Megunticook River Feasibility Report

Camden, ME

***July 31,* 2021**

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Executive Summary

Introduction to the Megunticook River: Flowing 3.5 miles from Megunticook Lake to Camden harbor, the Megunticook River has long been a cultural, ecological, and economic centerpiece of the historic Camden region. The river interacts with several structures along this length, flowing through seven road crossings, over seven relict dams, through former factories, and past several other features. The relict dams and factories witness the role of the river in the development and economic vitality of the Town following European settlement through the mid-1900s, with the energy of the river powering a plethora of mills over that time.

Of the remaining dams on the river, the Town of Camden owns four of the dams that it maintains and manages for a variety of objectives, including aesthetic and recreational considerations. The other three dams are in private ownership, receiving limited attention and use. Essential to the establishment and vitality of the Town in the bygone era, in the present day the dams influence flooding patterns, create fish passage barriers, and interrupt ecological processes in the river basin.

Goal and Objectives of the Initiative: As part of broader sustainability and public use initiatives, the Town is exploring options to manage the dams along the river to balance these considerations. In doing so, the Town has the opportunity to acknowledge and embrace the river for the future to meet economic objectives while enriching cultural values, as a recreational and aesthetic amenity, and as a thread that runs through the community, supporting the ecology of the natural environment and the well-being of the citizens alike. A successful initiative will improve flood and community resilience, reduce infrastructure management needs, restore habitat connectivity and ecosystem health, and provide habitat for native migratory and resident fish and wildlife. Further, it will enrich community values and experiences through enhanced public access and use, educational value, acknowledgement of Town history, and landscape aesthetics. Woven through these objectives is the intent to avoid change to pond, lake and river levels upstream of Seabright and East/West dams.

Initial strides in assessment of Megunticook River management options came in 2018 and 2019 through a feasibility study focused on the furthest downstream dam, the Montgomery dam, located at the head of Camden inner harbor. Through the current study detailed in this report, the Town of Camden expanded its focus to the remainder of the Megunticook River watershed, and specifically to the reach of the river that extends to the outlet of Megunticook Lake.

Historical and Current Conditions: This study provides a detailed feasibility assessment of options to manage the river to achieve the objectives that have been identified. First, review of the historical role and management of the river, combined with field observations, lead to interpretation of the condition of the river as it exists today. Outside the influence of the remaining dams, the river is a naturalized coastal river with a plethora of intact supporting processes and attributes, that are able to sustain native sea-run and resident fish such as brook trout, birds, and other wildlife.

Outside of the sites considered in the feasibility analysis, no other hard constraints were identified that would prevent the goal and objectives for the river from being achieved. Implemented through a long-term restoration initiative, the ultimately selected project options collectively will feasibly result in recovery of the Megunticook River and enhancement of resiliency for the benefit of generations to come.

Sediment Accumulated behind the Dams: The sediment that has accumulated behind the dams was measured and tested, with small amounts found at the Montgomery Dam, Knox Mill Dam, and Powder Mill Dam locations. A greater volume was measured at the Knowlton Street Dam. The sediment at these sites contains levels of some compounds such as selected heavy metals and hydrocarbons that reflect the hard work of the river in supporting the Town in the past. The sediment quality is not substantially different that that found in the harbor, does not pose a risk to human health, and does not represent unusual circumstances in management of the material when excavating from behind the dams. The sediment is not dissimilar from sediment successfully managed at many dam removal projects in the region. The primary impact of the accumulated sediment is on project implementation costs. The associated cost of sediment management at the Knowlton Street Dam site is substantial, whereas at the other three dam removal candidate sites the project cost of sediment removal and disposal is minimal.

Flooding Patterns: Detailed hydraulic modeling simulated river flow conditions for typical and flood flow conditions. The model results showed that flood conditions have likely improved along the river compared to when the effective FEMA floodplain mapping was completed in the 1980s. We interpreted simulated reductions in flood inundation extents as the likely result of changes to the Knox Mill factory buildings (river daylighted through the former factory) and Washington Street bridge (now a clear span, with no center pier). Model results show that dam removal can further reduce flood elevations and extents along the river, and open riparian areas to act as a buffer to flooding as the hydrology of the river shifts in response to climate change. The relative benefit is greatest for intermediate flood events, which are among those nuisance flooding events that are anticipated to increase in magnitude in the coming years.

With respect to restoration actions and objectives, model results showed that dam removal alone may not result in lowering the FEMA base flood elevations below the Camden Public Safety Building that is located directly adjacent to the Washington Street Bridge. Additional model focus was then applied to this vicinity, and the corresponding results showed that the relict structures beneath the former Brewster Shirt Factory Building and the Washington Street bridge also directly influence overbank flooding in this area. Based on this result, the Brewster site was added to the project considerations, with an option that entails removal of the water wheel and legacy control weirs that remain at that location. Future additional detailed data collection and model refinements, as well as landowner coordination, are needed to confirm the benefit of this option on removing the public safety building from the flood zone. The Washington Street bridge was not added to the list of candidate sites, since it was recently renovated (2017).

Dam Breach Risks: Dam breach analysis was performed for the Knox Mill and Knowlton Street dams. Although regarded as low hazard dams by the Maine Office of Dam Safety, the analysis was completed because of the age of the dams and proximity to the downtown area, and because the dams are not inspected regularly. The model results showed that breach of these dams would result in modest flood wave conditions in the downtown river reach. However, the results showed that if the breach were to occur at the same time as a peak flood event, the dam breach wave would result in additional inundation of areas already subjected to overbank flooding, such as the area adjacent to the public safety building.

Potential Project Constraints and Permitting: Queries filed with State and Federal resource agencies identified no listed species or habitats of special management concern. Given the historical role of the identified dam sites in the history of the Town, extended coordination with the Maine State Historical Preservation Office is expected, but is not considered a hard constraint that will prevent restoration from proceeding at the study sites. Project activities will require permits from the Maine Department of Environmental Protection and the U.S. Army Corps of Engineers, in addition to the Town of Camden Planning Board. There were no interactions with infrastructure that were identified as constraints on project options. One noteworthy potential interaction was flagged for more detailed study in future project phases, which is a sewer line passing beneath the Knowlton Street Dam impoundment across from the wastewater treatment plant, approximately 2000 feet upstream of the dam.

Megunticook River Restoration Options: The conditions, opportunities and constraints vary at each of the sites evaluated in the study. Of the options considered, dam removal achieves the objectives to the greatest degree, and was found to be a viable option at three of the relict dam sites, in addition to the Montgomery Dam site that was studied in 2018-19, for a total of four potential dam removal sites along the river. Associated with dam removal, management of accumulated sediment will require modest effort at three of these sites (10 to 20 truckloads of sediment each), but will require more substantial effort at the fourth potential dam removal site, the Knowlton Street Dam (over a thousand truckloads of sediment). The volume of sediment to be excavated from this impoundment may be optimized during the detailed design phase.

Removal of the existing dams along the river that are candidates for decommissioning (Montgomery, Knox Mill, Knowlton Street, and Powder Mill) will provide greater resilience to hydrologic intensification that may result from climate change than options which retain the dams in several key ways. First, the removal of aging dam structures eliminates the risk of structural failure of each dam, while maintenance and operation costs of the dams are similarly eliminated. Second, dam removal reduces the elevation of flood water surface profiles, reducing potential flood impacts upstream of each dam. Third, dam removal increases floodplain storage in formerly impounded areas, reducing flood elevations, slowing flow in overbank areas, and creating ecologically important lateral connections between the channel and floodplain areas. Lastly, dam removal provides a substantial buffer against the uncertainty in future flow conditions, by providing the maximum amount of flow capacity along the river.

The dam removal options clearly result in the lowest long-term costs, and at the sites with less substantial volume of accumulated sediment, clearly the lowest near-term cost to realize project objectives. In contrast to dam removal, viable fish passage construction was identified for two of these four sites, but is less able to satisfy the established objectives.

At the remaining three dams which comprise the outlets of Seabright Pond and Megunticook Lake, dam removal was not a viable option. Instead, fish passage options were found feasible at each of these sites. The options at the Seabright Dam site are generally less constrained than at the Megunticook Lake outlet, but successful fish passage can be restored at both locations.

Megunticook River Restoration Action Plan: Based on the results of the feasibility study, Table 1 summarizes recommended options. In addition to best meeting the goal and objectives, these options represent approaches with projected lower lifespan costs, and have the greatest likelihood of competing for grant funding, when compared with other options at each site. Detailed descriptions of the study analyses and results, along with detailed reviews of project options at each of the dam sites, are found on the following pages.

Table 1. Summary of recommended Megunticook River options to achieve the established goal and objectives.

Option	Comments
Montgomery Dam	
Dam Removal with River Restoration	**Recommended Option.** Greatest benefits to fish passage, flood risk, ecological conditions, and resiliency including significantly reduced operation, maintenance and repair requirements. Management of impounded sediment will be required.
Former Brewster Shirt Factory	
Remove Water Control Structures	**Recommended Option** along with additional evaluation. Benefits to fish passage, flood risk, and resiliency adjacent to the public safety building.
Knox Mill Dam	
Dam Removal	**Recommended Option.** Greatest benefits to fish passage, flood risk, ecological conditions, and resiliency including significantly reduced operation, maintenance and repair requirements. Management of impounded sediment will be required.
Knowlton Street Dam	
Dam Removal	**Recommended Option.** Greatest benefits to fish passage, flood risk, ecological conditions, and resiliency including significantly reduced operation, maintenance and repair requirements. Active management of impounded sediments will likely be required.
Powder Mills Dam Ruins	
Dam Removal	**Recommended Option.** Benefits to fish passage, flood risk, ecological conditions, and resiliency. Management of upstream sediments may not be required.
Seabright Dam	
Nature-like Fishway	**Recommended Short-List Option to be Discussed further with Stakeholders and Resource Agencies.** Sinuous alignment along west embankment.
Pool-and-Weir Fishway	**Recommended Short-List Option to be Discussed further with Stakeholders and Resource Agencies.** Alignment along eastern spillway margin.
East/West Dams	
Hybrid Nature-like and Pool-and-Weir Fishway	**Recommended Short-List Option to be Discussed further with Stakeholders and Resource Agencies.** Alignment downstream of West Dam.
Pool-and-Weir Fishway	**Recommended Short-List Option to be discussed further with Stakeholders and Resource Agencies.** Alignment on eastern embankment of East Dam.

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1. Introduction

Flowing 3.5 miles from Megunticook Lake to Camden harbor, the Megunticook River has long been a cultural, ecological, and economic centerpiece of the historic Camden region. Over this course, the river flows through naturalized, residential, and commercial areas, and through the densely-developed Camden historic downtown district. The river interacts with several structures along this length, flowing through seven road crossings, over seven relict dams, through former factories, and past several other features (Figure 1). The relict dams and factories witness the role of the river in the development and economic vitality of the Town following European settlement through the mid-1900s, with the energy of the river powering a plethora of mills over that time. At one point in time, as many as eleven dams existed on the river. Prior to settlement, the river played an equally critical role in the subsistence economy of the indigenous population of Midcoast Maine, the original inhabitants of the region.

Of the remaining dams on the river, the Town of Camden owns four of the dams that it maintains and manages for a variety of objectives, including aesthetic and recreational considerations, while the other three are in private ownership, receiving limited attention and use. Essential to the establishment and vitality of the Town in the bygone era, in the present day the dams influence flooding patterns, create fish passage barriers, and interrupt ecological processes in the river basin. A plethora of ecological processes are disrupted in a watershed fragmented by dams and road crossings, such as the case with the Megunticook River. The fragmentation disrupts connectivity of habitats for fish and other wildlife, impacts water quality, limits natural buffering of flood flows, and impacts sediment processes, which in turn influence freshwater and coastal resiliency to changing climate conditions.

The Town of Camden has established a goal to become the most sustainable community in Maine. As part of broader sustainability and public use initiatives, the Town is exploring options to manage the dams along river to balance these considerations. Communities around the country are contemplating similar cases, due to the state of aging infrastructure and the resources required to maintain it, and growing awareness of the impacts of dams that may have outlasted their intended uses. There are many potential community benefits to be derived from watershed revitalization, not the least of which includes improved adaptability to changing climate conditions.

Initial strides in assessment of Megunticook River management options came in 2018 and 2019 through a feasibility study focused on the furthest downstream dam, the Montgomery dam, located at the head of Camden inner harbor (Inter-Fluve and Gartley & Dorsky 2019). Through the current study detailed in this report, the Town of Camden expanded its focus to the remainder of the Megunticook River watershed, and specifically to the reach of the river that extends to the outlet of Megunticook Lake. This report details the results of the feasibility study, which was supported through a financial grant from the National Fish and Wildlife Foundation (NFWF) Coastal Resilience Fund.

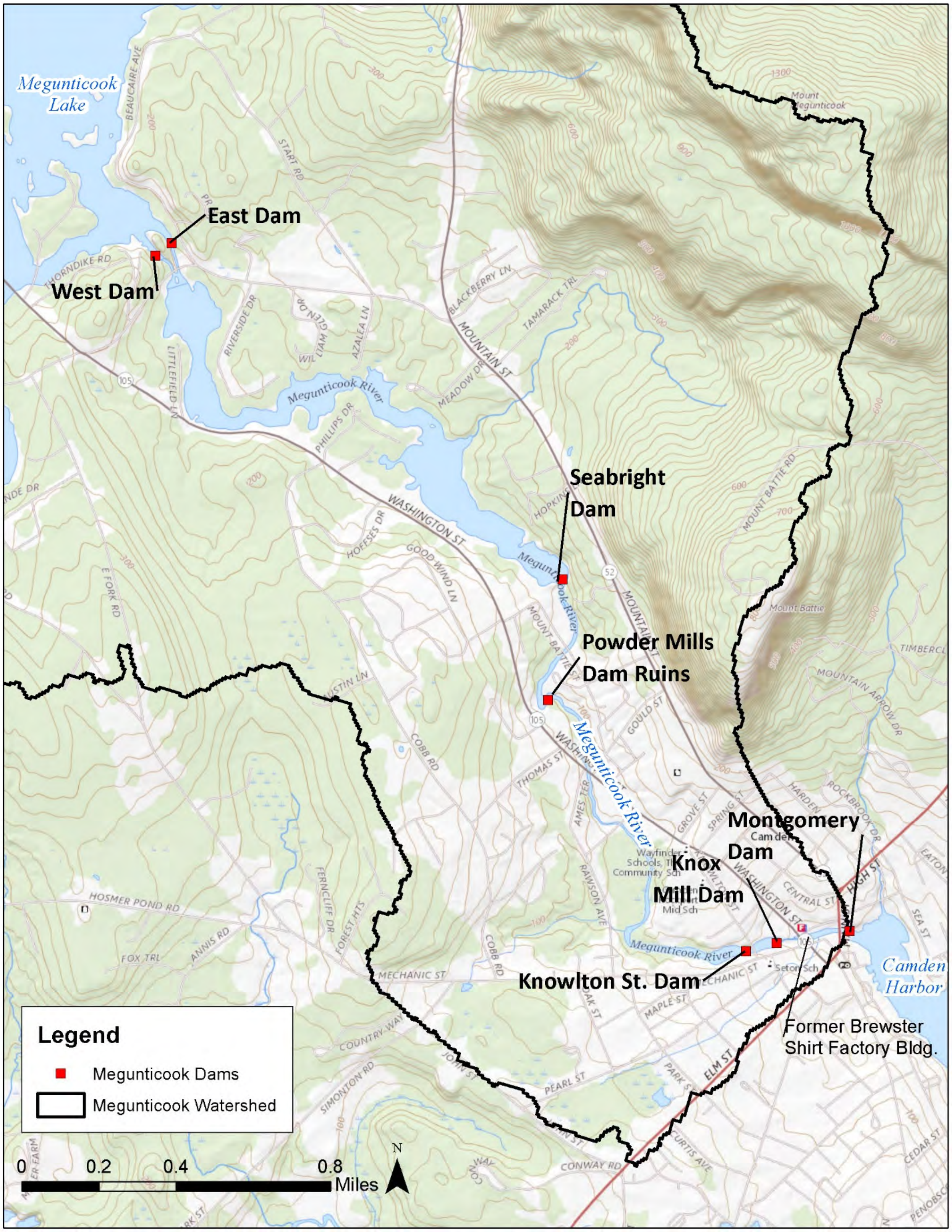

Figure 1. Map of the lower Megunticook watershed and the dam sites considered in this study.

2. Goals & Objectives

Through development of the approach for the feasibility study, the Town established a goal and associated objectives to guide the long-term initiative. The overarching ***Goal*** for the effort is the following:

- Identify and implement river management options for the Megunticook River that improve flood and community resilience, restore habitat connectivity and ecosystem health, reduce infrastructure management needs, and enrich community values and experiences through enhanced public access and use, educational value, acknowledgement of Town history, and landscape aesthetics.

In response to this goal, specific ***Objectives*** include the following:

- Reduce impacts to flood levels and enhance natural buffering of runoff by managing (remove or modify) no longer used dams and other infrastructure.
- Maintain water levels in Megunticook Lake and the Seabright impoundment according to current established patterns, where it is critical for property values and recreational use.
- Reduce the operation requirements of Town staff and private forces to manage the dams to limit flooding impacts.
- Reduce the Town and private resources required to maintain and repair aging infrastructure and manage risk.
- Enhance resilience to climate change by eliminating unused structures from the river corridor to maximize space for future floods and natural stormwater buffering.
- Avoid or mitigate impacts to infrastructure and buildings that will remain along the river corridor.
- Restore safe, timely, and effective passage potential for native sea-run and resident fish.
- Restore river connectivity to benefit fish and wildlife, water quality and ecological processes.
- Enhance public access and use of the river corridor by facilitating educational opportunities and interface with other access Initiatives such as the Camden Riverwalk.
- Enhance the acknowledgement of the historical role of the river in Town history through research, interpretation and dissemination of knowledge.
- Enhance the community landscape aesthetic through integration of the restored natural river corridor with the surrounding built environment.

3. Site History

Prior to European settlement, diadromous fish runs in the Megunticook River were likely staples of the Native American subsistence way of life, as was typical along the Maine coast. European settlers arrived in the area in the 1760s and shortly thereafter began to harness the river by constructing a series of dams that powered mills along its banks. The growth of the local economy was largely made possible by the power generated by dams on the Megunticook, which at one point numbered 11 (Wells 1869).

A combination of impacts from dam building and other development activities led to the elimination of the diadromous fish run. A warrant article from an 1806 town meeting proposed a fish passage requirement for the dams. Town residents voted to form a committee that would study the issue and potentially petition the state legislature to require it (Town of Camden 1806). However, it appears that changes to result in fish passage on the river did not result from this initiative (McKellar 2018).

These following sections provide a brief historical overview of the present-day dam sites that are considered in this study. The current conditions of each dam are described in Section 4.

3.1 MONTGOMERY DAM

The Montgomery Dam was established in 1771 by William Minot, who built and operated a grist mill as part of the conditions for settling the town. The site has supported many uses and undergone many changes over its life, from a grist mill in the late 18th century to the Alden Anchor Factory in the latter half of the 19th century. The anchor factory utilized a second spillway which was located to the south of Montgomery Dam adjacent to the public landing. The dam was rebuilt in the 1930s, with the last functional application of the dam was for small-scale hydropower production in the 1980s (MEMA 2018). The dam was transferred from the Montgomery family to the Town in 1993, who operates the dam during rain events to prevent inundation of the lower levels of the buildings located over the small impoundment.

The area surrounding Montgomery Dam has been highly modified throughout the years. The inner harbor was dredged substantially in the late 1800s (Figure 3). Fill has been placed on the north side of the river both upstream of Main Street (now a parking lot) and downstream of the Montgomery Dam (now Harbor Park; Figure 4). More detail on the history of the Montgomery Dam and surrounding area is provided in the 2019 feasibility study (Inter-Fluve and Gartley & Dorsky 2019).

Figure 2. Historical image of the Montgomery Dam, date unknown. Source: Camden Public Library, Walsh History Center.

Figure 3. Excerpt from 1864 US Coast Survey map showing shallow depths and mudflats in the inner harbor. Source: American Geographical Society.

Figure 4. Composite aerial photograph of the Montgomery Dam and surroundings in 2020. Buildings along Main Street are in the foreground, Camden Harbor is beyond the dam, the Harbor Park is to the left, and the public landing parking area is to the right. Photo courtesy of Tom Massey.

3.2 BREWSTER SHIRT FACTORY

Located near the upstream end of the Montgomery Dam impoundment, immediately downstream of Washington Street, the former Brewster shirt factory spans the channel. The shirt factory operated from the early 1900s until 1964 (Dyer 2012). Infrastructure associated with the factory, including a waterwheel and associated weirs remain in the channel. The building is presently occupied by several businesses, including the Camden Bagel Café.

Figure 5. Relict water wheel and weirs beneath the former Brewster Shirt Factory.

3.3 KNOX MILL DAM

Knox Mill Dam is a stone masonry and concrete overlay dam located near the center of Camden, approximately 980 feet upstream of the Montgomery Dam. James Richards, Camden's first settler, owned the first dam in the general vicinity. The Knox Woolen Mill subsequently produced felt belts for the paper industry from the mid-19th to late 20th century (Figure 6). Since the closure of the mill, the associated buildings have been converted for a range of commercial and residential uses, including hosting the offices of MBNA from 1993 to 2005.

The ruins of another dam composed of stones sit near the head of the Knox Mill impoundment (Figure 9). The dam ruins likely once served the Alden oakum factory that was located between Knox Mill and Knowlton Street (Wells 1868).

Figure 6. Looking downstream over the impoundment of the Knox Woolen Mill in an undated photograph (Camden Library).

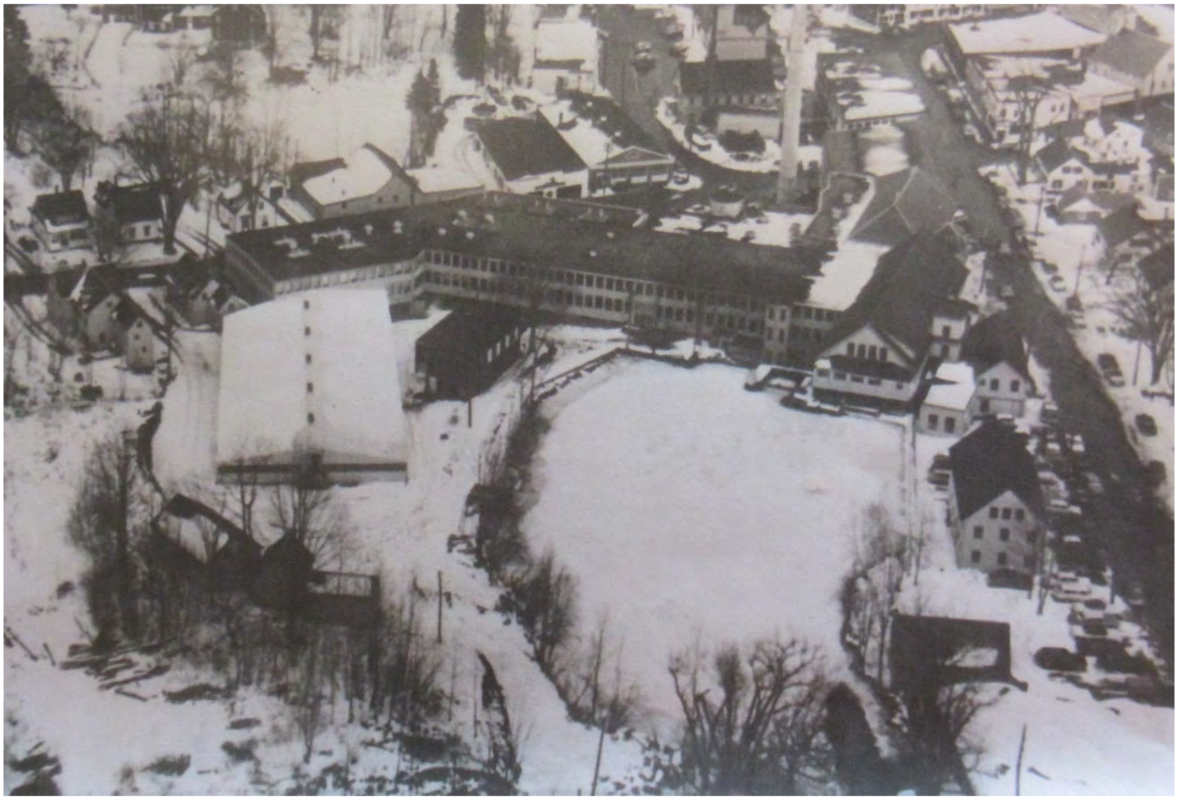

Figure 7. Looking downstream over the impoundment of the Knox Woolen Mill in the mid-1900s (Dan Flynn).

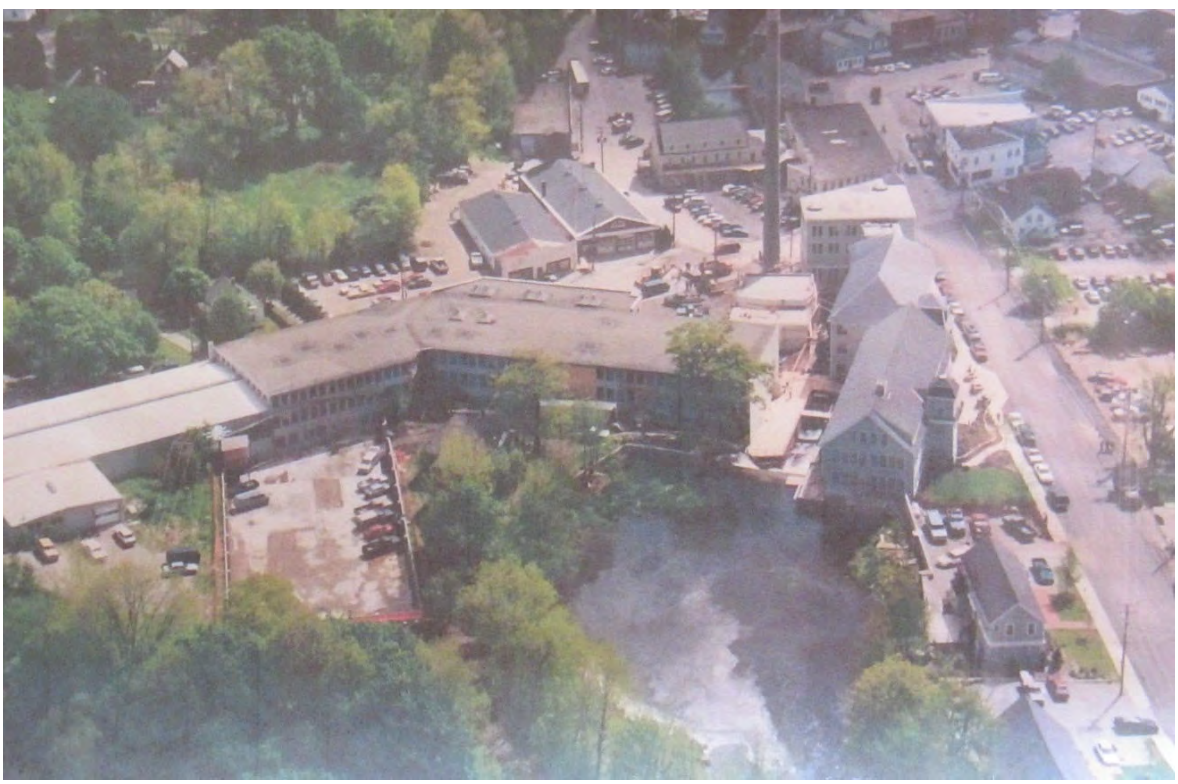

Figure 8. Looking downstream over the impoundment of the Knox Woolen Mill in the 1994 as the river was being daylighted through the mill buildings (Dan Flynn).

Figure 9. The remnants of an old stone dam on river left, upstream of the Knox Mill impoundment. Likely part of the Alden Oakum Factory.

3.4 KNOWLTON STREET DAM

This stone masonry and concrete dam is located approximately 490 feet upstream of the Knox Mill Dam. In the mid-19th century, David Knowlton established a factory at the Knowlton Street Dam that manufactured various essentials for sailing vessels. Knowlton's sons eventually took over the factory, naming it "Knowlton Brothers' Foundry" (Figure 10 and Figure 11), and continued to make components for sailboats. The factory burned down and was rebuilt several times (Dyer 2019b). At present, the existing building is an assisted living facility.

While repairs were being made to the dam in the spring of 1990, a release of impounded sediment occurred, some of which was delivered to Camden Harbor. This incident prompted an investigation into the quantity and quality of sediment trapped in the impoundment. The evaluations completed in the 1990s formed the backdrop for the sediment evaluation at this site completed for the current study (Section 4.4).

Figure 10. 1894 Sanborn Map of the Knox Mill and Knowlton Street Dam area. Map details the indicate the nature of work at each facility- a woolen mill at Knox and a foundry and block factory at Knowlton.

Figure 11. An undated drawing of the operations at the Knowlton Brothers Factories.

Figure 12. A 1913 photograph looking upstream at river left channel below the Knowlton Street Dam.

3.5 POWDER MILL DAM

Ruins are all that remain of this masonry dam structure located approximately 1.1 miles upstream of the Knowlton Street Dam in a more suburban setting. In the 1820s, a paper mill was constructed at the present-day Powder Mill Dam ruins. The mill burned in 1841 but was rebuilt as a powder mill in 1845 by D.H. Bisbee, providing blasting powder to the quarrying operations in the region. The powder operation included two dams - the stone dam that is partially breached today, and a smaller dam 330 feet downstream, whose remains consist of a small crib structure spanning the channel (Wells 1868). Perennial challenges with factory explosions led to the eventual closure of the powder mill and conversion to a range of operations over following decades, including a woolen mill, poultry factory, and tent manufacturer (Dyer 2019a).

Figure 13. The remains of the Powder Mills Dam in 2020.

3.6 SEABRIGHT DAM

The Seabright Dam is a high hazard stone masonry and concrete overlay dam owned by the Town of Camden and is located approximately 0.35 mile upstream of the Powder Mill Dam ruins. The Seabright Dam has been the site of a series of woolen mills over time, including the Seabright Woven Felt company, which was incorporated in the early 20th century by William Paige and had the first automatic looms in Camden. Joe Sawyer developed a hydroelectric plant at the dam in the 1980s which was transferred to the Town in 2007. The plant was decommissioned in 2017. Presently, the dam is operated by the Town and maintains water levels in Seabright impoundment.

Figure 14. An undated colorized postcard showing Seabright pond and the mill at the outlet.

Figure 15. The impoundment behind Seabright Dam in a drawn-down condition. Old tree stumps are visible along the lake bed. Date unknown. (Town of Camden)

Figure 16. Seabright Dam in 2020.

3.7 MEGUNTICOOK EAST AND WEST DAMS

The Megunticook East and West Dams are owned by the Town of Camden and control water levels in Megunticook Lake. They are both high hazard potential dams. The lake is a key recreational amenity for the area. These dams sit on either side of a bedrock knob at the outlet of Megunticook Lake. Dams were initially constructed there by William Molyneaux in the late 18th century. The dams initially served powered grist and saw mills (Wells, 1868). They were later integrated into water operations for the Knox Woolen Mill. The natural bedrock outlet of the lake was excavated and enhanced in the late 1800s to increase flow capacity out of the lake for manufacturing purposes (Rockland Courier-Gazette 1894). A fish hatchery was established just below the dams in the early 1900s (McKellar, 2018). Today the dams maintain the lake level in Megunticook Lake, and are operated to partially control flow in the downtown area during rainfall events.

Figure 17. Panorama of the East (right) and West (left) Dams. The East Dam was a grist mill and the West Dam was a saw mill (Camden Library Photo).

Figure 18. The West and East Megunticook Dams in 2020.

4. Site Conditions

The study area extends from the head of the Camden Harbor to the outlet of Megunticook Lake. Following a review of available background information, Inter-Fluve and Gartley & Dorsky conducted a series of site investigations from July through November of 2020. The investigations included a topographic and bathymetric survey of the river channel and adjacent infrastructure; geomorphic and habitat assessment of the river channel in the study reach; depth of refusal survey of selected impoundments; sampling of accumulated sediment in selected impoundments; and a structural condition assessment of the dam infrastructure. This section provides an overview of the existing conditions throughout the project area.

4.1 SITE CONTEXT

The Megunticook River drains a 30.9 square mile watershed that extends from the harbor into the hills and mountains surrounding the town (Figure 19). Elevations within the watershed range from sea level to 1376 feet (NAVD88). The watershed receives 49.5 inches of precipitation annually, on average (PRISM 2014). The watershed is mostly forested, with deciduous, conifer, or mixed forest making up 69% of landcover (Figure 20). Open water, such as Megunticook Lake, also makes up a notable portion (8%) of the watershed. The remaining area is a mix of headwater streams and ponds, wetlands, fields, and developed space (focused around downtown Camden).

The Megunticook watershed is underlain primarily by granite and mid- to high-grade metamorphic rock, with some outcrops of limestone (Caldwell 1998). The watershed is a heavily glaciated landscape, still bearing the marks of the Labrador ice sheet that flowed over the region from approximately 75,000 to 15,000 years ago. The erosive power of the ice sheet rounded the peaks of the Camden Hills and carved U-shaped valleys that parallel the flow of the ice, roughly trending southeast/northwest. The Megunticook River flows from Megunticook Lake to Penobscot Bay through one of these valleys.

The region's history of glaciation is also evident in the widespread coverage of glacial till, a poorly sorted mix of sediment ranging from fine silt to boulders. The Megunticook River has spent the last 15,000 years forming in this heterogeneous substrate, which accounts for the wide variation in grain size along the channel bed and banks. Due to high topographic relief of the watershed and the heterogeneity of the glacial till, the Megunticook River naturally exhibits pool-riffle and occasional step-pool morphology that is typical of a mountain stream. However, the natural morphology is intermittently submerged by backwatering behind the dams along the Megunticook. The result is a stream exhibiting natural morphology that is abruptly punctuated by backwater conditions upstream of dams.

From the East and West dams at the outlet of Megunticook Lake, the river drops approximately 140 feet before emptying into Camden Harbor. From the upper watershed, the river passes over six intact dams and the relict, degraded dam at the former Powder Mills site. The river profile is dominated by the series of dams and the knickpoint, or local increase in slope, that occurs naturally at the Knowlton Street Dam (discussed in Section 4.3; Figure 21).

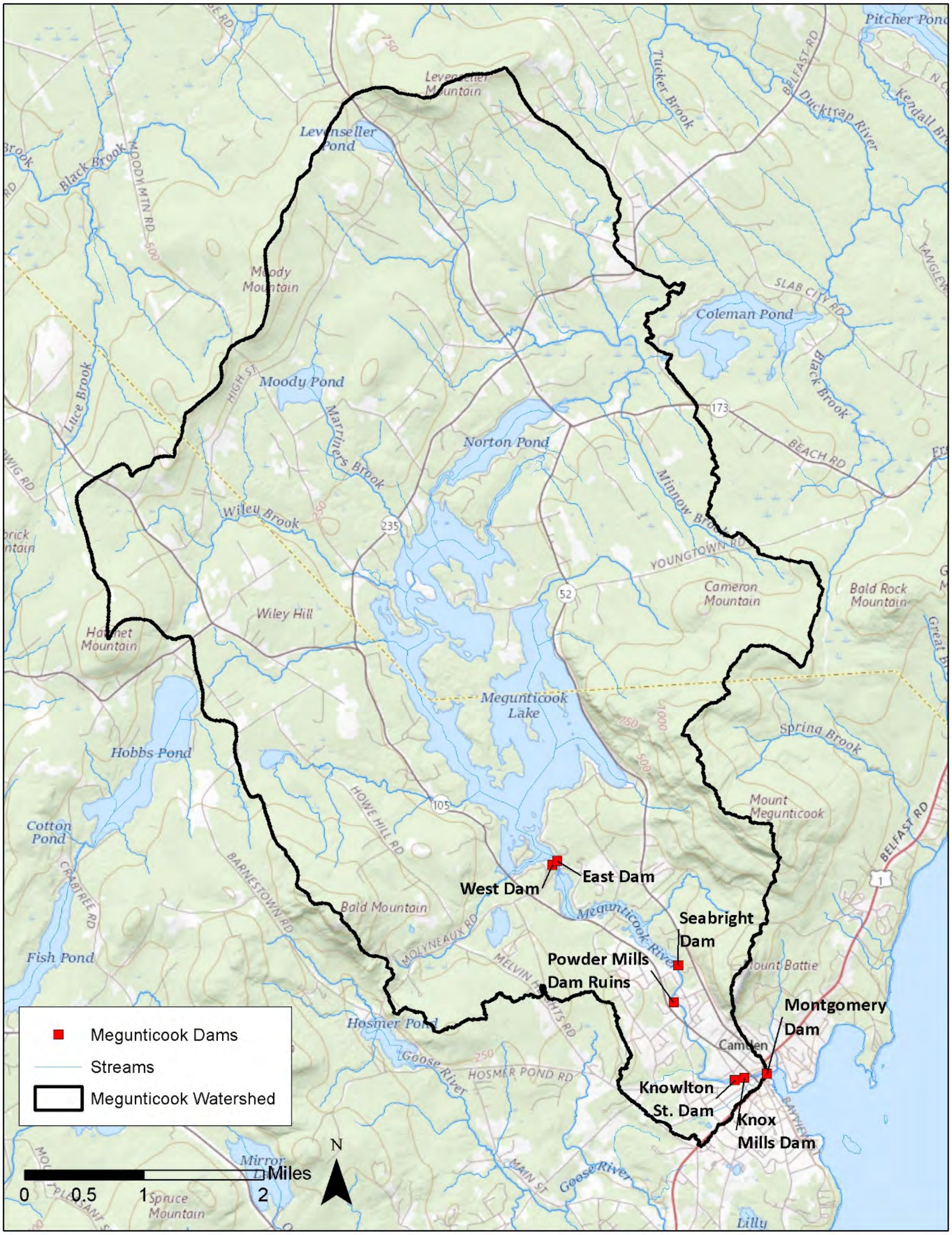

Figure 19. Topographic map showing location of dams within the Megunticook River watershed.

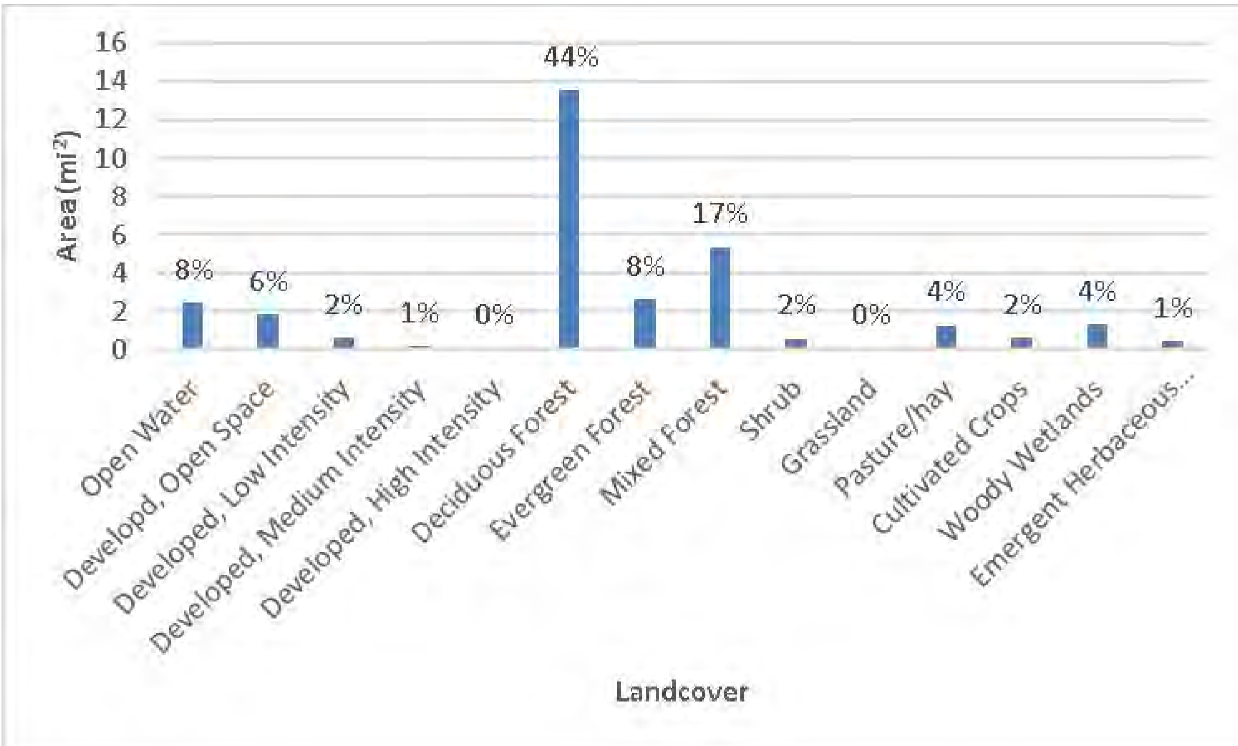

Figure 20. Landcover of the Megunticook River Watershed (NLCD, 2011)

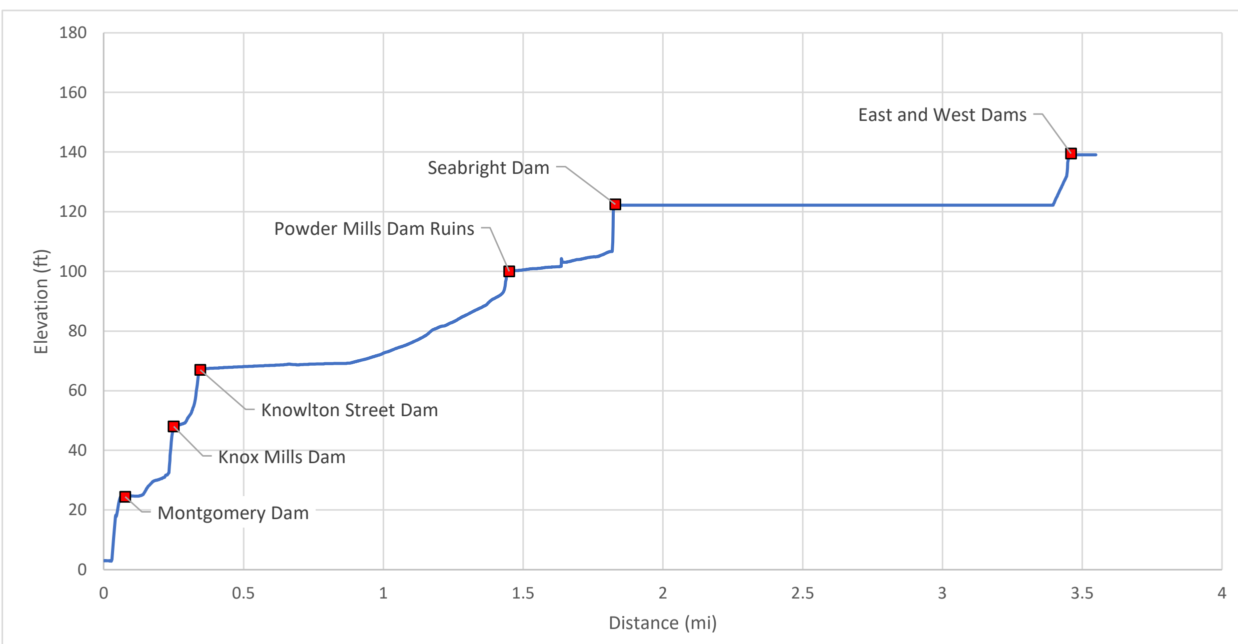

Figure 21. Elevation profile of the Megunticook River, from Camden Harbor to Megunticook Lake.

4.2 FISHERIES OVERVIEW[1]

The pre-settlement condition of the river and the status of the sea-run fish community that existed at that time are not conclusively known. However, there are lines of evidence which suggest that the river conditions supported sea-run fish, including the ability for the fish to ascend from the harbor upstream through the watershed to the headwater lakes (Town of Camden 1806, Camden Herald 1890, Kircheis et al. 2004). The Maine Stream Habitat Viewer (2019) suggests evidence that an alewife run existed historically. In particular, the headwater lakes and ponds provide promising potential reproduction habitat for a substantial alewife run. Presently, viable upstream passage for sea-run fish is not available at the site, due to the presence of dams and river's outflow over the ledge outcrop above Camden Harbor. In addition to sea-run fish, resident fish occupy the watershed, such as brook trout. These fish will benefit from restored habitat connectivity and habitat quality along the river to similar degrees as sea run fish

Based on consultation with Maine Department of Marine Resources, the primary sea run fish that might reoccupy the Megunticook River watershed following restoration are alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), American eel (*Anguilla rostrata,* already in portions of watershed), sea lamprey (*Petromyzon marinus*), and sea-run brook trout (*Salvelinus fontinalis*). With substantial recovery of their populations, Atlantic salmon (*Salmo salar)* and rainbow smelt (*Osmerus mordax*) could also be expected to utilize habitat in the Megunticook watershed. If unobstructed safe, timely, and effective fish passage were established from the Harbor to the headwater lakes including Megunticook Lake, MDMR (2018) suggested the potential for an alewife population of at least 300,000 fish based on the acreage of the potential habitat present in the watershed. Sketches of these fish are included in Figure 22.

The species designated in this list have shown a marked decline in abundance throughout the Atlantic region. This decline is attributed in large part to loss of habitat, especially relating to dam installation (Limburg and Waldman 2009). The Megunticook River reflects the experience of many rivers in the region, where insufficient fish passage contributed to a decline in diadromous species upstream of the dams.

The Megunticook River watershed is within the Penobscot salmon habitat recovery unit (SHRU) for Atlantic salmon and the Penobscot Habitat Focus Area under NOAA's Habitat Blueprint. The watershed also contains modeled potential Atlantic salmon rearing habitat (Maine Stream Habitat Viewer 2019). Recovery of sea-run fish that are co-evolved with Atlantic salmon such as river herring would support the goals of the recovery plan for the endangered salmon (U.S. Fish and Wildlife Service and NMFS 2018).

River herring (alewife and blueback herring) and American eel are attracted to the Megunticook River mouth during the spring migration, suggesting plausible restoration of the runs for these fish if effective fish passage were established. Bioperiod estimates for the fish considered in the study were subsequently derived from consultation with MDMR, which indicate the anticipated upstream

[1] The fisheries overview was first included in the Montgomery Dam Feasibility Study (Inter-Fluve 2019), and is repeated here for consistency.

migration timing of these species, were sufficient passage to be provided (Table 2). Through sustained and restored historical runs, including as a result of restoration efforts over the last several decades, alewife occupy over 200 ponds and lakes along the Maine Coast. Research is ongoing, but monitoring results suggest increased presence of alewife in lakes and ponds does not diminish water quality parameters such as total phosphorous (KELT 2019) and Secchi disk transparency (Mower 2019)

Table 2. Estimated bioperiods for potential upstream migration of diadromous fish species on the Megunticook River (MDMR 2018).

Species	**Bioperiod**
	Upstream Migration
Alewife	**May - June**
Blueback Herring	**May – July 15**
American Eel	**May - July**
Sea Lamprey	**May -June**
Sea Run Brook Trout	**September - December**
Rainbow Smelt	**March-May**
Atlantic Salmon	**May - July**

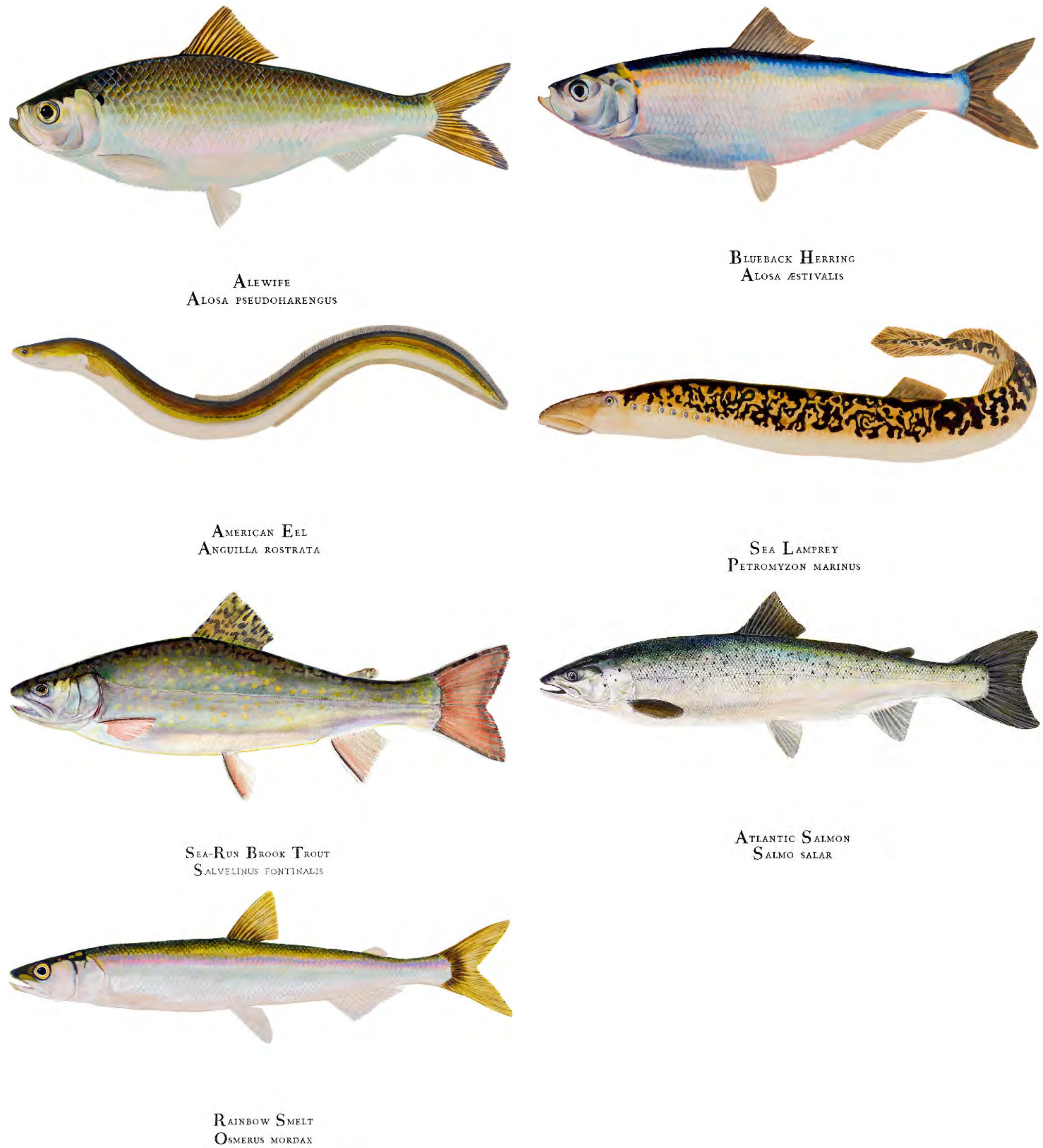

Figure 22. Sketches of the native sea-run fish that may utilize the Megunticook River watershed following restoration of fish passage in the river (Artwork by Karen Talbot, www.karentalbotart.com).

4.3 CURRENT RIVER CONDITIONS

From Camden Harbor to Megunticook Lake, the Megunticook River was divided into seven reaches based on geomorphic characteristics to organization the assessment. The reaches are shown in Figure 23 and listed in Table 3.

The geomorphic and habitat conditions of the project area were assessed during numerous site visits between July and November 2020. Throughout this period, the region was in a drought condition resulting in low flows in the channel. Measured discharges ranged from 6 to 12 cfs in the stream between Seabright dam and Rawson Avenue during field visits between late July and early October. The results of the geomorphic assessment for each reach are provided in the following sections.

Table 3. Lengths and slopes of study area reaches

Reach	Length (ft)	Elevation Drop (ft)	Average Slope (%)
Harbor to Main St (Montgomery Dam)	214	25	11.7
Main St to Knowlton St (Knox Mill Dam)	1,250	24	1.9
Knowlton St to Rawson Ave (Knowlton St Dam)	3,679	23	0.6
Rawson Ave to Washington St (Tannery Site)	1,013	7	0.7
Washington St to Mt Battie St (Powder Mills Dam)	2,335	23	1.0
Mt Battie St to Molyneaux Rd (Seabright Dam)	9,995	20	0.2
Molyneaux Rd to Lake (East and West Dams)	324	18	5.5
Total	**18,811**	**140**	**0.7**

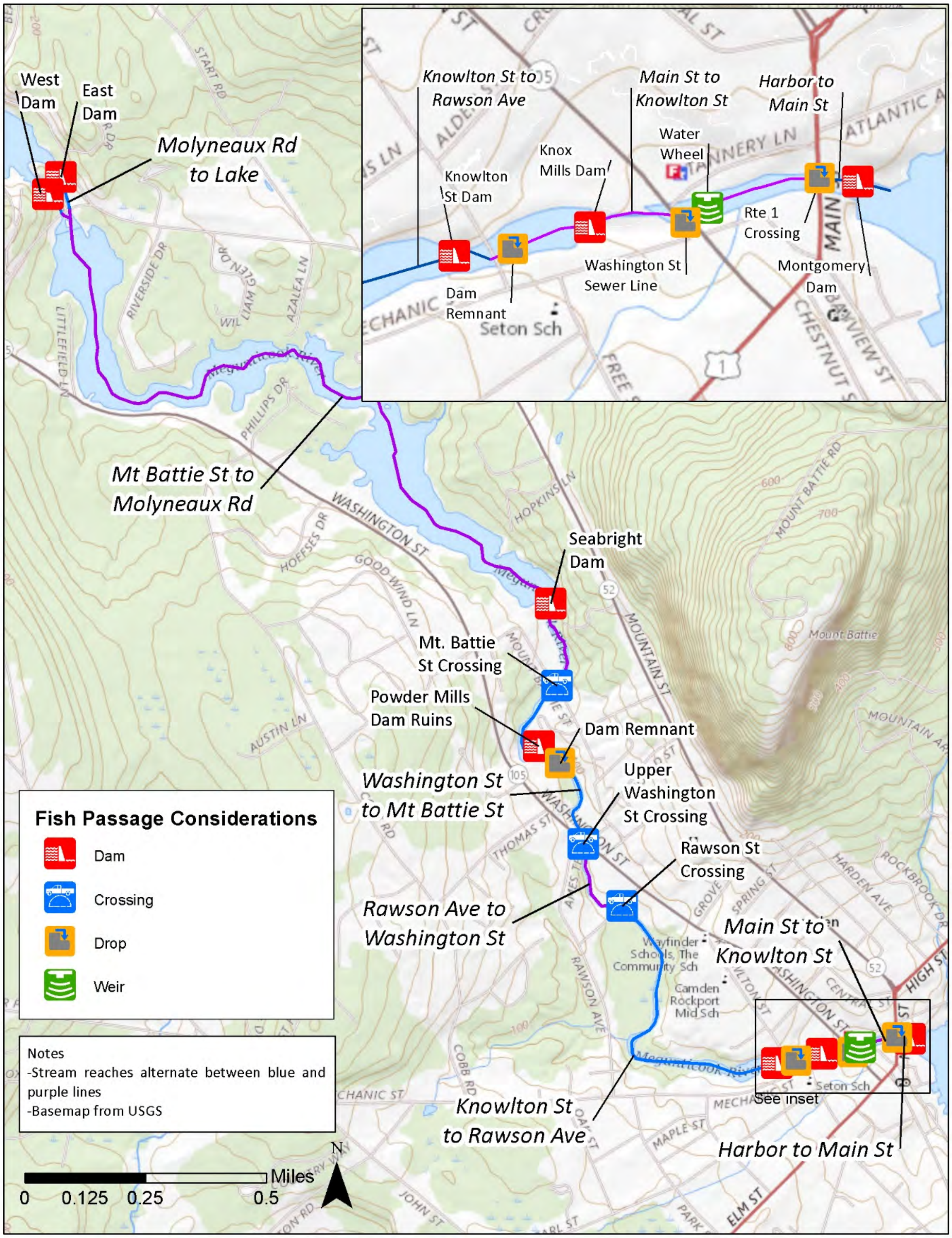

Figure 23. Overview of the study area, designated reaches, and fish passage considerations along the Megunticook River. The reaches are shown in alternating blue and purple streamlines and identified with italicized labels. Fish passage considerations are classified by type of structure. The Route 1 crossing is considered a drop and a crossing, but is labeled as a drop.

4.3.1 Reach 1: Harbor to Main Street (Montgomery Dam)

The Camden Harbor to Main Street reach is approximately 213 feet long (Figure 24). Over this distance the Megunticook falls 25 feet, from an elevation of 25 feet to 0 feet, with an average slope of 0.12 ft/ft. This reach is discussed in detail in Inter-Fluve's 2019 Feasibility/Alternatives Analysis for the Montgomery Dam[2].

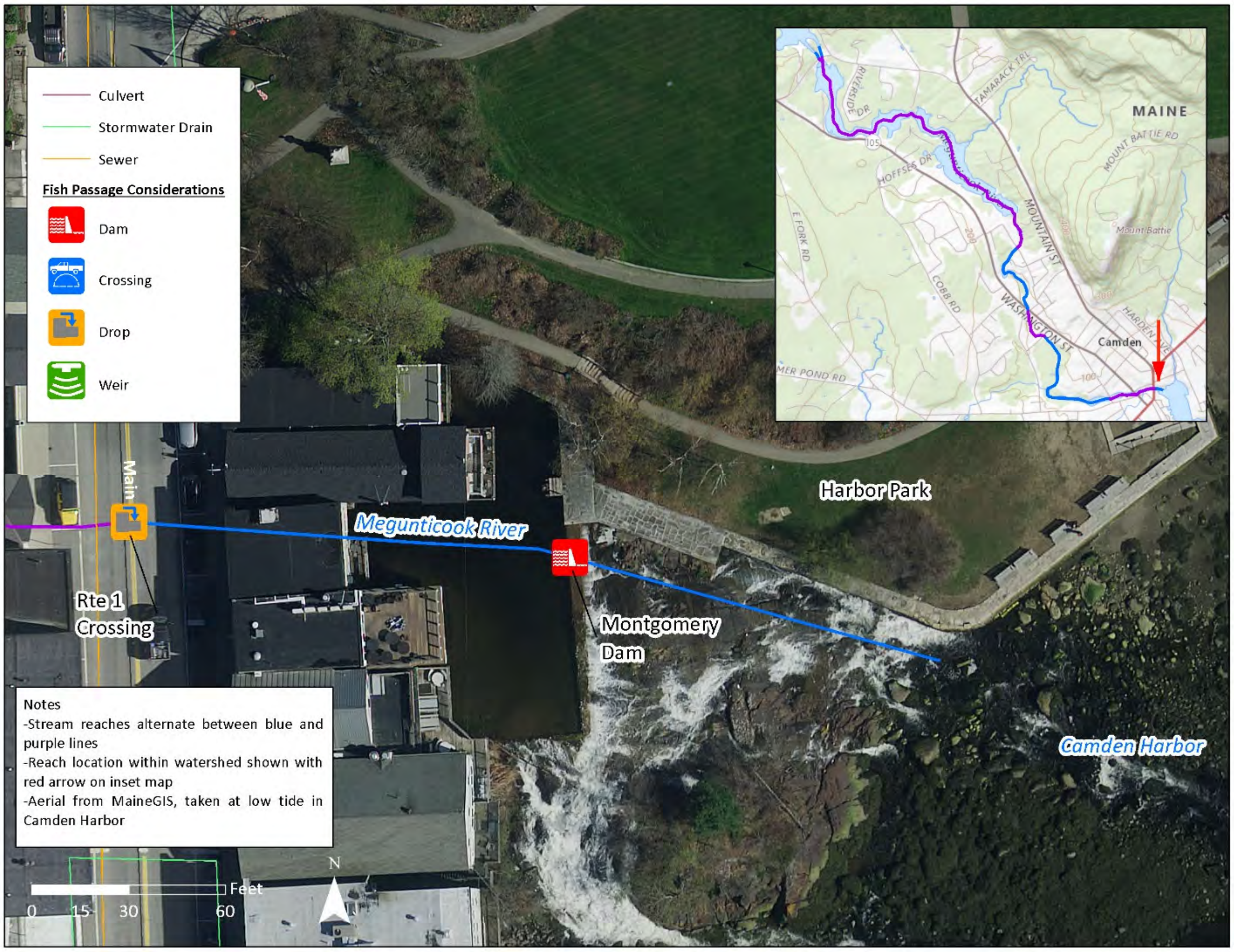

Figure 24. Overview of the Harbor to Main Street reach (blue line). Fish passage considerations are shown along the reach.

The Megunticook River flows over a bedrock outcrop on top of which the L-shaped Montgomery Dam was constructed. The river drops approximately 17 feet from the dam spillway to the highest annual tide (HAT) elevation, and 25 feet to the mean tide level in Camden Harbor. The dam itself and Megunticook Falls pose barriers to fish passage.

While the bedrock that forms the falls is natural, the present course of the river near the spillway is an unlikely one as it traverses over an erosion resistant, locally high spot in the topography. The natural alignment of the Megunticook as it enters the harbor was likely through the present-day

[2] The Montgomery Dam feasibility study report can be found on the Town website at the following link: https://cms8.revize.com/revize/camdenme/Montgomery%20Dam%20Feasabilty%20Alternative%20Analysis%20Report.pdf

Harbor Park, to the river left of its current alignment. The natural alignment of the channel is discussed in detail in Inter-Fluve's 2019 report.

Figure 25. The outlet of the Megunticook River from Camden Harbor. Montgomery Dam sits atop the bedrock. The Harbor Park is to the right of the photo and the Public Landing is to the left.

During the field investigation for the 2019 feasibility study (Inter-Fluve 2019), the impoundment was drawn down, which afforded an approximate view of the condition of the stream in the study reach if the dam were lowered. Immediately upstream of the dam, the channel concentrates in the vicinity of the existing head gate between ledge outcrops under a layer of accumulated sediment.

Between the Main Street (Route 1) crossing and the dam, the river flows under multiple commercial buildings with various supports and structural elements either landing in or adjacent to the river channel. Flow under Main Street (MEDOT# 2497) is split between parallel 14-foot-wide spans 68 feet in length. Multiple piped utilities cross beneath the bridge deck above the river and appear to be in various states of maintenance need (Figure 27). The river bed through the bridge is coarse-grained (gravel, cobbles and small boulders with some bricks).

Figure 26. View of lower impoundment and north end of spillway in drawn down condition, May 8, 2018.

Figure 27. View downstream through north span of Main Street bridge in drawn down condition, May 8, 2018. Stain lines indicate normal pool elevation.

At the downstream end of the bridge, the flow concentrates around ledge and large boulders to create a pair of hydraulic drops totaling 2.7 to 3.0 feet in water surface level change over approximately 20 feet of stream length (Figure 28). This area is backwatered when the dam impounds the river. If the selected project approach led to reduction of the impoundment level, fish passage through this transition at Main Street would need to be managed. The Town of Camden is having ongoing discussions with MEDOT regarding the condition and potential replacement of the Main Street bridge in the future.

Figure 28. View upstream at Main Street bridge in drawn down condition, May 8, 2018. Hydraulic drop at downstream bridge opening in center of photo. Stain lines apparent on posts indicate normal pool elevation.

4.3.1.1 Montgomery Dam

The Montgomery Dam sits at river station 125, with a dam crest elevation of 24.4 feet. The impoundment is approximately 100 feet across at its widest point, and extends approximately 500 feet upstream of the dam. The underlying bed slope is approximately 4%.

Structural Condition

Inter-Fluve's 2019 feasibility study[3] provided an assessment of the structural condition of Montgomery Dam. The findings of that study are summarized here. Please refer to that document for further detail.

Montgomery Dam is a mass gravity, cut stone and concrete dam founded on bedrock with an angled spillway discharging into Camden Harbor. The height of the dam varies between 12 feet at the low-level outlet and 3 feet at the west side of the spillway. The primary spillway is 2 feet wide and approximately 100 feet long, and is degrading, with the concrete/bedrock interface considered to be in poor condition (GEI Consultants, 2015). A low-level outlet is used to draw down the impoundment, and is closed under normal conditions.

A qualitative structural assessment of surrounding building and structure foundations was performed by Gartley and Dorsky in 2019 as a part of the feasibility study. In general, many of the building foundations were found to be structurally sound, though deficiencies were found at the Main Street bridge. The reader is directed to Appendix B of the 2019 feasibility study for further detail.

[3] The Montgomery Dam feasibility study report can be found on the Town website at the following link: https://cms8.revize.com/revize/camdenme/Montgomery%20Dam%20Feasabilty%20Alternative%20Analysis%20Report.pdf

4.3.2 Reach 2: Main Street to Knowlton Street (Knox Mill Dam)

The Main Street to Knowlton Street reach is approximately 1,250 feet long (Figure 29). Over this length, the Megunticook falls 24 feet, from an elevation of 49 feet to 25 feet, with an average slope of 2%.

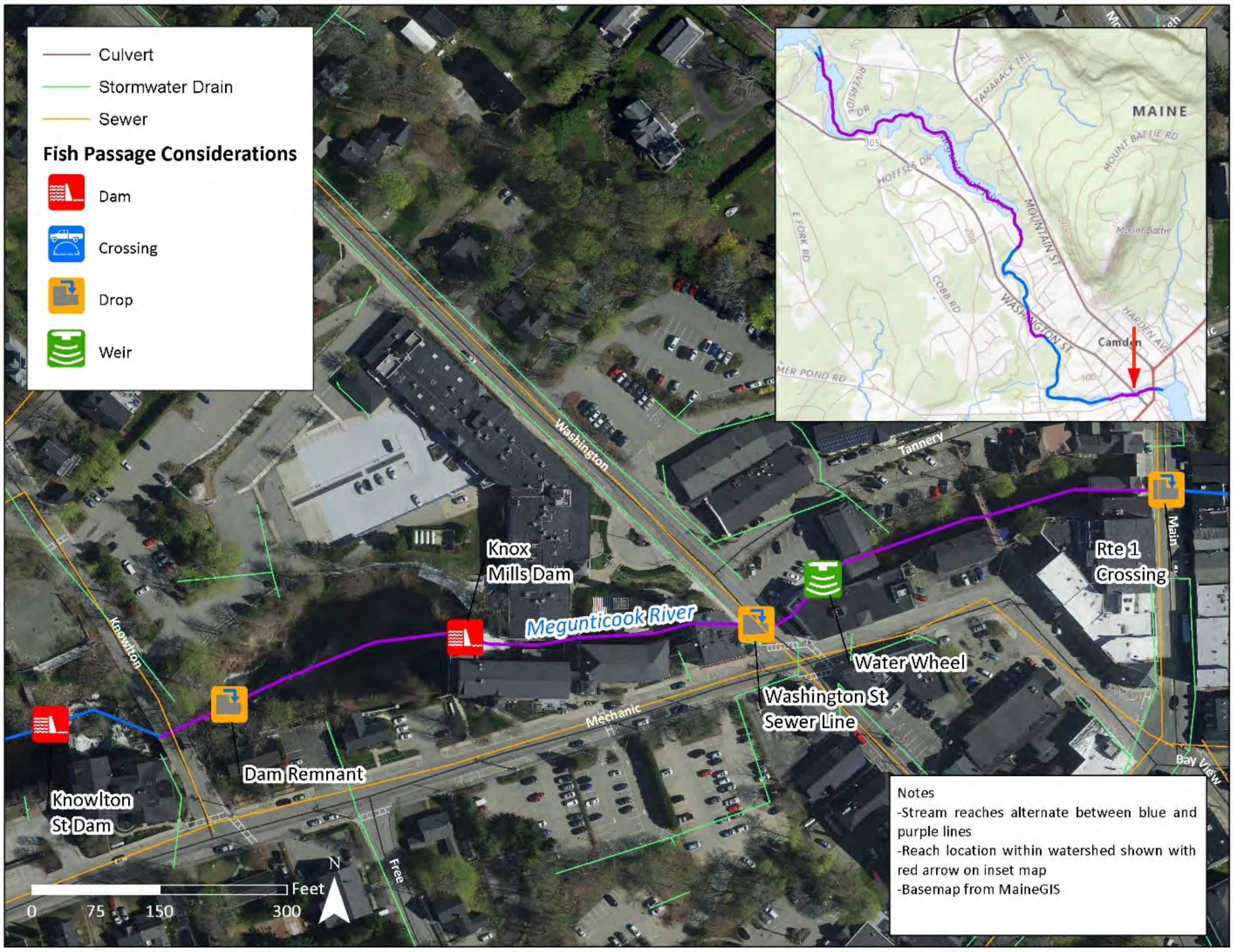

Figure 29. Overview of the Main Street to Knowlton Street reach (purple line). Fish passage considerations and other features are shown along the reach.

Immediately upstream of the Main Street bridge, additional commercial structures extend over one-half of the river for approximately 60 feet. In the drawn-down condition, the channel exhibits geomorphic sequences of a natural stream over the next 275 feet (Figure 30). Gravel bars, riffles, and pools are all present through this section. A clear-span footbridge crosses the river in the middle of this reach, but does not influence the river hydraulics. The river bed through this reach is also coarse-grained (gravel, cobbles and a few small boulders, with some bricks). The area upstream of the Main Street bridge exhibits depositional features in response to backwater during high flows.

Figure 30. Looking upstream from Main Street with impoundment drawn down, May 8, 2018. In addition to infrastructure in the river, natural features such as boulders, mid-channel bars, riffles, and pools are all present through this reach.

The upper end of the Montgomery dam impoundment is located approximately 350 feet upstream of the bridge and 525 feet upstream of the dam. From this point upstream to Washington Street, the river again flows under residential and commercial buildings, including the Brewster building, the site of a former shirt factory. A relict water wheel and a line of weirs extend across the channel beneath this building, creating a hydraulic drop of approximately 1 to 2 feet (Figure 31). These features are not a full fish passage barrier, but modest management of the conditions beneath the building would enhance fish passage potential. Additionally, analysis for the current study demonstrates that these legacy features influence peak flood water surface elevations near Washington Street.

Figure 31. Looking downstream beneath the Brewster building, May 8, 2018. Relict water wheels and weirs between pier footings visible in images.

Lastly, the river flows under the Washington Street ('Bakery') Bridge (MEDOT# 2981) approximately 500 feet upstream of Main Street. The super structure of the clearspan bridge was replaced in 2017. Beneath the bridge, a concrete-encased sewer pipe creates an approximate 9-inch to 12-inch hydraulic drop, assessed to not be a full fish passage barrier (Figure 32), but should be monitored for passage efficiency associated with future restoration activity.

Figure 32. View across channel beneath Washington Street bridge, May 8, 2018. Concrete sewer line encasement creates hydraulic drop of approximately 9 inches.

The subreach between the Washington Street crossing and the Knox Mill Dam is flanked by walls and much of it is below buildings (Figure 33). Limited complexity plane-bed morphology (devoid of pools or bedforms) dominates this portion of the reach, which would naturally exhibit pool-riffle morphology. The bed is armored with cobbles and gravel, depleted of fines. The plane-bed morphology and armoring are due to urbanization of the channel and a sediment transport regime disrupted by upstream dams.

Figure 33. Looking downstream from below The Jack restaurant. The channel is walled on both sides, with numerous building footings present in the channel. The coarse bed substrate is visible in the center of the channel.

The upper segment of the reach includes the Knox Mill Dam, which is discussed in detail below. The backwatering effect of the dam dominates the geomorphology of the upstream segment. The channel enters the impoundment approximately 300 feet upstream of the dam, transitioning from a steep, pool-riffle sequence to a large, languid pool. Just upstream is the Knowlton Street bridge, a clear span bridge that spans the outflow from Knowlton Street dam.

The impoundment was drawn down during the field investigation, affording a close look at its bed (Figure 34). The impoundment bed is notably rocky, with several outcroppings of ledge along the left bank, and contains only a modest volume of fines. A single-threaded channel emerged immediately upon draw down. This channel likely represents the natural alignment, as it follows a distinct low point in the valley and exhibits a steep slope and well-developed pool-riffle morphology similar to the channel upstream of the impoundment.

Figure 34. Looking downstream at the Knox Mill impoundment in a drawn down condition. The coarse bed material and relatively modest amount of impounded sediment are evident.

4.3.2.1 Knox Mill Dam

The Knox Mill dam sits at station 1200, with a dam crest elevation of 48.05 feet and a gate invert elevation at 32.27 feet. The dam is tied into a building foundation on river right and bedrock on river left. The impoundment is approximately 300 feet long and 140 feet wide at its widest point, with an area of approximately 0.6 acres. The small impoundment area is due to the relatively steep slope of the impoundment bed, which is approximately 4%.

Structural Condition

Knox Mill Dam is a stone masonry dam with a 54 foot-long concrete spillway. Its abutments are founded on bedrock, and the dam intersects bedrock on the north end and a granite retaining wall on the south end. Vegetation in the retaining wall suggests mortar loss between stones. Downstream of the dam, buildings directly abutting the river have granite foundation walls and wooden decks extending over approximately half the river. See also Appendix A.

Figure 35. Downstream view of Knox Mill Dam. Previously mill buildings extended completely across the river.

Figure 36. Downstream view of Knox Mill Dam. Previously mill buildings extended completely across the river.

4.3.3 Reach 3: Knowlton Street to Rawson Avenue (Knowlton Street Dam)

The reach from Knowlton Street to Rawson Avenue is approximately 3,680 feet long (Figure 37). Over this reach, the Megunticook River falls 23 feet, from an elevation of 72 feet to 49 feet, with an average slope of 0.6%.

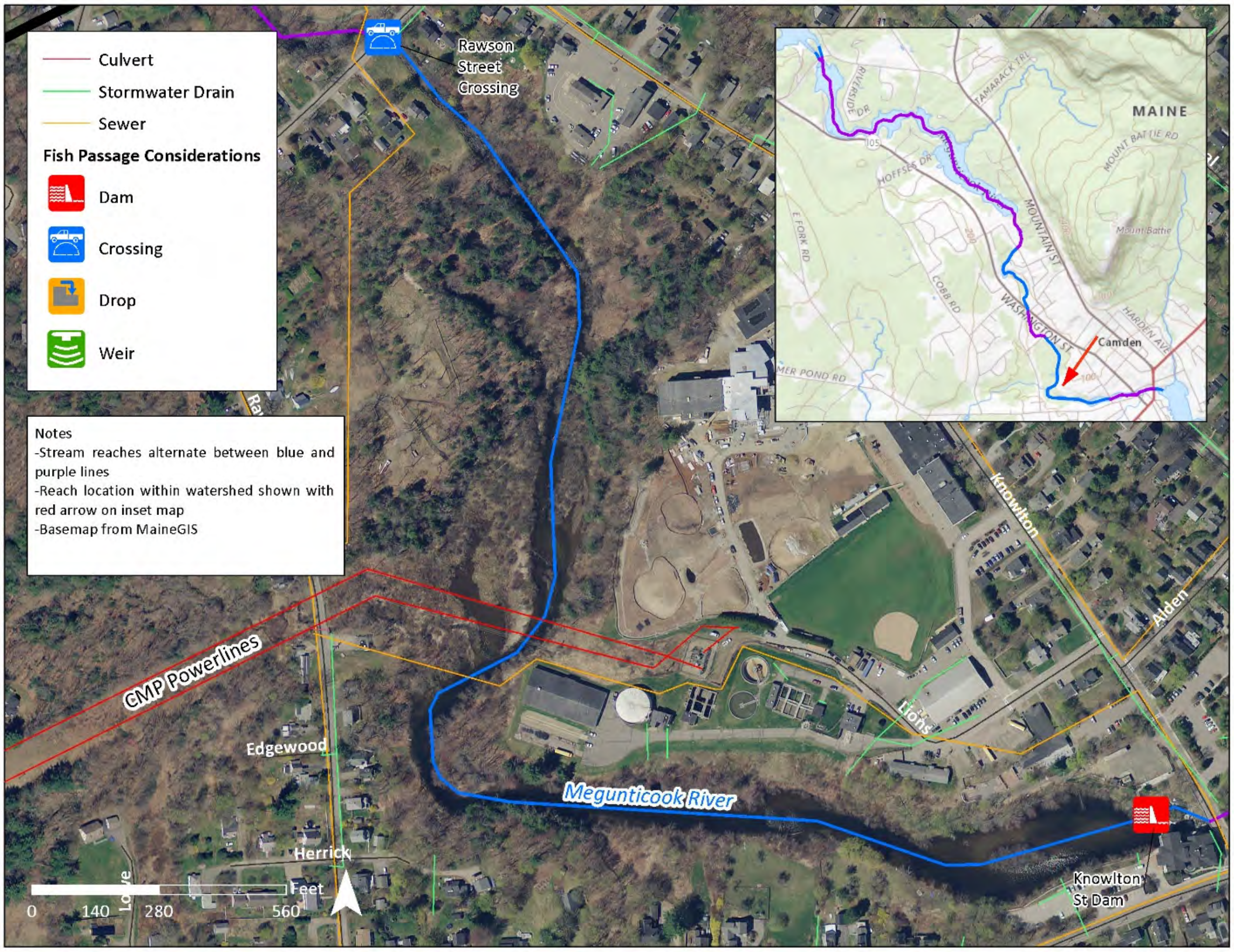

Figure 37. Overview of Knowlton Street to Rawson Street reach (blue line). Fish passage considerations and other features are shown along the reach.

