Appendix D.4 – Economic Investigation and Analyses

Jewell Watershed Dam Sites #1, #2, #3 and #5.

Supplemental Watershed plan and Environmental Assessment

January 10, 2023

APPENDIX D. INVESTIGATION AND ANALYSIS – ECONOMICS

I. Introduction

The economic investigation and analysis documents the flood damage estimation methodology and summarizes the analysis results for alternatives considered. The benefit-cost analysis follows the procedures outlined in:

- *Principles and Requirements for Federal Investments in Water Resources* (2013) and *Interagency Guidelines* (2014)
- *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (1983)
- *National Watershed Program Manual* (2014).
- DM 9500-013 *Guidance for Conducting Analyses Under the Principles, Requirements, and Guidelines for Water and Land Related Resources Implementation Studies and Federal Water Resource Investments (2017)*

Unless otherwise noted, values in the analysis are in 2021 prices and annual values have been discounted using the Fiscal Year (FY) 2021 federal discount rate for water resources projects of 2.5 percent.

The original watershed plan for the Jewell Brook watershed was prepared in April 1964. Three floodwater retarding structures, one multiple purpose floodwater retarding and recreation development structure, and a diversion channel were planned and later constructed over the period 1966-1970. The plan was supplemented in 1966 to revise the diversion channel design.

The benefits attributed to the proposed structures were quantified in the 1964 plan, and included direct, indirect, and secondary flood damage reduction benefits, and recreation benefits from Site 3. Indirect benefits consisted of reducing the flood related effects of loss of wages, rerouting of traffic and interruption of utility service, and loss of business income (SCS 1964). Secondary benefits, as defined in the plan, measured locally attributable benefits. Other benefits were described qualitatively in the 1964 plan. Other benefits consisted of improved economic stability, diminished hazard to life, and a reduction in the social costs associated with frequent flood events.

This analysis updates the flood damage reduction and recreation benefits quantified in the original watershed plan using the United States Army Corps of Engineers (USACE) Hydrologic Engineering Centers Flood Impact Analysis Software (HEC-FIA) to estimate structures and vehicle damages, and Geographic Information System (GIS) analysis to estimate damages to study area infrastructure. Recreation benefits are estimated using USACE unit day values for recreation activities. Under the Principles, Requirements and Guidelines (PR&G) framework, the flood protection benefits can be categorized as a regulating ecosystem service, and the recreation benefits can be categorized as a cultural service (USDA 2017).

In addition to flood damage reduction and recreation benefits, another benefit category was added to the current analysis: administrative cost savings to the National Flood Insurance Program (NFIP) from a reduction in the number of properties that must participate. This benefit can be categorized as a regulating ecosystem service under PR&G.

II. Study Area Inventory

The study area for the analysis was defined as the inundation limits of the 500-year floodplain in the absence of the dam (without-dam floodplain). This boundary encompasses the farthest extent of flooding for the flood events examined within the scope of the project. The study area is approximately 25,356 acres (39.6 square miles), beginning at Jewell Brook Dam, Ludlow, VT, and extending to the town of Perkinsville, VT (see *Exhibit D4.1. Economic Analysis Study Area Boundary*). The study area consists of developed land and undeveloped land in and adjacent to the towns of Ludlow, Smithville, Proctorsville, Cavendish, Whitesville, and Perkinsville, VT. Study area land uses consist of residential, commercial, industrial, and institutional.

