NY-NJ HARBOR ESTUARY PROGRAM CONCEPT DESIGN REPORT

OLD BRIDGE TOWNSHIP, MIDDLESEX COUNTY, NJ

APRIL 2023

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INTRODUCTION

Princeton Hydro was contracted by the NY-NJ Harbor & Estuary Program and the Hudson River Foundation to plan and design for aquatic connectivity through climate-ready infrastructure. The goal of the project was to address hydraulic capacity issues at priority road-stream crossings in the South River and Lower Raritan River (NJ) watersheds. To this end, Princeton Hydro developed a 30% engineering plan for a priority road-stream crossing – the Birch Street crossing over the Iresick Brook in Old Bridge, NJ. This report summarizes the work completed for this engineering design and describes the basis for the design.

SITE INVESTIGATION

Once the Birch Street road-stream crossing at Iresick Brook (IB5) was identified as the priority site, Princeton Hydro completed a site investigation on October 20th, 2022. The investigation process drew from design guidance produced by the United States Forest Service Stream-Simulation Working Group. The investigation included a geomorphic assessment, site observations, and simplified site survey of the channel alignment, profile, and cross sections both upstream and downstream of the culvert.

The existing pair of culverts were measured to be 36 inches in diameter, compared to the measured 16-foot bankfulll width. The drainage area to this culvert is approximately 2 square miles. At the time of the survey, flow was only a couple inches deep in the channel and slow-moving, especially in the upstream reach. Flocculant was evident, leaching into the channel from the banks. Waters were turbid with turbidity specifically pronounced in pools with very low velocities.

Despite the low flow at the time of the survey, during storm events the undersized culvert creates a hydraulic constriction. Conveyance is restricted into a smaller bankfull width than the rest of the stream, interrupting natural open-channel flow and increasing flow velocities. The elevated velocities and shear stress associated with the existing culvert have created a scour hole at the culvert outlet that is about 60 feet long. The maximum depth of the scour hole was observed to be 4.6 feet during the time of the investigation, located 45 feet downstream of the culvert. Substrate from the pool has been washed downstream, forming an island of large sand and small gravel. The substrate of this island is larger compared to the finer, sandy channel bottom seen throughout the upstream and downstream reaches.

It does not appear that the existing culvert is passable by aquatic organisms. During low flows, the water depth through the culvert is insufficient. During the higher flows, the hydraulic constriction creates a velocity barrier.

At the downstream extent of the surveyed area is a utility transmission line, which has allowed vegetation to grow across the channel. At the time of the survey, the vegetation created a hydraulic grade control, influencing the water surface elevation immediately upstream of the utility line.

Overall, the downstream channel is slightly incised and entrenched. It appears that this channel was historically straightened and anthropogenically manipulated. Erosion on the bank from the scour hole shows a tire becoming exposed. In addition, there seemed to be a berm on the river left bank. The downstream reach does maintain a pattern of shallow pools and riffles.

At the location of the culvert, Birch Street is a two-laned paved road. The road has a double yellow line approximately 100 feet west of the site, but not at the road-stream crossing itself. There was evidence of various utilities across the crossing, including a sanitary sewer, a water main, a gas line, an overhead electrical line, and stormwater outlet. The sanitary sewer, water main, and gas lines were design constraints. The overhead utility line does not appear to conflict with the project as the poles fall outside the project area. The stormwater pipe runs east of the project area, discharging into Iresick Brook at the upstream face of the culvert on the river right bank. The stormwater pipe will not present a barrier to the project and can be used to support floodplain restoration.

The upstream channel is generally similar to the downstream reach. However, there was significantly more woody debris within the channel, as the culvert does not allow for transport of the woody debris into the downstream reach. At the time of survey, there was minor woody debris accumulation at the upstream face. The woody debris created a more complicated flowpath with localized scour holes and minor pools.

Approximately 155 feet upstream of the culvert is a channel-spanning v-notch weir comprised of a combination of sheet pile and timber. The weir appeared to be a historical stream gage, as equipment was observed in the floodplain. There was 6-12-inch riprap stabilizing the channel immediately upstream and downstream of the weir. The sheet pile and riprap stabilization for the weir creates an artificially perched channel.

Princeton Hydro utilized two Survey-Grade GPS RTK units in a system of base and rover to collect topographic data. The base station was a Carlson BRx6+ while the rover was a Carlson BRx7+ unit. This data provided the thalweg profile, reach slopes, bankfull width, bankfull area, and the limited in-channel bedform features. In total, Princeton Hydro surveyed 8 cross sections through the downstream representative reach, downstream pool, downstream and upstream face of the culvert, upstream reaches, and across the v-notch weir. These survey points were imported into AutoCAD Civil3D and formed the basis of the 30% engineering design.