In the downstream segment of this reach, immediately downstream of the Knowlton Street dam, flow is split around a bedrock knoll that the dam is founded on (Figure 38). The left channel is a step-pool sequence with several outcroppings of ledge and a stone wall constructed along the left bank (Figure 39). To the right of the bedrock knob, flow cascades over a steep section of ledge before plunging into a deep pool. Flow merges with the left channel just upstream of the Knowlton Street crossing. A wall forms the right bank of the channel through this section.

Figure 38. Split flow downstream of Knowlton Street dam, with assisted living facility on river right.

Figure 39. Looking upstream towards the Knowlton Street dam at the left fork of the split channel.

Figure 40. Looking upstream from the Knowlton Street Crossing at the river right channel and confluence with the river left channel downstream of the dam.

The sub-reach between the dam and the Knowlton Street crossing is one of the steepest sections on the Megunticook River, which is unusual to find this low in a watershed. Rivers in mature (i.e., not volcanically or tectonically active) landscapes are typically steepest in the headwaters and approach their base level (Camden Harbor, in this case) with a diminishing slope. In the case of the Megunticook, however, a geologic contact between two bedrock formations occurs at the Knowlton Street Dam, with the Megunticook formation (a schist-grade metamorphic rock) located downstream, and the Mount Battie formation (a clastic sedimentary rock) located upstream. The Megunticook formation is less erodible than the Mount Battie formation, and as such forms the steep section below the contact location. Upstream of this knickpoint, the more erodible Mount Battie formation has been lowered by glacial and fluvial processes and the channel has a much shallower slope (Figure 21).

The Knowlton Street dam and impoundment are discussed in detail in sections 4.3.3.1 and 4.7.1. The impoundment is long (approximately 2,700 feet) and narrow, completely covered with fine sediment that has deposited in the low-velocity environment. A channel thalweg is present, but is mantled with a layer of impounded sediment. Immediately upstream of the dam, the thalweg runs to the right of the small island in the impoundment. Whether this is the natural alignment or a dredged channel is unclear. The depth of refusal survey shows low points on both sides of the impoundment, suggesting the pre-dam channel may have been on either side of the valley bottom.

Approximately 1,700 feet upstream of the dam, the channel bends to the north. Immediately upstream of this bend is a large floodplain area to the right of the channel (Figure 41). The floodplain is composed of a 1- to 5-foot-thick silty-sand deposit that is similar to the sediment in the impoundment. This sediment was likely deposited when the impoundment was raised historically through the addition of boards or stoplogs to the dam crest, a common practice to store more water and increase the available power.

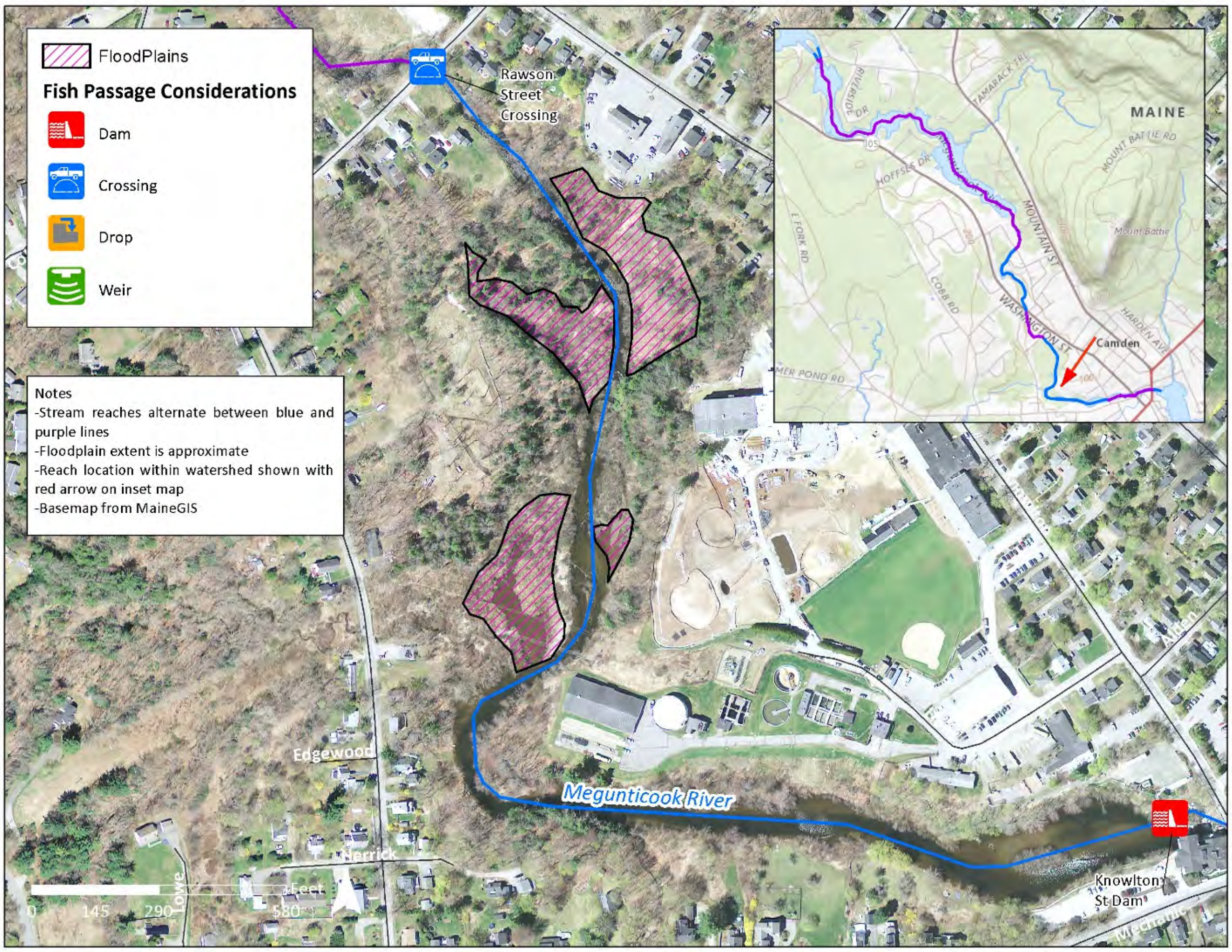

Figure 41. The impoundment upstream of Knowlton Street Dam, with floodplains shown in hatched polygons. The floodplain elevation in all four zones is generally around 68 feet, approximately 0.7 feet above the dam crest elevation.

The current head of the impoundment is approximately 2,700 feet upstream of the dam. Just upstream of this area is another silty-sand floodplain deposit on river left (Figure 41). Like the floodplain deposit described above, this sediment was likely accumulated when the dam was operated at a higher level and the impoundment extended farther upstream. With the dam at its present lowered level, the channel has incised into this deposit and reoccupied its natural bed elevation. Further evidence for this process includes the immature stands of floodplain alders, suggesting the area was historically inundated, and the nearly vertical banks that indicate channel incision. A similar channel evolution could be expected throughout the impoundment in the event of a dam removal.

The uppermost part of the reach, from the head of the impoundment to the Rawson Avenue crossing is a pool-riffle sequence with a bankfull channel width of approximately 40 feet. This section of channel appears to be straightened, likely to accommodate residential properties on either side of the channel.

4.3.3.1 Knowlton Street Dam

The Knowlton Street dam sits at station 1750, with a dam crest elevation of 67.3 feet. The dam is tied into a building foundation on river right, and sits atop a bedrock knob in the center of the dam. To the river left of the bedrock knob, the orientation of the dam crest changes, running towards the northeast into the side of the valley. The impoundment is approximately long and narrow, at 2,700 feet long and 130 feet wide at its widest point, with an area of approximately 6 acres. The average underlying slope of the impoundment bed is approximately 0.2%.

Structural Condition

Knowlton Street Dam consists of two spillway sections with concrete abutments on either bank and a central concrete abutment at the joint between spillway sections. It is classified as a low hazard dam. The dam and the abutments are founded on ledge, and the river-right abutment is integral with an adjoining building foundation at 51 Mechanic Street. All abutments are judged to be in satisfactory condition. The spillways were not visible for inspection. The retaining wall along the northwestern line of the dam is in poor condition; the retaining wall at the southern abutment is in satisfactory condition.

The pedestrian bridge above the dam is wood framed and is supported approximately 8 feet above the dam and is supported by the dam abutments. The bridge does not provide structural benefit to the dam. Numerous and significant conduit pipes traverse the river under the bridge deck.

See also Appendix A.

4.3.4 Reach 4: Rawson Avenue to Washington Street (Tannery Site)

The Rawson Avenue to Washington Street reach is approximately 1,013 feet long. Over this reach, the Megunticook River falls 7 feet, from an elevation of 79 feet to 72 feet, with an average slope of 0.7%. The channel bends around the former site of the Apollo Tannery on the river left overbank, which is now a vacant lot and site of the Camden Farmers Market (Figure 42). The short reach exhibits pool-riffle morphology with an alternating bar sequence (Figure 43). Legacy structures from site's industrial past, such as dam remnants, walls, and buried tanks are present in the channel and banks.

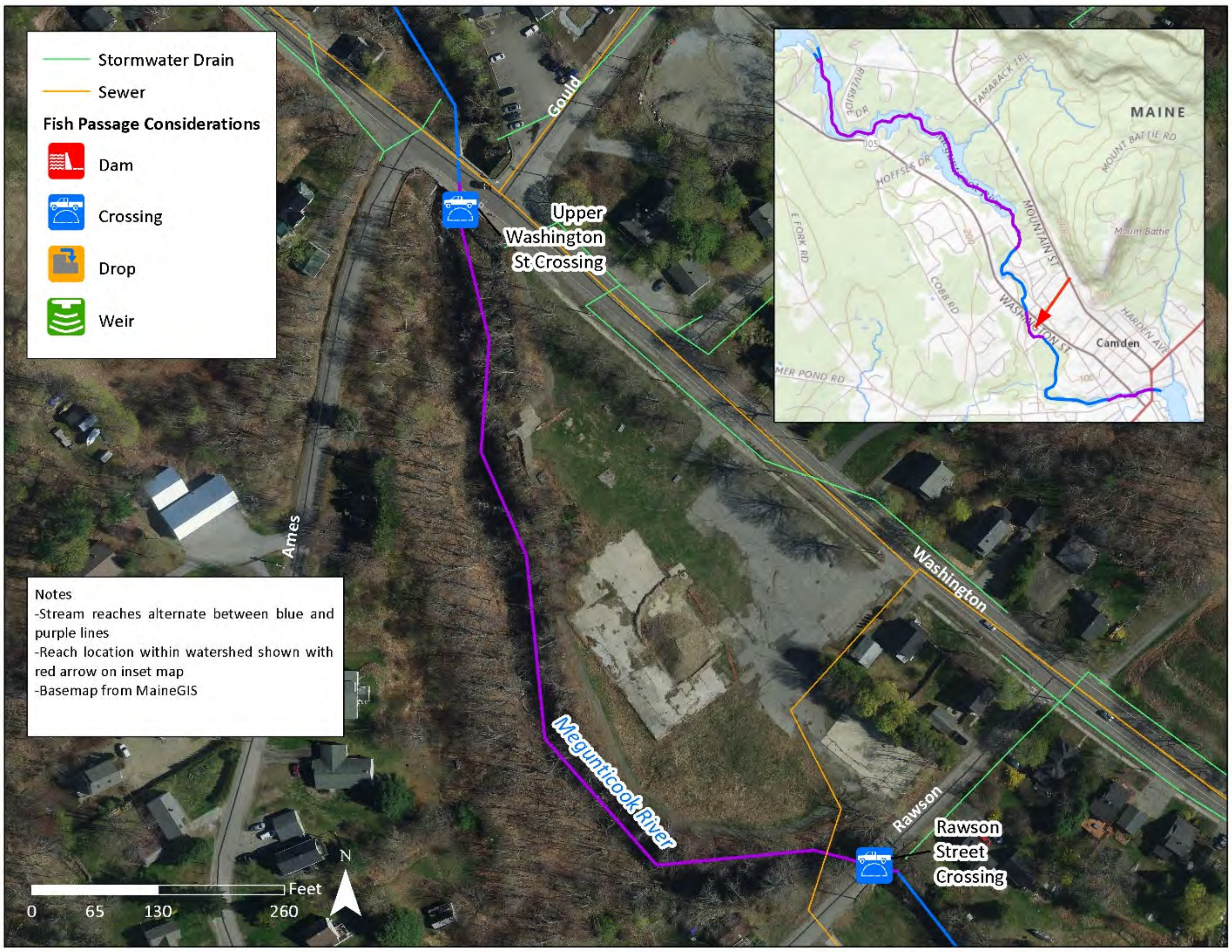

Figure 42. Overview of the Rawson Street to Washington Street reach (purple line). Fish passage considerations are shown along the reach.

The Rawson Street crossing at the downstream end of the reach is identified in this report as a fish passage consideration. Though the crossing itself does not present a significant obstacle to fish passage, it does constrict flow and impact instream habitat conditions, and has been prone to periodic debris accumulation including logs. The bridge also poses a navigation hazard for recreational paddlers at certain flow conditions. Because the crossing is condemned and no longer used for vehicle traffic, it presents an opportunity to improve fish passage by removing the structure, or replacing it with a clear span structure designed following Maine StreamSmart road crossing design guidelines.

Figure 43. Looking upstream at the reach between the Rawson Street and Washington Street crossings.

Figure 44. Looking downstream at the Rawson Street crossing.

The Washington Street crossing at the upstream end of the reach is also identified in this report as a fish passage consideration. The crossing is a clear span bridge with a grade control riffle constructed immediately downstream of the crossing to protect the bridge from scour. The slope and roughness of the riffle create a section of shallow, high velocity flow that may influence fish passage potential at some flows. Directly downstream of this location a historical dam was located which impoundment water and backwatered flow upstream to the Powder Mill dam area.

Figure 45. Looking upstream at the Washington Street crossing, A constructed grade control riffle is visible in the foreground.

4.3.5 Reach 5: Washington Street to Mt. Battie Street (Powder Mills Dam)

The Washington Street to Mt. Battie Street reach is approximately 2,335 feet long. Over this reach, the Megunticook River falls 23 feet, from an elevation of 102 feet to 79 feet, with an average slope of 1%.

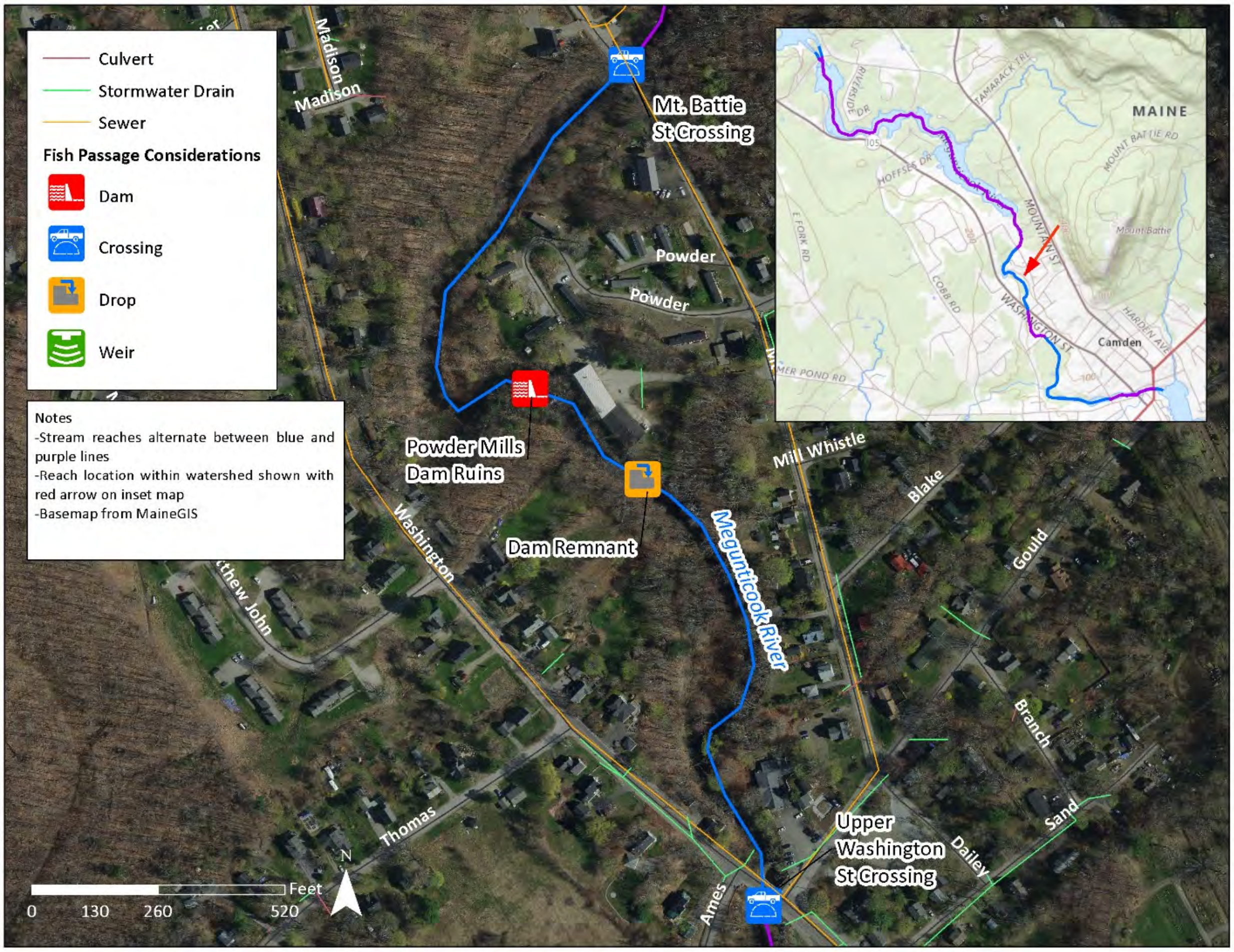

Figure 46. Overview of the Washington Street to Mt. Battie Street reach (blue line). Fish passage considerations are shown along the reach.

The downstream portion of the reach exhibits similar characteristics to the Tannery Reach, with pool-riffle sequences and alternating bars. Approximately 330 feet downstream of the Powder Mill Dam are the remnants of a small timber crib dam (Figure 47). The crib structure is what remains of the lower of two dams associated with the D.H. Bisbee powder mills, described as 20 rods (330 feet) downstream of the upper dam in the Maine Hydrographic Survey's inventory of dams on the Megunticook (Wells 1868). The cribbing is nearly flush with the bed, causing a modest hydraulic step and does not present a serious fish passage concern.

The ruins of the Powder Mill Dam sit approximately 1,300 feet upstream of the Washington Street crossing. The dam and impoundment are discussed in detail in sections 4.3.5.1 and 0. The channel slope begins to increase downstream of the dam site (Figure 21), with shorter riffle spacing and a slight narrowing of the channel width. Immediately downstream of the dam there is a mid-channel island that extends from the dam face. A break in the island allows flow to split around it with an alcove extending back towards the dam on river left. A building wall forms the left bank of the channel through this section. The dam itself is partially breached and passes flow through the low point (Figure 49). Large granite blocks that have fallen from the dam structure make up much of the bed immediately downstream of the dam.

Being partially breached, the dam has a relatively small impoundment area with limited impact on flow velocity. Since the breaching of the dam in mid-1900s, the channel has incised through the fine sediment that was trapped in the former impoundment. At present, the channel is flanked by legacy deposits of impounded sediments that now form the floodplain through the former impoundment area. These legacy deposits sit at an elevation of approximately 100 feet, which matches the dam crest elevation of the Powder Mills dam prior to breaching. The development of vegetation has stabilized floodplains, which are no longer a source of readily mobile sediment.

In the area between the impoundment area and Mt. Battie Street (the upstream end of the reach), the channel exhibits poorly developed pool-riffle morphology. Residential properties along the left bank maintain lawn areas up to the edge of the bank with little to no riparian vegetation. The absence of trees along this bank contributes to the instability and erosion observed on the left bank.

Figure 47. The remnants of a wooden crib dam approximately 330 feet downstream of the Powder Mill Dam.

Figure 48. Looking upstream at the remains of the Powder Mill Dam. The break in the mid-channel island is in the foreground, with water flowing towards the river left channel and the alcove visible upstream of the break.

4.3.5.1 Powder Mill Dam

The Powder Mill Dam ruins sit at station 7,610 and are a partially breached. The historic dam crest is at elevation 99.96 feet and the invert of the breached portion of the dam is at elevation 95.71 feet. Due to the breach, there is only a small backwater are upstream of the dam.

Structural Condition

The Powder Mill dam breached many years ago. The structure is subject to progressive incremental failure in the years to come. The structure does not retain a large volume of water, and hence poses limited hazard in its present state.

Figure 49. The Powder Mill Dam ruins. Granite blocks dislodged from the dam are visible in the channel in the foreground.

4.3.6 Reach 6: Mt. Battie Street to Molyneaux Road (Seabright Dam)

The reach from Mt. Battie Street to Molyneaux Road is approximately 9,995 feet long. Over this reach, the Megunticook River falls 20 feet, from an elevation of 122 feet to 102 feet, with an average slope of 0.002 ft/ft.

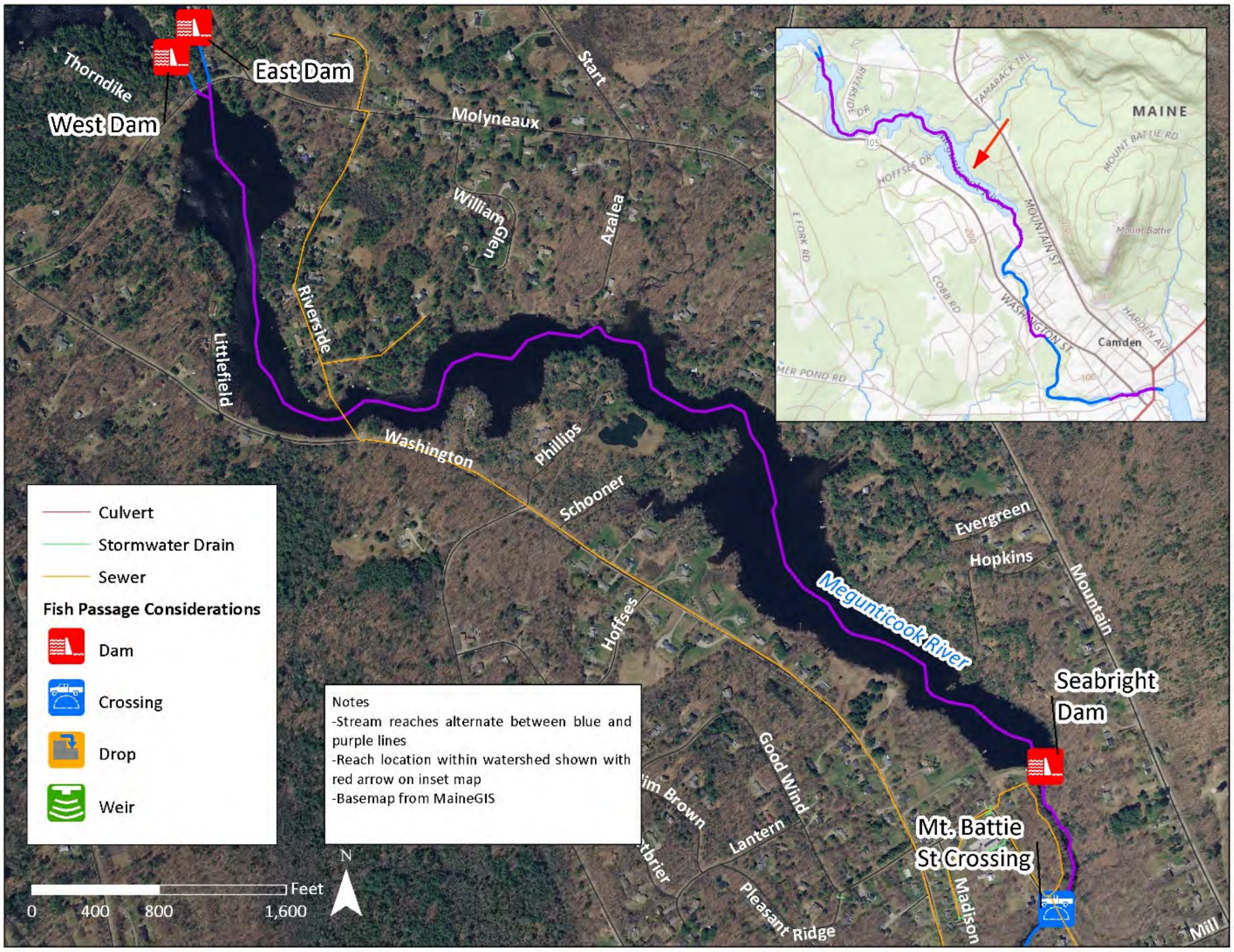

Figure 50. Overview of the Mt. Battie Street to Molyneaux Road reach (purple line). Fish passage considerations are shown along the reach.

The reach can be divided into two sections: below and above the Seabright Dam. Below the dam the channel exhibits pool-riffle morphology. Approximately 200 feet upstream of the twin culverts beneath Mt. Battie Street a small but steep ephemeral tributary enters the channel, and delivers a notable volume of sediment.

Figure 51. Boulders in the channel between Mount Battie Street and Seabright Dam.

Upstream of this confluence, the channel is split by a small island. The left channel has more flow than the right, though both are active at low flow. Additional complexity is added to the channel by large boulders and bedrock, which are both increasingly present in the subreach.

Downstream of the Seabright Dam, water plunges from the spillway into a pool. The downstream end of the pool is marked by bedrock grade control. A deteriorating wall forms the right bank along the edge of the pool.

The Seabright dam and impoundment are described in detail below. The impoundment is long, narrow, and shallow, with most soundings less 10 feet in depth. A DOR survey was not carried out on the Seabright impoundment as it is not being considered for breaching or removal.

4.3.6.1 Seabright Dam

The Seabright Dam sits at station 9,800. The dam crest elevation is approximately 123.4 feet. A concrete spillway wraps around the left flank of the dam area, plunging into a pool at the base of the dam. An earthen berm extends from the dam to the west. The dam is approximately 21’ tall.

Structural Condition

Seabright Dam is composed of stone masonry and concrete, and includes earth embankment wing walls. The dam features a 90-foot-long primary spillway and a 55-foot-long overflow spillway, and is classified as a high hazard dam. The most recent dam inspection report found a need for significant repairs in coming years, including remediation of a leaking joint in the concrete spillway that flows through the large rocks underneath and emerging in the sluiceway, resurfacing the spillway, and addressing the failed retaining wall downstream of the dam. Notable repair work was also completed in 2019 on the upstream face of the dam. See also Appendix A.

Figure 52. Seabright dam in 2020.

4.3.7 Reach 7: Molyneaux Road to Megunticook Lake (East and West Dams)

The reach from the Molyneaux Road crossing to Megunticook Lake is approximately 325 feet long. Over this reach, the Megunticook falls 18 feet, from an elevation of 140 feet to 122 feet, with an average slope of 5.5%. This reach is defined by the split flow around the bedrock knoll at the outlet of Megunticook Lake. The two channels enter the backwater of Seabright Pond and cross under Molyneaux Road through separate crossing structures. Below the West Dam, the west channel flows through a tight bedrock gorge before entering the backwater of the Seabright Pond upstream of Molyneaux Road. The east channel flows from the East Dam through a pool-riffle sequence and over west-dipping bedrock before entering the Seabright Pond backwater upstream of Molyneaux Road.

Approximately 125 feet downstream of the West dam, a small channel flows from the west channel to the east channel, crossing the forested area between the two channels. The channel is mix of step-pool and pool-riffle sequences and appears to convey perennial flow, being full at the time of the field assessment, conducted during drought conditions.

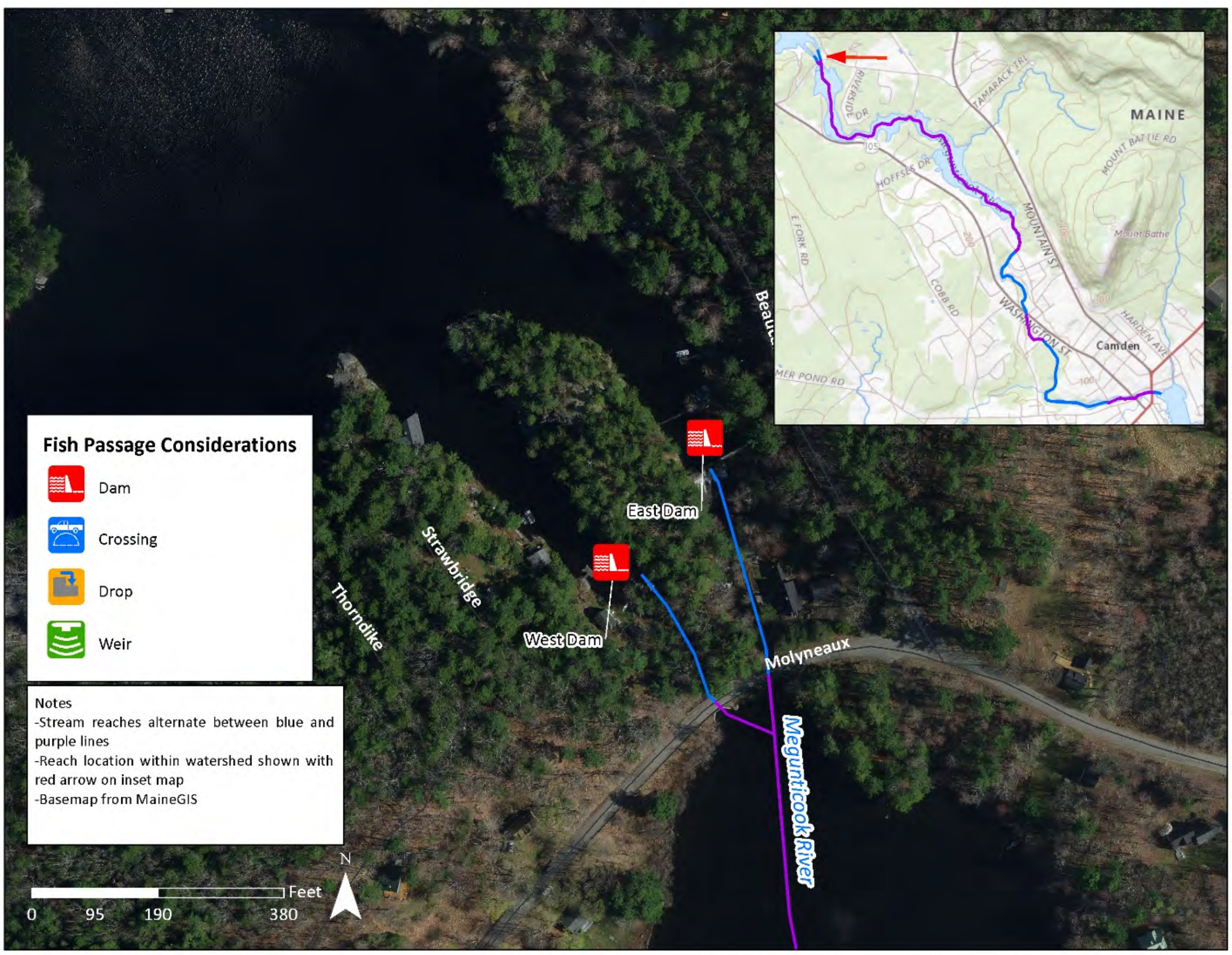

Figure 53. Overview of the Molyneaux Road to Megunticook Lake reach (blue line). Fish passage considerations are shown along the reach.

Figure 54. Looking upstream at the channel flowing from the West Dam. Steep bedrock forms the right bank of the channel.

Figure 55. Looking upstream towards the East Dam. From the dam, the stream flows over bedrock and enters the backwater of Seabright Pond in the foreground.

Figure 56. Looking downstream at the connector channel, flowing towards the east channel.

4.3.7.1 Megunticook East and West Dams

The East and West Dams sit at station 19,000. The dam crests are approximately 140.7 feet. Both structures are tied into bedrock on both sides of the channel.

Structural Condition

The East and West Dams at Megunticook Lake together impound the lake. The East Dam gate is used as the primary control on water levels, with the West Dam gate operated as needed to adjust lake levels.

East Dam is a gravity dam with two spillways, a gated sluice, and a trash rack structure, and is classified as a high hazard dam. The spillways are dry-laid masonry overlain with concrete. Past dam inspection reports conflict somewhat on the overall condition of the dam, with 2011 and 2019 reports prepared by Kleinschmidt reporting the dam to be in good condition, while a 2015 report from GEI found the dam to be in fair to poor condition.

West Dam is founded on ledge, features a spillway constructed of dry-laid stone masonry covered with a wood deck, and contains a Whipps gate installed in Fall 2020. A trash rack is located approximately 20 feet upstream of the dam. A large stone retaining wall is downstream of the dam on the river-right side. The dam is classified as a high hazard dam. Significant repairs to the spillway, trash rack, and other appurtenances were completed in 2020. See also Appendix A.

Figure 57. The East Dam in 2019.

4.4 IMPOUNDED SEDIMENT ASSESSMENT

Dams create backwater environments, known as impoundments, that are wider, deeper, and lower gradient than the stream is upstream of the impoundment or downstream of the dam. Flow velocity is reduced, which reduces the sediment transport capacity of a stream. As a result, a portion of sediment that is transported into an impoundment is deposited and trapped, resulting in sediment accumulation over time. Management of impounded sediment is an important consideration when contemplating dam management activities, in which the quantity and composition of impounded sediment are key factors.

Generally, downstream transport of sediment is a natural process, that is important for sustaining rivers and floodplains, estuaries, and coastal areas. In some instances, passive release of accumulated sediment associated with dam removal or modification may be planned when the net benefit to the downstream river facilitates restoration while avoiding risks. In other instances, a passive release of sediment can impact sensitive aquatic habitat or accumulate in downstream depositional areas where it would be viewed problematically. One such area along the Megunticook River may be the Camden inner harbor. Additionally, sediment impounded behind a dam can potentially bear the legacy of contamination from past or present upstream land or industrial uses, including urban runoff.

The site investigation included depth-of-refusal surveys in selected impoundments, which entailed surveying the surface of the impounded sediment and also probing through this layer and surveying the ledge or coarse sediment that made up the pre-dam ground or riverbed surface. These survey points are used to estimate the volume of sediment trapped behind the dam and also provide clues to what the site may look like if the dam were not in place.

Based on the industrial legacy of the river and the urban setting, samples of the accumulated sediment behind the dams for which dam removal is being considered were collected to screen for the presence of potential pollutants.

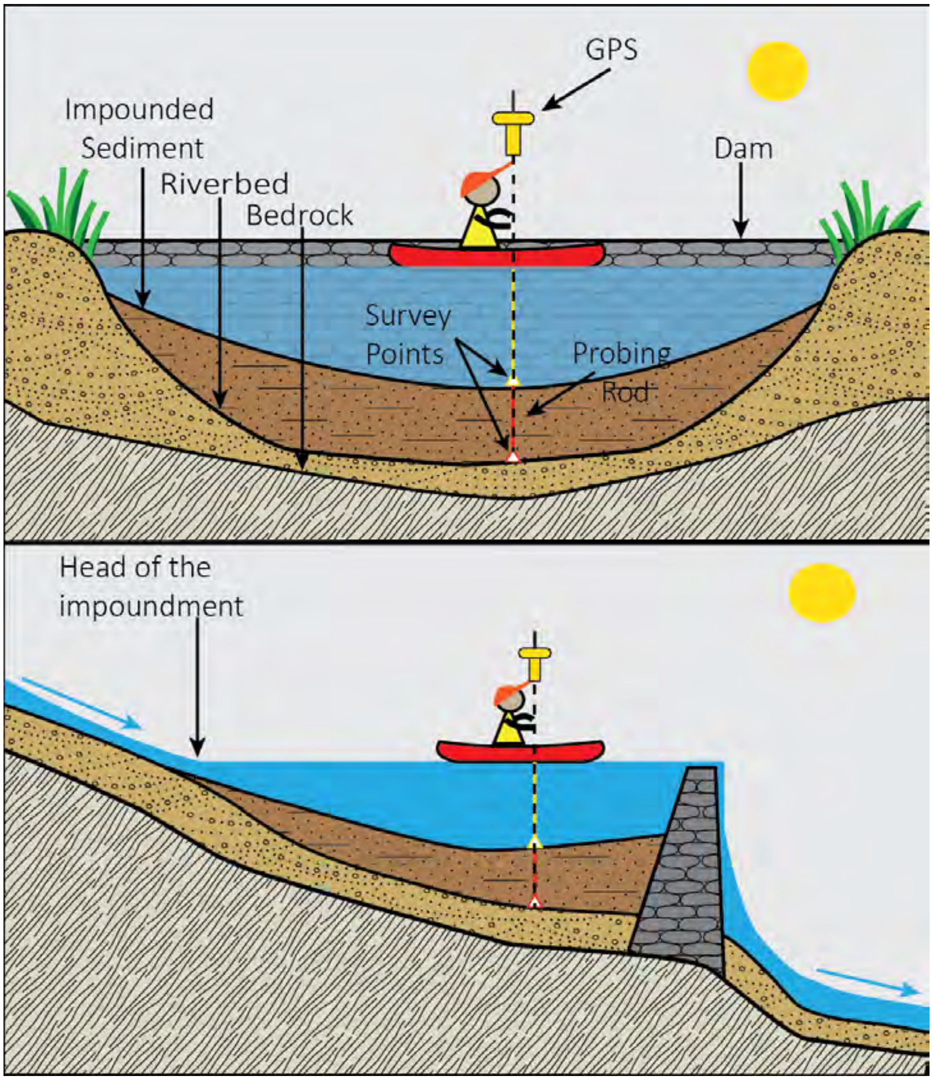

Figure 58. Schematic depiction of an impounded sediment survey. The upper frame shows the impoundment in cross section and the lower frame shows the impoundment in profile. This process of collecting a pair of points- one at the top of the impounded sediment and one at the pre-dam riverbed- is carried out throughout the impoundment.

4.4.1 Sediment Quantity

The following paragraphs summarize the estimated quantities of accumulated sediment behind each of the dams considered for dam removal or management.

Montgomery Dam

Results of the Montgomery Dam sediment investigation are discussed in detail in the feasibility study report for that site (Inter-Fluve 2019). It was estimated that 250-300 cubic yards (CY) of sediment were impounded behind the Montgomery Dam. This accumulated sediment is expected to be potentially mobile if the dam were to be removed. Montgomery Dam sediment test results are discussed in Section 4.4.2 of this report.

Knox Mill Dam

The Knox Mill Dam impoundment contains a modest volume of fine sediment estimated at approximately 200 CY. The sediment is concentrated in pockets on the left and right margins of the impoundments. This accumulated sediment is expected to be potentially mobile if the dam were to be removed.

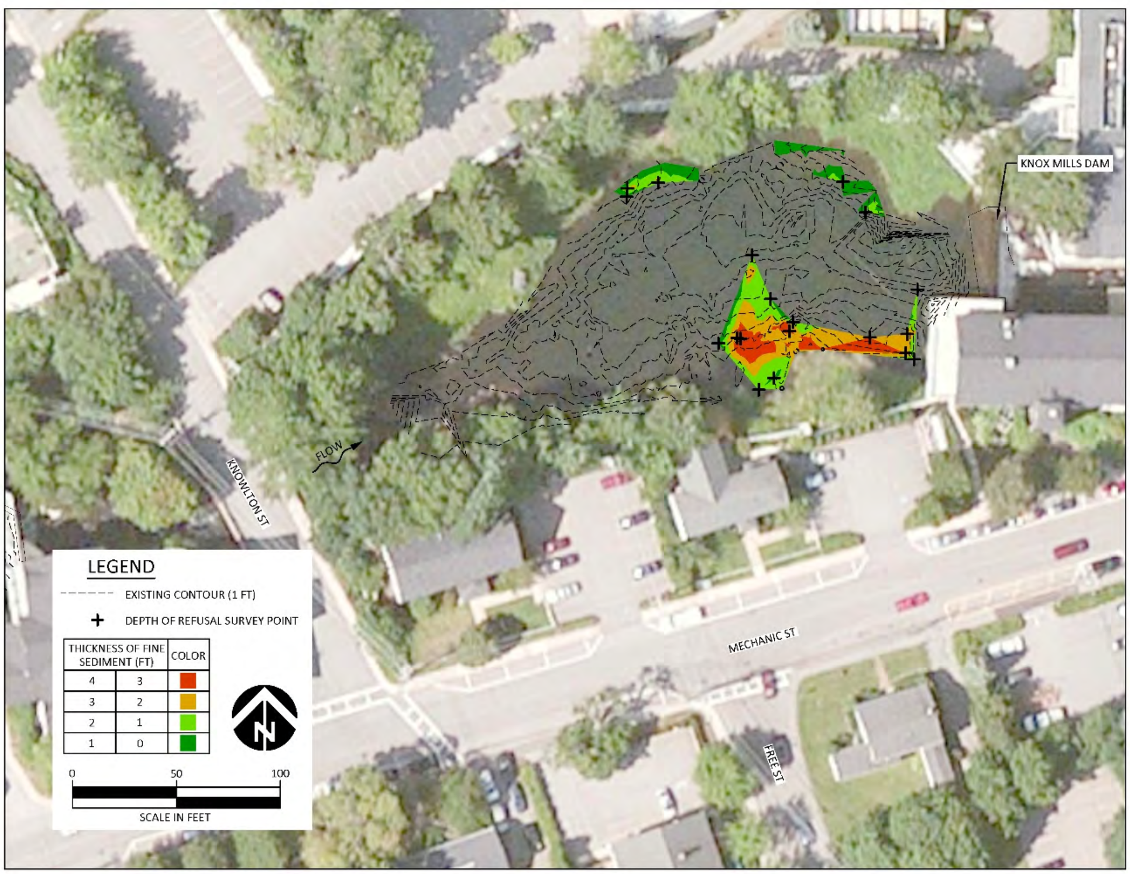

Figure 59. Spatial extent and thickness of accumulated fine sediment in the Knox Mill Dam impoundment. The estimated volume is approximately 200 cubic yards.

Knowlton Street Dam

A substantial volume of accumulated fine sediment was observed in the Knowlton Street Dam impoundment. The estimated volume of accumulated sediment is approximately 27,600 CY. Fine sediment covers the bed of the entire impoundment, with notably large deposits along the margins of the impoundment and throughout the area extending approximately 500 feet upstream of the dam, where the impoundment is widest.

Floodplain deposits at the upper end of the impoundment, discussed in Section 0, are likely composed of sediment that was trapped when the dam was operated at a higher level than at present. Readily mobile fine sediment is present throughout the impoundment, but not all of the accumulated sediment is expected to be mobile if the dam were removed. The floodplain deposits, for example are well vegetated and sit above the present-day impoundment, making them unlikely to mobilize in the event of dam removal. Sediment within the post-dam channel alignment is the most likely to mobilize following dam removal. By calculating the volume of sediment within this corridor and conservatively assuming that it will all be evacuated, we estimated the volume of mobile sediment to be approximately 11,000 CY.

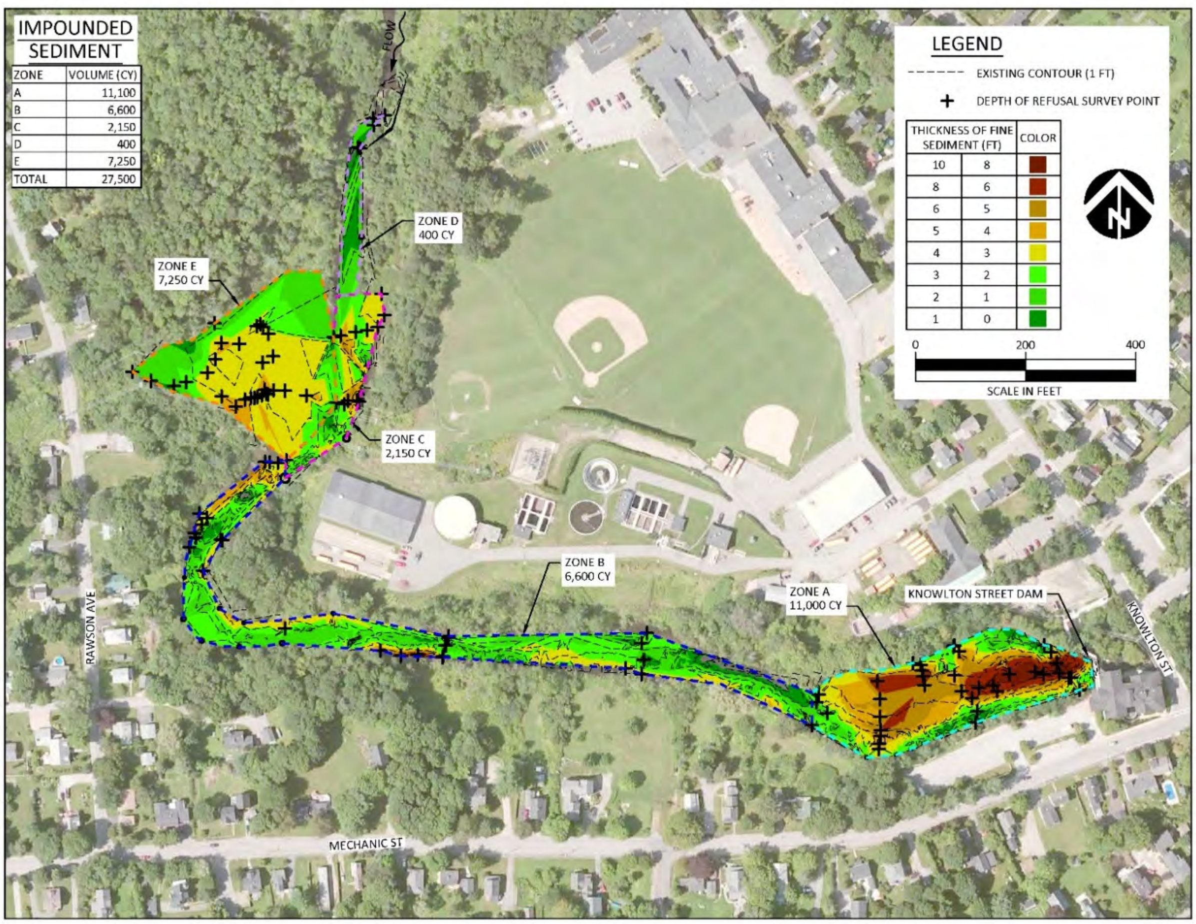

Figure 60. Spatial extent and thickness of accumulated fine sediment in the Knowlton Street Dam impoundment. The estimated volume is approximately 27,600 CY. The deposit is broken into 5 zones- A, B, C, D, and E.

Powder Mill Dam Ruins

There are only limited pockets of fine sediment stored upstream of the Powder Mill Dam Ruins. Sediment has likely evacuated from the impoundment in the years since the breaching of the dam. Through the former impoundment area, the channel appears to have incised through the impounded sediments, leaving small floodplains constructed of fine sediments flanking the channel (Figure 61). Due to the dispersed sediment conditions, it was not practical to complete depth-of-refusal probing in this impoundment and achieve measurable results. We visually estimated the volume of impounded fine sediment remaining in the channel to be on the order of 100 cubic yards (CY), spread over several discrete pockets. This accumulated sediment is expected to be potentially mobile if the dam were to be removed. While the floodplains are potentially composed of formerly impounded sediments - similar to those described along the Knowlton Street Dam impoundment - they are vegetated, stable, and high above the active channel. As such, these sediment deposits are not deemed likely to mobilize in the event of a dam removal. The volume of accumulated sediment in these overbank areas is estimated to range from 550 CY to 1,650 CY.

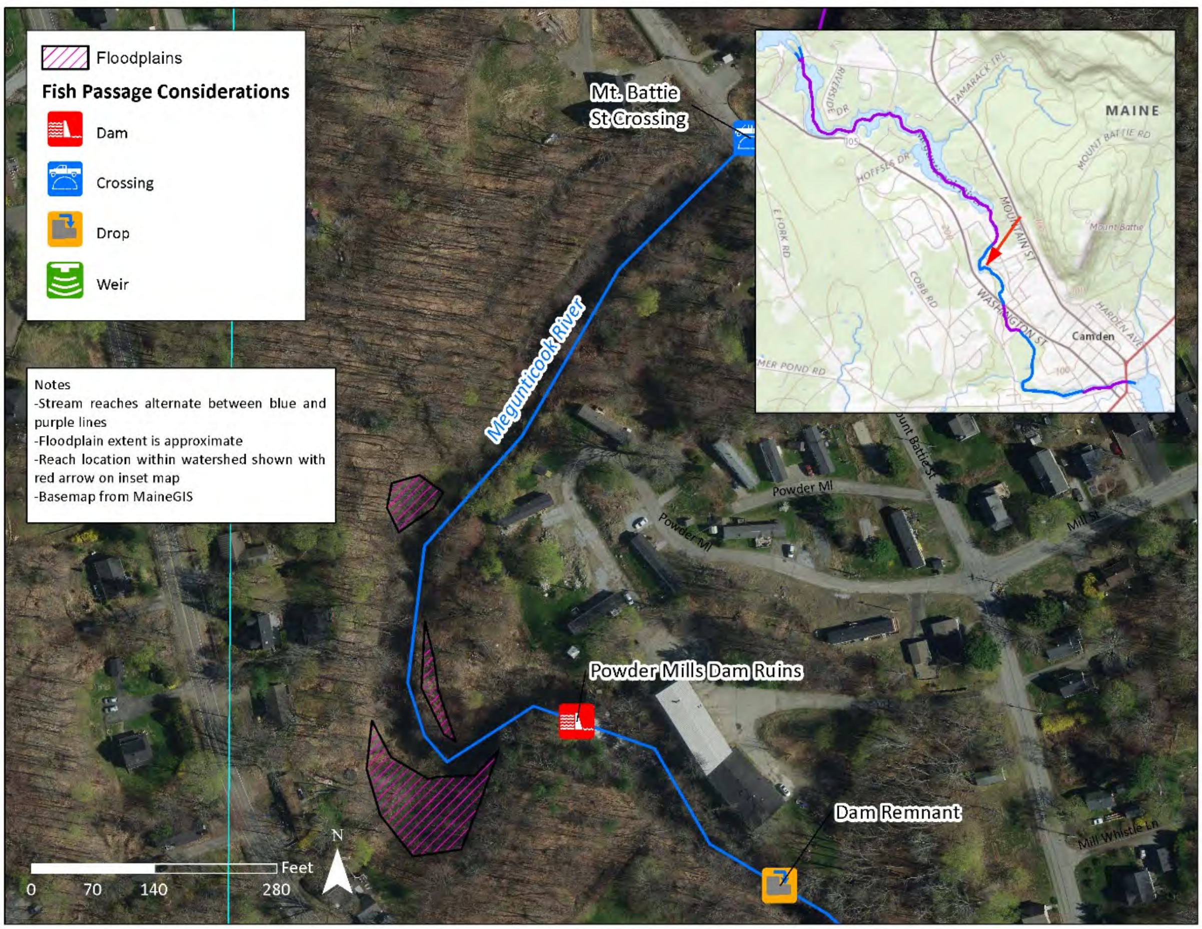

Figure 61. Overbank floodplain areas in the former Powder Mills dam impoundment area.

4.4.2 Sediment Quality

Sediment samples were collected from the impoundments at Montgomery (3 samples), Knox Mill (3 samples), Knowlton Street (8 samples), and Powder Mills (2 samples) dams, as well as a background sample from Camden Harbor and two locations in free-flowing reaches of the river (Figure 62).

Samples were analyzed by Alpha Analytical, a testing laboratory in Portsmouth, NH. Results of the testing were screened against ecological criteria that are typically used to evaluate accumulated sediment in impoundments in New England, human exposure criteria more typically used in construction or development settings, and Maine DEP beneficial sediment reuse screening criteria.

The ecological criteria are defined by the consensus-based sediment quality guidelines (MacDonald et al. 2000), which set thresholds for concentrations of pollutants that might result in possible effects (FTEC, MTEL) and probable effects (FPEC, MPEL) to organisms living in freshwater and marine ecosystems. These criteria are typically used to inform the determination of whether sediment is clean enough to allow it to pass downstream, to reuse the sediment on a project site, or whether it is advisable to remove the sediment from the project location and prevent further exposure.

The human exposure criteria are part of the Maine DEP's remedial action guidelines (ME-RAGs) for various levels of human exposure, in this case construction worker and park user (Maine DEP 2018a). The beneficial reuse criteria are used to screen whether sediment that is dredged from an impoundment may be repurposed for a beneficial use (such as fill), or if it would need to be disposed at a landfill (Maine DEP 2018b).

When compared to human health screening from the ME-RAGs for construction workers and park users, there were two exceedances: Mercury in sample 4-TNK (in the Montgomery Dam impoundment, next to the buried tank) and benzo (a) pyrene in sample KS-8 (at the upstream end of the Knowlton Street Dam former impoundment). The detection of mercury above the screening level is likely in connection with the buried tank that the sample was purposefully taken adjacent to. With three other samples in close proximity not detecting high levels of mercury, it is not considered a widespread result. Benzo (a) pyrene is a product of incomplete combustion of organic material, common sources of which are cigarette butts and burnt wood. It is possible a piece of charred wood or a discarded cigarette was in the sediment sampled at location KS-8, which is nearby a vagrant campsite. This sample location is in the overbank area near the upstream end of the impoundment on the left side of the river. It is an area that was inundated by the backwater from the dam historically, but under present spillway levels, is only inundated during floods. The area also receives substantial stormwater runoff from Washington Street. No other samples exceeded the human exposure screening levels for any analytes. Lastly, comparison of the results to beneficial reuse standards revealed concentrations of selected SVOCs and metals that were in excess of screening levels.

Selected results exceeded the ecological criteria threshold and probable effects screening levels, predominantly for metals and semi-volatile organic compounds. A summary of the exceedances is provided in Table 4. Chromium is notably high in samples from the Knowlton Street, Knox Mill, and Montgomery impoundments. The elevated presence of chromium may be a legacy of the former

Apollo tannery. Generally, chromium is present in the environment in two primary species, hexavalent chromium (Cr-VI) and trivalent chromium (Cr-III). The species are defined by their oxidation state, with Cr-VI (+6) being more oxidized than Cr-III (+3). Cr-VI is highly toxic to humans and Cr-III is not (it is, in fact, an essential nutrient for human health; Regan, 2019). The goal of many Cr-VI remediation efforts is to reduce the oxidation state of Cr-VI to Cr-III. Speciation of the chromium in the sediment found in this study indicated that no Cr-VI was present.

A comparison sample taken from the harbor sediments showed the presence of similar compounds and analytes to those found in the impounded sediments. Concentrations of semi-volatile organic compounds in the harbor sample were similar to or higher than in the upstream impoundment samples. Concentrations of metals were generally modestly lower, with the exception of lead. Comparison between the harbor sample and the upstream samples suggests that concentrations in the harbor may not change substantially in the event of a sediment release. In some cases, the harbor sample had higher concentrations of a given analyte, which would suggest that releasing the impounded sediment would not increase the concentration of that analyte in the harbor. The general similarity between the results in the harbor and in the impoundment leads to the interpretation that harbor has been receiving sediment from the Megunticook River historically, and that the overall sediment quality between the dams and the harbor are not markedly different, with some noted exceptions, discussed above. Complete results of the sediment testing program can be found in Appendix A.

Two points of comparison for the sediment testing results were obtained from other studies. First, a comparison for the harbor sample comes from sediment testing carried out for a proposed dredging project at Lyman-Morse Boatbuilding located within the harbor (Lyman-Morse Boatbuilding 2018). A review of the associated results indicated that they are in close agreement with the analysis of the harbor sample presented in this report. Secondly, testing carried out in the early 1990s in the impoundment upstream of Knowlton Street Dam (Kimball Chase Company 1991, Town of Camden 2019) revealed generally lower concentrations of analytes when compared to the 2020 sampling event, with the exception of chromium, which was higher than any sample analyzed in 2020. The early 1990s testing was carried out in response to a sediment release event from the impoundment when the gate was opened, which resulted in sedimentation in the inner harbor. Due to the lack of detail on where and how the sample was collected, a true comparison of the results is not possible, but they provide a confirmation that chromium concentrations were high at that time as well.

Typically, reuse or release options for impounded sediment are discussed with state regulatory bodies at the beginning of a detailed design phase, and formalized through the permitting process. As a result, it is not presently known whether release of the accumulated sediment would be permitted, or whether it would be acceptable to project stakeholders.

Given the modest volumes of impounded sediment and associated sediment quality at the Montgomery, Knox Mill, and Powder Mills dams, we assumed for current project evaluation and planning purposes that sediment release will not be permitted, and that the sediment will be removed from the impoundment and disposed at an offsite location. Initial comparison of the sediment at these sites to the beneficial reuse screening criteria (Maine DEP 2018b) show exceedances of arsenic at all sites, as well as naphthalene, and benzo(a)pyrene in samples from the Montgomery impoundment.

Offsite disposal will be far more costly for the Knowlton Street impoundment due to the notable volume of impounded and potentially mobile sediment. The volume of sediment may preclude a passive release of sediment, which could accumulate temporarily in downstream reaches and in the inner harbor. Initial comparison of the sediment at this site to the beneficial reuse screening criteria (Maine DEP 2018b) show exceedances of arsenic, naphthalene, and benzo(a)pyrene. Additional sampling to improve the spatial resolution of the analytes in the sediment may isolate "hot spots" as well as delineate zones that may satisfy the beneficial reuse criteria.

Cost estimates developed for the current study assume that the potentially mobile sediment will be required to be excavated and removed from the site. Onsite sediment management options should be further investigated in future project phases for the Knowlton Street impoundment. Further consultation with MaineDEP will provide guidance on the next steps, including whether additional sampling at each these sites will be recommended or necessary.

While there are a range of compounds and constituents found in the accumulated sediment, the sediment quality is not unlike that found in many impoundments along rivers throughout New England. Sediment management will be a project component requiring coordination and project resources, yet successful sediment management is achievable while limiting impacts to local residents, river users, and fish and wildlife. There is an extensive track record of sediment management at many similar sites across the region that have resulted in highly successful river restoration.

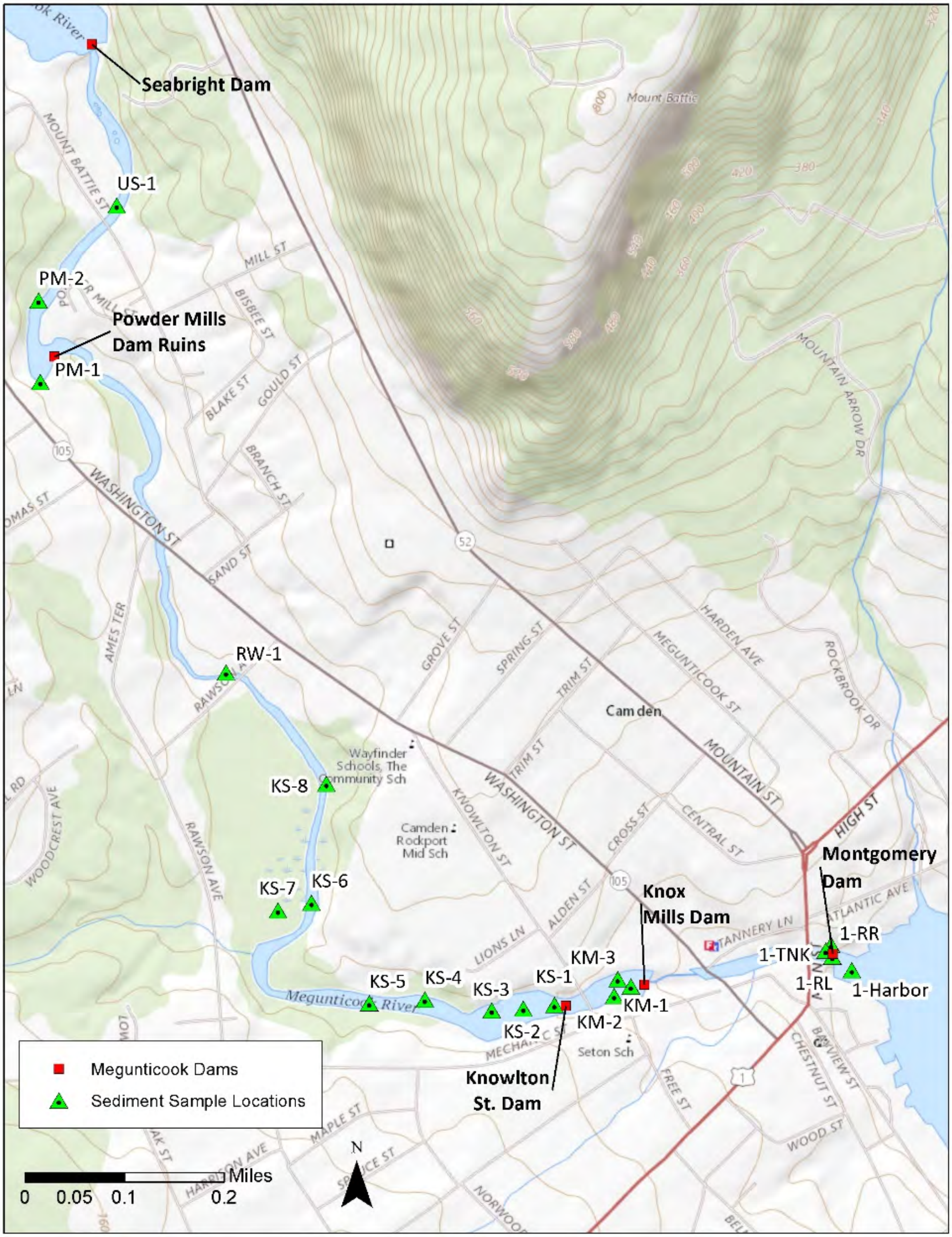

Figure 62. Overview of sediment sample locations.

Table 4. Summary of Screening Level Exceedances. Results presented as: 'Screening Criteria: Number of distinct analytes in the domain that exceed the criteria/Number of samples in the domain with at least 1 analyte exceeding the criteria'.

Sampling Domain	Herbicides	Pesticides	PCBs	SVOCs	VOCs	Metals
Camden Harbor • **2 samples**	• Below All Thresholds	• Not Analyzed	• Below All Thresholds	• **FTEC: 9 analytes/2 samples** • **FPEC: 9 analytes/2 samples** • **MTEL: 13 analytes/2 samples** • **MPEL: 13 analytes/2 samples** • RAGS : No Exceedances • **BR: 2 analytes/1 sample**	• Below All Thresholds	• **FTEC: 2 analytes/2 samples** • **FPEC: 1 analyte/1 sample** • **MTEL: 4 analytes/1 sample** • **MPEL: 3 analytes/1 sample** • RAGS : No Exceedances • **BR: 1 analyte/2 samples**
Montgomery Dam • **3 samples**	• Below All Thresholds	• **FTEC: 4 analytes/1 sample** • **FPEC: 2 analytes/1 sample** • **MTEL: 4 analytes/1 sample** • **MPEL: 3 analytes/1 sample** • RAGS : No Exceedances • BR: No Exceedances	• **FTEC: 1 analyte/1 sample** • FPEC: No Exceedances • **MTEL: 2 analytes/1 sample** • MPEL: No Exceedances • RAGS : No Exceedances • BR: No Exceedances	• **FTEC: 9 analytes/3 samples** • **FPEC: 9 analytes/3 samples** • **MTEL: 13 analytes/3 samples** • **MPEL: 13 analytes/3 samples** • RAGS : No Exceedances • **BR: 2 analytes/2 samples**	• Below All Thresholds	• **FTEC: 7 analytes/3 samples** • **FPEC: 3 analytes/2 samples** • **MTEL: 4 analytes/1 sample** • **MPEL: 3 analytes/1 sample** • **RAGS : 1 analyte/1 sample** • **BR: 1 analyte/2 samples**
Knox Mill Dam • **3 samples**	• Below All Thresholds	• **FTEC: 3 analytes/1 sample** • FPEC: No Exceedances • **MTEL: 3 analytes/1 sample** • MPEL: No Exceedances • RAGS : No Exceedances • BR: No Exceedances	• **FTEC: 2 analytes/2 samples** • FPEC: No Exceedances • **MTEL: 2 analytes/2 samples** • **MPEL: 2 analytes/1 sample** • RAGS : No Exceedances BR: No Exceedances	• **FTEC: 8 analytes/3 samples** • **FPEC: 2 analytes/1 sample** • **MTEL: 13 analytes/3 samples** • **MPEL: 9 analytes/3 samples** • RAGS : No Exceedances • BR: No Exceedances	• Below All Thresholds	• **FTEC: 7 analytes/3 samples** • **FPEC: 2 analytes/2 samples** • **MTEL: 4 analytes/1 sample** • **MPEL: 3 analytes/1 sample** • RAGS : No Exceedances • **BR: 1 analyte/2 samples**
Knowlton Street • **9 samples**	• Below All Thresholds	• **FTEC: 1 analyte/2 samples** • FPEC: No Exceedances • **MTEL: 3 analytes/2 samples** • MPEL: No Exceedances • RAGS : No Exceedances • BR: No Exceedances	• Below All Thresholds	• **FTEC: 9 analytes/8 samples** • **FPEC: 9 analytes/1 sample** • **MTEL: 13 analytes/8 samples** • **MPEL: 13 analytes/2 samples** • **RAGS : 1 analyte/1 sample** • **BR: 2 analytes/2 samples**	• Below All Thresholds	• **FTEC: 6 analytes/9 samples** • **FPEC: 2 analytes/5 samples** • **MTEL: 4 analytes/1 sample** • **MPEL: 3 analytes/1 sample** • RAGS : No Exceedances • **BR: 1 analyte/6 samples**
Powder Mills Dam • **2 samples**	• Below All Thresholds	• Below All Thresholds	• Below All Thresholds	• **FTEC: 5 analytes/1 sample** • FPEC: No Exceedances • **MTEL: 11 analytes/2 sample** • MPEL: No Exceedances • RAGS : No Exceedances • BR: No Exceedances	• Below All Thresholds	• FTEC: No Exceedances • FPEC: No Exceedances • **MTEL: 2 analytes/1 sample** • MPEL: No Exceedances • RAGS : No Exceedances • **BR: 1 analyte/1 sample**
Rawson Ave • **1 Sample**	• Below All Thresholds	• Below All Thresholds	• Below All Thresholds	• FTEC: No Exceedances • FPEC: No Exceedances • **MTEL: 8 analytes/1 sample** • MPEL: No Exceedances • RAGS : No Exceedances • BR: No Exceedances	• Below All Thresholds	• FTEC: No Exceedances • FPEC: No Exceedances • **MTEL: 2 analytes/1 sample** • MPEL: No Exceedances • RAGS : No Exceedances • **BR: 1 analyte/1 sample**
Upstream Sample • **1 Sample**	• Below All Thresholds	• Below All Thresholds	• Below All Thresholds	• Below All Thresholds	• Below All Thresholds	• FTEC: No Exceedances • FPEC: No Exceedances • **MTEL: 2 analytes/1 sample** • MPEL: No Exceedances • RAGS : No Exceedances • BR: No Exceedances

FTEC: NOAA Freshwater Sediment Threshold Effect Concentration (TEC) SQuiRTs Criteria per 2008 Screening Quick Reference Tables.
MTEL: Marine Sediment Threshold Effects Level (TEL) SQuiRTs Criteria per 2008 Screening Quick Reference Tables.
FPEC: NOAA Freshwater Sediment Probable Effect Concentration (PEC) SQuiRTs Criteria per 2008 Screening Quick Reference Tables.
MPEL: NOAA Marine Sediment Probable Effects Level (PEL) SQuiRTs Criteria per 2008 Screening Quick Reference Tables.
RAGS: Maine Park User Remedial Action Guidelines (RAGs) Criteria per Maine DEP RAGs dated October 19, 2018.
BR: Maine DEP Screening Levels for Beneficial Reuse, dated July 8, 2018.

4.5 CLIMATE CHANGE AND RESILIENCE CONSIDERATIONS

Climate change may have substantial impacts to Maine's coastal watersheds, including the Megunticook River. Coastal areas have warmed by 3.4 degrees F since 1895, and annual precipitation has increased by 5.8 inches over the same period (Fernandez et al. 2020). Warmer winters account for much of the increase in temperature and are associated with decreased snowpack. Increasing temperatures have introduced a regime of increased hydrologic variability, in which precipitation and droughts intensify, evaporation increases, winter snowpack decreases, winter rainfall increases, and snowmelt occurs earlier in the year (MCC STS 2020).

Long-term precipitation records in the Camden area dating to the early 20th century show annual average precipitation has increased by approximately 16 inches (Figure 63), and by the mid-21st century, 9 additional inches of annual rainfall is likely (Anderson et al., 2019). Much of this additional precipitation will fall as rain and sleet during the winter months. In the northeastern U.S., annual and extreme precipitation have increased by 7% and 41% since the early 20th century, but precipitation trends show marked increases in both values in the late 1990s to early 2000s . The increase in extreme precipitation events appears to be driven by increased precipitation from tropical storms beginning in the 1990s, and strongly impacts coastal areas (Huang et al. 2017).

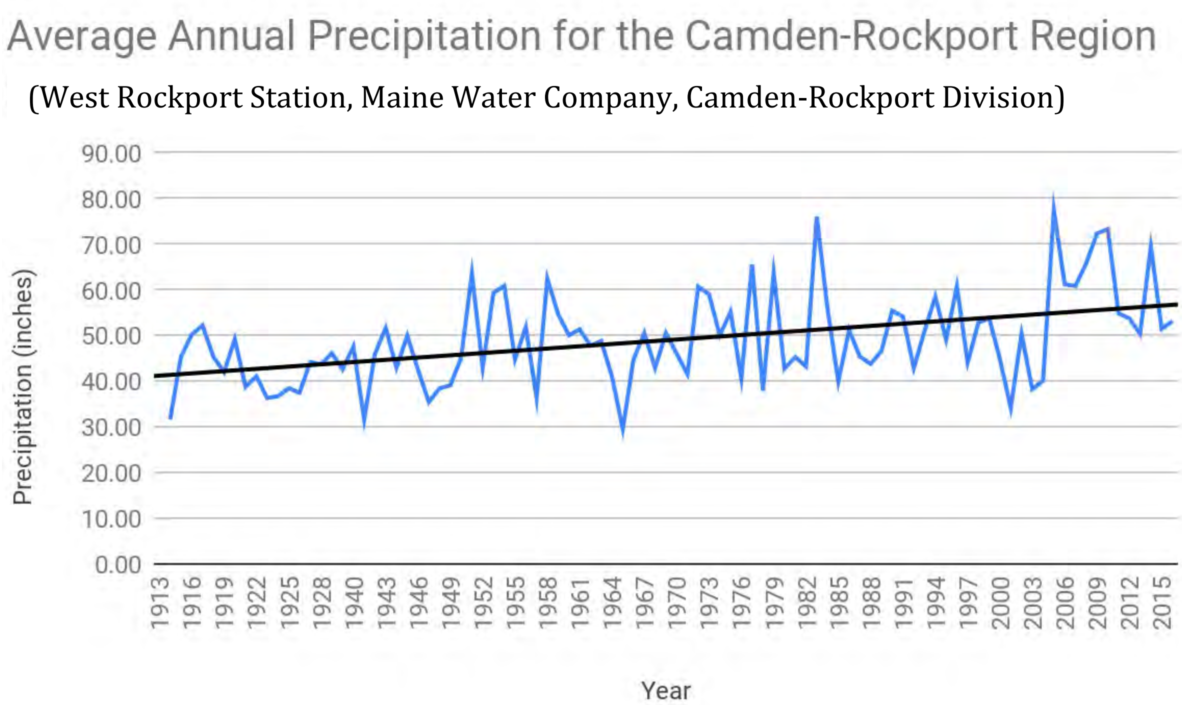

Figure 63. Long-term trend in average annual precipitation in the Camden-Rockport Region. Reprint from Anderson et al. 2019.

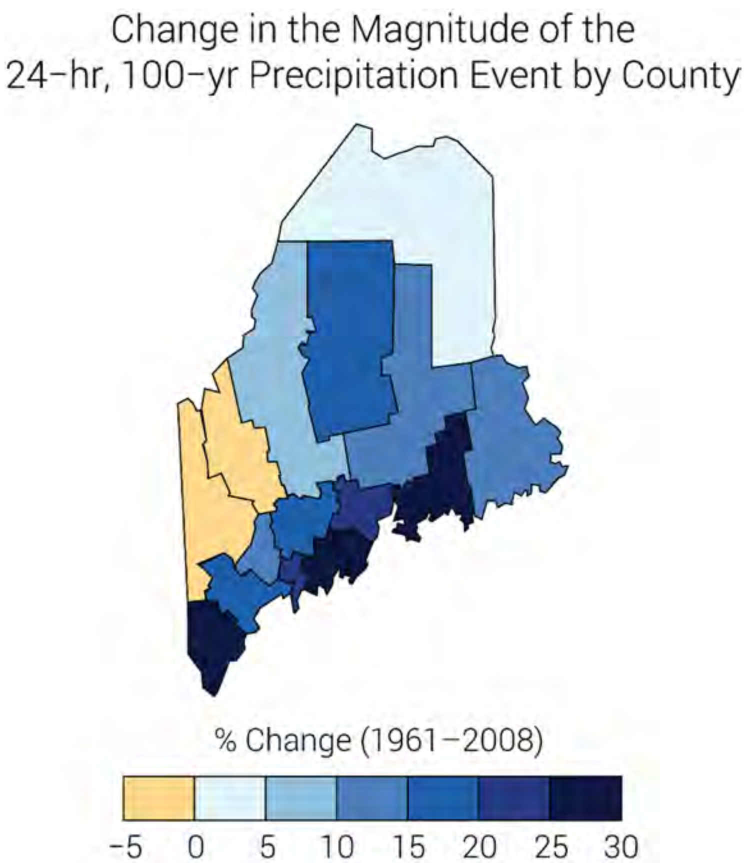

Figure 64. Change in intensity of precipitation by county in Maine. Reprint from Runkle et al. 2017.