A. Structures and Vehicles

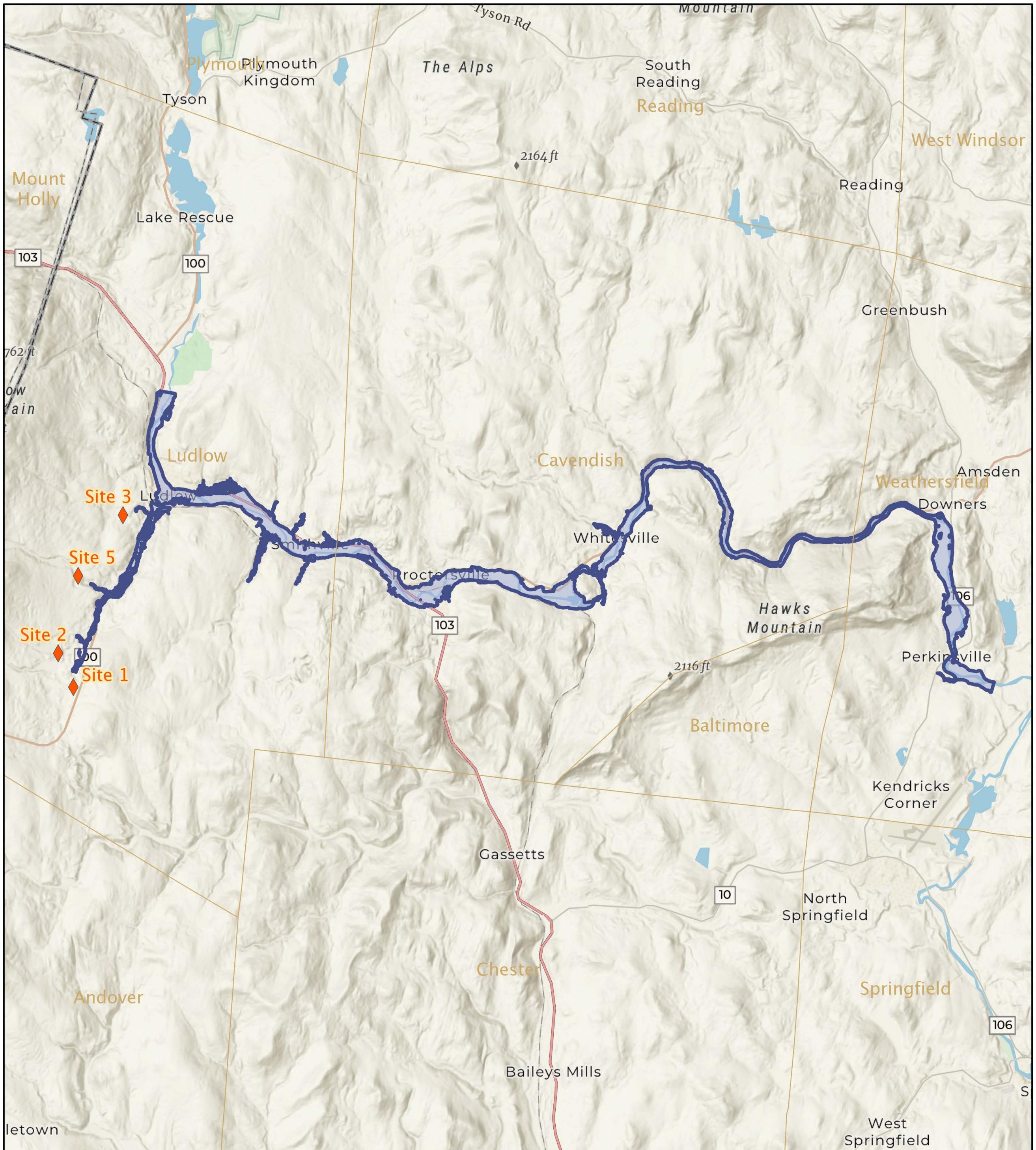
Study area structures were identified and categorized by land use type using GIS tax parcel data obtained from the Vermont Center for Geographic Information. The accuracy of the parcels database was verified via an examination of aerial photography. A total of 433 properties with structures fell within the inundation limits of the 500-year without-dam flood event, and a total of 309 properties with structures fell within the inundation limits of the 100-year without-dam flood event.

Properties within the 500-year without-dam floodplain boundary consisted of 233 single family homes, 27 multi-family homes, four duplexes, one condominium complex (total of 16 units), 21 apartment buildings (approximately 77 units), 14 mobile-homes, 19 garages, two hotels, two motels, four churches, one golf course, five warehouses, Cavendish Town Office Building, Ludlow Town Hall, Ludlow Fire Department, Cavendish Vol. Fire Department, Proctorsville Fire Department, Post Office, Ludlow Recreation Area/ Dorsey Park, Ludlow Little League Field, Baseball Field, Ludlow Parks and Recreation Department, and Fletcher Farm Craft School. The 90 additional commercial businesses include restaurants, gas stations, medical offices, auto care and repair shops, bakeries, beauty shops, hardware stores, banks, grocery stores, real estate offices, private clubs, and retail stores. The Cavendish Town Office Building, Ludlow Town Hall, Ludlow Fire Department, Cavendish Vol. Fire Department, and Proctorsville Fire Department are characterized as critical facilities under 7 CFR 650.25, Floodplain Management.

Properties within the 100-year without-dam floodplain boundary consisted of 155 single family homes, 16 multi-family home, four duplexes, one condominium complex (total of 16 units), 11 apartment buildings (approximately 37 units), nine mobile-homes, 12 garages, two hotels, two motels, four churches, one golf course, five warehouses, Cavendish Town Office Building, Ludlow Town Hall, Ludlow Fire Department, Cavendish Vol. Fire Department, Post Office, Ludlow Recreation Area/ Dorsey Park, Ludlow Little League Field, Baseball Field, Ludlow Parks and Recreation Department, and Fletcher Farm Craft School. The 74 additional commercial businesses include restaurants, gas stations, medical offices, auto care and repair shops, bakeries, beauty shops, hardware stores, banks, grocery stores, real estate offices, private clubs, and retail stores. The

Cavendish Town Office Building, Ludlow Town Hall, Ludlow Fire Department, and Cavendish Vol. Fire Department are characterized as critical facilities under 7 CFR 650.25, Floodplain Management.