DESIGN METHODOLOGY

The design described herein was developed following protocols set forth in *Stream Simulation: An ecological approach to providing passage for aquatic organisms at road-stream crossings* developed by the United States Forest Service Stream-Simulation Working Group (2008). The guidance is intentionally focused on the design of the stream channel, not the road, through the crossing and the sizing of the structure to adequately accommodate both the hydraulic and geomorphic aspects of the stream. Specifically, the crossing structure is designed to accommodate approximately 1.2x bankfull width of the channel, which provides continuous banks through the structure and a narrow swath of the overbank area (or floodplain), as well as the natural streambed features (i.e. riffle, step, or pool).

However, after examining the elevations of a proposed equilibrium profile, it was clear constraints from utility conflicts required consideration. Therefore, the design deviated from the 'pure' stream design methodology.

UTILITY DESIGN CONSTRAINTS

Initial site observations showed that utilities would be a design constraint for this project. Therefore, Princeton Hydro contacted local utility companies. Old Bridge Municipal Utilities Authority (OBMUA) provided the *Bridge Haven As-Builts: Maple Street and Birch Street Profiles* (1994) for the crossing, accounting for the sanitary sewer, the water main, and the stormwater sewer.

Based on surveyed data and As-Builts, Princeton Hydro has reason to believe that the existing sanitary sewer line lies approximately 0.25 feet below existing grade, and the water main casing sits approximately 1 foot below existing grade. Therefore, Princeton Hydro anticipated a conflict between installation of a proposed culvert and the utility lines. Princeton Hydro did not explore altering the existing utilities and instead pursued a design that would raise the proposed culvert invert to allow for an appropriate buffer of armored material between the utilities and the flow path.

Princeton Hydro discovered that the elevations of the existing culverts cited on the As-Builts did not correspond with the data Princeton Hydro recorded in the field. The discrepancy is likely caused by a datum shift. Princeton Hydro initially hypothesized that the discrepancy could be attributed to the As-Builts being measured according to NGVD29 and the PH survey calibrated to NAVD88. However, USGS-disseminated information about the typical elevation difference between the two datums in question does not support this claim. The elevation discrepancy is discussed further in the following section.

SANITARY SEWER

Old Bridge Municipal Utilities Authority (OBMUA) provided As-Built plans for the Birch Stream crossing for the sanitary sewer at the project location. They also confirmed the sanitary sewer line to be gravity-fed.

Figure 1 displays the sanitary sewer line in profile view from the OBMUA As-Built plans. To rectify elevation discrepancies, Princeton Hydro compared five points taken during the survey site assessment to the As-Builts in order to bring the As-Builts into North American Vertical Datum of 1988 (NAVD88), NJ State Plane. Princeton Hydro converted the sanitary sewer line invert shown at 20.96 ft in the Birch Street Profile As-Builts into 18.24 ft (NAVD88) on the proposed engineering plans.