4.5.1 Impacts on Streamflow

Maine's rivers, including the Megunticook, display modest seasonal variation of flow in a typical year with the highest magnitude flows occurring in the spring following snowmelt, and the lowest flows occurring in late summer. Climate change effects are leading to shifts in timing, magnitude, and frequency of streamflow in coastal Maine. Researchers have observed increasing March flows and decreasing May flows in New England in general and in coastal Maine in particular over the course of the 20th century. This pronounced change is attributed to earlier snowmelt timing and the shifting of winter/spring flows (Hodgkins and Dudley, 2005). The magnitudes of summer low flows and levels of groundwater have not changed significantly (Hodgkins et al., 2017; Dudley et al., 2019), though the duration of low flows may increase (MCC STS 2020). Coastal Maine has experienced extended late summer drought conditions in recent years.

Peak flows, especially for moderate flood events, are increasing in frequency and magnitude in Maine. The annual flood, which often occurs during the snowmelt season, increased by 19% between 1966 and 2015 (Dudley et al. 2018), and increases in moderate floods such as the 2- to 10-year peak flow events appear to be attributable to increases in precipitation (MCC STS 2020). Nevertheless, it remains unclear whether these floods will continue to increase along with precipitation, or if they will decrease with decreased snowpack and increased temperatures (Hodgkins and Dudley 2013).

Trends for larger floods such as the 100-year event are less clear, because of the characteristic infrequency of these events, and because of the variety of factors beyond precipitation that influence flooding. The projected trajectory of these large floods may increase or decrease depending on the particular modeled climatic changes (MCC STS 2020, Hodgkins and Dudley 2013). Decreases in major floods may be attributable to reduced snowpack, leading to shifts in timing and magnitude of peak runoff events. Alternatively, increases in these floods may instead result from increased potential for rain on snow events.

4.5.2 Sea Level Rise

Sea level rise is a direct consequence of increasing atmospheric CO2 concentrations and temperatures, and is primarily driven by thermal expansion of warming seawater and melting terrestrial ice sheets. Since 1993, sea levels in Maine have increased at a rate of approximately 3 mm per year (Figure 65; MCC STS, 2020). Current scientific projections indicate sea levels in Maine are likely to increase by 1.1 to 1.8 feet by 2050, and 3.0 and 4.6 feet by 2100 under the *Intermediate* sea level rise scenario (MCC STS, 2020). The Maine Climate Council recommended that the State 'commit to manage' for this sea lea rise scenario, but also went on to recommend that the State 'prepare to manage' for the *High* sea level rise scenario, with median estimated increases of 3.0 feet by 2050, and 8.8 by 2100. Sea level rise projections reported here are relative to year 2000 sea levels.

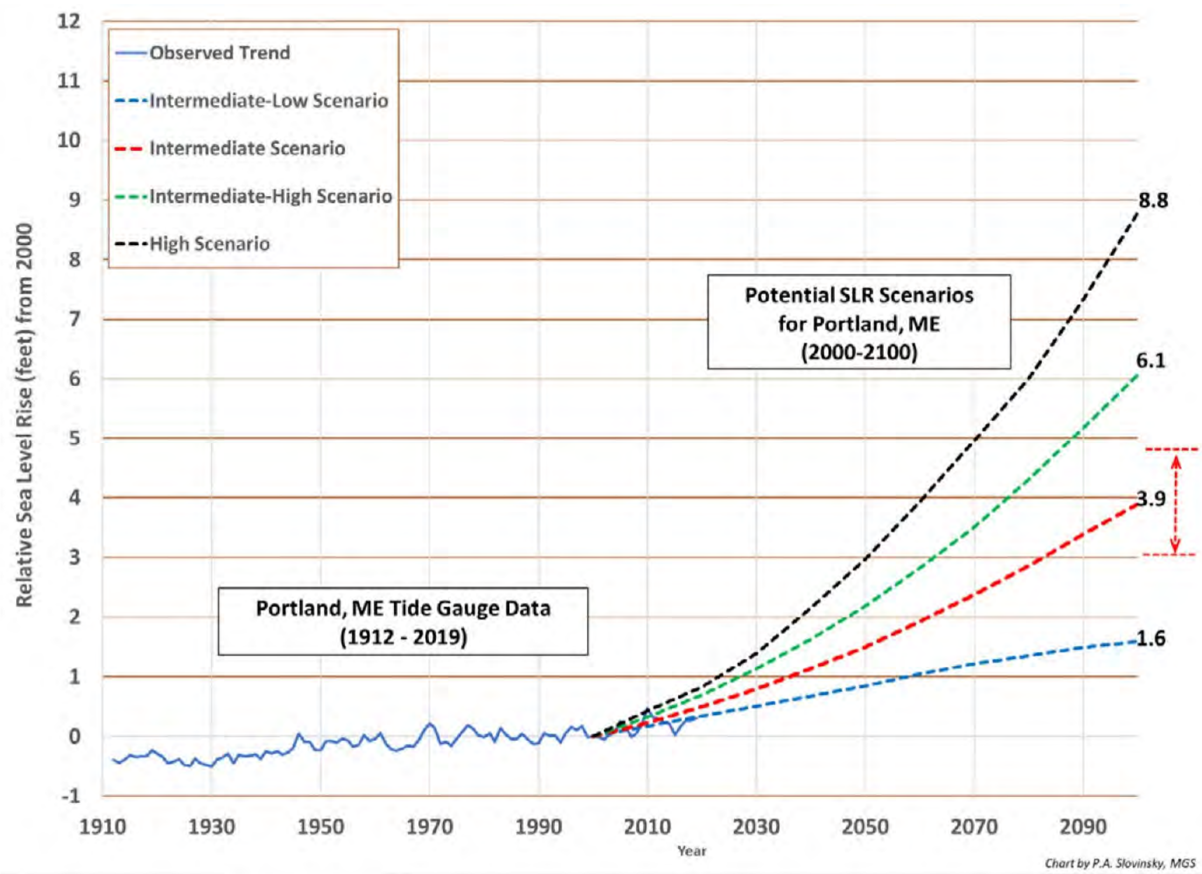

Figure 65. Historical sea level rise in Portland and scenarios from 2000-2010 showing projected trends based on central estimate of selected sea level rise scenarios from Sweet et al. (2017). Reprint from MCC STS 2020.

Near the mouth of the Megunticook River, spring tides (high tide when the sun and moon are in alignment) and storm tides (high tide combined with storm surge) commonly overtop the sea wall and inundate portions of the Harbor Park area. The Town of Camden has initiated vulnerability assessment and resilience planning for the inner harbor and working waterfront area along with the Maine Department of Marine Resources and others (Wood 2019), including integrating specific planning targets in the Town's comprehensive plan.

Figure 66. Tidal inundation of Harbor Park area in October 2019. Image credit: Jeff Senders.

Inter-Fluve collected tidal data in October and November 2020 to localize tidal datums in Camden Harbor (Table 5), which correlate elevations with specific phases of the tidal cycle during this period of observation. These observed datums provide a snapshot of tidal levels in Camden Harbor and will be used to determine potential boundary conditions for hydraulic modeling of the Megunticook River and Montgomery Dam. Selected sea level rise estimates would be added to these datums to project the impact of sea level rise on inundation patterns in the Harbor Park area.

Table 5. Tidal datums calculated for the data collection period October 8 to November 24, 2020 at Camden Harbor.

Datum	Elevation (ft, NAVD88)
MHHW	5.384
MHW	5.007
DTL	0.067
MTL	0.067
MSL	0.085
MLW	-4.873
MLLW	-5.214

4.5.1 Implications for Flooding Patterns

Hydraulic modeling results discussed later in this report demonstrate that moderate flood events (the 5-, 10-, and 25- year flood events) interface with existing infrastructure along the Megunticook River and overtop the channel banks at various cross sections in the Town area. These moderate flood events are likely to occur more frequently in future years (MCC STS 2020), increasing strain on infrastructure near the river.

Removal of the existing dams along the river that are candidates for decommissioning (Montgomery, Knox Mill, Knowlton Street, and Powder Mill) will provide greater resilience to hydrologic intensification than options which retain the dams in several key ways. First, the removal of aging dam structures eliminates the risk of structural failure of each dam, while maintenance and operation costs of the dams are similarly eliminated. Second, dam removal reduces the elevation of flood water surface profiles, reducing potential flood impacts upstream of each dam. Third, dam removal increases floodplain storage in formerly impounded areas, reducing flood elevations, slowing flow in overbank areas, and creating ecologically important lateral connections between the channel and floodplain areas. Lastly, dam removal provides a substantial buffer against the uncertainty in future flow conditions, by providing the maximum amount of flow capacity along the river.

4.5.2 Implications for Fish Migration and Habitat

Climate change may impact fish passage in several ways. Shifts in peak spring flows to earlier months may lead to relatively lower flows during the principal fish migration period in May and June, or may lead to shifts in the timing of fish migration due to collateral effects, including shifts in seasonal water temperatures. Hydrologic intensification may result in more frequent flood conditions or low flow conditions, so that flow is more varied, with greater chance of typical conditions near the extremes of monthly flow distributions predicted for the watershed. Increasing floods may also flush aquatic insects and other food sources from streams (MCC SRS, 2020). Earlier spring thaw and increased runoff from extreme precipitation events is leading to warming trends in Maine's lakes and rivers, which increase thermal stress on coldwater fishes such as the Atlantic salmon and Eastern brook trout, and will contribute to water quality issues detrimental to fish (MCC SRS, 2020). These shifts may directly affect fish passage potential, habitat availability, and habitat quality.

4.6 HYDROLOGY AND HYDRAULICS

Inter-Fluve evaluated the hydrologic characteristics of the Megunticook River and hydraulic patterns along the study reach.

4.6.1 Hydrologic Analysis

The hydrologic analysis gives us insight into flow conditions along the study reach for periods of low, normal, and peak flood flows. The Megunticook River is an ungaged stream with no long-term measurements of stream flow, therefore flow conditions must be estimated using statistical methods. As part of this work, we reviewed two historical hydrologic analyses by others (FEMA, MEDOT). In addition, we performed our own independent analyses using two standard statistical methods. The following paragraphs describe the data sources and methods we used to perform this analysis. Table 6 summarizes the results.

First, Inter-Fluve reviewed the results of the historical hydrologic and hydraulic analysis for the Megunticook River reported in the May 4, 1988 Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) report. This historical study was completed by Stone and Webster Engineering Corporation in April 1986. The 1988 FIS was subsequently integrated into the 2016 county-wide Knox County FIS (FIS Number 23013CV000A; FEMA 2016).

Second, Inter-Fluve reviewed a hydrologic analysis, performed by Maine DOT in 2014, to develop rehabilitation designs for the Washington Street ('Bakery') Bridge (MEDOT 2014). The Maine DOT study used the U.S. Geological Survey (USGS) Regional Regression Equation Method (described below) and included a supplemental estimate of the 1.1-year return period peak discharge.

Third, Inter-Fluve performed an independent analysis using the most current USGS regression equations to estimate discharge frequency statistics for the Megunticook River for a suite of typical flow conditions (Dudley 2015) and a suite of peak flood flows (Hodgkins 1999). These calculations were accomplished with the USGS StreamStats web-based application. The StreamStats application is a web-based user interface that estimates the hydrologic characteristics of watersheds, then implements the most current region-specific regression equations to estimate streamflow. For the purpose of this feasibility study, flows for the watershed were determined at the downstream limit of the study area near Camden Harbor.

Fourth, Inter-Fluve performed a gauge-transfer analysis using data from the USGS stream gage on the Ducktrap River near Lincolnville, Maine (USGS Gage No. 01037380) to estimate seasonal flows relevant to fish migration periods. The contributing area to the Ducktrap River gage is approximately 14.9 square miles, which is approximately half of the drainage area of the Megunticook River at Camden Harbor (31 square miles). Both watersheds share general land use and topographic characteristics. The Ducktrap River is less developed in its lower reaches than the Megunticook River, with open water area (3.7 percent compared to 7.9 percent). We estimated the average daily flows for the fish passage period of May and June at the Ducktrap River gage to the Megunticook River using basin transfer methods.

Table 6 summarizes the peak flow estimates reported in the historical FEMA FIS and the MEDOT hydraulic report and the new analyses we performed using the USGS Regression Equation method. Table 7 and Table 8 summarize estimates of typical flows and fish passage flows of interest, respectively. Fish passage flows are correlated with the percentage of time a discharge value is exceeded during a given month. For example, the 5% May flow (291 cfs) represents the discharge which is exceeded 5% of the time during May, and the 95% May flow (34 cfs) is exceeded 95% of the time during May.

Table 6. Peak flood flows in the Megunticook River.

Average Return Period (Years)	Annual Exceedance Probability (%)	Discharge (MaineDOT) (cfs)	Discharge (Hodgkins, 1999) (cfs)	Discharge (FEMA, 2016) (cfs)
1.1		375		
2	50%	720	724	
5	20%	1,090	1,090	
10	10%	1,360	1,360	1,095
25	4%	1,710	1,710	
50	2%	1,980	1,980	1,710
100	1%	2,270	2,270	2,030
500	0.2%	2,980	2,980	2,920

Table 7. Typical monthly flows in the Megunticook River based on regression equations (Dudley 2015).

	Discharge (cfs)	
Month	**mean**	**median**
January	50	27
February	63	36
March	91	90
April	111	92
May	130	110
June	58	39
July	20	7
August	11	3
September	12	3
October	47	14
November	85	54
December	75	48
Annual flow	63	28
Summer low-flow (7Q10)		1.3

Table 8. Estimated average daily flow during the fish passage period of May and June flows in the Megunticook River based on regression equations (Dudley 2015) and gage transfer from the Ducktrap River gage.

	Dudley (2015) Regression Equations		***Basin Transfer Ducktrap River Gage Simple Drainage Area Ratio***		***Basin Transfer Ducktrap River Gage Exponential Drainage Area Ratio***	
Exceedance %	**May Discharge (cfs)**	**June Discharge (cfs)**	**May Discharge (cfs)**	**June Discharge (cfs)**	**May Discharge (cfs)**	**June Discharge (cfs)**
5%	291	143	218	190	248	210
50%	110	39	59	24	65	26
95%	34	15	14	4	15	4

Hydraulic analysis results in the following sections reference the peak flow estimates derived from the current regression equations (utilized by MEDOT/StreamStats) because they are greater in magnitude and more complete than the estimates in the FEMA FIS, and should contribute to a conservative view of flooding along the Megunticook River.

Our hydrologic and hydraulic analyses rely on the latest regional streamflow estimation methods for peak flows and typical flows in Maine. These flows span the entire range of flows likely to be encountered in the watershed. Accurate projections of the frequency and magnitude of flows in the future are not available for the region. Thus, we use the current flow estimates as a guidepost for assessment purposes, but do not presuppose that these estimates are fully reflective of future conditions of the Megunticook River.

In general, the application of the flow estimates in hydraulic modeling are made to evaluate relative trends between scenarios, as opposed to absolute predictions. In this manner, a portion of the uncertainty regarding future flow conditions cancel out because both the existing conditions-future flows and restoration conditions-future flows scenarios are susceptible to the same hydrologic uncertainty. To explore the potential impact of increased flow magnitudes which may result from climate change, the user is able to review the range of conditions represented by successively high peak flow values represented by less frequent, higher magnitude flood events.

4.6.2 Regulatory FEMA Floodplain

One objective of this feasibility study is to document baseline characteristics of the Megunticook River watershed and to assess the feasibility of managing the existing dams to provide flood management and environmental benefits, including restored fish passage.

The river hydraulics in the Megunticook River were previously analyzed to support the 1988 FEMA FIS and integrated into 2016 county-wide FIS (FEMA 2016). The hydraulic analysis that supported the 1988 FIS was used to establish the FEMA regulatory floodplain. The following sections[4] detail

[4] The sections listed are based on the organization of the FIS, and therefore differ in extent to the reaches identified for organizing the stream reaches in this report.

the FEMA profiles over reaches that correspond to the extent of the profiles as shown on each profile page in the FIS.

Montgomery Dam to Knox Mill Dam

The FEMA FIS flood profile for the reach between Camden Harbor and Knox Mill Dam is presented in Figure 67. The profile from the FIS in the study area suggests the influence of Montgomery Dam on flood levels extends to a location just downstream of the Brewster building (the former Brewster Shirt Factory, labeled as the Highland Mill on the profile figure). The regulatory floodplain extends onto as many as 15 private and 2 public properties along the Montgomery Dam impoundment.

Knox Mill Dam to Powder Mill Dam Ruins

The FEMA FIS flood profile for the reach between Knox Mill Dam and Powder Mill Dam Ruins is presented in Figure 68. The profile from the FIS in the study area suggests the influence of Knox Mill extends to a location downstream of Knowlton Street. The FIS profile also demonstrates that Knowlton Dam (labeled Great Mill Works Dam on the FIS profile) extends to a location downstream of Rawson Avenue. The profile demonstrates both Rawson Avenue and Washington Street influence the elevations of flood flows. The regulatory floodplain extends onto as many as 9 properties along the Knox Mill impoundment. Along the Knowlton Street Dam impoundment, the regulatory floodplain extends onto as many as 36 properties. Between Rawson Avenue and the Powder Mill Dam Ruins, as many as 23 properties are located within the regulatory floodplain.

Powder Mill Dam Ruins to Megunticook Lake

The FEMA FIS flood profile for the reach between the Powder Mill Dam Ruins and Megunticook Lake is presented in Figure 69. The profile from the FIS suggests the influence of the Powder Mill Dam Ruins extends to a location downstream of Mount Battie Street. The FIS profile demonstrates that Mount Battie Street influences the flood profile to Seabright Dam. Both Seabright Dam (labeled Seabright Dam) and the East/West Dams are shown to have influences on flood flows throughout their respective impoundments. The regulatory floodplain extends onto as many as 9 properties between the Powder Mill Dam Ruins and Mount Battie Street. A further 6 properties lie within the regulatory floodplain adjacent to the Seabright Dam impoundment. Two (2) properties lie within the regulatory floodplain in the study area within 500 feet of Molyneaux Road.

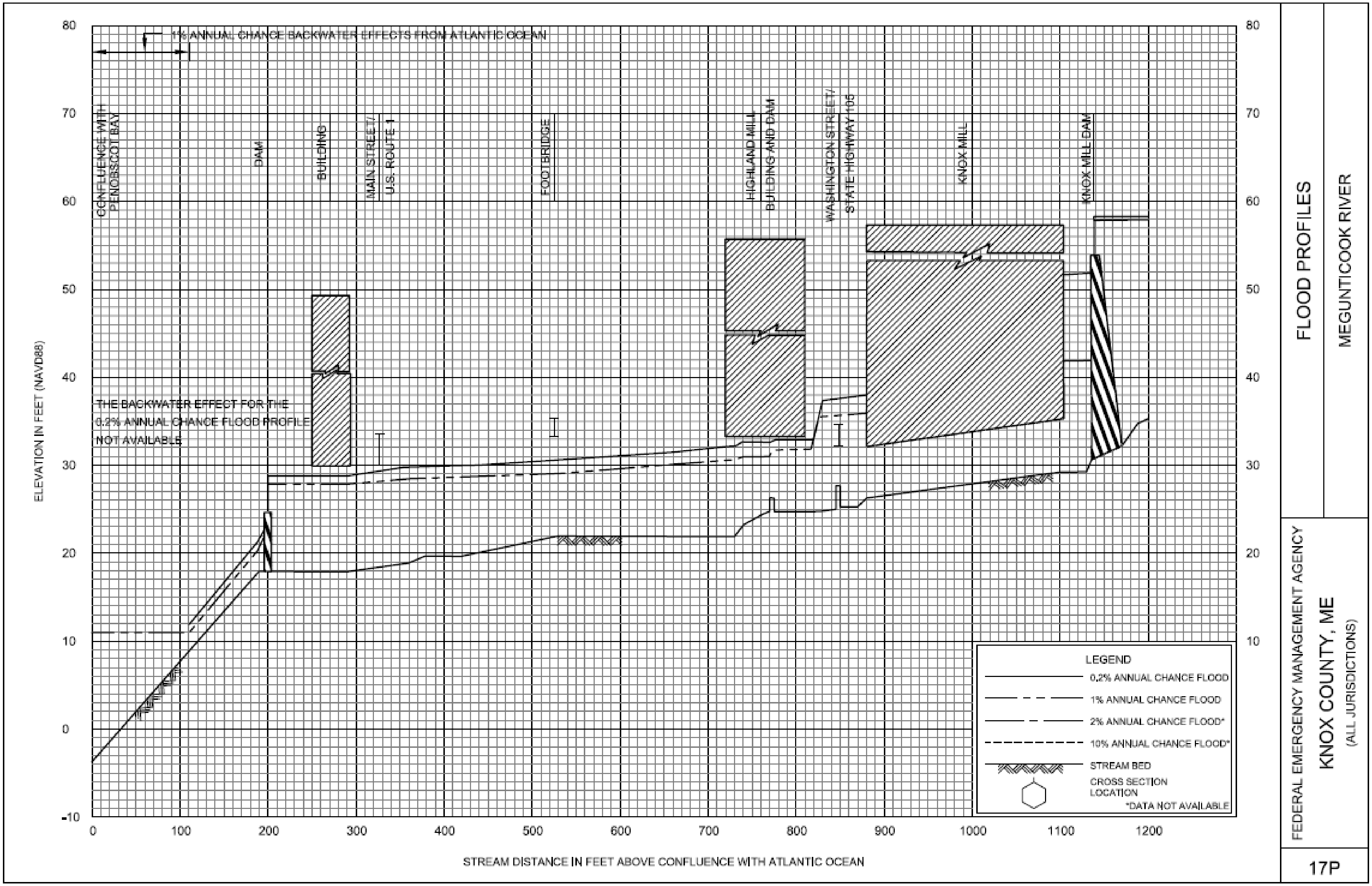

Figure 67. Flood profiles in the reach between Montgomery Dam and Knox Mill Dam from the 1988 FIS (FEMA, 2016).

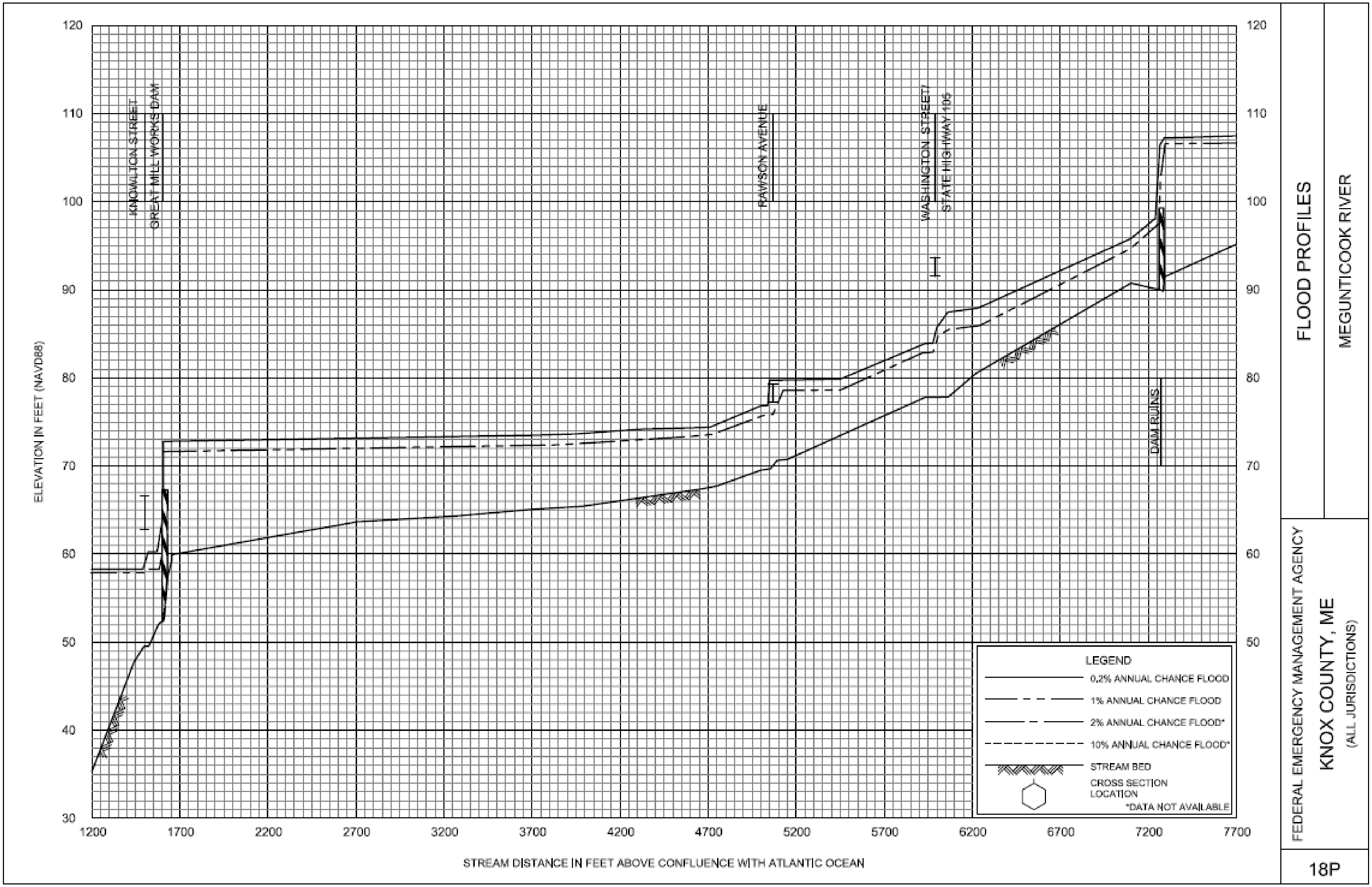

Figure 68. Flood profiles in the reach between Knox Mill Dam and Powder Mill Dam Ruins from the 1988 FIS (FEMA, 2016).

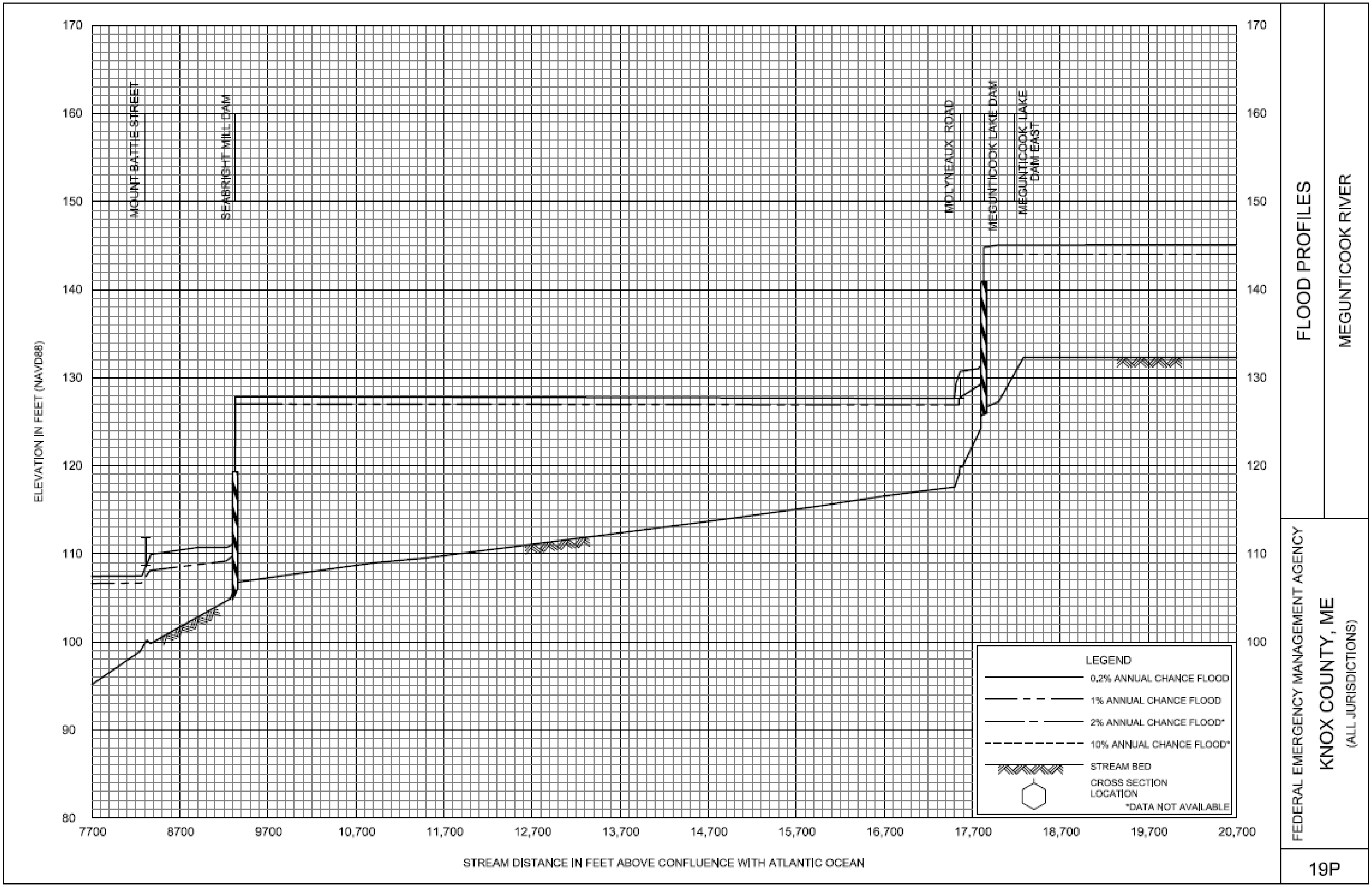

Figure 69. Flood profiles in the reach between Powder Mill Dam Ruins and Megunticook Lake from the 1988 FIS (FEMA, 2016).

4.6.3 Hydraulic Model Development

For this study, we developed hydraulic models to 1) simulate existing conditions and 2) evaluate potential hydraulic impacts over the short- and long-term arising from removal of the four lower dams. These dams-removed models serve to bookend the immediate and eventual conditions of the Megunticook River if the dams were to be removed, and are intended to facilitate more detailed evaluations of potential actions throughout the river.

Inter-Fluve developed a one-dimensional step-backwater hydraulic model of the Megunticook River using HEC-RAS Version 5.0.7 (USACE 2016). The model was used to simulate existing conditions and potential future conditions following the potential removal of selected dams. The hydraulic model extends from a point upstream of the East and West Dams at the outlet of Megunticook Lake to the Camden Inner Harbor, and includes dams, bridges, and other relevant hydraulic structures along the Megunticook River. The model developed for this study extends the model developed for the Montgomery Dam feasibility study, which terminated at Washington Street. Peak flood, typical flows and fish passage flows were considered during this analysis.

The existing conditions hydraulic model geometry upstream of Washington Street is based on field surveys of topography, bathymetry, and hydraulic structures conducted from July to October 2020 by Inter-Fluve and Gartley & Dorsky. The survey downstream of Washington Street was completed primarily in May and June 2018. Survey data was combined in AutoCAD Civil 3D and in GIS with topographic LiDAR to create a seamless terrain surface representing the topography and bathymetry. Model cross-sections co-located with survey cross sections (1) sampled this surface to define overbank geometry, and (2) used survey points within the river channel to define in-channel geometry.

Inter-Fluve used survey data, available MEDOT bridge plans, and available drawings of dams to define bridge, culvert, and inline structures within the model. Field observations and survey were also used to define ineffective flow areas, blocked obstructions, and bank stations within the model. Expansion and contraction coefficients were adjusted at bridges following the guidance in the user’s manual. Roughness values (Manning's n) were assigned to overbank areas using data obtained from the National Land Cover Database (NLCD) 2016 dataset available from the USGS. Channel and floodplain roughness values were assigned based on field observations, and through consideration of published reference methods (Arcement & Schneider 1989).

Future conditions hydraulic models were developed from the baseline existing conditions hydraulic model. Two future scenarios were investigated for this study. The first scenario considered hydraulic changes to the Megunticook River immediately following the removal of the Montgomery, Knox Mill, Knowlton and Powder Mill dams. This scenario did not consider changes to Seabright Dam or the East/West Dams as fish passage restoration options will not change water levels at those dams. This scenario represents an immediate post-removal snapshot of river conditions, assuming no sediment management has been completed.

The second future conditions scenario considered probable changes to the main channel of the Megunticook River after the river has adjusted to a new equilibrium condition following dam removal. To simulate hydraulic conditions representative of the long-term evolution of the channel, we developed a model geometry that included probable future channel geometry through the former impoundments at Montgomery, Knox Mill, Knowlton Street and the Powder Mills Dam Ruins dams. Channel geometries for this condition were estimated from analogue cross sections upstream of the respective impoundments, integrated with evidence of the pre-dam conditions determined from depth of refusal probing, and observations of bedrock in the vicinity of the dam sites.

4.7 FLOOD PATTERNS BASED ON HYDRAULIC MODEL RESULTS

Model Results

Results of the three model scenarios (Existing Conditions, Dams Removed, and Long Term Restored) are presented in the following section. The following paragraphs provide an overview of general trends, followed by more detailed results for each of the study reaches.

Under existing conditions, the water surface profile along the river is primarily controlled by the dams, which reduce the river's slope and velocity within their impoundments. Dam removal results in increased water surface slope and velocity upstream of each dam, with limited downstream changes that depend on site-specific hydraulic characteristics. The hydraulic changes associated with dam removal are expected to be most notable in the vicinity of each structure, due to the relatively steep slope of the river, and the bridges and other hydraulic structures which serve as hydraulic controls during floods.

Overall, under existing conditions, flow velocities are greatest in the steep reach between Knowlton Street Dam and Camden Harbor, and are moderated in upstream areas within the Knowlton and Seabright Dam impoundments. Flow velocities are estimated to reach 10-15 feet per second (ft/s) during the 100-year event and 7-9 ft/s during the 2-year event in the reach downstream of Knowlton Street Dam. During the mean May flow, flow velocities are estimated to range from 3 to 5 ft/s.

Both future dam removal scenarios demonstrate lowered water surface profiles and increased flow velocities through the former impoundments of the removed dams. For example, the model demonstrates that flow velocity upstream of Knowlton Street Dam would increase from 1-2 ft/s under existing conditions to 1.5-3 ft/s following dam removal for the 100-year event. For that scenario, the change in velocity decreases with distance upstream of the dam, and the model demonstrates no change in velocity or water surface elevation upstream of Rawson Avenue until the Powder Mill Dam ruins. A similar trend occurs with simulations of dam removal at Montgomery Dam, Knox Mill Dam, and the Powder Mill Dam ruins.

4.7.1 Reach 1: Harbor to Main Street (Montgomery Dam)

The reach between Camden Harbor and Main Street contains Montgomery Dam, the lowest dam on the Megunticook River. Inter-Fluve prepared a detailed feasibility and alternatives analysis report for the removal or modification or Montgomery Dam to facilitate aquatic organism passage (Inter-Fluve 2019[5]). Results for this reach duplicate the results presented in the 2019 study.

Flood Conditions

The reach between Camden Harbor and Main Street would be substantially impacted by the removal of Montgomery Dam. The flood profile during the 100-year event would be reduced by 9.2 and 3.9 feet upstream of Montgomery Dam and downstream of the Main Street bridge, respectively (Table 9; Figure 70 and Figure 72). At the Main Street bridge, the reduction in water surface elevation is greater for higher-frequency, lower magnitude events because the backwater created by Montgomery Dam is larger at more moderate flood than at the most extreme floods. During large flood events, the Main Street bridge constricts flow. Inundation extents of the 100-year flow would decrease downstream of Main Street under the dam removal scenario, though flood extents and elevations would be affected by the specific dam modification or removal scheme at Montgomery Dam (Figure 74). Further discussions of options at Montgomery Dam can be found in the feasibility report prepared by Inter-Fluve (2019).

Table 9. Estimated change in water surface elevation for select flood flows between Camden Harbor and Main Street, comparing existing conditions to the long term restored river scenario.

Location	Estimated Change in Water Surface Elevation (ft)		
	100-year	10-year	1.1-year
Downstream of Montgomery Dam	0.0	-0.4	0.0
Upstream of Montgomery Dam	-9.2	-8.6	-8.5
Downstream of Main Street Bridge	-3.9	-5.0	-6.2

[5] The Montgomery Dam feasibility study report can be found on the Town website at the following link: https://cms8.revize.com/revize/camdenme/Montgomery%20Dam%20Feasabilty%20Alternative%20Analysis%20Report.pdf

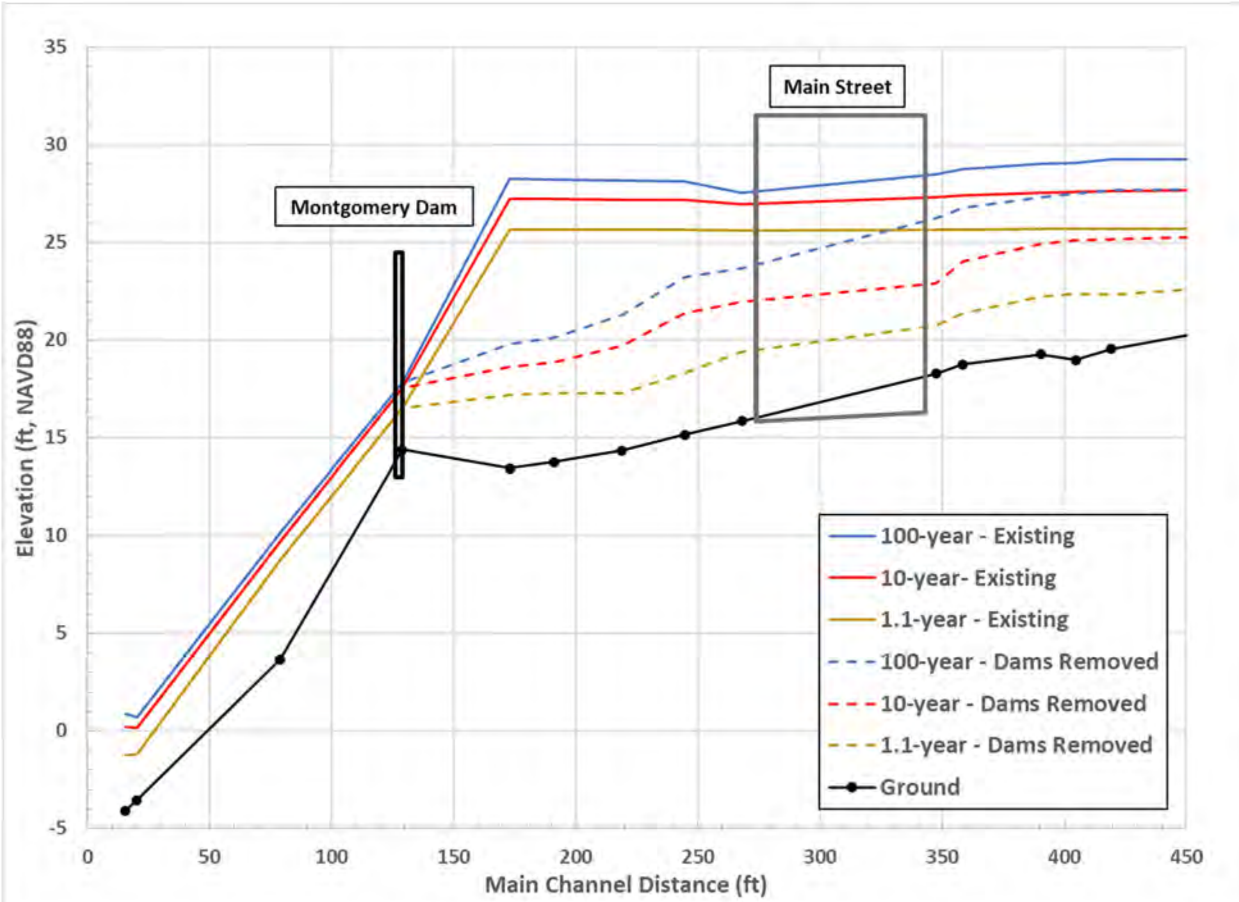

Figure 70. Simulated flood water surface profiles for the reach from Montgomery Dam to Main Street. Solid lines denote existing condition profiles; dashed lines denote water surface profiles associated with the long term restored river model scenarios. Flow events shown include the 100-year, 10-year, and 1.1-year events.

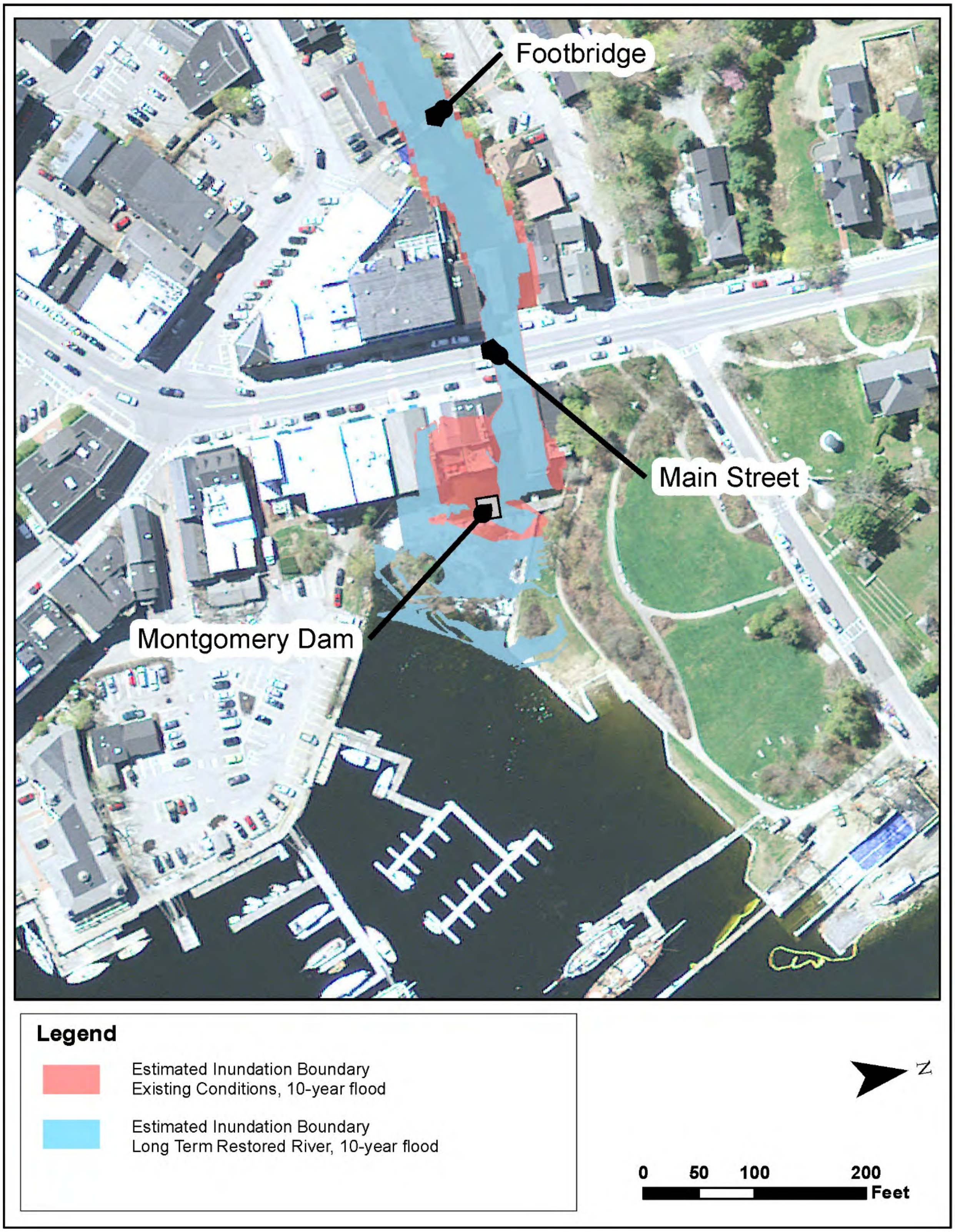

Figure 71. Estimated inundation extents in the reach between Camden Harbor and Main Street for the 10-year return period flood event for existing conditions and for the long term restored river scenario. Inundation at the road crossing is for the river channel beneath the bridge, model results do not indicate road overtopping at the simulated flow event.

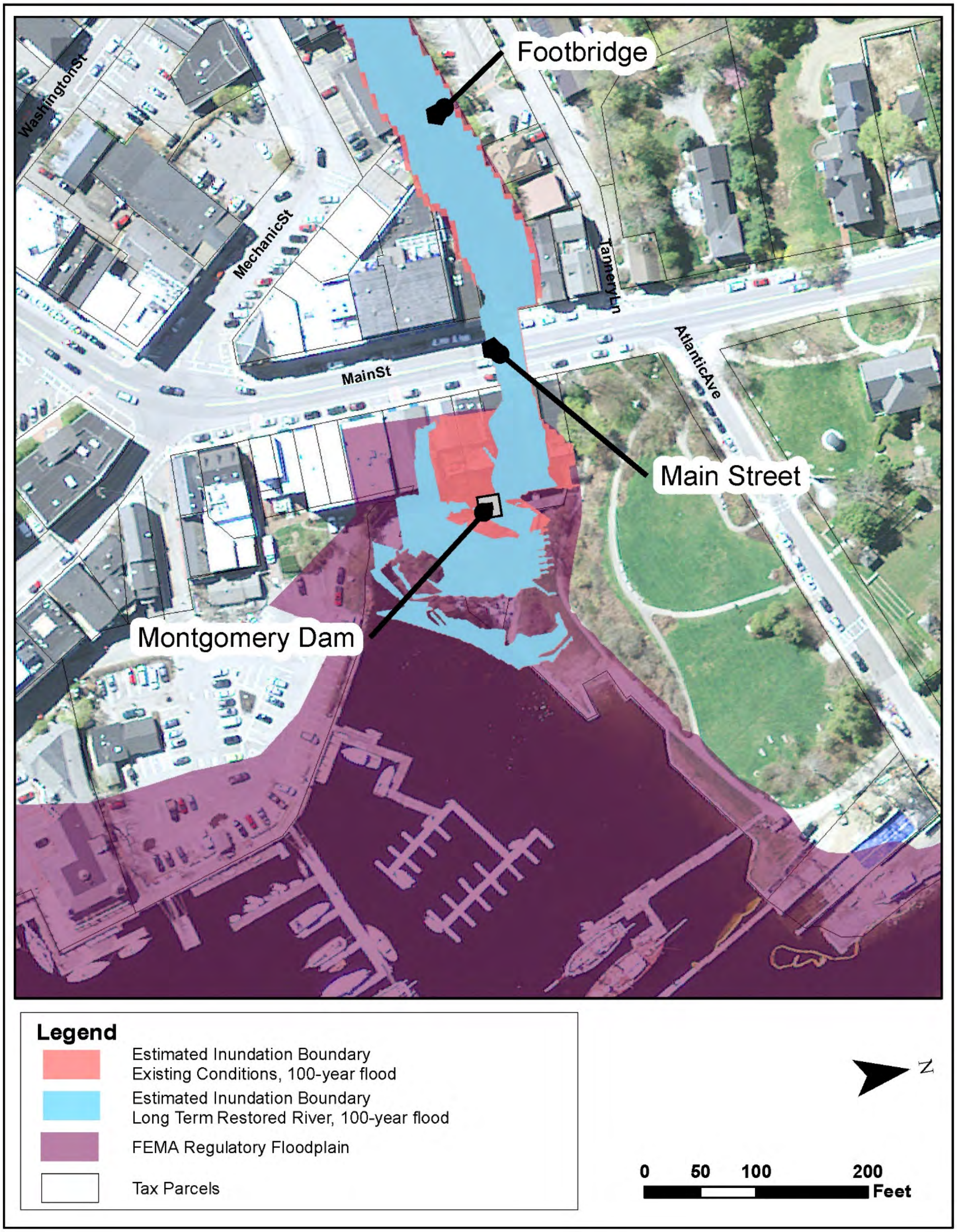

Figure 72. Estimated inundation extents in the reach between Camden Harbor and Main Street for the 100-year return period flood event for existing conditions and for the long term restored river scenario. Inundation at the road crossing is for the river channel beneath the bridge, model results do not indicate road overtopping at the simulated flow event.

4.7.2 Reach 2: Main Street to Knowlton Street (Knox Mill Dam & Brewster Shirt Factory)

The reach between Main Street and Knowlton Street contains Knox Mill Dam and a waterwheel with a series of small weirs beneath the former Brewster Shirt Factory, just downstream of Washington Street, which bisects the reach. Overbank areas within the reach are heavily developed along both banks of the river, and in many places the river is confined between buildings and structures on either bank. The overall slope of the reach is 2.4%. The area around Washington Street is notable because current the effective FEMA floodplain extends to the Camden public safety building, located adjacent to the crossing. The surrounding area is low-lying in elevation.

Under existing conditions, Knox Mill Dam creates a small impoundment downstream of Knowlton Street. While initially not a key feature for the study, sensitivity testing with the hydraulic model suggests that the relict water control features beneath the Brewster Shirt Factory building, and the adjacent Washington Street bridge both influence the overbank flooding near the public safety building.

Under the Knox Mill dam removal scenario, headcutting through the impoundment is not likely due to the limited amount of accumulated sediment, coarse substrate, and exposures of bedrock. Therefore, simulations of the long-term dam removal scenario consider flow over the bedrock outcrop present at the dam without additional channel evolution in the impoundment. Located near the upstream end of the impoundment, a small relic dam is submerged by the impoundment but locally affects flow with the impoundment drained, resulting in an approximate 3-foot hydraulic drop in the flow profile. Modification of this legacy structure to rearrange the boulders will be required to optimize fish passage at this location with the dam removal scenario.

Flood Conditions

Flood flow hydraulic conditions in the reach between Main Street and Knowlton Street are heavily influenced by Knox Mill Dam, numerous road crossings, and the constricted channel geometry. Backwater effects of hydraulic structures are localized due to the steep slope of the reach. Demonstrated reductions in the flood profile at Main Street and at the footbridge are caused by the removal of Montgomery Dam. Flood profile changes are limited in the subreach reach between the footbridge and Knox Mill Dam solely due to removal of Montgomery Dam and Knox Mill Dam. (Table 10; Figure 73).

After review of these results, preliminary model evaluations were performed to assess the incremental benefit of modifying the waterwheel and weir structures beneath the Brewster building. This analysis suggests additional modest reductions in flood water surface elevations are possible. While modest, these incremental reductions are significant, which potentially could result in removing the public safety building from the floodway. Because this area was not a focus in the initial project discussions (and hence data collection), additional data collection and model refinements in the area are required to more completely resolve the potential improvement resulting from removing the legacy structures beneath the Brewster building.

The estimated reduction in water surface resulting from dam removal is 9.4 feet for the 100-year flow immediately upstream of Knox Mill Dam, and ranges from approximately 5 to 10 feet throughout most of the Knox Mill impoundment (Figure 73). No change in the flood profile is expected at Knowlton Street, as the bridge crossing lies outside the Knox Mill Dam impoundment. Inundation extents of the 10-year flood flow would be reduced and confined within the existing Knox Mill Dam impoundment. Between Knox Mill Dam and Main Street, modeling demonstrates a slight narrowing during the 10-year and 100-year events relative to existing conditions (Figure 74 and Figure 75).

However, the model results showed that flood conditions have likely improved along the river compared to when the effective FEMA floodplain mapping was completed in the 1980s (Figure 75). We interpreted simulated reductions in flood inundation extents as the likely result of changes to the Knox Mill factory buildings (river daylighted through the former factory) and Washington Street bridge (now a clear span, with no center pier). This result would be further affected by modifications beneath the Brewster building, if implemented.

Table 10. Estimated change in water surface elevation for select flood flows between Main Street and Knowlton Street comparing existing conditions to the long term restored river scenario.

Location	Estimated Change in Water Surface Elevation (ft)		
	100-year	10-year	1.1-year
Upstream of Main Street Bridge	-2.3	-4.4	-4.9
Downstream of Footbridge	-1.6	-2.1	-2.2
Upstream of Footbridge	-1.4	-1.3	-1.6
Weir at waterwheel	0.0	0.0	0.0
Downstream of Washington Street	0.0	0.0	0.0
Upstream of Washington Street	0.0	0.0	0.0
Buildings downstream of Knox Mill Dam	0.0	0.0	0.0
Downstream of Knox Mill Dam	0.0	0.0	0.0
Upstream of Knox Mill Dam	-9.4	-9.7	-10.4
Downstream of Knowlton Street	0.0	0.0	0.0

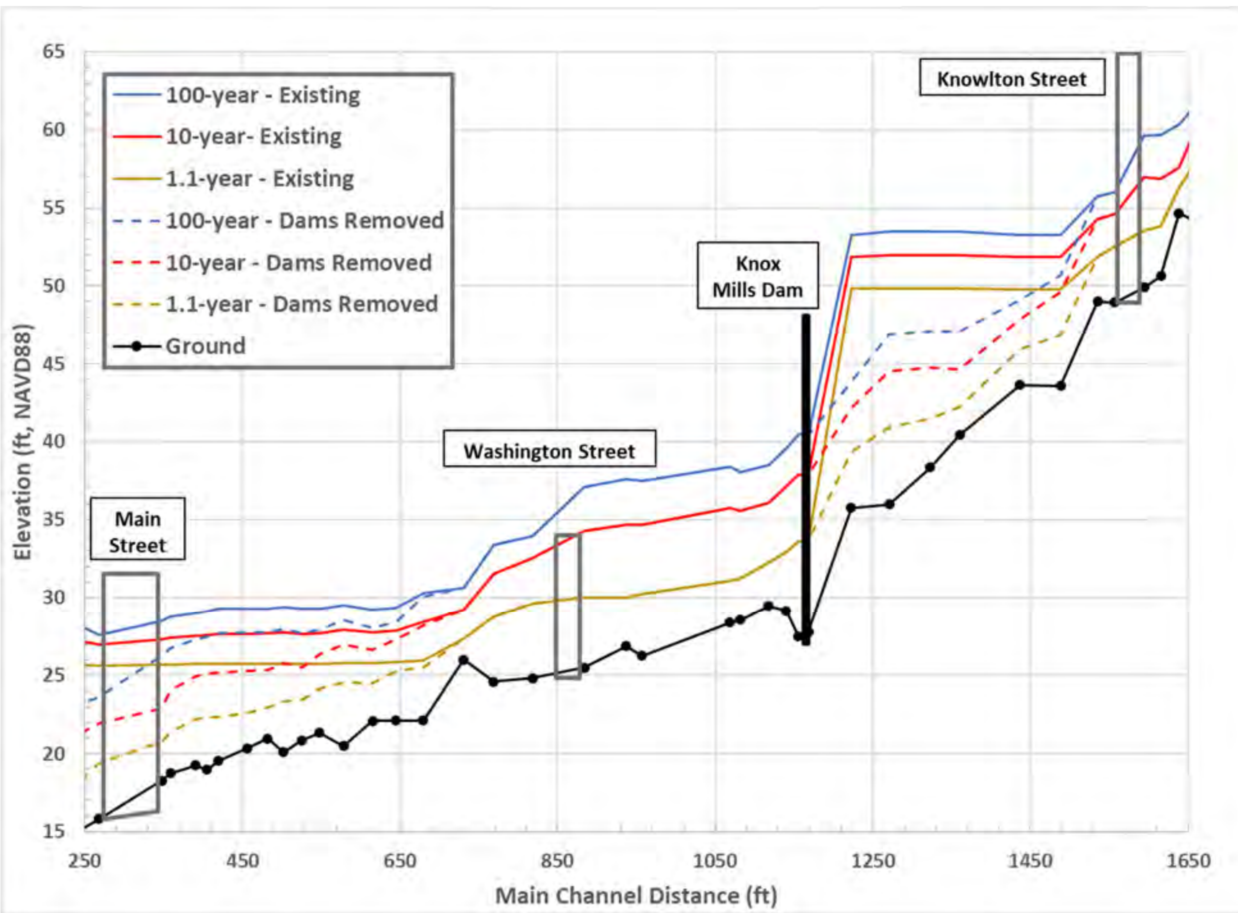

Figure 73. Simulated flood water surface profiles for the reach from Main Street to Knowlton Street. Solid lines denote existing condition profiles; dashed lines denote water surface profiles associated with the long term restored river model scenarios. Flow events shown include the 100-year, 10-year, and 1.1-year events.

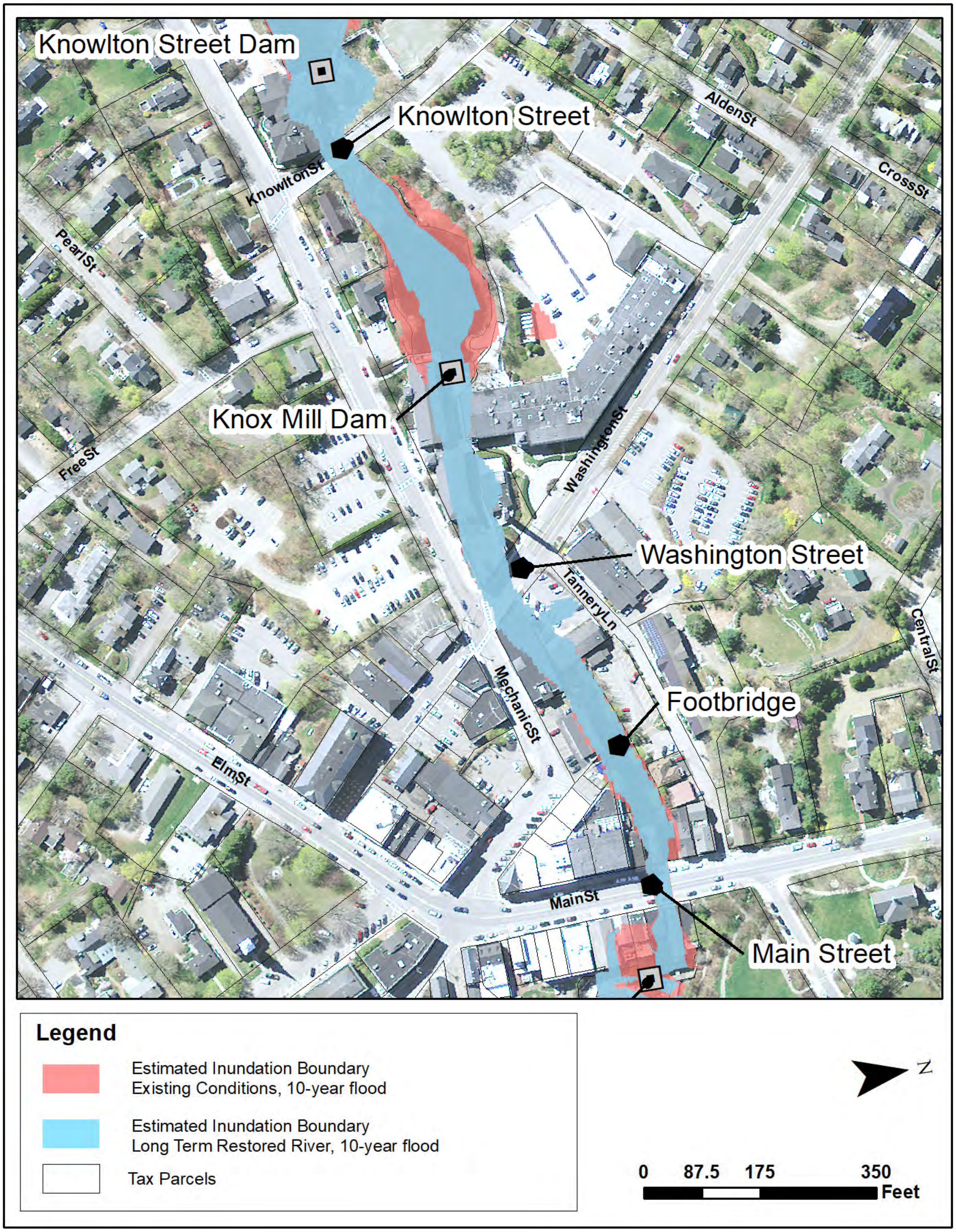

Figure 74. Estimated inundation extents in the reach between Main Street and Knowlton Street for the 10-year return period flood event for existing conditions and for the long term restored river scenario. Inundation at the Main Street and Knowlton Street crossings is for the river channel beneath the bridge, model results do not indicate road overtopping at these bridges. Model results indicate overtopping of the Washington Street bridge.

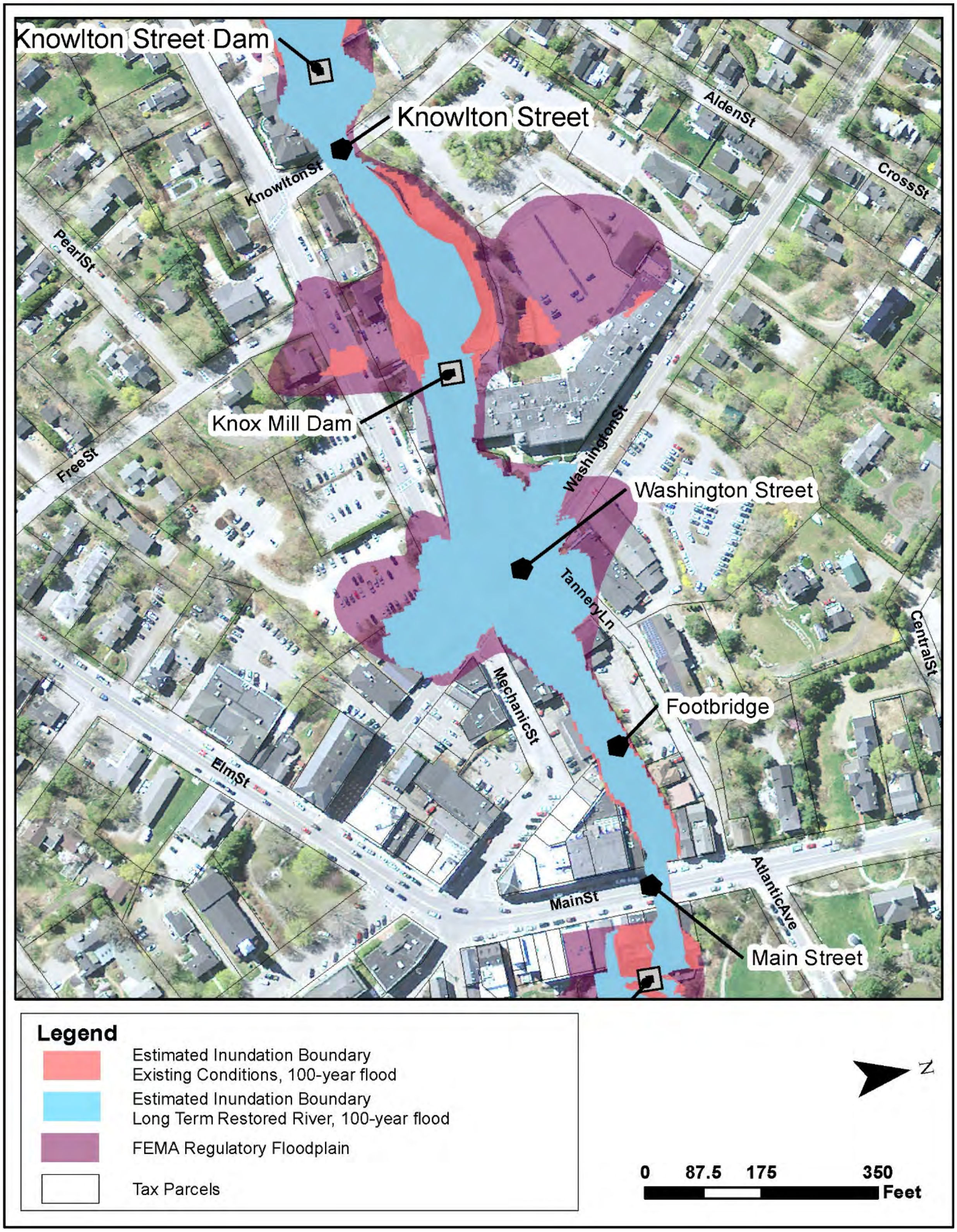

Figure 75. Estimated inundation extents in the reach between Main Street and Knowlton Street for the 100-year return period flood event for existing conditions and for the long term restored river scenario. Inundation at the Main Street and Knowlton Street crossings is for the river channel beneath the bridge, model results do not indicate road overtopping at these bridges. Model results indicate overtopping of the Washington Street bridge.

4.7.3 Reach 3: Knowlton Street to Rawson Ave (Knowlton Street Dam)

The reach between Knowlton Street and Rawson Avenue contains Knowlton Street Dam. The dam is located along a bedrock constriction in the stream, and the reach downstream of the dam is a bedrock channel with a slope of up to 10%. Upstream of the dam, the Megunticook River has a mild slope and is impounded for a distance of approximately 3,300 feet, to a point approximately 200 feet downstream of Rawson Avenue. The impoundment contains 3-10 feet of fine sediments, which have accumulated over time behind the dam. Following the removal of the dam, the stream will incise into the accumulated sediment until the channel reaches equilibrium, or is restored through sediment excavation. This future equilibrium channel condition was factored into the long-term restored condition model scenario.

Flood Conditions

Flood profiles between Knowlton Street and Rawson Avenue are chiefly controlled by Knowlton Street Dam, which is constructed on top of a bedrock outcrop. The reach downstream of Knowlton Street Dam is a steep bedrock and boulder channel with a slope of approximately 10%. Hydraulic modeling demonstrates that this area would not experience changes in water surface elevations up following dam removal for the 100-year flow event (Table 11; Figure 76). At Knowlton Street Dam, a reduction in water surface elevation of 4.1 feet is predicted for the 100-year flow event, and a reduction of 0.8-4.1 feet is expected throughout the impoundment following either restoration or long-term evolution of the channel within the impoundment, assuming the channel's geometric characteristics eventually take the form of the reach upstream of the impoundment. The Rawson Avenue bridge is upstream of the impoundment and no change to flood profiles is predicted at this location. Modeling suggests inundation extents of the 10-year and 100-year flow will be confined within the existing impoundment in the downstream half of the Knowlton Street Dam impoundment, and will occupy a broader low-lying area in the upper half of the impoundment (Figure 77 and Figure 78).

Table 11. Estimated change in water surface elevation for select flood flows between Knowlton Street and Rawson Avenue comparing existing conditions to the long term restored river scenario.

Location	Estimated Change in Water Surface Elevation (ft)		
	100 -year	10-year	1.1-year
Upstream of Knowlton Street	0.0	0.0	0.0
Downstream of Knowlton Street Dam	0.0	0.0	0.0
Upstream of Knowlton Street Dam	-4.1	-4.1	-4.5
125 feet upstream of Dam	-2.0	-2.4	-2.9
Downstream of Rawson Avenue	0.0	0.0	0.0

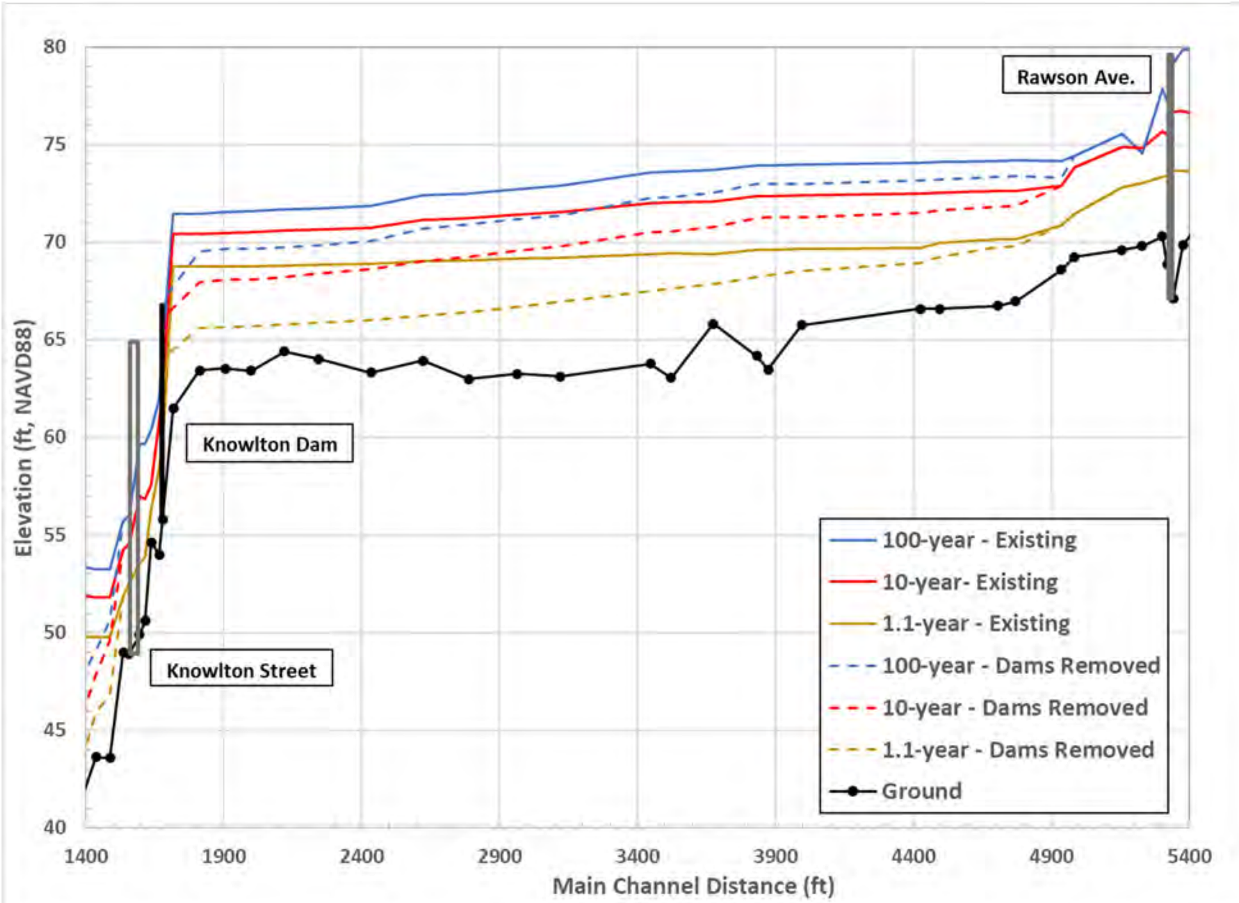

Figure 76. Simulated flood water surface profiles for the reach from Knowlton Street to Rawson Avenue. Solid lines denote existing condition profiles; dashed lines denote water surface profiles associated with the long term restored river model scenarios. Flow events shown include the 100-year, 10-year, and 1.1-year events.

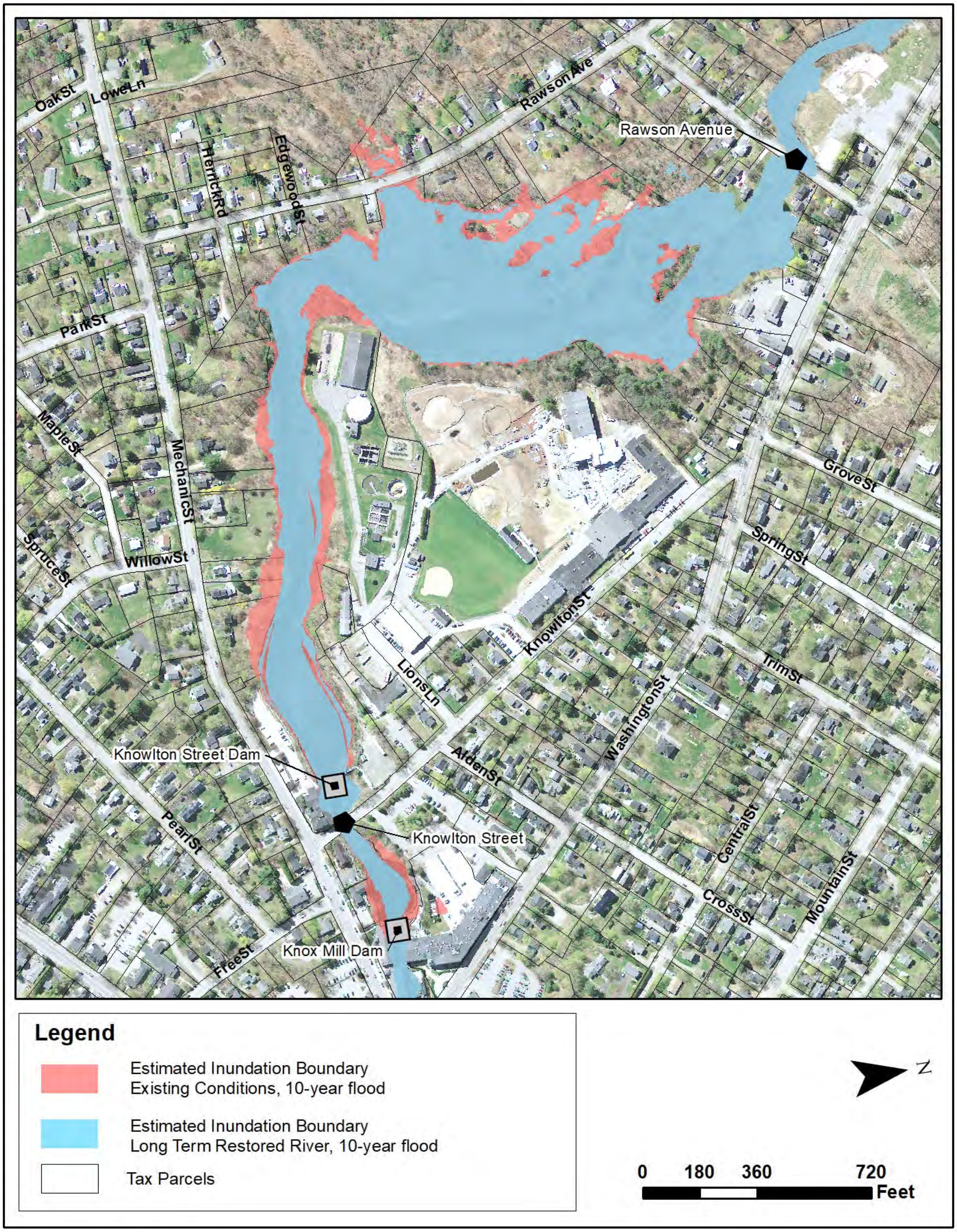

Figure 77. Estimated inundation extents in the reach between Knowlton Street and Rawson Avenue for the 10-year return period flood event for existing conditions and the long term restored river scenario. Inundation at the road crossings is for the river channel beneath the bridge, model results do not indicate road overtopping at the simulated flow event.