The U.S. Census Bureau defines a housing unit as a "house, an apartment, a mobile home, a group of rooms, or a single room that is occupied (or if vacant, is intended for occupancy) as separate living quarters (Census Bureau 2020)." The table below shows the number of housing units affected in the 500-year and 100-year without-dam flood events.



Legend
- Jewell Brook Dam Sites
- Jewell Brook Dam Study Area
- Town Boundary
- County Boundary

Exhibit D4.1

Jewell Brook Dams Economic Analysis Study Area Boundary

Windsor County, Vermont

0 0.75 1.5 Miles

Exhibit D4.2 Number of Housing Units Affected

Without-Dam Floodplain	Number of Housing Units
500-year event	402
100-year event	257

Structure value was estimated using the assessed value of buildings from the Windsor County tax database. Contents values for residential structures were valued at 50% of the total structure value, or 25% for garages, and commercial/institutional structures were valued at 200% of total structure value, based on NRCS guidance.

Study area communities are primarily rural, with compact mixed use village cores. Ludlow is an outdoor recreation destination. Based on review of Ludlow and Cavendish comprehensive planning documents, future development or redevelopment is expected to be concentrated in village centers. Population in study area communities is not forecast to grow substantially in the next 20 years (Town of Cavendish, 2020). No major development or redevelopment plans were identified for inclusion in the flood damage estimate.

Future infrastructure development activities consist of pedestrian and paving improvements, including the establishment of a multi-use path to connect the Villages of Cavendish, Proctorsville, and Ludlow. Rehabilitation of VT 131 within the study area due to Tropical Storm Irene damage is scheduled for 2021. No major infrastructure projects were identified for inclusion in the flood damage estimate (VTrans, 2021).

Vehicles were included in the model, using HEC-FIA default settings for number of vehicles per property. The Federal Emergency Management Agency HAZUS-MH MR3 Technical Manual methodology (FEMA HAZUS) was used to estimate personal vehicle value (FEMA, 2018). The FEMA HAZUS methodology provides vehicle age distribution data by vehicle classification and uses half of the average new car value for average used car vehicle values, based on National Automobile Dealers Association (NADA) data. Based on a 2020 average transaction price for a new mid-sized car (Kelley Blue Book, 2020), the average study area vehicle was assumed to be valued at $14,600. No vehicles were assigned to commercial or institutional structures in the model, which is a conservative estimate to avoid over counting flooded vehicles.

B. Roadways and Roadway Bridges

Roadways were divided into four categories: two-lane without shoulders, two-lane with shoulders, two-lane with sidewalks, and unpaved. Total mileage for each roadway type in the study area was estimated using ArcGIS and shown in Exhibit D4.3.

Exhibit D4.3 Roadways within the Without-Dam Floodplain

500-Year Without-Dam		100-Year Without-Dam	
Roadway Type	**Roadway Length (Miles)**	**Roadway Type**	**Roadway Length (Miles)**
Two-Lane without Shoulders	2.3	Two-Lane without Shoulders	2.8
Two-Lane with Shoulders	9.5	Two-Lane with Shoulders	6.8
Two-Lane with Sidewalks	2.1	Two-Lane with Sidewalks	1.7
Unpaved	2.1	Unpaved	1.7

There are 44 roadway bridges within the study area floodplain. Please refer to *Appendix C. Support Maps* for a map showing roadway and bridge locations.

C. Railroads and Railroad Bridges

The Green Mountain Railroad Corp (GMRC), operated by the Vermont Rail System, is present within the study area. The railroad runs seasonal passenger services during fall foliage and hauls freight year-round. Total mileage for the GMRC in the study area was estimated using ArcGIS. Railroad lines within the 500-year and 100-year without-dam floodplains consisted of approximately 1.2 and 1.0 miles, respectively.

There are six railway bridges within the study area floodplain. Please refer to *Appendix C. Support Maps* for a map showing bridge locations.

D. Recreation Activities

The land surrounding the four Jewell Brook dams is owned by the Town of Ludlow. Jewell Brook Dam Sites 1, 2, and 5 are not designated parks, nor is recreation a designated PL 83-566 use of the dam impoundments (Southern Windsor County, 2013). Jewell Brook Dam Site 3, known as West Hill, serves as a locally important recreational resource.

Youth sport leagues, fishing, swimming, picnicking and annual community events are common recreational activities during the summer months. The 10-acre lake is stocked annually with trout and crayfish. The dam is also a locally popular destination for sledding in the winter months. Additional recreation shelters and a dog park are approved proposed improvements (Ludlow Recreation Committee, 2021).

III. Flood Damage Reduction

A. Structures and Vehicles

Flood damages to structures were estimated using HEC-FIA version 3.0. The HEC-FIA model uses the following parameters to estimate the flooding depth and cost of damages to structures and vehicles:

- Flood frequency and depth, duration, and arrival time gridded data from the output flood model
- Terrain elevation grid in combination with user defined parameters to determine first floor elevation
- Foundation heights, which were assumed to be 1.0 feet from ground elevation
- Point locations of all structures
- Type and value of each structure and contents within the structure
- Damage coefficient data for each type of structure and contents

HEC-FIA uses the gridded data to determine depth, arrival, and duration of water at each structure point. The model then analyzes the water depth and first floor elevation with the default or user defined depth damage curve to determine damages for each flood event.