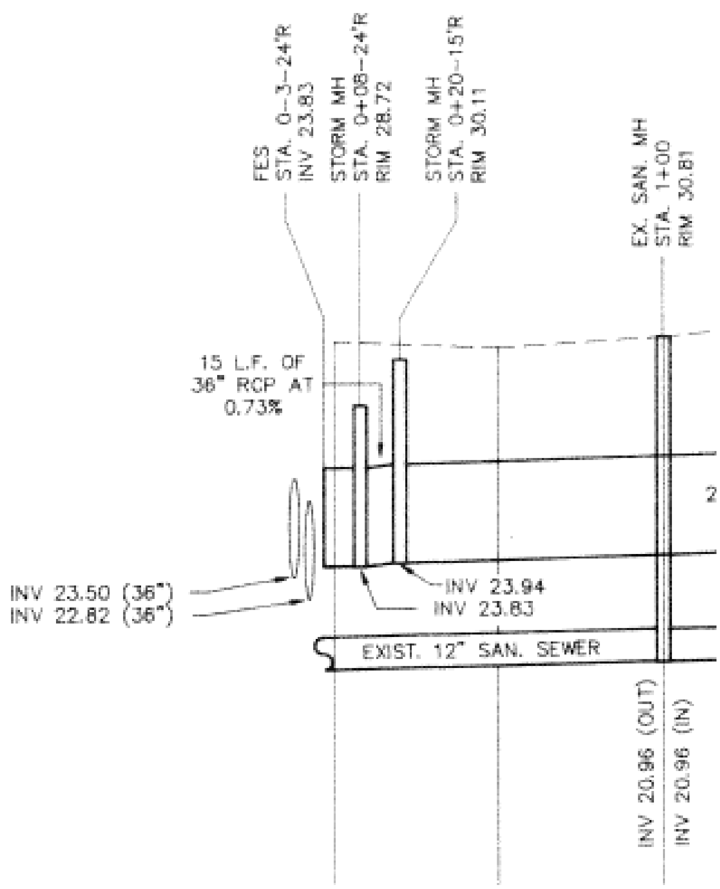

FIGURE 1: BIRCH STREET PROFILE SHOWING SANITARY SEWER

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After placing the sewer crossing on the engineering design plans, it was evident that drawing a proposed equilibrium channel slope would risk exposure of the sewer crossing. OBMUA expressed concerns regarding the permanent lowering or rerouting of existing sewer lines by a siphon. Therefore, Princeton Hydro updated the 30% design to provide sufficient protection for the sewer based on guidance from OBMUA's standard details. Princeton Hydro proposes a 21-inch steel encasement be installed around the utility line, extending a minimum of 10 feet beyond the top of bank on either side of the channel to observe OBMUA Standard Construction Details shown in Figure 2. In addition to the proposed steel encasement Princeton Hydro determined that 6 inches of grouted stone should be installed above the proposed encasement to provide supplementary protection. Therefore, a total of 10.5 inches of protection are proposed to armor the existing utility from erosive forces. Further details regarding the grouted riprap and substrate through the proposed culvert will be discussed in subsequent sections of the report.

Additional discussion with the utility should take place during the final design stage ultimately resulting in approval of the final design by OBMUA.

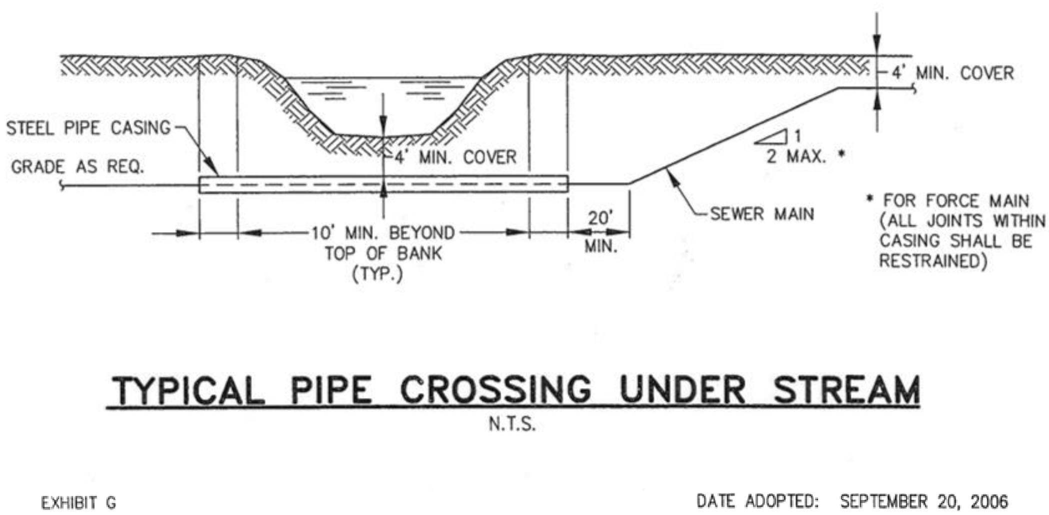

FIGURE 2: TYPICAL PIPE CROSSING UNDER STREAM

(OBMUA Sewer System and Pump Station Construction Standard Details, Exhibit G - Section 5, Page 25)

DRINKING WATER MAIN

The As-Built plans provided by OBMUA also included information about the water main within the project location. The As-Builts did not record elevations associated with the water main, rather showed an 18" vertical distance between the existing culvert inverts and the crown of the casing around the utility pipe (see Figure 3). Princeton Hydro included all other pipe measurements shown on the documents. Princeton Hydro used this 18-inch offset, as well as additional dimensions shown in the plans, to include the water main in the 30% engineering plans. Based on this assumed elevation, the drinking water main is lower than the elevation of the sanitary sewer. The drinking water main further directed the design by constricting the span and abutments of the proposed culvert to fit between the inflection points in the utility line.

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The proposed design plans may require consideration and/or rehabilitation of existing thrust blocks during construction, which will be addressed in a further design phase with guidance from OBMUA.