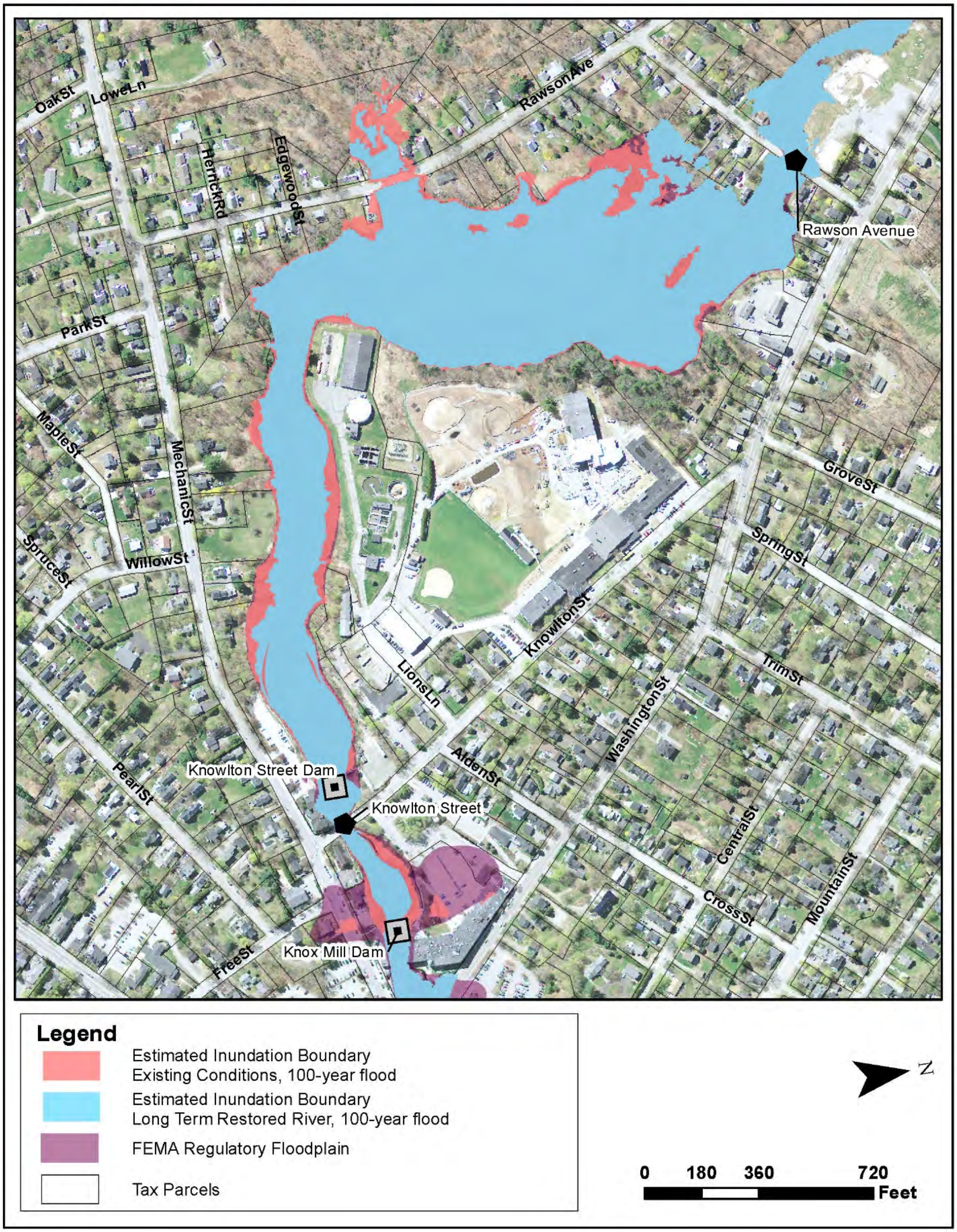

Figure 78. Estimated inundation extents in the reach between Knowlton Street and Rawson Avenue for the 100-year return period flood event for existing conditions and the long term restored river scenario. Inundation at the crossings is for the river channel beneath the bridges, model results do not indicate road overtopping at the simulated flow event at these bridges.

4.7.4 Reach 4: Rawson Ave to Route 105/Washington Street (Tannery Site)

No dams are present in the reach between Rawson Avenue and the Route 105/Washington Street bridge. In this reach, the Megunticook River features bank heights between 4 and 10 feet which confine lower magnitude floods to the channel. The former Apollo tannery site is present on the river-left bank.

Flood Conditions

Flood flow hydraulic conditions for the reach are influenced by the bridge crossings at Rawson Avenue and Route 105 (Washington Street). The reach does not lie within the range of influence of any dam which may be removed, and as such, no change in flood water surface elevation is predicted in the reach for the long-term dam removal scenario (Table 12; Figure 79). The Rawson Avenue bridge does locally impact flood profiles. The bridge is currently closed due to structural deterioration. The Town, in coordination with MEDOT, is considering whether the bridge will be replaced, or decommissioned, removed, and not replaced. The removal of the bridge would locally benefit flood profiles and habitat connectivity. If the bridge is replaced, it should be designed to comply with StreamSmart stream crossing standards, which would include elimination of the center pier and also include a clear span that is at least 20 percent greater than the assessed equilibrium channel width. The inundation extents for the 10-year and 100-year flood flows will not change in the reach following dam removal (Figure 80 and Figure 81).

Table 12. Estimated change in water surface elevation for select flood flows between Rawson Avenue and Route 105 comparing existing conditions to the long term restored river scenario.

Location	Estimated Change in Water Surface Elevation (ft)		
	100-year	10-year	1.1-year
Upstream of Rawson Avenue	0.0	0.0	0.0
Downstream of Route 105 Bridge	0.0	0.0	0.0

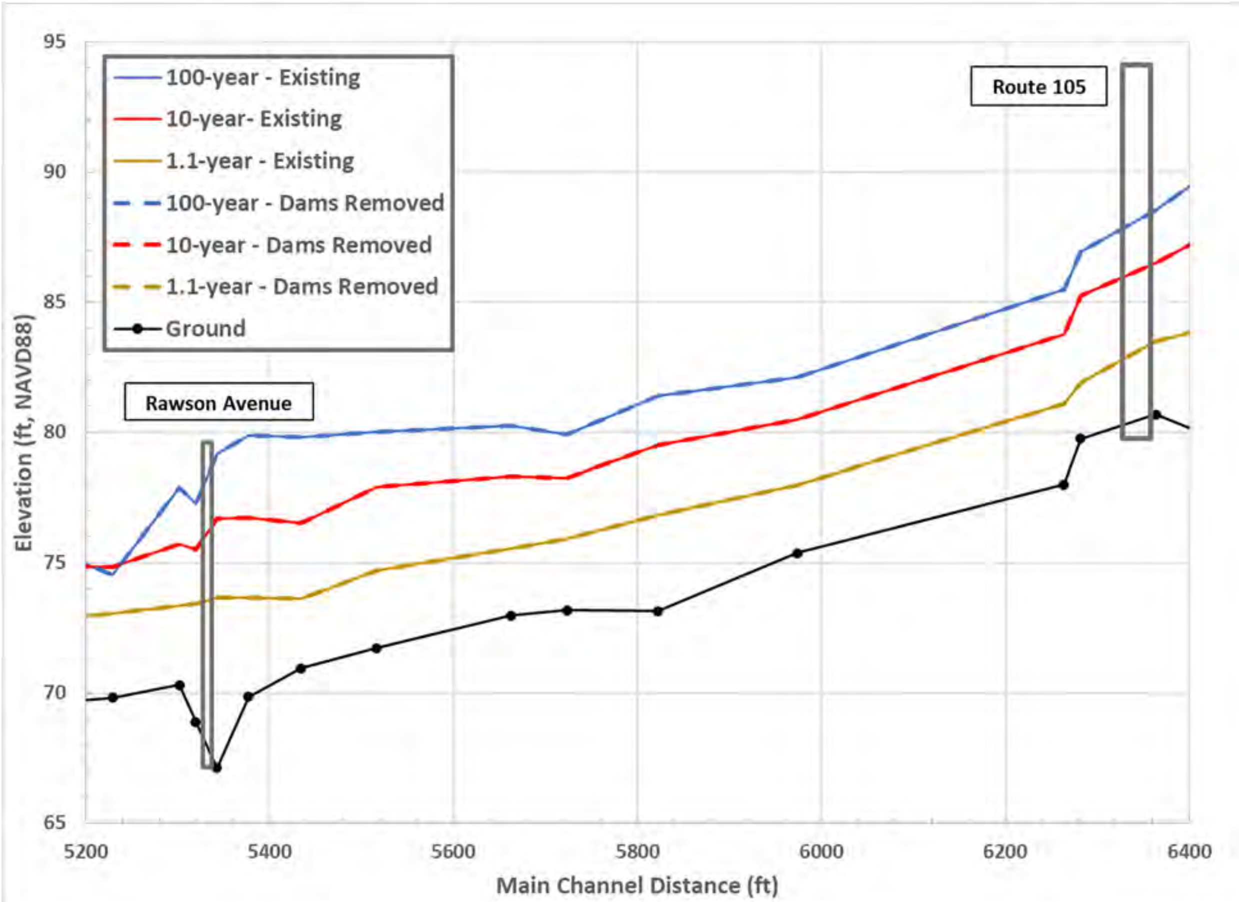

Figure 79. Simulated flood water surface profiles for the reach from Rawson Avenue to Route 105. Solid lines denote existing condition profiles; dashed lines denote water surface profiles associated with the long-term dam removal model scenarios. Note the lines overlap in this figure as there is no change in water surface profile. Flow events shown include the 100-year, 10-year, and 1.1-year events.

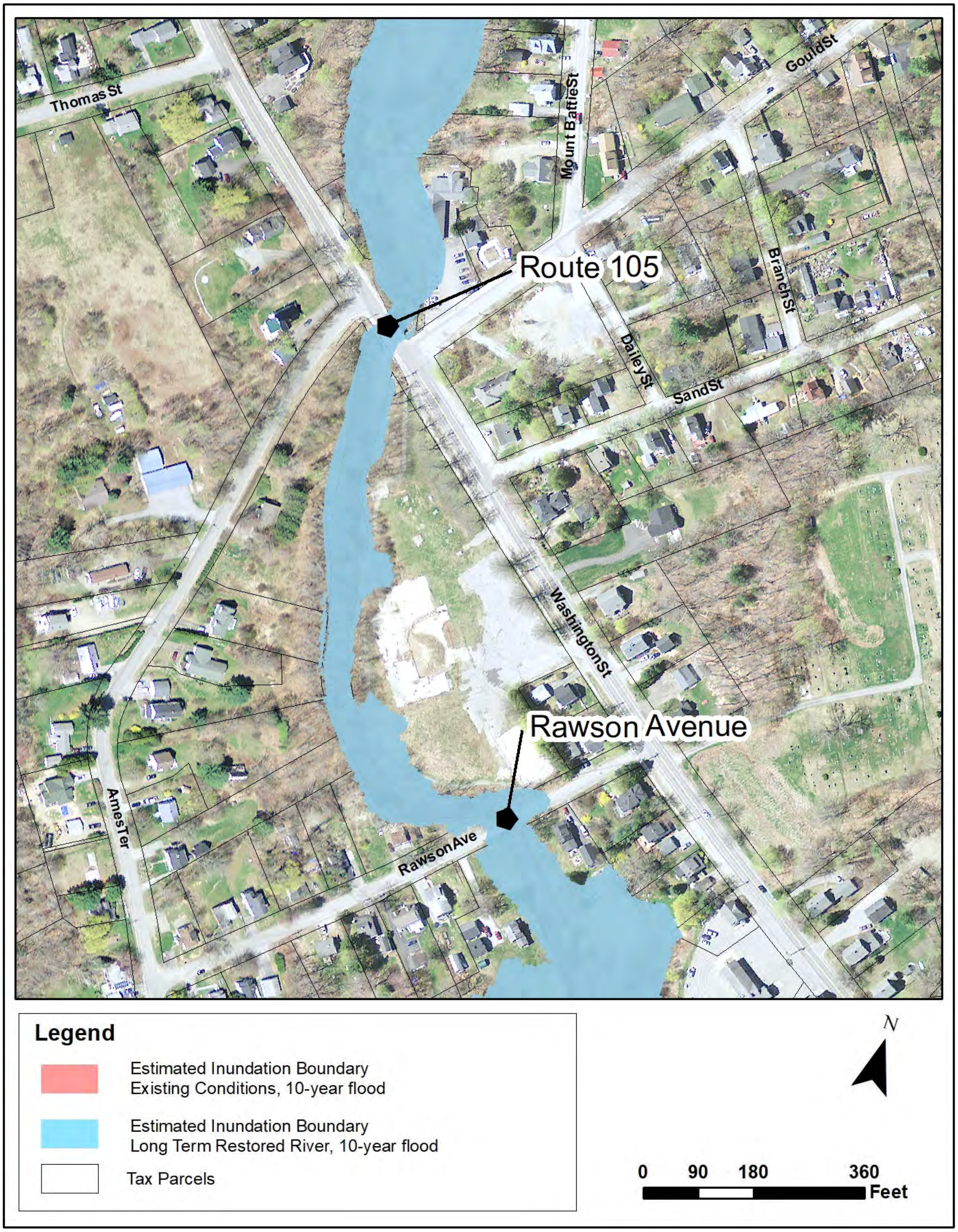

Figure 80. Estimated inundation extents in the reach between Rawson Avenue and Route 105/Washington Street for the 10-year return period flood event for existing conditions and the long term restored river scenario. Inundation at the road crossings is for the river channel beneath the bridges, model results do not indicate road overtopping at the simulated flow event.

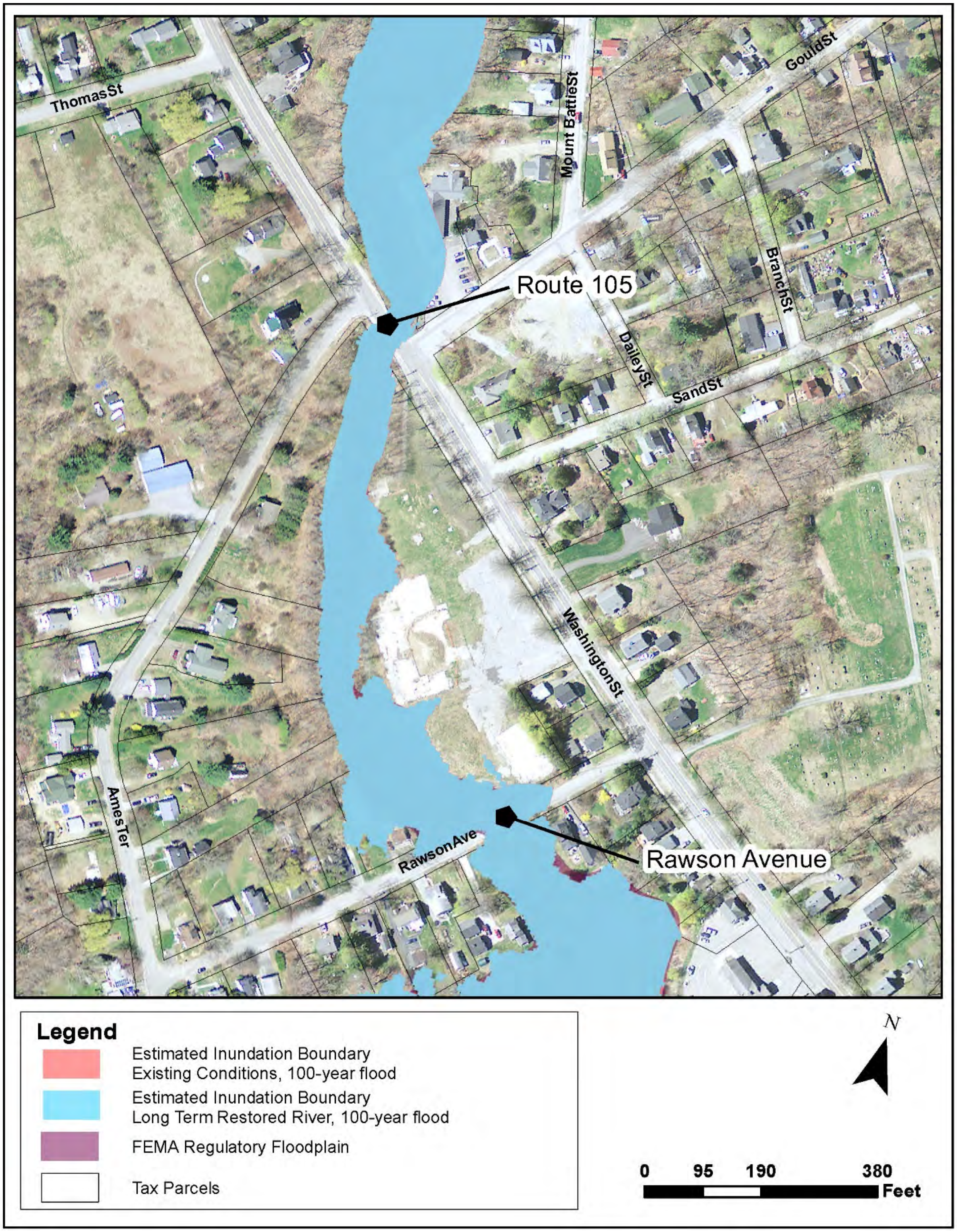

Figure 81. Estimated inundation extents in the reach between Rawson Avenue and Route 105/Washington Street for the 100-year return period flood event for existing conditions and the long term restored river scenario. Inundation at the road crossings is for the river channel beneath the bridges, model results do not indicate road overtopping at the simulated flow event.

4.7.5 Reach 5: Route 105/Washington Street to Mount Battie Street (Powder Mill Dam Ruins)

The reach between Route 105 and Mount Battie Street contains the Powder Mill Dam Ruins. Following removal of the dam ruins, it is expected that the channel upstream of the dam would incise to its new base level at the bedrock outcrop on which the dam was built. This incised channel is considered in the simulation of the effect of dam removal.

Flood Conditions

Flood flow hydraulic conditions for the reach between Route 105 and Mount Battie Street are influenced by both road crossings and the dam ruins, which still serve to constrict water flow. Upstream of the dam ruins, reductions in water surface of 5.3 and 3.1 feet are predicted for the 1.1-year and 100-year flow, respectively (Table 13, Figure 82). The upstream limit of the impoundment created by the Powder Mill Dam ruins is located at the Mount Battie Street bridge crossing. Immediately downstream of Mount Battie Street, the 100-year flow water surface elevation is expected to decrease by 0.4 feet following removal of the dam ruins. Inundation extents of the 10-year and 100-year flood flows will be largely confined to the stream channel and immediately adjacent floodplain areas, and demonstrate a notable narrowing following dam removal compared to existing conditions (Figure 83 and Figure 84).

Table 13. Estimated change in water surface elevation for select flood flows between Route 105 and Mount Battie Street comparing existing conditions to the long term restored river scenario.

Location	Estimated Change in Water Surface Elevation (ft)		
	100-year	10-year	1.1-year
Upstream of Route 105 Bridge	0.0	0.0	0.0
Downstream of Powder Mill Dam Ruins	0.0	0.0	0.0
Upstream of Powder Mill Dam Ruins	-3.1	-3.7	-5.3
Downstream of Mount Battie Street	-0.4	-0.6	-0.0

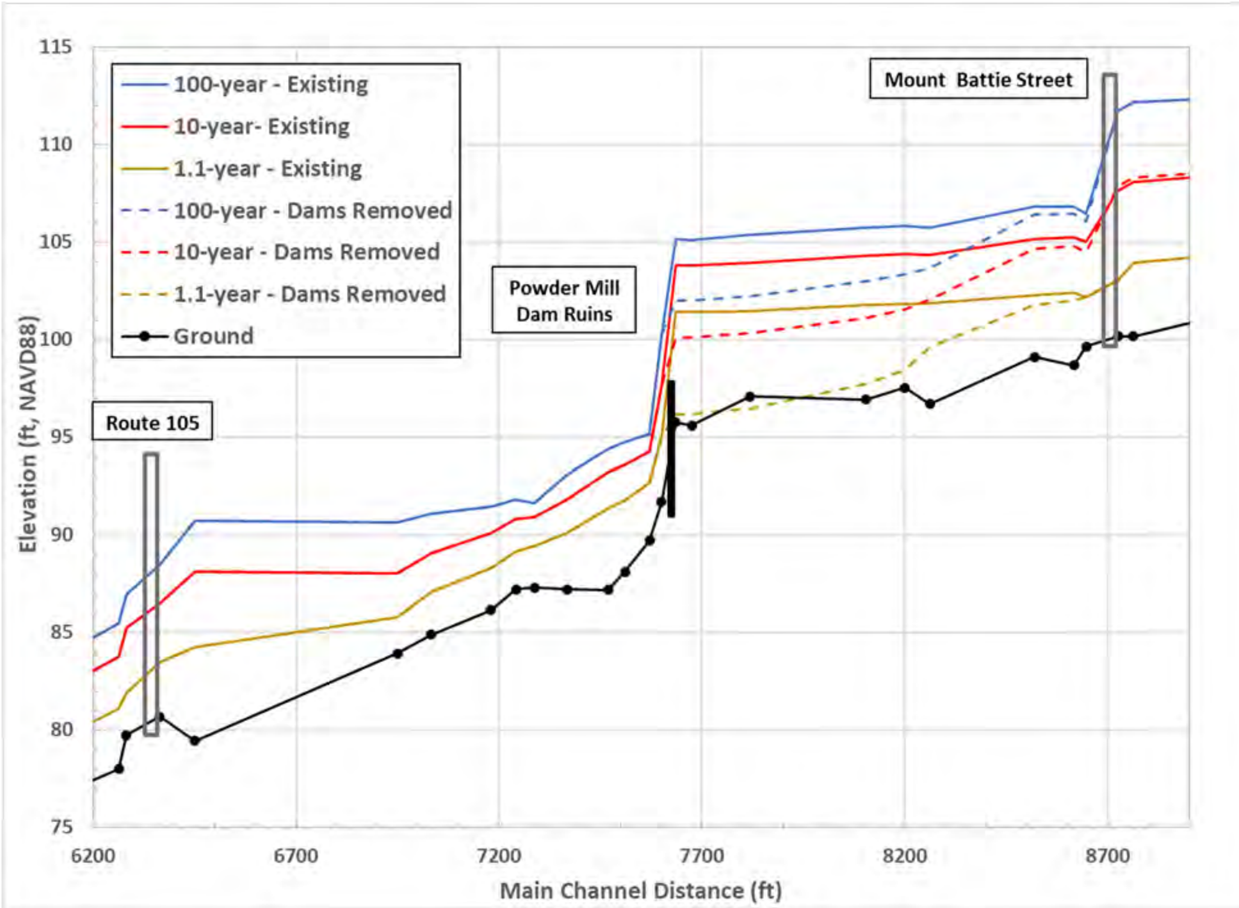

Figure 82. Simulated flood water surface profiles for the reach from Route 105 to Mount Battie Street. Solid lines denote existing condition profiles; dashed lines denote water surface profiles associated with the long-term dam removal model scenarios. Flow events shown include the 100-year, 10-year, and 1.1-year events.

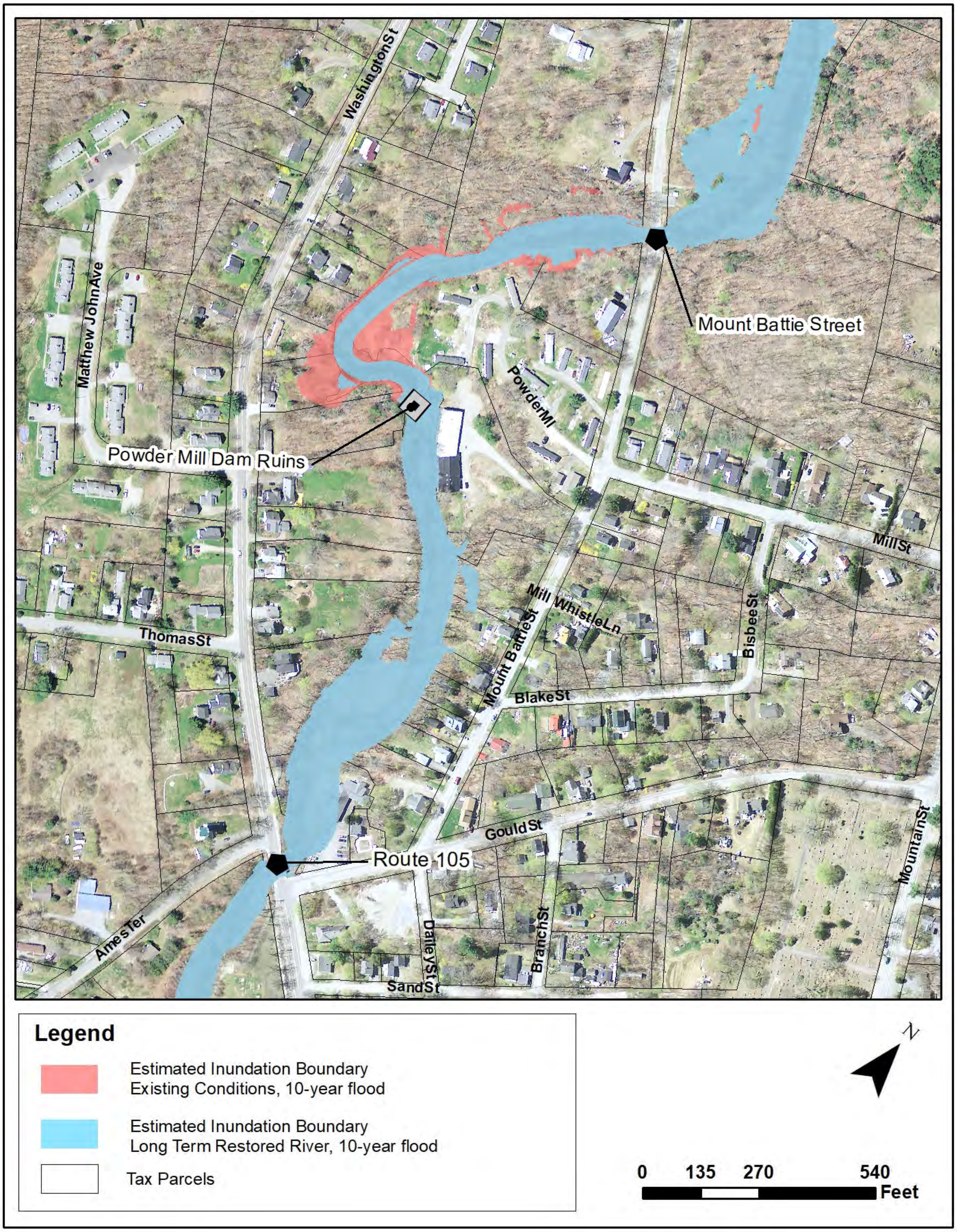

Figure 83. Estimated inundation extents in the reach between Route 105/Washington Street and Mount Battie Street for the 10-year return period flood event for existing conditions and the long term restored river scenario. Inundation at the road crossings is for the river channel beneath the bridges, model results do not indicate road overtopping at the simulated flow event.

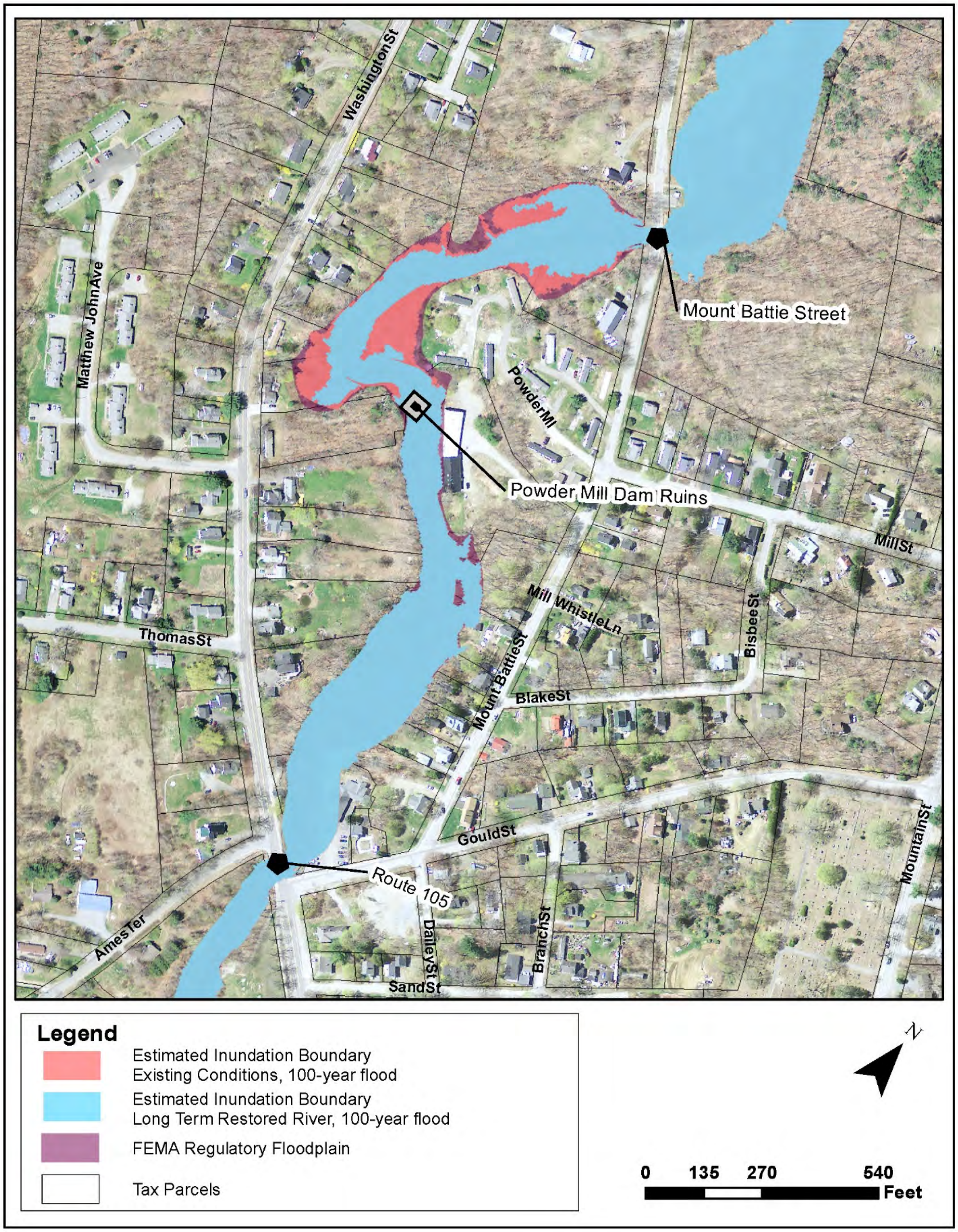

Figure 84. Estimated inundation extents in the reach between Route 105/Washington Street and Mount Battie Street for the 100-year return period flood event for existing conditions and the long term restored river scenario. Inundation at the road crossings is for the river channel beneath the bridges, model results do not indicate road overtopping at the simulated flow event.

4.7.6 Reach 6: Mount Battie Street to Molyneaux Road (Seabright Dam)

The reach between Mount Battie Street and Molyneaux Road contains Seabright Dam and its impoundment. Seabright Dam is not planned for dam removal or breaching, and in this reach, there are no differences between the existing conditions and dam removal modeling scenarios.

Flood Conditions

Flood profile for the reach between Mount Battie Street and Molyneaux Road are controlled by Seabright Dam, which has an impoundment that extends 8,920 feet to Molyneaux Road. During the 10-year flood, the hydraulic model demonstrates a slight rise in the water surface profile upstream of Mount Battie Street as a result of the decreased tailwater elevation and changed culvert hydraulics following the removal of the Powder Mill Dam Ruins. Note that this finding is contingent on assumptions regarding the form of the long-term evolution of the channel upstream of the dam ruins, with preliminary planning-level hydraulic modeling. Future detailed modeling and design may eliminate this result, either through improved model resolution, or design adaptations to mitigate the effect if it persists through more detailed modeling. The 100-year water surface profile is not predicted to change in the reach. There is no predicted change in flood water surface profiles upstream of Seabright Dam to Molyneaux Road (Table 14; Figure 85). Inundation extents of the flood flows, including the 10-year and 100-year floods, will not change in the reach under long term restored river scenario (Figure 86 and Figure 87).

Table 14. Estimated change in water surface elevation for select flood flows between Mount Battie Street and Molyneaux Road comparing existing conditions to the long term restored river scenario.

Location	Estimated Change in Water Surface Elevation (ft)		
	100-year	10-year	1.1-year
Upstream of Mount Battie Street	0.0	0.3	0.0
Downstream of Seabright Dam	0.0	-0.0	0.0
Upstream of Seabright Dam	0.0	0.0	0.0
Downstream of Molyneaux Road	0.0	0.0	0.0

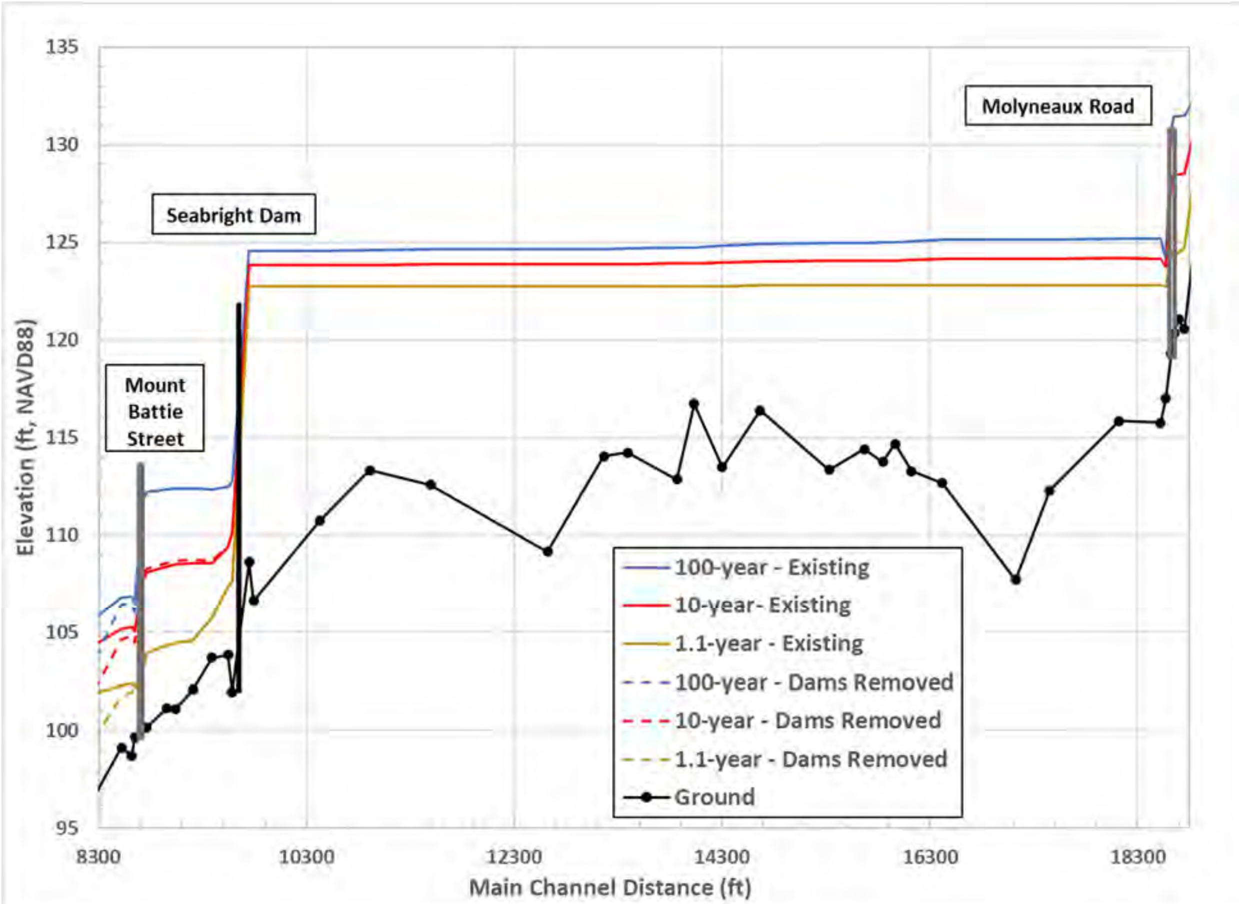

Figure 85. Simulated flood water surface profiles for the reach from Mount Battie Street to Molyneaux Road. Solid lines denote existing condition profiles; dashed lines denote water surface profiles associated with the long-term dam removal model scenarios. Note the lines overlap in portions of this figure as there is no change in water surface profile. Flow events shown include the 100-year, 10-year, and 1.1-year events.

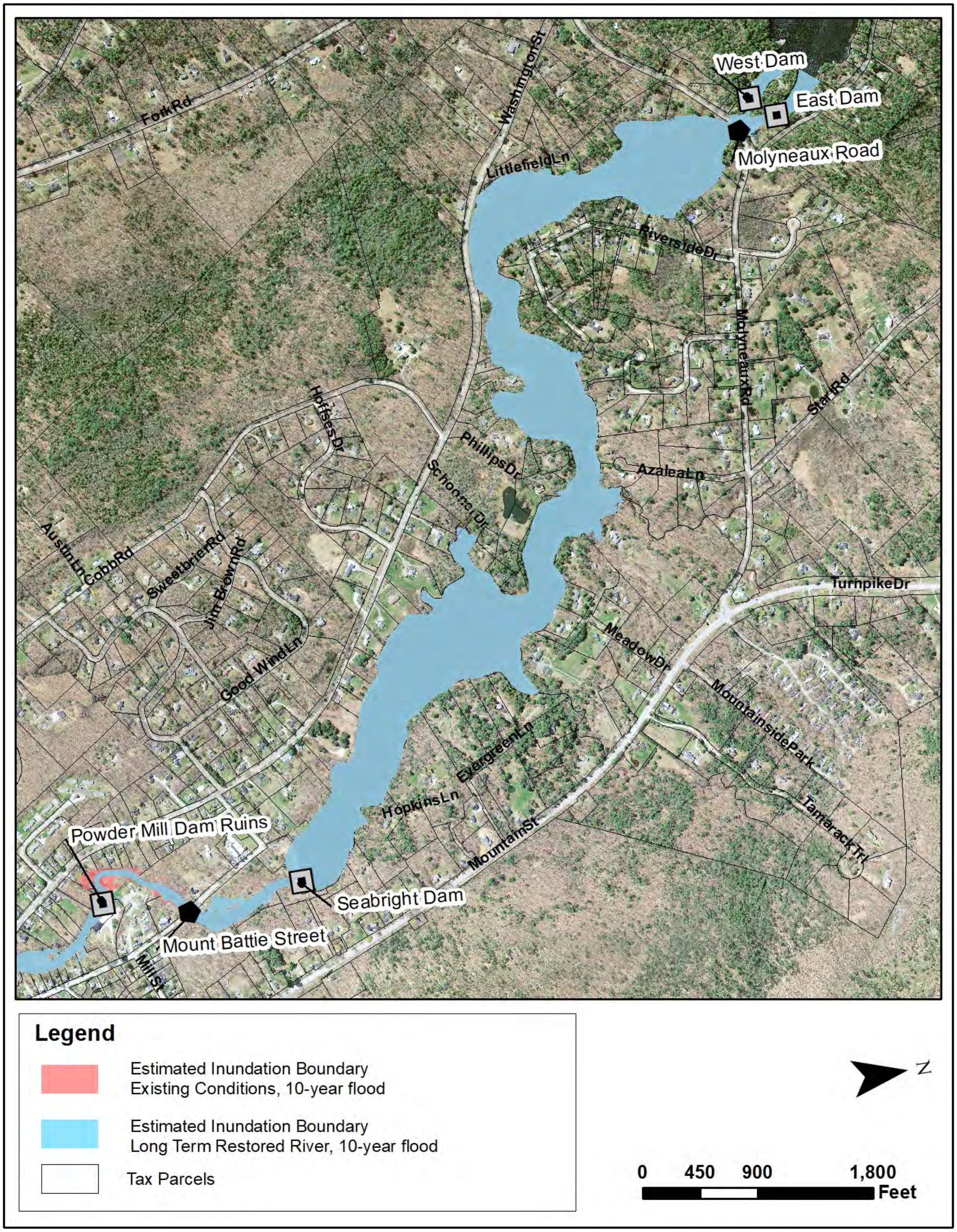

Figure 86. Estimated inundation extents in the reach between Mount Battie Street and Molyneaux Road for the 10-year return period flood event for existing conditions and the long term restored river scenario. Inundation at the road crossings is for the river channel beneath the bridges, model results do not indicate road overtopping at the simulated flow event.

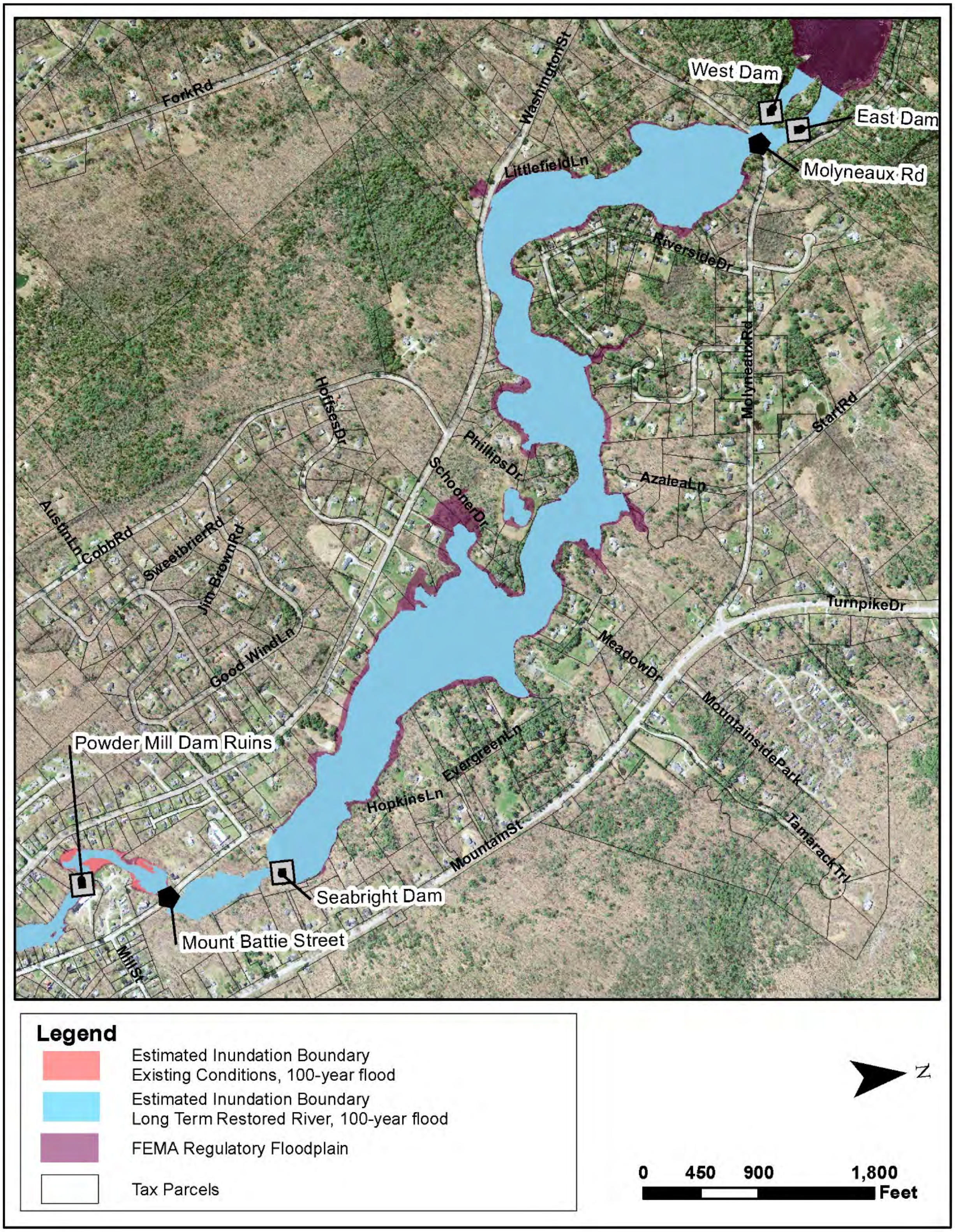

Figure 87. Estimated inundation extents in the reach between Mount Battie Street and Molyneaux Road for the 100-year return period flood event for existing conditions and the long term restored river scenario. Inundation at the road crossings is for the river channel beneath the bridges, model results do not indicate road overtopping at the simulated flow event, except for Molyneaux Rd., which is predicted to overtop.

4.7.7 Reach 7: Molyneaux Road to Megunticook Lake (East and West Dams)

The reach between Molyneaux Road and Megunticook Lake contains the East and West Dams. East and West Dams are located on either side of an island at the outlet of Megunticook Lake, and serve to maintain the water level in the lake. Separate channels convey the outflow from each dam to Molyneaux Road, where each stream flows through a separate box culvert into the Seabright impoundment.

Flood Conditions

Flood profiles between Molyneaux Road and Megunticook Lake are influenced by East and West Dams and the Molyneaux Road crossing. There are no predicted changes in flood water surface profiles in the reach. (Table 15; Figure 88). Inundation extents of flood flows, including the 10-year and 100-year flows, will not change in the reach under the long-term river restoration scenario (Figure 89 and Figure 90).

Table 15. Estimated change in water surface elevation for select flood flows between Molyneaux Road and Megunticook Lake comparing existing conditions to the long term restored river scenario.

Location	Estimated Change in Water Surface Elevation (ft)		
	100-year	**10-year**	**1.1-year**
Upstream of Molyneaux Road	0.0	0.0	0.0
Downstream of East/West Dam	0.0	0.0	0.0
Upstream of East/West Dam	0.0	0.0	0.0

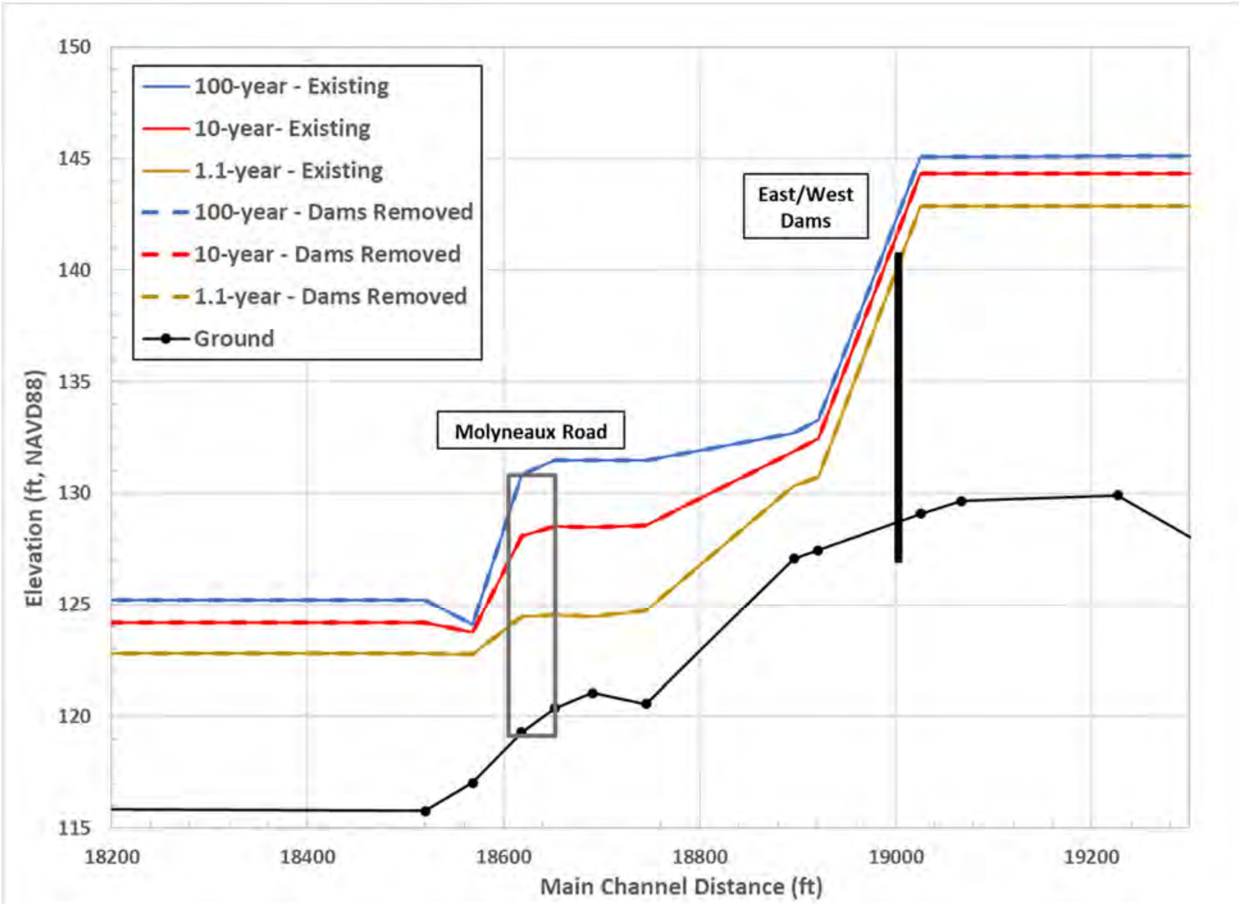

Figure 88. Simulated flood water surface profiles for the reach from Molyneaux Road to Megunticook Lake. Solid lines denote existing condition profiles; dashed lines denote water surface profiles associated with the long-term dam removal model scenarios. Note the lines overlap in this figure as there is no change in water surface profile. Flow events shown include the 100-year, 10-year, and 1.1-year events.

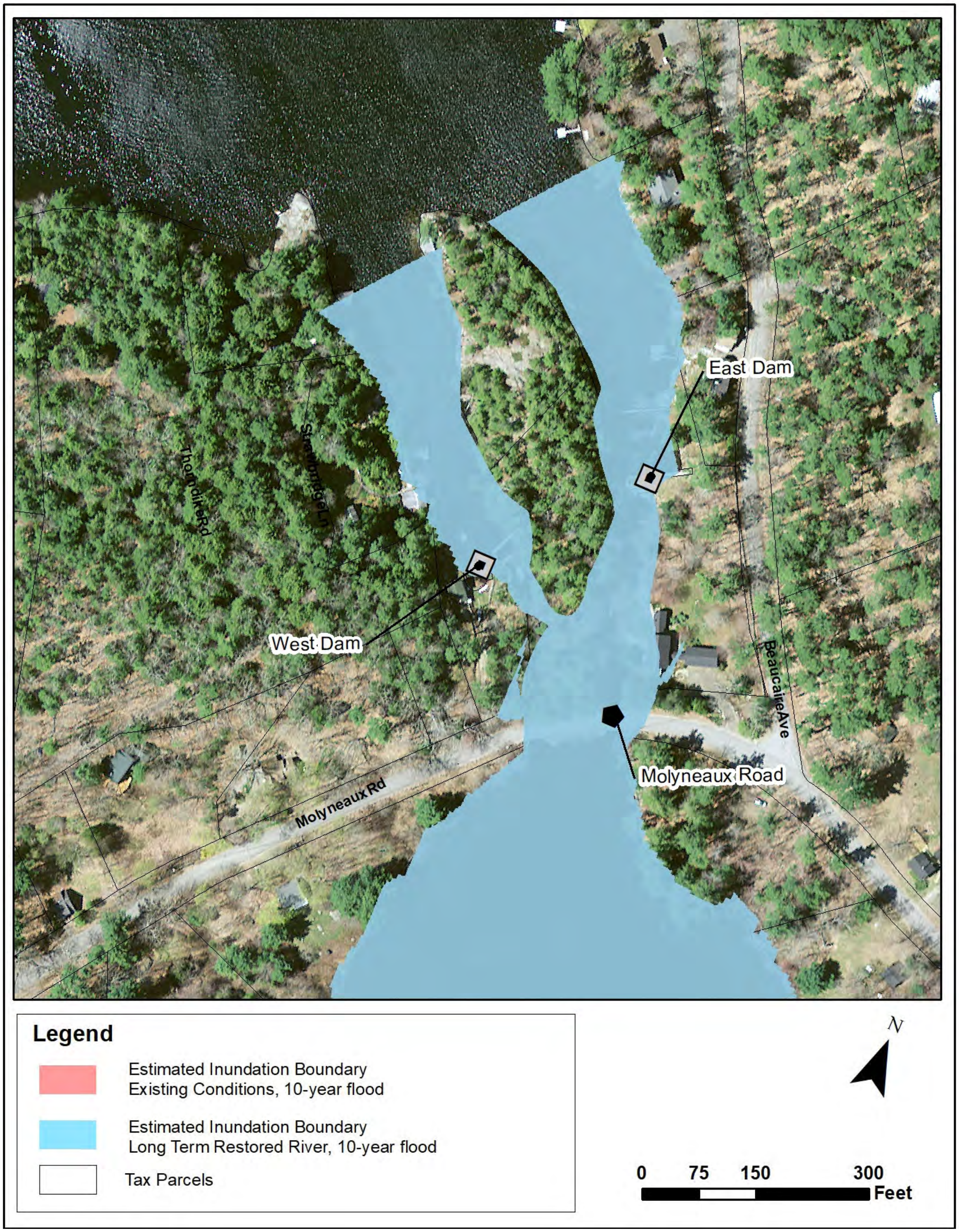

Figure 89. Estimated inundation extents in the reach between Molyneaux Road and Megunticook Lake for the 10-year return period flood event for existing conditions and the long term restored river scenario. Inundation at the road crossing is for the river channel beneath the bridges, model results do not indicate road overtopping at the simulated flow event.

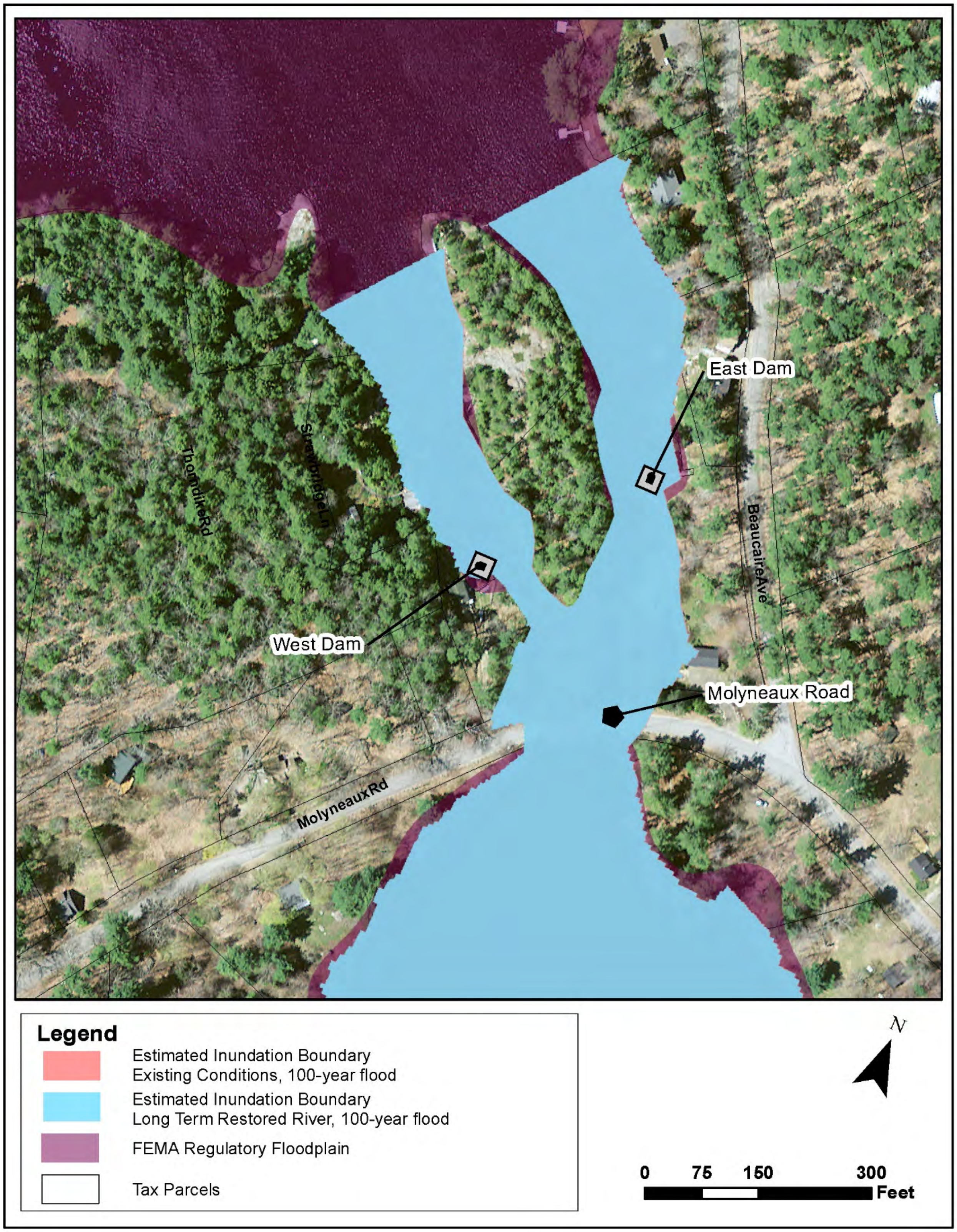

Figure 90. Estimated inundation extents in the reach between Molyneaux Road and Megunticook Lake for the 100-year return period flood event for existing conditions and the long term restored river scenario. Model results indicate that inundation at the road crossing over the road crossing.

4.8 DAM BREACH ANALYSIS

As part of this Feasibility Study, Inter-Fluve performed a dam breach analysis to simulate and quantify the incremental effect of catastrophic dam breaches of the Knowlton Street and Knox Mill Dams on water surface profiles, velocities, and inundation areas along the Megunticook River. Even though these two dams are classified as low hazard by the Maine Emergency Management Agency Dam Safety Office, they were selected for dam breach analysis due to their age (1800s) and proximity to the Camden town center. In addition, the dams are presently in private ownership and minimally managed and maintained. In contrast, Emergency Action Plans (EAPs) exist for the upstream Town-owned high hazard dams which include extensive storage impoundments (Seabright and Megunticook Lake outlet dams).

Appendix C contains a detailed description of the dam breach analysis. We provide a brief summary of the analysis and the conclusions here.

The dam breach analysis included evaluation of the following scenarios:

- Instantaneous failure of the Knowlton Street Dam
- Instantaneous failure of the Knox Mill Dam
- Instantaneous Failure of the Knowlton Street Dam causes subsequent failure of the Knox Mill Dam.

We evaluated the dam breach scenarios for two flow conditions:

- Sunny Day conditions, where failure is more likely to be unanticipated and unmonitored.
- Flood Event conditions (i.e., the 100-year flood), where failure coincides with a significant anticipated and monitored flood event.

Model results indicate that instantaneous failure of Knowlton Street Dam will produce a larger flood wave than a failure of the Knox Mill Dam. Successive failure of both dams will produce a flood wave that is similar to, but slightly larger than, failure of the Knowlton Street Dam alone. Failure of the Knowlton Street Dam would also result in an uncontrolled release of an undetermined volume of the sediment retained behind the dam.

The flood modeling results discussed in Section 4.7 indicate that under flooding scenarios without dam breach, hazards exist for the public in the river reach between Knox Mill dam and the harbor. For example, at the 100-year return period flood, the Washington Street bridge is predicted to overtop, as are areas where pedestrians are commonly observed, such as portions of Tannery Lane and Mechanic Street, areas of Harbor Park, and the granite block gate structure platform at Montgomery Dam. Model results indicate that these flooding hazards would increase if a dam breach were to occur at the same time as a major flood, discussed in more detail below.

For brevity in this report, we confine our discussion of results to the failure scenario where the two dams fail in succession. For a comprehensive summary of results refer to Appendix C.

4.8.1 Sunny Day Failure Event

Model results indicate that a dam failure that occurs on a sunny day will have a greater *incremental* impact on the water levels in the Megunticook River than a dam failure that occurs during a large flood. Specific to the sunny day failure event, model results indicate:

- The breach wave will be confined to the river channel (Figure 10 in Appendix C).
- The breach flood wave will cause the river profile to rise, but the rise is not likely to exceed 2 feet at any point downstream of the Knowlton Street Dam (Figure 6 in Appendix C). The effect of the breach wave on the sunny day river profile is attenuated downstream of Montgomery Dam.

4.8.2 High-Flow Failure Event

Model results indicate that a dam breach that occurs during a large flood will have a smaller incremental impact on the water levels in the Megunticook River than a dam breach that occurs during a sunny day. However, the incremental changes are more significant because they are estimated to occur outside the river channel, in the town center. Specific to the high-flow failure event, model results indicate:

- The typical (non-breach) flow during the flood event exceeds the capacity of the river channel through downtown Camden (Figure 15 in Appendix C).
- The typical (non-breach) flow during the flood event causes flooding at Washington Street, at the public safety building and overtops the granite gate structure at Montgomery Dam (Figure 15 in Appendix C).
- The typical (non-breach) flow during the flood event will submerge the lower levels (stone foundations, lower-level utility rooms, deck supports) of the Knox Mill buildings (Figure 15 in Appendix C).
- The breach wave will exacerbate flood conditions in areas typically prone to flooding (Figure 15 in Appendix C).
- The breach wave will cause the river flood profile to rise further, the most severe rise will occur on the bedrock section between the Knowlton Street Dam and the Knowlton Street bridge (2.2 feet). In other areas, the typical rise is not likely to exceed 1.5 feet (Figure 9 in Appendix C).
- The breach fave will cause the river flood profile to rise approximately 1.0 foot at Washington Street and will cause additional flooding at the public safety buildings (Figure 9 in Appendix C).
- The breach wave will cause the river flood profile to rise approximately 0.9 feet at the Knox Mill Building and will put additional stress on the submerged portions of the building (Figure 9 in Appendix C).
- The impact of the breach wave on the river flood profile is attenuated downstream of Montgomery Dam.

5. Potential Constraints

5.1 ENVIRONMENTAL AND HISTORICAL CONSTRAINTS

Dam modification or removal, while potentially net-beneficial to existing infrastructure and ecosystems, can impose short-term impacts on the environment during the construction phase of a project and disrupt species that had adapted to presence of the dam. Dam removals can also have cultural impacts if the dam or impoundment is adjacent to historically significant features. To identify sensitive ecological and cultural resources in the project area, Inter-Fluve submitted initial inquiries to various state and federal agencies. Responses from the Maine Natural Areas Program (MNAP), US Fish and Wildlife Service (USFWS), Maine Department of Inland Fisheries and Wildlife (MDIFW), and Maine Historic Preservation Commission (MHPC) are discussed below. There are no delineated wetlands in the vicinity of the potential project area, hence potential regulatory wetland impacts are not anticipated.

5.1.1 MNAP

The MNAP searched its data system and inquired with local experts for documentation of rare or unique botanical features in the vicinity of the project area. The results of the search indicate that no such features were documented in the project area.

5.1.2 USFWS

A federal threatened and endangered species review was conducted using the USFWS "Information for Planning and Consultation" system. The inquiry produced a potentially-present list that included two species: The Northern long-eared bat *(Myotis septentrionalis)* and the Atlantic salmon (*Salmo salar).* However, there were no critical habitats identified within the project area. The potential presence of these two species will be factored into the project planning, but are not expected to be a constraint on project actions.

Typical considerations for the long-eared bat center around removal of trees greater than 3 inches in diameter. In Maine, the typical implication is simply that USFWS is notified if trees of this size must be removed as a result of project actions, and may require the trees to be removed before the start of the regional nesting season (prior to April 1). Atlantic salmon are present in Penobscot Bay, but are not anticipated in the Megunticook River due to the site characteristics under the present condition. Federal permitting for a potential project may require informal consultation with USFWS or NOAA, but the likely impact to project planning relates to construction period sediment, erosion and pollution controls

5.1.3 MDIFW

The MDIFW found no indication of State endangered, threatened, or special concern species in the project area. Furthermore, no essential or significant wildlife habitats were mapped in the project area. MDIFW will be further consulted in subsequent phases regarding coordination of managing habitat and resources for resident and sea-run fish.

5.1.4 MHPC

Based on their review of the sites and potential project actions, the MHPC determined that historical consultation would be required. As detailed in Inter-Fluve's 2019 report, the Montgomery dam was found to be eligible for listing on the National Register of Historic Places as a part of a historic district if an associated historic district were to be applied for and established. In their consultation for this feasibility study, the MHPC concluded that all seven dams in the project area "appear to contribute to a National Register of Historic Places eligible historic district." Presently, the dams are not within an established historic district or listed on the National Register. Eligibility for the National Register does not imply that an application would be approved and status conferred. The Harbor Park area adjacent to the Montgomery Dam is included in the High Street National Historic District.

Depending on the selected proposed projects that emerge from this feasibility study, formal consultation with the MHPC would be initiated through the U.S. Army Corps of Engineers (USACE) permitting process, or other federal action such as use of federal funds for project construction. Because the permitting is at the federal level, any selected project would be reviewed for historic impacts under section 106 of the National Historic Preservation Act, ultimately leading to development of a memorandum of understanding between the federal action agency (USACE, NOAA or USFWS) and MHPC. A range of actions could be required, from documentation of potentially affected structures or resources for the Maine Historic Engineering Record, to avoidance and preservation in the extreme case. Based on prior project experience on fish passage restoration projects at historical dams in Maine and elsewhere in New England, these are not considered to be a hard project constraint. However, these considerations should be carefully integrated into ongoing project planning.

5.2 PROJECT PERMITTING

For the likely range of project actions considered, regulatory permits that may be required include the following:

- Maine Department of Environmental Protection (DEP), Natural Resources Protection Act (NRPA) Permit
- US Army Corps of Engineers Individual Permit, with associated ESA consultations
- Maine Historic Preservation Commission (Section 106) Memorandum of Agreement
- Town of Camden Development Act or Shoreland Zoning Permit

5.2.1 Maine DEP NRPA

Preliminary project consultation was conducted with Maine DEP related to potential project actions, primarily to understand potential opportunities or constraints on sediment management in addition to general project permitting considerations. Because the work will occur within protected resources, NRPA permits will be required. In some instances where the potential risk of impact to the protected resource or the scope of project actions are assessed to be minimal, a project action may qualify for permit-by-rule (PBR). However, based on prior project experiences with project actions of a similar scale, it is likely that individual NRPA permits will be required for all of the project sites. The NRPA permitting process will be the venue to initiate additional discussions for sediment disposal options (discussed also in Section 4.4). Early inter-agency (Maine DEP and USACE) pre-application coordination is strongly encouraged, beginning approximately one year in advance of the desired start of construction.

5.2.1 USACE Clean Water Act

Preliminary project consultation was conducted with USACE related to potential project actions, also primarily to understand potential opportunities or constraints on sediment management in addition to general project permitting considerations. Because the work will occur likely entail placement of temporary or permanent fill in the waters of the United States, federal permits will likely be required. The desired permitting approach is for each project to qualify under the USACE Maine General Permit. If project sequencing aligns, USACE would also welcome permitting multiple project actions at the same time (batch permitting). With respect to sediment management and potential passive downstream release, the USACE reiterated the need to understand potential adverse impacts to the environment or other stakeholder concerns. In addition, the USACE indicated that there is a federal anchorage in Camden Harbor, and the navigation division might be consulted for comment if notable downstream sedimentation was anticipated.

5.3 INFRASTRUCTURE CONSIDERATIONS AND POTENTIAL CONSTRAINTS

5.3.1 Road Crossings

Eight bridges of culvert cross the Megunticook river within the study reach. None of these crossings were assessed to be complete fish passage barriers, and no acute stability concerns were identified as a result of project actions. In each of the study reaches discussed in the report, the associated road crossings are discussed. As project actions are contemplated in each study reach, the associated road crossings should be evaluated further for potential effects or recommended upgrades. The Main Street, Washington Street (“Bakery’), and Rawson Avenue bridges are discussed in more detail in this section.

Main Street Bridge (MEDOT# 2497)

Discussed in detail in the Montgomery Dam feasibility study, the Main Street bridge bisects the Montgomery Dam impoundment. The bridge was assessed with several structural deficiencies, and creates hydraulic conditions that dampen the potential flood profile reduction benefit associated with the potential removal of Montgomery Dam. Additionally, if the dam is removed, the bed conditions near the downstream outlet of the bridge should managed to optimize fish passage past this location. The bridge is included in the MEDOT workplan (MEDOT 2021) for improvements in 2022-23. It is understood that discussions are ongoing between MEDOT and the Town related to the potential improvements.

Washington Street Bridge (MEDOT# 2981)

Also discussed in detail in the Montgomery Dam feasibility study, this bridge falls between the Montgomery Dam impoundment and Knox Mill. The bridge deck was replaced in 2017 with a clear span, which also entailed removal of the center pier. An existing sewer main crosses the river bed beneath the bridge, encased in concrete. The sewer line creates a 9- to 12-inch hydraulic, assessed, which was not assessed to form an insurmountable passage barrier. However, the site should be monitored in conjunction with future fisheries restoration actions. The 2017 construction reduced the impact of the bridge on flooding in the adjacent area, which is among the most vulnerable along the river. Based on hydraulic model results, the bridge appears to still influence flood water surface profiles. In conjunction with future efforts to manage flood risk at this location, consideration of additional modifications to this bridge may be warranted.

Rawson Street Bridge (MEDOT# 3173)

This bridge is located just upstream of the Knowlton Street impoundment. The bridge is closed due to structural issues, and is included in the MEDOT workplan (MEDOT 2021) for complete removal, currently slated for 2023. Hydraulic model results indicate that the bridge influences flood levels in the upstream reach. Removal of the bridge will result in an improvement to flood management within the reach. Eventually, a pedestrian bridge may be constructed at the location in conjunction with development of the Camden Riverwalk.

5.3.2 Utilities and other infrastructure

Several utilities and other infrastructure are located along or adjacent to the river within the study reach. The effect of potential project actions on adjacent structures at each of the dam sites are discussed in Section 7 and in Appendix A. Other utilities and infrastructure are discussed below.

Sewer Lines

Sewer lines appear to cross the river in eight locations within the study reach. Four of these locations include sewer lines mounted to bridge super structures (Main Street, Knowlton Street, Washington Street/Rte. 105, and Mt. Battie Street. The fifth sewer crossing associated with a road (Washington Street/Bakery Bridge) is encased in concrete in the river bed, discussed earlier in this section. A sixth crossing is located 25 feet upstream of the Rawson Avenue Bridge. All of these locations are unlikely to be affected by project actions described in this study, although the presence on the line in the bed upstream of Rawson Avenue should be considered carefully in future enhancement activities that may be planned in this area.

Two additional locations cross open water areas. The first is located in the upstream half of the Seabright Pond. This alignment similarly should not be affected by project actions. The last sewer crossing is through the Knowlton Street impoundment, extending northwest from the wastewater treatment plant through the powerline corridor. With potential removal of the Knowlton Street dam, water levels in the vicinity of this line could drop in elevation two or more feet. Additional detail regarding this line should be collected and evaluated during subsequent planning phases, but is not considered a hard constraint at this time.

Lastly, a sewer line parallels the river from Seabright dam to Mt. Battie Street, beneath a pedestrian footpath. This line is also not expected to interact with project activities, but should be considered carefully in subsequent design phases.

Storm Drainage

Storm drain outfalls are located along the river starting at and downstream from the Washington Street/Rte. 105 crossing, including at Rawson Avenue and Washington Street/bakery bridge stream crossings. In addition, there are at least three storm drains entering the river in the Knowlton Street impoundment, one each entering the Knox Mill and Montgomery Dam impoundments. It is suspected that the most upstream storm drain in the Knowlton Street impoundment may influence sediment and soil quality in the adjacent accumulated sediment (see Section 4.4.2). These drains are not likely to be significantly affected by project activities, but should be considered in more detail in subsequent design phases for impacts related to changed water levels. In some instances, additional stabilization or extension of the outfalls may be required in conjunction with project activities.

It is also noted that the Town is undergoing a more general evaluation of stormwater concerns, and have identified selected areas of chronic concern. One such location is the tributary crossing of Rawson Avenue west of the Knowlton Steet impoundment, near the sanitary pump station. Reduction of impoundment levels during floods may benefit locations such as this by reducing downstream water levels, and lowering risk to structures such as the pump station. The benefit of project implementation on locations such as this should continue to be evaluated in subsequent design phases.

6. Restoration and Resilience Design Considerations

To address the goals and objectives established for the project, we evaluated the feasibility of potential river management approaches to facilitate passage of fish and aquatic organisms, improve habitat connectivity and ecosystem health, and improve resilience to floods along the Megunticook River. The developed options focus on the dams along the river, which currently impact habitat connectivity and flood resilience.

While the focus of the options is on proposed modifications to the dams, it must be recognized that improvements to the river ecosystem extend far beyond the dams themselves. Dam modifications and fish passage schemes are critical to improved habitat connectivity and flood resilience. The benefits of these actions may extend upstream into headwaters, lakes, ponds and tributaries, downstream to Camden harbor and Penobscot Bay, and laterally into riparian areas as a result of the return of sea-run fish, restored connectivity for native resident fish, and reinvigoration of associated ecological processes.

6.1 FLOOD MANAGEMENT AND RESILIENCE

With increasing precipitation and changing flooding patterns as a result of climate change, there is opportunity to enhance flood management and resilience along the Megunticook River. For each of the options discussed in Section 7, the associated flood management benefits are discussed. The following paragraphs provide a general overview of potential benefits.

The downstream dams on the river were built to harness the power of the river, fostering historic economic development of the area. However, these structures are all run-of-the-river dams, meaning that they do not provide flood storage, but do raise river levels which inundate riparian areas that might otherwise store floodwaters, thereby exacerbating flooding patterns. Increased flood risk is a detriment to properties, infrastructure, and buildings within the floodplain or near the river, which will continue to increase with time.

Resilience to flooding patterns and climate change can be enhanced through management of the dams. For example, removal or breaching of dams in the lower reaches of the river would lower flood water elevations in the vicinity of each dam and realize gains in flood buffering and storage in adjacent riparian or riverside areas, or by reducing water levels in nearby tributary drainages, such as near the pump station at Rawson Avenue west of the Knowlton Street impoundment. By removing the controlling structures and increasing the space available for floodwaters within the river corridor, the ability to accommodate the uncertainty in changing climate is maximized. In general, strategies that benefit river ecosystems, especially dam removal, also provide the greatest benefits to risk reduction and resilience to flooding.

At the same time, eliminating aging structures which no longer serve their intended purpose alleviates maintenance requirements and the risk associated with damage to under-maintained structures, and associated damages to surrounding buildings and infrastructure if they become compromised. This strategy will improve conditions but is unlikely to prevent all flood damage to buildings present along the river in downtown Camden. Buildings within the floodplain could adopt strategies to reduce the impact of severe or nuisance flooding in subsequent phases, such as floodproofing structures or elevating or relocating utilities.

Seabright Dam and East/West Dams, which must be retained to maintain upstream water levels, are not candidates for breaching or removal. These dams are also run-of-the-river dams, but provide modest control of flow to the downstream reaches of the Megunticook River, and play a role in managing flooding in Camden. During periods of substantial rainfall and increased river flow, Town staff are required to diligently operate these upstream dams in order to control inundation of selected downstream properties. With reduction of flood levels in downstream areas, the ability to gain more benefit from the operation of these dams will be enhanced, both at present and in the future in response to climate change. The opportunities presented to provide fish passage at the dams may also represent opportunities to address maintenance or operational needs critical to improving resilience throughout the watershed.

6.2 FISH PASSAGE RESTORATION

There are numerous case studies around the region where sea-run fish populations are being restored with complex projects involving multiple dams, including on the Outlet Stream that leads from China Lake to the Sebasticook River, on the Sheepscot River, and in many other river systems throughout New England. Often, these efforts will include a range of fish passage technologies within a single river system, ranging from dam removal to nature-like bypass channels, and technical fish passages. The solution at each site is tailored to the particular opportunities and constraints present at each location. These projects all contribute to recovery of native sea-run fish populations within the Gulf of Maine. They also have innumerable collateral benefits to ecological health and environmental quality in each watershed and in the ocean, to management of aging infrastructure and flooding, and to community engagement and education.

Each dam presents a unique set of opportunities and constraints which must be addressed in order to re-establish sea-run fish populations in the Megunticook River and provide for passage of resident species throughout the watershed. These unique attributes were considered for each site in development of the options summarized in Section 7. The primary factors considered in the development of a successful fish passage facility are the overall height of the dam, the space available, the ability to attract fish to the fish passage, and the capacity to allow passage of the future restored fish population.

6.2.1 Site Characteristics

The overall height of the dam and the space available are characterized by the hydraulic height and effective gradient of the site. The hydraulic height and gradient are determined by the site characteristics, and dictate the types of fish passage technologies that can be considered at a site. In general, for a similarly constrained site, the level of difficulty and cost increases with increasing hydraulic height and effective gradient. In natural streams, sustained gradients that the anticipated fish species negotiate are typically less than approximately 3% to 5%, though there are instances where native sea-run fish are able to utilize steeper gradients for short distances in naturally functioning streams in Maine.

