Suffolk County Peconic Estuary Program
Conceptual Habitat Restoration Designs

Diadromous Fish Passage Restoration at Forge Dam Road (Riverhead), Ligonee Brook (Sag Harbor), and Moore's Drain (Greenport)

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1 Executive Summary

Three areas were evaluated for use and passage by migrating alewife and eels on eastern Long Island; Moore's Drain, Ligonee Brook, and the Forge Road Dam on the Peconic River (Figure 1). Moore's Drain is an artificial channel dug in the late 1800s and was found to lack flow and channel conditions suitable for use by migrating alewife. Ligonee Brook has historic and recent accounts of both eel and alewife use and was found to be sufficient for migration of both species when water was flowing. An investigation of groundwater records indicate that Ligonee Brook may flow on average in 4 out of every 10 years, allowing access to Long Pond, a spawning and rearing area for alewife. No significant barriers to alewife were noted, but many of the existing crossings included challenging conditions that could be improved. The Forge Road Dam is located on the Peconic River which fosters a substantial run of alewife and American eel. The 11 foot dam is a barrier to fish and three alternatives for providing fish and aquatic species passage were investigated including a fish ladder, a rock ramp fishway at the existing spillway, and a bypass channel around the spillway. Considering costs and effectiveness at passing the largest number and diversity of fish, the rock ramp fishway seems the best approach, with a fish ladder, targeting only alewife, a close second. The results of this conceptual feasibility and design study can be used to prioritize improvement efforts for fish passage on eastern Long Island. Feasibility level costs and other considerations, such as design constraints and regulatory permitting requirements, are included to inform the final design of construction plans and specifications for recommended structural remedies.

Figure 1: The study locations in Long Island's Peconic Estuary.

2 Background

2.1 River Herring

Alewife (*Alosa pseudoharengus)* and blueback herring (*Alosa aestivalis)* are part of the Clupeidae family. Alewives and blueback herring are morphologically similar species, roughly 250 mm (9.8 in.) in total length as adults, and are commercially referred to collectively as 'river herring'. Both species are present along the North American Eastern seaboard. Alewives have a geographic distribution from Newfoundland to South Carolina, whereas blueback herring have a wider and more southern geographical range, from Nova Scotia to the St. Johns River, FL (Bozeman, 1989). River herring are anadromous, spawning in freshwater and living predominantly in estuarine or Atlantic coastal waters. River herring spawn once a year, migrating in the springtime into freshwater streams and ponds. River herring play an important trophic role, linking zooplankton and piscivores in marine, estuarine, and freshwater environments (Bozeman, 1989).

2.1.1 Spawning Habitat and Migration Patterns

Though alewives and blueback herring share many similarities, it is important to note some distinct differences in their spawning and migration patterns. Several studies have found that alewives travel farther upstream than blueback herring to spawn. In addition, when alewives and blueback herring share spawning grounds, blueback herring will tend to occupy the lotic or flowing water environment while alewives tend to occupy the lentic or still and terrestrial waters (Loesch and Lund, 1977 and O'Connell, 1977).

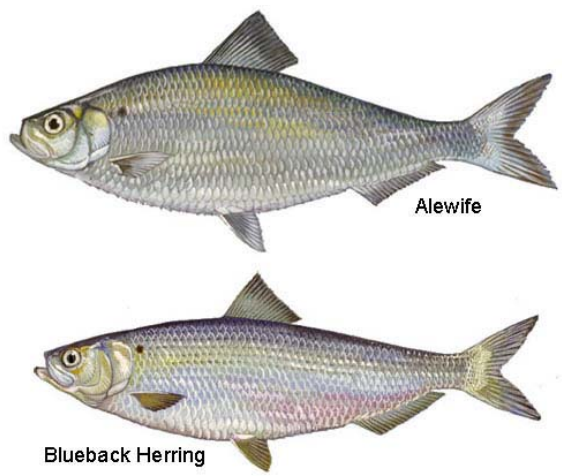


Figure 2: Image of Alewife and Blueback Herring (illustrations by Diane Rome

Alewives tend to travel further in the migratory search for spawning grounds (Jones et al. 1978) and exhibit a wider latitude of spawning habitats including large rivers, small streams and ponds with a variety of substrate conditions including gravel, sand, detritus and submerged vegetation with slow-moving water. The depth of water in the nursery can vary from 6 inches to almost 10 feet (Edsall 1964; Masnueti and Hardy, 1967 cited in USFWS, 1983). Alewives spawn 2-3 weeks earlier than blueback herring which is highly influenced by temperature (Jones et al. 1978; Fay et al. 1983; Scott and Scott, 1988 as cited in Iafrate, 2006). Research has found that blueback herring prefer spawning grounds in fast-flowing water over hard substrates, which may be due to the negative affect of sedimentation on fertilized eggs (Klauda and Palmer, 1987). Though preferring flowing water, blueback herring will also spawn in slower-flowing tributaries and flooded low-lying areas adjacent to main streams with soft substrates and detritus (Street et. Al. 1975; Sholar, 1975 & 1977; Fischer 1980; Hawkins 1980a). Blueback herring hatch in June and July. Fertilized river herring eggs are highly tolerant of suspended sediments, varying flow rates and salinity (Auld and Schubel 1978). Pardue (1983) concluded that substrata with 75% silt or other soft materials containing detritus and vegetation and combined with sluggish water flows were optimal to provide cover for spawning river herring and their eggs and larvae.

Alewife and blueback herring juveniles spend 3-7 months growing in their freshwater nurseries before emigrating downstream to coastal waters. However, the temporal pattern of emigration is quite different, as observed in a 2006 study by Iafrate and Oliveira of factors affecting the migration patterns of juvenile river herring in MA. They observed a distinct bimodal migration pattern of early and late migrating waves of alewives (unique hatch dates) and a single migration of blueback herring. The timing of the three migrations were staggered temporally, with the early alewives emigrating in July and August, followed by the blueback herring in September through October and the last wave of late migrating alewives in November and December before the winter freeze. Abiotic environmental factors affecting juvenile migration include water temperature, water levels, water visibility, changes in rainfall and lunar phase. For example, the migration of blueback herring is highly correlated to a significant drop in water temperature and the new moon (Iafrate, 2006). Water temperature peaks in the late summer are correlated with early alewife emigration, while dropping water temperatures correlate with late migratory peaks. Biotic factors, namely competition for food resources and food availability in the nurseries, may also play a role in the migration patterns of the species and deserves further study. Temporal separation of spawning and hatching between the two species may minimize competition.

Studies have also concluded that headwater spawning grounds may be ideal for river herring, however fish may not be able to reach them, either due to altered hydrology of the stream or barriers such as dams and culverts (O'Connell, 1997). Obstacles may result in the selection of less than desirable spawning conditions. Upstream habitats and headwaters may provide more cover from aerial predators, such as osprey (Colby, 1973), while open waters leave the herring and their larvae susceptible to aquatic predators such as striped bass and white perch (Scott and Scott, 1988). Additionally, lotic conditions of headwater streams prevents sedimentation over eggs, provides a source of dissolved oxygen and riparian habitat stabilizes stream temperature as well as provides needed cover (Uzee 1993). Providing access to headwater streams by removing dams, creating passable road crossings and preserving the ecological integrity of first and second order streams will increase the availability of suitable spawning environments for river herring.

2.1.2 Swimming Abilities and Barrier Passage

The ability of river herring to traverse physical and velocity barriers along their inland migration route determines the upstream boundary of their spawning potential. Velocity barriers, or reaches of high water flow, can be either natural or man-made. Although there is not a wealth of research on the swimming performance of river herring, a study by Haro et al. (2004) provides some useful data for understanding the species' limitations. The experiment tested the performance of alewife and blueback herring to successfully traverse four sustained velocity regimes, at varying lengths, in an open channel flume. The study focused on understanding sprinting performance, otherwise known as steady state burst swimming. The results of the study indicate that blueback herring are stronger swimmers than alewife, able to traverse longer distances in higher flow states (see Figure 3).

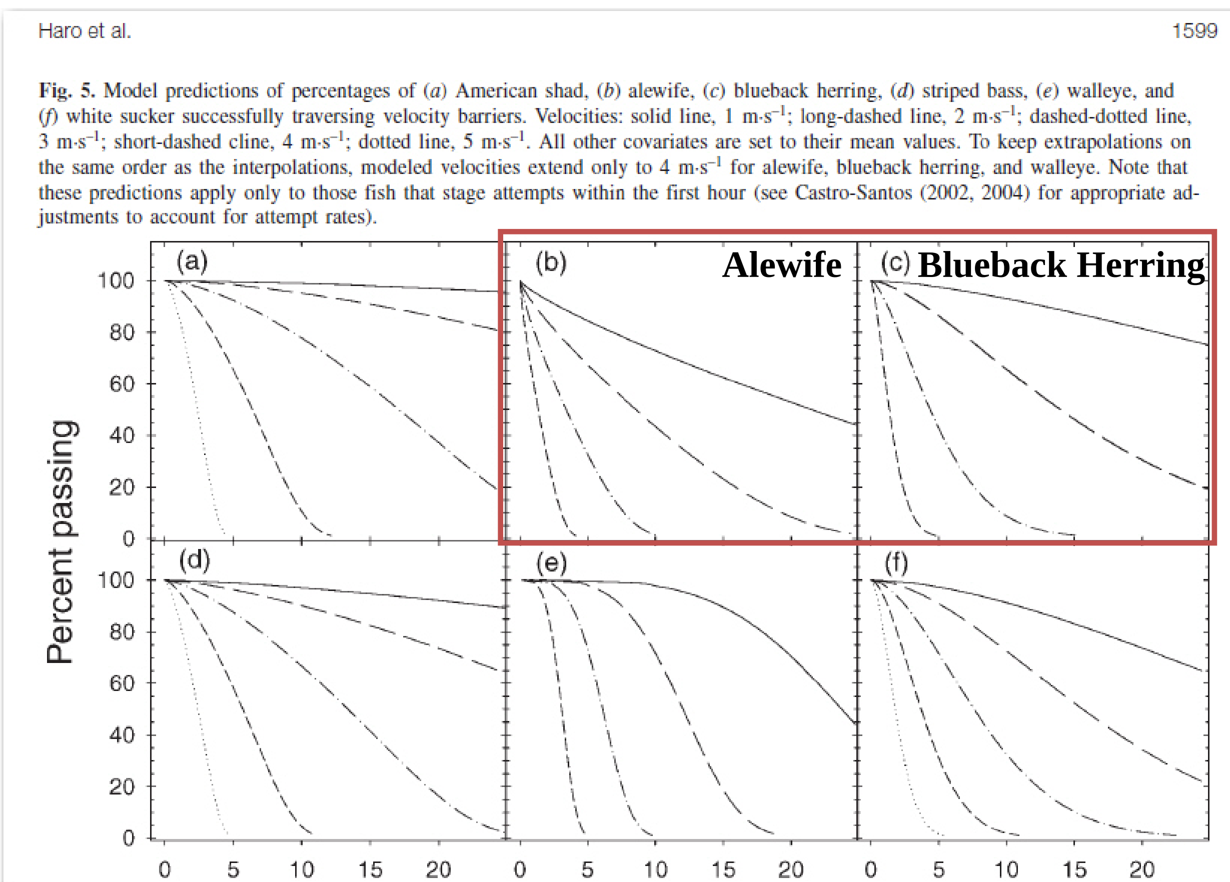


Fig. 5. Model predictions of percentages of (*a*) American shad, (*b*) alewife, (*c*) blueback herring, (*d*) striped bass, (*e*) walleye, and (*f*) white sucker successfully traversing velocity barriers. Velocities: solid line, 1 $m \cdot s^{-1}$; long-dashed line, 2 $m \cdot s^{-1}$; dashed-dotted line, 3 $m \cdot s^{-1}$; short-dashed cline, 4 $m \cdot s^{-1}$; dotted line, 5 $m \cdot s^{-1}$. All other covariates are set to their mean values. To keep extrapolations on the same order as the interpolations, modeled velocities extend only to 4 $m \cdot s^{-1}$ for alewife, blueback herring, and walleye. Note that these predictions apply only to those fish that stage attempts within the first hour (see Castro-Santos (2002, 2004) for appropriate adjustments to account for attempt rates).

Figure 3: From (Haro et al. 2004)

Interpretation of the graph in Figure 3 indicates the following quantitative information in Table 1:

Table 1: Table of interpreted quantities of model prediction graphs from Haro et al. 2004

Species	Distance	Flow Velocity	% Success (+/-)
Blueback Herring	15 m (49 ft.)	1 m/s (3.28 ft./s)	100%
Blueback Herring	15 m (49 ft.)	2 m/s (6.56 ft./s)	45%
Blueback Herring	5 m (16.4 ft.)	3 m/s (9.84 ft./s)	50%
Blueback Herring	1 m (3.2 ft.)	4 m/s (13.12 ft./s)	50%
Alewife	15 m (49 ft.)	1 m/s (3.28 ft./s)	65%
Alewife	15 m (49 ft.)	2 m/s (6.56 ft./s)	25%
Alewife	3.8 m (12.5 ft.)	3 m/s (9.84 ft./s)	50%
Alewife	1.2 m (4 ft.)	4 m/s (13.12 ft./s)	50%

In general, alosids are poor jumpers and minor barriers as small as 6 inches can present challenges and reduce migration success. However, their excellent swimming ability and burst speed allows relatively minor adjustments to be made to most velocity barriers to allow successful migration.

2.2 American eel

Unlike the alosids, the Americal eel is catadromous, predominantly living in freshwater and breeding in the ocean. The life cycle of an eel begins in the Sargasso Sea north of Cuba before drifting in its larval state on ocean currents to the Gulf of Mexico, up the eastern seaboard of the United States, or as far north as Greenland and Iceland. During the glass eel stage, when the translucent eel is no more than 1.8-2.8 inches long, it begins to swim toward the coast generally during the early summer, from April to July in the Gulf of Maine. It then metamorphoses into an elver, developing pigmentation and growing to 2.6-3.9 inches long. In their elver state, eel start the journey inland, through brackish, tidal channels and finally up freshwater channels to inland streams and ponds. The migration inland can take several years and hundreds of stream miles.

Eels continue to grow during the migration, and once they've exceeded six inches they are considered yellow eels. Yellow eels may live six to 30+ years growing to adulthood in fresh, inland waters. Once the eel has reached its final sexually mature life-cycle state known as a silver eel, it begins to prepare for the long migrational journey back to the Sargasso Sea, this time in a very different form. Silver eels have fat bodies, enlarged eyes, and thicker darker skin than yellow eels. The digestive tract degenerates during metamorphosis, evidence that the seaward migration is a one-way trip back. The average size of a female eel at maturity is 50 inches long. Fatality is more likely on the return journey to the ocean due to predation, harvesting, and injury or death in hydroelectric dams. Migration back to the sea occurs nocturnally in the fall, September to December. Eels spawn only once before they die.

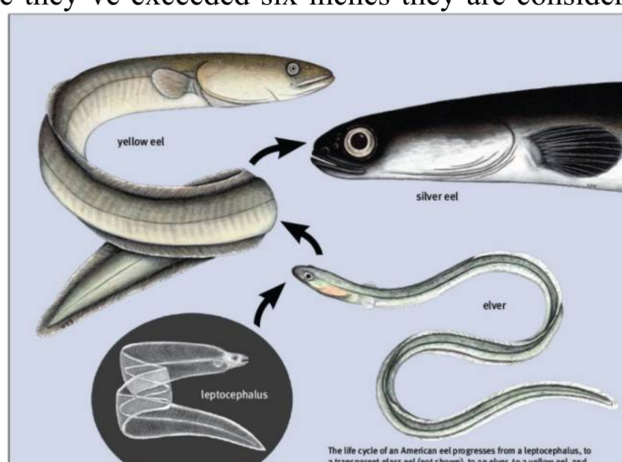


Figure 4: Diagram of American Eel Life Stages (source: Gulf of Maine, 2007)

2.2.1 Eel Passage Requirements:

Fish passage challenges for eel are quite different than for river herring due to the life cycle stage during migration. First, is the challenge to provide passage opportunities upstream for the small juveniles and secondly to ensure a safe passage for the large adult silver eels back to the sea.

Fish Passage Upstream

Barriers to eel passage upstream include vertical and velocity barriers caused by dams and culverts. Passage requirements for lower watershed barriers closest to the coast encountered by smaller eels (2.3-5.1 inches) with poorer swimming abilities, will be different than upper watershed barriers encountered by larger and stronger elvers and yellow eels. Refer to Table 2 for the average swimming abilities for a young juvenile.

Table 2: Swimming abilities of juvenile eel (McCleave, 1980 in Gulf of Maine, 2007)

Young Juvenile	Burst Speed	Burst Distance
70-100 mm (2.75-3.9 in.)	0.6-0.9 m/s (2-3 ft./s)	<1.5 m (4.9 ft.)

Younger juveniles can swim a maximum distance of 3 m (9.8 ft.) in a 1 cubic foot per second (cfs) flow velocity. Older juveniles can swim 4 ft/s but not for long distances in fast water (McCleave, 1980 in Gulf of Maine Council on the Marine Environment, 2007). Flow velocities over long distances, such as the conditions found in culverts, inhibit the migration of eels. In addition, strong flows and complex turbulence reduces swimming performance (McCleave, 1980 in Gulf of Maine Council on the Marine Environment, 2007). Reducing flow velocity by roughening the channel surface and providing more opportunities for refuge from high flow is desirable.

Interestingly, elvers have the ability to 'climb' damp, coarse surfaces. Although elvers are capable of climbing vertical surfaces, research has shown greater success with ramps with a climbing substrate (See Figure 6). In addition, some elvers may choose not to climb. A vertical barrier of even a few centimeters is enough to block the migration of a juvenile.

Eels have the ability to ascend damp vertical surfaces (left), but passage is far more successful if we provide ramps with climbing substrate, like this one on Mallemort Dam in France (right). Alex Haro

Figure 5: Eel Ramp Image from Gulf of Maine Council on the Marine Environment (2007)

Upstream passage solutions include: eel ramps, by-pass channels, rock ramps, and culvert modification. Eel ramps are suitable for conditions where dam removal is unfeasible and head differentials preclude more natural solutions. Eel ramps are a common and cost-effective fishway measure that can be retrofitted within the existing dam structure or alongside the structure. The ramp can be a fairly steep (near vertical), bottle-brush (astro-turf-like) climbing substrate that the elvers can climb over or through, and kept damp. It's important that the ramp is located near attractant flows so that elvers can find the entrance. By-pass channels around the dam can be constructed with riffle-pool sequences, natural substrates and riparian conditions with ample flow to attract elvers. Rock ramps provide a navigable transition between impoundments and downstream flows and are most effective with natural vegetation and roughened climbing mediums. Lastly, smooth-bottomed or perched culverts should be replaced or modified to include a bottom substrate level with the upstream and downstream channel bed.

Eel Passage Downstream

Low-head dams are generally not a barrier to downstream migration. Hydroelectric dams and turbines are by far the greatest threat. Some types of turbines kill half and injure 80-100% of the remaining attempting passage (Haro et al. 2003 in Gulf of Maine). Solutions for the safe passage of eels downstream include: dam removal, by-pass channels, and hydropower operation practices. Since silver eels migrate at night from September to December, plants can suspend operation nightly during the migration season.

2.3 Aquatic Species Passage and Stream Continuity

Historically streams flowed unimpeded between their headwaters and outlet, in this case on Long Island, into the ocean. Modern streams traverse a myriad of dams and road crossings along this path, each creating an unnatural condition. The adverse effects on passage of particular fish species, in this case river herring and American eel, are only a portion of the ecological impact that should be considered in the restoration of these streams. The swimming ability of river herring allows them to navigate all but vertical barriers within most streams. However, although an alewife can pass through, the impact of a road culvert on other species, as well as the stream system itself, remains substantial. Road culverts or crossings can act as small dams, trapping the normal flow of sediment downstream and creating areas of deposition upstream. In addition, other aquatic species such as amphibians must typically cross over roads instead of below, where they are often run over.

Continuity is the key to the healthy functioning of streams and rivers. The Massachusetts River and Stream Crossing Standards, developed by the River and Stream Continuity Partnership in 2006, supports road crossings that take a “stream simulation” approach, rather than species-based approach to fish passage issues. The standards developed support the goals of creating road crossings that are “invisible” to aquatic organisms by maintaining a variety of habitats, connectivity and ecological processes. Standard criteria for new crossings include:

1. Open bottom structures or embedded culverts (bridges, open bottom arches).
2. Spans = 1.2 times the bankfull channel width (minimum).
3. Spans should include at least one bank and allow dry passage for 90% of the year (optimum).
4. Natural bottom substrates that match upstream and downstream substrates.
5. Stream depth and velocities in crossing that match base-flow conditions.
6. Openness ratio of 0.75 (optimum) – 0.25 (min.) to allow wildlife passage.

The benefits of a holistic, ecosystem-based approach for fish passage and road crossings are many: unimpeded aquatic and terrestrial organism passage; hydrologic continuity; natural sediment transport; less maintenance and risk.

In the sections below, many barriers are noted ***not*** to have an effect on migrating alewifes but they still have an effect on stream continuity. In general, as the service life of a crossing is exceeded, they should be replaced with crossings that adhere to the guidelines of stream continuity. Different approaches for road and pedestrian crossings are discussed in the Alternatives Analysis section of Ligonee Brook and Moore’s Drain below.

2.3.1 Planning Level Costs – Stream Crossings

Costs associated with the replacement of culverts for structures that improve stream continuity are always specific to the site’s hydraulics, layout, and sub-surface conditions. However, at a planning level, the costs for different approaches can be broadly evaluated. Table 3 below provides typical guidance on this topic. Regional differences may be significant; in particular the cost for shipping to Long Island and the annual changes in costs for raw materials, such as asphalt – an oil-based product. Accordingly, local material suppliers and contractors should be contacted to verify costs.

