Final Feasibility Study for Removal of the McLane and Goldman Dams Souhegan River Milford, NH

Volume 1 of 3: Main Report

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Town of Milford

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Acronyms

ACHP	Advisory Council of Historic Preservation
ADKE	A & D Klumb Environmental, LLC
APE	area of potential effect
AR	American Rivers
CAD	computer aided design
CAB	Cellulose Acetate Butyrate
cfs	cubic feet per second
cfsm	cubic feet per second per square mile of drainage area
CR	CR Environmental, Inc.
CRREL	Cold Regions Research and Engineering Laboratory
CY	cubic yards
DIP	ductile iron pipe
DO	dissolved oxygen
DPW	Milford Department of Public Works
ft	feet
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FIS	Flood Insurance Study
GOMC	Gulf of Maine Council
GPR	ground penetrating radar
GPS	global positioning system
HABS	Historic American Buildings Survey
HAER	Historic American Engineering Record
HEC-RAS	Hydrologic Engineering Center- River Analysis System
HTA	Hoyle, Tanner & Associates, Inc.
kg	kilogram
LFA	lead federal agency
LOD	letter of deficiency
mi	mile(s)
mi^2	square mile(s)
mg	milligram
MOA	Memorandum of Agreement
NAVD	North American Vertical Datum
NDT	NDT[1] Corporation
NEPA	National Environmental Policy Act
NGO	non-government organization
NGVD	National Geodetic Vertical Datum
NHCF	New Hampshire Charitable Foundation
NHCWRP	New Hampshire Corporate Wetlands Restoration Partnership
NHDES	New Hampshire Department of Environmental Services
NHDOT	New Hampshire Department of Transportation
NHDHR	New Hampshire Division of Historic Preservation
NHFGD	New Hampshire Fish and Game Department
NHNHB	New Hampshire Natural Heritage Bureau
NHC	Northeast Hydrodevelopment Corporation
NHPA	National Historic Preservation Act
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Inspection

[1] There is no acronym for NDT.

Acronyms (continued)

NRHP	National Register of Historic Places
NRPC	Nashua Regional Planning Commission
OMR	Operation, Maintenance and Response Form
PAH	Polycyclic aromatic hydrocarbons
PAL	Public Archaeology Laboratory, Inc.
PCB	polychlorinated biphenyls
PEC	probable effects concentration
ppb	parts per billion
ppm	parts per million
PRG	Preliminary Remediation Goal
QAPP	Quality Assurance Project Plan
RPR	Request for Project Review
SAP	Sampling and Analysis Plan
SHPO	State Historic Preservation Officer
SRWA	Souhegan River Watershed Association
SRWR	Souhegan River Watershed Report
SVOC	semi-volatile organic compound
TEC	threshold effects concentration
THPO	Tribal Historic Preservation Officer
TOC	total organic carbon
TU	Trout Unlimited
USACOE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VOC	Volatile Organic Compound
VPH	Volatile Petroleum Hydrocarbons
WSE	water surface elevation
WSP	water surface profile

Conversions

1 mg/kg = 1 ppm
1 km= 0.62 miles
1 mi= 5,280 feet

Executive Summary

ES-1 Background

The McLane and Goldman Dams are located in downtown Milford, NH and represent the first and second dams on the Souhegan River, respectively (Figure ES-1). The McLane Dam is owned and operated by the town of Milford (town); the Goldman Dam is owned by the Helen Goodwin Estate[2], but is currently operated by the town (Figure ES-2). Historically, the McLane and Goldman Dams served to power various industries that no longer exist; today the dams serve no specific purpose.

The town and Helen Goodwin Estate conducted this feasibility study to determine the feasibility, impacts, and costs associated with potentially removing both dams. The study evaluated the impacts of two alternatives—no action (existing conditions) and dam removal-- on various resources including infrastructure, flooding, water quality, fish, wetlands, recreation, cultural, and aesthetics. The following key issues promulgated this study (in no particular order):

- In recent years (April 2007, March 2010), the town experienced floods of historic measure, with the most notable flooding occurring upstream of both dams. The Souhegan Valley Boys and Girls Club, located above Goldman Dam (Figure ES-2), and several apartment buildings were heavily damaged in the April 2007 flood. These historic floods were costly to the town, businesses and residents. The town would like to determine if removing the dams would decrease flooding upstream of the dams.

- The New Hampshire Department of Environmental Services (NHDES) determined that the Souhegan River, in those reaches impounded by the two dams, have water quality issues significant enough to warrant action. Both impoundments are on the 2012 303(d)[3] list, meaning they do not meet state water quality standards. The town and NHDES would like to determine if removing the dams could improve water quality such that both reaches would meet their designated uses and be removed from the 303(d) list.

- The dams are physical barriers to migratory fish, resident fish, and the movement of sediment and nutrients below the dams. With the removal of the Merrimack Village Dam in 2008[4], the next barrier to fish passage on the Souhegan River is the McLane and Goldman Dams.

- Taxpayer costs. There are long term operation, maintenance and administrative costs and liability associated with the McLane Dam. Historically, the town has overseen the same duties for the Goldman Dam, although as noted below, have no legal or financial obligation.

In the end, the town and Helen Goodwin Estate would like to determine if the option of removing both dams is prudent, feasible, and cost-effective. It is important to understand that no decisions relative to removing or retaining these dams has been made; the town and Helen Goodwin Estate are only seeking information and facts at this juncture to make an informed decision.

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[2] The Helen Goodwin Estate is held by a college student in New Mexico that has no financial means to operate and maintain the dam. Prior to embarking on this feasibility study, the town received a letter from the Helen Goodwin Estate indicating its support for conducting a dam removal feasibility study of the Goldman Dam.
[3] 303(d) refers to Section 303 of the Clean Water Act of 1972.
[4] The Merrimack Village Dam was the former lowermost dam on the Souhegan River. With its removal, migratory and resident fish can now ascend the Souhegan River up to the McLane Dam.

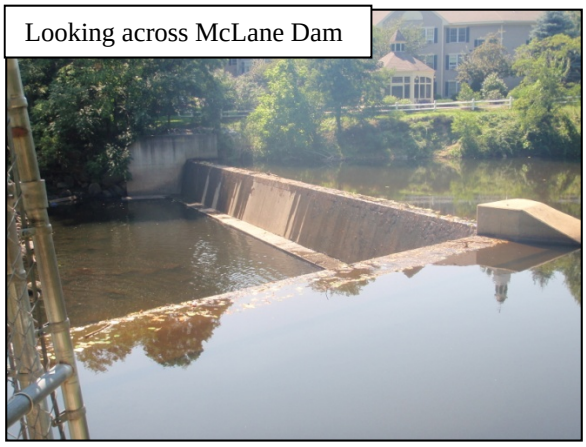
Project Partners, who actively participated in this feasibility study, whether financially or through technical assistance, included the United States Environmental Protection Agency (USEPA), NHDES, National Oceanic and Atmospheric Administration (NOAA), United States Fish and Wildlife Service (USFWS), NH Charitable Foundation (NHCF), American Rivers (AR), Trout Unlimited (TU), and the town.

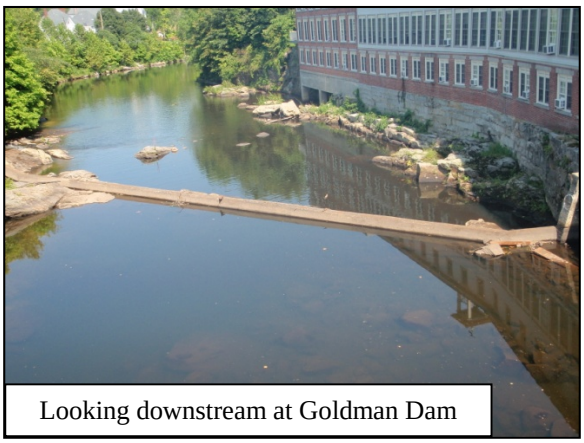
ES-2 Alternatives Considered

Based on early discussion with Project Partners, two alternatives were to be evaluated in this feasibility study including no action (existing conditions) and full removal of the McLane and Goldman Dams.

No Action (Existing Conditions)

Under this alternative, the dams would remain as is with no modification. Both dams are equipped with stoplog openings which permit lowering the water elevation below the spillway crest. The stoplogs at both dams have been permanently removed by the town such that under low flow conditions, all water is passed through the stoplog openings. When inflow exceeds the stoplog opening hydraulic capacity, water levels rise and pass over the spillways. The inset pictures for both dams show no water passing over the spillways as it is being passed through each dam's stoplog openings.


Looking across McLane Dam


Looking downstream at Goldman Dam

The NHDES Dam Bureau has classified both dams as low hazard, meaning failure is unlikely to result in the loss of life and would result in low economic loss to structures or property. NHDES Dam Bureau determines a dam's hazard classification based on the potential impacts to property and life downstream of the dam if failure were to occur and not solely on the dam's "condition". Low hazard dams are inspected by the NHDES Dam Bureau every six years. The most recent inspections of the McLane and Goldman Dams were conducted in April 2009 and April 2012, respectively. Following the inspections, the NHDES issued a Letter of Deficiency (LOD) for the McLane Dam (June 2009) and a Notice of Inspection (NOI) for the Goldman Dam (March 2013). Historically, even though the town does not technically own the orphaned Goldman Dam, they have been the liaison with the NHDES Dam Bureau and have provided operation and administrative support services associated with the dam.

The April 2009 McLane Dam LOD outlined various issues that must be addressed by the town and required follow-up actions and reporting to the NHDES Dam Bureau. All of the issues identified in the LOD have been addressed by the town; the next inspection is slated for 2015.

The Goldman Dam NOI identified various issues that should be addressed. However, as noted in NHDES's NOI letter sent to the Helen Goodwin Estate, it states the following relative to issues observed by the NHDES Dam Safety Inspector "*Since these items do not materially detract from the dam's*

structural integrity or operability at this time, DES has established no schedule for you to address them or does it intend to visit your dam again until the next scheduled inspection which is scheduled to occur in 2018".

There is an important distinction between receiving a LOD versus a NOI. In the LOD, the dam owner is responsible for addressing the deficiencies. In the NOI, the dam owner is not mandated to address issues identified during the inspection, thus there is no financial obligation. More importantly, the NHDES Dam Bureau has clarified that because the Goldman Dam is technically owned by another party, the town has no legal or financial responsibility to operate or maintain the dam. Because the town has overseen the Goldman Dam for years, the NHDES Dam Bureau, by default, has corresponded with them. There is no agreement between the town and the Helen Goodwin Estate to manage or operate the dam.

Full Dam Removal

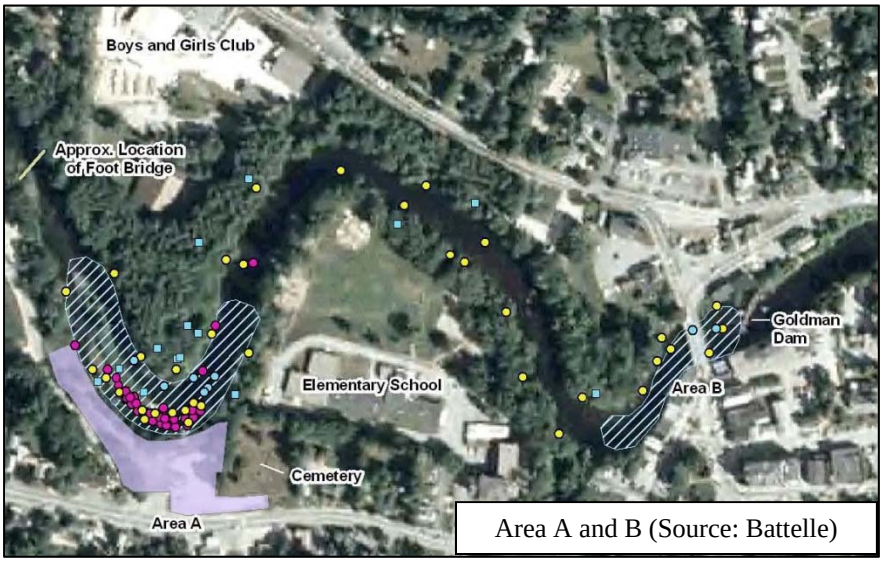
Goldman Dam

For the Goldman Dam, the full dam removal alternative currently consists of removing the river left[5] abutment and stoplog structure, spillway, and the small river right abutment. It was assumed that the inoperable gates that formerly controlled flow into the mill building (now the Milford Mill Apartments) would remain in place. Essentially, there would be little remaining structure; however, as noted later, the New Hampshire Division of Historical Resources (NHDHR) has recommended that the Goldman Dam be eligible for the National Register of Historic Places (NRHP) as a contributing element to the district due to its function of holding water (impoundment). The lead federal agency, NOAA, has determined that the Goldman Dam is not individually significant as a historic structure, but that the impoundment does contribute to the significance of the surrounding district (which has been determined eligible for listing in the NRHP). If the Goldman Dam were removed, a Memorandum of Agreement (MOA) would be developed with consulting parties, including NHDHR, on appropriate mitigation. In addition, Phase 1B archaeological surveys would likely occur to determine if the impact of the removal of archaeological resources.

The Goldman Dam impoundment extends upstream to approximately the Gregg Crossing Footbridge (Figure ES-2). Within this reach is the Fletcher's Paint Superfund Site, located on river right (Figure ES-2). Since the mid-1980s, upland soil testing has been conducted in the Superfund Site area to determine the geographic extent of contamination, with the primary contaminant of concern being polychlorinated biphenyl (PCBs). In addition, extensive sediment testing has been conducted within the Goldman Dam impoundment. The two areas of concern include Area A (impoundment adjacent to Fletcher's Paint Site) and Area B (impoundment just upstream of Goldman Dam). Both areas are shown in cross-hatching in the inset (next page); the colored dots represent sediment samples taken over various years (Source: Battelle for USEPA). As of today, the site has not been fully cleaned up and fencing is established around upland area to restrict access.

Issues related to the Fletcher's Paint site and Goldman Dam sediments have been coordinated closely between the town, Project Partners, USEPA and the US Army Corps of Engineers (USACOE) as part of this project. Numerous conference calls were held and memos developed relative to sediments contained in the Goldman Dam impoundment.

[5] Reference is made throughout this document relative to river-right or river-left. The right and left side of the river are based on looking in a downstream direction.



Area A and B (Source: Battelle)

In 2006[6], 18 transects spaced between Goldman Dam and the Gregg Footbridge were placed to measure the water depth and sediment thickness. Using this data, the total sediment volume in this reach was estimated as 24,400 cubic yards (CY).

Hydraulic modeling of the reach above Goldman Dam was conducted to predict the mean channel velocities with and without dam. The hydraulic model showed that with the dam removed (dam-out) under the 100-year flow, mean channel velocities between the Goldman Dam and confluence with Great Brook (Area B) would increase between 0.8 and 3.0 feet/second compared to dam-in conditions. This was expected as the Goldman Dam serves as a hydraulic control in the reach between Goldman Dam and the Great Brook confluence. However, above the Great Brook confluence other in-river hydraulic controls, such as channel width narrowing, influence depths and velocities. Between the Great Brook confluence and the Gregg Footbridge the hydraulics (water depth and velocity) did not change considerably between dam-in and dam-out conditions. Under dam-out conditions, the mean channel velocity between the Great Brook confluence and Gregg Footbridge increased less than approximately 0.5 feet/second under the 100-year flood compared to dam-in conditions. In fact, in Area A, the mean channel velocity under the 100-year flood increased less than 0.1 feet/second[7] under dam-out conditions. Although a sediment transport model was not developed for the Goldman Dam impoundment, sediments that could potentially mobilize and transport upon dam removal are those located between the Goldman Dam and Great Brook confluence (Area B), which is approximately 1,800 CY based on the 2006 sediment thickness mapping. Note that the 1,800 CY represents the total sediment volume; the mobile sediment volume is expected to be less as not all of the sediment will mobilize.

As of this publication, the USEPA has not finalized its approach to managing sediments within the Goldman Dam impoundment as part of the Fletcher's Paint site whether the dam stays or is removed. However, as noted in a January 23, 2014 conference call, USEPA is considering the following options relative to sediment management in Area A and Area B[8]:

Area A (Impoundment adjacent to Fletcher's Paint Site):

- No action;
- Limited action;
- Isolation cap with limited sediment removal;
- Removal of all sediment to one foot of depth and isolation cap, and;
- Total sediment removal.

[6] The transect data was collected by a consulting firm, Arcadis, on behalf of the General Electric Company.
[7] The mean channel velocity in Area A was estimated at 3.4 and 3.5 feet/second for dam-in and dam-out conditions under the 100-year flood, respectively; a net difference of only 0.1 feet/second.
[8] It is unknown when the USEPA will make a determination as to which alternative will be selected as the preferred alternative. It is also unknown what quantity of sediment would be removed for the various alternatives calling for full or partial sediment removal.

Area B (Impoundment between Goldman Dam and the Great Brook confluence):

- No action;
- Limited action with monitored natural recovery (MNR[9]), which would entail allowing for natural erosion of sediment regardless of whether the Goldman Dam remains or is removed, and;
- Sediment removal (~ 250 CY). Note that this quantity includes only those sediments exceeding the USEPAs Preliminary Remediation Goal of 0.5 ppm.

As part of this feasibility study, a professional having expertise as an ecological risk assessor was provided all of the historic contaminant testing data collected by USEPA and others. This person conducted an assessment of the potential impacts associated with allowing the Goldman Dam sediment to transport downstream following dam removal. Per the latest ecological risk assessor's memo it states:

The anticipated course of action by the USEPA is to not remove the sediments in the Goldman Dam impoundment, either with or without monitored natural attenuation (MNA). This is because the risk posed by the contaminant levels in those sediments to human health by all exposure routes, including fish consumption, is considered acceptable. Accordingly, the ensuing unacceptable risk of those sediments as they flow downstream upon dam removal must be acknowledged and managed. Nevertheless, management decisions must weigh the risk and costs of aggressive action. Based on sediment thickness mapping conducted in 2006, the total sediment volume in Area B (between the Goldman Dam and the confluence of Great Brook with the Souhegan River) is approximately 1,800 cubic yards (this represents the total volume; not necessarily the mobile volume). It is our understanding based on input from USEPA that approximately 250 cubic yards of sediment in Area B exceeds the USEPA's preliminary remediation goal of 0.5 ppm. The options must take into account that the channel bed is primarily small/large boulders, cobble and bedrock; that there is limited access to the sediment; and that the risk assessment is conservatively protective and still only suggests moderate risk. As such, the excessive costs and challenging logistics to dredge, which could potentially cause pulsed exposure of the hotspots as well as divert resources to address the greater risk associated with Area A, are not warranted. Instead, MNA will suffice and is strongly recommended so as to avoid the time and money and undue risk associated with more invasive action. This approach requires an MNA plan and implementation by NHDES to evaluate conditions downstream of the dam, i.e., in addition to any upstream monitoring performed by the USEPA.

Note that although the current proposal is to allow the impounded sediment to transport downstream if the dam is removed, it has not been agreed to by any state or federal agency at this juncture. For cost estimate purposes, it was assumed that the sediment would naturally mobilize following dam removal (no dredging and no monitoring was included in the cost estimate).

McLane Dam

For the McLane Dam, the full dam removal alternative currently consists of removing the abutments, spillway, and structure housing the stoplogs. Essentially, there would be no remaining structure; however, like Goldman Dam, the NHDHR has recommended that McLane Dam be eligible for the NRHP as a contributing element to the district. Again, NOAA has determined that the McLane Dam is not individually significant as a historic structure, but that the impoundment does contribute to the significance of the surrounding district. If the McLane Dam were removed an MOA would be needed.
Like the Goldman Dam, another issue with removing the McLane Dam is how to manage sediments (sand/silt) accumulated behind the dam. As part of this feasibility study, the total quantity of sediment

[9] It is unclear what party would be responsible for monitoring (including when and for what constituents) and the associated cost.

behind the McLane Dam was estimated at 4,700 CY, although this volume does not represent the mobile sediment volume, which is less. Sediment transport studies were conducted of the McLane Dam impoundment to estimate the volume of mobile sediment in the impoundment transported downstream under a 100-year flood event with and without the dam. The predicted net mobile[10] sediment volume lost from the impoundment under the 100-year flood with the dam in place was 2,588 CY, and with the dam removed, 3,585 CY. The difference between 2,588 CY and 3,585 CY, approximately 1,000 CY, represents the net volume of sediment that would pass below the dam if it were removed compared to existing conditions.

In addition to quantifying the sediment volume, sediment testing was conducted in the McLane Dam impoundment. Working with the USEPA, USACOE, NHDES, USFWS, and others, a USEPA-approved Quality Assurance Project Plan (QAPP) was developed and approved detailing the sediment sampling methods, procedures, and equipment. The plan called for collecting sediment samples in the McLane Dam impoundment, as well as above the upstream extent of the Goldman Dam impoundment and below McLane Dam (to document background conditions). The collected sediment samples were sent to a USEPA laboratory for testing. The results were compared to screening criteria to determine if any contaminants of concern exist at elevated levels or if any contaminants pose a threat to freshwater ecological resources. The screening criteria are categorized into threshold effects concentration (TEC) and probable effects concentration (PEC). Note that TEC values are screening thresholds below which adverse effects to freshwater ecosystems are unlikely. PEC values are screening thresholds above which adverse effects to freshwater ecosystem are likely.

The sediment sampling results were compared to the TEC and PEC; there were no exceedences of the PEC; however, a few contaminants (PCB, SVOC, VOC) exceeded the TEC. All sediment data, including the quantity and laboratory findings, were provided to an ecological risk assessor to evaluate the risk associated with allowing the sediments to natural transport downstream if the dam was removed. Per the ecological risk assessors finding: "*...if the McLane Dam impounded sediments were naturally transported downstream upon dam removal, the risks to downstream higher trophic organisms, sediment and aquatic invertebrates and humans are all acceptable*".

Similar to Goldman Dam, although the current proposal is to allow the impounded sediment to transport downstream if the dam were removed, it has not been agreed to by any state or federal agency at this juncture. For cost estimate purposes, it was assumed that the sediment would naturally mobilize following dam removal (no dredging).

ES-3 Impact Assessment

The feasibility study examined the impacts of the status quo and full dam removal alternatives on the following:

Dam Ownership, Liability and Safety

- Dam Ownership and Obligation
- Liability and Safety

Impacts on Infrastructure

- Flooding
- Ice jams
- Water and Sewer Lines traversing the reaches impounded by the dams

[10] The predicted net mobile sediment volume is the difference between sediment volume deposited in the impoundment during the 100-year flood less the sediment volume passed below the dam.

- Route 13 Bridge
- Wells
- Fire
- Traffic

Impacts on Environmental Resources

- Water Quality
- Fisheries
- Sediment- Risk Assessment
- Wetlands
- Rare, Threatened and Endangered Species

Impacts on Cultural Resources

- Historic Structures (dams)
- Archaeological Resources

Impacts on Recreation Resources

Impacts on Aesthetic Resources

Table ES-1, at the end of this Executive Summary, includes a matrix listing the two alternatives and the impact each alternative may have on the resources identified above. Note that in some instances the assessment was based on detailed analysis conducted as part of this feasibility study. For example, a hydraulic model of the project was developed to determine if there were any flood benefits associated with removing the dams. However, in other cases, a detailed resource assessment was not conducted, such as recreation and aesthetic resources, but was based on anecdotal information or observation. Table ES-1 notes if a detailed study was conducted, or if the findings are based anecdotal information or observation.

ES-4 Opinion of Probable Construction Costs

The feasibility assessment confirmed that either alternative- status quo or full dam removal- would be feasible from an engineering perspective.

Status Quo Alternative

McLane Dam

For the status quo alternative, the only known cost is annual dam registration fee of $400. Other costs, for which it is difficult to tease out a dollar value, are listed below:

- Labor expended by the Milford Department of Public Works (DPW) to maintain the dam.
- Labor expended by the Milford Administrative personnel associated with NHDES Dam Safety communications. The Town estimates the annual fee to operate and maintain the McLane Dam is approximately $1,200/year.
- Costs associated with addressing future LODs, which may require follow-up work and potentially having to seek professional engineering services.
- Due to the rebuild occurring 22 years ago, there is likely many more years of serviceable life of the dam before any major repairs or capital expenditures are needed. However as with any structure, it will eventually fail if not maintained. Although the dam is in good condition today,

over several decades it will require capital investment to maintain a properly operating and safe dam.

- If the low hazard classification of the dam was ever raised due to increased development below the dam, it could be subject to greater state regulation, different dam safety criteria, and as a result, could result in increased capital costs. As noted above, a dam's a hazard classification is based on the downstream impacts due to failure including loss of life and infrastructure impacts. The greater potential for loss of life or infrastructure impacts, the higher the hazard classification.
- It is possible that upstream fish passage facilities[11] could be required at McLane Dam in the future to pass migratory fish above the dam. If upstream fish passage facilities were required it would result in a sizeable capital expenditure.

Goldman Dam

As indicated by NHDES, because the dam is technically owned by a college student, the town has no financial or legal obligation to maintain or operate the dam, thus the town's cost is technically $0. However, the town has taken on the operation and maintenance of this orphaned dam. The town estimates the annual operation and maintenance of the dam as $1,000/year.

Full Dam Removal Alternative

For cost estimating purposes it was assumed that both dams would be removed and that natural sediment transport following dam removal would be permitted by the state and federal agencies. The following are costs associated with completion of the Section 106 consultation process relative to historic resources, further feasibility related tasks, construction/demolition costs, and follow-up work required by the Federal Emergency Management Agency (FEMA):

- Completion of the Section 106 Process including:
    - Phase 1B archaeological survey (it was assumed no Phase II survey would be required) ($17,000).
    - Development of a Memorandum of Agreement with SHPO and other consulting parties to determine mitigation ($5,000).
    - Mitigation costs ($10,000).
- Further feasibility-related tasks including:
    - Assessment of Sewer Line 2 ($8,000).
    - Assessment of need of any riverbank stabilization measures on river-right bank immediately above and below McLane Dam ($8,000).
- Cost Associated with Dam Removal[12] including the sub-bullets below
  McLane Dam Removal- $493,000, Goldman Dam Removal- $285,000 to $332,000:
    - Engineering, Permitting and Design.
    - Bid Documents.
    - Contractor Construction (Demolition) Costs.
    - On-Site Construction Oversight Services.
- Follow-Up Work including:
    - A Letter of Map Revision would be required by the FEMA since the 100-year floodplain would change, which could influence flood insurance rates ($10,000).

[11] Note that in 1998 the USFWS developed conceptual plans for downstream fish passage at McLane Dam to pass salmon smolts. It appears that a portion of the downstream fish passage facilities were developed, but never completed.

[12] The dam removal budgetary estimates include costs for engineering, permitting, bidding phase and construction management.

- Potential post dam removal monitoring work ($20,000).

Note that although the cost associated with removing the dams is based on conceptual engineering, it is considered a reliable way of assessing the cost of dam removal; the actual cost can be expected to change as additional engineering is completed, input is received from the state and federal agencies, and other factors change in the future

The opinion of probable construction costs (OPCC) to remove the McLane Dam is estimated at $493,000 (2014 dollars). In the case of the Goldman Dam, two OPCCs were developed to reflect two different access routes to remove the dam (from upstream and downstream). The OPCC to remove the Goldman Dam ranged from $285,000 to $332,000 (2014 dollars). The lower range reflects accessing the dam from the downstream side via the Milford Mill Apartment parking lot. The higher range reflects accessing the dam from the upstream side via Emerson Park and beneath the Route 13 Bridge.

ES-5 Funding Sources

Competitive grants are available to fund various phases of a dam removal project including feasibility-related tasks, design/engineering/permitting, the actual dam removal costs, and most (if not all) mitigation measures. The town has been successful in securing funding for this feasibility study and based on this assessment it appears feasible to remove both dams. Armed with this feasibility report, it is up to the town, its taxpayers, and the Helen Goodwin Estate to determine whether to proceed with removing the dams.

If the town and Helen Goodwin Estate opt to remove the dams, it is highly recommended that additional grant opportunities be explored to defray the towns and Helen Goodwin Estate cost. Generally, it is more challenging to secure grants for feasibility-related tasks as there is less certainty that a given dam could be removed. If the feasibility study suggests it is feasible to remove the dam, and the dam owner supports removal, there is a greater likelihood of securing grants for design/engineering/permitting and the demolition of the dam. Grantors generally prefer to allocate monies to projects having a higher likelihood of dam removal.

Similar to the process the town went through to secure grant monies for this feasibility study, if dam removal was the preferred alternative, the town could apply for numerous grants to help defray costs. It should be noted that the majority of funding opportunities are with federal entities and most of these require a 50-50 non-federal match. For example, if a federal agency awarded $50,000 to the town, they may require a $50,000 match – that match could come from the state, town, non-government organization or in-kind services. The NHDES has provided assistance to the town in securing grant monies for this feasibility study and it would likely provide the same assistance in identifying additional grants for engineering/design/permitting and the actual removal.

Note that the town has established a website pertaining to this dam removal feasibility study. This report and other documents can be obtained at the following weblink:

http://www.milford.nh.gov/departments/community-development/active-projects/dam-feasibility-removal-study

ES-6 Next Steps

A Draft Feasibility Report, including Volumes 1-3, was provided to the public for review prior to a public meeting on September 10, 2014. The Draft Feasibility Report was posted on the weblink above and paper copies were made available at the Wadleigh Memorial Library and town hall. The public meeting date,

time and location was noticed in the local paper and on the town's website. At the public meeting, the public was requested to provide written comments on the Draft Feasibility Report by September 30, 2014. Written comments are included in Appendix M. This Final Feasibility Report was provided to the town, and again posted on the weblink above. At this juncture, it is up to the town, taxpayers, and the Helen Goodwin Estate to determine, what, if any, steps are taken relative to the dams.

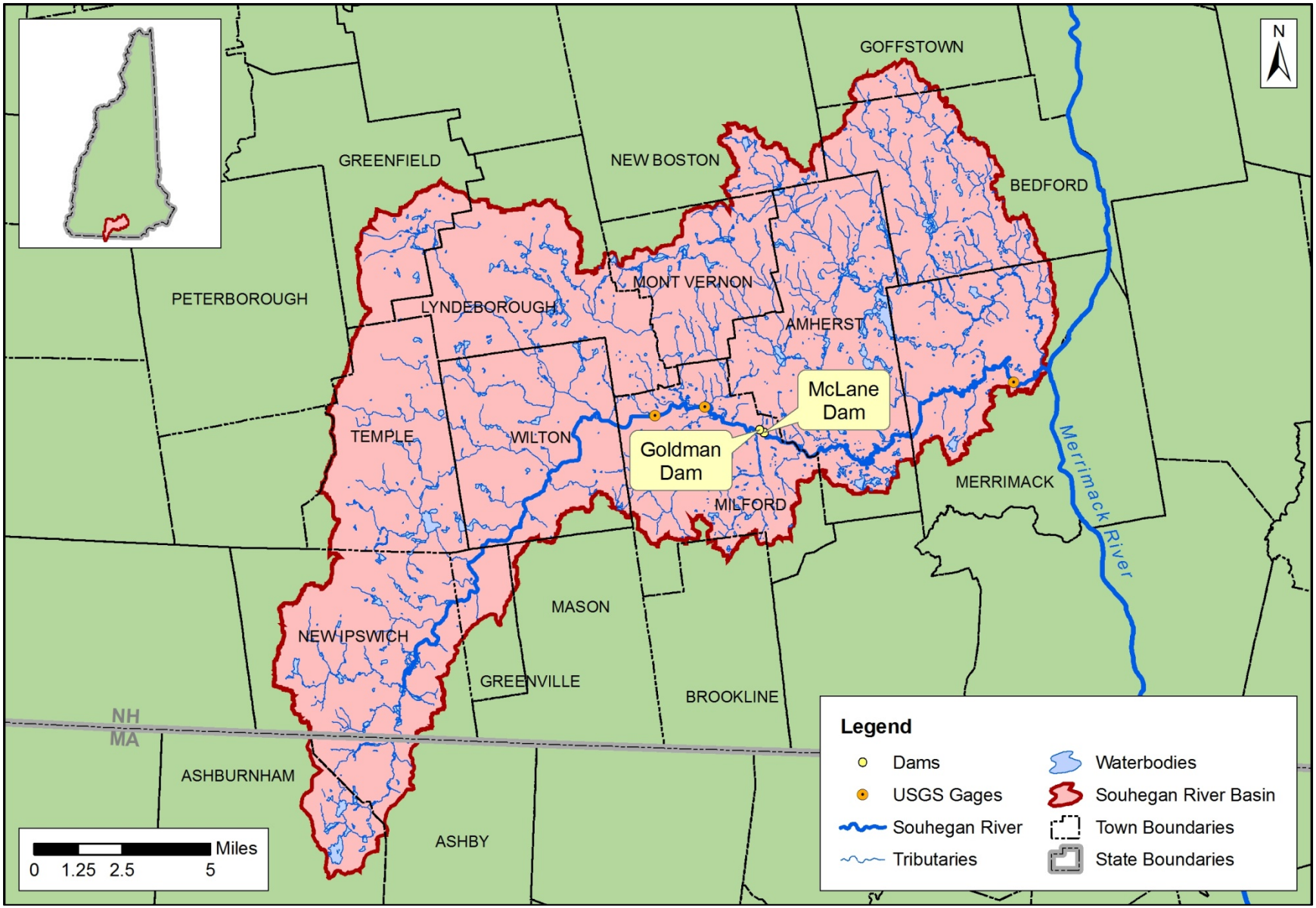


Figure ES-1: Project Locations within Souhegan River Basin

Figure ES-2: Location Map of Project Area including McLane and Goldman Dams

Table ES-1: Summary of Resource Impacts Under Two Alternatives- Status Quo and Full Dam Removal

Issue	Alternative- Existing Conditions or Status Quo	Alternative- Full Dam Removal
Dam Ownership, Liability and Safety		
Dam Ownership and Obligation	McLane Dam- the dam is owned by the town. The town is responsible for operation and maintenance of the dam as well as administrative support relative to communications with the NHDES Dam Bureau. Maintenance entails clearing debris and log jams at the stoplog opening or log jams atop the spillway. Every 6 years the NHDES Dam Bureau will inspect the dam and identify deficiencies that must be addressed. Although the dam is currently in good working condition, over time it will require capital investment to maintain a safe and properly working structure. Goldman Dam- the dam is owned by the Helen Goodwin Estate; a college student with no financial means. NHDES Dam Bureau concluded that the town has no financial or legal responsibility to operate or maintain the dam. The Goldman dam is in fair condition with undermining occurring.	If the McLane Dam were removed, the town would have no further obligations.
Liability and Safety	There are currently no boat barrier restraints above either dam to prevent on-water recreationist from potentially going over the spillway and becoming entrapped in a roller below the dam. Liability and safety concerns would remain. The McLane Dam is an attractive nuisance to juveniles observed on many occasions atop the dam during various site visits. It is assumed that the town is not liable for safety issues associated with the Goldman Dam since they technically do not own it.	If the McLane Dam were removed, the town would have no further liability or safety issues.
Impacts on Infrastructure		
Flooding	Neither dam provides any flood storage capacity; instead the dams artificially raise the river's water surface elevation. With the dams in place flooding occurs upstream of both dams. The areas of most critical flooding under a 100-year event include houses and infrastructure located on the inside right bend of the river between the McLane and Goldman Dams. Above the Goldman Dam, the Boys and Girls Club is flooded.	Based on hydraulic modeling, with McLane Dam removed, the area of inundation under the 100-year flood between the McLane and Goldman Dams is reduced to a point where houses and infrastructure on the inside right bend are not inundated- clearly a benefit to removing McLane Dam. With the Goldman Dam removed, there is a marginal lowering of the 100-year flood inundation area, but it did not result in much flood benefit relative to infrastructure impacts. The Boys and Girls Club will still flood if the dam is removed as it is located in the floodplain.
Water/Sewer Lines	There are 3 sewer lines and 2 water lines traversing the Souhegan River starting immediately below the McLane Dam and extending upstream to the Gregg Crossing Footbridge. Based on the plan and profile drawings all of the sewer lines are encased in 0.5 feet of concrete. In addition, riprap is shown lining the channel bed atop the sewer line. The lines are buried beneath the channel bed elevation with the exception of Water Line No. 1extending across the Souhegan River behind the Masonic Temple. At this location, the water line sits atop the channel bed and is exposed. It is recommended that this line be buried to protect it.	Based on hydraulic modeling, sediment transport modeling of the McLane Impoundment, and sediment probing in the McLane Impoundment, it appears that most of the buried lines are not susceptible to scour and erosion with the potential exception of Sewer Line No. 2 located between Goldman and McLane Dams and Water Line No. 1, located behind the Masonic Temple. Our preliminary finding is that Sewer Line No. 2 does not appear subject to scour; however, additional follow-up work is recommended since not much bed material is present between top of the sewer line and the channel bed. Because it is unclear if the drawings are as-built or design drawings, further investigation is recommended to confirm that the line is encased in concrete, the channel is lined with riprap, and the profile is correct. Additional probing immediately upstream and downstream of the sewer line is recommended as well as a grain size analysis. The substrate size would be used in the hydraulic model to determine if the velocities without the McLane Dam could result in mobilizing the substrate. Currently only one invert was surveyed; it is recommended the other invert be surveyed to verify the sewer line slope. Relative to Water Line No. 1, it sits atop the channel bed and is exposed. It is recommended that this line be buried to protect it whether the dams remain or are removed.
Route 13 Bridge	As part of this feasibility study, probing was conducted along the abutments and pier of the Route 13 bridge. Bathymetric mapping through the bridge openings showed no scour holes present. In addition, an independent geophysical study was conducted in 2009 using Ground Penetrating Radar to determine the likelihood that the abutments and pier were founded on bedrock. The geophysical study reported the following: "*The results of this test indicate that the abutments and pier have a high probability of being partially founded on bedrock*". Our probing supports the findings in the geophysical report.	If the Goldman Dam is removed, it is not anticipated that scour or headcutting of sediment along the Route 13 Bridge abutments or pier is likely given that the underlying strata consists of bedrock. The reach between Goldman Dam and the Route 13 Bridge consists primarily of ledge thus dam removal should not result in a headcut, whereby the channel bed starts to unravel in a downstream to upstream direction.
Wells, Fire	The town is provided drinking water via a public water supply system. Per the Milford Fire	Removing both dams would have no impact on wells since the town provides public water. In addition,

Issue	Alternative- Existing Conditions or Status Quo	Alternative- Full Dam Removal
	Department, the impoundments created by the dams are not used to fill pumper trucks or fight fires	removing the dams would have no impact on filling pumper trucks or fighting fires since the impoundments are not used as a water source.
Traffic	There would be no impact on traffic if the dams remain.	There would be a temporary impact to traffic when debris from the demolition process is hauled off-site to an approved landfill. This is likely not an issue for hauling debris from the McLane Dam since the first public road intersected would be Souhegan Road, which is not as congested. However, hauling debris from Goldman Dam could create traffic issues pending the access route. One access route considered is from Emerson Park. In this case, the first road intersected would be Mont Vernon Street (or Route 13), which is located in the heart of downtown. If the debris from Goldman Dam was hauled to the east, this area is particularly congested due to three roads (Grove, Amherst and Mont Vernon) converging over a short distance. The other access route is from the Milford Mill Parking Lot (access has not been granted), which also could create parking and traffic issues on Bridge Street. Restrictions can be placed such that hauling times occur during off-traffic hours and may require police or traffic control presence.
Ice	With dams in place sheet ice forms behind the dams. Based on review of the US Army Corp of Engineers Cold Regions Research and Engineering Laboratory ice jam database, ice jams have been reported in Milford in January 1976 and in January 1979.	If the dams are removed sheet ice will no longer form and ice floes could potentially become jammed against the Route 13 Bridge opening.
Impacts on Environmental Resources		
Water Quality	The impoundments created by both dams have water quality issues significant enough to warrant action. Both impoundments are on the 2012 303(d) list for not meeting water quality standards relative to the following: at Goldman Dam- dissolved oxygen (DO) saturation, DO concentration and mercury and at McLane Dam- *e.coli* and mercury.	Although no water quality monitoring was conducted as part of this study, there is ample scientific literature demonstrating the impacts of dams on water quality. Typically, dams/impoundments contribute to artificially raising the water temperature as it takes longer for a drop of water to move through an impoundment versus a free flowing river resulting in increased residence time and thermal loading. Removing the dams will improve water temperatures to natural background conditions. In addition, dams/impoundments can result in reducing DO levels in the water as DO typically declines with impoundment depth and warm water holds less oxygen than cold water. Converting to a free flowing river will result in water tumbling over rocks, becoming aerated, and increasing DO concentrations. The McLane impoundment is on the 303(d) list for *e.coli*. The source of the *e.coli* is unknown, but it could emanate from waterfowl using the impoundment. If the impoundment reverted to a free-flowing river, waterfowl may move to other impounded areas and potentially reduce *e.coli* levels. If sediment were allowed to transport downstream upon dam removal, there would be a short term impact on water quality due to increased turbidity.
Fisheries	The McLane and Goldman Dams are barriers to upstream fish passage. Any migratory fish ascending the Souhegan River are limited to the base of McLane Dam. Similarly resident fish located below the dam cannot access habitat above the dams. Neither dam is equipped with upstream or downstream fish passage facilities. Any fish moving downstream currently pass over the dams and pending on the location could be subject to injury or mortality if a plunge pool is not present. The dams also create impoundments that inundate riverine fish habitat. In addition, accumulated sediment within the impounded reaches may cover fish spawning grounds.	Removal of the dams would eliminate a barrier to upstream and downstream fish passage and would open up approximately 6 miles of free-flowing habitat on the Souhegan River and intervening tributaries between McLane Dam and the next upstream dam (Pine Valley) in Wilton. Assuming accumulated sediment is scoured and mobilized if the dams are removed, it may uncover additional spawning habitat for resident and migratory fish. As of today, the proposal is to allow the sediment accumulated behind both dams to naturally transport downstream following dam removal, although state and federal agencies have not approved this approach. There are only pockets of sediment above the Goldman Dam and the release of the material is not likely to have an impact on fish habitat below the dam. There is more accumulated sediment behind the McLane Dam. An assessment of the relatively steep riverine reach below the McLane Dam was conducted; this reach has relatively good aquatic habitat. If sediment from behind McLane Dam is permitted to move downstream, there would be a short term impact on fish and aquatic resource habitat in this reach as sand/silt may temporarily deposit here. However, due to the steep river gradient it is expected that this material will eventually scour and move downstream where the river becomes more sinuous and the channel bed is already covered with sand and

Issue	Alternative- Existing Conditions or Status Quo	Alternative- Full Dam Removal
		silt.
Sediment- Risk Assessment	The Fletcher's Paint Superfund site is located adjacent to the Goldman Dam impoundment. There has been numerous studies and testing conducted both upland and within the Goldman Dam impoundment since the mid-1980s. The primary contaminant of concern is PCBs. Based on the most recent testing in 2012 there are isolated pockets of PCBs exceeding 0.5 ppm immediately above the dam and adjacent to the Superfund Site. Sediment testing was conducted in the McLane Dam impoundment. There were no exceedences of the probable effects concentration, which is an indicator that the sediment has a high probability of impacting aquatic biota.	As part of this study, sediment testing and analysis was conducted on sediment contained in the McLane Dam impoundment. In addition, an assessment was conducted to determine the risk of allowing the sediment to transport downstream if the dam was removed. Per the ecological risk assessors finding: "*...if the McLane Dam impounded sediments were naturally transported downstream upon dam removal, the risks to downstream higher trophic organisms, sediment and aquatic invertebrates and humans are all acceptable*". A risk assessment was also conducted of the Goldman Dam sediments. The assessment evaluated the risk of allowing the sediment above the dam to naturally transport downstream if the dam is removed. Per the ecological risk assessors findings: "*The anticipated course of action by the USEPA is to not remove the sediments in the Goldman Dam impoundment, either with or without monitored natural attenuation (MNA). This is because the risk posed by the contaminant levels in those sediments to human health by all exposure routes, including fish consumption, is considered acceptable. Accordingly, the ensuing unacceptable risk of those sediments as they flow downstream upon dam removal must be acknowledged and managed. Nevertheless, management decisions must weigh the risk and costs of aggressive action. Based on sediment thickness mapping conducted in 2006, the total sediment volume in Area B (between the Goldman Dam and the confluence of Great Brook with the Souhegan River) is approximately 1,800 cubic yards (this represents the total volume; not necessarily the mobile volume). It is our understanding based on input from USEPA that approximately 250 cubic yards of sediment in Area B exceeds the USEPA's preliminary remediation goal of 0.5 ppm. The options must take into account that the channel bed is primarily small/large boulders, cobble and bedrock; that there is limited access to the sediment; and that the risk assessment is conservatively protective and still only suggests moderate risk. As such, the excessive costs and challenging logistics to dredge, which could potentially cause pulsed exposure of the hotspots as well as divert resources to address the greater risk associated with Area A, are not warranted. Instead, MNA will suffice and is strongly recommended so as to avoid the time and money and undue risk associated with more invasive action. This approach requires an MNA plan and implementation by NHDES to evaluate conditions downstream of the dam, i.e., in addition to any upstream monitoring performed by the USEPA.*" Note that although the sediment in Area A adjacent to the Fletcher's Paint Site is located within the Goldman Dam Impoundment, under the 100-year flood, the mean channel velocity with and without the Goldman Dam is 3.4 and 3.5 ft/sec, respectively, a difference of only 0.1 ft/sec. In addition, the difference in water depth is 0.4 feet. As such, removing the Goldman Dam is not expected to change hydraulic conditions in Area A or increase sediment scour above what already occurs.
Wetlands	There are minimal wetlands associated with either dam/impoundment.	Due to the limited wetlands, removal of the dams is not likely to have a major impact.
Rare, Threatened and Endangered Species	Based on feedback from the NH Natural Heritage Bureau (NHNHB), NHFGD and USFWS, no rare, threatened or endangered (RTE) species have been reported in the project area.	Since no RTE species have been reported in the project area, dam removal would have no impact. If the dams were to be removed, the owners would need to consult with the NHNHB, NHFGD and USFWS again, as the letters received from these agencies are effective for one year.
Cultural and Historic Resources		
Historic Structures	Under status quo conditions, there would be no additional impacts to existing historic and cultural resources. However, if the dams remain, over time any major change or rebuild of the dams could potentially impact the historical significance of the structures. In the case of Goldman Dam, because there is technically no obligation to maintain the dam, it will eventually fail.	A Phase I Historic Structures assessment was conducted by Public Archaeological Laboratory (PAL) and a report was sent to the NH Division of Historic Resources (NHDHR). PAL recommended that both dams are not eligible for individual listing to the NRHP. PAL noted that the McLane Dam's 1992 reconstruction resulted in the complete loss of integrity of the 1846/1909 structure. PAL also noted that the Goldman Dam is less than 50 years old and possesses no exceptional significance. In contrast, after reviewing the Phase I report, NHDHR made a determination that both dams were eligible as contributing elements of the Downtown Milford Commercial, Civic and Residential Historic District due to their function of holding water (impoundments). The lead federal agency, NOAA, has determined that both dams are not individually significant as a historic structure, but that the impoundments do contribute to the significance of the surrounding district (which has been determined eligible for listing in the NRHP). If the dams were removed, a Memorandum of Agreement (MOA) would be developed with consulting parties, including NHDHR, on appropriate mitigation.
Archaeological Resources	Under status quo conditions, for the McLane Dam there would be no impacts to archaeological resources. For Goldman Dam because there is no requirement to maintain the dam and it will eventually fail resulting in lowering of the water surface elevation about the dam. As noted in the box	A Phase 1A Archaeological Survey was conducted by PAL. Based on the Phase 1A study, PAL recommended that Phase 1B testing (subsurface testing) be conducted. Typically, subsurface testing is conducted in areas of ground disturbing activities or along riverbanks that could be subject to erosion if the dams were removed.