6.2.2 Fish Attraction

Fish attraction refers to the ability to enable ascending fish to find the entrance to the fish passage facility to allow the population to ascend the barrier without unnecessary delay due to overcrowding. Extended delay of fish in their upstream migration can lead to mortality due to energy expenditure and predation, and/or degraded condition when fish ultimately do reach spawning grounds, which in turn may lead to reduced reproductive success.

6.2.3 Biological Capacity

The capacity to allow passage of the future restored fish population, referred to as biological capacity, various between fish passage approaches. MDMR (2018) provided a preliminary opinion of the potential alewife population of 300,000 fish in the Megunticook River system which is primarily based on the habitat available in Megunticook Lake. They suggested this might be a conservative estimate based on a rule-of-thumb population estimate factor that considers the acreage of the lake. With time, evaluation of other potential habitats in the tributaries upstream of the lake may result in even greater population estimates. In addition, several local examples suggest that the rule-of-thumb population factor may run notably low. At Blackman Stream in Bradley, the restored alewife population represents roughly double that which was estimated based on the rule-of-thumb factor.

6.2.4 General Fish Passage Restoration Approaches

Four general potential fish passage restoration approaches were identified and evaluated for the dams along the Megunticook River. Each of these approaches were initially considered at each site and were screened for those most applicable based on the site characteristics. The four approaches are defined below, and technical information for each is provided in Table 16.

- **No Action:** No change from existing conditions.
- **Technical Fish Passage:** Sometimes referred to as a ‘technical fishway’ or fish ladder, this is a general descriptor of a range of fish passage designs which permit passage around a dam. Technical fish passage includes fishways constructed using concrete, metal, or wood materials to create an artificial channel. These passages are typically geometric in shape. They are able to be constructed at steeper effective gradients than natural stream channels and nature-like passages. The different technical designs are typically most effective for varying subsets of fish species. Technical fish passage technologies considered for this study include Pool and Weir and Denil fishways.
- **Nature-like Fish Passage:** These fishways emulate natural flow patterns and the appearance of a naturalized stream channel, and incorporate the landscape and naturalized materials, to provide fish passage over or around an existing dam structure that is left in place. Nature-like fish passages require milder gradients than technical fish passage. By emulating natural flow

patterns, it is reasoned that fish are able to more intuitively ascend the passage. These features are easily scaled for the available flow and biological needs. Nature-like fishways accommodate a broad range of fish species, including those considered in the Megunticook River.

- **Dam Removal:** This refers to the removal or breaching of the dam and spillway, with a reversion to a flowing stream. Depending on the site characteristics, abutments or other appurtenant structures may be left in place following removal if required to ensure the stability of adjoining areas.

Table 16. Available fish passage technologies considered for this study.

Type	Maximum Recommended Gradient	Flow Capacity	Biological Capacity	Species Effectiveness (sea-run and native resident species such as brook trout considered)
Pool & Weir (Technical)	10%[6]	Scalable	Scalable	Possible limitation for American eel
Denil (Technical)	16%[2]	~40 cfs	~200,000 to 300,000 river herring	Limitation for American eel and possibly sea lamprey. Capacity may be limited for river herring with fully restored fish population in watershed.
Steeppass (Technical)	20%[2]	< 8 cfs	~50,000 river herring	Limitation for American eel and possibly sea lamprey. Due to limited biological capacity for river herring not considered in project options.
Nature-like Fishway	5%[1]	Scalable	Scalable	All anticipated
Dam Removal	Natural channel gradient, 5% or less preferred[7]	Full river flow, scalable	Scalable	All anticipated

Of the technologies listed, there is a general gradient of preference among resource agencies, regulators, and funders in the region. Dam removal that does not require additional fish passage construction is by far the most preferred approach, followed by dam removal that requires proactive channel restoration. Dam removals also provide the ancillary benefit of relatively low operation and maintenance costs compared to other fish passage strategies. The next preference is for nature-like approaches as the flatter gradients and naturalized flow patterns are considered to provide very good fish potential passage conditions for the broadest range of fish.

[6] USFWS, 2019
[7] Turek et al., 2016

Among the technical passage approaches, the pool and weir approach is generally favored on the basis of performance and reduced constraints relative to Denil fishways. Pool and weir ladders are typically also easier to add aesthetic enhancements too. However, pool and weir fishways are more expensive than Denil ladders.

Figure 91. Examples of constructed nature-like fish passage (photo credits: Matt Bernier).

Figure 92. Pool and weir fishway at Blackman Stream (photo credit: Maine Sea Grant).

Lastly, Denil fishways are typically the least preferred approach. Although they can be very effective for river herring and salmonids including resident brook trout if sited and designed properly, they can be constrained by biological and flow capacity. Typically, standard Denil fish passage designs are considered to have biological capacity for approximately 200,000 to 300,000 river herring. They possess greater sensitivity to operating conditions, particularly flow conditions at the entrance and exit, can be susceptible to debris clogging, and the flow limitation may limit the attraction signal in some instances. This is especially true at locations where competing flow signals may occur, such as dispersed flow over ledge outcrops. Operation and maintenance costs for Denil fishways are typically high, especially those that use wooden baffles.

Yet, Denil fishways are often the technical fishway option with the lowest initial construction cost due to simpler construction and relatively smaller footprint. They are more utilitarian in nature, and although it is possible to add flourishes such as masonry veneer, they tend to be less pleasing aesthetically. There are many Denil fishways in Maine, with varying degrees of performance and success, from sites with highly efficient passage for river herring and trout, to sites that perform poorly and are presently subject to removal. With Denil fish passage facilities, typically a separate eel passage structure is required, although eel may be able to partially ascend sites with exposed ledge outcrops if suitable flow exists.

Figure 93. Example of a Denil fishway.

6.2.5 Fish Passage and Climate Resilience

Assessment of fish passage options considered the potential hydrologic effects associated with climate change. In general, dam removal strategies provide the greatest benefit to aquatic organism passage over wide flow ranges, while technical fishways are highly sensitive to the flow volume and hydraulic head, and may become impassible outside of prescribed conditions.

Dams with flow regulation means, such as the Seabright and East/West Dams, may be able to partially extend passable conditions of technical fishways in the face of increased precipitation and hydrologic extremes. Analysis of dam operations for optimal fish passage at the high and low flows of the fish migration period should be performed in subsequent design phases to ensure passage is possible over as wide a range of hydrologic conditions as possible.

6.3 SEDIMENT MANAGEMENT

Management of accumulated sediment behind a dam is a critical consideration when contemplating dam management activities. The sediment can potentially bear the legacy of contamination from past or present upstream land or industrial uses, including urban runoff. Release of this sediment in some instances could cause environmental harm to downstream areas due to its level of contamination. Release of accumulated sediment, if substantial in volume, could also cause downstream impacts through deposition in ecologically sensitive areas, or in locations that reduce flood conveyance. In some instances, removal of the accumulated sediment, if contaminated, is viewed beneficially by removing a potential contamination hazard from the aquatic system, as well as generally improving the ecological health of the habitat available to native flora and fauna.

At the same time, viewed from an ecological and sustainability perspective, the downstream transport of sediment is a natural process that is typically disrupted by the presence of a dam, which may have led to reduced habitat quality and stream integrity over time, both in the downstream river and in downstream coastal areas. Often, a stream reach downstream of a dam that is efficient at trapping sediment may be sediment 'starved', which may lead to channel instability or other impacts. In selected instances with limited downstream risks, accumulated sediment may be allowed to transport downstream to aid in recovery of the stream system.

These factors are weighed carefully along with potential project costs when determining the appropriate sediment management approach for each project. The range of options extends from proactive excavation or dredging of all of the accumulated sediment before a dam is breached at one end, to allowing the sediment to passively erode following dam removal at the other end of the spectrum. Between these two end points, there is a vast range of intermediate management options. This may include excavation of only that proportion of the accumulated sediment assessed to likely erode in the near-term following dam removal. Alternatively, this may include proactively restoring and stabilizing the river channel through the former impoundment in order to moderate erosion of the proportion of sediment that is left in place due to cost considerations, or other approaches.

Section 4.4 provides an overview for management of the measured and tested accumulated sediment for each of the dam removal options, discussed in more detail in Section 7. In general, there is anticipated to be relatively low tolerance for any notable passive sediment release on the Megunticook River due to the potential impacts to the extensive use of the Camden inner harbor, or possible impacts to downstream flood conveyance. Typically, reuse or release options for impounded sediment are discussed and confirmed at the beginning of a detailed design phase, through coordination with project stakeholders and regulatory agencies.

6.4 INVASIVE VEGETATION MANAGEMENT MANAGEMENT

Some stands of invasive vegetation such as Japanese knotweed are already present along the river corridor in selected areas. Measures will be put in place in project design and construction to prevent the spread of these species to the newly emergent former impoundment areas following dam removal. Invasive vegetation management may consist of pre-treatment, along with aggressive planting of native riparian plants in an effort out-complete the noxious weeds.

7. Megunticook River Project Options

To address the goals and objectives established for the project, in this section we evaluate the feasibility of potential river management approaches to facilitate passage of fish and aquatic organisms, improve habitat connectivity and ecosystem health, and improve resilience to flooding and climate change along the Megunticook River.

7.1 MONTGOMERY DAM

Potential fish passage approaches at Montgomery Dam are discussed in detail in the Montgomery Dam Feasibility Study Report (Inter-Fluve 2019[8]). Please refer to that document for detailed assessment of project options. The full dam removal option was found to provide the greatest benefits in terms of reducing operation and maintenance requirements and reducing upstream flooding impacts, while also providing the most advantageous fish passage conditions and greatest benefits in terms of ecological recovery of the watershed. This option would result in the most substantial change to the current status of the site, and may require selected countermeasures to address changed ambient conditions for the structures located directly adjacent to the dam. However, the option would also reduce the regular interaction of the river with these structures due to the reduced water levels, resulting in a net benefit. The primary options studied at Montgomery dam are included in the option summaries in Section 8.

Since completion of the Montgomery Dam study, the Harbor Park seawall, located adjacent to and downstream of the dam, has been assessed to be in a degrading condition. The seawall and adjacent area require retrofit or replacement by alternative means to enhance resiliency in the face of climate change and sea level rise. For these reasons, the seawall has been added to planning discussions for Montgomery Dam.

7.2 BREWSTER SHIRT FACTORY BUILDING

As noted earlier in this report, the relict water control structures located beneath the Brewster Shirt Factory building do appear to have a measurable effect of flooding patterns near Washington street, which is a critical location for flood management and resilience planning due to the low-lying topography and proximity to the Camden Public Safety building. Although not included in the original group of potential project sites, this site has been added for this reason. The water control structures also constrain fish passage potential at some flow volumes.

Recommendation: R**emoval of the water control structures beneath the Brewster building is the recommended action at this site.** Additional evaluation is also recommended to identify other actions that could be taken at this site to optimize flood management and resiliency adjacent to the public safety building**.**

[8] The Montgomery Dam feasibility study report can be found on the Town website at the following link: https://cms8.revize.com/revize/camdenme/Montgomery%20Dam%20Feasabilty%20Alternative%20Analysis%20Report.pdf

7.2.1 Remove Water Control

We evaluated a project option that would involve removing the relict water control structures to the extent possible, while leaving the existing building footings intact. The relict structures comprise a water wheel with solid concrete foundation block abutments, and seven concrete weir sections that span between building concrete footing blocks, which raise the bed grade approximately 18 inches. When the factory was in operation, stop logs would be deployed over these weirs to further raise the water levels and force the flow through the water wheel. Removal of the concrete weir sections would entail saw cutting the weirs at the edge of the footing, and chipping out the weirs. Decommissioning of the water wheel and abutment blocks would target removal of the maximum amount of blockage possible from the river channel.

Fish Passage Restoration

The existing structures do not appear to be a barrier to fish passage at lower flow levels as one of the weirs has a lower invert, and appears to provide adequate connectivity. It is unknown if this location may become a velocity barrier at higher flow conditions. Removal of the structures should fully restore fish passage past this area. However, these structures do provide the downstream hydraulic control for the Washington Street bridge, which includes an encased sewer line in the river bed that results in a 9- to 12-inch hydraulic drop at lower flow conditions. The effect of removing the structures on passage past the sewer line would need to be evaluated further in a design phase, and proactive measures incorporated if needed to reduce the resulting hydraulic drop.

Flood Management and Resilience

As noted earlier, the combined effects of the relict water control structures have a measurable effect on local flood water levels. Preliminary modeling of the effect of removing the structures suggests that local reductions of up to 1 foot may be possible. More detailed modeling activities would be required to clearly identify whether these improvements may be sufficient to lower the FEMA base flood elevation below the ground elevation at the public safety building. Additional flood proofing efforts could be required in the local area to achieve this goal, which may include changing the ground elevation of the low-lying parking area between the two buildings, and/or other local upgrades.

Sediment Management

There is a minor quantity of gravel and coarse substrate behind the concrete weir sections. Due to the small volume and character of the material, it would not require excavation, but could require some manipulation to achieve the full benefit of removing the control structures in the near term.

Infrastructure

The concrete weir sections are integrated into the building footing blocks. Provisions to cut out the weir sections while preserving footing stability would need to be detailed in the design phase. Also, the left water wheel abutment block presently supports two posts that support the overlying deck. With removal of the block, some retrofit of the deck supports would be required.

7.2.2 No Action

The no action approach at the Brewster building would not reduce the influence of the relict water control structures on flooding patterns, and therefore would not result in reduced flood risk to the public safety building or surrounding area. This approach would also not enhance fish passage, to the extent that the structures constrain passage presently. There is negligible sediment retained at the site, and additional notable accumulation is not expected. The structures are integrated with the building footings, so the no action approach would maintain the present building structural condition.

7.3 KNOX MILL DAM

Knox Mill Dam is a run-of-the-river dam with a hydraulic height of approximately 17 feet (Table 17). We evaluated three options at the dam: 1) dam removal, 2) technical Denil fishway, and 3) no-action. The primary constraint on development of fish passage options at this site is the confined setting leading to limited space, along with the presence of the surrounding buildings. We considered but ultimately discarded nature-like fishway and pool-and-weir fishway approaches at the site due to the constrained space at the site, that prevents these approaches to be constructed within the required slope range and also without affecting spillway capacity.

Table 17. Hydraulic heights and effective gradients for the options considered in this study at Knox Mill Dam. Water levels presented in this table correspond to the May median flow. Note that the upstream and downstream elevations listed for the dam removal option represent bed elevations, not water surface elevations.

Case	Upstream Water Level (ft)	Downstream Water Level (ft)	Hydraulic Height (ft)	Length (ft)	Effective Gradient
Dam Removal	33.7	32.3	1.4	33	4.5%
Denil Fishway	48.9	31.9	17.0	136	12.5%

Recommendation: Considering the balance between advantages and drawbacks, **dam removal is the recommended option at Knox Mill Dam.**

7.3.1 Dam Removal

Removal of Knox Mill Dam is a feasible option to provide safe, effective, and timely fish passage, and would entail removal of the spillway structure, though portions of the abutments of the dam may remain in place. Landscape renderings depicting the projected river conditions following removal of Knox Mill Dam are included in Appendix D.

Fish Passage Restoration

Following removal of the structure, the newly exposed bedrock channel may require modest proactive management to provide safe, timely, and effective fish passage conditions because the channel corridor is modified from the historical condition. Assessment of the impoundment after the summer 2020 drawdown suggests a relatively narrow channel would be present at the site of the dam with an effective gradient of 4.5% through the footprint of the dam (Table 17, Figure 94). The condition of the river bed beneath the dam spillway is not known. In the detailed design phase, various approaches would be developed to adapt to the unknown conditions that are revealed as the dam is removed.

If a bedrock ledge is present in the channel or other constraining channel condition were present, several approaches could be considered to enhance passage conditions. These approaches could include modifying the bedrock to create more favorable hydraulic conditions, or constructing a short segment of restored river channel utilizing step-pool and riffle morphologies to overcome a potential passage limitation. A step pool channel would require a slope less than 5%, while a steep riffle would require a slope less than 3%. The various options would be evaluated in more detail during final design.

Flood Management and Resilience

Removal of Knox Mill Dam would result in reduced flood elevations upstream of the dam, and reduced impacts to the buildings immediately adjacent to the dam, such as inundation of the deck structures from water projecting over the dam spillway during very high flow conditions. The reduction in flood elevations will accompany reduced flood risk for the properties on both sides of the impoundment, and maximize the ability to adapt to future changes in flooding conditions resulting from climate change.

Sediment Management

Under a dam removal scenario, sediment in the Knox Mill Impoundment will likely require management. Much of the sediment within the main channel is coarse river gravel and cobble, which will adjust naturally following dam removal. Fine sediment pockets are found in the channel margins, estimated at approximately 200 cubic yards. While sediment management specifics would need to be determined during detailed design phases, based on review of the sediment testing results for this site, it is likely that fine sediments would need to be actively managed through excavation and offsite disposal. See Section 4.4 for additional detail.

Infrastructure

Building foundations adjacent to the impoundment and the downstream channel are unlikely to be impacted by dam removal though minor repointing of stone foundations will likely be necessary. Scour downstream of the dam is likely to be limited (Gartley and Dorsky, 2021). Since bedrock underlies the channel bed throughout the impoundment and at the dam site, limited degradation of the channel bed and banks is expected. See also Appendix A.

Summary

Removal of the Knox Mill Dam would present the following advantages and drawbacks:

Advantages:

- Complete removal of an existing fish passage barrier at a downstream point in the Megunticook watershed.
- Increased biological capacity compared to a technical fishway approach.

- Safe, timely, and effective passage for a broad array of species.
- Few maintenance requirements, and eliminates maintenance required for the existing dam.
- Reduced flood elevations in upstream and adjacent areas.
- Renaturalization of the Megunticook River corridor in the heart of Camden, also providing public access through future integration with Riverwalk
- Contribute to improved water quality by reducing shallow ponded conditions along the river subject to solar heating and other impacts.
- Strong potential for grant funding.

Drawbacks:

- Fine sediments behind the dam will likely require active management.
- Change to current water levels in the impoundment area that some local residents may prefer compared to a flowing river.

Synthesis: *Provided the balance between advantages and drawbacks,* **a dam removal is recommended at Knox Mill Dam** *to meet the stakeholder goal and objectives.*

Figure 94. Photo of the channel immediately upstream of Knox Mill Dam in a drawn-down condition. The shadow of the open gate structure is visible in the bottom right corner.

7.3.2 Denil Fishway

We evaluated potential technical fishway approaches to provide safe, timely, and effective fish passage at Knox Mill Dam. While a technical fishway could provide fish passage for a subset of the target species, such an approach presents numerous challenges to flood mitigation and resilience considerations.

Fish Passage Restoration

The primary constraint at Knox Mill Dam is the tightly confined space available to install a fishway. Additionally, the relatively tall dam when considered in conjunction with the space limitation presents a constraint for fishway gradients.

The left bank of the river (looking downstream) would be the most likely location for a fishway. Due to the relatively steep gradient and limited space, we considered baffled chute-type fishways, including Denil or Steeppass technologies. Denil fishways may be installed at a maximum slope of 16.7% (1V:6H), while Steeppass fishways are recommended for slopes less than 20% (1V:5H; USFW, 2019).

A fishway constructed at the maximum design slopes would be challenging for weaker swimming species such as river herring to pass. Therefore, to maximize passage potential we investigated the feasibility of fishways installed at 12.5% (1V:8H) slopes, which would permit passage of non-salmonid species. The estimated annual biological capacity of a 4-foot wide Denil is 200,000 river herring, compared to 50,000 for a Steeppass. Based on comparison of the potential recovered population size for the watershed (greater than 300,000 river herring) to these estimated capacities, the Denil was selected as the technical passage approach for this site.

A Denil fishway option would need to extend upstream of the dam to avoid excessive downstream length or switchbacks. The alignment shown in Figure 95 displays a potential configuration of a Denil fishway. Turning pools at fishway bends would need to be incorporated, and resting pools would be needed for every 6 to 9 feet of elevation gain not featuring a turning pool.

Flood Management and Resilience

A Denil fishway would likely have a negative impact on flooding at Knox Mill Dam. To attain the length required for a 12.5% slope, the fishway would require modification of the left abutment of the dam or its spillway, and would decrease the flood routing capacity of the existing spillway. The fishway would also occupy a significant amount of space in the confined channel downstream of the dam. As a result, flood elevations may increase in areas adjacent to the fishway. A Denil fishway would not reduce the risk of dam failure.

Sediment Management

Impounded sediments would not be altered by a technical fishway, and management would be the same as described for the no action approach.

Infrastructure

A Denil fishway adds another component to the infrastructure at the dam. The fishway would ultimately need to be integrated with the channel bed and potentially with adjacent building foundations. Maintenance of the fishway would require inspection of these anchor points in addition to the fishway itself. Manipulation of the fishway water control may be required during the fish migration period. See also Appendix A.

Summary

A technical fishway at Knox Mill Dam would present the following advantages and drawbacks:

Advantages:

- Safe, timely, and effective passage could be provided for approximately 200,000 river herring with a single Denil fishway.
- Limited change to water levels during non-flood periods in the impoundment area.

Drawbacks:

- Turning pools required to negotiate switchbacks could create confusion or difficult-to-navigate hydraulics for some species.
- Reduced passage for American Eel and Sea Lamprey.
- Biological capacity: A single Denil fishway at Knox Mill Dam may be a limiting factor to the river herring population in the Megunticook watershed. Furthermore, a fishway may not be navigable for Sea Lamprey and American Eel.
- Flood conditions: A technical fishway at Knox Mill Dam would occupy space along the dam's spillway, limiting flood flow capacity and potentially impacting flood elevations. Flows overtopping a technical fishway would render the fishway impassible during high passage flows, and may result in damage during flood flows.
- Maintenance: Regular maintenance of the fishway would be required. Maintenance would include removing debris from the fishway, and possible manipulation of headwater elevations with baffles or the existing gate to extend passage conditions.
- Water Quality: Sustained ponded condition likely impacts stream water temperature and other water quality factors.

Synthesis: *Provided the balance between advantages and drawbacks,* **a Denil fishway is not recommended at Knox Mill Dam** *even though the approach is technically feasible.*

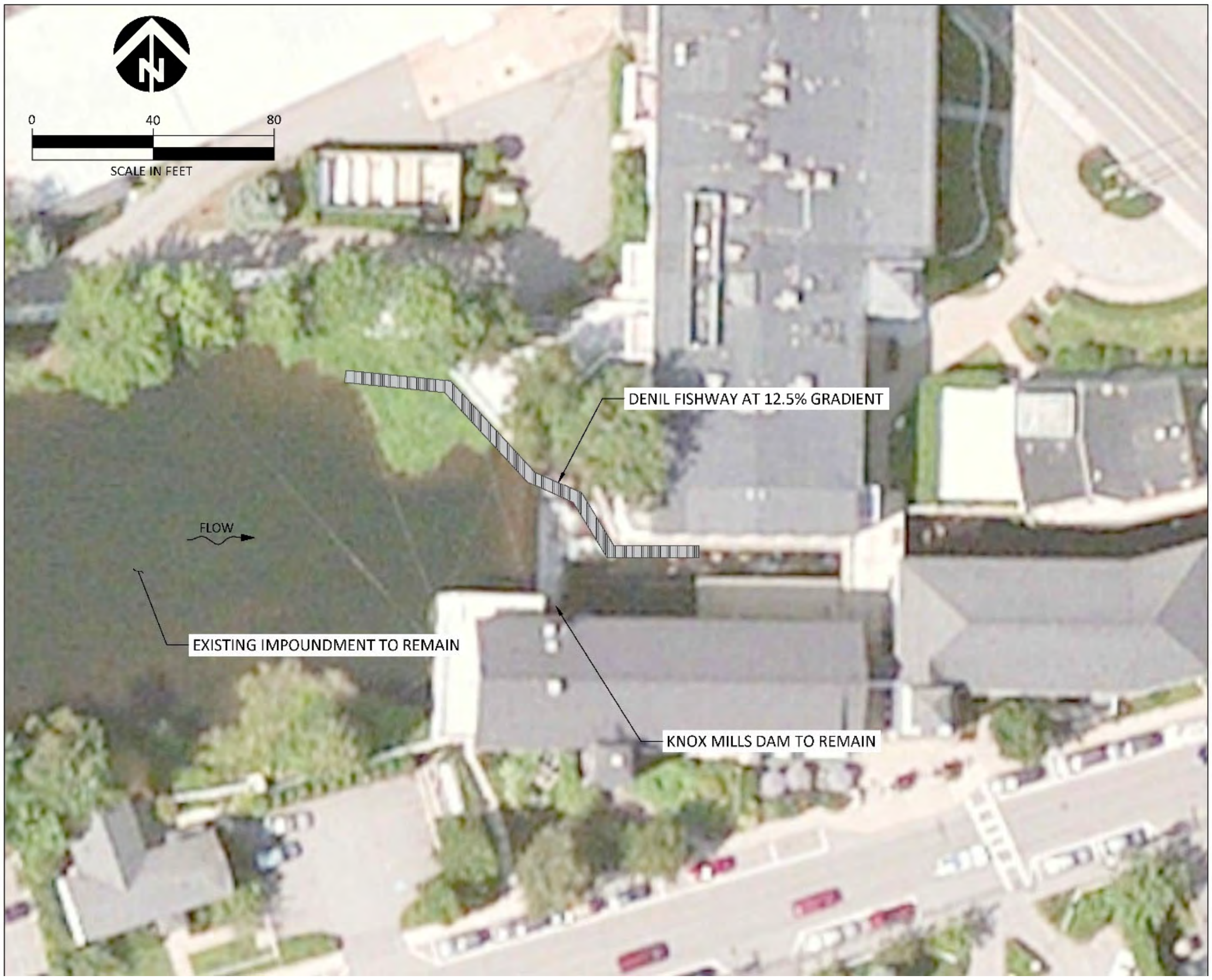

Figure 95. Schematic layout of a Denil fishway at Knox Mill Dam.

7.3.3 Other Fish Passage Considerations

Although Knox Mill Dam presents the primary constraint to fish passage in the surrounding reach, a remnant boulder dam is located just below the upstream end of the impoundment, and will influence flow if Knox Mill dam were removed. When the impoundment is full, the relict dam is submerged. This feature creates a drop of approximately 2-4 feet, depending on flow (Figure ***96***). This relict dam may be a passage barrier to non-leaping fish such as river herring at many flows. Fish passage at the feature would be restored by manipulating the boulders to manage the vertical drop along a more gradual gradient. Boulders could be moved to nearby areas where they would disperse flow, creating velocity refugia and habitat variability within the main channel for migrating fish and aquatic species.

Figure* 96*. Photo of the remnant dam upstream of Knox Mill Dam.

7.3.4 No Action

A "no action" approach at Knox Mill Dam would result in a continued barrier to fish passage near the mouth of the Megunticook River. Ongoing maintenance of the dam would be required.

Fish Passage Restoration

Knox Mill Dam is a complete barrier to fish passage in its existing conditions. If Montgomery Dam were to be modified to allow fish passage, Knox Mill Dam would prevent access of target fish species to the rest of the watershed.

Flood Management and Resilience

As a run-of-the-river dam, Knox Mill Dam does not provide flood storage and locally elevates flood water elevations, including splashing and spraying water on building and deck areas downstream of the dam. Under the no-action approach, no benefits to flood management will be realized, and escalated nuisance flood effects can be expected for the surrounding buildings in the future.

Sediment Management

Approximately 200 cubic yards of fine sediment is impounded behind Knox Mill Dam and primarily resides in localized deposits with low flow energy. No action at Knox Mill Dam would result in the continued presence of these deposits. These deposits appear to have adjusted to the present hydraulic conditions within the impoundment. Over time, additional sediment accumulation may occur within the impoundment, though at a relatively slow rate if the upstream impoundments are also maintained.

Infrastructure

Knox Mill Dam is tied into a building foundation along the right bank of the river, and both banks of the river consist of building foundations. If the dam is to remain in place, continued maintenance of the dam will be required. The dam is privately owned, with limited provisions in place to constrain the operation of the dam, which could lead to complexity for the Town's management of the river if the ownership changes over time. Controls for operation of the low-level gate are not readily accessible which also introduces complexity, as they are found in a former mill area presently occupied by inside a private residential apartment on the west side of the river. The risk of dam failure will not be eliminated, and may gradually increase over time as the structure progressively degrades. Model results from a simulation breach of Knox Mill Dam are discussed in Section 4.8.

7.4 KNOWLTON STREET DAM

Knowlton Street Dam is a run-of-the-river dam with a hydraulic height of approximately 11 feet (Table 18). We evaluated five options at the dam: dam removal, a nature-like fishway, a pool-and-weir fishway, a Denil fishway, and a no-action scenario. We ultimately discarded the nature-like fishway approach with the dam retained in place due to gradient and space limitations, resulting in the options discussed below.

Table 18. Hydraulic heights and effective gradients for the options considered in this study at Knowlton Street Dam. Water levels presented in this table correspond to the May median flow.

Case	Upstream Water Level (ft)	Downstream Water Level (ft)	Hydraulic Height (ft)	Length (ft)	Effective Gradient
Dam removal	61.0	54.4	7.2	105	6.3%
Pool-and-Weir Fishway (left bank)	67.9	54.4	13.5	152	8.8%
Denil Fishway (right bank)	67.9	51.9	16.0	128	12.5%

Recommendation: Considering the balance between advantages and drawbacks, **dam removal is the recommended option at Knowlton Street Dam.**

7.4.1 Dam Removal

Removal of Knowlton Street Dam would consist of removal of the vertical dam structure and the pedestrian bridge above the dam. It may be possible to replace the pedestrian bridge if desired by project stakeholders. To attain passable conditions for fish, manipulation of bedrock at the dam may be required. Significant effort would also be required to manage sediment within the existing impoundment. Removal of the dam would lower the profile of the Megunticook River and restore lotic (i.e., moving water) ecosystem processes to the impounded portion of the 2,800-foot reach between Knowlton Street Dam and Rawson Avenue.

Dam removal would be designed to result in high quality riverine habitat beneficial to both migrating and resident fish (such as brook trout), birds and other wildlife. As the slope of the river through the former impoundment would be lower gradient than other nearby river reaches, the area would offer improved paddling opportunities. Landscape renderings depicting the projected river conditions following removal of Knowlton Street Dam are included in Appendix D.

Restoration of the former impoundment following dam removal would also offer enhanced visitor experiences in conjunction with developed access from the planned Megunticook Riverwalk and other potential access locations. Presently, the Riverwalk terminates approximately 500 feet upstream of the dam on the river left (north) side of the river. In future design phases, additional evaluation of opportunistic alignments to extend the Riverwalk along the restored floodplain area would be investigated.

Fish Passage Restoration

Removal of Knowlton Street Dam would permit safe, effective, and timely fish passage. The dam is constructed on a bedrock ledge, which would be revealed following removal of the vertical dam structure. Following dam removal, flow would preferentially flow over the left side of the bedrock ledge, and through the channel on the left side of the island. This channel is composed of a series of three bedrock/boulder steps and pools and has a slope of approximately 6.3% from the downstream ledge to the exposed bedrock at the dam (Table 18; Figure 97).

The two downstream bedrock/boulder steps within side channel have heights of approximately 1 foot, and associated plunge pools, and should be passable by native fishes. At the downstream outlet of the channel, a boulder step approximately 1.75 feet high may pose a barrier to weaker swimming or non-leaping fishes. Here, a short immobile riffle could be placed downstream of the step to reduce its hydraulic height and provide passable conditions over a greater range of flows.

Based on the evidence that is observable at the site, at the upstream end of the channel near the existing dam, flow over exposed bedrock ledge creates a locally steep portion of channel with a drop of approximately 3.5 feet. This would present a barrier to non-leaping fishes. This bedrock ledge could be adaptively managed at the time of dam removal to provide conditions favorable for passage. Approaches could include manipulation and removal of bedrock along the ledge, or placed boulder elements to create a short series of manageable drops within approximately 30 feet of the ledge. It is also unclear what the bedrock structure is beneath the non-overflow left abutment and lawn area. In general, bedrock is lower on that half of the river. It may be that bedrock elevations are even lower in that area, but that would only be discoverable during construction as the area appears to be filled with boulders (Figure 12). Regardless of the approach taken, at the current stage the evidence of ledge does not preclude dam removal from consideration of feasible options to provide fish passage.

Flood Management and Resilience

The removal of Knowlton Street Dam would modestly reduce flood elevations over the reach extending to approximately 2,800 feet upstream to a location downstream of Rawson Avenue. As a result, flood risk to structures along Rawson Avenue, Mechanic Street, and Knowlton Street may be reduced, though not eliminated. Locations within 50 feet of the dam would experience decreased flood elevations. Removal of the dam would increase floodplain storage within the impoundment, slowing the timing of flood peaks elsewhere along the Megunticook River as well as introducing important ecological processes in what would be newly established floodplain areas. Risks associated with dam failure would be eliminated. Due to the uncertainty regarding actual bedrock elevations in below ground areas that cannot be observed, the flood reductions indicated in Section 4.7 should be considered conservative (i.e., potentially less reduction than actually realized).

Sediment Management

Without active management of sediment, removal of Knowlton Street Dam would result in the mobilization of a notable fraction of the 27,500 cubic yards of accumulated sediment. Impounded sediments comprise essentially the entire width of the impoundment and attain thicknesses of 8-10 feet. To prevent the mobilization of this sediment and potential negative impacts to downstream areas and Camden Harbor, active management of the mobile portion will likely be required.

The proposed management strategy consists of excavating a primary channel and establishing instream geomorphic and habitat features, such as pools and riffles. Channel banks would be restored with targeted vegetative bioengineering treatments and with large wood structures such as root wads to moderate channel migration in key locations and to provide fish habitat. Floodplain areas composed of formerly impounded sediments would be seeded and planted to facilitate stabilization and wildlife habitat value. Sediments in existing overbank areas in upstream portions of the impoundment that are already vegetated would be passively managed without intervention, except that control of invasive vegetative species is proposed. Due to the relatively long length and gradual slope of the former impoundment reach, this area would revert to high quality riverine habitat beneficial to both migrating and resident fish (such as brook trout), birds and other wildlife.

Infrastructure

Removal of the dam may impact the pedestrian bridge directly over the dam, and would likely require either the bridge also be removed or the piers be reconfigured and secured in the underlying bedrock (Gartley and Dorsky, 2021). Utilities currently hung from the deck of the bridge would need to be considered as well (Gartley and Dorsky, 2021). The structural tie-in between the right dam abutment and the foundation of the adjoining building would require attention during detailed design phases to avoid damaging building foundations, though if the building is founded on ledge, this should not be a substantial concern. The crossing of the utility line and the Knowlton Street bridge would require evaluation of foundations and/or piers. See also Appendix A.

In addition, there is a sewer line crossing beneath the impoundment, extending northwest from the wastewater treatment plant through the powerline corridor. With removal of the dam, water levels in the vicinity of this line could drop in elevation two or more feet. Additional detail regarding this line should be collected and evaluated during subsequent planning phases, but is not considered a hard constraint at this time.

Summary

A dam removal option presents the following advantages and drawbacks:

Advantages:

- Removal of a structure posing a significant barrier to fish passage in the Megunticook River.
- Increased passage capacity for a greater diversity of species compared to technical fishway approaches.
- Renaturalization of approximately 2,800 feet of the river in the current impoundment, and reestablishment of lotic ecological processes.
- Eliminates maintenance required for the existing dam.
- Reduces flood elevations in areas upstream of the dam.
- Contribute to improved water quality by reducing shallow ponded conditions along the river subject to solar heating and other impacts.
- Strong potential for grant funding.
- The experience of paddlers exploring the river on floating paddle craft with shift from that of a pond to that of a low gradient flowing river.

Drawbacks:

- The pedestrian bridge over the river will be removed.
- Active management of impounded sediments would be required.
- The experience of paddlers exploring the river on floating paddle craft with shift from that of a pond to that of a low gradient flowing river.

Synthesis: *Provided the balance between advantages and drawbacks,* **dam removal is recommended at Knowlton Street Dam** *to meet the stakeholder goal and objectives.*

Figure 97. Composite photo of the existing side channel (right side of photo) through which fish passage could be attained under a dam removal scenario at Knowlton Street Dam.

7.4.2 Pool-and-Weir Fishway

A pool-and-weir fishway at Knowlton Street Dam would take advantage of the existing side channel along the left bank downstream of the dam. In order for a pool-and-weir fishway to be feasible at Knowlton Dam, the fishway would need to extend upstream from the dam crest.

Fish Passage Restoration

A pool-and-weir fishway is a feasible option to provide safe, effective, and timely fish passage at Knowlton Street Dam (Table 18). The maximum allowable slope for a pool and weir fishway is 10%. To attain a slope passable to target species, the fishway entrance would be positioned at the small ledge currently defining the outlet of the left channel (Figure 98). This ledge would essentially serve as the first weir in the fishway. Approximately 50 feet upstream of the ledge, the fishway would adopt an alignment along the bank of the channel, and would pass through the left abutment of the dam underneath the pedestrian bridge. Depending on bedrock depths near the abutment, bedrock may need to be manipulated to attain fishway slopes.

Flood Management and Resilience

While detailed design of the fishway is needed to fully understand the impacts of this option on flood elevations, a pool-and-weir fishway with an isolation wall would likely have minimal impacts to the flood profile. Lowering the dam crest is one measure that could be implemented to eliminate impacts of the project on flood elevations.

Sediment Management

A pool-and-weir fishway option would require that impounded sediments are excavated and managed within the footprint of the structural elements of the project. An evaluation of the volume of sediments mobilized if the dam crest were lowered would be warranted during the detailed design process. In the broader impoundment, sediment management would not differ from the no action scenario.

Infrastructure

A pool-and-weir fishway will require modification to the non-overflow section of the left abutment. The fishway would pass under the existing pedestrian bridge, with the intent of maintaining the bridge. The fishway would need to be maintained and kept free of debris. Other infrastructure elements would remain in place and would largely not change from existing conditions. See also Appendix A.

Summary

A pool-and-weir fishway at Knowlton Street Dam presents the following advantages and drawbacks:

Advantages:

- Safe, effective, and timely fish passage could be provided for an array of native fish species.
- Increased biological capacity compared to Denil fishways. The specific biological capacity of the fishways would be identified during detailed design.
- Smaller decrease of spillway flow capacity compared to the right-bank Denil fishway option.

Drawbacks:

- Modification of the left abutment may be required.
- Limited or impossible passage for American Eel and Sea Lamprey.
- Flood conditions: flow separation measures upstream of the dam would require dam modifications to avoid impacts to flood elevations.
- Water Quality: Sustained ponded condition likely impacts stream water temperature and other water quality factors.
- Maintenance: Regular maintenance of the pool-and-weir fishway would be required. Maintenance would include removing debris from the fishway, especially following high flow events.

Synthesis: *Provided the balance between advantages and drawbacks, **if the Knowlton Street Dam is required to be retained,*** **the pool-and-weir fishway on the left bank is the recommended technical fish passage approach**. *A Denil fishway would also be feasible in the same general vicinity, but is not recommended due to reduced biological capacity and passage effectiveness.*

Figure 98. Schematic layout of a pool-and-weir fishway at Knowlton Street Dam.

7.4.3 Denil Fishway

We evaluated a Denil fishway option to determine if the approach would provide safe, timely, and effective fish passage at Knowlton Street Dam. While a Denil fishway could provide fish passage, such an approach presents numerous practical challenges as well as important flood mitigation and resilience considerations.

<u>Fish Passage Restoration</u>

The right bank of the river, which abuts building foundations, would provide space available for a Denil fishway. Knowlton Street Dam has a hydraulic height of 11 feet, and downstream of the dam the Megunticook River has an average slope of approximately 10%. As a result, considerable length is required to attain fishway slope requirements. Knowlton Street bridge, located approximately 105 feet downstream of the dam, limits the downstream extent of a fishway.

To attain a slope of 12.5%, a switchback alignment would be necessary (Table 18). The fishway would extend from the dam crest to approximately 10 feet upstream of the Knowlton Street bridge. Turning pools at the switchbacks would need to be incorporated into the design, as would resting pools every 6 to 9 feet of elevation gain where turning pools are not present.

Flood Management and Resilience

A Denil fishway option would not improve flood management at Knowlton Dam, and would most likely have a negative impact on flood elevations. The fishway exit would decrease the existing spillway length, which might require modifications to other areas of the spillway to maintain the same capacity. A switchback alignment would occupy significant amount space downstream of the dam and may increase flood elevations in adjacent areas. A fishway would not reduce the risk of dam failure.

Sediment Management

A Denil fishway option would not alter sediment management comparted to a no-action scenario or existing conditions.

Infrastructure

A technical fishway option would require minimal changes to nearby infrastructure. The fishway could be anchored to the building foundation along the right bank of the river, and dam alterations would be necessary to accommodate the fishway exit. The fishway would require continued maintenance and potentially may need headwater control to extend its operating range over the fish passage period. See also Appendix A.

Summary

A Denil fishway presents considerable challenges. The following bullet points detail the advantages and drawbacks of such an approach.

Advantages:

- Safe, effective, and timely fish passage could be provided without structural alteration of the dam for approximately 200,000 fish with a Denil fishway.
- No change would be required to tie-ins between the dam abutments and nearby building foundations.

Drawbacks:

- Biological capacity: A single Denil fishway at would likely serve as a limiting factor to the river herring population would constrain access for sea lamprey and American Eel.
- Reduced passage for American Eel and Sea Lamprey.
- Turning pools required to negotiate switchbacks could create confusion or difficult-to-navigate hydraulics for some species.

- Flood conditions: A right bank Denil fishway would reduce the spillway capacity and occupy space in the channel downstream of the dam, and would likely impact the flood profile.
- Water Quality: Sustained ponded condition likely impacts stream water temperature and other water quality factors.
- Maintenance: Regular maintenance of the fishway would be required. Maintenance would include removing debris from the fishway, especially following high flow events, and possible manipulation of headwater elevations to extend passage conditions.

***<u>Synthesis:</u> Provided the balance between advantages and drawbacks*, a Denil fishway on the right bank is not recommended at Knowlton Street Dam** *even though the approach is technically feasible.*

7.4.4 Other Fish Passage Considerations

Upstream of the dam, conditions within the dam's impoundment would return to riverine ecological and geomorphic conditions. Flow depths and velocities would be favorable throughout the former impoundment. At the Rawson Avenue bridge crossing, flows above and including the 5% May exceedance flow would likely present adverse hydraulic conditions for weaker-swimming fishes. The bridge has been determined to be unsafe for vehicle traffic and is presently closed. Decommissioning of the bridge is planned in the MEDOT 2021-23 workplan and will remove this impediment.

7.4.5 No Action

"No Action" at Knowlton Street Dam would result in a continued barrier to fish passage. Ongoing maintenance of the dam would be required.

<u>Fish Passage Restoration</u>

Knowlton Street Dam is a complete barrier to fish passage in its existing condition, and the no-action approach would continue to block aquatic organisms from accessing upstream areas.

<u>Flood Management and Resilience</u>

As a run-of-the-river dam, Knowlton Street Dam does not provide flood storage and locally elevates flood water elevations. With no-action, no benefit to flood management will be realized. Continued maintenance of the dam will be required, and the present modest risk of dam failure will perpetuate and may incrementally increase in the future. As a result, buildings that are located within the regulatory floodplain near Knowlton Street Dam and downstream of Rawson Avenue will not benefit from decreased flood risk. The dam is privately owned, and in the past, sediment releases have occurred during storm events, as well as during maintenance and other operations conducted by previous owners of the dam. Due to the current low hazard rating assigned to the dam, periodic inspections are not required and there are no binding requirements for maintaining the operability of the dam.

Sediment Management

As discussed in Section 4.4, Knowlton Street Dam impounds approximately 27,500 CY of fine sediment. Under the no-action scenario, these sediments will remain in place and will not be substantially altered by natural river processes. However, periodic storm-related partial sediment releases have occurred in the past and will continue in the future, posing some risk to the watershed. The sediments are notable in volume and do contain a modest level of contamination that will impact on river ecology and water quality.

Infrastructure

The right abutment of Knowlton Street Dam is tied into a building foundation. A pedestrian bridge crosses over the dam of the river, and downstream of the dam a power line and bridge cross the Megunticook River. Under a no-action scenario, all of these elements will require continued maintenance and inspection in line with current practices.

7.5 POWDER MILL DAM RUINS

The Powder Mill Dam Ruins consists of a partially breached relict dam with existing masonry abutments still in place and stone blocks that have tumbled into the channel. While the primary spillway has failed, the structure still constricts flow and poses at least a partial barrier to fish passage (Table 19). The hydraulic height of the relict dam is 8.5 feet. We evaluated dam removal as well as a no-action option.

We also considered technical fishway and nature-like fishway options at the site. However, these options were assessed to be not feasible based on initial screening. Primarily, since the dam is in a failing condition, we determined it was not practical or sustainable to construct new permanent features to integrate with the failing structure.

Recommendation: Considering the balance between advantages and drawbacks, **dam removal is the recommended option at Powder Mill Dam Ruins.**

Table 19. Hydraulic heights and effective gradients for the option considered in this study at Powder Mill Dam ruins.

Case	Upstream Water Level (ft)	Downstream Water Level (ft)	Hydraulic Height (ft)	Length (ft)	Effective Gradient
Dam Removal	94.4	91.6	2.8	65	4.3%

7.5.1 Dam Removal

Removal of the Powder Mill Dam Ruins would permit safe, effective, and timely fish passage with few drawbacks. The structure is composed of stacked masonry blocks founded on bedrock. Removal would eliminate a notable local restriction to flood flows.

Fish Passage Restoration

The removal of the dam would result in an effective gradient across the dam of 4.3%, which is assessed to be generally passable for native fishes (Table 19). Ledge is present at the base of the dam and constituted a local pre-dam hydraulic control. As the ledge is partially obscured by the structure itself, there is some uncertainty to the actual shape and configuration of the ledge, which would be revealed as the dam were removed. During the detailed design phase, contingency measures would be evaluated to adapt the design to the conditions beneath the dam once it is dismantled.

If bedrock ledge features are exposed following dam removal, cobbles and boulders could be placed downstream of the ledge to form a riffle passable by target native fish species. This riffle, if necessary, would be constructed with immobile river substrate at a slope of 3% or less. A less intensive approach may entail adding boulders in the stream to break up flow and provide refugia to fish in order to overcome locally high velocities over the ledge. Provided that post-removal bedrock conditions do not impede passage or are able to be managed adaptively, removal of the remaining dam and abutments would fully restore fish passage in this location.

Flood Management and Resilience

Removal of the Powder Mill Dam Ruins would result lower flood elevations between the Dam Ruins and Mount Battie Street due to absence of in-stream vertical structures and abutments on the overbanks. While floods currently access floodplain areas, the constriction posed by the dam forces a majority of the water through the breached dam, resulting in high in-channel velocities and elevated flood water surface elevations. With a complete removal of the abutments, flood flows would have lower water surface elevations, increased conveyance capacity on floodplain surfaces, and reduced in-channel velocities. Additionally, removal of the dam ruins eliminates risk associated with of additional structural failure.

Sediment Management

The historical breaching of the dam has resulted in the evacuation of the mobile fine sediments from behind the dam, with primarily coarse river substrate (gravel and gobble) materials remaining. Pockets of fine sediments comprising less than 100 CY may incrementally mobilize following dam removal. The remaining gravel and cobble materials are expected to gradually transport downstream as the channel evolves to post-removal conditions, which will be beneficial to instream habitat quality. Existing upstream overbank composed of impounded sediments that have substantially vegetated since the dam breached are unlikely to substantially erode following removal.

Infrastructure

Removal of the dam ruins would have minimal impacts to nearby infrastructure. Detailed design phases would evaluate structure removal options, and proposed grading at the left abutment near the former mill building, and at the right abutment near the valley slope.

Summary

The following advantages and drawbacks are associated with the removal of the dam ruins:

Advantages:

- Removal of the remnant dam structure will alleviate a fish passage constraint.

- Flood elevations upstream of the dam to Mt. Battie Street will be reduced.
- The historical dam breach has evacuated most of the mobile impounded fine sediments, so removal of dam ruins poses little risk of further fine sediment evacuation.
- Relatively low-effort net beneficial project option.
- Removal would eliminate a navigation hazard for paddlers, and may provide a point of future access through coordination with the Riverwalk.
- Strong potential for grant funding.

Drawbacks:

- Greater near-term cost compared to no-action option.

Synthesis: *Provided the balance between advantages and drawbacks,* **dam removal is recommended at Powder Mill Dam Ruins** *to meet the stakeholder goal and objectives.*

7.5.2 Other Fish Passage Considerations

At the Mount Battie Street crossing, flow velocities at high fish passage flows may present a partial barrier to fish passage. The crossing features twin pipe arch culverts with a rise of 9.4 feet. Flow contraction and expansion at the culverts results in velocities that exceed 6 ft/s for the highest expected May flows. Modifications to this crossing may permit passage over the full fish passage flow range. Future replacement of the crossing with a clear span following Maine StreamSmart guidelines would facilitate complete fish passage potential, and also enhance geomorphic compatibility of the crossing with reach-scale river processes.

7.5.3 No Action

A no action approach at the dam ruins would maintain a partial to full barrier to fish passage and would leave the abutments and failed spillway in place. Over long periods of time, it is reasonable to expect ongoing failure of vertical structures and continued partial restriction of fish passage.

Fish Passage Restoration

With a no-action approach, the Powder Mill Dam Ruins will continue to deteriorate over time. Given the size of the masonry blocks composing the dam and the competency of flows, it is unlikely that the ruins would ever become fully passable without active removal of the dam structures.

Flood Management and Resilience

Under a no-action approach, the existing abutments in the dam ruins will prevent significant overbank flow conveyance, and will impound water during floods. Ongoing deterioration of the dam is unlikely to significantly reduce flood elevations.

Sediment Management

The impounded sediments behind the dam ruins are relatively coarse, and no management would be required under a no-action approach.

<u>Infrastructure</u>

Infrastructure adjacent to the dam ruins consists of the former mill building along the left bank downstream of the dam. No changes to the building would result from a no-action approach.

7.6 SEABRIGHT DAM

Seabright Dam impounds flow and maintains water levels over a 1.75-mile length of the Megunticook River. It has a hydraulic height of 16.1 feet (Table 20) and poses a complete barrier to migrating fish. We evaluated pool-and-weir fishway, nature-like fishway, Denil fishway, and no action approaches. Dam removal was eliminated early in screening of project options due to the importance of maintaining water levels in the impoundment based on residential and recreational concerns.

Table 20. Hydraulic heights and effective gradients for the options considered in this study at Seabright Dam.

Case	Upstream Water Level (ft)	Downstream Water Level (ft)	Hydraulic Height (ft)	Length (ft)	Effective Gradient
Denil Fishway	122.1	106.0	16.1	129	12.5%
Pool-and-weir fishway	122.1	106.0	16.1	165	8.2%
Nature-like Fishway	122.1	106.0	16.1	387	4.2%

<u>Recommendations:</u> Considering the balance between advantages and drawbacks, **it is recommended that the Town and stakeholders further evaluate two options before final selection of a fish passage option for this site.** A **pool-and-weir fishway on the left bank is a recommended technical fish passage approach at Seabright Dam,** due to biological capacity, attraction flow location, and potential to be coordinated with future planned repair and rehabilitation of the spillway channel. However, a **nature-like fishway on the right bank is also recommended for consideration in final selection** if a similar biological capacity as the pool and weir fishway can be attained. Nature-like flow patterns are generally preferred to technical fishway flow patterns. The advantage for nature-like flow patterns should be weighed against potentially superior attraction signal for the pool-and-weir fishway option on the river left side of the dam when making a final selection of preferred option for the site. The river right location of the nature-like fishway also offers advantages of greater simplicity in constructing its opening through the dam, and ease of access for educational and visitor experiences.

7.6.1 Nature-like Fishway

A nature-like fishway is a feasible option to provide safe, effective, and timely fish passage at Seabright Dam. A nature-like fishway with a sinuous alignment could be constructed with a slope of 4.2% (Table 20; Figure 99). The west side of the river offers easier access, fewer structural changes to the dam compared to eastern spillway modifications, and enhanced educational opportunities with the adjacent Coastal Mountain Land Trust office. A maintenance access would need to cross the fishway.

Fish Passage Restoration

A right-bank nature like fishway option has a proposed sinuous alignment descending the right embankment of the dam, with an entrance immediately downstream of Seabright Dam. The fishway would consist of a channel with bioengineered or rock banks and boulder steps with pools, which provide grade control and energy dissipation functions, respectively. The fishway exit geometry must be designed to provide adequate depth and velocity for fish passage during the migration period while maintaining required water levels in the impoundment. Similar to the other options considered at Seabright Dam, consideration would be given to ensuring acceptable water levels in the impoundment corresponding to the acceptable operating range of the fishway during the May-June migration period for river herring, as well as other periods of the year for residential fish that may desire passage past the site.

Flood Management and Resilience

A nature-like fishway option would not occupy space along the primary spillway, and would not impact flood elevations upstream or downstream of Seabright Dam.

Sediment Management

No sediment management within the Seabright Dam impoundment would be necessary with a nature-like fishway option.

Infrastructure

A nature-like fishway option would require modification of the eastern non-overflow embankment at the dam. The sinuous alignment would avoid the sewer line downstream of the dam, but additional detailed consideration of this utility would be necessary during detailed design. A maintenance access crossing of the fishway would be required. Current dam maintenance and operation would continue, along with maintenance activities required to remove debris from the fishway. See also Appendix A.

Summary

A nature-like fishway presents the following advantages and drawbacks:

Advantages:

- Safe, effective, and timely fish passage around a significant barrier to fish passage in the Megunticook River.
- Access to habitat within the impoundment behind Seabright Dam.
- Educational and outreach opportunities associated with the neighboring Coastal Mountain Land Trust, and the existing Town Park and Riverwalk.
- Does not obstruct kayak portage across the dam
- Easier construction access and fewer dam modifications compared to a left-bank option.

- Greater biological capacity and operating range than technical fishway approaches.
- Strong potential for grant funding.

Drawbacks:

- Maintenance of the fishway would be required.
- Positioning the fishway entrance opposite of the spillway flow is a less preferred option, as fish may have a diminished response to its attraction signal.
- Flood flows may render the fishway inaccessible for periods of time.
- A maintenance access crossing of the fishway would be required.

Synthesis: *Nature-like flow patterns are generally preferred to technical fishway flow patterns. If similar biological capacity could be supported between nature-like and pool-and-weir designs for the right overbank,* **the nature-like approach is recommended** *for this alignment. The advantage for nature-like flow patterns should be weighed against potentially superior attraction signal for the pool-and-weir fishway option on the river left side of the dam, when making a final selection of preferred option for the Seabright Dam site.*

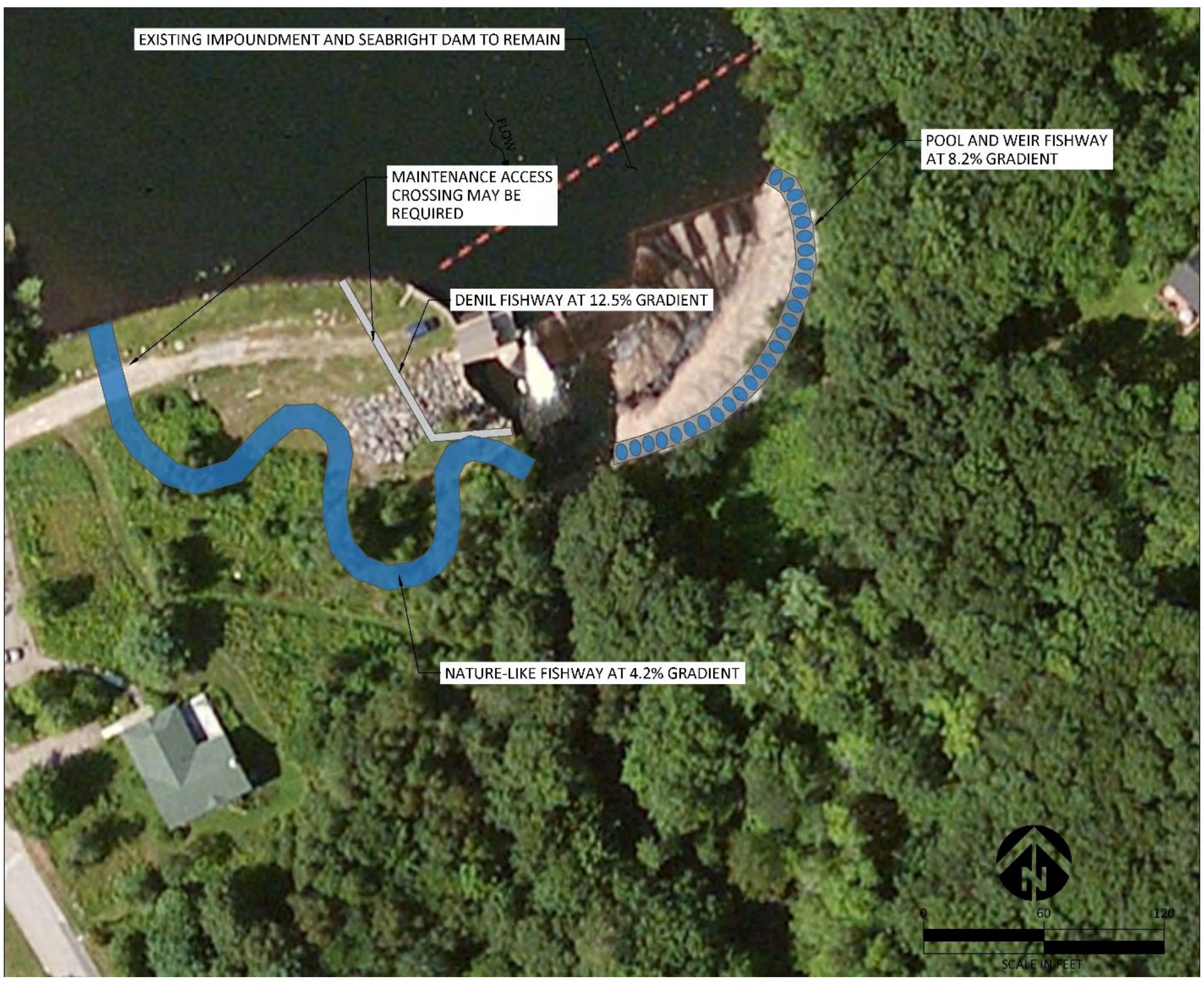

Figure 99. Schematic layouts of a Denil fishway, pool-and-weir fishway, and nature-like fishway options at Seabright Dam.

7.6.2 Pool-and-Weir Fishway

A pool-and-weir fishway is feasible at Seabright Dam (Table 20), and we propose an alignment along the far left (east) boundary of the existing dam spillway (Figure 99). A pool-and-weir fishway could also conceivably be constructed through the western embankment of the dam, and would have an alignment with less sinuosity that shown for the nature-like fishway in Figure 99. A west bank fishway would likely require a maintenance access crossing of the fishway.

Fish Passage Restoration

A pool-and-weir fishway through the eastern spillway of Seabright Dam would feature a slope of 9.2%, which is near the upper limit for pool-and-weir spillways. Additional switchbacks, increased pool size, and sections of variable slope could be considered during detailed design to minimize energy requirements for fish to ascend the fishway. The fishway entrance would be positioned immediately downstream of Seabright Dam to provide a competing attraction signal to flow over the dam's spillway. The attraction signal is a primary advantage of locating the fishway on the east side of the dam.

A critical aspect of fishway design at Seabright Dam is to maintain water levels in accordance within the dam's operational guidelines. Detailed design phases of the project would determine the fishway exit geometry that provides adequate depth and velocity for fish passage during the migration period while maintaining required water levels in the impoundment.

Flood Management and Resilience

A pool-and-weir fishway would occupy the far boundary of the eastern spillway on Seabright Dam, and must be designed such that the capacity of the dam to pass flood flows is not impacted. Ultimately, a pool-and-weir fishway would not impact flood elevations upstream or downstream of Seabright Dam.

Sediment Management

No sediment management within the Seabright Dam impoundment would be necessary with a pool-and-weir option.

Infrastructure

A pool-and-weir fishway would require modification of the dam spillway, which is currently features a concrete apron. A constructed berm separating the fishway from the spillway may be required to minimize the impact of transverse flow across the spillway. The spillway's crest may also need to be modified, depending on the final location of the fishway exit. Current dam maintenance and operation would continue, along with maintenance activities required to maintain an operable fishway. Maintenance would include removing debris from the fishway and possible manipulation of headwater elevations with baffles or dam gates to extend passage conditions. See also Appendix A.

Summary

A pool-and-weir fishway at Seabright Dam presents the following advantages and drawbacks:

Advantages:

- Safe, effective, and timely fish passage could be provided for an array of native fish species.
- Increased biological capacity compared to Denil fishways.
- Better fish attraction conditions compared to a right bank nature-like fishway.
- Likely potential for grant funding

Drawbacks:

- Modification of the left spillway would be required.
- Limited or impossible passage for American Eel and Sea Lamprey.
- Regular maintenance of the pool-and-weir fishway would be required. Maintenance would include removing debris from the fishway, especially following high flow events.

Synthesis: *Provided the balance between advantages and drawbacks,* **pool-and-weir fishway on the left bank the recommended technical fish passage approach at Seabright Dam***, due to optimized fish passage attraction potential and biological capacity. A Denil fishway would also be feasible in the same general vicinity, but is not recommended due to reduced biological capacity and passage effectiveness. Pool-and-weir fishway on the right bank would also be a feasible and viable approach, with potentially less optimal passage attraction signal, but with easy construction access. For this option, a maintenance crossing of the fishway would be required.*

7.6.3 Denil Fishway

A technical Denil fishway is feasible for attaining safe, effective, and timely fish passage at Seabright Dam (Table 20). The fishway could be aligned along the right embankment of the dam west of the powerhouse, avoiding modifications to the spillway.

Fish Passage Restoration

A Denil fishway would require a slope of 12.5% (1V:8H; Figure 99). The fishway would require resting pools at every 6-9 feet of elevation gain and at any turns in the alignment. Entrance and exit conditions would be engineered during the detailed design phase of the project. Primary consideration would be given to ensuring acceptable water levels in the impoundment correspond to the acceptable operating range of the fishway during the May-June migration period for river herring, as well as other periods of the year for residential fish that may desire passage past the site. The fishway entrance would be positioned immediately downstream of the dam to provide a competing attraction signal to the spillway flow.

As discussed in Sections 6.1.2 and 6.1.3 (Knox Mill Dam and Knowlton Street Dam, respectively), the biological capacity of a standard single Denil fishway (200,000 river herring) approaches, but is less than the conservative population estimate (over 300,000 river herring) for the watershed. A single

Denil fishway at Seabright Dam may constitute a limiting factor to the fish population over the long term. A second Denil may need to be added to serve the potential long-term restored river herring population.

Flood Management and Resilience

The Denil fishway would be designed to not impact normal or flood water levels and flows in the impoundment. The proposed location of the fishway is located on the western embankment of the dam, entering the impoundment through the non-overflow portion of the embankment and would not reduce the capacity of the dam's spillway.

Sediment Management

No sediment management within the Seabright Dam impoundment would be necessary with the Denil fishway option.

Infrastructure

The Denil fishway would require modification of the dam's earthen embankment. Further evaluation is needed to determine the extent to which the riprap on the embankment slope can be manipulated, or if a Denil fishway would need to avoid the riprap. Current dam maintenance and operation would continue, along with added maintenance required to maintain an operable fishway. A maintenance crossing would be required. Utilities present downstream of the dam on the right bank of the river would not be impacted by the fishway. Maintenance would include removing debris from the fishway and possible manipulation of headwater elevations with baffles or dam gates to extend passage conditions. See also Appendix A.

Summary

A Denil fishway at Seabright Dam would present the following advantages and drawbacks:

Advantages:

- Safe, effective, and timely fish passage could be provided adjacent to the powerhouse structure of the dam for approximately 200,000 river herring.
- A Denil fishway would have no impact on flood elevations. Least construction impact to the site.

Drawbacks:

- Reduced passage for American Eel and Sea Lamprey.
- Biological capacity: A single Denil fishway at Seabright Dam would likely serve as a limiting factor to the upstream river herring population. A second Denil may need to be added to support the fully restored river herring population.
- The fishway effectiveness may be limited when water levels in the impoundment are required outside of the operating range of the fishway (for example, during low-flow when water is stored to maintain impoundment levels)
- Regular maintenance of the fishway would be required.

<u>Synthesis</u>: *Provided the balance between advantages and drawbacks*, **a Denil fishway on the right bank is not recommended at Seabright Dam** *even though the approach is technically feasible. This is due to the potentially limiting biological capacity.*

7.6.4 Other Fish Passage Considerations

Seabright Dam presents the only barrier to fish migration between Mount Battie Street and East and West Dams. A fishway solution at the dam would therefore provide access to habitat within the Seabright Dam impoundment with no further actions required.

7.6.5 No Action

The no-action approach at Seabright Dam would maintain the current configuration of the site. Operations of the dam and water levels in the impoundment would not be affected.

<u>Fish Passage Restoration</u>

Under a no-action approach, Seabright Dam will continue to present a complete barrier to fish passage.

<u>Flood Management and Resilience</u>

No change to flood elevations or management would occur under the no-action approach. Ongoing water level control operations would continue. Seabright is a high-hazard dam with applicable regulatory requirements, including periodic inspections, and maintenance and repair obligations.

<u>Sediment Management</u>

No sediment management activities would be necessary with a no-action approach.

<u>Infrastructure</u>

The existing dam facility, operations, and maintenance would not be impacted with the no-action approach. Adjacent infrastructure would also be unaffected.

7.7 EAST AND WEST DAMS

The East and West Dams at Megunticook Lake are the upstream-most dams on the Megunticook River. East Dam has a hydraulic height of 12.1 feet and routes flow over a 51-foot-long spillway and through a bottom-release gate. West Dam has a hydraulic height of 12.9 feet and releases flow through a sluice gate. Both dams pose a complete barrier to migrating fish. Present operations of the site utilize the East Dam for primary lake outflow control, with West Dam used for fine-tuning of outflow volumes.

We evaluated four options: a pool-and-weir fishway at East Dam, a pool-and-weir/hybrid fishway at West Dam, a Denil fishway at East Dam, and no-action. Fishway alternatives that were also considered but found to be not feasible include strictly nature-like fishways at both dams, and fishway options occupying the channel linking West Dam to the East Dam outflow channel to facilitate attraction. Dam removal options were not considered, as the ability to control water levels in Megunticook Lake is required.

Table 21. Hydraulic heights and effective gradients for the options considered in this study at East and West Dams.

Option	Upstream Water Level (ft)	Downstream Water Level (ft)	Hydraulic Height (ft)	Length (ft)	Effective Gradient
Nature-like and Pool-and-Weir hybrid fishway (West Dam)	141.9	123.5	18.4	250	4.5% (NLF); 9.5% (PW); 7.5% Average
Pool-and-Weir fishway (East Dam)	141.9	128.9	13.0	178	7.3%
Denil Fishway (East Dam)	141.9	128.9	13.0	105	12.5%

Recommendations: Similar to the case at Seabright Dam, **it is recommended that the Town and stakeholders further evaluate two options before final selection of a fish passage option for this site.** The two short-listed options include a **hybrid pool-and-weir / nature-like fishway at West Dam and pool-and-weir fishway at East Dam.** The West dam hybrid approach may be more complex, but the footprint of the option is within an existing channel, affords superior maintenance access, and offers the potential to coordinate with future upgrades that may be needed for the West Dam. The East Dam pool-and-weir option is less complex, but requires multiple switchbacks, potentially extensive bedrock excavation, and is located on private property adjacent to the dam.

7.7.1 Nature-like and Pool-and-Weir Hybrid Fishway at West Dam

A hybrid nature-like and pool-and-weir fishway is a feasible option at West Dam. The alignment would extend along the existing channel downstream of West Dam to the Molyneaux Road crossing.

Fish Passage Restoration

A hybrid nature-like and linear pool-and-weir fishway option would take advantage of the existing channel downstream of West Dam, which has an overall average slope of approximately 4.5% downstream of the dam. The downstream-most 100-foot section of the channel near Molyneaux Road would be enhanced to provide passage at a nature-like slope of 4.5%. From the upstream end of the nature-like channel, a pool-and-weir fishway would extend at a 9.5% slope to meet grades at the West Dam. The resulting average slope would be approximately 7.5%.

The success of this option would depend on future adaptions to West Dam such that passable conditions could be maintained in the fishway while simultaneously maintaining water levels in Megunticook Lake. Substantial retrofits or replacement of the dam may be required to enable this option to be implemented. It the dam is replaced in kind, relocating the primary outflow nearer the location of the existing trashrack would provide about 20 feet of additional length to the fishway and reduce energy requirements for fish ascending the spillway.

The current channel downstream of West Dam features limited boulder steps and pools; it is possible these native materials could be used to configure the nature-like channel.

The entrance to this option would be located near the Molyneaux Road crossing. Therefore, the attraction signal would be competing with flow attraction signals from the eastern channel. Under some flow conditions, the attraction signal could be diminished, unless the balance of primary lake outflow control shifted from the East Dam to the West Dam. In this circumstance, the intent would be for the lake outflow to be routed directly through the fish passage itself.

Flood Management and Resilience

The hybrid fishway option would be designed to not impact normal or flood water levels and flows in the impoundment. Ultimately, the management of flows between West Dam and East Dam would dictate the respective flow levels in the channels downstream of the dams.

Sediment Management

No sediment management in Megunticook Lake would be necessary with a hybrid fishway option at West Dam.

Infrastructure

A hybrid fishway would require modifications to West Dam to permit passage around the dam, including potential replacement in-kind, with new water control at the replacement dam crest. Possible manipulation of headwater elevations may be necessary to extend passage conditions in compliance with the dam's operational guidelines. See also Appendix A.

Summary

A hybrid fishway at West Dam presents the following advantages and drawbacks:

Advantages:

- Safe, effective, and timely fish passage could be provided for an array of native fish species.
- Potential for increased fishway size, which could allow most of the flow to be routed through the fishway during passage periods, resulting in effective attraction signal.
- Access to habitat in Megunticook Lake and in the upstream watershed.
- Increased biological capacity compared to Denil fishway options.
- The fishway would not impact flood elevations.
- Located in an existing channel alignment
- Located along an existing access road (private, with right-of-way privileges)
- Likely potential for grant funding

Drawbacks:

- Potentially significant modification to West Dam may be required. Additionally, modification of dam operations at East/West Dams may be required.
- Fish attraction signals would be located near Molyneaux Road, and attraction may be sub-optimal, unless the majority of lake outflow were shifted from the East Dam to the West Dam, and through the fish passage.
- The fishway would be located on property that is presently privately owned and would require negotiation of access and right-of-way, or acquisition, to construct.

<u>Synthesis</u>: *Provided the balance between advantages and drawbacks,* **the hybrid pool-and-weir/nature-like fishway at the West Dam is a recommended short-list option**. *This option is contingent on the willingness to effect more substantial change at the West Dam. If this is acceptable, this option has the potential to provide the greatest degree of biological capacity at the Megunticook Lake outlet. To provide the most viable attraction flow for this option, shifting the primary outflow from the West Dam to the East Dam would allow the majority of flow to be routed through the fish passage during the migration season. This shift in flow operations would need to be assessed and accepted by the Town.*

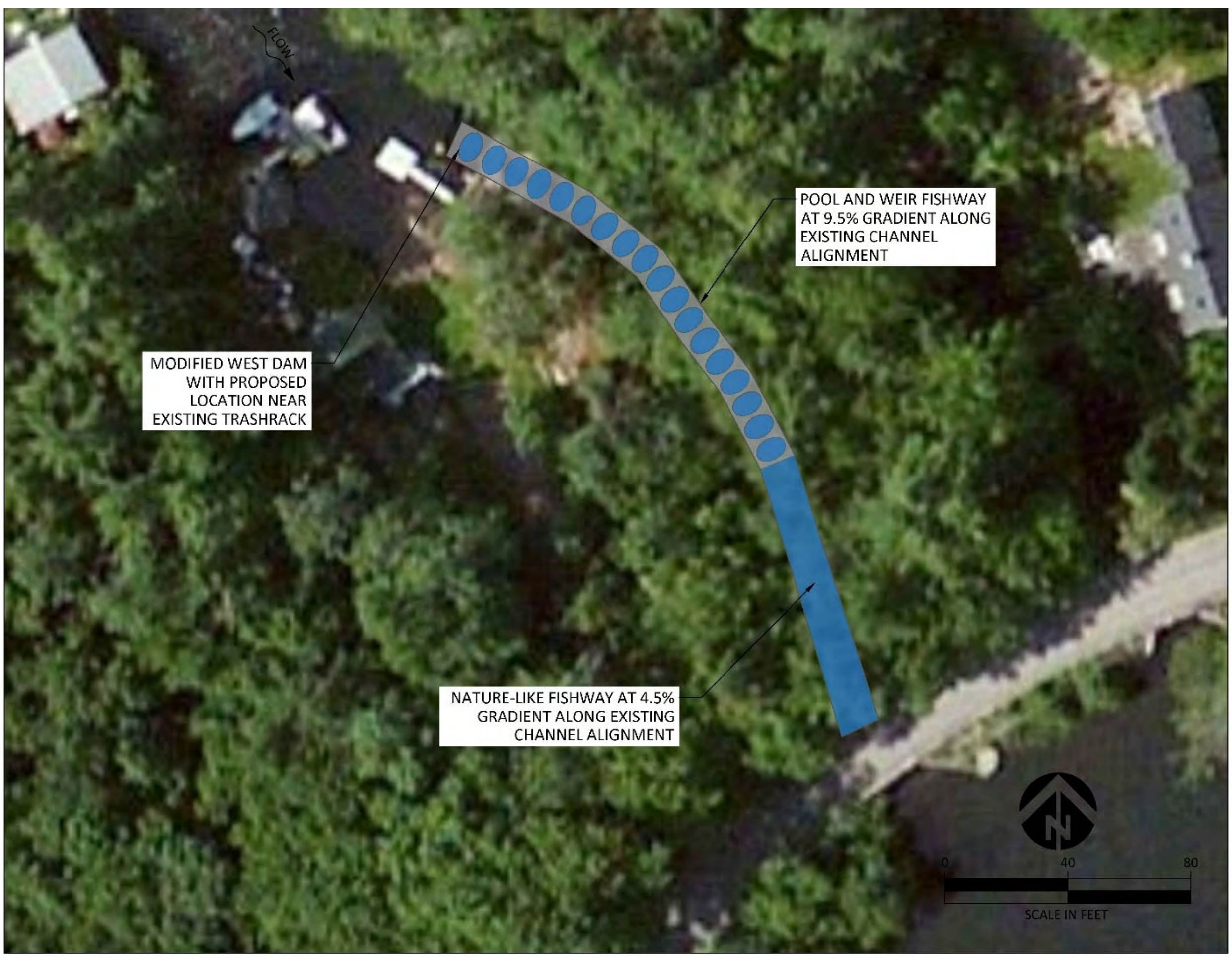

Figure 100. Schematic layout of a hybrid nature-like fishway and pool-and-weir fishway at West Dam.

7.7.2 Pool-and-Weir Fishway at East Dam

A pool-and-weir fishway is feasible at East Dam and would occupy a switchback alignment along the eastern spillway embankment downstream of the dam (Table 21; Figure 101). The alignment is located on private property adjacent to the dam, and will require ledge excavation (potentially substantial).

Fish Passage Restoration

A pool-and-weir fishway option would have a slope of approximately 7%. Increased pool size, and sections of variable slope could be considered during detailed design to minimize energy requirements for fish to ascend the fishway. Alignments featuring a longer downstream extension were discarded, as those would feature weaker attraction signals compared to an alignment with the fishway entrance near the dam. Fairly shallow conditions are currently present at the fishway exit location.