Table 3: Planning level costs for various road crossing improvements.

Alternative	Cost**	Notes
Corrugated Metal Pipe	$60-100 / LF	- Diameter should be 1.2 x bankfull, bury the lower half below stream grade - No footer needed - Cheapest option but durability can be an issue
Concrete Box Culvert	$100-150 / LF	- Typical to bury the invert below channel grade, deeper for high energy streams - No footer needed, increased load capacity if cover is shallow - Can mount boulders, logs to culvert bottom to create permanent flow obstruction or bank feature for amphibians
Bottomless Arch Culvert	$300-500 /LF	- Requires footings which can be $200-300/LF of added cost. Precast footings may reduce cost - Best option for streams with significant adjustment (vertical)
Installation and Road Repair	$800-1700 / LF	- Typically includes removal of old structure, necessary base courses, asphalt repair, traffic control etc. Less expensive on secondary roads than primary. - Variable cost of asphalt is large factor

*End sections are not included **Cost Range captures small to large sizes

3 Forge Road Dam

3.1 Watershed Position and Fish Passage Challenges

The Peconic River flows through Riverhead from its source near Brookhaven National Laboratory to its mouth in Flanders Bay. Much of the watershed is forested, but the land use is mixed with residential, agricultural, commercial, and industrial areas as well as the Brookhaven National Laboratory and Enterprise Park at Calverton. The Peconic is the longest river on Long Island and, until recently, had six dams along its length that prevented river herring and American eels from migrating upstream. A fish ladder installed annually at the Grangebel Park North spillway to provide passage during migratory periods and recently a permanent fish passageway was built around the Grangebel Park South spillway, opening up an additional 25 acres of spawning and maturation habitat. The Forge Road Dam (New York State Department of Environmental Conservation (NYSDEC) ID #253-0696) lies 1.5 miles upstream of the Upper Mills Dam, and is followed by the Edwards Avenue and Connecticut Avenue fish barrier, two and four miles upstream from the Forge Road Dam respectively. Providing fish passage at Forge Road Dam would open 2 miles of river and 107 acres of habitat and is the next step in a goal to restore over 300 acres of habitat along the Peconic River with passage around the remaining dams.

3.2 Site Description, Opportunities & Constraints

Forge Road Dam is approximately 4.3 miles from the mouth of the Peconic River in Flanders Bay (Figure 7). The Town of Riverhead owns the northern half of Peconic Lake and the floodplain north of the River downstream of the dam. Peconic Lake is the impoundment on the upstream side of the Forge Road Dam. Below the dam, the south bank of the river is characterized by a wooded bluff and residential property, while the land to the north of the river is an undeveloped forested wetland owned by the Town of Riverhead. The forested wetlands site shows evidence of historic ditching and possible agricultural use (i.e. cranberry production), with a vegetated earthen berm parallel to the Peconic River. A relic channel is present on the north side of the berm, with active flow assumed to be subsurface seepage under the Peconic Lake earthen dam.

Figure 6: Dams on the Upper Peconic River

Figure 7: Forge Road Dam Existing Conditions Exhibit. Suffolk County owns all three parcels on the south bank between Dam Road and the first house.

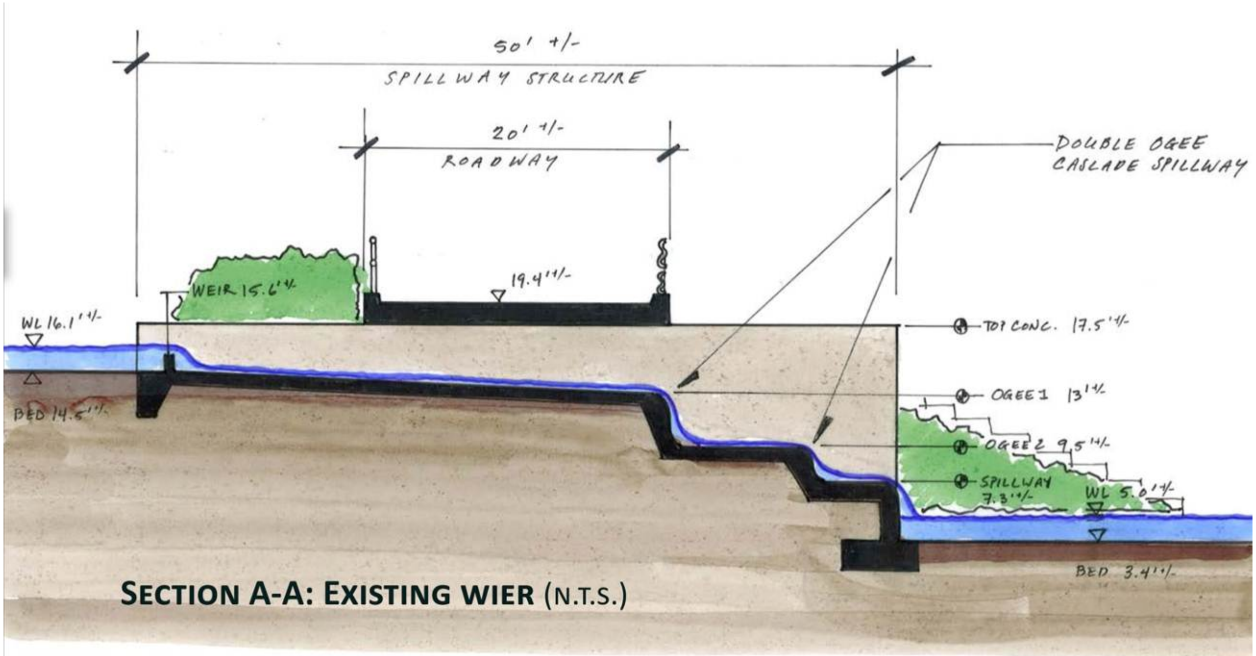


Figure 8: Approximate Cross-Section of Forge Road Dam spillway structure.

The dam and spillway is owned and operated by the Town of Brookhaven. In 2007 the dam was classified as a low hazard dam (Hazard Code A) by the NYSDEC. The spillway creates $11^{+/-}$ feet of vertical head making it a small (less than 40 feet) dam per NYSDEC criteria (NYSDEC, 1989). The spillway is a 10 foot wide concrete sluice that terminates in a double ogee cascade on the downstream side of Forge Road. The length of the spillway is approximately 50 feet. In 2011, James Wiesenfeld, P.E, performed a structural review of Forge Road Dam. In his letter to Nelson & Pope Engineers dated December 5, 2011, Mr. Wiesenfeld found that the concrete walls and spillway of the culvert appear structurally sound, however the road deck, specifically the upset beams which support the railings have 'severely deteriorated'. The letter outlines four possible courses of action, and recommends replacing the structure with a new cast-in-place or precast concrete sluiceway/culvert as the best long-term solution.

The three alternatives for providing fish and aquatic species passage that were investigated all may require modification of the existing Forge Road Dam. NYSDEC requires a Dam Safety Construction permit for any modification of a dam including reconstruction and repair (NYSDEC, 2009) and NYSDEC requirements state any existing dam with a Hazard Code A that is being rehabilitated should have adequate spillway capacity to pass the 100 year flood (design flow) without overtopping (NYSDEC, 1989).

The Forge Road Dam spillway acts as a culvert under Forge Road. Flow conditions resulting in a water surface elevation exceeding the bottom elevation of the road deck are assumed to exceed the maximum spillway capacity and are not considered here. The stop logs approximately 15 feet upstream of the road are fully submerged under maximum flow conditions and because of this distance from the spillway (culvert) opening are assumed to not influence flow through the spillway at flood flow. The spillway at the upstream end of the double ogee at the road deck edge is approximately 9.6 feet higher than the streambed elevation where the spillway terminates (Figure 8). It is assumed this elevation difference is adequate to prevent backwatering of the spillway under full spillway flow conditions, and that the spillway is inlet controlled. A rough approximation of the spillway capacity under flood conditions indicates the road is overtopped somewhere between 200 and 300 cfs. The entire structure includes complex hydraulics that were not modeled in detail and thus this estimate should only be used to indicate that capacity may be near the required 244 cfs for the 100 yr event predicted in the hydrology section. The spillway may be defined to include overtopping of the road however, thus adding capacity at the dam, discussions with DEC did not indicate the specific definition of the term "spillway." When considering alternatives to fish passage, the specific hydraulics of the spillway should be modeled, including the effects of backwater from the Peconic River downstream to fully inform decisions.

For the purpose of this study, it is understood that a dam removal option shall not be pursued and ***that the dam spillway will be either completely replaced or repaired by the Town of Brookhaven. All options presented below assume this replacement will occur***. Should an upgrade or retrofit to the existing spillway structure be performed, all of the options presented below to achieve fish passage can be easily adjusted to this new condition. In addition to the culvert/bridge structure, other existing structures at the dam include canoe launch platforms, stairways, and canoe ramp that provide a portage between the Peconic Lake and the Peconic River. These structures and their function are preserved in all alternatives. A detailed investigation of utilities and subsurface infrastructure was not performed in the area. A visible conduit at the spillway containing two to three rubber clad cables contains a telephone line, abandoned in 2001, per Verizon. No other utilities were investigated.

3.3 Geology

The bedrock underlying most of Long Island, including the area around Forge Road Dam, is crystalline metamorphic material, or gneisses and schists, created from Precambrian granite or sandstone more than 400 million years ago. The surficial geology consists of outwash sand and coarse to fine gravel that is well-rounded and stratified. This coarse material provides a medium that induces very fast rates of infiltration throughout Long Island. Consequently, 90% of the annual flow in the Peconic River is derived from base flow (groundwater discharge) and only 10% from precipitation runoff (Scorca et al. 1999). In fact, the highest recorded discharge at the Riverhead gage (#01304500) occurred without any precipitation the day of the flow or the three days preceding it (225 cfs on January 30, 1978) (Dunn Engineering Associates 2005). Because of the composition of the surficial geology, the channel substrate of the Peconic River is primarily gravel and sand with pockets of fine material fostering submersed macrophytes. This variable substrate is important for creating geomorphic complexity and variable habitat for macroinvertebrates, fish, and other aquatic organisms.

3.4 Fisheries

A detailed investigation of the historic Peconic fisheries was not performed. Historically, the Peconic River likely supported large populations of native diadromous fish species. In its natural form, the river would have provided variable fines, sand and gravel substrate, copious canopy cover, and sufficient in-stream habitat with large woody debris, deep pools, and riffles. With the many dams built on the river, fish passage problems have limited the ability of these fish species to access this habitat. Today, alewife and American eel spawn and mature in the Peconic River downstream of Upper Mills Dam with the recent completion of the rock ramp at Grangebel Park. In addition, blueback herring have been observed in the system (B. Young, pers. comm), though not in significant numbers. A volunteer monitoring program was organized by the Peconic River Fish Restoration Commission in 2010 following the completion of the rock ramp. This monitoring suggests that the rock ramp was successful as a minimum of 24,000 alewives (and as many as 40-50,000) entered the Peconic River to spawn in the spring of 2010 (Young, 2010).

3.5 Hydrology

Flow hydrology is important to characterize to provide context for fish passage. Fish movement occurs deliberately each season during the spring spawning migration and the late summer or fall outmigration. Of the two, the upstream migration of adults in the spring is the most critical design point for passage projects. Spring typically brings the widest range of flows to a river. Depending on precipitation through the winter, base flow may be at or near its lowest value from the previous fall or significantly increased by winter snowmelt. Spring storms typically provide floods during this period. Understanding these flows informs, or perhaps confirms, the various options available for fish passage. Eventually, during the design of a preferred option, these flows will become design flows, ensuring hydraulics are suitable for passage during average to low flow periods and confirming the stability of the design during large flood events. Flow statistics for the Peconic are well established by the USGS gage located below the Upper Mills Dam, downstream of FRD.

Hydrologic characteristics at the Forge Road Dam (FRD) were obtained from the USGS gaging station (01304500) on the Peconic River. The gage is located 1.6 miles downstream from FRD. The drainage area to the stream gage is 75 sq. mi. while the drainage area to FRD is 69.7 sq. mi. Peak flows and low flow statistics were scaled from the USGS gage using the ratio of drainage area to each site. The stream gage was in operation between 1943 and 2007 which provided 65 years of data. Despite the relatively long gaging record, flow data before 1971 was disregarded due to a shift in discharge pattern. Specifically, the standard deviation of the annual peak discharges before 1971 was 23 cfs, and after 1971 the standard deviation almost doubled to 43 cfs. This change reflects a shift in precipitation variability with climate change. Drought conditions prevailed prior to 1971, resulting in low variability in peak discharges. After 1971, annual average precipitation and its variability increased (Ron Busciolano, personal communication, 2011). These shifts are indicative of hydrologic patterns found throughout the region. Collins (2009) suggests omitting discharge data before 1970 for New England rivers due to a step-like increase in precipitation and floods flows. Although the FRD is not in New England, its proximity suggests it is generally governed by the same climatic conditions. Collins (2009) also suggests that these trends are representative of the entire Northeastern U.S.

3.5.1 Low Flow Statistics

Flow characteristics during the spring are most critical since this is the time period that alosids are migrating upstream to spawn. Spawning runs typically start in early April and end in May (Scott and Crossman, 1973). Actual spawning run observations in the spring of 2010 were provided by Young (2010) for the Peconic River at the new rock ramp fish passage at Grangebel Park, approximately 2.8 miles downstream from the FRD. The observed peak in alewife numbers occurred between April 5th and May 1st in 2010. This range falls within that suggested by Scott and Crossman (1973). Considering the natural variability of flow temperatures that induce spawning, we assume the period between March 15th and June 15th encompasses the entire migration interval. The 90%, 50% and 10% exceedance probability discharges (the percentage of time a specific flow was equaled or exceeded) were calculated for this time frame.

Table 4: Discharges for specific exceedance probabilities during the spawning period.

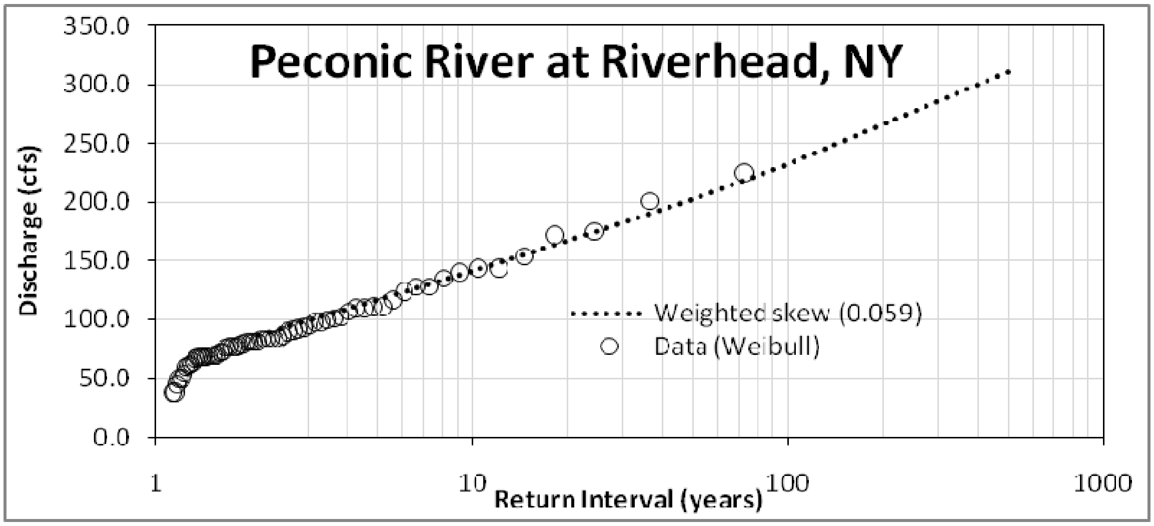
	Discharge for specific exceedance probability (cfs)		
Date Range	90%	50%	10%
March 15-30	25.7	43.1	65.6
April 1-30	25.7	47.0	70.5
May 1-31	28.0	51.4	76.5
June 1-15	24.7	48.0	73.4
Average	26.0	47.4	71.6

3.5.2 High Flow (Flood) Estimates

The Log-Pearson Type III probability distribution was fit to the measured annual peak flow data at the USGS gage (01304500) to estimate flood quantiles (IACWD, 1982). This procedure was used in conjunction with a generalized skew coefficient that accounts the individual station and skew at other regional gaging stations. In addition, no high and low outliers were detected, historical data was not available to supplement the gaging record, mixed populations were not used, and flood estimates from precipitation were not included.

Table 5: Estimated flood discharges at various recurrence intervals at the Forge Road Dam.

Recurrence Interval (years)	2	5	10	25	50	100
Discharge (cfs)	85	121	148	185	213	244



3.6 Forge Road Dam - Alternatives Investigation

Three alternatives were considered to improve fish passage at Forge Road Dam: (1) installing an Alaskan steeppass fish ladder; (2) constructing a natural fishway / fish ramp along the river right bank; or (3) constructing a by-pass channel through the river on the left floodplain, utilizing the seepage channel location.

The following assumptions and performance criteria were also used in the development of the three alternatives:

- **Function of dam and spillway to remain. Dam removal not an option.**
- **Maintain ability for Town to control and operate water levels in Peconic Lake.**
- **Preservation of canoe launch structures and function.**
- **Provision of a permanent fish passage solution for diadromous species, specifically alewife and eels.**
- **Efficient utilization of the dam repair in the fish passage solution.**

Figure 9: Installation of an Alaska Steeppass structure

3.6.1 Alternative 1 - Alaskan Steeppass Fish Ladder

The first alternative is the installation of an Alaskan steeppass fish ladder retrofitted into the existing or renovated weir structure. Fish ladders are becoming a more common solution for providing temporary and permanent fish passage solutions in locations where vertical barriers, such as dams are left in place. Alaskan steeppass ladders are prefabricated structures with baffles or fins on the sides and bottom which disrupt the flow of water, decreasing its velocity, and providing refuge and resting areas behind (Figure 11).

Design parameters for the ladder depend upon the swimming abilities of the targeted fish species, in this case river herring and elvers. Per correspondence with Alexander J. Haro, Research Ecologist with the USGS, and author of the 2004 open channel flume test of swimming performance, the 'evolving' criteria for river herring steeppass fishways include a maximum height of 3 m. (9.8 ft.), a maximum slope ≤ 1:6 (16%) and maximum straight run lengths of 12 m. (39'). This criteria was used to develop the conceptual configuration for Alternative 1 (Figure 12 & 13).

Figure 10: Looking downstream at an Alaskan steeppass fish ladder installed on the Parker River (photo from NOAA library)

Based upon these height and length guidelines, the dimensions of the Forge Road Dam are slightly longer (approximately 50 ft. total length) and taller (approximately 11 feet of vertical head) than the maximum dimensions, and therefore may require more than one straight ladder run.

There are many possible configuration options for adding a fish ladder into the existing or modified dam structure. Here we present one solution that may elegantly solve the challenge at Forge Road Dam. The solution involves dividing the fish ladder into three, 1:6 slope segments, connected by a resting pool cast into the existing roadway berm and second resting pool formed into the concrete base of the spillway.

Two 17 foot-long ladder segments traverse the grade up the Forge Road Dam berm, while the final 36' foot-long ladder can be retrofitted within the existing spillway. Alternatively, the spillway can be modified or reconstructed to create a roughened channel in place of one or more of the ladder segments. The entrance to the downstream fish ladder in the Peconic River is positioned adjacent to the spillway. Attraction flow for the ladder will be critical to the final positioning of the entrance during design. The entrance must be positioned as near to the spillway as possible, yet outside the influence of re-circulating eddies and underwater currents.

Alaskan steeppass ladders do not provide natural channel conditions, nor do they provide any type of habitat, but they are effective at passing river herring. Alaskan steeppass ladders will present a velocity barrier for resident fishes such as largemouth bass, chain pickerel, bluegill, brown bullhead and others in the Peconic River (Coastal Fish & Wildlife Habitat Assessment Form, 2002) that prefer slower moving waters (Scott and Crossman, 1973). The Alaskan steeppass ladder will also present a velocity barrier for elvers. Therefore, to create opportunities for elver passage, the installation of appropriate substrate should be completed either on the ladder structure (shown in Figure 13) or on the main spillway. Elver passage can be placed in a location that provides the best advantage for passage, maintenance, and perhaps cover from predators.

While a segmented ladder is slightly more complex to construct than a straight-run ladder, it may provide the public with a unique educational opportunity. The positioning of the ladders and resting pools allow the public to observe fish migration from interesting angles from existing infrastructure, such as views from the canoe landing and stairway and from the walkway along Forge Road (if constructed). In the concept sketches we have shown a slightly widened roadway section that provides a curbed walkway with guardrail along the downstream side of the road to provide safe access for pedestrians and a balcony view to the river below. If well designed, the fish ladder solution can be an attractive and educational addition to the Forge Road Fishway.

Once the criteria listed for passage are met (maximum slopes and lengths) the fish ladder option can be designed within an array of solutions for improvement of the existing roadway and spillway structure. If the existing spillway is utilized the ladder would require a widening of the spillway to maintain the existing capacity. Minor advantages and challenges also exist with this option. The roadway embankment at the location of the 17 foot ladder segments consists of a dense thicket of invasive vines, mostly multiflora rose (*Rosa multiflora*). Therefore, the installation of the fish ladder could be coupled with invasive plant control between the existing spillway and canoe launch, an overall positive for the site. Minor challenges include the potential for the fish ladder to trap debris, though the existing spillway likely requires a similar level of care. The ladder can be blocked seasonally to reduce wear on the structure. The open resting pool may provide a location for illegal collection of migrating alewives. Adding a grate can eliminate this issue. Discussions with local DEC biologist Chart Guthrie indicate challenges presented by bends in fish ladders that confuse fish swimming upstream.

