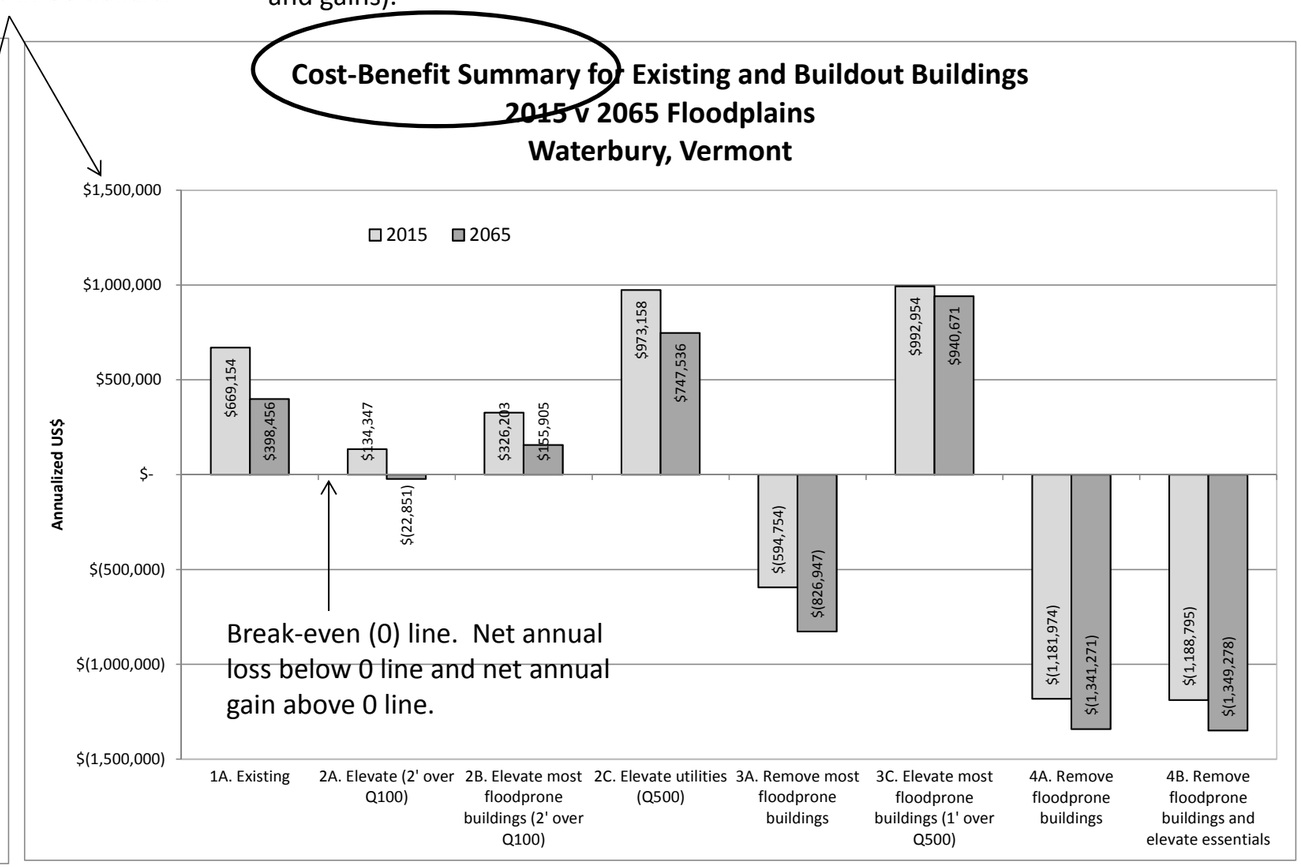
Annualized gains and (losses) are shown on each bar and on the vertical axis in US dollars.

This plot shows the annualized cost-benefit summary (losses and gains).



Note current versus future or existing versus floodplain restoration in each plot.

Each bar shows the results for a given floodplain management scenario as shown on horizontal axis.



Break-even (0) line. Net annual loss below 0 line and net annual gain above 0 line.

INTERPRETING BUILDING DAMAGE PLOT

- Note magnitude of building losses as scales vary between plots.
- Compare like-colored bars to see change in building damages between floodplain management scenarios.
- Compare bars of different colors to compare either current versus future or existing versus floodplain restoration across management scenarios.

INTERPRETING COST-BENEFIT SUMMARY PLOT

- Note magnitude of cost-benefit balance relative to break-even (0) line as scales vary between plots.
- Compare like-colored bars to see change in cost-benefit balance between floodplain management scenarios.
- Compare bars of different colors to compare either current versus future or existing versus floodplain restoration across management scenarios.

Cost-Benefit Summary – Existing/Buildout for Waterbury, Vermont

EX	Floodplain Management Scenario		Ecosystem Services		Buildout/Conservation		Flood Mitigation		Current Flood Damages (2015)			Flood Insurance	Balance	Δ	Future Flood Damages (2065)			Balance	Δ
	ID	Description	Δ Value ($/yr)	Description	Δ Value ($)	Δ Tax Value ($/yr)	Description	Cost ($/yr)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	Δ Premium ($/yr)	($ 2015)	($ 2015)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	($ 2065)	($ 2065)
EX	1A	Existing condition with updated floodplain. (282 buildings damaged in the 500-year floodplain)	$ -	Base value of naturally functioning land in 500-year floodplain = $5,844,765	$ -	$ -	None	$ -	$ (50,881)	$ (40,737)	$ (4,940)	$ -	$ (96,558)	$ -	$ (94,909)	$ (76,837)	$ (9,486)	$ (181,232)	$ -
ELEVATE	2A	Elevate (103) existing buildings in the 500-year floodplain to 2 feet above the 100-year flood level.	$ -	No change from base value upon building elevation.	$ 14,524,380	$ 298,970	Elevate 103 buildings.	$ (309,000)	$ (25,562)	$ (24,633)	$ (2,431)	$ 54,075	$ (8,581)	$ 87,977	$ (48,534)	$ (46,402)	$ (4,501)	$ (55,393)	$ 125,839
	2B	Elevate (49) existing buildings that are most prone to flooding (see map) to 2 feet above the 100-year flood level.	$ -	No change from base value upon building elevation.	$ 6,909,657	$ 142,228	Elevate 49 buildings.	$ (147,000)	$ (31,087)	$ (30,835)	$ (4,086)	$ 71,400	$ 621	$ 97,179	$ (59,429)	$ (58,740)	$ (7,751)	$ (59,291)	$ 121,940
	2C	Elevate utilities in all (282) existing buildings in the 500-year floodplain to the 500-year flood elevation.	$ -	No change from base value upon building elevation.	$ 7,262,190	$ 149,485	Elevate utilities in 282 buildings.	$ (112,800)	$ (26,621)	$ (40,763)	$ (4,940)	$ 25,380	$ (10,259)	$ 86,299	$ (50,173)	$ (76,851)	$ (9,486)	$ (74,445)	$ 106,786
AVOIDANCE AND NO FILL	3A	Remove (50) existing buildings that are most prone to flooding.	$ 34,000	Increase of ecosystem services on naturally vegetated land with removals.	$ (14,601,560)	$ (300,559)	Remove 50 buildings.	$ (30,000)	$ (24,924)	$ (25,384)	$ (3,699)	$ 75,000	$ (275,565)	$ (179,007)	$ (47,799)	$ (48,542)	$ (7,031)	$ (324,931)	$ (143,699)
	3C	Elevate (50) existing buildings to 1 foot above the 500-year flood elevation upon rebuild of the most floodprone buildings	$ -	No change from base value upon building elevation.	$ 7,050,670	$ 145,131	Elevate 50 buildings.	$ (150,000)	$ (25,117)	$ (25,520)	$ (3,702)	$ 26,250	$ (32,959)	$ 63,599	$ (48,156)	$ (48,754)	$ (7,039)	$ (82,567)	$ 98,664
EXTREME AVOIDANCE	4A	Remove (116) existing buildings that are prone to flooding (see map).	$ 82,450	Increase of ecosystem services on naturally vegetated land with removals.	$ (38,090,160)	$ (784,048)	Remove 116 buildings.	$ (69,600)	$ (11,133)	$ (11,224)	$ (1,291)	$ 174,000	$ (620,846)	$ (524,288)	$ (21,145)	$ (20,993)	$ (2,387)	$ (641,723)	$ (460,491)
	4B	Remove (116) existing buildings that are prone to flooding. Elevate sewer pump station and medical center, elevate utilities in police station and fire station.	$ 82,450	Increase of ecosystem services on naturally vegetated land with removals.	$ (38,090,160)	$ (784,048)	Remove 116 buildings. Elevate 2 buildings. Elevate utilities in 2 buildings.	$ (76,400)	$ (11,720)	$ (11,888)	$ (1,291)	$ 175,230	$ (627,667)	$ (531,109)	$ (22,198)	$ (22,377)	$ (2,387)	$ (649,730)	$ (468,498)

BO	Floodplain Management Scenario		Ecosystem Services		Buildout/Conservation		Flood Mitigation		Current Flood Damages (2015)			Flood Insurance	Balance	Δ	Future Flood Damages (2065)			Balance	Δ
	ID	Description	Δ Value ($/yr)	Description	Δ Value ($)	Δ Tax Value ($/yr)	Description	Cost ($/yr)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	Δ Premium ($/yr)	($ 2015)	($ 2015)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	($ 2065)	($ 2065)
EX	1B	Existing condition with updated floodplains and full buildout (56 SF residential, 62 MF residential, and 33 commercial buildings). (433 buildings damaged in the 500-year floodplain)	$ (120,275)	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 64,670,300	$ 1,331,173	None	$ -	$ (138,781)	$ (127,079)	$ (49,385)	$ (226,500)	$ 669,154	$ -	$ (254,983)	$ (240,319)	$ (90,641)	$ 398,456	$ -
ELEVATE	2A	Elevate (103) existing buildings and (87) buildout buildings in the 500-year floodplain to 2 feet above the 100-year flood level.	$ (120,275)	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 43,887,340	$ 903,377	Elevate 190 buildings.	$ (570,000)	$ (82,974)	$ (73,024)	$ (22,507)	$ 99,750	$ 134,347	$ (534,807)	$ (156,967)	$ (136,970)	$ (41,766)	$ (22,851)	$ (421,307)
	2B	Elevate (49) existing buildings that are most prone to flooding and (87) new buildout buildings in the existing 500-year floodplain to 2 feet above the 100-year flood level.	$ (120,275)	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 49,584,157	$ 1,020,640	Elevate 136 buildings.	$ (408,000)	$ (88,499)	$ (79,226)	$ (24,162)	$ 25,725	$ 326,203	$ (342,950)	$ (167,861)	$ (149,309)	$ (45,016)	$ 155,905	$ (242,551)
	2C	Elevate utilities in all (282) existing buildings and all (151) buildout buildings in the 500-year flood elevation.	$ (120,275)	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 71,932,490	$ 1,480,658	Elevate utilities in 433 buildings.	$ (173,200)	$ (85,888)	$ (127,105)	$ (40,003)	$ 38,970	$ 973,158	$ 304,004	$ (162,275)	$ (240,333)	$ (76,009)	$ 747,536	$ 349,080
AVOIDANCE AND NO FILL	3A	Remove (50) existing buildings that are most prone to flooding and (26) buildout buildings.	$ 48,875	Increase of ecosystem services on naturally vegetated land with removals.	$ (22,034,560)	$ (453,559)	Remove 76 buildings.	$ (45,600)	$ (114,340)	$ (106,258)	$ (37,871)	$ 114,000	$ (594,754)	$ (1,263,908)	$ (216,944)	$ (201,815)	$ (71,904)	$ (826,947)	$ (1,225,402)
	3C	Elevate (50) existing buildings and (140) buildout buildings to 1 foot above the 500-year flood elevation upon rebuild of most floodprone buildings	$ (120,275)	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 79,713,270	$ 1,640,818	Elevate 190 buildings.	$ (570,000)	$ (27,224)	$ (26,324)	$ (3,791)	$ 99,750	$ 992,954	$ 323,801	$ (52,153)	$ (50,246)	$ (7,223)	$ 940,671	$ 542,215
EXTREME AVOIDANCE	4A	Remove (116) existing buildings and (80) buildout buildings that are prone to flooding.	$ 130,475	Increase of ecosystem services on naturally vegetated land with removals.	$ (63,726,060)	$ (1,311,737)	Remove 196 buildings.	$ (117,600)	$ (68,286)	$ (74,446)	$ (34,381)	$ 294,000	$ (1,181,974)	$ (1,851,128)	$ (129,539)	$ (141,635)	$ (65,235)	$ (1,341,271)	$ (1,739,727)
	4B	Remove (116) existing buildings and (80) buildout buildings that are prone to flooding. Elevate sewer pump station and medical center, elevate utilities in police station and fire station.	$ 130,475	Increase of ecosystem services on naturally vegetated land with removals.	$ (63,726,060)	$ (1,311,737)	Remove 196 buildings. Elevate 2 buildings. Elevate utilities in 2 buildings.	$ (124,400)	$ (68,874)	$ (75,109)	$ (34,381)	$ 295,230	$ (1,188,795)	$ (1,857,949)	$ (130,591)	$ (143,019)	$ (65,235)	$ (1,349,278)	$ (1,747,734)

Ecosystem Value Notes
Assume naturally functioning land loss (gain) per added (removed) building is equal to average building footprint + 25% for residential (0.05 acres) and commercial (0.2 acres).
Assume land conversion between developed and combination of forest and village greenspace for average ecosystem service value of $8,500/acre/yr.

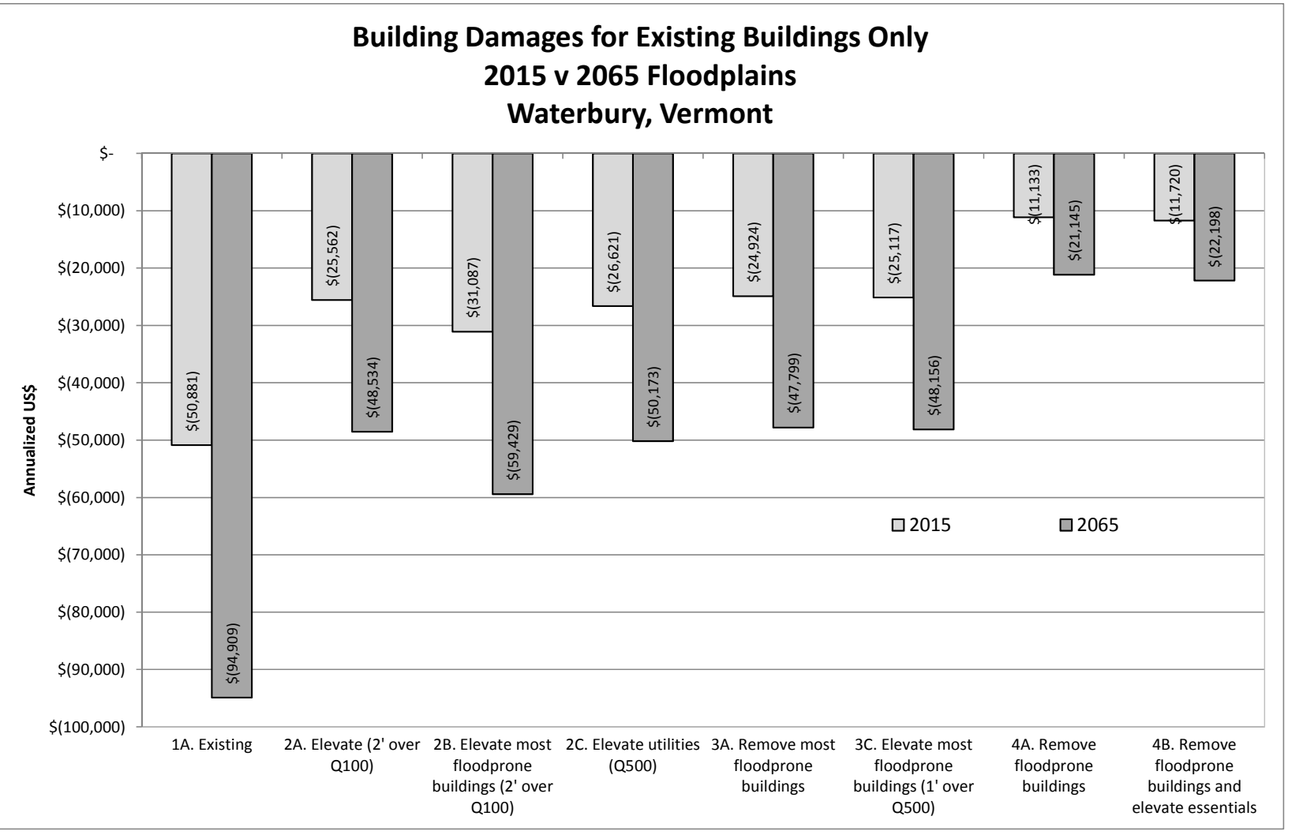
Buildout/Conservation Notes
EX = existing building stock and BO = maximum buildout building stock.
Waterbury Village grand list taxable properties = $192,808,100.
The portion of the taxable properties in the current 100-year floodplain is $28,380,100 (12%). Use as approximate base value for 10-year and 50-year floodplains.
The portion of the taxable properties in the future 100-year floodplain is $48,414,600 (19%). Use as approximate base value for Irene and 500-year floodplains.
Tax rate taken as 2.0584% that is the average of residential and non-residential rates (including school, Town, Village, and local agreement).
Pilot payment in lieu of taxes made to Village for State Complex of $44,155 in 2014 included in tax value.
Costs for building construction for buildout not included.
Assume 15% increase in value and tax revenue for elevated utilities and a 30% increase for elevated buildings.

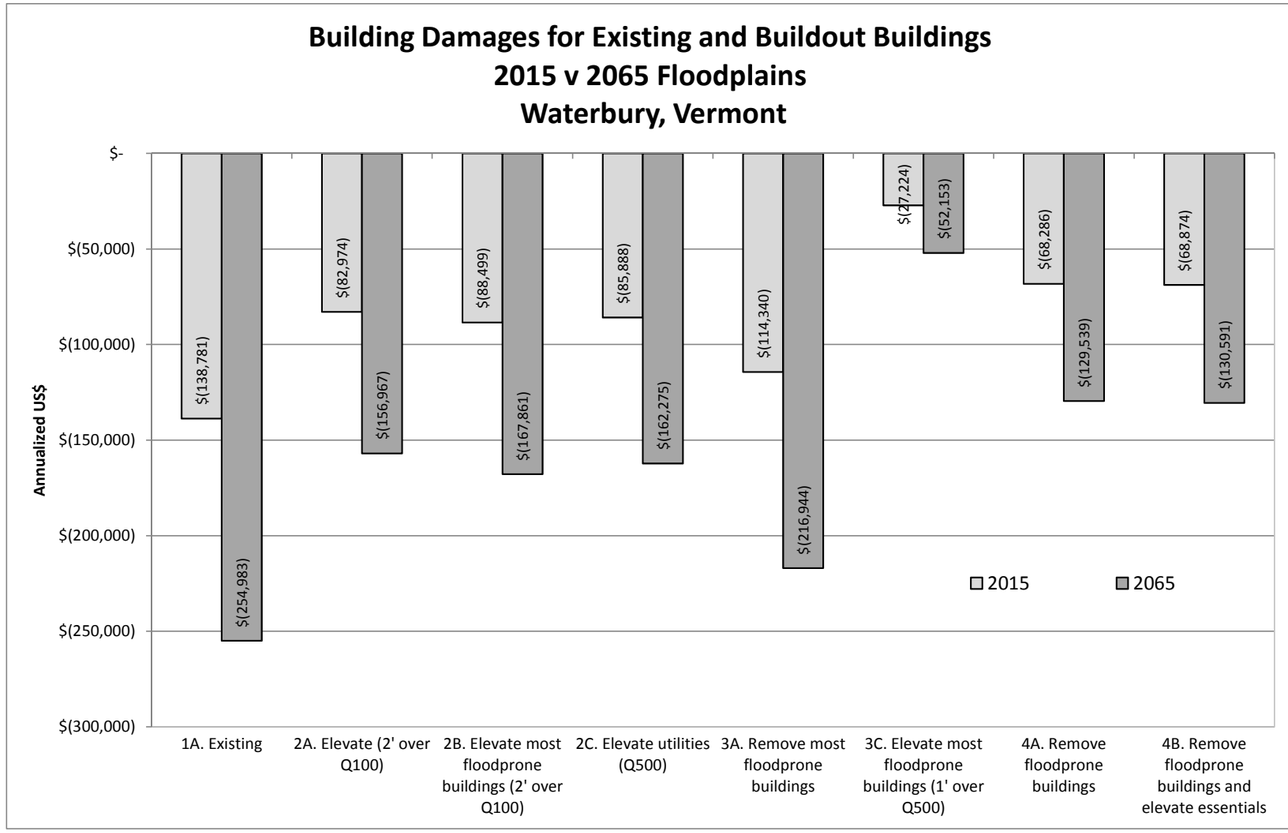
Mitigation Notes
Assume $20,000 to elevate utilities and $150,000 to elevate building.
Assume $30,000 to remove building and restore natural vegetation.
Mitigation cost divided by 50 to estimate per year value over a 50-year time period.
Costs for building acquisition for removals not included.

Flood Insurance Notes
Current total premium for the Village = $360,089 per year that includes mandatory and non-mandatory policies most of which are pre-firm, flat rate policies.
Typical premium taken as $1,500 per year that is the average post-firm premium of the 9 policies in the Village.
Assume flood insurance carried (eliminated) for new (removed) buildings ($1,500/yr) and reduced for elevated buildings (-35% or -$525/yr) or utilities (-6% or -$90/yr).

Future Damages
The 2065 balance considers future flood damages while other values remain in today's currency.

Existing and Future Building Damages – Waterbury, Vermont

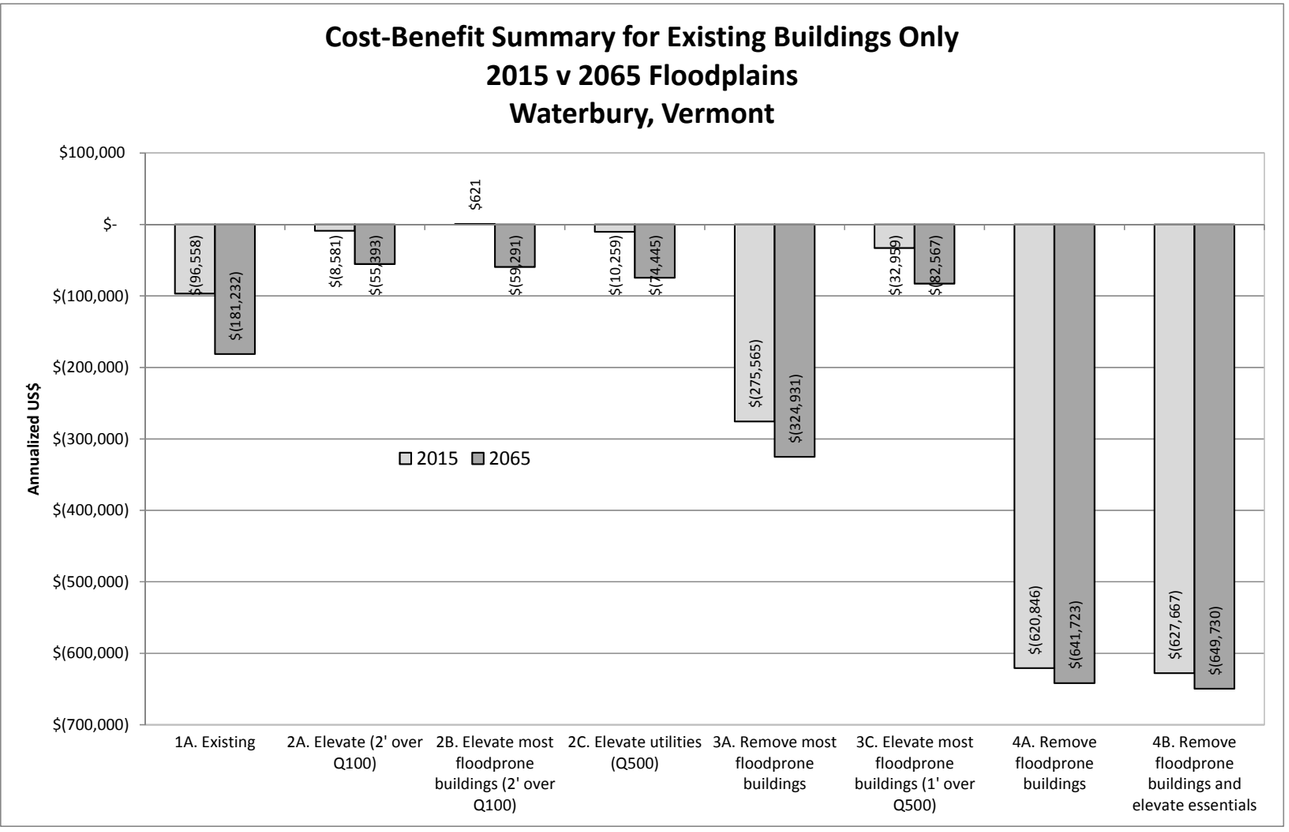


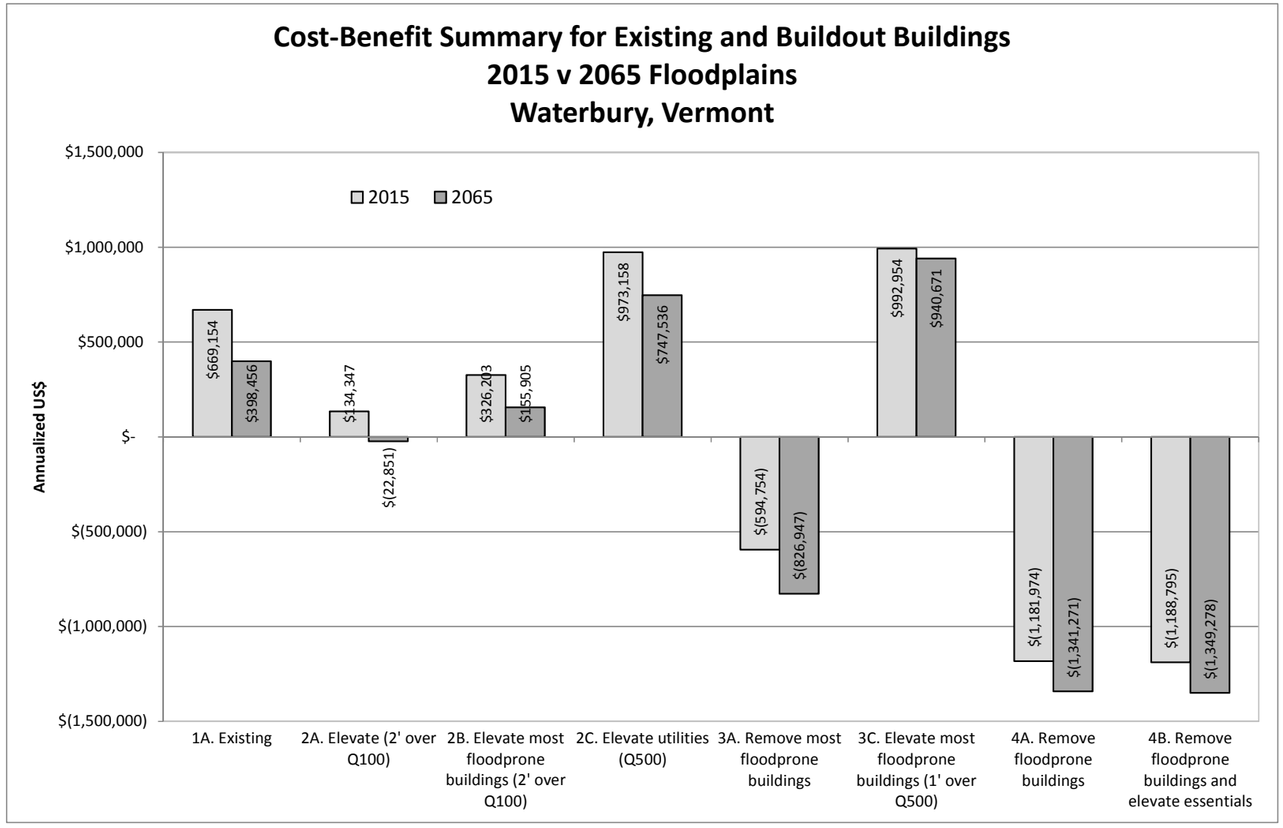


- Existing annualized building damages are $51,000 and future annualized building damages are $95,000.
- Building damages, along with loss of contents and inventory (not shown here), decrease as mitigation strategies get more aggressive such as from elevating to removing floodprone buildings. Avoidance is the best way to limit building damages.
- Future damages increase due to predicted larger floodplains and deeper flood levels under all mitigation strategies.
- Elevating buildings maintain damages at current annualized levels in the future, while removing most of the floodprone buildings reduces future damage levels below today's levels.

- When considering both the existing buildings and the buildout buildings, damages increase due to the presence of more buildings that are susceptible to flooding when placed on the land following current local floodplain ordinances.
- The increased building damages are reduced with flood mitigation strategies such as removal of the most floodprone structures and elevations.
- Removal of the most floodprone buildings (3C), and avoiding building in these locations, reduces damages the most with an increasing building stock.
- Future damages increase due to predicted larger floodplains and deeper flood levels under all mitigation strategies.

Existing and Future Cost-Benefit Summary – Waterbury, Vermont





- Summarizing ecosystem service change, changes in tax revenue, the cost of flood mitigation activities, flood damages, and changes in flood insurance premiums indicates that living in the floodplain today costs $97,000 per year while living in the floodplain in 2065 will cost $181,000 per year.
- Elevating the most floodprone buildings to 2 feet above the 100-year flood level (2B) leads to a net benefit of $620 per year.
- Future costs of floodplain living all increase due to predicted larger floodplains and deeper flood levels under all mitigation strategies.
- Removal of floodprone buildings results in a net increase in cost mostly due to the loss of tax revenue. Removals would show a larger benefit if buildings were relocated or new construction took place outside of the floodplain yet remained in town to sustain the tax base.

- When considering both the existing buildings and the buildout buildings, benefits increase due to an increase in tax revenue with the new building stock.
- Under all mitigation strategies the trajectory of larger floods leads to increased future damages and growing costs.
- Elevating utilities and the most floodprone structures lead to the largest benefit with the increased building stock.
- Removal of floodprone buildings results in a net increase in cost mostly due to the loss of tax revenue. Removals would show a larger benefit if buildings were relocated or new construction took place outside of the floodplain yet remained in town to sustain the tax base.

Cost-Benefit Summary – Floodplain Restoration for Waterbury, Vermont

REX	Floodplain Management Scenario		Ecosystem Services		Buildout/Conservation		Flood Mitigation		Current Flood Damages (2015)			Flood Insurance	Balance	Δ	Future Flood Damages (2065)			Balance	Δ
	ID	Description	Δ Value ($/yr)	Description	Δ Value ($)	Δ Tax Value ($/yr)	Description	Cost ($/yr)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	Δ Premium ($/yr)	($ 2015)	($ 2015)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	($ 2065)	($ 2065)
EX	1A	Existing condition with updated floodplain. (282 buildings damaged in the 500-year floodplain)	$ 314,500	Base value of naturally functioning land in 500-year floodplain = $5,844,765.	$ -	$ -	Restore 36.8 acres of floodplain.	$ (77,020)	$ (40,700)	$ (27,486)	$ (3,231)	$ -	$ 166,063	$ -	$ (74,300)	$ (50,832)	$ (6,102)	$ 106,246	$ -
ELEVATE	2A	Elevate (103) existing buildings in the 500-year floodplain to 2 feet above the 100-year flood level.	$ 314,500	No change from base value upon building elevation.	$ 14,524,380	$ 298,970	Elevate 103 buildings.	$ (386,020)	$ (16,415)	$ (11,213)	$ (844)	$ 54,075	$ 253,052	$ 86,990	$ (30,857)	$ (20,874)	$ (1,562)	$ 228,232	$ 121,986
	2B	Elevate (49) existing buildings that are most prone to flooding (see map) to 2 feet above the 100-year flood level.	$ 314,500	No change from base value upon building elevation.	$ 6,909,657	$ 142,228	Elevate 49 buildings.	$ (224,020)	$ (20,694)	$ (16,802)	$ (2,349)	$ 71,400	$ 264,263	$ 98,200	$ (39,429)	$ (31,922)	$ (4,466)	$ 228,291	$ 122,045
	2C	Elevate utilities in all (282) existing buildings in the 500-year floodplain to the 500-year flood elevation.	$ 314,500	No change from base value upon building elevation.	$ 7,262,190	$ 149,485	Elevate utilities in 282 buildings.	$ (189,820)	$ (22,495)	$ (24,500)	$ (10,018)	$ 25,380	$ 242,531	$ 76,468	$ (40,852)	$ (46,177)	$ (21,859)	$ 190,658	$ 84,412
AVOIDANCE AND NO FILL	3A	Remove (50) existing buildings that are most prone to flooding.	$ 348,500	Increase of ecosystem services on naturally vegetated land with removals.	$ (14,601,560)	$ (300,559)	Remove 50 buildings.	$ (107,020)	$ (16,185)	$ (14,027)	$ (2,238)	$ 75,000	$ (16,529)	$ (182,592)	$ (30,995)	$ (26,747)	$ (4,259)	$ (46,079)	$ (152,325)
	3C	Elevate (50) existing buildings to 1 foot above the 500-year flood elevation upon rebuild of the most floodprone buildings	$ 314,500	No change from base value upon building elevation.	$ 7,050,670	$ 145,131	Elevate 50 buildings.	$ (227,020)	$ (16,185)	$ (14,027)	$ (2,238)	$ 26,250	$ 226,411	$ 60,348	$ (30,995)	$ (26,747)	$ (4,259)	$ 196,861	$ 90,615
EXTREME AVOIDANCE	4A	Remove (116) existing buildings that are prone to flooding (see map).	$ 396,950	Increase of ecosystem services on naturally vegetated land with removals.	$ (38,090,160)	$ (784,048)	Remove 116 buildings.	$ (146,620)	$ (6,574)	$ (3,937)	$ (614)	$ 174,000	$ (370,843)	$ (536,905)	$ (12,530)	$ (7,288)	$ (1,150)	$ (380,686)	$ (486,932)
	4B	Remove (116) existing buildings that are prone to flooding. Elevate sewer pump station and medical center, elevate utilities in police station and fire station.	$ 396,950	Increase of ecosystem services on naturally vegetated land with removals.	$ (38,090,160)	$ (784,048)	Remove 116 buildings. Elevate 2 buildings. Elevate utilities in 2 buildings.	$ (153,420)	$ (7,222)	$ (5,152)	$ (614)	$ 175,230	$ (378,276)	$ (544,338)	$ (13,698)	$ (9,640)	$ (1,150)	$ (389,776)	$ (496,022)

RBO	Floodplain Management Scenario		Ecosystem Services		Buildout/Conservation		Flood Mitigation		Current Flood Damages (2015)			Flood Insurance	Balance	Δ	Future Flood Damages (2065)			Balance	Δ
	ID	Description	Δ Value ($/yr)	Description	Δ Value ($)	Δ Tax Value ($/yr)	Description	Cost ($/yr)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	Δ Premium ($/yr)	($ 2015)	($ 2015)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	($ 2065)	($ 2065)
EX	1B	Existing condition with updated floodplains and full buildout (56 SF residential, 62 MF residential, and 33 commercial buildings). (433 buildings damaged in the 500-year floodplain)	$ 194,225	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 64,670,300	$ 1,331,173	Restore 36.8 acres of floodplain.	$ (77,020)	$ (117,223)	$ (87,600)	$ (33,702)	$ (226,500)	$ 983,352	$ -	$ (216,529)	$ (163,073)	$ (60,281)	$ 781,996	$ -
ELEVATE	2A	Elevate (103) existing buildings and (87) buildout buildings in the 500-year floodplain to 2 feet above the 100-year flood level.	$ 194,225	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 43,887,340	$ 903,377	Elevate 190 buildings.	$ (647,020)	$ (53,315)	$ (32,129)	$ (6,489)	$ 99,750	$ 458,399	$ (524,954)	$ (99,989)	$ (59,514)	$ (11,906)	$ 378,922	$ (403,073)
	2B	Elevate (49) existing buildings that are most prone to flooding and (87) new buildout buildings in the existing 500-year floodplain to 2 feet above the 100-year flood level.	$ 194,225	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 49,584,157	$ 1,020,640	Elevate 136 buildings.	$ (485,020)	$ (57,594)	$ (37,718)	$ (7,994)	$ 25,725	$ 652,264	$ (331,088)	$ (108,561)	$ (70,563)	$ (14,810)	$ 561,636	$ (220,360)
	2C	Elevate utilities in all (282) existing buildings and all (151) buildout buildings in the 500-year flood elevation.	$ 194,225	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 71,932,490	$ 1,480,658	Elevate utilities in 433 buildings.	$ (250,220)	$ (67,567)	$ (82,491)	$ (31,107)	$ 38,970	$ 1,282,468	$ 299,116	$ (124,269)	$ (155,108)	$ (61,406)	$ 1,122,850	$ 340,855
AVOIDANCE AND NO FILL	3A	Remove (50) existing buildings that are most prone to flooding and (26) buildout buildings.	$ 363,375	Increase of ecosystem services on naturally vegetated land with removals.	$ (22,034,560)	$ (453,559)	Remove 76 buildings.	$ (122,620)	$ (79,518)	$ (68,926)	$ (23,112)	$ 114,000	$ (270,360)	$ (1,253,713)	$ (150,481)	$ (129,978)	$ (43,417)	$ (422,680)	$ (1,204,676)
	3C	Elevate (50) existing buildings and (140) buildout buildings to 1 foot above the 500-year flood elevation upon rebuild of most floodprone buildings	$ 194,225	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 79,713,270	$ 1,640,818	Elevate 190 buildings.	$ (647,020)	$ (17,001)	$ (14,255)	$ (2,238)	$ 99,750	$ 1,254,278	$ 270,926	$ (32,558)	$ (27,185)	$ (4,259)	$ 1,223,770	$ 441,774
EXTREME AVOIDANCE	4A	Remove (116) existing buildings and (80) buildout buildings that are prone to flooding.	$ 444,975	Increase of ecosystem services on naturally vegetated land with removals.	$ (63,726,060)	$ (1,311,737)	Remove 196 buildings.	$ (194,620)	$ (49,310)	$ (47,461)	$ (21,013)	$ 294,000	$ (885,167)	$ (1,868,519)	$ (92,784)	$ (89,414)	$ (39,428)	$ (989,009)	$ (1,771,004)
	4B	Remove (116) existing buildings and (80) buildout buildings that are prone to flooding. Elevate sewer pump station and medical center, elevate utilities in police station and fire station.	$ 444,975	Increase of ecosystem services on naturally vegetated land with removals.	$ (63,726,060)	$ (1,311,737)	Remove 196 buildings. Elevate 2 buildings. Elevate utilities in 2 buildings.	$ (201,420)	$ (49,958)	$ (48,676)	$ (21,013)	$ 295,230	$ (892,600)	$ (1,875,952)	$ (93,952)	$ (91,766)	$ (39,428)	$ (998,099)	$ (1,780,094)

Ecosystem Value Notes

Add in value for improved floodplain function on 37 acres of restored floodplain for the three sites combined for value of $314,000.
Assume naturally functioning land loss (gain) per added (removed) building is equal to average building footprint + 25% for residential (0.05 acres) and commercial (0.2 acres).
Assume land conversion between developed and combination of forest and village greenspace for average ecosystem service value of $8,500/acre/yr.

Buildout/Conservation Notes

REX = existing building stock with floodplain restoration and RBO = maximum buildout building stock with floodplain restoration.
Waterbury Village grand list taxable properties = $192,808,100.
The portion of the taxable properties in the current 100-year floodplain is $28,380,100 (12%). Use as approximate base value for 10-year and 50-year floodplains.
The portion of the taxable properties in the future 100-year floodplain is $48,414,600 (19%). Use as approximate base value for Irene and 500-year floodplains.
Tax rate taken as 2.0584% that is the average of residential and non-residential rates (including school, Town, Village, and local agreement).
Pilot payment in lieu of taxes made to Village for State Complex of $44,155 in 2014 included in tax value.
Costs for building construction for buildout not included.
Assume 15% increase in value and tax revenue for elevated utilities and a 30% increase for elevated buildings.

Mitigation Notes

Estimated floodplain mitigation cost of $3,851,000 divided by 50 to estimate 50-year time period.
Assume $20,000 to elevate utilities and $150,000 to elevate building.
Assume $30,000 to remove building and restore natural vegetation.
Mitigation cost divided by 50 to estimate per year value over a 50-year time period.
Costs for building acquisition for removals not included.

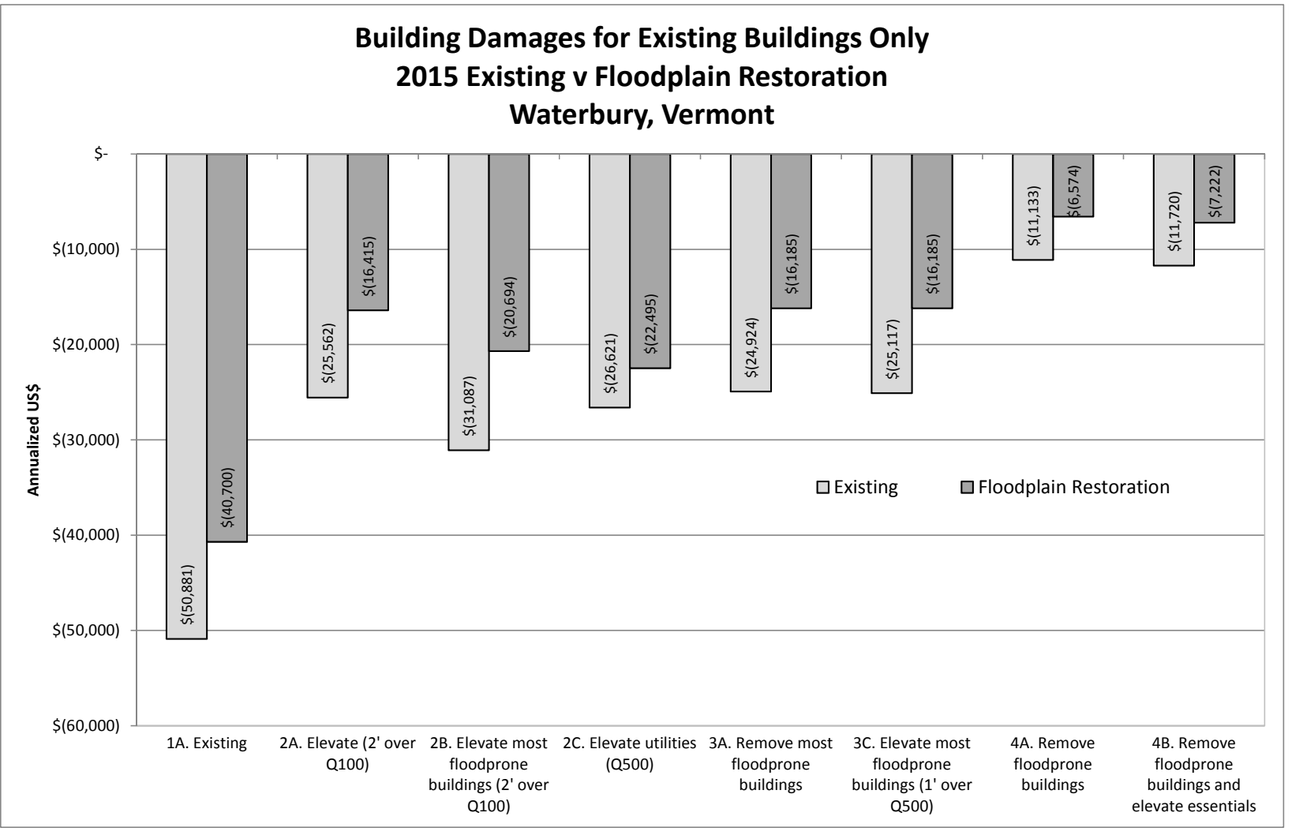
Flood Insurance Notes

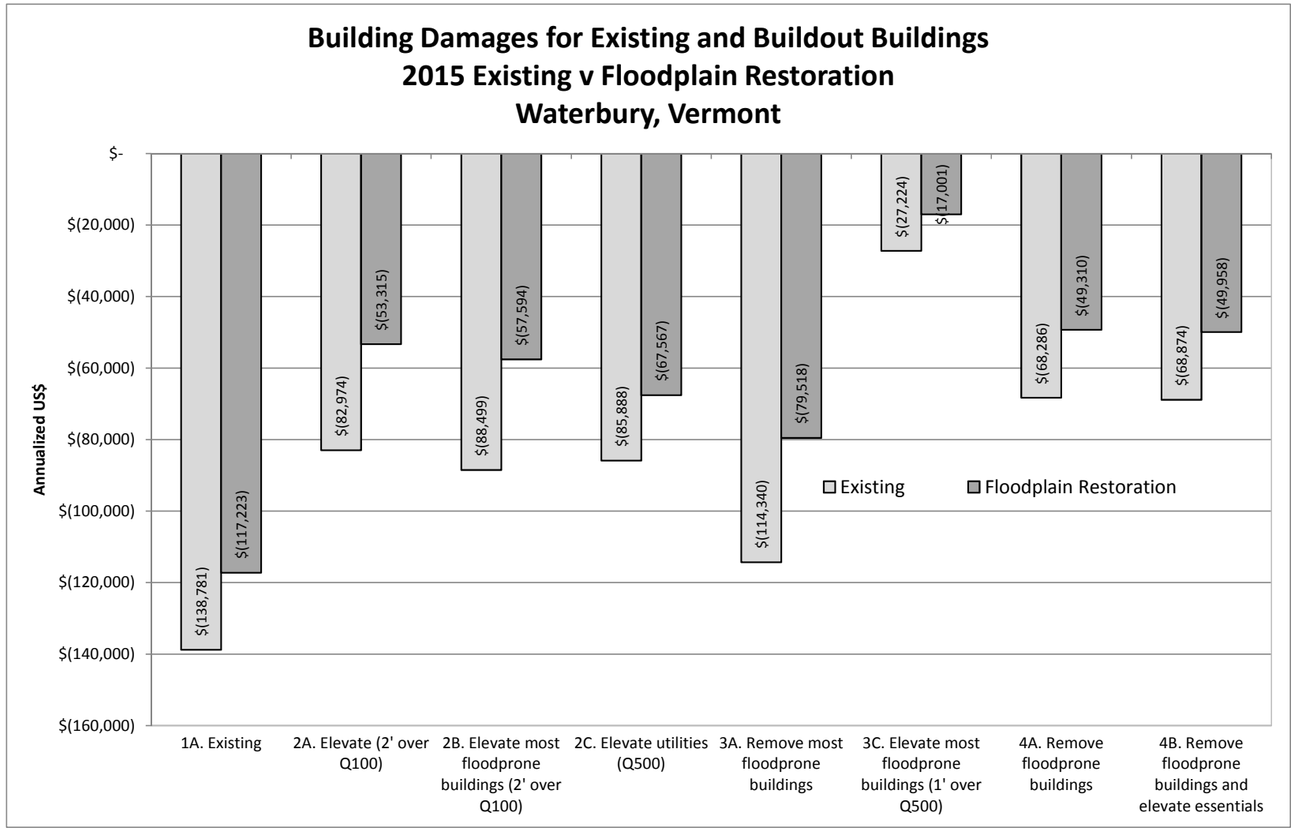
Current total premium for the Village = $360,089 per year that includes mandatory and non-mandatory policies most of which are pre-firm, flat rate policies.
Typical premium taken as $1,500 per year that is the average post-firm premium of the 9 policies in the Village.
Assume flood insurance carried (eliminated) for new (removed) buildings ($1,500/yr) and reduced for elevated buildings (-35% or -$525/yr) or utilities (-6% or -$90/yr).