Entrance and exit conditions would be engineered during the detailed design phase of the project. Primary consideration would be given to ensuring acceptable water levels in Megunticook Lake correspond to the acceptable operating range of the fishway during the May-June migration period for river herring, as well as during other periods of the year that are important for key residential fish such as brook trout. The fishway entrance would be positioned immediately downstream of the dam to provide a competing attraction signal to the primary spillway flow. In order to achieve the acceptable pool-and-weir slope, substantial switchbacks would be required. The alignment of the fishway would be refined during the detailed design phase.

Flood Management and Resilience

A pool-and-weir fishway option would be designed to not impact normal or flood water levels and flows in the impoundment. The proposed location of the fishway is located on the eastern embankment of the dam and would not impact the flood flow routing capacity of the dam.

Sediment Management

No sediment management in Megunticook Lake would be necessary with a pool-and-weir fishway option.

Infrastructure

A pool-and-weir fishway would require modifications to the eastern embankment of East Dam. No modification to the dam's spillway or gates would be required. Current dam maintenance and operation would continue, along with added maintenance required to maintain an operable fishway. Maintenance would include removing debris from the fishway and upstream trashrack. Possible manipulation of headwater elevations may be necessary to extend passage conditions in compliance with the dam's operational guidelines. See also Appendix A.

Summary

A pool-and-weir fishway at East Dam presents the following advantages and drawbacks:

Advantages:

- Safe, effective, and timely fish passage could be provided for an array of native fish species.
- Access to habitat in Megunticook Lake and in the upstream watershed.
- Increased biological capacity compared to a single Denil fishway.
- The fishway would not impact flood elevations.
- Would facilitate continued primary operation of the East Dam for lake outflow control.
- Potential for grant funding.

Drawbacks:

- Potentially reduced passage for American Eel and Sea Lamprey.
- Turning pools required to negotiate switchbacks could create confusion or difficult-to-navigate hydraulics for some species.
- Modification to the dam embankment is required.
- Shallow conditions in the vicinity of the fishway exit.
- Substantial switchbacks required.
- Regular maintenance of the fishway would be required. Maintenance would include removing debris from the fishway, especially following high flow events.
- The fishway would be located on property that is presently privately owned and would require negotiation of access and right-of-way, or acquisition, to construct.
- May require substantial ledge removal.

Synthesis: *Provided the balance between advantages and drawbacks, a* **pool-and-weir fishway at East Dam is a recommended short-list option.** *While this option can provide increased biological capacity, it is hampered by the needed switchbacks to attain an acceptable fishway slope. Due to this, this option is considered approximately equivalent to the Denil fishway option, which is able to be constructed with fewer switchbacks.*

Figure 101. Schematic layout of a pool-and-weir fishway option at East Dam.

7.7.3 Denil Fishway at East Dam

A Denil fishway is feasible for attaining safe, effective, and timely fish passage at East Dam (Table 21). To attain an acceptable slope, a fishway is proposed with a switchback alignment along the left embankment (non-overflow) portion of the dam.

Fish Passage Restoration

A Denil fishway option would adopt a switchback alignment along the left embankment of East Dam and maintain a slope of 12.5% (1V:8H) slope, which is recommended for weaker-swimming fish species (USFWS, 2019; Figure 102). The fishway would require resting pools at every 6-9 feet of elevation gain and at switchbacks. Entrance and exit conditions would be engineered during the detailed design phase of the project. Primary consideration would be given to ensuring acceptable water levels in Megunticook Lake correspond to the acceptable operating range of the fishway during the May-June migration period for river herring, as well as during other periods of the year that are important for key residential fish such as brook trout. The fishway entrance would be positioned immediately downstream of the dam to provide a competing attraction signal to the primary spillway flow.

The biological capacity of a standard Denil fishway (200,000 river herring) approaches, but is less than the conservative population estimate (over 300,000 river herring) in Megunticook Lake. A single Denil fishway at East Dam may constitute a limiting factor to the upstream fish populations over the long term. To meet the biological demand, a second Denil fishway could be required with restoration of the native fish population.

While not discussed in detail, alignment of a Denil fishway extending from the West Dam along the crossing channel to the East Dam outlet channel (discussed in more detail below) would also be an option. Water control for a Denil at the West Dam may be more complicated however, as this option would likely maintain the primary lake outflow at the East Dam.

Flood Management and Resilience

The Denil fishway option would be designed to not impact normal or flood water levels and flows in the impoundment. The proposed location of the fishway is located on the eastern embankment of the dam and would not impact the flood flow routing capacity of the dam.

Sediment Management

No sediment management in Megunticook Lake would be necessary with a technical fishway option.

Infrastructure

A Denil fishway would require modifications to the eastern embankment of East Dam. No modification to the dam's spillway or gates would be required. Current dam maintenance and operation would continue, along with added maintenance required to maintain an operable fishway. Maintenance would include removing debris from the fishway and upstream trash rack. Possible manipulation of headwater elevations may be necessary to extend passage conditions in compliance with the dam's operational guidelines. See also Appendix A.

Summary

A Denil fishway at East Dam would present the following advantages and drawbacks:

Advantages:

- Safe, effective, and timely fish passage could be provided through the powerhouse structure of the dam for approximately 200,000 river herring per year.
- Access to habitat in Megunticook Lake and upstream areas.
- No impact to the regulatory flood profile.
- No major structural alterations of the dam would be required.
- Would facilitate continued primary operation of the East Dam for lake outflow control.

Drawbacks:

- Reduced passage for American Eel and Sea Lamprey.
- Turning pools required to negotiate switchbacks could create confusion or difficult-to-navigate hydraulics for some species.
- Biological capacity: A single Denil fishway at East Dam would likely serve as a limiting factor to upstream fish population. A second Denil may be required with a substantially recovered river herring population.
- The fishway may be impassible when water levels in the impoundment are outside of the operating range of the fishway.
- Regular maintenance of the fishway would be required.
- The fishway would be located on property that is presently privately owned and would require negotiation of access and right-of-way, or acquisition, to construct.
- Potentially substantial bedrock excavation may be required.

Synthesis: *Provided the balance between advantages and drawbacks,* **a Denil fishway at the East Dam should be considered** *among the viable options, but is not recommended as a short-list option. The option requires compromises due to required number of switchbacks, and to the potentially limiting biological capacity.*

Figure 102. Schematic layout of a Denil fishway option at East Dam.

7.7.4 Nature-like Fishways and Other Approaches

Several other layouts of nature-like fishways and other concepts were examined to determine feasible solutions. These options included utilizing the channel linking the outflow below West Dam to the channel below East Dam as a fish passage channel, as well as an option extending a nature-like fishway on the left bank around and upstream of East Dam. Ultimately, the average channel grade defined by the hydraulic gradient between the lake at West Dam and the water level at Molyneaux Road is too steep (7.5%) to serve as a nature-like fishway. The alignment linking the two outflow channels across the peninsula was also too steep (11% or steeper) for nature-like or pool-and-weir approaches. Extending a nature-like fishway around and upstream of East Dam is not feasible due to constraints arising from lake level control requirements. Future design phases could revisit additional potential alignments, including hybrid approaches, or those that utilize the middle peninsula for switchback alignments, for example.

7.7.5 No Action

The East and West Dams maintain water levels and impound flow at the upstream end of the Megunticook River. A "no action" approach at East and West Dams would result in a continued barrier to fish passage. Operations of the dams and water levels in Megunticook Lake would not be affected.

Fish Passage Restoration

Under a no-action approach, no fish passage will be possible at East or West Dams.

Flood Management and Resilience

No change to flood elevations would occur under a no-action approach. Ongoing water level manipulation operations in Megunticook Lake would continue.

Sediment Management

No sediment management activities would be necessary with a no-action approach.

Infrastructure

The existing dam facility's structures, operations, or maintenance would not be impacted with a no-action approach.

8. Summary of Options

A summary of the highlights and constraints of each option is included in Table 22. The options are contrasted against the project objectives in Table 23. To provide a comprehensive view of the options along the river, Montgomery dam is added to the discussion below. For detailed discussion of the options at Montgomery dam, see the 2019 feasibility study report for that site.

Dam Maintenance and Flooding Benefits

The options which eliminate structures from the river will yield the greatest flood relief benefits, including dam removal at Montgomery, Knox Mill, Knowlton Street and Powder Mill dams, as well as removal of the water control structures at the Brewster building. These options will also result in the least amount of long-term dam management, maintenance and repair. The options considered at Seabright and East/West dams do not offer direct flood management and resiliency benefits, but when considered in conjunction with the downstream structure removals may experience increased operational flexibility in operations to manage downstream flood conditions. The no action approaches would not provide flood management and resilience benefits, resulting in greater long-term operation, management and repair costs compared to the other options.

Fish passage and Ecological Recovery Benefits

The dam removal options will result in the best opportunities for successful fish passage and make the greatest contribution to recovery of ecological health in the watershed. This would include improvements of water quality at the sites themselves (Zaidel 2018, Horne 2001, Poole and Berman 2001). These options would be generally followed by the nature-like and pool and weir fishway options, subsequently followed by the Denil fishway options. The no action approaches would maintain the current fragmented and impacted status of the watershed.

Historical/Aesthetic Qualities and Public Amenity

All of the options could be accomplished in a manner to enhance the aesthetics and acknowledge the historical attributes of each site, while enhancing the public use and educational components to the extent desired by the dam or property owner. This includes integration with other initiatives, such as the Camden Riverwalk. The dam removal options will provide the most dramatic change to the sites, resulting in the most naturalized conditions, while the technical fishway options will most closely preserve the current conditions.

Structural Implications

The dam removal options would result in the greatest change to the current condition for the existing structures, with the potential for selected required countermeasures. However, these options would also reduce the interaction of the river with these structures, which should yield a long-term positive outcome. Conversely, the options which retain the dams change the ambient conditions around the structures the least, or not at all. With these options, near-term countermeasures may not be required to account for the change induced by the project. It should be noted that the current conditions do contribute to the selected observed impacts due to the ongoing interaction of the structures with the river, such as elevation of floodwaters along the Knox Mill buildings, or near the public safety building.

Table 22. Action options summary table. Note that 'No Action' approaches for each site are omitted from the table.

Option	Comments
Montgomery Dam	
Dam Removal with Restored Channel	**Recommended Option.** Greatest benefits to fish passage, flood risk, ecological conditions, and resiliency including significantly reduced operation, maintenance and repair requirements. Management of impounded sediment will be required.
Partial Spillway Reconstruction with Optimized Fish Passage	Intermediate benefits to fish passage, flood risk, ecological conditions, and resiliency, perpetuates operation, maintenance and repair requirements. Management of impounded sediment will be required.
Full Spillway Reconstruction with Optimized Fish Passage	Most challenging fish passage design. Ecological benefits limited to fish passage attained. No flood risk or resiliency benefits, perpetuates current operation, maintenance and repair requirements.
Former Brewster Shirt Factory	
Remove Water Control Structures	**Recommended Option** along with additional evaluation. Benefits to fish passage, flood risk, and resiliency adjacent to the public safety building.
Knox Mill Dam	
Dam Removal	**Recommended Option.** Greatest benefits to fish passage, flood risk, ecological conditions, and resiliency including significantly reduced operation, maintenance and repair requirements. Management of impounded sediment will be required.
Denil Fishway	Not recommended due to spatial constraints and impacts to regulatory flood profile. Alignment would extend upstream of dam. Limited biological capacity for single Denil. No improvement to resiliency changes caused by climate change.
Knowlton Street Dam	
Dam Removal	**Recommended Option.** Greatest benefits to fish passage, flood risk, ecological conditions, and resiliency including significantly reduced operation, maintenance and repair requirements. Active management of impounded sediments will likely be required.
Pool-and-Weir Fishway	Intermediate biological capacity. No improvement to resiliency.
Denil Fishway	May have impacts to flood profile. Limited biological capacity for single Denil. No improvement to resiliency.

Option	Comments
Powder Mills Dam Ruins	
Dam Removal	**Recommended Option.** Benefits to fish passage, flood risk, ecological conditions, and resiliency. Management of upstream sediments may not be required.
Seabright Dam	
Nature-like Fishway	**Recommended Short-List Option.** Sinuous alignment along west embankment. Intermediate to full biological capacity. Downstream entrance has less optimal attraction conditions, favorable nature-like flow patterns. Substantial educational and public access potential. Must maintain impoundment water levels.
Pool-and-Weir Fishway	**Recommended Short-List Option.** Alignment along eastern spillway margin. Intermediate to full biological capacity. Improved entrance attraction conditions compared to nature-like fishway. Must maintain impoundment water levels.
Denil Fishway	Alignment along west embankment. Limited biological capacity with single Denil. Must maintain impoundment water levels.
East/West Dams	
Hybrid Nature-like and Pool-and-Weir Fishway	**Recommended Short-List Option.** Alignment downstream of West Dam. Likely would require significant modifications to West Dam. Intermediate to full biological capacity. Must maintain impoundment water levels. Attraction signal enhanced if primary lake outflow shifted from East to West dam.
Pool-and-Weir Fishway	**Recommended Short-List Option.** Alignment on eastern embankment of East Dam. Intermediate biological capacity. Multiple switchback alignment sub-optimal. Must maintain impoundment water levels. Attraction signal close to base of main spill under current operation.
Denil Fishway	Switchback alignment on eastern embankment of East Dam. Limited biological capacity for single Denil. Multiple switchback alignment sub-optimal. Must maintain impoundment water levels. Attraction signal close to base of main spill under current operation.

Table 23. Evaluation table comparing project options to objectives identified in Section 2. Recommended Options at each site in Bold. Relative cost calculations explained in Section 9. For discussion of Montgomery Dam options, see 2019 Montgomery Dam Feasibility Study Report[9].

Site	Flood Management	Operations, Maintenance & Repair	Infrastructure Risk	Climate Change Resilience	Adverse Impacts	Fish Passage Effectiveness	River Connectivity	Public Access and Use	Educational Value	Community Aesthetic	Construction Cost ($)[1]	Total Aggregate Lifespan Cost ($)[2]
Montgomery Dam												
Dam Removal with Restored Channel	• Measurable Benefit	• Significant Reduction	• Significant Reduction	• Greatest Benefit	• Limited	• Best	• Restored	• Increased	• Significant	• Enhanced	750,000	• 380,000
Partial Spillway Reconstruction with Optimized Fish Passage	• Moderate Measurable Benefit	• No Change, Required	• Reduced	• Reduced Benefit	• Limited	• Good	• Incremental	• Moderate Increase	• Significant	• Incremental Enhanced	• 1,100,000	• 700,000
Full Spillway Reconstruction with Optimized Fish Passage	• No Change	• No Change, Required	• No Change	• No Change	• No Change	• Moderate	• No Change	• No Change	• Significant	• Maintain Similar	• 1,100,000	• 1,100,000
No Action[3]	• No Change	• No Change, Required	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• N/A	• N/A
Brewster Shirt Factory Building												
Remove Water Control	• Improve near Public Safety	• Reduced	• Reduced	• Increased	• No Change	• Incremental Improvement	• Incremental Improvement	• No Change	• Interpretation Opportunity	• Remove Water Wheel	• 320,000	• 250,000
No Action[3]	• No Change	• No Change, Required	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• Maintain Water Wheel	• N/A	• N/A
Knox Mill												
Dam Removal	• Measurable Benefit	• Significant Reduction	• Significant Reduction	• Greatest Benefit	• Limited	• Best	• Restored	• Increased	• Significant	• Enhanced	• 590,000	• 380,000
Denil Fishway	• Reduce Capacity	• No Change, Required	• No Change	• Reduced	• increased	• Moderate	• No Change	• No Change	• Moderate	• Maintain Similar	• 760,000	• 840,000
No Action[3]	• No Change	• No Change, Required	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• N/A	• N/A
Knowlton Street												
Dam Removal	• Measurable Benefit	• Significant Reduction	• Significant Reduction	• Greatest Benefit	• Limited	• Best	• Restored	• Increased	• Significant	• Enhanced	• 3,300,000 – 5,000,000	• 380,000
Pool & Weir Fishway	• No Change	• No Change, Required	• No Change	• No Change	• No Change	• Good	• Incremental	• No Change	• Moderate	• Incremental Enhanced	• 1,200,000	• 700,000
Denil Fishway	• Reduce Capacity	• No Change, Required	• No Change	• Reduced	• increased	• Moderate	• No Change	• No Change	• Moderate	• Maintain Similar	• 750,000	• 836,000
No Action[3]	• No Change	• No Change, Required	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• N/A	• N/A
Powder Mills												
Dam Removal	• Measurable Benefit	• Significant Reduction	• Significant Reduction	• Greatest Benefit	• Limited	• Best	• Restored	• Increased	• Moderate	• Enhanced	• 296,000	• 66,000
No Action[3]	• No Change	• No Change, Required	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• N/A	• N/A
Seabright												
Nature-like Fishway	• No Change	• No Change, Required	• No Change	• No Change	• No Change	• Good	• Incremental	• No Change	• Significant	• Incremental Enhanced	• 1,100,000	• 580,000
Pool & Weir Fishway	• No Change	• No Change, Required	• No Change	• No Change	• No Change	• Good	• Incremental	• No Change	• Moderate	• Incremental Enhanced	• 1,400,000	• 1,100,000
Denil Fishway	• No Change	• No Change, Required	• No Change	• Reduced	• increased	• Moderate	• No Change	• No Change	• Moderate	• Maintain Similar	• 900,000	• 1,200,000
No Action[3]	• No Change	• No Change, Required	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• N/A	• N/A

[9] The Montgomery Dam feasibility study report can be found on the Town website at the following link: https://cms8.revize.com/revize/camdenme/Montgomery%20Dam%20Feasabilty%20Alternative%20Analysis%20Report.pdf

Table 23. Evaluation table comparing project options to objectives identified in Section 2. Recommended Options at each site in Bold. Relative cost calculations explained in Section 9. For discussion of Montgomery Dam options, see 2019 Montgomery Dam Feasibility Study Report[9].

Site	Flood Management	Operations, Maintenance & Repair	Infrastructure Risk	Climate Change Resilience	Adverse Impacts	Fish Passage Effectiveness	River Connectivity	Public Access and Use	Educational Value	Community Aesthetic	Construction Cost ($)[1]	Total Aggregate Lifespan Cost ($)[2]
East/West												
Hybrid Nature-like / Pool & Weir Fishway	• No Change	• No Change, Required	• No Change	• Increased	• No Change	• Good	• Incremental	• No Change	• Moderate	• Incremental Enhanced	• 1,700,000	• 1,100,000
Pool & Weir Fishway	• No Change	• No Change, Required	• No Change	• No Change	• No Change	• Good	• Incremental	• No Change	• Moderate	• Incremental Enhanced	• 1,300,000	• 1,100,000
Denil Fishway	• No Change	• No Change, Required	• No Change	• No Change	• increased	• Moderate	• No Change	• No Change	• Moderate	• Maintain Similar	• 710,000	• 1,200,000
No Action[3]	• No Change	• No Change, Required	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• No Change	• N/A	• N/A

[1] Includes estimated construction cost, plus 30% contingency. Rounded.

[2] Includes total aggregated lifespan cost over 50-year period, escalated for 3% inflation. Rounded.

[3] Included for contrast to the options which meet the combined project objectives. However, as no fish passage improvements are included it is not considered a viable project approach.

9. Cost Analysis

Opinions of probable cost were developed for each of the options discussed in Sections 7 and 8. These cost opinions are intended at the present juncture primarily to enable relative comparison between options, with additional design development recommended to result in cost opinions that are suitable for advanced planning and fundraising.

According to the definitions developed by the American Association of Cost Engineering (AACE 2016), the goal for the cost analysis fits in the range of Class 4 estimates. The cost analysis includes design, permitting, construction, and estimated operation and maintenance costs for a fifty-year planning horizon.

The cost opinions have been developed based on review of construction costs for similar items in past projects and applicable reference cost data. The actual implemented cost may vary from these estimates, based on market factors, detailed design development and possible optimization, and other factors. Refinement of quantities and unit prices will occur in future more detailed design phases.

The actual costs of implementation of the project may vary from the cost opinions due to heavy construction market fluctuations and other unforeseen factors. In particular, recent bid results (2018-2020) have seen substantial escalation and volatility in bid pricing. Anecdotally, conversations with construction contractors suggest costs may also escalate with increased stimulus and infrastructure spending currently being discussed nationally. To account for potential variation, a 30% construction cost contingency has been included in the cost opinions.

9.1 ASSUMPTIONS

Several assumptions were required to facilitate preparation of the cost analysis, discussed below.

Sediment management associated with dam removal

As noted in Section 4, a modest amount of accumulated sediment is present behind the Knox Mill and Powder Mill dams. It was assumed in the cost opinions that sediment in these impoundments would be excavated and disposed. There is a much more substantial volume of accumulated sediment in the Knowlton Street dam impoundment. The preliminary estimate of accumulated sediment at the site made in this study is 30,000 cubic yards or more. This volume estimate will be refined in future design phases through additional sediment probing. Sediment management is the primary cost factor at this site.

Due to the uncertainty associated with accumulated sediment volume at the Knowlton Street dam site and how much of the volume will be required to be excavated and removed from the site, two separate estimates were made for the dam removal option. The first estimate for the option assumes approximately half of the accumulated will be excavated, while the second estimate assumes that a more substantial volume of sediment will need to be removed. In addition, supplemental sediment testing at the site in the next design phase will allow the sediment management options, and therefore costs, to be refined and optimized.

Mitigation of potential infrastructure impacts associated with dam removal

Potential infrastructure impacts associated with dam management were reviewed in Section 5 and Appendix A. Preliminary potential costs for mitigation of impacts to infrastructure that may result from dam management were included in the cost analysis. Follow-up analyses of selected impacts will be required in future phases of project planning.

Analysis of Lifespan Costs

Annual operation and maintenance costs and periodic inspection and repair costs were included in the cost analysis. Dam removal was associated with the least lifespan cost, although some ongoing costs were assumed, especially at the sites in the town center area. Among options that retained the dams, compared to the nature-like fishways, the technical fishways were assessed to have greater annual operation and maintenance costs, and greater periodic inspection and repair costs. Costs associated with Denil fishways were assumed higher than for pool and weir fishways. Among the dam site, the upstream dams that will require more ongoing management during the fish passage season relative to maintaining lake levels were assigned higher lifespan costs than the options where the dam sites in the town center would be maintained, as those facilities would require less notable management.

Lifespan costs are presented in two ways. First, the estimated recurring costs in 2021 dollars were escalated for an assumed 3% rate of inflation over the 50-year period and aggregated to represent a total lifespan cost. Second, the total lifespan costs were discounted to estimate the sum in 2021 dollars that would be required to be invested (in 2021) at a 2% effective interest rate (actual interest minus inflation) to pay for the total aggregated cost.

The 3% rate of inflation was selected based on review of average rates of inflation over the 50-year period 1986-2015-. Over this period, inflation in the Consumer Price Index calculated by the U.S. Bureau of Labor Statistics was 2.67 for the nation and 2.89 for the northeast region. These rates were compared to inflation in the RS Means Heavy Construction Index (RS Means 2016) over the same period (3.15), to result in the selected value of 3.0.

9.2 COST ANALYSIS SUMMARY

The results of the cost analysis are summarized in Table 11. In general, the initial construction costs for dam removal were lower, except for the Knowlton Street site due to potential sediment excavation costs. Estimated costs for the pool and weir fishways were greater than for the other fish fishway design approaches. This trend is consistent with expectations. In terms of lifespan costs, the estimated costs for the Denil fishways were the highest at the upstream dams, followed by pool and weir approaches. The dam removal options were estimated to have the lowest life span costs of the options that were considered. Lastly, the full dam removal options are most likely to draw support from external funding sources associated with ecological recovery and infrastructure resiliency initiatives, particularly if included as a component of a comprehensive program to address the aging dams, habitat fragmentation, and ecological recovery of the overall Megunticook River watershed.

Conversely, the availability of external funding to maintain the dams with limited ecological or resilience improvements will likely be limited.

Table 24: Summary of cost analysis, rounded. Recommended options in Bold.

Option	**Initial Costs**		**Lifespan Cost**	
	Construction Cost* ($)	**Project Delivery Cost** ($)**	**Total Aggregated Lifespan Cost*** (3% Inflation over 50 years) ($)**	**Capitalized Cost**** (2021 Investment to Finance Aggregated Lifespan Cost) ($)**
Montgomery Dam				
Dam Removal ††	750,000	200,000	380,000	100,000
Partial Spillway Reconstruction	1,100,000	200,000	700,000	190,000
Full Spillway Reconstruction †	1,100,000	200,000	1,100,000	300,000
Brewster Shirt Factory				
Remove Water Control	320,000	110,000	250,000	61,000
Knox Mill Dam				
Dam Removal ††	590,000	210,000	380,000	100,000
Denil Fishway †	760,000	220,000	840,000	230,000
Knowlton Street Dam				
Dam Removal ††	3,300,000 - 5,000,000	380,000 - 450,000	380,000	100,000
Pool and Weir Fishway	1,250,000	280,000	700,000	190,000
Denil Fishway †	750,000	230,000	840,000	230,000
Powder Mills Dam				
Dam Removal ††	300,000	150,000	66,000	15,000
Seabright Dam				
Nature-like Fishway ††	1,100,000	340,000	580,000	160,000
Pool and Weir Fishway	1,400,000	390,000	1,100,000	300,000
Denil Fishway	900,000	310,000	1,200,000	330,000
East/West Dam				
Hybrid Pool and Weir / Nature-like Fishway	1,700,000	450,000	1,100,000	300,000
Pool and Weir Fishway	1,300,000	360,000	1,100,000	300,000
Denil Fishway	710,000	320,000	1,200,000	330,000

*Includes 30% design and construction contingency.

**Includes project management, permitting, design, construction management and construction observation.

***Includes annual and periodic repair costs escalated at 3%, estimated for relative comparison

****Estimate of set-aside investment amount required to finance lifespan costs, discounted at estimated 2% effective interest rate (actual interest rate minus inflation)

†Likely limited potential for grant funding

††Likely greatest potential for grant funding

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Appendix A - Structural Condition Assessment

MEGUNTICOOK RIVER FISH PASSAGE FEASIBILITY STUDY
DAM & IMPACTED STRUCTURES ASSESSMENT
MEGUNTICOOK RIVER
CAMDEN, MAINE

Prepared for
Inter-Fluve
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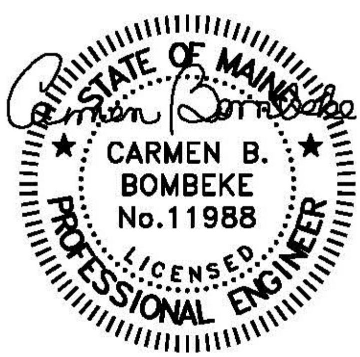

08-20-2021

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1. INTRODUCTION & BACKGROUND

Megunticook River runs approximately 3 ½ miles from Megunticook Lake through residential districts into downtown Camden village then outlets into Camden Harbor. The river served as a power source during the late 1800s through the 1900s, propelling turbines in multiple mills along the river path. The river is currently a source of recreation, wildlife habitat and scenic beauty, to varying degrees along the 3 ½ miles stretch. The current river flows continue to be impacted by several dams that remain to this day, including the following which are discussed in this report:[1]

- Megunticook Lake Dam East, owned and operated by the Town of Camden
- Megunticook Lake Dam West, owned and operated by the Town of Camden
- Seabright Dam, owned and operated by the Town of Camden
- Knowlton Street Dam, owned and operated by Knox Mill Holdings, LLC
- Knox Mill Dam, owned and operated by Knox Mill Holdings, LLC

The Megunticook Lake Dam East and Megunticook Lake Dam West together create the impoundment that is Megunticook Lake. Downstream of Megunticook Lake East and West Dams, the river becomes a slow, wide river with high quality opportunities for human recreation and wildlife. This section of the river is approximately 1 ½ miles long and includes numerous residences along both riverbanks and a public beach at Shirttail Point Park.

Downstream from Shirttail Point Park is Seabright Dam which was decommissioned in 2017 after the costs to maintain the dam outweighed the economic credit the Town received from the hydropower it generated. Downstream of Seabright Dam, Megunticook River becomes a flowing stream which meanders through residential neighborhoods, under Mt. Battie Street, Route 105 and Rawson Avenue bridges, toward more commercialized areas of town. The currently town-owned former tannery property provides public access to a significant stretch of the river in this section.

As the river nears town there are two closely spaced dams: Knowlton Street Dam then Knox Mill Dam approximately 380’ further downstream. Knowlton Street Dam is a relatively long dam which impounds Megunticook River. It is located on the edge of the commercial downtown area.

Knox Mill Dam also impounds Megunticook River. It spans between two building foundations (formerly Knox Mill buildings) and begins the most constricted portion of Megunticook River that flows between, under and around several existing commercial buildings before opening up to a more natural riverbed toward the Footbridge.

Megunticook River continues into the impoundment above Montgomery Dam and eventually outlets into Camden harbor between the Public Landing to the south and Camden Harbor Park to the north.

We understand Megunticook Lake Dam East, Megunticook Lake Dam West and Seabright Dam are not being considered for any modifications which would significantly alter water surface profiles or flows upstream or downstream. Fish passage at these locations would likely be achieved through a fish ladder (or similar construct) which would allow fish to navigate around the dams. Knowlton Street Dam and Knox Mill Dam may be candidates for alteration which would impact water surface profiles and flows upstream or downstream.

[1] Montgomery Dam at the outlet of Megunticook River in Camden Harbor was studied previously and is not included in this report.

2. PURPOSE

This dam and impacted structures assessment is part of a larger study seeking to evaluate the physical, biological, ecological and engineering performance of the dams between Montgomery Dam and Megunticook Lake in an effort to assess possible fish passage alternatives. This assessment aims to identity the potential impacts on existing structures due to the change in ambient water levels and altered flood hydraulics upstream and downstream of Knowlton Street Dam and Knox Mill Dam that may result from dam removal. This study also includes a general overview of the dam structures considerations that may impact fish passage alternatives at Megunticook Lake Dam East, Megunticook Lake Dam West and Seabright Dam.

3. SCOPE OF CONDITIONS ASSESSMENT

We are familiar with the dams from multiple site visits conducted for this study, in addition to visits to several of the sites for other purposes in past years. We visited the vicinity of Knowlton Street Dam and Knox Mill Dam October 20, 2020 to observe the existing dam construction and building foundations within the potentially impacted zones upstream and downstream of each dam. The Town released water for this visit to allow for closer inspection of the foundations and Knox Mill Dam. We revisited these sites March 30, 2021 to observe the dams and foundations under more typical (but naturally low) water flows.

We have visited Seabright Dam on multiple occasions, including October 20, 2020 and March 30, 2021 for this study. We visited Megunticook Lake Dam East March 30, 2021 and have visited Megunticook Lake Dam West on multiple occasions, including March 30, 2021 for this study. All inspections were conducted by Carmen Bombeke, PE, Senior Engineer at Gartley & Dorsky Engineering & Surveying. Mike Burke of Inter-Fluve was present at the site during part of the structural site visit to Knowlton Street Dam and Knox Mill Dam October 20, 2020.

This conditions assessment aims to provide a general understanding of the existing structural condition of the dams and nearby building and infrastructure foundations at the time of our inspection. The assessment is based on qualitative observation of the dams, structures and surrounding features only. This assessment does not include engineering calculations to determine the structural capacity and/or structural stability of any dam or foundation elements observed and/or documented.

4. DAMS & IMPACTED STRUCTURES

This assessment included observation of Megunticook Lake Dam East, Megunticook Lake Dam West, Seabright Dam, Knowlton Street Dam and Knox Mill Dam.

The assessment included observation of the following buildings and infrastructure elements at Knowlton Street Dam and Knox Mill Dam:

1. 32 Mechanic Street (Buildings 1, 2 and 3 are contiguous; same address)
2. 32 Mechanic Street (Buildings 1, 2 and 3 are contiguous; same address)
3. 32 Mechanic Street (Buildings 1, 2 and 3 are contiguous; same address)
4. 36 Washington Street
5. 40 Washington Street
6. 51 Mechanic Street
7. 49 Mechanic Street – Parking Lot
8. 2 Knowlton Street – Parking Lot
9. 51 Mechanic Street – Parking Lot

5. KNOWLTON STREET DAM AND KNOX MILL DAM REMOVAL ASSESSMENTS

In this assessment we consider the existing conditions model as a benchmark that represents the current status quo. We attempt to assess the impact of potential changes to the water surface profile with regard to the structures and parking lots in close proximity to the waterway.

It is challenging to assess the impact of the projected water surface profiles on the structures within the river due to a variety of unknowns, including perhaps most significantly the unknown conditions and construction below grade. Original construction, existing conditions, frost and ice are considered primary factors affecting whether and how the proposed water surface profile alterations may adversely impact structures within and surrounding the river. In general, dam removals will lower the water levels and potentially increase water velocity in some sections. Reduced water levels would typically be a favorable change structurally, although there are plausible scenarios where it could worsen unique situations. The most plausible unfavorable conditions to result from reduced water levels are a potential reduction in frost protection and the possible direction of debris and ice toward a different elevation on a foundation. Increased flows could impact scour and erosion around foundations.

It is anticipated that water in the river seeps through soils below and/or directly adjacent to the river bed and minimizes frost penetration in these area. As such, increased frost penetration may occur in select areas if water flow is no longer present near foundation elements. The impact of frost penetration depends largely on the depth of the foundation below grade and the bearing conditions. Foundations which bear on ledge are not susceptible to heaving from frost; foundations on soils are susceptible to frost to varying degrees depending on the soil characteristics, moisture, etc. Foundations which extend at least 4-feet below grade typically provide adequate protection from frost locally. Neither the depth of foundations nor the bearing conditions are exposed in most cases.

Local ice formation may decrease due to reduced surface area of the river and fewer slow-moving stretches. However, the interaction with ice supplied from upstream or forming locally may occur at a different elevation than previously.

Based on the simulated water surface profiles and the observed conditions in the field, we make the preliminary projections identified in the following sections for each proposed dam removal. These projections are specific to potential impacts from change in ambient water levels and altered flood hydraulics upstream and downstream of the dam resulting from full dam removal.

5.1 KNOWLTON STREET DAM

EXISTING CONDITIONS

Knowlton Street Dam is composed of two spillway sections, approximately 36’ long and 20’ long, with concrete abutments at each end and one central concrete abutment. The south abutment on river right is integral with the concrete foundation of 51 Mechanic Street, which is also integral with a concrete retaining wall that extends south and west to form the perimeter of the impoundment at the dam. The central abutment occurs at the transition point where the dam skews northwesterly. The dam and abutments are founded on ledge. A concrete retaining wall continues the line of the dam from the north abutment northwesterly until grades are approximately equal on either side.

A pedestrian bridge follows the shape of the dam, extending in a straight line from the concrete retaining wall along the west side of 51 Mechanic Street to the south abutment to the central abutment, then skews northwesterly following the dam shape to the north abutment, then skews north to connect to an orthogonal deck with stairs to 2 Knowlton Street parking lot. The pedestrian bridge is wood framed and is elevated approximately 8’ above the spillway elevation. The pedestrian bridge relies on the elevated dam abutments for structural support; however, the pedestrian bridge provides no structural benefit to the dam itself. The pedestrian bridge has numerous and significant conduit pipes below the deck.

The south concrete retaining wall at 51 Mechanic Street and the three dam abutments appear to be in satisfactory condition. The spillway was not visible for close inspection. The low concrete retaining wall that extends the northwesterly line of the dam is in poor condition. Significant concrete degradation is present and corroded steel is visible.

The parking lot for 51 Mechanic Street is built on soil retained by a gravity retaining wall set back a few feet from the edge of the impoundment. The retaining wall is constructed atop soil with a relatively steep section of natural rip rap and/or stone retaining wall which extends down to the river.

The parking lot for 2 Knowlton Street is built on soil retained by a concrete retaining wall structure on the south side. The retaining wall is set back a reasonable distance from the edge of the river. The closest points of contact between the retaining wall and the river occur slightly upstream and downstream of the Knowlton Street Dam. The retaining wall is estimated to be approximately 20' from the river edge in these locations.

POTENTIAL IMPACTS OF DAM REMOVAL

Removal of the Knowlton Street Dam would result in a decrease in ambient water levels at and upstream of the existing dam, gradually tapering to no impact slightly downstream from Rawson Avenue Bridge (approximately 0.7 miles upstream). The ambient water levels at the dam would decrease approximately 5-6' during normal flows and 3-4' during extreme events and decrease approximately linearly between there and just downstream of Rawson Avenue Bridge.

The decrease in ambient water levels in this section of the river may impact the 51 Mechanic Street foundation, although it is strongly anticipated that the building foundation was erected directly on ledge which would negate most concerns. If the building is indeed constructed on ledge, frost penetration, erosion and scour all become negligible. The change in flow would also primarily affect the area that has already been reinforced with a concrete retaining wall and foundation. Areas of the foundation with exposed stone occur downstream of the dam, where ambient water levels are anticipated to be similar to existing. Decreased flow velocity downstream in this area would be an advantage of dam removal. Eliminating the impoundment which creates constant hydrostatic pressure on the concrete retaining wall and west building foundation would also be structurally preferable and may reduce moisture in the building.

Removal of the dam may impact the pedestrian bridge that connects the parking lots of 51 Mechanic Street to 2 Knowlton Street. At a minimum, reinforcement or replacement of the existing abutments may be required if the spillways were demolished or substantially lowered. The pedestrian bridge does not appear to be heavily used. Its primary function may be to support the utilities hung from the deck. Further exploration of the functional needs of the pedestrian bridge may be warranted. If the pedestrian bridge is not a necessary asset to maintain, it may be practical to remove it along with the dam.

The decrease in ambient water levels in this section of the river may impact the 51 Mechanic Street parking lot retaining wall, depending on the conditions below the water line at the river edge. Potential adverse impacts could include increased frost penetration and erosion. Shoreline stabilization could presumably be a practical solution if erosion were a concern.

The decrease in ambient water levels in this section of the river is anticipated to have no significant impact on the 2 Knowlton Street parking lot and associated retaining wall.

The decrease in ambient water levels in this section of the river may adversely affect the short concrete retaining wall north of the dam which is already in distress. It is anticipated that this wall would be removed and replaced with stone rip rap if the dam were removed.

POTENTIAL IMPACTS OF FISH PASSAGE CHANNEL ON RIVER LEFT

We understand that if the dam were removed, one scenario for fish passage may be to create a fish passage channel on river left (north). This would potentially direct some amount of water closer to the existing concrete retaining wall that supports the 2 Knowlton Street parking lot. We anticipate this concept is feasible without compromising the existing retaining structure.

5.2 KNOX MILL DAM

EXISTING CONDITIONS

Knox Mill Dam was constructed circa 1900. The dam was modified in 1988-1990, including a significant reduction in the spillway elevation which eventually resulted in reclassification of the dam as a low hazard dam. The existing structure is a stone masonry dam, approximately 13' high on the upstream side and 18' high on the downstream side, with a 54' long concrete spillway. The abutments are founded on bedrock. The north end of the dam is exposed granite block directly on ledge. The south end of the dam intersects a similarly constructed granite retaining wall that forms the foundation for 32 Mechanic Street. There is vegetation, including small trees, growing from the foundation of 32 Mechanic Street, suggesting some mortar loss between the stones.

Directly downstream of the dam are granite block structures on both sides of the river. As the river continues downstream from Knox Mill Dam it enters a highly constricted area with former Knox Mill buildings along each riverbank, including 32 Mechanic Street on river right (south) and 40 Washington Street on river left (north). 32 Mechanic Street has an exterior deck which extends over approximately half of the river. The north side of this deck is supported by braced wood posts on a stacked granite wall which runs parallel with the river flow. 40 Washington Street has a deck at the same elevation, although most of it is set back behind the granite foundation wall that forms the river boundary on river left (and supports the upper stories and roof of the building above). A boardwalk connects the two decks at the easterly end of 40 Washington Street.

The foundations of 32 Mechanic Street and 40 Washington Street are both composed of stone with some amount of concrete infill or reinforcing above. The foundation of 40 Washington Street appears to be composed of larger blocks. The foundation of 32 Mechanic Street appears to be composed of smaller blocks. It is possible that one or both buildings was originally pier-supported on top of these walls; however, both structures have continuous foundation walls at this point. The foundation of 32 Mechanic Street has some evidence of mortar loss between stones and undercutting at the existing water flow elevation.

POTENTIAL IMPACTS OF DAM REMOVAL

Removal of the Knox Mill Dam would result in a decrease in ambient water levels at and upstream of the existing dam. In lieu of the existing impoundment, the river would follow the natural ledge profile from the Knowlton Street Dam downstream, matching in with existing flows just downstream of the existing Knox Mill Dam. The water levels at the dam would decrease approximately 11-12' during normal flows and 9-10' during extreme events, with diminishing decreases back to Knowlton Street. The existing steep waterfall flow over the spillway would be eliminated for more uniform flows throughout.

The decrease in ambient water levels in this section of the river would not appear to have a significant impact on the 32 Mechanic Street foundation. The foundation is anticipated to be on ledge. Repointing of the existing stones may be required (regardless of dam removal, although the critical repointing may be at different elevations if water levels changed). The elimination of the waterfall effect directly at and downstream of the existing Knox Mill Dam would likely be beneficial to the existing foundation.

The decrease in ambient water levels in this section of the river would not appear to have any impact on the 40 Washington Street foundation since the building does not extend upstream of the dam where the surface profile will change the most. The elimination of the waterfall effect directly at and downstream of the existing Knox Mill Dam would reduce water splash on the foundation and overtopping of the deck; however it is otherwise anticipated to have no impact on the existing conditions at the foundation of 40 Washington Street.

The decrease in ambient water levels in this section of the river would not appear to have any impact on the 49 Mechanic Street parking lot. Change to the river channel upstream of the dam would appear to have limited effect on surrounding structures. Erosion or scouring are anticipated to be limited.

The decrease in ambient water levels in this section of the river would not appear to have any impact on the 46 Washington Street or the eastern blocks of 32 Mechanic Street where river flows would remain essentially unchanged.

6. MEGUNTICOOK LAKE DAM EAST & WEST AND SEABRIGHT DAM CONSIDERATIONS

6.1 SEABRIGHT DAM

BACKGROUND

Seabright Dam was constructed circa 1895 and has been modified numerous times, including alterations for hydropower which was decommissioned as recently as 2017. The dam impounds Megunticook River in a section widely used for recreation. The dam is classified as a high hazard dam. The Emergency Action Plan for Seabright Dam (2018) describes the structure as 23' high, 372' long dam (inclusive of earth embankment wing walls). The dam is composed of mortar laid stone masonry and concrete gravity dam with earth embankment wing walls. The dam has an approximately 90' long spillway with a 55' overflow spillway.

The most recent Inspection Report issued by Kleinschmidt in June 2020 notes a need for minor repairs, with more significant repairs in coming years. Significant repairs include resurfacing the spillway within five years (by 2025). The Inspection Report notes that the new deep sluice gate was leaking more than expected and should be remediated by the installing contractor. We understand that subsequent investigation revealed that the sluice gate is not leaking; rather, water is entering a joint in the concrete on the spillway and flows through the large rocks under the concrete, coming out in the sluiceway. This issue is anticipated to be rectified by the spillway resurfacing repairs. The report also discusses the potential collapse of the existing retaining wall downstream of the dam on river right, suggesting that the wall may be left in place after collapse or may be demolished and used to stabilize the riverbank that will become exposed from the loss of the wall.

Review of previous DEP application approvals provides insight into alterations between 1985 and 1990 to support modern hydropower generation. Alterations included installation of a hydropower system, changes to the spillway, constructing a new concrete retaining wall along the east bank below the dam and clearing and recontouring the embankment area immediately downstream of the spillway. Recontouring included filling the area with 1,500 cubic yards of graded stone, heavy rip rap and concrete grout.

FISH PASSAGE

There appears to be sufficient area around the dam to allow for a fish passage system without adversely affecting the dam structure. Given the significant recent and ongoing costs to repair and maintain Seabright Dam, it seems probable that a thoughtful fish passage system could potentially simultaneously produce improved fish passage and potentially result in a more durable and/or stronger structure.

6.2 MEGUNTICOOK LAKE DAM EAST

BACKGROUND

Megunticook Lake Dam East was constructed circa 1900. Together with Megunticook Lake Dam West, it impounds Megunticook Lake. Reports indicate the Megunticook Lake Dam East gate is operated first to adjust the lake level, then the west dam gate is opened as needed. The dam is classified as a high hazard dam. The Dam Emergency Action Plan (2019) describes the structure as an 18' high, 115' long gravity dam with east and west spillways, gated sluice, east and west wingwalls and a trash rack structure. The 30' long east spillway and 18' long west spillway are broad crested weirs. The top of the spillway is approximately 12' to 18' wide and slopes downstream. Spillways are dry-laid masonry construction with the top and upstream surfaces overlain with concrete. The gated sluice (between east and west spillways) consists of an opening in the spillway masonry equipped with a timber gate and a rack-and-pinion type hoist. There are two stone retaining walls running parallel with flow downstream. Exposed ledge is present on both sides of the dam. A concrete and steel trash rack system is located approximately 90' upstream of the dam.

The most recent Inspection Report issued by Kleinschmidt in August 2019 identifies the dam as being in good condition overall with no significant damage noted since Kleinschmidt's 2011 inspection (8 years). Minor monitoring and potential future repair items were identified but no immediate action or capital repairs were noted at that time. A prior Inspection Report issued by GEI in 2015 rated the dam in fair to poor condition and recommended repairs within 1 fiscal year.

FISH PASSAGE

The site is relatively constrained by ledge on either side. Fish passage at this site may be challenging given the physical constraints in the vicinity; however it is anticipated to be easier and more practical that achieving fish passage at Megunticook Lake Dam West. The structure of this dam may also be easier to modify for fish passage than Megunticook Lake Dam West.

6.3 MEGUNTICOOK LAKE DAM WEST

BACKGROUND

Megunticook Lake Dam West was constructed circa 1900. Together with Megunticook Lake Dam East, it impounds Megunticook Lake. The dam is classified as a high hazard dam. The Dam Emergency Action Plan (2019) describes the structure as a 14' high, 109' long dam with spillways, gated sluice, east and west wingwalls and a trash rack structure. The dam is founded on ledge. The 18' long spillway is a broad crested weir of dry-laid stone masonry. The top of the spillway is approximately 14' wide and slopes downstream. The top of the spillway is covered with a wood deck with sidewalls to confine the flow. The gated sluice consists of an opening in the spillway masonry equipped with a recently installed Whipps gate (2020). The area downstream east has a large stone retaining wall adjacent to the spillway. Exposed ledge is present on both sides of the dam. An L-shaped concrete and steel trash rack system is located approximately 20' upstream.

The most recent Inspection Report issued by Kleinschmidt in August 2019 identifies the dam as being in good condition overall with no significant damage noted since Kleinschmidt's 2011 inspection (8 years). Minor monitoring and potential future repair items were identified but no immediate action or capital repairs were noted at that time. A prior Inspection Report issued by GEI in 2015 rated the dam in fair to poor condition and recommended localized repairs. The Kleinschmidt Inspection Report (2019) references maintenance and repair work scheduled for fall 2019 (performed 2020).

A review of the fall 2020 Town of Camden Megunticook West Dam Repairs bid scope identified significant repairs, including: install a new Whipps stainless steel gate; replace spillway I-beams and reconstruct rock cribwork; modify the existing walkway to sit on top of the concrete wall; replace metal supports at trash rack walls; repair leaks in outer trash rack and dam concrete structures; demolish the inner trash rack; replace the spillway elevation board with a steel plate; adjust width of the sluiceway wood structure; and remove a tree next to a dam wing wall. Based on our observations, this work appears to have been completed as outlined in the bid scope.

FISH PASSAGE
The site immediately downstream of the dam is highly constrained by the existing massive stone retaining wall on river left and soil/ledge on river right. Fish passage at this site may not be practical given the structure and physical constraints in the vicinity. It may be necessary to completely replace the dam with an integral fish passage design if fish passage is desired at this location. If the dam is anticipated to have significant ongoing maintenance and repair needs, replacement with a fish passage option may be worth considering.

7. SUMMARY

This dam and impacted structures assessment is part of a larger study seeking to evaluate the physical, biological, ecological and engineering performance of the dams between Montgomery Dam and Megunticook Lake in an effort to assess possible fish passage alternatives. This assessment identifies potential impacts on existing structures due to the change in ambient water levels and altered flood hydraulics upstream and downstream of Knowlton Street Dam and Knox Mill Dam that may result from dam removal. This study also includes a general overview of the dam structures considerations that may impact fish passage alternatives at Megunticook Lake Dam East, Megunticook Lake Dam West and Seabright Dam.

Our conclusion is that there would be limited adverse structural impacts if Knowlton Street Dam and Knox Mill Dam were removed. We reviewed six (6) buildings and three (3) parking lots in the area, as requested. Although we noted some potential negative impacts of the changes, all are anticipated to be surmountable and would not be expected to add substantially to the total project cost for any proposed dam removal.

The pedestrian bridge over Knowlton Street Bridge poses the most significant challenge in the downstream area studied. If the bridge were to remain after dam removal, new support structure would be required. The utilities under the pedestrian bridge connecting 51 Mechanic Street to 2 Knowlton Street are non-structural; further exploration by a qualified professional to identify potential alternatives for these utilities if the pedestrian bridge were demolished during dam removal.

We further conclude the existing three upstream dams to remain appear to require significant ongoing maintenance. It may be possible to integrate fish passage options with future upgrades to reduce long-term maintenance costs. It is anticipated that the fish passage systems would bypass the existing dams. The prevalence of ledge at the outlet of Megunticook Lake may create constrictions that are difficult to overcome without dam alteration, upgrade or replacement, particularly in the case of the west dam.

8. PHOTO DOCUMENTATION

Please refer to the enclosed photos for additional clarification and detail.

END OF REPORT

1) Megunticook Lake Dam East

2) Megunticook Lake Dam East

3) Megunticook Lake Dam East –
View downstream

4) Megunticook Lake Dam West

5) Megunticook Lake Dam West

6) Megunticook Lake Dam West –
View downstream


7) Seabright Dam


8) Seabright Dam spillway


9) Seabright Dam – View downstream


10) Seabright Dam – Recontoured area visible at right


11) Knowlton Street Dam, 51 Mechanic Street and pedestrian bridge to 2 Knowlton Street


12) Knowlton Street Dam (south spillway) and 51 Mechanic Street

13) Knowlton Street Dam (north spillway), 51 Mechanic Street and pedestrian bridge to 2 Knowlton Street

14) Knowlton Street Dam (north spillway), pedestrian bridge to 2 Knowlton Street, shoreline downstream river left (possible fish passage zone)

15) Knowlton Street Dam (south spillway) and 51 Mechanic Street

16) 51 Mechanic Street foundation – Repairs are needed; dam removal would change but not significantly worsen existing conditions

17) Knowlton Street Dam – North retaining wall (degraded)

18) Knowlton Street Dam – North retaining wall (degraded)

19) Knowlton Street Dam (north spillway) and pedestrian bridge to 2 Knowlton Street

20) Knowlton Street Dam – Underside of pedestrian bridge with utility conduits

21) 51 Mechanic Street and parking lot – gravity retaining wall along shore

22) 51 Mechanic Street and parking lot – gravity retaining wall along shore is rotated with some misaligned elements

23) Knox Mill Dam, 32 Mechanic Street (left) and 40 Washington Street (right) – View upstream

24) Knox Mill Dam – High water overtopping 32 Mechanic Street deck and impacting the upstream end of 40 Washington Street deck (Photo courtesy of Alison McKellar, Town of Camden)

25) Knox Mill Dam and 32 Mechanic Street – Lowered water condition

26) 32 Mechanic Street (NW corner) – Lowered water condition

27) 40 Washington Street (left), 32 Mechanic Street (right) and connecting decks – Stone foundations

28) 36 Washington Street (left) and 32 Mechanic Street (right) – Stone foundations

29) 32 Mechanic Street – Minor repairs are needed; dam removal may change but not significantly worsen existing conditions

30) 32 Mechanic Street – Minor repairs are needed; dam removal may change but not significantly worsen existing conditions

Appendix B - Sediment Sampling Results

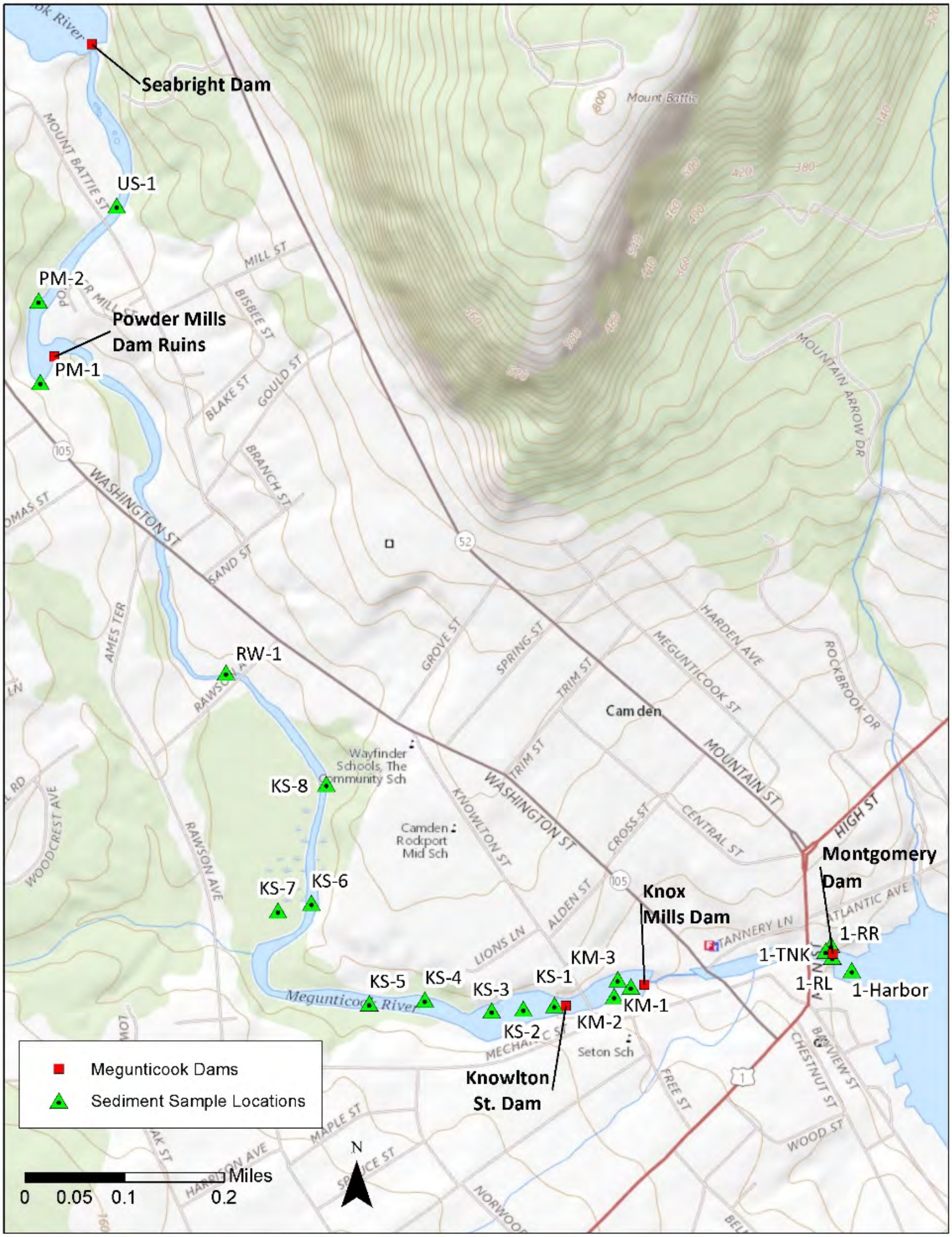

Figure 103. Overview of sediment sample locations.

Table A-1. Sediment sampling results compared to ***consensus freshwater ecological screening standards***. Exceedence indicated by shaded values. Analytes shown only if one or more samples detected the analyte. Analytes that were not detected in any samples are omitted from the results table. Full list of analytes available upon request.

				Camden Inner Harbor		Montgomery Dam Impoundment			Knox Mills Dam Impoundment			Knowlton Street Dam Impoundment									Rawson	Powder Mill Dam Impound.		Upstream
						Est. Accum. Sediment (C 300			Est. Accum. Sediment (CY): 300			Est. Accum. Sediment (CY): 28,000										Est. Accum. Sed. (CY) 100		
						Est. Mobile Sediment (CY 300			Est. Mobile Sediment (CY): 300			Est. Mobile Sediment (CY): 10,800										Est. Mobile Sed. (CY): 100		
			LOCATION	1-HARBOR	LM-HARBOR**	2-RR	3-RL	4-TNK	KM-1	KM-2	KM-3	KS-1	KS-2	KS-3	KS-4	KS-5	KS-6	KS-5A	KS-7	KS-8	RW-1	PM-1	PM-2	US-1
			SAMPLING DATE	6/28/2018	11/12/18	6/28/2018	6/28/2018	6/28/2018	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	10/8/2020	10/8/2020	10/8/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020
	NOAA FPEC	NOAA FTEC	Units																					
Chlorinated Herbicides by GC																								
No Detections			ug/kg																					
General Chemistry																								
Solids, Total			%	64.1	68.25	58.7	68.4	45.7	64.3	64.3	68.8	49.9	41.5	65.7	41.3	53.6	60.6	66.5	43.4	59.9	71.9	66	61.9	56.4
Organochlorine Pesticides by GC																								
Aldrin			ug/kg	-	-	18.6	-	-	-	ND	-	-	ND	-	-	-	-	-	ND	ND	ND	ND	-	ND
Oxychlordane			ug/kg	-	-	15.1	-	-	-	ND	-	-	ND	-	-	-	-	-	ND	ND	ND	ND	-	ND
gamma-Chlordane			ug/kg	-	-	5.1	-	-	-	ND	-	-	ND	-	-	-	-	-	ND	ND	ND	ND	-	ND
2,4'-DDE			ug/kg	-	-	ND	-	-	-	8.36	-	-	6	-	-	-	-	-	ND	ND	0.889	0.83	-	ND
alpha-Chlordane			ug/kg	-	-	4.52	-	-	-	ND	-	-	0.457	-	-	-	-	-	ND	ND	ND	ND	-	ND
trans-Nonachlor			ug/kg	-	-	5.77	-	-	-	3.08	-	-	2.15	-	-	-	-	-	ND	ND	1.02	0.279	-	ND
4,4'-DDE	31.30	3.16	ug/kg	-	-	28.7	-	-	-	3.9	-	-	4.64	-	-	-	-	-	5.11	0.096	0.494	ND	-	ND
Dieldrin	61.80	1.90	ug/kg	-	-	142	-	-	-	ND	-	-	ND	-	-	-	-	-	ND	ND	ND	ND	-	ND
2,4'-DDD			ug/kg	-	-	22.3	-	-	-	4.63	-	-	2.04	-	-	-	-	-	ND	ND	0.492	ND	-	0.433
4,4'-DDD	28.00	4.88	ug/kg	-	-	58.7	-	-	-	7.79	-	-	3.7	-	-	-	-	-	0.708	0.138	0.281	ND	-	ND
2,4'-DDT			ug/kg	-	-	2.5	-	-	-	ND	-	-	0.498	-	-	-	-	-	ND	ND	0.55	ND	-	0.568
4,4'-DDT	62.90	4.16	ug/kg	-	-	6.03	-	-	-	1.91	-	-	0.864	-	-	-	-	-	1.75	0.089	0.563	ND	-	ND
Polychlorinated Biphenyls by GC																								
Aroclor 1254	676.00		ug/kg	ND	ND	66.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
Aroclor 1268	676.00	59.80	ug/kg	ND	ND	ND	ND	ND	232	ND	76.5	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
PCBs, Total	676.00	59.80	ug/kg	ND	-	66.5	ND	ND	232	ND	76.5	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
Semivolatile Organics by GC/MS																								
Dibenzofuran			ug/kg	1000	-	ND	ND	890	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	2900	ND	ND	ND	ND
2,4,6-Trichlorophenol			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	170	-	ND	ND	ND	ND	ND	ND
Carbazole			ug/kg	1200	-	350	ND	1200	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	3400	ND	ND	ND	ND
Semivolatile Organics by GC/MS-SIM																								
Acenaphthene			ug/kg	980	ND	340	51	1100	25	95	20	21	19	10	ND	18	240	-	ND	1800	9.1	ND	24	ND
2-Chloronaphthalene			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	230	-	ND	ND	ND	ND	ND	ND
Fluoranthene	2,230	423	ug/kg	6100	1500	4500	1400	9400	950	1900	830	970	740	650	180	360	1000	-	340	20000	220	62	420	76
Hexachlorobutadiene			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	240	-	ND	-	ND	ND	ND	ND
Naphthalene	561	176	ug/kg	1600	-	270	48	1400	39	55	37	ND	ND	ND	ND	14	240	-	29	2300	ND	ND	ND	ND
Benzo(a)anthracene	1,050	108	ug/kg	3400	720	2000	710	5500	670	1000	720	590	580	480	92	170	540	-	160	10000	96	51	200	32
Benzo(a)pyrene	1,450	150	ug/kg	2600	640	2000	730	4500	540	850	570	500	480	360	110	180	550	-	190	7000	89	29	200	27
Benzo(b)fluoranthene			ug/kg	3400	840	2800	970	5500	640	1000	600	560	560	440	130	200	640	-	220	8500	110	36	220	30
Benzo(k)fluoranthene			ug/kg	960	300	1100	350	1900	230	320	170	170	120	130	39	40	280	-	78	1900	32	11	76	ND
Chrysene	1,290	166	ug/kg	3500	800	2300	810	5500	550	860	520	450	460	340	100	180	580	-	180	7500	97	32	220	27
Acenaphthylene			ug/kg	730	150	270	190	430	160	130	180	53	110	98	42	59	320	-	62	960	18	10	35	ND
Anthracene	845	57	ug/kg	2000	200	680	190	2300	100	290	130	120	87	75	22	60	310	-	41	6500	36	ND	50	18
Benzo(ghi)perylene			ug/kg	1000	360	720	310	1600	310	500	300	220	220	170	72	100	400	-	110	3000	47	15	110	13
Fluorene	536	77	ug/kg	1300	nd	330	76	1300	54	100	71	27	35	24	ND	32	270	-	26	2900	11	ND	24	ND
Phenanthrene	1,170	204	ug/kg	7000	790	3000	750	8500	560	1400	660	370	370	260	94	270	710	-	220	23000	150	25	310	73
Dibenzo(a,h)anthracene		33	ug/kg	320	120	200	97	500	83	120	78	62	85	46	20	28	260	-	25	770	14	ND	29	ND
Indeno(1,2,3-cd)Pyrene			ug/kg	1200	410	830	350	1800	270	410	250	210	200	150	78	110	430	-	120	3900	53	13	120	16
Pyrene	1,520	195	ug/kg	5300	1300	3900	1200	8100	930	1700	970	860	730	600	200	370	980	-	340	16000	190	53	440	63
1-Methylnaphthalene			ug/kg	520	ND	82	17	320	ND	ND	27	ND	ND	ND	ND	ND	230	-	ND	730	ND	ND	ND	ND
2-Methylnaphthalene			ug/kg	670	ND	97	22	500	ND	ND	22	ND	ND	ND	ND	ND	230	-	ND	1100	ND	ND	ND	ND
Pentachlorophenol			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	290	-	ND	-	ND	ND	ND	ND
Hexachlorobenzene			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	240	-	ND	-	ND	ND	ND	ND
Hexachloroethane			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	160	-	ND	-	ND	ND	ND	ND
Total Metals																								
Arsenic, Total	33,000	9,790	ug/kg	9620	13000	17000	7830	8940	12,600	6,670	10,300	8,560	13,400	7,230	12,400	11,100	7,030	5,740	13,800	18,600	8,860	9,600	5,100	7,510
Beryllium, Total			ug/kg	ND	-	410	ND	ND	ND	328	279	ND	570	ND	ND	356	ND	289	ND	374	ND	321	ND	ND
Cadmium, Total	4,980	990	ug/kg	766	ND	950	976	1320	1,580	614	876	ND	ND	ND	ND	783	ND	ND	ND	ND	ND	ND	ND	ND
Chromium, Total	111,000	43,400	ug/kg	25500	32000	1460000	98300	600000	113,000	524,000	87,800	147,000	355,000	100,000	268,000	1,780,000	50,100	47,400	546,000	24,000	21,200	23,400	14,000	19,600
Chromium, Hexavalent	46,000	12,000	ug/kg	-	ND	-	-	-	-	-	-	-	-	-	-	-	-	ND	ND	ND	-	-	-	-
Copper, Total	149,000	31,600	ug/kg	20000	-	40100	30500	73200	66,000	56,300	59,400	48,600	24,700	12,100	45,800	27,200	14,800	14,400	33,000	20,700	27,700	13,700	7,820	10,300
Lead, Total	128,000	35,800	ug/kg	198000	24000	122000	67000	141000	78,200	77,900	61,100	31,700	52,200	27,700	86,000	61,000	26,000	17,800	52,000	31,100	28,200	13,400	7,920	5,610
Mercury, Total	1,060	180	ug/kg	ND	170	229	133	3610	320	144	215	ND	ND	ND	1,280	166	ND	ND	236	ND	ND	ND	ND	ND
Nickel, Total	48,600	22,700	ug/kg	14000	-	15000	15100	20900	16,000	17,700	16,000	14,900	23,700	14,800	20,800	19,200	12,700	13,200	18,800	20,000	15,900	19,600	11,400	16,600
Zinc, Total	459,000	121,000	ug/kg	70400	-	120000	106000	165000	309,000	132,000	194,000	86,600	120,000	80,600	244,000	106,000	62,000	63,800	102,000	155,000	62,400	48,000	36,600	37,500
Volatile Organics by EPA 5035																								
Acetone			ug/kg	ND	-	21	130	85	200	98	400	220	310	140	300	120	160	-	160	110	59	62	110	150
2-Butanone			ug/kg	ND	-	ND	21	ND	46	21	97	59	78	29	63	31	37	-	31	ND	14	ND	26	31
sec-Butylbenzene			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	2.5	ND	ND	ND	ND	ND	-	ND	ND	3.7	ND	ND	ND
tert-Butylbenzene			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	3.9	ND	ND	ND
p-Isopropyltoluene			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	2	ND	ND	ND	ND
1,3,5-Trimethylbenzene			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.3	ND	-	ND	ND	ND	ND	ND	ND
1,2,4-Trimethylbenzene			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	19	ND	ND	ND	4.8	ND	-	ND	ND	ND	ND	ND	ND

- Sample not analyzed for this analyte
ND: No detection
** Sample LM-HARBOR collected and analyzed by Lyman-Morse Boatbuilding, November 2018. Results extracted from Maine DEP Natural Resource Protection Act application for maintenance dredging, copy submitted to Town of Camden, received 11/28/18
NOAA-FPEC: NOAA Freshwater Sediment Probable Effect Concentration (PEC) SQuiRTs Criteria per 2008 Screening Quick Reference Tables.
NOAA-FTEC: NOAA Freshwater Sediment Threshold Effect Concentration (TEC) SQuiRTs Criteria per 2008 Screening Quick Reference Tables.

Table A-2. Sediment sampling results compared to ***consensus marine ecological screening standards***. Exceedence indicated by shaded values. Analytes shown only if one or more samples detected the analyte. Analytes that were not detected in any samples are omitted from the results table. Full list of analytes available upon request.

				Camden Inner Harbor		Montgomery Dam Impoundment			Knox Mills Dam Impoundment			Knowlton Street Dam Impoundment									Rawson	Powder Mill Dam Impound.		Upstream
						Est. Accum. Sed. (CY): 300			Est. Accum. Sed. (CY): 300			Est. Accum. Sed. (CY): 28,000										Est. Accum. Sed. (CY): 100		
						Est. Mobile Sed. (CY): 300			Est. Mobile Sed. (CY): 300			Est. Mobile Sed. (CY): 10,800										Est. Mobile Sed. (CY): 100		
			LOCATION	1-HARBOR	LM-HARBOR**	2-RR	3-RL	4-TNK	KM-1	KM-2	KM-3	KS-1	KS-2	KS-3	KS-4	KS-5	KS-6	KS-5A	KS-7	KS-8	RW-1	PM-1	PM-2	US-1
			SAMPLING DATE	6/28/2018	11/12/18	6/28/2018	6/28/2018	6/28/2018	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	10/8/2020	10/8/2020	10/8/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020
	NOAA MPEL	NOAA MTEL	Units																					
Chlorinated Herbicides by GC																								
No Detections			ug/kg																					
General Chemistry																								
Solids, Total			%	64.1	68.25	58.7	68.4	45.7	64.3	64.3	68.8	49.9	41.5	65.7	41.3	53.6	60.6	66.5	43.4	59.9	71.9	66	61.9	56.4
Organochlorine Pesticides by GC																								
Aldrin			ug/kg	-	-	18.6	-	-	-	ND	-	-	ND	-	-	-	-	-	ND	ND	ND	ND	-	ND
Oxychlordane			ug/kg	-	-	15.1	-	-	-	ND	-	-	ND	-	-	-	-	-	ND	ND	ND	ND	-	ND
gamma-Chlordane			ug/kg	-	-	5.1	-	-	-	ND	-	-	ND	-	-	-	-	-	ND	ND	ND	ND	-	ND
2,4'-DDE			ug/kg	-	-	ND	-	-	-	8.36	-	-	6	-	-	-	-	-	ND	ND	0.889	0.83	-	ND
alpha-Chlordane			ug/kg	-	-	4.52	-	-	-	ND	-	-	0.457	-	-	-	-	-	ND	ND	ND	ND	-	ND
trans-Nonachlor			ug/kg	-	-	5.77	-	-	-	3.08	-	-	2.15	-	-	-	-	-	ND	ND	1.02	0.279	-	ND
4,4'-DDE	374	2.07	ug/kg	-	-	28.7	-	-	-	3.9	-	-	4.64	-	-	-	-	-	5.11	0.096	0.494	ND	-	ND
Dieldrin	4.3	0.72	ug/kg	-	-	142	-	-	-	ND	-	-	ND	-	-	-	-	-	ND	ND	ND	ND	-	ND
2,4'-DDD			ug/kg	-	-	22.3	-	-	-	4.63	-	-	2.04	-	-	-	-	-	ND	ND	0.492	ND	-	0.433
4,4'-DDD	7.81	1.22	ug/kg	-	-	58.7	-	-	-	7.79	-	-	3.7	-	-	-	-	-	0.708	0.138	0.281	ND	-	ND
2,4'-DDT			ug/kg	-	-	2.5	-	-	-	ND	-	-	0.498	-	-	-	-	-	ND	ND	0.55	ND	-	0.568
4,4'-DDT	4.77	1.19	ug/kg	-	-	6.03	-	-	-	1.91	-	-	0.864	-	-	-	-	-	1.75	0.089	0.563	ND	-	ND
Polychlorinated Biphenyls by GC																								
Aroclor 1254	709	63.3	ug/kg	ND	ND	66.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
Aroclor 1268	189	21.6	ug/kg	ND	ND	ND	ND	ND	232	ND	76.5	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
PCBs, Total	189	21.6	ug/kg	ND	-	66.5	ND	ND	232	ND	76.5	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
Semivolatile Organics by GC/MS																								
Dibenzofuran			ug/kg	1000	-	ND	ND	890	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	2900	ND	ND	ND	ND
2,4,6-Trichlorophenol			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	170	-	ND	ND	ND	ND	ND	ND
Carbazole			ug/kg	1200	-	350	ND	1200	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	3400	ND	ND	ND	ND
Semivolatile Organics by GC/MS-SIM																								
Acenaphthene	88.9	6.71	ug/kg	980	ND	340	51	1100	25	95	20	21	19	10	ND	18	240	-	ND	1800	9.1	ND	24	ND
2-Chloronaphthalene			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	230	-	ND	ND	ND	ND	ND	ND
Fluoranthene	1494	113	ug/kg	6100	1500	4500	1400	9400	950	1900	830	970	740	650	180	360	1000	-	340	20000	220	62	420	76
Hexachlorobutadiene			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	240	-	ND	-	ND	ND	ND	ND
Naphthalene	391	34.6	ug/kg	1600	-	270	48	1400	39	55	37	ND	ND	ND	ND	14	240	-	29	2300	ND	ND	ND	ND
Benzo(a)anthracene	693	74.8	ug/kg	3400	720	2000	710	5500	670	1000	720	590	580	480	92	170	540	-	160	10000	96	51	200	32
Benzo(a)pyrene	763	88.8	ug/kg	2600	640	2000	730	4500	540	850	570	500	480	360	110	180	550	-	190	7000	89	29	200	27
Benzo(b)fluoranthene			ug/kg	3400	840	2800	970	5500	640	1000	600	560	560	440	130	200	640	-	220	8500	110	36	220	30
Benzo(k)fluoranthene			ug/kg	960	300	1100	350	1900	230	320	170	170	120	130	39	40	280	-	78	1900	32	11	76	ND
Chrysene	846	108	ug/kg	3500	800	2300	810	5500	550	860	520	450	460	340	100	180	580	-	180	7500	97	32	220	27
Acenaphthylene	128	5.87	ug/kg	730	150	270	190	430	160	130	180	53	110	98	42	59	320	-	62	960	18	10	35	ND
Anthracene	245	46.9	ug/kg	2000	200	680	190	2300	100	290	130	120	87	75	22	60	310	-	41	6500	36	ND	50	18
Benzo(ghi)perylene			ug/kg	1000	360	720	310	1600	310	500	300	220	220	170	72	100	400	-	110	3000	47	15	110	13
Fluorene	144	21.2	ug/kg	1300	nd	330	76	1300	54	100	71	27	35	24	ND	32	270	-	26	2900	11	ND	24	ND
Phenanthrene	544	86.7	ug/kg	7000	790	3000	750	8500	560	1400	660	370	370	260	94	270	710	-	220	23000	150	25	310	73
Dibenzo(a,h)anthracene	135	6.22	ug/kg	320	120	200	97	500	83	120	78	62	85	46	20	28	260	-	25	770	14	ND	29	ND
Indeno(1,2,3-cd)Pyrene			ug/kg	1200	410	830	350	1800	270	410	250	210	200	150	78	110	430	-	120	3900	53	13	120	16
Pyrene	1398	153	ug/kg	5300	1300	3900	1200	8100	930	1700	970	860	730	600	200	370	980	-	340	16000	190	53	440	63
1-Methylnaphthalene			ug/kg	520	ND	82	17	320	ND	ND	27	ND	ND	ND	ND	ND	230	-	ND	730	ND	ND	ND	ND
2-Methylnaphthalene	201	20.2	ug/kg	670	ND	97	22	500	ND	ND	22	ND	ND	ND	ND	ND	230	-	ND	1100	ND	ND	ND	ND
Pentachlorophenol			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	290	-	ND	-	ND	ND	ND	ND
Hexachlorobenzene			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	240	-	ND	-	ND	ND	ND	ND
Hexachloroethane			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	160	-	ND	-	ND	ND	ND	ND
Total Metals																								
Arsenic, Total	41600	7240	ug/kg	9620	13000	17000	7830	8940	12,600	6,670	10,300	8,560	13,400	7,230	12,400	11,100	7,030	5,740	13,800	18,600	8,860	9,600	5,100	7,510
Beryllium, Total			ug/kg	ND	-	410	ND	ND	ND	328	279	ND	570	ND	ND	356	ND	289	ND	374	ND	321	ND	ND
Cadmium, Total	4210	680	ug/kg	766	ND	950	976	1320	1,580	614	876	ND	ND	ND	ND	783	ND	ND	ND	ND	ND	ND	ND	ND
Chromium, Total	160000	52300	ug/kg	25500	32000	1460000	98300	600000	113,000	524,000	87,800	147,000	355,000	100,000	268,000	1,780,000	50,100	47,400	546,000	24,000	21,200	23,400	14,000	19,600
Chromium, Hexavalent	46,000	12,000	ug/kg	-	ND	-	-	-	-	-	-	-	-	-	-	-	-	ND	ND	ND	-	-	-	-
Copper, Total	108,000	18,700	ug/kg	20000	-	40100	30500	73200	66,000	56,300	59,400	48,600	24,700	12,100	45,800	27,200	14,800	14,400	33,000	20,700	27,700	13,700	7,820	10,300
Lead, Total	112,000	30,240	ug/kg	198000	24000	122000	67000	141000	78,200	77,900	61,100	31,700	52,200	27,700	86,000	61,000	26,000	17,800	52,000	31,100	28,200	13,400	7,920	5,610
Mercury, Total	700	130	ug/kg	ND	170	229	133	3610	320	144	215	ND	ND	ND	1,280	166	ND	ND	236	ND	ND	ND	ND	ND
Nickel, Total	42,800	15,900	ug/kg	14000	-	15000	15100	20900	16,000	17,700	16,000	14,900	23,700	14,800	20,800	19,200	12,700	13,200	18,800	20,000	15,900	19,600	11,400	16,600
Zinc, Total	271,000	######	ug/kg	70400	-	120000	106000	165000	309,000	132,000	194,000	86,600	120,000	80,600	244,000	106,000	62,000	63,800	102,000	155,000	62,400	48,000	36,600	37,500
Volatile Organics by EPA 5035																								
Acetone			ug/kg	ND	-	21	130	85	200	98	400	220	310	140	300	120	160	-	160	110	59	62	110	150
2-Butanone			ug/kg	ND	-	ND	21	ND	46	21	97	59	78	29	63	31	37	-	31	ND	14	ND	26	31
sec-Butylbenzene			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	2.5	ND	ND	ND	ND	ND	-	ND	ND	3.7	ND	ND	ND
tert-Butylbenzene			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	3.9	ND	ND	ND
p-Isopropyltoluene			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	2	ND	ND	ND	ND
1,3,5-Trimethylbenzene			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.3	ND	-	ND	ND	ND	ND	ND	ND
1,2,4-Trimethylbenzene			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	19	ND	ND	ND	4.8	ND	-	ND	ND	ND	ND	ND	ND

- Sample not analyzed for this analyte
ND: No detection
** Sample LM-HARBOR collected and analyzed by Lyman-Morse Boatbuilding, November 2018. Results extracted from Maine DEP Natural Resource Protection Act application for maintenance dredging, copy submitted to Town of Camden, received 11/28/18
NOAA Marine Sediment Probable Effects Level (PEL) SQuiRTs Criteria per 2008 Screening Quick Reference Tables.
NOAA Marine Sediment Threshold Effects Level (TEL) SQuiRTs Criteria per 2008 Screening Quick Reference Tables.