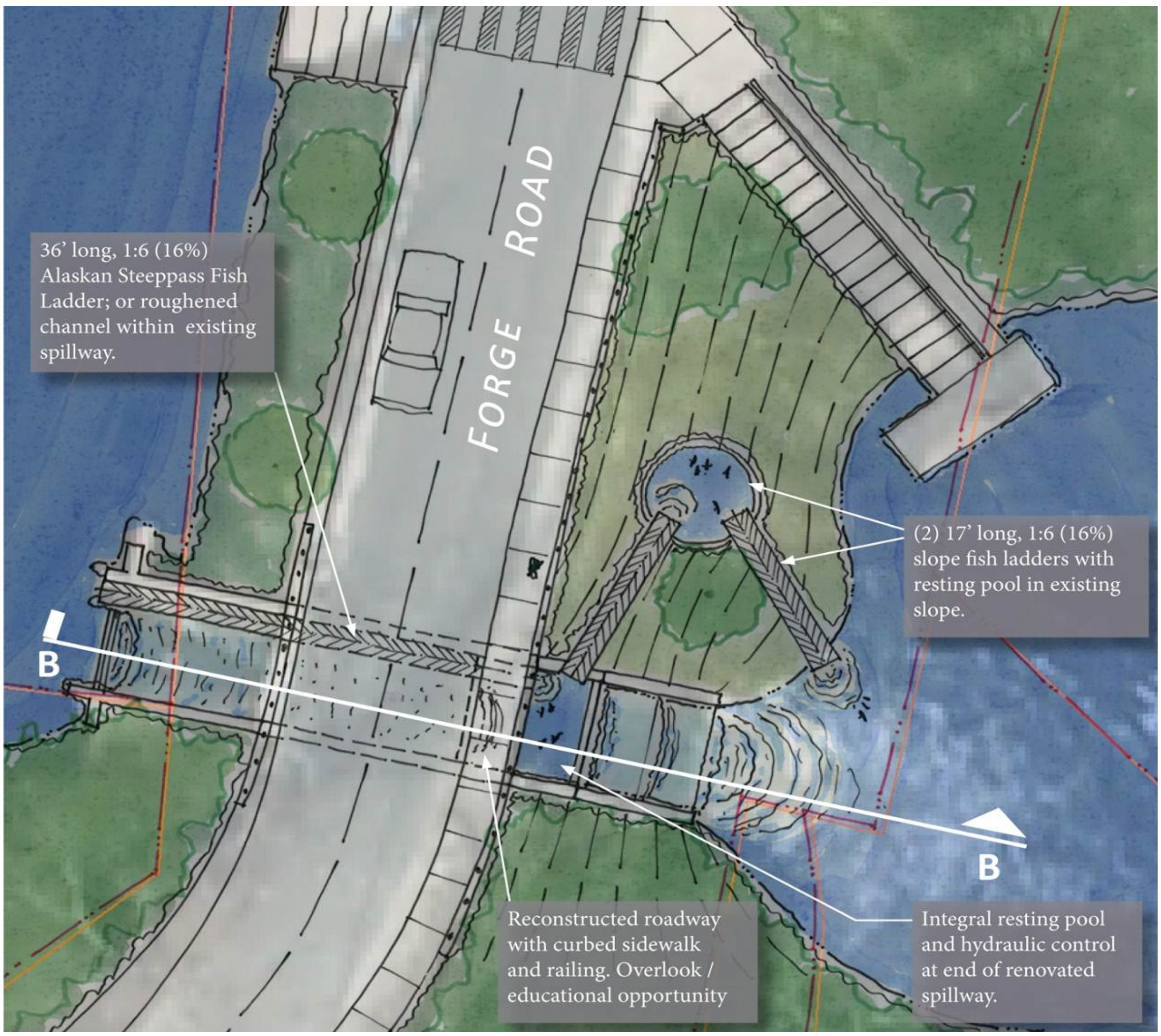


Figure 11: Concept Plan Sketch: Fish Ladder incorporated into Forge Road Dam Spillway structure.

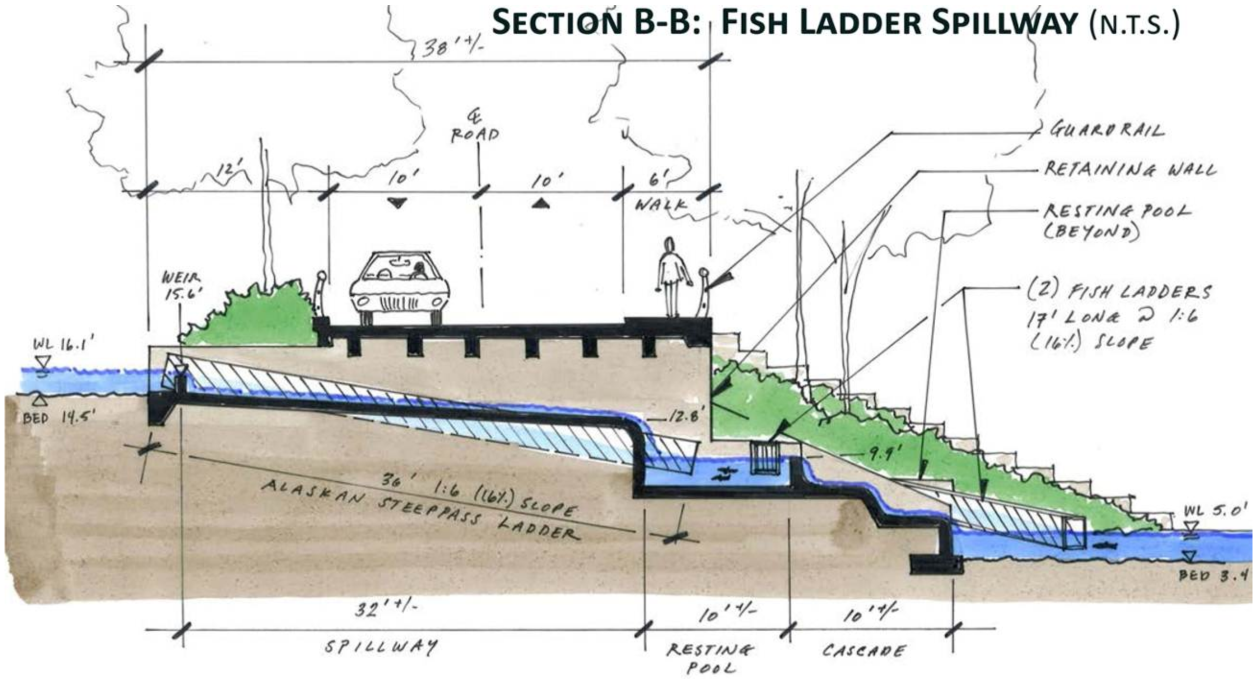


Figure 12: Concept Section sketch - fish ladder retrofit into *new or existing* Forge Road Dam spillway structure.

Table 6: Summary of costs and advantages for Alaskan Steep Pass Fish Ladder

Estimated cost	Advantages	Disadvantages
$131-157K	- Improved fish passage for alewives - Retrofit possible within repaired spillway structure - Provides an attractive and unique educational opportunity - Flexible design can be adapted to a variety of spillway and road configurations	- No habitat provided - Routine maintenance of ladder is likely - Bends in ladder may be challenging - Fish passage for resident (non-migrating) species is likely not improved - Height of dam and length of spillway requires a multiple segment ladder and reconstruction or retrofit of existing upper sluiceway and ogee if utilized

3.6.2 Alternative 2 – Natural Fishway / Fish Ramp

The second alternative is 200-foot long natural fishway or fish ramp. Fish ramps are feasible alternatives for sites with low-head dams and ample river area to provide the roughened channel length and width. A fishway provides a more natural solution than the fish ladder with increased opportunities for a greater diversity of fish species to navigate the passage.

Guidelines for roughened channel design vary. The NRCS recommends using a cobble and gravel streambed for ramp slopes up to 1:20 (5%) and a concrete channel subgrade for slopes 5-9%. It also recommends strategically placing and anchoring boulders in the channel to provide refuge and resting areas. According to research performed by the USGS Conte Labe, (A. Haro, pers. comm.) 'evolving' criteria for river herring in nature-like fishways include a slope ≤ 1:20 (5%), channel width ≥ 3 m. (9.8 ft) and a depth ≥ 0.5 m. (19").

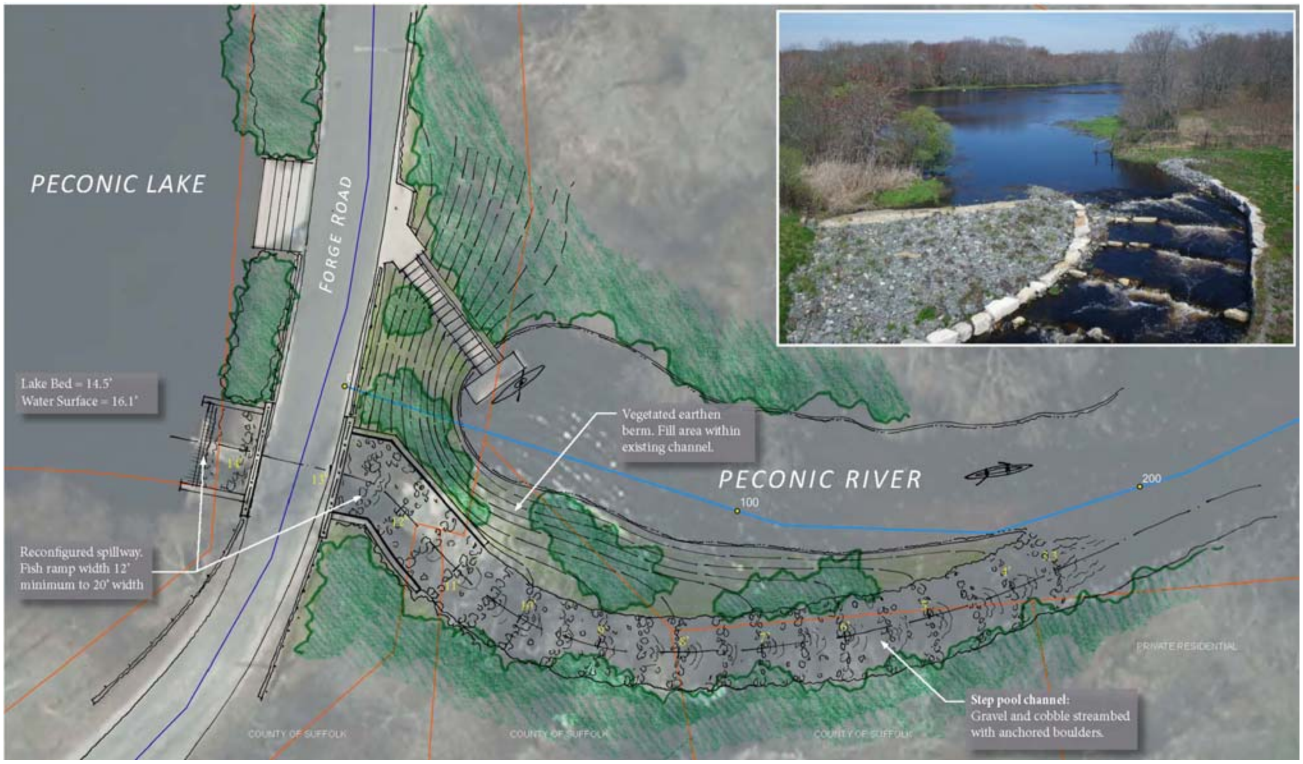


Figure 13: Concept Plan - Fish Ramp / Natural Fishway

The concept design for the fish ramp alternative suggests using the current location of the existing dam as the head of the channel and following the right bank of the Peconic river downstream at the recommended 5% slope to meet the existing channel bed. Vertical head for the Forge Road Dam is 11$^{+/-}$ feet, requiring 200$^{+/-}$ linear-feet of ramp.

The southern (right bank) of the Peconic River is a steep wooded bluff. Land use and ownership along this edge is a mix of private and public property. The three parcels closest to the dam are owned by Suffolk County. The concept plan illustrates the advantage natural grade provides in forming the right bank of the new channel. In order to preserve reasonable channel depths for fish passage, the left bank of the fishway channel will be built within the footprint of the river as a peninsula feature. This would require fill within 0.16$^{+/-}$ acres of the existing river. A sloped landform will be constructed between the new channel and the river to take up grade as the ramp climbs to the elevation of the lake bed upstream. Measures may be required to ensure stability of this slope and should be investigated during design. If the footprint of the fish ramp needs to be reduced to accommodate regulatory restrictions and environmental permit conditions, structural measures (such as hardened slopes or retaining walls) may be a useful, though expensive, option.

The new channel would be configured to maintain adequate depth and velocity for alewives migrating upstream. A detailed hydraulic design was not completed. However, the design of the roughened channel is expected to be 12-20 feet wide with a natural cobble and boulder bottom. Large boulders will be placed throughout this channel to provide resting areas and increase the depth of the channel. The bottom of the channel will be lined with a compacted clay bottom and the channel bottom and banks lined with a water proof membrane to control seepage from the raised channel.

The fish ramp provides greater benefits than the fish ladder alternative, including a natural substrate and in-stream habitat, lower channel gradient, decreased water velocities, refuge and cover and the ability to pass both migratory and resident species (Table 7). Although some trees and vegetation may need to be removed to complete construction, much of the existing vegetation and canopy along this forested edge will remain to provide cover and shade for the passage. In addition the fish ramp would be a highly visible feature from Forge Road and the canoe portage area.

The fish ramp alternative is the highest cost of all alternatives, due to the volume of rock and fill material required to construct the ramp, berms and roughened channel. Costs may be offset slightly if the ramp can reduce the amount of repair and retrofitting required of the existing spillway, though this was not investigated in detail. Another challenge with this alternative is construction within the existing river and filling within the river footprint, which may be a regulatory challenge with respect to New York's Freshwater Wetlands (Article 24) and Wild, Scenic, Recreational Rivers (Article 15, Title 27) regulations and will require careful attention to project staging and dewatering. A discussion on environmental permitting requirements for all passage alternatives at Forge Road Dam is provided later in this report.

Table 6: Summary of costs and advantages for 200 ft long Natural Fishway

Estimated cost	Advantages	Disadvantages
$150-175K	- Passage for resident and migratory species - Some habitat value - Excellent attraction flow - Aesthetic attraction	- Possible regulatory difficulties associated with proposed filling in existing river bed - Dewatering during construction

3.6.3 Alternative 3 - By-pass Channel

The third alternative presented for the Forge Road dam fish passage is a by-pass channel. By-pass channels are low-gradient, natural channels, often used to navigate around low-head dams. The most feasible location for a by-pass channel at the Forge Road dam is in the forested wetland area north of the river. The mouth of the channel would begin at the existing relic channel mouth near river station 2+50, and connect to Peconic Lake via a culvert underneath Forge Road approximately 350 feet north of the spillway structure.

The existing seepage channel can be used for most of the length up to the proposed culvert location. The channel will make up some of the $11^{+/-}$ feet of grade change along its length but will still require a steep riffle or similar structure near or through the road crossing. The seepage channel is located entirely within the NYSDEC-regulated red maple hardwood swamp adjacent to the river. Fill within this freshwater wetland will be required to construct the channel bed to design elevations and will require clearing of some existing wetland vegetation. A culvert will be required under Forge Road to connect the by-pass channel to the lake. A concrete box culvert, partially buried with a natural substrate bottom and a terrestrial bench, would provide a natural channel connection and ecological corridor for aquatic and riparian species under Forge Road. During non-migratory periods, the channel can be blocked to control lake levels while still maintaining access to the terrestrial benches.

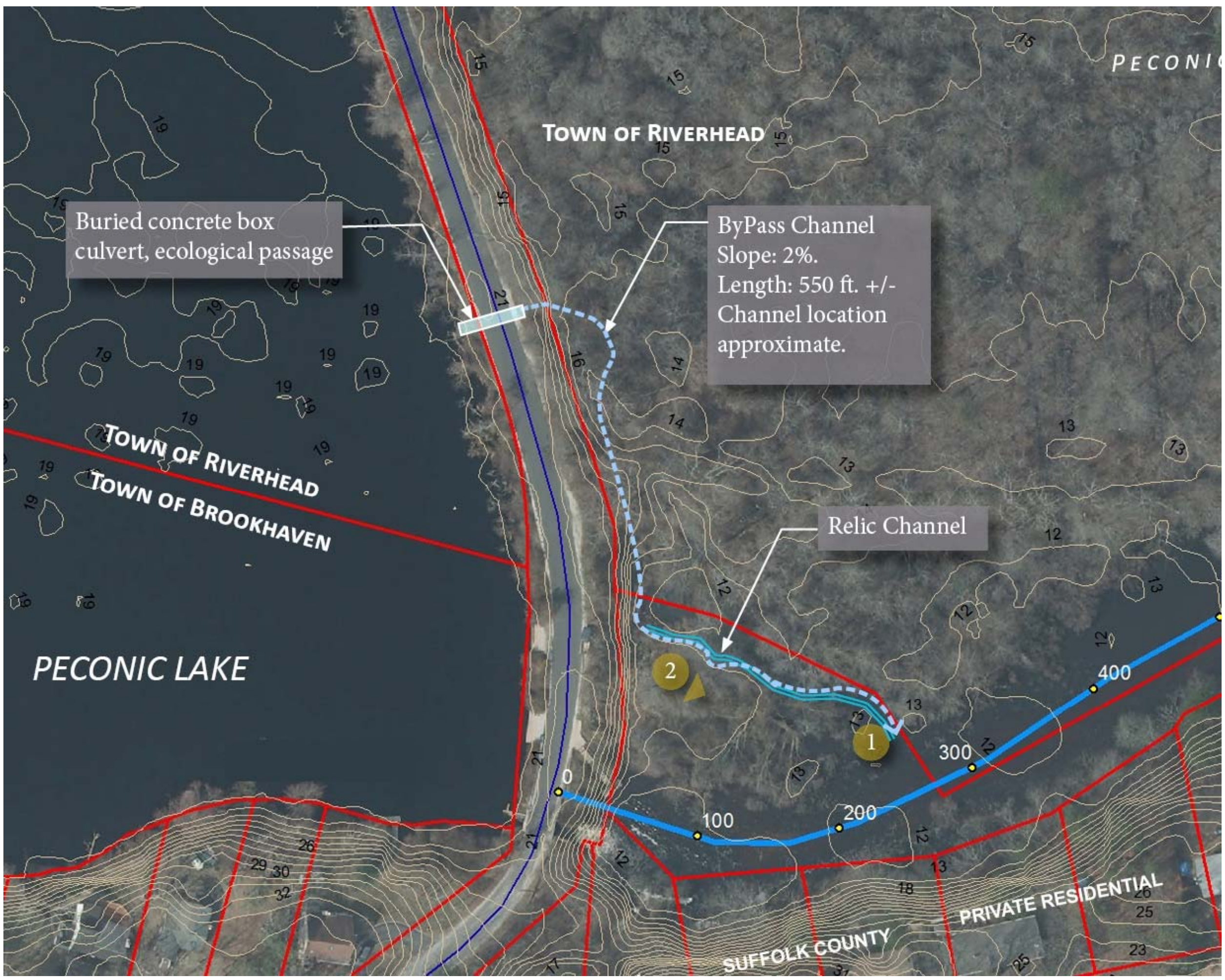


Figure 14: Layout for a by-pass channel

A by-pass channel would provide the lowest gradient and most natural passage for migratory and resident fish species. However, the greatest flaw to this alternative is the lack of attractant flow at the mouth of the channel and its long distance from the main spillway at the dam. Depending on river flows, discharge at the main spillway location may be reduced with weir boards, pushing most flow into the by-pass channel, but the hydraulics and efficacy of this option would need to be developed further and require careful attention and maintenance during spring migrations. Without sufficient attractant flow, fish may not locate the by-pass channel, rendering it useless. Construction of the channel and associated features would require construction within the within the forested wetland, and would require authorization from the NYSDEC pursuant to the Freshwater Wetlands (Article 24) and Wild, Scenic, Recreational Rivers (Article 15, Title 27) regulations.

Table 7: Summary of costs and advantages for a natural by-pass channel

Estimated cost	Advantages	Disadvantages
$200-240K	- Passage for resident and migratory species - Some habitat value	- Poor attraction flow - High Cost - Doesn't incorporate necessary repairs on primary spillway - Requires second road crossing

3.7 Alternative Costs Summary

Costs for the alternatives <u>do not</u> take into account the repair or replacement of the spillway and upgrades to the roadway. Given the age and status of the structure, and the possible need to increase spillway capacity, it appears that significant retrofit or maintenance would be completed along with design for proposed fish passage. Either Alternative 1 – Fish Ladder or Alternative 2 – Natural Fishway can easily be integrated into this process to accommodate road improvements or upgrades to spillway capacity and configuration. If either of these is selected, a design team should include an expert in road and dam design in addition to one familiar with the design of the proposed alternative.

Costs here are concept level engineer estimates to provide approximate values for comparison purposes. Actual design and construction costs will vary following a more detailed data collection effort and ensuing design. A detailed account of costs is provided in Appendix B. These costs have been based on knowledge of similar projects and construction components. A 20% contingency was added to each estimate to provide the range noted below.