Issue	Alternative- Existing Conditions or Status Quo	Alternative- Full Dam Removal
	to the right PAL recommended, and NHDHR concurred, that Phase 1B subsurface testing be conducted. It is unknown if there are any sensitive cultural resources on the river banks along the Goldman Dam impoundment. If there were sensitive sites, a dam failure could potentially impact documented sites.	NHDHR agreed with PAL's finding and thus a Phase 1B evaluation is required if the dams were removed. Depending on the findings of the Phase IB study, it is possible that Phase II studies could be required to determine if an archaeological site(s) are eligible for listing to the National Register.
Recreation Resources		
Recreation	A recreation assessment was not conducted as part of this project, although anecdotal information is available from the numerous site visits to the project area outside the winter season and from town personnel. There is passive recreation use along numerous walking trails located along the river's edge, including paths from the Boys and Girls Club to Emerson Park, and trails from McLane Dam downstream. Anglers were observed in the Emerson Park area and further upstream on several occasions. No on-water recreation (kayak, canoes, and non-motorized boats) was observed during site visits presumably because water depths are too shallow in the Goldman Dam impoundment and although the McLane impoundment is deeper it is a short reach in an urban setting.	Since there is minimal on-water recreation, removing the dams would likely have negligible impacts on recreation. Converting to a free-flowing river may result in increased angler activity in the impounded reaches as the number and diversity of fish will likely change.
Aesthetic Resources		
Aesthetics (Visual and Auditory)	An aesthetic assessment was not conducted as part of this study. However, the dams and impoundments are readily visible to the public. Starting upstream, views of the Souhegan River are readily available from Gregg Crossing Footbridge and Emerson Park. In addition, the Milford Mill Senior Housing Apartments overlook the Goldman Dam as well as the impounded river above and below the Goldman Dam. J's Tavern, a restaurant, has outside seating overlooking the Goldman Dam. The Granite Square Senior Housing Apartments overlook the McLane Dam, which also includes a gazebo and patio. With the stoplogs permanently removed from both dams during the low flow period in the summer (July-September), water passes over the dams only 25% and 5% of the time at the Goldman Dam and McLane Dams, respectively. Only when flows exceed the hydraulic capacity of the stoplog openings does water pass over the spillway. These two conditions – water passing through the stoplog openings or over the spillway- have different aesthetic appeal from a visual and auditory perspective.	The aesthetic resource impact of removing the dams is subjective and open to individual interpretation as some may view water passing over the spillways and the creation of an impoundment as aesthetically pleasing from a visual and auditory standpoint. In contrast, others may view a free flowing river with no dam/impoundment as aesthetically pleasing. The parties most directly impacted—whether positively or negatively-- would be the two apartment complexes and residents located along the river banks between the Goldman and McLane Dams. If the dams were removed, the river width and depth will be reduced and the former impounded reaches would appear like a natural river. Removal of the Goldman Dam would also reduce the river width and depth between the Goldman Dam to just upstream of the confluence with Great Brook. There would not be much change in river width further up the Goldman impoundment. One of the potential access routes to remove Goldman Dam is via Emerson Park, through one of the Route 13 bridge bays and then to the dam. Given this, there will be a short term aesthetic impact to the Emerson Park area when work activities are occurring. It is assumed that after the dam is removed, the park would be returned to the same condition as prior to the work. The other option is via the Milford Mill Apartment parking lot and then along the face of the Apartment complex, which would also have a short term aesthetic impact to residents. Dam removal typically involves an excavator equipped with a hoe-ram that is used to demolish the dam using short pulses, which results in a banging sound. Because both dams are located in downtown Milford, there would be a short-term auditory impact during the demolition and hauling of debris process. Conditions can be placed on what days and time of day demolition may occur so as to limit auditory impacts.
Cost Estimates		

Opinion of Probable Cost	McLane Dam- since the dam is classified as low hazard the town pays an annual registration fee of $400. The town estimates the annual operation and maintenance cost as $1,200/year. Other costs for which it is difficult to tease out a dollar value include:
	
	• Milford DPW labor associated with maintaining the dam (see $1,200/yr above).
	• Milford administrative labor associated with communications with NHDES Dam Safety.
	• Addressing Letters of Deficiencies, which may require follow-up work and potentially having to seek professional engineering services.
	• As with any structure, it will eventually fail if not maintained. Although the dam is in good condition, several decades into the future will likely require capital investment to maintain the dam in a safe//working condition.
		The following items were included in the budgetary estimate to remove the dams:
		
		• Completion of the Section 106 Process including:
		  • Phase 1B archaeological survey (it was assumed no Phase II survey would be required) ($17,000).
		  • Development of a Memorandum of Agreement with SHPO and other consulting parties to determine mitigation ($5,000).
		  • Mitigation costs ($10,000).
		• Further feasibility-related tasks including:
		  • Assessment of Sewer Line 2 ($8,000).
		  • Assessment of need of any riverbank stabilization measures on river-right bank immediately

Issue	Alternative- Existing Conditions or Status Quo	Alternative- Full Dam Removal

	• It is possible that upstream fish passage structures could be required at the dam.
	
	Goldman Dam- as indicated by NHDES, the town has no financial or legal obligation to maintain or operate the dam, thus the cost is technically $0. However, the town has taken on the operation and maintenance of this orphaned dam and estimates $1,000/year is expended.
	
	Typically, there is no funding to operate, maintain and repair dams.
		above and below McLane Dam ($8,000).
		• Cost Associated with Dam Removal[13] including the sub-bullets below
		McLane Dam Removal- $493,000, Goldman Dam Removal- $285,000 to $332,000 (range reflects different access routes):
		  • Engineering, Permitting and Design.
		  • Bid Documents.
		  • Contractor Construction (Demolition) Costs.
		  • On-Site Construction Oversight Services.
		• Follow-Up Work including:
		  • A Letter of Map Revision would be required by the FEMA since the 100-year floodplain would change, which could influence flood insurance rates ($10,000).
		  • Potential post dam removal monitoring work ($20,000).
		
		Competitive grants are available to help defray the costs associated with dam removals. The same funding sources used to complete this feasibility study, as well as other sources, should be pursued if the dam owners elect the removal alternative.

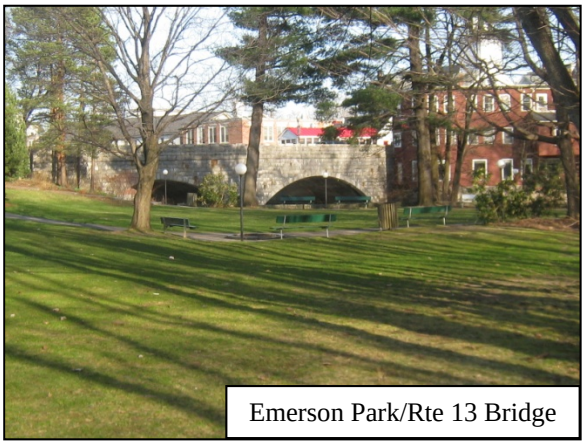
[13] The dam removal budgetary estimates include costs for engineering, permitting, bidding phase and construction management.

1.0 Introduction and Purpose of Study

1.1 Background

The McLane and Goldman Dams, located in downtown Milford, NH, represent the first and second dams on the Souhegan River, respectively. The Souhegan River is a tributary to the Merrimack River; its 220 square mile (mi^2) watershed is flanked by the Piscataquog River Basin to the north and the Nashua River Basin to the south (Figure 1.1-1). The McLane Dam is owned and operated by the town of Milford (town); the Goldman Dam is owned by the Helen Goodwin Estate[14], but operated by the town (Figure 1.1-2). Between the McLane Dam and the Atlantic Ocean there are two other dams on the Merrimack River equipped with upstream and downstream fish passage. Historically, the McLane and Goldman Dams served to power various industries that no longer exist; today the dams serve no specific purpose.

Project Setting


Emerson Park/Rte 13 Bridge

Main features of the project area are shown in Figure 1.1-3. The dams/impoundments are an integral part of downtown Milford. Walking trails are established along the river-left bank[15] below McLane Dam and along the river-left bank above Goldman Dam. Emerson Park, which flanks river-left immediately upstream of the Route 13 Bridge, provides benches and walking trails offering the public views of the river. Between the two dams there is considerable infrastructure along both river banks. Besides a handful of business buildings and residential houses between the two dams, there are two senior housing complexes - Milford Mill and Granite Square Apartments-- overlooking the Goldman and McLane Dams, respectively. The Granite Square Apartments include a gazebo and patio located adjacent to McLane Dam. The Milford Mill Apartments, once the Milford Cotton and Woolen Manufacturing Corporation, is a historical landmark and is listed on the National Register of Historic Places (NRHP). The foundation of the Milford Mill complex extends vertically into the river, serving as the river-right bank, immediately below Goldman Dam.

J's Tavern, a restaurant attached to the same Milford Mill Apartment building, is located immediately downstream of the Route 13 Bridge and has seating overlooking the river. Finally, residential homes are scattered along the McLane Dam impoundment[16] offering views of the river. Above the Route 13 Bridge, and along the Goldman Dam impoundment, there is less development within the river corridor, although some walking trails are present. Located adjacent to the Goldman Dam impoundment on river-right is the Fletcher's Paint Superfund site (see Figure 1.1.3), which is described in more detail in this report. Also located near the upstream end of the Goldman Dam impoundment is the Gregg Crossing Footbridge and the Souhegan Valley Boys and Girls Club (see Figure 1.1-3), which has been subjected to flooding in the past.

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[14] The Helen Goodwin Estate is held by a college student in New Mexico having no financial means to operate and maintain the dam. Prior to embarking on this feasibility study, the town received a letter from the Helen Goodwin Estate indicating its support for conducting a dam removal feasibility study of the Goldman Dam.

[15] Reference is made throughout this document relative to river-right or river-left. The right and left side of the river is based on looking in a downstream direction.

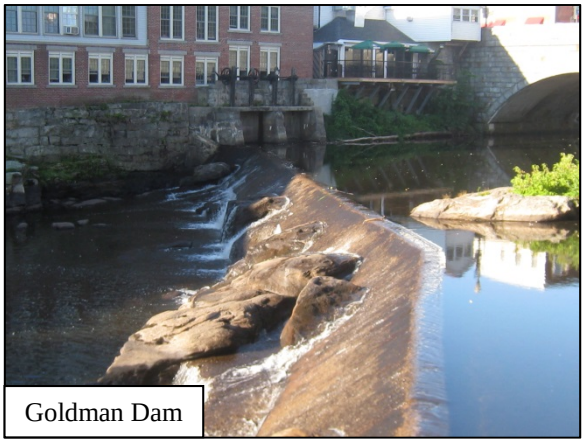
[16] An impoundment is that reach of a river that is "backed up" or "pooled" due to the presence of a dam.

Dams

The McLane Dam currently consists of an L-shaped (in plan view) spillway along with three stoplog[17] bays on river-left. Removal of the stoplogs permits lowering of the impoundment level. The latest dam rebuild occurred in 1992, when hydropower was considered, but never materialized due to poor economics. McLane Dam was historically utilized to support the manufacture of furniture at the McLane Furniture Mill.

McLane Dam

Approximately 1,270 feet upstream from McLane Dam is the Goldman Dam. The dam currently consists of an angled spillway and a single stop log bay on river-left equipped with stoplogs to permit lowering of the impoundment. Historically, two sluice gates on river-right allowed water to flow into the former Milford Cotton and Woolen Manufacturing Corporation; however, these gates are no longer functional.



Goldman Dam

1.2 Purpose of Feasibility Study

The town and Helen Goodwin Estate opted to consider the feasibility of removing both dams for the following reasons (in no particular order):

- In recent years (April 2007, March 2010), Milford experienced floods of historic measure, with the most notable flooding occurring upstream of both dams. The Souhegan Valley Boys and Girls Club, located above Goldman Dam, and several buildings of workforce housing were heavily damaged in the April 2007 flood. These historic floods were costly to the town, businesses and residents. The town would like to determine if removing the dams would decrease flooding upstream of the dams.

- The NH Department of Environmental Services (NHDES) determined that the Souhegan River, in those reaches impounded by the two dams, have water quality issues significant enough to warrant action. Both impoundments are on the 2012 303(d)[18] list, meaning they do not meet state water quality standards. The McLane Dam impoundment reach is impaired for failure to support primary and secondary contact recreation for swimming due to Escherichia coli (*e.coli*). The Goldman Dam impoundment reach is impaired for failure to support aquatic life due to dissolved oxygen (DO) saturation and DO concentration. The town and NHDES would like to determine if removing the dams would improve water quality such that both reaches would meet their designated uses and be removed from the 303(d) list.

[17] Stoplogs are long rectangular timber beams or boards placed on top of each other and dropped into slots inside a weir, gate or channel causing the upstream water elevation to rise.
[18] 303(d) refers to Section 303 of the Clean Water Act of 1972.

- The dams are physical barriers to migratory and resident fish. The NH Fish and Game (NHFGD) National Oceanic and Atmospheric Administration (NOAA) and US Fish and Wildlife Service (USFWS) are working on revisions to the Anadromous Fish Restoration Program for the Merrimack River which will identify the management plans for several diadromous[19] fish species for the Souhegan River. Removing the dams would result in free-flowing conditions allowing diadromous and resident fish and aquatic organisms to move unimpeded throughout the Souhegan River and upstream tributaries. Removing the dams would create an additional six miles of free-flowing habitat between McLane Dam and the next upstream dam located in Wilton, NH as well as access to intervening tributaries.

- The cost to Milford taxpayers to complete this feasibility study was minimal. The town successfully applied for, and received, several federal and state grants to defray the bulk of the feasibility study costs.

In the end, the town and Helen Goodwin Estate would like to determine if the option of removing both dams is prudent, feasible, and cost-effective. It is important to understand that no decisions relative to removing or retaining these dams has been made; the town and Helen Goodwin Estate are only seeking information and facts at this juncture to make an informed decision.

This feasibility study evaluated the impacts of two alternatives- status quo conditions (meaning the McLane/Goldman Dams remain) and removal of both dams to the extent practicable. For both alternatives, the impacts on water quality, wetlands, wildlife, fisheries, recreation, cultural resources, infrastructure, flooding, and sediment[20] movement were evaluated. The impact of removing the Goldman Dam on the Fletcher's Paint Superfund site is also evaluated in this report.

In addition to assessing environmental impacts, a cultural resource assessment was conducted to determine if the dams are of historical significance and if dam removal could potentially impact archaeological resources. The cultural resource assessment, completed by Public Archaeological Laboratory (PAL), was completed as a stand-alone document and is appended to this document as Volume 3.

In addition to the impact analysis, order-of-magnitude cost estimates for retaining and removing both dams were developed to help inform the dam owners.

1.3 Project Partners

Project Partners, who actively participated in this feasibility study, whether financially or through technical assistance, included the United States Environmental Protection Agency (USEPA), NHDES, NOAA, United States Fish and Wildlife Service (USFWS), NH Charitable Foundation (NHCF), American Rivers (AR), Trout Unlimited (TU), and the town.

The feasibility study was performed by Gomez and Sullivan Engineers, P.C. (Gomez and Sullivan) in coordination with Hoyle, Tanner & Associates, Inc. (HTA), A & D Klumb Environmental, LLC (ADKE) and PAL.

[19] Diadromous fish include both anadromous and catadromous fish—collectively called migratory fish. Anadromous fish, such as river herring, and American shad spawn in freshwater and return to the ocean. Alternatively, catadromous fish, such as American eel, spawn in the ocean and migrate to freshwater.
[20] Sediment is commonly considered mud, silt, sand, gravel, cobble, or boulder— that sits on the river bed bottom.

1.4 Public Outreach

The town has, and continues to make, a concerted effort to educate and engage the public as part of this feasibility study. A contact list (see Appendix A[21]) was developed early-on to facilitate communications and was updated to notify parties of public meeting dates. The following public meetings were held at the onset of the project, with the goal of explaining the purpose of the study and to solicit public input prior to conducting any work:

- An evening meeting was held at the Milford Town Hall on August 16, 2010.
- An evening meeting was held at the Granite Square Apartments on August 17, 2010.
- An afternoon meeting was held at the Milford Mill Apartments on August 23, 2010.

In advance of the public meeting, parties on the contact list were notified via letter and were encouraged to attend the meeting and ask questions. Meeting notifications were also posted on the town's website[22]. Additionally, the August 16, 2010 presentation was recorded by the town for playback on the local cable access channel.

The presentation offered at the public meeting was virtually the same as the presentation at the two apartment complexes. Prior to the meetings with the Milford Mill and Granite Square apartment residents, flyers were distributed under each door notifying residents of the meeting purpose, time, and location. Because of the number of residents and close proximity of these apartment complexes to the dams/impoundments, the town felt that meetings directly with these residents were warranted. After each presentation, a question and answer session was held.

Between the initial public outreach meetings and publication of the Draft Feasibility Report the project was in a holding pattern for roughly 1.5 years while issues pertaining to the management of Goldman Dam sediments associated with the USEPA Fletcher's Paint Superfund site were assessed further. Throughout the study period, the town and Project Partners have consulted with USEPA, NHDES and NOAA as these three regulators have a long history with the Fletcher's Paint Superfund site. As of this publication, the USEPA has preliminarily identified three alternatives for addressing Goldman Dam sediments, although a preferred alternative has not been selected. Given this, rather than further delaying completion of this Final Feasibility Report, Gomez and Sullivan has proposed a sediment management plan for both dams based on reviewing the data.

Similar to the initial outreach meetings, a public meeting was held on September 10, 2014 to review the Draft Feasibility Report. As before, parties on the contact list were sent letters notifying them of where the report was available (electronically on the town's website and paper copies at the town library and town office) and the date, time, and location of the September 10, 2014 public meeting. A presentation was provided on the findings of the report and a question and answer session was held after the presentation. It was requested at the meeting that written comments on the Draft Feasibility Report be submitted by September 30, 2014. Written comments are included in Appendix M of this Final Feasibility Report. At this juncture, it is up to town, taxpayers, and the Helen Goodwin Estate to determine, what, if any, steps are taken relative to the dams.

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[21] The list was updated in February 2014 given that years had elapsed between the introductory meetings in August 2010.

[22] The towns' website has link dedicated to the dam removal feasibility study. See the following weblink: http://www.milford.nh.gov/departments/community-development/active-projects/dam-feasibility-removal-study

1.5 Report Format and Survey Datum

Report Format

This report consists of three volumes. Volume 1 contains text and smaller tables. Volume 2 contains all of the figures, larger tables and the appendices. Volume 3 contains correspondence with the New Hampshire Division of Historic Resources as well as PAL's cultural resource assessment entitled "*McLane & Goldman Dams Removal and River Restoration Feasibility Study, Phase IA Archaeological Sensitivity Survey Results, Summary Report*".

Survey Datum

As described later, a survey of the dams and other infrastructure was conducted as part of this study. The vertical control of the survey is based on the North American Vertical Datum (NAVD) of 1988 (NAVD 88). All elevations reported herein are based on NAVD88, unless otherwise noted. The horizontal control of the survey is based on NH state plane coordinates.

2.0 Souhegan River Watershed

2.1 Basin Description

The Souhegan River originates in the town of Ashburnham, MA and flows in a northeasterly direction approximately 17 miles until it turns easterly in the town of Wilton, NH before flowing another approximate 17 miles to the Merrimack River. The south and west branches of the Souhegan Rivers converge in New Ipswich, forming its headwaters. The approximate 34-mile river flows through the NH communities of New Ipswich, Greenville, Wilton, Milford, Amherst and Merrimack before discharging into the Merrimack River. The drainage area of the entire Souhegan River basin is approximately 220 mi^2.

Figure 2.1-1 is a land use map depicting the forested, wetlands, developed, and other land uses within the watershed. The upper portions of the watershed in New Ipswich, Greenville and Wilton are relatively undeveloped, heavily forested and have considerable wetlands. Urbanization increases in close proximity to the Souhegan River in the communities of Milford, Amherst and Merrimack where more concentrated business centers are located.

Bedrock in the basin consists of hard crystalline Paleozoic rock. Soils are composed of variable, unstratified, silty, gravelly sand and clays with interspersed cobbles and boulders. General soil conditions are acidic, stony and thin to bedrock. The geology of the Souhegan River corridor provides many of the communities with their only source of public water supplies. The stratified drift aquifers that follow the river corridor provide a source of high quality/high quantity drinking water used for public supplies by the towns of Merrimack, Milford and Wilton. Milford's primary water supply consists of three gravel packed wells, known as the Curtis Wells, located in southwestern Amherst.

The topography of the watershed varies considerably from flat floodplains in the east to rolling hills and steep slopes in the west. Watershed elevations range from a high of 2,280 feet at the summit of Pack Monadnock in Peterborough and 2,276 feet at the summit of North Pack Monadnock in Greenfield to roughly 100 feet at the confluence of the Souhegan and Merrimack Rivers in Merrimack. In its 34 miles, the river drops approximately 850 feet from New Ipswich (950 feet) to Merrimack (100 feet) an average drop of 25 feet per mile. Major drops in river gradient are concentrated in rapids within Greenville, Wilton and Merrimack.

Site 35 Flood Control Dam

Numerous dams are located on the Souhegan River mainstem as shown in Figure 2.1-2. The majority of dams are concentrated in the upper portions of the basin, where the river gradient was harnessed to power various historic mills. Many dams, once an integral component of the industrial revolution, are now abandoned and serve no useful purpose, although a few functioning hydropower facilities currently operate. In addition to the mainstem dams, numerous other dams are located on tributaries including 12 state-operated flood control facilities designed to reduce and attenuate floods- a picture of the Site 35 flood control facility is shown in the inset. The flood control facilities came on-line in the late 1960s and early 1970s to reduce peak flows in the Souhegan River. If not for these flood control dams located upstream of Milford, the 2007 and 2010 floods would have been worse in Milford.

The McLane and Goldman Dams have a drainage area of approximately 139 mi^2; there is little meaningful inflow between the two dams. If the McLane and Goldman Dams were removed, it would

create an approximate six miles of free-flowing river as measured from McLane Dam to the next upstream barrier, Pine Valley Hydroelectric Project Dam located in Wilton, NH (drainage area= 101 mi^2). As noted later, the Goldman and McLane Dams provide no flood protection as impoundments do not contain capacity to "store" water like the flood control dams located in basin; in fact, the dams raise the water surface elevation above the dams.

The Souhegan River is one of several rivers designated by the NHDES to establish long-term instream flows for protection of fish, wetlands, wildlife, recreation and a host of other resources. An instream flow evaluation was conducted on the Souhegan River to establish future protected instream flows. A final report, entitled *Final Souhegan River Protected Instream Flow Report*, was completed in 2008. The study resulted in developing protected instream flows for environmental and recreational purposes, while requiring changes in the amount and timing of water supply withdrawals if river flows fell below protected levels.

3.0 Project Features and Operation

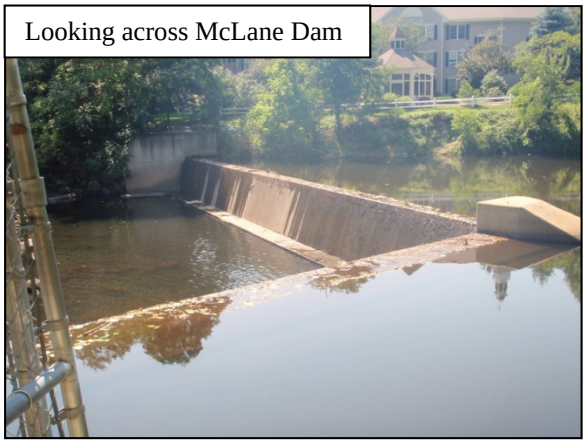
This section includes a description of the main features in the Project area starting at McLane Dam and continuing upstream to the upstream extent of the Goldman Impoundment located near the Gregg Crossing Footbridge. A Project area map denoting the key features described below is shown in Figure 1.1-3. Appendix B contains several numbered photographs, which are referenced throughout this section as well as the entire report.

3.1 McLane Dam

Dam Features and Project Operation

The town-owned McLane Dam, a stone concrete gravity structure reconstructed in 1992[23], is L-shaped in a downstream direction. The dam consists of a spillway and three stoplog bays. L-shaped spillways are typically constructed to increase the dam's spillway capacity as the amount of water passing over the spillway is directly related to the spillway's length- the longer the spillway, the more water it can convey downstream. The total spillway length is 178.7 feet-long; the western section is 116.9 feet-long and the eastern section is 61.8 feet-long foot. Photos of McLane Dam are shown in Appendix B (photos 13-21).

Looking across McLane Dam



There are three 6.5 feet-wide by 12 foot-high stoplog bays fitted with stoplogs (Appendix B, photo 18). The town permanently removed the stoplogs in 2011 such that during low flow periods flows all flow is passed through the opening and water level drops below the spillway crest elevation. In fact, during the 2010 summer, inflows were exceptionally low and the spillway was dry (see photo inset above) as leakage through the stoplogs exceeded inflow. Since 2011, the town has removed the majority of stoplogs and under low flows all water is passed through the stoplog opening. As shown in Appendix B, photo 18, debris can become lodged against the stoplog openings requiring the town to clear the opening as needed.

The spillway crest elevation is 230.6 feet; the approximate dam height is 18 feet, but it varies across the structure with the underlying topography. The sill elevation of the stoplog bays is 225.2 feet, thus the water level can be drawn down 5.4 feet if the stoplogs are removed and inflow is conveyed through the bays. However, although the sill elevation is at 225.2 feet, there is a build-up of cobble upstream of the stoplog opening (based on July 26, 2012 observations), thus the impoundment cannot be lowered to the sill elevation unless the build-up is cleared.

Note that in 1998, the USFWS developed conceptual plans for downstream fish passage at McLane Dam to pass salmon smolts. It appears that a portion of the downstream fish passage facilities were developed, but never completed. As described later in this section, when hydropower was being contemplated at the McLane Dam in 2009, the USFWS and NHFGD indicated that they would require functioning upstream and downstream fish passage facilities at the dam.

Based on Geographic Information System (GIS) mapping, the McLane Dam creates an approximate 3.4-

[23] A dam has been at this site since approximately 1846.

acre impoundment. Based on bathymetric mapping, the gross storage capacity is approximately 17.1 acre-feet at the spillway crest. The water level impounded by McLane Dam backwaters to just below the Goldman Dam, but varies pending the magnitude of river flow.

Shown in Figures 3.1-1 is a plan map of McLane Dam and Goldman Dam. Shown in Figure 3.1-2 is plan map and cross-sections of McLane Dam based on a 2010 survey. Appendix C includes all of the computer aided design (CAD) drawings obtained from Meridian Land Services, Inc, the consulting company who designed the dam rebuild in 1992[24].

The McLane Dam is operated as a run-of-river facility, whereby inflow equals outflow on a near continuous basis, meaning water levels behind the dam are typically maintained at the spillway crest elevation or higher as inflow increases. If, for example, inflow to the dam was 30 cubic feet per second (cfs), then the discharge over the spillway would be approximately 30 cfs; no water is "stored" behind the dam. Only during floods, when the magnitude of inflow exceeds the discharge capacity of the spillway, does water start backing up behind the dam—as experienced in the April 2007 and March 2010 floods.

The McLane Dam provides no flood protection; it cannot store inflow like a United States Army Corps of Engineers (USACOE) Flood Control Dam or one of the many flood control reservoirs in the Souhegan River Basin. In fact, the McLane Dam actually contributes to flooding as it creates an approximate 18-foot high wall in the river, which backs up water. Removing McLane Dam would not change the magnitude and timing of flow passing below the dam. In other words, removing the dam will reduce the width and depth of the river previously above the dam, but will not "dry up" the river.

Hazard Classification and Letter of Deficiency

Per the NHDES, the hazard classification of McLane Dam is Class A or "low". Per the NHDES Dam Safety Guidelines a "Class A structure" is a dam that has a low hazard potential because it is in a location and of a size that failure or mis-operation of the dam would result in any of the following (NHDES Dam Safety Regulations, Env-Wr 101.07):

- No probable loss of life;
- Low economic loss to structures or property;
- Structural damage to a town or city road or private road accessing property other than the dam owner's which could render the road impassable or otherwise interrupt public safety services;
- The release of liquid industrial, agricultural, or commercial wastes, septage, or contaminated sediment if the storage capacity is less than 2 acre-feet and is located more than 250 feet from a water body or water course, or;
- Reversible environmental losses to environmentally-sensitive sites.

On April 8, 2009, the NHDES inspected McLane Dam. On June 12, 2009, NHDES issued the town a *Letter of Deficiency* (LOD) (see Appendix D for correspondence), indicating that the following issues should be addressed:

- Complete an operation, maintenance and response plan;
- Replace the boards on the stoplog bay walkway;

[24] The 1992 drawings are not as-built (post construction) drawings. Survey of the dam was conducted in 2010. The surveyed spillway crest elevation was 230.6 feet, whereas the design drawings in Appendix C list the spillway crest elevation at 230.4 feet. For purposes of this report, we relied on the 2010 survey as it reflects post construction elevation data. In addition, the vertical datum used for the 1992 drawings was not shown on the drawings.

- Add material (stone or loam and seed) to bring the right and left embankments level with the spillway training walls.

According to the NHDES, the town has addressed the deficiencies, but NHDES has not performed a follow-up inspection. NHDES does not plan on visiting the dam again until the next regular inspection in 2015. In short, the dam is in good condition given that it was rehabilitated in 1992.

Hydropower Development

In the late 1980's Northeast Hydrodevelopment Corporation (NHC) received a license through the Federal Energy Regulatory Commission (FERC) to construct, operate, and maintain a hydropower facility at the McLane Dam. To complete the project, NHC needed to reconstruct the dam and construct a new powerhouse adjacent to the dam that would house two turbines. In 1992, the dam, abutments, and stoplog structure was rehabilitated. However, due to poor economics, the powerhouse was never constructed. In 1997, NHC filed a request to surrender the FERC license, which was approved by the FERC in 1999. No further work was conducted after 1999.

In March 2009, the same hydropower developer, NHC, filed for a preliminary permit with the FERC to once again consider adding a powerhouse with turbines adjacent to the McLane Dam. FERC granted NHC a preliminary permit, which granted NHC the exclusive right to study the economic feasibility of installing hydropower at the site. As part of the permit, NHC was required to demonstrate progress relative to conducting the feasibility study and consulting with the federal and state resource agencies to identify studies needed to evaluate the impact of the proposed hydropower development on environmental, recreational and cultural resources. FERC's preliminary permit required NHC to file progress reports every six months throughout the 3-year permit period to ensure they were making progress. NHC filed with the FERC untimely progress reports, and demonstrated no substantive progress. After FERC issued NHC numerous warnings about the lateness of the progress report and lack of demonstrated progress, they revoked the preliminary permit from NHC.

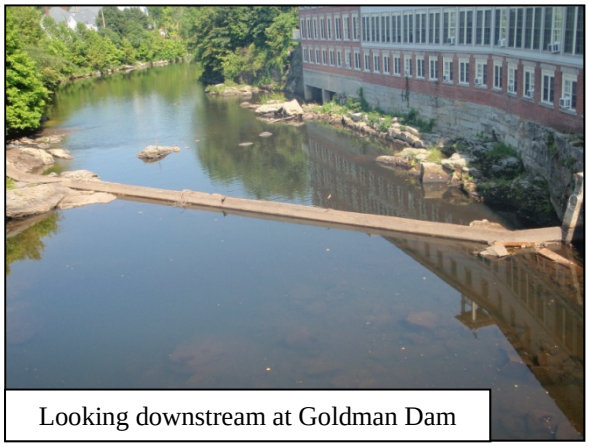
The town closely followed the preliminary permit proceeding. In fact, the town questioned the economic viability of constructing hydropower at the McLane Dam. Under a separate contract, Gomez and Sullivan conducted a cursory feasibility study[25] to determine if hydropower was economical. In short, the study found that it was uneconomical to construct, operate and maintain hydropower facilities at the McLane Dam as the cost of developing the facility exceeded the value of power it would deliver.

Hydropower generation is a function of the vertical drop in water (called "head") and the magnitude of flow. The vertical drop in water at McLane Dam is greater than at the Goldman Dam. Based on this, it is logical to conclude that Goldman Dam would also not be a candidate for economical hydropower development.

[25] The feasibility report, entitled *Pre-Feasibility Evaluation for Hydropower Development of McLane Dam*, was transmitted via a June 22, 2009 letter to the town of Milford. It is available at the following weblink: http://www.milford.nh.gov/departments/community-development/active-projects/dam-feasibility-removal-study.

3.2 Goldman Dam

Dam Features and Project Operation



Looking downstream at Goldman Dam

Goldman Dam (Appendix B, Photos 28-35) is a concrete gravity type dam angled in a downstream direction. It includes an approximate 173-foot long overflow spillway and a sluiceway equipped with stoplogs on river-left. The stoplogs were permanently removed by the town in 2011.

The spillway crest is at elevation 235.5 feet. The invert elevation of the sluiceway (photo 34) is 231.1 feet, thus with the stoplogs removed the water level could be drawn down by approximately 4.4 feet. The sluiceway width is approximately 3.5 feet wide. Note that over time the downstream side of the sluiceway opening has filled with sediment. This material would require removal to maximize the drawdown of the impoundment level to the sluiceway invert elevation.

There are no drawings showing the two sluice gates (photo 31) that previously controlled flow into the mill on river-right. The two timber sluice gates, 9 feet wide and 8.5 feet high, are no longer functional.

Shown in Figure 3.1-1 is a plan map of McLane and Goldman Dams. Shown in Figure 3.2-1 is a plan map and cross-sections of Goldman Dam based on a 2010 survey. In addition, 1964 drawings of the dam were obtained from NHDES files (see Figures 3.2-2, 3.2-3, 3.2-4, and 3.2-5), showing the dam secured to the underlying bedrock with dowel pins set every 4 feet on center. The vertical elevation shown on these drawings is based on an assumed datum of 100 feet. Assuming the spillway crest elevation has not changed since these 1964 drawings, the elevations on the older drawings can be adjusted relative to the 2010 surveyed spillway crest elevation of 235.5 feet. Figure 3.2-5 shows 15 equally spaced cross-sections of the dam. The cross-sections appear to match those obtained during the 2010 survey. The 1964 drawings also shows the location of bedrock beneath the dam, which will be used to simulate the native channel bed in the hydraulic model (described later) absent Goldman Dam.

Based on Figure 3.2-4, the spillway height varies from as low as 0.5 feet near the center of the spillway to as much as 6 feet near the southern abutment. The low spillway height near the center of the dam is the result of higher bedrock in this area.

Based on GIS mapping calculations, the Goldman Dam creates an approximate 7.2-acre impoundment. Based on the bathymetric mapping, the gross storage capacity of the reservoir is approximately 21.3 acre-feet at the spillway crest elevation. The water level impounded by Goldman Dam creates a backwater extending upstream to at least the Gregg Crossing Footbridge located near the Keyes Memorial Park. The upstream extent of the backwater varies depending on the magnitude of flow- the higher the flow the impoundment backwaters further upstream.

Similar to McLane Dam, Goldman Dam is operated as a run-of-river facility, whereby inflow equals outflow on a near continuous basis, meaning water levels behind the dam are maintained at the spillway crest elevation or higher as inflow increases. Also, like McLane Dam, the Goldman Dam does not provide any flood protection as it cannot “store” water. Instead the dam contributes to flooding. Removal of the Goldman Dam would have no impact on the timing and magnitude river flows; however, the river width and depth upstream of the dam would decrease.

Hazard Classification and Letter of Deficiency

On April 30, 2012, NHDES conducted a site inspection of Goldman Dam and sent their findings in a *Notice of Inspection* (NOI) to the Helen Goodwin Estate via letter dated March 11, 2013 (Appendix D). The inspector noted the following items:

- Debris was observed near the center of the spillway;
- Minor brush and trees were observed within 15 feet of the left abutment; and
- Submit an Operation, Maintenance and Response (OMR) form.

In the March 11, 2013 letter, NHDES stated the following: "*Since these items do not materially detract from the dam's structurally integrity or operability at this time, DES has established no schedule for you to address them nor does it intend to visit your dam again until the next scheduled inspection which is scheduled to occur in 2018. We do, however, urge you to continue to monitor, maintain and operate your dam in accordance with the OMR plan which DES recommends that you develop*".

Also, on March 11, 2013, NHDES sent the town a letter (Appendix D) regarding the classification and regulation of the Goldman Dam. NHDES noted the following relative to hazard classification of Goldman Dam:

DES generally regulates dams based on the hazard they pose to downstream lives, structures and properties in the event of a failure. Dams with no recognized downstream impacts are typically classified as non-menace structures unless they fall outside the criteria of Env-Wr 101.06(a) or (b), below. DES deems dams that exceed these criteria as structures that warrant routine review to ensure that any changes that occur along their downstream reaches are periodically evaluated.

> *Env-Wr 101.06 "Class AA structure" means a dam that is not a menace because it is in a location and of a size that failure or misoperation of the dam would not result in probable loss of life or loss to property, provided the dam is:*
>
> *(a) Less than 6 feet in height if it has a storage capacity greater than 50 acre-feet; or*
>
> *(b) Less than 25 feet in height if it has a storage capacity of 15 to 50 acre-feet.*

The Goldman Dam has a maximum height and storage capacity of 6 feet and 112 acre-feet, respectively, and is therefore a low hazard potential dam even though there are no currently recognized hazards downstream of the dam. DES currently regulates dams such as the Goldman Dam, which are low hazard only by Env-Wr 101.06 (a) or (b), as non-menace structures with the exception that these dams are inspected every 6 years and an Annual Dam Registration Fee (ADRF) of $400 is collected. Following the periodic inspection a Notice of Inspection is issued describing the deficiencies DES observes and making recommendations for action; however, these are recommendations only and formal proceedings for compliance are not pursued.

In the case of the Goldman Dam in Milford, due to the relatively low height of the dam and its location in a well-defined river channel where future development is unlikely, dam breach risks are minimized. In addition, based on the nature, location and physically [sic] characteristics of the dam and adjacent mill building foundation at the right abutment, DES does not believe impacts to the building are probable.

With no existing hazard potential and no likely development in the downstream reach, regulation of this jurisdictional dam will likely remain minimal. However, if the downstream reach changes such that a potential hazard is recognized in the future, the regulation of the dam would change to match that of the

appropriate revised hazard classification and physical repairs, maintenance and/or engineering studies would likely be required. In addition, future changes to the statutes and/or administrative rules regulating dams in New Hampshire could result in changes to the way this dam is regulated, though no such changes are currently envisioned.

Based on our observations of the dam when the structure was exposed/visible, we noticed undermining occurring (see photo inset) on the downstream side of the dam. No slumping or settling of the dam was observed.

There is an important distinction between receiving a LOD as issued for McLane Dam versus a NOI as issued for Goldman Dam. In the LOD, the dam owner is responsible for addressing the deficiencies. In the NOI, the dam owner is not mandated to address issues identified during the inspection, thus there is no financial obligation.

As noted above, the Goldman Dam is owned by the Helen Goodwin Estate, which is held by a college student in New Mexico having no financial means to operate and maintain Goldman Dam. The NHDES Dam Bureau has clarified that because the orphaned dam is technically owned by another party, the town of Milford has no legal or financial responsibility to operate or maintain Goldman Dam.

3.3 Water and Sewer Line Infrastructure

The Milford Department of Public Works (DPW) was contacted to determine if there is any sewer or water lines located in the proximity of the dams or in the impounded reaches that could be impacted if the dams were removed. The DPW provided information on sewer/water lines traversing the impounded reaches, as removal of the dams could potentially scour the channel bed. If the dams were removed, water velocities in the former impoundment will increase resulting in the potential of increased scour on the channel bed. The concern would be if the channel bed scours too much, it could potentially leave the sewer/water line exposed.

Per the DPW, there are three sewer lines and two water lines in the Project area traversing the Souhegan River, which are described below starting at McLane Dam and working upstream. The location of all sewer/water lines in the project area are shown in Figure 1.1-3. All figures showing plan and profiles of the sewer/water lines were provided by DPW. Per the DPW, all profile drawings of the sewer/water lines referenced below are based on the NAVD88 survey datum. It is not clear from the drawings if they represent as-built or design drawings.

<u>Sewer Line 1</u>: Figure 3.3-1 (plan) and 3.3-2 (profile) shows a 36-inch reinforced concrete sewer pipe traversing the Souhegan River below the McLane Dam. Because of the proximity of the sewer line, it is not expected that access routes and/or disturbance areas associated with a potential dam removal would impact this sewer line.