Table A-3. Sediment sampling results compared to ***Maine Remedial Action Guidelines (ME-RAGs) for Contaminated Sites***. Exceedence indicated by shaded values. Analytes shown only if one or more samples detected the analyte. Analytes that were not detected in any samples are omitted from the results table. Full list of analytes available upon request.

				Camden Inner Harbor		Montgomery Dam Impoundment Est. Accum. Sediment (CY): 300 Est. Mobile Sediment (CY): 300			Knox Mills Dam Impoundment Est. Accum. Sediment (CY): 300 Est. Mobile Sediment (CY): 300			Knowlton Street Dam Impoundment Est. Accum. Sediment (CY): 28,000 Est. Mobile Sediment (CY): 10,800									Rawson	Powder Mill Dam Impound. Est. Accum. Sed. (CY): 100 Est. Mobile Sed. (CY): 100		Upstream
			LOCATION	**1-HARBOR**	**LM-HARBOR****	**2-RR**	**3-RL**	**4-TNK**	**KM-1**	**KM-2**	**KM-3**	**KS-1**	**KS-2**	**KS-3**	**KS-4**	**KS-5**	**KS-6**	**KS-5A**	**KS-7**	**KS-8**	**RW-1**	**PM-1**	**PM-2**	**US-1**
			SAMPLING DATE	**6/28/2018**	**11/12/18**	**6/28/2018**	**6/28/2018**	**6/28/2018**	**7/27/2020**	**7/27/2020**	**7/27/2020**	**7/27/2020**	**7/27/2020**	**7/27/2020**	**7/27/2020**	**7/27/2020**	**7/27/2020**	**10/8/2020**	**10/8/2020**	**10/8/2020**	**7/27/2020**	**7/27/2020**	**7/27/2020**	**7/27/2020**
	Excavation Worker	**Park User**	**Units**																					
Chlorinated Herbicides by GC																								
No Detections	2100	2000	ug/kg																					
General Chemistry																								
Solids, Total			%	64.1	68.25	58.7	68.4	45.7	64.3	64.3	68.8	49.9	41.5	65.7	41.3	53.6	60.6	66.5	43.4	59.9	71.9	66	61.9	56.4
Organochlorine Pesticides by GC																								
Aldrin	14,000	1,600	ug/kg	-	-	18.6	-	-	-	ND	-	-	ND	-	-	-	-	-	ND	ND	ND	ND	-	ND
Oxychlordane			ug/kg	-	-	15.1	-	-	-	ND	-	-	ND	-	-	-	-	-	ND	ND	ND	ND	-	ND
gamma-Chlordane			ug/kg	-	-	5.1	-	-	-	ND	-	-	ND	-	-	-	-	-	ND	ND	ND	ND	-	ND
2,4'-DDE			ug/kg	-	-	ND	-	-	-	8.36	-	-	6	-	-	-	-	-	ND	ND	0.889	0.83	-	ND
alpha-Chlordane			ug/kg	-	-	4.52	-	-	-	ND	-	-	0.457	-	-	-	-	-	ND	ND	ND	ND	-	ND
trans-Nonachlor			ug/kg	-	-	5.77	-	-	-	3.08	-	-	2.15	-	-	-	-	-	ND	ND	1.02	0.279	-	ND
4,4'-DDE	100,000	79,000	ug/kg	-	-	28.7	-	-	-	3.9	-	-	4.64	-	-	-	-	-	5.11	0.096	0.494	ND	-	ND
Dieldrin	12,000	1,300	ug/kg	-	-	142	-	-	-	ND	-	-	ND	-	-	-	-	-	ND	ND	ND	ND	-	ND
2,4'-DDD			ug/kg	-	-	22.3	-	-	-	4.63	-	-	2.04	-	-	-	-	-	ND	ND	0.492	ND	-	0.433
4,4'-DDD	7,700	7,400	ug/kg	-	-	58.7	-	-	-	7.79	-	-	3.7	-	-	-	-	-	0.708	0.138	0.281	ND	-	ND
2,4'-DDT			ug/kg	-	-	2.5	-	-	-	ND	-	-	0.498	-	-	-	-	-	ND	ND	0.55	ND	-	0.568
4,4'-DDT	160,000	73,000	ug/kg	-	-	6.03	-	-	-	1.91	-	-	0.864	-	-	-	-	-	1.75	0.089	0.563	ND	-	ND
Polychlorinated Biphenyls by GC	-	-																						
Aroclor 1254			ug/kg	ND	ND	66.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
Aroclor 1268			ug/kg	ND	ND	ND	ND	ND	232	ND	76.5	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
PCBs, Total	74,000	9,600	ug/kg	ND	-	66.5	ND	ND	232	ND	76.5	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
Semivolatile Organics by GC/MS	-	-																						
Dibenzofuran	1,200,000	280,000	ug/kg	1000	-	ND	ND	890	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	2900	ND	ND	ND	ND
2,4,6-Trichlorophenol	260,000	250,000	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	170	-	ND	ND	ND	ND	ND	ND
Carbazole	6,700,000	750,000	ug/kg	1200	-	350	ND	1200	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	3400	ND	ND	ND	ND
Semivolatile Organics by GC/MS-SIM	-	-																						
Acenaphthene	48,000,000	14,000,000	ug/kg	980	ND	340	51	1100	25	95	20	21	19	10	ND	18	240	-	ND	1800	9.1	ND	24	ND
2-Chloronaphthalene	48,000,000	19,000,000	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	230	-	ND	ND	ND	ND	ND	ND
Fluoranthene	24,000,000	9,300,000	ug/kg	6100	1500	4500	1400	9400	950	1900	830	970	740	650	180	360	1000	-	340	20000	220	62	420	76
Hexachlorobutadiene	17,000	16,000	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	240	-	ND	-	ND	ND	ND	ND
Naphthalene	130,000	1,300,000	ug/kg	1600	-	270	48	1400	39	55	37	ND	ND	ND	ND	14	240	-	29	2300	ND	ND	ND	ND
Benzo(a)anthracene	1,700,000	45,000	ug/kg	3400	720	2000	710	5500	670	1000	720	590	580	480	92	170	540	-	160	10000	96	51	200	32
Benzo(a)pyrene	9,900	4,500	ug/kg	2600	640	2000	730	4500	540	850	570	500	480	360	110	180	550	-	190	7000	89	29	200	27
Benzo(b)fluoranthene	1,700,000	45,000	ug/kg	3400	840	2800	970	5500	640	1000	600	560	560	440	130	200	640	-	220	8500	110	36	220	30
Benzo(k)fluoranthene	17,000,000	450,000	ug/kg	960	300	1100	350	1900	230	320	170	170	120	130	39	40	280	-	78	1900	32	11	76	ND
Chrysene	100,000,000	4,500,000	ug/kg	3500	800	2300	810	5500	550	860	520	450	460	340	100	180	580	-	180	7500	97	32	220	27
Acenaphthylene	48,000,000	14,000,000	ug/kg	730	150	270	190	430	160	130	180	53	110	98	42	59	320	-	62	960	18	10	35	ND
Anthracene	100,000,000	70,000,000	ug/kg	2000	200	680	190	2300	100	290	130	120	87	75	22	60	310	-	41	6500	36	ND	50	18
Benzo(ghi)perylene	72,000,000	7,000,000	ug/kg	1000	360	720	310	1600	310	500	300	220	220	170	72	100	400	-	110	3000	47	15	110	13
Fluorene	96,000,000	9,300,000	ug/kg	1300	nd	330	76	1300	54	100	71	27	35	24	ND	32	270	-	26	2900	11	ND	24	ND
Phenanthrene	72,000,000	7,000,000	ug/kg	7000	790	3000	750	8500	560	1400	660	370	370	260	94	270	710	-	220	23000	150	25	310	73
Dibenzo(a,h)anthracene	170,000	4,500	ug/kg	320	120	200	97	500	83	120	78	62	85	46	20	28	260	-	25	770	14	ND	29	ND
Indeno(1,2,3-cd)Pyrene	1,700,000	45,000	ug/kg	1200	410	830	350	1800	270	410	250	210	200	150	78	110	430	-	120	3900	53	13	120	16
Pyrene	72,000,000	7,000,000	ug/kg	5300	1300	3900	1200	8100	930	1700	970	860	730	600	200	370	980	-	340	16000	190	53	440	63
1-Methylnaphthalene	6,000,000	680,000	ug/kg	520	ND	82	17	320	ND	ND	27	ND	ND	ND	ND	ND	230	-	ND	730	ND	ND	ND	ND
2-Methylnaphthalene	960,000	930,000	ug/kg	670	ND	97	22	500	ND	ND	22	ND	ND	ND	ND	ND	230	-	ND	1100	ND	ND	ND	ND
Pentachlorophenol	190,000	40,000	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	290	-	ND	-	ND	ND	ND	ND
Hexachlorobenzene	3,400	15,000	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	240	-	ND	-	ND	ND	ND	ND
Hexachloroethane	450,000	210,000	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	160	-	ND	-	ND	ND	ND	ND
Total Metals	-	-																						
Arsenic, Total	54,000	26,000	ug/kg	9620	13000	17000	7830	8940	12,600	6,670	10,300	8,560	13,400	7,230	12,400	11,100	7,030	5,740	13,800	18,600	8,860	9,600	5,100	7,510
Beryllium, Total	110,000	610,000	ug/kg	ND	-	410	ND	ND	ND	328	279	ND	570	ND	ND	356	ND	289	ND	374	ND	321	ND	ND
Cadmium, Total	42,000	280,000	ug/kg	766	ND	950	976	1320	1,580	614	876	ND	ND	ND	ND	783	ND	ND	ND	ND	ND	ND	ND	ND
Chromium, Total			ug/kg	25500	32000	1460000	98300	600000	113,000	524,000	87,800	147,000	355,000	100,000	268,000	1,780,000	50,100	47,400	546,000	24,000	21,200	23,400	14,000	19,600
Chromium, Hexavalent	46,000	12,000	ug/kg	-	ND	-	-	-	-	-	-	-	-	-	-	-	-	ND	ND	ND	-	-	-	-
Copper, Total	3,400,000	12,000,000	ug/kg	20000	-	40100	30500	73200	66,000	56,300	59,400	48,600	24,700	12,100	45,800	27,200	14,800	14,400	33,000	20,700	27,700	13,700	7,820	10,300
Lead, Total	450,000	290,000	ug/kg	198000	24000	122000	67000	141000	78,200	77,900	61,100	31,700	52,200	27,700	86,000	61,000	26,000	17,800	52,000	31,100	28,200	13,400	7,920	5,610
Mercury, Total	3,100	3,100	ug/kg	ND	170	229	133	3610	320	144	215	ND	ND	ND	1,280	166	ND	ND	236	ND	ND	ND	ND	ND
Nickel, Total	990,000	6,100,000	ug/kg	14000	-	15000	15100	20900	16,000	17,700	16,000	14,900	23,700	14,800	20,800	19,200	12,700	13,200	18,800	20,000	15,900	19,600	11,400	16,600
Zinc, Total	100,000,000	91,000,000	ug/kg	70400	-	120000	106000	165000	309,000	132,000	194,000	86,600	120,000	80,600	244,000	106,000	62,000	63,800	102,000	155,000	62,400	48,000	36,600	37,500
Volatile Organics by EPA 5035	-	-																						
Acetone	98,000,000	81,000,000	ug/kg	ND	-	21	130	85	200	98	400	220	310	140	300	120	160	-	160	110	59	62	110	150
2-Butanone	11,000,000	25,000,000	ug/kg	ND	-	ND	21	ND	46	21	97	59	78	29	63	31	37	-	31	ND	14	ND	26	31
sec-Butylbenzene	34,000,000	30,000,000	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	2.5	ND	ND	ND	ND	ND	-	ND	ND	3.7	ND	ND	ND
tert-Butylbenzene			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	3.9	ND	ND	ND
p-Isopropyltoluene			ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	2	ND	ND	ND	ND
1,3,5-Trimethylbenzene	180,000	170,000	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.3	ND	-	ND	ND	ND	ND	ND	ND
1,2,4-Trimethylbenzene	220,000	200,000	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	19	ND	ND	ND	4.8	ND	-	ND	ND	ND	ND	ND	ND

\- Sample not analyzed for this analyte
ND: No detection
** Sample LM-HARBOR collected and analyzed by Lyman-Morse Boatbuilding, November 2018. Results extracted from Maine DEP Natural Resource Protection Act application for maintenance dredging, copy submitted to Town of Camden, received 11/28/18
ME-RAGS-ME: Maine Excavation/Construction Worker Remedial Action Guidelines (RAGs) Criteria per Maine DEP RAGs dated October 19, 2018.
ME-RAGS-MP: Maine Park User Remedial Action Guidelines (RAGs) Criteria per Maine DEP RAGs dated October 19, 2018.

Table A-4. Sediment sampling results reported by ***Kimball Chase (1991) in the Knowlton Street Dam Impoundment, compared to consensus freshwater ecological screening standards***. Exceedence indicated by shaded values. Analytes shown only if one or more samples detected the analyte. Analytes that were not detected in any samples are omitted from the results table.

			LOCATION	KS-1990
			SAMPLING DATE	10/5/90
	NOAA FPEC	NOAA FTEC	Units	
Chlorinated Herbicides by GC				
No Detections or Not Tested			ug/kg	
General Chemistry				
Solids, Total			%	47.9
Organochlorine Pesticides by GC				
No Detections or Not Tested			ug/kg	
Polychlorinated Biphenyls by GC				
No Detections or Not Tested	676.00		ug/kg	
Semivolatile Organics by GC/MS				
No Detections or Not Tested			ug/kg	
Semivolatile Organics by GC/MS-SIM				
Pyrene	1,520	195	ug/kg	3.7
Total Metals				
Arsenic, Total	33,000	9,790	ug/kg	10,200
Beryllium, Total			ug/kg	ND, or Not Tested
Cadmium, Total	4,980	990	ug/kg	5,000
Chromium, Total	111,000	43,400	ug/kg	2,320,000
Chromium, Hexavalent				Not Speciated
Copper, Total	149,000	31,600	ug/kg	52,200
Lead, Total	128,000	35,800	ug/kg	109,000
Mercury, Total	1,060	180	ug/kg	500
Nickel, Total	48,600	22,700	ug/kg	25,100
Zinc, Total	459,000	121,000	ug/kg	ND, or Not Tested
Volatile Organics by EPA 5035				
Acetone			ug/kg	190

- Sample not analyzed for this analyte
ND: No detection
NOAA-FPEC: NOAA Freshwater Sediment Probable Effect Concentration (PEC) SQuiRTs Criteria per 2008 Screening Quick Reference Tables.
NOAA-FTEC: NOAA Freshwater Sediment Threshold Effect Concentration (TEC) SQuiRTs Criteria per 2008 Screening Quick Reference Tables.

Table A-5. Sediment sampling results compared to ***Maine Beneficial Use Guidelines for Construction Fill, Reduced Procedure Screening Criteria*** . Exceedence indicated by shaded values. Analytes shown only if one or more samples detected the analyte. Analytes that were not detected in any samples are omitted from the results table. Full list of analytes available upon request.

			Camden Inner Harbor		Montgomery Dam Impoundment			Knox Mills Dam Impoundment			Knowlton Street Dam Impoundment										Rawson	Powder Mill Dam Impound.		Upstream
					Est. Accum. Sed. (CY): 300			Est. Accum. Sed. (CY): 300			Est. Accum. Sed. (CY): 28,000											Est. Accum. Sed. (CY): 100		
					Est. Mobile Sed. (CY): 300			Est. Mobile Sed. (CY): 300			Est. Mobile Sed. (CY): 10,800											Est. Mobile Sed. (CY): 100		
		LOCATION	1-HARBOR	LM-HARBOR**	2-RR	3-RL	4-TNK	KM-1	KM-2	KM-3	KS-1	KS-2	KS-3	KS-4	KS-5	KS-6	KS-5A	KS-7	KS-8	KS-1990	RW-1	PM-1	PM-2	US-1
		SAMPLING DATE	6/28/2018	11/12/18	6/28/2018	6/28/2018	6/28/2018	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	10/8/2020	10/8/2020	10/8/2020	10/5/90	7/27/2020	7/27/2020	7/27/2020	7/27/2020
	Beneficial Reuse Standards	Units																						
Polychlorinated Biphenyls by GC																								
Aroclor 1254		ug/kg	ND	ND	66.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND
Aroclor 1268		ug/kg	ND	ND	ND	ND	ND	232	ND	76.5	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND
PCBs, Total	2700	ug/kg	ND	-	66.5	ND	ND	232	ND	76.5	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND
Semivolatile Organics by GC/MS-SIM																								
Benzo(a)anthracene	13000	ug/kg	3400	720	2000	710	5500	670	1000	720	590	580	480	92	170	540	-	160	10000	ND	96	51	200	32
Benzo(a)pyrene	1300	ug/kg	2600	640	2000	730	4500	540	850	570	500	480	360	110	180	550	-	190	7000	ND	89	29	200	27
Benzo(b)fluoranthene	13000	ug/kg	3400	840	2800	970	5500	640	1000	600	560	560	440	130	200	640	-	220	8500	ND	110	36	220	30
Benzo(k)fluoranthene	134000	ug/kg	960	300	1100	350	1900	230	320	170	170	120	130	39	40	280	-	78	1900	ND	32	11	76	ND
Chrysene	1340000	ug/kg	3500	800	2300	810	5500	550	860	520	450	460	340	100	180	580	-	180	7500	ND	97	32	220	27
Dibenzo(a,h)anthracene	1300	ug/kg	320	120	200	97	500	83	120	78	62	85	46	20	28	260	-	25	770	ND	14	ND	29	ND
Indeno(1,2,3-cd)Pyrene	13000	ug/kg	1200	410	830	350	1800	270	410	250	210	200	150	78	110	430	-	120	3900	ND	53	13	120	16
Total Metals																								
Arsenic, Total	16000	ug/kg	9620	13000	17000	7830	8940	12,600	6,670	10,300	8,560	13,400	7,230	12,400	11,100	7,030	5,740	13,800	18,600	10,200	8,860	9,600	5,100	7,510
Cadmium, Total	22000	ug/kg	766	ND	950	976	1320	1,580	614	876	ND	ND	ND	ND	783	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium, Total		ug/kg	25500	32000	1460000	98300	600000	113000	524000	87,800	147000	355000	100000	268000	1780000	50,100	47,400	546000	24,000	2320000	21,200	23,400	14,000	19,600
Chromium, Hexavalent	3600	ug/kg	-	ND	-	-	-	-	-	-	-	-	-	-	-	-	ND	ND	ND	-	-	-	-	-
Lead, Total	200000	ug/kg	198000	24000	122000	67000	141000	78,200	77,900	61,100	31,700	52,200	27,700	86,000	61,000	26,000	17,800	52,000	31,100	109000	28,200	13,400	7,920	5,610
Mercury, Total	27000	ug/kg	ND	170	229	133	3610	320	144	215	ND	ND	ND	1,280	166	ND	ND	236	ND	ND	ND	ND	ND	ND
Dioxin																								
Dioxon TEQ																								

- Sample not analyzed for this analyte
ND: No detection
** Sample LM-HARBOR collected and analyzed by Lyman-Morse Boatbuilding, November 2018. Results extracted from Maine DEP Natural Resource Protection Act application for maintenance dredging, copy submitted to Town of Camden, received 11/28/18
Result with ORANGE text would require additional TCLP testing
Maine Solid Waste Management Rules: Chapter 418. Beneficial Use of Solid Wastes. July 8, 2018.

Table A-6. Sediment sampling results compared to ***Maine Beneficial Use Guidelines for Construction Fill, Full Licensing Procedure Screening Criteria***. Exceedence indicated by shaded values. Analytes shown only if one or more samples detected the analyte. Analytes that were not detected in any samples are omitted from the results table. Full list of analytes available upon request.

			Camden Inner Harbor		Montgomery Dam Impoundment			Knox Mills Dam Impoundment			Knowlton Street Dam Impoundment										Rawson	Powder Mill Dam Impound.		Upstream
					Est. Accum. Sediment (CY): 300			Est. Accum. Sediment (CY): 300			Est. Accum. Sediment (CY): 28,000											Est. Accum. Sed. (CY): 100		
					Est. Mobile Sediment (CY): 300			Est. Mobile Sediment (CY): 300			Est. Mobile Sediment (CY): 10,800											Est. Mobile Sed. (CY): 100		
	LOCATION		1-HARBOR	LM-HARBOR**	2-RR	3-RL	4-TNK	KM-1	KM-2	KM-3	KS-1	KS-2	KS-3	KS-4	KS-5	KS-6	KS-5A	KS-7	KS-8	KS-1990	RW-1	PM-1	PM-2	US-1
	SAMPLING DATE		6/28/2018	11/12/18	6/28/2018	6/28/2018	6/28/2018	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	7/27/2020	10/8/2020	10/8/2020	10/8/2020	10/5/90	7/27/2020	7/27/2020	7/27/2020	7/27/2020
	Beneficial Reuse Standard	Units																						
Chlorinated Herbicides by GC																								
No Detections	--	ug/kg																						
General Chemistry	--																							
Solids, Total	--	%	64.1	68.25	58.7	68.4	45.7	64.3	64.3	68.8	49.9	41.5	65.7	41.3	53.6	60.6	66.5	43.4	59.9	47.9	71.9	66	61.9	56.4
Organochlorine Pesticides by GC	--																							
Aldrin	460	ug/kg	-	-	18.6	-	-	-	ND	-	-	ND	-	-	-	-	-	ND	ND	ND	ND	ND	-	ND
Oxychlordane	--	ug/kg	-	-	15.1	-	-	-	ND	-	-	ND	-	-	-	-	-	ND	ND	-	ND	ND	-	ND
gamma-Chlordane	--	ug/kg	-	-	5.1	-	-	-	ND	-	-	ND	-	-	-	-	-	ND	ND	-	ND	ND	-	ND
2,4'-DDE	--	ug/kg	-	-	ND	-	-	-	8.36	-	-	6	-	-	-	-	-	ND	ND	-	0.889	0.83	-	ND
alpha-Chlordane	--	ug/kg	-	-	4.52	-	-	-	ND	-	-	0.457	-	-	-	-	-	ND	ND	-	ND	ND	-	ND
trans-Nonachlor	--	ug/kg	-	-	5.77	-	-	-	3.08	-	-	2.15	-	-	-	-	-	ND	ND	-	1.02	0.279	-	ND
4,4'-DDE	23,000	ug/kg	-	-	28.7	-	-	-	3.9	-	-	4.64	-	-	-	-	-	5.11	0.096	ND	0.494	ND	-	ND
Dieldrin	400	ug/kg	-	-	142	-	-	-	ND	-	-	ND	-	-	-	-	-	ND	ND	ND	ND	ND	-	ND
2,4'-DDD	--	ug/kg	-	-	22.3	-	-	-	4.63	-	-	2.04	-	-	-	-	-	ND	ND	-	0.492	ND	-	0.433
4,4'-DDD	26,000	ug/kg	-	-	58.7	-	-	-	7.79	-	-	3.7	-	-	-	-	-	0.708	0.138	ND	0.281	ND	-	ND
2,4'-DDT	--	ug/kg	-	-	2.5	-	-	-	ND	-	-	0.498	-	-	-	-	-	ND	ND	-	0.55	ND	-	0.568
4,4'-DDT	22,000	ug/kg	-	-	6.03	-	-	-	1.91	-	-	0.864	-	-	-	-	-	1.75	0.089	ND	0.563	ND	-	ND
Polychlorinated Biphenyls by GC	--																							
Aroclor 1254	--	ug/kg	ND	ND	66.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND
Aroclor 1268	--	ug/kg	ND	ND	ND	ND	ND	232	ND	76.5	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND
PCBs, Total	2,700	ug/kg	ND	-	66.5	ND	ND	232	ND	76.5	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND
Semivolatile Organics by GC/MS	--																							
Dibenzofuran	85,000	ug/kg	1000	-	ND	ND	890	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	2900	ND	ND	ND	ND	ND
2,4,6-Trichlorophenol	74,000	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	170	-	ND	ND	ND	ND	ND	ND	ND
Carbazole	317,000	ug/kg	1200	-	350	ND	1200	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	3400	ND	ND	ND	ND	ND
Semivolatile Organics by GC/MS-SIM	--																							
Acenaphthene	78,000	ug/kg	980	ND	340	51	1100	25	95	20	21	19	10	ND	18	240	-	ND	1800	ND	9.1	ND	24	ND
2-Chloronaphthalene	--	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	230	-	ND	ND	-	ND	ND	ND	ND
Fluoranthene	2,790,000	ug/kg	6100	1500	4500	1400	9400	950	1900	830	970	740	650	180	360	1000	-	340	20000	ND	220	62	420	76
Hexachlorobutadiene	38,000	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	240	-	ND	-	-	ND	ND	ND	ND
Naphthalene	78	ug/kg	1600	-	270	48	1400	39	55	37	ND	ND	ND	ND	14	240	-	29	2300	ND	ND	ND	ND	ND
Benzo(a)anthracene	13,000	ug/kg	3400	720	2000	710	5500	670	1000	720	590	580	480	92	170	540	-	160	10000	ND	96	51	200	32
Benzo(a)pyrene	1,300	ug/kg	2600	640	2000	730	4500	540	850	570	500	480	360	110	180	550	-	190	7000	ND	89	29	200	27
Benzo(b)fluoranthene	13,000	ug/kg	3400	840	2800	970	5500	640	1000	600	560	560	440	130	200	640	-	220	8500	ND	110	36	220	30
Benzo(k)fluoranthene	134,000	ug/kg	960	300	1100	350	1900	230	320	170	170	120	130	39	40	280	-	78	1900	ND	32	11	76	ND
Chrysene	1,340,000	ug/kg	3500	800	2300	810	5500	550	860	520	450	460	340	100	180	580	-	180	7500	ND	97	32	220	27
Acenaphthylene	74,000	ug/kg	730	150	270	190	430	160	130	180	53	110	98	42	59	320	-	62	960	ND	18	10	35	ND
Anthracene	825,000	ug/kg	2000	200	680	190	2300	100	290	130	120	87	75	22	60	310	-	41	6500	ND	36	ND	50	18
Benzo(ghi)perylene	2,090,000	ug/kg	1000	360	720	310	1600	310	500	300	220	220	170	72	100	400	-	110	3000	ND	47	15	110	13
Fluorene	75,000	ug/kg	1300	nd	330	76	1300	54	100	71	27	35	24	ND	32	270	-	26	2900	ND	11	ND	24	ND
Phenanthrene	83,000	ug/kg	7000	790	3000	750	8500	560	1400	660	370	370	260	94	270	710	-	220	23000	ND	150	25	310	73
Dibenzo(a,h)anthracene	1,300	ug/kg	320	120	200	97	500	83	120	78	62	85	46	20	28	260	-	25	770	ND	14	ND	29	ND
Indeno(1,2,3-cd)Pyrene	13,000	ug/kg	1200	410	830	350	1800	270	410	250	210	200	150	78	110	430	-	120	3900	ND	53	13	120	16
Pyrene	2,090,000	ug/kg	5300	1300	3900	1200	8100	930	1700	970	860	730	600	200	370	980	-	340	16000	ND	190	53	440	63
1-Methylnaphthalene	--	ug/kg	520	ND	82	17	320	ND	ND	27	ND	ND	ND	ND	ND	230	-	ND	730	-	ND	ND	ND	ND
2-Methylnaphthalene	2,700	ug/kg	670	ND	97	22	500	ND	ND	22	ND	ND	ND	ND	ND	230	-	ND	1100	-	ND	ND	ND	ND
Pentachlorophenol	12,000	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	290	-	ND	-	-	ND	ND	ND	ND
Hexachlorobenzene	1,700	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	240	-	ND	-	ND	ND	ND	ND	ND
Hexachloroethane	61,000	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	160	-	ND	-	ND	ND	ND	ND	ND
Total Metals	--																							
Arsenic, Total	7,900	ug/kg	9620	13000	17000	7830	8940	12,600	6,670	10,300	8,560	13,400	7,230	12,400	11,100	7,030	5,740	13,800	18,600	10,200	8,860	9,600	5,100	7,510
Beryllium, Total	58,000	ug/kg	ND	-	410	ND	ND	ND	328	279	ND	570	ND	ND	356	ND	289	ND	374	-	ND	321	ND	ND
Cadmium, Total	22,000	ug/kg	766	ND	950	976	1320	1,580	614	876	ND	ND	ND	ND	783	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium, Total	10,000,000	ug/kg	25500	32000	1460000	98300	600000	113,000	524,000	87,800	147,000	355,000	100,000	268,000	1,780,000	50,100	47,400	546,000	24,000	2,320,000	21,200	23,400	14,000	19,600
Chromium, Hexavalent	3,600	ug/kg	-	ND	-	-	-	-	-	-	-	-	-	-	-	-	ND	ND	ND	-	-	-	-	-
Copper, Total	1,700,000	ug/kg	20000	-	40100	30500	73200	66,000	56,300	59,400	48,600	24,700	12,100	45,800	27,200	14,800	14,400	33,000	20,700	52,200	27,700	13,700	7,820	10,300
Lead, Total	200,000	ug/kg	198000	24000	122000	67000	141000	78,200	77,900	61,100	31,700	52,200	27,700	86,000	61,000	26,000	17,800	52,000	31,100	109,000	28,200	13,400	7,920	5,610
Mercury, Total	--	ug/kg	ND	170	229	133	3610	320	144	215	ND	ND	ND	1,280	166	ND	ND	236	ND	ND	ND	ND	ND	ND
Nickel, Total	530,000	ug/kg	14000	-	15000	15100	20900	16,000	17,700	16,000	14,900	23,700	14,800	20,800	19,200	12,700	13,200	18,800	20,000	25,100	15,900	19,600	11,400	16,600
Zinc, Total	10,000,000	ug/kg	70400	-	120000	106000	165000	309,000	132,000	194,000	86,600	120,000	80,600	244,000	106,000	62,000	63,800	102,000	155,000	-	62,400	48,000	36,600	37,500
Volatile Organics by EPA 5035	--																							
Acetone	47,000	ug/kg	ND	-	21	130	85	200	98	400	220	310	140	300	120	160	-	160	110	190	59	62	110	150
2-Butanone	5,460,000	ug/kg	ND	-	ND	21	ND	46	21	97	59	78	29	63	31	37	-	31	ND	-	14	ND	26	31
sec-Butylbenzene	--	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	2.5	ND	ND	ND	ND	ND	-	ND	ND	-	3.7	ND	ND	ND
tert-Butylbenzene	--	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	-	3.9	ND	ND	ND
p-Isopropyltoluene	--	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	2	-	ND	ND	ND	ND
1,3,5-Trimethylbenzene	--	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.3	ND	-	ND	ND	-	ND	ND	ND	ND
1,2,4-Trimethylbenzene	--	ug/kg	ND	-	ND	ND	ND	ND	ND	ND	19	ND	ND	ND	4.8	ND	-	ND	ND	-	ND	ND	ND	ND

\- Sample not analyzed for this analyte
ND: No detection
** Sample LM-HARBOR collected and analyzed by Lyman-Morse Boatbuilding, November 2018. Results extracted from Maine DEP Natural Resource Protection Act application for maintenance dredging, copy submitted to Town of Camden, received 11/28/18
Result with ORANGE text would require additional TCLP testing
Maine Solid Waste Management Rules: Chapter 418. Beneficial Use of Solid Wastes. July 8, 2018.

Appendix C - Dam Breach Analysis Memo

TECHNICAL MEMORANDUM

To: Audra Caler, Town of Camden; Mike Burke, PE (Inter-Fluve)

From: Sarah Widing, PE

Date: March 23, 2021

Project: Megunticook River Feasibility Study

Re: Dam Breach Analysis

As part of the Megunticook River feasibility study, Inter-Fluve performed an incremental dam breach analysis to estimate the potential impact of catastrophic failures of the Knowlton Street and Knox Mill Dams. Even though these two dams are classified as low hazard by the Maine Emergency Management Agency Dam Safety Office, they were selected for dam breach analysis due to their age (1800s) and proximity to the Camden town center. In addition, the dams are presently in private ownership and minimally managed and maintained. In contrast, Emergency Action Plans (EAPs) exist for the upstream Town-owned high hazard dams which include extensive storage impoundments (Seabright and Megunticook Lake outlet dams).

This technical memorandum provides a detailed description of the methods and the results of the analysis. Refer to the Megunticook River Feasibility Report (Inter-Fluve 2021)[1] for conclusions and recommendations based on these results.

STUDY DESCRIPTION

As described in the feasibility study, Inter-Fluve developed a 1-dimensional steady flow hydraulic model of the Megunticook River using U.S. Army Corps of Engineers software HEC-RAS version 5.0.7. As part of this breach analysis, we modified the hydraulic model to simulate dam breach flood waves for the Knowlton Street and Knox Mills Dams (the Dams). Figure 1 provides a locus map of the study area. Modifications to the model included:

- converting the steady-flow model to an unsteady-flow model and
- entering dam breach geometries and times of breach formation for each of the dams.

We used the model to simulate conditions in the Megunticook River during normal, non-breach conditions to establish a baseline for water surface elevations, velocities, and the footprint of the inundated area. Then, we used the model to simulate the flood wave(s) that could occur during potential catastrophic failure of one or both of the Dams. The differences in the model results between the breach and non-breach conditions represents the incremental impact of dam failure on conditions in the Megunticook River.

[1] 2021, Inter-Fluve. Megunticook River Feasibility Report.

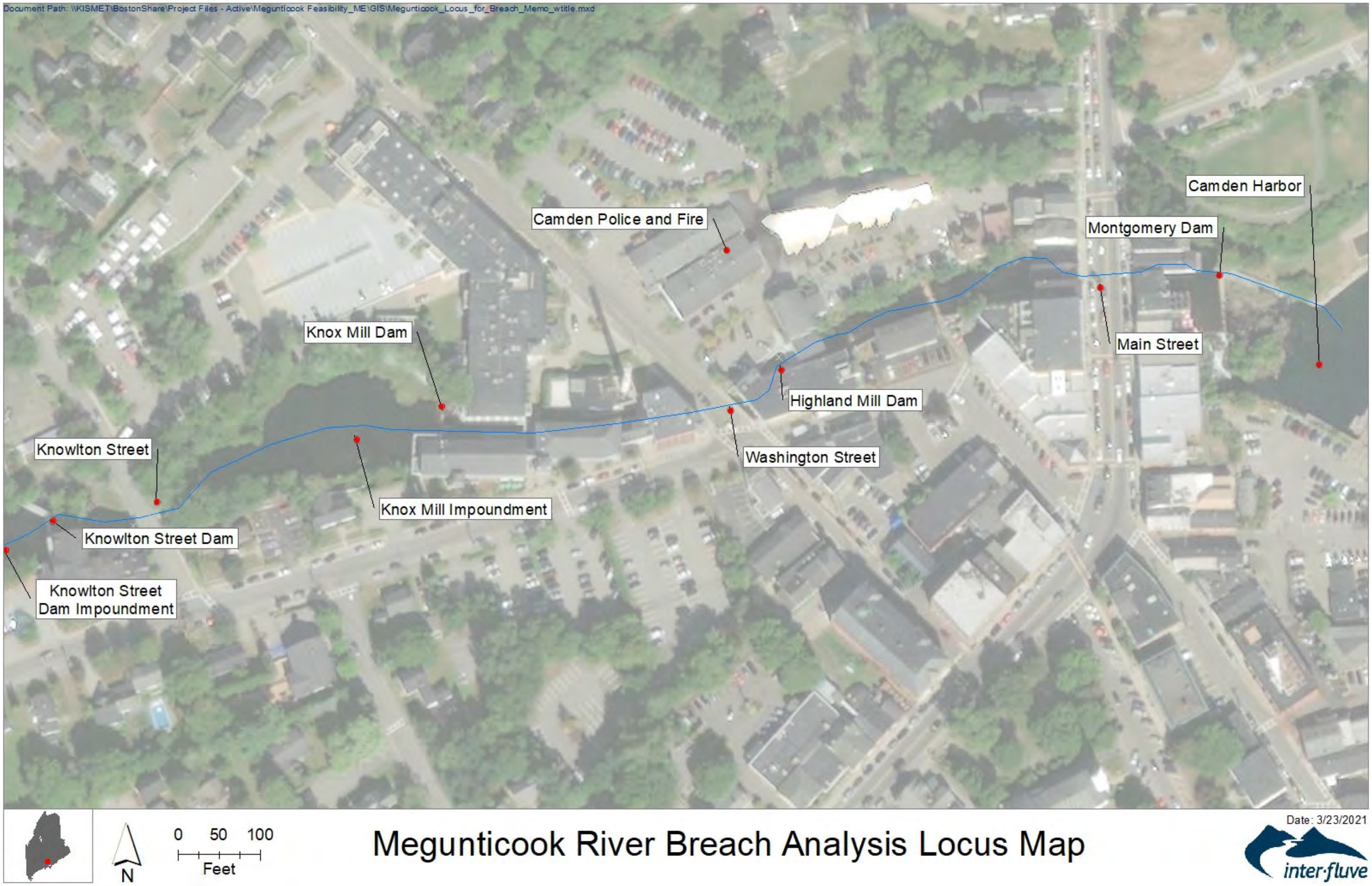

Figure 1. Locus Map

Table 1 summarizes the failure scenarios we evaluated as part of this work.

Table 1. Breach Event Scenarios

Event	Design Flow	Scenario
Sunny Day	$Q_{1.1}$ = 375 cfs	Instantaneous failure of the Knowlton Street Dam
		Instantaneous failure of the Knox Mills Dam
		Instantaneous failure of the Knowlton Street Dam causes subsequent failure of the Knox Mills Dam.
100-Year Flood	Q_{100} = 2270 cfs	Instantaneous failure of the Knowlton Street Dam
		Instantaneous failure of the Knox Mills Dam
		Instantaneous failure of the Knowlton Street Dam causes subsequent failure of the Knox Mills Dam.

For the scenarios where both dams breach, we assumed that the (larger, upstream) Knowlton Street Dam would breach first and that the flood wave would cause subsequent failure of the (smaller, downstream) Knox Mill Dam. We used preliminary model results to estimate the time it would take for the Knowlton Street breach wave to reach Knox Mills (less than 6 minutes) and set the time of the Knox Mill Dam breach accordingly.

BREACH GEOMETRY

We used the methods described in "Breaching Parameters for Earth and Rockfill Dams[2]" to develop our assumptions for breach condition geometries at the Dams; Table 2 summarizes the assumptions. Figure 2 and Figure 3 illustrate the breach geometries as compared to the Knox Mill and Knowlton Street dam profiles, respectively.

---

[2] Xu, Y. and L.M. Zhang. Breaching Parameters for Rockfill Dams, Journal of Geotechnical and Geoenvironmental Engineering, American Society of Civil Engineering, December 2009. pp 1957-1970.

Table 2. Breach Assumptions at the Knox Mill Dam

Breach Characteristic	Knox Mill Dam	Knowlton Street Dam
Final Bottom Width (feet)	14.0	20.0
Final Bottom Elevation (feet NAVD88)	37.0	63.4
Left Side Slope (H:V)	1.0	4.0
Right Side Slope (H:V)	2.0	0.0
Weir Coefficient	2.6	2.6
Time of Formation (hours)	0.5	0.1

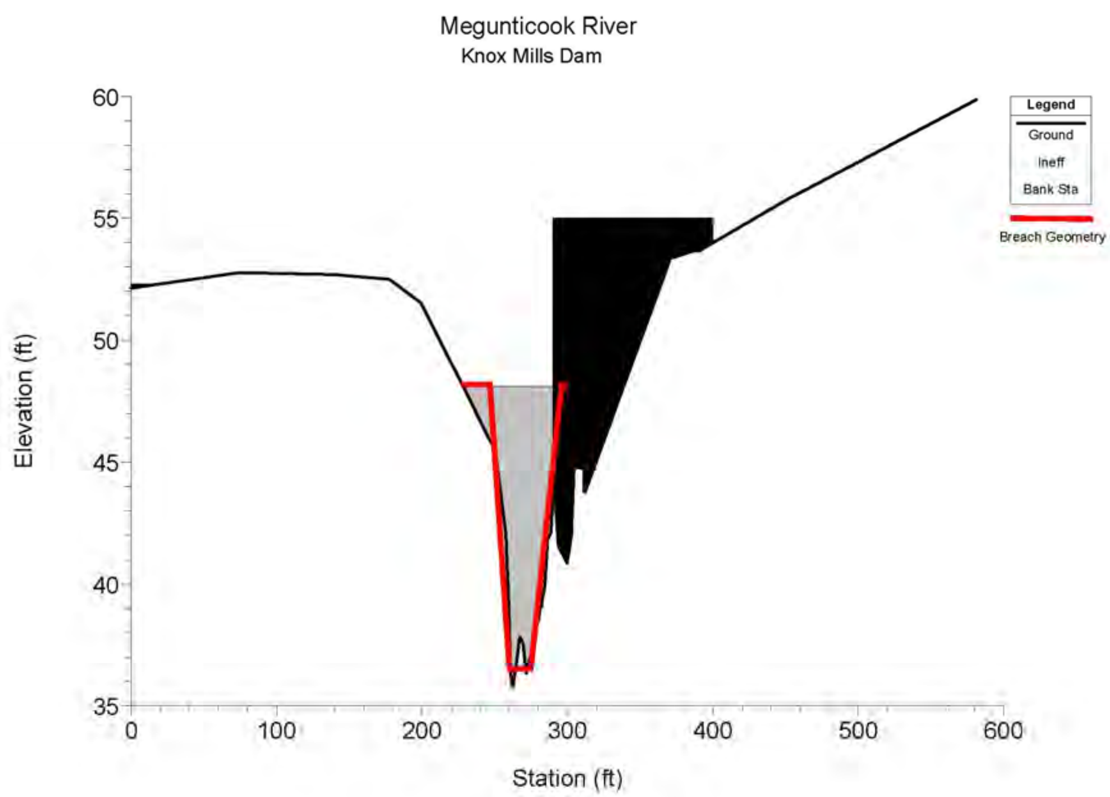

Figure 2. Knox Mills Dam Breach Geometry

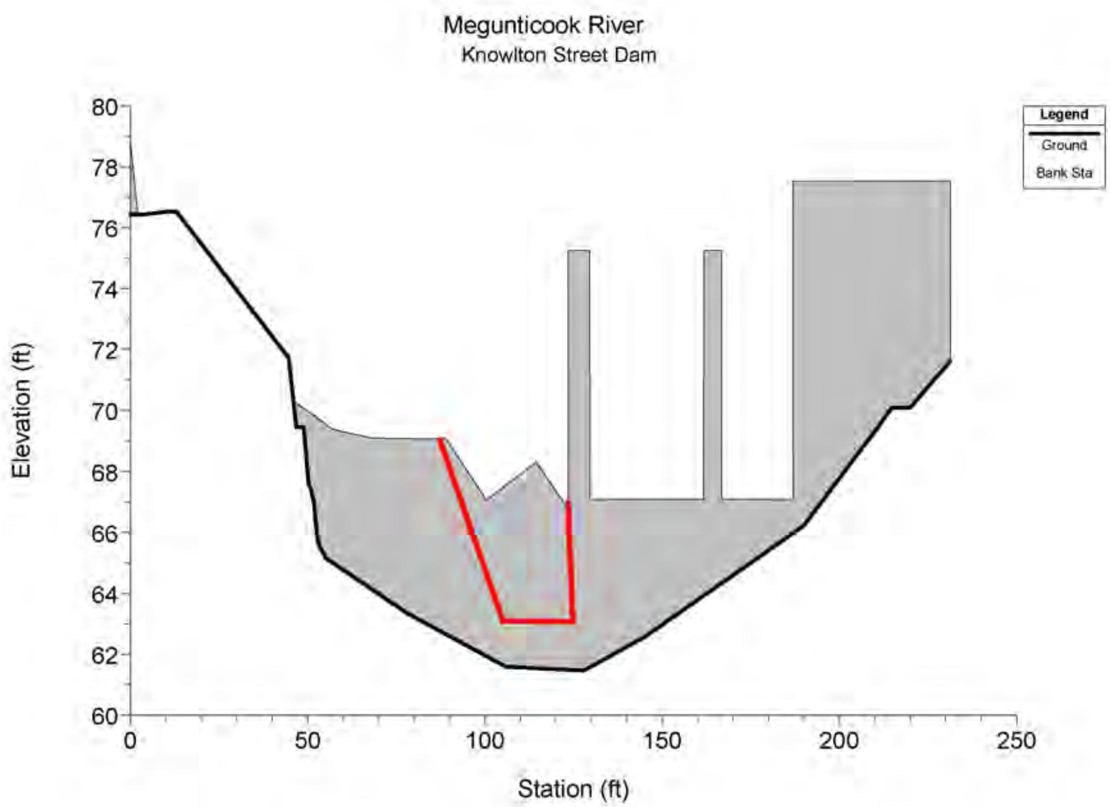

Figure 3. Knowlton Street Breach Geometry

MODEL RESULTS

Figure 4 through Figure 9 illustrate the incremental impact of the dam failure conditions on flood profiles and velocities along the study reach. Figure 10 through Figure 15 illustrate the impact of the dam failure conditions on the footprint of inundation along the study reach. Figure 16 and Figure 17 present the baseline and dam breach velocities along the Megunticook River.

Sunny Day Failure Event

Model results indicate that a dam failure that occurs on a sunny day will have a greater *incremental* impact on the water levels in the Megunticook River than a dam failure that occurs during a large flood. Specific to the sunny day failure event, model results indicate:

- The breach wave will remain within the channel (Figure 10, Figure 11, Figure 12).
- The breach wave will not cause the water surface profile to rise more than 2 feet at any point along the river (Figure 4, Figure 5, Figure 6).
- If the Knowlton Street Dam were to fail, the impact on flow velocities[3] would be greatest (+ ≤ 5.5 feet per second) immediately downstream of the dam, just upstream of Knowlton Street (Figure 4). The maximum velocity downstream of the dam would reach approximately 15 feet per second (Figure 16b).
- If the Knox Mills Dam were to fail, the impact on flow velocities would be greatest (+ ≤ 8 feet per second) in the Knox Mills Dam impoundment (Figure 5). The maximum velocity in the impoundment would reach approximately 15 feet per second. (Figure 16c).
- If either or both dams were to fail, the impact on velocities downstream of the Knox Mill Dam would range from + 0.5 feet per second to + 1.5 feet per second (Figure 4, Figure 5, Figure 6). The maximum velocity downstream of Knox Mills Dam (with the exception of the flow over Montgomery Dam), would reach approximately 7.0 feet per second (Figure 16a).

High-Flow Failure Event

Model results indicate that a dam breach that occurs during a large flood will have a smaller incremental impact on the water levels in the Megunticook River than a dam breach that occurs during a sunny day. However, the incremental changes are more significant because they are estimated to occur outside the river channel, in the town center. Specific to the high-flow failure event, model results indicate:

- The flood profile does not remain within the channel, the breach wave increases the footprint of the inundated areas (Figure 13, Figure 14, Figure 15).
- The flood elevation at the public safety building along Washington Street increases by approximately 0.7 feet for approximately 1 hour.
- The breach wave will not cause the water surface profile to rise more than 2 feet at any point along the river (Figure 7, Figure 8, Figure 9).
- If the Knowlton Street Dam were to fail, the impact on flow velocities would be greatest (+ ≤ 1.2 feet per second) just upstream of the Knowlton Street Dam impoundment (Figure 7). The maximum velocity in the vicinity of the dam would reach approximately 22 feet per second. (Figure 17b)
- If the Knox Mills Dam were to fail, the impact on flow velocities would be greatest (+ ≤ 7 feet per second) in the Knox Mills Dam impoundment (Figure 8). The maximum velocity in the impoundment would reach approximately 24 feet per second (Figure 17c).

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[3] In this report, the phrase, 'the impact on flow velocities' refers to the relative difference between the velocity in the channel assuming a dam failure does NOT occur and the velocity in the channel assuming a dam failure DOES occur.

- If the Knowlton Street Dam were to fail and cause subsequent failure of the Knox Mills Dam, the impact on flow velocities would be greatest (+ ≤ 8.5 feet per second) in the Knox Mills Dam impoundment (Figure 9). The maximum velocity in the Knox Mills Dam impoundment would reach approximately 24 feet per second (Figure 17a).
- If either or both dams were to fail, the impact on velocities downstream of the Knox Mill Dam would range from + 0.2 feet per second to + 1.5 feet per second (Figure 7, Figure 8, Figure 9). With the exception of the flow over Montgomery Dam, the maximum velocity would reach approximately 10 feet per second (Figure 17a).

INDEX OF RESULTS

Figure 4. Sunny Day Event: Knowlton Street Dam Breach

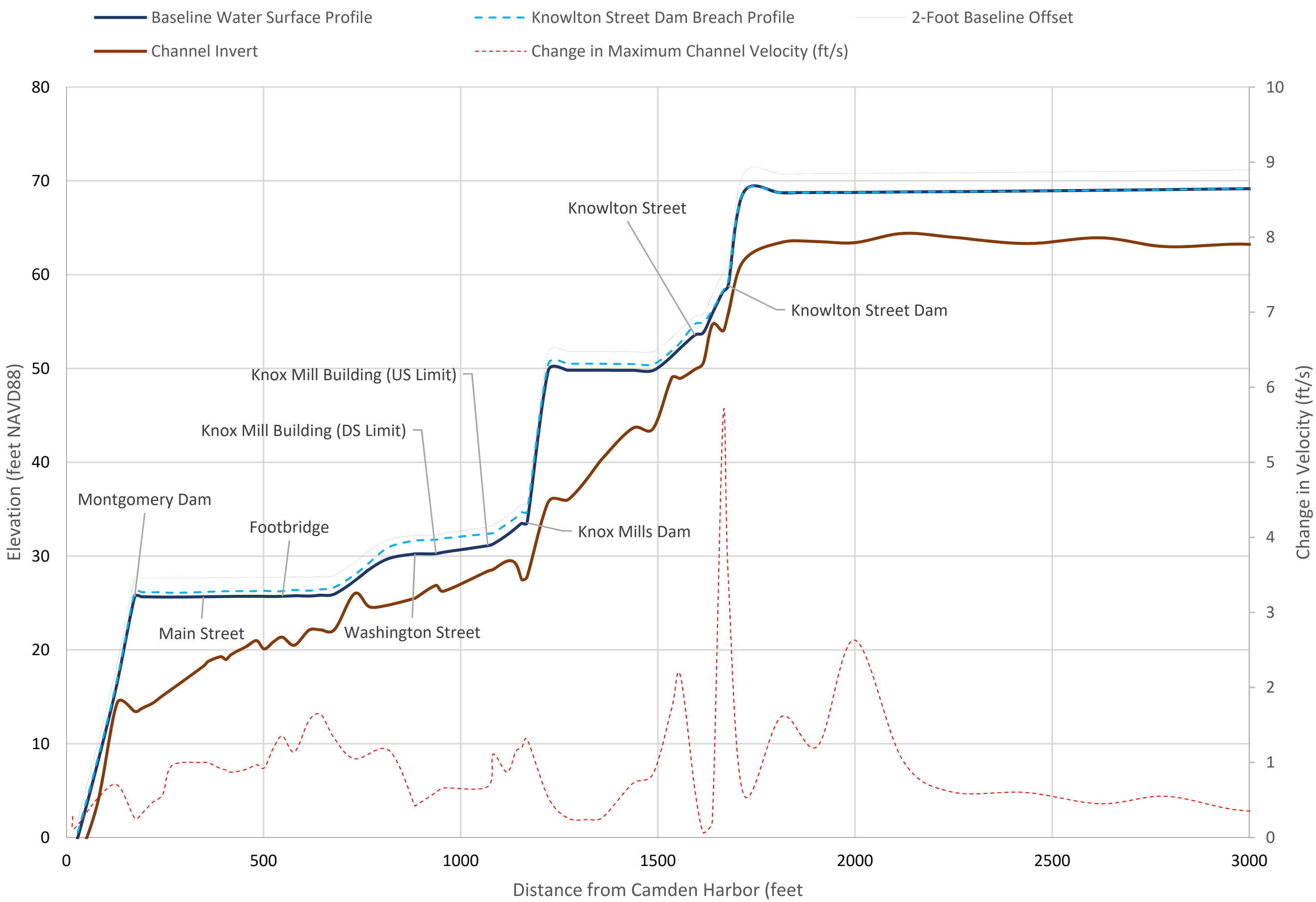


Figure 5. Sunny Day Event: Knox Mills Dam Breach

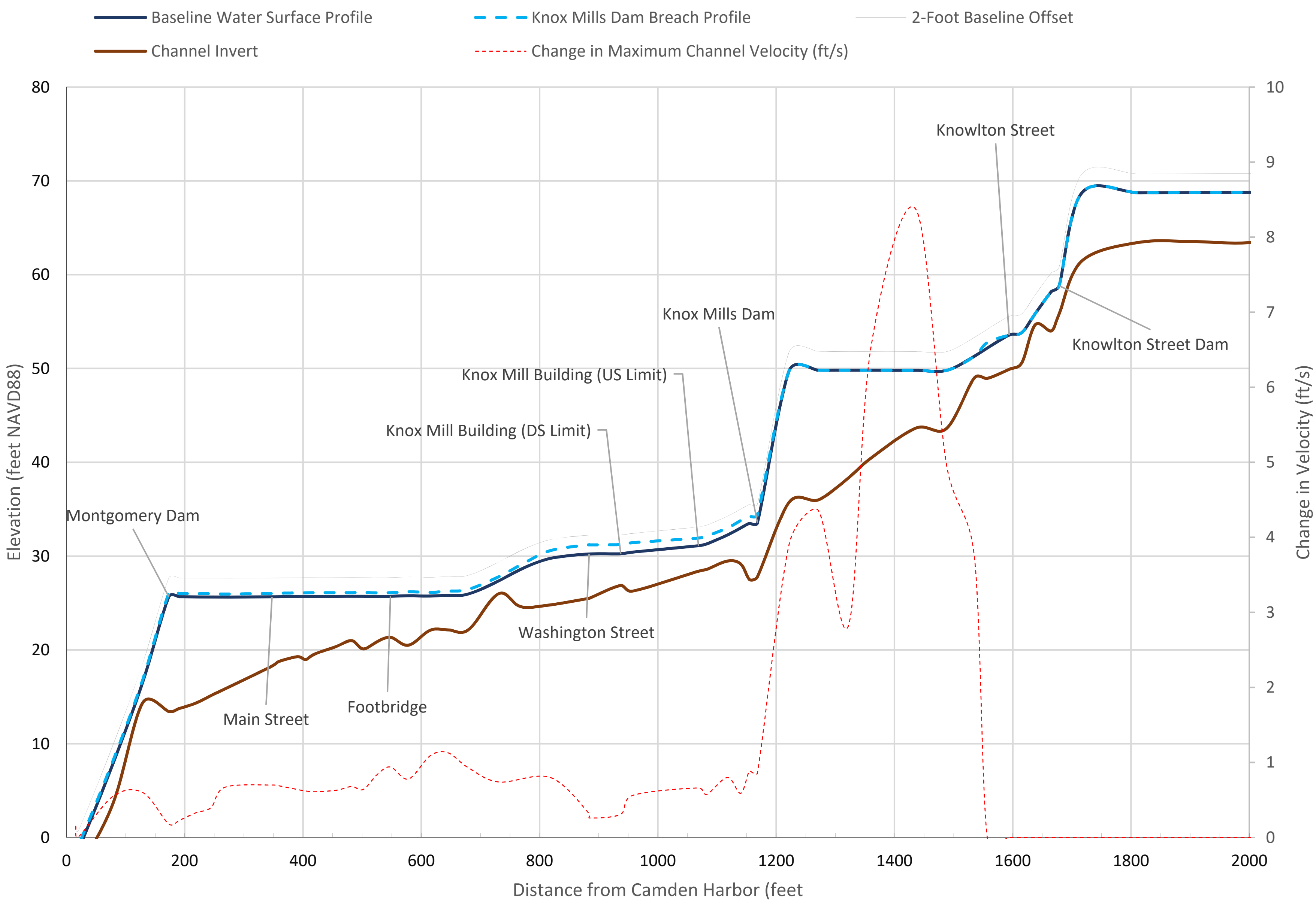


Figure 6. Sunny Day Event: Failure of Both the Knowlton Street and Knox Mills Dams

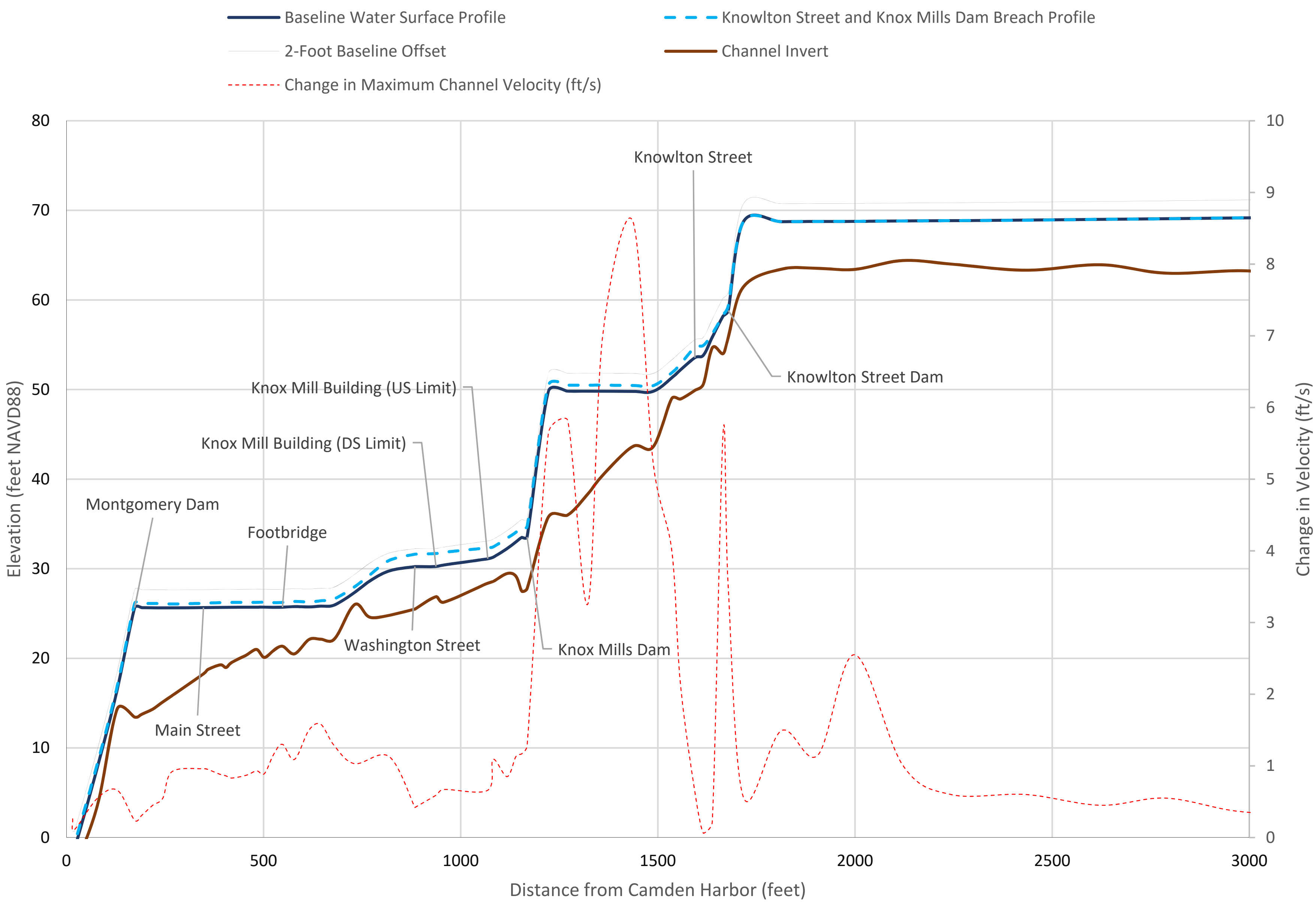


Figure 7. 100-Year Event: Knowlton Street Dam Breach

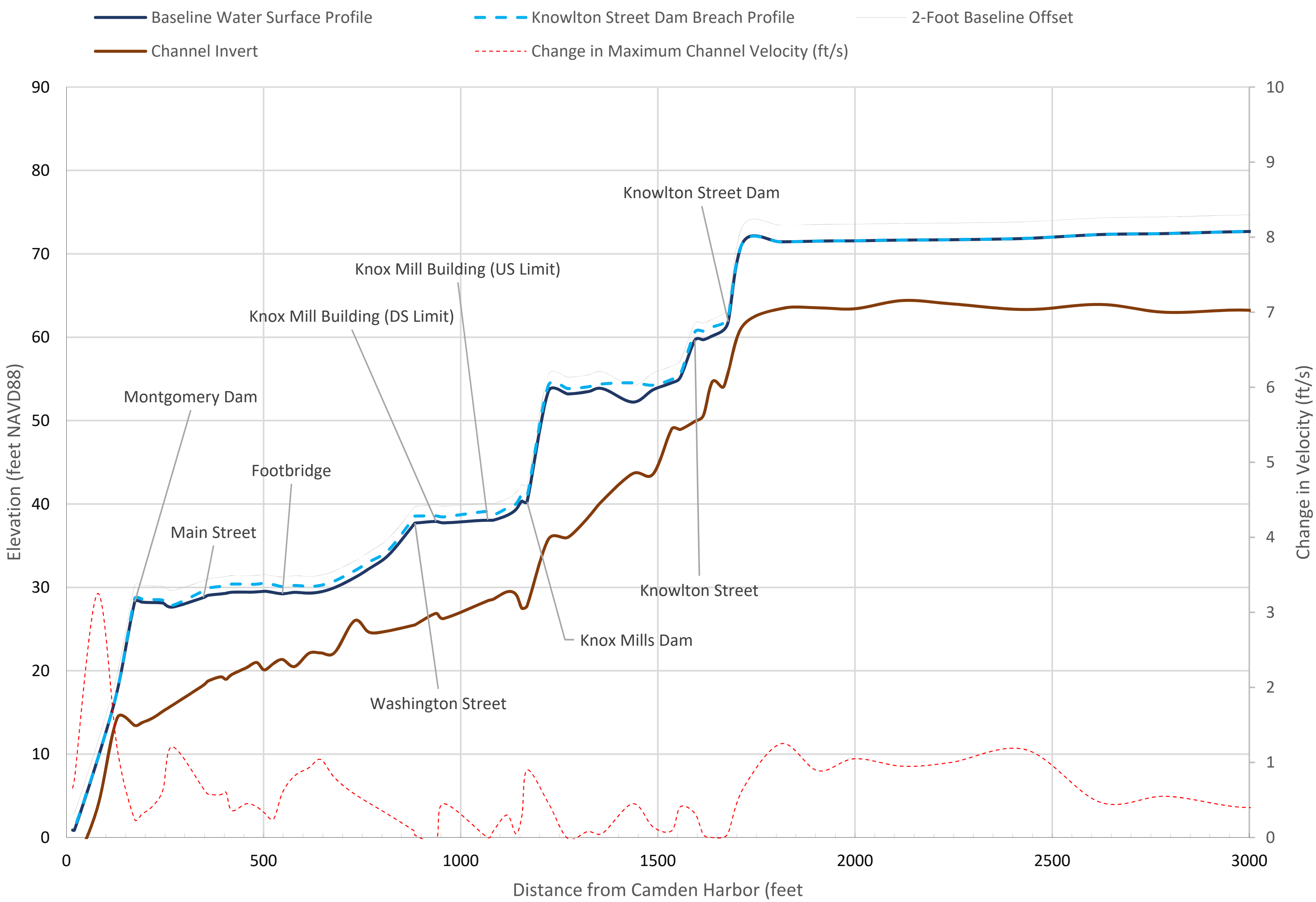


Figure 8. 100-Year Event: Knox Mills Dam Breach

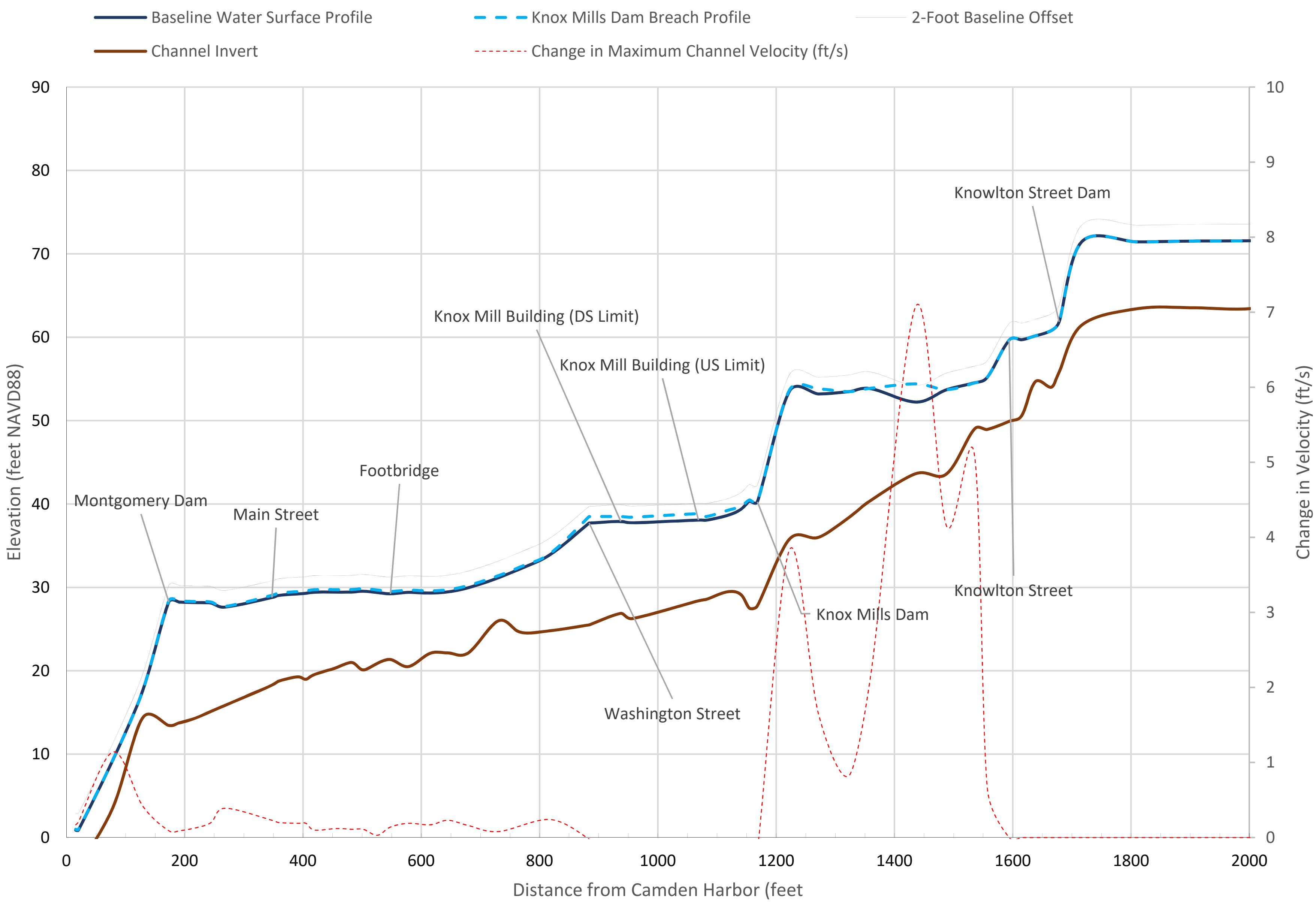
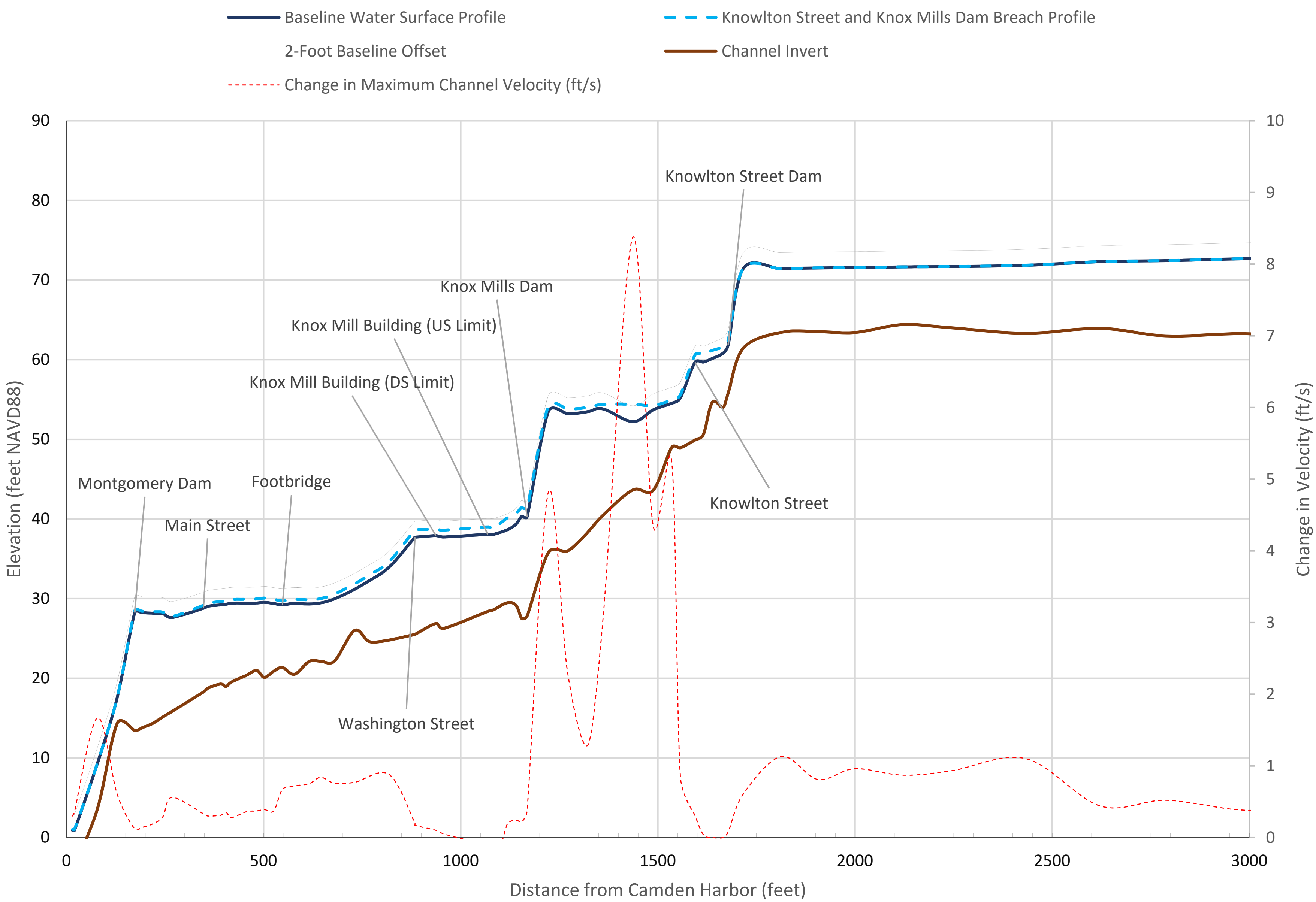
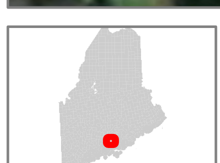


Figure 9. 100-Year Event: Failure of Both the Knowlton Street and Knox Mills Dams