Table 8: Range of Costs for fish passage around Forge Road Dam

Alternative	Design Cost	Construction Cost	Notes
Alternative 1: Alaskan Steeppass Fish Ladder	$25-75K	$131-157K	- Assumes about $10,000 per vertical foot of rise - Assumes construction of cast-in-place resting basin in roadway berm, and associated earthwork and planting. - Does not include improvements to Forge Road or Spillway (specific spillway elements for ladder and roughened channel should be minor costs within overall repair expense)
Alternative 2: Natural Fishway/ Fish Ramp	$50-100K	$150-175K	- Assumes 200$^{+/-}$ feet of channel (beyond the spillway) with imported fill, 2 feet of field stone and anchored boulders, and water-proof seepage barrier under channel - Requires spillway improvements - Assumes a 15 foot wide average channel width - Assumes imported fill for an earthen berm to form the northern channel edge - Cost does not include improvements to Forge Road or Spillway
Alternative 3: By-pass channel	$50-100K	$200-240K	- Utilizes existing seepage channel - Requires rock riffle to make up grade near the roadway - Assumes earthwork and planting to restore areas disturbed during grading. - Assumes the placement of a culvert and associated roadway reconstruction at $1750 / lf at 60 linear feet - Does not include improvements to Forge Road or Spillway

3.8 Environmental Permitting

The installation of fish passage alternatives at the Forge Dam will require the following environmental permits:

- *United States Army Corps of Engineers:*
  - Section 404 of Clean Water Act, Section 10 of Rivers and Harbors Act
- *New York State Department of Environmental Conservation:*
  - Article 24 (Freshwater Wetlands)
  - Article 15 (Protection of Waters)
  - Article 15 Title 27 (Wild, Scenic, and Recreational Rivers Act, WSRRA)
  - Article 15, Titles 507, 511, and 516 (Dam Safety Permit)
- *New York State Department of State, Division of Communities and Waterfronts:*
  - Consistency Determination under Coastal Zone Management Act
- *New York State Office of Parks, Recreation, and Historic Preservation:*
  - Review under NYS Historic Preservation Act of 1980 (Section 14.09)
- *Town of Brookhaven:*
  - Wetlands and Waterways
  - Building and Fire Prevention

- *Town of Riverhead:*
    - Conservation Advisory Council Review under Section 107 (Tidal and Freshwater Wetlands) of Town Code
    - Building Construction

The Alaskan steeppass fish ladder alternative would be easiest to obtain regulatory approvals for, as this alternative requires no or minimal fill in the Peconic River or its adjacent wetlands. However, this alternative provides passage for only river herring (and possibly American eel) and provides the least natural habitat within the passage structure. The fish ramp and by-pass channel provide more natural habitat conditions and provide passage for a greater diversity of aquatic species; however, both alternatives require fill and clearing of native vegetation in and adjacent to the site's wetlands. New York State's Freshwater Wetlands Act requires that unavoidable loss of and disturbance to freshwater wetlands be minimized and mitigated. Consultation with the NYSDEC Bureau of Habitat is recommended prior to preparation of construction plans to determine if 1) the establishment of fish passage opportunities provides sufficient mitigation for the loss of freshwater wetland and river habitat and 2) if the environmental, economic, and/or social benefits of the ramp and bypass channel outweigh the wetland and river habitat loss. The NYSDEC Bureau of Habitat should also be consulted to confirm that these alternatives and the associated filling would be considered a "stream improvement structure" under the WSRRA and, therefore, could be authorized.

Under Alternative 3, the by-pass channel would be routed through a red maple-hardwood swamp. Red maple-hardwood swamps are a relatively abundant wetland community and are characterized as demonstrably secure globally (G5) and apparently secure (S4) in New York State. As stated previously, there are relict channels/ditched and artificial berms throughout this hardwood swamp. Construction of a natural bypass channel through this community will make maximum use of the existing channels and existing berms should be utilized for construction access to the maximum extent possible. No staging of equipment or materials should occur within this wetland community.

3.9 Endangered and Threatened Species

The New York Natural Heritage Program indicated in correspondence dated February 23, 2012 that the following rare or state-listed animals, plants, and significant natural communities occur, or may occur, in the vicinity of Forge Dam:

Tiger Salamander (*Ambystoma tigrinum*), NYS-Endangered
Banded Sunfish (*Enneacanthus obesus*), NYS-Threatened
Golden Dock (*Rumex maritimus*), NYS-Endangered
Minute Duckweed (*Lemna perpusilla*), NYS-Endangered
Coastal Barrens Buckmoth (*Hemileuca maia*), NYS-Special Concern
Long-beaked Beakrush (*Rhynchospora scirpoides*), NYS-Rare
Coastal Plain Pond Shore
Pitch Pine-Oak Forest

As described below, none of the three alternatives have potential adverse impacts on these protected species or their habitats.

The NYSDEC Bureau of Wildlife was contacted to determine the location of know tiger salamander habitat relative to the Forge Dam site to access potential impacts to this species. The known tiger salamander habitats are more than 1,000 feet from the project site; accordingly, the project has no potential impacts for tiger salamanders or their habitat (Kelly Hamilton and Michelle Gibbons-NYSDEC Bureau of Wildlife, pers. comm.)

Banded sunfish are not known to occur in the surface waters adjacent to the project site (Chart Guthrie-NYSDEC Bureau of Fisheries, pers comm) and are not expected to be impact by the proposed project.

Golden dock (*Rumex maritimus*) typically inhabits brackish wetlands, brackish interdunal swales, and ocean beaches. Three specimens were observed growing on a rotted wooden dock at the edge of Peconic Lake in 1984. This sighting was atypical of this species. Golden dock is not expected to be present in the upland and wetland habitats in potential work areas and, therefore, is not likely to be adversely impacted by the proposed project.

The NYNHP indicates that there are historical reports (prior to 1979) of minute duckweed (*Lemna perpusilla*) from the Peconic River. This species is found on the surface of quiet waters in rivers, ponds, springs, lakes, and kettlehole ponds (NYNHP, 2012). Suitable habitat for this species is present at the Forge Dam site; however, no suitable habitat for minute duckweed will be degraded or destroyed by this project and no adverse impacts are expected.

Long-beaked beakrush (*Rhynchospora scirpoides*) is known to occur in the Kroemer Avenue Pond, located 1.25 miles to the northwest of the project site. This species occurs primarily on mucky or sandy soils on the margins of coastal plain ponds in pine barrens habitats, although it can be found in a variety of wet habitats in swamps and marshes; on the shorelines of streams, ditches, and ponds; and in depressions in savannahs (NYNHP, 2011). This species is not expected to be found at the Forge Dam site.

No coastal plain pond or pitch pine-oak forest habitats are located adjacent to the Forge Dam project site and, accordingly, shall not be impacted by the project. Similarly, coastal barrens buckmoth is not expected to be present as no scrub oak thickets are present in the project area.

3.10 Cultural Resources

The dam at Peconic Lake was the historical location of a mill and iron forge in the 18th and 19th centuries. Accordingly, regulatory approval from the New York State Office of Parks, Recreation, and Historic Preservation is likely to require field and literature investigations by an experienced archaeological consultant. The fish ramp and bypass channel alternatives likely have the greater potential to affect cultural, historical, and archeological resources than the Alaskan steeppass ladder alternative. It is recommended that the construction design and permitting phase of this project provide adequate budget and time for a cultural and archaeological investigation of the project site.

3.11 Recommendations

Considering the balance of fish passage, spillway improvements, and projected costs, we recommend Alternative 2 – the construction of the fish ramp option. The fish ladder, Alternative 2 was a close second. The difference between the two are cost and species passage. The fish ladder will pass migrating species only at a lower cost whereas the fish ramp will pass both migratory species and some resident species at a slightly higher cost. The ecological benefits of the latter are desired by the stakeholder group above the added cost for construction.

Both the ladder and fish ramp alternatives require re-construction or retrofit of the existing spillway, assumed to represent a similar effort and cost between the two options. The fish ramp alternative requires more substantial modifications to the river and its shoreline and requires disturbance of the right bank of the river with a few hardwoods and a disturbed berm largely vegetated by invasive vines. The proposed fill and riverbank modifications and potential cultural and archeological resource concerns associated with the fish ramp alternative will likely make procurement of regulatory approvals more difficult and time consuming, but not impossible. The ecological benefits realized for the additional cost and regulatory challenges appear tenable.

The challenges of attraction flow provided by the by-pass channel may render the solution ineffective for successfully passing alewives. This, coupled with the need to create a second crossing of Forge Rd for this option, creates the highest cost alternative.

All three of these options should be revisited within the context of proposed spillway improvements after an experienced structural engineer has provided options for retrofit or rehabilitation of the structure.

4 Ligonee Brook

4.1 Overview

Ligonee Brook is about 1 mile in length, flowing from Long Pond to Sag Harbor Cove (Figure 16). Long Pond appears to offer optimal conditions for alewife spawning and rearing. Ligonee Brook is tidal up to the first road crossing at Brick Kiln Road. Above Brick Kiln Road, the channel ponds groundwater up to the next crossing at the Bridgehampton-Sag Harbor Turnpike (hereafter Turnpike), above which the channel is often dry, flowing only during seasonally wet periods. The brook has a number of historic references to both eels and alewife dating back to the early records of Sag Harbor (ca. 1870s) where it is referred to as Long Pond drain. In the early 1900s the Sag Harbor water company constructed a dam at the outlet of Long Pond to supply municipal water that appears to have blocked flow in the brook, and eliminated seasonal migration of fish and eels. Remnants of this structure persist but it appears to have no modern effect on the pond elevation. Migrating alewife have been found in the brook when water is flowing in substantial numbers. Several dead fish were noted during the 2012 survey in the section below Brick Kiln Rd. No recent records of eels have been documented. The primary challenge to eels and alewife attempting to reach Long Pond is a lack of water during seasonal migration periods (spring and fall). A number of difficult crossings exist as well, but observations indicate these crossings have been navigated previously by alewife and eels.

Figure 15: Ligonee Brook begins as an outlet to Long Pond, flowing about 1 mile to Sag Harbor Cove.

4.2 Hydrology

The presence or absence of flowing water in Ligonee Brook determines migration success to Long Pond. Frequently, years pass where the stream bed remains dry between Long Pond and Sag Harbor Cove. In other years, water is present for only part of the year when alewives are either migrating upstream or downstream. Consequently, the suitability of Ligonee Brook for consistent, successful alewife spawning runs and recruitment of juveniles to the harbor is severely limited, depending on flow during spring and fall to complete the alewife life cycle.

Water in Ligonee Brook is controlled by the surrounding groundwater table elevation and the water surface elevation at Long Pond. When groundwater levels and/or the Long Pond water surface are high, water discharges into the stream allowing alewives to migrate. By correlating observed water presence in the brook (J. Held - observed data) with measured groundwater levels in the field, an approximate threshold elevation of 17 ft was determined as the point at which water begins to flow in the brook.

Daily groundwater elevations at the USGS gage adjacent to Crooked Pond (405756072173502) were compiled and correlated with the nearby USGS gage at the Brookhaven National Laboratory (405149072532201). The Crooked Pond gage is located about a mile from the Long Pond outlet to Ligonee Brook, and is the nearest real-time groundwater level gage. The high groundwater levels at Crooked Pond appeared to correlate with observed flows in Ligonee Brook. The Brookhaven gage includes a gaging record extending to 1948, allowing an extension of the Crooked Pond gage which only recorded data since 2003. We correlated the data using the maintenance of variance extension type 1 procedure (Hirsch, 1982). This method represents the statistical properties of the base station compared to a simple regression (Hirsch, 1982). These data were then ranked according to elevation and given exceedance percentages.

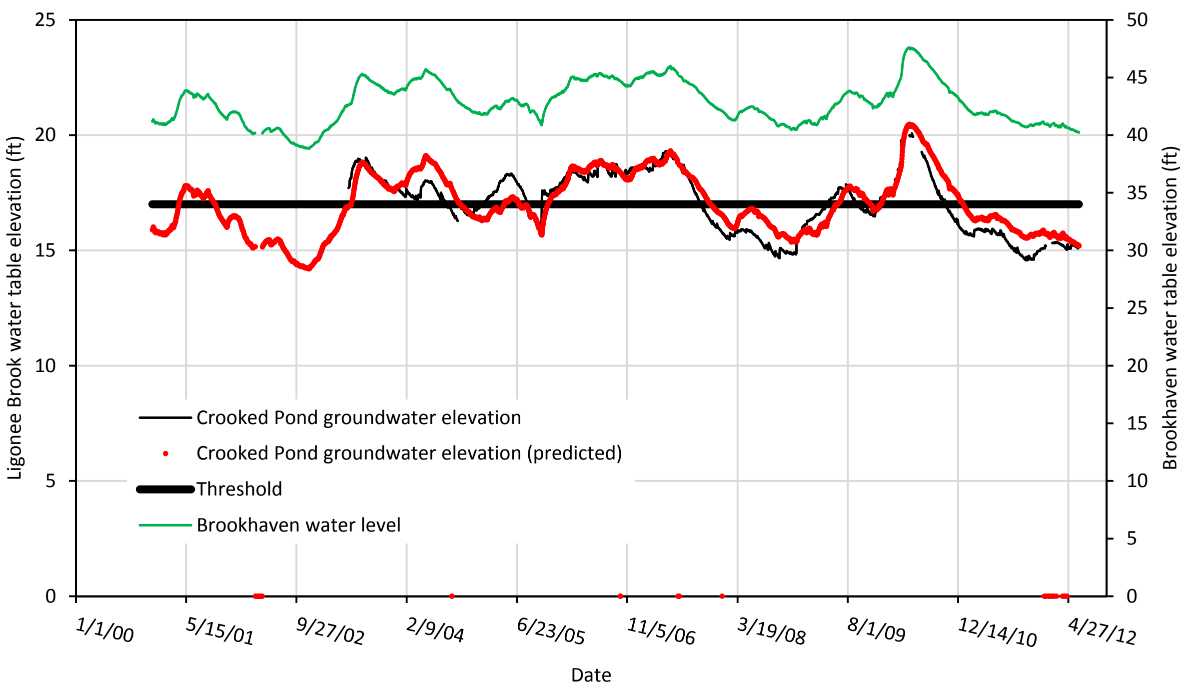


Figure 16: Groundwater table elevations at the Crooked Pond USGS gage 405756072173502. Water levels generally correlate with Ligonee Brook flow presence at a minimum threshold elevation of 17 ft.

The gage extension results indicate non-stationarity, meaning average conditions vary from year to year. This pattern is due to larger decadal scale atmospheric oscillations and climate change. Between 1948 and 1964 high water table elevations are evident (Figure 18). In 1964, groundwater levels dropped during the drought of the 1960s induced by drier conditions brought on by the North Atlantic Oscillation atmospheric circulation pattern (Bradbury et al., 2002). Since this time, groundwater elevations have been steadily increasing. The trend of increasing groundwater recharge and water table elevations also reflects a pattern found elsewhere in the Northeastern United States. Hodgkins and Dudley (2011) found an average increase in summer stream base flows of 20% in western New England between 1950 and 2006.

Tabulating the dates where the groundwater elevation exceeded 17 ft results in predicted water presence at least 50% of the time since 1948 (Table 10). Nevertheless, spring flow conditions are most critical for alewives as this is the time that they migrate upstream. For this analysis we assumed the migration period to occur during April and May of each year. Investigating this critical period, water was present in the stream 40% of the years since 1948. Thus in 4 out of 10 years, water can be expected in the brook during the spring adult migration.

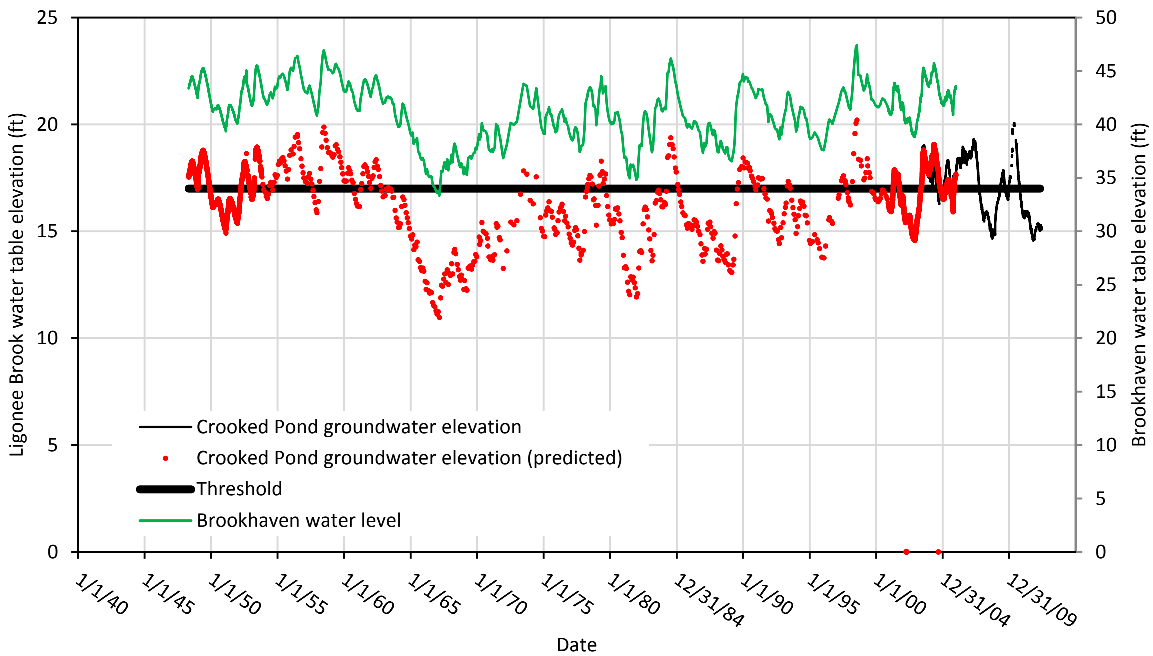


Figure 17: Groundwater table elevations at the Crooked Pond gage (USGS 405756072173502) using the MOVE.2 gaging record extension method. Groundwater levels were high between 1948 and 1964 then dropped significantly. From 1964, groundwater levels have generally been increasing.

Table 9: Exceedance periods for groundwater table elevations at Crooked Pond (USGS gage 405756072173502). Water typically flows in Ligonee Brook when Crooked Pond groundwater levels reach an elevation of 17 ft.

% time exceeded	95	90	80	70	60	50	40	30	20	10	5
Elevation (ft)	15.21	15.46	15.79	16.29	16.53	16.92	17.40	17.78	18.40	18.75	18.99

Anecdotal evidence of seasonal stream flow in Ligonee Brook for the last twenty years has been compiled in the "Photographic evidence of water level and flow in Ligonee Brook and Long Pond 1991 – Presented by Jean Held. The brook was dry during the drought of 1995 and again during the drought years between 1999 and 2002. The first decade of the 21st century experienced greater than average precipitation and higher lake levels with continuous flow in Ligonee Brook. Analysis of these anecdotal records indicate that 1991 through 2011 had more frequent spring flow for adult alewives, thirteen out of twenty years, than the long-term average of four out of ten years. However, sufficient flow in autumn for out-migrating juvenile alewives was also present in only eight of these thirteen years (Figure 19).

	1991	1993	1994	1995	1996
Spring	FLOW	FLOW	FLOW	DRY	DRY
Fall	DRY	DRY	DRY	DRY	FLOW
	1997	**1998**	**1999**	**2000**	**2001**
Spring	FLOW	FLOW	DRY	DRY	DRY
Fall	DRY	FLOW	DRY	DRY	DRY
	2002	**2003**	**2004**	**2005**	**2006**
Spring	DRY	FLOW	FLOW	FLOW	FLOW
Fall	DRY	FLOW	FLOW	FLOW	FLOW
	2007	**2008**	**2009**	**2010**	**2011**
Spring	FLOW	DRY	FLOW	FLOW	FLOW
Fall	FLOW	DRY	FLOW	FLOW	DRY

** 8 Successful years in 20 for alewife spawning

Figure 18: Summary of seasonal flow in Ligonee Brook from "Photographic evidence of water level and flow in Ligonee Brook and Long Pond 1991 – Present, compiled by Jean Held. Yellow circles indicate years where Ligonee flows for both the adult in-migration and the juvenile out-migration.

4.3 Fish Passage and Stream Continuity

Based on actual observations of migrating alewives, Ligonee Brook does not include any barriers that prohibit fish from reaching Long Pond under ideal flow conditions. However, several crossings severely limit natural stream continuity and should be improved immediately or replaced once their service life has been exceeded. Table 11 below includes a summary of each barrier. Photos of each are included in Appendix D and potential solutions are included in Appendix A. High quality oak woodlands are located adjacent to most of these crossings and clearing of native vegetation and ground disturbance can be minimized during implementation of any potential solutions. Each of the potential barriers are accessible from the existing trails within Town of Southampton park lands or existing paved road surfaces. Construction equipment and placement of staging materials can be limited to the existing trail and road surfaces to the maximum extent practical.

Table 10: Summary of stream crossings on Ligonee Brook (See Appendix A Drawings)

Crossing	Alewife Barrier	Stream Continuity Barrier	Cost	Description
Brick Kiln Rd	No	Yes	$$	- Downstream side is a poured square culvert 2'x2' - Connects to 18" pipe in middle of road with a dog leg to upstream side *Recommendation:* replace with pipe arch or wider rectangular box when need arises
Bridgehampton-Sag Harbor Turnpike	No	Yes	$$$	- Downstream side is twin 30" pipes, filled about 1/3 with sediment - Transition into stormwater basin between 2 roads - Upstream from stormwater basin is 2'x5' box in good condition *Recommendation:* replace lower pipes and basin with pipe arch or wider rectangular box when need arises. Consider complete removal of Old Turnpike. crossing.
Old RR Xing	Partial	Yes	$	- 2' diameter cast iron pipe - Alewife were seen passing this pipe in previous years, though were congregated on the downstream side due to the difficult conditions *Recommendation:* remove and replace immediately with a small pedestrian bridge
Old Dam	No	Partial	$	- Old dam, in channel creates an unnatural condition *Recommendation:* remove or reroute stream around dam if historic structure
Pedestrian Trail	Partial	Yes	$	- 2' diameter cast iron pipe, ½ filled with sand *Recommendation:* remove, replace with bridge (only necessary when flowing)
$ = <$5K $$ = $5K-$30K $$$ = >$30K				*see Table 3 above for culvert cost options

4.4 Other Options for Alewife Spawning

The presence or absence of water within Ligonee Brook is the limiting factor to alewife and eel access to Long Pond. Review of historical groundwater data indicates that since 1948 adequate water levels are present for the spring alewife run in 4 out of 10 years. It may be possible to alter the elevation of Ligonee Brook along the entire length to ensure a constant or near constant flow of groundwater in the channel all the way to Long Pond. Alternatively, a highly managed outlet structure at Long Pond could be installed to supply water to the brook at critical times. Both options would potentially alter the hydrology of Long Pond. The substantial plant diversity of Long Pond, and other coastal plain ponds, results from natural fluctuations in groundwater elevation. Thus, any potential fish passage or stream channel improvements in Ligonee Brook must not affect the hydrology of Long Pond in order to maintain its plant diversity. Accordingly, options to alter the elevation of Ligonee Brook or manage the discharge of water from Long Pond were considered unrealistic and not investigated.