The flood stage within the Town of Ludlow and other downstream areas is a function of flow from both the Jewell Brook and the Black River. The Black River was included in the hydraulic model to capture the joint effect of the two watercourses on the study area during a flood event. However, to avoid completing a detailed hydrologic analysis of the approximately 58 sq. mi. upstream Black River watershed and watersheds of downstream tributaries, steady peak discharges, referenced from the FEMA FIS and from USGS StreamStats, were used in the modeling. The outflow hydrographs from SITES were input for flow from the Jewell Brook Dams.

The models utilize an equivalent steady peak discharge in the Black River to the recurrence-interval event occurring in the Jewell Brook watershed. This means that if the 100-yr recurrence interval (1% annual exceedance probability) discharge was being routed through the Jewell Brook watershed, the 100-yr recurrence interval (1% AEP) discharge was also routed within the Black River. It is possible for a storm event to have 100-yr flooding within the Jewell Brook, but a different recurrence-interval flooding within the Black River. In addition, due to the timing of the rainfall and travel times associated with the arrival of this discharge to the study area, the peaks of each of these flood events would arrive at different times and would produce a lower maximum flood stage than if the peaks arrived at the same time. By using the steady peak discharge in the Black River, the peak flow from Jewell Brook occurs at the same time as the Black River, which increases flooding downstream.

Using the output hydraulic data, the 10-year, 25-year, 50-year, 100-year, 200-year, and 500-year flood events were modeled in HEC-FIA for without-dam and Preferred Alternative conditions. Depth-damage factors for the various structure types and contents were obtained from USACE data provided by NRCS (NRCS 2018). The model extents continue to the point at which flow becomes channelized, and no more damage occurs. The without-dam condition is used to quantify the regulating ecosystem service (flood damage reduction) provided by the dams.

Model results for without-dam conditions are shown in Exhibits D4.4 and D4.5, including damages by structure type and number of structures inundated for the six flood events modeled. Please refer to *Appendix C. Support Maps* for floodplain delineation mapping showing the inundation limits for the flood events modeled.

Exhibit D4.4 HEC-FIA Output, Without-Dam Conditions

Flood Event	# of Structures Damaged	Structure Type	Sum of Structure Damage	Sum of Contents Damage	Sum of Vehicle Damage	Sum of Total Damage	Avg. Depth of Flooding (ft.)
500-yr	100	Commercial	$4,268,677	$27,986,101	$0	$32,254,778	3.86
200-yr	93	Commercial	$3,014,653	$23,127,252	$0	$26,141,905	2.94
100-yr	88	Commercial	$2,289,919	$18,206,308	$0	$20,496,227	2.19
50-yr	82	Commercial	$1,290,123	$12,980,861	$0	$14,270,983	1.28
25-yr	72	Commercial	$823,917	$8,727,153	$0	$9,551,071	0.76
10-yr	47	Commercial	$354,230	$6,120,172	$0	$6,474,401	0.29
500-yr	15	Institutional	$301,513	$3,974,471	$0	$4,275,984	4.09
200-yr	15	Institutional	$228,661	$2,659,908	$0	$2,888,569	2.98
100-yr	14	Institutional	$158,191	$1,702,622	$0	$1,860,813	2.38
50-yr	11	Institutional	$164,334	$1,094,209	$0	$1,258,543	2.17
25-yr	10	Institutional	$74,217	$628,126	$0	$702,343	1.82
10-yr	8	Institutional	$23,015	$112,124	$0	$135,139	0.97
500-yr	318	Residential	$11,562,672	$10,907,650	$2,037,452	$24,507,774	2.06
200-yr	243	Residential	8,655,525	8,560,056	1,442,774	18,658,355	1.81
100-yr	207	Residential	$7,102,189	$7,295,911	$1,087,717	$15,485,816	1.5
50-yr	173	Residential	$5,483,361	$5,678,910	$739,282	$11,901,553	1.02
25-yr	142	Residential	$4,256,800	$4,466,884	$490,081	$9,213,766	0.73
10-yr	103	Residential	$3,103,018	$3,365,905	$33,196	$6,787,379	0.56

Exhibit D4.5 HEC-FIA Model Results Summary, Without-Dam Conditions

Flood Event	# of Structures Damaged	Structures by Type			Total Structure Damage	Total Contents Damage	Total Vehicle Damage	Total Damage
		Res.	Comm.	Inst.				
500-yr	433	318	100	15	$16,132,862	$42,868,222	$2,037,451	$61,038,535
200-yr	351	243	93	15	$11,898,838	$34,347,217	$1,442,774	$47,688,829
100-yr	309	207	88	14	$9,550,299	$27,204,841	$1,087,717	$37,842,857
50-yr	266	173	82	11	$6,937,818	$19,753,979	$739,282	$27,431,079
25-yr	224	142	72	10	$5,181,210	$14,515,432	$490,081	$20,186,723
10-yr	158	103	47	8	$3,480,263	$9,598,200	$333,196	$13,411,659