N

1-Year Event, Failure of Knowlton Dam

- Impact of the Dam Breach
- Inundation Area

Megunticook River
Breach Analysis Model Results
Page 1 of 2

Figure 10

0 37.5 75 150
Feet

1 inch = 75 feet

Date: 1/29/2021

inter·fluve

1-Year Event, Failure of Knowlton Dam

- Impact of the Dam Breach
- Inundation Area

N

Megunticook River
Breach Analysis Model Results
Page 2 of 2

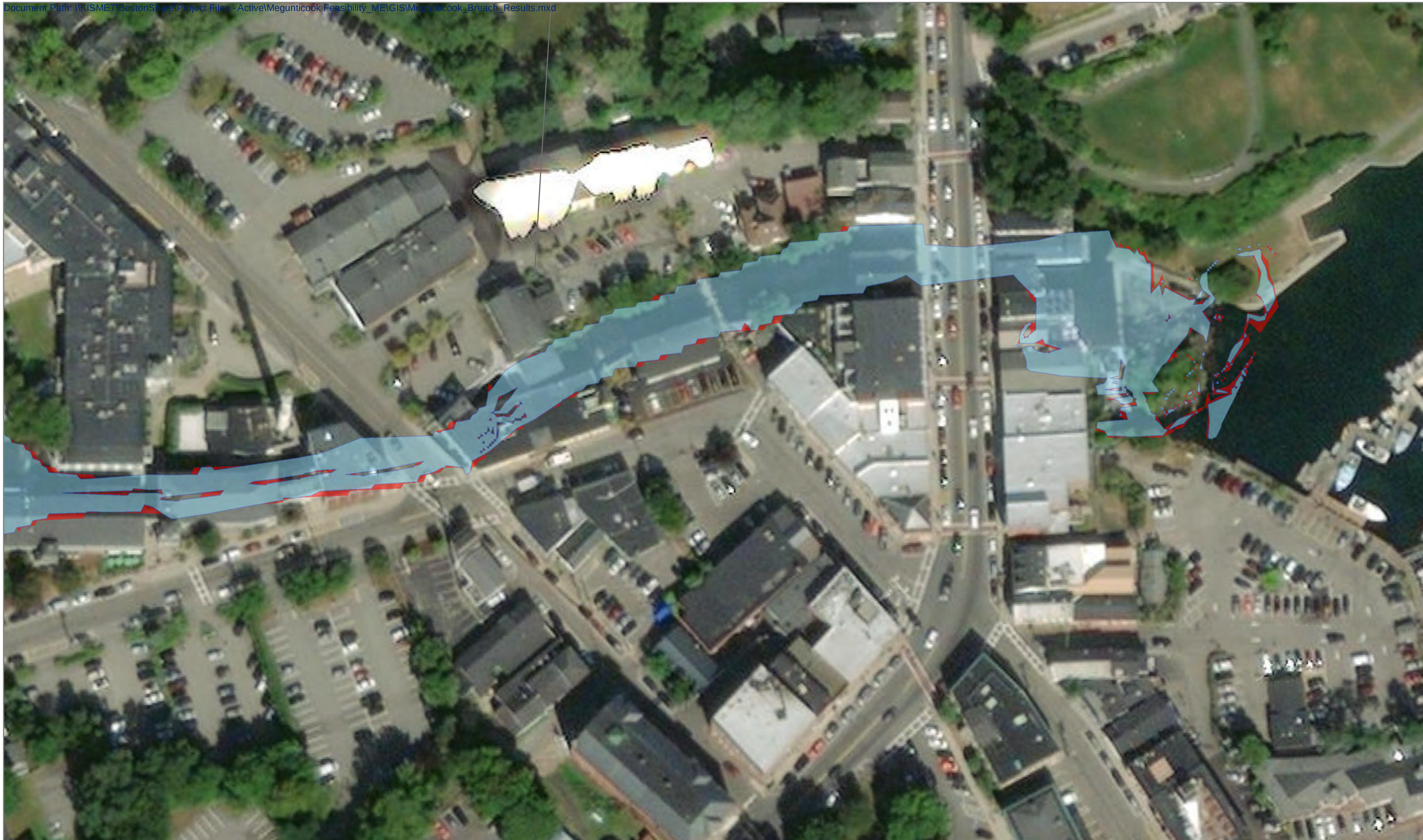
Figure 10

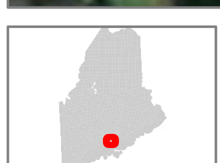
0 37.5 75 150
Feet

1 inch = 75 feet

Date: 1/29/2021

inter·fluve





N

1-Year Event, Failure of Knox Dam

Impact of the Dam Breach

Inundation Area

Megunticook River
Breach Analysis Model Results
Page 1 of 2

Figure 11

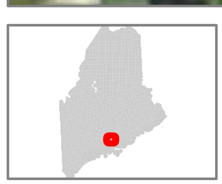
0 37.5 75 150
Feet

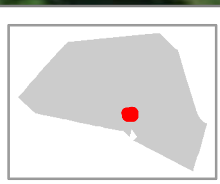
1 inch = 75 feet

Date: 1/29/2021

inter·fluve

Document Path: \\KISMET\BostonShare\Project Files - Active\Megunticook Feasibility_ME\GIS\Megunticook_Breach_Results.mxd





N

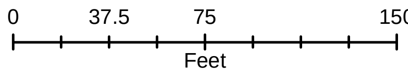
1-Year Event, Failure of Knox Dam

Impact of the Dam Breach

Inundation Area

Megunticook River
Breach Analysis Model Results
Page 2 of 2

Figure 11



1 inch = 75 feet

Date: 1/29/2021

inter·fluve

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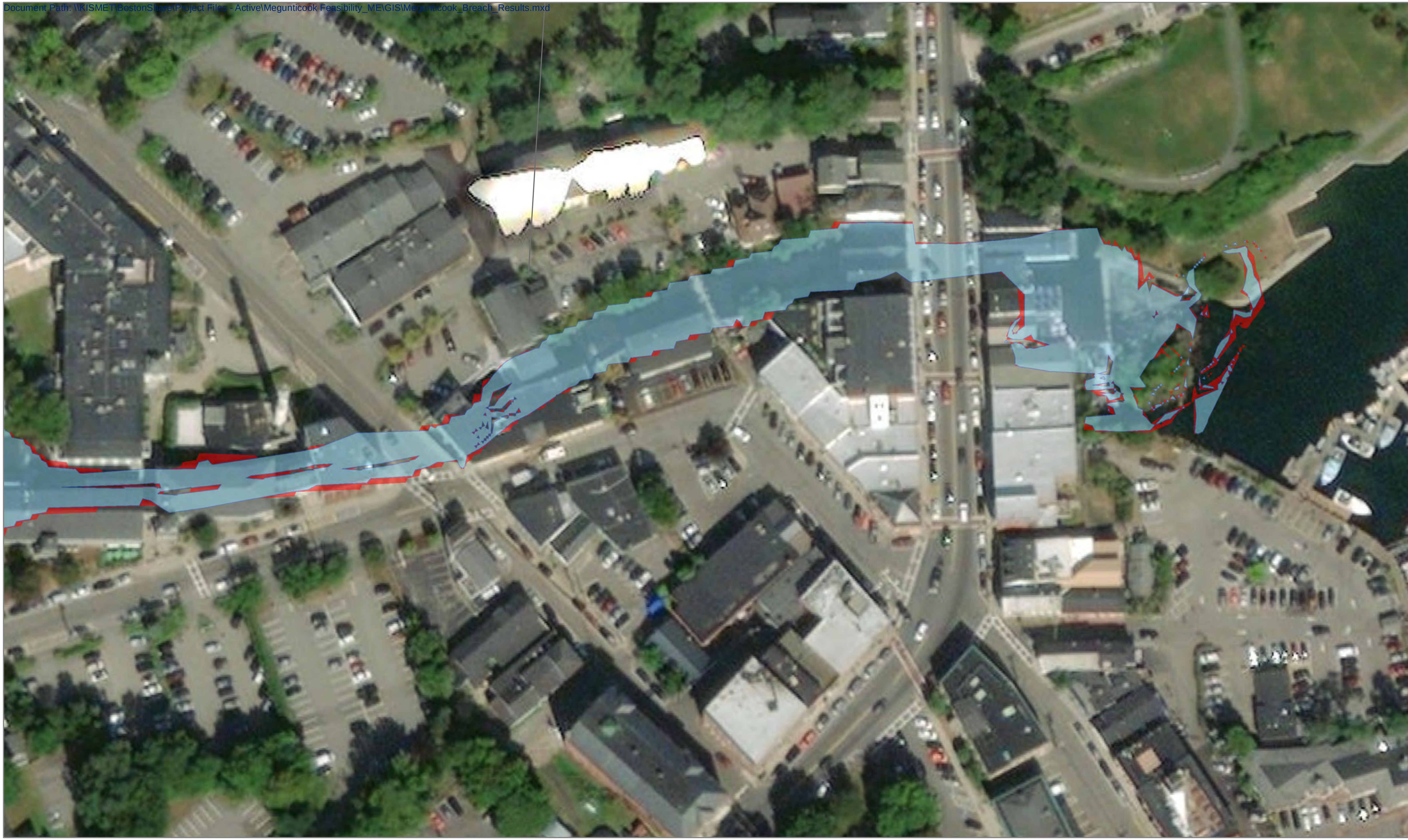

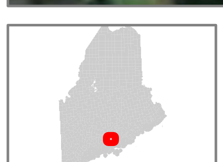

1-Year Event, Failure of Knowlton Street and Knox Mills Dams

Non-Breach Inundation Area

Incremental Impact of Dam Failure

Megunticook River
Breach Analysis Model Results
Page 1 of 2

Figure 12

Date: 1/29/2021

inter·fluve

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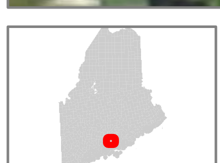

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1-Year Event, Failure of Knowlton Street and Knox Mills Dams

Non-Breach Inundation Area

Incremental Impact of Dam Failure

Megunticook River
Breach Analysis Model Results
Page 2 of 2

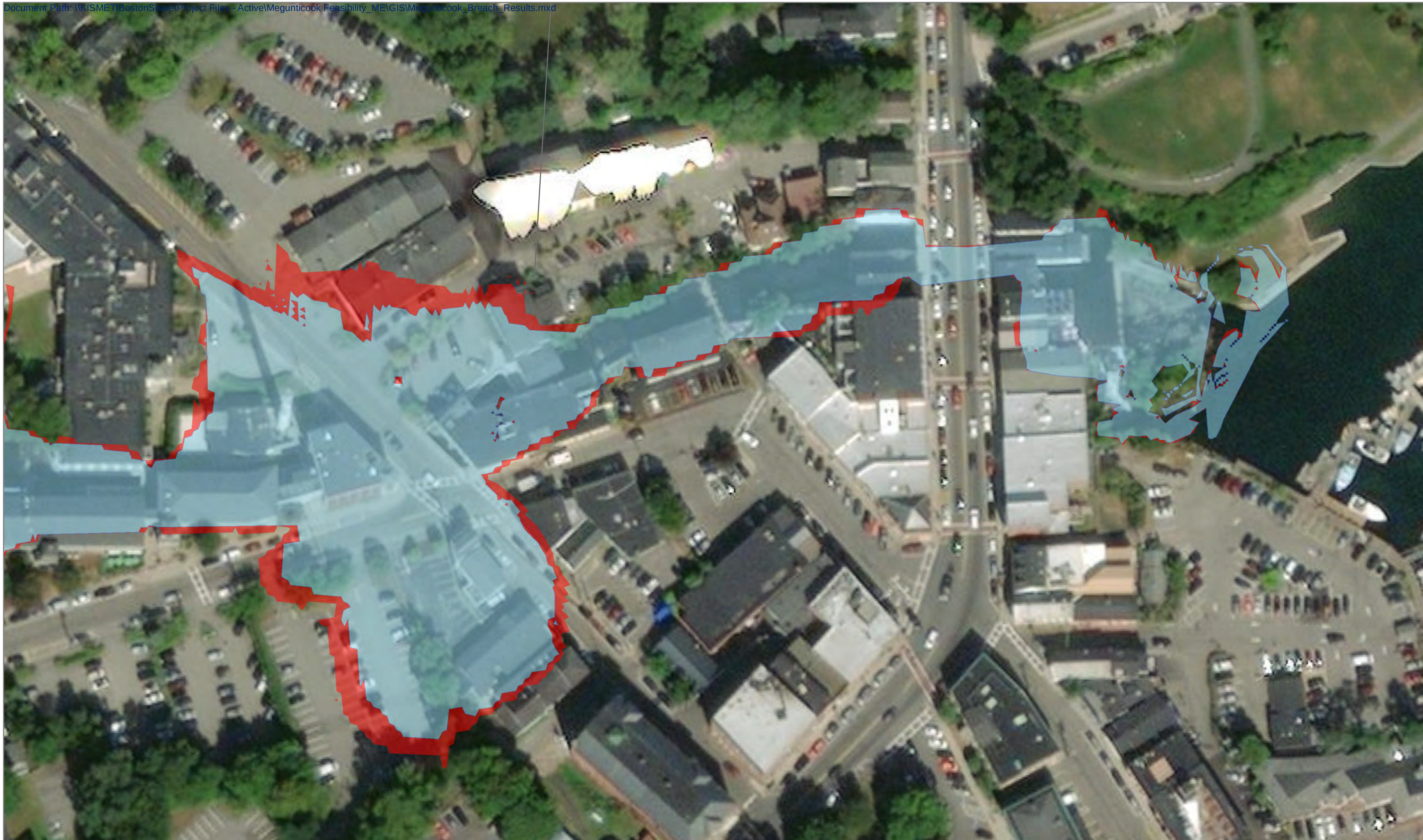
Figure 12

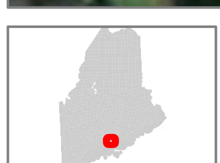
Date: 1/29/2021

0 37.5 75 150
Feet

1 inch = 75 feet

inter·fluve





N

100-Year Event, Failure of Knowlton Dam

- Inundation Area
- Impact of the Dam Breach

Megunticook River
Breach Analysis Model Results
Page 1 of 2

Figure 13

0 37.5 75 150
Feet

1 inch = 75 feet

Date: 1/29/2021

inter·fluve

100-Year Event, Failure of Knowlton Dam

Inundation Area

Impact of the Dam Breach

Megunticook River
Breach Analysis Model Results
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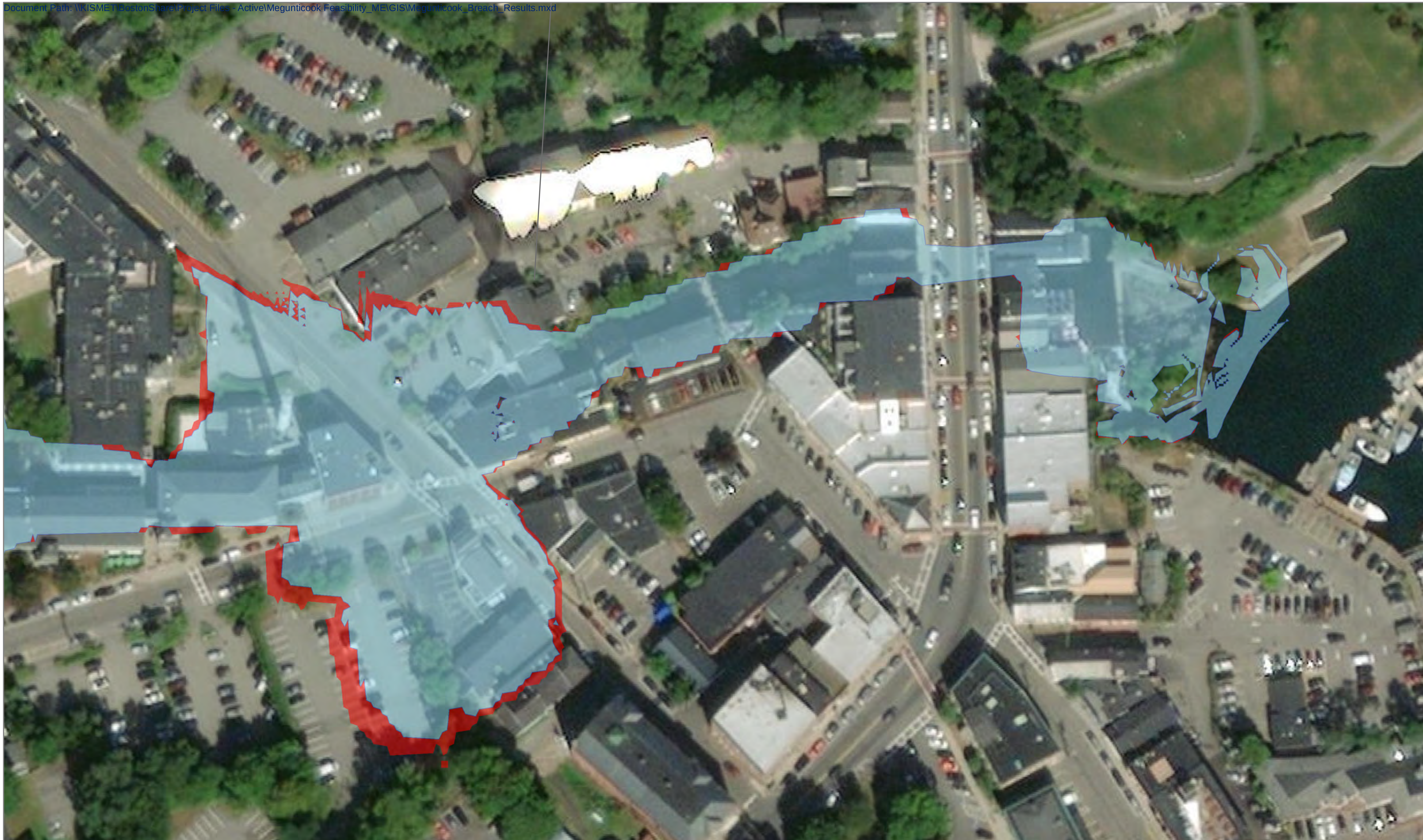
Figure 13

Date: 1/29/2021

0 37.5 75 150
Feet
1 inch = 75 feet

N

inter·fluve



N

100-Year Event, Failure of Knox Dam

Inundation Area

Impact of the Dam Breach

Megunticook River
Breach Analysis Model Results
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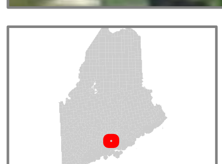
Figure 14

0 37.5 75 150
Feet

1 inch = 75 feet

Date: 1/29/2021

inter·fluve



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100-Year Event, Failure of Knox Dam

Inundation Area

Impact of the Dam Breach

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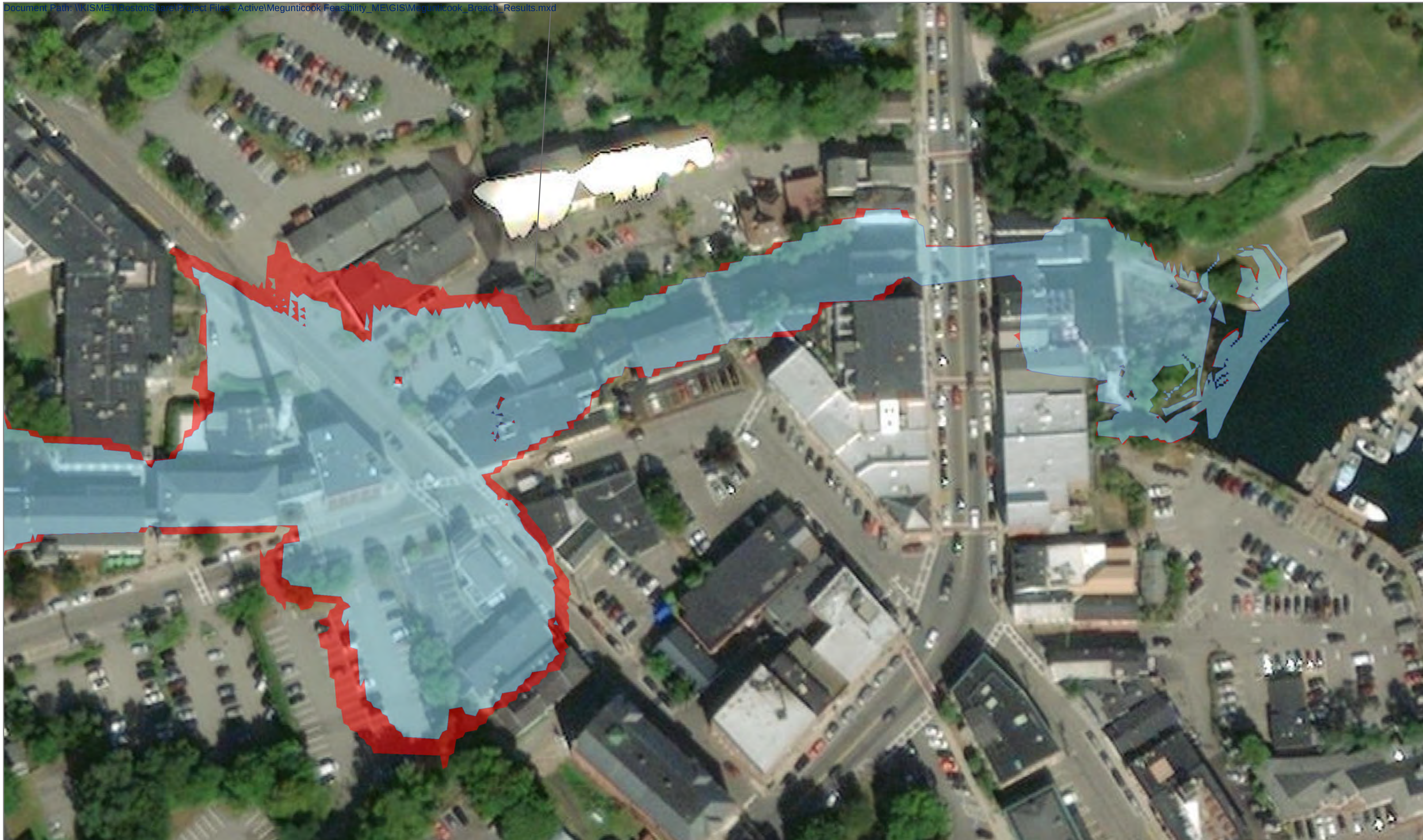
Figure 14

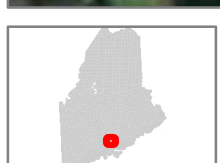
0 37.5 75 150
Feet

1 inch = 75 feet

Date: 1/29/2021

inter·fluve





N

100-Year Event, Failure of Knowlton Street and Knox Mills Dams

- Incremental Impact of Dam Failure
- Non-Breach Inundation Area

Megunticook River
Breach Analysis Model Results
Page 1 of 2

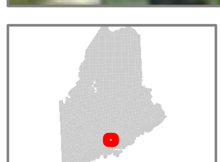
Figure 15

0 37.5 75 150
Feet

1 inch = 75 feet

Date: 1/29/2021

inter·fluve



N

100-Year Event, Failure of Knowlton Street and Knox Mills Dams

Incremental Impact of Dam Failure

Non-Breach Inundation Area

Megunticook River
Breach Analysis Model Results
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Figure 15

0 37.5 75 150
Feet

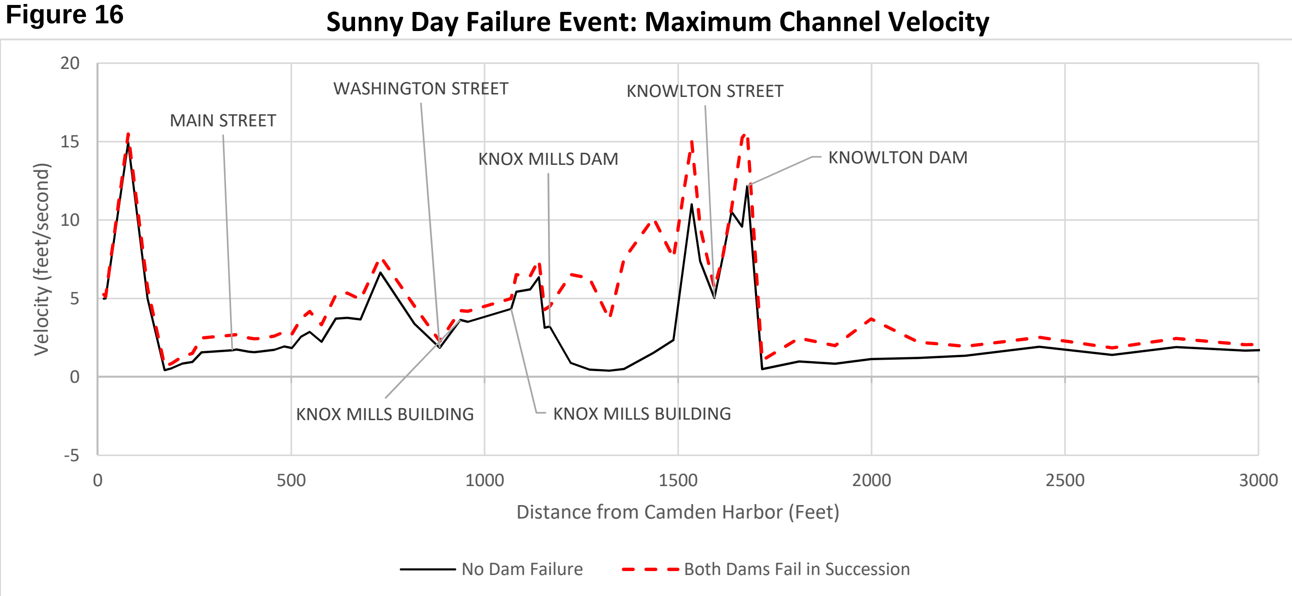
1 inch = 75 feet

Date: 1/29/2021

inter·fluve

Figure 16

a



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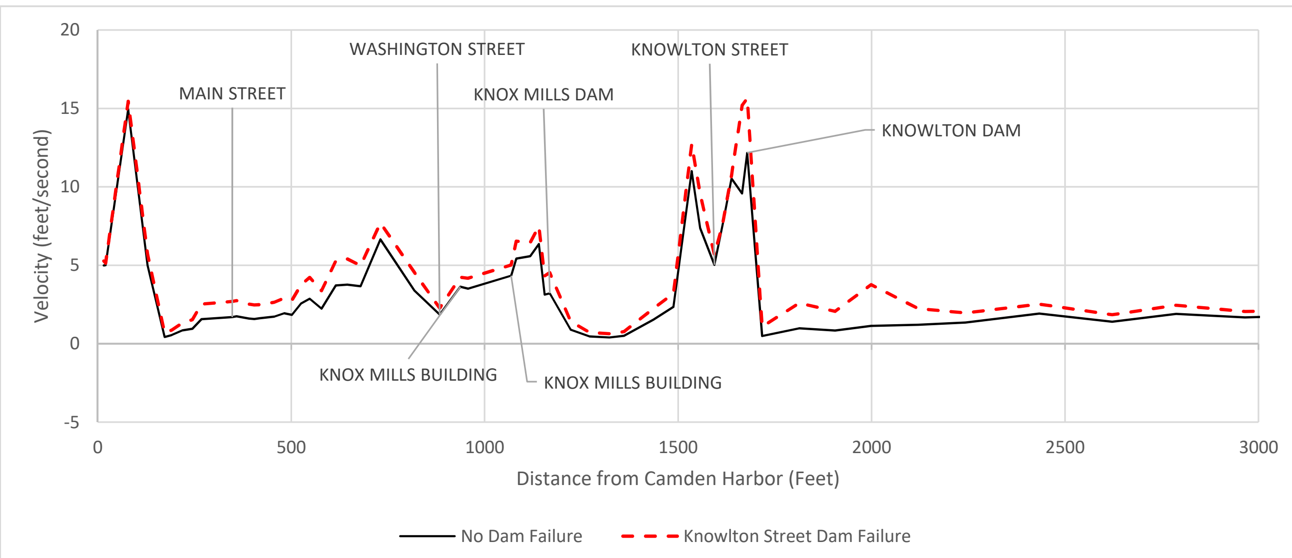

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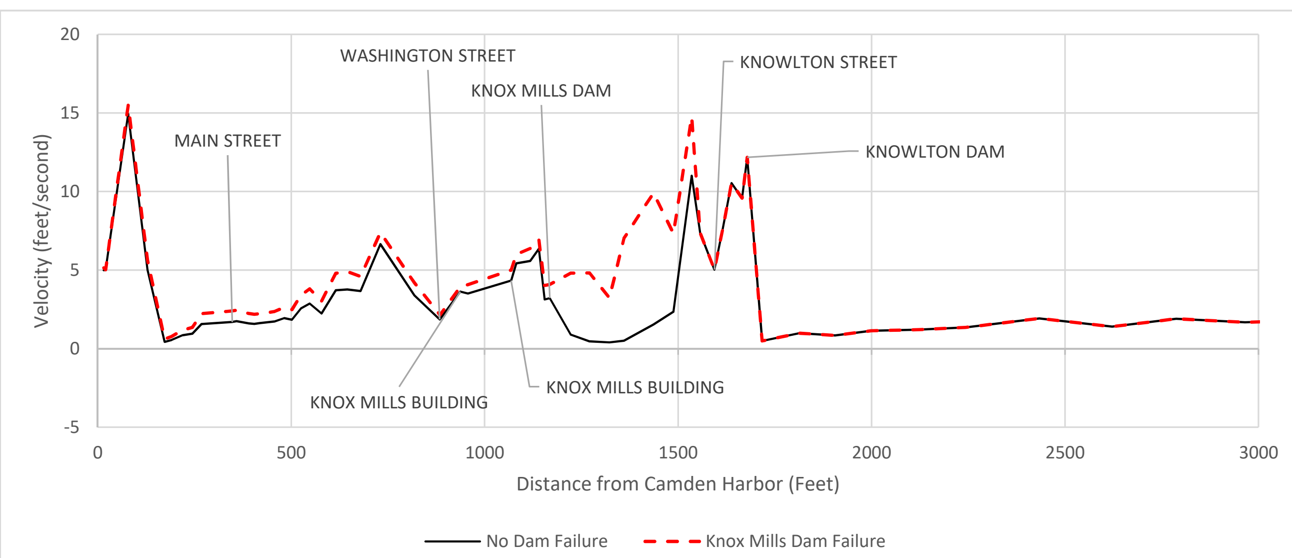
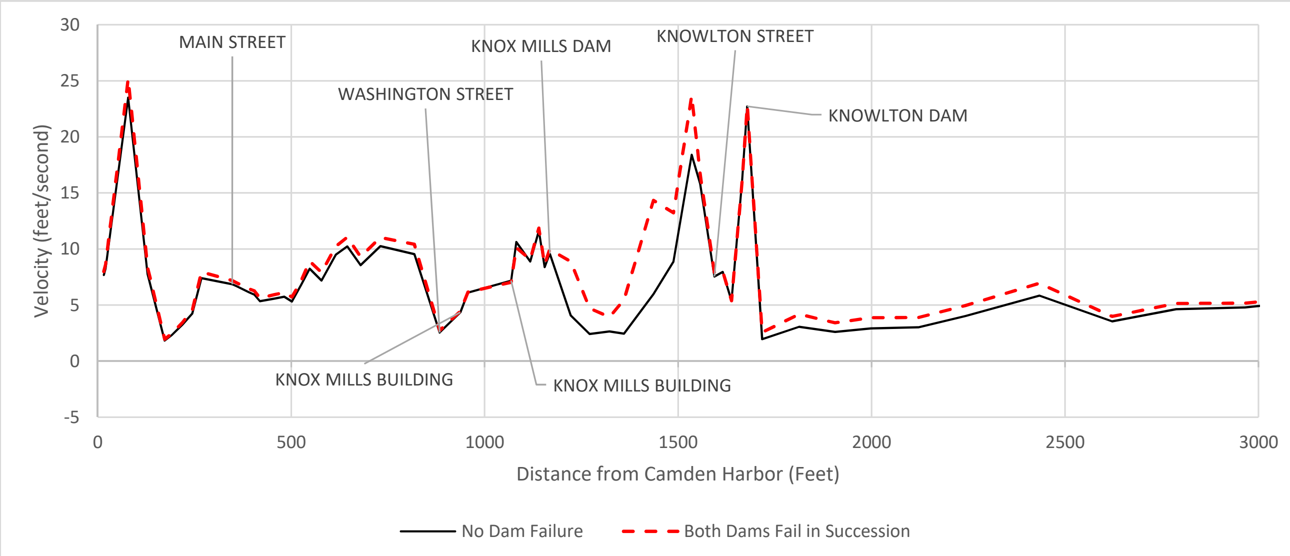


Figure 17

High-Flow Failure Event: Maximum Channel Velocity

a



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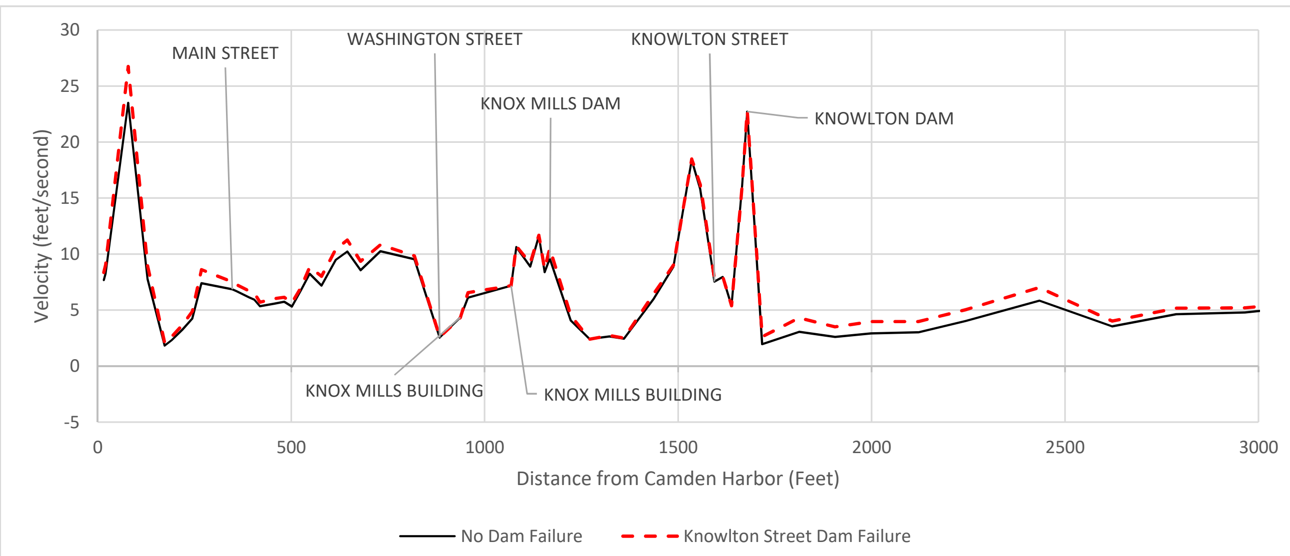

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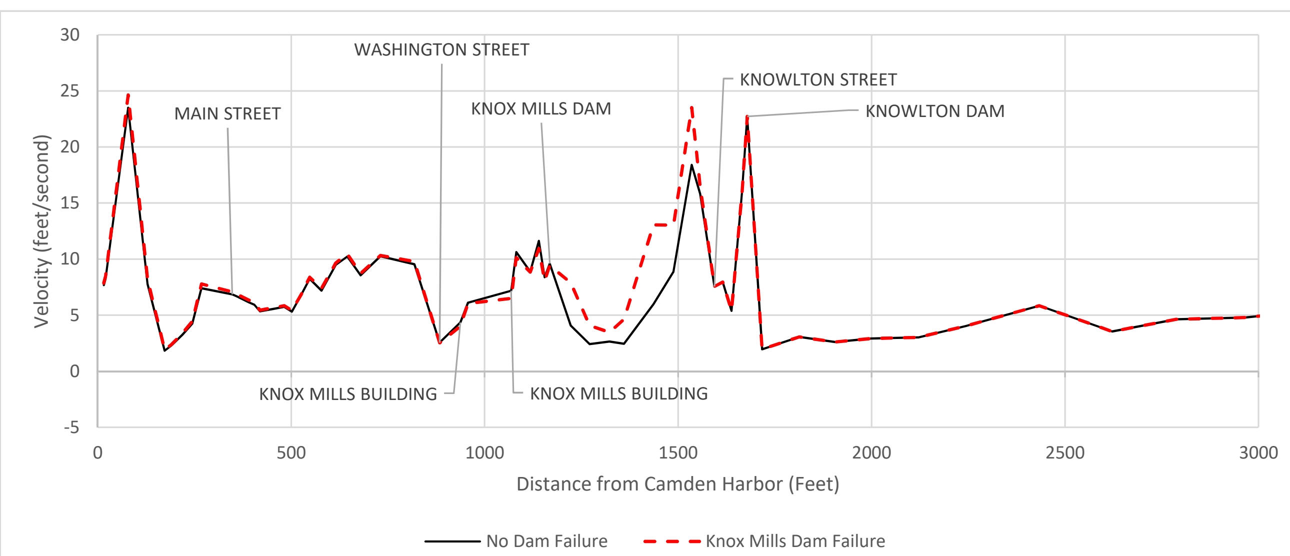

Appendix D - Dam Removal Renderings

Figure* 104*. Drone image of the Knox Mill dam site during draw down, July 2020.

Figure 105. Plan rendering of the long-term conditions of the Knox Mill dam site following dam removal.

Figure 106***. Ground-level composite image of the Knox Mill dam site during draw down, July 2020.***

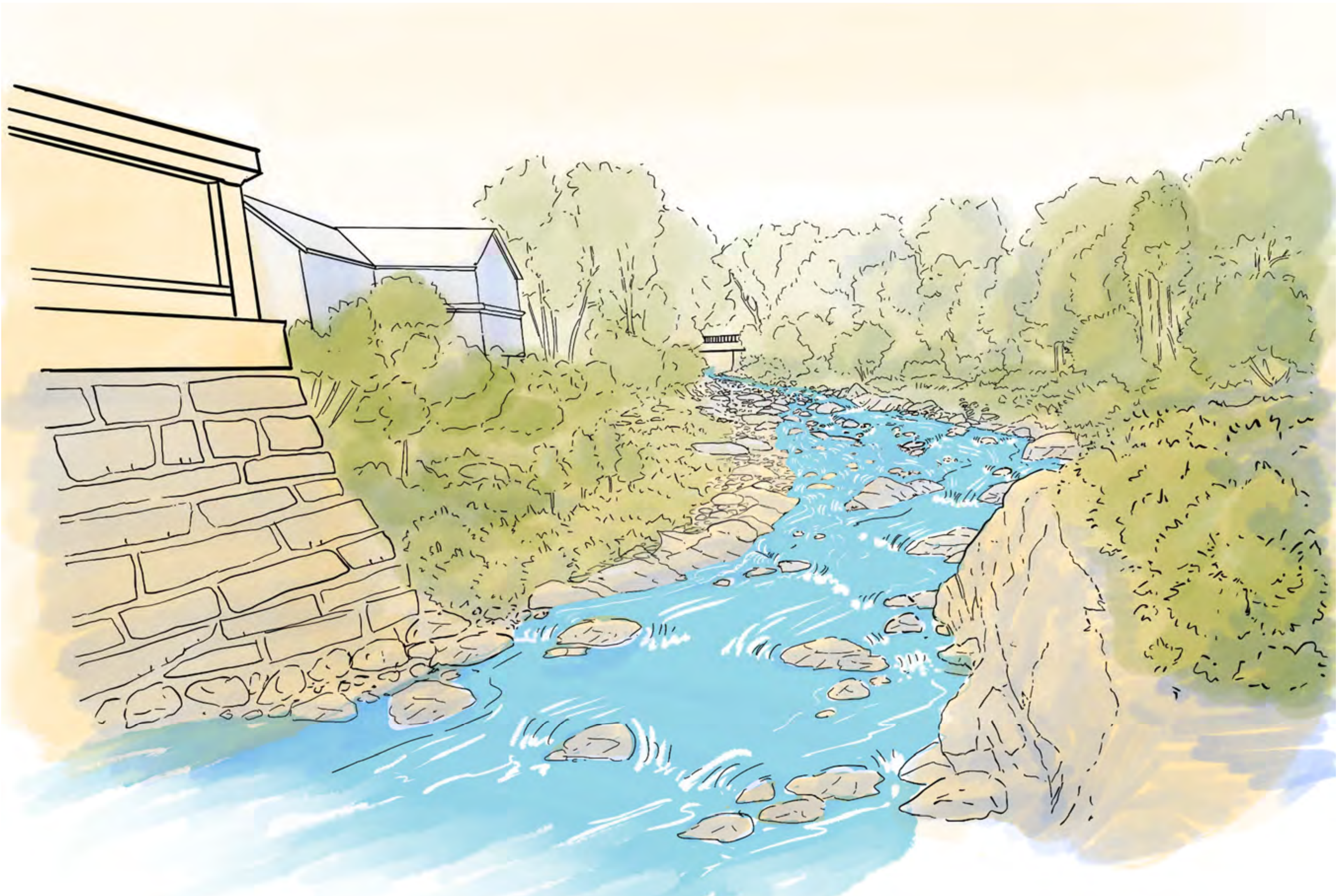

Figure** 107. **Ground-level rendering of the long- term conditions of the Knox Mill dam site following dam removal, looking upstream from the dam location.

Figure* 108*. Drone image of the Knowlton Street dam site during draw down, July 2020.

***Figure* 109. Plan rendering of the long-term conditions at the Knowlton Street dam site following dam removal.**

Figure* 110*. Ground-level composite image of the Knowlton Street dam site, March 2021.

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Figure* 111*. Ground-level rendering of the long-term conditions at the Knowlton Street dam site following dam removal, looking upstream from the dam location.

Appendix E - Detailed Cost Tables

Table BSF-1. Conceptual Cost Analysis for *__Brewster Shirt Factory Building, Remove Water Wheel and Flood Conveyance/Flood Control Improvements__*

Initial Project Costs						
Construction Cost Items						
No.	**Item**	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**	**Notes**
Direct Costs						
1	Mobilization	1	LS	$ 32,300	$ 32,300	15% of other items; includes clearing and grubbing; traffic control as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 10,000	$ 10,000	Misc Control Activities
Site Work						
3	Remove Water Wheel	1	LS	$ 10,000	$ 10,000	Estimated, Placeholder
4	Remove Concrete Weirs and Unused Footings	1	LS	$ 35,000	$ 35,000	Estimated, Needs Design to Refine
5	Building Foundation Upgrades	1	LS	$ 50,000	$ 50,000	Estimated, Needs Design to Refine
6	Flood Curb and Parking Lot Upgrades	1	LS	$ 100,000	$ 100,000	Estimated, Needs Design to Refine
Site Landscape & Restoration						
7	Repair/Upgrade Deck and Stairs	1	LS	$ 10,000	$ 10,000	Replace/upgrade deck supports/area that is braced on water wheel foundation
			Construction Subtotal		$ 247,300	
			Contingency (30%)		$ 74,200	
			Project Contruction Total		**$ 321,500**	

Initial Project Delivery Costs			
Item	**Estimated % of Construction Cost**	**Total Cost**	**Notes**
Project Management	2.5%	$8,000	
Permitting	5.0%	$16,100	
Engineering Design	20%	$64,300	
Construction Contract Administration	2.5%	$8,000	
Construction Observation	5.0%	$16,100	
Initial Project Delivery Costs Total	**35%**	**$112,500**	
Total Initial Project Costs		**$434,000**	

Lifespan Costs - 50-year planning horizon					
Item	**Event Cost (2021 dollars)**	**Intervals**	**Total Cost (2021 dollars)**	**Total Aggregated Cost (Escalated for 3% Inflation over 50 years)**	**Total Capitalized Cost (2021 Investment to Finance Total Aggregated Cost, Assumes Interest Exceeds Inflation by 2%)**
Annual Operation and Maintenance Estimated Cost (Every Year, On Average)	$1,000	50	$50,000	$112,800	$31,800
Repair and Rehabilitation Estimated Cost (Every 10 Years)	$10,000	5	$50,000	$132,200	$29,100
Total Lifespan Costs			**$100,000**	**$245,000**	**$60,900**

Table KM-1. Conceptual Cost Analysis for *Knox Mills Dam, Dam Removal Option*

Initial Project Costs						
Construction Cost Items						
No.	**Item**	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**	**Notes**
Direct Costs						
1	Mobilization	1	LS	$ 76,000	$ 76,000	20% of other items; includes clearing and grubbing; traffic control as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 40,000	$ 40,000	Misc Control Activities
Site Work						
3	Dam Removal	1	LS	$ 75,000	$ 75,000	Removal of Dam to River Bed/Bedrock
4	Building Retrofits	1	LS	$ 50,000	$ 50,000	Foundation Repair
5	Sediment Excavation	200	CY	$ 100	$ 20,000	Excavate Sediment From Impoundment
6	Channel Work DS/at Dam	100	LF	$ 500	$ 50,000	Ledge Shaping/Tailwater Riffle for Ledge Drop
7	Restore Passage at US Legacy Dam	1	LS	$ 30,000	$ 30,000	Shape Existing Boulders, Minor Supplements
8	Fencing, Signage, and Appurtenances	1	LS	$ 40,000	$ 40,000	Estimated, Needs Advanced Design to Optimize
Site Landscape & Restoration						
9	Site Enhancement	1	LS	$ 75,000	$ 75,000	Invasives Control, Planting, Pedestrian Access, Site Amendments
			Construction Subtotal		$ 456,000	
			Contingency (30%)		$ 136,800	
			Project Contruction Total		**$ 592,800**	

Initial Project Delivery Costs			
Item	**Estimated % of Construction Cost**	**Total Cost**	**Notes**
Project Management	2.5%	$14,800	
Permitting	7.5%	$44,500	
Engineering Design	15%	$88,900	
Construction Contract Administration	2.5%	$14,800	
Construction Observation	7.5%	$44,500	
Initial Project Delivery Costs Total	**35%**	**$207,500**	
Total Initial Project Costs		**$800,300**	

Lifespan Costs - 50-year planning horizon					
Item	**Event Cost (2021 dollars)**	**Intervals**	**Total Cost (2021 dollars)**	**Total Aggregated Cost (Escalated for 3% Inflation over 50 years)**	**Total Capitalized Cost (2021 Investment to Finance Total Aggregated Cost, Assumes Interest Exceeds Inflation by 2%)**
Annual Operation and Maintenance Estimated Cost (Every Year, On Average)	$2,500	50	$125,000	$282,000	$79,600
Repair and Rehabilitation Estimated Cost (Every 10 Years)	$7,500	5	$37,500	$99,200	$21,900
Total Lifespan Costs			**$162,500**	**$381,200**	**$101,500**

Table KM-2. Conceptual Cost Analysis for *Knox Mills Dam, Denil Fishway Option*

Initial Project Costs						
Construction Cost Items						
No.	**Item**	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**	**Notes**
Direct Costs						
1	Mobilization	1	LS	$ 97,600	$ 97,600	20% of other items; includes clearing and grubbing; traffic control as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 30,000	$ 30,000	Misc Control Activities
Site Work						
3	Dam Modifications	1	LS	$ 25,000	$ 25,000	Modify Spillway for Denil Entrance
4	Building Retrofits	1	LS	$ 25,000	$ 25,000	Estimated. Needs advanced design to optimize.
5	Subgrade Preparation and Demolition	1	LS	$ 30,000	$ 30,000	Misc. for installation of new fishway, including minor ledge removal
6	Denil Fishway Concrete	130	CY	$ 1,600	$ 208,000	17' lift, 4' Wide, 1:8 gradient, 5 ft deep, 3 sections plus 2 resting pools, entrance and exit channel, 200 ' total length
7	Denil Masonry Facing	1,200	SF	$ 100	$ 120,000	Fascia on visible exposed wall, 200 ft long, 6 ft tall
8	Gates, Fencing, Signage, and Appurtenances	1	LS	$ 25,000	$ 25,000	Estimated. Needs advanced design to optimize
Site Landscape & Restoration						
9	Site Enhancement	1	LS	$ 25,000	$ 25,000	Pedestrian Access, Site Amendments
				Construction Subtotal	$ 585,600	
				Contingency (30%)	$ 175,700	
				Project Contruction Total	**$ 761,300**	
Initial Project Delivery Costs						
Item				**Estimated % of Construction Cost**	**Total Cost**	**Notes**
Project Management				2.5%	$19,000	
Permitting				7.5%	$57,100	
Engineering Design				10%	$76,100	
Construction Contract Administration				2.5%	$19,000	
Construction Observation				6%	$45,700	
Initial Project Delivery Costs Total				**29%**	**$216,900**	
Total Initial Project Costs					**$978,200**	

Lifespan Costs - 50-year planning horizon					
Item	**Event Cost (2021 dollars)**	**Intervals**	**Total Cost (2021 dollars)**	**Total Aggregated Cost (Escalated for 3% Inflation over 50 years)**	**Total Capitalized Cost (2021 Investment to Finance Total Aggregated Cost, Assumes Interest Exceeds Inflation by 2%)**
Annual Operation and Maintenance Estimated Cost (Every Year, On Average)	$6,000	50	$300,000	$676,800	$190,900
Repair and Rehabilitation Estimated Cost (Every 10 Years)	$12,000	5	$60,000	$158,700	$35,000
Total Lifespan Costs			**$360,000**	**$835,500**	**$225,900**

Table KS-1a. Conceptual Cost Analysis for *Knowlton St Dam, Dam Removal Option, Moderate Sediment Removal*

Initial Project Costs						
Construction Cost Items						
No.	**Item**	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**	**Notes**
Direct Costs						
1	Mobilization	1	LS	$ 336,000	$ 336,000	15% of other items; includes clearing and grubbing; traffic control as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 60,000	$ 60,000	Misc control activities
Site Work						
3	Dam Removal	1	LS	$ 50,000	$ 50,000	Removing Dam to Existing Riverbed/Bedrock
4	Infrastructure Retrofits	1	LS	$ 100,000	$ 100,000	Removing Ped Bridge, Foundation Repair, Grading, Etc.
5	Sediment Excavation	13,000	CY	$ 75	$ 975,000	Excavate Sediment From Impoundment
6	Channel Work DS of Dam	200	LF	$ 750	$ 150,000	Ledge Shaping/Enhance channel for passage and stability DS of Dam.
7	Restore Impounded Channel	2,600	LF	$ 300	$ 780,000	Build Channel with Fabric Lifts and Riparian Habitat
8	Fencing, Signage, and Appurtenances	1	LS	$ 25,000	$ 25,000	Estimated, needs advanced design to optimize
Site Landscape & Restoration						
9	Site Enhancement	1	LS	$ 100,000	$ 100,000	Planting, Pedestrian Access, Site Amendments
				Construction Subtotal	$ 2,576,000	
				Contingency (30%)	$ 772,800	
				Project Contruction Total	**$ 3,348,800**	

Initial Project Delivery Costs			
Item	**Estimated % of Construction Cost**	**Total Cost**	**Notes**
Project Management	1%	$33,500	
Permitting	2.5%	$83,700	
Engineering Design	4%	$134,000	
Construction Contract Administration	1.3%	$43,500	
Construction Observation	2.5%	$83,700	
Initial Project Delivery Costs Total	**11%**	**$378,400**	
Total Initial Project Costs		**$3,727,200**	

Lifespan Costs - 50-year planning horizon					
Item	**Event Cost (2021 dollars)**	**Intervals**	**Total Cost (2021 dollars)**	**Total Aggregated Cost (Escalated for 3% Inflation over 50 years)**	**Total Capitalized Cost (2021 Investment to Finance Total Aggregated Cost, Assumes Interest Exceeds Inflation by 2%)**
Annual Operation and Maintenance Estimated Cost (Every Year, On Average)	$2,500	50	$125,000	$282,000	$79,600
Repair and Rehabilitation Estimated Cost (Every 10 Years)	$7,500	5	$37,500	$99,200	$21,900
Total Lifespan Costs			**$162,500**	**$381,200**	**$101,500**

Table KS-1b. Conceptual Cost Analysis for *Knowlton St Dam, Dam Removal Option, High Sediment Removal*

Initial Project Costs						
Construction Cost Items						
No.	**Item**	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**	**Notes**
Direct Costs						
1	Mobilization	1	LS	$ 499,100	$ 499,100	15% of other items; includes clearing and grubbing; traffic control as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 60,000	$ 60,000	Misc control activities
Site Work						
3	Dam Removal	1	LS	$ 50,000	$ 50,000	Removing Dam to Existing Riverbed/Bedrock
4	Infrastructure Retrofits	1	LS	$ 100,000	$ 100,000	Removing Ped Bridge, Foundation Repair, Grading, Etc.
5	Sediment Excavation	27,500	CY	$ 75	$ 2,062,500	Excavate Sediment From Impoundment
6	Channel Work DS of Dam	200	LF	$ 750	$ 150,000	Ledge Shaping/Enhance channel for passage and stability DS of Dam.
7	Restore Impounded Channel	2,600	LF	$ 300	$ 780,000	Build Channel with Fabric Lifts and Riparian Habitat
8	Fencing, Signage, and Appurtenances	1	LS	$ 25,000	$ 25,000	Estimated, needs advanced design to optimize
Site Landscape & Restoration						
9	Site Enhancement	1	LS	$ 100,000	$ 100,000	Planting, Pedestrian Access, Site Amendments
				Construction Subtotal	$ 3,826,600	
				Contingency (30%)	$ 1,148,000	
				Project Contruction Total	**$ 4,974,600**	

Initial Project Delivery Costs			
Item	**Estimated % of Construction Cost**	**Total Cost**	**Notes**
Project Management	1%	$49,700	
Permitting	2%	$99,500	
Engineering Design	3%	$149,200	
Construction Contract Administration	1%	$49,700	
Construction Observation	2%	$99,500	
Initial Project Delivery Costs Total	**9%**	**$447,600**	
Total Initial Project Costs		**$5,422,200**	

Lifespan Costs - 50-year planning horizon					
Item	**Event Cost (2021 dollars)**	**Intervals**	**Total Cost (2021 dollars)**	**Total Aggregated Cost (Escalated for 3% Inflation over 50 years)**	**Total Capitalized Cost (2021 Investment to Finance Total Aggregated Cost, Assumes Interest Exceeds Inflation by 2%)**
Annual Operation and Maintenance Estimated Cost (Every Year, On Average)	$2,500	50	$125,000	$282,000	$79,600
Repair and Rehabilitation Estimated Cost (Every 10 Years)	$7,500	5	$37,500	$99,200	$21,900
Total Lifespan Costs			**$162,500**	**$381,200**	**$101,500**

Table KS-2. Conceptual Cost Analysis for *Knowlton St Dam, Pool & Weir Option*

No.	Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Initial Project Costs						
Construction Cost Items						
Direct Costs						
1	Mobilization	1	LS	$ 160,200	$ 160,200	20% of other items; includes clearing and grubbing; traffic control as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 40,000	$ 40,000	Misc control activities
Site Work						
3	Dam Modifications	1	LS	$ 25,000	$ 25,000	Modify Spillway/Sideslope for Pool & Weir Entrance
4	Subgrade Preparation and Demolition	1	LS	$ 60,000	$ 60,000	Misc. for installation of new fishway, Including Ledge Removal
5	Pool & Weir Fishway Concrete	180	CY	$ 2,200	$ 396,000	10' wide, 155 ft long, including 21 weirs
6	Pool & Weir Masonry Facing	1,550	SF	$ 100	$ 155,000	Interior Walls, 155 ft long, 5 ft deep.
7	Sediment Excavation	500	CY	$ 100	$ 50,000	Excavate Sediment From Impoundment
8	Gates, Fencing, Signage, and Appurtenances	1	LS	$ 25,000	$ 25,000	Estimated, needs advanced design to optimize
Site Landscape & Restoration						
9	Site Enhancement	1	LS	$ 50,000	$ 50,000	Pedestrian Access, Site Amendments
				Construction Subtotal	$ 961,200	
				Contingency (30%)	$ 288,400	
				Project Contruction Total	**$ 1,249,600**	

Item	Estimated % of Construction Cost	Total Cost	Notes
Initial Project Delivery Costs			
Project Management	2%	$25,000	
Permitting	4%	$50,000	
Engineering Design	10%	$125,000	
Construction Contract Administration	2%	$25,000	
Construction Observation	4%	$50,000	
Initial Project Delivery Costs Total	**22%**	**$275,000**	
Total Initial Project Costs		**$1,524,600**	

Item	Event Cost (2021 dollars)	Intervals	Total Cost (2021 dollars)	Total Aggregated Cost (Escalated for 3% Inflation over 50 years)	Total Capitalized Cost (2021 Investment to Finance Total Aggregated Cost, Assumes Interest Exceeds Inflation by 2%)
Lifespan Costs - 50-year planning horizon					
Annual Operation and Maintenance Estimated Cost (Every Year, On Average)	$5,000	50	$250,000	$564,000	$159,100
Repair and Rehabilitation Estimated Cost (Every 10 Years)	$10,000	5	$50,000	$132,200	$29,100
Total Lifespan Costs			**$300,000**	**$696,200**	**$188,200**

Table KS-3. Conceptual Cost Analysis for *Knowlton St Dam, Denil Fishway Option*

No.	Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Initial Project Costs						
Construction Cost Items						
Direct Costs						
1	Mobilization	1	LS	$ 115,300	$ 115,300	25% of other items; includes clearing and grubbing; Access Development, traffic control as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 30,000	$ 30,000	Misc Control Activities
Site Work						
3	Dam Modifications	1	LS	$ 25,000	$ 25,000	Modify Spillway/SideSlope for Denil Entrance
4	Subgrade Preparation and Demolition	1	LS	$ 50,000	$ 50,000	Misc. for installation of new fishway, Including notable ledge removal
5	Denil Fishway Concrete	120	CY	$ 1,600	$ 192,000	16' lift, 4' Wide, 1:8 gradient, 5 ft deep, 3 sections plus 2 resting pools, entrance and exit channel, 190' total length
6	Denil Masonry Facing	1,140	SF	$ 100	$ 114,000	Fascia on visible exposed wall, 190 ft long, 6 ft tall
7	Gates, Fencing, Signage, and Appurtenances	1	LS	$ 25,000	$ 25,000	Estimated. Needs advanced design to optimize
Site Landscape & Restoration						
8	Site Enhancement	1	LS	$ 25,000	$ 25,000	Pedestrian Access, Site Amendments
			Construction Subtotal		$ 576,300	
			Contingency (30%)		$ 172,900	
			Project Contruction Total		**$ 749,200**	

Item	Estimated % of Construction Cost	Total Cost	Notes
Initial Project Delivery Costs			
Project Management	2.5%	$18,700	
Permitting	7.5%	$56,200	
Engineering Design	12.5%	$93,700	
Construction Contract Administration	2.5%	$18,700	
Construction Observation	6%	$45,000	
Initial Project Delivery Costs Total	**31%**	**$232,300**	
Total Initial Project Costs		**$981,500**	

Item	Event Cost (2021 dollars)	Intervals	Total Cost (2021 dollars)	Total Aggregated Cost (Escalated for 3% Inflation over 50 years)	Total Capitalized Cost (2021 Investment to Finance Total Aggregated Cost, Assumes Interest Exceeds Inflation by 2%)
Lifespan Costs - 50-year planning horizon					
Annual Operation and Maintenance Estimated Cost (Every Year, On Average)	$6,000	50	$300,000	$676,800	$190,900
Repair and Rehabilitation Estimated Cost (Every 10 Years)	$12,000	5	$60,000	$158,700	$35,000
Total Lifespan Costs			**$360,000**	**$835,500**	**$225,900**

Table PM-1. Conceptual Cost Analysis for *Powder Mill Dam Ruins, Dam Removal, Channel Restoration Option*

Initial Project Costs						
Construction Cost Items						
No.	**Item**	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**	**Notes**
Direct Costs						
1	Mobilization	1	LS	$ 33,000	$ 33,000	20% of other items; includes clearing and grubbing; traffic control as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 30,000	$ 30,000	Misc control activities
3	Develop Site Access	1	LS	$ 25,000	$ 25,000	Misc control activities
Site Work						
3	Dam Removal	1	LS	$ 35,000	$ 35,000	Removing Masonry Dam Remnants to Riverbed/Bedrock, difficult site access
4	Restore Abutments/Slopes	1	LS	$ 30,000	$ 30,000	Removing Abutments, Other Existing Features
5	Sediment Excavation	100	CY	$ 100	$ 10,000	Excavate Sediment From Impoundment
6	Channel Work DS/at Dam	50	LF	$ 500	$ 25,000	Modify Ledge / Tailwater riffle for ledge drop
7	Fencing, Signage, and Appurtenances	1	LS	$ 20,000	$ 20,000	Estimated, needs advanced design to optimize
Site Landscape & Restoration						
8	Site Enhancement	1	LS	$ 20,000	$ 20,000	Pedestrian Access, Planting, Additional Site Amendments
			Construction Subtotal		$ 228,000	
			Contingency (30%)		$ 68,400	
			Project Contruction Total		**$ 296,400**	

Initial Project Delivery Costs			
Item	**Estimated % of Construction Cost**	**Total Cost**	**Notes**
Project Management	4%	$11,900	
Permitting	10%	$29,600	
Engineering Design	20%	$59,300	
Construction Contract Administration	4%	$11,900	
Construction Observation	12%	$35,600	
Initial Project Delivery Costs Total	**50%**	**$148,300**	
Total Initial Project Costs		**$444,700**	

Lifespan Costs - 50-year planning horizon					
Item	**Event Cost (2021 dollars)**	**Intervals**	**Total Cost (2021 dollars)**	**Total Aggregated Cost (Escalated for 3% Inflation over 50 years)**	**Total Capitalized Cost (2021 Investment to Finance Total Aggregated Cost, Assumes Interest Exceeds Inflation by 2%)**
Annual Operation and Maintenance Estimated Cost (Every Year, On Average)	$0	50	$0	$0	$0
Repair and Rehabilitation Estimated Cost (Every 10 Years)	$5,000	5	$25,000	$66,100	$14,600
Total Lifespan Costs			**$25,000**	**$66,100**	**$14,600**

Table SB-1. Conceptual Cost Analysis for *Seabright Dam, Nature-Like Fishway Option*

No.	Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Initial Project Costs						
Construction Cost Items						
Direct Costs						
1	Mobilization	1	LS	$ 146,000	$ 146,000	20% of other items; includes clearing and grubbing; traffic control as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 30,000	$ 30,000	Misc control activities
Site Work						
3	Dam Modifications	1	LS	$ 20,000	$ 20,000	Modify embankment for Nature-Like Fishway Entrance
4	Infrastructure Retrofits	1	LS	$ 150,000	$ 150,000	Access Bridge, Other Infrastructure Needs
5	Misc Grading/Excavation	1,500	CY	$ 30	$ 45,000	Channel grading, Slopework, etc.
6	Channel Construction	390	LF	$ 1,000	$ 390,000	387 ft long, and width to be determined
7	Fencing, Signage, and Appurtenances	1	LS	$ 20,000	$ 20,000	Estimated, needs advanced design to optimize
Site Landscape & Restoration						
8	Site Enhancement	1	LS	$ 75,000	$ 75,000	Planting, Pedestrian Access, Additional Site Amendments
				Construction Subtotal	$ 876,000	
				Contingency (30%)	$ 262,800	
				Project Contruction Total	**$ 1,138,800**	

Initial Project Delivery Costs

Item	Estimated % of Construction Cost	Total Cost	Notes
Project Management	2%	$22,800	
Permitting	7.5%	$85,400	
Engineering Design	12.5%	$142,400	
Construction Contract Administration	2%	$22,800	
Construction Observation	6%	$68,300	
Initial Project Delivery Costs Total	**30%**	**$341,700**	
Total Initial Project Costs		**$1,480,500**	

Lifespan Costs - 50-year planning horizon

Item	Event Cost (2021 dollars)	Intervals	Total Cost (2021 dollars)	Total Aggregated Cost (Escalated for 3% Inflation over 50 years)	Total Capitalized Cost (2021 Investment to Finance Total Aggregated Cost, Assumes Interest Exceeds Inflation by 2%)
Annual Operation and Maintenance Estimated Cost (Every Year, On Average)	$4,000	50	$200,000	$451,200	$127,300
Repair and Rehabilitation Estimated Cost (Every 10 Years)	$10,000	5	$50,000	$132,200	$29,100
Total Lifespan Costs			**$250,000**	**$583,400**	**$156,400**

Table SB-2. Conceptual Cost Analysis for *Seabright Dam, Pool & Weir Option*

Initial Project Costs						
Construction Cost Items						
No.	**Item**	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**	**Notes**
Direct Costs						
1	Mobilization	1	LS	$ 176,600	$ 176,600	20% of other items; includes clearing and grubbing; traffic control as necessary
2	Access	1	LS	$ 75,000	$ 75,000	Acces to the project site
3	Erosion, Pollution & Water Control	1	LS	$ 40,000	$ 40,000	Misc control activities
Site Work						
4	Dam Modifications	1	LS	$ 100,000	$ 100,000	Modify dam spillway for pool and weir, does not include full cost of concrete spillway channel repair whose maintenance is already required.
5	Subgrade Preparation and Demolition	1	LS	$ 30,000	$ 30,000	Misc. for installation of new fishway
6	Pool & Weir Fishway Concrete	190	CY	$ 2,200	$ 418,000	10' wide, 165 ft long, including 25 weirs
7	Pool & Weir Masonry Facing	1,650	SF	$ 100	$ 165,000	Walls, 165 ft long, 5 ft deep.
8	Gates, Fencing, Signage, and Appurtenances	1	LS	$ 25,000	$ 25,000	Estimated, needs advanced design to optimize
Site Landscape & Restoration						
9	Site Enhancement	1	LS	$ 30,000	$ 30,000	Planting, Pedestrian Access, Additional Site Features
			Construction Subtotal		$ 1,059,600	
			Contingency (30%)		$ 317,900	
			Project Contruction Total		**$ 1,377,500**	
Initial Project Delivery Costs						
Item			**Estimated % of Construction Cost**		**Total Cost**	**Notes**
Project Management				2.0%	$27,600	
Permitting				6.0%	$82,700	
Engineering Design				12.5%	$172,200	
Construction Contract Administration				2.0%	$27,600	
Construction Observation				6.0%	$82,700	
Initial Project Delivery Costs Total				**29%**	**$392,800**	
Total Initial Project Costs					**$1,770,300**	

Lifespan Costs - 50-year planning horizon					
Item	**Event Cost (2021 dollars)**	**Intervals**	**Total Cost (2021 dollars)**	**Total Aggregated Cost (Escalated for 3% Inflation over 50 years)**	**Total Capitalized Cost (2021 Investment to Finance Total Aggregated Cost, Assumes Interest Exceeds Inflation by 2%)**
Annual Operation and Maintenance Estimated Cost (Every Year, On Average)	$8,000	50	$400,000	$902,400	$254,600
Repair and Rehabilitation Estimated Cost (Every 10 Years)	$15,000	5	$75,000	$198,300	$43,700
Total Lifespan Costs			**$475,000**	**$1,100,700**	**$298,300**

Table SB-3. Conceptual Cost Analysis for *Seabright Dam, Denil Fishway Option*

Initial Project Costs						
Construction Cost Items						
No.	**Item**	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**	**Notes**
Direct Costs						
1	Mobilization	1	LS	$ 115,200	$ 115,200	20% of other items; includes clearing and grubbing; traffic control as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 30,000	$ 30,000	Misc control activities
Site Work						
3	Dam Modifications	1	LS	$ 15,000	$ 15,000	Modify embankment for Denil Entrance
4	Infrastructure Retrofits	1	LS	$ 100,000	$ 100,000	Maintenance Access Bridge, Other Infrastructure Needs
5	Subgrade Preparation and Demolition	1	LS	$ 25,000	$ 25,000	Misc. for installation of new fishway
6	Denil Fishway Concrete	120	CY	$ 1,600	$ 192,000	16' lift, 4' Wide, 1:8 gradient, 5 ft deep, 3 sections plus 2 resting pools, entrance and exit channel, 190' total length
7	Denil Masonry Facing	1,140	SF	$ 100	$ 114,000	Fascia on visible exposed wall portions, estimated, 190 ft long, 6 ft tall averages
8	Gates, Fencing, Signage, and Appurtenances	1	LS	$ 25,000	$ 25,000	Estimated. Needs advanced design to optimize
Site Landscape & Restoration						
9	Site Enhancement	1	LS	$ 75,000	$ 75,000	Estimated, planting, Pedestrian and Maintenance Access, Additional Site Amendments
			Construction Subtotal		$ 691,200	
			Contingency (30%)		$ 207,400	
			Project Contruction Total		**$ 898,600**	
Initial Project Delivery Costs						
Item			**Estimated % of Construction Cost**		**Total Cost**	**Notes**
Project Management				2%	$18,000	
Permitting				7.5%	$67,400	
Engineering Design				15%	$134,800	
Construction Contract Administration				2%	$18,000	
Construction Observation				7.5%	$67,400	
Initial Project Delivery Costs Total				**34%**	**$305,600**	
Total Initial Project Costs					**$1,204,200**	

Lifespan Costs - 50-year planning horizon					
Item	**Event Cost (2021 dollars)**	**Intervals**	**Total Cost (2021 dollars)**	**Total Aggregated Cost (Escalated for 3% Inflation over 50 years)**	**Total Capitalized Cost (2021 Investment to Finance Total Aggregated Cost, Assumes Interest Exceeds Inflation by 2%)**
Annual Operation and Maintenance Estimated Cost (Every Year, On Average)	$9,000	50	$450,000	$1,015,200	$286,400
Repair and Rehabilitation Estimated Cost (Every 10 Years)	$15,000	5	$75,000	$198,300	$43,700
Total Lifespan Costs			**$525,000**	**$1,213,500**	**$330,100**

Table EW-1. Conceptual Cost Analysis for *East & West Dams, Hybrid Fishway Option*

Initial Project Costs						
Construction Cost Items						
No.	**Item**	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**	**Notes**
Direct Costs						
1	Mobilization	1	LS	$ 215,800	$ 215,800	20% of other items; includes clearing and grubbing; traffic control as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 50,000	$ 50,000	Misc control activities
Site Work						
3	Dam Modifications	1	LS	$ 250,000	$ 250,000	Major Upgrades / replacement of existing structure
4	Infrastructure Retrofits	1	LS	$ 20,000	$ 20,000	Additional Modifications to Nearby Infrastructure
5	Subgrade Preparation and Demolition	1	LS	$ 50,000	$ 50,000	Misc. for dam retrofit and installation of new fishway
6	Misc Grading/Excavation	500	CY	$ 60	$ 30,000	Channel grading, Slopework, etc.
7	Channel Construction	100	LF	$ 1,000	$ 100,000	100 ft long, and width to be determined
8	Pool & Weir Fishway Concrete	170	CY	$ 2,200	$ 374,000	10' wide, 150 ft long, including 20 weirs
9	Pool & Weir Masonry Facing	1,500	SF	$ 100	$ 150,000	Walls, 150 ft long, 5 ft deep.
10	Gates, Fencing, Signage, and Appurtenances	1	LS	$ 25,000	$ 25,000	Estimated, needs advanced design to optimize
Site Landscape & Restoration						
11	Site Enhancement	1	LS	$ 30,000	$ 30,000	Pedestrian Access, Planting, Site Amendments
			Construction Subtotal		$ 1,294,800	
			Contingency (30%)		$ 388,400	
			Project Contruction Total		**$ 1,683,200**	

Initial Project Delivery Costs			
Item	**Estimated % of Construction Cost**	**Total Cost**	**Notes**
Project Management	2%	$33,700	
Permitting	5%	$84,200	
Engineering Design	12.5%	$210,400	
Construction Contract Administration	2%	$33,700	
Construction Observation	5%	$84,200	
Initial Project Delivery Costs Total	**27%**	**$446,200**	
Total Initial Project Costs		**$2,129,400**	

Lifespan Costs - 50-year planning horizon					
Item	**Event Cost (2021 dollars)**	**Intervals**	**Total Cost (2021 dollars)**	**Total Aggregated Cost (Escalated for 3% Inflation over 50 years)**	**Total Capitalized Cost (2021 Investment to Finance Total Aggregated Cost, Assumes Interest Exceeds Inflation by 2%)**
Annual Operation and Maintenance Estimated Cost (Every Year, On Average)	$8,000	50	$400,000	$902,400	$254,600
Repair and Rehabilitation Estimated Cost (Every 10 Years)	$15,000	5	$75,000	$198,300	$43,700
Total Lifespan Costs			**$475,000**	**$1,100,700**	**$298,300**

Table EW-2. Conceptual Cost Analysis for *East & West Dams, Pool & Weir Option*

Initial Project Costs						
Construction Cost Items						
No.	**Item**	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**	**Notes**
Direct Costs						
1	Mobilization	1	LS	$ 161,000	$ 161,000	20% of other items; includes clearing and grubbing; traffic control as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 40,000	$ 40,000	Misc control activities
Site Work						
3	Dam Modifications	1	LS	$ 30,000	$ 30,000	Modify Spillway for Pool and Weir Entrance
4	Subgrade Preparation and Demolition	1	LS	$ 50,000	$ 50,000	Misc. for installation of new fishway, including notable ledge
5	Pool & Weir Fishway Concrete	200	CY	$ 2,200	$ 440,000	10' wide, 180 ft long, including 20 weirs
6	Pool & Weir Masonry Facing	1,800	SF	$ 100	$ 180,000	Walls, 180 ft long, 5 ft deep.
8	Gates, Fencing, Signage, and Appurtenances	1	LS	$ 25,000	$ 25,000	Estimated, needs advanced design to optimize
Site Landscape & Restoration						
9	Site Enhancement	1	LS	$ 40,000	$ 40,000	Pedestrian Access, Planting, Site Amendments
			Construction Subtotal		$ 966,000	
			Contingency (30%)		$ 289,800	
			Project Contruction Total		**$ 1,255,800**	

Initial Project Delivery Costs			
Item	**Estimated % of Construction Cost**	**Total Cost**	**Notes**
Project Management	2%	$25,100	
Permitting	6%	$75,300	
Engineering Design	12.5%	$157,000	
Construction Contract Administration	2%	$25,100	
Construction Observation	6%	$75,300	
Initial Project Delivery Costs Total	**29%**	**$357,800**	
Total Initial Project Costs		**$1,613,600**	

Lifespan Costs - 50-year planning horizon					
Item	**Event Cost (2021 dollars)**	**Intervals**	**Total Cost (2021 dollars)**	**Total Aggregated Cost (Escalated for 3% Inflation over 50 years)**	**Total Capitalized Cost (2021 Investment to Finance Total Aggregated Cost, Assumes Interest Exceeds Inflation by 2%)**
Annual Operation and Maintenance Estimated Cost (Every Year, On Average)	$8,000	50	$400,000	$902,400	$254,600
Repair and Rehabilitation Estimated Cost (Every 10 Years)	$15,000	5	$75,000	$198,300	$43,700
Total Lifespan Costs			**$475,000**	**$1,100,700**	**$298,300**

Table EW-3. Conceptual Cost Analysis for *East & West Dams, Denil Fishway Option*

Initial Project Costs						
Construction Cost Items						
No.	**Item**	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**	**Notes**
Direct Costs						
1	Mobilization	1	LS	$ 90,600	$ 90,600	20% of other items; includes clearing and grubbing; traffic control as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 30,000	$ 30,000	Misc control activities
Site Work						
3	Dam Modifications	1	LS	$ 20,000	$ 20,000	Modify Spillway for Denil Entrance
4	Subgrade Preparation and Demolition	1	LS	$ 60,000	$ 60,000	Misc. for installation of new fishway, including notable ledge
5	Denil Fishway Concrete	110	CY	$ 1,600	$ 176,000	13' lift, 4' Wide, 1:8 gradient, 5 ft deep, 3 sections plus 2 resting pools, entrance and exit channel, 170' total length
6	Denil Masonry Facing	1,020	SF	$ 100	$ 102,000	Fascia on visible exposed wall portions, estimated, 170 ft long, 6 ft tall averages
7	Gates, Fencing, Signage, and Appurtenances	1	LS	$ 25,000	$ 25,000	Estimated. Needs advanced design to optimize
Site Landscape & Restoration						
8	Site Enhancement	1	LS	$ 40,000	$ 40,000	Pedestrian Access, Planting, Site Amendments
				Construction Subtotal	$ 543,600	
				Contingency (30%)	$ 163,100	
				Project Contruction Total	**$ 706,700**	

Initial Project Delivery Costs			
Item	**Estimated % of Construction Cost**	**Total Cost**	**Notes**
Project Management	2.5%	$17,700	
Permitting	10%	$70,700	
Engineering Design	20%	$141,300	
Construction Contract Administration	2.5%	$17,700	
Construction Observation	10%	$70,700	
Initial Project Delivery Costs Total	**45%**	**$318,100**	
Total Initial Project Costs		**$1,024,800**	

Lifespan Costs - 50-year planning horizon					
Item	**Event Cost (2021 dollars)**	**Intervals**	**Total Cost (2021 dollars)**	**Total Aggregated Cost (Escalated for 3% Inflation over 50 years)**	**Total Capitalized Cost (2021 Investment to Finance Total Aggregated Cost, Assumes Interest Exceeds Inflation by 2%)**
Annual Operation and Maintenance Estimated Cost (Every Year, On Average)	$9,000	50	$450,000	$1,015,200	$286,400
Repair and Rehabilitation Estimated Cost (Every 10 Years)	$15,000	5	$75,000	$198,300	$43,700
Total Lifespan Costs			**$525,000**	**$1,213,500**	**$330,100**