The summer of 2012 was extremely dry within the Sag Harbor area. During the survey of Ligonee Brook, water was noted in the channel up to the Turnpike, above which the channel was dry. Digging into the bed of the channel, water was discovered within several feet of the surface just above the Turnpike and again just above the railroad trail crossing. The profile of the stream also indicates the section below the Turnpike is markedly lower in elevation than upstream of the Turnpike with a distinct topographic break apparent at the Turnpike crossing (Figure 20). In addition, the stream reach just downstream of the Turnpike is lower in elevation relative to the outlet at Sag Harbor Cove

Given that alewives are pond spawners and that adequate flow in Ligonee Brook is inconsistent, other potential options for increasing alewife populations in Ligonee Brook were evaluated. The construction of pond habitat in the lower sections of Ligonee Brook presented an option that seemed in-line with reasonable goals for the project. Two locations were noted, shown in detail in Appendix A.

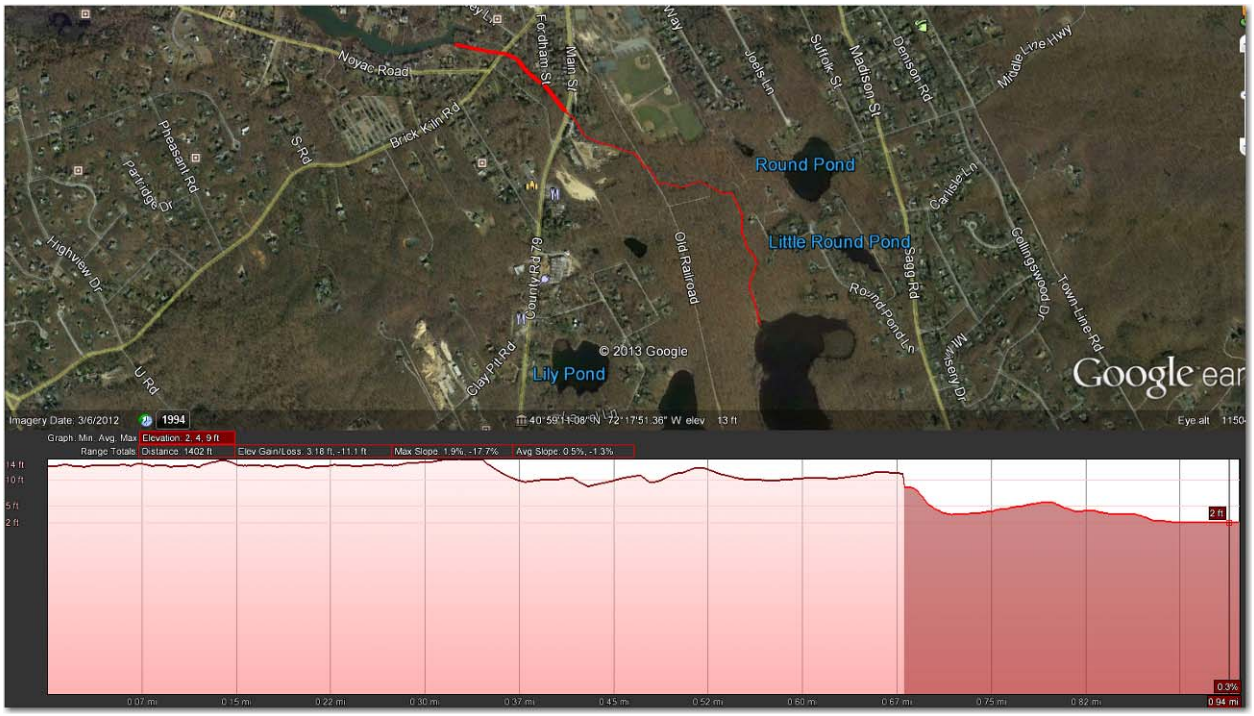


Figure 19: The lower section of Ligonee Brook (below Bridgehampton-Sag Harbor Turnpiket) exhibits lower elevation than the sections above.

The first site (Potential Spawning Pond A) is located just below the Main St crossing on property owned by the Sag Harbor Antique Fire Truck, Inc. (SHAFT). This entity was not approached about any aspect of this project, but has pursued the construction of a museum for historic fire trucks (Menu, 2011). The location of the property downstream of the Turnpike provides a higher degree of confidence that the pond will maintain a water level sufficient for alewife spawning. As drawn in Appendix A, the pond is 0.67 acres but could be expanded or contracted slightly within the constraints of willing property owners (See Exhibit 8 in Appendix A). The second site (Potential Spawning Pond B) is located within Mashashimuet Park, upstream of the Turnpike. This site is owned in part by the Mashashimuet Parks and Recreation Association and in part by the Town of Southampton. Though the site grade is above the natural topographic break noted in Figure 20 above, groundwater was found several feet below the surface. Spawning Pond B is drawn at 2.6 acres, taking advantage of the ample space within the publically-owned parklands (See Exhibit 9 in Appendix A). Both spawning ponds could be created to provide 2-3 feet of water. Shading from perimeter trees may not be as critical in the larger pond in Mashashimuet Park, though depth below the existing surface may have to be extended to ensure connection with groundwater. To allow fish to reach this location, additional modifications to the channel between here and the section below the Turnpike would be required.

Restoration projects aimed at increasing alewife populations have focused on removal of barriers to migration rather than restoration or creation of spawning and rearing habitats. As a result, little information is available on the specific requirements for optimal alewife spawning conditions. Researchers know they utilize a wide range of still freshwater habitats with a variety of substrates for spawning and their young are planktivorous within the pond until out-migrating in the fall. Design of a spawning habitat for alewives should be supported by preceding field research and observation of productive spawning habitats on Long Island and consultation with experienced local fisheries biologists. It is critical that a spawning pond be of a size to allow sufficient sunlight through summer to support primary production, and a depth to allow the development of natural aquatic vegetation and phyto- and zooplankton assemblages within the constructed pond. As a result, management of forest trees near the edge of the pond may be necessary to ensure ample sunlight. The depth of the pond would be excavated at or beyond a yet-to-be-determined minimum depth to ensure a groundwater connection even in dry periods.

Considering the significant declines in alewife populations in the eastern United States (Limburg and Waldman, 2009) and loss of historic spawning habitats due to filling, degradation, or passage barriers, it is reasonable to consider the feasibility of restoring or creating alewife spawning habitats in stream systems with known history of returning spawning adults.

The costs and critical elements associated with implementing the design and construction of a spawning pond would be straightforward and are noted below (Table 12). Costs assume an unusually large unit price for excavation – indicated to be typical on Long Island. If these unit prices can be decreased, significant savings can be expected. Critical elements of the project to consider would be:

- *Land Acquisition* – Potential Spawning Pond A is located on private property below Bridgehampton-Sag Harbor Turnpike and would require acquisition of property. Understanding the goals of SHAFT may open opportunities to trade property elsewhere that would be better suited to their goals. An integrated design of a museum and pond may be possible as well. Negotiations with private landowners of the channel segment between the Turnpike and the pond would be required as well. Potential Spawning Pond B is located on land controlled by the non-profit Mashashimuet Parks and Recreation Association and the Town of Southampton and would require negotiations and approval with these agencies.
- *Investigation of Existing Spawning Habitats* – during the design phase at least 2 other ponds of similar size known to be used for successful spawning should be investigated
- *Groundwater Study* – for a period of at least 1 year, install piezometer wells with monitors of water level to guide design for pond depth and elevation
- *Access to the Pond* – ensure crossings and channel improvements (if pursuing the pond above the Turnpike) are made to ensure ease of fish access to constructed pond
- *Public Involvement* – the design would be a community feature and should be implemented with community input where needed and at a minimum education and updates on project goals and progress

Table 11: Summary of Costs and Concerns for Construction of Alewife Spawning Ponds

Pond Location	Design Cost	Construction Cost	Notes
Below Bridgehampton-Sag Harbor Turnpike	$50K-100K	$300K -$400K	- Assumes about 10-15K CY of Excavation hauled off at $40/CY - Does not include property acquisition, if needed - Does not include improvements to Brick Kiln Road
Above Bridgehampton-Sag Habor Turnpike	$75K-125K	$800K - $1.1M	- Assumes about 35-45K CY of Excavation hauled off at $30/CY (economy of scale) - Assumes 800 LF Channel Work at $100/LF - Does not include property acquisition - Does not include improvements to Turnpike crossing or channel between Turnpike and pond

4.5 Environmental Permitting

Modification of existing culverts along Ligonee Brook to improve fish passage opportunities and/or creation of new alewife spawning habitats would require the following environmental permits:

- United States Army Corps of Engineers:
  - Section 404 of Clean Water Act
- New York State Department of Environmental Conservation:
  - Article 24 (Freshwater Wetlands)
  - Article 15 (Protection of Waters)
- New York State Department of State, Division of Communities and Waterfronts:
  - Consistency Determination under Coastal Zone Management Act
- New York State Department of Transportation:
- New York State Office of Parks, Recreation, and Historic Preservation:
  - Review under NYS Historic Preservation Act of 1980 (Section 14.09)
- Town of Southampton:
  - Southampton Town Trustees
  - Southampton Conservation Board
- Village of Sag Harbor:
  - Wetlands
  - Building Construction
  - Board of Historic Preservation and Architectural Review

4.6 Endangered and Threatened Species

The Long Pond Greenbelt is listed as a Significant Coastal Fish and Wildlife Habitat by the New York State Department of State-Division of Coastal Resources (NYSDOS, 2005). The New York State Natural Heritage Program lists 20 species of rare and protected wildlife and plants found in or in the vicinity of Ligonee Brook and Long Pond. The potential presence for these species to be found at potential work sites in the stream or adjacent woodlands or wetlands is discussed below.

Tiger Salamander (*Ambystoma tigrinum*), NYS-Endangered

The NYSDEC Bureau of Wildlife was contacted to determine the location of known tiger salamander habitat relative to the potential Ligonee Brook work sites. Potential improvements to the culverts in Ligonee Brook are not likely to involve disturbance or excavation in natural habitats and equipment and materials can be staged on the existing trails. Accordingly, the potential to impact tiger salamander habitat is minimal. However, several known tiger salamander habitats are within 1,000 feet from Ligonee Brook (Kelly Hamilton and Michelle Gibbons- NYSDEC Bureau of Wildlife, pers. comm.). Potential Spawning Pond B would require clearing of several acres of upland forest within 1,000 feet of known tiger salamander breeding ponds. Accordingly, in both cases, environmental permitting review by the NYSDEC and Town of Southampton would need to consider the impacts to tiger salamanders and their habitat.

Coastal oak-heath forest

Coastal oak-heath forests are listed as a significant natural community by the New York Natural Heritage Program. This forest community is characterized as apparently secure globally (G4) and S3 in New York State indicating that this community is known to occur at only 21-100 locations statewide. The majority of the upland forest located to the south of the old railroad easement crossing consists of coastal oak-heath forest. Potential improvements to the culverts at Ligonee are not likely to involve disturbance, clearing, or excavation in these oak forests and equipment and materials can be staged on the existing trails. Accordingly, potential impacts to the surrounding oak forest can be minimized by restriction of equipment access routes, work areas, and staging areas. Potential Spawning Pond B would require clearing of several acres of upland oak-heath forest. In this case, regulatory agencies (i.e. the NYSDEC and Town of Southampton) would need to concur that the provision of alewife spawning habitats and increases to alewife stocks would provide sufficient ecological benefits to warrant the destruction of several acres of coastal oak-heath forest.

Tiger Beetle (*Cicindela patruela consentanea*), NYS-Unlisted

This rare beetle species is historically known from eastern Long Island with a report from the Sag Harbor area in 1932. This tiger beetle is closely associated with high-quality pine-oak barrens. The ecological community surrounding the work sites is coastal oak-heath, rather than pine-oak woodlands and barrens. The project site is not expected to provide habitat for this rare species and, therefore, this species is not likely to be adversely impacted by any fish passage improvements.

Endangered, Threatened, or Rare Plants

A number of rare plant species may inhabit sandy openings in the dry oak forests on the Long Pond Greenbelt. For example, the Velvety Bush-clover (*Lespedeza stuevei*, NYS-Threatened) is found in dry woodlands and openings and roadsides in oak forests. This species is known to occur in the Long Pond Greenbelt and a 1925 record from the NYNHP lists this species as occurring on a “dry railroad bank” near Long Pond. Similarly, Small White Snakeoot (*Argeratina aromatica var. aromatica*; NYS Endangered), Flax-leaved whitetop (*Sericarpus linifolius*), Tiny Blue-curls (*Trichostema setaceum*), Silvery Aster (*Symphyotrichum concolor* var *concolor*), Cut-leaved Evening-Primrose (Oenothera laciniata; NYS Endangered), Southern yellow flax (*Linum medium* var *texanum* ; NYS-Threatened), and slender crabgrass (*Digiteria filiformis,* NYS-Rare) are listed as potentially occurring in the dry woodlands of the Long Pond Greenbelt by the New York Natural Heritage Program and the US Fish and Wildlife Service.

Clearly, suitable habitat for these species exists in the vicinity of the potential project sites. For some of these species, the margins of the roadway, fire breaks, and railroad easement may provide habitat. Accordingly, for potential work at the upper three culverts, the work areas should be of minimal size possible and a survey for these species should be conducted prior to commencement of construction.

Coastal plain pondshores within the Long Pond Greenbelt are habitat for a number of rare and state-listed plant species according guidance documents and databases provided by the New York Natural Heritage Program (NYNHP, 2012), the United State Fish and Wildlife Service, and the Town of Southampton. Rare plants species that may occur on the upper margins of coastal plain ponds, such as Long Pond, include:

Carolina Redroot (Lachnanthes caroliniana), NYS-Endangered
Drowned Beakrush (*Rynchospora inundata*), NYS-Threatened
Short-beaked Beakrush (*Rynchospora nitens*), NYS-Threatened
Orange-fringed Orchid (Platanthera ciliaris), NYS-Endangered
Crested-fringed Orchid (Platanthera cristata), NYS-Endangered
Creeping St. Johnswort (*Hypericum adpressum*), NYS-Endangered
Golden Dock (*Rumex fuegnis*), NYS-Endangered
Water Pennywort (Hydrocotyle *verticillata*), NYS-Endangered
Pygmyweed (*Tillaea aquatica*), NYS-Endangered
Knotted Spikerush (*Eleocharis equisetoides*), NYS-Threatened
Long-tuberculed Spikerush (*Eleocharis tuberculosa*), NYS-Threatened
Round-fruited Ludwigia (*Ludwigia spaerocarpa*), NYS-Rare
Rose Tickseed (*Coreopsis rosea*), NYS-Rare
Wafer Ash (*Ptelea trifoliata*), NYS-Rare

The diverse plant communities of the shorelines of coastal plain ponds are dependent on seasonal and annual variation in water level driven by fluctuating groundwater levels. No alteration of Long Pond's shoreline or hydrology, excavation, or ground disturbance is proposed to provide improved alewife passage. Accordingly, no impacts to this sensitive community or its rare species are expected. However, any disturbance to the emergent marsh and sandy shoreline present along the northwestern shoreline of Long Pond would need to consider potential impacts to the plants which inhabit the coastal plain pondshore.

4.7 Ecological Considerations for Alewife Passage to Long Pond

Ligonee Brook is an artificial water body constructed at least 140 years ago to connect Long Pond with Sag Harbor Cove for unknown purposes. Although historic records indicate that alewives have migrated to and spawned in Long Pond for at least a century, Ligonee Brook's alewife run is unnatural. Accordingly, it is necessary to consider the potential for ***adverse*** impacts to the existing Long Pond community that may potentially result from improved alewife access to Long Pond and increased abundance of alewife spawning in Long Pond. This is especially important considering Long Pond's designation as a Significant Coastal Fish and Wildlife Habitat and its position within the Long Pond Greenbelt.

Alewives have resulted in adverse ecological impacts in landlocked lakes in and near the Great Lakes by reducing zooplankton abundance and by causing thiamin deficiency and reproductive failure in trout and salmon. In the St. Croix River watershed in Maine, there was concern that the re-introduction of anadromous alewives in 1981 resulted in decreased smallmouth bass population in Spednic Lake, as result of predation of juvenile bass by adult alewives and competition between juvenile alewives and juvenile bass for food resources. Recent studies have concluded that there are no adverse impacts of alewives on smallmouth bass populations in the river (Willis, 2006). Other studies have found that Connecticut lakes with landlocked alewife populations have reduced abundance of common zooplankton (i.e. *Daphnia*), smaller bodied zooplankton, and greater phytoplankton abundance than lakes with anadromous alewives or no alewives (Palkovacs and Post, 2008). Anadromous and landlocked alewives have different impacts on zooplankton and phytoplankton communities. Anadromous alewives feed heavily on seasonally abundant zooplankton during the spring and summer, the adult and juvenile alewives migrate from the lakes allowing zooplankton populations to rebound. In contrast, landlocked alewives feed year-round on zooplankton resulting in consistently low zooplankton populations. The reduced zooplankton populations results in decreased grazing pressure on phytoplankton resulting in higher phytoplankton abundance in lakes with landlocked alewives, in essence upsetting the food web balance within the lake.

Landlocked populations of alewives in the Northeastern United States have been attributed to 19th century canal construction, colonial dam building, and unintended stocking of landlocked fish into additional lake systems (Scott and Crossman, 1973; Palkovacs et al. 2008). Considering the potential effects of landlocked alewives on zooplankton and phytoplankton communities in lakes, it is prudent to consider if increased access for anadromous alewives would increase the likelihood of a landlocked population becoming established in Long Pond. Unfortunately, there is little scientific literature available to address this concern.

Adult anadromous alewives often spawn several weeks after migrating into fresh waters when water temperatures reach 10 to 22 ºC (Mather et al., 2012) and return to salt waters after spawning. Juvenile alewives migrate out of their natal streams and lakes between June and December in response to low water temperature, increased stream discharge, and rainfall events (Iafrate and Oliveira, 2006; Gahagan et al. 2010). The out-migration of adults and juveniles are physiologically programmed behaviors and, therefore, the establishment of a landlocked alewife population in Long Pond is contradictory to the biological nature of these anadromous alewives. Furthermore, the limited number of fisheries studies of Long Pond including surveys in the 1930s by the New York Conservation Department and a 2008 survey by Norman Soule found no evidence of a landlocked population of alewives in Long Pond (Soule 2008). Considering long history of alewife migration to and spawning in Long Pond, it seems that if Long Pond was conducive for the establishment of a landlocked alewife population it may have occurred already. Furthermore, a landlocked population of alewives has not established in nearby Big Fresh Pond in Southampton which has consistently supported one of the largest alewife runs on Long Island. As described previously, there are no complete barriers to fish passage along Ligonee Brook and only the old railroad crossing acts as a partial passage barrier. Therefore, it seems reasonable to conclude that the potential removal of the partial barrier at the old railroad crossing and modification of other crossings would slightly increase the possibility of a landlocked alewife population establishing in Long Pond.

4.8 Recommendations – Ligonee Brook

Ligonee Brook lacks a consistent source of water to develop into a robust spawning stream for alewife. It doesn't appear that any anthropogenic reasons exist for this hydrologic regime, therefore Ligonee follows the natural cycle of wet and dry years specific to the micro-climate of eastern Long Island. When water allows access, alewives have the ability to reach Long Pond to spawn. This journey could be made easier with improvements to crossings noted above, but is occurring under current conditions when flows permit. During years when flows do not permit access to Long Pond, roughly 6 in every 10 years, the options for providing spawning in a lower portion of the Brook have been brought forward. Of these, the lower pond below the Turnpike may present a lower cost and higher potential for success than the one above the Turnpike. However, this lower spawning pond site is located on private property and agreements would be necessary with current property owners. Significant risk is associated with implementing any solution that relies on man-made, constructed structures to provide natural function. However, with careful consideration and design, a functioning alewife spawning area may be feasible and the depleted status of alewife populations on Long Island and throughout the eastern United States may justify such an endeavor.

5 Moore's Drain

5.1 Overview

Silver Lake lies at the head of the 1.7 mile length of Moore's Drain. Moore's Drain is an artificial channel, dug by hand in 1889 to reduce flooding within Greenport. Known as Moore's Folly – as it did little to reduce flooding, the drain has never been used by migrating alewife or eel. A paucity of anecdotal accounts of dead alewife exist; 3 fish in 1960 and one in 1976, encompassing the whole of the record for the drain. The stream is shallow (typically 1-2' in depth) with nearly imperceptible flow and is largely contained within a steeply banked channel approximately 10-20' in width. Between Route 25 and Moore's Lane, the stream flows though Moore's Woods which is composed of high quality, mature oak-tulip forests and forested wetlands. Moore's Drain, its surrounding wetlands, and Moore's Woods encompass ~300 acres consisting largely of protected lands owned by the Village of Greenport. Moore's Drain and Moore's Woods are listed as a Significant Coastal Fish and Wildlife Habitat by the New York State Department of State-Division of Coastal Resources (NYSDOS, 2005).