<u>Sewer Line 2</u>: Figure 3.3-3 (plan) and 3.3-4 (profile) shows a 30-inch ductile iron pipe (DIP) traversing the McLane impoundment between Amherst Street and Bridge Street. According to the profile drawing, the channel bed along the sewer line is lined with six (6) inch crushed stone, and the DIP is encased with 6 inches of concrete. In addition, the channel bed and the overbank areas leading to the manhole are lined with riprap.

Water Line 1: The DPW has no surveyed plan or profile of the water line traversing the Goldman Dam impoundment behind the Masonic Temple (location shown in Figure 1.1-3). This water line is not buried below the channel bed; rather it sits on the channel bed. In fact, when the Goldman Dam water levels were purposely lowered in the summer 2010, the water line became exposed (see insets). This water line could potentially be displaced due to an ice jam floe or undermining of sediment beneath the pipe. It is recommended that this pipe be buried, regardless of whether the Goldman Dam is removed. In our cost estimate for the Goldman Dam removal provided later in this document we did not account for protection of this water line from potential scour as it should be protected under current conditions.

Water Line 1 behind Masonic Temple

Sewer Line 3: Figure 3.3-5 (plan) and 3.3-6 (profile) shows a 30-inch reinforced concrete sewer pipe traversing the Souhegan River just downstream of the Gregg Crossing Footbridge near Keyes Memorial Field (note that the plan view does not show the Gregg Crossing Footbridge as this was constructed after the sewer line was installed). According to the profile drawing, the channel bed along the sewer line is lined with 6-inch crushed stone, and the DIP is encased with 6 inches of concrete. In addition, the channel bed and the overbank areas leading to the manhole are lined with riprap.

Water Line 2: Figure 3.3-5 (plan) and 3.3-6 (profile) shows a "proposed" 10-inch DIP traversing the Souhegan River at the Gregg Crossing Footbridge near Keyes Memorial Field. Note that these drawings are described as "proposed", but the water line was eventually installed. No as-built drawings were provided.

3.4 Other Infrastructure

If the dams were removed, the impact on infrastructure needs to be evaluated as the river hydraulics (depth, width, and velocity) in the former impounded reaches would change. With the dam's in-place the river's speed (velocity) above the dams is reduced, depth is greater, and channel width is wider. If the dams are removed, the impounded reaches would revert back to free-flowing conditions, with river velocity increasing, and depth/width decreasing. This change in river hydraulics could impact existing infrastructure. Of specific concern is the potential of increased scour (erosion of sediments) due to a faster moving and shallower river. Below is a brief description of infrastructure in the Project area. Later in this report are a) a baseline inventory of the existing infrastructure in the vicinity of Goldman Dam and b) an evaluation of the potential impacts on infrastructure if the dams were removed.

Swinging Bridge

Approximately 170 feet upstream of McLane Dam is the Swinging Bridge, a footpath spanning the river. The first foot bridge at the site of the present Swinging Bridge was built in 1850, connecting Souhegan Street with Maple Street, now Bridge Street. The present iron bridge was built in 1889. As noted in the town's history, a dam was formerly located at the location of the Swinging Bridge, which appears reasonable as

Looking downstream at Swinging Bridge

there is a bedrock shelf present beneath the bridge. The bridge is set on elevated stone abutments placed above the water line and thus is not likely to be impacted if the McLane Dam was removed.

Riverbank Armoring

On the river-left bank from Goldman Dam downstream to where the river veers to the right (the reach running parallel to Grove Street), the bank is heavily armored with large granite blocks. In some areas (see photo inset), the granite blocks are stacked vertically creating a wall. However, the majority of the river bank is armored with granite blocks laid in-line with the steep bank slope extending from Souhegan Street to the river.

Riverbank Armoring below Goldman Dam

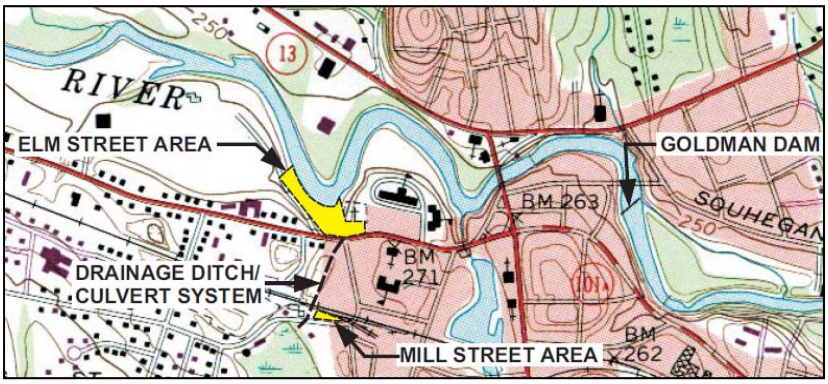
Foundations/Route 13 Bridge

On river-right, the foundation of the Milford Mill Apartment complex extends vertically in the Souhegan River from approximately the Route 13 Bridge downstream- the foundation essentially serves as the river-right "bank". Also on river-right is a continuous foundation wall of different vintage and materials extending vertically in the Souhegan River from the Route 13 Bridge upstream.

The town-owned Route 13 Bridge spans the Souhegan River and is located approximately 135 feet upstream of Goldman Dam. The stone bridge includes a center pier and abutments; it was originally constructed in 1846 and subsequently widened in 1931.

A separate assessment of the foundations and Route 13 Bridge is provided in Section 4.0 of this report.

Fletcher's Paint Superfund Site

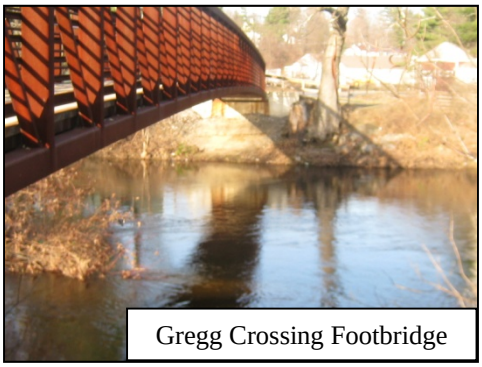


Although not considered "infrastructure" it is important to note that the Fletcher's Paint Superfund site is located approximately 2,200 feet upstream of the Route 13 Bridge (see inset), within the Goldman Dam impoundment. From 1949 until 1990, Fletcher's Paint Works manufactured oil-base and latex paints and stains, and engaged in other chemical processing activities. The Fletcher's Paint Works Site included the following areas: 1) the Paint Works Plant on Elm Street, 2) a former storage facility on Mill Street, and 3) a drainage ditch that ran from the Mill Street facility through the Paint Works and into the Souhegan River. In 1985, the USEPA discovered volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs) and heavy metals in the soils near the plant and in the Souhegan River sediments. High levels of PCBs were also detected in the soils around the paint storage building.

As part of this study, a summary of past sediment sampling within the impounded reach from approximately Goldman Dam to the Gregg Crossing Footbridge is provided.

Gregg Crossing Footbridge

The Gregg Crossing Footbridge, installed in November 2004, spans the Souhegan River near Keyes Memorial Field. It is a pre-cast structure set on elevated abutments above the water line.



Gregg Crossing Footbridge

4.0 Route 13 Bridge and Foundations

On August 18, 2010 two representatives of HTA visited the Route 13 Bridge (New Hampshire Department of Transportation, NHDOT Bridge No. 123/133) as well as the area immediately upstream and downstream of the bridge. The purpose of the site visit was to gather field data as part of an evaluation of potential effects of removing the Goldman and McLane Dams on the Route 13 Bridge and foundations. Access was on foot using waders; the water level was very low due to summer low flows and no stop logs in place.

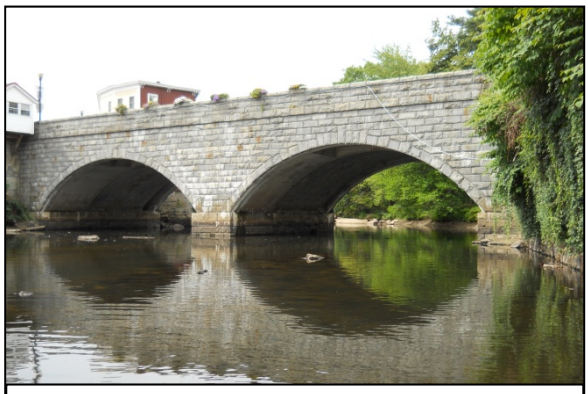
The physical limits of the inspection were from approximately 120 feet upstream of the Route 13 Bridge to 180 feet downstream between river banks. Only visual observations were included as parts of HTAs evaluation; no structural calculations or testing were completed. Additionally, the inspection did not include any underwater observations. For purposes of this section, north is considered to be along Route 13 towards Amherst Street with the Souhegan River flowing west to east. HTAs findings are discussed first as they relate to the Route 13 Bridge and then by quadrant.

In preparation of this study section, HTA relied upon the following information:

- "*Geophysical Seismic Refraction Testing of Bridge Foundation Conditions for NHDOT Scour Project; Bridge 123/133; NH Route 13 over Souhegan River; Milford, NH; Prepared for CHA Inc.; October 2009*" by NDT Corporation.
- NHDOT Bridge Inspection Report of 8/5/2009 and file correspondence.
- State of New Hampshire Highway Department Plan of "*Proposed Trunk Line Bridge 1931; Town of Milford over Souhegan River on Baboosic Road in the Village*" dated 2-9-31.
- Gomez and Sullivan Engineers, P.C. Memo dated August 9, 2010 Re: Wamser summary notes and photograph log from August 4, 2010 inspection of the McLane/Goldman Dam Project Area.

4.1 Route 13 Bridge over the Souhegan River

The Route 13 Bridge, also known as the Colonel John Shepard Bridge, is a two span masonry arch with reinforced concrete sections carrying two lanes of traffic and two sidewalks over the Souhegan River. The bridge was built in 1846 and subsequently widened in 1931 to create a two lane bridge- the widened section is on the downstream side of the bridge. The bridge consists of two abutments and a center pier. The NHDOT lists the condition of the deck and superstructure as 'Fair' and the substructure as 'Good', with the bridge not being listed on the NHDOT Red List[26]. The bridge is currently posted 'E-2' which

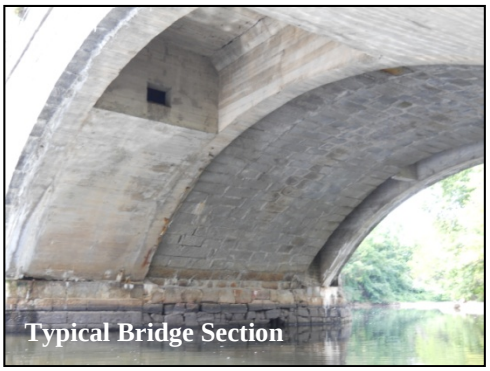


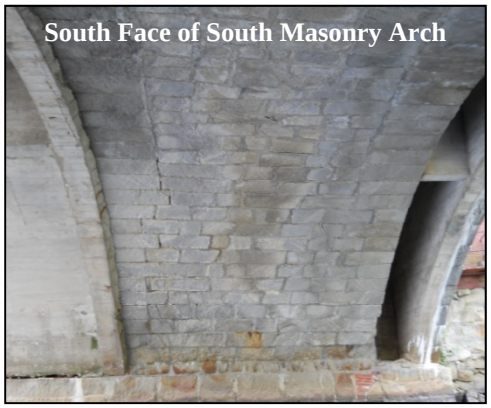
Looking upstream (west) at Route 13 Bridge

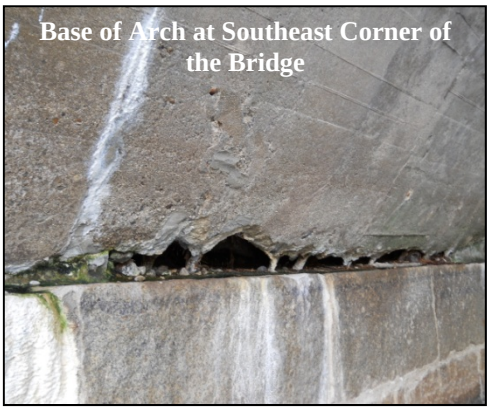
Route 13 Bridge looking south

[26] State owned bridges on the red list require interim inspections due to known deficiencies, poor conditions, weight restrictions, or type of construction. These structures are inspected twice yearly.

excludes all combination and single unit certified vehicles from crossing the bridge.


Typical Bridge Section


South Face of South Masonry Arch


Base of Arch at Southeast Corner of the Bridge

The bridge typical section consists of two reinforced concrete arch ribs and reinforced concrete deck for the downstream portion, a middle section of dry-laid, partially pointed masonry, and an upstream portion of a reinforced concrete arch rib and reinforced concrete deck. Both the upstream and downstream elevations of the bridge consist of dry-laid stone fascias (face).

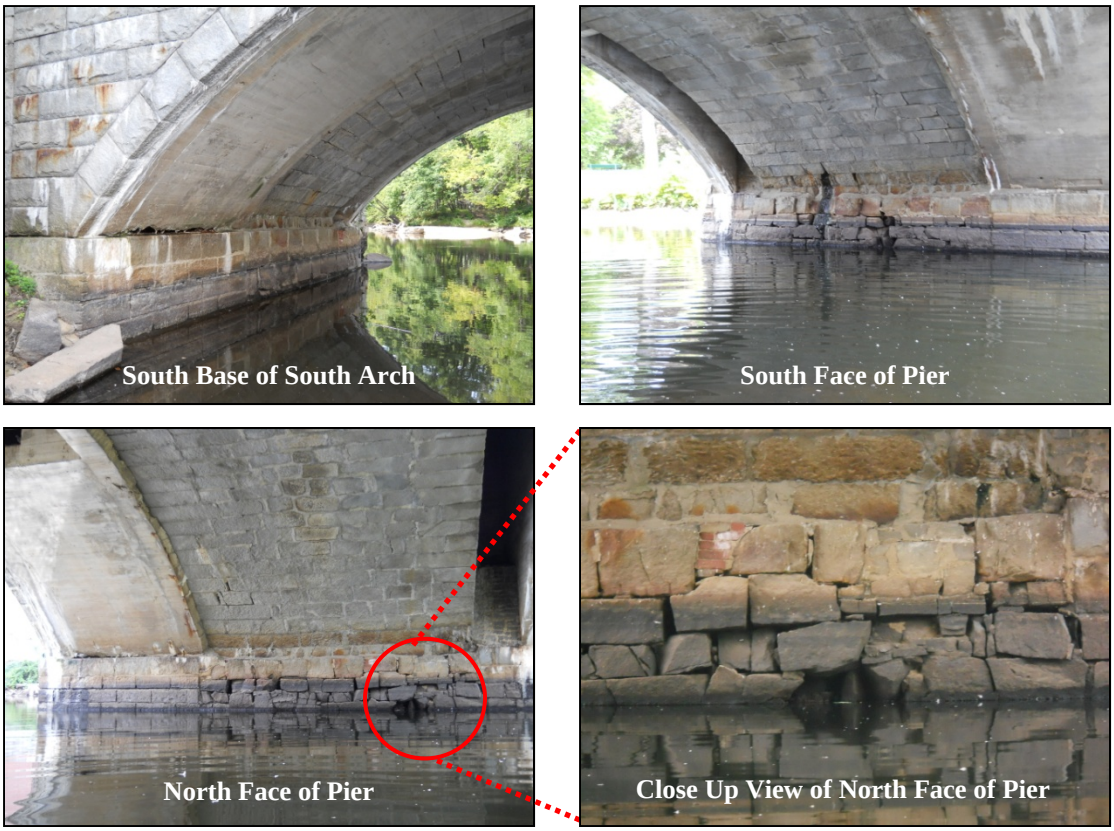
The overall condition of the bridge is fair to good with some small portions in poor condition. The masonry arches and bridge fascias are in good condition with cracking of the arch stones noted in both spans. The reinforced concrete sections of the bridge are in fair to poor condition with cracking, sections of exposed reinforcing and laitenance[27] or efflorescence[28] throughout. A portion of the reinforced concrete arch base at the southeast corner of the bridge (see lowermost inset) has been damaged exposing reinforcing that attaches the arch to the stone base. HTA speculates that the damage in this area may be from river/ice action.

The visible portions of the arch footings are in good to fair condition. The arch footings at the north and south abutments are generally in good condition and consist of larger, rectangular shaped stones. There are few cracks and very few voids in these portions of the bridge. The pier base consists of dry-laid stone, however, the size and shape of the stone varies over its length. The upstream and downstream ends of the pier consist of the same type of stone as in the arch bases at the abutments; however the middle portion of the pier long face consists of smaller stones of various sizes. This change in stone type may correspond to a stepped footing noted by NDT Corporation/Clough Harbor and Associates (NDT/CHA). The middle portion has several stones with poor bearing and missing stones. It has also been previously repaired with metal dogs and brick. Despite the fair condition of the middle portion of the pier, there does not appear to be any evidence of settlement or bulging of the pier base.

According to the 1931 bridge plan, the bottom of the bridge footings were to be between 5 to 10 feet below existing grade with a note indicating "*Footings to be carried to firm foundation*." During HTAs site inspection they walked along the inside face of each abutment and the south face of the pier in waders. The river bottom along the base of the wall was flat with some areas of stone fill. No scour holes or voids were noted during their visual inspection.

[27] Laitenance- a residue of weak and non-durable material consisting of cement, aggregate, fines or impurities brought to the surface of concrete.

[28] Efflorescence is the usual terms for deposit of soluble salts, formed in or near the surface of a porous material, as a result of evaporation of water in which they have been dissolved. It is the white powdery material on the surface of the concrete as shown in lowermost photo.



The NHDOT inspection report provided ratings on a scale of 1 (bad) to 9 (good) for the substructure (7), channel stability (7), hydraulic adequacy (8), and scour (3). Given the low rating on the scour, a geophysical study was conducted.

In October 2009, a geophysical refraction study of the bridge was performed by NDT Corporation to further evaluate the scour rating of 3. The seismic refraction study included obtaining geophysical information along transect lines as shown in Figure 4.1-1. NDT reported that the abutments and pier have a high probability of being partially founded on bedrock. It was noted that rock elevations are fairly flat throughout the site and it is assumed the footings would have been constructed on rock given the downstream outcroppings. NDT noted that bedrock was beneath the bridge with the depth varying from 0 to 2.5 feet +/- below the bottom of footing elevation indicated on the 1931 bridge plan. Based on a lack of any undermining evidence, successful resistance to many floods for over 116 years, and in combination with the geophysical refraction findings, NDT recommended that the scour rating be upped to 5. A 5 listing for this category corresponds to "*Bridge foundations determined to be stable for calculated scour conditions; scour within limits of footings or piles*". With a rating of 5, this removes the structure from a scour critical designation. NDT recommended that underwater inspections be performed on a 2-year cycle. Riverbed elevations along the pier and both abutments should be monitored for changes during the inspections. NDT noted that if there is any evidence of undermining, the scour rating should be reviewed.

The NHDOT inspection report notes that the abutment and pier footings appear to be "stepped footings", with the step located on the downstream end of the abutments and on both ends of the pier. Both abutments are stone masonry, founded on a stepped spread footings, and located at the channel banks. Likewise, the pier is also stone masonry, founded on a stepped spread footing, and located at the center of the channel. According to the bridge widening plans (1931- full size drawing), the pier is embedded 4 feet.

The most recent diving inspection (2007) shows the pier stepped footing was partially exposed at both ends (maximum of 2.5 feet of exposure). The river-right (south) abutment original embedment depth was approximately 5 feet and currently there is 4-5 feet of remaining embedment. The river-left (north) abutment had roughly 6 feet of original embedment. Based on the current footing exposure of approximately 3.8 feet vertically and horizontal length of 16 feet at the downstream end (2007 inspection), the calculated remaining embedment is 1 foot. Per the report, no undermining was observed.

Northeast Quadrant (Downstream of Route 13 Bridge on River Left)

Gap in stones at base of retaining wall

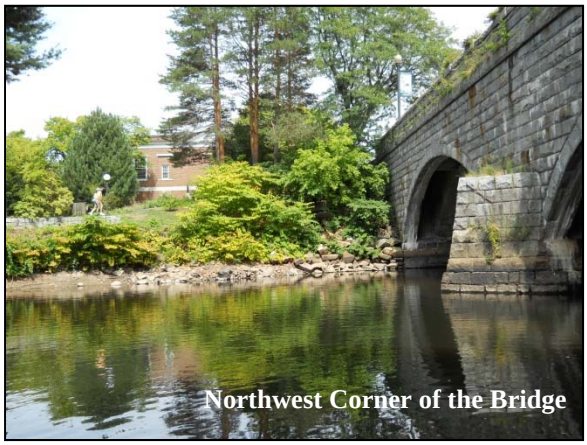
Bulging of Northeast Foundation Wall

The northeast quadrant of the bridge includes a large retaining wall (obscured by vegetation) extending downstream where it abuts a building foundation (see inset). Downstream beyond the building, and at the face of the dam, the foundation wall transitions to a shorter retaining wall. There is a noticeable change in construction of the retaining wall/foundation at the face of the building. The base of the wall and foundation at the bottom of channel elevation transitions between sand and ledge throughout its length.

The retaining wall adjacent to the bridge consists of large, dry laid stones and is covered with extensive vegetation. Due to the vegetation, it was not possible to determine the condition of a large portion of the wall or to determine if there is any bulging or lean to the wall. HTA did note several areas at the base of the wall with voids up to 3 feet deep into the wall. As the stones extend much further into the backfill, it was not possible to determine if these stones were resting upon another foundation stone or ledge.

Adjacent to the retaining wall is a stone building foundation wall (see inset) with extensive chinking and pointing above mean high water. This wall consists of stones of various sizes and shapes which does not allow for a running bond pattern. At the top of the wall there is a cast in place concrete foundation with a wooden building above. As with the adjacent retaining wall, portions of the foundation wall are heavily vegetated precluding a complete visual examination. The section of the foundation wall that was not vegetated is in fair to good condition, although bulging of this section estimated at 6" to 8" out of vertical was noted. It is not known if this bulging occurred before or after installation of the cast in place foundation above.

Northwest Quadrant (Upstream of Route 13 Bridge on River Left)



The northwest quadrant of the bridge largely consists of natural stream bank with some large stones. The only structure within site of the bridge is a dry-laid stone block retaining wall which is oriented perpendicular to the northwest fascia wall. The wall is covered in thick vegetation; therefore it was not possible to determine its condition in detail. Directly in front of the wall is a large volume of dumped stone extending to the interface with the bridge.

Southeast Quadrant (Downstream of Route 13 Bridge on River Right)

The southeast quadrant of the bridge consists of several adjacent buildings (see inset) supported on various foundations. Most of the foundations consist of mortared stone abutments supported on ledge. In other locations the buildings are supported directly on ledge or on concrete foundations. Just upstream of the dam is the former sluiceway intake that controlled flow into the building and exited downstream at what is now a concrete framed outlet.

The stone foundation walls and buildings in this quadrant are generally in good condition. Portions of the stone walls are clearly bearing on ledge while other portions have a stone toe wall (see photo below) in front so it is not possible to directly observe the foundation support condition. The foundation wall concrete is also in good condition with no delamination noted.

Adjacent to the southeast wingwall of the bridge, there is a cantilevered deck of recent construction (see inset below). The wood framed deck is supported by galvanized steel support columns that are then supported by the foundation wall on steel bearing plates bolted to the wall. The wall and deck framing in this area are in good condition.

Stone Toe Wall in Front of Foundation Wall

Cantilevered Deck Adjacent to Bridge

Southwest Quadrant (Upstream of Route 13 Bridge on River Right)

Foundation Wall Adjacent to Southwest Wingwall

Southwest of the bridge are several buildings (likely wood framed) supported on stone foundations. The foundations for these buildings are built up to the wingwall of the bridge. At the time of HTAs visit, foundation repairs were being completed for a large portion of the foundations in this quadrant, therefore HTA was unable to perform a close up review. The extent of the repairs is unknown but appeared to include installation of a concrete toe wall and pointing of the stone walls. Some portions of the foundations were freshly pointed while others remained unpointed. Per the town, the foundation repair work was successfully completed.

Southwest Quadrant Buildings and Foundations

The foundation stones vary greatly in size, shape and pattern of construction. Most portions appear to be structural, while a few sections may only be a facing based on the stone shapes and orientation. Due to the variety of wall types, stone composition and inconsistent geometry, it is difficult to determine if there is bulging or leaning in the walls of if the walls are “as-constructed”.

There are ledge outcrops visible along the base of the building retaining walls, while the base of the wall is not visible in other areas. Based on the NDT test results and exposed ledge it appears that the majority of the buildings in this area are founded on ledge or on material lying directly above ledge.

5.0 Hydrologic Analysis

The potential removal of the dams requires an understanding of the magnitude, timing, and duration of Souhegan River flows in the Project area. As noted above, the water velocity within the impoundments is slow and can result in sediment deposition above the dams from the upstream free-flowing river carrying sediment. If the dams are removed, velocities through the former impoundments will increase and potentially mobilize accumulated sediment for transport downstream.

To evaluate the potential impacts on sediment transport and reduction in flooding if the dams were removed, a hydraulic model is developed. The hydraulic model simulates the changes in the river's width, depth, and velocity with and without the dams in place over a range of flow conditions—from low flows to flood flows.

To determine the potential changes in the river's hydraulics, hydrologic (flow) data in the Project area is needed. Below is a description of how flood flows, average flows, and low flows were determined in the Project area.

5.1 Mean Daily Flows

There are two United States Geological Survey (USGS) gages that continuously measure streamflow on the Souhegan River as summarized in Table 5.1-1.

Table 5.1-1: USGS Gages on Souhegan River

Gage No.	Gage Name	Drainage Area	Period of Record	Comments
01093852	Souhegan River (Site WLR-1) near Milford, NH	103 mi^2	6/15/1994-9/30/2012[1]	Reflects upstream regulation from State-owned flood control facilities
01094000	Souhegan River at Merrimack, NH	171 mi^2	7/13/1909-9/30/1976, 10/1/2001-9/30/2012[1]	Reflects upstream regulation from State-owned flood control facilities

[1]Note that at the time the flow analysis below was completed, the period of flow record terminated in Sep 2012; however, both gages remain active.

As Table 5.1-1 shows, the gage in Milford has been operational for 20+ years, whereas the gage in Merrimack has been operational for 70+ years. The drainage area at the dams is 139 mi^2, thus the Merrimack gage, from a drainage area size perspective, is slightly closer to the dams. Between the Project dams and Merrimack gage there is no source of flow regulation[29]; flows are seasonally regulated due to the in-basin flood controls facilities. Given this, and the longer period of record, the mean daily flows recorded at the Merrimack gage were multiplied by a ratio of the drainage areas (139 mi^2/171 mi^2 or 0.81) to estimate the mean daily flows at the dams. Note that prorating of flows is a commonly used practice in the hydrology field so long as there is no major source of regulation between the measured flow location and predicted location. Using the adjusted flows for the full period of record, various flow statistics were developed to understand the duration, magnitude and frequency of flows at the dams.

The computed mean daily flows were used to develop flow duration curves, reflecting flow conditions at the dams. Shown in Figures 5.1-1 through 5.1-4 are monthly flow duration curves (three months per figure) and shown in Figure 5.1-5 is the annual flow duration curve. The flow duration curves show the

[29] Flow "regulation" could be due to other dams that change magnitude, timing or frequency of flows compared to a naturally flowing river. Sources of flow regulation could be a flood control dam, a peaking hydroelectric project, or major water supply withdrawals.

percent of time a given flow is equaled or exceeded over the period of record at the dams. For example, a flow of 50 cfs in August is equaled or exceeded approximately 66% of the time. Conversely, 34% of the time the flow is less than 50 cfs.

Shown in Table 5.1-2 are the estimated minimum, maximum, mean, median and mean flows at the dams.

Table 5.1-2: Estimated Minimum, Maximum, Median, and Mean Monthly Flows at the McLane and Goldman Dams

Stat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Min	18	20	28	72	44	19	6	3	3	3	10	19	3
Max	4,373	2,414	11,543	6,869	4,520	4,869	1,959	3,130	6,316	4,576	3,414	2,902	11,543
Med	157	159	356	480	237	107	49	34	33	45	114	163	130
Mean	228	229	517	629	318	183	89	67	77	104	198	251	240
Drainage Area at Dams = 139 mi^2.													

5.2 Flood Flows

As noted in the far right-hand column of Table 5.1-1, the flows measured at the Milford and Merrimack USGS gages reflect regulation from state-operated flood control facilities located in the Souhegan River Basin. During the early 1960s, the provisions of Public Law 566 (the Watershed Protection and Flood Prevention Act) were implemented in NH. This initiative, spurred by the occurrences of repetitive flooding and the large floods of 1936 and 1938, was intended to reduce flooding by constructing strategically located flood control sites. Twelve flood control facilities were constructed in the Souhegan River basin upstream of Milford in the 1960s. These flood control facilities serve to store runoff with the goal of reducing flows in the Souhegan River and flooding in towns like Milford. Note that absent these flood control facilities, the amount of flooding that occurred in the April 2007 and March 2010 floods in Milford would have been greater as the flood control dams retained flow.

The Federal Emergency Management Agency (FEMA) conducted a flood insurance study (FIS) in the Project area in November 1979, which included estimating the 10-, 50-, 100- and 500-year floods. FEMA recently repackaged the FIS; however, this effort did not result in any changes to the original flood flow estimates. Per the FIS, the peak discharges for the 10-, 50-, 100[30]- and 500-year floods for the Souhegan River were computed by the Soil Conservation Service using the convex routing method. Shown in Table 5.2-1 are the peak flows near the Project area as published in the 1979 FIS.

Table 5.2-1: Flood Insurance Study Peak Flood Flows

Flooding Source and Location	Drainage Area (mi^2)	10-year	50-year	100-year	500-year
Souhegan River at Wilton-Milford boundary	102.0	3,740 cfs	6,360 cfs	7,550 cfs	11,000 cfs
Souhegan River at confluence with Hartshorn Brook	120.0	4,500 cfs	7,800 cfs	9,300 cfs	13,600 cfs
Souhegan River at the Amherst-Milford boundary	144.0	5,150 cfs	9,020 cfs	10,800 cfs	16,000 cfs
Souhegan River at McLane and Goldman Dams*	139.0	4,971 cfs	8,707 cfs	10,425 cfs	15,444 cfs

**The flood flows at the McLane and Goldman Dams were estimated by adjusting the flood flows at the Amherst-Milford boundary by a ratio of drainage areas (139/144). For example, the 100-year flood at the Amherst-Milford*

[30] The 100-year flood is a flood event that has a 1% probability of occurring in any given year.

boundary is 10,800 cfs. The value was multiplied by 139/144 (0.96) to estimate the 100-year flood at the dams or 10,425 cfs.

Given that another 30+ years has passed since FEMA's flood estimates, including the April 2007 and March 2010 floods, the peak flows were re-computed using a different method. A Log-Pearson Type III[31] flood frequency analysis was conducted to estimate the 10-, 50-, 100-, and 500-year floods. This method is commonly used by hydrologists and is an accepted technique to estimate flood recurrence intervals; it estimates flood flows using annual instantaneous peak flows for a period of record. Similar to the mean daily flows, the annual instantaneous peak flows recorded on the Souhegan River in Merrimack were used to estimate the 10-, 50-, 100- and 500-year flood flows at the dams. The flood frequency analysis was conducted at the Merrimack USGS gage, and then adjusted, based on drainage area, to the dams. Shown in Figure 5.2-1 (and in Table 5.2-2 below) are the updated flood flows as well as the original flood flows reported in the 1979 FIS.

Table 5.2-2: Comparison of Flood Frequency Flows at McLane/Goldman Dams based on 1979 FIS and Log-Pearson Type III Revised Estimates

Method	10-year	50-year	100-year	500-year
1979 FIS (estimated at dams)	4,971 cfs	8,707 cfs	10,425 cfs	15,444 cfs
Updated from Log-Pearson Type III analysis	5,154 cfs	8,462 cfs	10,226 cfs	15,355 cfs
Percent Increase or Decrease Relative to 1979 FIS	+3.7%	-2.8%	-1.9%	-0.6%

Interestingly, the original and revised flood flows for the 10-, 50-, 100- and 500-year floods are similar. As Table 5.2-2 shows there is less than a 4% difference in flows. Given how close the values are, and the 1979 FIS generally predicted higher flows (with the exception of the 10-year flood), for purposes of hydraulic modeling the original 1979 FIS flood flows were used.

The April 2007 flood had an instantaneous peak flow at the Merrimack[32] USGS gage of 10,500 cfs. Multiplying this flow by a ratio of drainage areas (139/171), the estimated instantaneous peak flow at the dams was 8,535 cfs. Interpolating from Figure 5.2-1, the April 2007 flood was equivalent to approximately the 50-year flood in Milford.

Hydrologists typically rely on long-term flow data at existing USGS gages to develop flood flow estimates. Recent research suggests increases in the magnitude and frequencies of precipitation and flooding events in New England over the last century, especially in recent decades (Collins, 2011). If this trend continues in the future, updated flood frequency estimates will be needed. The purpose for mentioning this is currently the McLane and Goldman Dams are required to pass the 50-year flood based on its low hazard classification. Per NHDES Dam Safety Regulations all dams must be able to pass the design storm (in this case the 50-year flood) with one foot of freeboard between the water surface elevation and top of the lowest abutment. Currently, the dams can meet this regulation. If the trend of higher flood flows continues in the future, and the 50-year flood flow is recalculated to be a higher value, the dams would again need to be reassessed to determine if they can safely pass the updated 50-year flood with one foot of freeboard. If the dams cannot pass a future 50-year flood flow with one foot of freeboard, modifications to the dams may be required.

[31] A generalized skew was used in the Log-Pearson Type III flood frequency analysis.

[32] Note that the USGS has reported annual instantaneous peak flows at the Milford gage for 1994-1996 only (3 years).

5.3 Flows Used in Hydraulic Model

Table 5.3-1 lists the flows used to simulate hydraulics (depth, width, velocity) in the Souhegan River with and without the dams in place. The flows simulated generally fall into three categories: flood flows, low flows, and flows during the river herring and American shad upstream and downstream migration periods. Flows are given for three different "flow change locations" as used in the 1979 hydraulic model: flows starting at the upstream extent of the model, flows below Great Brook (a tributary discharging into the Goldman Impoundment just upstream of the dam), and flows below FIS cross-section 'W' to the downstream extent of the model. For lower (non-FIS) flows at the two upper locations, flows were interpolated from the trend of decreases between FIS flows.

Table 5.3-1: Proposed Flows for Simulation in Hydraulic Model

Flow Name	Flow (cfs) at Location:			Rationale	Source
	Upstream Extent	*Below Great Brook*	*FIS XS 'W' to Amherst*		
Median Sep	31	32	33	Representative of low flow; to determine if depths are sufficient to pass resident/anadromous fish	Flow duration curves for USGS Gage No. 01094000 (Souhegan River at Merrimack), adjusted based on drainage area ratio (171 at gage / 139 at dams), for period of record ending 9/30/2009
Mean Oct	90	95	97	Representative of flows during the river herring outmigration season	
Mean Apr 15 - May 15	417	438	448	Representative of flows during the river herring migration season	
2-yr Flood	337	355	363	Approximate channel forming flow	Interpolated from a natural log best fit curve of the 1979 FIS flood flows
10-yr Flood	4,800	5,051	5,152*	For comparison to previous FIS	1979 FIS (HEC-2 input file)
50-yr Flood	8,400	8,852	9,018*	For comparison to previous FIS	1979 FIS (HEC-2 input file)
100-yr Flood	10,000	10,500	10,800*	Base flood flow	1979 FIS (HEC-2 input file)

**Note that these values may differ slightly than rounded values reported in the FIS; exact values were taken from the input data file for the HEC-2 model used in the FIS.*

*** For lower (non-FIS) flows at the two upper locations, flows were interpolated from the trend of decreases between FIS flows.*

5.3 Ice Jams

The McLane and Goldman Dams slow the river velocity resulting in sheet ice developing on the impoundments (see inset of McLane impoundment). Absent the dams, sheet ice would not likely develop as river velocities will increase.

Dam removal and ensuing changes in river hydraulics cause changes to the ice regime that may have significant local impacts on ice formation, ice cover growth and progression, ice cover break-up and movement and jamming of ice.

The USACOE Cold Regions Research and Engineering Laboratory (CRREL) were contacted to determine if ice jams on the Souhegan River in the project area had occurred previously. The CRREL ice jam database was queried and two ice jams were noted as summarized below:

Location: Milford, NH
River: Souhegan River
Jam Date: Jan ?, 1978
Jam Type: Break-up
Damages: Mobile home park and two businesses flooded
Local Contact: New England Division (NED)
Visuals: None
Reports: None
Description: Two jam locations annually (reported as of 1980)- Dam in Milford forms 750 foot long ice jam- January 1978 was worst ice jam. Ice jams have occurred in 10 of 11 years 1969-1980

Location: Milford, NH
River: Souhegan River
Jam Date: Jan 29, 1976
Jam Type: ?
Damages: ?
Visuals: Available at CRREL
Reports: None
Description: As reported in the Union Leader on Jan. 29, 1976, "*Ice Jams along the Souhegan River also caused flooding in private homes in Wilton and Milford. In Milford, an ice jam caused a portion of the river to divert its course through the center of a mobile home park on Elm Street. There were no evacuations, but residents in some sections were forced to make their way to their homes by wading through hip-deep water on flooded roads*."

6.0 Fisheries Resources and Physical Habitat Characteristics below McLane Dam

6.1 Resident Fish

Native fish in the Souhegan River include blacknose dace, brook trout, brown bullhead, chain pickerel, common shiner, common white sucker, creek chub sucker, fallfish, golden shiner, longnose dace, pumpkinseed, redbreast sunfish, spottail shiner and yellow perch (Souhegan River Watershed Report, SRWR, 1997). Introduced species include brown trout, largemouth bass, smallmouth bass, margined madtom, yellow bullhead, and rainbow trout (SRWR, 1997). In addition, the river is stocked annually, typically in April and May, by the NHFGD with brown trout, rainbow trout and eastern brook trout. Table 6.1-1 shows the stocking locations, numbers, and pounds; the towns are listed from the lower basin (Merrimack) to the upper basin (New Ipswich). Virtually all of the trout in the Souhegan River basin is the result of the stocking program (Souhegan River Nomination, 1999). When released, the trout are typically of a legal size for angling, representing what is called a "put and take" program.

Table 6.1-1: 2012 Trout Stocking Data in Souhegan River Basin

Location	Species	Age	No. of Fish	Total Pounds
Merrimack	Brown Trout	1+ year	550	295
	Eastern Brook Trout	1+ year	315	101
	Rainbow Trout	1+ year	120	70
Amherst	Brown Trout	1+ year	900	468
	Eastern Brook Trout	1+ year	1,330	408
	Rainbow Trout	1+ year	760	693
Milford	Brown Trout	1+ year	875	454
	Eastern Brook Trout	1+ year	935	276
	Rainbow Trout	1+ year	970	892
Wilton	Brown Trout	1+ year	975	512
	Eastern Brook Trout	1+ year	1,460	449
	Rainbow Trout	1+ year	1,050	959
Greenville	Brown Trout	1+ year	500	260
	Eastern Brook Trout	1+ year	200	60
	Rainbow Trout	1+ year	500	450
New Ipswich	Eastern Brook Trout	1+ year	765	280
	Rainbow Trout	1+ year	200	167

Source: NHFGD Website: http://www.wildlife.state.nh.us/Fishing/Stocking/2012/full.html

6.2 Merrimack River Anadromous Fish Restoration Program

With the removal of the Merrimack Village Dam in 2008, formerly the lowermost dam on the Souhegan River, the McLane Dam now represents the first barrier to upstream fish passage of diadromous fish on the Souhegan River. There are two dams on the Merrimack River located below the Souhegan River confluence. They include: a) the Essex Dam in Lawrence, MA, located approximately 33 river miles downstream of the confluence and b) the Pawtucket Dam in Lowell, MA, located approximately 21 river miles downstream of the confluence. Approximately 11 river miles upstream of the Souhegan River confluence is the Amoskeag Dam in Manchester, NH. All three dams are equipped with upstream and downstream fish passage structures, thus diadromous fish have passageways to migrate up the Souhegan River.

Diadromous fish spend part of their lives in freshwater and saltwater. These include anadromous and catadromous fish. Anadromous fish (such as river herring, Atlantic salmon, American shad, sea lamprey) spawn and develop in freshwater, before returning to the ocean. These fish seasonal occupy freshwater primarily during the spring through fall period. Once anadromous fish reach sexual maturity, they repeat

the cycle and return to freshwater to spawn. Alternatively, catadromous fish (such as American eel) spawn and develop in saltwater, and move into freshwater to grow. American eel may spend 25 years in freshwater before returning to saltwater.

The USFWS monitors and counts the number of returning American shad, Atlantic salmon, striped bass, Sea lamprey, gizzard shad and river herring[33] that utilize the upstream passage structures at Essex and Pawtucket Dams. The NHFGD is responsible for obtaining counts at Amoskeag Dam. Shown in Table 6.2-1 are the returns of river herring, Atlantic salmon and American shad from 2000-2011.

Table 6.2-1: Anadromous Fish Returns at the Essex, Pawtucket and Amoskeag Dams, Merrimack River, 2000-2011

	Essex Dam			Pawtucket Dam			Amoskeag Dam		
Year	River Herring	Atlantic Salmon	American shad	River Herring	Atlantic Salmon	American shad	River Herring	Atlantic Salmon	American shad
2000	19,405	82	69,257	673	[1]N/A	12,716	316	[1]N/A	39
2001	1,550	83	73,840	58	[1]N/A	7,578	[2]N/A	[1]N/A	[2]N/A
2002	526	56	54,560	0	[1]N/A	5,283	0	[1]N/A	[2]N/A
2003	10,607	147	55,620	0	[1]N/A	6,276	0	[1]N/A	[2]N/A
2004	15,051	129	36,593	7,448	[1]N/A	11,028	[2]N/A	[1]N/A	[2]N/A
2005	99	34	6,382	0	[1]N/A	716	[2]N/A	[1]N/A	[2]N/A
2006	1,297	91	1,205	0	[1]N/A	0	[2]N/A	[1]N/A	[2]N/A
2007	1,169	74	15,876	0	[1]N/A	1,653	[2]N/A	[1]N/A	[2]N/A
2008	108	119	25,116	0	[1]N/A	4,152	[2]N/A	[1]N/A	[2]N/A
2009	1,456	81	23,199	139	[1]N/A	2,799	[2]N/A	[1]N/A	[2]N/A
2010	518	85	10,442	43	[1]N/A	479	[2]N/A	[1]N/A	[2]N/A
2011	740	402	13,835	*	[1]N/A	*	[2]N/A	[1]N/A	[2]N/A
2012	8,992	137	21,396	1,809	0	1,728	[2]N/A	[1]N/A	[2]N/A
2013	17,359	22	37,149	13,490	0	9,350	[2]N/A	[1]N/A	[2]N/A

[1]N/A- all Atlantic salmon are captured at Essex Dam for brood stock, thus no adults are passed upstream.
[2]N/A- typically there is little monitoring of river herring and American shad at the Amoskeag Fishway, counts are not available.
*Data not provided.
Source: Joe McKeon, USFWS

As the fish returns above show, the numbers of American shad passing the Essex Dam from 2000-2006 steadily declined, although there has been a rebound from 2010-2013. River herring returns at the Essex Dam have also rebounded from 2010-2013. American shad and river herring passing the Pawtucket Dam have also increased in 2012 and 2013.

The Souhegan River is an important part of the Merrimack River Anadromous Fish Restoration Program and is considered one of the most productive rivers in the Merrimack watershed. Restoration efforts of anadromous fish on the Merrimack River have been on-going for several years. The upper reaches of the Souhegan River and its tributaries provide the appropriate habitat - gravelly, sloping bottoms, water temperatures, oxygen levels and food sources - for excellent growth and survival of Atlantic salmon fry and juveniles. On average, 125,000 hatchery-raised Atlantic salmon fry were historically stocked in the Souhegan River and tributaries including Stony Brook, Blood Brook, and King Brook annually.