Future Damages

The 2065 balance considers future flood damages while other values remain in today's currency.

2015 Existing and Floodplain Restoration Building Damages – Waterbury, Vermont

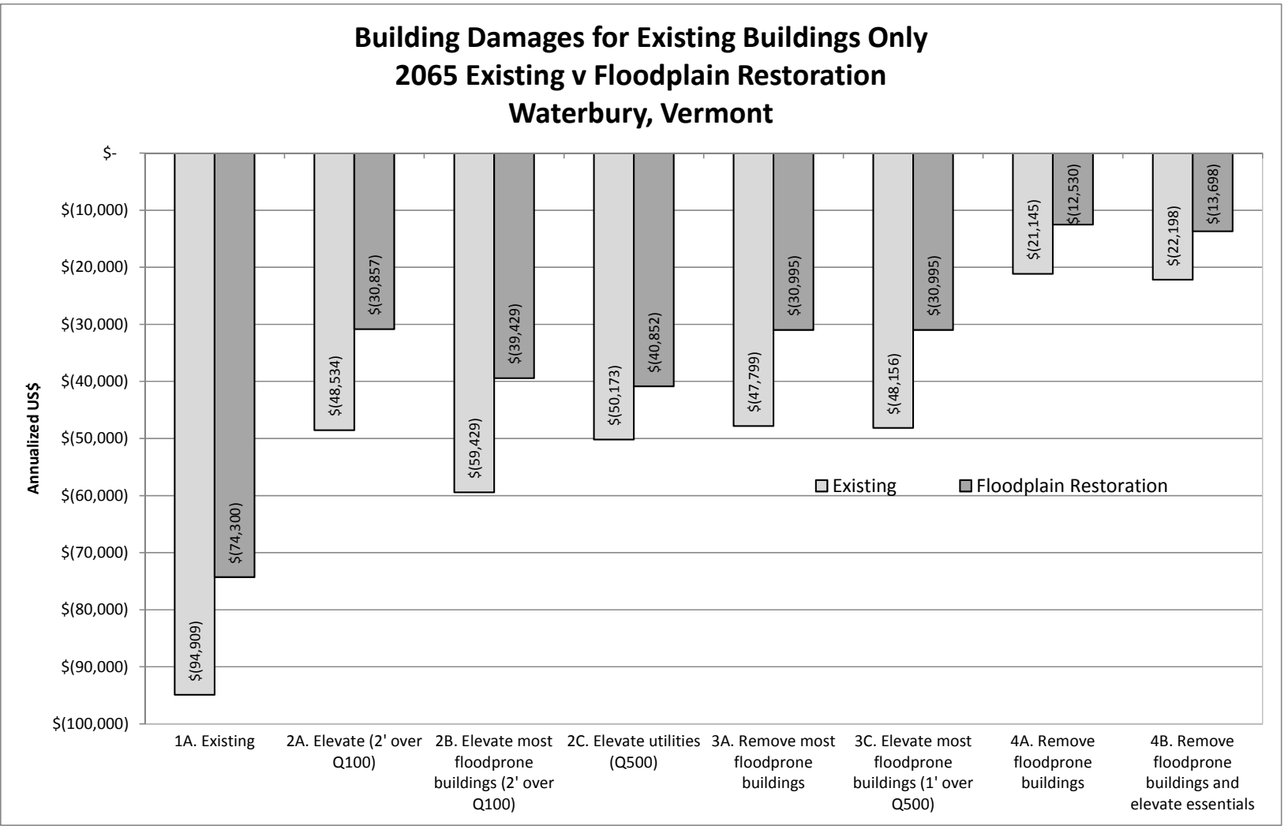


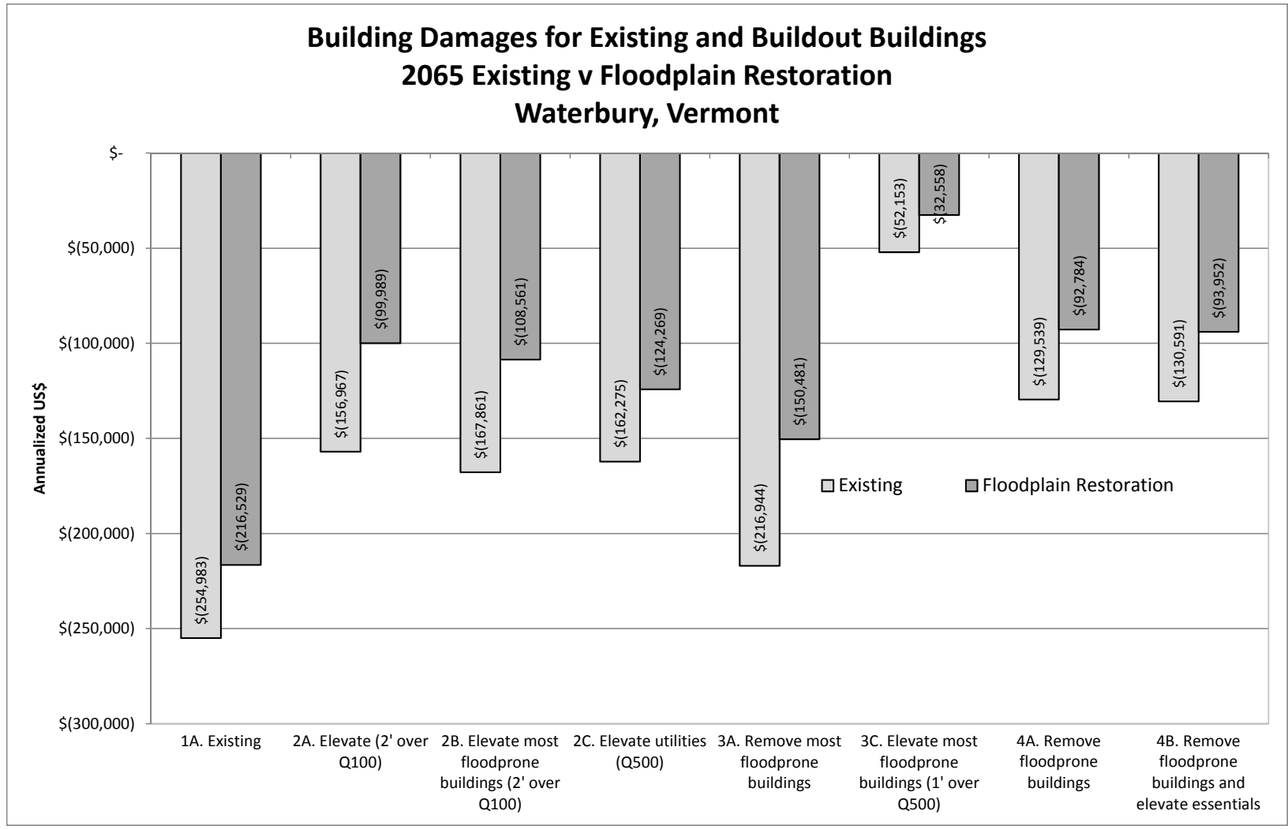


- The proposed floodplain restoration decreases existing annual building damages from $51,000 to $41,000 (~20% damage reduction).
- The proposed floodplain restoration reduces annual damages across all flood mitigation activities, and improves the effectiveness of each mitigation approach.
- Floodplain restoration in conjunction with removing floodprone properties (4A) leads to the lowest building damages.
- Floodplain restoration leads to a reduction of $2.6 million dollars in simulated damages for a single modeled Tropical Storm Irene flood event.
- The recommended alternative consists of floodplain restoration in three previously identified locations – two on state lands in Waterbury and one on a private parcel in Duxbury. An alternative consisting of floodplain restoration in just the two Waterbury locations was investigated and yielded more limited damage reduction benefits so was dropped from the analysis.

- When considering both the existing buildings and the buildout buildings the proposed floodplain restoration decreases existing annual building damages from $139,000 to $117,000 (~15% damage reduction).
- With a larger building stock the proposed floodplain restoration reduces annual damages across all flood mitigation activities, and improves the effectiveness of each mitigation approach.
- Floodplain restoration in conjunction with elevating the most floodprone buildings 1 foot over the 500-year flood level (3C) leads to the lowest building damages.

2065 Existing and Floodplain Restoration Building Damages – Waterbury, Vermont

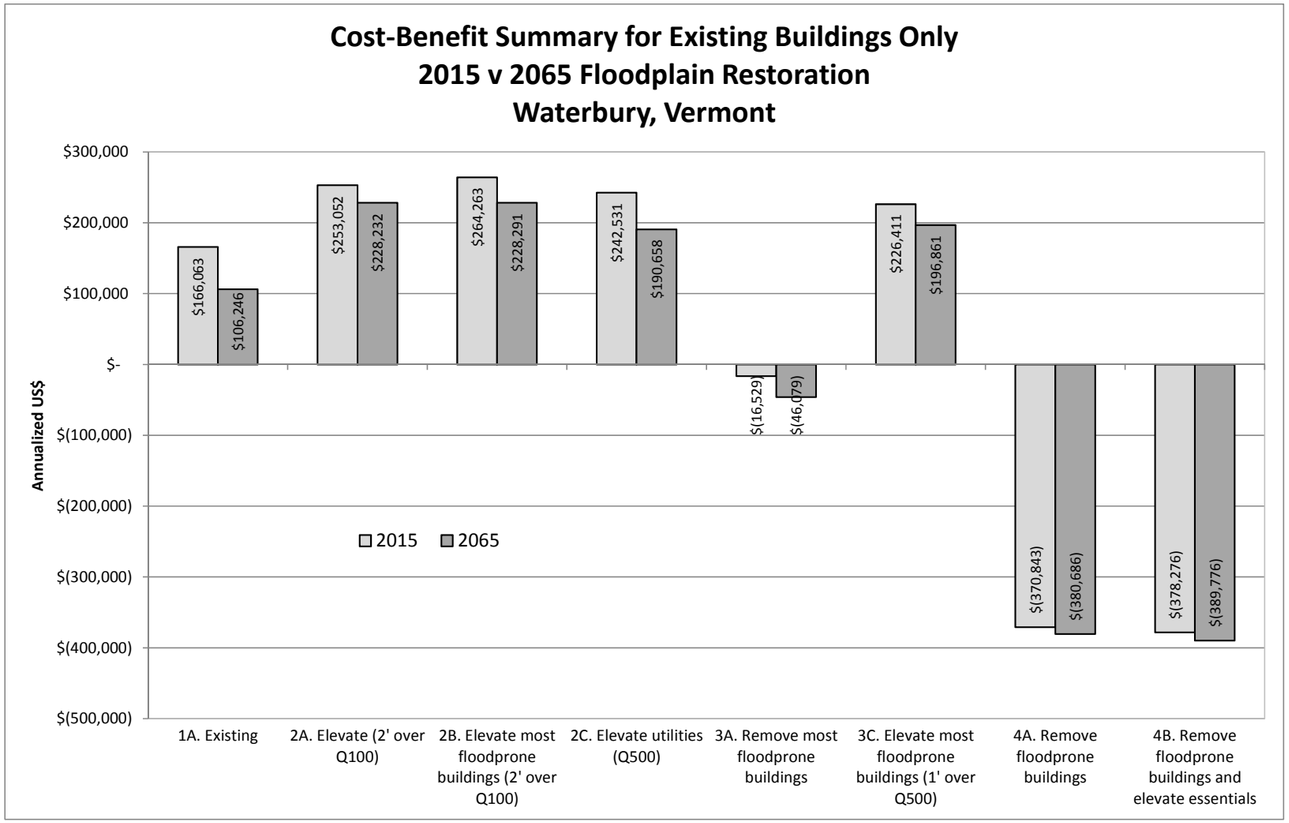


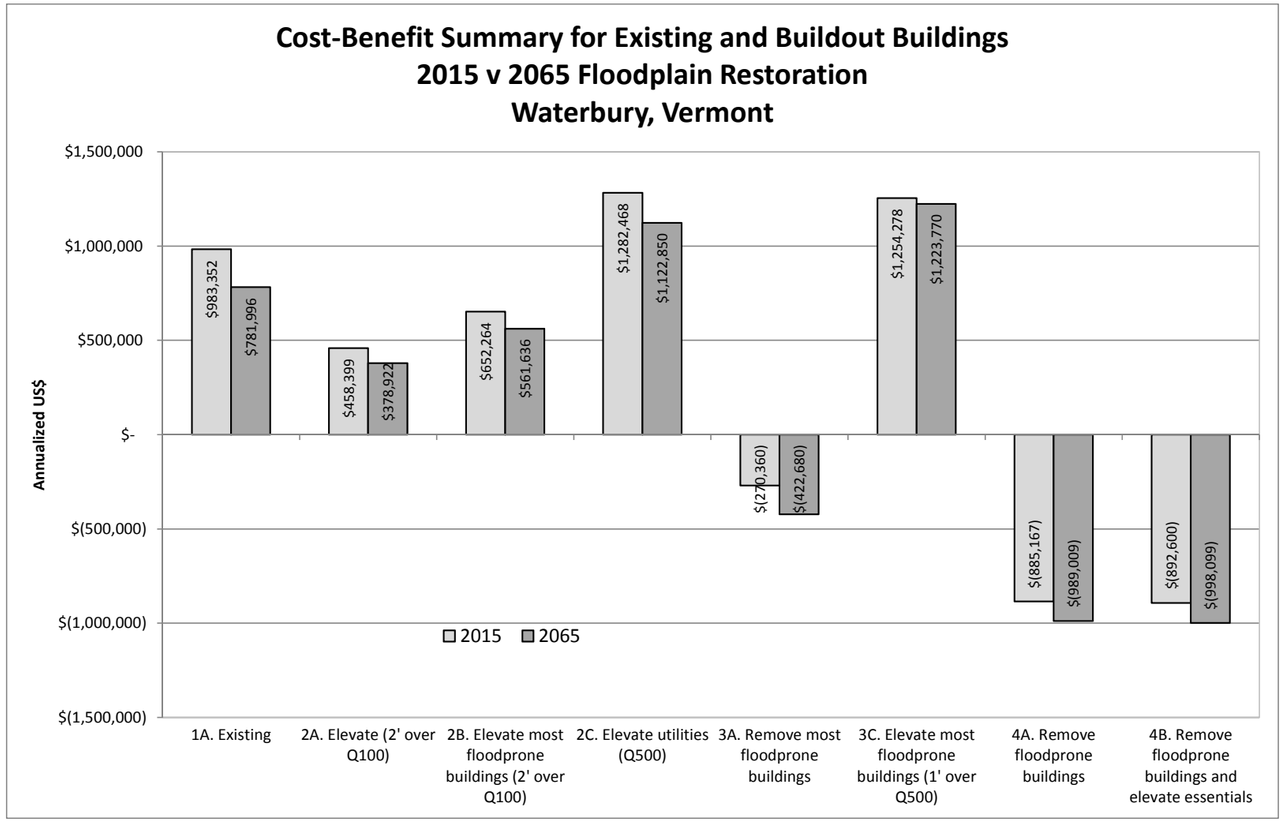


- The proposed floodplain restoration decreases future annual building damages from $95,000 to $74,000 (~20% damage reduction).
- The proposed floodplain restoration reduces future annual damages across all flood mitigation activities, and improves the effectiveness of each mitigation approach.
- Floodplain restoration in conjunction with removing floodprone properties (4A) leads to the lowest building damages.
- Floodplain restoration leads to a reduction of $2.4 million dollars in simulated damages for a single modeled future 100-year flood event.

- When considering both the existing buildings and the buildout buildings the proposed floodplain restoration decreases future annual building damages from $255,000 to $217,000 (~15% damage reduction).
- With a larger building stock the proposed floodplain restoration reduces annual damages across all flood mitigation activities, and improves the effectiveness of each mitigation approach.
- Floodplain restoration in conjunction with elevating the most floodprone buildings 1 foot over the 500-year flood level (3C) leads to the lowest building damages.

Existing and Floodplain Restoration Cost-Benefit Summary – Waterbury, Vermont

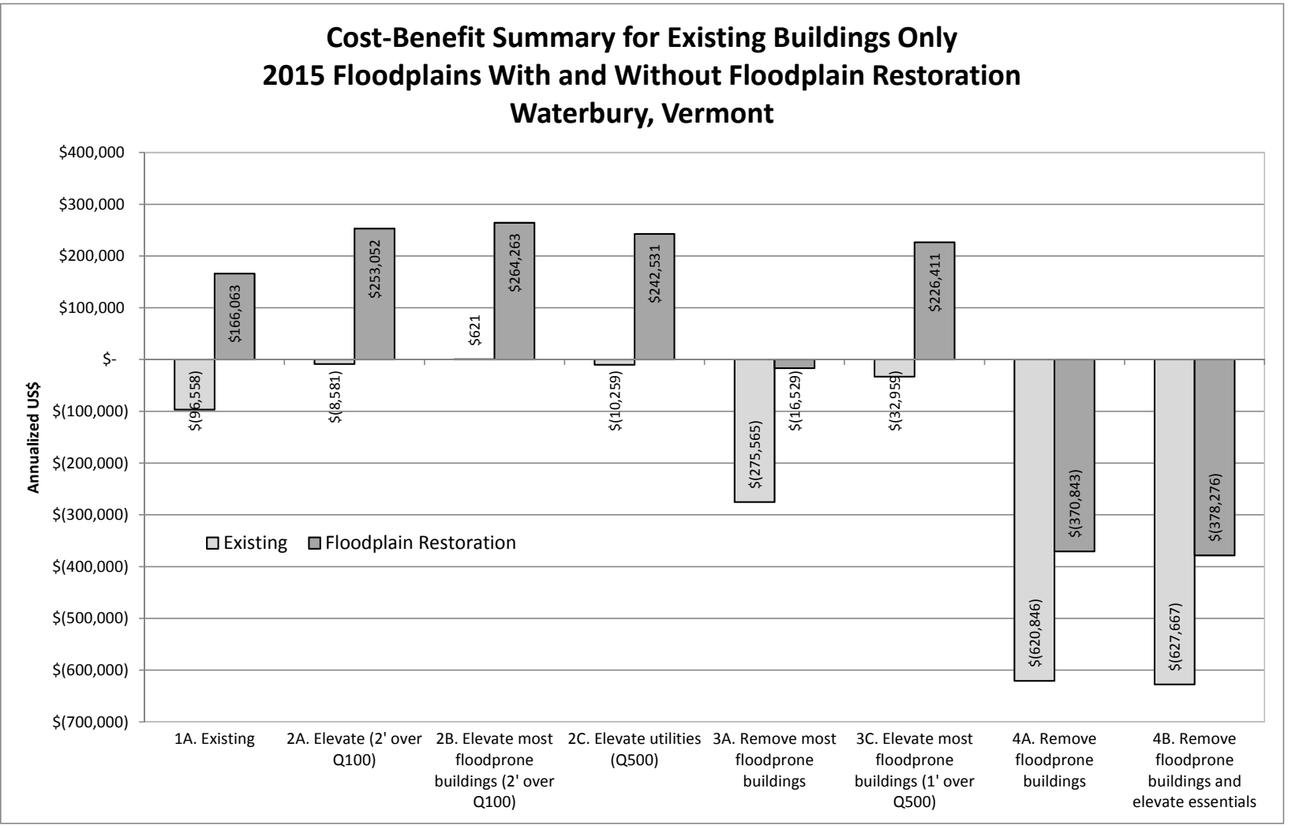


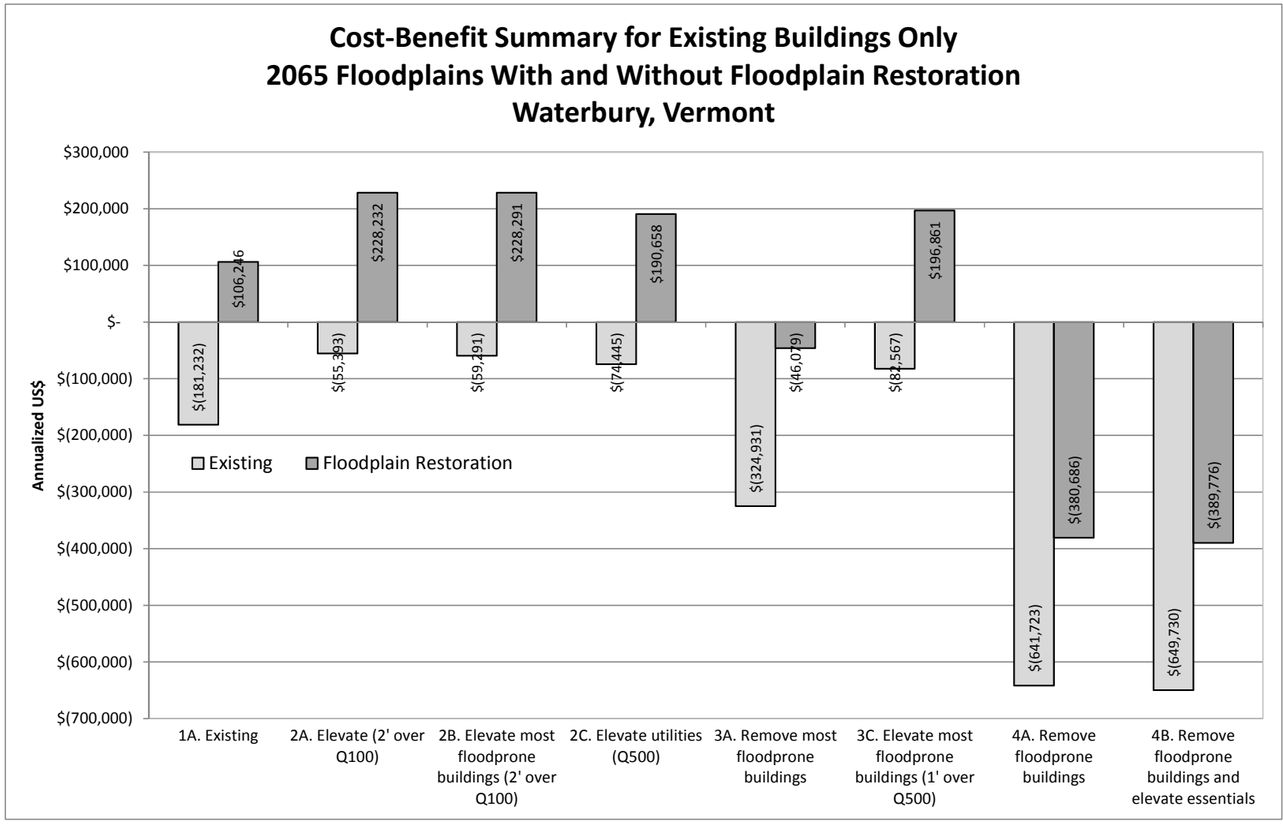


- The improvement in natural function of 38 acres of restored floodplain creates a current and future benefit that pushes the annualized balance of living in the floodplain positive for existing conditions and building or utility elevations.
- Elevating the most floodprone buildings 2 feet above the 100-year flood level (2B) leads to a net current benefit of $264,000 per year and a future benefit of $228,000 per year.
- Future costs of floodplain living all increase, yet the increase with floodplain restoration seen over 50 years is less than if floodplain restoration was not performed.
- The removal of floodprone buildings results in a net increase in cost mostly due to the loss of tax revenue. This cost is reduced with floodplain restoration due to reduction in remaining building damages. Removals would show a larger benefit if buildings were relocated or new construction took place outside of the floodplain yet within the town to sustain the tax base.

- When considering both the existing buildings and the buildout buildings in conjunction with floodplain restoration, benefits increase due to an increase in tax revenue and expanded natural floodplain function value.
- Elevating utilities to the 500-year flood level (2C) maximizes benefits of living in the floodplain due to reduced damages and the lower cost to elevate utilities than to elevate buildings.
- Elevating the most floodprone buildings to 1 foot over the 500-year flood level leads to benefits and decreases the modeled cost increase between 2015 and 2065.
- Widespread utility elevations appear to be a beneficial flood mitigation activity to reduce damages. Utility elevations can often be implemented during flood recovery and are less costly than building elevation. The down side of utility elevations is that the chance of recurring building damages is higher than for elevations.

Existing and Floodplain Restoration Cost-Benefit Summary – Waterbury, Vermont

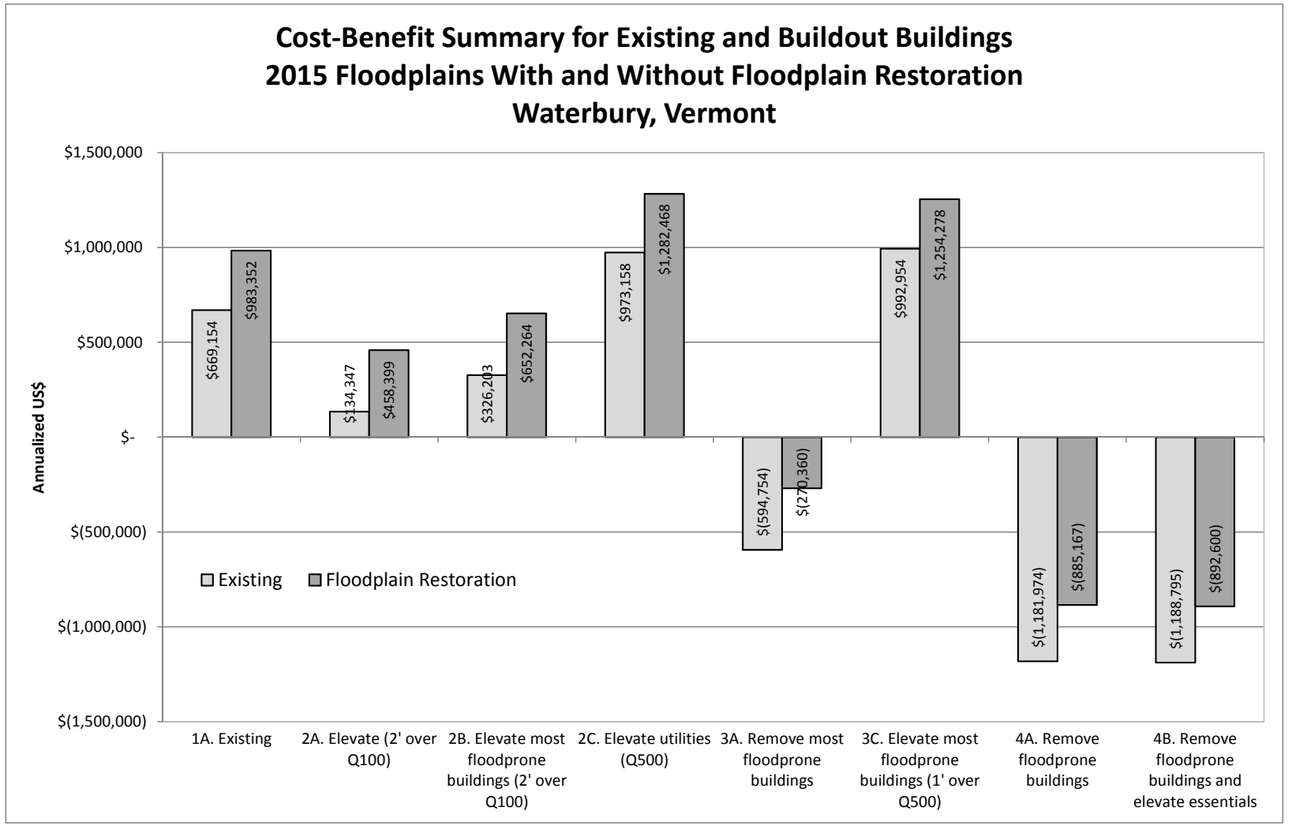


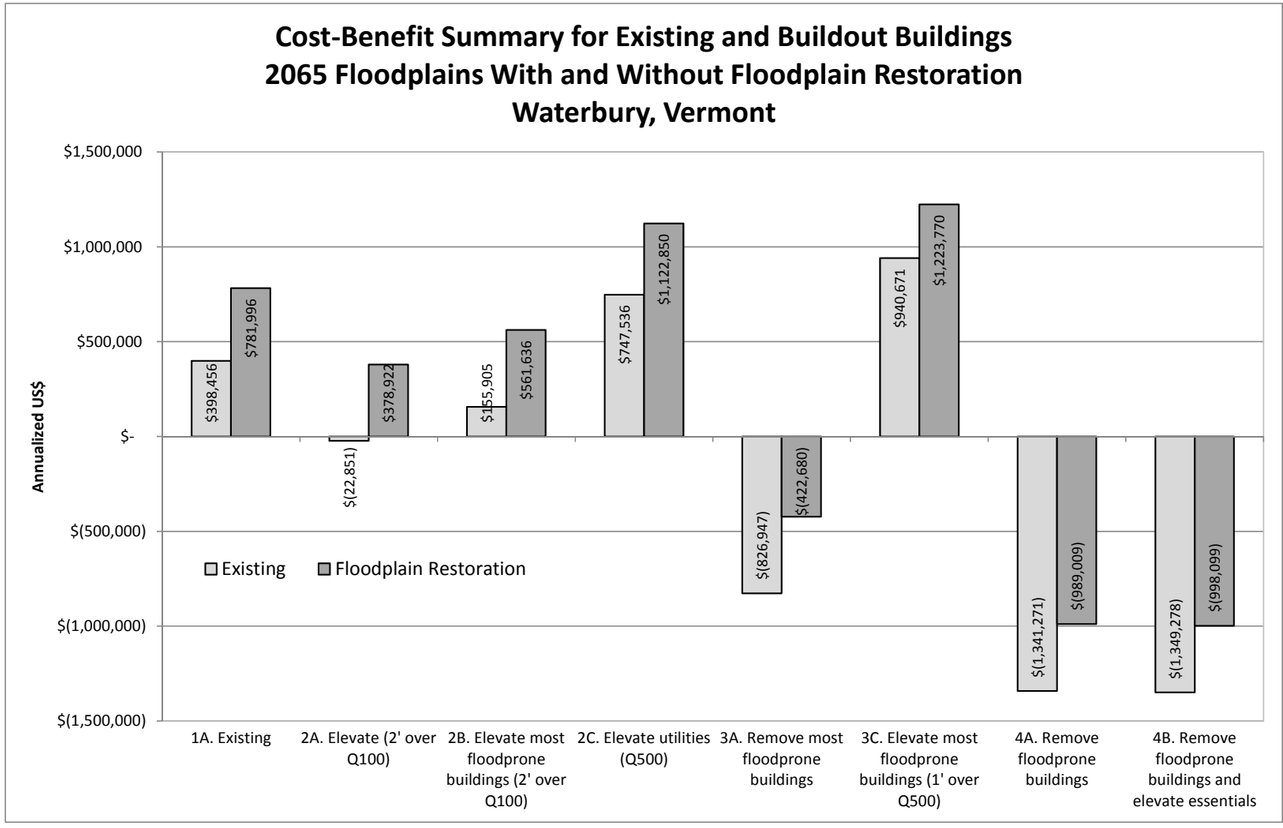


- Under existing conditions it costs $97,000 to live in the floodplain, while living in the floodplain results in a net benefit of $166,000 with floodplain restoration, or an increase of 270%.
- The improvement in natural function of 38 acres of restored floodplain creates a current and future benefit that pushes the annualized balance of living in the floodplain positive for existing conditions and elevations.
- Elevating the most floodprone buildings 2 feet above the 100-year flood level (2B) leads to a net current benefit of $264,000 per year.
- The annual loss of tax revenue is offset by the annual benefit of the expansion of ecosystem services on the restored floodplain, especially for targeted removals in the most floodprone locations.

- Under future conditions in 2065 it costs $181,000 to live in the floodplain, while living in the floodplain results in a net benefit of $106,000 with floodplain restoration, or an increase of 160%.
- The higher costs of future conditions is due to the increase in future damages associated with larger future floods.
- Elevating the buildings in the 500-year floodplain 2 feet over the 100-year flood (2A) leads to a maximum net future benefit of $228,000 per year.
- Floodplain restoration reduces future damages.

Existing and Floodplain Restoration Cost-Benefit Summary – Waterbury, Vermont





- When considering existing and buildout buildings, living in the floodplain results in a net annual benefit of $669,000 and a net annual benefit of $983,000 with floodplain restoration, or an increase of 45%.
- When considering both the existing buildings and the buildout buildings in conjunction with floodplain restoration, benefits increase due to an increase in tax revenue and expanded natural floodplain function value.
- Elevating utilities to the 500-year flood level (2C) leads to a maximum net current benefit of $1.3 million per year with floodplain restoration.

- Under future conditions in 2065 when considering existing and buildout buildings, living in the floodplain results in a net annual benefit of $398,000 and a net annual benefit of $782,000 with floodplain restoration, or an increase of 96%.
- The lower benefits of future conditions compared to today's values are due to the increase in future damages beyond current conditions associated with larger future floods.
- Elevating the most floodprone buildings 1 foot over the 500-year flood (3C) leads to a net future annual benefit of $941,000 per year without floodplain restoration and $1.2 million with floodplain restoration
- Floodplain restoration reduces future damages.

Cost-Benefit Summary – Existing/Buildout for Willsboro, New York

EX	Floodplain Management Scenario		Ecosystem Services		Buildout/Conservation		Flood Mitigation		Flood Damages			Flood Insurance	Balance	Δ	Future Flood Damages (2065)			Balance	Δ
	ID	Description	Δ Value ($/yr)	Description	Δ Value ($)	Δ Tax Value ($/yr)	Description	Cost ($/yr)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	Δ Premium ($/yr)	($ 2015)	($ 2015)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	($ 2065)	($ 2065)
EX	1A	Existing condition with updated floodplain. (21 buildings damaged in the 500-year floodplain)	$ -	Base value of naturally functioning land in 500-year floodplain = $941,774.	$ -	$ -	None	$ -	$ (1,578)	$ (1,201)	$ (747)	$ -	$ (3,526)	$ -	$ (5,769)	$ (5,457)	$ (4,026)	$ (15,251)	$ -
ELEVATE	2A	Elevate (14) existing buildings in the 500-year floodplain to 2 feet above the 100-year flood level.	$ -	No change from base value upon building elevation.	$ 435,420	$ 3,366	Elevate 14 buildings.	$ (42,000)	$ (531)	$ (453)	$ (192)	$ 1,960	$ (37,851)	$ (34,325)	$ (2,680)	$ (2,185)	$ (1,490)	$ (43,030)	$ (27,779)
	2B	Elevate (6) existing buildings that are most prone to flooding (see map) to 2 feet above the 100-year flood level.	$ -	No change from base value upon building elevation.	$ 186,609	$ 1,442	Elevate 6 buildings.	$ (18,000)	$ (731)	$ (691)	$ (348)	$ 840	$ (17,488)	$ (13,962)	$ (3,482)	$ (3,526)	$ (2,278)	$ (25,003)	$ (9,752)
	2C	Elevate utilities in all (21) existing buildings in the floodplain to the 500-year flood elevation.	$ -	No change from base value upon utility elevation.	$ 217,710	$ 1,683	Elevate utilities in 21 buildings.	$ (8,400)	$ (708)	$ (1,201)	$ (747)	$ 504	$ (8,869)	$ (5,343)	$ (2,926)	$ (5,457)	$ (4,026)	$ (18,621)	$ (3,370)
AVOIDANCE AND NO FILL	3A	Remove (7) existing buildings that are most prone to flooding.	$ 2,853	Increase of ecosystem services on naturally vegetated land with removals.	$ (1,805,000)	$ (13,953)	Remove 7 buildings.	$ (4,200)	$ (495)	$ (484)	$ (357)	$ 2,800	$ (13,836)	$ (10,310)	$ (2,707)	$ (3,031)	$ (2,181)	$ (20,418)	$ (5,167)
	3C	Elevate (4) existing buildings to 1 foot above the 500-year flood elevation upon rebuild of the most floodprone buildings	$ -	No change from base value upon building elevation.	$ 124,406	$ 962	Elevate 4 buildings.	$ (12,000)	$ (777)	$ (719)	$ (365)	$ 560	$ (12,339)	$ (8,812)	$ (3,704)	$ (3,565)	$ (2,240)	$ (19,988)	$ (4,736)
EXTREME AVOIDANCE	4A	Remove (15) existing buildings that are prone to flooding (see map).	$ 6,522	Increase of ecosystem services on naturally vegetated land with removals.	$ (4,715,000)	$ (36,447)	Remove 15 buildings.	$ (9,000)	$ (131)	$ (113)	$ -	$ 6,000	$ (33,169)	$ (29,643)	$ (532)	$ (742)	$ -	$ (34,199)	$ (18,948)
	4B	Remove (15) existing buildings that are prone to flooding, and elevate essential buildings and select historic structures following damages selected to remain (same as 4A).	$ 6,522	Increase of ecosystem services on naturally vegetated land with removals.	$ (4,715,000)	$ (36,447)	Remove 15 buildings.	$ (9,000)	$ (131)	$ (113)	$ -	$ 6,000	$ (33,169)	$ (29,643)	$ (532)	$ (742)	$ -	$ (34,199)	$ (18,948)

BO	Floodplain Management Scenario		Ecosystem Services		Buildout/Conservation		Flood Mitigation		Flood Damages			Flood Insurance	Balance	Δ	Future Flood Damages (2065)			Balance	Δ
	ID	Description	Δ Value ($/yr)	Description	Δ Value ($)	Δ Tax Value ($/yr)	Description	Cost ($)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	Premium ($/yr)	($ 2015)	($ 2015)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	($ 2065)	($ 2065)
EX	1B	Existing condition with updated floodplains and full buildout (5 SF residential, 5 MF residential, and 6 commercial buildings). (28 buildings damaged in the 500-year floodplain)	$ (16,304)	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 9,886,000	$ 76,419	None	$ -	$ (5,076)	$ (3,389)	$ (2,227)	$ (6,400)	$ 43,023	$ -	$ (23,193)	$ (18,608)	$ (14,086)	$ (2,173)	$ -
ELEVATE	2A	Elevate (14) existing buildings and (11) buildout buildings in the 500-year floodplain to 2 feet above the 100-year flood level.	$ (16,304)	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 6,035,420	$ 46,654	Elevate 25 buildings.	$ (75,000)	$ (1,929)	$ (1,061)	$ (424)	$ 3,500	$ (44,563)	$ (87,586)	$ (11,426)	$ (6,406)	$ (3,373)	$ (62,356)	$ (60,183)
	2B	Elevate (6) existing buildings that are most prone to flooding and (10) new buildout buildings in the existing 500-year floodplain to 2 feet above the 100-year flood level.	$ (16,304)	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 2,086,609	$ 16,129	Elevate 16 buildings.	$ (48,000)	$ (2,152)	$ (1,357)	$ (651)	$ 2,240	$ (50,095)	$ (93,118)	$ (12,360)	$ (8,067)	$ (4,549)	$ (70,911)	$ (68,738)
	2C	Elevate utilities in all (21) existing buildings and all (16) buildout buildings in the 500-year flood elevation.	$ (16,304)	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 10,103,710	$ 78,102	Elevate utilities in 37 buildings.	$ (14,800)	$ (2,758)	$ (3,396)	$ (2,227)	$ 2,648	$ 41,266	$ (1,757)	$ (13,306)	$ (18,658)	$ (14,086)	$ 3,595	$ 5,768
AVOIDANCE AND NO FILL	3A	Remove (7) existing buildings that are most prone to flooding and (9) buildout buildings.	$ 6,522	Increase of ecosystem services on naturally vegetated land with removals.	$ (3,655,000)	$ (28,253)	Remove 16 buildings.	$ (9,600)	$ (1,364)	$ (1,749)	$ (1,837)	$ 6,400	$ (29,881)	$ (72,904)	$ (8,580)	$ (11,866)	$ (12,242)	$ (57,619)	$ (55,446)
	3C	Elevate (4) existing buildings and (7) buildout buildings to 1 foot above the 500-year flood elevation upon rebuild of most floodprone buildings	$ (16,304)	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 342,115.71	$ 2,645	Elevate 11 buildings.	$ (33,000)	$ (2,283)	$ (2,192)	$ (1,844)	$ 1,540	$ (51,439)	$ (94,462)	$ (14,195)	$ (13,947)	$ (12,301)	$ (85,563)	$ (83,390)
EXTREME AVOIDANCE	4A	Remove (15) existing buildings and (11) buildout buildings that are prone to flooding.	$ 10,598	Increase of ecosystem services on naturally vegetated land with removals.	$ (7,445,000)	$ (57,550)	Remove 26 buildings.	$ (15,600)	$ (779)	$ (933)	$ (939)	$ 10,400	$ (54,803)	$ (97,826)	$ (4,763)	$ (6,227)	$ (6,054)	$ (69,196)	$ (67,024)
	4B	Remove (15) existing buildings and (11) buildout buildings that are prone to flooding, and elevate essential buildings and select historic structures following damages selected to remain (same as 4A).	$ 10,598	Increase of ecosystem services on naturally vegetated land with removals.	$ (7,445,000)	$ (57,550)	Remove 26 buildings.	$ (15,600)	$ (779)	$ (933)	$ (939)	$ 10,400	$ (54,803)	$ (97,826)	$ (4,763)	$ (6,227)	$ (6,054)	$ (69,196)	$ (67,024)

Ecosystem Value Notes

Assume naturally functioning land loss (gain) per added (removed) building is equal to average building footprint + 25% for residential (0.05 acres) and commercial (0.25 acres).
Assume land conversion between developed and combination of forest and village greenspace for average ecosystem service value of $8,152/acre/yr .

Buildout/Conservation Notes

EX = existing building stock and BO = maximum buildout building stock.
Willsboro taxable properties = $343,703,785
The portion of the taxable properties in the current 100-year floodplain is $830,800 (0.2%). Use as approximate base value for 10-year and 50-year floodplains.
The portion of the taxable properties in the future 100-year floodplain is $1,451,400 (0.04%). Use as approximate base value for Irene and 500-year floodplains.
Tax rate taken as 0.773% that is the sum of all applicable taxes in the floodplain area districts (includes county, general, highway, fire, light, and water).
Costs for building construction for buildout not included.
Assume 15% increase in value and tax revenue for elevated utilities and a 30% increase for elevated buildings.