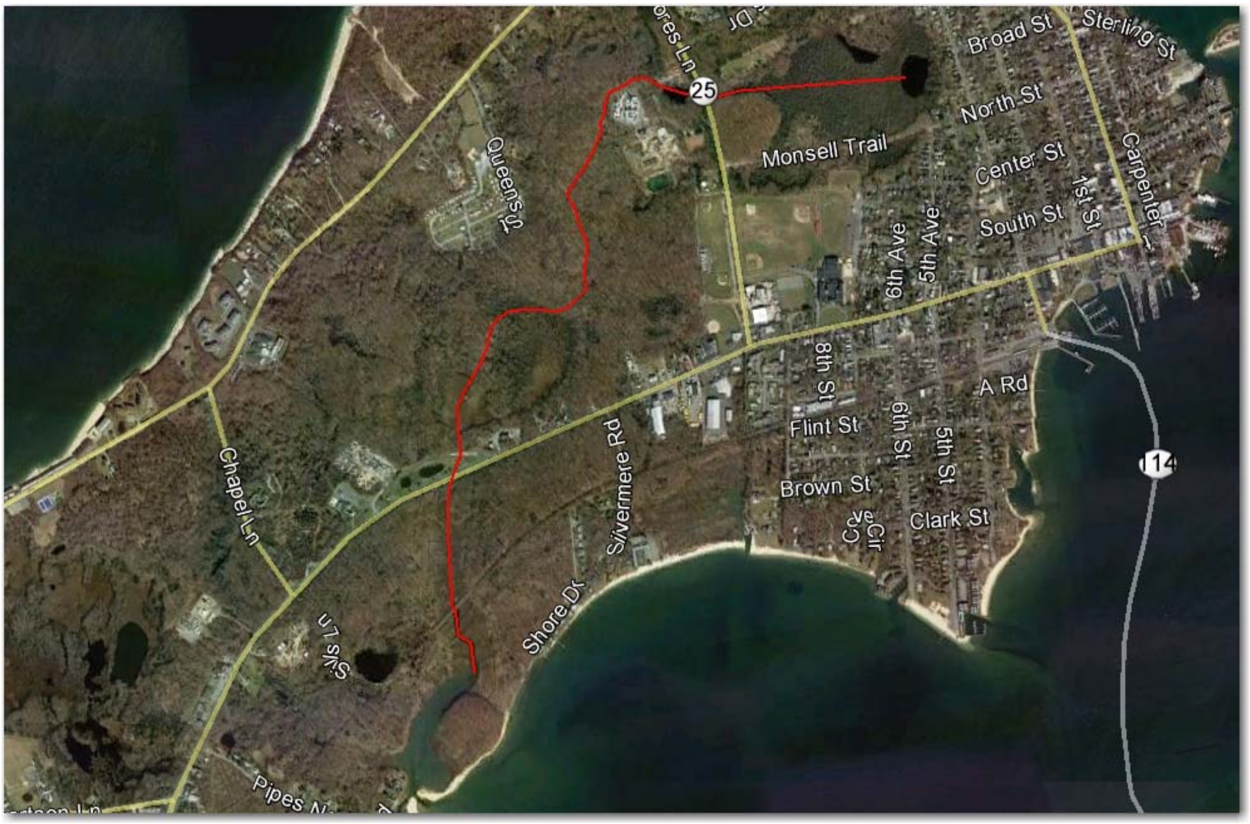


Figure 20: Moore's Drain located just west of Greenport

5.2 Hydrology

Moore's Drain is constrained by the presence/absence of water in the stream. Little data was available to analyze the frequency of flow presence, though all accounts indicate that flow occurs only during significant rain events. One USGS groundwater elevation gage (410634072223601) is located 1300 ft to the north of the drain. However, only two observations of alewife presence were available to correlate to groundwater elevations, both of which were prior to the installation of the gage. To circumvent this problem, another USGS groundwater elevation gage (410858072171501) was found just east of Greenport near Orient. This data was correlated with the gage adjacent to Moore's Drain.

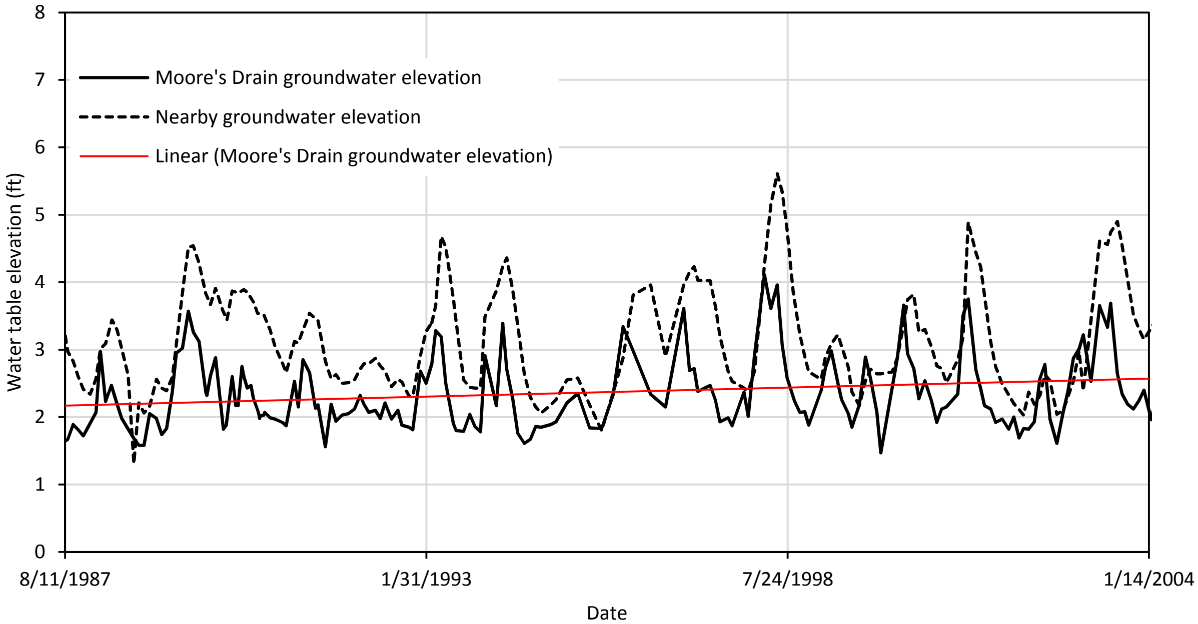


Figure 21: Comparison of groundwater elevations at the gage adjacent to Moore's Drain (USGS 410634072223601) and the nearby gage (USGS 4108580721).

In 1960 three dead alewives were found along the streambanks and in 1976 one was found. Water level measurements were taken on 11 dates in 1960 and 4 dates in 1976. In 1960, the average of the water level measurements was 2.58 ft, while in 1974 the average was 3.00. Assuming that 2.58 feet is the threshold for water flow in the drain, then all groundwater levels at or above this level should permit fish passage. In spring 2012, however, water levels average 3.61 ft and no water was observed flowing through the drain. Consequently, it is doubtful that groundwater elevations ever reach an elevation to permit continual water flow adequate for fish passage. Moreover, a general linear trendline fit through the data at the nearby groundwater gage indicates that water levels have generally been rising since 1958. This trend is also reflected in the gage adjacent to Moore's Drain. Given this trend and the continued lack of both flow and use by alewife, it appears the drain will remain an artificial conduit for surface water runoff.

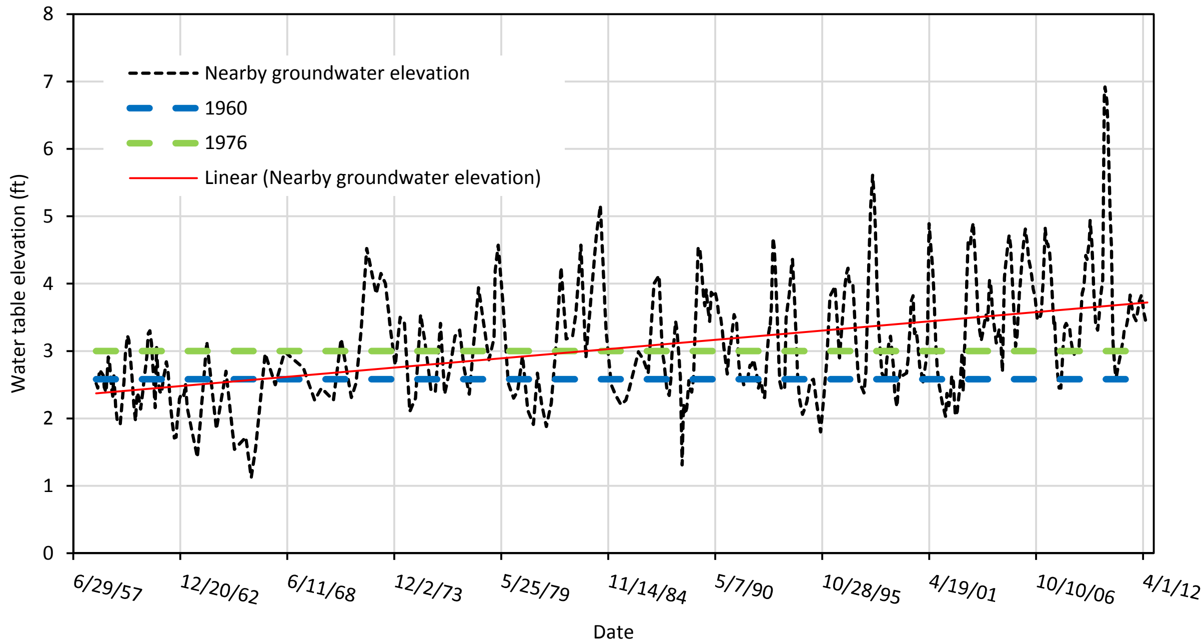


Figure 22: Groundwater elevation at a nearby USGS gage (410858072171501). The 1960 line pertains to the average groundwater elevation that year when three dead alewives were found along the stream bank. The 1976 line pertains to the average groundwater elevation that year when one dead alewife was found along the stream bank.

5.3 Fish Passage and Stream Connectivity

Moore's Drain does not include any barriers until the upper stretch at the Moores Lane crossing where a squashed culvert is choked with debris. Fish access through the tidal wetlands and into the *Phragmites* marsh upstream of Route 25 appears good, with only the Old Route 25 crossing creating a challenge. Table 14 below includes a summary of each barrier.

Given the lack of flowing water in Moore's Drain, fish access above and through Moore's Woods should not be considered. Habitat potential and passage for other aquatic (i.e. amphibians) and terrestrial species could be improved by removing or repairing the stream culverts at Old Main Road and Moores Lane. Photos of each crossing are included in Appendix E and potential solutions are included in Appendix A

Table 12: Summary of stream crossings on Moore's Drain. Detailed maps are included in Appendix A.

Crossing	Alewife Barrier	Stream Continuity Barrier	Cost	Description
RR Crossing	No	Partial	N/A	- Two 30" concrete pipes, control tidal influences upstream *Recommendation:* None – salt marsh upstream is in good condition
RT 25	No	No	N/A	- Concrete pipe arch 3.5'Rise 7' Span *Recommendation:* None
Old RT 25	No	Yes	$	- 2' square poured concrete *Recommendation:* Remove Crossing
Old Farm Crossing	No	No	N/A	- Brick arch 3.5' Rise, 9'Span *Recommendation* : None
Municipal Pond	No	No	N/A	- 5.5' square culvert – unknown hydraulic control *Recommendation* : None
RT 25 Truck Route	Yes	Yes	$$$	- Sliplined 1.7' diameter HDPE, blocked with debris *Recommendation* : If desired, replace with pipe arch or buried box culvert
$ = <$5K $$ = $5K-$30K $$$ = >$30K *see Table 3 above for culvert cost options				

5.4 Environmental Permitting

Modification of the existing culverts at Old Route 25 and Moores Lane to improve stream habitat and passage for aquatic species would require the following environmental permits:

- United States Army Corps of Engineers:
  - Section 404 of Clean Water Act
- New York State Department of Environmental Conservation:
  - Article 24 (Freshwater Wetlands)
  - Article 15 (Protection of Waters)
- New York State Department of State, Division of Communities and Waterfronts:
  - Consistency Determination under Coastal Zone Management Act
- New York State Department of Transportation:
- New York State Office of Parks, Recreation, and Historic Preservation:
  - Review under NYS Historic Preservation Act of 1980 (Section 14.09)
- Town of Southold:
  - Southold Town Trustees
- Village of Greenport:
  - Wetlands, Floodplains, and Drainage
  - Building Construction

5.5 Endangered and Threatened Species

The New York State Natural Heritage Program lists over 20 species of rare and protected wildlife and plants found in the woodlands or wetlands adjacent to Moore's Drain including:

Cat-tail Sedge (*Carex typhina*), NYS-Threatened
Swamp cottonwood (*Populus heterophylla*), NYS-Threatened
Cranefly Orchid (*Tipularia discolor*), NYS-Endangered
Northern Cricket Frog (*Acris crepitans*), NYS-Endangered
Tiger Beetle (*Cicindela patruela consentanea*), NYS-Unlisted
Marsh Straw Sedge (*Carex hormathodes*), NYS-Threated
Orange-fringed Orchid (*Platanthera ciliaris*), NYS Endangered
Nuttall's Tick-Trefoil (*Desmodium nuttallii*) and Smooth Tick-Trefoil (*Desmodium laevigatum*), NYS Endangered
Green Parrot's Feather (*Myriophyllum pinnatum*), NYS-Endangered
Cut-leaved Evening-Primrose (*Oenothera laciniata*), NYS-Endangered
Opelousa Smartweed (*Polygonum hydropiperoides* var. opelousa), NYS-Threatened
Swamp Smartweed (*Persicaria setaceum*), NYS-Endangered
Red Pigweed (*Chenopodium rubrum*), NYS-Threatened
Velvet Panic Grass (*Dichanthelium scoparium*), NYS-Endangered
Small-flowered Pearlwort (*Sagina decumbens*), NYS-Endangered
Maryland Milkwort (*Polygala mariana*), Presumed Extirpated

Potential improvements to stream crossings at Old Route 25 and Moores Lane could be accomplished from existing paved and lawn surfaces. Accordingly, no clearing or ground disturbance in natural habitats and no potential impacts to endangered or threatened species in the wetlands or woodlands of Moore's Woods shall occur.

5.6 Recommendations

Due to the lack of flowing water in Moore's Drain and the absence of any natural drainage along this pathway, the attraction of saltwater species to the freshwater outlet of the drain appears unlikely. Significant habitat does exist however within the wetland section below Moore's Woods and in the intertidal area, though not for the species of interest. Moore's Drain should be managed for the unique habitats and faunal assemblages that exist within these two areas but will never be optimal for use by neither migrating alosids nor eels. Recommendations are provided in Table 14 above for stream continuity, should other circumstances require such measures.

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Appendices

Appendix A – Concept Drawings (All Sites)

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Forge Road Dam - Existing Conditions

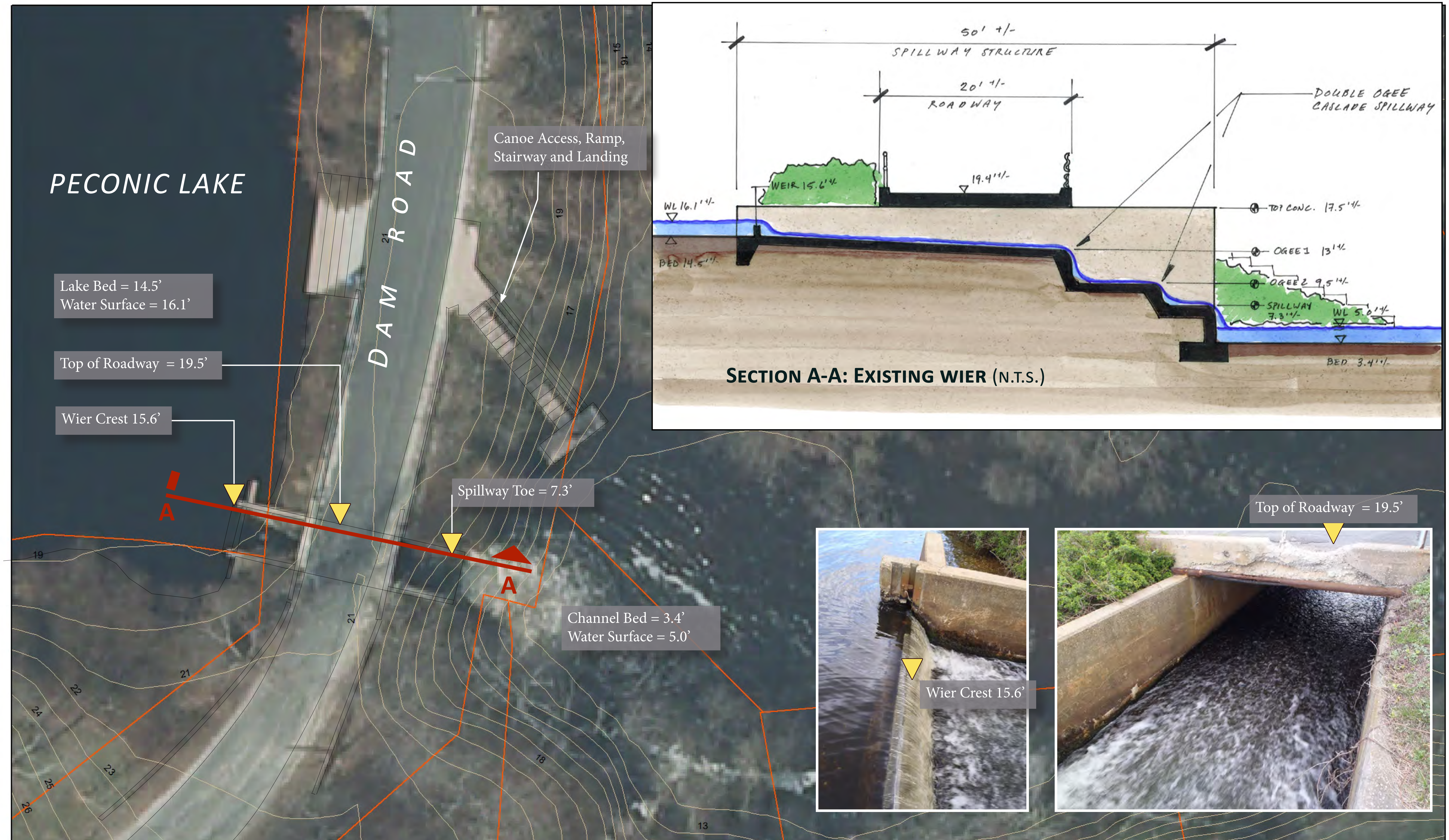
Suffolk County, Long Island, NY

0 50 100 200 ft.

N

February 2013

Exhibit 1



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Forge Road Dam - Existing Conditions

Suffolk County, Long Island, NY

0 10 20 40 ft.

N

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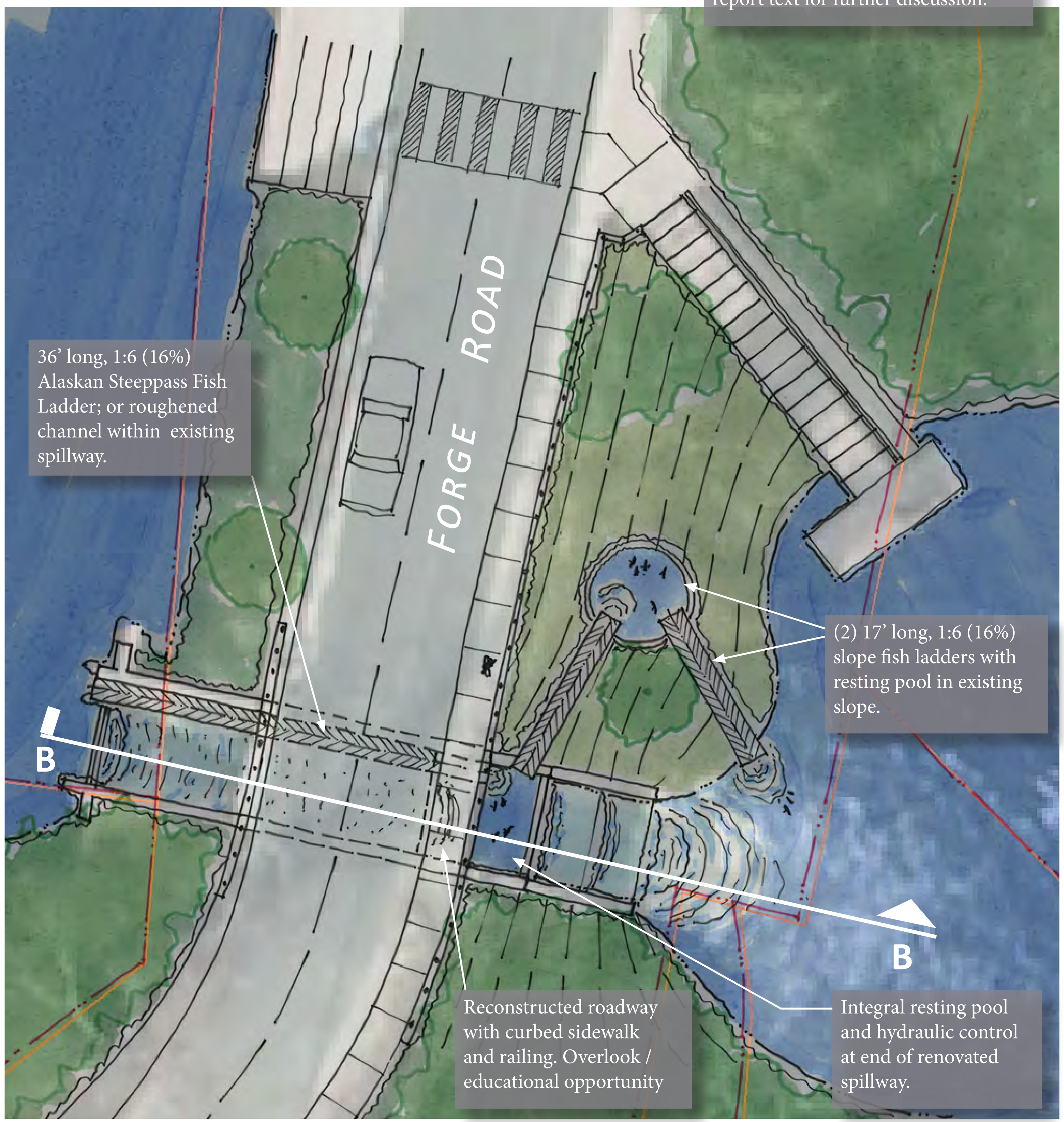
Exhibit 2

Concept plan: Fish ladder with resting pools

Note: Final configuration of fish ladder and renovated / reconstructed spillway to be determined. Refer to report text for further discussion.