Under the Preferred Alternative, the rehabilitated structures would protect the downstream area through the 100-year event from flooding caused by Jewell Brook. However, because the Black River was included in the hydraulic model, damages still show for the 100-year and smaller events under the Preferred Alternative. And because the Black River was modeled using steady peak discharges, the remaining damages are likely higher than what would occur in an actual flood event. However, the Black River portion of the model is the same under both alternatives, and therefore does not affect the comparison of alternatives (see P&G 2.4.11(b)). Damages and structures inundated under the Preferred Alternative are shown in Exhibit D4.6 and D4.7.

Exhibit D4.6 HEC-FIA Output Results, Preferred Alternative

Flood Event	# of Structures Damaged	Structure Type	Sum of Structure Damage	Sum of Contents Damage	Sum of Vehicle Damage	Sum of Total Damage	Average Depth of Flooding (ft.)
500-yr	81	Commercial	$2,148,562	$16,448,367	$0	$18,596,929	2.45
200-yr	66	Commercial	$1,343,507	$11,388,525	$0	$12,732,032	1.84
100-yr	54	Commercial	$786,938	$6,932,489	$0	$7,719,427	1.07
50-yr	40	Commercial	$504,113	$3,498,479	$0	$4,002,592	0.75
25-yr	29	Commercial	$273,911	$1,960,352	$0	$2,234,262	0.56
10-yr	20	Commercial	$109,415	$948,223	$0	$1,057,638	0.05
500-yr	13	Institutional	$191,356	$1,726,038	$0	$1,917,393	2.45
200-yr	13	Institutional	$82,988	$880,680	$0	$963,668	1.53
100-yr	10	Institutional	$63,812	$400,645	$0	$464,457	1.34
50-yr	7	Institutional	$50,867	$269,617	$0	$320,483	1.49
25-yr	5	Institutional	$35,502	$216,503	$0	$252,005	1.74
10-yr	3	Institutional	$28,191	$160,230	$0	$188,421	2.17
500-yr	185	Residential	$7,084,098	$7,427,713	$1,183,828	$15,695,639	1.84
200-yr	161	Residential	$5,595,328	$5,971,342	$846,995	$12,413,665	1.27
100-yr	124	Residential	$4,187,026	$4,685,110	$549,692	$9,421,828	0.87
50-yr	98	Residential	$3,154,388	$3,705,408	$343,589	$7,203,385	0.54
25-yr	78	Residential	$2,567,165	$3,099,462	$242,423	$5,909,049	0.31
10-yr	51	Residential	$1,800,677	$2,194,804	$136,167	$4,131,649	0.06

Exhibit D4.7 HEC-FIA Model Results Summary, Preferred Alternative

Flood Event	# of Structures Damaged	Structures by Type			Total Structure Damage	Total Contents Damage	Total Vehicle Damage	Total Damage
		Res.	Comm.	Inst.				
500-yr	279	185	81	13	$9,424,016	$25,602,118	$1,183,828	$36,209,962
200-yr	240	161	66	13	$7,021,823	$18,240,547	$846,995	$26,109,365
100-yr	188	124	54	10	$5,037,776	$12,018,243	$549,692	$17,605,711
50-yr	141	98	36	7	$3,709,368	$7,473,504	$343,589	$11,526,461
25-yr	112	78	29	5	$2,876,577	$5,276,317	$242,423	$8,395,317
10-yr	74	51	20	3	$1,938,284	$3,303,257	$136,167	$5,377,708

Exhibit D4.8 presents the calculation of the expected annual damage for structures and vehicles under without-dam conditions and the Preferred Alternative. Calculation of the expected annual damage (EAD) accounts for the probability of exceedance of each flood event magnitude. The expected annual damage is the area under the frequency-damage curve. The difference in damages between the two conditions, **$1,276,200,** represents the annual benefit of implementing the Preferred Alternative. Benefits are rounded to the nearest hundred dollars per NRCS guidance.

Exhibit D4.8 Expected Annual Flood Damages to Structures and Vehicles

Flood Event	Exceedance Probability	Without Dam		Preferred Alternative	
		Damages	Contribution to EAD	Damages	Contribution to EAD
500-yr	0.002	$61,038,535	$122,077	$36,209,962	$72,420
200-yr	0.005	$47,688,829	$163,091	$26,109,365	$93,479
100-yr	0.01	$37,842,857	$213,829	$17,605,711	$109,288
50-yr	0.02	$27,431,079	$326,370	$11,526,460	$145,661
25-yr	0.04	$20,186,724	$476,178	$8,395,316	$199,218
10-yr	0.1	$13,411,659	$1,007,951	$5,377,708	$413,191
		TOTAL	**$2,309,496**	**TOTAL**	**$1,033,257**

B. Infrastructure

Roadways and Roadway Bridges

Roadway damages from flooding depend on unique study area factors, such as the roadways' height, distance from and position relative to the flood water. Therefore, published damage factors for roadways were not readily available. To estimate roadway damages, project civil engineers used project data (fieldview, mapping, and hydraulic modeling) to develop a series of assumptions regarding flood impacts on study area roadways.