Mitigation Notes

Assume $20,000 to elevate utilities and $150,000 to elevate building.
Assume $30,000 to remove building and restore natural vegetation.
Mitigation cost divided by 50 to estimate per year value over a 50-year time period.
Costs for building acquisition for removals not included.

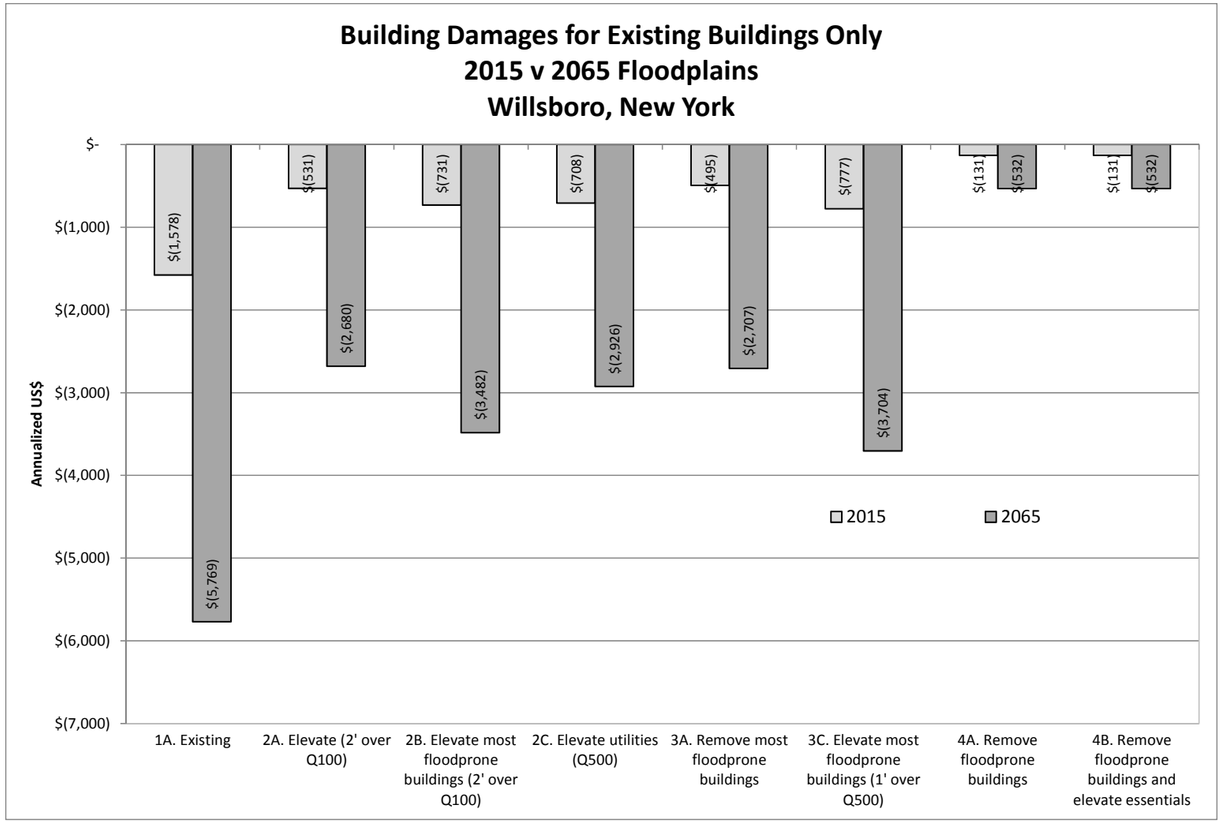
Flood Insurance Notes

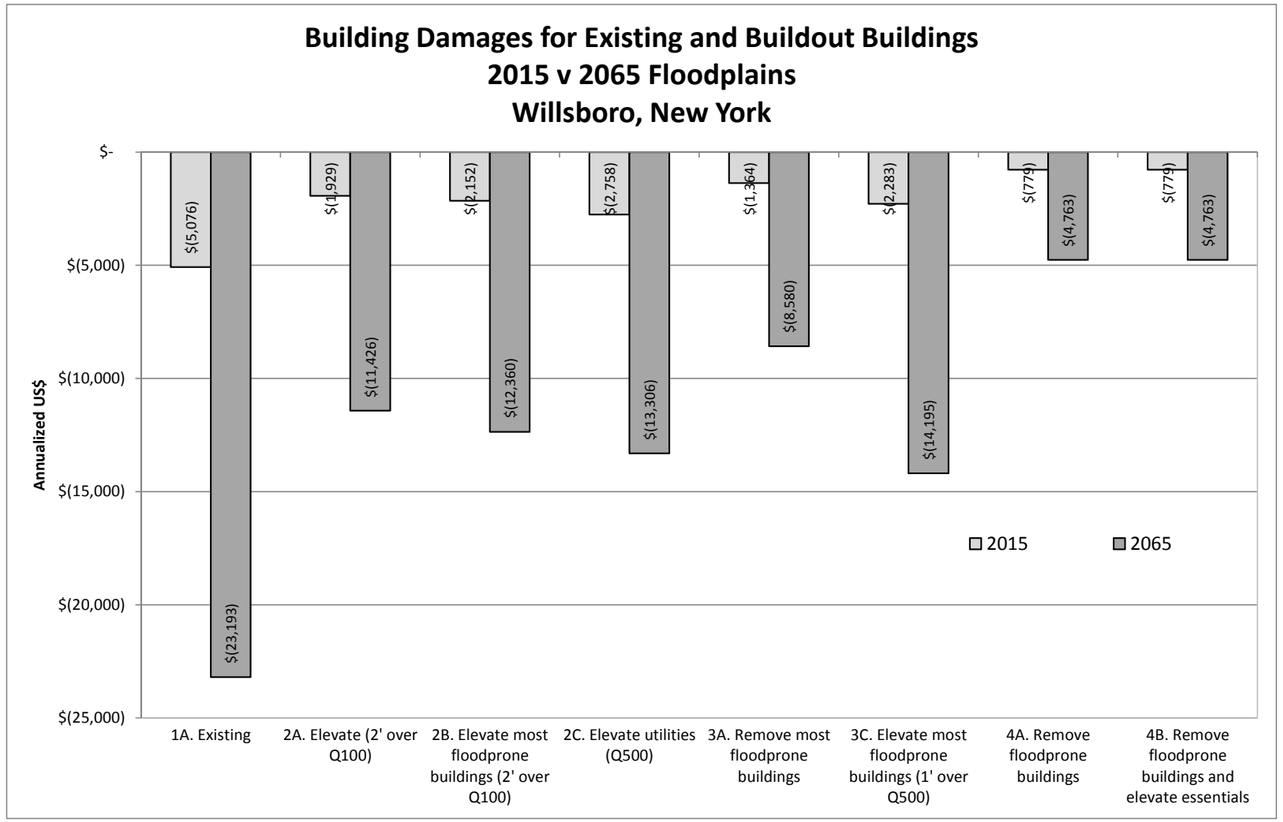
Current total premium for the Town = $26,745 per year that includes mandatory and non-mandatory policies most of which are pre-firm, flat rate policies.
Typical premium taken as $400 per year that is the average post-firm premium of the 4 policies in the Town.
Assume flood insurance carried (eliminated) for new (removed) buildings ($400/yr) and reduced for elevated buildings (-35% or -$140/yr) or utilities (-6% or -$24/yr).

Future Damages

The 2065 balance considers future flood damages while other values remain in today's currency.

Existing and Future Building Damages – Willsboro, New York

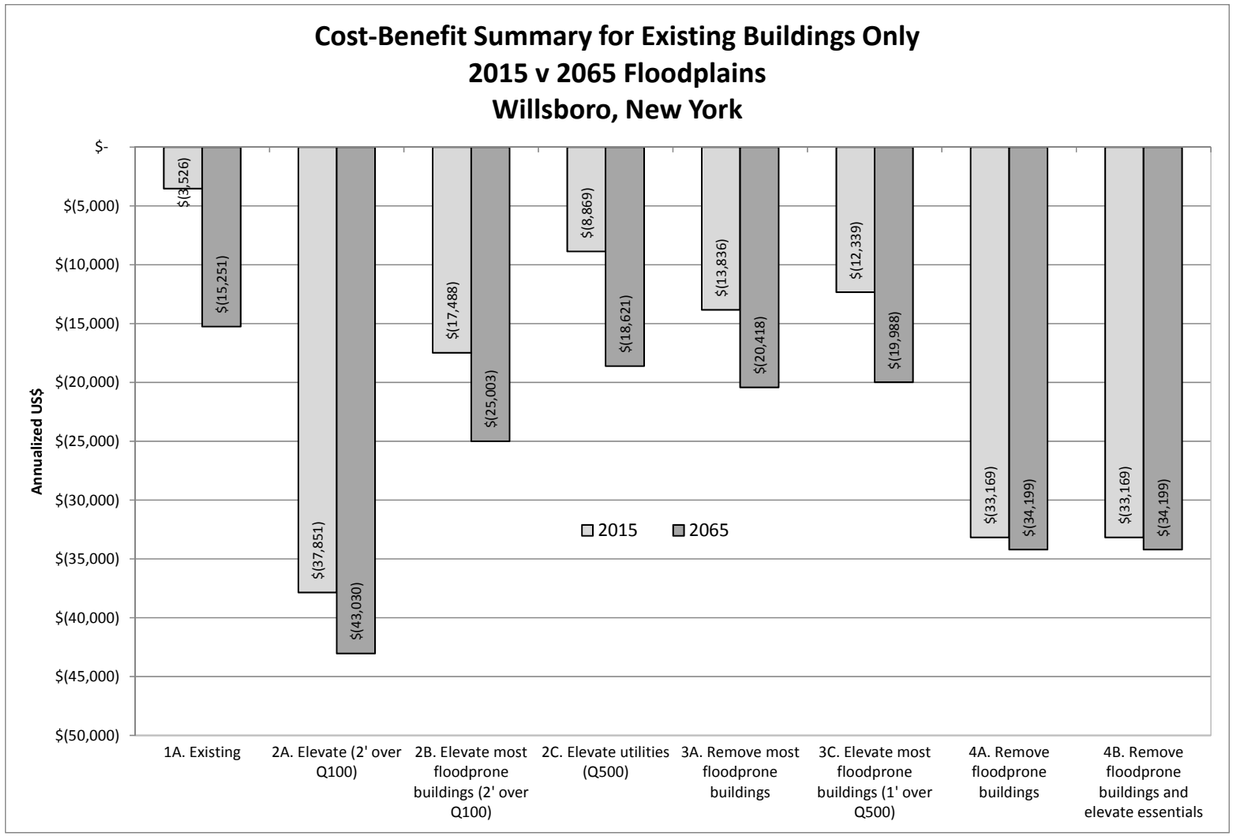


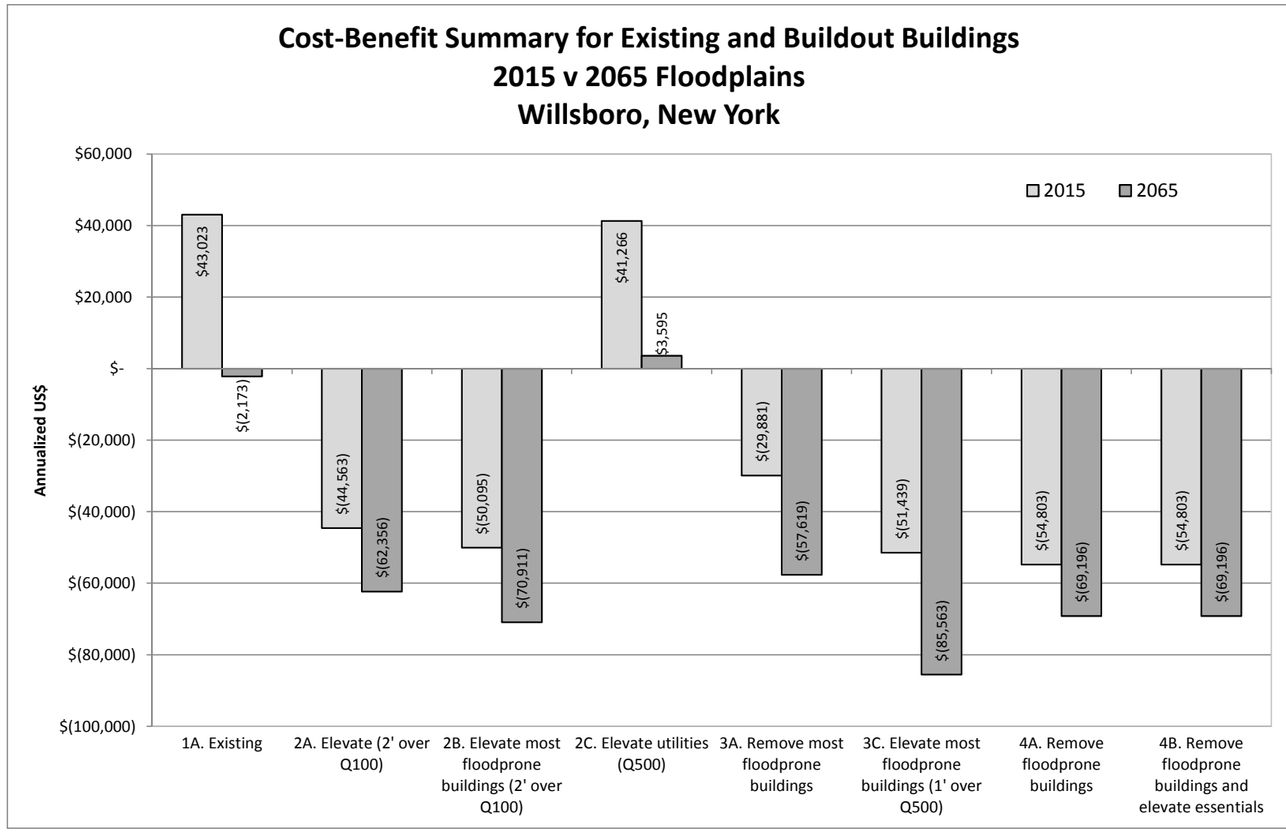


- Existing annualized building damages are $1,600 and future annualized building damages are $5,800.
- Building damages, along with loss of contents and inventory (not shown here), decrease as mitigation strategies get more aggressive such as from elevating to removing floodprone buildings. Avoidance is the best way to limit building damages.
- Future damages increase due to predicted larger floodplains and deeper flood levels under all mitigation strategies.
- Removing floodprone buildings reduces future damage levels below today's levels.

- When considering both the existing buildings and the buildout buildings, damages increase due to the presence of more buildings that are susceptible to flooding when placed on the land following current local floodplain ordinances.
- The increased building damages are reduced with flood mitigation strategies such as removal of the most floodprone structures and elevations.
- Removal of the floodprone buildings (4A), and avoiding building in these locations, reduces damages the most with an increasing building stock.
- Future damages increase due to predicted larger floodplains and deeper flood levels under all mitigation strategies.

Existing and Future Cost-Benefit Summary – Willsboro, New York





- Summarizing ecosystem service change, changes in tax revenue, the cost of flood mitigation activities, flood damages, and changes in flood insurance premiums indicates that living in the floodplain today costs $3,500 per year while living in the floodplain in 2065 will cost $15,300 per year.
- The high cost to implement mitigation strategies relative to the damage reduction benefits creates a net loss for living in the floodplain under existing conditions and all mitigation strategies.
- Future costs of floodplain living all increase due to predicted larger floodplains and deeper flood levels under all mitigation strategies.
- The widespread removals of floodprone buildings show a net increase in cost mostly due to the loss of tax revenue. Removals would show a larger benefit if buildings were relocated or new construction took place outside of the floodplain yet within the Town to sustain the tax base.

- When considering both the existing buildings and the buildout buildings, benefits increase due to an increase in tax revenue with the new building stock.
- Under all mitigation strategies the trajectory of larger floods leads to increased future damages and growing costs.
- Elevating utilities leads to the largest benefit with the increased building stock due to the relatively low implementation cost compared to the benefits.

Cost-Benefit Summary – Floodplain Restoration for Willsboro, New York

REX	Floodplain Management Scenario		Ecosystem Services		Buildout/Conservation		Flood Mitigation		Flood Damages			Flood Insurance	Balance	Δ	Future Flood Damages (2065)			Balance	Δ
	ID	Description	Δ Value ($/yr)	Description	Δ Value ($)	Δ Tax Value ($/yr)	Description	Cost ($/yr)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	Δ Premium ($/yr)	($ 2015)	($ 2015)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	($ 2065)	($ 2065)
EX	1A	Existing condition with updated floodplain. (21 buildings damaged in the 500-year floodplain)	$ 7,335	Base value of naturally functioning land in 500-year floodplain = $941,774.	$ -	$ -	None	$ (15,000)	$ (916)	$ (555)	$ (222)	$ -	$ (9,358)	$ -	$ (4,113)	$ (2,978)	$ (1,474)	$ (16,230)	$ -
ELEVATE	2A	Elevate (14) existing buildings in the 500-year floodplain to 2 feet above the 100-year flood level.	$ 7,335	No change from base value upon building elevation.	$ 435,420	$ 3,366	Elevate 14 buildings.	$ (57,000)	$ (411)	$ (284)	$ (160)	$ 1,960	$ (45,194)	$ (35,836)	$ (2,408)	$ (1,749)	$ (1,205)	$ (49,702)	$ (33,471)
	2B	Elevate (6) existing buildings that are most prone to flooding (see map) to 2 feet above the 100-year flood level.	$ 7,335	No change from base value upon building elevation.	$ 186,609	$ 1,442	Elevate 6 buildings.	$ (33,000)	$ (544)	$ (434)	$ (222)	$ 840	$ (24,583)	$ (15,224)	$ (2,900)	$ (2,596)	$ (1,474)	$ (30,353)	$ (14,123)
	2C	Elevate utilities in all (21) existing buildings in the floodplain to the 500-year flood elevation.	$ 7,335	No change from base value upon utility elevation.	$ 217,710	$ 1,683	Elevate utilities in 21 buildings.	$ (23,400)	$ (422)	$ (555)	$ (222)	$ 504	$ (15,077)	$ (5,719)	$ (2,076)	$ (2,978)	$ (1,474)	$ (20,406)	$ (4,176)
AVOIDANCE AND NO FILL	3A	Remove (7) existing buildings that are most prone to flooding.	$ 10,188.20	Increase of ecosystem services on naturally vegetated land with removals.	$ (1,805,000)	$ (13,953)	Remove 7 buildings.	$ (19,200)	$ (412)	$ (358)	$ (222)	$ 2,800	$ (21,156)	$ (11,798)	$ (2,353)	$ (2,374)	$ (1,474)	$ (26,366)	$ (10,135)
	3C	Elevate (4) existing buildings to 1 foot above the 500-year flood elevation upon rebuild of the most floodprone buildings	$ 7,335	No change from base value upon building elevation.	$ 124,406	$ 962	Elevate 4 buildings.	$ (27,000)	$ (588)	$ (449)	$ (222)	$ 560	$ (19,403)	$ (10,044)	$ (3,171)	$ (2,685)	$ (1,474)	$ (25,475)	$ (9,244)
EXTREME AVOIDANCE	4A	Remove (15) existing buildings that are prone to flooding (see map).	$ 13,857	Increase of ecosystem services on naturally vegetated land with removals.	$ (4,715,000)	$ (36,447)	Remove 15 buildings.	$ (24,000)	$ (118)	$ (103)	$ -	$ 6,000	$ (40,811)	$ (31,453)	$ (510)	$ (700)	$ -	$ (41,801)	$ (25,571)
	4B	Remove (15) existing buildings that are prone to flooding, and elevate essential buildings and select historic structures following damages selected to remain (same as 4A).	$ 13,857	Increase of ecosystem services on naturally vegetated land with removals.	$ (4,715,000)	$ (36,447)	Remove 15 buildings.	$ (24,000)	$ (118)	$ (103)	$ -	$ 6,000	$ (40,811)	$ (31,453)	$ (510)	$ (700)	$ -	$ (41,801)	$ (25,571)

RBO	Floodplain Management Scenario		Ecosystem Services		Buildout/Conservation		Flood Mitigation		Flood Damages			Flood Insurance	Balance	Δ	Future Flood Damages (2065)			Balance	Δ
	ID	Description	Δ Value ($/yr)	Description	Δ Value ($)	Δ Tax Value ($/yr)	Description	Cost ($)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	Premium ($/yr)	($ 2015)	($ 2015)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	($ 2065)	($ 2065)
EX	1B	Existing condition with updated floodplains and full buildout (5 SF residential, 5 MF residential, and 6 commercial buildings). (28 buildings damaged in the 500-year floodplain)	$ (8,969)	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 9,886,000	$ 76,419	None	$ (15,000)	$ (4,864)	$ (2,831)	$ (1,616)	$ (6,400)	$ 36,738	$ -	$ (22,668)	$ (15,704)	$ (10,427)	$ (2,750)	$ -
ELEVATE	2A	Elevate (14) existing buildings and (11) buildout buildings in the 500-year floodplain to 2 feet above the 100-year flood level.	$ (8,969)	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 6,035,420	$ 46,654	Elevate 25 buildings.	$ (90,000)	$ (2,315)	$ (1,076)	$ (464)	$ 3,500	$ (52,670)	$ (89,408)	$ (13,122)	$ (6,941)	$ (3,663)	$ (72,541)	$ (69,791)
	2B	Elevate (6) existing buildings that are most prone to flooding and (10) new buildout buildings in the existing 500-year floodplain to 2 feet above the 100-year flood level.	$ (8,969)	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 2,086,609	$ 16,129	Elevate 16 buildings.	$ (63,000)	$ (2,448)	$ (1,226)	$ (525)	$ 2,240	$ (57,799)	$ (94,538)	$ (13,614)	$ (7,788)	$ (3,933)	$ (78,934)	$ (76,184)
	2C	Elevate utilities in all (21) existing buildings and all (16) buildout buildings in the 500-year flood elevation.	$ (8,969)	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 10,103,710	$ 78,102	Elevate utilities in 37 buildings.	$ (29,800)	$ (2,751)	$ (2,838)	$ (1,616)	$ 2,648	$ 34,776	$ (1,962)	$ (13,270)	$ (15,754)	$ (10,427)	$ 2,530	$ 5,280
AVOIDANCE AND NO FILL	3A	Remove (7) existing buildings that are most prone to flooding and (9) buildout buildings.	$ 13,857	Increase of ecosystem services on naturally vegetated land with removals.	$ (3,655,000)	$ (28,253)	Remove 16 buildings.	$ (24,600)	$ (1,562)	$ (1,629)	$ (1,616)	$ 6,400	$ (37,403)	$ (74,142)	$ (8,791)	$ (10,506)	$ (10,427)	$ (62,320)	$ (59,570)
	3C	Elevate (4) existing buildings and (7) buildout buildings to 1 foot above the 500-year flood elevation upon rebuild of most floodprone buildings	$ (8,969)	Reduction of ecosystem services on naturally vegetated land with buildout.	$ 342,116	$ 2,645	Elevate 11 buildings.	$ (48,000)	$ (2,496)	$ (1,974)	$ (1,616)	$ 1,540	$ (58,871)	$ (95,609)	$ (14,714)	$ (12,607)	$ (10,427)	$ (90,533)	$ (87,783)
EXTREME AVOIDANCE	4A	Remove (15) existing buildings and (11) buildout buildings that are prone to flooding.	$ 17,933	Increase of ecosystem services on naturally vegetated land with removals.	$ (7,445,000)	$ (57,550)	Remove 26 buildings.	$ (30,600)	$ (1,167)	$ (1,178)	$ (1,148)	$ 10,400	$ (63,310)	$ (100,048)	$ (6,136)	$ (7,228)	$ (6,972)	$ (80,153)	$ (77,403)
	4B	Remove (15) existing buildings and (11) buildout buildings that are prone to flooding, and elevate essential buildings and select historic structures following damages selected to remain (same as 4A).	$ 17,933	Increase of ecosystem services on naturally vegetated land with removals.	$ (7,445,000)	$ (57,550)	Remove 26 buildings.	$ (30,600)	$ (1,167)	$ (1,178)	$ (1,148)	$ 10,400	$ (63,310)	$ (100,048)	$ (6,136)	$ (7,228)	$ (6,972)	$ (80,153)	$ (77,403)

Ecosystem Value Notes

Add in value for improved floodplain function on 0.9 acres of restored floodplain upstream of Route 22 Bridge for a value of $7,335.
Assume naturally functioning land loss (gain) per added (removed) building is equal to average building footprint + 25% for residential (0.05 acres) and commercial (0.25 acres).
Assume land conversion between developed and combination of forest and village greenspace for average ecosystem service value of $8,152/acre/yr .

Buildout/Conservation Notes

REX = existing building stock and RBO = maximum buildout building stock.
Willsboro taxable properties = $343,703,785
The portion of the taxable properties in the current 100-year floodplain is $830,800 (0.2%). Use as approximate base value for 10-year and 50-year floodplains.
The portion of the taxable properties in the future 100-year floodplain is $1,451,400 (0.04%). Use as approximate base value for Irene and 500-year floodplains.
Tax rate taken as 0.773% that is the sum of all applicable taxes in the floodplain area districts (includes county, general, highway, fire, light, and water).
Costs for building construction for buildout not included.
Assume 15% increase in value and tax revenue for elevated utilities and a 30% increase for elevated buildings.

Mitigation Notes

Estimated floodplain mitigation cost of $750,000 divided by 50 to estimate 50-year time period.
Assume $20,000 to elevate utilities and $150,000 to elevate building.
Assume $30,000 to remove building and restore natural vegetation.
Mitigation cost divided by 50 to estimate per year value over a 50-year time period.
Costs for building acquisition for removals not included.

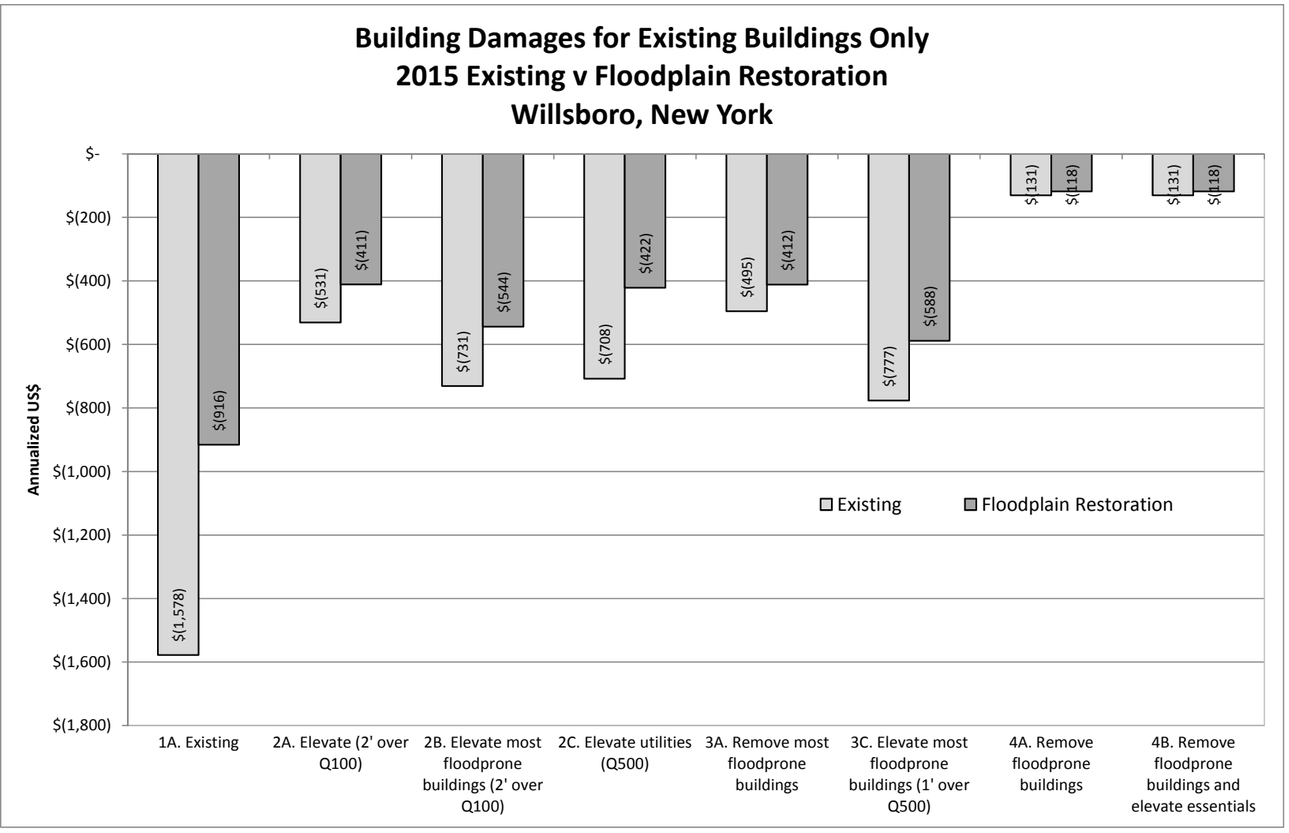
Flood Insurance Notes

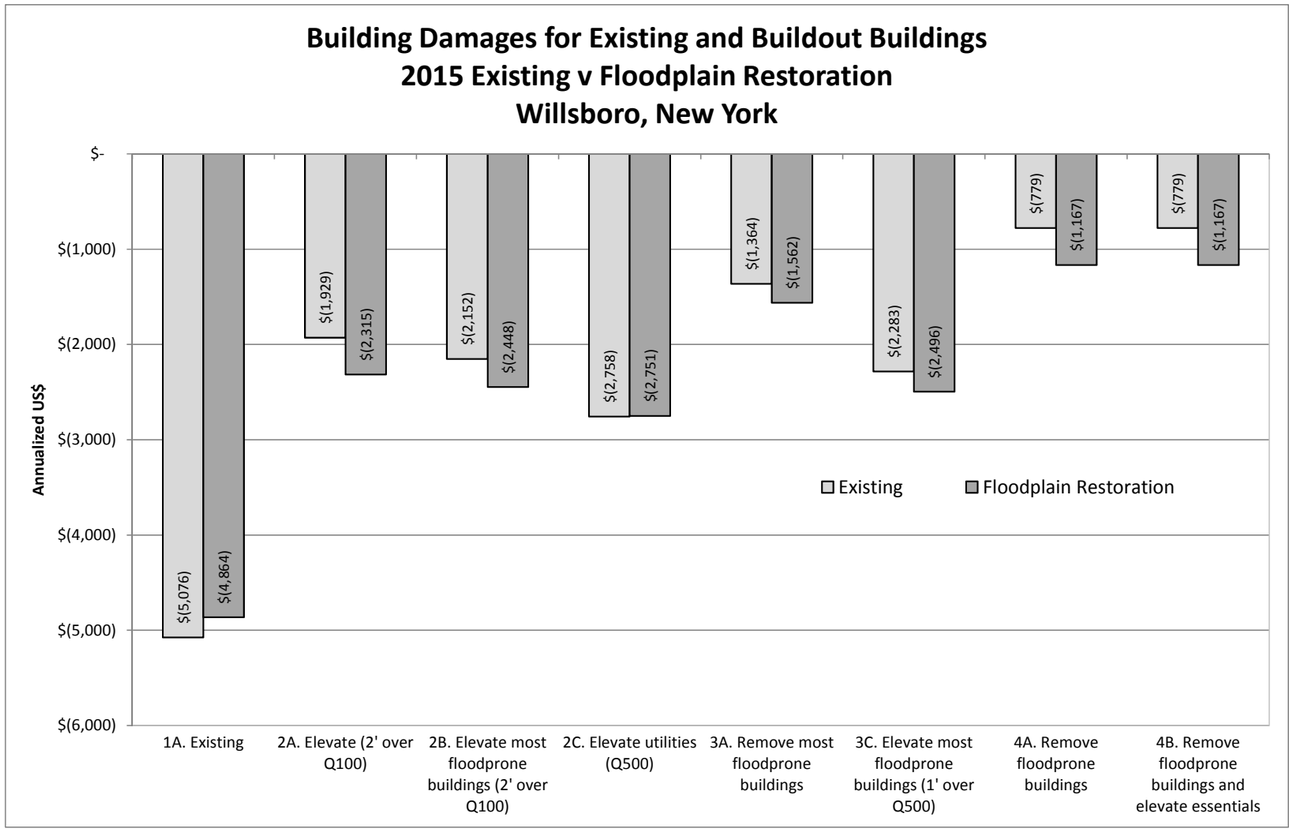
Current total premium for the Town = $26,745 per year that includes mandatory and non-mandatory policies most of which are pre-firm, flat rate policies.
Typical premium taken as $400 per year that is the average post-firm premium of the 4 policies in the Town.
Assume flood insurance carried (eliminated) for new (removed) buildings ($400/yr) and reduced for elevated buildings (-35% or -$140/yr) or utilities (-6% or -$24/yr).

Future Damages

The 2065 balance considers future flood damages while other values remain in today's currency.

2015 Existing and Floodplain Restoration Building Damages – Willsboro, New York

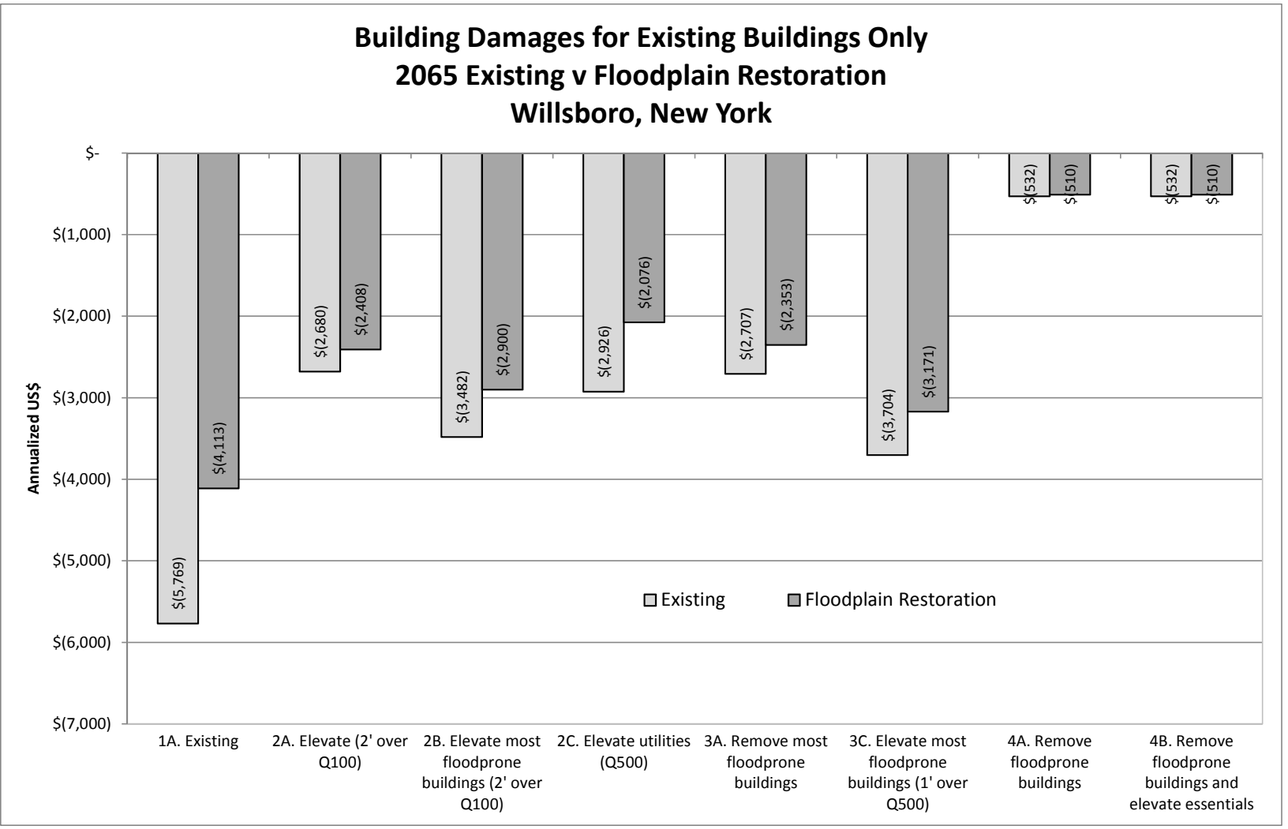


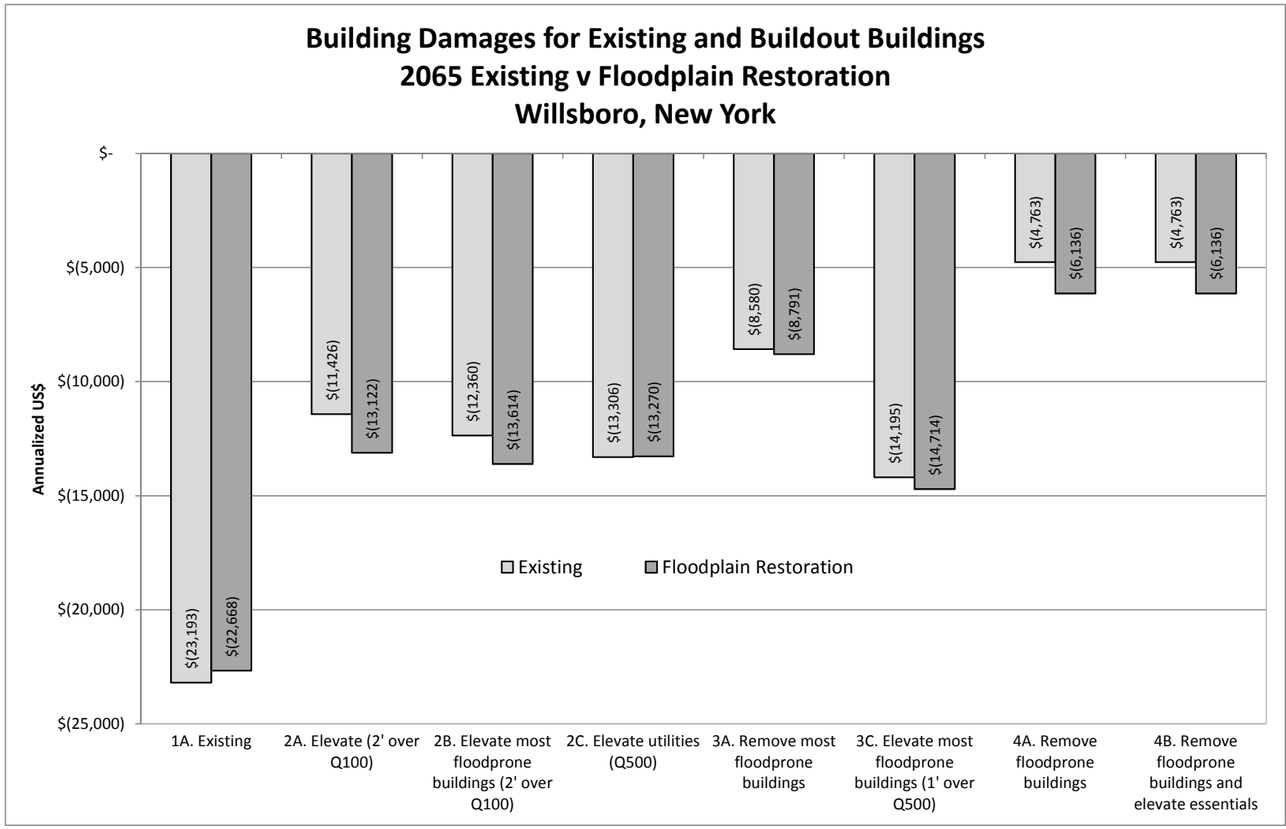


- The proposed dam removal, floodplain restoration, and building elevations decreases existing annual building damages from $1,600 to $900 (~40% damage reduction).
- The proposed dam removal, floodplain restoration, and building elevations reduces annual damages across all flood mitigation activities, and improves the effectiveness of each mitigation approach.
- Dam removal, floodplain restoration, and building elevations in conjunction with removing floodprone properties (4A) leads to the lowest building damages.
- Dam removal, floodplain restoration, and building elevations leads to a reduction of $12,300 in simulated building damages for a single modeled 100-year flood.
- The modeled alternative consists of dam removal, floodplain restoration, and building elevations upstream of the Route 22 Bridge.

- When considering both the existing buildings and the buildout buildings the proposed dam removal, floodplain restoration, and building elevations decreases existing annual building damages from $5,100 to $4,900 (~5% damage reduction).
- The unexpected result that the proposed dam removal, floodplain restoration, and building elevations leads to some increases in current annual building damages is due to the fill to elevate commercial structures on Main Street increasing local flood levels that impact added buildings. The fill is not recommended given the narrow floodplain setting to reduce damages.
- With a larger building stock the proposed dam removal, floodplain restoration, and building elevations is less effective at reducing annualized building damages in the floodplain compared to just the existing buildings.
- Dam removal, floodplain restoration, and building elevations in conjunction with removing floodprone properties (4A) leads to the lowest building damages.

2065 Existing and Floodplain Restoration Building Damages – Willsboro, New York

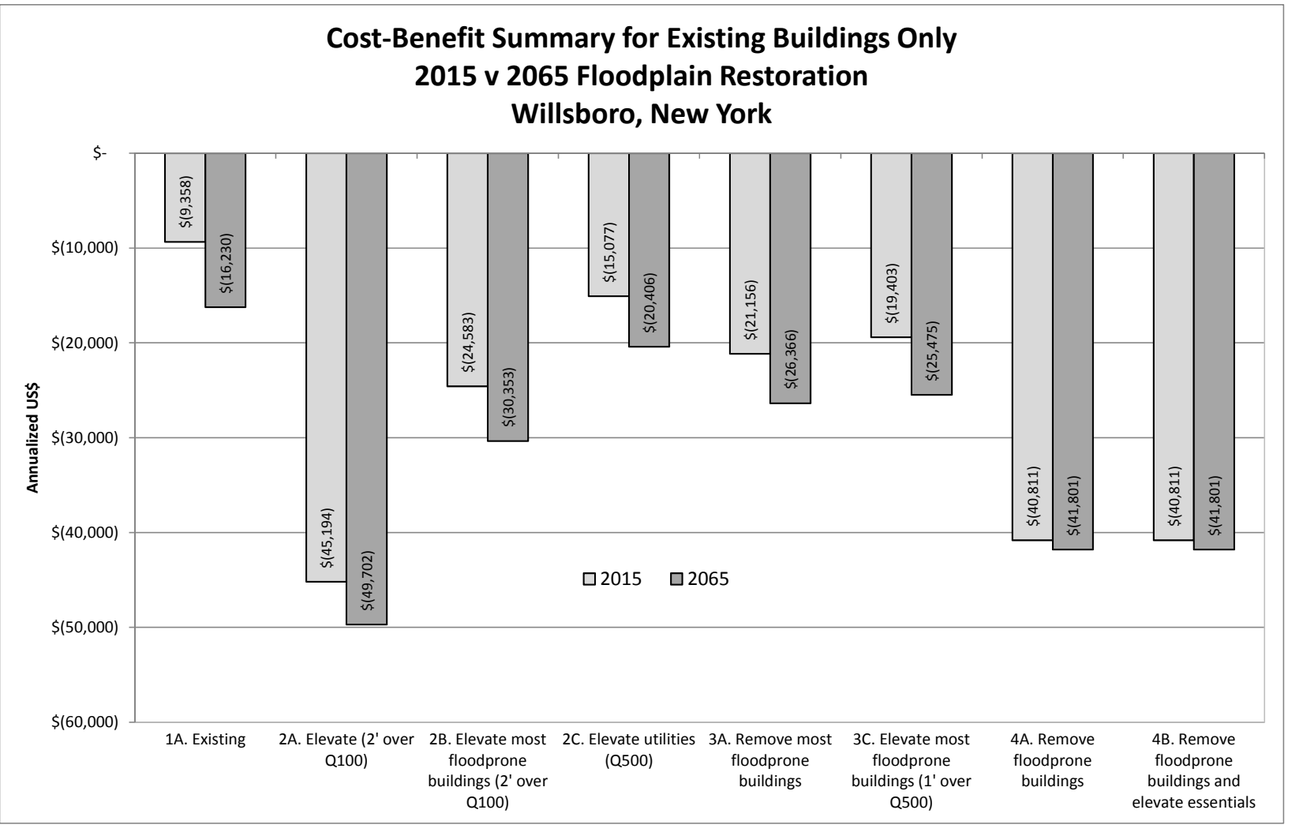


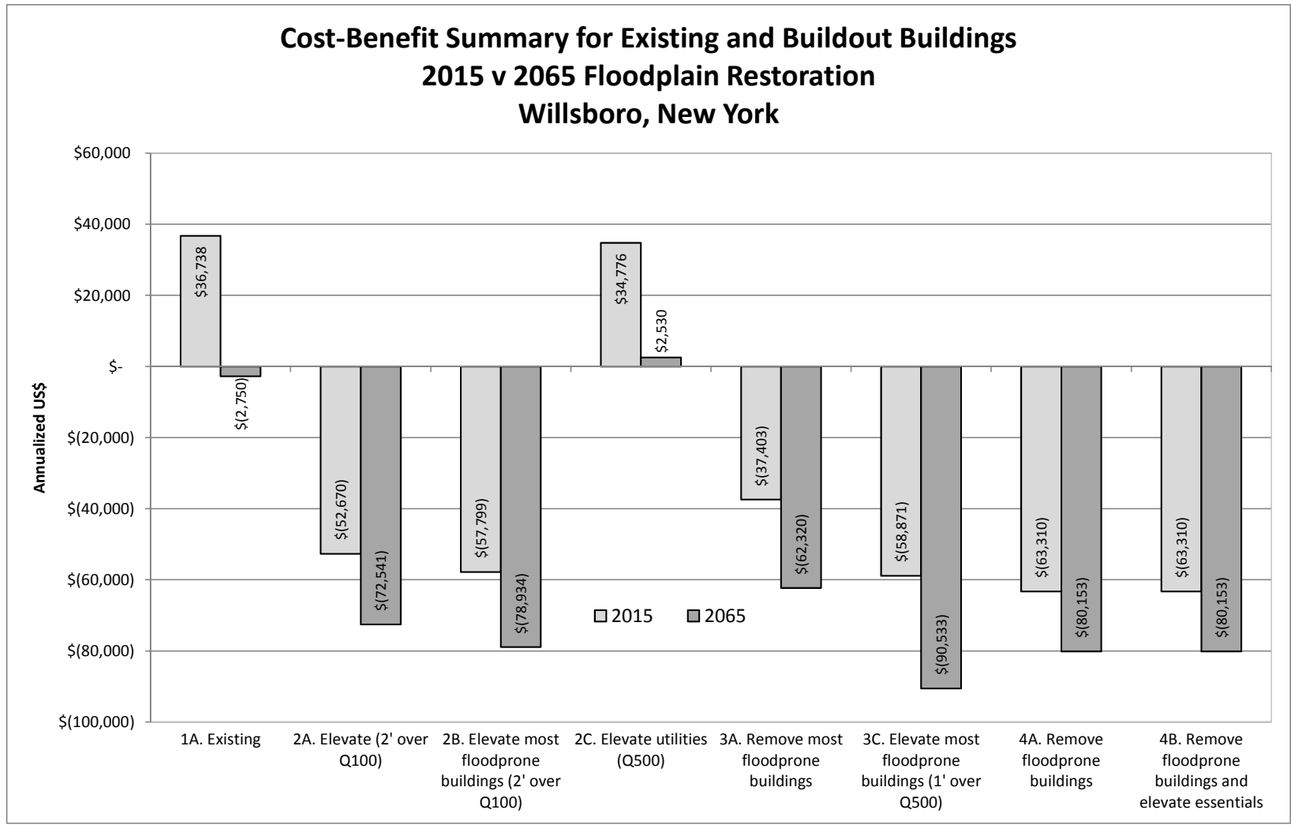


- The proposed dam removal, floodplain restoration, and building elevations decreases future annual building damages from $5,800 to $4,100 (~30% damage reduction).
- The proposed floodplain restoration reduces future annual damages across all flood mitigation activities, and improves the effectiveness of each mitigation approach.
- Floodplain restoration in conjunction with removing floodprone properties (4A) leads to the lowest building damages.
- Dam removal, floodplain restoration, and building elevations leads to a reduction of $243,000 in simulated building damages for a single modeled future 100-year flood.