The removal of the Merrimack Village Dam, at the mouth of the Souhegan River, in 2008 made the Souhegan River accessible to migrating fish for the first time since the early 1800's. To take advantage

[33] River herring collectively refers to two fish species: blueback herring and alewife.

of this opportunity, staff at the Nashua National Fish Hatchery began stocking the Souhegan River with salmon smolts marked with adipose fin clips, in addition to fry stocking. In 2011, 75 returning adult salmon with adipose fin clips were released into the Souhegan River to spawn naturally. Twenty of these fish were monitored with radiotags. Spawning activity was confirmed in the fall of 2011. Fry were not stocked in the Souhegan River in 2012 so that successful reproduction could be documented with electrofishing surveys for young-of-year (YOY) salmon. Electrofishing surveys in the summer of 2012 documented the first naturally reared YOY salmon in the Souhegan River since the Merrimack River Salmon Restoration Program began in the late 1970's. YOY salmon were recorded at several locations, with the highest densities found in the reach upstream of the McLane and Goldman Dams. Due to the success of natural spawning in the Souhegan River, adult pre-spawn salmon will continue to be released into the Souhegan River in place of fry stocking.

However, in September 2013 the USFWS announced that due to federal budget cuts and low annual returns of sea-run Atlantic salmon, it ended its investment in the 30-year-long Atlantic salmon restoration program in the Merrimack River watershed. It was noted that salmon returns to the Merrimack River were limited because of poor ocean survival, in-river habitat degradation, and dams that impede migration. The USFWS is now shifting its resources toward higher priority restoration efforts such as American shad, American eels and river herring, which have shown higher returns.

As described above, the McLane Dam was re-constructed in 1992 and during that time numerous pictures of the rebuild were obtained. One picture taken during this period was in a pool, presumably in the plunge pool immediately below McLane Dam (see inset). The picture shows what appears to be an American eel, suggesting that some eels were able to ascend the former Merrimack Village Dam before its removal in 2008. Although some eels may be able to negotiate some dams, the structures are still an impediment to eel passage.

6.3 Historical Distribution of Diadromous Fish

According to the USFWS American shad, Atlantic salmon, sea lamprey, blueback herring, alewife and American eel are believed to have historically utilized the Souhegan River basin. To confirm whether sea-run fish were historically present in the Souhegan River numerous contacts were made and research was conducted. Contacts were made with the USFWS, NHFGD, Souhegan River Watershed Association (SRWA), and the Nashua Regional Planning Commission (NRPC). All contacts were asked about historical accounts of diadromous fish in the Souhegan River, and if they knew of other written documentation. In addition to personal communications, several books were reviewed and visits to some town libraries were conducted. Books that were reviewed included:

- *A Week on the Concord and Merrimack River*, 1849.
- *The History of Manchester formerly Derryfield, in New Hampshire*, 1851.
- *The Merrimack River; Its Sources and Its Tributaries*, 1869.
- *History, Town of Wilton*, 1888.
- *Biological Survey of the Merrimack Watershed*, 1938.
- *Fishing in New Hampshire*, 2003.
- *Three Centuries on New Hampshire's Souhegan River, Birthplace of Ideas and Industry*, 2004.

In general, no party was aware of specific historical accounts of sea-run fish, but recommended some of the references listed above.

It is clear from the references that diadromous fish were historically present in the Merrimack River. It was reported that spring spawning runs on the Merrimack River included salmon, shad, lamprey and alewives. In Jack Noon's book, *Fishing in New Hampshire*, he writes: "*Once in New Hampshire sea-run fish would continue to branch off into various tributaries. Those that kept ascending the Merrimack eventually reached Franklin, where the Merrimack River begins. Of the Merrimack River fishing sites in New Hampshire, Amoskeag Falls in Manchester was the largest and most famous. There the configurations of channels, rocks and small islands right where the fish were slowed in their upriver progress by the falling water gave fishermen good chances to get close to them with hand nests and eel hooks. Though all accounts describe the fishing at Amoskeag Falls as spectacular, few include any numbers of fish caught.*"

Noon indicated that most likely "*we will never get a sense of the vastness of the spawning runs arriving at Amoskeag Falls when the spot was an Abenaki subsistence fishery*."

He notes that there is the strong likelihood that the first white men fishing for salmon at Manchester- probably in the 1720s- would have encountered an already depleted salmon fishery due to Massachusetts fishermen and commercial harvesting.

There is little documentation of the extent of anadromous fish populations since they thrived during the Abenaki Indian era. It seems the first white settlers to the Souhegan River valley over fished the river and soon depleted the plentiful fish resources. From the Wilton Town History- "*That's why, in 1797, residents of the town petitioned the State Legislature to help preserve what they saw as the Merrimack's dwindling resources. It seems that too many folks were rigging nets (or weirs) that snared fish in the river, particularly Salmon, Shad & Alewives... whereby they have been much decreased for many years past*".

From Henry David Thoreau's book it states "*The salmon once frequented the cold shaded branches of the Merrimack River while the Shad and Alewife sought the smaller, warmer streams and ponds to spawn*." According to Thoreau, the settlers in Lowell blocked anadromous fish from swimming up the Merrimack River toward the Souhegan River with the creation of an industrial center. "*Salmon, shad and Alewives were formerly abundant here . . . until the dam . . . and the factories at Lowell, put an end to their migrations hitherward. . . . Perchance, after a few thousands of years, if the fishes will be patient, and pass their summers elsewhere . . . nature will have leveled . . . the Lowell factories, and the Grass-ground River [will] run clear again*."

With respect to the Souhegan River, the Wilton Town History offered the most insight regarding the presence of anadromous fish in the Souhegan River. In the introduction section of the Wilton Town History it states "*It is a tradition that in early times alewives, shad and salmon penetrated as high up the river as Greenville*." This statement suggests that alewives, shad and salmon were able to ascend other barriers in the Souhegan River on their migration to Greenville, such as Wildcat Falls and other sharp gradient drops. Later in the town history it states "*Of fishes, the largest, the salmon, were caught in the Souhegan as late as 1773-4*." Thus, although there is no information on the population of anadromous fish there is documentation suggesting that salmon, alewives and shad were historically present in the Souhegan River.

6.4 Physical Habitat Characteristics in approximate 1,125 foot reach below McLane Dam

A reconnaissance level habitat assessment was conducted from McLane Dam downstream to the first bend in the river as shown in Figure 6.4-1, a distance of approximately 1,125 feet (375 meters). The habitat assessment was conducted on September 11, 2011, and the flow below McLane Dam was measured in the field at 198 cfs. A flow of 198 cfs is equaled or exceeded approximately 35% of the time annually and 6% of the time in September—in short it was a relatively high flow for September. Note that during the habitat assessment all flow was passed through the McLane Dam stoplog opening; no water was passed over the spillway. The purpose of the reconnaissance survey was to document the quality of physical habitat in this reach as it could be directly impacted if sediments contained in the McLane Dam impoundment were allowed to naturally transport downstream if the dam was removed.

To document the physical habitat a standardized methodology developed by the United States Environmental Protection Agency (USEPA) was used entitled *Rapid Bioassessment Protocols for use in Streams and Rivers: Periphyton, Benthic, Macroinvertebrates, and Fish*. The protocols contain several appendices with separate forms or field data sheets. For purposes of this assessment, two forms were used to document physical habitat characteristics as listed in the bullets below (forms pertaining to periphyton, benthic, macroinvertebrates and fish sampling were not applicable).

- Form 1: Physical Characterization/Water Quality Field Data Sheet
- Form 2: Habitat Assessment Field Data Sheet - High Gradient Streams

Appendix E includes the completed forms. Appendix E also includes an aerial map showing the location and direction in which photographs were taken, followed by the actual photographs.

The physical characteristics (Form 1) were documented as follows:

- The riparian zone is comprised primarily of trees (white pine, red oak, sycamore) and shrubs (alder and dogwood).
- This type of streamside vegetation results in a partly open canopy in the river reach.
- The approximate reach length is 1,125 feet (375 m) and the approximate stream width is 99 feet (30 m) for a reach area of 111,372 ft^2 (11,250 m^2). The maximum stream depth at the time of the survey was 5 feet (1.5 m) and thalweg surface velocity of 1.0 m/sec (under a flow of approximately 198 cfs).
- The proportion of the reach represented by different stream morphology types includes: 28% riffle, 64% run and 6% pool under a flow of approximately 198 cfs. Figure 6.4-1 shows the location of riffles, runs and pools.
- The channel bed slope is relatively steep in this reach dropping approximately 1 foot every 145 feet (slope of 0.007).

The habitat assessment field data sheet (Form 2) includes ten[34] habitat parameters that are ranked in the field on a scale of 1 to 20, where the ranking is broken out as 0-5: poor, 6-10: marginal, 11-15: suboptimal and 16-20: optimal. In the end, the rankings (0-20) for each of the ten habitat parameters are summed to produce a total score; a "perfect" score would be 200. In this case, the total score was 152 (76% of the maximum score).

[34] The ten parameters include: substrate/available cover, embeddedness, velocity/depth regime, sediment deposition, channel flow status, channel alteration, frequency of riffles (or bends), bank stability, and vegetative protection, riparian vegetative zone width.

The dominant channel substrates are cobble and gravel with approximately 15% sand. Some boulders provide cover for aquatic organisms, however, there was minimal large woody debris found in this reach. Embeddedness scored on the high end of suboptimal, primarily due to sandy deposits near the channel edges and in the pools (See Photo P5).

As shown in Figure 6.4-1, this reach of river is dominated by riffle/run sequences. Overall, a variety of velocity/depth habitats types were present, although pool features were limited.

The vegetated riparian zone is narrow and steep on river-right, limited by residential development. The river-left riparian zone is wider and contains well-developed vegetation. As a result, bank stability and vegetative cover was scored as optimal for the left bank and suboptimal for the right bank.

In summary, the aquatic habitat assessment of this reach resulted in a condition on the low end of the optimal range. The instream cover and habitat types were diverse but slightly suboptimal in terms of substrate embeddedness and sediment deposition.

6.5 Physical Habitat Characteristics further downstream of McLane Dam

Below the river reach studied (1,125 feet), the channel bed slope lessens, and in some instances becomes nearly flat. Figure 6.5-1 (includes 5 individual profiles, Maps 1-5) is the FEMA FIS profiles of the Souhegan River starting from the McLane Dam downstream to the Boston Post Road Bridge in Amherst, NH. As the channel bed slope lessens, the channel bed substrates also change primarily to sand.

The channel substrate changes primarily to sand approximately 2,400 feet below the McLane Dam. Through the Amherst Country Club, on Ponemah Road in Amherst the river winds through the golf course, where substrates remain silt/sand. A few pictures showing the sandy substrates in this area are shown below.

Further research of instream habitat and structure in the Souhegan River was obtained from the Final Souhegan River Protected Instream Flow Report, completed for the NHDES in February 2008 (UNH, et al). This report included an aquatic habitat assessment of the entire Souhegan River. Figure 6.5-2, from the UNH report, is a plan map showing reaches of similar channel habitat, which was further divided into sections. Reach 5 (Sections 33-40) starts at the McLane and Goldman Dams and extends below McLane Dam, whereas Reach 6 (Sections 41-54) includes the reach well downstream of McLane Dam, where the river slope flattens (through the Amherst Country Club golf course). Descriptions of both reaches, as stated in the 2008 report, are provided below.

Reach 5: (Sections 33-40; 5.27 km- 3.27 mi)
Section 33 crosses the town of Milford where the river is impounded by two dams over the length of approximately 1.5 km (0.93 mi). This 1.5 km stretch comprises 28% of the total length of this reach. Downstream of the dams (section 34 and 35), the river continues to flow through residential areas and is high gradient. It cuts through bedrock ledge, which is also expected under the impoundments. The river banks in this area have an abundance of riprap as well as overhanging vegetation that does not provide much shading, but indicates the age of construction. Some woody debris was observed. Downstream of the impoundment, the habitat consisted of rapids, riffles and runs with coarse but mixed substrate embedded in sand.

Reach 6: (Sections 41-54; 7.08 km-4.40 mi)
Nearly 5 km of this reach is accompanied by a golf course that reduces canopy shading and woody debris. Meandering banks were active. In the areas of bridges was observed heavy bank stabilization with riprap. The substrate was dominated by sand with the presence of submerged aquatic vegetation. Hydraulic habitat consisted of runs, pools, and glides accompanied by some low gradient riffles.

Beginning with Section 48, the Souhegan River meanders through more forested and residential areas where the abundance of woody debris and canopy shading increases. Also observed were increases in shallow margins and the appearance of a few backwaters. Submerged underwater vegetation was less abundant. The banks were still high and eroded. The hydraulic habitat consisted of runs, pools, and glides accompanied by low gradient riffles associated with woody debris."

The findings contained in the 2008 report corroborate the habitat conditions observed below McLane Dam- riffles, runs, coarse substrate (cobble) and boulders, and a steep gradient. And further below this reach, the river gradient is mild and substrates consist of sand and silt.

7.0 Wetlands and Rare, Threatened and Endangered Species

7.1 Rare, Threatened and Endangered Species Consultation

Prior to conducting the wetlands delineation, a letter dated August 4, 2010 was sent to the USFWS, NHFGD and the NH Natural Heritage Bureau (NHNHB) describing the purpose of the Project (potential dam removal) along with a map showing the potential area of impact. The purpose of the letters was to request information on any known federal or state rare, threatened, endangered (RTE) or species of concern (plant, fish, wildlife) in the Project area prior to conducting any field work. A copy of these letters is included in Appendix F.

In response to the request, the USFWS noted in an August 24, 2010 letter (see Appendix F) that "*no federally-listed or proposed, threatened or endangered species or critical habitat under the jurisdiction of the U.S. Fish and Wildlife Service are known to occur in the project area(s)*".

The NHNHB and NHFGD noted in their August 16, 2010 letter (see Appendix F) that "*It was determined that, although there was a NHB record (e.g. rare wildlife plant, and/or natural community) present in the vicinity, we do not expect that it will be impacted by the proposed project*".

Although no RTE species were identified by the agencies, while conducting the wetlands assessment, the certified wetlands scientist (Audra Klumb of A&D Klumb Environmental, NH CWS #222) was requested to take note of any RTE species observed in the field while conducting the wetlands delineation. No sensitive, rare, or endangered species or communities were found during the September 13, 2010 field survey. It should be noted that if the dams were removed, the NHNHB, NHFGD and USFWS would have to be consulted again, as the letters identifying potential RTE species are sufficient for one year.

7.2 Wetlands Delineation

On September 13, 2010 Audra Klumb, NH delineated the river's edge (top of bank) and wetland boundaries on the Souhegan River from the Gregg Crossing Footbridge (approximately 3,100 feet upstream of the Goldman Dam) to approximately 900 feet downstream of the McLane Dam.

The wetlands were delineated according to the NHDES rules and *Army Corps of Engineers Delineation Manual* and the Interim Regional Supplement (2009). During the delineation the wetlands were reviewed and classified using the *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin et.al, 1979). The wetland classifications are shown in Figure 7.2-1.

The Souhegan River was delineated with A1 marked on pink and black striped flagging starting below McLane Dam and continuing northwesterly to the Gregg Crossing Footbridge ending with flag A82. The south side of the river was flagged B1 beginning at the Gregg Crossing Footbridge and continuing westerly and ending with B60 at the confluence with Great Brook. Flag C1 is located opposite of B60 and the flagging continued westerly to approximately 900 feet below the McLane Dam ending with flag C43. Several sections of the river are directly flanked by building foundations --these areas could not be delineated due to the lack of river edge. In these cases the buildings foundation served as the river edge.

The dominant vegetation cover on the banks of the Souhegan River include trees of red oak, white pine, pignut hickory, sugar maple, silver maple, sycamore, black locust, green ash, and American elm; the shrub and sapling layer included many of the trees mentioned above along with hornbeam, poison sumac, staghorn sumac, black willow, sassafras, silky dogwood, red osier dogwood, and honeysuckle. The ground cover varied from none below the white pines to a dense covering of raspberries, poison ivy, grape vines, bracken fern, many types of grasses, goldenrod, and royal fern.

The National Wetland Inventory map of the USFWS classify the Souhegan River as Riverine, Lower Perennial, Unconsolidated Bottom, Permanently Flooded (R2UBH) above the Route 13 Bridge, Palustrine, Unconsolidated Bottom, Permanently Flooded, Diked/Impounded (PUBHh) from the Route 13 Bridge downstream to the McLane Dam, and then Riverine, Lower Perennial, Unconsolidated Bottom, Permanently Flooded (R2UBH) below the McLane Dam. The wetland delineation concurred with these classifications.

8.0 Bathymetric and Sediment Thickness Mapping

8.1 Bathymetric Mapping- Methods and Results

Field Conditions

On October 8 and 11, 2010, CR Environmental Inc. (CR) collected depth soundings in both the McLane and Goldman Dam impoundments to create bathymetric[35] maps. The survey provides information on the depth of water and slopes from the river banks to the channel thalweg[36]. The estimated mean flow in the Project area on October 8 and 11 was 129 cfs and 41 cfs[37], respectively. Note that water elevations in both impoundments were high enough to pass water over the spillways and in 2010 the stoplogs were in place.

Methods

CR utilized a boat equipped with a depth finder and global positioning system (GPS) to obtain depth measurements throughout both impoundments. All water depth measurements were relative to the water surface elevation (WSE). Although the impoundments appear flat, there can be a slight "slope" to the WSE, which was the case with the Goldman Dam impoundment (not with the McLane impoundment). There are in-channel hydraulic controls within the Goldman Dam impoundment causing a slightly sloped WSE. Given this, surveyed WSE's were obtained immediately upstream of each dam and at the upstream extent of each impoundment (for purposes of this study, the upstream end of the Goldman Dam impoundment terminated at the Gregg Crossing Footbridge). Measured water depths were subsequently converted to an elevation and then "adjusted" to reflect any minor slope in the impoundment's WSE.

Water depth measurements were collected using a SyQwest, Inc. HydroBox precision echosounder equipped with a 200-kHz transducer. The accuracy of the Hydrobox is approximately 0.1% of the water depth with a (1 cm) resolution. System accuracy was checked before and after the survey by comparing echosounder water depth measurements to known water depths. Known water depths were obtained using the "bar check" method, in which a metal plate was lowered beneath the echosounder's transducer to several known distances.

As noted above, measured depths were converted to bottom elevations based on the surveyed WSE. Navigation was accomplished using a Trimble AgGPS 132 Differential GPS capable of receiving the U.S. Coast Guard (USCG) Beacon corrections and OmniStar subscription-based satellite correction service. The Trimble DGPS and echosounder were interfaced to a laptop computer that ran the latest version of HYPACK® hydrographic surveying software. During the survey, the system calculated x-y positions in the desired grid system, recorded the depth and navigation data, and provided a steering display for the boat captain.

Results

Shown in Figures 8.1-1 and 8.1-2 are bathymetric maps of McLane and Goldman Dam impoundments, respectively. As Figure 8.1-2 shows, it was not possible to obtain bathymetric data in the Goldman

[35] A bathymetric map displays the elevation contours below the water.
[36] The thalweg is the lowest point (deepest) along a transect of the river.
[37] The flow measured at the USGS gage on the Souhegan River in Merrimack on Oct 8 and 9, 2010, was 159 cfs and 51 cfs, respectively. A drainage area factor of 0.81 was applied to these numbers to estimate the flow in the Project area.

Impoundment to the right side of the island located just upstream of the Fletcher's Paint Site as water depths were too shallow.

8.2 McLane Dam Sediment Thickness Findings

As part of the feasibility study, sediment thickness mapping within the McLane Impoundment was conducted. No mapping of the Goldman Impoundment was conducted as past studies associated with the Fletcher's Paint site included sediment thickness and volumes estimates as described later.

Field Conditions

A two-person field crew from Gomez and Sullivan collected sediment depth measurements within the McLane Dam Impoundment on September 21 and 22, 2010. During the field survey, the WSE at McLane Dam was below the spillway crest as leakage through the stoplogs exceeded the magnitude of inflow. The flow recorded on the Souhegan River at the USGS gages at the Milford and Merrimack gages are shown in Table 8.2-1. The flow varied minimally between the two survey days.

Table 8.2-1: Flow Conditions during Sediment Depth Measurements in McLane Impoundment

Gage Name	Drainage Area	Flow on September 21, 2010	Flow on September 22, 2010	Average Flow
Souhegan River at WLR-1 near Milford, NH	103 mi^2	8.0 cfs	7.2 cfs	7.6 cfs
Souhegan River at Merrimack, NH	171 mi^2	20.0 cfs	19.0 cfs	19.5 cfs

To put flow conditions into perspective, 19.5 cfs at the Merrimack gage is equaled or exceeded 91% of the time during the month of September. In short, flow conditions were well below normal.

Methods

The methods for collecting the sediment depth measurements were as follows:

- Pre-marked ropes, in one foot increments, were strung across 15 transects, approximately one transect every 100 feet of the impoundment's length.
- The endpoints, or tie-off locations for the ropes, were set on the left and right banks by attaching the ropes to eyebolts secured into rocks or trees. The vertical elevation of each eyebolt was surveyed at all locations. At each transect, ropes were secured to the right and left eyebolts and tightened. By establishing monumented endpoints, if in the future additional monitoring of sediment within the McLane Impoundment is desired, it can be compared to the sediment measurements collected as part of this survey.
- Starting at the left bank and moving to the right bank in approximately 10 foot station increments, a stainless steel pre-marked rod measured the water depth. At the same station, the rod was then hammered to refusal and the water/sediment depth recorded. The difference between the water depth and the water/sediment depth represents the sediment depth.

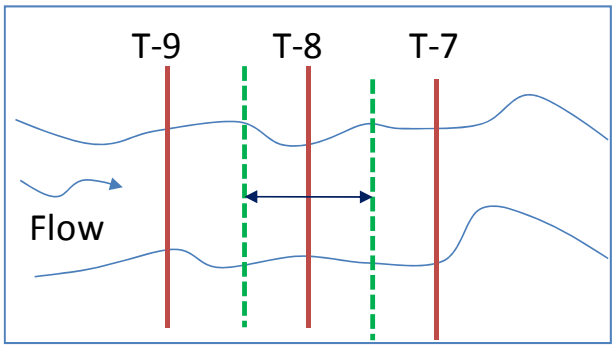
Results

As shown in Figure 8.2-1 sediment depth measurements were taken at 15 transects, between the McLane and Goldman Dams. Transects T-5 through T-14 were obtained on September 21, while transects T-0 through T-4 were obtained on September 22. Shown in Figures 8.2-2 through 8.2-16 are cross-section plots of Transects T-0 through T-14, respectively, where T-0 is located along the upstream face of

McLane Dam and T-14 is located just below Goldman Dam. To allow for comparison between transects, the y-axis scale on all of the cross-section plots are fixed between elevation 216 feet and 232 feet. As the transect figures show, sediment deposition was primarily located on river-right.

The cross-sectional area of sediment (ft^2) was computed for each transect. To estimate the approximate total sediment volume (ft^3), the cross-sectional area of sediment was multiplied by the distance midway to the next upstream and downstream transect, respectively, as shown in the inset. Shown in Figure 8.2-17 is the sediment volume between transects as measured in cubic yards (CY). The total sediment volume in the McLane Impoundment is approximately 4,700 CY.

Note that the total sediment volume is not the mobile sediment volume if the McLane Dam is removed. Further hydraulic and sediment transport analyses is conducted in Sections 12.0 and 13.0, respectively, of this report to approximate the mobile sediment volume. Some of the deposited sediment in the areas along the impoundment fringes may also be exposed and stabilized in place if vegetation becomes established.



Field observations and probing indicate that the sediment deposits within the McLane Dam impoundment are predominately sand. The thickest layer of sediment was located at transect T-01, where the sediment depth was 5.7 feet at station 120 (near the right bank). Sediment in this area was comprised of sand and fine gravel. Upstream of McLane Dam, sediment deposits up to five feet deep were found on river right, up to Transect T-06. The sediment appeared to be overlaying bedrock and was comprised primarily of sands and fine gravel. There are limited areas of finer silt and organic sediment located along the right bank. Upstream, from Transect T-07 to the base of Goldman Dam, there is very limited benthic sediment as the bottom substrate is primarily bedrock and boulder.

Other Field Observations

In July 2012, river flows were exceptionally low and the stoplogs had been removed at McLane Dam such that the impoundment level was also quite low. This offered an opportunity to view previously submerged areas of the impoundment. A walkover was conducted in the vicinity of the Swinging Bridge and McLane Dam. On river-left (see Photo 1 below), the shoreline is well-armored with bedrock (closer to the dam stone walls are present, but not shown in the photo). Just below the Swinging Bridge, a bedrock shelf is present (see Photo 2) that is angled in a downstream direction towards the river-right bank. If the McLane Dam were removed, it appears that the bedrock shelf would direct flow toward the river-right bank, which is steep, not armored, and in close proximity to the Granite Square Apartments. The water level was also low enough to expose sediment deposition just upstream of the dam along river-right (see Photo 3).

With the reconstruction of the McLane Dam in 1992, photographs were taken of the rebuild that provide evidence that at least a portion of the existing dam sits on some bedrock. Photo 4 shows exposed bedrock immediately below the L-shape of the spillway.

Photo 1: Standing on McLane Dam looking upstream along river-left (7/26/2012).

Photo 2: Standing on river-left bank looking across bedrock shelf (7/26/2012).

Photo 3: Standing atop McLane Dam looking upstream- note exposed sediment on river right (7/26/2012).

Photo 4: Looking at bedrock at base of former dam (1992).

8.3 Goldman Dam Sediment Thickness Findings

As part of the Fletcher's Paint Superfund Site, Arcadis (consultant to General Electric, GE) conducted sediment probing in 2006 at transects along an approximate one mile long section of the Souhegan River, extending from Goldman Dam to approximately 0.38 miles upstream of the Gregg Crossing Footbridge.

As part of the sediment probing survey, transects were performed at varying intervals within three distinct sections of the river. The three sections are listed below (in parenthesis is the transect spacing):

- the backwater immediately upstream of Goldman Dam (50-foot intervals);
- the approximate 0.5-mile reach upstream of the Route 13 Bridge to the Gregg Crossing Footbridge (200-foot intervals), and;
- the approximate 0.38 mile reach above the Gregg Crossing Footbridge (400-foot intervals).

In summary, sediment probing was conducted along 23 transects (see Figure 8.3-1) between June 27 and 28, 2006. At each transect location, the edge of water and transect endpoints were surveyed for geographic reference. Per discussions with the USEPA, the surveyed endpoints are not on a common vertical datum and hence are not "tied-together". Starting at the endpoints, the sediment thickness and water depth was measured at approximately eight regular intervals (or stations) across the river channel. Any physical changes in the river channel (e.g. boulder fields, small islands, etc.) were also documented. The results of the sediment probing along the 23 transects are shown in Table 8.3-1 (see Vol 2), while transect descriptions and observations are presented in Table 8.3-2 (see Vol 2). Shown in Figures 8.3-2 through 8.3-19 are plots for Transects T-1 through T-18 showing the depth of water and sediment thickness from Goldman Dam to the Gregg Footbridge (note that the scales on the x- and y-axis are the same for all 18 transects such that they can be compared).

The total sediment volume between Goldman Dam and the Gregg Footbridge was estimated from the 18 transects located in this reach (see Figure 8.3-1). Similar to the process applied to the McLane Impoundment transects, the cross-sectional area of sediment (ft^2) was computed for each transect. To estimate the approximate total sediment volume (ft^3), the cross-sectional area of sediment was multiplied by the distance midway to the next upstream and downstream transect.

The sediment distribution in the Goldman impoundment is different from the McLane impoundment. In the case of the McLane impoundment, there was generally sediment thickness across the entire transect. In the case of the Goldman impoundment, there are some transects where the sediment is located in "pockets" as opposed to across the entire transect. Shown in Figure 8.3-20 is a bar chart showing the approximate sediment volume (CY) at each transect from Goldman Dam to the Gregg Footbridge. The total sediment volume between the Goldman Dam and Gregg Footbridge is approximately 24,400 CY; however, this does not represent the mobile sediment volume.

The total sediment volume in Area B (between Goldman Dam and the confluence of Great Brook with the Souhegan River) is approximately 1,800 CY.

Summary:

Total Sediment Volume in McLane Impoundment to Goldman Dam:	4,700 CY
Total Sediment Volume in Goldman Impoundment to Gregg Footbridge:	24,400 CY
Total Sediment Volume in Goldman Impoundment up to Great Brook confluence:	1,800 CY

9.0 Goldman Dam Impoundment Sediments

9.1 Due Diligence

As part of the Goldman and McLane Dam removal feasibility study, the quality and quantity of sediment must be evaluated to inform sediment management alternatives, should the dams be removed. Depending on the sediment quality/quantity and the sediment transport analysis, different sediment management alternatives are considered including: a) allowing the sediment to naturally migrate downstream, b) partial or full dredging of impounded sediments, or c) partial dredging of sediments and stabilizing the remaining material in-place.

Due diligence was conducted to:

- Summarize historic sediment data collected within the Goldman Dam impoundment as part of the USEPAs Fletcher's Paint Superfund Site. Relative to sediment quality, considerable sediment testing was conducted sporadically between 1991 and 2012 within the Souhegan River in the proximity of the Fletcher's Paint site with some samples collected closer to Goldman Dam as well as above the Gregg Crossing Footbridge.

- Summarize other potential sources of contamination, with emphasis on the USEPA's Savage Well Superfund Site (two miles west of downtown Milford), the Snack Corner Mobil Station (located on Elm Street, across from the Fletcher's Paint Site), and local stormwater runoff (see Figure 9.1-1 for locations).

- Inform development of a proposed sediment sampling plan based on the due diligence effort.

9.2 Fletcher's Paint Superfund Site- Background

As noted above, located approximately 2,200 feet upstream of the Route 13 Bridge, on river-right, is the Fletcher's Paint Superfund Site.

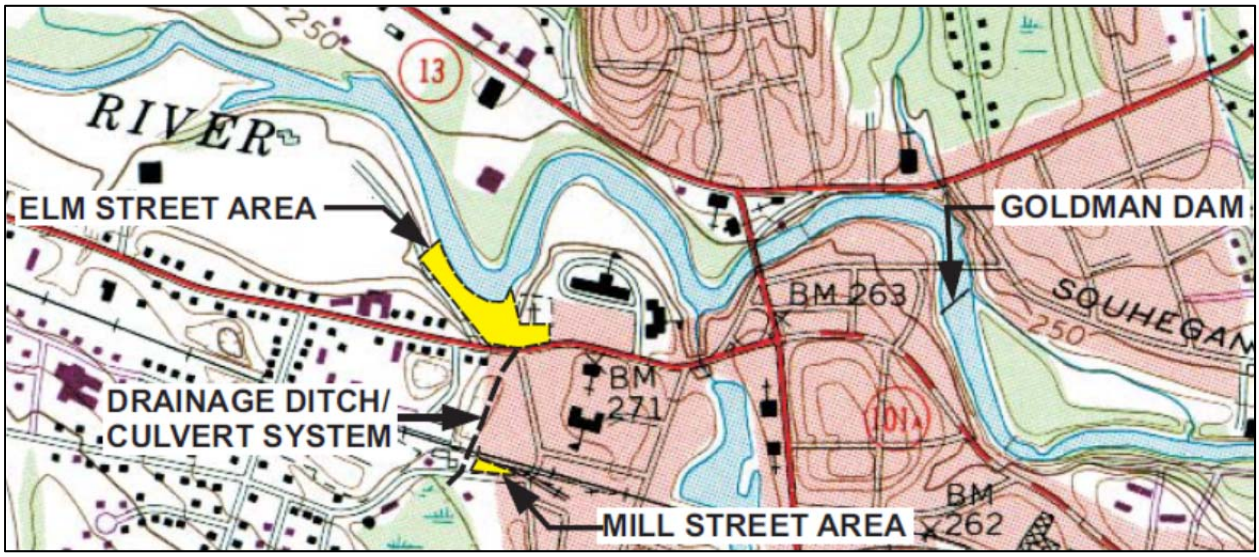
In 1984, contamination was discovered in the Keyes well, now a former municipal water supply for Milford. In 1985, the USEPA discovered volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs) and heavy metals in the soils near the former paint plant and in the Souhegan River sediments. High levels of PCBs were also detected in the soils around the paint storage building. In 1988, USEPA removed 863 drums from the site and shipped them to an authorized hazardous waste disposal facility. Higher than expected levels of PCBs and paint waste material were detected in the subsurface soils at Elm Street. Since the Plant was located adjacent to the Goldman Dam impoundment, sediments and surface waters from the river were examined and found to contain VOCs, including benzene and toluene; heavy metals including nickel and lead; and PCBs. Soil contamination consists primarily of PCBs, Polycyclic Aromatic Hydrocarbons (PAHs), and VOCs.

General Electric (GE), former owner[38] of the Fletcher's Paint Site, hired Arcadis, a consulting firm to conduct much of the work involving sediment and soil testing at the Fletcher's Paint site.

The Superfund site was broken up into Operating Units (OU), called OU-1 and OU-2. OU-1 consists of the Elm Street Area, Mill Street Area, and a drainage ditch/culvert system connecting these two areas. It also includes a plume of groundwater contamination extending from the Mill Street Area through the Elm

[38] The town now owns the Fletcher's Paint parcel as a result of a tax deed in November 1999.

Street Area to the Souhegan River. OU-2 is comprised of the Keyes Municipal Well Field and the portion of the Souhegan River location in the vicinity of the Elm Street Area of the site (see inset below, Arcadis, 2007).



9.3 Fletcher's Paint Superfund Site- Historic Sediment Sampling

Extensive sediment testing within the Goldman Dam impoundment has been conducted in association with the Fletcher's Paint site. A brief summary of the sampling dates, analytes tested, and sampling locations is provided below.

<u>1991-1994</u>
Investigations associated with OU-2 were performed on behalf of the USEPA (in assistance from the USFWS for biological sampling) and included the collection of surface water, sediment and biota samples. Most of the surface water and sediment samples were collected between 1991 and 1993 in support of the Remedial Investigation (RI). Additional surface water and sediment samples (as well as biota samples) were collected in November 1994. According to the USEPA, the November 1994 sampling event was performed on two occasions, once between November 8 through 11, 1994 and again on November 21, 1994 when the holding times for the first sampling event were missed.

The sampling activities performed involved the collection of sediment and surface water samples from 22 locations for miscellaneous analyses within the Souhegan River (see Figure 9.3-1). Sample locations extended from approximately 1,600 feet upstream to 2,000 feet downstream of the Gregg Crossing Footbridge, respectively. Sample locations were labeled as SW for surface water sample and SED for sediment sample (see Figure 9.3-1). Samples were tested for VOCs, semi-volatile organic compounds (SVOCs), PCBs, pesticides, and inorganics. Sediment sampling depths were listed as 0 to 0.5 feet deep. In addition to sediment sampling, biological samples were collected from several species of fish captured in the Souhegan River. These samples included the collection of 20 fillet samples, 20 offal[39] samples, and 40 whole fish samples for analysis of pesticides and PCBs. Twenty mussel samples were also collected for analysis of pesticides and PCBs. Note that the five samples were collected upstream of the Gregg

[39] Offal refers to the fishes internal organs.

Crossing Footbridge, well upstream of the Fletcher's Paint site, but potentially within the upstream extent of the impoundment[40].

2004

Supplemental sediment sampling activities were performed on behalf of the USEPA in June 2004 in the Souhegan River immediately adjacent to Elm Street Area. Surficial sediment samples (top three inches) were collected from 31 sampling locations (see Figure 9.3-2) and analyzed for VOCs, PAHs, PCBs, pesticides, and inorganics. Elevated PCB concentrations were found in the sediments collected near the Fletcher's Paint site.

2006

In 2006, USEPA, NOAA, USACOE, GE and their contractor, collectively undertook additional sediment sampling activities, fish tissue sampling, and sediment probing from the areas immediately upstream, adjacent to, and downstream of the Fletcher's Paint site. A total of 42 sediment cores were obtained in the areas listed below and shown in Figure 9.3-3.

- Upstream reference area (Area C) - Five (5) cores.
- Vicinity of Elm Street Area (Area A) - Nineteen (19) cores.
- Between Elm Street (Area A) and Goldman Dam (Area B) - Eleven (11) cores.
- Immediately upstream of Goldman Dam (Area B) - Seven (7) cores.

A stratified sampling approach was implemented, allowing the sediment sampling to be appropriately biased toward fine-grain sediments (where higher constituent concentrations are more likely to be present). Sediment collection was conducted in increments of 0 to 6 inches, 6 to 12 inches, and in 1 foot depth increments thereafter to the total depth of the probe-able sediment. In addition, only the samples from the top three intervals at each sampling location (i.e., the 0 to 6 inch, 6 to 12 inch, and 12 to 24 inch depth increments) were submitted for laboratory analysis.

In total, 139 sediment samples were collected for laboratory analysis. This included an average of three samples each from 42 sediment cores. Per the study plan developed for this work, only the samples from the top two feet of sediment were subject to PCB analyses, with the remaining deeper samples archived for potential future analysis. Based on this approach, 115 of the collected sediment samples were subject to PCB analyses. In addition to PCB testing, other testing included total organic carbon (TOC), moisture content, metals, PAHs, and particle size analysis.

2007 (Arcadis, 2007)

In June and July 2007, supplemental investigations were conducted by GE (and Arcadis) and USEPA with input from USFWS, USACOE and NOAA. This work was conducted after a significant flooding event in April 2007. The purpose of the investigation was to obtain supplemental data to support the boundary of the contamination and to determine if the significant flooding in April 2007 had re-deposited contaminated sediments onto the river banks.

Arcadis performed the USEPA-approved field activities, including fish collection, sediment probing, and sediment sampling between June 12 and July 27, 2006. Representatives of the above agencies participated in the field reconnaissance following GE's sediment probing activities for the purpose of selecting the sediment sampling locations. The objectives of the supplemental investigation were to:

[40] Based on sporadic staff gage measurements in 2010, the Goldman Dam creates a backwater extending approximately to the base of the Gregg Crossing Footbridge.

- Provide supplemental data regarding the presence and extent of PCBs and other select constituents in Souhegan River sediment and fish tissue samples collected upstream of, adjacent to, and downstream of OU-1.

- Provide data that could be used to revise USEPA's baseline human health risk assessment and baseline ecological risk assessment, if necessary.

Samples were obtained both in the upland area and eight samples were taken within the Souhegan River as shown in Figure 9.3-4. The USEPA and USACOE planned to use this data to determine the potential risks posed by the contaminated sediment and the potential ingestion of fish.

2012 (TechLaw, Inc)

Sediment sampling was again conducted during three events from July 2012 to August 2012. Results and findings are contained in a report entitled "*Field Activities Report for the 2012 Sediment Sampling Effort in the Souhegan River*" (TechLaw, 2012).

Per the final report, this effort consisted of collecting sediment samples for PCB analysis and characterizing the riverbed in terms of substrate composition. The sediment samples were submitted for chemical analysis to determine if total Aroclor levels exceeded the USEPA's Preliminary Remediation Goal (PRG) of 0.5 ppm. The original plan called for collecting 2-foot long sediment cores at each of the pre-selected sampling locations. The top 2 inches and bottom 22 inches were to be homogenized separately to create two subsamples. This approach was modified according to the USEPA direction on the first day of sampling such that sediment core samples were homogenized in 6 inch depth interval to better match the sample collection methods used historically in this section of the Souhegan River.

Samples were collected from 14 transects (A through N), wherever there was enough sediment sample that could be obtained for analysis. The transects were spaced approximately 20 feet apart. All sediment samples were submitted to Region 1 New England Regional Laboratory for total Aroclor analysis after each day of sampling.

Seventy-seven sediment samples (including two duplicates and four additional sets of samples) were collected at 39 sampling locations over four different sampling events. Figure 9.3-5 shows the sampling locations, which samples exceeded the PRG (shown in red), and if so, at what depths they exceed the PRG. The field team was only able to collect between one and three sediment samples per transect due to difficulties with substrate composition or presence of bedrock.

USEPA requested that sediment samples be obtained from two additional transects (i.e. T10 and T15) designated by Arcadis during a previous sampling event further upstream of the dam to both confirm historically-high PCB concentration at depth and to note surface sediment contaminant concentrations (specifically at T-15) which were evaluated because extremely low river conditions in 2012 left them exposed.

9.4 Fletcher's Paint Superfund Site- Historic Sediment Sampling- Findings

Although water sampling and fish/mussel sampling was previously conducted, only the sediment sampling results are reported herein as this material has the potential to mobilize if the Goldman Dam is removed. Contaminant concentrations were compared to the consensus based screening criteria presented in MacDonald et al., 2000 to determine if any contaminants of concern exist at elevated levels or if any contaminants pose a threat to freshwater ecological resources. The screening criteria are categorized into

threshold effects concentration (TEC) and probable effects concentration (PEC). Definitions of TEC, PEC and total organic carbon (TOC) are provided below.

- TEC - Threshold Effects Concentration- TEC values are screening thresholds below which adverse effects to freshwater ecosystems are unlikely.
- PEC - Probable Effects Concentration- PEC values are screening thresholds above which adverse effects to freshwater ecosystem are likely.
- TOC- Total Organic Carbon- TOC in sediment, in general, is inversely related to bioavailability of organic contaminants. Typically, the higher the TOC, the less likely the contaminants are bioavailable because the sediment organic matter acts as an absorbent, where the organic compounds dissolve into the sediment organic matter matrix.

Shown in Table 9.4-1 (see Vol 2) is the TEC and PEC values based on the MacDonald et al., 2000 screening criteria. These values are also shown on numerous tables referenced below.

1991-1994

Table 9.4-2 (Vol 2) includes the laboratory results for the Phase 1A and 1B remedial investigations conducted in 1991 and 1993. Table 9.4-3 (Vol 2) includes the results for the 1994 investigation (see Figure 9.3-1 for sample locations). For all tables appearing in this section and following sections, concentration levels highlighted in **bold green** represent sediment samples exceeding the TEC. Concentration levels highlighted in **bold red** represent sediment samples exceeding the PEC. A brief summary of the sampling results, relative to the TEC and PEC, is provided below for each sampling event. Note that if there was a non-detect (no contaminant detected at the detection limit), no "value" was entered into the table; rather it was left blank. All units in the tables are expressed in part per million (ppm). Note that 1 mg/kg = 1 ppm.

Total PCBs

Seven (7) of the 22 sediment samples had total PCB levels above the TEC criteria (0.0598 ppm) and four above the PEC criteria (0.676 ppm). Concentrations exceeding the PEC criteria occurred at sampling locations adjacent to the Fletcher's Paint site: SED-02A (25 ppm), SED-09 (1.1 ppm), and SED-11 (47 ppm) as well as downstream at site SED-04A (0.76 ppm).

Pesticides

Eight (8) of the 22 sediment samples had detections of pesticides above the TEC criteria. No detections were found above the PEC criteria. Detections occurred upstream, adjacent to, and downstream of the Fletcher's Paint site.

PAHs

Nine (9) of the 22 sediment samples had PAH levels above the TEC criteria, and no detections above the PEC criteria. The highest levels were found at sites SED-09 (adjacent to Fletcher's Paint), SED-10 (upstream of Fletcher's Paint), and SED-21 (downstream of Fletcher's Paint). These results suggest that the PAH sources are not exclusive to the Fletcher's Paint site.

Metals

Metals detected above the TEC criteria included arsenic, copper and lead. Arsenic was found above the TEC criteria upstream and downstream of Fletcher's Paint (SED-10 and SED-21) whereas lead was found above the TEC criteria only adjacent to Fletcher's Paint (SED-2A). Copper was found above the TEC criteria upstream (SED-15) and adjacent to Fletcher's Paint (SED-2A and SED-11). No detections were found above the PEC criteria.