Average flood depths for the without-dam flood events ranged from 1.7-4.8 feet while average flood velocities for the flood events ranged from 2.1-4.3 fps.

Cleaning and repair costs per linear foot were estimated by project civil engineers for roadways in the study area, based on removing flood debris and repairing damaged roadway. The cost assumptions for roadway cleaning and replacement are summarized in Exhibit D4.9. Detailed cost estimates are shown in Exhibit D4.10.

Exhibit D4.9 Cleaning and Repair Costs and Assumptions for Study Area Roadways

Roadway Type	% Cleaning	Cleaning cost $/LF	% Damage	Repair cost $/LF
Two-Lane with Shoulders	80%	$136	20%	$495
Two-Lane with Sidewalks	90%	$213	10%	$996
Two-Lane without Shoulders	70%	$90	30%	$197
Unpaved	50%	$90	50%	$142

Source: Gannett Fleming, 2021.

Exhibit D4.10 Detailed Cost Estimates

Roadway Cleaning and Replacement

Assumed Roadway Width - unpaved and two lanes with no shoulders	20	ft
Assumed Roadway Width - two lanes with sidewalks	30	ft
Assumed Roadway Width - two lanes with shoulders	40	ft
Assumed Sidewalk Width x two sides	10	ft
Assumed Clearing Area Adjacent to Road x two sides	20	ft
Assumed Depth of Debris	1.5	ft
Assumed Depth of unpaved road	6	in
Assumed Pavement Depth of two lane with no shoulders	11.5	in
Assumed Pavement Depth of two lane with shoulders or sidewalk	21	in
Assume upaved and two lanes with no shoulders = 20' roadway		
Assume two lanes with sidewalk = 30' roadway + two 5' sidewalks		
Assume two lanes with shoulders = 24' roadway + two 8' shoulders = 40'		

Construction Items		
Excavation of Debris	$30	/CY
Pipe Cleaning	$35	/LF
Foreign Borrow (Soil)	$20	/CY
Rock Armor	$95	/CY
Select Material Surfacing - 6" depth	$11	/SY
Pavement for Two Lanes - No Shoulders		
1.5" Bituminous Wearing Course	$11.00	/SY
4" Bituminous Base Course	$13.50	/SY
6" Subbase	$6.30	/SY
Pavement for Two Lanes with Sidewalk or Shoulders		
1.5" Bituminous Wearing Course	$11.00	/SY
2.5" Bituminous Binder Course	$16.50	/SY
7" Bituminous Base Course	$23.60	/SY
10" Subbase	$10.50	/SY
Catch Basin	$4,000	EACH
18" Concrete Pipe	$90.00	/LF
Curbing	$55.00	/LF
Sidewalk	$145	/SY

Cleaning - Unpaved and Two lanes with no shoulders

Assume cleaning is needed for roadway area next to road + One 30-foot long cross pipe every 200'

Volume of Debris	40	ft	x	1.5	ft	=	60	SF/LF	=	2.22	CY/LF
Excavation of Debris	$30.00	/CY	x	2.22	CY/LF	=	$67	/LF			
Pipe Cleaning	$35.00		x	0.15	ft pipe/ft road	=	$5	/LF			
					Total	=	$72	/LF			
					With 25% Contingency	=	$90	/LF			

Cleaning - Two Lanes with Sidewalks

Assume cleaning is needed for roadway + 2 sidewalks +area next to road + 2 pipes running length of road beneath centerline

Volume of Debris	60	ft	x	1.5	ft	=	90	SF/LF	=	3.33	CY/LF
Excavation of Debris	$30.00	/CY	x	3.33	CY/LF	=	$100	/LF			
Pipe Cleaning	$35.00		x	2	ft pipe/ft road	=	$70	/LF			
					Total	=	$170	/LF			
					With 25% Contingency	=	$213	/LF			

Cleaning - Two Lanes with Shoulders

Assume cleaning is needed for roadway + sidewalk (both sides) + One 50-foot long cross pipe every 200'

Volume of Debris	60	ft	x	1.5	ft	=	90	SF/LF	=	3.33	CY/LF
Excavation of Debris	$30.00	/CY	x	3.33	CY/LF	=	$100	/LF			
Pipe Cleaning	$35.00		x	0.25	ft pipe/ft road	=	$9	/LF			
					Total	=	$109	/LF			
					With 25% Contingency	=	$136	/LF			