- When considering both the existing buildings and the buildout buildings the proposed dam removal, floodplain restoration, and building elevations is less effective at reducing future building damages due to floodplain fill elevating local flood levels.
- The unexpected result that the proposed dam removal, floodplain restoration, and building elevations leads to some increases in annual future building damages due to the fill to elevate commercial structures on Main Street increasing local flood levels. The fill is not recommended to reduce damages.
- Dam removal, floodplain restoration, and building elevations in conjunction with removing floodprone properties (4A) leads to the lowest building damages.

Existing and Floodplain Restoration Cost-Benefit Summary – Willsboro, New York

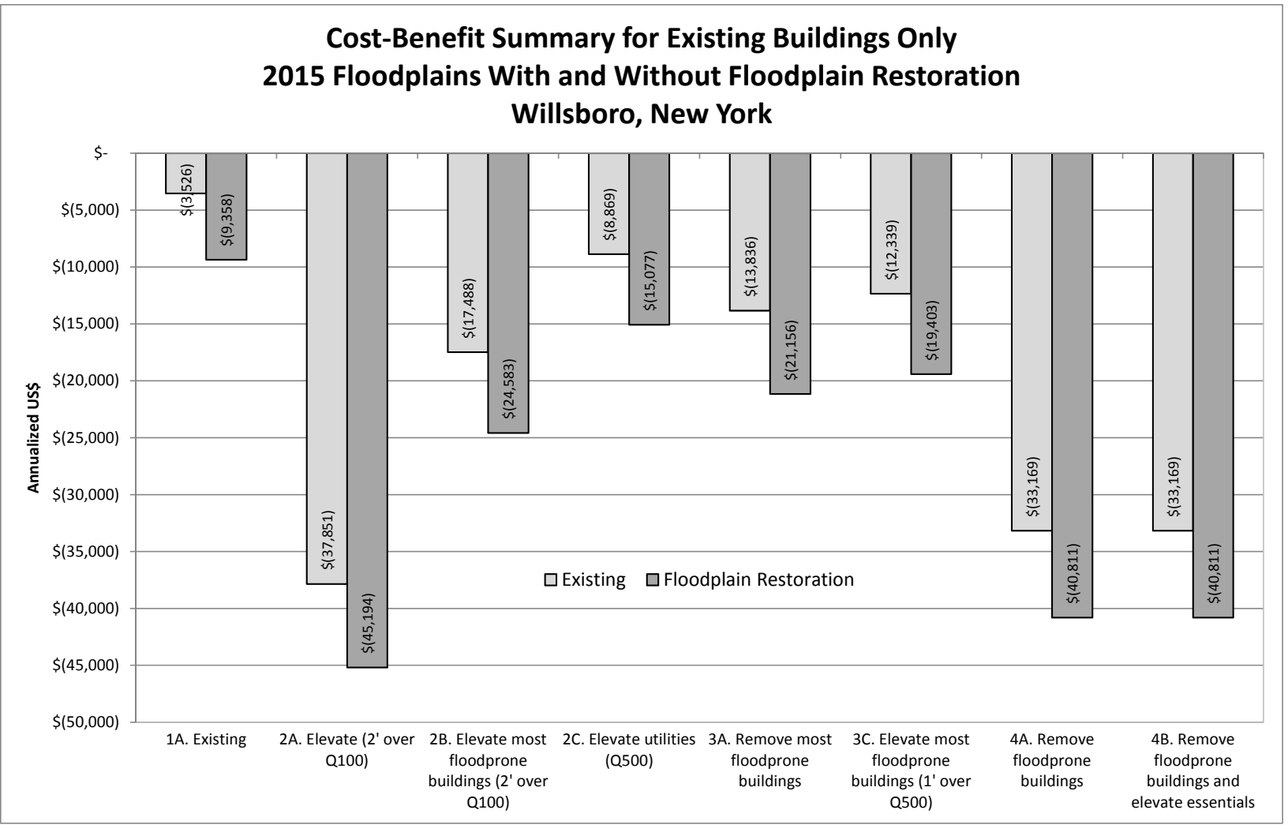


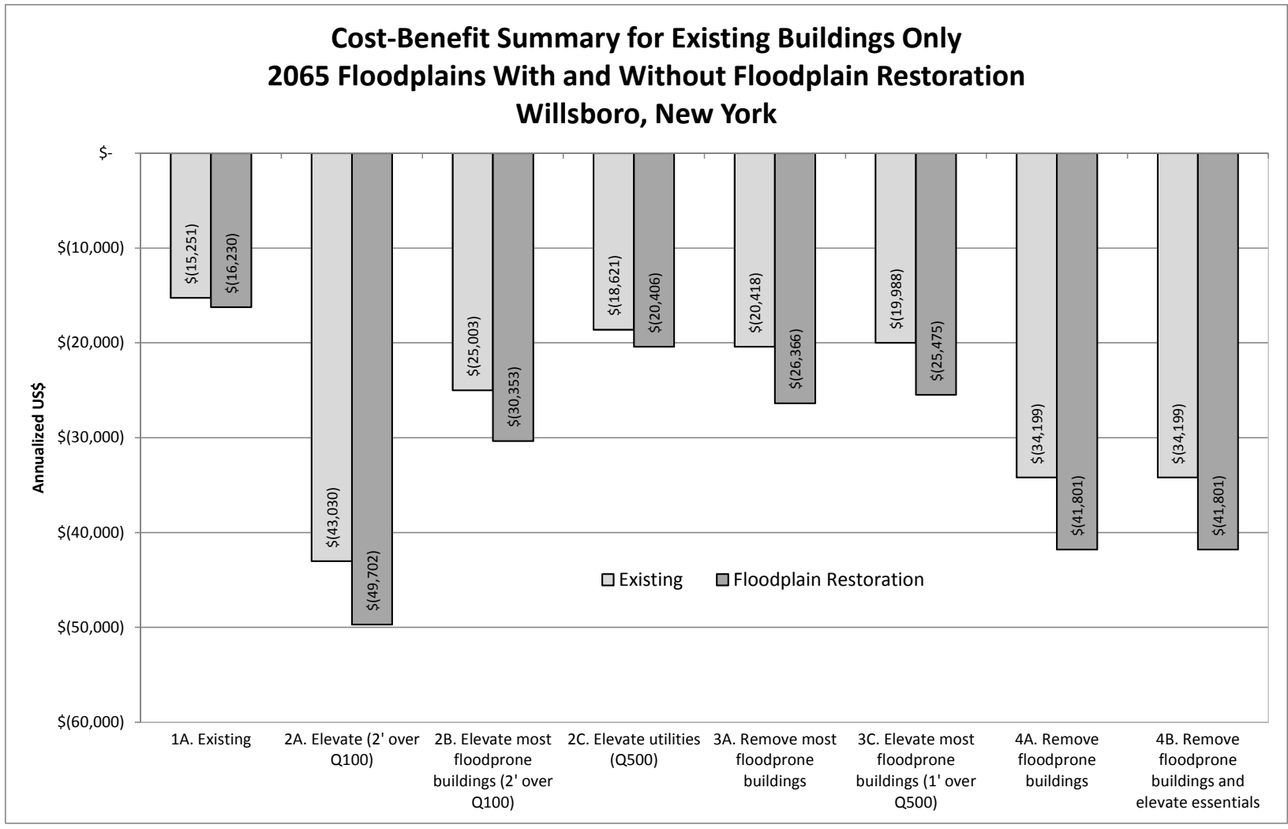


- Even with the proposed dam removal, floodplain restoration, and building elevations, there is an annual cost to pay for living in the floodplain today and in the future.
- None of the mitigation strategies reduce costs beyond existing conditions.
- Elevating utilities to the 500-year level is the best mitigation strategy, yet does not increase benefits beyond existing conditions now or in the future.
- Future costs of floodplain living all increase compared to today's costs.
- The removal of floodprone buildings show a net increase in cost mostly due to the loss of tax revenue. This cost is similar under the floodplain restoration alternative. Removals would show a larger benefit if buildings were relocated or new construction took place outside of the floodplain yet within the Town to sustain the tax base.

- When considering both the existing buildings and the buildout buildings in conjunction with dam removal, floodplain restoration, and building elevations, benefits increase due to an increase in tax revenue and expanded natural floodplain function value.
- Elevating utilities to the 500-year flood level (2C) minimizes the annual cost of living in the floodplain in the future.
- Utility elevations are less expensive than elevations, yet leave more chance of incurring future damages.

Existing and Floodplain Restoration Cost-Benefit Summary – Willsboro, New York

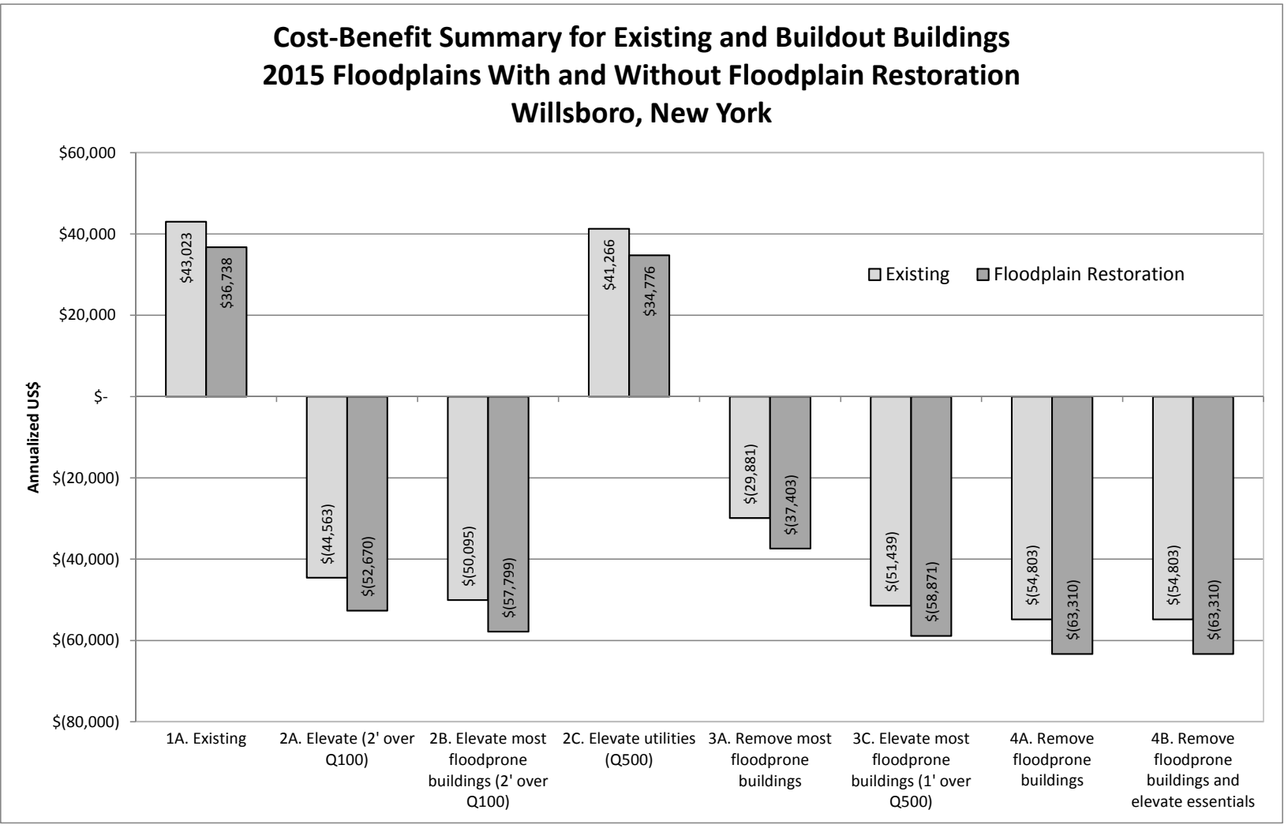


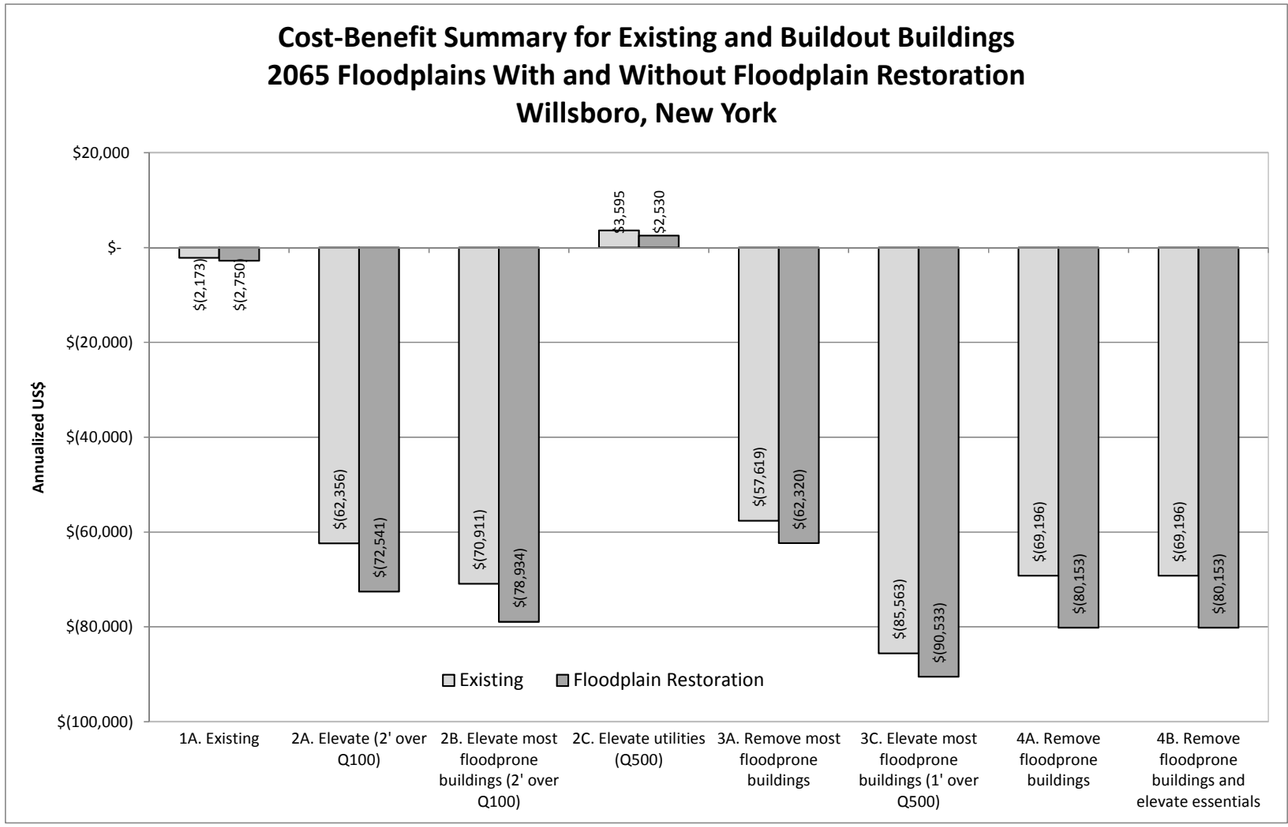


- Under existing conditions it costs $3,500 to live in the floodplain, while living in the floodplain results in a cost of $9,400 with dam removal, floodplain restoration, and elevations, or a cost increase of 170%.
- Each flood mitigation activity creates more cost with the floodplain restoration alternative than under existing conditions.
- The reduction in costs is outweighed by the increase in the cost of the mitigation activities, including the alternative to remove the dam, restore floodplain, and elevate three buildings.
- Elevating utilities to the 500-year level is the best mitigation activity, yet nothing increases benefits above existing conditions.

- Under future conditions in 2065 it costs $15,300 to live in the floodplain, while with dam removal, floodplain restoration, and elevations it costs $16,200, or a cost increase of 6%.
- The higher costs of future conditions is due to the increase in future damages beyond current conditions associated with a local increase in flood level due to fill to elevate three buildings in the narrow floodplain.
- Elevating utilities to the 500-year level is the best mitigation activity, yet nothing increases benefits above existing conditions.

Existing and Floodplain Restoration Cost-Benefit Summary – Willsboro, New York





- When considering existing and buildout buildings, living in the floodplain results in a net annual benefit of $43,000 and a net annual benefit of $36,700 with dam removal, floodplain restoration, and building elevations, or a cost increase of 15%.
- When considering both the existing buildings and the buildout buildings in conjunction with dam removal, floodplain restoration, and building elevations, benefits decrease due to the high cost of mitigation activities relative to the benefits and the loss of ecosystem service value.
- Elevating utilities to the 500-year flood level (2C) leads to a net current benefit of $41,300 per year, and $34,800 with the proposed alternative in place.

- Under future conditions in 2065 when considering existing and buildout buildings, living in the floodplain results in a net annual loss of $2,200 and a net annual loss of $2,800 with dam removal, floodplain restoration, and elevations in place.
- The fill in the proposed alternative is driving up local flood levels and damages, in addition to the cost of flood mitigation activities.
- Elevating utilities to the 500-year flood level (2C) leads to a net future benefit of $3,600 per year, and $2,500 with the proposed alternative in place.

Cost-Benefit Summary – Existing for Duxbury, Vermont

EX	Floodplain Management Scenario		Ecosystem Services		Buildout/Conservation		Flood Mitigation		Current Flood Damages (2015)			Flood Insurance	Balance	Δ	Future Flood Damages (2065)			Balance	Δ
	ID	Description	Δ Value ($/yr)	Description	Δ Value ($)	Δ Tax Value ($/yr)	Description	Cost ($/yr)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	Δ Premium ($/yr)	($ 2015)	($ 2015)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	($ 2065)	($ 2065)
EX	1A	Existing condition with updated floodplain. (40 buildings damaged in the 500-year floodplain)	$ -	Base value of naturally functioning land in 500-year floodplain	$ -	$ -	None	$ -	$ (11,429)	$ (4,412)	$ -	$ -	$ (15,841)	$ -	$ (22,028)	$ (8,485)	$ -	$ (30,513)	$ -
ELEVATE	2A	Elevate (34) existing buildings in the 500-year floodplain to 2 feet above the 100-year flood level.	$ -	No change from base value upon building elevation.	$ 868,380	$ 18,149	Elevate 34 buildings.	$ (102,000)	$ (4,724)	$ (2,224)	$ -	$ 17,850	$ (72,949)	$ (57,108)	$ (8,940)	$ (4,181)	$ -	$ (79,122)	$ (48,609)
	2B	Elevate (29) existing buildings that are most prone to flooding (see map) to 2 feet above the 100-year flood level.	$ -	No change from base value upon building elevation.	$ 514,080	$ 10,744	Elevate 29 buildings.	$ (87,000)	$ (5,690)	$ (2,511)	$ -	$ 15,225	$ (69,232)	$ (53,391)	$ (11,040)	$ (4,812)	$ -	$ (76,883)	$ (46,370)
	2C	Elevate utilities in all (40) existing buildings in the 500-year floodplain to the 500-year flood elevation.	$ -	No change from base value upon building elevation.	$ 562,860	$ 11,764	Elevate utilities in 40 buildings.	$ (16,000)	$ (7,402)	$ (4,412)	$ -	$ 3,600	$ (12,451)	$ 3,390	$ (14,437)	$ (8,485)	$ -	$ (23,558)	$ 6,955
AVOIDANCE AND NO FILL	3A	Remove (30) existing buildings that are most prone to flooding.	$ 15,300	Increase of ecosystem services on naturally vegetated land with removals.	$ (7,066,660)	$ (147,693)	Remove 30 buildings.	$ (18,000)	$ (2,949)	$ (1,076)	$ -	$ 45,000	$ (109,418)	$ (93,578)	$ (5,906)	$ (2,137)	$ -	$ (113,436)	$ (82,924)
	3C	Elevate (29) existing buildings to 1 foot above the 500-year flood elevation upon rebuild of the most floodprone buildings	$ -	No change from base value upon building elevation.	$ 514,080	$ 10,744	Elevate 29 buildings.	$ (87,000)	$ (3,055)	$ (1,097)	$ -	$ 15,225	$ (65,182)	$ (49,341)	$ (6,102)	$ (2,175)	$ -	$ (69,307)	$ (38,795)
EXTREME AVOIDANCE	4A	Remove (35) existing buildings that are prone to flooding (see map).	$ 17,425	Increase of ecosystem services on naturally vegetated land with removals.	$ (7,554,660)	$ (157,892)	Remove 35 buildings.	$ (3,000)	$ (1,024)	$ (389)	$ -	$ 52,500	$ (92,380)	$ (76,540)	$ (1,988)	$ (751)	$ -	$ (93,706)	$ (63,194)
	4B	Remove (35) existing buildings that are prone to flooding. No critical facilities to elevate.	$ 17,425	Increase of ecosystem services on naturally vegetated land with removals.	$ (7,554,660)	$ (157,892)	Remove 35 buildings.	$ (3,000)	$ (1,024)	$ (389)	$ -	$ 52,500	$ (92,380)	$ (76,540)	$ (1,988)	$ (751)	$ -	$ (93,706)	$ (63,194)

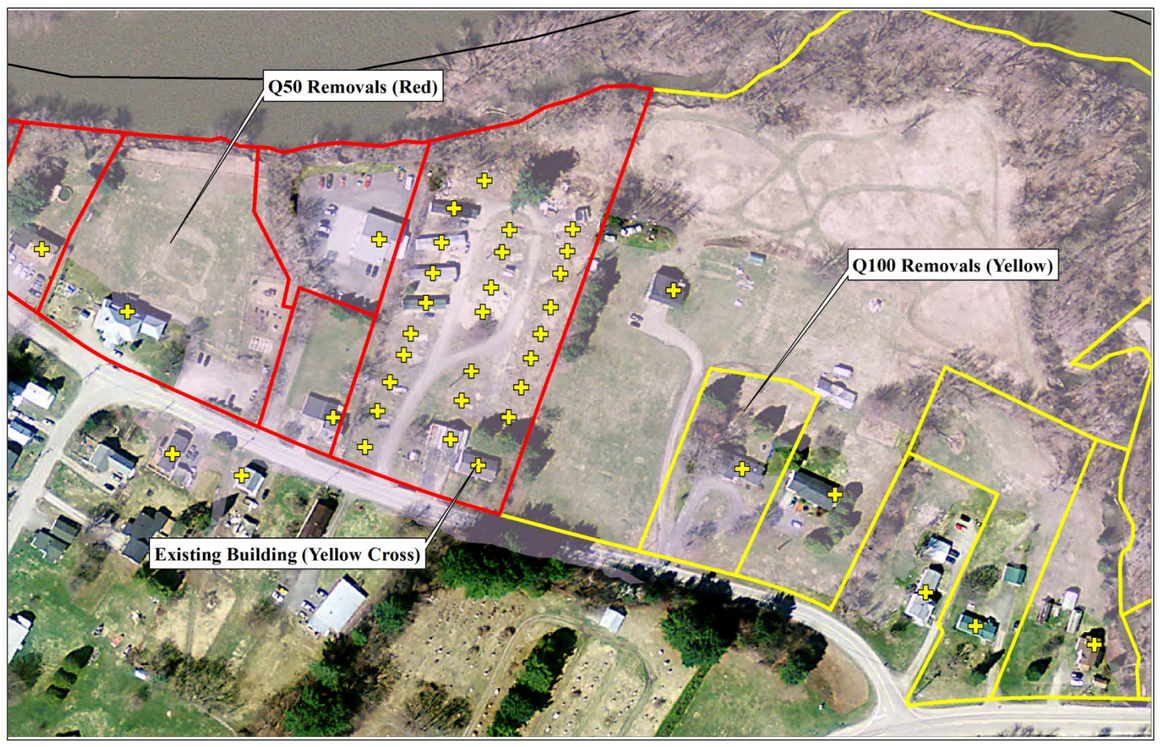
Ecosystem Value Notes
Assume naturally functioning land loss (gain) per added (removed) building is equal to average building footprint + 25% for residential (0.05 acres) and commercial (0.2 acres).
Assume land conversion between developed and combination of forest and village greenspace for average ecosystem service value of $8,500/acre/yr.

Buildout/Conservation Notes
EX = existing building stock.
The portion of the taxable properties in the future 100-year floodplain of the Winooski River over the project site has a value of $3,752,400
Tax rate taken as 2.090% that is the average of residential and non-residential rates (includes local agreement, town, and eduction).
Costs for building construction for buildout not included.
Assume 15% increase in value and tax revenue for elevated utilities and a 30% increase for elevated buildings.

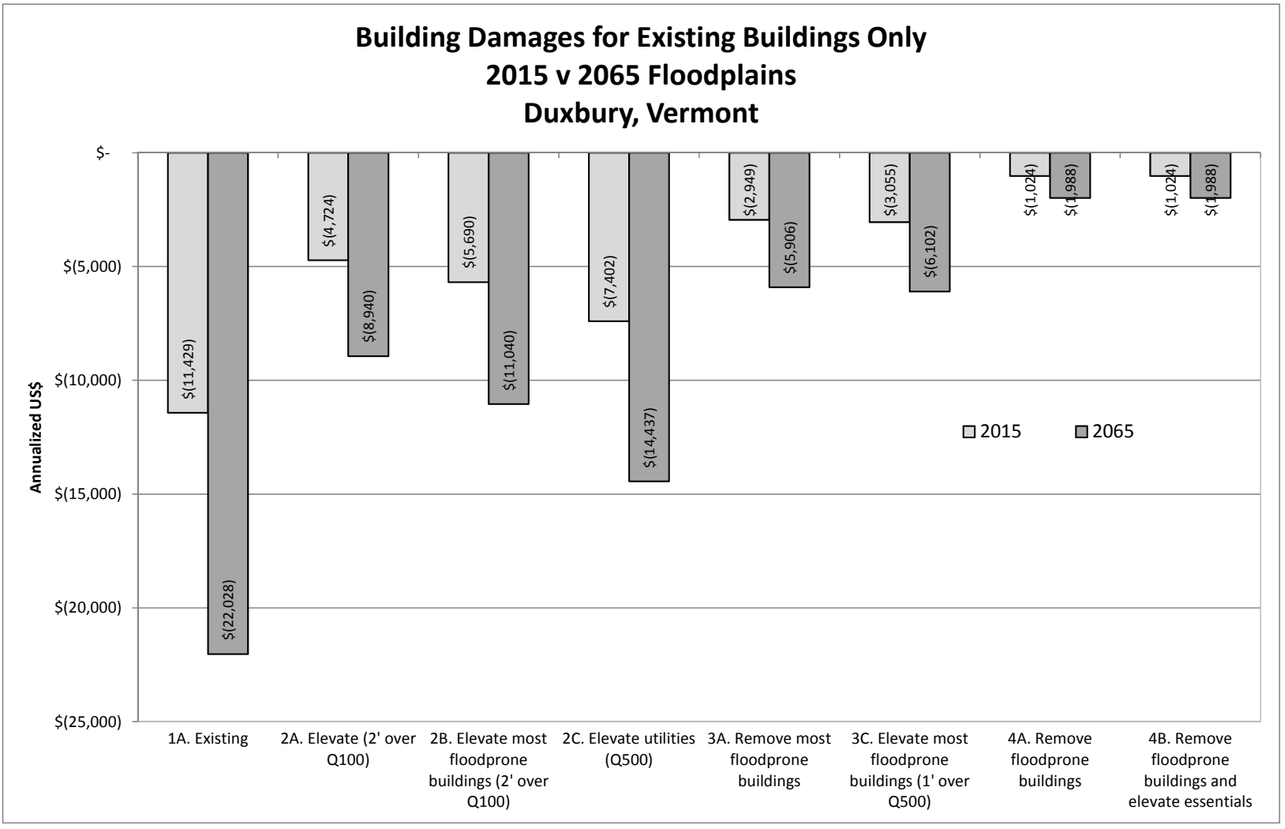
Mitigation Notes
Assume $20,000 to elevate utilities and $150,000 to elevate building.
Assume $30,000 to remove building and restore natural vegetation.
Mitigation cost divided by 50 to estimate per year value over a 50-year time period.
Costs for building acquisition for removals not included.

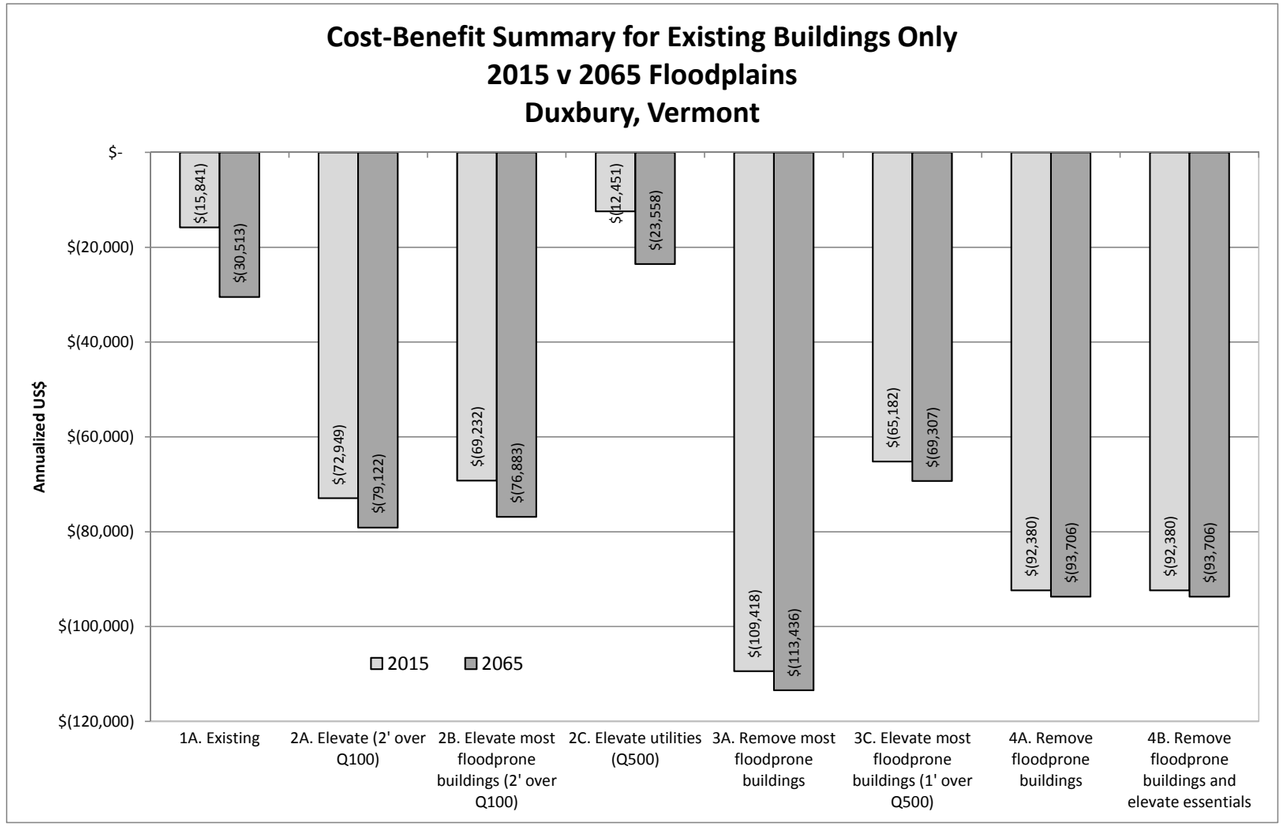
Flood Insurance Notes
Assume similar flood insurance characteristics as in Waterbury along the Winooski River.
Typical premium taken as $1,500 per year that is the average post-firm premium of the 9 policies in the Village.
Assume flood insurance carried (eliminated) for new (removed) buildings ($1,500/yr) and reduced for elevated buildings (-35% or -$525/yr) or utilities (-6% or -$90/yr).

Future Damages
The 2065 balance considers future flood damages while other values remain in today's currency.



Existing and Future Building Damages – Duxbury, Vermont





- Existing annualized building damages are $11,400 and future annualized building damages are $22,000.
- Building damages, along with loss of contents and inventory (not shown here), decrease as mitigation strategies get more aggressive such as from elevating to removing floodprone buildings. Avoidance is the best way to limit building damages.
- Future damages increase due to predicted larger floodplains and deeper flood levels under all mitigation strategies.
- Elevating buildings and removing floodprone buildings reduces future damage levels below today's levels.

- Summarizing ecosystem service change, changes in tax revenue, the cost of flood mitigation activities, flood damages, and changes in flood insurance premiums indicates that living in the floodplain today costs $15,800 per year while living in the floodplain in 2065 will cost $30,500 per year.
- The high cost to implement mitigation strategies relative to the benefits creates a net loss for living in the floodplain under existing conditions and all mitigation strategies.
- Future costs of floodplain living all increase due to predicted larger floodplains and deeper flood levels under all mitigation strategies.
- The widespread removals of floodprone buildings show a net increase in cost mostly due to the loss of tax revenue. Removals would show a larger benefit if buildings were relocated or new construction took place outside of the floodplain yet within the Town to sustain the tax base.
- Elevating utilities leads to the largest benefit that is above existing values.

Cost-Benefit Summary – Floodplain Restoration for Duxbury, Vermont

REX	Floodplain Management Scenario		Ecosystem Services		Buildout/Conservation		Flood Mitigation		Current Flood Damages (2015)			Flood Insurance	Balance	Δ	Future Flood Damages (2065)			Balance	Δ
	ID	Description	Δ Value ($/yr)	Description	Δ Value ($)	Δ Tax Value ($/yr)	Description	Cost ($/yr)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	Δ Premium ($/yr)	($ 2015)	($ 2015)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	($ 2065)	($ 2065)
EX	1A	Existing condition with updated floodplain. (40 buildings damaged in the 500-year floodplain)	$ -	Base value of naturally functioning land in 500-year floodplain	$ -	$ -	None	$ -	$ (7,591)	$ (2,739)	$ -	$ -	$ (10,330)	$ -	$ (14,665)	$ (5,237)	$ -	$ (19,902)	$ -
ELEVATE	2A	Elevate (34) existing buildings in the 500-year floodplain to 2 feet above the 100-year flood level.	$ -	No change from base value upon building elevation.	$ 868,380	$ 18,149	Elevate 34 buildings.	$ (102,000)	$ (2,998)	$ (1,095)	$ -	$ 17,850	$ (70,094)	$ (59,764)	$ (5,621)	$ (2,026)	$ -	$ (73,647)	$ (53,745)
	2B	Elevate (29) existing buildings that are most prone to flooding (see map) to 2 feet above the 100-year flood level.	$ -	No change from base value upon building elevation.	$ 514,080	$ 10,744	Elevate 29 buildings.	$ (87,000)	$ (3,341)	$ (1,273)	$ -	$ 15,225	$ (65,645)	$ (55,314)	$ (6,267)	$ (2,369)	$ -	$ (69,667)	$ (49,764)
	2C	Elevate utilities in all (40) existing buildings in the 500-year floodplain to the 500-year flood elevation.	$ -	No change from base value upon building elevation.	$ 562,860	$ 11,764	Elevate utilities in 40 buildings.	$ (16,000)	$ (5,380)	$ (2,739)	$ -	$ 3,600	$ (8,755)	$ 1,575	$ (10,371)	$ (5,237)	$ -	$ (16,245)	$ 3,658
AVOIDANCE AND NO FILL	3A	Remove (30) existing buildings that are most prone to flooding.	$ 15,300	Increase of ecosystem services on naturally vegetated land with removals.	$ (7,066,660)	$ (147,693)	Remove 30 buildings.	$ (18,000)	$ (1,881)	$ (674)	$ -	$ 45,000	$ (107,949)	$ (97,619)	$ (3,545)	$ (1,272)	$ -	$ (110,210)	$ (90,307)
	3C	Elevate (29) existing buildings to 1 foot above the 500-year flood elevation upon rebuild of the most floodprone buildings	$ -	No change from base value upon building elevation.	$ 514,080	$ 10,744	Elevate 29 buildings.	$ (87,000)	$ (1,888)	$ (675)	$ -	$ 15,225	$ (63,593)	$ (53,263)	$ (3,556)	$ (1,273)	$ -	$ (65,859)	$ (45,957)
EXTREME AVOIDANCE	4A	Remove (35) existing buildings that are prone to flooding (see map).	$ 17,425	Increase of ecosystem services on naturally vegetated land with removals.	$ (7,554,660)	$ (157,892)	Remove 35 buildings.	$ (3,000)	$ (716)	$ (227)	$ -	$ 52,500	$ (91,910)	$ (81,580)	$ (1,334)	$ (421)	$ -	$ (92,723)	$ (72,820)
	4B	Remove (35) existing buildings that are prone to flooding. No critical facilities to elevate.	$ 17,425	Increase of ecosystem services on naturally vegetated land with removals.	$ (7,554,660)	$ (157,892)	Remove 35 buildings.	$ (3,000)	$ (716)	$ (227)	$ -	$ 52,500	$ (91,910)	$ (81,580)	$ (1,334)	$ (421)	$ -	$ (92,723)	$ (72,820)

Ecosystem Value Notes

Value for improved floodplain function on 37 acres of restored floodplain accounted for in Waterbury table.
Assume naturally functioning land loss (gain) per added (removed) building is equal to average building footprint + 25% for residential (0.05 acres) and commercial (0.2 acres).
Assume land conversion between developed and combination of forest and village greenspace for average ecosystem service value of $8,500/acre/yr.

Buildout/Conservation Notes

REX = existing building stock.
The portion of the taxable properties in the future 100-year floodplain of the Winooski River over the project site has a value of $3,752,400
Tax rate taken as 2.090% that is the average of residential and non-residential rates (includes local agreement, town, and eduction).
Costs for building construction for buildout not included.
Assume 15% increase in value and tax revenue for elevated utilities and a 30% increase for elevated buildings.

Mitigation Notes

Estimated floodplain mitigation cost of $3,851,000 applied to Waterbury table.
Assume $20,000 to elevate utilities and $150,000 to elevate building.
Assume $30,000 to remove building and restore natural vegetation.
Mitigation cost divided by 50 to estimate per year value over a 50-year time period.
Costs for building acquisition for removals not included.