Although the Gregg Crossing Footbridge roughly approximates the upstream extent of the Goldman Dam impoundment, for purposes of this evaluation, it was assumed that samples collected above this location would not be impacted by the Fletcher's Paint Site, and would reflect background conditions. Five sediment samples were collected upstream of the Gregg Crossing Footbridge including SED-15 (1994), SED-12 (1993), SED-14 (1994), SED-10A (1993) and SED-10 (1991).

SED-15: TEC exceedence: Metals- copper
SED-12: Non-detects
SED-14: TEC exceedences: SVOCs- benzo(a)anthracene, benzo(a)pyrene, chrysene, phenanthrene, pyrene, Pesticides: methoxychlor
SED-10A: TEC exceedences: Total PCBs
SED-10: TEC exceedences: SVOCs- anthracene, benzo(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, phenanthrene, pyrene, Pesticides: DDE, DDT, DDD, dieldrin, Metals- arsenic

There were TEC exceedences in the upstream samples for certain SVOCs, pesticides and metals. In addition sample SED-10A was above the TEC for total PCBs. As described later, the EPA Savage Well Superfund site is located further upstream in Milford. The contaminants detected at Savage well were related to VOCs.

2004

Table 9.4-4 (Vol 2) includes sediment sampling results for 31 locations immediately adjacent to and downstream of the Fletcher's Paint site in June 2004 (see Figure 9.3-2 for sampling locations).

Total PCBs

The 2004 data indicates that PCB contamination was still prevalent in the sediment particularly adjacent to Fletcher's Paint site. Ten (10) of the 31 sites had PCB levels above the TEC criteria, and eight (8) of the 31 sites had PCB levels above the PEC criteria. The highest PEC exceedences for total PCBs occurred at sampling locations adjacent to the Fletcher's Paint site: SD-13 (36.3 ppm), SD-15 (7.14 ppm), and SED-08 (15 ppm). Of the three sediment samples that were collected downstream of the Fletcher's Paint Site, PCBs were not detected at two sites, while one site (SED-34) had total PCBs levels below the TEC criteria.

Pesticides

The 2004 data reported that all 31 samples were non-detect for pesticide parameters.

PAHs

Ten (10) of the 31 sites had PAH levels above the TEC criteria with no detections above the PEC criteria. Parameters of concern include benzo(a)anthracene, benzo(a)pyrene, chrysene, and phenanthrene. No TEC exceedences were observed in the three sediment samples downstream of the Fletcher's Paint site (SD-30, SD-32, and SD-34).

Metals

Only one site had a TEC exceedence for metals. Arsenic was detected at 11 ppm at site SD-22, adjacent to the Fletcher's Paint site No detections were found above the PEC criteria for metals.

2006

Table 9.4-5 (Vol 2) includes sediment sampling results for 42 sediment cores collected adjacent to the Fletcher's Paint site as well as upstream and downstream samples, including one sample (T-1-4) just upstream of Goldman Dam (see Figure 9.3-3 for sampling locations). The samples were obtained in July 2006, compared to the TEC and PEC criteria, and evaluated to determine trends related to contaminants in deeper sediment (up to 24 inches deep).

Total PCBs

The 2006 data indicates that PCB contamination is still prevalent in the Souhegan River in the vicinity of the Fletcher's Paint site. Twenty-three (23) of the 42 sample sites contained total PCBs levels higher than the TEC criteria. Six (6) sites had total PCBs higher than the PEC criteria, including five (5) sample locations adjacent to the Fletcher's Paint site SD26, SD27, SED-2A, T-15-6, and T-15-7A, and one site just upstream of Goldman Dam (T-1-4). The core collected at T-1-4 (see inset) was split into two subsamples representing different depths. The top layer (0-6 inches) was relatively clean having a total PCB concentration of 0.048 ppm which is below the TEC. The bottom layer (6-10 inches) was reported having total PCBs of 1.4 ppm, in excess of the PEC criteria (0.676 ppm). This suggests that perhaps historical PCB contamination from upstream is trapped in deeper layers of sediment.

For the other five (5) samples containing PCBs exceeding the PEC criteria, a similar trend of higher contaminant levels deeper in the sediment column was observed at SD-27, T-15-6, and T-15-7A. The highest total PCBs were found in the 6-13 inch layer at site SD-27, which is near the Fletcher's Paint site.

Pesticides

Pesticide parameters were detected above the TEC in 9 of the 42 samples, including sampling locations adjacent to, and downstream of, the Fletcher's Paint site. At one site (SD-27), the pesticide heptachlor epoxide was detected in exceedence of the PEC criteria within the 6-13 inch layer, similar to the elevated levels of PCBs detected in this sample. Other parameters of concerns detected above the TEC criteria include DDT and derivatives, endrin, and lindane (gamma-BHC).

PAHs

Various PAH parameters were detected at levels above the TEC criteria at 22 of the 42 sampling locations, including upstream, adjacent to, and downstream of the Fletcher's Paint site. PAH detections were reported above the PEC for pyrene and benzo(a)anthracene at site DEP-05, located downstream of Fletcher's Paint site.

Metals

Arsenic, cadmium, chromium, and lead were detected in at least one sample above the TEC criteria. Lead exceeded the TEC at sites upstream, adjacent to, and downstream of the Fletcher's Paint site. Arsenic and cadmium were detected above the TEC at upstream and downstream sites, while chromium was detected above the TEC at only one sample location (T-6-8) below the Fletcher's Paint site. No detections were above the PEC for metals.

<u>2007</u>

Nine (9) sediment samples were collected from June to August 2007 and analyzed for PCBs (see Figure 9.3-4 for sampling locations). These samples were taken after the April 2007 flood. The results of the sample analysis (see

Table 9.4-6, Vol 2) show exceedences of the TEC criteria for PCBs at two sampling locations adjacent to the Fletcher's Paint site (SD-26 and SD-42). Samples were also collected from a site just upstream of Goldman Dam (SD-35- see inset above), similar to the sample collected in 2006. The 2007 results showed a similar pattern of PCB contamination at this site. The top layer (0-6 inches) was relatively clean having a total PCB concentration of 0.029 ppm which is below the TEC. The bottom layer (6-10 inches) was reported to have total PCBs of 0.69 ppm, slightly above the PEC criteria.

2012

Total PCB's collected in 2012 were compared to the TEC and PEC. Table 9.4-7 lists the samples exceeding the TEC, PEC and the PRG (see Figure 9.3-5 for sampling locations and the inset). Note that samples D-1 to SED dep 2 in Table 9.4-7 below are located between the Goldman Dam and approximately 350 feet upstream of the dam. Samples T10-1 and T10-2 are located roughly half way between Goldman Dam and Fletcher's Paint Site and samples T15-1, -2 and -3 are located adjacent to Fletcher's Paint site.

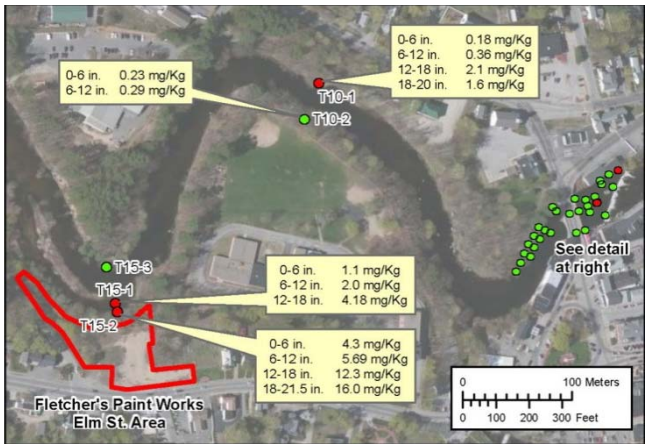


Table 9.4-7: Summary of Sediments Exceeding the TEC, PEC and PRG for Total PCBs (2012)

Sample Location	Sample Date	Sample depth	*Total PCBs (mg/kg)	Exceed TEC (0.0598 mg/kg)	Exceed PEC (0.676 mg/kg)	Exceed PRG (>0.5 mg/kg)
D-1	08-24-2012	0-6 inches	0.15	X		
F-1	08-08-2012	0-6 inches	0.14	X		
H-3	08-07-2013	0-6 inches	0.13	X		
K-3	07-31-2012	6-8 inches	23.00	X	X	X
K-3a	08-24-2012	6-12 inches	0.36	X		
K-3b	08-24-2012	6-12 inches	0.16 j(p)	X		
N-1	07-31-2012	0-5 inches	1.00	X	X	X
SED dep 2	07-06-2012	6-16 inches	0.16	X		
T10-1	08-24-2012	0-6 inches	0.18	X		
T10-1	08-24-2012	6-12 inches	0.36	X		
T10-1	08-24-2012	12-18 inches	2.1	X	X	X
T10-1	08-24-2012	18-20 inches	1.6	X	X	X
T10-2	08-24-2012	0-6 inches	0.23	X		
T10-2	08-24-2012	6-12 inches	0.29	X		
T15-1	08-24-2012	0-6 inches	1.1	X	X	X
T15-1	08-24-2012	6-12 inches	2	X	X	X
T15-1	08-24-2012	12-18 inches	4.18	X	X	X
T15-2	08-24-2012	0-6 inches	4.3	X	X	X
T15-2	08-24-2012	6-12 inches	5.69	X	X	X
T15-2	08-24-2012	12-18 inches	12.3	X	X	X
T15-2	08-24-2012	18-21.5 inches	16	X	X	X

*Total PCBs: Value of total detected PCB concentrations.
j- Estimated value.
p- The confirmation value exceeded 35% difference and is less than 100%. The lower value is reported.
Note the grey and blue highlighting is meant to show the same sample location but different sample depths.

As Table 9.4-7 shows eight (8) samples between Goldman Dam and approximately 350 feet upstream exceeded the TEC and two samples exceeded the PEC and PRG. For the sampling roughly halfway between the dam (samples T10-1, -2) and the Fletcher's Paint site there were exceedences of the TEC (and PEC for depths greater than 12 inches). In addition, all sample sites (T15-1, -2, and -3) adjacent to the Fletcher's Paint Site there were several exceedences of the PEC and PRG throughout the sediment profile (0-20+ inches).

Human Health and Ecological Risks (September 2012)

In the Final Remediation Investigation Report, issued in September 2012 (Watermark, 2012, contractor for USACOE), the findings of a human health and ecological risk assessment are provided. The general conclusions noted in this report (Executive Summary Page ES-4) are as follows:

"*…there is unacceptable risk to human and ecological receptors from exposure to PCBs in Souhegan River sediments within Area A/B of the Fletcher's Paint Superfund Site. There is risk to human receptors from direct contact with sediments and fish ingestion, with fish ingestion risks being of particular concern. There is also risk to benthic invertebrates from exposure to metals and pesticides in sediment. The observed risk is unacceptable relative to background Area C. A PCB Hot Spot Area was identified within Area A/B of the Souhegan River study area where there are statistically significant elevated concentrations of PCBs. Within this area, there are also elevated concentrations of PCBs in subsurface sediments that could pose greater risk to human and ecological receptors if storm and flood events, or winter ice flows, expose these deeper sediment layers. Consequently, the PCB Hot Spot Area could become dispersed and provide a continuing source of bioavailable PCBs to the Souhegan River if not remediated*".

9.5 Other Potential Pollutant Sources

9.5.1 Savage Well Superfund Site

Another USEPA Superfund site, Savage Well, is located about two miles west of the center of Milford (see Figure 9.1-1), and consists of a municipal well and the underlying aquifer within the Souhegan River floodplain. The Savage Well operated from 1960 to 1983, during which it supplied approximately 45% of the town of Milford's needs, averaging 200,000 gallons per day. However, in February 1983, NHDES detected concentrations of VOCs in the well exceeded drinking water standards and shut the well down. At that time, the State began investigations to locate the source of contaminants that were also present in the wastes of nearby industries. The VOCs detected in the groundwater include tetrachloroethylene (PCE), trichloroethylene (TCE), 111-trichloroethane, and vinyl chloride; and heavy metals including lead, chromium, and nickel. The soil is also contaminated with VOCs. Numerous measures have been implemented to clean up the Site; it is unknown if work still continues on clean up.

9.5.2 Mobil Station- Elm Street

A diesel fuel spill occurred in March 2009 at the Mobil Station located on Elm Street across from the Fletcher's Paint Site (see Figure 9.1-1). A leak of approximately 1,500 gallons of fuel discharged into the Souhegan River due to a break in a pipe connecting an above-ground storage tank containing the diesel to a pump. The leak occurred over three days, flowing into the soil beneath the pump, and into a granite culvert that discharges in the Souhegan River.

9.5.3 Stormwater Runoff in Project Area

The Goldman and McLane Dams are located in the heart of "downtown" Milford. Stormwater runoff

from the surrounding buildings and pavement eventually empties into the Souhegan River within the Project Area. Of potential concern is stormwater runoff (gasoline and oils) from vehicles, and winter road treatment (salt, sand).

9.5.4 Oil Leak

On August 2, 2011, the town of Milford Conservation office notified the NHDES Oil Remediation and Compliance Bureau (ORCB) that a sheen was observed on the Souhegan River. That same day NHDES personnel conducted a site reconnaissance. The leak was detected near 15 Amherst Street, just below the Goldman Dam on river-left. Immediate action was taken as absorbent booms were placed around the site to contain the sheen. Although not part of this study, a sample of the sheen material was collected on August 4, 2011 for laboratory analysis to identify the material. On August 17, 2011, the laboratory reported that the material was identified as No. 6 fuel oil, a highly viscous oil. All correspondence relative the oil leak is included in Appendix G.

On August 31, 2011, NHDES contracted with GeoInsight, Inc. to conduct a subsurface investigation on the two properties, 9 and 15 Amherst Street, which abut the Souhegan River where the No. 6 fuel oil seepage was observed. Soil contaminated with No. 6 fuel oil above NHDES's S-1 standards for TPH (total petroleum hydrocarbons) was observed in soil collected on the 15 Amherst St property only. Contaminated soil was observed 20 feet or more below the ground surface. Groundwater just above NHDES ambient groundwater quality standards for benzene was observed in a sample collected from one monitoring well on the 15 Amherst St. property. No other compounds were detected in this sample. Groundwater collected from the other two monitoring wells did not contain any compounds exceeding the NHDES' ambient groundwater quality standards.

The NHDES' ORCB plan for site clean-up is detailed in Appendix G (along with more detailed photographs showing the leak). The ORCB's plan was to remove the contaminated sediments within the riverbed during low flow conditions and installing a limited concrete (less than 10 feet wide) seepage prevention cap on the bedrock surface to prevent further seepage and water contamination. The exact amount of material to be removed was to be determined on-site based on visual observations and screening of materials for VOCs. It was estimated that there is 6 cubic yards (CY) of impacted material. After the contaminated material was removed, the excavation area was to be stabilized with stone, concrete and sediment material to prevent further petroleum seepage.

The NHDES provided the following status update via email on November 21, 2012.

> *On October 26, 2012 a vacuum truck was used to remove the visible contaminated sediment around the seepage area. When possible, boulders found coated with oil were moved aside. Upon removing the sediment near the rock retaining wall to about 18 – 24 inches, groundwater (presumably) immediately filled the hole. There was a visible layer of oil on the water surface. Below this flowing water a layer of densely packed cobble was observed. The cobble layer did not appear to be oil coated. This cobble layer was found in the river below the sediment. As the work moved towards the river edge, the cobble layer was oil coated. NHDES decided to install a collection/observation well in the area adjacent to the rock wall (picture below). As a temporary measure, the collection well was filled with sorbent material. The well is being held in place by rocks and roped to a nearby tree. NHDES cancelled the second day of steam cleaning due to Hurricane Sandy and high water levels.*

NHDES noted that based on their observation, they need to reassess the approach, as installing a concrete barrier on cobbles may not be reasonable. Once the river flow drops, NHDES plans to re-visit and discuss next steps.

On July 23, 2013, the NHDES sent a letter to the owner of the 15 Amherst Street property (Appendix G), indicating that they are the responsible party with respect to the oil discharge and required they complete an Initial Site Characterization. The Initial Site Characterization is necessary to assess impact to soil and groundwater and identify human and environmental receptors. More specifically, the NHDES requested the property owner to locate the oil storage system source and determine the extent of the oil leak. The NHDES requested that the Initial Site Characterization be prepared by an environmental consultant and submitted to NHDES by August 15, 2013. On August 2, 2013, nine soil borings were installed to locate and delineate soil contamination. A report summarizing investigation results is expected to be submitted in June 2014.

Based on email communications the NHDES ORCB on February 4, 2014, the NHDES plans to continue annually placing booms in the river in the spring to contain the seeping, highly viscous No. 6 fuel oil and remove the booms in the late fall/early winter when seepage stops. This will continue until the seepage stops or permanent containment is installed. Per NHDES ORCB over the last three years, the seepage rate appears to have declined and the seepage is confined to a very limited area of the river bank.

Looking at Boom, Goldman Dam in background (Source: NHDES, 2011)

Looking at Collection/Observation Well, (Source: NHDES, 2012)

10.0 McLane Dam Sediment Sampling Plan

10.1 McLane Dam Impoundment- Correspondence relative to Sediment Sampling Plan

No information is available on the sediments within the McLane Dam Impoundment, thus a sediment sampling plan was needed. Due to the proximity of the Fletcher's Paint Superfund Site, the town sent the USEPA a letter dated March 8, 2011 (see Appendix D) seeking funding associated with sediment sampling in the McLane Dam impoundment. In a letter dated March 31, 2011 (see Appendix D), the USEPA responded indicating they would participate through the use of their laboratory at no cost to the town. As part of this offer, the USEPA required the development of a Quality Assurance Project Plan (QAPP) detailing the sampling locations, methods, and procedures to complete the sediment sampling.

Between April and July 2011, numerous conference calls and drafts of the QAPP were circulated between USEPA, USACOE, USFWS, NHDES, the town and its consultant. On July 27, 2011, NHDES and USEPA formerly approved the "*McLane Dam, Milford, NH, Sediment Sampling Plan and Quality Assurance Project*" which is contained in Appendix H. Much of the information contained in the QAPP is described in the preceding sections of this report; however, the following sections of this report describe the McLane Dam sediment sampling plan.

10.2 McLane Dam Impoundment- Sediment Sampling Locations

Sediment samples were collected from the McLane Dam impoundment and from upstream and downstream locations to evaluate sediment quality and determine risk to freshwater ecological resources from potential contaminants. The sediment sampling plan was developed in accordance with: a) the NHDES' Evaluation of Sediment Quality Guidance Document (Draft April 2005), b) NHDES' Evaluation of Sediment Quality for Dam Removals, October, 2006, c) EPA Technical Manual EPA 823-B-01-002 (2001), and d) consultation with the Project Partners and USEPA New England Regional Laboratory. In addition, methods were developed to be consistent with previous sampling performed upstream at the Fletcher's Paint site (BBL, 2006) to the extent practical.

<u>Sediment Sampling Locations</u>

This section lays out the proposed sediment sampling locations and procedures that were agreed upon by Project Partners. The following sections summarize the proposed sediment sampling per the QAPP, before any sampling was conducted (so it is written in a tense that the work is yet-to-be completed) Note that actual sediment sampling findings are discussed in Section 11.0.

NHDES' guidance recommends that four sediment samples be collected to evaluate sediment quality on a screening level for dam removal investigations. Based on the due diligence work, and the sediment depth measurements in the McLane Dam impoundment, additional sediment sampling was proposed at the locations described in Table 10.2-1 (end of section). Based on discussions with the Project Partners, it was agreed that full sediment cores would be collected within the McLane Dam impoundment to examine the horizontal and vertical distribution of potential sediment contaminants. Sediment will be collected from seven locations for this investigation, as follows:

- One sample upstream of the Goldman Dam impoundment
- Five full depth core samples in the McLane Dam impoundment
- One sample downstream of the dam

Upstream Sampling Location

No sediment sampling is proposed in the Goldman Dam impoundment due to the extensive sampling conducted previously and summarized earlier in this report.

The location of the upstream sample was discussed with Project Partners and USEPA and it was decided that one (1) sample will be collected in the Souhegan River above the upstream extent of the Goldman Dam impoundment, but downstream of the Savage Well Superfund site. This sample will document "background" or "reference" conditions. The proposed upstream sampling location is shown in Figure 10.2-1; fine-grained sediments will be collected from this location to the point of refusal and if the sediment is deeper than 12 inches, the core sample will be partitioned in one-foot increments for subsample analysis.

McLane Dam Impoundment Sites

Full depth sediment core samples will be collected from five (5) targeted locations in the McLane Dam impoundment for vertical subsampling. Sample sites were chosen based on the maximum sediment depth locations and extend from transect T-1 upstream to transect T-6, where the majority of sediments are deposited. Each core sample will be subsampled in one foot depth intervals and submitted for laboratory analysis. Actual impoundment sampling locations are shown in Figures 10.2-1 and 10.2-2 (blown up). Samples may be collected either by boat, or on foot, depending on the site conditions.

Downstream Sampling Location

In addition, one (1) sediment sample will be collected in the Souhegan River below McLane Dam. The proposed downstream sampling location is shown in Figure 10.2-1; fine-grained sediments will be collected from this location the point of refusal and if the sediment is deeper than 12 inches, the core sample will be partitioned in one-foot increments for subsample analysis.

10.3 Chemical and Physical Parameters and Laboratory Testing Methods

Parameters

The sediment samples will be analyzed for both physical and chemical parameters. As per NHDES guidelines, the analysis will include:

- Total organic carbon
- Grain size distribution via sieve and hydrometer by American Society for Testing and Materials (ASTM) Method D-422, or a comparable method (porosity and bulk density will also be tested)
- Polynuclear aromatic hydrocarbons (PAHs) by USEPA Method 8270C
- Polychlorinated biphenyls (PCBs) by USEPA Method 8082
- Pesticides by USEPA Method 8081
- Selected metals (arsenic, barium, cadmium, chromium (total), copper, lead, mercury, nickel, zinc by USEPA Methods 6010 and 7174 (mercury only)
- VOCs by USEPA Method 8260B
- SVOCs by USEPA Method 8270C

Table 10.3-1 (end of section) lists the analysis proposed for each subsample.

PCBs
Based on the previous sediment sampling conducted in the Goldman Dam impoundment, PCBs will be analyzed from all sample locations including deeper core subsamples.

SVOCs, Pesticides, Metals
USEPA suggested that in light of the upstream information gathered as part of the Fletcher's Paint Site that a full suite of chemical analyses (VOCs, SVOCs, Pesticides, PCBs and metals) may not be needed for every sample collected. Only the surficial layer from all sample locations will be analyzed for SVOCs, pesticides and metals.

Volatile Organic Compounds
The surficial layer from all sample locations will be analyzed for volatile organic compounds (VOCs). Due to the unstable nature of VOCs, it was recommended that the sediment samples being analyzed for these parameters be done so as soon as possible (USEPA, 2001). Based on the previous sediment sampling conducted in the Goldman Dam impoundment, VOCs do not appear to be an issue for this project. However, it was agreed to limit VOC sample collection to one surficial sample from each sample location in order to meet the NHDES's screening requirements. VOC sampling methods described below were developed after NHDES's *Final Policy- Preservation of VOCs in Soil Samples* dated March 2000.

Physical Parameters
The physical parameters, including grain size, porosity and bulk density were proposed for evaluating sediment transport and refining sediment volume in a dewatered condition and will be collected and analyzed from the surface of each sampling location. Additional subsamples will be collected for these parameters if the core sample indicates presence of stratified sediment layers (as indicated by differences in color or texture of the core sample).

Total organic carbon (TOC) is related to contaminant uptake and availability and would be conducted on all subsamples from each location.

Table 10.2-1: Proposed Sediment Sampling Locations in the McLane Dam Project Area

Sample No.	Location	Type/Depth
MD-2011-US A: 0-12” B: 12-24”	Upstream Reference Site, in an area of fine-grained sediment deposition. See Figure 10.2-1.	Core - Subsample sediment in 1 foot depth increments for separate analysis (as field conditions dictate)
MD-2011-T-1 A: 0-12” B: 12-24” C: 24-36” D: 36-48” E: 48” +	Impoundment T-1 Station 120 Max sed depth = 5.7’	Core Subsample sediment in 1 foot depth increments for separate analysis
MD-2011-T-2 A: 0-12” B: 12-24” C: 24-36” D: 36-48” +	Impoundment T-2 Station 140 Max sed depth = 4.2’	Core Subsample sediment in 1 foot depth increments for separate analysis
MD-2011-T-3 A: 0-12” B: 12-24” C: 24-36” D: 36-48” E: 48” +	Impoundment T-3 Station 110 Max sed depth = 5.1’	Core Subsample sediment in 1 foot depth increments for separate analysis
MD-2011-T-4 A: 0-12” B: 12-24” C: 24-36” D: 36-48” +	Impoundment T-4 Station 100 Max sed depth = 4.5’	Core Subsample sediment in 1 foot depth increments for separate analysis
MD-2011-T-6 A: 0-12” B: 12-24” C: 24-36” D: 36-48” E: 48” +	Impoundment T-6 Station 50-60 Max sed depth = 4.4’	Core Subsample sediment in 1 foot depth increments for separate analysis
MD-2011-DS A: 0-12” B: 12-24”	Downstream of the dam, in an area of fine-grained sediment deposition. See Figure 10.2-1.	Core - Subsample sediment in 1 foot depth increments for separate analysis (as field conditions dictate)

Table 10.3-1: Proposed Analysis Required for Each Subsample.

Sample No.	Sample Depth	Constituent						
		PCBs	TOC	VOCs	SVOCs	Pesticides	Metals	Physical Parameters
MD-2011-US	A: 0-12”	x	x	x	x	x	x	x
	B: 12-24”	x	x					
MD-2011-T-1	A: 0-12”	x	x	x	x	x	x	x
	B: 12-24”	x	x					
	C: 24-36”	x	x					
	D: 36-48”	x	x					
	E: 48” +	x	x					
MD-2011-T-2	A: 0-12”	x	x	x	x	x	x	x
	B: 12-24”	x	x					
	C: 24-36”	x	x					
	D: 36-48” +	x	x					
MD-2011-T-3	A: 0-12”	x	x	x	x	x	x	x
	B: 12-24”	x	x					
	C: 24-36”	x	x					
	D: 36-48”	x	x					
	E: 48” +	x	x					
MD-2011-T-4	A: 0-12”	x	x	x	x	x	x	x
	B: 12-24”	x	x					
	C: 24-36”	x	x					
	D: 36-48” +	x	x					
MD-2011-T-6	A: 0-12”	x	x	x	x	x	x	x
	B: 12-24”	x	x					
	C: 24-36”	x	x					
	D: 36-48”	x	x					
	E: 48” +	x	x					
MD-2011-DS	A: 0-12”	x	x	x	x	x	x	x
	B: 12-24”	x	x					
Total Estimated Samples		**27**	**27**	**7**	**7**	**7**	**7**	**7**

11.0 McLane Dam Sediment Sampling Results

11.1 McLane Dam Impoundment- Background

The McLane Dam Sediment Sampling Plan and QAPP was approved by the signatories (USEPA, NHDES, and Gomez and Sullivan), on July 27, 2011. As noted earlier, an oil sheen (the No. 6 fuel oil as described earlier) was observed in the Goldman Dam impoundment on August 3, 2011, a few days prior to the scheduled August 11, 2011 sediment sampling. A conference call was held on August 5, 2011 with USEPA, NOAA, USFWS, USACOE, NHDES, the town of Milford, and Gomez and Sullivan to discuss whether to proceed with the sediment sampling given the sheen. In the end, the group agreed to proceed with the sampling and to note any sheen observed during the sampling. Gomez and Sullivan conducted the sediment sampling, per the approved plan, on August 11, 2011. Prior to the work, the Milford DPW removed the McLane Dam stoplogs to purposely lower the impoundment level to facilitate sediment sampling. The flows, as measured at the USGS gages in Milford and Merrimack, were 45 cfs and 80 cfs, respectively on August 11. With low flows and the impoundment drawn down, it permitted sediment sampling collection.

Per the proposed sampling plan, coring was attempted with a 5-foot stainless steel corer with a liner tube and core catcher for those samples in the impoundment. An alternate method involved using just the liner tube with core catcher and capping the top end to provide suction upon retrieval of the core. The core sampling in the impoundment proved difficult for a few reasons, but primarily because of sediment corer issues. The sediment was course sand with some gravel/cobble at most locations, which generally prevented hand driving the coring equipment all the way to the parent material. Recovery of the non-cohesive sandy cores was poor, even with the core catcher. After multiple attempts at the impoundment sites, the deepest core obtained was 18 inches. In the end, Gomez and Sullivan collected between 12-18 inch deep cores at each of the five impoundment sites. The sediment from each site was composited into one sample (after collecting the VOC), and all of the parameters were evaluated (PCB, pesticides, SVOC, VOC, TOC, and grain size). Samples were also collected above the Goldman Dam impoundment and below McLane Dam per the QAPP. All samples were provided to the USACOE for delivery to the USEPA New England Regional Laboratory for chemical and TOC analysis on August 11, 2011. In addition, samples were provided to Miller Engineering and Testing for grain size analysis. Photographs taken during the sampling are shown in Appendix I.

11.2 McLane Sediment Sampling Results

Appendix J contains a summary of the findings along with the chemical sampling results as provided by the USEPA laboratory and the physical testing results (distribution of sediments composition) as provided by Miller Engineering and Testing, Inc.

Physical Testing

Figure 11.2-1 shows the TOC findings, and Figure 11.2-2 shows the grain size distribution for each sample. The bulk of the sediment retrieved in the impoundment samples is classified as medium sand.

Chemical Testing

Table 11.2-1 includes a summary of those contaminants exceeding the TEC screening criteria, which are shown in **green bold**. Note that none of the contaminants exceeded the PEC screening criteria. Shown in the two far right-hand columns are the MacDonald screening criteria for TEC and PEC, with the exception of VOCs. For the one detected VOC (toluene) there is no MacDonald screening criteria, and thus the screening criteria was from the EPA Ecotox- Sediment Quality Benchmarks (SQB).

Table 11.2-1: Contaminants Exceeding Screening Criteria

Parameter	Results per Sample Location (units, parts per billion, ppb)								Screening Criteria	
	Down-stream	Imp-T1	Imp-T2	Imp-T3	Imp-T4	Imp-T4 duplicate	Imp-T6	Up-stream	TEC MacD	PEC MacD
Sample Depth (inches)	0-18	0-12	0-12	0-15	0-18	0-18	0-18	0-13		
PCBs										
Total PCBs	ND	ND	**120**	**410**	**160**	**130**	ND	ND	59.8	676
Pesticides										
4,4'-DDE	ND	ND	3.0	**4.6**	ND	ND	ND	ND	3.16	31.3
SVOCs										
Benzo(a)anthracene	**230**	**130**	**590**	**280**	ND	**180**	ND	**230**	108	1050
Benzo(a)pyrene	ND	110	**680**	**270**	110	130	ND	**220**	150	1450
Benzo(b)fluoranthene	**150**	**100**	**810**	**280**	ND	**160**	ND	**230**	27.2	
Benzo(g,h,i)perylene	120	ND	**520**	**190**	ND	ND	ND	150	170 (LEL)	3200 (SEL)
Benzo(k)fluoranthene	ND	ND	**560**	230	ND	170	ND	170	240 (LEL)	13400 (SEL)
Bis(2-ethylhexy)phthalate	ND	ND	**280**	ND	ND	ND	ND	ND	180	2600
Chrysene	**210**	130	**800**	**330**	130	**360**	ND	**280**	166	1290
Fluoranthene	**500**	260	**1600**	**650**	280	**470**	ND	**490**	423	2230
Indeno(1,2,3-cd)pyrene	100	ND	**480**	180	ND	ND	ND	130	200 (LEL)	320 (SEL)
Phenanthrene	**330**	150	**810**	**340**	160	160	ND	**270**	204	1170
Pyrene	**410**	**220**	**1300**	**560**	**240**	**380**	ND	**450**	195	1520
VOCs										
Toluene	ND	**3200**	ND	ND	ND	ND	ND	ND	670 EPA-Ecotox	

Notes: All PCB detected results were Aroclor-1242. LEL = Lowest Effect Level, and SEL = Severe Effect Level used as screening criteria if TEC/PEC were not reported. Toluene screening criteria obtained from EcoTox Thresholds (EPA, 1996). Bis(2-ethylhexyl)phthalate screening criteria from McDonald, et al 1996. Benzo(a)fluoranthene screening criteria obtained from EPA Region 3 (threshold effect levels for *Hyalella azteca* in 28 day tests (TEL-HA28) (U.S.EPA 1996a; Ingersoll et al. 1996)).
ND- non detect.

11.3 Next Steps

Following the sediment sampling several conference calls were held and follow-up assessments were conducted using existing sediment data. The chronology of events just prior to the McLane sediment sampling, and thereafter are summarized in Table 11.3-1 below. Below the table is more information on major milestones, which are related to sediment at Goldman and McLane Dams.

Table 11.3-1: Chronology of Events Relative to Goldman and McLane Dam Sediments

Date	Action
07/27/11	McLane Sediment Sampling Plan and QAPP approved
08/02/11	Sheen noted on Goldman Impoundment (discovered later to be No. 6 diesel fuel)
08/05/11	Conference call held to determine whether the McLane sediment sampling should proceed given sheen. Parties agree to proceed with sampling, but request those conduct the field work note anything unusual relative to the sheen during the sampling.
08/11/11	McLane Dam sediment sampling conducted. Difficulties with the sediment corer- originally planned on obtaining deep cores (up to 5 feet in some areas). Instead sediment was collected from the top 18

Date	Action
	inches.
08/22/11	Conference call held to determine if sediment sampling in the McLane Dam impoundment should be replicated after sediment corer issue was resolved. Parties agreed to re-do analysis; however, flows and impoundment levels were too high to obtain the cores. In the meantime, the USEPA laboratory results for the sediment sampling conducted on August 11, 2011 were obtained.
09/30/11	A status update memo was sent out via email, including a summary of the laboratory findings.
10/13/11	Conference call held to review laboratory findings. Group agreed to have an ecological risk assessor review the laboratory results, QAPP, and background information on the Fletcher's Paint site and render an opinion on ecological risk and whether additional sediment sampling was needed.
03/09/12	Memo No. 1 prepared by Gomez and Sullivan Ecological Risk Assessor was circulated.
03/19/12	Conference call held to review Ecological Risk Assessor's Memo No. 1. Group agreed that a dilution study should be conducted to determine if the sediments were naturally transported downstream upon dam removal, whether they presented an ecological or human risk. Group also agreed that no additional sediment sampling was warranted.
08/22/12	Memo No. 2 prepared by Gomez and Sullivan regarding Dilution and Sediment Transport was circulated.
08/29/12	Conference call to review Gomez and Sullivan Memo No. 2.
12/28/12	TechLaw issues the following report "*Field Activities Report for the 2012 Sediment Sampling Effort in the Souhegan River*" submitted to USEPA
01/28/13	Call between Gomez and Sullivan and USEPA relative to USEPA's schedule for making a determination on any clean-up of Goldman Dam sediments.
04/13	Project Update/Status Summary placed on town website relative to sediments and reasoning for project being on hiatus.
01/23/14	Conference call to bring all parties up-to-date on USEPA activities relative to sediment management above Goldman Dam.
03/19/14	Memo No. 3 prepared by Gomez and Sullivan Ecological Risk Assessor.

08/05/2011 Conference Call to Discuss Oil Sheen Prior to Sediment Sampling (see Appendix K for Minutes)

A conference call was held with the town of Milford, USEPA, USACE, NOAA, USFWS, NHDES and Gomez and Sullivan to discuss the oil sheen and whether to proceed with the August 11, 2011 sediment sampling. The outcome of the conference call was to proceed with the sediment sampling, but document field conditions.

8/22/2011 Conference Call to Discuss Next Steps Relative to Sediment Sampling (see Appendix K for Minutes)

Because sediment samples in the impoundment could not be collected below 18 inches, the town, USEPA, USACOE, NOAA, USFWS, NHDES and Gomez and Sullivan held a conference call on August 22, 2011 to discuss next steps. The group concluded that with modifications to the corer, the sampling within the impoundment should be replicated to obtain the full core depths. It was agreed that Gomez and Sullivan would monitor flows and water elevations in the McLane impoundment to determine when to mobilize. To effectively retain sediment cores, flows and impoundment elevations must be low (low water levels were needed to hammer the corer into the sediment by standing on the substrate rather than from a boat, which would not provide enough leverage).

Modifications to the corer were made and Gomez and Sullivan planned to remobilize with the goal of obtaining the deeper cores in the impoundment per the approved plan. Gomez and Sullivan mobilized to McLane Dam on September 14, 2011. The flows, as recorded at the USGS gages in Milford and Merrimack on that day, were 162 cfs and 308 cfs, respectively. Although the intent of the site visit was

for a different purpose-- habitat mapping below McLane Dam--- an attempt was made to obtain a deep sediment core within the impoundment to test the modified corer. Although the stoplogs were still removed, the water levels in the impoundment were too high (flows were too high) to allow for an effective sampling attempt. In the end, flows and impoundment water levels in the fall 2011 were too high to repeat the sampling.

09/30/2011 Status Update Memo on August 11, 2011 Sediment Findings (see Appendix K for Memo)

A status update memo on the sediment sampling findings was provided to the town, USEPA, USACOE, NOAA, USFWS, and NHDES.

10/13/2011 Conference Call to Review August 11, 2011 Sediment Sampling Results and Next Steps

A conference call was held with the town, USEPA, USACOE, NOAA, USFWS, NHDES and Gomez and Sullivan to a) review the sediment sampling results, b) discuss the need for deeper sediment cores, c) solicit input of the ecological risk based on the surface sediment sampling. Based on this call, it was agreed that an independent ecological risk assessor review the past Fletcher's Paint testing data, and the McLane Impoundment sediment sampling results (sediment thickness, testing, etc.) to render an opinion as to whether further sampling was warranted. Following this conference call, an ecological risk assessor was hired to review all of the background data. To ensure that NHDES issues would be addressed by the ecological risk assessor, the letter requesting the assessment as well as the background attachments were provided to NHDES on November 2, 2011 for review and comment. NHDES approved the proposed assessment.

03/09/12 Ecological Risk Assessor Memo #1 (see Appendix K for memo)

On March 9, 2012, a memo assessing the sediment relative to ecological and human risk was prepared by the ecological risk assessor and sent to USEPA, NOAA, USFWS, USACOE, NHDES, and the town for review and comment. The ecological risk assessor reviewed the available database of sediment testing findings and evaluated the potential for ecological and human health risk if the Goldman and McLane Dams were removed. Highlights of the memo are below.

- It was noted that sediment testing was conducted in 1991, 1993, 1994, 2004, 2006 and 2007 (data from 2012 was not available at the time of review). The literature reveals that there is an unacceptable risk in the Goldman Dam sediment, with the contaminants of primary concern (COPC) being PCBs and DDD (and derivatives). The memo notes that the Goldman Dam should not be removed prior to the completion of remedial action on this sediment. The target cleanup level was established by the USEPA as 0.5 mg/L.

- The memo notes that sediment samples in the McLane Dam impoundment at MD-2001-T2, -T3 and –T4 had concentrations of PCBs exceeding the TEC, but below the PEC. All of the concentrations are less than the Goldman target cleanup level.

The memo concludes: *Sediment in the Goldman impoundment following remediation plans and the sediment observed in the McLane impoundment are acceptable for higher trophic organisms such as mink, birds, and humans. However, PCB sediment concentrations in the McLane sediment, as well as the target cleanup level determined for the Goldman sediment, which is greater than the maximum McLane concentration, pose unacceptable risk to fish downstream. Accordingly, it is prudent to develop a management plan for sediments in the McLane Dam impoundment. The management plan should aim to slow the transport of sediment downstream upon dam removal, e.g., planting vegetation. Such measures would also slow the transport of sediment from further upstream in the Goldman Dam. Although the TEC*

exceedences would typically warrant sediment bioassays to test for impacts to survival and/or growth of benthic organisms, the risk to fish already drives the need for risk management. Without PEC exceedences, the level of risk, if any, to benthic organisms is likely less than that to the fish.

03/19/2012 Conference Call to Discuss Ecological Risk Assessor's Memo No. 1(see Appendix K for minutes)

Following issuance of the ecological risk assessor's Memo No. 1, a conference call was held with USEPA, NOAA, USFWS, USACOE, NHDES, town and Gomez and Sullivan. The outcome of the conference call was the group agreed that a spatial averaging method could be employed to model downstream concentrations of sediment below McLane Dam under various sediment removal scenarios, including allowing the sediments to naturally mobilize upon dam removal. The NHDES could then evaluate this information to determine what is acceptable for meeting water quality standards (and preparation of a Water Quality Certificate, if needed). It was thought that dilution--allowing impounded sediments to naturally transport downstream and mix upon dam removal --- may mitigate the risk to acceptable levels. It was also agreed on the conference call that no additional sediment sampling was warranted. Lastly, NHDES did request information on a) the total volume of sediment in the McLane impoundment, b) the estimated total volume of mobile sediment leaving McLane impoundment if the dam were removed and c) the likely area of sediment deposition below the dam.

08/22/2012 Ecological Risk Assessor Memo #2 (see Appendix K for memo)

On August 22, 2012, a memo summarizing the dilution study and sediment transport analysis was sent to USEPA, NOAA, USFWS, USACOE, NHDES, NHFG, American Rivers and the town for review and comment. The dilution analysis for McLane Dam sediments indicated the following: "*..if the McLane Dam impounded sediments were naturally transported downstream upon dam removal, the risks to downstream higher trophic organisms, sediment and aquatic invertebrates and humans are all acceptable*".

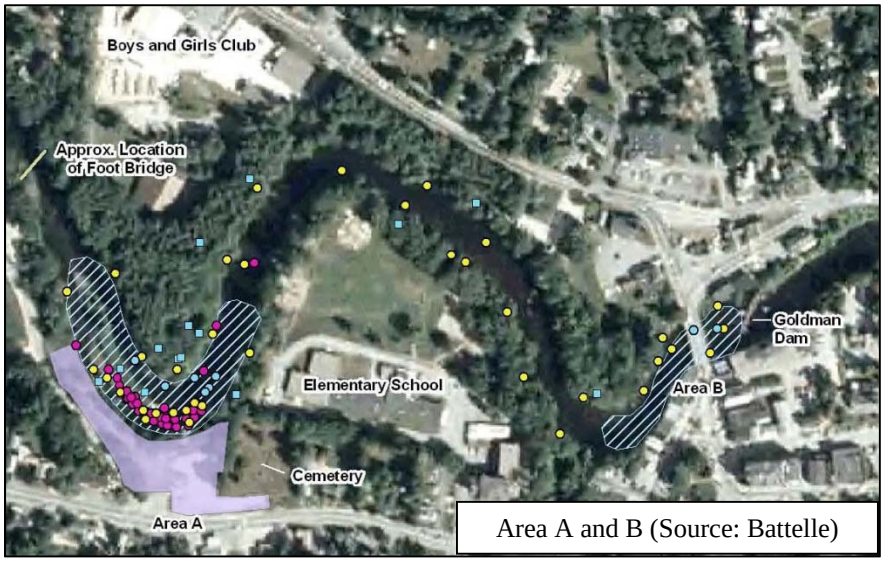
The memo continues relative the dilution and attenuation findings for Goldman Dam. It states: "*Assuming the EPA remedial actions for the Goldman Dam sediments achieves the target average of not exceeding 0.5 mg/Kg, the carbon-normalized concentration was determined using the average FOC of 0.89% (USACE, 2011). Using the same approach as for the McLane sediments, the risks posed by this normalized concentration to fish under various averaging and dilution scenarios were determined. Table 3 summarizes the calculated risks, which are acceptable to downstream fish upon removal of the post-remediated Goldman Dam sediments*".

08/29/2012 Conference Call to Ecological Risk Assessor Memo No. 2 (see Appendix K for Minutes)

Following issuance of Memo No. 2, a conference call was held with USEPA, NOAA, USFWS, USACOE, NHDES, NHFG, American Rivers, town and Gomez and Sullivan. The dilution analysis, oil leak and sediment transport analysis was reviewed. In the end, Gomez and Sullivan indicated that, based on the dilution analysis, they are proposing to allow the sediment above the Goldman and McLane Dams to naturally transport downstream upon removal. In addition to the dilution analysis, NHDES and NHFG sought information on the habitat mapping conducted below McLane Dam, state and federal correspondence relative rare, threatened and endangered species and the wetland delineation. These data was provided to NHDES and NHFG on August 29, 2012. Gomez and Sullivan was seeking input from the permitting agencies as to whether allowing for the natural transport of sediment upon removal of the dams was acceptable.