Replacement - unpaved

Select Mat. Surface - 6"	$11.00	/SY	x	20	FT (width)	x	200	LF (per 200')	/	9	SF/SY	=	$4,889
Sidewalk	$145	/SY	x	10	FT (width)	x	0	LF (per 200')	/	9	SF/SY	=	$0
Curbing	$55.00	/LF				x	0	LF (per 200')				=	$0
Catch Basin	$4,000	EA	x			x	0					=	$0
18" pipe	$90.00	/LF				x	50	LF (per 200')				=	$4,500
											Subtotal		$9,389

$9,389	per 200 feet	=	$47	per LF
+	cleaning	=	$67	per LF
	Total	=	$114	per LF
With 25% Contingency		=	$142	per LF

Replacement - 2 lanes with no shoulders

Roadway Subbase & Paving	$30.80	/SY	x	20	FT (width)	x	200	LF (per 200')	/	9	SF/SY	=	$13,689
Sidewalk	$145	/SY	x	10	FT (width)	x	0	LF (per 200')	/	9	SF/SY	=	$0
Curbing	$55.00	/LF				x	0	LF (per 200')				=	$0
Catch Basin	$4,000	EA	x			x	0					=	$0
18" pipe	$90.00	/LF				x	50	LF (per 200')				=	$4,500
											Subtotal		$18,189

$18,189	per 200 feet	=	$91	per LF
+	cleaning	=	$67	per LF
	Total	=	$158	per LF
With 25% Contingency		=	$197	per LF

Replacement - Two lanes with sidewalks

Roadway Subbase & Paving	$61.60	/SY	x	30.00	FT (width)	x	200	LF (per 200')	/	9	SF/SY	=	$41,067
Sidewalk	$145	/SY	x	10.00	FT (width)	x	200	LF (per 200')	/	9	SF/SY	=	$32,222
Curbing	$55.00	/LF				x	400	LF (per 200')				=	$22,000
Catch Basin	$4,000	EA	x			x	2					=	$8,000
18" pipe	$90.00	/LF				x	400	LF (per 200')				=	$36,000
											Subtotal		$139,289

$139,289	per 200 feet	=	$696	per LF
+	cleaning	=	$100	per LF
	Total	=	$796	per LF
With 25% Contingency		=	$996	per LF

Replacement - Two lanes with shoulders

Roadway Subbase & Paving	$61.60	/SY	x	40.00	FT (width)	x	200	LF (per 200')	/	9	SF/SY	=	$54,756
Sidewalk	$145	/SY	x	10.00	FT (width)	x	0	LF (per 200')	/	9	SF/SY	=	$0
Curbing	$55.00	/LF				x	0	LF (per 200')				=	$0
Catch Basin	$4,000	EA	x			x	0					=	$0
18" pipe	$90.00	/LF				x	50	LF (per 200')				=	$4,500
											Subtotal		$59,256

$59,256	per 200 feet	=	$296	per LF
+	cleaning	=	$100	per LF
	Total	=	$396	per LF
With 25% Contingency		=	$495	per LF

Using ArcGIS, the roadway mileage inundated under each flood event was calculated. Mileage inundated was multiplied by the percentage of flooded surface that would require cleaning and repair. Damaged surface (feet) was multiplied by the cleaning and repair costs (per foot) to obtain damages. Expected annual damages to roadways under without-dam conditions was estimated at $822,727 and at $2,694 under the Preferred Alternative (Exhibit D4.11). The difference in damages between the two conditions, **$820,000,** represents the annual benefit of implementing the Preferred Alternative. Benefits are rounded to the nearest hundred dollars per NRCS guidance.

Exhibit D4.11 Expected Annual Flood Damages to Roadway Infrastructure

Flood Event	Exceedance Probability	Without Dam		Preferred Alternative	
		Damages	Contribution to EAD	Damages	Contribution to EAD
500-yr	0.002	$17,144,230	$34,288	$66,126	$132
200-yr	0.005	$14,104,125	$46,873	$52,852	$178
100-yr	0.01	$12,953,366	$67,644	$40,845	$234
50-yr	0.2	$9,867,220	$114,103	$30,839	$358
25-yr	0.4	$7,752,922	$176,201	$24,584	$554
10-yr	0.1	$5,034,354	$383,618	$16,683	$1,238
		TOTAL	**$822,727**	**TOTAL**	**$2,694**

GIS analysis was conducted to determine if roadway bridges located within the study area would be impacted by flooding. Roadway bridges impacted by flooding are summarized in the Exhibit D4.12 below. These bridges would require debris cleaning and some repair. Roadway bridge cleaning and repair costs were captured within the roadway repair costs above.