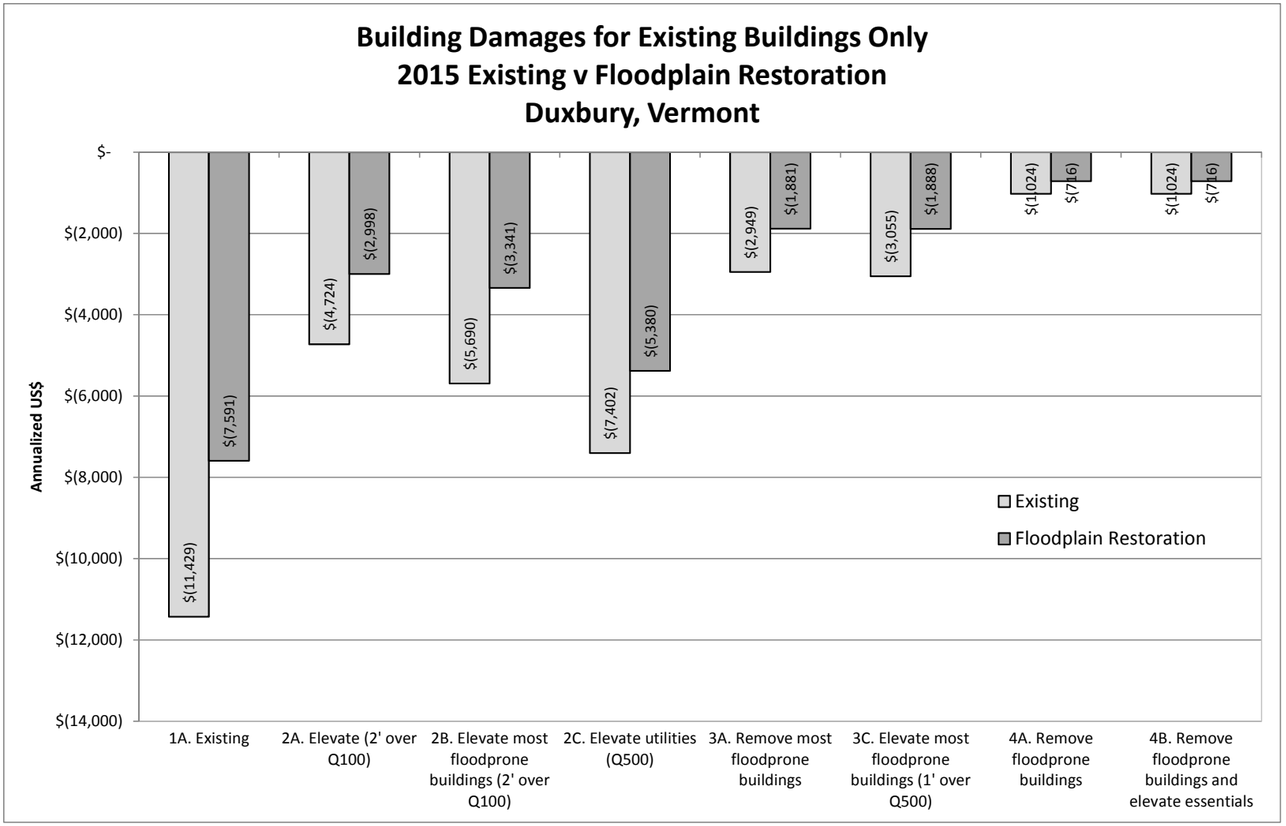
Flood Insurance Notes

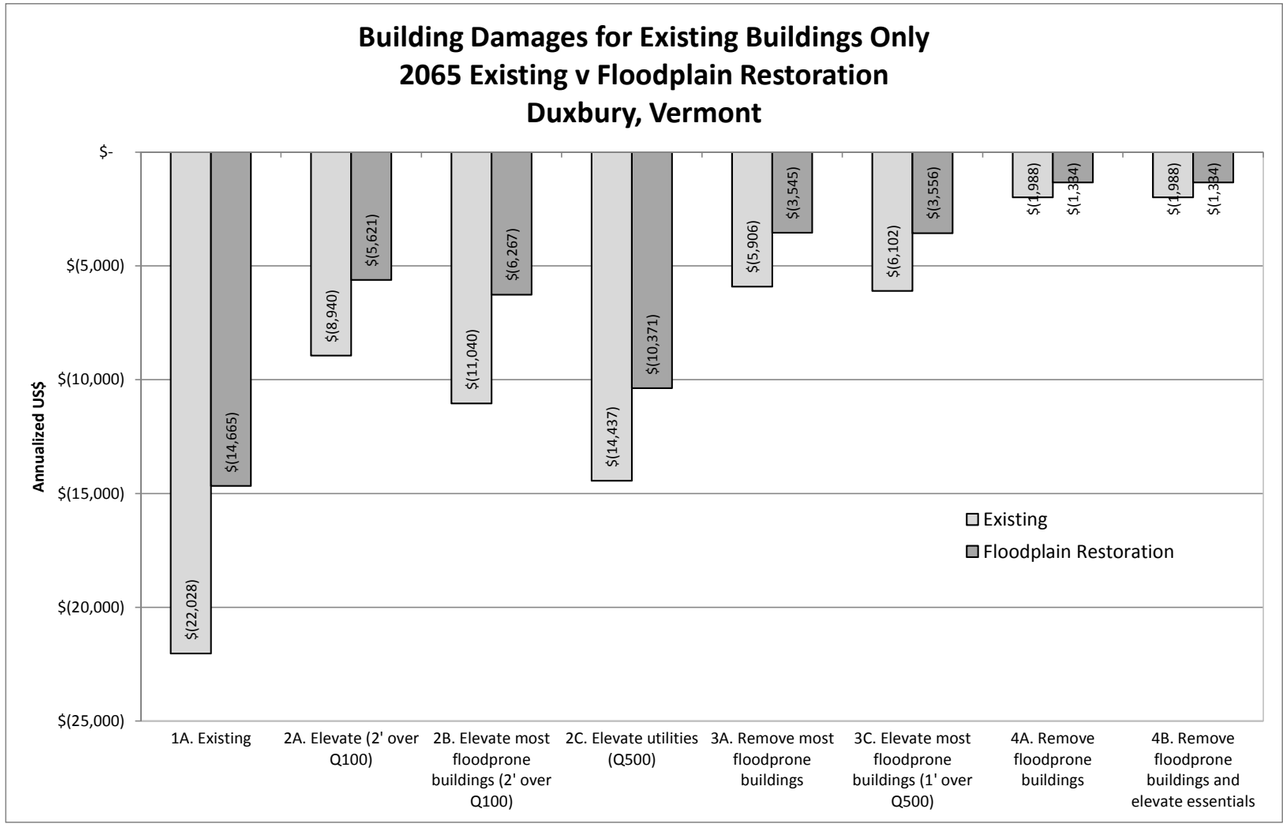
Assume similar flood insurance characteristics as in Waterbury along the Winooski River.
Typical premium taken as $1,500 per year that is the average post-firm premium of the 9 policies in the Village.
Assume flood insurance carried (eliminated) for new (removed) buildings ($1,500/yr) and reduced for elevated buildings (-35% or -$525/yr) or utilities (-6% or -$90/yr).

Future Damages

The 2065 balance considers future flood damages while other values remain in today's currency.

Existing and Floodplain Restoration Building Damages – Duxbury, Vermont

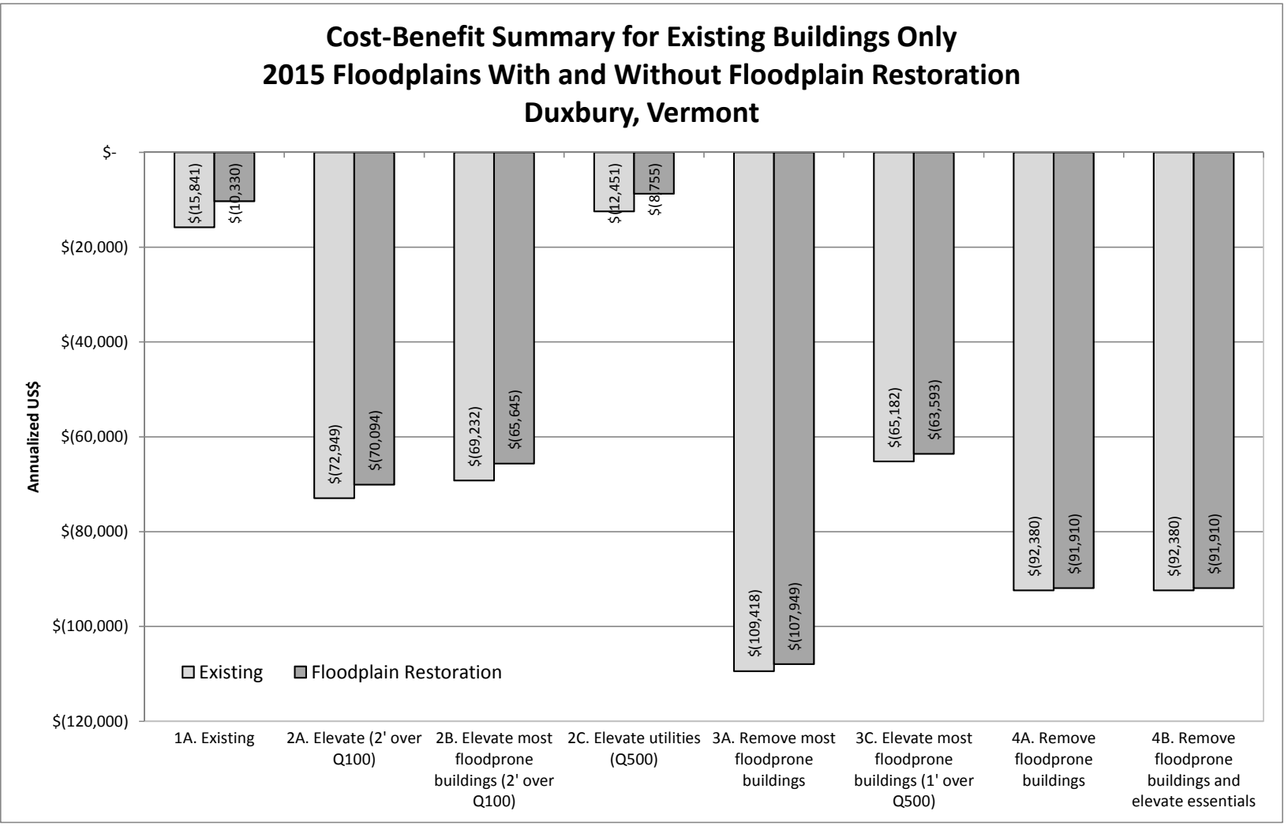


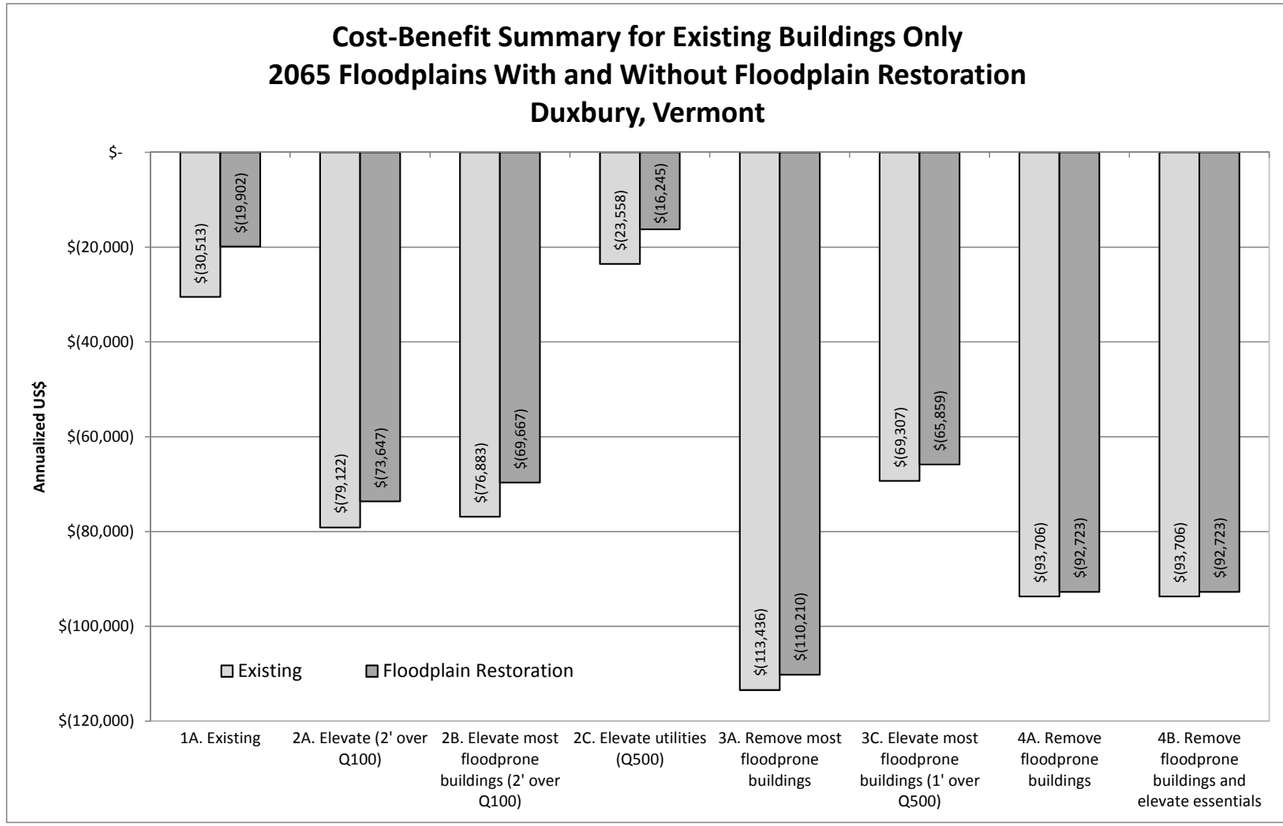


- The proposed floodplain restoration decreases existing annual building damages from $11,400 to 7,600 (~30% damage reduction).
- The proposed floodplain restoration reduces annual damages and improves the effectiveness of each mitigation approach.
- Floodplain restoration in conjunction with removing floodprone properties (4A) leads to the lowest building damages.
- Floodplain restoration leads to a reduction of $239,000 in simulated damages for a single modeled Tropical Storm Irene flood event.
- The proposed floodplain restoration at three locations – two in Waterbury and one in Duxbury – reduces the cost of living in the floodplain in Duxbury.

- The floodplain restoration decreases future annual building damages from $22,000 to $14,700 (~30% damage reduction).
- The proposed floodplain restoration reduces future annual damages and improves the effectiveness of each mitigation approach.
- Floodplain restoration in conjunction with removing floodprone properties (4A) leads to the lowest building damages.
- Floodplain restoration leads to a reduction of $269,000 in simulated damages for a single modeled future 100-year flood event.

Existing and Floodplain Restoration Cost-Benefit Summary – Duxbury, Vermont

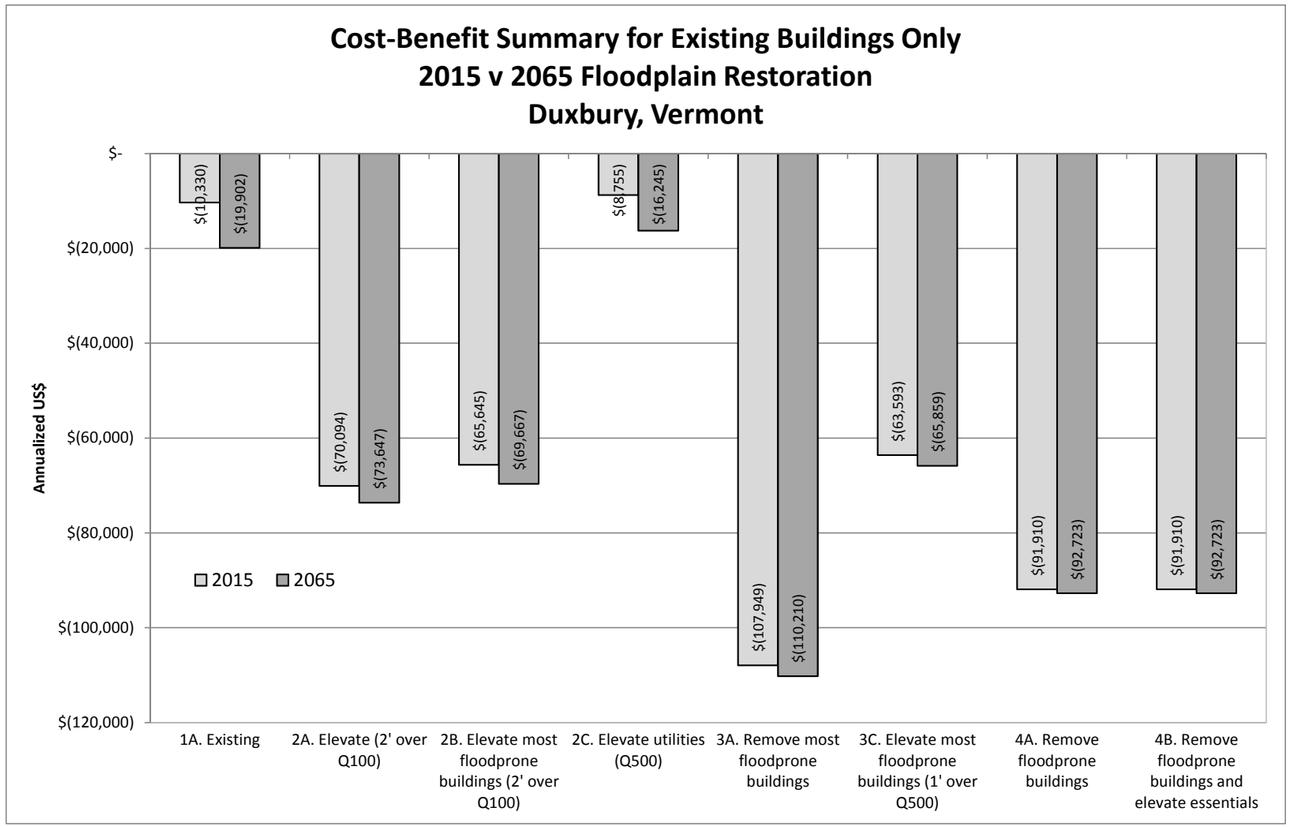




- Under existing conditions it costs $15,800 to live in the floodplain, while living in the floodplain results in a cost of $10,300 with floodplain restoration, or a cost decrease of 30%.
- Elevating utilities to the 500-year level is the best alternative that lowers costs under existing conditions and the proposed floodplain restoration.
- Floodplain restoration reduces the costs for each flood mitigation activity due to a reduction in damages.
- The high cost of building removals due to lost tax revenue can be offset if buildings are moved or rebuilt out of the yet within the Town.

- Under future conditions in 2065 it costs $30,500 to live in the floodplain, while with floodplain restoration the cost goes down to $19,900, or a cost decrease of 30%.
- The higher costs of future conditions is due to the increase in future damages beyond current conditions associated with larger future floods.
- Elevating utilities to the 500-year level is the best mitigation activity and drives costs down below existing levels.

Existing and Floodplain Restoration Cost-Benefit Summary – Duxbury, Vermont



- Future costs increase due to increasing damages with larger floods.
- Even with the proposed floodplain restoration, there is an annual cost to pay for living in the floodplain today and in the future.
- Elevating utilities to the 500-year level is the best mitigation strategy.
- The removals of floodprone buildings show a net increase in cost mostly due to the loss of tax revenue. Removals would show a larger benefit if buildings were relocated or new construction took place outside of the floodplain, yet within the community to sustain the tax base.

Cost-Benefit Summary – Existing for Moretown, Vermont

EX	Floodplain Management Scenario		Ecosystem Services		Buildout/Conservation		Flood Mitigation		Current Flood Damages (2015)			Flood Insurance	Balance	Δ	Future Flood Damages (2065)			Balance	Δ
	ID	Description	Δ Value ($/yr)	Description	Δ Value ($)	Δ Tax Value ($/yr)	Description	Cost ($/yr)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	Δ Premium ($/yr)	($ 2015)	($ 2015)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	($ 2065)	($ 2065)
EX	1A	Existing condition with updated floodplain. (9 buildings damaged in the 500-year floodplain)	$ -	Base value of naturally functioning land in 500-year floodplain	$ -	$ -	None	$ -	$ (4,142)	$ (6,785)	$ (5,563)	$ -	$ (16,490)	$ -	$ (8,291)	$ (13,486)	$ (11,138)	$ (32,916)	$ -
ELEVATE	2A	Elevate (9) existing buildings in the 500-year floodplain to 2 feet above the 100-year flood level.	$ -	No change from base value upon building elevation.	$ 460,250	$ 8,389	Elevate 9 buildings.	$ (27,000)	$ (2,388)	$ (2,931)	$ (2,267)	$ 4,725	$ (21,472)	$ (4,982)	$ (4,579)	$ (5,539)	$ (4,263)	$ (28,268)	$ 4,648
	2B	Elevate (0) existing buildings that are most prone to flooding (see map) to 2 feet above the 100-year flood level.	$ -	No change from base value upon building elevation.	$ -	$ -	Elevate 0 buildings.	$ -	$ (4,142)	$ (6,785)	$ (5,563)	$ -	$ (16,490)	$ -	$ (8,291)	$ (13,486)	$ (11,138)	$ (32,916)	$ -
	2C	Elevate utilities in all (18) existing buildings in the 500-year floodplain to the 500-year flood elevation.	$ -	No change from base value upon building elevation.	$ 411,120	$ 7,494	Elevate utilities in 18 buildings.	$ (7,200)	$ (2,227)	$ (6,785)	$ (5,563)	$ 1,620	$ (12,661)	$ 3,829	$ (4,329)	$ (13,486)	$ (11,138)	$ (27,039)	$ 5,876
AVOIDANCE AND NO FILL	3A	Remove (0) existing buildings that are most prone to flooding.	$ -	No change from base value upon building elevation.	$ -	$ -	Remove 0 buildings.	$ -	$ (4,142)	$ (6,785)	$ (5,563)	$ -	$ (16,490)	$ -	$ (8,291)	$ (13,486)	$ (11,138)	$ (32,916)	$ -
	3C	Elevate (0) existing buildings to 1 foot above the 500-year flood elevation upon rebuild of the most floodprone buildings	$ -	No change from base value upon building elevation.	$ -	$ -	Elevate 0 buildings.	$ -	$ (4,142)	$ (6,785)	$ (5,563)	$ -	$ (16,490)	$ -	$ (8,291)	$ (13,486)	$ (11,138)	$ (32,916)	$ -
EXTREME AVOIDANCE	4A	Remove (5) existing buildings that are prone to flooding (see map).	$ 7,225	Increase of ecosystem services on naturally vegetated land with removals.	$ (1,247,500)	$ (22,739)	Remove 5 buildings.	$ (3,000)	$ (1,456)	$ (1,068)	$ (705)	$ 7,500	$ (14,242)	$ 2,247	$ (2,845)	$ (2,029)	$ (1,333)	$ (17,221)	$ 15,695
	4B	Remove (5) existing buildings that are prone to flooding. No critical facilities to elevate.	$ 7,225	Increase of ecosystem services on naturally vegetated land with removals.	$ (1,247,500)	$ (22,739)	Remove 5 buildings.	$ (3,000)	$ (1,456)	$ (1,068)	$ (705)	$ 7,500	$ (14,242)	$ 2,247	$ (2,845)	$ (2,029)	$ (1,333)	$ (17,221)	$ 15,695

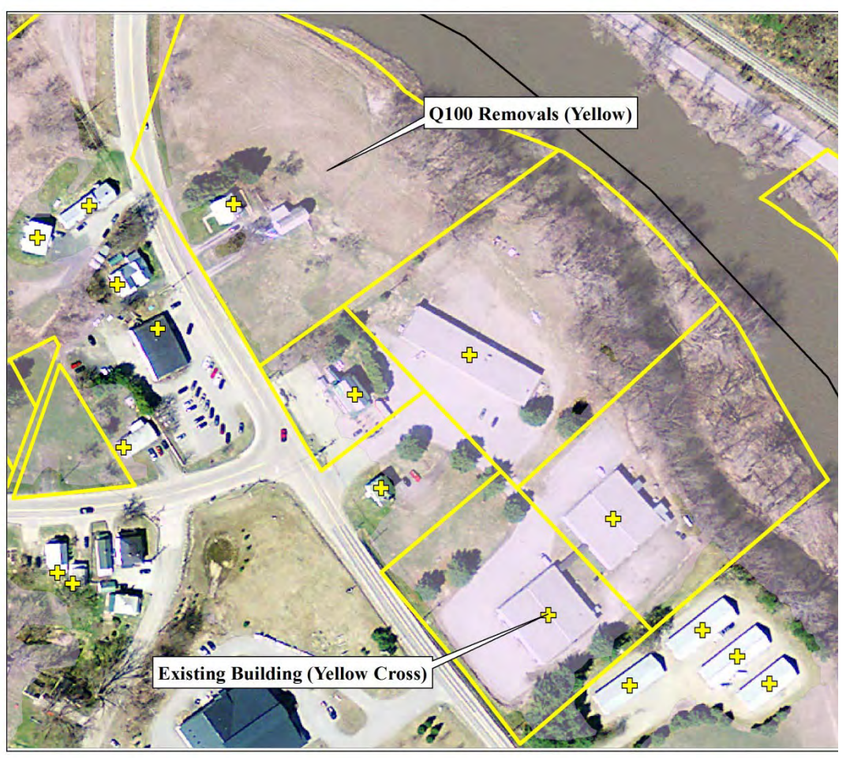
Ecosystem Value Notes
Assume naturally functioning land loss (gain) per added (removed) building is equal to average building footprint + 25% for residential (0.05 acres) and commercial (0.2 acres).
Assume land conversion between developed and combination of forest and village greenspace for average ecosystem service value of $8,500/acre/yr.

Buildout/Conservation Notes
EX = existing building stock.
The portion of the taxable properties in the future 100-year floodplain of the Winooski River over the project site has a value of $2,740,799.
Tax rate taken as 1.82275% that is the average of residential and non-residential rates (includes local agreement, town, and eduction).
Costs for building construction for buildout not included.
Assume 15% increase in value and tax revenue for elevated utilities and a 30% increase for elevated buildings.

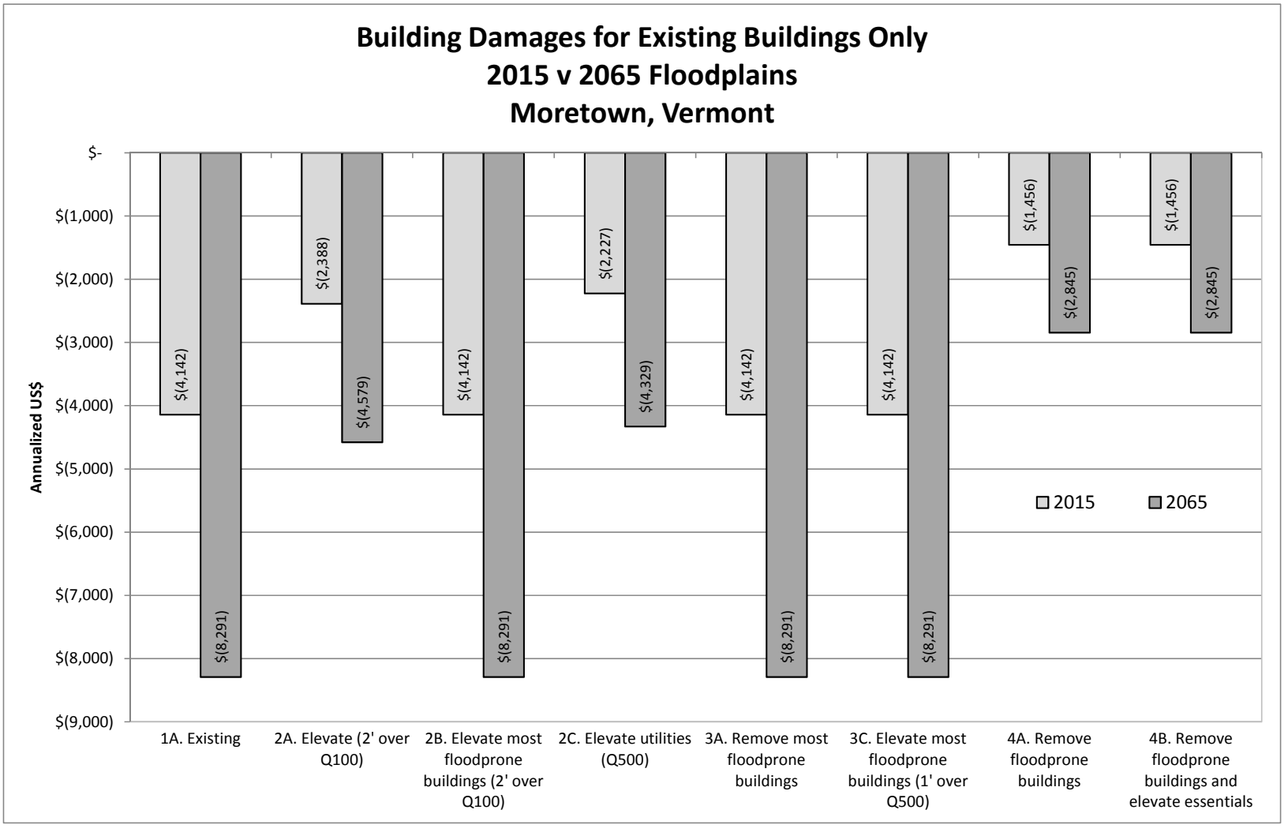
Mitigation Notes
Assume $20,000 to elevate utilities and $150,000 to elevate building.
Assume $30,000 to remove building and restore natural vegetation.
Mitigation cost divided by 50 to estimate per year value over a 50-year time period.
Costs for building acquisition for removals not included.

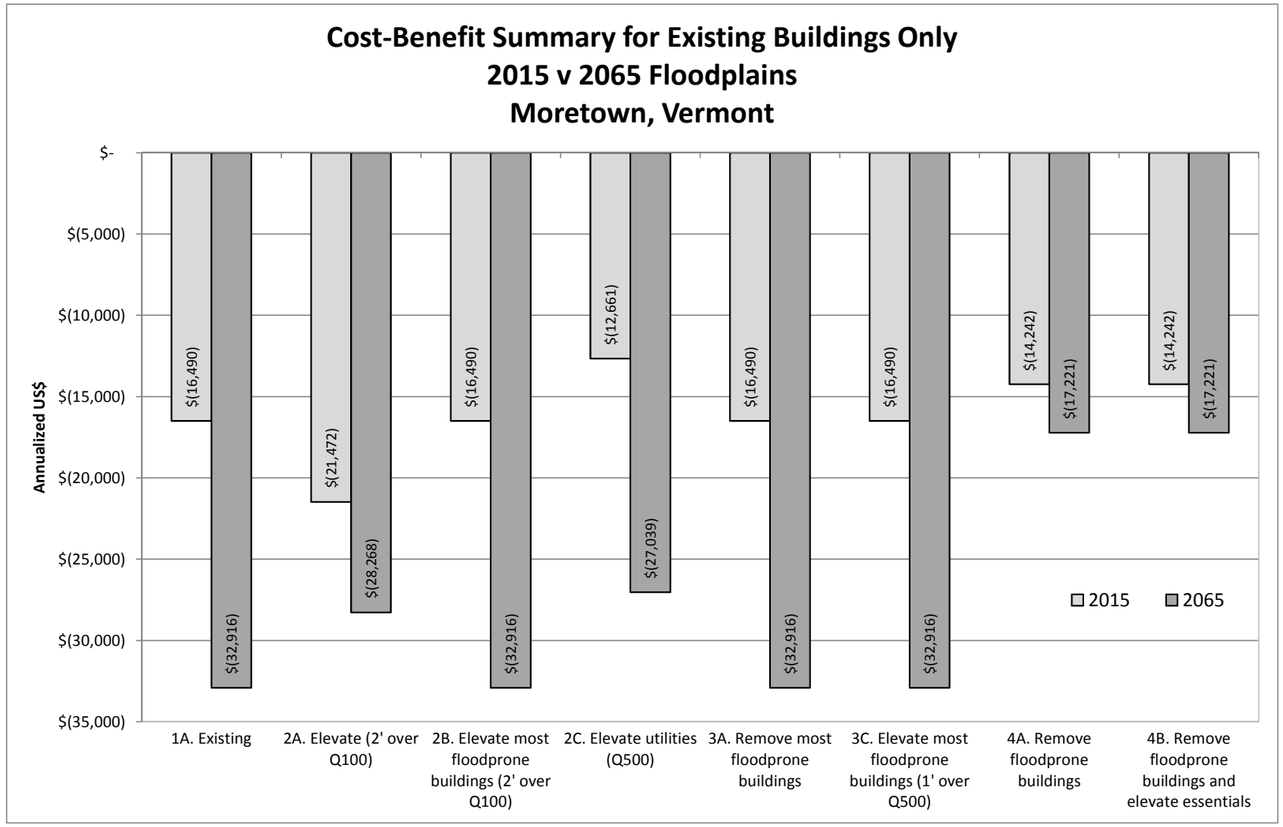
Flood Insurance Notes
Assume similar flood insurance characteristics as in Waterbury along the Winooski River.
Typical premium taken as $1,500 per year that is the average post-firm premium of the 9 policies in the Village.
Assume flood insurance carried (eliminated) for new (removed) buildings ($1,500/yr) and reduced for elevated buildings (-35% or -$525/yr) or utilities (-6% or -$90/yr).

Future Damages
The 2065 balance considers future flood damages while other values remain in today's currency.



Existing and Future Building Damages – Moretown, Vermont





- Existing annualized building damages are $4,100 and future annualized building damages are $8,300.
- Building damages, along with loss of contents and inventory (not shown here), hold steady for elevations and decrease when removing floodprone buildings. Avoidance is the best way to limit building damages.
- Future damages increase due to predicted larger floodplains and deeper flood levels under all mitigation strategies.
- Removing floodprone buildings reduces future damage levels below today's levels.

- Summarizing ecosystem service change, changes in tax revenue, the cost of flood mitigation activities, flood damages, and changes in flood insurance premiums indicates that living in the floodplain today costs $16,500 per year while living in the floodplain in 2065 will cost $32,900 per year.
- The high cost to implement mitigation strategies relative to the benefits creates a net loss for living in the floodplain under existing conditions and all mitigation strategies.
- Future costs of floodplain living all increase due to predicted larger floodplains and increased flood levels.
- Removals would show a larger benefit if buildings were relocated or new construction took place outside of the floodplain yet within the Town to sustain the tax base.

Cost-Benefit Summary – Floodplain Restoration for Moretown, Vermont

REX	Floodplain Management Scenario		Ecosystem Services		Buildout/Conservation		Flood Mitigation		Current Flood Damages (2015)			Flood Insurance	Balance	Δ	Future Flood Damages (2065)			Balance	Δ
	ID	Description	Δ Value ($/yr)	Description	Δ Value ($)	Δ Tax Value ($/yr)	Description	Cost ($/yr)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	Δ Premium ($/yr)	($ 2015)	($ 2015)	Building ($/yr)	Contents ($/yr)	Inventory ($/yr)	($ 2065)	($ 2065)
EX	1A	Existing condition with updated floodplain. (9 buildings damaged in the 500-year floodplain)	$ -	Base value of naturally functioning land in 500-year floodplain	$ -	$ -	None	$ -	$ (3,116)	$ (5,597)	$ (4,955)	$ -	$ (13,668)	$ -	$ (6,163)	$ (10,970)	$ (9,806)	$ (26,939)	$ -
ELEVATE	2A	Elevate (9) existing buildings in the 500-year floodplain to 2 feet above the 100-year flood level.	$ -	No change from base value upon building elevation.	$ 460,250	$ 8,389	Elevate 9 buildings.	$ (27,000)	$ (1,575)	$ (2,207)	$ (1,772)	$ 4,725	$ (19,440)	$ (5,772)	$ (2,946)	$ (4,129)	$ (3,308)	$ (24,269)	$ 2,670
	2B	Elevate (0) existing buildings that are most prone to flooding (see map) to 2 feet above the 100-year flood level.	$ -	No change from base value upon building elevation.	$ -	$ -	Elevate 0 buildings.	$ -	$ (3,116)	$ (5,597)	$ (4,955)	$ -	$ (13,668)	$ (0)	$ (6,163)	$ (10,970)	$ (9,806)	$ (26,939)	$ (0)
	2C	Elevate utilities in all (18) existing buildings in the 500-year floodplain to the 500-year flood elevation.	$ -	No change from base value upon building elevation.	$ 411,120	$ 7,494	Elevate utilities in 18 buildings.	$ (7,200)	$ (1,759)	$ (5,597)	$ (4,955)	$ 1,620	$ (10,397)	$ 3,271	$ (3,408)	$ (10,970)	$ (9,806)	$ (22,270)	$ 4,669
AVOIDANCE AND NO FILL	3A	Remove (0) existing buildings that are most prone to flooding.	$ -	No change from base value upon building elevation.	$ -	$ -	Remove 0 buildings.	$ -	$ (3,116)	$ (5,597)	$ (4,955)	$ -	$ (13,668)	$ -	$ (6,163)	$ (10,970)	$ (9,806)	$ (26,939)	$ -
	3C	Elevate (0) existing buildings to 1 foot above the 500-year flood elevation upon rebuild of the most floodprone buildings	$ -	No change from base value upon building elevation.	$ -	$ -	Elevate 0 buildings.	$ -	$ (3,116)	$ (5,597)	$ (4,955)	$ -	$ (13,668)	$ (0)	$ (6,163)	$ (10,970)	$ (9,806)	$ (26,939)	$ (0)
EXTREME AVOIDANCE	4A	Remove (5) existing buildings that are prone to flooding (see map).	$ 7,225	Increase of ecosystem services on naturally vegetated land with removals.	$ (1,247,500)	$ (22,739)	Remove 5 buildings.	$ (3,000)	$ (824)	$ (678)	$ (617)	$ 7,500	$ (13,132)	$ 536	$ (1,600)	$ (1,292)	$ (1,164)	$ (15,069)	$ 11,870
	4B	Remove (5) existing buildings that are prone to flooding. No critical facilities to elevate.	$ 7,225	Increase of ecosystem services on naturally vegetated land with removals.	$ (1,247,500)	$ (22,739)	Remove 5 buildings.	$ (3,000)	$ (824)	$ (678)	$ (617)	$ 7,500	$ (13,132)	$ 536	$ (1,600)	$ (1,292)	$ (1,164)	$ (15,069)	$ 11,870

Ecosystem Value Notes

Value for improved floodplain function on 37 acres of restored floodplain accounted for in Waterbury table.
Assume naturally functioning land loss (gain) per added (removed) building is equal to average building footprint + 25% for residential (0.05 acres) and commercial (0.2 acres).
Assume land conversion between developed and combination of forest and village greenspace for average ecosystem service value of $8,500/acre/yr.

Buildout/Conservation Notes

REX = existing building stock.
The portion of the taxable properties in the future 100-year floodplain of the Winooski River over the project site has a value of $2,740,799.
Tax rate taken as 1.82275% that is the average of residential and non-residential rates (includes local agreement, town, and eduction).
Costs for building construction for buildout not included.
Assume 15% increase in value and tax revenue for elevated utilities and a 30% increase for elevated buildings.

Mitigation Notes

Estimated floodplain mitigation cost of $3,851,000 applied to Waterbury table.
Assume $20,000 to elevate utilities and $150,000 to elevate building.
Assume $30,000 to remove building and restore natural vegetation.
Mitigation cost divided by 50 to estimate per year value over a 50-year time period.
Costs for building acquisition for removals not included.

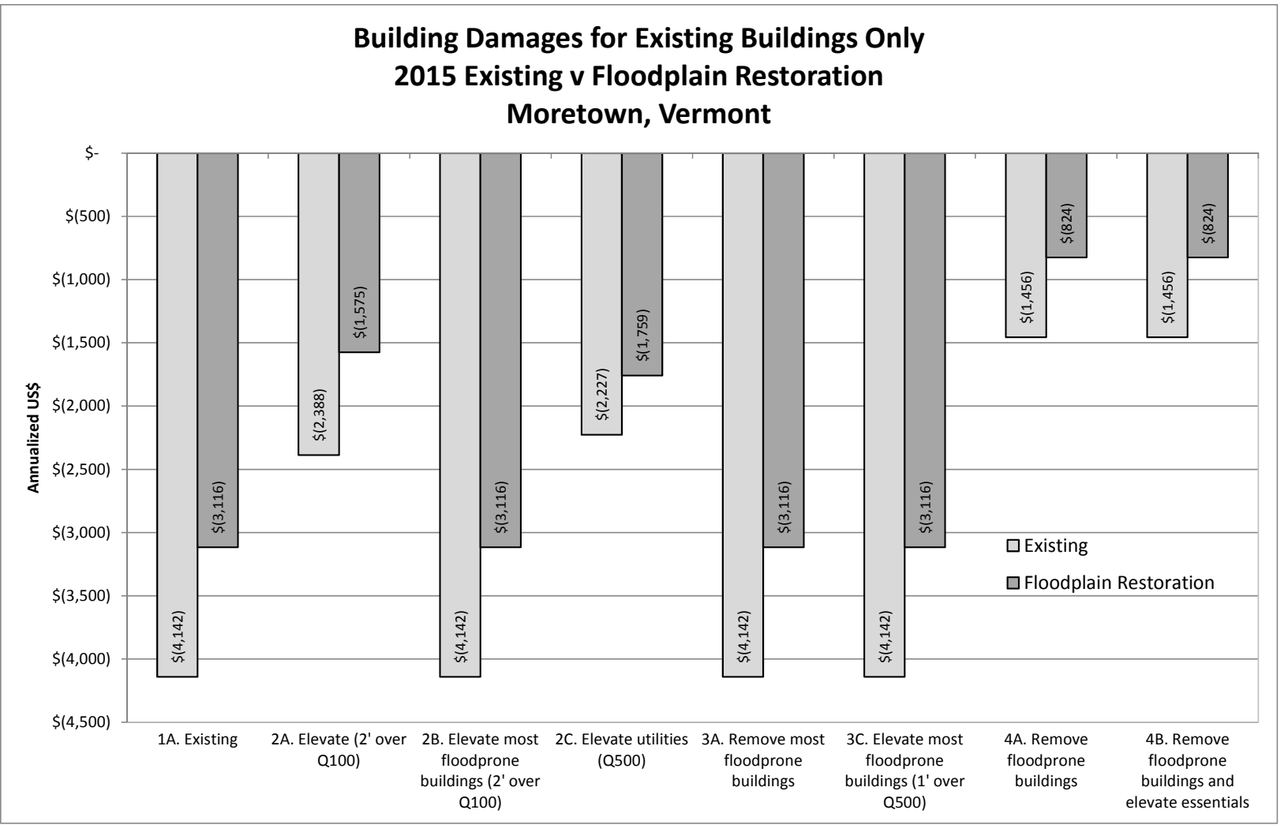
Flood Insurance Notes

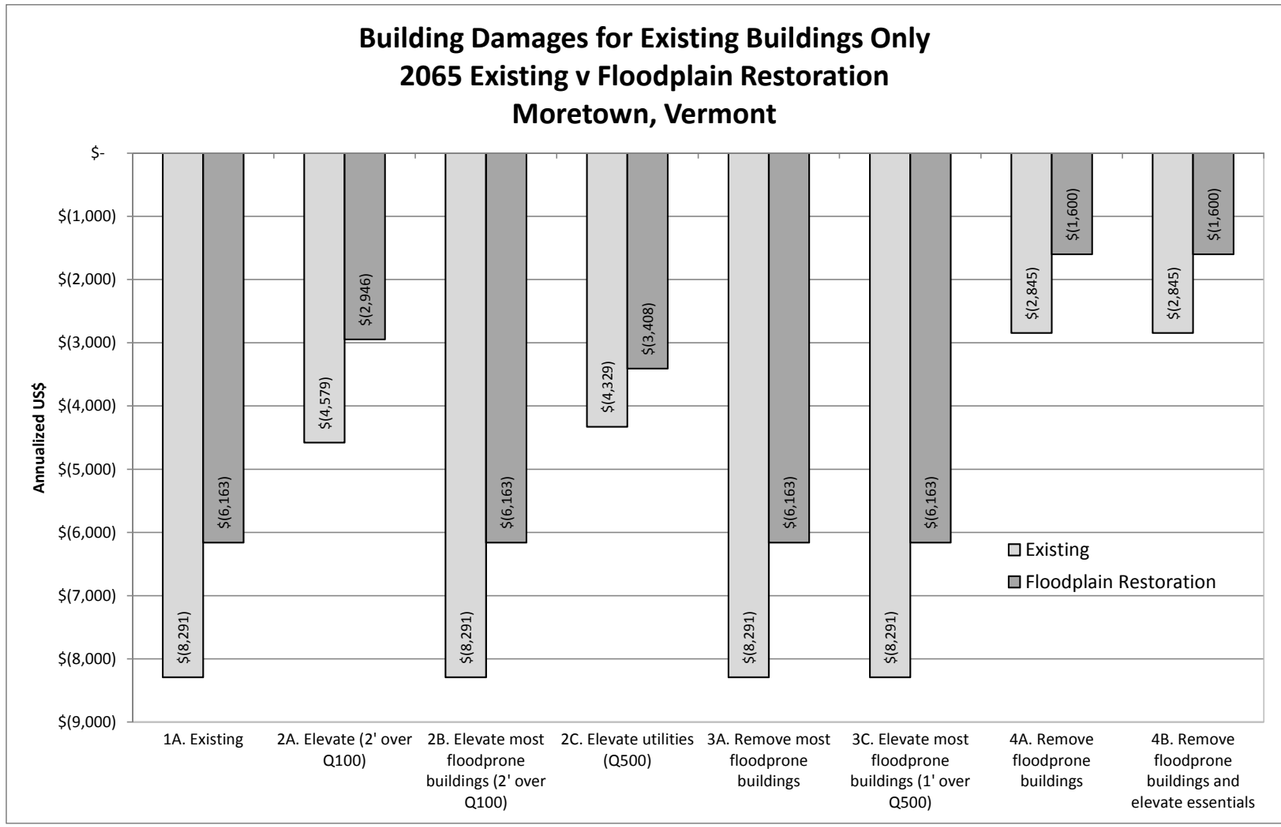
Assume similar flood insurance characteristics as in Waterbury along the Winooski River.
Typical premium taken as $1,500 per year that is the average post-firm premium of the 9 policies in the Village.
Assume flood insurance carried (eliminated) for new (removed) buildings ($1,500/yr) and reduced for elevated buildings (-35% or -$525/yr) or utilities (-6% or -$90/yr).

Future Damages

The 2065 balance considers future flood damages while other values remain in today's currency.