01/23/14 Conference Call (see Appendix K for Minutes)

A conference call was held with USEPA, NOAA, USFWS, NHDES, town and Gomez and Sullivan to obtain an update on USEPA sediment management alternatives above Goldman Dam. Although not final, USEPA is considering the following alternatives for sediment in Area A and Area B:



Area A and B (Source: Battelle)

- In Area A (Goldman impoundment adjacent to Fletcher's Paint Site), five (5) alternatives:
  - No action;
  - Limited action;
  - Isolation cap with limited sediment removal;
  - Removal of all sediment to one foot of depth and isolation cap, and;
  - Total sediment removal.

- In Area B (Goldman impoundment just upstream of dam), three (3) alternatives:
  - No action;
  - Limited action with monitored natural recovery (MNR)[41], which would entail allowing for natural erosion of sediment regardless of whether the Goldman Dam remains or is removed. The MNR could entail collecting fish and evaluating for contaminants or other measures.
  - Sediment removal- estimated at approximately 250 cubic yards (CY).

USEPA concluded that Goldman Dam sediments tested above 0.5 ppm for PCBs in 2012 could be allowed to naturally migrate downstream as contaminants would become diluted. USEPA clarified that its 0.5 ppm PCBs is the target clean-up level for fish, for human consumption; it does not reflect the target clean-up level for fish. In contrast, the ecological risk assessor assessed the risk to both humans and aquatic biota, including fish. There is some level of risk to fish.

It was requested that the ecological risk assessor prepare another memo addressing USEPAs approach.

[41] "Natural processes that are fundamental to the recovery of contaminated sediments include chemical transformation, reduction in contaminant mobility/bioavailability, physical isolation, and dispersion. The monitored natural recovery (MNR) remedy relies on these processes to reduce ecological and human health risks to acceptable levels, while monitoring recovery over time to verify remedy success." (USEPA Technical Guide, Monitored Natural Recovery at Contaminated Sediment Sites, May 2009).

03/19/14 Ecological Risk Assessor Memo No. 3 (see Appendix K for Memo)

On March 19, 2014, Memo 3 was sent to NOAA, USFWS, NHDES, and the town. The memo states the following:

> *"The anticipated course of action by the USEPA is to not remove the sediments in the Goldman Dam impoundment, either with or without monitored natural attenuation (MNA). This is because the risk posed by the contaminant levels in those sediments to human health by all exposure routes, including fish consumption, is considered acceptable. Accordingly, the ensuing unacceptable risk of those sediments as they flow downstream upon dam removal must be acknowledged and managed. Nevertheless, management decisions must weigh the risk and costs of aggressive action. Based on sediment thickness mapping conducted in 2006, the total sediment volume in Area B (between the Goldman Dam and the confluence of Great Brook with the Souhegan River) is approximately 1,800 cubic yards (this represents the total volume; not necessarily the mobile volume). It is our understanding based on input from USEPA that approximately 250 cubic yards of sediment in Area B exceeds the USEPA's preliminary remediation goal of 0.5 ppm. The options must take into account that the channel bed is primarily small/large boulders, cobble and bedrock; that there is limited access to the sediment; and that the risk assessment is conservatively protective and still only suggests moderate risk. As such, the excessive costs and challenging logistics to dredge, which could potentially cause pulsed exposure of the hotspots as well as divert resources to address the greater risk associated with Area A, are not warranted. Instead, MNA will suffice and is strongly recommended so as to avoid the time and money and undue risk associated with more invasive action. This approach requires an MNA plan and implementation by NHDES to evaluate conditions downstream of the dam, i.e., in addition to any upstream monitoring performed by the USEPA."*

12.0 Hydraulics

12.1 Purpose of Hydraulic Model

Hydraulic models of river systems are developed to predict water surface elevations (WSE), depths, and velocities under a range of flows. A hydraulic model of the Souhegan River, from the downstream corporate limits of Milford (below McLane Dam) to well upstream of the Gregg Crossing Footbridge, was developed for the following purposes:

- To predict WSEs and velocities in the McLane and Goldman Dam impoundments under dam-in and dam-out[42] conditions under a range of flows.
- To determine whether impounded sediments could become mobilized if the dams were removed.
- To determine whether water velocities under dam-out conditions could scour existing infrastructure, including the Route 13 Bridge abutments and pier, sewer/water lines, or buildings (such as the Milford Mill foundation and the building foundations that line the river immediately upstream of the Route 13 Bridge)

For this project, a program called Hydraulic Engineering Center River Analysis System (HEC-RAS) was used to develop a hydraulic model.

12.2 Hydraulic Model Description

This section provides brief technical background on how HEC-RAS predicts water depths, velocities, and water surface profiles (WSP) and methods used in modeling the dam-out condition. This section contains technical terms relating to hydraulics and hydrology. Whenever possible effort has been made to simplify hydraulic concepts presented; however, if further clarification or explanation is desired, the reader is referred to the HEC-RAS Hydraulic Reference Manual (Brunner, 2002) or any standard open channel flow text.

HEC-RAS is designed to perform one-dimensional, steady (flow does not change over time), gradually-varied flow calculations in natural and manmade channels, as well as to perform unsteady (flow over a time increment) flow routing, and elementary sediment transport computations. The model can simulate depths and velocities for a single reach, a branched system, or a full network of channels. HEC-RAS can simulate subcritical, supercritical, and mixed flow regimes.

Hydraulic analyses performed by HEC-RAS are based upon a step-wise solution of the one-dimensional energy equation. In instances of rapid change in the WSE causing turbulence and energy loss, HEC-RAS uses the momentum equation. In HEC-RAS, rapid changes in the WSE may occur under the following conditions: bridge constrictions, inline structures (dams and weirs), confluence of two or more flows, rapid changes in the channel bed elevation, and hydraulic jumps. Energy losses in the channel are associated with friction (solved with Manning's equation) or with contraction and expansion (solved by multiplying a loss coefficient by the change in velocity head between transects). Flows over weirs and other inline structures (dams) are determined with the standard weir equation. HEC-RAS also permits the modeler to include gate structures that accompany inline structures such as dams.

[42] Dam-out is referenced throughout this document and assumes that the spillway and abutments would be removed from the McLane and/or Goldman Dams.

12.3 Model Inputs

12.3.1 Transects

Figure 12.3-1 shows the transects that were included in the HEC-RAS hydraulic model. Topographic data for transects were obtained from several sources. For those transects located well below McLane Dam, and above the Gregg Crossing Footbridge (shown in red on Figure 12.3-1), the transects were obtained from the original hydraulic model developed by FEMA for the FIS. Note that these FEMA transects were originally surveyed in the National Geodetic Vertical Datum of 1929 (NGVD 29), but were converted into the North American Vertical Datum of 1988 (NAVD 88) to match survey data obtained during this study. As Figure 12.3-1 shows, there is considerable spacing between the FIS transects, which is common for a flooding level of analysis.

For the reach just below McLane Dam to the Gregg Crossing Footbridge, in-channel data for most transects (shown in green on Figure 12.3-1) were obtained from the 2010 bathymetric mapping survey. This was supplemented with survey data near each dam, as well as the sediment transect data, both collected in 2010. Sediment depths obtained during sediment probing in the McLane Dam impoundment were also used to simulate dam-out conditions with the bottom of sediment representing the channel bottom. Upland topography was generally obtained from town survey data, which was updated in 2010, as well as USGS topographic basemaps. Elevations and layouts for structures (McLane and Goldman Dams, Route 13 bridge, Gregg Crossing Footbridge) were obtained by looking at various sets of historical and recent drawings and comparing with the 2010 survey data and spot elevation checks. Where elevation discrepancies occurred, the survey data was used.

With the bathymetry, survey data, upland topography, aerial imagery, and locations of dams, bridges, water/sewer lines, and other structures collected in GIS, the transects were 'cut' in GIS—meaning that the line of the cross-section was digitized in GIS and its station and elevation data was loaded directly into the hydraulic model. There are two major benefits of linking the GIS and hydraulic model. First, there is the considerable time savings of drawing the transects and having them uploaded directly to HEC-RAS, rather than manually entering the station/elevation data. Second, once the HEC-RAS model is run for a flood event, the results can be loaded back into the GIS to delineate the area of inundation on the aerial imagery. For example, the hydraulic model could be run for the 100-year flood with and without the dams in place. The resulting inundation area can be readily uploaded to the GIS and visually compared on the aerial imagery.

12.3.2 Manning's n Values

HEC-RAS requires the user to define Manning's n-values at each transect. Manning's n-values are used to describe the roughness of a channel; the higher the n-value, the rougher the channel. For example, a Manning's n-value of 0.03 is representative of channel substrates such as sand, whereas a Manning's n-value of 0.05 is more representative of cobbles. The HEC-RAS program requires the user to enter the Manning's n-values for at least the right overbank, main channel, and left overbank at each transect (additional delineations can be and often are made). When flow moves beyond the right/left overbanks, which is typically defined as the top of bank, it may be conveyed through trees and upland vegetation. In these instances, the Manning's n-values in these overbanks are higher to reflect the greater flow resistance.

The original FIS study contained Manning's n values ranging from 0.03 to 0.06 for the Souhegan River channel and from 0.05 to 0.12 for the overbank areas. We reviewed the Manning's n-values, and based on our field observations, they are representative of existing conditions. Thus, no changes were made to

the values. Manning's n-values selected for the new cross-sections (between McLane Dam and the Gregg Crossing Footbridge) fell within the same ranges and followed the same patterns.

12.3.3 Expansion and Contraction Coefficients

HEC-RAS requires the user to define expansion and contraction coefficients at each transect. When a river constricts—meaning the width decreases—it creates a 'bottleneck' and the water level upstream will rise. The coefficients for gradual transitions of contraction and expansion are 0.1 and 0.3, respectively. For a typical bridge, the values rise to 0.3 and 0.5, respectively. In most instances expansion and contraction coefficients of 0.1 and 0.3 were applied to the transects. However, where abrupt changes occurred such as at the Route 13 Bridge, the contraction and expansion coefficients were increased to 0.6 and 0.8, respectively.

12.3.4 Coefficients of Discharge at McLane and Goldman Dams

The McLane and Goldman Dams were simulated in the HEC-RAS model. The model requires as input a coefficient of discharge (C) for each dam. The coefficient of discharge is used in the following equation to compute the head, or the depth of water flowing over the spillway of each dam. The higher the coefficient of discharge, the more water can be passed over the spillway.

$Q = CLH^{1.5}$, where

Q = flow (cfs)
L = length of the spillway (feet)
H = head or water depth atop the spillway (meaning the vertical distance between the water surface elevation and the spillway crest, feet)
C = coefficient of discharge (unitless)

The coefficient of discharge is dependent on several factors including the breadth of the spillway, geometry of the spillway, and head conditions. Technically, the coefficient of discharge changes with head, becoming a higher value as the head increases; however only one C-value is permitted in HEC-RAS. Also, for dams with atypical layouts (i.e., on a skew across the river, such as McLane and Goldman Dams), C-values may be adjusted to account for longer effective spillways or other factors. Thus, although McLane and Goldman dams would typically be assigned a C-value of approximately 3.3, values were increased to 3.7 for Goldman Dam and 4.0 for McLane Dam to simulate longer effective spillway lengths and more closely match WSE's in the FIS.

12.3.5 Upstream and Downstream Boundary Conditions

A mixed flow regime was used in the model to simulate both subcritical and supercritical (e.g., hydraulic jumps near dams) conditions. The HEC-RAS program requires an upstream and downstream boundary condition for mixed flow. For the three FIS flows (10-year, 50-year, and 100-year floods), water surface elevations taken from the FIS HEC-2 model output file were used as boundary conditions at the downstream extent of the model. For non-FIS flows, the slope of the channel bottom at the downstream extent was used to approximate the slope of the energy grade line for use in the normal depth method of boundary condition calculation. The channel slope at the upstream extent of the model was used in the normal depth method as an upstream boundary condition for all flows.

12.4 Model Calibration and Verification

After all model inputs had been entered to simulate existing conditions, the model was run for calibration purposes. Water surface elevations were compared to both FIS water surface elevations (from the HEC-2 output file, which may differ slightly from published values), as well as flood photographs, surveyed WSEs, and other field observations. Manning's n-values, contraction/expansion coefficients, and/or ineffective flow areas were adjusted slightly (remaining within normal ranges) to more closely match FIS results. A comparison of WSEs between the FIS and the updated existing conditions model is shown in Table 12.4-1 below.

Table 12.4-1: Comparison of FIS vs. Existing Conditions Water Surface Elevations

Location	Station (ft)	WATER SURFACE ELEVATION (ft)								
		10-yr Flood			50-yr Flood			100-yr Flood		
		FIS	*Existing*	*Diff.*	*FIS*	*Existing*	*Diff.*	*FIS*	*Existing*	*Diff.*
U/S of Rte 13 Bridge	10420	239.4	239.5	0.1	241.2	241.4	0.2	242.2	242.1	-0.1
U/S of Goldman Dam	10289	239.1	239.2	0.1	240.7	240.8	0.1	241.3	241.3	0.0
U/S of McLane Dam	8986	233.7	234.1	0.4	235.5	235.6	0.1	236.0	236.1	0.1

**Note: FIS WSEs were taken directly from the HEC-2 model output file (adjusted for datum differences) and may differ slightly from those published in the FIS.*

The model was found to be in good agreement with the FIS, with a maximum difference in WSE in the area of interest of 0.4 feet (upstream of McLane Dam under the 10-year flood).

12.5 Hydraulic Modeling Results

Once the model was found to reasonably match the FEMA results, removal of the dams were simulated (by removing the structures in HEC-RAS and adjusting channel elevations, contraction/expansion coefficients, ineffective flow areas, and other factors accordingly), and the results compared to existing conditions. Table 12.5-1 below compares WSEs at key cross-sections (from just below McLane Dam to the upstream extent of the model) between Alternative 1 – Existing Conditions and Alternative 2 – Dams Removed. In addition, Table 12.5-2 below compares velocities at the same key cross-sections.

Table 12.5-1: Comparison of Flood Water Surface Elevations under Existing Conditions vs. Dams Removed

Location	Station (ft)	WATER SURFACE ELEVATION (ft)											
		2-yr Flood			10-yr Flood			50-yr Flood			100-yr Flood		
		Existing	*Dams Out*	*Diff.*	*Existing*	*Dams Out*	*Diff.*	*Existing*	*Dams Out*	*Diff.*	*Existing*	*Dams Out*	*Diff.*
FIS XS 'AH'	20857	241.4	241.4	0.0	247.6	247.6	0.0	248.6	248.6	0.0	249.1	249.1	0.0
FIS XS 'AF'	16984	237.4	237.2	-0.2	244.2	244.1	-0.1	246.9	246.8	-0.1	247.9	247.8	-0.1
FIS XS 'AE'	15373	236.7	236.4	-0.3	243.7	243.5	-0.2	246.5	246.3	-0.2	247.6	247.3	-0.3
FIS XS 'AD'	13621	236.6	236.2	-0.4	242.7	242.5	-0.2	245.4	245.1	-0.3	246.4	246.0	-0.4
Water Line #2	13466	236.6	236.1	-0.5	242.4	242.0	-0.4	245.1	244.7	-0.4	246.2	245.8	-0.4
U/S of Gregg Hill Bridge	13338	236.6	236.1	-0.5	242.4	242.0	-0.4	245.0	244.6	-0.4	246.0	245.7	-0.3
D/S of Gregg Hill Bridge	13288	236.5	236.1	-0.4	242.3	241.9	-0.4	244.9	244.6	-0.3	246.0	245.6	-0.4
Fletcher's Paint Site Discharge	12612	236.3	234.9	-1.4	242.0	241.6	-0.4	244.8	244.4	-0.4	245.9	245.5	-0.4
	12216	236.3	234.7	-1.6	241.6	241.0	-0.6	244.3	243.8	-0.5	245.4	244.9	-0.5
	11558	236.3	234.6	-1.7	241.2	240.6	-0.6	243.9	243.3	-0.6	244.9	244.3	-0.6
Water Line #1	11347	236.2	234.5	-1.7	241.0	240.2	-0.8	243.6	242.9	-0.7	244.5	243.9	-0.6
	11144	236.2	234.2	-2.0	240.7	239.8	-0.9	243.2	242.4	-0.8	244.2	243.5	-0.7
D/S of Great Brook	10767	236.2	233.2	-3.0	240.3	239.0	-1.3	242.8	241.7	-1.1	243.8	242.9	-0.9
	10521	236.2	232.9	-3.3	239.7	237.6	-2.1	241.8	239.9	-1.9	242.6	241.0	-1.6
U/S of Rte 13 Bridge	10420	236.2	232.9	-3.3	239.5	237.2	-2.3	241.4	239.3	-2.1	242.1	240.4	-1.7
U/S of Goldman Dam	10289	236.2	232.7	-3.5	239.2	236.6	-2.6	240.8	237.6	-3.2	241.3	238.5	-2.8
D/S of Goldman Dam	10172	231.3	229.3	-2.0	235.5	234.5	-1.0	237.8	237.0	-0.8	238.6	237.9	-0.7
McLane Dam Impoundment	9693	231.2	227.2	-4.0	234.5	231.0	-3.5	236.2	233.1	-3.1	236.9	233.9	-3.0
U/S of McLane Dam	8986	231.2	224.8	-6.4	234.1	228.7	-5.4	235.6	230.0	-5.6	236.1	230.6	-5.5
D/S of McLane Dam	8807	221.1	221.1	0.0	225.7	225.7	0.0	228.7	228.7	0.0	229.8	229.8	0.0

As can be seen from Table 12.5-1, the largest impact of dam removal occurs in the area between McLane Dam and the Route 13 Bridge, with a drop in WSE ranging from approximately 5.5 to 6.4 feet at McLane Dam (depending on the flood flow), dissipating to a range of 1.7 to 3.3 feet upstream of the Route 13 Bridge. The difference further up in the Goldman Dam impoundment is smaller, with a range of 0.3 to 0.5 feet at the Gregg Crossing Footbridge.

Table 12.5-2: Comparison of Flood Velocities under Existing Conditions vs. Dams Removed

Location	Station (ft)	WATER SURFACE ELEVATION (ft)											
		2-yr Flood			10-yr Flood			50-yr Flood			100-yr Flood		
		Existing	*Dams Out*	*Diff.*	*Existing*	*Dams Out*	*Diff.*	*Existing*	*Dams Out*	*Diff.*	*Existing*	*Dams Out*	*Diff.*
FIS XS 'AH'	20857	1.8	1.8	0.0	3.7	3.7	0.0	5.0	5.0	0.0	3.4	3.5	0.1
FIS XS 'AF'	16984	1.9	2.1	0.2	6.0	6.1	0.1	3.6	3.7	0.1	3.4	3.5	0.1
FIS XS 'AE'	15373	1.3	1.5	0.2	2.7	2.8	0.1	2.9	3.0	0.1	2.9	3.0	0.1
FIS XS 'AD'	13621	0.8	0.9	0.1	4.6	4.7	0.1	6.1	6.3	0.2	6.5	6.7	0.2
Water Line #2	13466	1.7	2.0	0.3	6.0	6.3	0.3	6.8	7.2	0.4	6.9	7.3	0.4
U/S of Gregg Hill Bridge	13338	1.0	1.2	0.2	4.9	4.9	0.0	6.2	6.5	0.3	6.7	7.0	0.3
D/S of Gregg Hill Bridge	13288	1.2	1.5	0.3	4.8	5.0	0.2	6.0	6.2	0.2	6.3	6.6	0.3
Fletcher's Paint Site Discharge	12612	0.5	0.7	0.2	2.8	2.9	0.1	3.2	3.4	0.2	3.4	3.5	0.1
	12216	1.1	2.5	1.4	4.8	5.3	0.5	5.8	6.1	0.3	6.0	6.4	0.4
	11558	0.4	0.6	0.2	3.2	3.4	0.2	4.4	4.6	0.2	4.8	5.0	0.2
Water Line #1	11347	0.8	1.5	0.7	4.1	4.6	0.5	5.4	5.8	0.4	5.8	6.2	0.4
	11144	0.9	2.6	1.7	4.8	5.5	0.7	6.0	6.6	0.6	6.5	7.0	0.5
D/S of Great Brook	10767	0.8	2.7	1.9	5.0	6.2	1.2	6.3	7.2	0.9	6.6	7.4	0.8
	10521	0.8	2.1	1.3	6.5	8.9	2.4	8.9	11.1	2.2	9.6	11.5	1.9
U/S of Rte 13 Bridge	10420	0.7	1.8	1.1	6.3	8.8	2.5	8.9	11.3	2.4	9.9	11.8	1.9
U/S of Goldman Dam	10289	0.6	2.1	1.5	4.7	7.2	2.5	6.8	10.4	3.6	7.6	10.6	3.0
D/S of Goldman Dam	10172	1.0	3.2	2.2	5.3	6.2	0.9	7.0	7.7	0.7	7.6	8.2	0.6
McLane Dam Impoundment	9693	0.7	3.3	2.6	5.5	10.2	4.7	7.5	11.8	4.3	8.2	12.4	4.2
U/S of McLane Dam	8986	0.5	1.7	1.2	4.0	7.1	3.1	5.7	9.9	4.2	6.4	10.7	4.3
D/S of McLane Dam	8807	4.6	4.6	0.0	6.7	6.7	0.0	7.1	7.1	0.0	7.4	7.4	0.0

As Table 12.5-2 shows, the biggest difference in velocities of the various flood flows between existing and dam-out conditions occurs between the Great Brook confluence with the Souhegan River down to the McLane Dam. In this reach the difference in velocities exceed 1.0 foot/second. The difference in velocities above the Great Brook confluence is considerably less (generally less than 0.2 feet/sec on the area of the Fletcher's Paint Site- Station 12612).

The hypothetical removal of the Route 13 Bridge (both under dam-in and dam-out conditions) was also evaluated to determine how it contributes to upstream flooding. A comparison of WSEs between the dam out scenario (Alternative 2 above) and the removal of both dams plus the Route 13 Bridge is shown in Table 12.5-3 below.

Table 12.5-3: Comparison of Flood Water Surface Elevations under Dams Removed vs. Dams and Route 13 Bridge Removed

Location	Station (ft)	WATER SURFACE ELEVATION (ft)											
		2-yr Flood			10-yr Flood			50-yr Flood			100-yr Flood		
		Dams Out	*All Out*	*Diff.*	*Dams Out*	*All Out*	*Diff.*	*Dams Out*	*All Out*	*Diff.*	*Dams Out*	*All Out*	*Diff.*
FIS XS 'AH'	20857	241.4	241.4	0.0	247.6	247.6	0.0	248.6	248.6	0.0	249.1	249.0	-0.1
FIS XS 'AF'	16984	237.2	237.2	0.0	244.1	244.1	0.0	246.8	246.7	-0.1	247.8	247.7	-0.1
FIS XS 'AE'	15373	236.4	236.4	0.0	243.5	243.4	-0.1	246.3	246.3	0.0	247.3	247.3	0.0
FIS XS 'AD'	13621	236.2	236.2	0.0	242.5	242.4	-0.1	245.1	245.0	-0.1	246.0	245.9	-0.1
Water Line #2	13466	236.1	236.1	0.0	242.0	242.0	0.0	244.7	244.7	0.0	245.8	245.7	-0.1
U/S of Gregg Hill Bridge	13338	236.1	236.1	0.0	242.0	242.0	0.0	244.6	244.6	0.0	245.7	245.6	-0.1
D/S of Gregg Hill Bridge	13288	236.1	236.1	0.0	241.9	241.9	0.0	244.6	244.5	-0.1	245.6	245.5	-0.1
Fletcher's Paint Site Discharge	12612	234.9	234.9	0.0	241.6	241.5	-0.1	244.4	244.3	-0.1	245.5	245.3	-0.2
	12216	234.7	234.7	0.0	241.0	241.0	0.0	243.8	243.7	-0.1	244.9	244.7	-0.2
	11558	234.6	234.6	0.0	240.6	240.5	-0.1	243.3	243.1	-0.2	244.3	244.1	-0.2
Water Line #1	11347	234.5	234.5	0.0	240.2	240.2	0.0	242.9	242.8	-0.1	243.9	243.7	-0.2
	11144	234.2	234.2	0.0	239.8	239.8	0.0	242.4	242.3	-0.1	243.5	243.2	-0.3
D/S of Great Brook	10767	233.2	233.2	0.0	239.0	239.0	0.0	241.7	241.5	-0.2	242.9	242.6	-0.3
	10521	232.9	232.9	0.0	237.6	237.4	-0.2	239.9	238.9	-1.0	241.0	239.5	-1.5
U/S of Rte 13 Bridge	10420	232.9	232.8	-0.1	237.2	237.3	0.1	239.3	238.8	-0.5	240.4	239.3	-1.1
U/S of Goldman Dam	10289	232.7	232.7	0.0	236.6	236.6	0.0	237.6	237.6	0.0	238.5	238.5	0.0
D/S of Goldman Dam	10172	229.3	229.3	0.0	234.5	234.5	0.0	237.0	237.0	0.0	237.9	237.9	0.0
McLane Dam Impoundment	9693	227.2	227.2	0.0	231.0	231.0	0.0	233.1	233.1	0.0	233.9	233.9	0.0
U/S of McLane Dam	8986	224.8	224.8	0.0	228.7	228.7	0.0	230.0	230.0	0.0	230.6	230.6	0.0
D/S of McLane Dam	8807	221.1	221.1	0.0	225.7	225.7	0.0	228.7	228.7	0.0	229.8	229.8	0.0

As can be seen from Table 12.5-3 above, the reduction in flood elevations with Route 13 Bridge removed (in addition to the dams) is slight, and really only significant just upstream of the bridge under larger floods (50-year and 100-year), ranging from 1.0 to 1.5 feet. Looking at the shape of the inundation area in Figure 12.5-1 above, this may be a result of the fact that although the Route 13 Bridge abutments and pier provide some degree of constriction, the location itself seems to create a constriction regardless of the bridge, perhaps due to both the natural bedrock in the area as well as the encroaching wall of buildings on river- right upstream and downstream of the bridge. This may also be why the difference between existing conditions and dam removal scenarios (in Table 12.5-1 above) is not as high upstream of the bridge.

WSEs for all cross-sections under all flows are provided in Table 12.5-4 for existing conditions and in Table 12.5-5 for the dam removal scenario at the end of this section. Similarly, velocities for all cross-sections under all flows are provided in Table 12.5-6 for existing conditions and in Table 12.5-7 for the dam removal scenario at the end of this section.

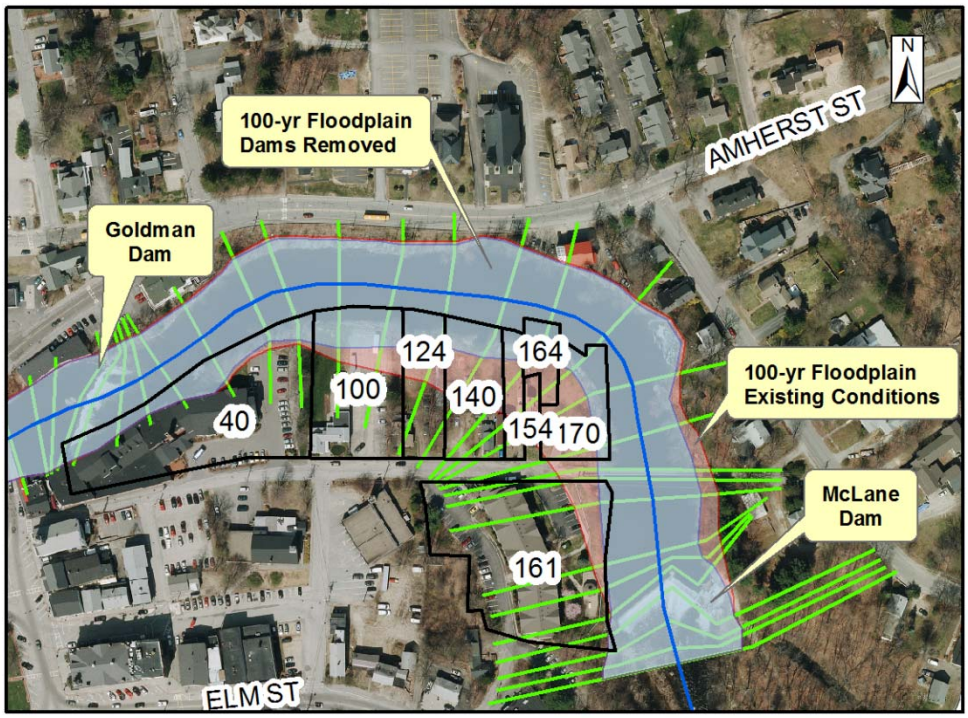
Inundation Mapping

The following figures were developed to compare the inundation areas under existing conditions versus removal of both dams. The blue shading reflects the dams removed, while the red shading reflects the dams in place. The figures were visually assessed- specifically those areas shown in red shading- as these areas would not be inundated if the dams removed.

Figure 12.5-1: Comparison of 100-year Flood Inundation Areas under Existing Conditions vs. Dams Removed
Figure 12.5-2: Comparison of 10-year Flood Inundation Areas under Existing Conditions vs. Dams Removed
Figure 12.5-3: Comparison of 2-year Flood Inundation Areas under Existing Conditions vs. Dams Removed
Figure 12.5-4: Comparison of Low Flow (median September flow) Inundation Areas under Existing Conditions vs. Dams Removed

As shown in Figure 12.5-1 the 100-year flood inundation area is marginally reduced upstream of the Goldman Dam. As the figure shows, regardless of whether the dams are removed or remain, certain areas remain susceptible to flooding such as the Boys and Girls Club, which is located in the floodplain. It does not appear, based on the visual assessment, that removing the dams eliminates any infrastructure flooding.

However, between the McLane and Goldman Dams, there is a reduction in the inundation area on river right with the dams removed. In this case, the reduction (shown as red shading on the inset) eliminates flooding to several houses and structures located on the inside bend of the river. Dam removal would provide a flood benefit to these property owners under a 100-year event.



In addition to the 100-year flood, the same inundation maps were provided for the 10- and 2-year floods (Figure 12.5-2 and 12.5-3 respectively). In the case of the 10-

year flood, removal of the dams would again reduce flooding on the inside bend of the river between McLane and Goldman Dams. Keep in mind that that 10-year flood occurs more frequently than a 100-year flood, so again, there are benefits to dam removal. In the case of the 2-year flood, there does not appear to be any reduction in infrastructure flooding with the dams removed.

Figure 12.5-4 shows the area of inundation for a summer low flow. The purpose of this plan map is to provide a rough approximation of how the river width would reduce if the dams were removed. There would not be a sizable change in the river width above the Goldman Dam; however, between the dams the channel width would narrow.

Water Surface Profiles

In addition to evaluating the area of inundation with and without the dams, the same was conducted along the length or profile of the river. The following figures were developed to evaluate the change in the water depth with and without the dams in place. Note that the **blue** line represents the water surface profile (WSP) with the dams in place and the **red** line represents the WSP with the dams removed.

Figure 12.5-5: Comparison of 100-year Flood Water Surface Profile under Existing vs Dams Removed
Figure 12.5-6: Comparison of 10-year Flood Water Surface Profile under Existing vs Dams Removed
Figure 12.5-7: Comparison of 2-year Flood Water Surface Profile under Existing vs Dams Removed
Figure 12.5-8: Comparison of Low Flow (33 cfs) Flood Water Surface Profile under Existing vs Dams Removed

Note that the channel bed elevation, with and without the dams, is the same on the figures. However, if the dams are removed and sediment above the dams is allowed to naturally transport downstream upon removal, the channel bed elevation will lower as sediment is scoured. As discussed later, there is minimal sediment above Goldman Dam and the channel bed is already well armored thus the channel bed is not expected to change considerably. From the McLane Dam upstream to approximately Transect T-6, there is depositional sediment that would scour with the McLane Dam removed and thus the channel bed is expected to lower in this area (however, this also depends on the geographic extent and height of any bedrock located immediately beneath McLane Dam as many dams are located at existing falls).

As Figure 12.5-5 shows, the greatest change in water depth occurs between the McLane and Goldman Dams and immediately above the Goldman Dam. Further above Goldman Dam, the WSP does not change considerably from roughly the Gregg Crossing Footbridge upstream. Similar trends are seen in the 10- and 2-yr floods (Figure 12.5-6 and 12.5-7, respectively).

Figure 12.5-8 shows the greatest change in river depth under a low flow of 33 cfs. In this case, with Goldman Dam removed, the WSE drops further even above the Gregg Crossing Footbridge.

Table 12.5-4: Water Surface Elevations for All Flows under Existing Conditions

Station	Water Surface Elevations (feet)						
	Low Flow	Outmigration	Migration	2-yr flood	10-yr flood	50-yr flood	100-yr flood
20857	238.85	239.72	241.71	241.35	247.63	248.58	249.13
18397	236.21	237.18	238.91	238.58	245.89	247.43	248.34
16984	235.67	236.04	237.71	237.37	244.23	246.93	247.94
15373	235.64	235.87	237.01	236.74	243.65	246.49	247.55
13621	235.64	235.86	236.85	236.62	242.74	245.35	246.35
13466	235.64	235.85	236.79	236.57	242.38	245.11	246.18
13338	235.64	235.85	236.78	236.56	242.36	245.01	246.03
13325	235.64	235.85	236.77	236.56	242.34	244.98	245.99
13288	235.64	235.85	236.75	236.54	242.29	244.94	245.97
13174	235.63	235.82	236.64	236.45	242.17	244.90	245.94
12928	235.63	235.80	236.50	236.33	242.07	244.83	245.87
12612	235.63	235.80	236.49	236.32	241.99	244.80	245.86
12216	235.63	235.80	236.44	236.28	241.56	244.29	245.35
11835	235.63	235.79	236.40	236.25	241.25	243.90	244.92
11558	235.63	235.79	236.40	236.25	241.21	243.86	244.87
11347	235.63	235.79	236.38	236.24	240.98	243.55	244.54
11144	235.63	235.79	236.35	236.22	240.70	243.23	244.21
10767	235.63	235.79	236.31	236.19	240.29	242.81	243.84
10521	235.63	235.79	236.29	236.17	239.69	241.76	242.63
10420	235.63	235.79	236.28	236.17	239.49	241.41	242.13
10416	**Route 13 Bridge**						
10367	235.63	235.79	236.28	236.16	239.29	240.86	241.34
10317	235.63	235.78	236.27	236.16	239.22	240.79	241.26
10289	235.63	235.78	236.27	236.16	239.21	240.78	241.25
10247	235.63	235.78	236.26	236.15	238.95	240.43	241.18
10243	**Goldman Dam**						
10221	230.72	230.86	231.40	231.28	235.84	238.30	239.21
10172	230.72	230.86	231.39	231.27	235.53	237.78	238.60
10139	230.72	230.86	231.36	231.25	235.12	237.09	237.78
10103	230.72	230.86	231.36	231.24	235.07	237.00	237.68
10022	230.72	230.86	231.35	231.24	234.90	236.81	237.50
9922	230.72	230.86	231.34	231.24	234.90	236.80	237.49
9867	230.72	230.86	231.34	231.23	234.88	236.78	237.47
9781	230.72	230.86	231.34	231.23	234.68	236.51	237.19
9693	230.72	230.86	231.33	231.22	234.51	236.22	236.86
9606	230.72	230.86	231.33	231.22	234.45	236.17	236.82
9516	230.72	230.86	231.33	231.22	234.44	236.16	236.81
9436	230.72	230.86	231.32	231.22	234.41	236.09	236.73
9345	230.72	230.86	231.32	231.22	234.35	235.97	236.58
9256	230.72	230.86	231.32	231.22	234.34	235.94	236.54
9174	230.72	230.86	231.32	231.22	234.30	235.84	236.41
9071	230.72	230.86	231.32	231.22	234.20	235.70	236.25
8986	230.72	230.86	231.32	231.22	234.12	235.57	236.10
8968	230.72	230.86	231.32	231.22	234.11	235.54	236.08
8949	230.72	230.86	231.32	231.22	234.11	235.55	236.09
8939	**McLane Dam**						
8918	221.45	221.79	222.98	222.74	226.48	229.40	230.46
8874	220.68	221.05	221.95	221.80	226.11	229.05	230.11
8831	220.59	220.90	221.65	221.54	225.75	228.77	229.85
8807	220.13	220.45	221.31	221.12	225.68	228.73	229.80
8151	215.64	216.08	217.02	216.83	224.03	227.19	228.15
6827	211.67	212.09	213.94	213.56	221.93	224.74	225.36
5157	210.55	211.22	213.31	212.90	220.98	223.39	223.64
3143	209.10	210.05	212.33	211.92	219.80	222.10	223.06
924	207.34	208.08	210.10	209.72	217.95	220.72	221.71
252	206.97	207.57	209.56	209.19	217.61	220.44	221.53
0	206.53	207.22	209.29	208.92	217.30	220.30	221.40

Notes:

Out-Migration Season: Oct
Migration Season: Apr 15-May 15

Table 12.5-5: Water Surface Elevations for All Flows under Dam Removal Scenario

	Water Surface Elevations (feet)						
Station	Low Flow	Outmigration	Migration	2-yr flood	10-yr flood	50-yr flood	100-yr flood
20857	238.72	239.64	241.74	241.36	247.64	248.56	249.05
18397	236.82	237.32	238.91	238.60	245.85	247.32	248.20
16984	235.00	235.66	237.56	237.21	244.11	246.77	247.76
15373	234.90	235.31	236.64	236.36	243.45	246.29	247.33
13621	234.89	235.29	236.44	236.20	242.45	245.05	246.03
13466	234.89	235.27	236.34	236.12	242.04	244.74	245.80
13338	234.89	235.27	236.32	236.10	242.01	244.64	245.66
13325	234.89	235.27	236.31	236.10	241.99	244.61	245.62
13288	234.89	235.26	236.27	236.06	241.93	244.57	245.59
13174	234.74	235.09	235.96	235.74	241.77	244.51	245.56
12928	233.23	233.64	235.17	234.88	241.63	244.41	245.47
12612	233.24	233.66	235.15	234.86	241.55	244.37	245.45
12216	233.23	233.60	234.93	234.66	241.00	243.77	244.85
11835	233.23	233.60	234.81	234.57	240.60	243.30	244.35
11558	233.23	233.59	234.80	234.56	240.55	243.25	244.30
11347	233.22	233.58	234.74	234.51	240.24	242.87	243.90
11144	233.03	233.24	234.39	234.15	239.81	242.43	243.47
10767	231.04	231.93	233.49	233.21	239.03	241.74	242.89
10521	230.96	231.83	233.18	232.94	237.61	239.87	240.95
10420	230.94	231.81	233.12	232.89	237.17	239.31	240.37
10367	230.94	231.80	233.10	232.86	236.92	238.06	238.85
10317	230.84	231.72	232.94	232.71	236.69	237.70	238.58
10289	230.80	231.69	232.89	232.66	236.63	237.60	238.52
10247	230.21	230.88	232.00	231.87	235.41	237.37	238.37
10221	227.98	228.47	229.66	229.44	234.89	237.52	238.50
10172	227.88	228.31	229.49	229.26	234.51	236.98	237.88
10139	227.20	227.63	228.67	228.48	233.51	235.81	236.60
10103	226.51	227.12	228.37	228.12	233.52	235.81	236.60
10022	226.49	226.97	228.11	227.90	233.01	235.32	236.13
9922	226.48	226.95	228.04	227.84	232.99	235.31	236.11
9867	226.48	226.94	228.02	227.83	232.93	235.26	236.06
9781	226.46	226.88	227.85	227.68	232.33	234.58	235.38
9693	226.24	226.56	227.37	227.22	231.00	233.10	233.85
9606	224.93	225.30	226.04	225.92	230.50	232.79	233.59
9516	223.27	223.95	225.36	225.14	230.44	232.65	233.48
9436	223.27	223.96	225.35	225.14	230.36	232.50	233.31
9345	223.27	223.95	225.33	225.12	230.13	232.13	232.89
9256	223.27	223.95	225.33	225.12	230.13	232.12	232.87
9174	223.27	223.95	225.32	225.12	229.97	231.83	232.52
9071	223.20	223.82	225.05	224.89	229.09	230.57	231.20
8986	223.16	223.77	224.94	224.80	228.72	229.96	230.56
8968	223.09	223.64	224.81	224.69	227.06	229.31	230.36
8949	222.56	223.05	224.18	224.07	226.04	229.30	230.39
8918	220.68	221.06	222.01	221.85	226.46	229.40	230.48
8874	220.68	221.05	221.95	221.80	226.11	229.05	230.11
8831	220.59	220.90	221.65	221.54	225.75	228.77	229.85
8807	220.13	220.45	221.31	221.12	225.68	228.73	229.80
8151	215.64	216.08	217.02	216.83	224.03	227.19	228.15
6827	211.67	212.09	213.94	213.56	221.93	224.74	225.36
5157	210.55	211.22	213.31	212.90	220.98	223.39	223.64
3143	209.10	210.05	212.33	211.92	219.80	222.10	223.06
924	207.34	208.08	210.10	209.72	217.95	220.72	221.71
252	206.97	207.57	209.56	209.19	217.61	220.44	221.53
0	206.53	207.22	209.29	208.92	217.30	220.30	221.40

Notes:

Out-Migration Season: Oct
Migration Season: Apr 15-May 15

Table 12.5-6: Velocities for All Flows under Existing Conditions

Station	Water Surface Elevations (feet)						
	Low Flow	Outmigration	Migration	2-yr flood	10-yr flood	50-yr flood	100-yr flood
20857	238.72	239.64	241.74	241.36	247.64	248.56	249.05
18397	236.82	237.32	238.91	238.60	245.85	247.32	248.20
16984	235.00	235.66	237.56	237.21	244.11	246.77	247.76
15373	234.90	235.31	236.64	236.36	243.45	246.29	247.33
13621	234.89	235.29	236.44	236.20	242.45	245.05	246.03
13466	234.89	235.27	236.34	236.12	242.04	244.74	245.80
13338	234.89	235.27	236.32	236.10	242.01	244.64	245.66
13325	234.89	235.27	236.31	236.10	241.99	244.61	245.62
13288	234.89	235.26	236.27	236.06	241.93	244.57	245.59
13174	234.74	235.09	235.96	235.74	241.77	244.51	245.56
12928	233.23	233.64	235.17	234.88	241.63	244.41	245.47
12612	233.24	233.66	235.15	234.86	241.55	244.37	245.45
12216	233.23	233.60	234.93	234.66	241.00	243.77	244.85
11835	233.23	233.60	234.81	234.57	240.60	243.30	244.35
11558	233.23	233.59	234.80	234.56	240.55	243.25	244.30
11347	233.22	233.58	234.74	234.51	240.24	242.87	243.90
11144	233.03	233.24	234.39	234.15	239.81	242.43	243.47
10767	231.04	231.93	233.49	233.21	239.03	241.74	242.89
10521	230.96	231.83	233.18	232.94	237.61	239.87	240.95
10420	230.94	231.81	233.12	232.89	237.17	239.31	240.37
10367	230.94	231.80	233.10	232.86	236.92	238.06	238.85
10317	230.84	231.72	232.94	232.71	236.69	237.70	238.58
10289	230.80	231.69	232.89	232.66	236.63	237.60	238.52
10247	230.21	230.88	232.00	231.87	235.41	237.37	238.37
10221	227.98	228.47	229.66	229.44	234.89	237.52	238.50
10172	227.88	228.31	229.49	229.26	234.51	236.98	237.88
10139	227.20	227.63	228.67	228.48	233.51	235.81	236.60
10103	226.51	227.12	228.37	228.12	233.52	235.81	236.60
10022	226.49	226.97	228.11	227.90	233.01	235.32	236.13
9922	226.48	226.95	228.04	227.84	232.99	235.31	236.11
9867	226.48	226.94	228.02	227.83	232.93	235.26	236.06
9781	226.46	226.88	227.85	227.68	232.33	234.58	235.38
9693	226.24	226.56	227.37	227.22	231.00	233.10	233.85
9606	224.93	225.30	226.04	225.92	230.50	232.79	233.59
9516	223.27	223.95	225.36	225.14	230.44	232.65	233.48
9436	223.27	223.96	225.35	225.14	230.36	232.50	233.31
9345	223.27	223.95	225.33	225.12	230.13	232.13	232.89
9256	223.27	223.95	225.33	225.12	230.13	232.12	232.87
9174	223.27	223.95	225.32	225.12	229.97	231.83	232.52
9071	223.20	223.82	225.05	224.89	229.09	230.57	231.20
8986	223.16	223.77	224.94	224.80	228.72	229.96	230.56
8968	223.09	223.64	224.81	224.69	227.06	229.31	230.36
8949	222.56	223.05	224.18	224.07	226.04	229.30	230.39
8918	220.68	221.06	222.01	221.85	226.46	229.40	230.48
8874	220.68	221.05	221.95	221.80	226.11	229.05	230.11
8831	220.59	220.90	221.65	221.54	225.75	228.77	229.85
8807	220.13	220.45	221.31	221.12	225.68	228.73	229.80
8151	215.64	216.08	217.02	216.83	224.03	227.19	228.15
6827	211.67	212.09	213.94	213.56	221.93	224.74	225.36
5157	210.55	211.22	213.31	212.90	220.98	223.39	223.64
3143	209.10	210.05	212.33	211.92	219.80	222.10	223.06
924	207.34	208.08	210.10	209.72	217.95	220.72	221.71
252	206.97	207.57	209.56	209.19	217.61	220.44	221.53
0	206.53	207.22	209.29	208.92	217.30	220.30	221.40