Exhibit D4.12 Expected Annual Flood Damages to Bridges

Flood Event	No. of Bridges Overtopped	Average Flood Depth (ft)
500-yr	25	3.8
200-yr	22	2.7
100-yr	16	2.5
50-yr through 10-yr	3	1.5 to 5.5

Railroads and Railroad Bridges

GIS analysis was conducted to determine whether study area railroad lines and bridges would be impacted by flooding. For each flood event, portions of the Green Mountain Railroad would be impacted. Depending on event, between 0.1 and 1.2 miles of railroad track would be overtopped by average depths ranging from 2.5 to 4.0 feet. Three railroad bridges would be overtopped in the 500-year without-dam flood event by 2.5 to 4.8 feet and in the 200-year without-dam flood by 2.1 feet.

Project track engineers determined that track flooding at these depths would result in fouled ballast, i.e., washouts or destabilization of the subgrade supporting the tracks. Fouled ballast occurs when finer materials mix with fresh or clean materials in the subgrade. The effects of fouled ballast include poor passenger comfort, speed restrictions and potential derailments (Kumara and Hayano, 2016). Project engineers estimated the cost for track subgrade rebuilding at a minimum of $200 per track/foot. Study area railroad bridges were expected to be severely damaged and require repair at a minimum of $100,000 per bridge.

Damaged surface was multiplied by the repair costs to obtain damages per event. Expected annual damages to railroad lines and railroad bridges was estimated at $60,080 under without-dam conditions and $27,760 under the Preferred Alternative (Exhibit D4.13). The difference in damages between the two conditions, **$32,300**, represents the annual benefit of implementing the Preferred Alternative. Benefits are rounded to the nearest hundred dollars per NRCS guidance.

Like the structures analysis results, because the Black River simplified model is included, the remaining railroad damages under the Preferred Alternative are likely higher than what would occur in an actual flood event. However, the Black River portion of the model is the same under both alternatives, and therefore does not affect the comparison of alternatives (see P&G 2.4.11(b)).

Exhibit D4.13 Expected Annual Flood Damages to Railroad Infrastructure

Flood Event	Exceedance Probability	Without Dam		Preferred Alternative	
		Damages	Contribution to EAD	Damages	Contribution to EAD
500-yr	0.002	$1,550,215	$3,100	$1,232,696	$2,465
200-yr	0.005	$1,466,376	$4,525	$968,308	$3,302
100-yr	0.01	$1,016,074	$6,206	$482,468	$3,627
50-yr	0.20	$837,574	$9,268	$342,408	$4,124
25-yr	0.40	$469,832	$13,074	$205,857	$5,483
10-yr	0.1	$327,047	$23,906	$86,112	$8,759
		TOTAL	**$60,080**	**TOTAL**	**$27,760**

C. Administrative Cost Savings to the National Flood Insurance Program (NFIP)

By reducing the size of the 100-year floodplain, the Jewell Brook dams reduce the number of properties that must participate in the NFIP, which enables a savings in the administrative costs of the program. According to NRCS technical guidance based on a FEMA actuarial rate review, each policy is estimated to incur an administrative cost of $335.47 per year (updated from the original 2015 NRCS estimate using the Bureau of Economic Analysis (BEA) Gross Domestic Product Implicit Price Deflator) (Townsley, 2016, FEMA 2011, BEA 2020).

The 100-year floodplain under without-dam conditions and the Preferred Alternative were compared using ArcGIS. It was determined that the dam reduces the number of properties required to participate in the NFIP by 136 properties. This reduction represents a savings in administrative costs of **$45,600** per year.

D. Recreation

It was assumed that the open space and recreation facilities around the Site 3 impoundment would be maintained regardless of the alternative selected. Therefore, the annual recreation benefit provided by Jewell Brook Dam Site No. 3 was limited to fishing activity.

USACE unit day values for general fishing and hunting were used to estimate the recreation benefit provided by the dam. The USACE guidance uses a point rating method to provide unit day values based on the quality and type of recreation. Criteria consist of 1) number of recreation activities present at a site, 2) availability of similar opportunities at nearby sites, 3) carrying capacity or quality of facilities, 4) accessibility, and 5) environmental quality.

Total annual user days of fishing were estimated based on a review of the Ludlow Recreation Committee 2021 minutes (the Parks and Recreation Department did not have available user data). Table D4.14 shows the annual fishing recreation benefit provided by Jewell Brook Dam Site No. 3, calculated at **$7,000**.

Exhibit D4.14 Annual Recreation Benefits, Jewell Brook Dam Site 3

Structure	Annual Recreation Days	Unit Day Value[1] (2021 $)	Annual Value
Site 3	770	$9.08	$7,000

1 - FY 2021 mid-range unit day value for general fishing and hunting, USACE 2021.

E. Total Benefits

The Jewell Brook Dams provide a total of $2,181,100 in annual flood damage reduction benefits (Exhibit D4.15).

Exhibit D4.15 Jewell Brook Dams Expected Annual Flood Reduction and Recreation Benefits

Benefit Category	EAD 2021 $
Structures and Vehicles Flood Damage Reduction	$1,276,200
Infrastructure Flood Damage Reduction	$852,300
NFIP	$45,600
Recreation	$7,000
TOTAL	$2,181,100

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