Existing and Floodplain Restoration Building Damages – Moretown, Vermont

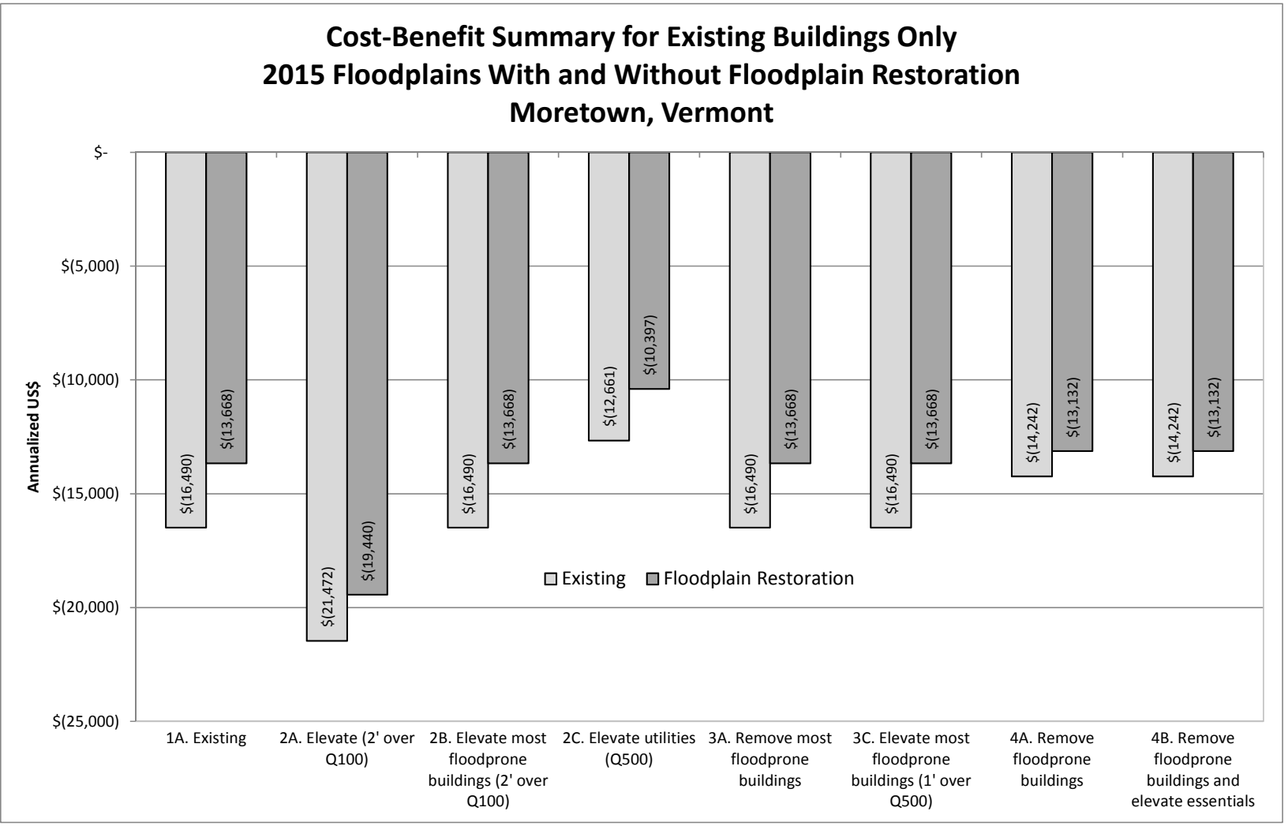


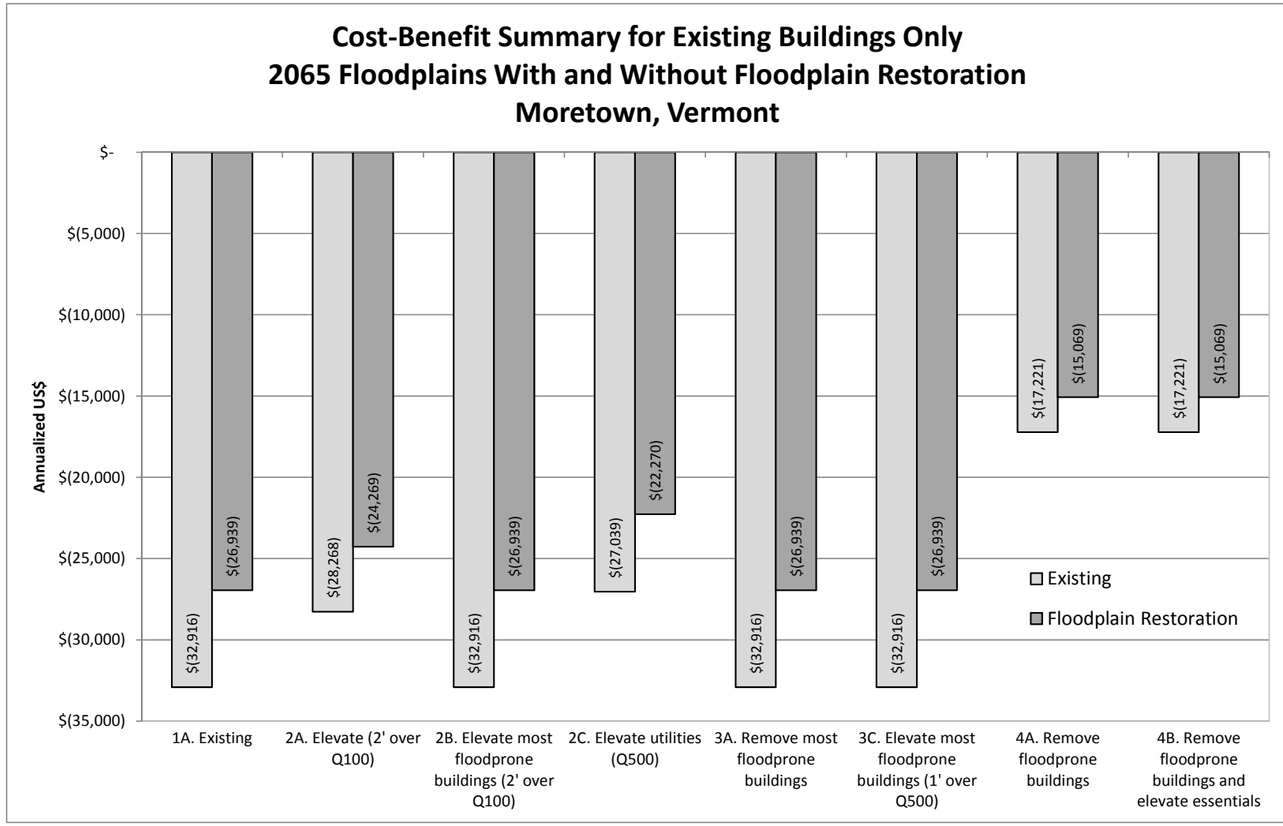


- The proposed floodplain restoration decreases existing annual building damages from $4,100 to $3,100 (~20% damage reduction).
- The proposed floodplain restoration reduces annual damages and improves the effectiveness of each mitigation approach.
- Floodplain restoration in conjunction with removing floodprone properties (4A) leads to the lowest building damages.
- Floodplain restoration leads to a reduction of $199,000 in simulated damages for a single modeled Tropical Storm Irene flood event.
- The proposed floodplain restoration at three locations – two in Waterbury and one in Duxbury – reduces the cost of living in the floodplain in Moretown.

- The floodplain restoration decreases future annual building damages from $8,300 to $6,200 (~30% damage reduction).
- The proposed floodplain restoration reduces future annual damages and improves the effectiveness of each mitigation approach.
- Floodplain restoration in conjunction with removing floodprone properties (4A) leads to the lowest building damages.
- Floodplain restoration leads to a reduction of $192,000 in simulated damages for a single modeled future 100-year flood event.

Existing and Floodplain Restoration Cost-Benefit Summary – Moretown, Vermont

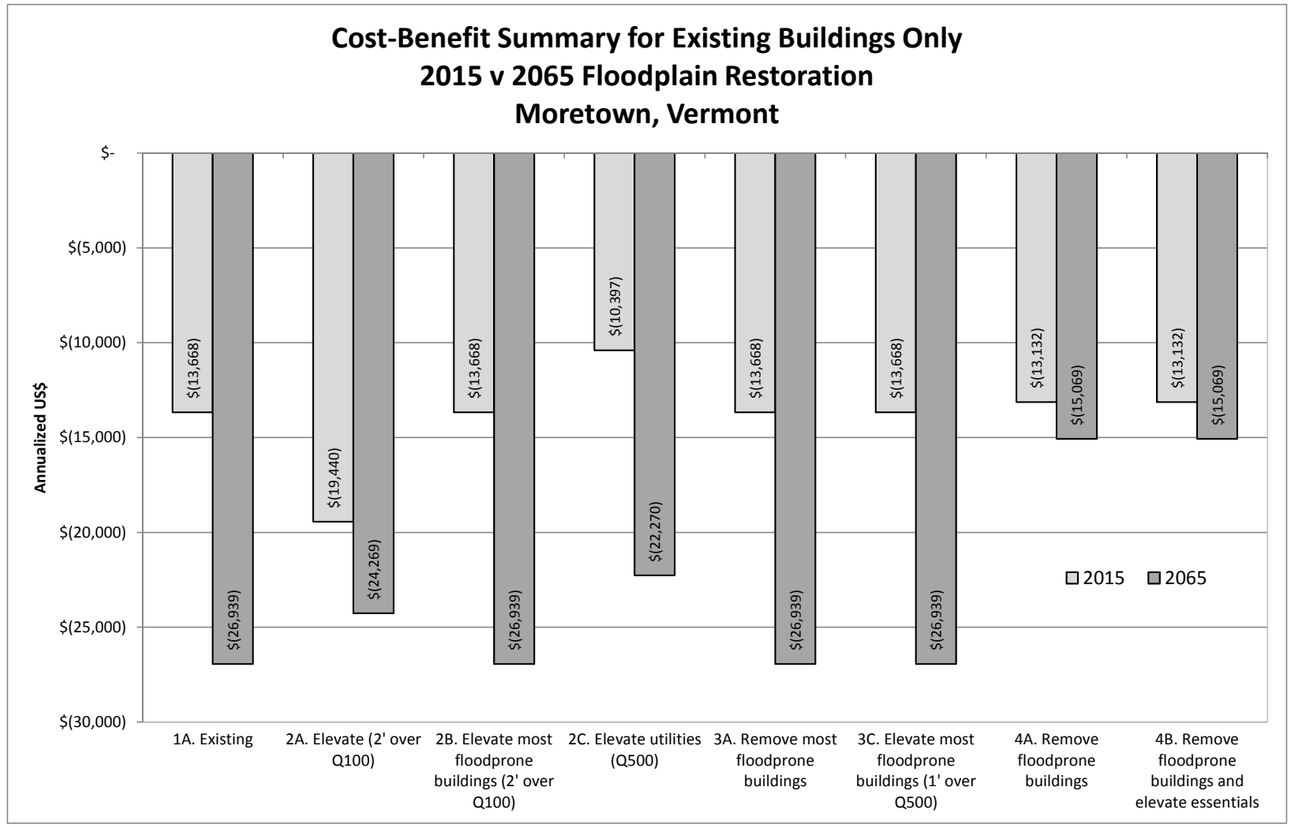




- Under existing conditions it costs $16,500 to live in the floodplain, while living in the floodplain results in a cost of $13,700 with floodplain restoration, or a cost decrease of 20%.
- Elevating utilities to the 500-year level is the best mitigation strategy that lowers costs just under existing conditions and the proposed floodplain restoration.
- Floodplain restoration reduces the costs for each flood mitigation activity due to a reduction in damages.
- The high cost of building removals due to lost tax revenue can be offset if homes are moved out of the floodplain, but remain in town or people relocate within the Town.

- Under future conditions in 2065 it costs $32,900 to live in the floodplain, while with floodplain restoration the cost goes down to $26,900, or a cost decrease of 20%.
- The higher costs of future conditions is due to the increase in future damages beyond current conditions associated with larger future floods.
- Removing floodprone buildings is the best mitigation strategy.

Existing and Floodplain Restoration Cost-Benefit Summary – Moretown, Vermont



- Future costs increase due to increasing damages with larger floods.
- Even with the proposed floodplain restoration, there is an annual cost to pay for living in the floodplain today and in the future.
- Elevating utilities to the 500-year level is the best mitigation strategy.
- The removals of floodprone buildings show a net increase in cost mostly due to the loss of tax revenue. Removals would show a larger benefit if buildings were relocated or new construction took place outside of the floodplain within the community to sustain the tax base.

Floodplain Management Summary and Recommendations

Waterbury, Vermont

- Waterbury, Vermont "pays" thousands of dollars in annualized damages to live in the floodplain and may pay larger amounts in the future due to the potential for increasing floods. Simulated damages increase as more buildings are placed in the floodplain.
- Building damages, loss of contents, and loss of inventory decrease as mitigation strategies get more aggressive, such as from elevating to removing select buildings in the most floodprone areas to removing buildings in a larger area across the floodplain.
- Avoidance is the best way to minimize future damages. However, the reduction of damages and increase in ecosystem function value are often outweighed by the projected maximum loss of tax revenue. For building removals to make financial sense, moving existing buildings or building new structures out of the floodplain yet in the Village and Town is needed to maintain tax revenue.
- Elevating utilities across the entire floodplain to the 500-year flood level and elevating the most floodprone structures to 1 foot above the 500-year flood level lead to the largest benefits.
- Cost-benefit data suggest that utility elevations should be implemented following flood damages to existing buildings given the lower cost compared to other mitigation strategies and the ability to implement utility elevations as part of flood recovery.
- Future building construction should be located outside of the 500-year floodplain (preferred), be elevated to 1 foot above the 500-year flood level if within the floodplain, or at a minimum have elevated utilities.
- The proposed floodplain restoration at three locations reduces current and future damages and improves the effectiveness of each mitigation approach. The project should be implemented when possible due to its large financial benefit.
- With floodplain restoration in place, elevating the most floodprone buildings 2 feet over the 100-year flood level provides good benefits.
- The future costs of floodplain living will likely increase due to the expectation of larger floods, yet the increase in cost with floodplain restoration as seen over 50 years is less than if floodplain restoration was not performed.
- Waterbury has a large base of naturally functioning land that provides ecosystem services such as flood mitigation benefits that is of high value and important to preserve and expand for the future viability of the Village and Town.

Willsboro, New York

- Even with just 21 buildings in the 500-year floodplain, Willsboro, New York "pays" $1,600 dollars in annualized damages to live in the floodplain and could pay $5,800 in 2065 due to the potential for increasing floods. Simulated damages increase as more buildings are placed in the floodplain.
- The high cost to implement mitigation strategies relative to the benefits creates a net loss for living in the floodplain.
- Future costs of floodplain living all increase due to predicted larger floodplains and deeper flood levels under all mitigation strategies.
- Elevating utilities across the entire floodplain to the 500-year flood level leads to the largest current and future benefit with the buildout building stock due to the relatively low implementation cost compared to the damage reduction benefits, yet none of the mitigation strategies lower costs beyond existing conditions.
- The proposed dam removal, floodplain restoration, and building elevations decreases existing annual building damages from $1,600 to $900 (~40%), yet lead to more damages with increased building stock due to a localized increase in flood levels where building construction on fill would take place.
- Dam removal and floodplain restoration are recommended, yet fill and building elevations in the floodplain are not recommended due to increases in local flood depths with filling in the narrow floodplain leading to damage increases.
- Even with the proposed dam removal, floodplain restoration, and building elevations, there is a cost to pay for living in the floodplain today and in the future that amounts to thousands of dollars annually.
- Future building construction should be located outside of the 500-year floodplain (preferred), be elevated to 1 foot above the 500-year flood level if within the floodplain, or at a minimum have elevated utilities.
- Cost-benefit data suggest that utility elevations should be implemented following flood damages to existing buildings given the lower cost compared to other mitigation strategies and the ability to implement utility elevations as part of flood recovery.
- Willsboro has a large base of naturally functioning land that provides high-value ecosystem services that are important to preserve and expand for the future viability of the Town.

Floodplain Management Summary and Recommendations

Duxbury, Vermont

- Duxbury, Vermont "pays" $11,400 dollars in annualized damages to live in the floodplain and could pay $22,000 in the future due to increasing floods.
- Building damages, loss of contents, and loss of inventory decrease as more aggressive mitigation strategies are simulated. Avoidance is the best way to limit building damages.
- The high cost to implement mitigation strategies relative to the damage reduction benefits creates a net loss for living in the floodplain under existing conditions and all mitigation strategies.
- Future costs of floodplain living all increase due to predicted larger floodplains and increased flood levels.
- Elevating utilities across the entire floodplain to the 500-year flood level leads to the largest current and future cost reductions.
- The floodplain restoration project proposed in the Waterbury Flood Study (MMI, 2013a,b) reduces building damages 30% saving thousands of dollars per year.
- Flood damages can be reduced by implementing floodplain restoration along the Winooski River, limiting development in the floodplain, and elevating utilities during flood recovery and for new construction.

Moretown, Vermont

- Moretown, Vermont "pays" $4,100 dollars in annualized damages to live in the floodplain and could pay $8,300 in the future due to increasing floods.
- Avoidance is the best way to limit building damages.
- The high cost to implement mitigation strategies relative to the benefits creates a net loss for living in the floodplain under existing conditions and all mitigation strategies.
- Future costs of floodplain living all increase due to predicted larger floodplains and deeper flood levels under all mitigation strategies.
- Removing floodprone buildings reduces simulated damage levels.
- The floodplain restoration project proposed in the Waterbury Flood Study (MMI, 2013a,b) reduces building damages 20% saving a thousand dollars per year.
- Flood damages can be reduced by implementing floodplain restoration along the Winooski River, limiting development in the floodplain, removing floodprone structures, and elevating utilities during flood recovery and new construction.

Conclusions

1. The benefits of floodplain protection outweigh the costs over the long term because a complete accounting includes high-value ecosystem services.

The Towns in this study have a large base of naturally functioning land that provides ecosystem services such as flood mitigation benefits that is of high value and important to preserve and expand for future viability. A sweet spot appears to exist where benefits of floodplain protection outweigh the costs when damage reductions are high, the loss of tax revenue is low, the cost of the mitigation activity is low, and ecosystem service value is high. Removing buildings in the floodplain reduces damages the most, yet the loss of tax revenue must be offset by relocating or creating buildings in town but out of the floodplain. Costs are reduced when elevating utilities, and this activity is appealing as it can be performed during flood recovery. Building elevation makes sense when raising the most floodprone buildings to 1 foot over the 500-year flood level in Waterbury where damages are widespread. The results suggest that floodplain restoration and targeted mitigation activities of the most floodprone buildings most efficiently lowers the costs of living in floodplains. More work is needed to refine the number of floodprone buildings where the costs and benefits balance.

2. Floodplain protection reduces future flood damages, improves public safety, and enhances water quality because the most at risk parcels are not developed.

With the potential increase in the size and magnitude of flooding in the region, the size of floodplains, flood depths, and flood damages will likely increase. All mitigation activities reduced building damages for both today's floodplains as well as those predicted in 2065. The more naturally functioning floodplain that exists, the lower the damages to buildings in the floodplain due to the ecosystem service of flood mitigation. A partial accounting of ecosystem services indicates a high value of naturally functioning land, and this resource needs to be protected and expanded to control future damages and the predicted increase in the cost of living in floodplains. Erosion control is an important service that takes place on floodplains to reduce loss of land and to store sediment that can impact downstream receiving waters.

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Appendices

Evaluating the Costs and Benefits of Floodplain Protection Activities in Waterbury, Vermont and Willsboro, New York, Lake Champlain Basin, U.S.A.

NEIWPCC Job Code: 984-003-006
Project Code: L-2013-033
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Appendix 1: Project Introduction
(Adapted from Approved Workplan)

Appendix 2: Methodology – Ecosystem Valuation in the Lake Champlain Basin

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Appendix 1: Project Introduction (Adapted from Approved Workplan)

This project entails a study that evaluates the costs and benefits of flood risk reduction for two municipalities in the Lake Champlain Basin, U.S.A. The purpose was to develop a process by which communities can make informed decisions on how to reduce their flood risk and maximize total benefits. Work tasks generally included:

- Research on the floodplain ecosystem service of natural flood mitigation and resulting economic benefits;
- Establishment of floodplain management scenarios for each participating municipality;
- Assessment of environmental and social aspects of the floodplain management scenarios;
- Hydrologic calculations of existing and predicted future floods;
- Hydraulic modeling of existing and future floodplains;
- Damage modeling at the community scale;
- Cost-benefit summary for each community; and
- Reporting.

The primary elements of the project will include ecosystem services benefits, hydrologic calculations, hydraulic modeling, and damage estimate modeling. Flood frequency analysis (USGS, 1982) was performed using USGS stream gauge data to predict current and predicted future design flood flows. Hydraulics were evaluated with HEC-RAS (USACE, 2010) to map floodplains. HAZUS-MH loss estimation software (FEMA, 2013) was used to determine potential loss estimates that include physical damages (buildings, contents, inventory). The Ecosystem Valuation Toolkit (EVT) (EE, 2012) was used to evaluate the ecosystem services and quantify the benefits provided by the current or projected land uses.

The project was led by the Lake Champlain Basin Program (LCBP), and was supported by funds awarded to the New England Interstate Water Pollution Control Commission (NEIWPCC) by the U.S. Environmental Protection Agency (EPA).

Does floodplain protection make sound economic sense? This is the underlying question to be addressed by this project, and one that many municipalities in the region are grappling with in the wake of large damaging floods over the past decade. Where and to what level does floodplain protection make sense now and in the future? Do the benefits of floodplain protection (i.e., reduction of flood damages, lower recovery costs, increased health and safety, enhanced ecosystem services) outweigh the costs (i.e., loss of economic opportunity, reduced tax base, floodplain restoration project implementation, increased costs to flood-proof structures, and recovery of structures remaining in the floodplain)?

Reducing flood risks and supporting economic development is difficult given that historic development patterns have landed many municipalities in floodplains. Recent studies in the northeast United States

have shown an increase in the size and frequency of floods (Collins, 2009; Armstrong et al., 2012). A discontinuity in long-term gauge records often takes place around 1970 with larger floods occurring in more recent times. Designs must now look at stratified gauge records to determine current and predict future peak flood flows (NMFS, 2011).

The outcomes of this project are important, as municipalities need evidence to support making tough planning and regulatory decisions about floodplain management. Should a town rely on minimum standards in the FEMA National Flood Insurance Program – limited fill in the FEMA floodway and required elevation of structures to the base flood elevation? This approach accounts only for inundation-based hazards based upon historic conditions whereas many of the damages in the northeast United States stem from damages due to excessive erosion and deposition in channels, and there remains the increased frequency of flood events in the gauge record. The NFIP seems to have the unintended consequence of incentivizing floodplain development in risky areas with flood insurance while not properly mapping the real dangers to property, public safety, and the environment in the river corridor. Elevating can increase flood risks to others if fill is placed to raise buildings.

Municipalities in Vermont and other northeast states are considering use of a fluvial erosion hazard zone to more accurately map flood and erosion risks for floodplain protection (VTDEC, 2007). The creation of the fluvial erosion hazard zone in Vermont stemmed from a long history of attempting various flood mitigation activities and the realization that the best method of reducing flood and erosion risks was to give a river the space it needs to meander in its valley (Kline and Cahoon, 2010). Some Vermont municipalities have elected to regulate activities in the fluvial erosion hazard zone through zoning beyond the minimum FEMA standards, while others loosely enforce the minimum standards. This project will result in creation of several floodplain management scenarios (i.e., the combination of a specified area such as the FEMA floodplain or the Vermont fluvial erosion hazard zone and an allowed level of development) that will present municipalities with better options to reduce risks.

The immediate losses following damaging floods are often followed by long-term economic loss and social fatigue in floodprone municipalities with no easy risk reduction solutions. Remaining damages, low building occupancy, and stress over the next flood permeate floodprone areas that include many Main Streets in the region. While human spirit and will typically drive rapid recovery and rebuilding, this work often leads to similar or even increased future risks. This project will provide municipalities with information to recover in a smarter, safer, and more resilient way following floods. If a floodplain management strategy is in place resulting from this project, better decisions can be made on whether or not to rebuild, buyout, demolish, conserve, or restore.

This project resulted in the creation of a framework for studying the economics of local floodplain protection that will be transferrable to other municipalities. Although a fully transferrable model was not developed due to details being specific to each study site (Hawley et al., 2012), the methods will result in a decision-making process to help communities select high value mitigation choices.

The Towns of Waterbury, Vermont and Willsboro, New York participated in this project. Both Towns have experienced flood damages in the past decade, are working on flood risk reduction projects, have detailed flood studies (i.e., hydraulic modeling), and are interested in the information that would come from this project (Table 1). The project was extended to include portions of Duxbury and Moretown, Vermont across the Winooski River from Waterbury that experience flood damages in the project area (Table 2).

Table 1: Participating Municipalities

	Waterbury, Vermont	**Willsboro, New York**
Flood sources	Winooski River	Bouquet River and Lake Champlain
Flood damages	Main Street flooding during Tropical Storm Irene and flood of 1927.	Main Street flooding during Tropical Storm Irene, shoreline flooding during 2011 high lake level, and periodic ice jam flooding.
Existing model	LIDAR-based HEC-RAS model updated by MMI with local floodplain survey.	HEC-2 model converted to HEC-RAS between Town and Lake Champlain. Model extended upstream to Town limits.
Flood risk reduction	Considering floodplain restoration	Considering dam removal and working on river bank stabilization

Table 2: Added Municipalities

	Duxbury, Vermont	**Moretown, Vermont**
Flood sources	Winooski River	Winooski River
Flood damages	Flooding along River Road and damages in Patterson Park during Tropical Storm Irene.	Limited flooding along Routes 2 and damages along Commercial Drive during Tropical Storm Irene.
Existing model	LIDAR-based HEC-RAS model updated by MMI with local floodplain survey.	LIDAR-based HEC-RAS model updated by MMI with local floodplain survey.
Flood risk reduction	FEMA minimum standards.	FEMA minimum standards.

The National Flood Insurance Act of 1968 established the National Flood Insurance Program (NFIP) to protect people and property from flood damage (44CFR Ch60). The NFIP establishes minimum standards for a FEMA designated Special Flood Hazard Area (SFHA) such as no fill in the floodway, elevating structures above the based flood elevation (BFE) (typically taken as the flood that has 1% chance of occurring each year or the 100-year flood), and waterproofing new or improved structures. Communities are encouraged to go beyond the minimum standards to reduce flood risks. The FEMA Community Rating System provides discounted insurance rates for communities that go beyond the minimum standards.

The State of Vermont recommends 1 foot of freeboard above the BFE for houses and either 1 foot of freeboard or 2 feet of flood-proofing for non-residential buildings. Basements are not allowed within the SFHA. No filling can take place in the floodway unless an engineering analysis is performed to confirm no change in flood levels.

The Town and Village of Waterbury, Vermont require new or substantially improved structures to have the lowest floor 1 foot or more above the base flood elevation. For non-residential buildings, 2 feet of freeboard above the BFE are recommended and existing non-residential structures should be dry flood-proofed to at least 2 feet above the BFE.

The State of Vermont is currently developing new floodplain rules for its lands and state-regulated infrastructure to reduce flood and erosion risks. The draft standards include prohibition of encroachments in the river corridor, elevation of the lowest floor of houses to 2 feet above the BFE, elevation for flood-proofing of the lowest floor of non-residential structures 2 feet above the BFE, elevation of critical facilities to the 500-year flood or 2 feet above the BFE, prohibition of toxics in the flood hazard area, and no adverse impact (NAI) analysis of development proposed in floodplains outside of village centers and farm production areas.

New York State recommends locating all of its projects outside of flood hazard areas. If that is not possible, 1 foot of freeboard above the BFE for the lowest floor of houses and non-residential buildings is required. Critical facilities such as hospitals, power stations, chemical storage areas, and emergency services are prohibited in flood hazard areas.

New York State has developed a model law for towns to adopt that recommends elevating residential structures 2 feet above the BFE and non-residential structures 2 feet above the BFE or water tight flood-proofing to 2 feet above the BFE. When floodplain filling is permitted, compensatory storage is recommended to offset the fill area. Critical facilities are recommended to be located outside of the 500-year floodplain.

The Town of Willsboro establishes a Flood Hazard Area District in its zoning based on FEMA floodplain mapping and designates a Flood Protection Elevation of 1 foot above the 100-year flood. No structures or filling are allowed in the Flood Hazard District lying outside of the General Business District and Industrial District and outside the portion of the Residential - Medium Density District downstream from the Route 22 Bridge over the Boquet River. Construction within these districts in the Hamlet of Willsboro are subject to requirements such as the structures must be reasonably safe from flooding, flood-resistant materials area used in construction, and the lowest floor is the Flood Protection Elevation. Utilities in non-residential structures in the Flood Hazard District must also be elevated to the Flood Protection Elevation.

Milone & MacBroom, Inc. collaborated with Earth Economics of Tacoma, Washington and Fitzgerald Environmental of Colchester, Vermont on this project (Table 3).

Table 3: Work Task Distribution

Objective	Milone & MacBroom	Earth Economics	Fitzgerald Environmental
Floodplain valuation	Assist	Lead	Assist
Floodplain scenarios	Assist	Lead	Assist
Hydrology	Lead		Assist

Hydraulics	Lead		Assist
Damage modeling	Lead		
Reporting	Lead	Assist	Assist

This project supports *Opportunities for Action* (LCBP, 2010) goals to:

- Promote healthy and diverse economic activity and sustainable development principles within the Lake Champlain Basin while improving water quality and conserving the natural and cultural heritage resources on which the regional economy is based [Chapter 10]; and
- Identify potential changes in climate and develop appropriate adaptation strategies to minimize adverse impacts on Lake Champlain's ecosystem and natural, heritage, and socioeconomic resources [Chapter 8].

The establishment of economically viable floodplain management alternatives for current and expected future conditions specifically fulfills the following *Opportunities for Action* tasks:

- 4.8.4: Recommend adjustments needed in management practices to effectively respond to climate change by 2012 and
- 10.1.2: Identify long-term economic benefits that will be generated through near-term investment in conservation and restoration of the ecological engine of the Basin economy.

This project promoted adherence to the flood resilience management guidelines put forth in the report on Flood Resilience in the Lake Champlain Basin and Upper Richelieu River (USFS, 1992). More specifically, this work contributed to the following flood policy recommendations:

- Identify and promote economic benefits for improved flood resilience;
- Develop a comprehensive hydrological model for Lake Champlain, including flood frequency and severity analyses for flood hazard mapping;
- Identify Fluvial Erosion Hazard (FEH) Areas;
- Establish floodplain development standards; and
- Promote community acceptance of floodplain management principles and regulations.

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Appendix 2: Methodology – Ecosystem Valuation in the Lake Champlain Basin

Lake Champlain Basin Write-up

Benefit Transfer Methodology – Opportunities and Limitations

The results of this attempt to include monetary value for ecosystem services in a benefit cost analysis have important and significant implications on the restoration and management of natural capital. Valuation exercises have limitations that must be noted, although these limitations should not detract from the core finding that ecosystems produce a significant economic value to society. A benefit transfer analysis estimates the economic value of a given ecosystem (e.g., wetlands) from prior studies of that ecosystem type. Like any economic analysis, this methodology has strengths and weaknesses. Some arguments against benefit transfer include:

1. Every ecosystem is unique; per-hectare values derived from another location may be irrelevant to the ecosystems being studied.

2. Even within a single ecosystem, the value per acre depends on the size of the ecosystem; in most cases, as the size decreases, the per hectare value is expected to increase and vice versa. (In technical terms, the marginal cost per hectare is generally expected to increase as the quantity supplied decreases; a single average value is not the same as a range of marginal values).

3. Gathering all the information needed to estimate the specific value for every ecosystem within the study area is not feasible. Therefore, the true value of all of the wetlands, forests, pastureland, etc. in a large geographic area cannot be ascertained and will be underestimated. In technical terms, we have far too few data points to construct a realistic demand curve or estimate a demand function.

4. To value all, or a large proportion, of the ecosystems in a large geographic area is questionable in terms of the standard definition of exchange value. We cannot conceive of a transaction in which all or most of a large area's ecosystems would be bought and sold. This emphasizes the point that the value estimates for large areas (as opposed to the unit values per hectare) are more comparable to national income account aggregates and not exchange values.[i] These aggregates (i.e., GDP) routinely impute values to public goods for which no conceivable market transaction is possible. The value of ecosystem services of large geographic areas is comparable to these kinds of aggregates (see below).

Proponents of the above arguments recommend an alternative valuation methodology that amounts to limiting valuation to a single ecosystem in a single location. This method only uses data developed expressly for the unique ecosystem being studied, with no attempt to extrapolate from other

ecosystems in other locations. An area with the size and landscape complexity of the Lake Champlain Basin will make this approach to valuation extremely difficult and costly. Responses to the above critiques can be summarized as follows (See Costanza et al., 1998; and Howarth and Farber, 2002 for more detailed discussion):

1. While every wetland, forest or other ecosystem is unique in some way, ecosystems of a given type, by their definition, have many things in common. The use of average values in ecosystem valuation is no more or less justified than their use in other macroeconomic contexts; for instance, the development of economic statistics such as gross domestic or gross National product. This study's estimate of the aggregate value of the ecosystem service values for Waterbury, VT and Willsboro, NY is a valid and useful (albeit imperfect, as are all aggregated economic measures) basis for assessing and comparing these services with conventional economic goods and services.

2. The results of the spatial modeling analysis that are described in other studies do not support an across the board claim that the per acre value of forest or agricultural land depends on the size of the parcel. While the claim does appear to hold for nutrient cycling and other services, the opposite position holds up fairly well for what ecologists call "net primary productivity" or NPP, which is a major indicator of ecosystem health. It has the same position, by implication, of services tied to NPP — where each hectare makes about the same contribution to the whole, regardless of whether it is part of a large plot of land or a small one. This area of inquiry needs further research, but for the most part, the assumption that average value is a reasonable proxy for marginal value is appropriate for a first approximation. Also, a range of different parcel sizes exists within the study site, and marginal value will average out.

3. As employed here, the prior studies we analyzed encompass a wide variety of time periods, geographic areas, investigators and analytic methods. Many of them provide a range of estimated values rather than single-point estimates. The present study preserves this variance; no studies were removed from the database because their estimated values were deemed to be "too high" or "too low," although studies that used antiquated methods and data were removed. Limited sensitivity analyses were also performed. This approach is similar to determining an asking price for a piece of land based on the prices of comparable parcels; even though the property being sold is unique, realtors and lenders feel justified in following this procedure to the extent of publicizing a single asking price rather than a price range.

4. The objection to the absence of even an imaginary exchange transaction was made in response to the study by Costanza et al. (1997) of the value of all of the world's ecosystems. Leaving that debate aside, one can conceive of an exchange transaction in which, for example, all of, or a large portion of a watershed was sold for development, so that the basic technical requirement of an economic value reflecting the exchange value could be satisfied. Even this is not necessary if one recognizes the different purpose of valuation at this scale — a purpose that is more analogous to national

income accounting than to estimating exchange values, which are highly volatile and poor indicators for making long-term investment decisions.[ii]

In this report, we have displayed our study results in a way that allows one to appreciate the range of values and their distribution. It is clear from inspection of the tables that the final estimates are not extremely precise. However, they are much better estimates than the alternative of assuming that ecosystem services have zero value, or, alternatively, of assuming they have infinite value. Pragmatically, in estimating the value of ecosystem services, it seems better to be approximately right than precisely wrong.

The estimated value of the world's ecosystems presented in Costanza et al. (1997), for example, has been criticized as both (1) a serious underestimate of infinity and (2) impossibly exceeding the entire gross World product. These objections seem to be difficult to reconcile, but that may not be so. Just as a human life is priceless so are ecosystems, yet people are paid for the work they do.

Upon some reflection, it should not be surprising that the value ecosystems provide to people exceeds the gross world product. Costanza's estimate of the work that ecosystems do is an underestimate of the "infinity" value of priceless systems, but that is not what he sought to estimate. Consider the value of one ecosystem service, such as photosynthesis, and the ecosystem good it produces: atmospheric oxygen. Neither is valued in Costanza's study. Given the choice between breathable air and possessions, informal surveys have shown the choice of oxygen over material goods is unanimous. This indicates that the value of photosynthesis and atmospheric oxygen to people exceeds the value of the gross world product — and oxygen production is only a single ecosystem service and good.

General Limitations

- **Static Analysis**. This analysis is a static, partial equilibrium framework that ignores interdependencies and dynamics. Though new dynamic models have been developed, they are often costly, time consuming, and data-intensive. The effect of this omission on valuations is difficult to assess.

- **Increases in Scarcity.** The valuations probably underestimate shifts in the relevant demand curves as the sources of ecosystem services become more limited. The values of many ecological services rapidly increase as they become increasingly scarce.[iii] If the Lake Champlain Basin's ecosystems' ecosystem services are scarcer than assumed here, their value has been underestimated in this study. Such reductions in supply appear likely as land conversion and development proceed; climate change may also adversely affect the ecosystems, although the precise impacts are more difficult to predict.

- **Existence Value**. The approach does not fully include the infrastructure or existence value of ecosystems. It is well known that people value the existence of certain ecosystems, even if they never plan to use or benefit from them in any direct way. Estimates of existence value are rare; including this service will obviously increase the total values.

- **Other non-economic Values**. Economic and existence values are not the sole decision-making criteria. A technique called multi-criteria decision analysis is available to formally incorporate economic values with other social and policy concerns.[iv] Having economic information on ecosystem services usually helps this process because traditionally, only opportunity costs of forgoing development or exploitation are counted against non-quantified environmental concerns.

GIS Limitations

- **GIS Data**. Since this valuation approach involves using benefit transfer methods to assign values to land cover types based, in some cases, on their contextual surroundings, one of the most important issues with GIS quality assurance is reliability of the land cover maps used in the benefits transfer, both in terms of accuracy and categorical precision.
    - *Accuracy:* The source GIS layers are increasingly accurate, and highly accurate in comparison to historical standards, but may contain some minor inaccuracies due to land use changes after the data was sourced, inaccurate satellite readings and other factors.
    - *Categorical Precision*: The absence of certain GIS layers that matched the land cover classes used in the Earth Economics database created the need for multiple datasets to be combined.
- **Ecosystem Health.** There is the potential that ecosystems identified in the GIS analysis are fully functioning to the point where they are delivering higher values than those assumed in the original primary studies, which would result in an underestimate of current value. On the other hand, if eco- systems are less healthy than those in primary studies, this valuation will overestimate current value. There is ongoing research into ecosystem health that will inform future studies.
- **Spatial Effects**. This ecosystem service valuation assumes spatial homogeneity of services within ecosystems, i.e., that every hectare of forest produces the same ecosystem services. This is clearly not the case. Whether this would increase or decrease valuations depends on the spatial patterns and services involved. Solving this difficulty requires spatial dynamic analysis. More elaborate system dynamic studies of ecosystem services have shown that including interdependencies and dynamics leads to significantly higher values (Boumans et al., 2002), as changes in ecosystem service levels ripple throughout the economy. Earth Economics received a National Science foundation grant to help examine this issue. In the future, spatial effects will be easier to include in valuation studies. For the purposes of this study, time and financial considerations prohibited the use of such models.

Benefit Transfer/Database Limitations

- **Incomplete Coverage.** That not all ecosystems have been valued or studied well is perhaps the most serious limitation of this study, because it results in a significant underestimate of

the value of ecosystem services. More complete valuation coverage would certainly increase the values shown in this report; since no known valuation studies exist, these clearly valuable ecosystem services yet have reported estimated values of zero. The following table illustrates which ecosystem services were identified in the study site for each land cover type, and which of those were valued.

Data Gaps Analysis Summary		Agriculture	Forest	Shrubland/Grassland	River	Village Greenspace	Wetland
	Air Quality		x				
	Biological Control		x	x			
	Climate Stability	x	x	x			x
	Erosion Control	x	x	x			
	Flood Mitigation			x			x
	Pollination	x					
	Soil Formation	x					
	Waste Treatment		x				x
	Water Regulation	x				x	
	Water Supply		x				x
	Energy & Raw Materials		x	x			
	Food Production	x					x
	Genetic Resources						
	Medicinal Resources						
	Ornamental Resources						
	Habitat & Nursery			x			x
	Aesthetic Information	x	x		x	x	x
	Cultural & Artistic	x					
	Recreation & Tourism	x	x		x	x	
	Science & Education						
	Spiritual & Historic						

Key:

	Ecosystem service exists with the land cover but is not valued in this report
X	Ecosystem service produced by land cover and valued in this report
	Ecosystem service not produced by land cover

- **Selection Bias**. Bias can be introduced in choosing the valuation studies, as in any appraisal methodology. The use of a range partially mitigates this problem.

- **Consumer Surplus.** Because the benefit transfer method is based on average rather than marginal cost, it cannot provide estimates of consumer surplus. However, this means that valuations based on averages are more likely to underestimate total value.

Primary Study Limitations

- **Willingness-to-Pay Limitations**. Most estimates are based on current ability and willingness to pay or proxies, which are limited by people's incomes, perceptions and knowledge base. Often the "ability to pay" is omitted from WTP discussions. Wealth distribution has a clear impact on valuation. Often coastal communities highly dependent upon ecosystem services have lower purchasing power than urban communities. This places a bias in valuation data. In addition, improving people's knowledge base about the contributions of ecosystem services to their welfare would almost certainly increase the values based on ability and willingness to pay, as people would realize that ecosystems provided more services than they had previously known.

- **Price Distortions**. Distortions in the current prices used to estimate ecosystem service values are carried through the analysis. These prices do not reflect environmental externalities and are therefore again likely to be underestimates of true values.

- **Non-Linear/Threshold Effects**. The valuations assume smooth responses to changes in ecosystem quantity with no thresholds or discontinuities. Assuming (as seems likely) that such gaps or jumps in the demand curve would move demand to higher levels than a smooth curve, the presence of thresholds or discontinuities would likely produce higher values for affected services.[v] Further, if a critical threshold is passed, valuation may leave the normal sphere of marginal change and larger-scale social and ethical considerations predominate, such as an endangered species listing.

- **Sustainable Use Levels.** Value estimates are not necessarily based on sustainable use levels. Limiting use to sustainable levels would imply higher values for ecosystem services as the effective supply of such services is reduced.

If the above problems and limitations were addressed, the result would most likely be a narrower range of values and significantly higher values overall. At this point, however, it is impossible to determine more precisely how much the low and high values would change.

Carbon Valuation

Caron sequestration is the removal of carbon dioxide (CO2) from the atmosphere, thus regulating the atmospheric concentrations of this significant greenhouse gas. This also contributes to the complex and critically valuable service of climate stability. Forests, wetlands, grasslands, and shrub ecosystems all play a role in carbon sequestration; in the Lake Champlain Basin, carbon sequestration occurs primarily in wetlands and forests. Croplands are also integral to carbon cycles, although the rate of sequestration of carbon depends on the end uses of crops and soil management practices.

Storage of greenhouse gases contributes to the build-up of carbon "stocks." Carbon stocks refer to carbon that is being retained rather than released into the atmosphere. Living plants sequester and store carbon. Non-living biomass, organic matter, sediments, and rocks also store large stocks of carbon. Decaying organic matter releases carbon dioxide back into the atmosphere. Thus there are flows of

carbon to and from the atmosphere through geological and biological stocks of carbon. Both the flow of carbon in sequestration and the stocks of carbon in trees and soils are assessed in this report.

This study determined sequestration rates for land cover classes within the Basin for calculating sequestration values. Different land cover classes, such as grasslands, different forest types, and wetlands, have different carbon sequestration rates and different carbon stocks. The carbon price was pulled from the Interagency Working Group on the Social Cost of Carbon report for the year 2011. Values were converted to 2014 USD. Multiple sources were used to estimate carbon sequestration rates and carbon stock values for each land cover type in the Basin floodplains. Differences in carbon sequestration and storage values were represented by a value range. Carbon sequestration rates were converted to metric tons of CO2 per acre per year (mTC/acre/year), multiplied by the social cost per metric ton of carbon, and compared with relevant ecosystem service valuation studies.

Understanding Aesthetic Value

These values may not be applied to the analysis but we want to call out the multitude of studies that easily justify an estimated 4-5% decrease in housing prices when they're located in the floodplain. Translation: if there is a house that is valued at $100,000 **outside** the floodplain, it would be worth $4,000-$5,000 less located inside the floodplain. Keeping in mind that this is in spite of numerous regulatory holes that encourage floodplain residential development. Immediately after a flood, when people are highly aware of the potential damage, there could be a loss of nearly $13,000 on that $100,000 house. We know that asymmetric information is a huge problem in floodplain housing situations.

This is obviously measured by the indirectly termed "100-year flood zone." People hear of a one-in-a-hundred year chance and think "That won't happen to me!" but they don't consider that a 1% chance flood has a 26% chance of occurring during the average 30 year mortgage.

How to Value the Floodplain: Establishing Baselines for Waterbury and Willsboro

Dealing with an ecosystem service valuation of "the floodplain" can be quite difficult. The floodplain is a regulatory and geomorphological designation, *not* a single ecosystem type. There are agricultural lands in the floodplain that should be considered separate, ecologically from both agricultural lands outside the floodplain and other floodplain ecosystems, such as floodplain grasslands, or floodplain wetlands. Therefore, there is a need for specificity when valuing each ecosystem type found within the floodplain. However, that specificity becomes burdensome when applying the valuation to decision-making, because planners aren't necessarily partitioning out the floodplain ecosystems in their heads; they're thinking of the cost-benefit of trading one acre of *floodplain* for one acre of development. In order to try to speak to that for these communities, we have applied a weighted average to the current distribution of floodplain ecosystem types to find an estimate for the high and low dollar-per-year and dollar-per-acre-per-year of the floodplains in Waterbury and Willsboro. Because the two towns differ in their distribution of land cover types their weighted averages are distinct and unique. These averages only

apply to the floodplains as they are currently divided and are only to be considered as estimates. When seriously considering one floodplain development scenario versus another, the detailed ecosystem type classification and valuation (for which we have provided numbers) should be conducted. However we hope that the weighted averages can be useful for planners and decision-makers to have in mind.

Bringing Ecosystem Services into Benefit Cost Analysis & Scenario Modeling

In order to bring the ecosystem service values calculated into the benefit cost analyses of floodplain development scenarios, the team used average annual marginal change values. A single value was necessary for the final accounting tables. Each value in those final tables represents the average value of the change in annual flow of ecosystem service benefits between each development scenario based on the current annual flow.