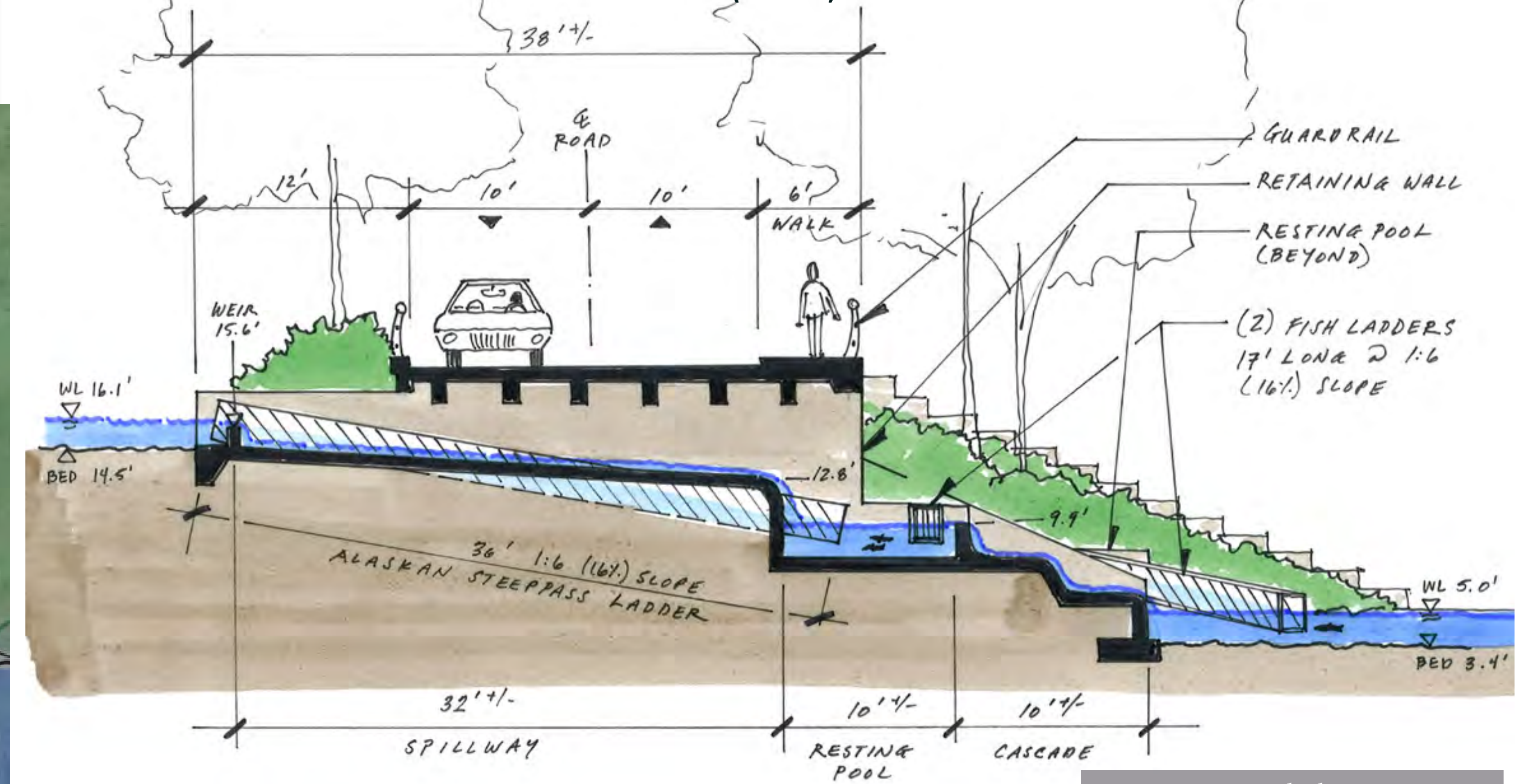
36' long, 1:6 (16%) Alaskan Steeppass Fish Ladder; or roughened channel within existing spillway.

(2) 17' long, 1:6 (16%) slope fish ladders with resting pool in existing slope.

Reconstructed roadway with curbed sidewalk and railing. Overlook / educational opportunity

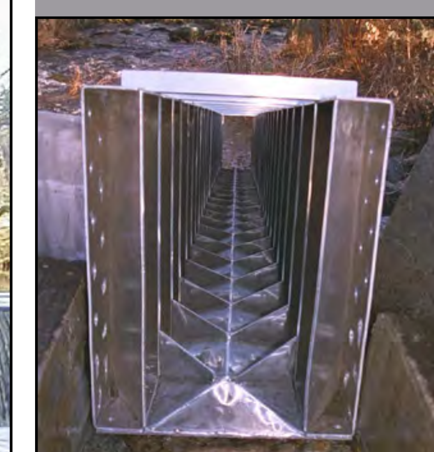
Integral resting pool and hydraulic control at end of renovated spillway.

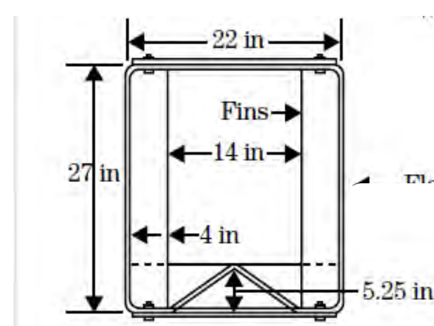
Section B-B: Fish Ladder Spillway (N.T.S.)



Installation of Alaska Steeppass ladder at low-head dam

Cross-section: Alaska Steeppass Ladder





Cross section

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Forge Road Dam - Alternative A
Alaskan Steeppass Fish Ladder

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Suffolk County, Long Island, NY

0 5 10 20 ft.

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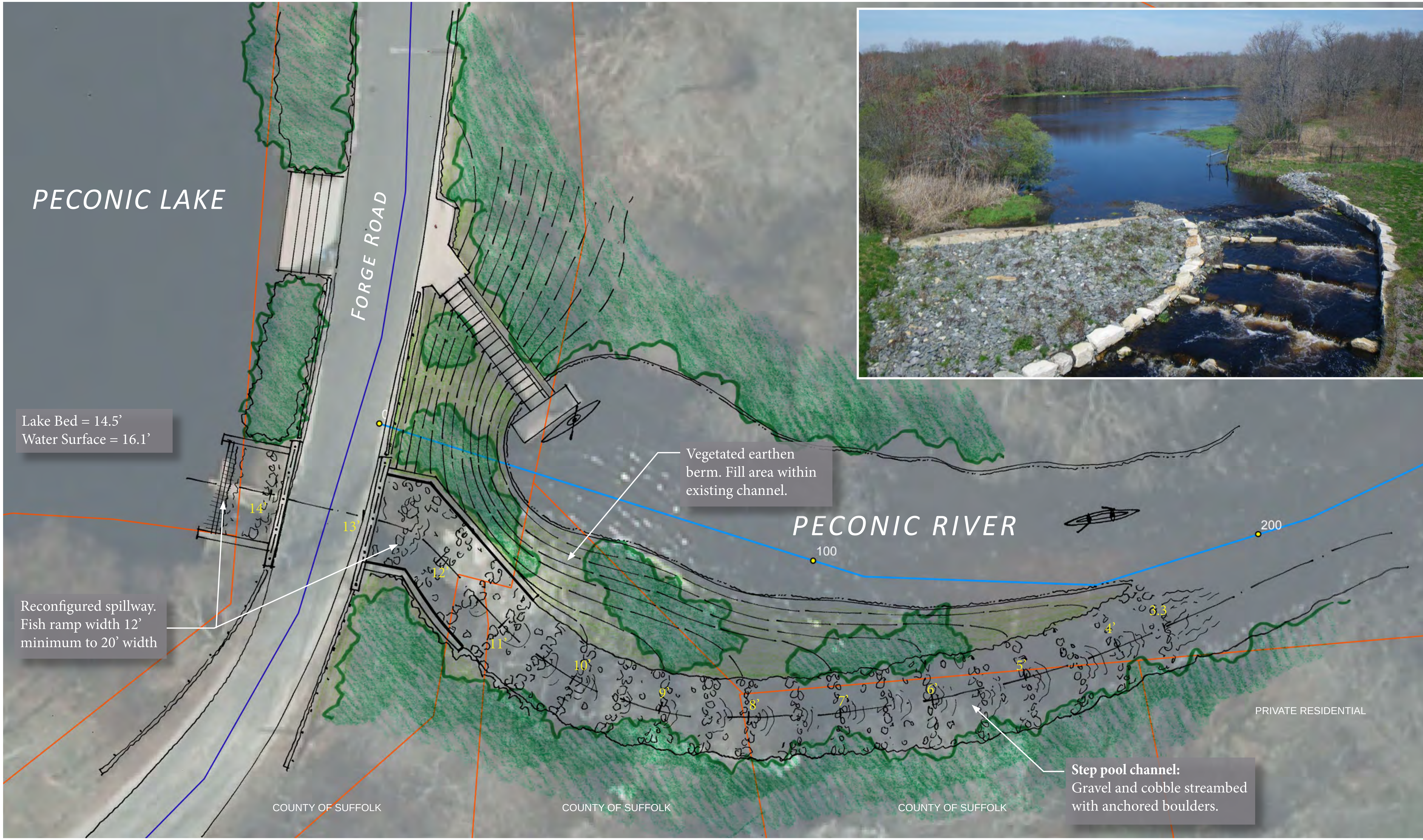
Exhibit 3



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Forge Road Dam - Alternative B
Fish Ramp, Roughened Channel

Suffolk County, Long Island, NY

0 10 20 40 ft.

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Exhibit 4

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Forge Road Dam - Alternative C
By-Pass Channel

Suffolk County, Long Island, NY

0 50 100 200 ft.

N

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Exhibit 5

Peconic Estuary Conceptual Habitat Restoration Design

Ligonee Brook - Stream Crossings Plan

Suffolk County, Long Island, NY

0 225 450 900 ft.

N

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Exhibit 6

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Ligonee Brook - Spawning Pond Plan

Suffolk County, Long Island, NY

0 333 666 ft.

N

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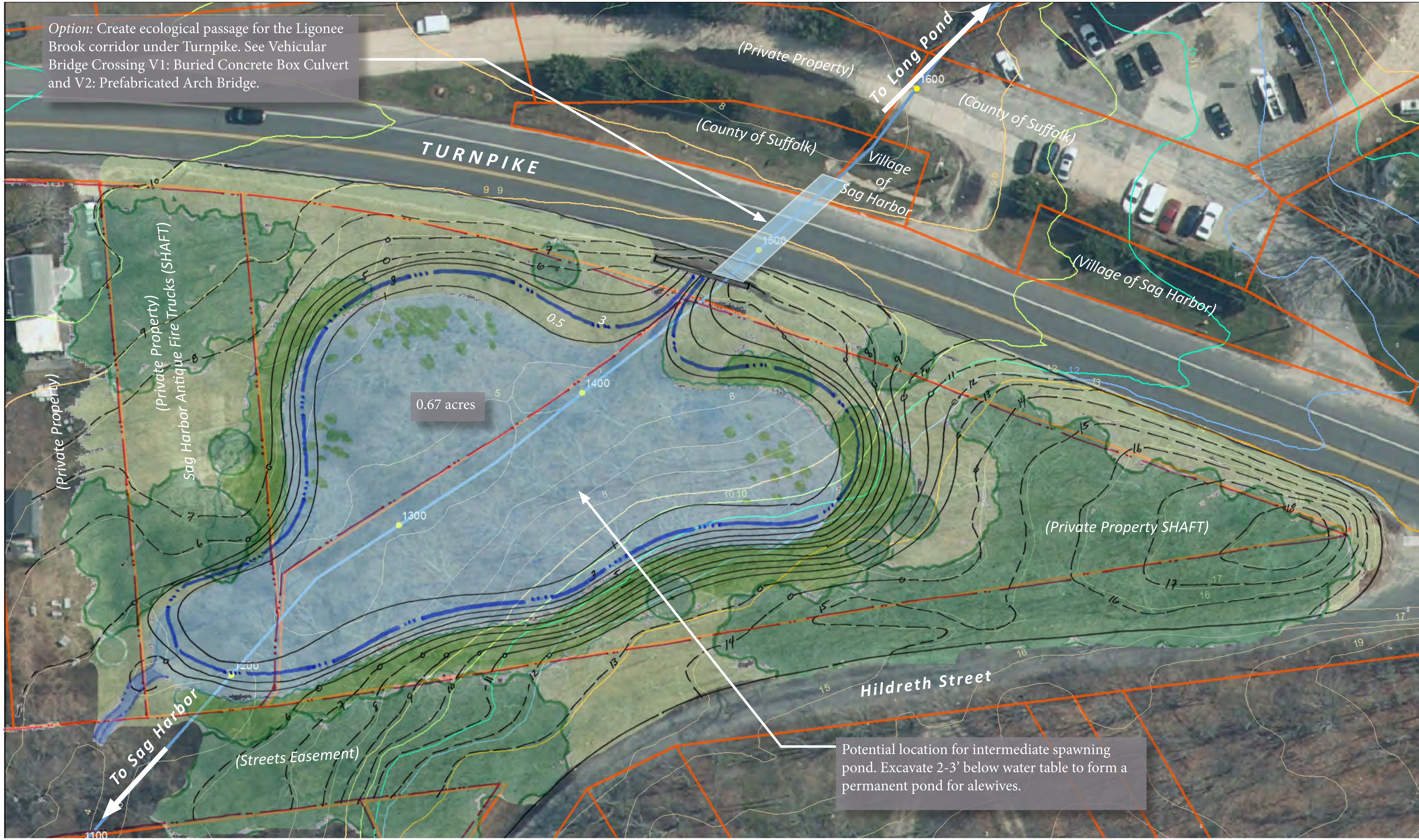
Exhibit 7



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Ligonee Brook - Potential Spawning Pond A

Suffolk County, Long Island, NY

0 20 40 80 ft.

N

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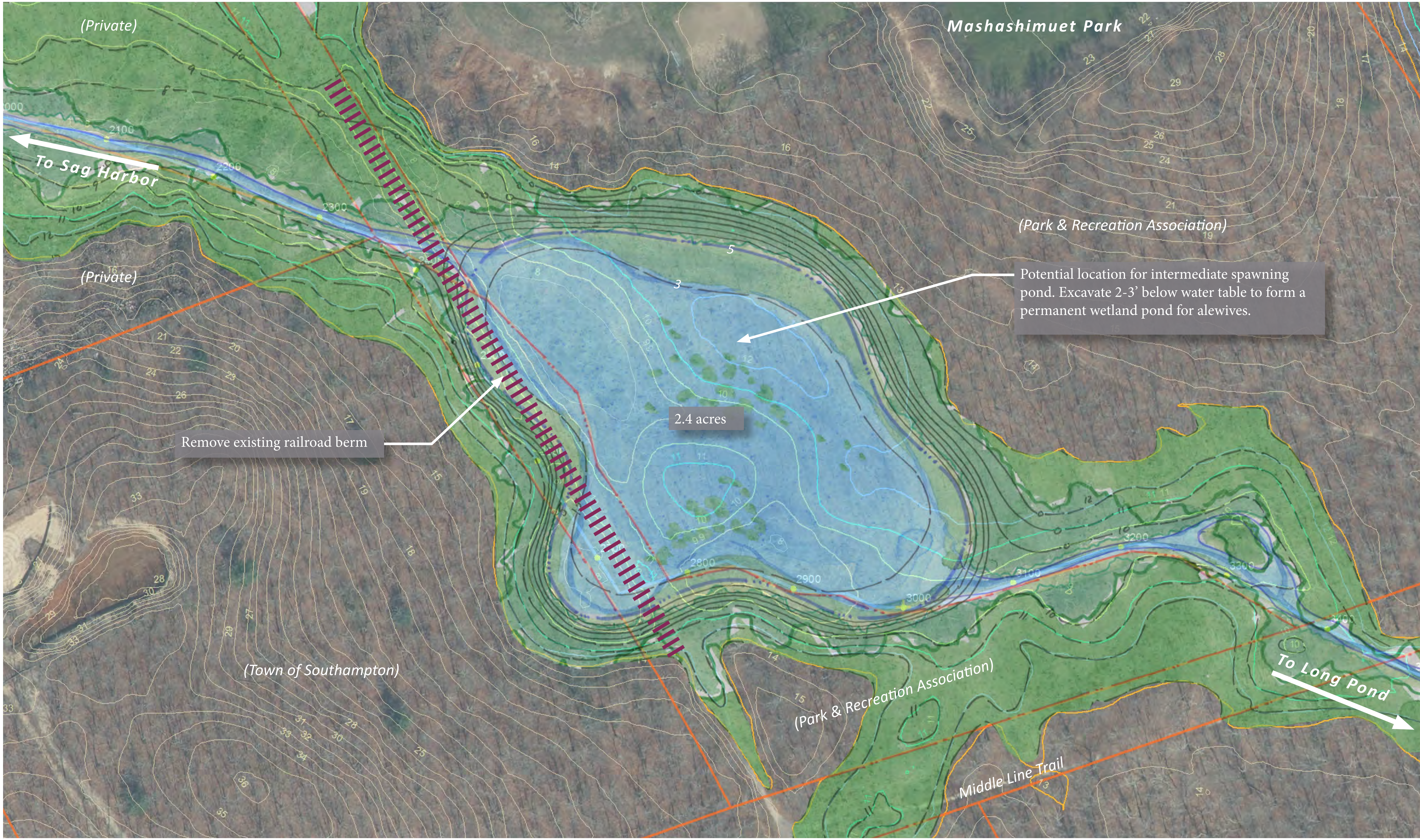
Exhibit 8



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Ligonee Brook - Potential Spawning Pond B

Suffolk County, Long Island, NY

0 40 80 160 ft. N

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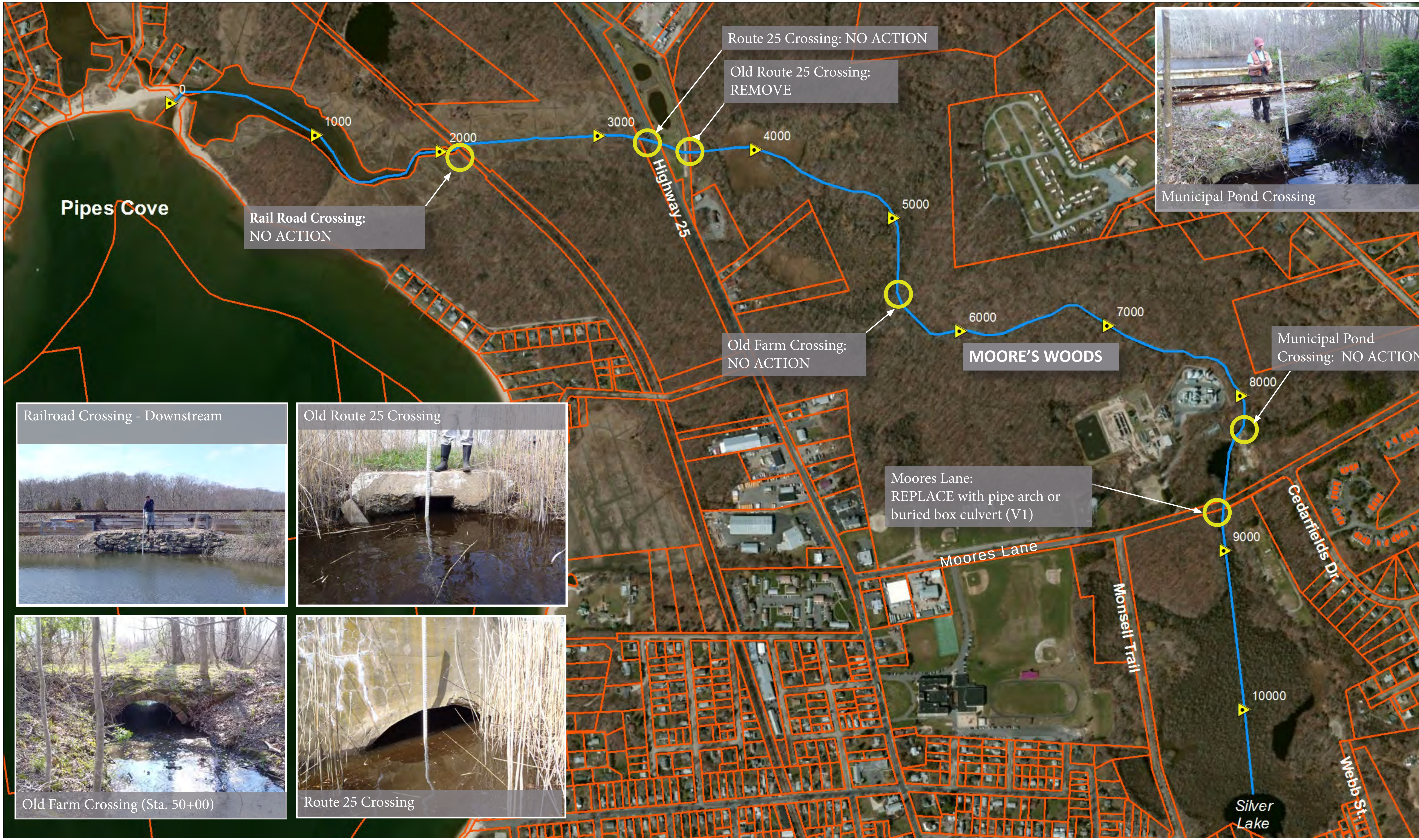
Exhibit 9