Notes:

Out-Migration Season: Oct
Migration Season: Apr 15-May 15

Table 12.5-7: Velocities for All Flows under Dam Removal Scenario

	Velocities (feet/sec)						
Station	Low Flow	Outmigration	Migration	2-yr flood	10-yr flood	50-yr flood	100-yr flood
20857	0.62	1.00	2.00	1.82	3.72	5.03	3.53
18397	0.90	1.22	1.92	1.79	3.03	2.46	2.32
16984	0.98	1.41	2.21	2.06	6.08	3.71	3.53
15373	0.25	0.59	1.65	1.46	2.83	2.95	3.02
13621	0.11	0.29	1.02	0.87	4.72	6.27	6.72
13466	0.42	0.91	2.27	2.04	6.25	7.21	7.32
13338	0.17	0.43	1.35	1.17	4.94	6.45	6.97
13325	0.21	0.50	1.46	1.29	5.02	6.52	7.05
13288	0.31	0.68	1.72	1.54	5.01	6.23	6.60
13174	2.72	2.41	3.14	3.15	4.96	5.63	5.86
12928	1.14	1.82	2.75	2.57	3.37	3.70	3.74
12612	0.12	0.29	0.84	0.74	2.93	3.40	3.53
12216	0.75	1.60	2.63	2.54	5.26	6.14	6.39
11835	0.14	0.37	1.19	1.03	4.74	6.09	6.49
11558	0.07	0.20	0.68	0.58	3.38	4.57	4.99
11347	0.48	0.84	1.66	1.52	4.60	5.77	6.17
11144	1.21	2.12	2.66	2.58	5.53	6.64	7.00
10767	2.36	2.04	2.84	2.72	6.16	7.23	7.38
10521	0.59	0.95	2.37	2.12	8.92	11.12	11.54
10420	0.51	0.79	2.03	1.79	8.80	11.27	11.79
10367	0.41	0.68	1.84	1.62	8.56	12.60	13.45
10317	1.90	1.75	2.81	2.66	8.44	12.04	12.23
10289	1.24	1.30	2.20	2.06	7.18	10.40	10.56
10247	4.48	5.52	5.91	5.50	9.46	9.65	9.42
10221	0.46	0.89	1.73	1.59	4.36	5.40	5.78
10172	2.37	2.82	3.16	3.17	6.24	7.68	8.21
10139	3.61	4.64	6.61	6.23	9.52	11.01	11.68
10103	2.09	2.56	4.47	4.17	8.11	10.03	10.79
10022	0.65	1.32	2.96	2.68	8.20	9.94	10.55
9922	0.36	0.74	1.90	1.68	6.34	8.18	8.88
9867	0.30	0.63	1.66	1.46	6.11	7.93	8.61
9781	0.89	1.45	2.81	2.56	7.73	9.50	10.11
9693	1.39	2.00	3.59	3.28	10.18	11.84	12.36
9606	3.51	3.85	5.12	4.81	8.54	9.82	10.27
9516	0.67	1.23	2.41	2.19	6.39	7.88	8.29
9436	0.13	0.32	1.03	0.88	4.93	6.77	7.40
9345	0.19	0.43	1.24	1.08	5.52	7.54	8.24
9256	0.08	0.20	0.72	0.61	4.56	6.59	7.32
9174	0.11	0.27	0.90	0.76	5.05	7.29	8.10
9071	1.98	2.78	3.87	3.52	7.98	10.32	11.01
8986	0.56	0.91	1.98	1.73	7.07	9.91	10.67
8968	1.51	2.26	2.66	2.41	10.42	10.75	10.62
8949	3.74	4.35	4.70	4.53	11.10	7.75	7.65
8918	0.10	0.24	0.75	0.64	3.36	4.16	4.45
8874	0.57	0.96	1.97	1.77	5.44	6.04	6.31
8831	1.74	2.34	3.85	3.50	6.73	7.05	7.28
8807	3.11	3.84	4.49	4.64	6.70	7.10	7.37
8151	0.75	1.29	3.04	2.75	6.52	8.14	8.88
6827	2.56	2.41	2.52	2.45	5.55	7.28	8.16
5157	0.40	0.62	1.10	1.02	3.57	5.02	5.83
3143	3.59	2.22	2.26	2.21	3.08	3.29	2.02
924	0.55	0.98	1.96	1.79	4.28	4.04	4.16
252	1.35	1.55	2.05	1.94	3.43	3.65	3.11
0	0.91	1.34	2.27	2.10	4.65	4.14	3.93

Notes:

Out-Migration Season: Oct
Migration Season: Apr 15-May 15

13.0 Sediment Transport, Scour Analysis and Sediment Management

13.1 Sediment Transport

13.1.1 Fundamentals

Sediment transport is the process whereby sediment is eroded from an upstream location and transported downstream. Though it sounds simple, it is difficult to quantify. Unlike most areas of study in hydraulics, sediment transport has an almost unlimited number of variables ranging from the usual hydraulic properties (flow, velocity, channel slope, bank slope, channel depth, and channel width) and sediment properties (size, density, shape, angle of repose, cohesiveness, size distribution) to atmospheric conditions (air and water temperature, presence of ice and ice jams), various anthropogenic factors (presence of levees and dams, urban development, and dredging activities), and random factors such as turbulence. The following is a brief description of the governing principles of sediment transport and their application to the feasibility of dam removal.

Sediment transport is a naturally occurring, continuous process in all streams. Streams are in dynamic-equilibrium between sediment deposition and scour, usually resulting in a stable channel configuration. In upland areas of the watershed, physical, chemical, and biological erosive forces break down rock to provide a continuous source of sediment for transport. Glacial deposits can also become mobilized. This coarse sediment is collected by runoff and eventually enters tributaries and the mainstem of the river. From here the coarse sediment is degraded until it is small enough to be transported by the local flow velocity. Flow velocity varies with the channel gradient, width, and depth and the magnitude of flow, which is always changing. Usually, sediment deposits exhibit a range of sediment sizes from fine clays to boulders because the river passes through varied geologic deposits. This range of sediment sizes leads to armoring, whereby fine particles are carried away, and eventually leaving large sediment on top to protect the channel bed from further erosion.

Channel stability, whether flow will cause sediment transport, is determined by comparing the tractive force needed to initiate sediment motion to the shear force that flow creates against the channel bed and banks. As in most areas of sediment transport, there are a multitude of available methods for determining stability. With a known sediment size distribution, it is possible to determine the velocity needed to initiate erosion or deposition. Once sediment has begun to move, it can be transported as either suspended load, sediment entrained in the flow and actually lifted from the channel bed, or bed load, sediment that is dragged along the bottom or tumbles downstream with the current.

Sediment transport processes are complex and difficult to quantify. Although numerous equations have been developed based on laboratory experiment data and (less frequently) on field data, the results of the different transport functions often vary significantly from each other. Additionally, most of the equations have not generally been found to be very accurate in predicting sediment transport rates when compared to measured data. Even though the equations may not accurately predict the sediment transport rates, they are useful in quantitatively comparing the sediment transport processes before and after dam removal.

13.1.2 McLane Dam Sediment Transport Analysis

A HEC-RAS sediment transport analysis was performed to evaluate sediment transport in the McLane Dam impoundment under the full dam removal scenario; a sediment transport analysis was not conducted for the Goldman Dam impoundment. The existing HEC-RAS model and dam-out geometry file described earlier were used for the sediment transport analysis, with the exception of leaving the sediment in place at the start of the scenario. In the dam-out model, the McLane and Goldman spillways were removed, while the transects immediately above and below the spillways were left in place to

approximate the native channel geometry beneath the dam. For modeling purposes, it was assumed that there was no elevated bedrock beneath the existing spillway and that the former channel elevation (thalweg) was at the base of the spillway. Note that this assumption will result in higher sediment transport quantities than if elevated bedrock were present beneath the dam; elevated bedrock would result in higher backwater elevations and less sediment transport.

Sediment Depth

Sediment thickness data for the model was obtained from sediment probing conducted during 2010 by Gomez and Sullivan in the McLane Dam impoundment and during 2006 by Arcadis in the Goldman Dam impoundment (as described earlier). HEC-RAS model cross-sections were assigned a representative sediment transect based on proximity or other similar features. Depth data for some cross-sections between measured transects were interpolated. Because HEC-RAS cannot accept input of varying sediment depths at intervals along a cross-section, sediment thickness was averaged across the portion of each cross-section containing sediment (i.e., if one side of the channel was dominated by bedrock with little to no overlying sediment, it was not included in the average).

Sediment Particle Size Distribution

Sediment grain size analyses from samples collected in 2011 by Gomez and Sullivan (McLane impoundment) and in 2006 by Arcadis (Goldman impoundment) were used to develop sediment gradations for use in the HEC-RAS model. For the upper and lower extents of the model, samples collected in 2011 upstream of the Goldman Dam impoundment and downstream of McLane Dam were used. The smallest 10% of the particle sizes were excluded from the computations as recommended by H.A. Einstein (1950) when using multiple-grain-size functions (USACE, 1995). Sediment transport functions are very sensitive to the grain size distribution and higher transport rates will be computed for the smaller sized particles unless the sampling method can assure that these smaller sized particles are accurately represented in the distribution.

Suspended Sediment Load

A suspended sediment rating curve was developed from suspended sediment discharge data (tons per day) collected periodically by the USGS at the gage in Merrimack from 1967 to 1974. Measurements taken during flows ranging from 300-2,333 cfs were used to develop a rating curve covering flows from 300-11,000 cfs. Linear extrapolation for the higher flows may produce slightly lower than actual values, which is conservative because it would allow a greater capacity to transport mobile sediment for a given flow.

Sediment Transport Function

Sediment transport equations were developed by different researchers based on specific conditions (i.e. depth, width and slope of river, size of sediment), so the range of applicability and accuracy of each equation is somewhat limited by those parameters. Several applicable functions were investigated, and the Wilcock equation was selected as the final modeling method. The Wilcock equation was developed as a multiple-grain-size approach, where the sediment transport rate is computed for different sized particles within the sediment sample. (Some sediment transport equations are “single-grain-functions” and calculate the sediment transport rate based on the mean sediment size.) Multiple-grain-size functions are the most appropriate to use when studying the effect of a project on sediment transport characteristics (USACE, 1995).

Flows

The most significant amount of sediment is transported during large flow events, when the stresses on the bed of the river are greatest, and more sediment is lifted from the bed and transported by the river. Several flow scenarios were investigated, but those chosen for more thorough analysis include the estimated 100-year flood flow, and the range of flows that were actually experienced leading up to and during the April 17, 2007 flood (an approximate 50-year event with a peak flow of about 8,648 in the project area). The 100-year flood flow, estimated at approximately 10,563 cfs in the project area, was run for a period of 30 days. For the 2007 flood scenario, average daily flows between March 15 and April 30 (45 days) were used, with more detailed delineations down to one-hour flows in the days surrounding the peak flow.

Results

The results of the sediment transport analysis are presented in Table 13.1.2-1. Net volume bed change for cross-sections of interest within the McLane Dam impoundment is presented for both flow scenarios (2007 flood and 100-year flood) under existing and dam-out conditions. As described above, sediment transport is a dynamic process in which sediment may be deposited and/or transported downstream, usually concurrently within the same flow scenario. The parameter presented—net volume bed change—represents the volume of sediment deposited (volume "in") minus the volume of sediment transported downstream (volume "out") for a given cross-sectional volume (cross-sectional area extended up- and downstream to the midpoints between adjoining cross-sections) at the end of the flow scenario.

These values are summed at the bottom of the columns to give the cumulative volume bed change for the McLane impoundment. Using the total volume of sediment in the impoundment estimated during the 2010 probing (4,700 CY), percent changes in sediment volume were also calculated. For the April 2007 flood and 100-year flood scenarios, the McLane impoundment sediment is predicted to be reduced by approximately 7% and 36%, respectively, compared to the roughly 4% and 24% depositions expected under existing conditions.

These totals reflect two relatively large sediment depositions that are predicted to occur—upstream of the sewer line (near the head of the impoundment), and upstream of Swinging Bridge. Both these locations are at the base of drop in gradient, and upstream of a natural grade control. In other words, they are areas where flow slows somewhat and sediment is expected to settle out and deposit. To exclude these cross-sections with a net sediment deposit from the overall impoundment calculation, sums of cross-sections with net loss of sediment only are presented at the bottom of Table 13.1.2-1. Considered this way, the McLane impoundment can be expected to lose about 43% and 76% of its sediment during the April 2007 and 100-year flood scenarios, respectively, compared to approximately 7% and 55% lost under existing conditions.

Figures 13.1.2-1 and 13.1.2-2 present graphically the change in channel invert (i.e., thalweg, or lowest elevation) expected under the April 2007 and 100-year flood scenarios, respectively, for the McLane impoundment. The new invert elevation predicted after the flow event is shown in red. Water surface elevations at the beginning and end of the flow scenario (which occurs over multiple days) are shown for reference, but note that they may not represent the peak flow/elevation experienced during the event. Also note that a drop in channel invert does not necessarily correspond to a net loss of sediment volume at that cross-section, as sediment can deposit along the sides of the channel even though it has been scoured from the thalweg. This can be seen in the example described above where there is relatively large amount of sediment deposited upstream of Swinging Bridge, but no change in the channel invert elevation. The inverse may also apply (increase in channel invert, net loss of sediment).

In summary, the most significant movement of sediment from the McLane impoundment is predicted to occur immediately upstream of the dam, up to the Swinging Bridge. In this area, after the 100-year flood scenario, a net of about 1400 CY of sediment is expected to move downstream, and the channel invert elevation is expected to drop by about 2 feet.

Table 13.1.2-1: Sediment Transport Predicted for McLane Dam Impoundment under Flood Scenarios

MODEL STA.	LOCATION	NET VOLUME BED CHANGE (yd^3)			
		Existing Conditions		Full Dam Removal Scenario	
		2007 Flood (~50-yr)	100-yr Flood	2007 Flood (~50-yr)	100-yr Flood
10103	D/S of Goldman Dam	-61	-79	-47	-71
10022		-45	-46	-35	-46
9922		54	-20	-25	-26
9867		208	603	587	-26
9781		45	995	154	-58
9693	Sewer Line	-23	-64	-48	-64
9606		-64	-202	-193	-202
9516		58	-156	-142	-156
9436		40	-681	-89	-760
9345		48	151	316	-439
9256		55	1,683	619	1,881
9174	U/S of Swinging Bridge	1	275	-321	-357
9071	D/S of Swinging Bridge	-55	-515	-478	-514
8986		-73	-520	-471	-515
8968		-24	-148	-38	-128
8949	U/S of McLane Dam	25	-158	-123	-223
Total McLane Impoundment Volume Change		**190**	**1,118**	**-335**	**-1,703**
Percent of Total Sediment (4700 yd^3)		4%	24%	-7%	-36%
Total from Cross-Sections with Net Loss Only *(net sediment transported downstream)*		**-345**	**-2,588**	**-2,012**	**-3,585**
Percent of Total Sediment (4700 yd^3)		-7%	-55%	-43%	-76%

(A negative value means the loss of sediment, while a positive value means the gain of sediment)

13.1.3 Goldman Dam Sediment Transport

As noted above, a sediment transport analysis (like that conducted for the McLane impoundment) was not conducted for the Goldman impoundment. However, based on the sediment thickness mapping and hydraulic modeling, a rough approximation of the potentially mobile sediment volume was estimated. The mean channel velocities under dam-in and dam-out conditions were compared under different flood flows (see Table 12.5-2). As Table 12.5-2 shows, under dam-out conditions, the incremental increase in velocity is greater from the Goldman Dam to the confluence of Great Brook with the Souhegan River (Area B). Mean channel velocities in Area B increased between 1 to 3 feet/sec under dam-out conditions

over the range of flood flows. The total sediment volume in Area B was estimated from sediment thickness mapping conducted in 2006 as approximately 1,800 CY. There is the potential that some of the 1,800 CY of sediment could become mobilized during a high flow event under dam-out conditions. It should be noted that a) not all of 1,800 CY of sediment would likely be mobilized and b) some of this sediment would likely be replaced from inflowing sediment that re-deposits in Area B.

Again, mean channel velocities under dam-in and dam-out conditions were compared under different flood flows (see Table 12.5-2) above the Great Brook confluence. As Table 12.5-2 shows mean channel velocities increase generally less than 0.4 feet/second under dam-out conditions, a nominal increase. It is believed that regardless of whether the dams are removed or not, the sediment transport properties through this reach will remain as it currently does.

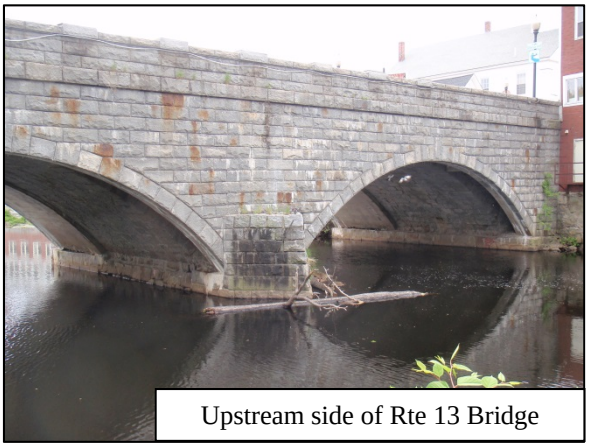
To expand further, Area A is located within the Goldman Dam impoundment adjacent to the Fletcher's Paint Site. Station No. 12612 is a cross-section through Area A of the Fletcher's Paint Site area. The hydraulic model was used to determine the change in hydraulic conditions at this representative transect of Area A under existing and dam-out conditions. Shown below are the WSE's and mean channel velocities at Station No. 12612 under the 2-, 10-, 50 and 100-yr flood under existing and dam-out conditions.

Parameter	**2-yr Flood**			**10-yr Flood**			**50-yr Flood**			**100-yr Flood**		
	Existing	*Dams Out*	*Diff.*	*Existing*	*Dams Out*	*Diff.*	*Existing*	*Dams Out*	*Diff.*	*Existing*	*Dams Out*	*Diff.*
Water Surface Elevation	236.3	234.7	-1.6	242.0	241.0	-1.0	244.8	243.8	-1.0	245.9	244.9	-1.0
Velocity	0.5	0.7	0.2	2.8	2.9	0.1	3.2	3.4	0.2	3.4	3.5	0.1

As expected the WSE drops between 1 to 1.6 feet and mean channel velocities increase slightly (between 0.1 to 0.2 feet/second) under dam-out conditions. Given that the velocities are not that much different in Area A with or without the dams, the sediment transport properties in this area are not expected to vary. In short, any sediment transport/scour that occurs now in Area A would be virtually the same under dam-out conditions.

13.2 Scour Analysis

Route 13 Bridge Scour


Upstream side of Rte 13 Bridge

One potential concern with removing the dams is that velocities near the abutments and center pier of the Route 13 Bridge will increase. If these weight bearing structures are founded on erodible material and the Goldman Dam is removed, there is concern the underlying supports could erode and thus compromise the structural integrity of the Route 13 Bridge. Two field related activities – one by our study team and another conducted in 2009-- were conducted to assess the underlying supports for the abutments and pier. As part of our study, considerable probing was conducted along the base of the abutments and the pier using a steel rod. The rod was extended through the water column until the channel bed was reached and it was attempted to hammer the rod to refusal. In the many probes conducted around the abutment and center pier, the sediment could not be penetrated and, in fact, made a "ping" noise suggesting that bedrock or large boulders were present. It was difficult to see through the water column and visually identify the channel bed material. However, immediately below the bridge where the channel bed could be seen due to sunlight, there was considerable bedrock present.

In addition to the probing, a previous field investigation of the Route 13 Bridge was conducted in 2009 to determine potential scour issues at Route 13. As noted earlier the report is entitled:

Geophysical Seismic Refraction Testing of Bridge Foundation Conditions for NHDOT Scour Project; Bridge 123/133; NH Route 13 over Souhegan River; Milford, NH; Prepared for CHA Inc.; October 2009 by NDT Corporation for Clough, Harbor and Associates (CHA). See Appendix L for full report.

NDT Corporation did the evaluation for CHA. The following is summarized in the report:

> *A geographic seismic refraction test was performed at this bridge in October 2009. The results of this test indicate that the abutments and pier have a high probability of being partially founded on bedrock. Rock elevations are fairly flat throughout the site and it is assumed the footings would have been constructed on rock given the downstream outcroppings. Based on the lack of any undermining evidence, successful resistance to many floods over 116 years, and in combination with this NDE information, CHA recommends that the Item 113 be rated as 5. This removes the structure from a scour critical designation as such no Plan of Action is required. Since routine bridge inspections cannot gain access beneath the bridge, CHA recommends underwater inspections be performed on a 2-year cycle. Riverbed elevations along the pier and both abutments should be monitored for changes during the regular biennial inspection process. Should any evidence of undermining be reported, the scour rating should be reviewed. The regular biennial bridge inspection should continue to document the river bed elevation at this bridge.*

Based on our probing and visual assessment as well as the more detailed geophysical study, it does not appear that removal of the dams will result in bridge scour. It should be noted that the average channel velocity will increase if the Goldman Dam is removed. For example, the average channel velocity under dam-in and dam-out conditions for the 100-yr flood is approximately 10.2 ft/sec and 13.4 ft/sec respectively.

Sewer and Water Line Scour

As noted earlier, there are three sewer lines and three water lines traversing the Souhegan River within the two impoundments as shown in Figure 1.1-3. One of the concerns with removing the dams is the potential of scouring the channel bed and potentially exposing the sewer/water lines. Discussed below are the lines in a downstream to upstream order. Note that drawings were provided, but it is unclear if they reflect as-built or design drawings.

Sewer Line 1 (see Figures 3.3.1 and 3.3.1 for plan and profile views) is located below McLane Dam and is currently located outside the envisioned project impact area. Thus, no modifications to this sewer line are anticipated at this time.

Sewer Line 2 (see Figure 3.3-3 and 3.3-4 for plan and profile views) is located between the McLane and Goldman Dams. To determine the potential impact of removing the McLane Dam on this sewer line the following was reviewed: sewer line drawings, the sediment thickness mapping, hydraulic model, and sediment transport analysis. Based on the profile drawing the sewer line is encased with six (6) inches of concrete and the bottom of the sewer line has six (6) inches of crushed stone. In addition, the drawing shows riprap lining the channel bed from bank-to-bank, but does not indicate the size of riprap. The sewer line is sloped 0.0015 ft/ft downward from river-left to river-right.

The sewer manhole rim elevations were originally surveyed; however, the rim elevations did not match the elevations on the drawings. To confirm our elevations, the survey crew returned and ran the survey to a known benchmark at town hall to verify the original survey (it checked properly). In addition, some manhole covers were lifted to obtain the invert elevation of the ductile iron pipe (DIP), rather than relying on the drawings. The Milford DPW was concerned with opening certain manhole covers, so for Sewer Line 2 only the manhole cover on river-right was lifted. Based on our survey, the bottom of the DIP on river-right was surveyed at 221.8 feet versus 221.31 feet on the drawing (0.49 foot difference). Thus, the top of the 2.5-ft diameter pipe on river-right is at elevation 224.3 feet (221.8 + 2.5). The surveyed distance between the manhole covers is approximately 145 feet long, and per the drawings is sloped at 0.0015 ft/ft. Thus, the top elevation of DIP on river left is 0.22 feet higher or at elevation 224.52 feet.

Sewer Line 2 is located between sediment depth transects T-9 and T-10, but is closer to T-9 and thus T-9 was considered representative of the channel bed along the sewer line. Shown in Figure 13.2-1 is transect T-9 along with the sewer line. The location of lowest cover (the distance between the top of the DIP and channel bed) atop the sewer line is near station 42, where the difference between the channel bed elevation and top of the sewer line is approximately 1.39 feet. Recall that according to the drawings the DIP is also encased with 0.5 feet of concrete so the distance from the channel bed to the top of concrete is closer to 0.89 feet.

Based on hydraulic modeling, sediment transport modeling, and sediment probing, our preliminary finding is that Sewer Line No. 2 does not appear subject to scour; however, additional follow-up work is recommended since not much sediment is present between the top of the sewer line and the channel bed. Because it is unclear if the drawings are as-built or design drawings, further investigation is recommended to confirm that the line is truly encased in concrete, the channel lined is line with riprap, and the profile is correct. Additional probing immediately above and just downstream of the sewer line is recommended as well as a grain size analysis. The substrate size would be used in the hydraulic model to determine if the velocities without the McLane Dam could result in mobilizing the substrate. As shown in Table 13.2-1, the velocity increases with the dam removed and confirmation is needed that removal will not jeopardize the sewer line.

Note that the sewer line invert on river-right was surveyed, but the river-left invert was not since the DPW had concerns with lifting some manhole covers. It is recommended that the river-left invert also be surveyed to confirm the sewer line slope since the invert on river-left is higher (closer to the channel bed)—the sewer line slopes downward from river-left to river-right.

For cost estimating purposes we have not included costs associated with protecting the sewer line if found to be in jeopardy.

Table 13.2-1: Average Channel Velocities at Sewer Line 2 under Goldman/McLane Dam-In and Dam-Out Conditions

Flow	**Goldman/McLane Dam In** Avg Channel Velocity near Sewer Line 2 (XS 9693 from HEC-RAS model)	**Goldman/McLane Dam Out** Avg Channel Velocity near Sewer Line 2 (XS 9693 from HEC-RAS model)
2-yr flow, 355 cfs	0.7 ft/sec	3.3 ft/sec
100-yr flow, 10,500 cfs	8.2 ft/sec	12.4 ft/sec

Water Line 1 is located behind the Masonic Temple. As noted above, the water line already sits atop the channel bed and regardless of whether the dam stays or is removed it is recommended that the line be buried to prevent potential dislodging of the pipe.

Sewer Line 3 (see Figure 3.3-5 and 3.3-6 for plan and profile views) is located just downstream of the Gregg Crossing Footbridge. Like Sewer Lines 1 and 2, the drawings show the DIP being encased with six (6) inches of concrete, bedding consisting of six (6) inches of crushed stone and the channel bed above the DIP is lined with riprap. Based on the hydraulic modeling and the sediment transport analysis channel bed scour is not anticipated in this area. As shown in Table 13.2-2, the average channel velocity with and without the dams under the 2-year and 100-year flow are similar.

Table 13.2-2: Average Channel Velocities at Sewer Line 3 under Goldman/McLane Dam-In and Dam-Out Conditions

Flow	**Goldman/McLane Dam In** Avg Channel Velocity near Sewer Line 2 (XS 13288 from HEC-RAS model)	**Goldman/McLane Dam Out** Avg Channel Velocity near Sewer Line 2 (XS 13288 from HEC-RAS model)
2-yr flow, 355 cfs	1.2 ft/sec	1.5 ft/sec
100-yr flow, 10,500 cfs	6.3 ft/sec	6.6 ft/sec

Water Line 2 (see Figure 3.3-7 and 3.3-8 for plan and profile views) is located just upstream of the Gregg Crossing Footbridge. Using the same rationale as for Sewer Line 3, the average channel velocity with and without the dams under the 2-year and 100-year flows are similar as shown in Table 13.2-3. Given this, channel bed scour in this area is not anticipated.

Table 13.2-3: Average Channel Velocities at Water Line 2 under Goldman/McLane Dam-In and Dam-Out Conditions

Flow	**Goldman/McLane Dam In** Avg Channel Velocity near Sewer Line 2 (XS 13466 from HEC-RAS model)	**Goldman/McLane Dam Out** Avg Channel Velocity near Sewer Line 2 (XS 13466 from HEC-RAS model)
2-yr flow, 355 cfs	1.6 ft/sec	2.0 ft/sec
100-yr flow, 10,500 cfs	6.9 ft/sec	7.3 ft/sec

None of the sewer or water lines are present impediments to fish passage.

14.0 Cultural Resource Studies

14.1 Consultation Requirements

The potential removal of the McLane or Goldman Dams must take into account impacts to historic resources including archaeological and architectural resources. Section 106 of the National Historic Preservation Act (NHPA) of 1966 requires federal agencies to take into account the effects of their undertakings (such as dam removal) on known or potential historic properties and afford the Advisory Council of Historic Preservation (ACHP) a reasonable opportunity to comment. Properties greater than 50 years old may be eligible for listing to the NRHP. Compliance with Section 106 of the NHPA is required of most dam removal projects that require a federal permit (such as a USACOE permit for activities involving the placement of fill in waters of the United States) or receive federal funding or assistance.

All federal agencies (e.g. USFWS, USEPA, NOAA, and National Resource Conservation Services) are responsible for addressing Section 106 of the NHPA. To make the process more efficient, typically a lead federal agency (LFA) is identified. For this project, the LFA is NOAA. The LFA is responsible for ensuring compliance with Section 106 of the NHPA. As part of that responsibility, the LFA must coordinate with the State Historic Preservation Office (in this case NHDHR) regarding the project affects, if any, on known or potential historic properties.

The purpose of the historic preservation review process as defined under state law RSA 227-C:9 and Section 106 of the NHPA of 1966, as amended (16 U.S.C. 470), implemented by ACHP procedures, is to balance the public interest in historic preservation with the public benefit from a variety of governmental initiatives.

Steps in the Section 106 Process

Step 1: Initiate Section 106 Process

The responsible federal agency(s) first determines whether it has an undertaking that could affect historic properties. Historic properties are properties that are included in the NRHP or that meet the criteria for the National Register. If so, it must identify the appropriate State Historic Preservation Officer (SHPO)/Tribal Historic Preservation Officer (THPO) to consult with during the process. It should also plan to involve the public, and identify other potential consulting parties. If the federal agency determines that it has no undertaking, or that its undertaking is a type of activity that has no potential to affect historic properties, the agency has no further Section 106 obligation.

Step 2: Identification/Evaluation of Historic Properties

If the federal agency's undertaking has the potential to affect known or potential historic properties, it determines the scope of appropriate identification efforts and then proceeds to identify historic properties in the area of potential effect (APE[43]). The agency reviews background information, consults with the SHPO/THPO and others, seeks information from knowledgeable parties, and conducts additional studies as necessary. Districts, sites, buildings, structures, and objects listed in the National Register are considered; unlisted properties are evaluated against the National Park Service's published criteria, in consultation with the SHPO/THPO any Indian tribe, consulting parties, Project Partners and the dam owner.

[43] The area of potential effect is defined as the area in which eligible properties may be affected by the undertaking, including direct effects (such as destruction of the property) and indirect effects (such as visual, audible, and atmospheric changes which affect the character and setting of the property).

If questions arise about the eligibility of a given property, the agency may seek a formal determination of eligibility. Section 106 review gives equal consideration to properties that have already been included in the National Register as well as those that have not been so included but that meet National Register criteria and are eligible for listing.

If the agency finds that no historic properties are present or affected, it provides documentation to the SHPO/THPO and, barring any objection in 30 days, proceeds with its undertaking.

If the agency finds that historic properties are present, it proceeds to assess possible adverse effects.

Step 3. Determination of Effect

The agency, in consultation with the SHPO/THPO, makes an assessment of adverse effects on the identified historic properties based on criteria found in ACHP's regulations. If they agree that there will be **no adverse effect,** the agency proceeds with the undertaking and any agreed-upon conditions. If they find that there is an **adverse effect,** or if the parties cannot agree and ACHP determines within 15 days that there is an adverse effect, the agency begins consultation to seek ways to avoid, minimize, or mitigate the adverse effects.

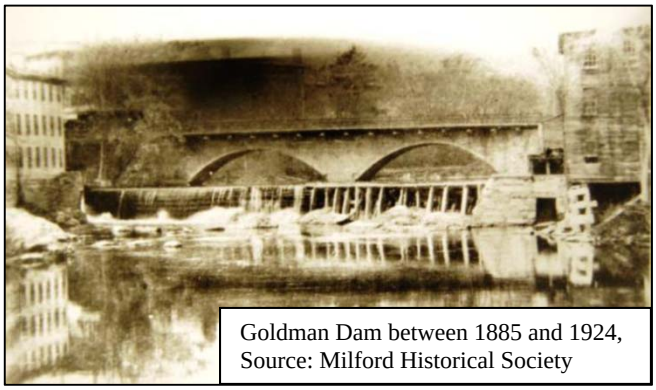
Step 4. Resolve Adverse Effects

The agency consults to resolve adverse effects with the SHPO/THPO and others. Consultation usually results in a Memorandum of Agreement (MOA), which outlines agreed-upon measures that the agency will take to avoid, minimize, or mitigate the adverse effects. In some cases, the consulting parties may agree that no such measures are possible, but that the adverse effects must be accepted in the public interest.

For this project, NOAA consulted with the town of Milford, Project Partners and the NHDHR from the onset of the project. Included in Volume 3 of 3 is the full correspondence log and reports that were completed as part of the Section 106 regulations. The following sections briefly summarize the studies that were conducted.

14.2 Phase I Assessment of Historic, Architectural and Engineering Resources

A Phase I assessment was conducted, which requires a qualified architectural historian to complete a Project Area Form for submittal to NHDHR for their review and approval. Briefly, the information for the Project Area Form includes:



Goldman Dam between 1885 and 1924, Source: Milford Historical Society

- Background research on the history and evolution of the dam(s) and study area,
- Visual assessment of the project area including the dam(s) (photo-documentation),
- Description of the dam(s) and other historical resources present within the study area. Historical resources could include standing structures, foundations, bridges, abutments, etc.
- Description of the possible effects on the historic viewshed.

- Once the above is completed, the Project Area Form including text, maps, and photographs is sent to the NHDHR.

It should be noted that if any resources are part of a larger historic district, the evaluation is typically extended outside of the impact area to define that district.

14.3 Phase I Archaeological Assessment

A Phase I Archaeological Reconnaissance-level survey is typically divided into two sub-phases (Phase IA, and pending the findings of Phase IA, potentially Phase IB and Phase II).

The Phase IA survey consists of collecting archival research materials and conducting fieldwork to record information about existing conditions of historic structures and the environmental setting within the preliminary Area of Potential Effect (APE)[44]. Similar to the historic assessment, a qualified archaeologist conducts the study.

Generally, Phase IA surveys require the following:

- Background research typically consists of reviewing archaeological site files at the NHDHR for known archaeological resources, both Native American and historical sites.
- An evaluation of the possible impacts to areas upstream and downstream of the dam(s) after removal. Dam removal may result in disturbance to upland areas and riverine areas due to demolition equipment and potential mechanical dredging of sediment in the impoundment. These activities have the potential to disturb archaeological resources. Removing the dams will also lower impoundment water levels, which has the potential to expose artifacts. Removal will also result in higher velocities through the impoundment and thus there is the potential to erode sensitive streambank sites.
- A detailed project map with the area of impact defined including the areas proposed for access, staging and fill/removal disposal.
- A visual assessment of the proposed project area with regard to archaeological resources is required including a site description and photo-documentation.
- A detailed map is needed to define the study area including known historic and archaeological resources in close proximity.
- The NHDHR Archaeological Inventory Forms must be completed.

Depending on the findings of the Phase IA study, a Phase IB study may be required. The level of effort recommended by the NHDHR in Phase IB generally includes subsurface testing. Furthermore, pending the findings of the Phase IB investigation, a Phase II archaeological investigation may be required in order to test or evaluate an archaeological site's eligibility for inclusion in the NRHP.

14.4 Correspondence with NHDHR and Findings

To begin review and consultation with the NHDHR, project proponents must complete and submit a Request for Project Review (RPR) form. For this project, PAL submitted the RPR to NHDHR on July 1,

[44] The preliminary APE, as used in this assessment, is the area for which initial background research and review is conducted in order to develop an appropriate context for identified cultural resources. The preliminary APE is designed to identify the range of archaeological resources that could potentially be impacted directly or indirectly by a potential dam removal. The APE extended from 100 feet from either river bank beginning approximately 525 feet downstream of McLane Dam and continuing upstream along the length of the river to the Gregg Crossing Footbridge.

2010. All correspondence with NHDHR relative to the Phase 1A archaeological survey and Phase I Historic Structures survey is included in Volume 3 of 3. Note that due to privacy and protection laws, the full Phase 1A archeological survey report is not contained in Volume 3 of 3. Instead, a redacted version has been included for public review.

On July 15, 2010, NHDHR noted that based on the RPR an archaeological assessment should be conducted as well as inventories on the dams. Before starting the Phase 1A archaeological survey or the Phase I Historic/Architectural/Engineer survey, PAL submitted for NHDHR approval their proposed technical approach and methodology for conducting these two surveys- NHDHR approved the approach with no changes.

On June 7, 2011, the Phase IA Archaeological Survey and Phase I Historic/Architectural/Engineer Survey Reports were sent to NHDHR. Relative to the Phase I Historic Structure Survey, PAL recommended that the dams are not eligible for individual listing in the NRHP. PAL noted that McLane Dam's 1992 reconstruction resulted in complete loss of integrity of the 1846/1909 structure. PAL also noted that Goldman Dam is less than 50 years of age and possesses no exceptional significance. PAL stated that the Downtown Milford Commercial, Civic, and Residential Historic District, which the NHDHR determined as eligible for listing in the NRHP in 2010, identifies both dams as contributing resources to the district. PAL's survey; however, found that the two dam structures do not appear eligible for inclusion as contributing resources to this district. PAL notes that the McLane Dam's lack of integrity renders it unable to convey its historical associations with Milford's industrial or hydroelectric generation history. The Goldman Dam's construction date is outside of the district's determined period of significance. PAL recommended no further survey for the dams.

Relative to the archaeological survey, PAL notes that "*Pending the completion of engineered project plans detailing construction and/or demolition activities upstream and downstream hydraulic impacts that would be associated with the removal of the McLane and Goldman Dams, a Phase IB archaeological survey will need to be conducted in accordance with NHDHR standards and Section 106 of the National Historic Preservation Act*". In short, PAL found that removal of the dams could potentially impact archaeological sites and thus recommended a Phase 1B (subsurface testing) survey.

On July 1, 2011, NHDHR made a determination that the Goldman and McLane dams were eligible in the district, in contrast to PAL's recommendation. NHDHR agreed with PAL's finding that a Phase 1B archaeological surveys are needed. On August 11, 2011, NOAA sent NHDHR a letter requesting additional information regarding NHDHR's opinion that the dams are eligible as contributing resources within a District for listing in the NRHP given that it differs from PAL's recommendation. Accompanying this letter was a report entitled *McLane and Goldman Dams National Register Integrity Assessment*. On September 8, 2011, NHDHR sent NOAA a response letter. In it, NHDHR states "*However, after extensive discussion the DOE Committee holds to the opinion that confirms the 2010 determination that both the Goldman and McLane Dams are contributing elements of the Downtown Milford Commercial, Civic, and Residential Historic District*". NHDHR further states in its letter "*The development of Milford as a community relied on engineered elements of the river system and how the water was harnessed for various uses by the community. Taking into consideration the integrity of the historic district as a whole, the dams and their physical impact on the river in the district are important. The impoundment of water, and the spatial relationship of water to the historic district, is intact despite the diminished integrity of original dam designs*".

On June 24, 2014, NOAA sent the Milford Heritage Commission a letter inquiring if they would like to be a consulting party relative to the Section 106 process review of the two dams. In the letter, NOAA states "*Based on more recent consultation with NHDHR, NOAA has determined that the two dams are not individually significant as historic structures. The impoundments they create, however, contribute to the*

significance of the surrounding Downtown Milford Commercial, Civic, and Residential Historic District, which has been determined eligible for listing in the National Register of Historic Places". .

Relative to next steps, if the town and Helen Goodwin Estate opt to remove the dams, the Section 106 process will continue.

15.0 Alternatives Analysis

Two alternatives were evaluated in this study including status quo (dams remain) and full dam removal. The impact of each alternative on various resources such as water quality, wetlands, recreation, fisheries, flooding, ice jams, cultural resources, and infrastructure was evaluated. In addition, opinion of probable construction costs (OPCC) were developed for each alternative as well as a conceptual level plan for removing each dam.

15.1 Status Quo- McLane /Goldman Dams Remain

The status quo alternative assumes no action is taken and the dams remain as is. In this section is a description of the impacts of no action on operation and maintenance, liability, infrastructure, environmental, cultural, recreation and aesthetic resources.

15.1.1 Dam Condition, Maintenance and Liability

If the dams remain, the town (McLane Dam) and Helen Goodwin Estate (Goldman Dam) are subject to ongoing operation and maintenance costs and liability.

<u>Dam Condition and Maintenance</u>

McLane Dam

As noted earlier, the McLane Dam has no outstanding deficiencies. An inspection of the dam was conducted by Gomez and Sullivan in the summer 2010, when a large portion of the structure was exposed. Overall, based on the above water visual inspection the dam is in good condition, given that it was reconstructed in 1992. Due to the rebuild occurring 22 years ago, there is likely many more years of serviceable life of the dam before any major repairs or capital expenditures are needed.

Only minor issues were detected during the above water inspection. A joint along the base of the dam had some minor deterioration; otherwise based on the above-water visual appearance the structure had no other major signs of deterioration. Based on discussions with the town, the stoplogs have been permanently removed from the three bays thus routine maintenance associated with installing or removing the stoplogs is longer an issue. Operation and maintenance activities associated with the dam include:

- Clearing and removing debris (trees, leaves, etc.) that commonly becomes jammed against the stoplog bay openings and trees that get hung up on the spillway.
- Maintaining the access road leading to the base of the dam- although this dirt road appears well established and likely requires minimal maintenance.
- Addressing any future deficiencies identified in NHDES LODs.
- If the low hazard classification for both dams were to ever be raised to a higher classification due to increased development in the downstream reaches below the dams, it could result in further evaluation of the dam and potentially increased capital costs. Hazard classifications are based on the potential loss of life and infrastructure impacts if the dam were to suddenly fail.
- Long term maintenance and capital costs associated with routine upkeep of the dam.
- It is possible that in the future upstream fish passage facilities at the dam could be desired or required to facilitate passage of migratory fish. If this were to occur there would be added capital costs for the fish ladder and operation and maintenance requirements. As noted earlier, downstream fish passage facilities were partially developed but never completed.

Goldman Dam

The Goldman Dam, reconstructed in the 1960's, is considerably older than the McLane Dam and is in fair condition. An above-water visual inspection of the dam was conducted by Gomez and Sullivan in August 2010, when flow was being passed through the sluiceway, showed undermining occurring along the toe of the dam. Over time, any manmade structure, such as a dam, requires long term maintenance and routine repairs to maintain a safe, functional structure. If neglected, the structure will abruptly or slowly fail, which could have downstream and upstream impacts.