It would be preferable to continue to employ a range of values, but such an approach would have obscured the interpretation of the results by requiring twice as many accounting tables. Selecting the average annual change was determined to have a sufficient level of clarity for the issues being investigated by the project team.

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[i] Howarth, R.B., and Farber, S. (2002). Accounting for the value of ecosystem services. Ecological Economics, 41(3), 421-429.

[ii] Howarth, R.B., and Farber, S. (2002). Accounting for the value of ecosystem services. Ecological Economics, 41(3), 421-429.

[iii] Boumans, R., Costanza, R., Farley, J., Wilson, M.A., Portela, R., Rotmans, J., Villa, F., and Grasso, M. (2002). Modeling the dynamics of the integrated earth system and the value of global ecosystem services using the GUMBO model. Ecological Economics, 41(3), 529-560.

[iv] De Montis, A., De Toro, P., Droste-Franke, B., Omann, I., and Stagle, S. (2004) Assessing the Quality of Different MCDA Methods, in M. Getzener, Spash, C., and Stagle, S., (eds.). Alternatives for Environmental Valuation, Routledge, London.

[v] Limburg, K.E., O'Neil, R.V., Costanza, R., and Farber, S. (2002). Complex systems and valuation. Ecological Economics, 41, 409-420.

Appendix 3: Lake Champlain Basin Floodplain Ecosystem Service Values – Literature Review and Annotated Bibliography

Hybrid Analysis

The following studies offer the possibility of calculating a hybrid value with data provided by the study sites. We are extremely safe in estimating a 4 to 5 percent decrease in housing prices when they're located in the floodplain.

The Impact of Flood Zones on Property Values

Chivers, J. and N. E. Flores. 2002. Market Failure in Information: The National Flood Insurance Program. Land Economics (78) 4: 515-521.

This article explores market failure in the NFIP as a result of asymmetric information in the housing market. Economists have noted that a compulsory NFIP could improve economic efficiency in floodplain housing markets, but the authors of this study use a case study in Boulder, Colorado to show that asymmetric information is the primary driver of market failure in the NFIP. A survey and subsequent analysis shows that lack of knowledge of flood risk and lack of knowledge of the cost of insuring on the part of the buyer impedes economic efficiency in the NFIP. 84 percent of respondents said that the cost of insurance was higher than expected. Only two percent of respondents said that they cost of flood insurance associated with the home was discussed prior to closing.

Bin, O and S. Polasky. 2004. Effects of Flood Hazards on Property Values: Evidence Before and After Hurricane Floyd. Land Economics (80) 4: 490-500.

Using a hedonic price model, the authors estimated the effects of flood hazard on residential property values. The data were collected from over 8,000 homes in Pitt County, North Carolina. Hurricane Floyd, in September 1999, provides a basis around which to evaluate the impact of flooding on housing prices. The results demonstrate that houses in the floodplain have a lower market value than they would outside the floodplain. The results also show that the housing market within a floodplain takes a major dive in the years following a major flood. On average, the authors found that property values are reduced by 5.8 percent when located in a floodplain. However, after Hurricane Floyd the discount more than doubled, rising to 12.7 percent.

Troy, A. and J. Romm. 2004. Assessing the Price Effects of Flood Hazard Disclosure Under the California Natural Hazard Disclosure Law (AB 1195). Journal of Environmental Planning and Management (47) 1: 137-162.

This study uses the hedonic price method to estimate the effect that a flood hazard disclosure law had on property values throughout California. The discount that the authors found totaled to 4.3 percent for floodplain homes.

Pope, J. C. 2008. Do Seller Disclosures Affect Property Values? Buyer Information and the Hedonic Model. Land Economics (84) 4: 551-572.

This article explores the extent of the impact that asymmetric information related to environmental disamenities has on the housing market. Using a hedonic model, the results indicate a 4 percent decline in housing prices after a flood hazard disclosure took place.

Bin, O. and C. E. Landry. 2013. Changes in Implicit Flood Risk Premiums: Empirical Evidence from the Housing Market. Journal of Environmental Economics and Management (65) 3: 361-376.
Author Bin returns to the results from Bin and Polasky 2004 to re-examine the findings after Hurricane Floyd. The authors also evaluate the flood zone price differentials for Hurricane Fran. After Hurricane Fran they find a 5.7 percent decrease, and after Hurricane Floyd they find an 8.8 percent decrease. They also find that the flood zone price differential diminishes over time; around six years after Hurricane Floyd the differential nearly disappears. This demonstrates the variability in buyers' and sellers' risk perceptions over time. It suggests that these actors have a short memory; infrequent flooding is less likely to impact housing prices over the long term.

Carbon Sequestration and Storage

Carbon Price

Interagency Working Group on Social Cost of Carbon (for year 2011)

Carbon Sequestration Rates

Smith, W.N., Desjardins, R.L., Grant, B. 2001. Estimated changes in soil carbon associated with agricultural practices in Canada. Canadian Journal of Soil Science 81: 221-227.

- Cultivated Low

Lasco, R.D., Ogle, S., Raison, J., Verchot, L., Wassmann, r., Yagi, K., Bhattacharya, S., Brenner, J.S., Daka, J.P., Gonzalez, S.P., Krug, T., Li, Y., Martino, D.L., McConkey, B.G., Smith, P., Tyler, S.C., Zhakata, W. 2006. Chapter 5: Cropland. In 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

- Cultivated High

Post, W., Kwon, K. 2000. Soil carbon sequestration and land-use change: processes and potential. Global Change Biology 6(3): 317-327.

- Forest Low

Goulden, M.L., Munger, J.W., Fan, S.M., Daube, B.C., Wofsy, S.C. 1996. Exchange of carbon dioxide by a deciduous forest: response to interannual climate variability. Science 271(5255): 1576-1578.

- Forest High

ECCP. Working ground sinks related to agricultural soils: final report. European climate change programme.

- Grassland Low

Malmer, N., Johansson, T., Olsrud, M., Christensen, T.R. 2005. Global Change Biology 11: 1895-1909.

- Grassland High

Bridgeham, S.D., Megonigal, J.P., Keller, J.K., Bliss, N.B., Trettin, C. 2006. The carbon balance of North American wetlands. Wetlands 26(4): 889-916.

- Inland Wetlands Low & High

Carbon Storage Rates

Liu, S., Liu, J., Young, C.J., Werner, J.M., Wu, Y., Li, Z., Dahal, D., Oeding, J., Schmidt, G., Sohl, T.L., Hawbaker, T.J., Sleeter, B.M. 2012. "Chapter 5: Baseline carbon storage, carbon sequestration, and greenhouse-gas fluxes in terrestrial ecosystems of the western United States". In: Baseline and projected future carbon storage and greenhouse-gas fluxes in ecosystems of the western united states. Zhu, Z. and Reed, B.C., eds. USGS Professional Paper 1797.

- Cultivated High

Manley, J., van Kooten, G.C., Moeltner, K., Johnson, D.W. 2005. Creating carbon offsets in agriculture through no-till cultivation: a meta-analysis of costs and carbon benefits. Climatic Change 68: 41-65.

- Cultivated Low

Aalde, H., Gonzalez, P., Gytarsky, M., Krug, T., Kurz, W.A., Ogle, S., Raison, J., Schoene, D., Ravindranath, N.H., Elhassan, N.G., Heath, L.S., Higuchi, N., Kainja, S., Matsumoto, M., Sanchez, M., Somogyi, Z. 2006. Chapter 4: Forest land. In 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 4 Agriculture, Forestry, and other land use.

- Forest Low

- Inland Wetlands Low

Heath, L.S., Smith, J.E., Birdsey, R.A. 2003. Carbon Trends in U.S. forestlands: a context for the role of soils in forest carbon sequestration. The Potential of U.S. Forest Soils to Sequester Carbon. Chapter 3 in: Kimble, J M., Heath, Linda S., Richard A. Birdsey, and Rattan Lal, editors. 2003. “The Potential of US Forest Soils to Sequester Carbon and Mitigate the Greenhouse Effect”, CRC Press, Boca Raton, FL. P. 35-45

- Forest High

Verchot, L., Krug, T., Lasco, R.D., Ogle, S., Raison, J., Li, Y., Martino, D.L., McConkey, B.G., Smith, P. 2006. Chapter 6: Grassland. 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 4 Agriculture, Forestry, and other land use.

- Grassland Low & High

Bridgeham, S.D., Megonigal, J.P., Keller, J.K., Bliss, N.B., Trettin, C. 2006. The carbon balance of North American wetlands. Wetlands 26(4): 889-916.

- Inland wetlands High

Davies, Z.G., Edmondson, J.L., Heinemeyer, A., Leake, J.R., Gaston, K.J. 2011. Mapping an urban ecosystem service: quantifying above-ground carbon storage at a city-wide scale. Journal of applied ecology 48: 1125-1134.

- Urban Low & High

Benefit Transfer

The following studies will be used in a benefit-transfer capacity. Several studies report values for multiple land cover types, and thus will be repeated in the following sections.

Agriculture

Beasley, S.D., Workman, W.G., and N.A. Williams. 1986. Non-Market Valuation of Open Space And Other Amenities Associated with Retention of Lands in Agricultural Use: The Matanuska-Susitna Valley of Southcentral Alaska: A Case Study. Agricultural and Forestry Experiment Station, School of Agriculture and Land Resources Management, University of Alaska-Fairbanks, [1986]. Bulletin; 71.

- Agriculture
    - Cultural and artistic
- This study estimates the cultural and artistic value of farmland via the contingent valuation method. The survey sample size was 119 households in the Matanuska-Susitna Basin in Alaska. The authors asked respondents to offer their willingness-to-pay to prevent development on farmland. This value was transferred to Lake Champlain Basin farmland.

Bergstrom, J.C., and R.C. Ready. 2009. What Have We Learned from Over 20 Years of Farmland Amenity Valuation Research in North America?

- Agriculture
    - Aesthetic Info - Amenity Value
- The authors conducted a meta-analysis of North American ecosystem service valuations estimating the amenity value of farmland. The values transferred to the Lake Champlain Basin are all based on studies conducted with the hedonic pricing methodology.

Moore, R.G, McCarl, B.A. 1987. Off-Site Costs of Soil Erosion: A Case Study in the Willamette Valley. Western Journal of Agricultural Economics. 12(1):42-49.

- Agriculture
    - Erosion Control
- This study evaluates the average and marginal off-site costs of erosion for Willamette Valley agriculture in the state of Oregon. This is then expressed in terms of a potential avoided cost, should erosion control methods be employed.

Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., Crist, S., Shpritz, L., Fitton, L., Saffouri, R., and R. Blair. 1995. Environmental and Economic Costs of Soil Erosion and Conservation Benefits. Science. 267(5201):1117-1123

- Agriculture
  - Erosion Control
- This article estimates the avoided damages to agriculture if a specific suite of erosion control methods were adopted nationally in the United States.

Sandhu, H.S., Wratten, S.D., Cullen, R., Case, B. 2008. The Future of Farming: The Value of Ecosystem Services in Conventional and Organic Arable Land. An Experimental Approach. Ecological Economics. 64(4):835-848.

- Agriculture
  - Soil Formation
  - Water Regulation

- This study from Canterbury, New Zealand focuses on a comparison of ecosystem services provided by conventional and organic farmland. For both soil formation and water regulation, the authors use the replacement cost of the service to value it. Soil formation was determined to be provided by micro-organisms, earthworms, and other invertebrates.

Schwörer, T. 2014. The Mat-Su Borough in 2040: What Would Residents Like to See? Institute of Social and Economic Research – University of Alaska Anchorage. Research Summary No. 76.

- Agriculture
  - Cultural and Artistic
- This publication from the University of Alaska summarizes survey results from residents of the Matanuska-Susitna Basin. The survey asked participants to estimate their willingness-to-pay for policies that would change current trends regarding salmon population decline, loss of farmland and access to recreation areas, industry investment, and population growth. The results found that residents of the basin would pay a significant amount to keep existing farmland, and they would pay even more to add more farmland. These values were transferred as cultural and artistic values for Lake Champlain Basin farmland.

Wilson, S.J. 2010. Natural Capital in BC's Lower Mainland: Valuing the Benefits from Nature. David Suzuki Foundation.

- Agriculture
  - Food
  - Rec & Tourism
- Wilson uses a mixture of primary and secondary valuation methodologies to arrive at a valuation for all of British Columbia's Lower Mainland ecosystems. Several of the values for cultivated land and forests were transferred to Lake Champlain Basin ecosystems. For air quality in forests, CITYgreen software was used to assess the amount of air pollutants removed by the tree campy cover across the study area. CITYgreen calculates the value of

air cleansing by trees using average removal rates of carbon monoxide, nitrogen dioxide, particulate matter, and sulphur dioxide by trees. CITYgreen calculates the dollar value externality costs of this service. An average of each state in the U.S. is used.

Winfree, R., Gross, B., and C. Kremen. 2011. Valuing pollination services to agriculture. Ecological Economics 71: 80-88

- Agriculture
  - Pollination
- The authors use the replacement cost method to value pollination services in agricultural lands. The study focuses on agricultural lands in New Jersey and New York. The replacement cost evaluated is attributable net income. This value has been transferred to Lake Champlain croplands.

Floodplain Forest

Everard, M. and S. Jevons. 2010. Ecosystem Services Assessment of Buffer Zone Installation on the Upper Bristol Avon, Wiltshire. Report for the Environment Agency, U.K.

- Forests
  - Water Supply – Pre Treatment Water Supply
- The authors evaluate the avoided cost of municipal water supply provided by local forests by looking at the improved quality of pre-treatment water for the next town downstream. Authors assumed a 0.2% reduction in treatment costs of potable water supply for the next down downstream (Chippenham, UK), assuming their annual treatment costs were 200,000 GBP per year.

Gren, I.M., Groth, K.H., and M. Sylven. 1995. Economic Values of Danube Floodplains. Journal of Environmental Management 45(4):333-345

- Floodplain Forests
  - Energy and Raw Mats – Forest Products
  - Rec & Tourism
- The authors of this study consider three floodplain land covers: forest, grassland, and wetland. This study is itself a benefit transfer. All values used from this study were from primary valuations calculated in Austria and Sweden. Values transferred from this study include wetland values for commercial fishery production, grassland values for energy and raw materials, and forest values for energy and raw materials and recreation and tourism.

Olewiler, N. 2004. The Value of Natural Capital in Settled Areas of Canada. Department of Economics & Public Policy Program, Simon Fraser University, British Columbia

- Forests
  - Rec & Tourism – Fishing, Hunting, Wildlife Viewing

    - Erosion Control
- This report has both primary and secondary valuations. All values applied to Lake Champlain are secondary, taken from a Canadian report on Conservation Cover Incentive Programs. This valuation assesses the habitat and nursery value of grasslands as well as recreation and tourism and erosion control for forests.

Qiu, Z., Prato, T. 1998. Economic Evaluation of Riparian Buffers in an Agricultural Watershed. Journal of the American Water Resources Association. 34(4):877-890

- Forests
    - Waste Treatment – Water Filtration
- Qiu and Prato value forested riparian areas in Missouri. They use the Soil and Water Assessment Tool (SWAT), a mathematical model that simulates water quality, combined with experimental data on riparian buffers. Scenarios of agricultural pollution of farms with and without forested riparian buffers are simulated to establish a waste treatment value for those areas. These values have been transferred to Lake Champlain Basin riparian forests.

Thompson, R., Hanna, R., Noel, J., and D. Piirto. 1999. Valuation of tree aesthetics on small urban-interface properties.

- Forests
    - Aesthetic Info - Amenity Value
- This study evaluates the contribution of small forest plots on the urban-wildland interface to residential property values. Research was located in the Lake Tahoe Basin in California. The authors used a hedonic pricing model to estimate a dollar value per household. This value has been transferred as an aesthetic value to Lake Champlain Basin floodplain forests.

Wilson, S.J. 2010. Natural Capital in BC's Lower Mainland: Valuing the Benefits from Nature. David Suzuki Foundation.

- Forests
    - Air Quality
    - Pest Control
- Wilson uses a mixture of primary and secondary valuation methodologies to arrive at a valuation for all of British Columbia's Lower Mainland ecosystems. Several of the values for cultivated land and forests were transferred to Lake Champlain Basin ecosystems. For air quality in forests, CITYgreen software was used to assess the amount of air pollutants removed by the tree campy cover across the study area. CITYgreen calculates the value of air cleansing by trees using average removal rates of carbon monoxide, nitrogen dioxide, particulate matter, and sulphur dioxide by trees. CITYgreen calculates the dollar value externality costs of this service. An average of each state in the U.S. is used.

Floodplain Grassland

Gren, I.M., Groth, K.H., and M. Sylven. 1995. Economic Values of Danube Floodplains. Journal of Environmental Management 45(4):333-345

- Floodplain Grasslands
    - Energy and Raw Mats – Fodder for Animals
- The authors of this study consider three floodplain land covers: forest, grassland, and wetland. This study is itself a benefit transfer. All values used from this study were from primary valuations calculated in Austria and Sweden. Values transferred from this study include wetland values for commercial fishery production, grassland values for energy and raw materials, and forest values for energy and raw materials and recreation and tourism.

Olewiler, N. 2004. The Value of Natural Capital in Settled Areas of Canada. Department of Economics & Public Policy Program, Simon Fraser University, British Columbia

- Grasslands
    - Habitat and Nursery
- This report has both primary and secondary valuations. All values applied to Lake Champlain are secondary, taken from a Canadian report on Conservation Cover Incentive Programs. This valuation assesses the habitat and nursery value of grasslands as well as recreation and tourism, erosion control, and phosphorus reduction for forests.

Rein, F.A. 1999. An economic analysis of vegetative buffer strip implementation. Case study: Elkhorn Slough, Monterey Bay, California. Coastal Management 27(4): 377-390.

- Grasslands
    - Bio Control – Pest and Weed Control
    - Soil Retention – Erosion Control, Farm Protection, Road Protection (short and long term)
    - Waste Treatment – Nitrogen and Phosphorus
- Vegetative buffer strips (VBS) are being proposed as a tool to protect water quality from nonpoint pollution nationwide, yet not studies have investigated the economics of implementing VBS. This study evaluates environmental costs and benefits of implementing VBS, both to the grower and to society as a whole, as a means of capturing nonmarket ecosystem values and informing decision making. Most values were determined by evaluating actual market prices gathered from the region or by the replacement-cost method, in which values are determined by comparison with the value of a marketed substitute.

Floodplain Wetland

Denhardt, A. 2002. The Replacement Value of Flood Plains as Nutrient Sinks: A Case Study of the River Elbe. Institute for Ecological Economy Research.

- Floodplain Wetlands
  - Waste Treatment
- This study uses the replacement cost method for valuing denitrification provided by floodplain wetlands on the Elbe in Germany. This value was transferred to provide a waste treatment value for Lake Champlain Basin floodplain wetlands.

Gren, I.M., Groth, K.H., and M. Sylven. 1995. Economic Values of Danube Floodplains. Journal of Environmental Management 45(4):333-345

- Floodplain Wetlands
  - Food – Commercial Fisheries
- The authors of this study consider three floodplain land covers: forest, grassland, and wetland. This study is itself a benefit transfer. All values used from this study were from primary valuations calculated in Austria and Sweden. Values transferred from this study include wetland values for commercial fishery production, grassland values for energy and raw materials, and forest values for energy and raw materials and recreation and tourism.

Gupta, T R, Foster, J H. 1975. Economic Criteria for Freshwater Wetland Policy in Massachusetts. American Journal of Agricultural Economics. 57(1):40-45.

- Floodplain Wetlands
  - Water Supply
- Gupta and Foster use the replacement cost method to value water supply provided by wetlands purchased by the Massachusetts Division of Fisheries and Wildlife between 1969 and 1971. These values have been transferred to Lake Champlain Basin wetlands.

Leschine, T.M., Wellman, K.F. and T.H. Green. 1997. The Economic Value of Wetlands: Wetlands' Role in Flood Protection in Western Washington. Washington State Department of Ecology publication, Report Volume 97-100, 62 pages.

- Floodplain Wetlands
  - Flood Mitigation
- A report for Washington State Department of Ecology establishes the value of wetlands for flood protection. The authors modeled the flood reduction effect of existing wetlands, expressed in terms of water flow (cubic feet of water per second, or cfs) passing by particular points in the system. The hydrologic effect of new proposed detention facilities on flows was modeled assuming future full build-out conditions. The value is described as "the cost of replacing an acre-foot of storage that could be lost as a result of further impacts to the existing inventory of wetlands."

Mahan, B.L. 1997. Valuing Urban Wetlands: A Property Pricing Approach. Published in Portland, Oregon Prepared by U.S. Army Corps of Engineers, Portland District, Hydroelectric Design Center. Prepared for U.S. Army Corps of Engineers, Institute for Water Resources and Waterways Experiment Station. IWR Report 97-R-1.

- Floodplain Wetlands
    - Amenity Value
- A hedonic model is used to establish value added to home prices by proximity to wetlands. All observations are taken within the urban growth boundary of Portland, Oregon. The values that are transferred to the Lake Champlain Basin are from a log-log model that established willingness-to-pay for proximity to wetlands.

Meyerhoff, J. and A. Dehnhardt. 2007. The European Water Framework Directive and Economic Valuation of Wetlands: the Restoration of Floodplains along the River Elbe. European Environment. 17(1):18-36.

- Floodplain Wetlands
    - Habitat and Nursery
    - Waste Treatment – Nitrogen
- This valuation study looks at the restoration of 15,000 hectares of Elbe Watershed floodplains. To establish a floodplain wetland value for habitat and nursery, the authors designed a survey using the contingent valuation method to determine a willingness-to-pay for improved habitat. The survey spoke of the array of benefits restored habitat would provide. The survey intentionally did not distinguish between use and non-use valuation. The survey sample was not limited to residents of the Elbe Watershed. The sample size was 1304. To establish a waste treatment value, numerous literature sources were used to estimate nitrogen retention by the restored floodplain, and the costs of reducing nitrogen load by other means.

Thibodeau, F.R., and B.D. Ostro. 1981. An economic analysis of wetland protection. Journal of Environmental Management. 12: 19-30

- Floodplain Wetlands
    - Rec & Tourism
    - Water Quality
    - Water Supply
    - Amenity Value
- This paper quantifies some of the economic benefits of wetlands in the Charles River Basin in Massachusetts (U.S.). The benefits resulting from flood mitigation, pollution reduction, water supply, and recreation were monetized. The value of flood mitigation was estimated by the cost of property damage that would occur if the wetlands were filled. Pollution reduction was estimated by determining the replacement cost of wastewater treatment plants. Water supply value was calculated as the difference between the cost of wetland

wells and the cost of providing water form the next best source. Lastly, recreation value was estimated using a mixture of travel cost and contingent valuation.

Rivers

Berman, M., and J. Armagost. 2013. Contribution of Land Conservation and Freshwater Resources to Residential Property Values in the Matanuska-Susitna Borough.

- Rivers
    - Aesthetic Info - Amenity Value
- The hedonic price method is used to calculate the value of natural amenities to the economy of the Matanuska-Susitna Borough in Alaska. The authors find that streams contribute $6,140 per acre to properties sold in the borough and protected open space $114. The estimated contribution of ecosystem services to private vacant land and residential appraised value was $2.56 billion in the Mat-Su Borough.

Duffield, J.E, Neher, C.J., and T.C. Brown. 1992. Recreation Benefits of Instream Flow: Application to Montana's Big Hole and Bitterroot Rivers. Water Resources Research 28(9): 2169-2181

- Rivers
    - Rec & Tourism – Fishing, Floating & Shoreline Use
- This study uses the criteria of "maximization of net economic benefits" to identify the appropriate level of instream flows in Montana's Big Hole and Bitterroot Rivers. The authors then found the marginal value of instream flow for water based recreational activities. Recreational activities on these rivers are heavily centered around trout fishing, floating, and shoreline recreation. The ecosystem service values were determined by a willingness to pay, dichotomous choice survey. The willingness to pay values was then estimated as a function of water level in the river.

Gramlich, F.W. 1977. The demand for clean water: the case of the Charles River. National Tax Journal 30(2): 183-194.

- Rivers
    - Aesthetic Info
- This study surveyed 165 families in the Boston metropolitan area to evaluate the demand for swimmable Charles River water. The demand was then used to estimate the net benefit of a policy that would achieve swimmable water. At the time, the water quality in the Charles near Boston was generally defined as "limited wildlife, some unpleasant odor." The willingness to pay was transferred as an aesthetic value because it is believed that the population surveyed would be unlikely to use the Charles for swimming even if the water quality was improved. The greatest benefit Boston metropolitan area residents would get from improved water quality would be decreased smell and a higher aesthetic value.

Loomis, J.B. 2002. Quantifying Recreation Use Values from Removing Dams and Restoring Free-Flowing Rivers: A Contingent Behavior Travel Cost Demand Model for the Lower Snake River. Water Resources Research 38(6): 2.1-2.8.

- Rivers
    - Rec & Tourism
- This study evaluates the potential demand for recreation on the Lower Snake River in Washington State if dams are removed and the river is restored. Demand for recreation was based on data collected from mail surveys. The travel cost method was used to determine the economic value of increased recreational demand. The value was transferred as the recreational value of free-flowing rivers.

Village Greenspace

Bolitzer, B, and N. Netusil. 2000. The impact of open spaces on property values in Portland, Oregon.

- Urban
    - Aesthetic Info - Amenity Value
- This study evaluated the effect proximity to public parks, natural areas, and golf courses have on the sale price of residential homes. Using a hedonic pricing model, the authors found that proximity to urban greenspace is statistically significant in determining the price of a home in Portland, Oregon. The dataset used to evaluate the impact of urban greenspace on property values included over 16,000 observations. The results of this analysis were transferred to developed, open space in Waterbury, Vermont and Willsboro, New York.

Brander, L.M., and M.J. Koetse. 2007. The Value of Urban Open Space: Meta-Analyses of Contingent Valuation and Hedonic Pricing Results. IVM Working Paper: I. 07/03. Date: December 2007

- Urban
    - Rec and tourism
- This study is a global meta-analysis of urban open space valuations with the contingent valuation and hedonic pricing valuation methodologies. The authors included parks, green space, agricultural, and undeveloped land. Recreation was the only statistically significant coefficient. Preservation and aesthetic were estimated in the study, but not found to be statistically significant services.

Nowak, D.J., Crane, D.E., and D.F. Dwyer. 2002. Compensatory Value of Urban Trees in the United States. Journal of Arboriculture. 28(4). 194-199.

- Urban
    - Aesthetic Info - Amenity Value

- This study uses the replacement cost method to establish the "compensatory value" of urban trees in several U.S. cities. Compensatory value is transferred as amenity value because the authors describe the service as based on "the procedures regularly used to determine monetary settlement for damage or death of plants through litigation, insurance claims, loss of property value for income tax deductions, and real estate assessments." This most closely matches the Earth Economics taxonomy definition for Aesthetic – Amenity value. The values transferred to the Lake Champlain Basin are from Syracuse, New York.

Trust for Public Land. 2010. The Economic Benefits and Fiscal Impact of Parks and Open Space in Nassau and Suffolk Counties, New York.

- Urban
    - Water Reg – Stormwater
- This study estimates the avoided cost of stormwater retention in two suburban counties on Long island using the ITree Model calculator. These values were transferred to Lake Champlain Basin urban greenspace.

Trust for Public Land. 2011. The Economic Benefits of Seattle's Park and Recreation System.

- Urban
    - Water Reg – Stormwater
- This study estimates the avoided cost of stormwater retention in Seattle, Washington using the ITree Model calculator. These values were transferred to Lake Champlain Basin urban greenspace.

Appendix 4: Methodology – Buildout Analysis

Waterbury, Vermont

This build-out analysis uses the Town and Village of Waterbury Zoning Regulations dated April 15, 2013 as the basis for calculations.

The Town of Willsboro Zoning Ordinance defines the following for all zones:

Lot Area	Frontage	Height	Coverage	Front Yard Setback	Side Yard Setback	Back Yard Setback

It also defines Dwelling Units per acres (43,560 square feet) and Dwelling Units per Building for multi-family developments. Multi-family housing is allowed by right in the Downtown Commercial and Village Neighborhood Center District. They are, respectively:

Downtown Commercial (DC): 25, 15
Village Neighborhood Commercial (VNC): 20, 15
Town Neighborhood Commercial (TNC): 8, 8
Village Commercial (VCOM): 6, 8
Town Commercial (TCOM): 6, 8
Route 100 (RTlOO): 2, 6
Town Mixed Residential (TMR): 2, 4
Village Mixed Residential (VMR): 15, 12
Mill (MIL): 4, 8
This build-out is considered a maximum total build-out meaning that the land is cleared of all current development and rebuilt at its maximum allowable by-right density.

To calculate the residential build-out potential, each parcel was assigned a zone. For the purposes of this exercise, if the large majority of the parcel fell into one zone, that zoning was applied, or if all street frontage was in one zone, that zoning was applied.

There are three overlay districts in the Town and Village. The Ridgeline/ Hillside/Steep Slope Overlay, Design Review Overlay District, and the Interim Campus Overlay district. The Steep Slope overlay does not affect any parcels in the floodway and therefore has not been analyzed. The downtown Design Review Overlay District requires design review, and would apply to many of the parcels in the study area, however, because of it affects the specifics of a project, it is not applicable to a general build-out. The Campus overlay district mostly concerns those parcels owned by the State of Vermont as part of the State campus, along Park Row. Those parcels which are not State Owned, were analyzed with the alternate dwelling unit yields, as the overlay regulations specify.

Parcels that are subdivided into four or more parcels have special restrictions as well, however, again, these are not dimensional restrictions and therefore cannot be analyzed as part of this calculation.

Two build-out analyses were used to determine potential dwelling units. All parcels were determined to meet minimum lot size before any calculations were done.

Assuming everything is built to maximum density:

[Parcel Size, sq ft]*43560/ [Dwelling Units per Acre] = [*Potential Number of Units per Parcel*]

The square feet of each parcel was converted to acres. The acreage of the parcel was divided by allowable dwelling units per acre for each zone (from the Zoning Regulation) to determine the maximum number of dwelling units per parcel. This number was rounded down to the nearest whole number. In many case the actual subdivision of these lots is not expected under normal circumstances.

Assuming everything is built to maximum allowable by-right density:

For parcels in zones that allow multi-family housing by-right:

[Parcel Size, sq ft]*43560/ [Dwelling Units per Acre] = [*Potential Number of Units per Parcel*]

For parcels in zones that allow two-family homes by-right:

[Parcel Size, sq ft] / [Lot Area]*2 = [*Potential Number of Units per Parcel*]

For parcels in zones that allow single-family homes by-right:

[Parcel Size, sq ft] / [Lot Area] = [*Potential Number of Units per Parcel*]

For parcels that allow multifamily housing by-right, the square feet of each parcel was converted to acres. The acreage of the parcel was divided by allowable dwelling units per acre for each zone (from the Zoning Regulation) to determine the maximum number of dwelling units per parcel. For parcels that allow single or two family houses by right, the parcel size was divided by the minimum lot size, and multiplied by 1 or by 2, respectively to determine the maximum number of dwelling units. This number was rounded down to the nearest whole number.

Potential commercial/industrial square footage was also calculated for Waterbury. The zoning regulations in Waterbury include several zones that are clearly commercial or industrial, and several more that have a mixed use intention. In order to distinguish which of these zones should be included, zones which allow, by right, retail uses have been included in the Commercial Build-Out. These zones are:

Downtown Commercial
Industrial (Town and Village)
Town Commercial
Mill
Town Mixed Residential

Town Neighborhood Commercial
Village Commercial
Village Mixed Residential
Village Neighborhood Commercial

If the parcel was deemed to meet the minimum lot size, it was included in the build-out. For these parcels, it was assumed that there would be a FAR of 1.0. These numbers are considered averages that reflect the existing commercial development in the Town. Floor Area Ratio (FAR) is the total floor area of a building or buildings divided by the area of the lot on which it sits. Based what is currently built in Waterbury and through discussions with Planning staff, it was determined that a 50% lot coverage calculation would be most accurate, and the average building height would be 2 stories. Therefore the potential commercial or industrial square feet can be calculated as:

[Parcel Size, sq ft] *50% coverage *2 stories

For parcels in the Village Mixed Residential Zone, it was assumed that roughly half the buildings would have commercial development, so only those parcels on the southerly side of Main Street were included in the commercial build-out.

Existing Value

Current parcel value was calculated using the Town and Village assessor data, joined to the parcel data to provide a Real Estate, Land, and Building Value for each parcel.

In several instances, Condo units are held by individual owners, while the parcel and land are a single location. For each of these instances, the singular parcel of land was given an additional value—Condo Value—which is the value of all buildings on that parcel.

For the preapproved development on Marvin Street, assessed value was maintained as is, however, 26 units were concluded to "exist" on the parcel for purposes of the build-out.

Potential Future Values

The potential future value of residential development is extremely hard to calculate because the items that effect residential value (bedrooms and square footage) are not regulated by zoning, and change significantly from development to development. In order to assign a value to the future development, however, the current average value of single family and multi-family residential structures was used, assuming that these averages could at least provide a future baseline. A single family residential structure was valued at $213,000 and a multi-family residential structure was assumed to have 6 units and valued at $364,000. Therefore the following calculations were used to determine potential future value of residential development using the potential dwelling units calculated above.

For single family residential development:

[Pot_DwellU] * $213,000

For multifamily residential development:

ROUND UP ([Pot_DwellU] / 6) * $364,000

Commercial and industrial value was calculated using $130/ per square feet of buildings. This number was supplied by the Town to be a reasonable current value of commercial and industrial buildings. The Commercial/ Industrial buildout was calculated using square feet, so a simple calculation was used to reach these values.

[CommInduSqFt] *130

Willsboro, New York

Willsboro is within the Adirondack Park blue line, but it has, in consultation with the Adirondack Park Agency (APA) developed its own zoning ordinance to apply to Class B projects in most instances within Hamlet Land Use areas, and to private development outside of the Hamlet areas. Areas of special conservation concern including wetlands, and projects of a large scale such as more than 100 houses, regardless of where they are located, are Class A projects, and therefore reviewed by the APA. This build-out analysis uses the Town of Willsboro Zoning Ordinance dated April 2002 as the basis for calculations. Projects that meet the aforementioned conditions may be subject to the more stringent APA Class A project review.

The Town of Willsboro Zoning Ordinance defines the following for all zones:

Minimum Lot Size Acres/ Sq. Ft.	Setback Front yard (ft.)	Setback Rear Yard (ft.)	Side Yard One/Both	Maximum Lot Coverage	Maximum Building Height (Feet)	Maximum Building Height (Stories)

It also defines Permitted Principal uses; Permitted Accessory uses; and Special uses. Most zones allow single or two family housing by-right (Permitted Principal), including single family mobile homes. No zone allows multi-family housing by-right, but some allow it by special permit (Special). For the purposes of this analysis, each zone was therefore determined to allow either 0, 1, or 2 dwelling units per parcel to represent the number of units allowed by-right.

This build-out is considered a maximum total build-out meaning that the land is cleared of all current development and rebuilt at its maximum allowable by-right density. Development is allowed on some existing undersized vacant lots, however these lots have not been included in the calculation. It also means that some parcels that are currently built upon, but that do not meet minimum lot size or other

parts of the ordinance, may not be included as part of the build-out. This is addressed in the Zoning Ordinance by the following section:

> Section 3.45 Restoration
> No building structure, or sign damaged by fire or other causes to the extent of more than 50 percent of the equalized assessed value shall be repaired or rebuilt except in conformity with the regulations of this Ordinance or according to a duly granted order of the Zoning Board of Appeals provided, however, that any single family dwelling or mobile home in existence on the effective date of this Ordinance in the Industrial (M) District which is so damaged may be repaired, rebuilt or replaced with another single family dwelling or mobile home on the same lot or location without an order of the Zoning Board of Appeals, provided such repair, re-building or replacement is substantially commenced within one year of such damage.

To calculate the residential build-out potential, each parcel was assigned a zone. For the purposes of this exercise, if the large majority of the parcel fell into one zone, that zoning was applied, or if all street frontage was in one zone, that zoning was applied. If the zone was more evenly split, the more restrictive zone was applied to the parcel. The regulation states the following:

> Section 6.31 Lots in Two Districts
> Where a district boundary line divides a lot in single or joining ownership of record at the time such line is adopted, the regulations for the less restricted portion of such lot may extend not more than thirty feet into the more restricted portions, provided the lot has frontage on a street in the less restricted district.

The following restrictions apply to all projects, and would be determined on a site by site basis, therefore they have not been calculated as part of this buildout, however, they should be kept in consideration:

> Section 3.29 Lots Under Water or Subject to Flooding
> No more than ten percent of the minimum area requirement of a lot may be filled by land which is under water or subject to periodic flooding. Land which is under water that is open to use by persons other than the owner of the lot, shall be excluded entirely from the computation of the minimum area of that lot. For the purpose of this section, land in the bed of a stream not exceeding five feet in width at mean water level, and land in any pond not exceeding 150 square feet in area shall not be considered as under water.

Wetlands

The build-out analysis used the following calculation to determine potential dwelling units:

[Parcel Size, sq ft]/ [Minimum Lot Size, sq ft] = [*Potential Number of Lots*]

[*Potential Number of Lots*]* [Dwelling Units Allowed by Right] = *Potential Dwelling Units per Parcel*

The square feet of each parcel was divided by allowable minimum lot size for each zone (from the Zoning Ordinance) to determine the maximum number of lots allowed under current zoning. This number was rounded down to the nearest whole number. In many case the actual subdivision of these lots is not expected under normal circumstances.

These potential number of lots were then multiplied by the maximum number of units allowed by-right for each zone (0, 1, or 2 as defined in the Zoning Ordinance) to determine the total number of housing units possible on each parcel.

For example, a parcel that is 90,000 square feet and located in the RM1 Zone (which has a minimum lot size of 15,000 sq feet) and allows single family housing by-right, could yield 6 parcels each with a single family house on them, and therefore 6 dwelling units.

Potential commercial square footage was also calculated for Willsboro. The zoning regulations in allow commercial or residential development in the GB zone, however for this analysis, it was assumed that only those parcels in the GB zone that are currently commercial would be rebuilt as commercial properties. Vacant parcels were counted towards residential build-out estimates, as developers often find residential development more monetarily feasible.

The GB zone allows, by right, commercial properties that have 80% lot coverage and an FAR of 3.0. This does not include parking requirements and may therefore over estimate the amount of square footage that could actually be built, but due to the limited number of properties that would fit the above specifications, this number is considered reasonable.

Existing Value

Current parcel value was calculated using the assessor's property card for each parcel in the study area.

Potential Future Values

The potential future value of residential development is extremely hard to calculate because the items that effect residential value (bedrooms and square footage) are not regulated by zoning, and change significantly from development to development. In order to assign a value to the future development, however, the current average value of single family and duplex structures was used, assuming that these averages could at least provide a future baseline. Current zoning only allows single family or two family (duplex) structures. A single family residential structure was valued at $150,000 and a duplex structure valued at $250,000. Therefore the following calculations were used to determine potential future value of residential development using the potential dwelling units calculated above.

For single family residential development:

[Pot_DwellU] * $150,000

For duplex residential development:

ROUND UP ([Pot_DwellU] / 2) * $250,000

Commercial and industrial value was calculated using $100/ per square feet of buildings. This number was supplied by the Town to be a reasonable current value of commercial and industrial buildings. The Commercial buildout was calculated using square feet, so a simple calculation was used to reach these values.

[CommInduSqFt] *100

Appendix 5: Methodology – Hydrology and Hydraulics

HYDROLOGY

Estimating Existing Flows

Hydrologic analysis was performed to estimate peak flood flow rates for each project location to be used as input into the hydraulic models and ultimately to define the various floodplain areas. A variety of methods for estimating flow rates were compared including FEMA flood study hydrology (FEMA, 1992, 2013), regional regression using USGS StreamStats (Olson, 2002), and flood frequency analysis of nearby USGS stream flow gauges (USGS, 1982).

For the Boquet River project site in Willsboro, flow rates for existing conditions were selected using the flood frequency analysis of the full USGS gauge data record. Flow values for Tropical Storm Irene were defined from peak flow rates recorded on the nearby USGS gauge #04276500 located on the Boquet River upstream of the Route 22 Bridge. Peak flow rates used for the Winooski River in Waterbury were obtained from the FEMA flood study updated in 2013.

Estimates for Tropical Storm Irene were developed by a previous calculation of the superposition of the flood hydrographs from the three upstream USGS gauge sites recorded during the flood – Winooski River at Montpelier (USGS #04286000, drainage area = 397 square miles), the Mad River near Moretown (USGS #04288000, drainage area = 139 square miles), and the Dog River at Northfield Falls (USGS #04287000, drainage area = 76 square miles). This analysis assumes that the additional drainage area and flow attenuation in the floodplain offset. Timing was incorporated into the estimate for Irene peak flows by translating the peaks from each gauge to Waterbury using average velocities from the HEC-RAS hydraulic model or the average velocity from the FEMA flood insurance study in locations that were downstream of the USGS gauges and outside of the location of the current hydraulic model.

The predicted Irene peak flow in Waterbury was estimated to be 56,200 cubic feet per second (cfs). This value is within 5% of an initial estimate made from the US Geological Service (personal communication with Scott Olson, 2013). The large amount of precipitation that fell in the mountains led to record floods in mountainous watersheds that seemed to have converged in Waterbury near the same time leading to a very high flows and limited safe floodplain storage (see table below). Further downstream, large areas of floodplain were inundated and storing flood waters between Waterbury and Essex Junction and thus the peak flood level declined likely due to valley storage and distance from the highest rainfall levels during Irene (Dunne and Leopold, 1978). The peak flood passed Montpelier at 10:30pm on August 28, 2011 while the peak flood passed Essex Junction at 4:15pm the following day.

Location	Drainage Area (mi^2)	Irene Peak Flow (cfs)	Flow / Drainage Area (csm)
Winooski River at Montpelier	397	14,000	35
Dog River	76	22,200	292
Mad River	139	24,200	174
Winooski River at Waterbury	683	56,200 (estimated)	82
Winooski River at Essex Junction	1,044	35,000	34

The difference between the superposition calculation for estimating the Tropical Storm Irene flood flow (56,200) and a simplified approximation off adding the peaks from the upstream gauges (60,200 cfs) is just 7%. The similarities in the estimated flood flow is likely due to the fact that the three USGS gauge locations cover 90% of the drainage area of the Winooski River at Winooski Street in Waterbury (drainage area = 683 square miles). We thus elected to use a simple addition of peak flows for predicting future flood flows by evaluating trends at each of the upstream gauges.

Predicting Future Flows

A perfect method to predict future floods does not exist. Amongst the variability in peak flows over the data records at the subject gauges, trends show minor increases, minor increases, minor decreases or no change. Yet, recent studies show regional increases in the frequency and size of floods (Collins, 2009; Armstrong et al., 2014). Intense flooding is increasing in the region (Horton et al., 2014). Intense precipitation events have increased 84% in Vermont and 64% in New York (Madsen and Willcox, 2012). The research on change in flooding points to the time period around 1970 where the precipitation and flood regime seems to have changed, and a recommendation to make hydrologic predictions before and after this time was established (NMFS, 2011). This recommendation was used for this exploratory analysis of predicting future peak flows.

For example, in Willsboro flood frequency analysis at the Boquet River gauge site indicates that the 100-year flood calculated from the post-1970 record is 38% higher than a flood frequency analysis using the entire gauge record. In Waterbury, the estimated increase in the 100-year flood flow using a simple addition of upstream peak flows calculated using just the post-1970 record is 9%.

Future flood flows were estimated for the 100-year and 500-year recurrence intervals at each project location for the year 2065. The analysis explored gauge trends by placing data into bins to explore the change in trends over time. Flood frequency analysis was performed for data that were split into two, three, or four bins to see if a trend existed over time. The average number of years in each bin was 39 years (2 bins), 26 years (3 bins), and 20 years (4 bins). This non-traditional approach follows the NOAA guidelines to compare data from the past and more recent data (NMFS, 2011). A major assumption of this approach is that stationarity, the variation around a constant envelope, does not exist for water resources (Milly et al., 2008).

The 100- and 500-year flows calculated from flood frequency analysis for each bin were plotted against the last year in the bin and a trend line was fitted through each series of points. The slope of a trend line thus represents the possible change in flow over time. A constant rate of change was assumed over the next 50 years. The average of the lowest and highest slope from the three different binning sizes was used to predict the average rate of change of the flows (cfs/ years). The number was multiplied by 10 to get the predicted change in the 100- and 500-year peak flows per decade and 50 to get the predicted flow change in 2065.

For the Boquet River in Willsboro, the 100-year flood flow is predicted to increase by 6,300 cfs by 2065. The 2065 100-year flow would be 19,781 cfs, which is 46% higher than the current FEMA effective flow.