Peconic Estuary Conceptual Habitat Restoration Design

Moore's Drain - Existing Conditions

Suffolk County, Long Island, NY

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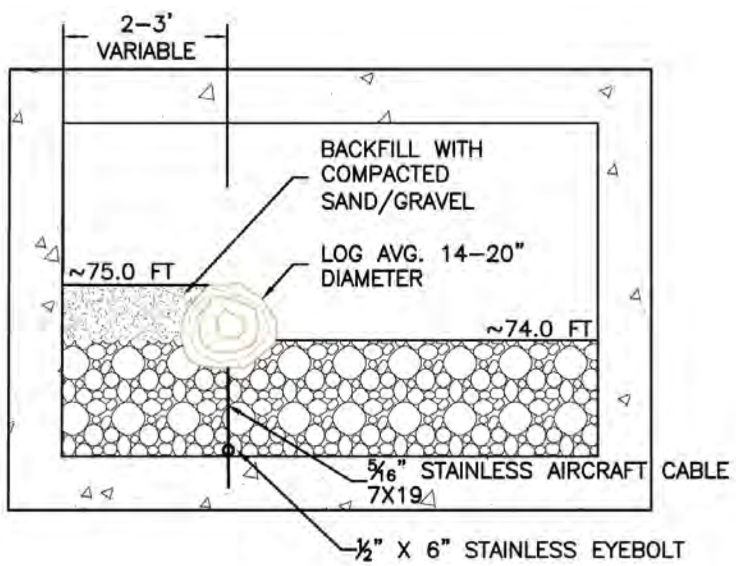
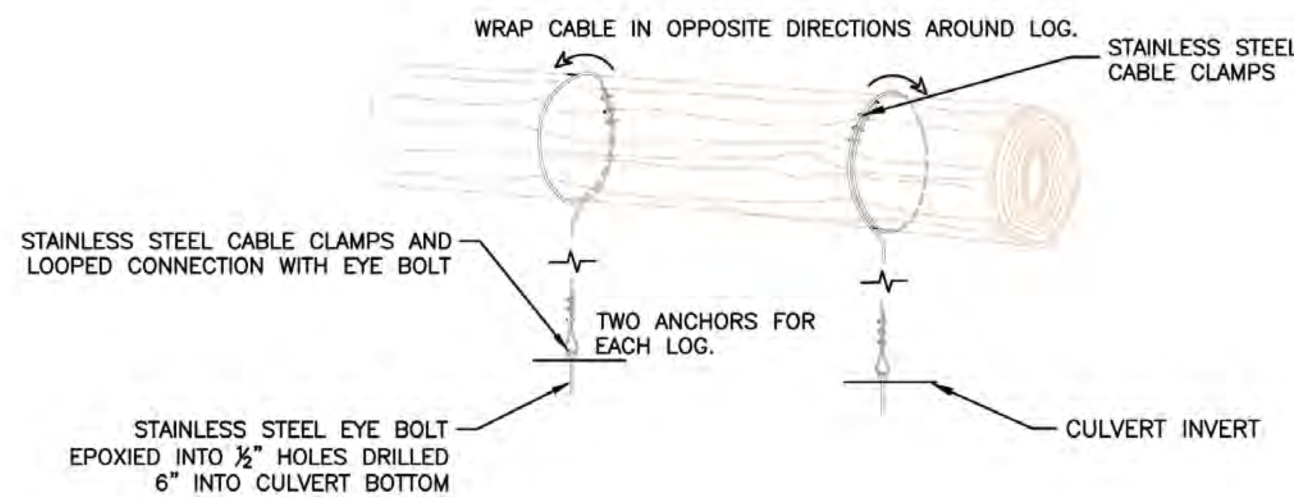
Exhibit 10



TYPICAL CROSS-SECTION (n.t.s.)



Pre-fabricated concrete box culverts, partially buried to allow a natural bottom substrate, are an effective solution for aquatic passage under roadways and other linear infrastructure barriers. Terrestrial benches incorporated within the cross-section also provide passage for a diversity of riparian species.

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Vehicular Bridge Option (V1) - Buried Concrete Box Culvert:
Applicable to all road crossings

Suffolk County, Long Island, NY

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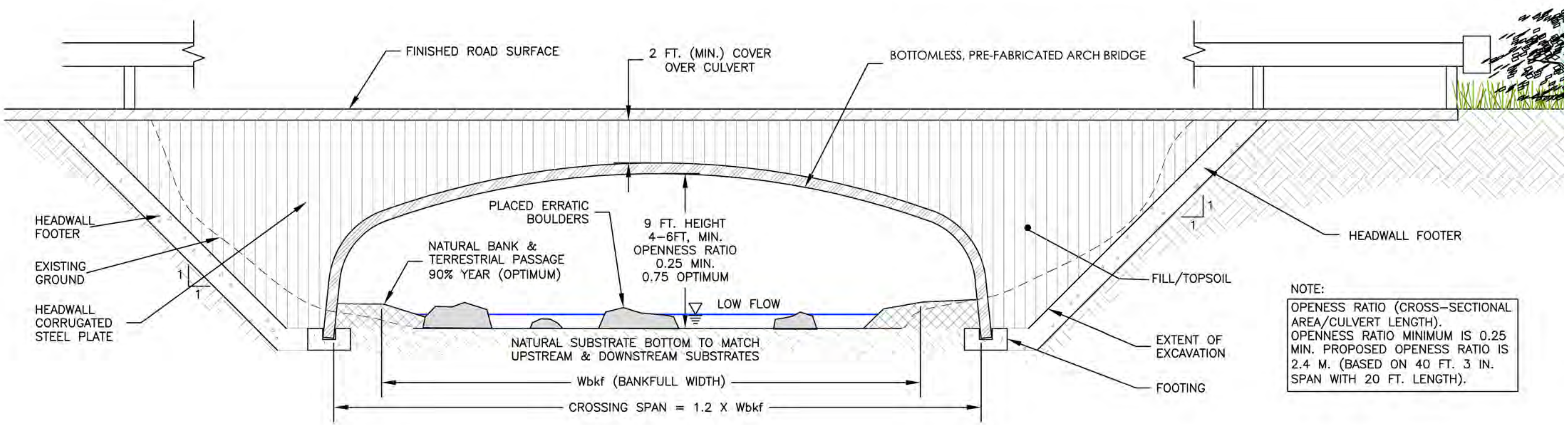
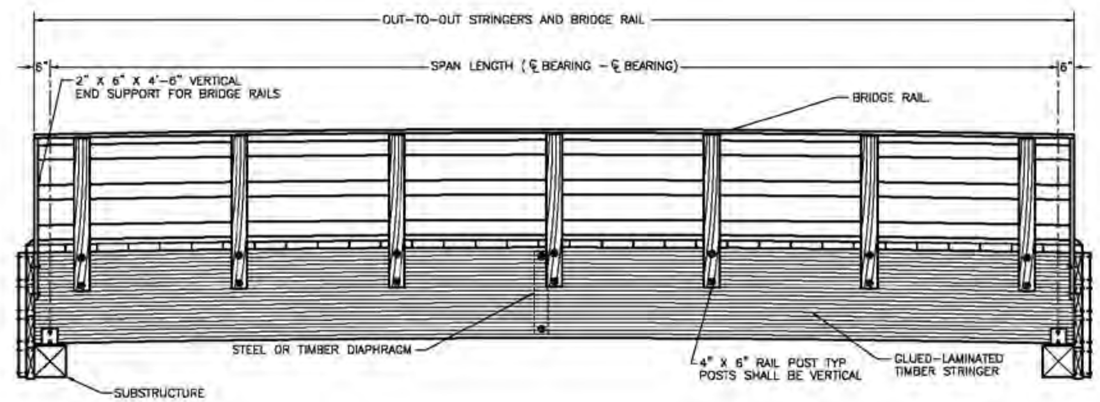
Exhibit 11



NOTE:
OPENESS RATIO (CROSS–SECTIONAL AREA/CULVERT LENGTH).
OPENNESS RATIO MINIMUM IS 0.25 MIN. PROPOSED OPENESS RATIO IS 2.4 M. (BASED ON 40 FT. 3 IN. SPAN WITH 20 FT. LENGTH).

Pre-fabricated steel truss bridge with wooden deck

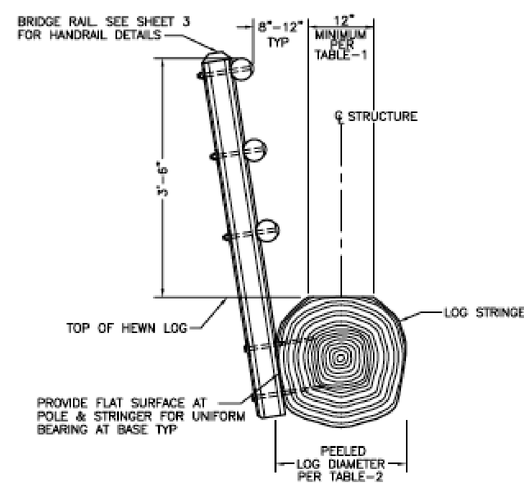
Constructed and Pre-Fabricated Bridge Structures can be used to connect paved paths and to span wider stream crossings, or for crossings with greater foot traffic and accessibility needs. Bridge options include prefabricated steel truss bridges, glu-laminated truss stringer bridges, stringer log bridges with railings, and boardwalk bridge design with wooden curbs.



Glu-laminated stringer bridge

Glu-Laminated Stringer Bridge

Wood deck pedestrian bridge with wooden curb



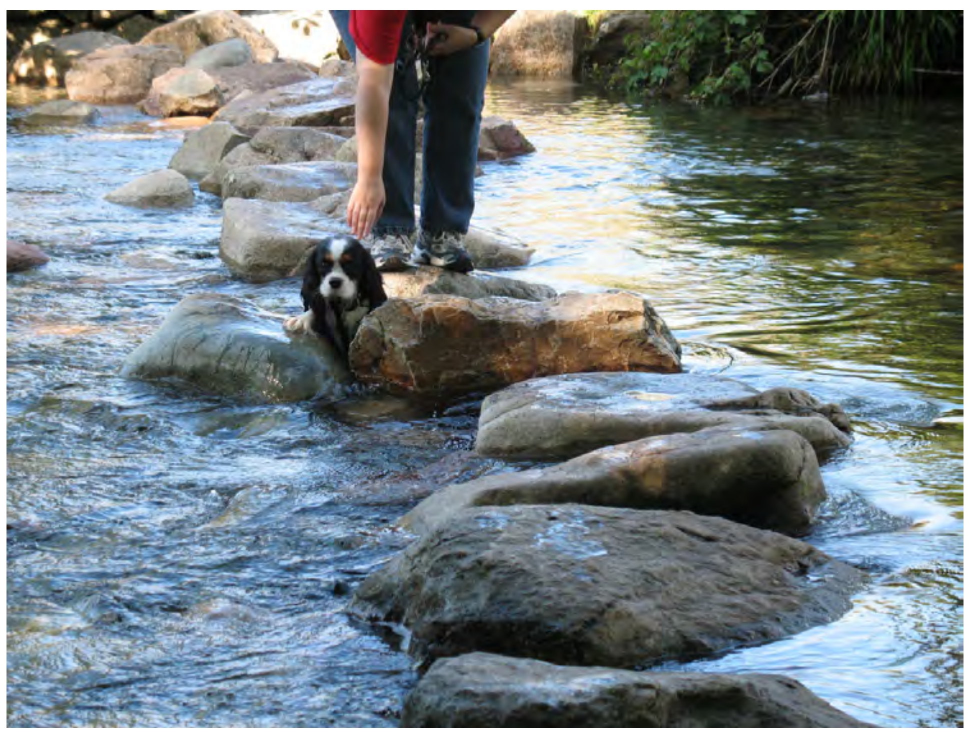
Stringer log bridge

Stringer log bridge with railing

Stepping Pads

Stepping Stones

Wooden Planks



Fallen Logs

For smaller, less traversed pedestrian crossings, **rustic stream crossings** may be used. Rustic crossings emulate those found naturally in the stream corridor, such as stepping stones or pads, and fallen logs or planks. Rustic crossings blend with the natural environment, provide adventure and enjoyment, and can be used to discourage access by unwanted vehicles. Design of rustic crossings should keep in mind user levels, desired ease or challenge of crossings, and hydraulic forces of the stream.

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Pedestrian Bridge Option (P2) - Rustic Crossings:
Recommended for Upper Trail Crossing near Long Pond (Ligonee Brook)

Appendix B – Costs Estimates

Forge Road Dam - Feasibility Costs

Alternative C - By - pass channel (2% gradient with step pool channel construction, 550 foot length, assume 60 feet across roadway)

Description	*length*	*width*	*depth*	*CF*	*Qty*	*Unit*	*Unit Cost*	*Total*	*Notes*
Channel bed construction (rock fill)	175	10	2	3500	130	Ton	200	$ 25,926	rock furnished and installed
Geotextile Lining	175	10		1750	194	SY	12	$ 2,333	geotextile
Clearing / Earthwork		18000	2	36000	1333	CY	30	$ 40,000	assume disturbance area by 2 ft depth
Roadway and Culvert construction					60	LF	1750	$ 105,000	linear foot cost based on similair culverts
Planting		18000	sf		2000	SY	3	$ 6,000	seed, plugs and trees
							subtotal	$ 179,259	
							dewatering (7.5%)	$ 13,444	
							Mobilization (5%)	$ 8,963	
								$ 201,667	**BASE TOTAL**
							20% Contingency	$ 40,333	
								$ 242,000	**With Contingency**

Alternative B - Fish Ramp, Total Length +/-220'

Description	*length ft.*	*width ft.*	*depth*	*total (ft)*	*Qty*	*Unit*	*Unit Cost*	*Total*	*Notes*
concrete retaining walls	70	1	6	277	0	CY	$ 200.00	$ -	assume 8" thick, average 6' tall
Roughened channel cobble/field stone	220	20	2	8800	326	Ton	$ 200.00	$ 65,185	furnished and installed
Seepage lining	220	30	1	6600	733	SY	$ 12.00	$ 8,800	geotextile
Imported fill under channel bed	172	15	7	8385	350	CY	$ 40.00	$ 14,000	assumes 2ft of rock on top
Berm fill/ earthwork	172	32	11	14222	650	CY	$ 40.00	$ 26,000	prism
Planting				6500	722	SY	$ 4.00	$ 2,889	seed, plugs and trees
							subtotal	$ 116,874	
							dewatering (20%)	$ 23,375	
							Mobilization (5%)	$ 5,844	
								$ 146,093	**BASE TOTAL**
							20% Contingency	$ 29,219	
								$ 175,311	**With Contingency**

Alternative A - Alaskan Steeppass Ladder

Description	*length*	*width*	*depth*	*CF*	*Qty*	*Unit*	*Unit Cost*	*Total*	*Notes*
Alaskan Steeppass Ladder	71		11		11	VF	$ 10,000.00	$ 110,000.00	
Resting pool in berm	30	0.5	3	45	1	LS	$ 15,000.00	$ 15,000.00	Assumed Concrete
Planting				1000	111	SY	$ 3.00	$ 333.33	seed, plugs and trees
							subtotal	$ 125,333	
							Mobilization (5%)	$ 6,267	
								$ 131,600	**BASE TOTAL**
							20% Contingency	$ 26,320	
								$ 157,920	**With Contingency**

Ligonee Ponds

Lower Pond at the Turnpike

Description	*Qty*	*Unit*	*Unit Cost*	*SubTotal*	*20% Contingency*	***TOTAL (Range)***
Low Volume of Excavation Estimate	6300	CY	$ 40.00	$ 252,000	$ 50,400	**$ 302,400**
High Volume of Excavation Estimate	8500	CY	$ 40.00	$ 340,000	$ 68,000	**$ 408,000**

Upper Pond above the Turnpike

Description	*Qty*	*Unit*	*Unit Cost*	*Total*		
Low Volume of Excavation Estimate	22600	CY	$ 30.00	$ 678,000	$ 135,600	**$ 813,600**
High Volume of Excavation Estimate	30400	CY	$ 30.00	$ 912,000	$ 182,400	**$ 1,094,400**

Appendix C – Forge Road Photos

Standing on the road looking downstream at the Peconic. The bar is from scoured material at the spillway of the dam

Looking downstream at the left bank below the dam – note the bar from the previous photo

Looking downstream of the dam – note the steps down to the river from the first property

Standing on the bar looking upstream at the spillway (left) and canoe launch (right)

The seepage channel running parallel to the mainstem Peconic on the north side

One of two canoe takeouts on Peconic Lake – the spillway can be seen in the background

The main dam spillway before it flows under Forge Rd.

The weir structure at the head of the spillway

Forge Rd at the spillway

Looking downstream at the head of the spillway and the canoe take out on Peconic Lake

Appendix D – Ligonee Brook Photos


Looking upstream just above the outlet of Ligonee


Looking downstream from Brick Kiln Rd

The culvert under Brick Kiln. Note the concrete box transitions to a sliplined corrugated metal pipe with a lip. Not a barrier – but a significant challenge, particularly at low tide

Looking upstream at the Brick Kiln crossing

Looking downstream at the Brick Kiln crossing

The reach between Brick Kiln and the Turnpike – water is present but not flowing

Looking downstream from the Turnpike – water is present here absent above the road

The downstream side of the Turnpike crossing – these two pipes merge into a concrete between the active Turnpike and the old road.

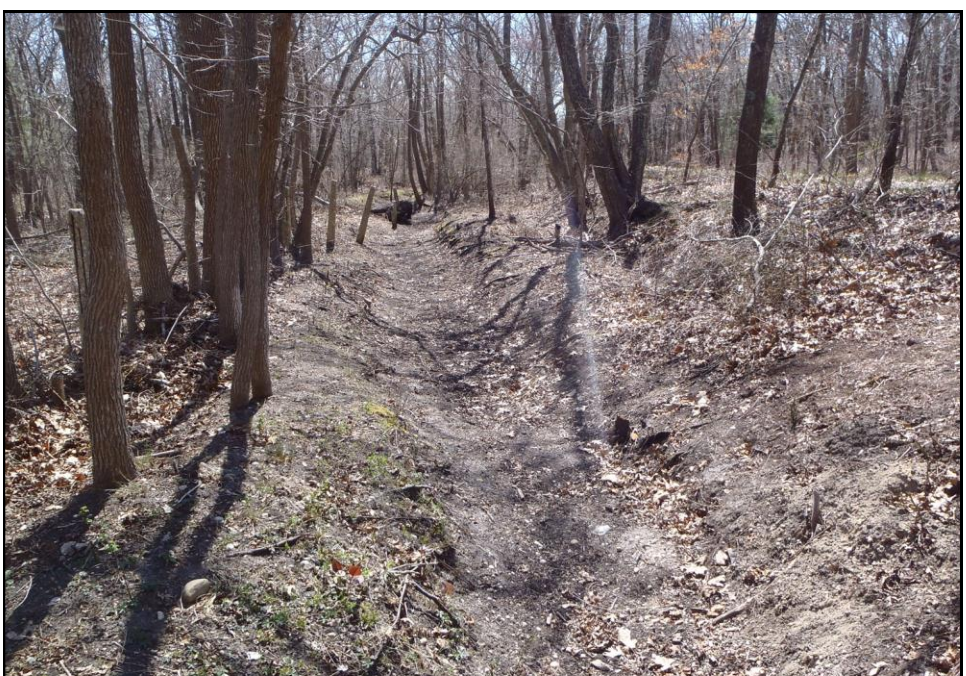

Looking downstream at the 2nd (old) crossing at the Turnpike


The upstream side of the turnpike crossing – a concrete box


The channel above the Turnpike is dry


The channel parallel a construction yard just above the Turnpike

The old railroad crossing. Alewife have been reported to congregate here – having difficulty making it through this pipe when flowing



The channel parallel to the railroad berm (right)

An old dam or water control structure along the brook

An old trail crossing along the brook – a challenge to fish passage – it should be removed

Leading up to Long Pond in the background – the channel narrows considerably

An old structure at the outlet of Long Pond to Ligonee Brook

Long pond outlet to Ligonee Brook

Appendix E – Moore's Drain Photos

Looking upstream at the railroad crossing – 2 culverts though only 1 is visible

Looking upstream above the railroad crossing – a tidal wetland marsh

The concrete culvert at RTE 25 – not a fish barrier

Looking through the RTE 25 culvert

The old RTE 25 (Main St) culvert – a challenge but not a barrier to fish

The old RTE 25 culvert – upstream side

The drain moving into the wetland above RTE 25 – note the spoils on the banks from the channel excavation

An old tractor crossing through Moore's woods

Moore's Drain through Moore's woods

The channel has little to no flow and is full of organic material – likely with low DO

A bridge across the drain just below Moore's Lane

The bridge across Moore's Drain accessing the city yard


Looking downstream from Moore's Lane


The upstream side of Moore's Lane – the culvert is blocked