Although the dam is technically owned by a college student, the town appears to provide limited resources relative to operation and maintenance activities. The limited activities have historically included installing and removing the stoplogs at the gate to raise and lower the impoundment elevation. However, like McLane Dam, the town has permanently removed the stoplogs.

Summary

The dam owners pay an annual registration fee to the NHDES for each dam. The annual registration fee varies depending on the hazardous classification, which includes low ($400), significant ($750), and high ($1,500). Both dams are currently classified as low hazard.

As noted earlier, there is an important distinction between receiving a LOD as issued for McLane Dam versus a NOI as issued for Goldman Dam. In the LOD, the dam owner is responsible for addressing the deficiencies and thus the owner could incur future capital expenditures to bring the dam into compliance with state regulations. In the NOI, the dam owner is not mandated to address issues identified during the inspection, thus there is no financial obligation.

The Goldman Dam is owned by the Helen Goodwin Estate, which is held by a college student in New Mexico having no financial means to operate or maintain Goldman Dam. The NHDES Dam Bureau has clarified that because the dam is technically owned by another party, the town has no legal responsibility to maintain or operate Goldman Dam.

<u>Liability</u>

In term of liability, no warning signs or boat restraint systems are present above either dam. Although no canoeists or kayakers were observed on either impoundment during Gomez and Sullivan's various field visits, there is the potential for boaters or swimmers to go over the dam. In addition, there is a plunge pool below each dam. Under high discharges, "rollers" can develop directly in these plunge pool areas and could potentially entrap people thus creating a safety issue.

Also of note is public access to the dams. The Goldman Dam is not easily accessible by foot due to it being flanked by the Milford Mill Apartment complex on the right bank and an extremely steep-sided left bank. In contrast, the McLane Dam is readily accessible from numerous paths. On many occasions during Gomez and Sullivan's site visits, juveniles and young children were present around or even atop the McLane Dam, which could also present a safety issue.

15.1.2 Infrastructure

Flooding

Both dams operate as run-of-river projects, whereby inflow equals outflow on a nearly continuous basis, meaning water levels behind the dams are typically maintained at the stoplog opening crest elevation (when flows are low) or at the spillway crest elevation as flows increase. Under status quo conditions, neither dam provides any flood storage capacity, but instead the dams artificially raise the river's WSE.

Sewer/Water Lines

Under existing conditions, there is no impact to the sewer and water lines, with the exception of Water Line 1 (Figure 1.1-3) located behind the Masonic Temple in the Goldman Impoundment. This water line currently sits on the river bed and remains exposed. Whether the dam remains or is removed, it is recommended that this water line be buried to protect it.

Route 13 Bridge

An assessment of the bridge abutments and pier was conducted by Gomez and Sullivan by driving a steel rod to refusal along the periphery of the supporting structures. Based on the probing it appears bedrock or large boulders are present beneath the abutments and pier. An independent geophysical evaluation was also conducted using Ground Penetrating Radar and the findings were similar to Gomez and Sullivan's. The geophysical study report notes the following: *The results of this test indicate that the abutments and pier have a high probability of being partially founded on bedrock.* Given this, scour along the bridge abutments and pier is unlikely due to the underlying bedrock. In addition, based on the bathymetric mapping, no scour hole currently exists through the bridge opening.

Water Supply/Fire/Traffic

The town is serviced by public water supply.

Based on discussions with the town fire department (2/13/2014), the impoundments are not used as a source of water to fight fires or fill pumper trucks. The fire department reported that access to the Souhegan River is difficult and limited for a fire truck.

There would be no impact to traffic if the dams remain.

15.1.3 Environmental Resources (Water Quality, Fisheries, Wetlands)

Water Quality

As noted earlier, the NHDES determined that the Souhegan River, in those reaches impounded by the two dams, have water quality issues significant enough to warrant action. Both impoundments are on the 2012 303(d) list, meaning they do not meet state water quality standards. Shown in Table 15.1.3-1 (Volume 2) is a summary of the impairments for both impoundments, which include at Goldman Dam- dissolved oxygen (DO) saturation, DO concentration and mercury and at McLane Dam- Escherichia coli (*e.coli*) and mercury. Note that elevated concentrations of mercury in surface waters are due to atmospheric deposition and is a common impairment to many rivers and waterbodies in New Hampshire.

Although a detailed water quality study was not conducted as part of this feasibility study, there is ample scientific literature demonstrating the impact of dams on water quality. Three of the more common water

quality issues associated with dams includes artificially increasing water temperature, lowering DO concentrations and causing DO supersaturation (when saturation exceeds 100%). The Goldman Dam and McLane impoundments are approximately 1.5 miles and 1,270 feet long, respectively. The shallow impoundments are subject to thermal loading as sunlight penetrates the majority of the water column. The impoundment water temperature warms as it takes longer for a cubic foot of water entering the impoundment to leave it compared to a natural free-flowing river. For example, if the inflow to the dams was 33 cfs (median September flow), the residence time[45] of the McLane and Goldman Dam impoundments would be approximately 6 and 8[46] hours, respectively. The higher residence time allows the water within each impoundment to artificially heat compared to a natural river.

Relative to DO, fish, mussels, macroinvertebrates and other aquatic biota require DO to breathe and survive. DO is a relative measure of the amount of oxygen dissolved in water. DO in rivers is affected by three primary factors: water temperature, atmospheric pressure and dissolved solids. Also important is the amount of decaying matter in the river, turbulence at the air-water interface and the amount of photosynthesis occurring from aquatic plants within the river. Converting from an impoundment to a free-flowing river will result in increased aeration (and hence increased DO concentrations) as water tumbles over rocks. In addition, warm water holds less oxygen than cold water. As noted above, the impoundments are subject to thermal loading and thus will result in lower DO concentrations than a cooler natural river. DO supersaturation, which has been noted at the Goldman Dam, commonly occurs when aquatic plants emit oxygen. In some instances, there can be a large diurnal swing in DO concentration when plants emit oxygen during the day potentially causing supersaturation, followed by plants consuming oxygen in the night resulting in lower DO concentrations.

If the dams were removed and the Souhegan River reverted back to a free-flowing system, it is believed the segments of river running through downtown Milford would no longer fail to support the designation of aquatic life use support. Subsequently, it is expected this portion of the Souhegan River could then be removed from the 305(b)/303(d) list of impaired waters

Fisheries

Currently, the dams serve as physical barriers to the free movement of fish and other aquatic resources above and below the dams. With the removal of the Merrimack Village Dam in 2008, the former lowermost barrier, migratory and resident fish can now ascend up the Souhegan River as far as the McLane Dam. The McLane Dam has a partially constructed downstream fish passage facility that was never completed, but has no upstream fish passage facility. Goldman Dam has no upstream or downstream fish passage facilities. In addition to serving as physical barriers to fish passage, the dams create impoundments that inundate riverine fish habitat. In addition, accumulated sediment may potentially cover fish spawning grounds.

Wetlands and Rare, Threatened and Endangered (RTE) Species

Under existing conditions, there are minimal wetlands located in the project area. The dominant vegetation along the river banks include trees of red oak, white pine, pignut hickory, sugar maple, silver maple, sycamore, black locust, green ash, and American elm; the shrub and sapling layer included many of the trees mentioned above along with hornbeam, poison sumac, staghorn sumac, black willow,

[45] Residence time is a broadly useful concept that expresses how fast something moves through a system in equilibrium. It is the average time a substance (water in this case) spends within a specified region of space, such as an impoundment.

[46] The gross storage volumes of the McLane and Goldman dam at their spillway crest are 17.1 acre-feet (206 cfs-hours) and 21.3 acre-feet (257 cfs-hours), respectively.

sassafras, silky dogwood, red osier dogwood, and honeysuckle. The ground cover varied from none below the white pines to a dense covering of raspberries, poison ivy, grape vines, bracken fern, many types of grasses, goldenrod, and royal fern.

The National Wetland Inventory map of the USFWS classify the Souhegan River as Riverine, Lower Perennial, Unconsolidated Bottom, Permanently Flooded (R2UBH) above the Route 13 Bridge, Palustrine, Unconsolidated Bottom, Permanently Flooded, Diked/Impounded (PUBHh) from the Route 13 Bridge downstream to the McLane Dam, and then Riverine, Lower Perennial, Unconsolidated Bottom, Permanently Flooded (R2UBH) below the McLane Dam. The wetland delineation concurred with these classifications.

The NH Natural Heritage Bureau, NHFGD, and USFWS were contacted in 2010 and provided a map showing the Project Area extending from roughly 1,000 feet below the McLane Dam to the Gregg Crossing Footbridge. These agencies were asked to review their records and databases to determine if any known RTE species had been identified in the project area. Based on the reply letters, no RTE species have been located in the project area.

15.1.4 Cultural and Historic Resources

Under status quo conditions, there would be no impacts to existing historic and cultural resources. However, if the dams remain, over time any major change or rebuild of the dams could potentially impact the historical significance of the structures. In the case of the Goldman Dam, if no maintenance of the dam is conducted, it will eventually fail.

15.1.5 Recreation Resources

A recreation assessment was not conducted as part of this study. However, Gomez and Sullivan visited the project area on many occasions outside of winter and have anecdotal information on recreation use. There is passive recreation use along numerous trails located along the river's edge. People were observed on many occasions walking along a well-defined path on river left starting from the Boys and Girls Club downstream to Emerson Park. The park has several benches for siting and concerts occur during the summer. The park overlooks the Souhegan River just upstream of the Route 13 Bridge. From McLane Dam downstream there is also an informal, but well-worn, path on river left along the river bank. Again, the public were observed walking and biking along this path.

Anglers were observed in the Emerson Park area and further upstream on several occasions. No anglers were observed using the McLane impoundment. People were also wading in the river near the Gregg Crossing Footbridge under summer low flows. No on-water recreation (kayak, canoes, non-motorized boats) were observed during our site visits. Based on our experience water depths in the Goldman Dam impoundment are too shallow to support on-water recreation. In the reach between the Goldman and McLane Dams, where water depths would support on-water recreation, access is difficult due to steep banks and private land ownership. In addition, this reach is short, is located in a high-density area, and may not be of interest to the public for boating.

15.1.6 Aesthetic Resources

An aesthetic assessment was not conducted as part of this study. However, the dams and impoundments are readily visible to the public. Starting upstream, views of the Souhegan River are readily available from Emerson Park. In addition, the Milford Mill Apartments overlook the Goldman Dam as well as the impounded river above and below the Goldman Dam. J's Tavern, a restaurant, has outside seating

overlooking the Goldman Dam. The Granite Square Apartments overlook the McLane Dam, which also includes a gazebo and patio.

With the stoplogs permanently removed from both dams during the low flow period in the summer (July-September), water passes over the dams only 25% and 5% of the time at the Goldman Dam and McLane Dams, respectively. Only when flows exceed the hydraulic capacity of the stoplog openings does water pass over the spillway. These two conditions – water passing through the stoplog openings or over the spillway- have different aesthetic appeal from a visual and auditory perspective.

15.1.7 Opinion of Probable Construction Costs

McLane Dam

For the status quo alternative, the only known cost is the annual dam registration fee of $400. The town estimates the annual operation and maintenance cost as $1,200/year. Other cost, for which a dollar value is unknown, is listed below:

- Milford Department of Public Works (DPW) labor associated with maintaining the dam (see $1,200 estimate above).
- Milford administrative labor associated with communications with NHDES Dam Safety every few years.
- Costs associated with addressing LODs, which may require follow-up work, capital expenditures, and potentially having to seek professional engineering services.
- Due to the rebuild occurring 22 years ago, there is likely many more years of serviceable life of the dam before any major repairs or capital expenditures are needed. However as with any structure, it will eventually fail if not maintained. Although the dam is in good condition today, over several decades it will require capital investment to maintain a properly operating and safe working dam.
- If the low hazard classification of the dam were ever raised to a higher classification it could result in further evaluation of the dam and potentially increased capital costs. Hazard classifications are based on the potential loss of life and infrastructure impacts if the dam were to suddenly fail.
- It is possible that upstream fish passage facilities could be required at McLane Dam (as well as functioning downstream fish passage facilities). In addition to capital costs there would be increased operation and maintenance needs.

Typically there is no grant funding available to assist in the operation, maintenance or rebuild of dams.

Goldman Dam

Relative to the Goldman Dam, as confirmed by NHDES Dam Safety, the town has no financial obligation to maintain or operate the dam given that it is owned by another party. The town estimates expending approximately $1,000/year for operation and maintenance of the dam.

15.2 Full Dam Removal Alternative

At this juncture, the full dam removal alternative assumes the entire structure including the abutments, gates, and spillways would be removed from both dams[47]; however, this could be modified pending the

[47] The former sluice gate on river right adjacent to the Goldman Dam would remain in place.

Section 106 process and MOA. Since the dams were found eligible for the NRHP by the NOAA, the lead federal agency, an MOA is required. Through the Section 106 consultation process, the MOA could recommend that portions of the dam or gates may remain in place for historical purposes, which has occurred on other NH dam removals. For conceptual level purposes it was assumed that the only structure remaining in place are the non-functioning sluice gates on river-right at the Goldman Dam.

For now, this alternative assumes that the natural transport of impounded sediments downstream following both dam removal; however, as noted earlier input is needed from state and federal agencies as to whether this sediment management alternative would be permitted.

McLane Dam

It was assumed that McLane Dam would be removed first, followed by Goldman Dam with the goal of lowering the water level immediately below Goldman Dam prior to its removal.

Shown in Figure 15.2-1 is a conceptual plan for removing the McLane Dam and shown in Figure 15.2-2 are the removal limits. The conceptual level plan calls for the following general steps relative to removing the dam (it was assumed that removal would occur during the summer low flow period):

- As already is the case, fully remove the stoplogs to dewater the impoundment as much as possible.
- Mobilization. Install construction entrance, if required, where the dirt road leading from the dam enters the unnamed paved road perpendicular to Souhegan Street (see inset below for access location).
- Access would be provided via the dirt road[48] from Souhegan Street. Modify the dirt road, if needed, leading up to the dam to support dump trucks and an excavator.
- Install appropriate soil and erosion control measures in all work areas prior to any work activities.
- Clear and grub the area below the dam to create a staging and work area.
- Install an oil boom below the dam.
- Install vibration monitoring equipment near Granite Square Apartments and other locations, as required.
- Install a trap rock road leading from river-left along the base of the dam to river-right.
- Create a large enough breach on river-right so as to pass all inflow through the breach. Breach should be deep enough to dewater the impoundment further.
- Install the stoplogs so all water now passes through the breach.
- Working from river-right to river-left remove the abutment and spillway.
- Allow the natural transport of sediment to occur.
- Stockpile demolition debris in the staging area for later hauling. The façade of the dam consists of concrete and rebar, while the inter-core is composed of large stone blocks. The large stones may of use to the town for other purposes.
- Establish traffic control at the Souhegan Street intersection, if deemed necessary, during hauling times.
- Remove the trap rock simultaneous to removing the spillway when moving from river-right to river-left.
- Store the dam debris on river-left in the work area.
- Haul debris using dump trucks during appropriate hours and dispose at an approved landfill.
- Continue demolition of the spillway and continue to haul.

[48] It is our understanding that the lands leading from paved unnamed road perpendicular to the Souhegan Street up to the McLane Dam area owned by the town and thus no easements would be necessary (town to confirm).

- Remove the river-left stoplog structure and abutment.
- If needed (pending further feasibility) install armoring along the river-left bank immediately above and below the dam to protect from shoreline erosion.
- Remove all debris from the work area. Reseed any work areas. Remove oil boom.
- Demobilization.

One potential concern is the river-right bank just upstream and downstream of the dam. This bank is steep and currently consists of low-lying vegetation. During a July 2012 walkover of the area, when the water level above McLane Dam was quite low, the bedrock upstream of the dam was exposed. Based on the formation of the bedrock it appears that flow could be directed to the right bank. Given this, it is recommended that further evaluation be conducted of the bank to determine if stabilization measures are needed along this bank. Stabilization could consist of installing toe protection and armoring the bank to prevent erosion. It is possible that the large block stones from the dam could be used for this purpose. The additional recommended work would include probing along the toe of the bank, conducting shear calculations, further inspection of the bank material and making a determination if any protection is warranted. For now, we have included erosion protection measures along the bank as part of the OPCC.

Goldman Dam

For the Goldman Dam, the most challenging aspect of removal is access. There is no easy access to the dam given the extremely steep river bank on river-left and the Milford Mill Apartments on river-right. In addition, properties bordering the area are privately owned. Given this, two access routes were considered. One route assumes access would be granted at the Masonic Temple and extend into Emerson Park. A temporary easement may be required to cross lands owned by the Masonic Temple; Emerson Park lands are owned by the town. The second route assumes access would be granted by the Milford Mill Apartment complex via its parking lot. Again, a temporary easement may be required and it is fully understood that access via this route would have a temporary impact on parking availability. No discussions with the Masonic Temple or Milford Mill Apartments has been conducted thus it is unknown if access would be granted from either location. Shown in Figure 15.2-3 and 15.2-4 are conceptual plans

for removing the Goldman Dam via Emerson Park and the Milford Mill Apartment parking lot, respectively. The dam removal limits are shown in Figure 15.2-2. The construction sequencing varies pending the access routes as described below:

Access via Emerson Park

- As already is the case, fully remove the stoplogs to dewater the impoundment as much as possible.
- Mobilization. Install construction entrance, if required, where the dirt road leading from the Masonic Temple driveway enters Mont Vernon Street (Route 13).
- Place signage that Emerson Park is temporarily closed.
- Access would be provided via from the Masonic Temple parking area through Emerson Park as shown in the inset below.
- Clear and grub the access road as needed to support dump trucks and an excavator.
- Install appropriate soil and erosion control measures in all work areas prior to any work activities.
- Establish a staging/work area within Emerson Park.
- Install vibration monitoring equipment near Milford Mill Apartments, the building on river left upstream of the dam, and at Route 13 Bridge abutments and pier.
- Install an oil boom below the dam.
- Install trap rock road in the Souhegan River leading from Emerson Park, through the river-left Route 13 bridge bay and extend to river-right.
- Create a large enough breach on river-right so as to pass all inflow through the breach. Breach should be deep enough to dewater the impoundment further.
- Install the stoplogs so all water now passes through the breach.
- Create a clean vertical cut where the dam attaches to the Milford Mill building.
- Working from river-right to river-left remove the abutment and spillway.
- Allow the natural transport of sediment to occur.
- Stockpile demolition debris in the staging area for later hauling.
- Establish traffic control at the Mont Vernon Street intersection, if deemed necessary during hauling hours.
- Remove the trap rock simultaneous to removing the spillway when moving from river-right to river-left.
- Store the dam debris in the work area in Emerson Park.
- Haul debris during appropriate hours and dispose at an approved landfill.
- Continue demolition of the spillway and continue to haul.
- Remove the river-left stoplog structure and abutment.
- Remove all debris from the work area. Reseed any work areas and restore Emerson Park to its original condition. Remove oil boom.
- Demobilization.

Access via Milford Mill Apartment Complex

- As already is the case, fully remove the stoplogs to dewater the impoundment as much as possible.
- Mobilization. Install construction entrance, if required, in the transition between the unpaved and paved Milford Mill Apartment parking lot.
- Install appropriate soil and erosion control measures in all work areas prior to any work activities.
- Clear and grub the area from the unpaved section to the river as needed to support dump trucks and an excavator.
- Because of the steep topography, a ramp would be constructed from the unpaved area to the river.

- Establish a staging/work area.
- Install vibration monitoring equipment near Milford Mill Apartments, the building on river-left upstream of the dam, and at Route 13 Bridge abutments and pier.
- Install an oil boom below the dam.
- Install trap rock road leading from the bottom of ramp leading into the river, along the face of the Milford Mill Apartments, and then along the downstream face of the dam.
- Create a large enough breach on river-left so as to pass all inflow through the breach. Breach should be deep enough to dewater the impoundment further.
- Working from river-left to river-right, remove the dam and access road simultaneously.
- Continue removing the dam and access road and create a clean vertical cut where the dam attaches to the Milford Mill building.
- Allow the natural transport of sediment to occur.
- Establish traffic control at the Bridge Street intersection, if deemed necessary during hauling hours.
- Haul debris during appropriate hours and dispose at an approved landfill.
- Remove all debris from the work area. Reseed any work areas and restore Milford Mill Parking Lot to its original condition. Remove oil boom.
- Demobilization.

Note that the preferred route is via the Milford Mill Apartment parking lot as access from upstream would result in constructing a temporary road through one of the bridge bay openings which would reduce the hydraulic capacity of the bridge if a high flow event were to occur during the removal process. In addition, after placing the temporary road through the bay it may result in limited headspace for trucks to drive under the bay.

15.2.1 Dam Condition, Maintenance and Liability

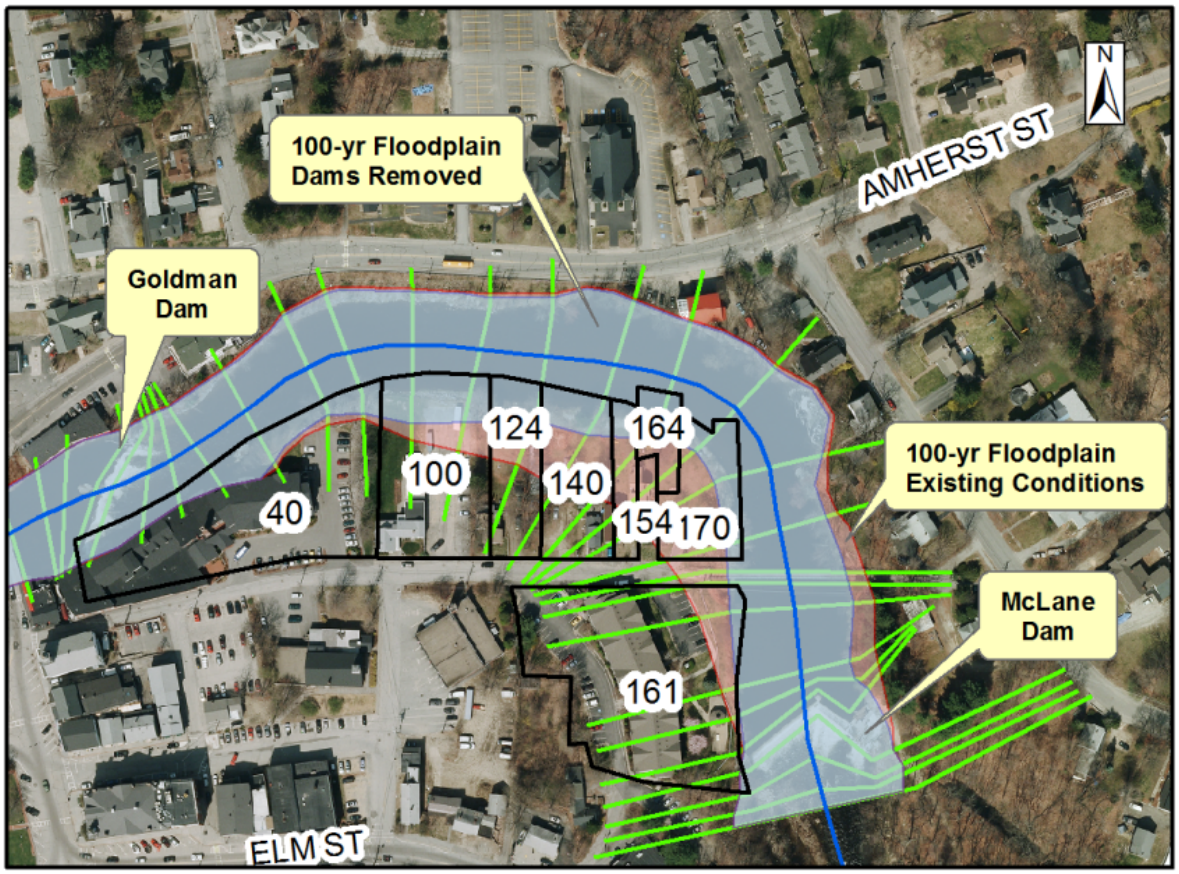
If the McLane Dam is removed there are no longer any operation and maintenance costs or liability. In the case of the Goldman Dam, the town currently has no legal requirement or obligation to maintain or operate the dam.

15.2.2 Infrastructure

Flooding

One reason for conducting the feasibility study was to determine if the removing the dams would lessen upstream flooding as was experienced during the April 2007 and March 2010 floods. A hydraulic model was developed to determine if removing the dams would directly reduce the 100-year floodplain. In reviewing the findings, removing the Goldman Dam showed only minor reductions in the 100-yr floodplain. In the impounded reach between the Gregg Crossing Footbridge and the confluence with Great Brook, removing the dam lowered the 100-year floodplain between 0.3 and 0.7 feet. Between the confluence with Great Brook and Goldman Dam, the 100-year floodplain was lowered between 0.9 to 2.8 feet. In this reach, the floodplain was primarily reduced in the area of Emerson Park; however, this area does not contain critical infrastructure or roads. Note that whether the Goldman Dam is removed or not, flooding at the Boys and Girls Club will occur since it is located within the Souhegan River floodplain. In summary, removal of the Goldman Dam marginally lowers the 100-year floodplain and does not appear to provide much flood benefit relative to infrastructure impacts.

Alternatively, removing McLane Dam results in flood benefits, particularly on those lands located on river-right—on the inside bend of the river (see inset). Under the 100-year flood, the WSE is lowered approximately 3 feet and would reduce flooding of infrastructure, specifically houses along Bridge Street.



Sewer/Water Lines

Based on the analysis conducted it does not appear the removing the dam would impact most of the sewer and water lines with the exception of potentially Sewer Line No. 2 and Water Line No. 1

Based on hydraulic modeling, sediment transport modeling, and sediment probing, our preliminary finding is that Sewer Line No. 2 does not appear subject to scour; however, additional follow-up work is recommended since not much sediment is present between the top of the sewer line and the channel bed. Because it is unclear if the drawings are as-built or design drawings, further investigation is recommended to confirm that the line is encased in concrete, the channel is lined with riprap, and the profile is correct. Additional probing immediately upstream and downstream of the sewer line is needed as well as a grain size analysis. The substrate size would be used in the hydraulic model to determine if the velocities without the McLane Dam could result in mobilizing the substrate. With the dam removed, velocity increases and confirmation is needed that removal will not jeopardize the sewer line.

Note that sewer line invert on river-right was surveyed, but the river-left invert was not since the DPW had concerns with lifting some manhole covers. It is recommended that the river left invert be surveyed to confirm the sewer line slope since the invert on river-left is higher (closer to the channel bed)—the sewer line slopes downward from river-left to river-right.

Note that for cost estimating purposes relative to the dam removal alternative, we have included additional follow-up study costs, but have not included costs associated with protecting the sewer line if found to be in jeopardy.

Water Line No. 1, located behind the Masonic Temple, should be buried regardless of whether the Goldman Dam remains or is removed.

Route 13 Bridge

Removal of the dams will result in higher velocities along the bridge abutments and piers, but these structural supports appear to be founded on bedrock. As such, removal of the dams is not expected to cause additional scour.

Water Supply/Fire/Traffic

The town is serviced by public water supply and thus removal of the dams would have no impact on drinking water. In addition, as noted above, the impoundments are not used as a source of water to fight fires or fill pumper trucks.

There would be a temporary impact to traffic when debris from the demolition process is hauled off-site to an approved landfill. This is likely not an issue for hauling debris from the McLane Dam since the first public road intersected would be Souhegan Road, which is not as congested. However, hauling debris from Goldman Dam, regardless of the access route, could create traffic issues as these roads are in the heart of downtown. If the debris from Goldman Dam was hauled to the east, this area is particularly congested due to three roads (Grove, Amherst and Mont Vernon) converging over a short distance. Restrictions can be placed such that hauling times occur during off-traffic hours and may require police or traffic control presence.

One issue that would require resolution if access was via the Milford Mill Apartment parking lot is temporary loss of parking spots due to access and hauling.

15.2.3 Environmental Resources (Water Quality, Fisheries, Wetlands)

Water Quality

If the dams were removed it is expected that water temperatures and DO concentrations would improve. Removal of the Goldman Dam would likely improve DO levels to a point where it could likely be removed from the 303(d) listing for impairments relative to DO saturation and DO concentration. Instead of an impounded reach susceptible to thermal loading and reduced DO, the free-flowing river would tumble over the channel bed resulting in increased aeration and hence DO concentration.

If sediment is allowed to be naturally transported downstream upon dam removal, there would be a short term impact relative to increased turbidity.

Fisheries

Removal of the dams would eliminate a physical barrier to fish and aquatic biota. In addition, accumulated sediments would eventually erode and could uncover potential fish spawning habitat. Removing the dams would create approximately six miles of riverine habitat as measured from McLane Dam to the next upstream barrier, Pine Valley Hydroelectric Project Dam located in Wilton, NH. In addition, removing both dams would allow fish and other aquatic organisms' unimpeded movement in the Souhegan River and its tributaries located between the McLane Dam and the Pine Valley Dam.

If the dams were removed and if the natural transport of sediment was permitted, there would be a short term impact on fish habitat below the McLane Dam. The river gradient below McLane Dam to the first major bend in the river is steep and scattered with boulders, cobble and gravel. The bulk of impounded sediment is located above McLane Dam and, if removed, some mobile sediment will transport downstream. There will be a short term impact of having sand and silt deposit in this river stretch that currently consists of relatively good fish habitat. Over time it is expected that the sand and silt will erode and move further downstream where the river is more sinuous and the river gradient flattens. In these areas, the channel bottom consists of sand and silt, similar to the material being transported.

There are only small pockets of sediment above the Goldman Dam and again, with the removal, some of these pockets may mobilize and move downstream but it is not expected to impact fish habitat.

Wetlands and Rare, Threatened and Endangered Species

As noted above, under existing conditions, there are minimal wetlands located in the project area. Thus, it is not expected that removal of the dams will have a major impact on wetlands.

Since no RTE species are known to occur, dam removal will have no impact. Note that the letters received from NHNHB, NHFGD and USFWS are sufficient for a year. If the dam removal alternative were advanced, consultation with these same agencies would be required to confirm no RTE species area present in the impact areas.

15.2.4 Cultural and Historic Resources

<u>Structures</u>

NHDHR has recommended that both dams be eligible for the NRHP as a contributing element to the Downtown Milford Commercial, Civic and Residential Historic District due to their function of holding water (impoundment). The lead federal agency, NOAA, has determined that the two dams are not

individually significant as historic structures. However, NOAA has stated that the impoundments created by the dams contribute to the significance of the surrounding Downtown Milford Commercial, Civic, and Residential Historic District, which has been determined eligible for listing in the NRHP. At this juncture, if the dams were removed, it is unclear what mitigation may be required.

Archaeological

Per PALs report, and supported by the NHDHR, if dam removal were pursued a Phase IB archaeological investigation would be required. The Phase IB work would entail conducting subsurface test pits to identify any artifacts and whether dam removal could impact archaeological resources. Pending the findings of the Phase IB investigation it could result in a Phase II study. Phase II archaeological investigations are conducted in order to test or evaluate an archaeological site's eligibility for inclusion in the NRHP.

15.2.5 Recreation Resources

As noted above, during field visits there was little on-the-water recreation observed and thus it is expected that removal of the dams would not have a major impact on recreation. The Goldman Dam impoundment is already relatively shallow making on-water recreation difficult. In addition, on-water recreation was never observed on the McLane Impoundment. If the dams are removed, the impounded reaches would revert to free-flowing conditions that may result in increased habitat use by fish and thus would likely provide more angling opportunities. In addition, under higher flows, it would allow for paddling opportunities through the reach.

15.2.6 Aesthetic Resources

The aesthetic resource impact of removing the dams is subjective and open to individual interpretation. Some may view water passing over the spillways and the creation of an impoundment as aesthetically pleasing from a visual and auditory standpoint. In contrast, others may view a free-flowing river and natural cascade or falls with no dam/impoundment as aesthetically pleasing. The parties directly impacted—whether positively or negatively-- would be primarily the two senior housing apartments and residents located along the river banks between the Goldman and McLane Dams. If the dams were removed, the river width and depth will be reduced and the former impounded reaches would appear like a natural river. Removal of the Goldman Dam would also slightly reduce the river width and depth between the Goldman Dam to just upstream of the confluence with Great Brook. Those in Emerson Park area would observe a reduction in river width.

In addition, the access route for removing the Goldman Dam include via Emerson Park or via the Milford Mill Apartment parking lot. In either case, there would be a short term aesthetic impact to the aesthetics in these areas. In the case of the Milford Mill Apartments, there would be an impact on parking spaces that would need to be resolved.

The dam removal typically involves an excavator equipped with a hoe-ram that transmits short pulses to demolish the dam, which results in a banging sound. Because both dams are located in downtown Milford, there would be a short-term auditory impact during the removal process. The duration of time to remove the dams is unknown at this juncture, but it is envisioned to be less than one month per dam. In addition it is likely the work would be conducted during the low flow summer season when windows may be open. Note that stipulations can be placed on the time of day when work is permitted so as to not disturb people. As a side note, it is recommended that vibration monitoring be implemented at key locations (Route 13 Bridge, Milford Mill Apartment foundation, Granite Square Apartment foundation) before and during the removal process to ensure the removal is not impacting nearby infrastructure.

15.2.7 Opinion of Probable Construction Costs

The OPCC for removing McLane Dam is shown in Table 15.2.7-1. The OPCC for removing Goldman Dam via Emerson Park and via the Milford Mill Parking Lot is shown in Table 15.2.7-2 and 15.2.7-3, respectively. The cost estimates include not only removal costs but engineering design, development of permit applications, pre-bid meeting, and administration.

Summary OPCC estimates:

McLane Dam		$493,000
Goldman Dam	(via Milford Mill access)	$285,000
	(via Emerson Park access)	$332,000
Total Range (both dams)		$778,000-$825,000

The items listed below will be required, but are not included in the OPCC:

- Completion of the Section 106 Process including:
  - Phase 1B archaeological survey (it was assumed no Phase II survey would be required) ($17,000).
  - Development of a Section 106 MOA with the lead federal agency, Town of Milford, and SHPO and other consulting parties to determine mitigation ($5,000).
  - Mitigation costs (TBD). Based on other dam removals in NH, the following are some examples of mitigation measures:
    - Completion of a Historic American Building Survey (HABS) and Historic American Engineering Record (HAER) by qualified professionals.
    - Interpretative Signage
    - Plaque memorializing the dams
- Further feasibility-related tasks including:
  - Assessment of Sewer Line 2 ($8,000).
  - Assessment of need of any riverbank stabilization measures on river-right bank immediately above and below McLane Dam ($8,000).
- Follow-Up Work including:
  - A Letter of Map Revision would be required by the FEMA since the 100-year floodplain would change, which could influence flood insurance rates (TBD).
  - Potentially post dam removal monitoring work (TBD).

Although OPCCs are based on conceptual engineering, they are considered a reliable way of assessing the cost of full dam removal; the actual cost can be expected to change as additional engineering is completed, input is received from the state and federal agencies, and other factors change in the future. A 25% contingency was added to the total costs.

Unlike dam rebuilds, competitive grants are available to help defray the costs associated with dam removals. The same funding sources used to complete this feasibility study, as well as other funding sources, could be pursued if the dam owners elect the removal alternative.

Table 15.2.7-1 Opinion of Probable Construction Cost to Remove McLane Dam

Estimate for: **McLane Dam - Dam Removal**

Item	Description	Quantity	Unit	Unit Price	Cost
Contractor Gen. Requirements[1] (mob/demob, on-site facilities, etc.)		10%	EA	$249,864.45	$24,986
Dam Removal	Water Control	14	DAY	$1,100.00	$15,211
Dam Removal	Vibration Monitoring Equipment	3	WK	$5,100.00	$15,300
Dam Removal	Demolish Gate Structure (2 laborers, 1 excavator, 1 operator, and 1 dump truck, and 1 driver)	2	DAY	$3,730.00	$7,460
Dam Removal	Dam Concrete Demolition	886	CY	$180.00	$159,480
Dam Removal	Hauling (8 CY Dump Truck and Driver)	852	CY	$12.00	$10,224
Dam Removal	Install and Remove Temporary 24" CMP Culverts	2	EA	$1,000	$2,000
Dam Removal	Riprap Armor (Class B Stone)	211	CY	$65.50	$13,821
Dam Removal	Gravel Bedding for Riprap	116	CY	$40.00	$4,640
Dam Removal	Geotextile for Riprap	345	SY	$2.60	$897
Access Road	Erosion Control	1	LS	$5,000.00	$5,000
Access Road	Clearing and Grubbing	0.1	ACRE	$19,550	$1,955
Access Road	Geotextile for Stabilized Construction Entrance	103	SY	$2.60	$268
Access Road	Stabilized Construction Entrance 1-1/4" Crushed Stone	17	CY	$50.00	$850
Access Road	Remove Construction Entrance 1-1/4" Crushed Stone	17	CY	$10.00	$170
Access Road	Remove Geotextile for Stabilized Construction Entrance	103	SY	$1.00	$103
Access Road	Geotextile for Temporary Access Road	345	SY	$2.60	$897
Access Road	Trap Rock (Class C Stone) for Temporary Access Road	170	CY	$40.00	$6,800
Access Road	Remove Trap Rock (Class C Stone) for Temporary Access Road	170	CY	$10.00	$1,700
Access Road	Hauling (8 CY Dump Truck and Driver)	187	CY	$12.00	$2,244
Access Road	Remove Geotextile	345	SY	$1.00	$345
Access Road	Seed cleared and grubbed area	1	LS	$500.00	$500
				Subtotal Direct Cost	**$274,851**
				Contingency Allowance (25%)[2]	$68,713
				Total Direct Cost[3]	**$344,000**
				Engineering, Administration, Permitting and Construction Management[4]	$130,000
				Total OPCC $2013	$474,000
				Total OPCC $2014	**$493,000**

Notes:

1. Contractor General Requirements taken as 10% of the remaining itemized costs totaled.
2. Contingency Allowance taken as 25%.
3. Rounded to the nearest $1,000.
4. Engineering & Administration =$70,000

Permits = $35,000

Bidding Phase = $5,000

Construction Management = $20,000

Table 15.2.7-2 Opinion of Probable Construction Cost to Remove Goldman Dam (Access Route via Emerson Park)

Estimate for: **Goldman Dam - Dam Removal-Upstream Access via Emerson Park**

Item	Description	Quantity	Unit	Unit Price	Cost
Contractor Gen. Requirements[1] (mob/demob, on-site facilities, etc.)		10%	EA	$137,201.40	$13,720
Dam Removal	Water Control	10	DAY	$1,100	$11,000
Dam Removal	Vibration Monitoring Equipment	3	WK	$5,100.00	$15,300
Dam Removal	Install and Remove Temporary 24" CMP Culverts	2	EA	$1,380	$2,760
Dam Removal	Dam Concrete Demolition	111	CY	$180.00	$19,980
Dam Removal	Hauling (8 CY Dump Truck and Driver)	111	CY	$12.00	$1,332
Access Road	Erosion Control	1	LS	$5,000	$5,000
Access Road	Clearing and Grubbing	0.1	ACRE	$19,550	$1,955
Access Road	Geotextile for Stabilized Construction Entrance	91	SY	$2.60	$237
Access Road	Stabilized Construction Entrance 1-1/4" Crushed Stone	15	CY	$50.00	$750
Access Road	Remove Construction Entrance 1-1/4" Crushed Stone	15	CY	$10.00	$150
Access Road	Remove Geotextile for Stabilized Construction Entrance	91	SY	$1.00	$91
Access Road	Repair Paved Walkway	1	LS	$1,000.00	$1,000
Access Road	Geotextile for Temporary Access Road	653	SY	$2.60	$1,698
Access Road	1-1/4" Crushed Stone for Temporary Access Road	110	CY	$50.00	$5,500
Access Road	Remove 1-1/4" Crushed Stone for Temporary Access Road	110	CY	$10.00	$1,100
Access Road	Geotextile for Temporary Cofferdam	735	SY	$2.60	$1,911
Access Road	Trap Rock (Class C Stone) for Temporary Access Road	1025	CY	$40.00	$41,000
Access Road	Remove Trap Rock (Class C Stone) for Temporary Access Road	1025	CY	$10.00	$10,250
Access Road	Hauling (8 CY Dump Truck and Driver)	1150	CY	$12.00	$13,800
Access Road	Remove Geotextile	1388	SY	$1.00	$1,388
Access Road	Seeding	1	LS	$1,000.00	$1,000
			Subtotal Direct Cost		**$150,922**
			Contingency Allowance (25%)[2]		$37,730
			Total Direct Cost[3]		**$189,000**
			Engineering, Administration, Permitting and Construction Management[4]		$130,000
			Total OPCC $2013		$319,000
			Total OPCC $2014		**$332,000**

Notes:

1. Contractor General Requirements taken as 10% of the remaining itemized costs totaled.
2. Contingency Allowance taken as 25%.
3. Rounded to the nearest $1,000.
4. Engineering & Administration =$70,000

Permits = $35,000

Bidding Phase = $5,000

Construction Management = $20,000

Table 15.2.7-3 Opinion of Probable Construction Cost to Remove Goldman Dam (Access Route via Milford Mill Apartment Parking Lot)

Estimate for: **Goldman Dam - Dam Removal - Downstream Access via Milford Mill Apartments**

Item	Description	Quantity	Unit	Unit Price	Cost
Contractor Gen. Requirements[1] (mob/demob, on-site facilities, etc.)		10%	EA	$104,720.20	$10,472
Dam Removal	Water Control	10	DAY	$1,100	$11,000
Dam Removal	Vibration Monitoring Equipment	2	WK	$5,100.00	$10,200
Dam Removal	Dam Concrete Demolition	111	CY	$180.00	$19,980
Dam Removal	Hauling (8 CY Dump Truck and Driver)	111	CY	$12.00	$1,332
Dam Removal	Super Sacks	1	LS	$8,800.00	$8,800
Access Road	Erosion Control	1	LS	$5,000	$5,000
Access Road	Clearing and Grubbing	0.10	ACRE	$19,550	$1,955
Access Road	Remove Damaged Parking Lot	105	CY	$10.00	$1,050
Access Road	Hauling (8 CY Dump Truck and Driver)	105	CY	$12.00	$1,260
Access Road	Repair Paved Parking Lot	2,230	SF	$5.00	$11,150
Access Road	Geotextile for Temporary Access Road	925	SY	$2.60	$2,405
Access Road	Trap Rock (Class C Stone) for Temporary Access Road	348	CY	$40.00	$13,920
Access Road	Remove 1-1/4" Crushed Stone for Temporary Access Road	348	CY	$10.00	$3,480
Access Road	Hauling (8 CY Dump Truck and Driver)	348	CY	$12.00	$4,176
Access Road	Excavation for Access	60	CY	$10.00	$600
Access Road	Hauling (8 CY Dump Truck and Driver)	60	CY	$12.00	$720
Access Road	1-1/4" Crushed Stone for Temporary Access Road	68	CY	$50.00	$3,400
Access Road	Remove 1-1/4" Crushed Stone for Temporary Access Road	68	CY	$10.00	$680
Access Road	Hauling (8 CY Dump Truck and Driver)	68	CY	$12.00	$816
Access Road	Remove Access Road Geotextile	925	SY	$1.00	$925
Access Road	Access Ramp Geotextile	242	SY	$2.60	$629
Access Road	Remove Access Ramp Geotextile	242	SY	$1.00	$242
Access Road	Seeding	1	LS	$1,000.00	$1,000
			Subtotal Direct Cost		**$115,192**
			Contingency Allowance (25%)[2]		$28,798
			Total Direct Cost[3]		**$144,000**
			Engineering, Administration, Permitting and Construction Management[4]		$130,000
			Total OPCC $2013		$274,000
			Total OPCC $2014		**$285,000**

Notes:

1. Contractor General Requirements taken as 10% of the remaining itemized costs totaled.
2. Contingency Allowance taken as 25%.
3. Rounded to the nearest $1,000.
4. Engineering & Administration =$70,000

Permits = $35,000

Bidding Phase = $5,000

Construction Management = $20,000

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