Note that the effective FEMA flow is calculated from historic gauge records dating as far back as 1924 that assumes stationarity does exist and that the past records, even the older portion of that record, is suitable for estimating current flood levels. Note that the future flood flow prediction is only 5% higher than the estimated peak 100-year flow calculated using only post-1970 gauge data (without binning) suggesting that we may now be in an era of higher floods and that stationarity may not exist.

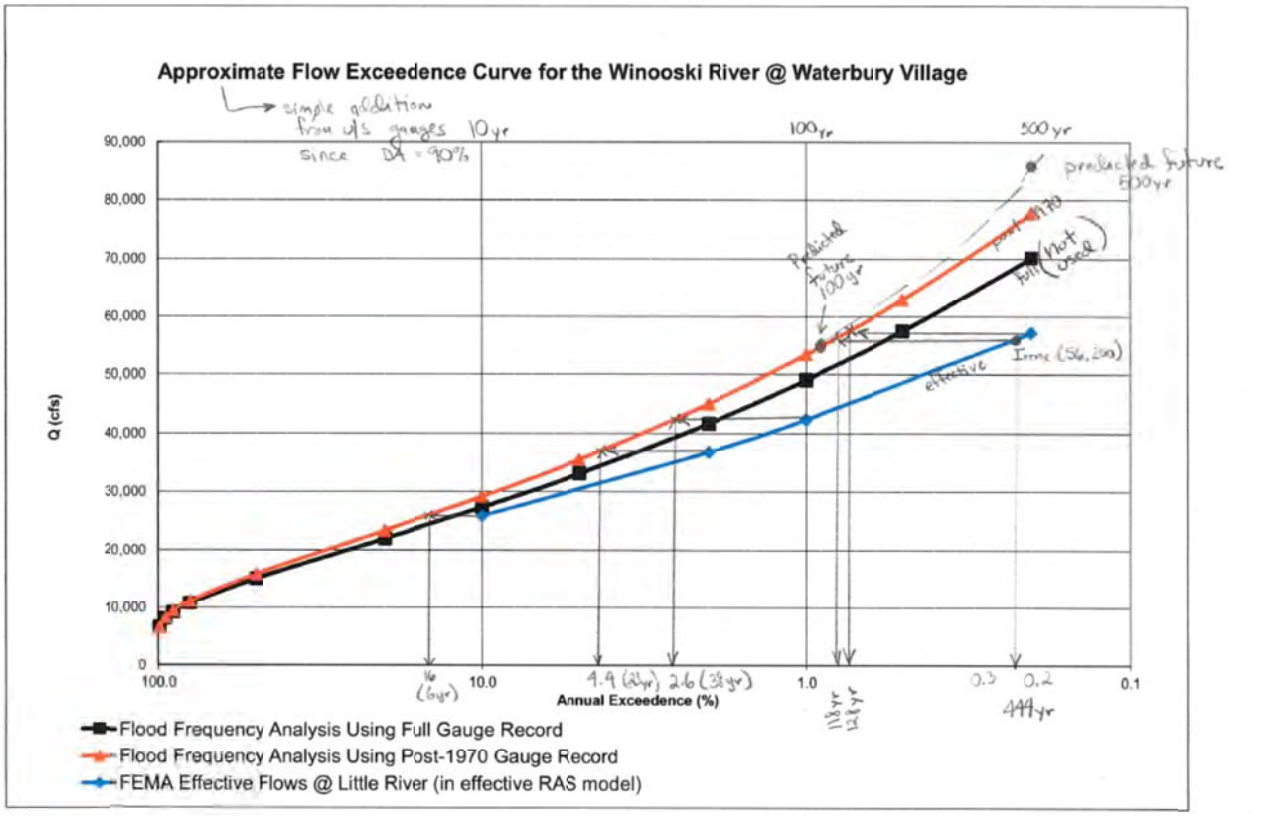
For Waterbury, the predicted increase in the 100-year flood by 2065 is 12,100 cfs leading to a future 100-year flow of 54,500 cfs. This value was approximated by adding the future predictions at each upstream gauge. The predicted 2065 100-year flood flow is 29% higher than the current FEMA effective flow, but only 3% higher than a simplified estimate of the peak 100-year flood in Waterbury calculated by summing up the peaks at upstream gauges just using post-1970 gauge data. As in Willsboro, the analysis suggests that we are now in an era of larger floods.

The predicted future flood levels agree with a recent study (AECOM, 2013) that predicts an 11-20% increase in the 100-year flood flow by 2060 and a 21-30% increase by 2080 in our region. This study indicates that the resulting 100-year floodplain is expected to increase in size 31-40% by 2060 and 41-50% by 2080.

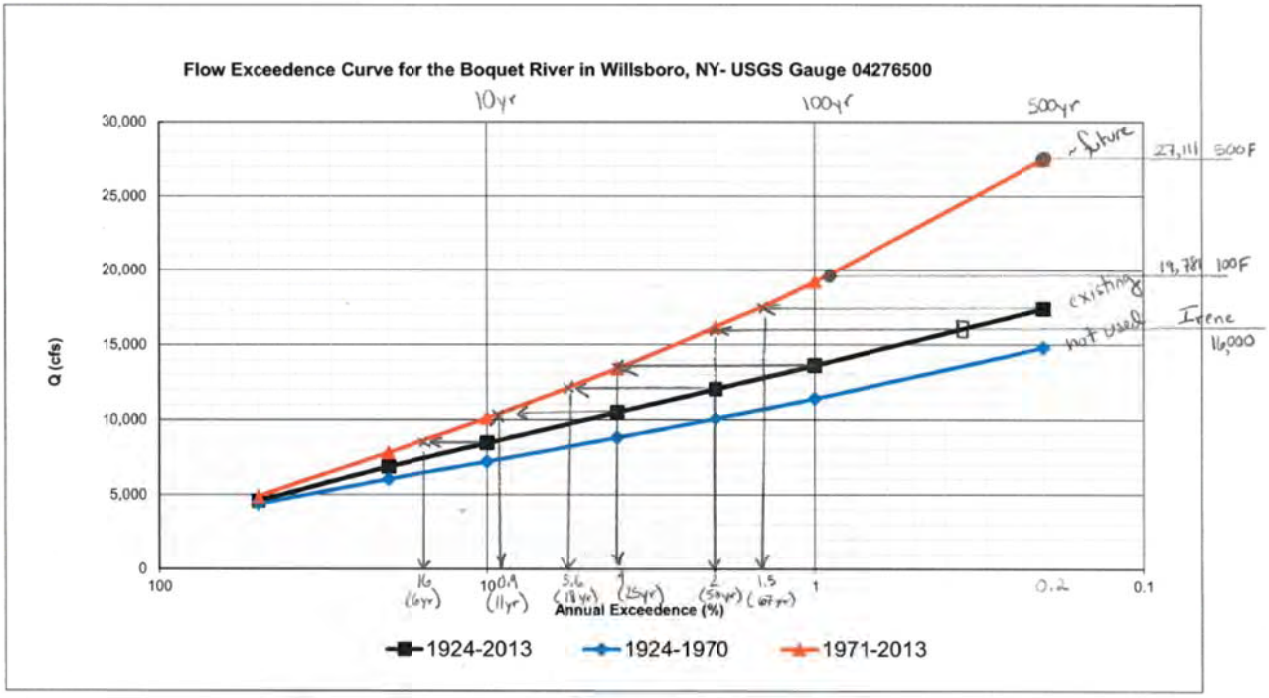
The future flood flow predictions are intended to accomplish the objective of modeling possible changes in floodplain hydraulics, damages, and economics. Although this non-traditional approach is not suitable for design-level floodplain management, it is a useful planning tool given that the findings do agree with several studies on predicted increased future flows (e.g., AECOM, 2013). Furthermore, the fact that the predictions using gauge trends are within 5% of the estimated 100-year flood flow calculated with just the modern gauge record (i.e., post-1970 data) indicates that this approach is a suitable prediction method for large floods. These floods are happening now as is evident from Tropical Storm Irene in 2011 that was the flood of record at many USGS stream gauges and is similar to the predicted future 100-year flood flow in Waterbury (Irene is 3% larger than the predicted 100-year flow) and Willsboro (Irene is 20% less that the predicted 100-year flow).

Estimating Future Recurrence Intervals

Future flow predictions were made for the 100- and 500-year flows for each project site, yet a full range of future flows is needed to be able to annualize damage estimates from the HAZUS modeling. To accomplish this, the existing flow values for the 10-, 25- (Willsboro only), 50-, 100-, and 500-year floods and Tropical Storm Irene were evaluated on the future flow exceedance curve to predict a future recurrence interval for each flow value. For example, gauge trends on the Winooski River show that over the past 70 years the flood that had a 1% chance of occurring in a given year (i.e., the existing 100-year flood) will have a 2.6% chance of occurring in the future (i.e., the future 38-year flood). The following figures show the flow exceedance curves for predicting future recurrence intervals (red, post-1970 gauge data) from existing flows. The flood frequency analysis shows that the post-1970 flow exceedance curves nearly contain the predicted future 100-year flood and thus suggest that a new era of larger floods is already here.



Irene: effective (older) data 444yr
full record 172yr
post-1970 118 yr



HYDRAULICS (FLOODPLAIN MAPPING)

Floodplain delineations were created based on hydraulic modeling of the study rivers using HEC-RAS (USACE, 2010). Flood water surface profiles and floodplain extents were created for each of the peak flows. The hydraulic models were started with an existing hydraulic study completed by FEMA and were updated to follow current modeling techniques and use all available current data.

For Willsboro a hardcopy of a 1989 HEC-2 model of the Boquet River (USACE, 1996) was obtained from FEMA (1992), manually input to HEC-RAS, and updated with limited field survey in the vicinity of the Saw Mill Dam collected by Dean Lashway Surveying in September 2013, supplemental field survey collected by Fitzgerald Environmental and Milone & MacBroom, and plans for the NY Route 22 Bridge. For Waterbury the effective HEC-RAS model was obtained from the Vermont Rivers Program that was recently updated as part of the map updates for Washington County (FEMA, 2013). Milone & MacBroom previously updated the model as part of the Winooski Street Bridge Choke Study (also known as the Waterbury Flood Study) that was completed in 2013. During this study the FEMA modeling was updated with supplemental field survey collected in May and June 2013 by Little River Survey of Stowe.

Hydraulic results were exported to GIS and the initial floodplain boundaries were mapped using HEC-GeoRAS (USACE, 2013). HEC-GeoRAS software uses water surface profiles from the hydraulic model and intersects them with ground topography to map floodplains. A floodplain boundary delineation and a raster grid of water depths within the floodplains were created for each flood level to be used for input into the damage modeling. The Willsboro model was georeferenced using cross section locations on published FEMA FIRM maps to link the hydraulic results to the topography. Topography used for Willsboro was compiled from multiple sources including limited field survey in the vicinity of the dam collected by Dean Lashway September 2013, supplemental field survey collected by Fitzgerald Environmental and Milone & MacBroom in November 2014, and the National Elevation Dataset. Topography used for Waterbury was compiled from multiple sources of LiDAR data. Recent data collection managed by Central Vermont Regional Planning Commission that covers all of the Village was used for the modeling. The new LIDAR data eliminates a gap in previous data that complicated floodplain mapping in the Village.

Floodplain delineations in GeoRAS were checked and manually fine-tuned to correct any errors based on field information and known flood patterns.

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Appendix 6: Methodology – Damage Modeling

Modeling of floodplain damages was conducted using FEMA's Multi-hazard loss estimation software (HAZUS-MH version 2.1 service pack 3). This program runs within ESRI's ArcGIS Desktop (version 10.0, service pack 2). Due to backward compatibility issues with both more current versions of ArcGIS as well as Windows 7, the software was run within a Virtual Machine with the Windows XP operating system (Service Pack 3).

A Level 2 flood analysis was performed. This level of analysis expects the user to provide manually created flood depth grids and specific facility data to be used in place of the default demographic data (which is averaged by census block) typically used for the Level 1 flood analysis. Studies have shown the Level 2 analyses generate damage values that are much more reasonable than Level 1 analyses (Rozelle, et. al., 2011).

The damage modeling consisted of three distinct phases including data collection, data processing for model input, and finally running the model and processing model output. These are described in more detail below.

Data Collection

HAZUS-MH requires a variety of inputs to calculate damages, although not all are necessary. These are discussed in the HAZUS-MH manuals (FEMA, 2012) and by ASFPM (2010). Inputs are presented in Table 1, including fields that were not utilized for this analysis.

Table 1.

Building Stock Information for HAZUS-MH

Field	Description	Imported?	Data Source
Name	Name of building or property owner	Yes	Parcel data
Address	Street address	Yes	Parcel data
City	City, town, or village	Yes	Parcel data
State	State	Yes	Parcel data
ZipCode	Postal Code	Yes	Parcel data
Contact	Owner or contact person	No	Not used
Phone	Phone number of contact	No	Not used
Occupancy	Building occupancy type	Yes	Codes defined by FEMA in HAZUS-MH User Manual, based on parcel data and land use
BldgType	Building construction material	Yes	Codes defined by FEMA in HAZUS MH User Manual, based on parcel data and assessor's cards
Cost	Building replacement value	Yes	Parcel data, assessor's cards
YearBuilt	Year of construction	Yes	Parcel data, assessor's cards
Area	Building footprint (not including open porches, decks, etc.)	Yes	Parcel data, assessor's cards, or estimated in GIS from aerial photography where data not available
NumStories	Number of stories	Yes	Assessor's cards, Google street view, field work
DesignLevel	Defined by Year built	Yes	Codes defined by FEMA in HAZUS-MH User Manual
FoundationType	Type of building foundation	Yes	Parcel data, assessor's cards, Google street view, field work. Codes defined by FEMA in HAZUS-MH User Manual.

FirstFloorHt	Height of 1st Floor above grade	Yes	Field work (did not use default values), Google street view
ContentCost	Value of building contents	Yes	Based on building cost, Equation provided by FEMA in HAZUS-MH User Manual
BldgDamageID	Defines a specific depth-damage curve to be utilized for building damages	Yes, for Scenario #2C	Default curves modified to reflect elevation of utilities as described later in this section.
ContDamageID	Defines a specific depth-damage curve to be utilized for content damages	No	Not used
InvDamageID	Defines a specific depth-damage curve to be utilized for inventory damages	No	Not used
FloodProtection	Used to define level of protection due to dam or dike	No	Not used
ShelterCapacity	Capacity if building is used as a shelter	No	Not used
BUPower	Availability of backup power	No	Not used
Latitude	Building point location	Yes	Calculated in ArcGIS
Longitude	Building point location	Yes	Calculated in ArcGIS
County	County	Yes	Parcel data
Comment	Additional information	Yes	Used to record Parcel ID

Data collection generally followed the procedures outlined by ASFPM (2010) except where differences occurred due to the availability of better data than was available for that study. Parcel data were collected from each assessor for the communities of Waterbury, Willsboro, Duxbury, and Moretown, with additional information provided by the Central Vermont Regional Planning Commission. Parcel data containing a significant amount of information was received from Waterbury, as well as assessor's cards for the more floodprone areas such as Randall Street. Parcel boundaries received from the remaining three communities were supplemented with pertinent data provided in spreadsheet format. Local building officials provided assistance in answering specific questions pertaining to structures. Where data were not available (such as first floor heights or basement type), this information was estimated from a field visit to the property or from images of the buildings in Google Street view.

HAZUS-MH utilizes a single point location to estimate damages based on the building stock information. Building centerpoints were manually generated in ArcGIS based on parcel data and recent aerial photography and assigned latitude and longitude values. The parcel data, assessor's data, google street view, and field work were utilized to determine if any structures on the property were outbuildings that should not be simulated by HAZUS-MH.

In areas where only a portion of a building lay within a floodplain, the building centerpoint was adjusted to be on the portion of the building more likely to be impacted by flooding. As HAZUS-MH only calculates damages for building centerpoints that lie within the limits of the floodplain being modeled, this ensured that buildings are not arbitrarily left out of the damage modeling. Latitude and longitude data were updated following centerpoint adjustment.

Note that the existing condition modeling took into account buildings that may not have been normally considered to be "existing". For example:

- An elevated development was being constructed in Waterbury just east of Route 100 was included as being completed.
- Buildings in Willsboro that were scheduled for removal were included to assist the evaluation of the floodplain alternative.
- The mobile home park in Duxbury was modeled as being completely intact even though many of the homes were not present following the Irene event.

As discussed in the main body of the report, the damage modeling assumed a "reasonable" build-out condition as opposed to a "by-right" build-out condition. This methodology simplified the damage estimation process for the build-out condition and was chosen for several reasons:

- Waterbury and Willsboro have many examples of historic and aged buildings that demonstrate expansions have occurred. For example, several buildings on South Main Street in Waterbury appear to have been expanded two, three, or even four times. As such, demolition and rebuild was considered to be less likely for residential properties than expansion.
- Expansion provides the ability to provide a more direct comparison between existing condition properties and the "build-out" properties because the existing condition properties are still modeled in the build-out condition as a separate point.
- While demolition and rebuild of commercial and industrial properties is likely more common, expanding the amount of space with a similar occupancy type provided the above benefit without needing to estimate how the occupancy types would change over time.

This methodology considered parcel-specific information for determining the amount of expansion possible. This included zoning (including setbacks), topography, and wetlands. Note that the availability or parking was not directly considered.

For residential buildings, new homes were assumed to be 1,600 square feet for a single family, 2,400 square feet for a duplex, and 3,600 square feet for a triplex. Many of the residential properties in Waterbury Village are allowed accessory structures, and these were fit on the parcel up to these limits when possible. Commercial and industrial expansion were performed to the limits of zoning and parcel restrictions. Basements were only allowed when structures were outside of the Special Flood Hazard Area established by FEMA (note that this is a smaller area than the Q100) as this was consistent with current zoning.

Note that a build-out condition was not performed for Duxbury and Moretown. The existing buildings in these communities were analyzed to determine the effectiveness of the two floodplain creation alternatives. For completeness, a full suite of floodplain management scenarios was also performed for these communities.

Running HAZUS-MH

Two HAZUS-MH study regions were developed within HAZUS-MH for Waterbury and Willsboro, respectively. A third study region was generated when Duxbury and Moretown were added to the study. The required building stock inputs were summarized in Microsoft Excel, imported into Microsoft Access, and then imported into HAZUS-MH by following the revised import procedure presented by ASFPM (2010).

Depth grids generated from the hydraulics portion of the study were imported into the HAZUS-MH study regions for the respective rivers. HAZUS-MH utilized these depth grids to generate hydraulics for the study areas. Model simulations were developed to analyze damages within each floodplain based on imported depth grids for the existing conditions and for the two floodplain restoration alternatives in each community. At this point, each study region contained the facilities and hydraulics required to successfully run the model.

HAZUS-MH can only define a single user-defined facilities database to be used with each hydraulic simulation. The floodplain management scenarios required adjustments to the user defined facilities database in order to model the changes. As such, copies of each study region were made to analyze each of the floodplain management scenarios. As an additional benefit, this allowed for a record to be retained of each model simulation and each floodplain management scenario in case additional model runs were necessary.

Changes due to floodplain management scenarios resulted primarily in changes to first floor height and foundation type. Changes for each model run are summarized below:

- 1A/1B: Scenario 1B was not run for Duxbury and Moretown, as this represented the build-out condition (which was not performed for these communities). Existing damages were backed out of the 1B output for Waterbury and Willsboro. This provided the baseline to which other floodplain management scenarios were compared for the existing and build-out condition. Table 2 presents the number of buildings.

Table 2.

Number of Buildings per Town for Scenario 1A/1B

Scenario	Community	# of Buildings				Footprint Square Footage			
		Res. Single	Res. Multi	Com./Ind.	Other	Res. Single	Res. Multi	Com./Ind.	Other
1A	Duxbury	34	4	1	1	35,293	9,390	3,550	4,932
1A	Moretown	9	0	9	0	10,239	0	49,150	0
1A	Waterbury	117	66	69	30	163,100	148,929	473,096	185,187
1B	Waterbury	173	128	102	30	216,780	227,389	796,206	185,187
1A	Willsboro	10	4	5	2	16,814	7,600	28,960	3,400
1B	Willsboro	15	9	11	2	26,114	13,050	78,860	3,400

- 2A: Elevation of buildings to this standard resulted in changes in first floor height and foundation type (if necessary) as shown in Table 3.

Table 3.

Number of Buildings Modified per Town for Scenario 2A

Scenario	Community	# of Buildings Modified				Footprint Square Footage Modified			
		Res. Single	Res. Multi	Com./Ind.	Other	Res. Single	Res. Multi	Com./Ind.	Other
Existing	Duxbury	30	2	1	1	30,992	4,140	3,550	4,932
Existing	Moretown	1	0	8	0	942	0	45,700	0
Existing Only	Waterbury	44	26	25	8	54,943	41,393	131,952	32,657
Ex. & Build-out	Waterbury	73	67	42	8	81,963	95,574	243,044	121,712
Existing Only	Willsboro	6	3	3	2	8,380	5,950	25,150	3,400
Ex. & Build-out	Willsboro	9	7	7	2	15,080	10,750	66,650	3,400

- 2B: Elevation of buildings to this standard resulted in changes in first floor height and foundation type (if necessary) as shown in Table 4.

Table 4.

Number of Buildings Modified per Town for Scenario 2B

Scenario	Community	# of Buildings Modified				Footprint Square Footage Modified			
		Res. Single	Res. Multi	Com./Ind.	Other	Res. Single	Res. Multi	Com./Ind.	Other
Existing	Duxbury	27	0	1	1	26,150	0	3,550	4,932
Existing	Moretown	0	0	0	0	0	0	0	0
Existing Only	Waterbury	20	19	8	2	24,647	30,461	24,712	11,010
Ex. & Build-out	Waterbury	49	60	25	2	51,707	87,221	190,662	11,010
Existing Only	Willsboro	4	1	1	0	6,290	2,200	7,050	0
Ex. & Build-out	Willsboro	7	4	5	0	12,990	5,800	48,550	0

- 2C: Elevation of utilities was performed for all buildings by modifying the depth-damage curves within HAZUS-MH based on the procedure described by Mawby (2014). Addition of additional building footprint was not considered because it was assumed that wherever the utilities ended up they would be above the Q500 floodplain elevation (and essentially no longer floodprone).

  Utilities to be elevated (which include such things such as oil tanks, hot water heaters, furnaces, electrical boxes, basement/first floor heating elements) were assumed to be equivalent to approximately 6% of the building value. In other words, for a $200,000 residential structure, $12,000 of value would be tied up into these utilities. This was estimated based on the types of utilities common in the basements in Waterbury, although it is understood that some homes have much more value tied up in utilities than others. The 6% value was also applied to the commercial and industrial buildings for lack of more detailed information.

  Depth damage curves were modified by reducing the value for each flooding threshold by 6% (but never below zero). The lower ends of the curves were smoothed to ensure that a low percentage of building damage would still occur for lower floods, and would increase with depth. See the example for a two-story single-family home with a basement in Table 5.

Table 5.

Sample Depth Damage Curve Modification for Scenario 2C

Occupancy Type	Number of Stories	Basement Present?	Depth Damage Curve (% Damage per foot)									
			-4 ft	-3 ft	-2 ft	-1 ft	0 ft	1 ft	2ft	3ft	4ft	5ft
RES1	2-Story	Basement	4	4	8	14	19	21	26	29	34	39
After modification for 2C:			0	1	2	8	13	15	20	23	28	33

- 3A: Removals were simulated within a spreadsheet by removing buildings from the 1A/1B output. The Q50 removals list was generated based on the deepest areas of the Q100 floodplain. Statistics regarding the removals by town are presented in Table 6.

Table 6.

Number of Buildings Modified per Town for Scenario 3A

Scenario	Community	# of Buildings Modified				Footprint Square Footage Modified			
		Res. Single	Res. Multi	Com./Ind.	Other	Res. Single	Res. Multi	Com./Ind.	Other
Existing	Duxbury	28	0	1	1	27,130	0	3,550	4,932
Existing	Moretown	0	0	0	0	0	0	0	0
Existing Only	Waterbury	21	19	8	2	24,935	30,461	24,712	11,010
Ex. & Build-out	Waterbury	36	27	11	2	37,395	38,661	34,912	11,010
Existing Only	Willsboro	4	2	1	0	5,180	3,850	7,050	0
Ex. & Build-out	Willsboro	8	7	1	0	12,280	9,300	7,050	0

- 3C: Elevation of buildings to this standard resulted in changes in first floor height and foundation type (if necessary) as shown in Table 7.

Table 7.

Number of Buildings Modified per Town for Scenario 3C

Scenario	Community	# of Buildings Modified				Footprint Square Footage Modified			
		Res. Single	Res. Multi	Com./Ind.	Other	Res. Single	Res. Multi	Com./Ind.	Other
Existing	Duxbury	27	0	1	1	26,150	0	3,550	4,932
Existing	Moretown	0	0	0	0	0	0	0	0
Existing Only	Waterbury	21	19	8	2	24,935	30,461	24,712	11,010
Ex. & Build-out	Waterbury	71	77	40	2	72,615	103,821	339,332	11,010
Existing Only	Willsboro	2	1	1	0	2,590	2,200	7,050	0
Ex. & Build-out	Willsboro	5	5	1	0	9,290	7,000	7,050	0

- 4A: Removals were simulated within a spreadsheet by removing buildings from the 1A/1B output. The Q100 removals list (Irene removals list for Willsboro) was generated based on structures most likely to be damages within the Q100 (Irene) floodplain. Statistics regarding the removals by town are presented in Table 8.

Table 8.

Number of Buildings Modified per Town for Scenario 4A

Scenario	Community	# of Buildings Modified				Footprint Square Footage Modified			
		Res. Single	Res. Multi	Com./Ind.	Other	Res. Single	Res. Multi	Com./Ind.	Other
Existing	Duxbury	32	1	1	1	32,972	1,900	3,550	4,932
Existing	Moretown	1	0	4	0	1,082	0	32,250	0
Existing Only	Waterbury	59	31	21	5	77,341	51,753	109,532	23,710
Ex. & Build-out	Waterbury	92	67	32	5	107,970	85,953	151,862	23,710
Existing Only	Willsboro	8	4	3	0	13,900	7,600	25,150	0
Ex. & Build-out	Willsboro	12	9	5	0	21,000	13,050	33,950	0

- 4B: Elevation of selected buildings was based on a list received from Waterbury. This floodplain management scenario did not apply for Willsboro, Duxbury, or Moretown as conditions were no different than for 4A. The buildings in Waterbury that were elevated instead of being removed included the sewer pump station (between the railroad bridge and Rowe field) and Waterbury Medical Associates at 130 South Main Street (both elevated to Q500). The utilities at the Police station and the Fire Station / Town Office building were also elevated above the Q500 level by adjusting the depth damage curve as in scenario 2C. Table 9 presents the statistics for 4B for Waterbury.

Table 9.

Number of Buildings Modified in Waterbury for Scenario 4B

Scenario	Community	# of Buildings Modified				Footprint Square Footage Modified			
		Res. Single	Res. Multi	Com./Ind.	Other	Res. Single	Res. Multi	Com./Ind.	Other
Existing Only	Waterbury	59	31	22	5	77,341	51,753	118,432	23,710
Ex. & Build-out	Waterbury	92	67	33	5	107,970	85,953	160,762	23,710

Processing Model Output

Raw results were output from HAZUS-MH in Microsoft Excel format for each floodplain management scenario and floodplain alternative. The data was post-processed in Microsoft excel. Prior to running all of the scenarios, a calibration exercise was performed as discussed below.

The Town of Waterbury provided a calibration number for the Irene scenario of $2.6 million in reported building damages not including the State Complex. Prior to performing model simulations, the 1A simulation for Waterbury was run using the Irene floodplain condition in an attempt to calibrate the output to be within reasonable proximity of this known value. Buildings that did not exist in 2011 and buildings associated with the State Complex were not included in this calibration. There are a number of uncertainties to consider when attempting to calibrate output, including:

- Not all damage may have been reported, particularly for properties at edge of the floodplain that were minimally affected. This could cause the $2.6 million estimate to be underreported.
- Damage to the properties may not have been as extensive as would be reported by the default depth damage curves used by HAZUS, which could cause the simulated damage to be over-reported. Defining specific depth damage curves for the four communities was beyond the scope of this study.

- The Irene depth grid was considered acceptable for use in the damage modeling, but actually varied from 0.5 to 1.5 feet from known high water marks. This variation could cause a significant swing in damage percentage on the depth damage curves for individual buildings.
- Building footprints were likely overestimated when drawn in ArcGIS where building field cards were not available, as covered porches should not be included in the building footprint. This could cause the HAZUS damages to be over-reported.

Based on these uncertainties, a range of values of +/- 50% of the $2.6 million damages was considered to be calibrated. Initial runs were significantly higher than this range. First, adjustments were made to the model output to remove the percentage of building footprints that were outside of the range of the floodplain (and therefore no susceptible to flooding damage). Second, first floor elevations were more closely scrutinized that resulted in first floor elevations being raised for several buildings. Finally, the field cards obtained for the deeper parts of the floodplain were used to reduce the building footprint. These adjustments brought the calibration building damage for Waterbury down to $3.48 million, well within the upper limit of $3.9 million established to determine calibration.

The adjustments to building footprint were carried through for the remaining floods in Waterbury, although these adjustments were not applied in the remaining three communities as damage calibration numbers were not available. The adjustment was also carried through for content and inventory damage. In addition, total content and inventory damage was reduced by 30% to account for flood warning based on the Day Curve as presented in the HAZUS-MH Technical Manual (FEMA, 2012).

The building, content, and inventory data were summarized into annualized damages for each floodplain management scenario and floodplain alternative based on recurrence intervals of the changes to hydrology (for existing and 2065 conditions) using the equations presented in the HAZUS-MH Technical Manual (FEMA, 2012). The annualized damage results were then used in the overall floodplain valuation.

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Appendix 7: Tasks and Deliverables Completed (Adapted from Approved Workplan)

OBJ1. Conducted a review of the natural and beneficial functions of floodplains with an emphasis on the ecosystem service of natural flood mitigation and resulting economic benefits. Determined the range of value for specific ecosystem benefits for floodplain lands in their natural state, as currently modified, or in a buildout analysis.

Task 1:

1.1 Created a GIS map of existing land uses and a listing of ecosystem services at the two study sites. Recently released NLCD land use data (Jin et al., 2013) was used for the mapping. Local land cover data were verified with existing aerial photographs obtained from the Towns or state GIS data centers, and field observations.

1.2 Conducted a literature search and prepared an annotated bibliography to build on past research on the natural and beneficial functions of floodplains, and the economic benefits of floodplains. Formal peer-reviewed literature and gray literature was reviewed via internet searches. Research included floodplain function benefits that are now being recognized by FEMA, along with others that are yet to be considered. Environmental and social aspects of floodplain management were investigated.

1.3 Determined the range of values for ecosystem benefits for floodplains in the Lake Champlain Basin using the Ecosystem Valuation Toolkit (EE, 2012).

1.4 Archive all documents on CD-ROM following report approval and project completion.

Completed Deliverables:

1a GIS map of existing land uses and value of existing ecosystem services.
1b Annotated bibliography
1c Summary of range of values
1d Digital data archive of all documents

OBJ2. For each of the two municipalities, established up to four floodplain management alternatives that consider possible management areas (e.g., FEMA floodway, the Vermont fluvial erosion hazard zone, a 100-foot vegetated buffer, the FEMA 100-year floodplain, and the FEMA 500-year floodplain), development scenarios (e.g., build-out, building demolition, and conservation), environmental, social and economic aspects of floodplains, and the local and state floodplain management regulatory framework.

Task 2:

2.1 Delineated four to six possible floodplain management areas for each municipality and created a GIS map of the areas. Areas were established in the context of the existing

floodplain management regulatory framework. Several field reconnaissance trips took place to review and update the floodplain mapping and hazards in each Town. A meeting was held with the Towns to review the areas, possible build-out analyses, local environmental, social, and economic values, and floodplain regulations.

2.2 Considered the environmental, social, and economic aspects of the existing floodplains and how they would influence possible management alternative. Environmental issues such as wetlands, aquatic and terrestrial habitat, and water quality were considered. Social aspects were considered that include public sentiment, aesthetics, socioeconomics, relocation, and quality of life. Social trends will be developed from conversations during the meetings with the Towns. Information on economic aspects such as transportation infrastructure, housing, and employment projections will be requested from the Town and State and considered. A list of relevant parameters was assembled to guide the build-out analysis and development of floodplain management alternatives.

2.3 Performed a build-out analysis for each municipality to identify four levels of development or conservation – full buildout, existing building stock, removal of the most floodprone buildings, and removal of floodprone buildings. A full build-out analysis was performed for parcels within the study areas based on current zoning, local plans, and economic development initiatives will be conducted. Data for the build-out analysis will be requested from the Towns and States. This task was done in consultation with the local communities to capture the institutional knowledge and to assure that all assumptions and methodologies are mutually agreed upon. The alternative scenarios were designed to reflect market realities as well as local community goals for future development. The results of the build-out analysis were expressed as gross building square footage for non-residentially zoned parcels and as the number of potential dwelling units for residentially zoned parcels and disaggregated on a parcel-by-parcel basis. Results were displayed on a GIS map.

2.4 Prepared up to four management scenarios, with each having several sub-categories for a total of nine (9) for each municipality by combining the delineated areas in the context of the local regulatory floodplain management framework; the local environmental, social, and economic aspects; the results of the build-out analysis; and possible building demolition/floodplain protection/floodplain restoration projects. The floodplain management scenarios were expended to explore a wider range of scenarios that included proposed floodplain projects in addition to flood mitigation activities.

2.5 Met with the Towns to review the development of the floodplain management alternatives. Several rounds of edits were made to reach consensus on the floodplain management alternatives to be used in the study.

Deliverables Completed:

2a GIS mapping of floodplain management areas in each municipality
2b A list of the environmental, social, and economic aspects of floodplain management
2c GIS mapping and quantification of build-out/mitigation scenarios in each floodplain management area for each municipality
2d Creation of nine floodplain management alternatives for each municipality.
2e Notes and table documenting edits and final floodplain management alternatives.

OBJ3. Performed hydrologic calculations to confirm existing flood flows and predict future flood flows based on trends in USGS stream gauge data.

Task 3:

3.1 Updated existing analyses of USGS stream gauge data to confirm existing peak flood flow rates. The analysis was performed following standard flood frequency methods (USGS, 1982) using common flood analysis software (USACE, 2010b).

3.2 Stratified the gauge data around 1970 and other years where natural breaks exist in the gauge records, and re-run flood frequency data to indicate observed changes in peak flows and identify trends in the data to predict future flood flows given climate change.

Deliverables Completed:

3a Revised existing flood flows
3b Predicted future flood flows

OBJ4. Updated the existing HEC-RAS hydraulic models to evaluate current and predicted future flooding for each of the floodplain management alternatives.

Task 4:

4.1 Revised the existing conditions hydraulic modeling to include the proper project reach for the current study and the revised peak flood flow rates. Modeling was performed in HEC-RAS (USACE, 2010a). Additional data were collected in the field and from Towns. Model refinement for the Winooski River in Waterbury, Vermont included adding additional LIDAR data. Model setup for the Boquet River in Willsboro, New York included extending the existing HEC-RAS model by interpreting more of the HEC-2 data from microfiche already in the possession of the project team. Survey was also performed around the floodplain to improve the coarse topography mapping available around the Boquet River. The models were run using HEC-GeoRAS to allow for rapid floodplain delineation. The revised existing models were run for each of the current and predicted future flood flows. An emphasis was initially placed on large floods such as the 100-year and Irene floods for exploring flood damages, yet smaller floods were needed to annualize damage estimates

so several design flows were ultimately used. The main product of the hydraulics analyses were depth grids for input into the damage modeling.

4.2 Prepared a GIS map of the existing conditions floodplain for the current and predicted future design flood for each municipality. The floodplains were delineated with existing topographic mapping gathered from project partners and from field data collection. Several field trips were conducted to verify the limits of the existing floodplains.

4.3 Inserted two floodplain management alternatives into the hydraulic model for each Town and run the hydraulic model to observe the proposed conditions floodplain for the current and predicted future design flood for each municipality.

4.4 Prepared a GIS map of the proposed conditions floodplains for the current and predicted future design flood for each municipality. A field trip was conducted to verify the limits of the proposed floodplains.

Deliverables Completed:

4a HEC-GeoRAS hydraulic model existing conditions input and output

4b Existing conditions floodplain GIS map for current and predicted design floods

4c HEC-GeoRAS proposed conditions hydraulic model input and output

4d Proposed conditions floodplain GIS maps for current and predicted design floods

OBJ5. Performed damage modeling and created an accounting sheet that compares the costs (e.g., loss of economic development and project implementation costs) and benefits (e.g., reduced flood damages and long-term flood risk reduction) of each floodplain management alternative, and improved ecosystem services

Task 5:

5.1 Performed data collection that is required for the HAZUS-MH model (FEMA, 2013). Hydrologic and hydraulic data were utilized within the Flood Information Tool with updated digital elevation model data to develop inundation grids. Data collection took place by looking at Town property cards, coordinating with local assessors, and doing measurements in the field. The lowest elevation of water entry, and the first floor elevation were collected for all houses in the project area. Measurements were made with a laser level or measurement rod and compared to topographic data or past survey data. Field work was conducted to identify common types of structures, basement types, heights, and other required information.

5.2 Set up and ran HAZUS-MH for existing conditions to determine baseline potential loss estimates for the current and predicted design floods for range of flood mitigation activities.

5.3 Set up and ran HAZUS-MH for proposed conditions to determine potential loss estimates for the current and predicted design flood for each floodplain management alternative under range of flood activities.

5.4 Tabulated data and compared loss estimates for the different floodplain management alternatives to the baseline condition. Collected information on changes in building footprints under different building scenarios, flood mitigation costs, flood insurance, and tax revenue to create a table of costs and benefits to determine what, if any, floodplain management scenario makes the most economic sense.

5.5 Meet with the Towns to review the model output for the floodplain management alternatives and damage estimates, and seek consensus on a recommended alternative.

Deliverables Completed:

5a Summary of past flood damage and other data

5b HAZUS-MH model input and output for existing conditions

5c HAZUS-MH model input and output for proposed conditions for each of the floodplain management alternatives

5d Quantification of damages and the costs and benefits of each floodplain management alternative, including the net change of ecosystem services

OBJ6. Completed reporting

Task 6:

6.1 Developed a Quality Assurance Project Plan (QAPP) approved by LCBP and EPA prior to the start of data collection and analysis.

6.2 Prepared and submitted quarterly progress reports via email to LCBP on March 10, June 20, September 30 in 2014 and January 9 in 2015.

6.3 Prepared a final project report and submitted to the LCBP and the participating municipalities for review.

6.4 Report will be finalized once feedback is received.

Deliverables Completed:

6b LCBP/EPA QAPP

6c Quarterly progress reports

6d Final report (1st submission)

6e Final report (will be revised if needed)

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Appendix 8: Quality Assurance Tasks Completed (Adapted from Approved QAPP)

All primary data met the data quality assurance criteria set forth in the approved QAPP. The primary data sources included:

- River channel survey along the Boquet River and around the Boquet River floodplain; and
- Approximate elevation survey of the first floor of most buildings in the floodplain at both study sites. Building data collection also included the type of basement (full, crawl space, or slab), the building construction type (brick, wood, etc.), and a qualitative assessment of the building condition. For each Town, primary building information was supplemented by a subset of property building cards provided by Town personnel.

Primary data collection:

- Fell within a value range that is reasonable; and
- Can be easily reproduced under similar conditions (within a reasonable range of accuracy and precision).

All primary data collection and analysis results was performed by trained personnel of Milone & MacBroom or Fitzgerald Environmental who completed tasks using proper methods and having suitable training. All information was properly documented, archived, and then displayed for use in this project.

The survey along the Boquet River took place as planned.

The first-floor building elevation survey expanded due to the desire to have more accurate data than an approximate relationship as originally anticipated. Rather than surveying a sub-set of buildings, all buildings were surveyed with either a survey rod or a laser level with vertical measurement capability. This allowed for complete coverage in the floodplain to create a better simulation of building damages. Data were recorded on field maps where known elevation data of first floors collected from the Town were displayed to provide a way to check measurements in the field.

As planned, this project relied on existing secondary data sources. The following data sources were used as planned in the original project QAPP.

- *Approximate Vermont River Corridor:* These GIS data were provided to the project team for internal investigation only to not confuse people about the pending Vermont State River Corridor that has subsequently been released and is now in use in place of this data set.
- *Vermont State River Corridor:* These GIS data were released for the State of Vermont in 2015 and are now in use.

- *Social trends information:* Informal information on social trends and what changes to floodplain development patterns are expected.

- *Economic information:* A request will be made to each Town for economic information such as the cost of essential infrastructure locally managed (Public Works), housing market indicators (Planning and Zoning), and employment projections (Planning and Zoning).

- *Property Information:* A request will be made to each Town for GIS parcel mapping and assessor's data that includes addresses, owners, building information, and zoning information. The property information will be used for the build-out analysis.

- *Inland Wetland Mapping:* Maps of wetlands were obtained from the states web-based systems and from the Towns. The wetland information was used for the build-out analysis.

- *Zoning Regulation:* Zoning Regulations were collected from each Town and will be used as part of the build-out analyses.

- *Soil Mapping*: NRCS soil data were obtained for each project site and were used for the build-out analysis and to help map floodplains. Soils data were obtained from the NRCS Web Soil Survey, VCGI, the VANR Atlas, and the NYDEC Environmental Resource Mapper.

- *Flow Data:* USGS stream gauge data will primarily be downloaded from the USGS website for Vermont and New York. Additional data came from the existing hydraulic models. The analysis was performed following standard flood frequency methods (USGS, 1982) using common flood analysis software (USACE, 2010). Statistical analysis was performed to identify trends in the data before and after 1970 (NMFS, 2011) to establish future projected flood levels. Gauge data will be used for the Boquet River (USGS 04276500 BOUQUET RIVER AT WILLSBORO NY) and the Winooski River and upstream tributaries (USGS 04286000 WINOOSKI RIVER AT MONTPELIER, VT; USGS 04288000 MAD RIVER NEAR MORETOWN, VT, USGS 04287000 DOG RIVER AT NORTHFIELD FALLS, VT). Flow estimates were also be made using the USGS StreamStats website for Vermont (Olson, 2002) and New York (Lumia et al., 2006).

- *Stream Hydraulics:* The project team had the effective FEMA HEC-RAS model (Waterbury) or the HEC-2 model (Willsboro) from past projects. In addition, MMI already has assembled hydraulic model from these data and other sources such as past survey of the river channel, floodplain mapping, and LIDAR data. These models were refined as needed with similar data to cover the project areas.

- *USGS Survey of the Winooski River:* USGS surveyed the Winooski River in Waterbury, Vermont and has agreed to share data to improve existing hydraulic modeling. These data define the channel and floodplain, and will be added to the existing model. The Boquet River model will be extended with the HEC-2 data, and supplemented with the channel cross section survey collected as part of this project.

- *One-foot contours based on DEM developed from LIDAR:* This information will be used to provide land elevation data of the project site and surrounding area. In Waterbury, Vermont LIDAR data exist to map floodplains and additional LIDAR was provided by Central Vermont Regional Planning Commission in 2014. These data were incorporated into existing LIDAR to complete floodplain mapping.

- *NHD Digital Elevation Model:* The 10-meter digital elevation model associated with the National Hydrography Dataset was used to map the floodplain along the Boquet River. The field survey was used to improve mapping in select floodplain locations.

- *USGS topographic maps:* Coarse topography was used to assist with floodplain mapping along the Boquet River.

- *Town Damage Estimates:* Requests were made to each town to collect damage data from Tropical Storm Irene and from past floods. This included damaged homes and private property. Infrastructure loss was not included in this information. Default Benefit-Cost Analysis Software (FEMA, 2013) will also be referenced to generate potential benefits and cost of damages where data gaps exist and no additional information is available. Site-specific damage curves for neighborhoods at the census block level and for specific essential facilities that are part of the HAZUS software will be used initially and then these default data will be updated with data from the Towns and with collected data.

- *Historical aerial photographs:* These photographs were reviewed to provide information related to the historical land use in the project vicinity and provide information regarding possible temporal changes to the landscape. Some maps are in hand from previous project work, while others will be obtained from the Town, Vermont Center for Geographic Information, and New York GIS.

The following additional secondary data sources were used in the project.

- *Property Information:* Assessors property cards were provided to look up information for damage modeling such as basement type, building footprints, building age, building condition, and building cost. These data were invaluable for improving the project outcome.

- *National Flood Insurance Program Information:* Each state provided Town records of insurance policies to help understand potential changes in insurance with mitigation activities.

- *Typical Building Information:* The size and cost of typical residential and commercial buildings was obtained from the each Town to understand the change in buildings with flood mitigation activities.

- *Flood Mitigation Costs:* The cost to implement flood mitigation activities or floodplain restoration alternatives were taken from previous related work such as the Waterbury Flood Study (MMI, 2013b, a) and past project history in the region.

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