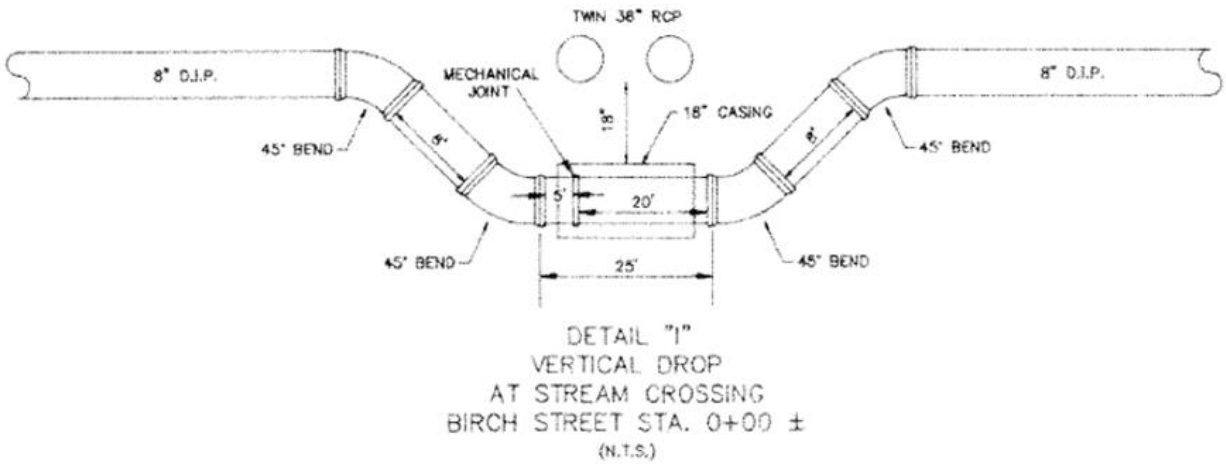

FIGURE 3: CROSS SECTION OF WATER MAIN UTILITY BENEATH CROSSING

STORMWATER OUTLET

The existing stormwater outlet upstream of the road crossing should be avoided during access, demolition, and construction. The channel geometry through the proposed culvert is to tie into existing grades within 10 feet of the culvert upstream. The stormwater outlet is to remain undisturbed but may be used to provide stability for the proposed 4-foot-wide floodplain bench. Proposed channel geometry characteristics will be discussed in greater detail in the Representative Cross Section portion of the report.

GAS LINE

Princeton Hydro was unable to obtain plans or elevations from the gas utility. This should be further investigated during the final design phase. Contingency for relocation of the gas utility has been built into the cost estimate.

CULVERT DESIGN

CHANNEL SLOPE

Princeton Hydro developed the proposed longitudinal profile slope to be consistent with the slope of the existing reach of channel. The overall existing slope through the project area is 0.44% when disregarding localized high and low points that represent normal stream geomorphological features.

Princeton Hydro proposes the slope through the proposed culvert be set at 0.40% during culvert replacement, consistent with the existing slope and guidelines from the United States Forest Service Stream-Simulation Working Group design approach. The channel invert was set at 10.5 inches above the estimated crown of the existing sewer line, described in the Utility Design Constraints section, above. Slope upstream of the culvert is anticipated to be 0.40% (Stations 4+80' to 7+00'). To naturalize the upstream slope the rip rap, sheet pile, and v-notch weir at the upstream extent of the project area will be removed. The Parks Department of Middlesex County has granted approval and is supportive of the goals of the project.

Setting the channel invert elevation to avoid conflict with the existing sanitary sewer lines creates the conditions that would increase flow velocities, erosion, and the existing drop at the culvert outlet if not addressed. Princeton Hydro designed a nature-like step-pool fishway to minimize anticipated geomorphological changes downstream of the road-stream crossing while allowing for aquatic organism passage. The step-pools would provide dual functionality by dissipating the energy of water flowing through the area of relatively high slope and providing resting areas for the fish. Boulder weirs would separate pools to ensure consistent water levels and grade control.

The proposed design outlines lengths, depths, and heights for pools, weirs, and notches in accordance with the *Federal Interagency Atlantic Coast Nature-Like Fishway Passage Design Guidelines*. Princeton Hydro selected the Sea Run Brook Trout as an analogy for local trout and the target species for the design. Therefore, proposed step-pools are defined by minimum lengths of 10 feet, widths of 5 feet, and depths of 2.5 feet. Proposed boulder weirs are defined by approximate crest lengths of 2.5 feet, crests spanning the bankfull width of 16 feet, and depths of 6-9 feet of 2–3-foot boulders. Notches in the weirs are defined by minimum opening widths of 1.50 feet and opening depths of 1.25 feet. The design features a 0.6-foot hydraulic drop between each successive weir, excluding the first weir which matches grade with the culvert outlet and the fourth and final weir which is flush with proposed grade. The 0.6-foot hydraulic drop was calculated to ensure the drop would corroborate with pool and weir lengths to result in a friction slope (the rate at which energy is lost along the channel) equal to a 0.05% slope, the maximum fishway channel slope provided by the Federal Interagency guidance. The geometry of the pools and weirs are modeled after the representative cross-sectional geometry discussed below.

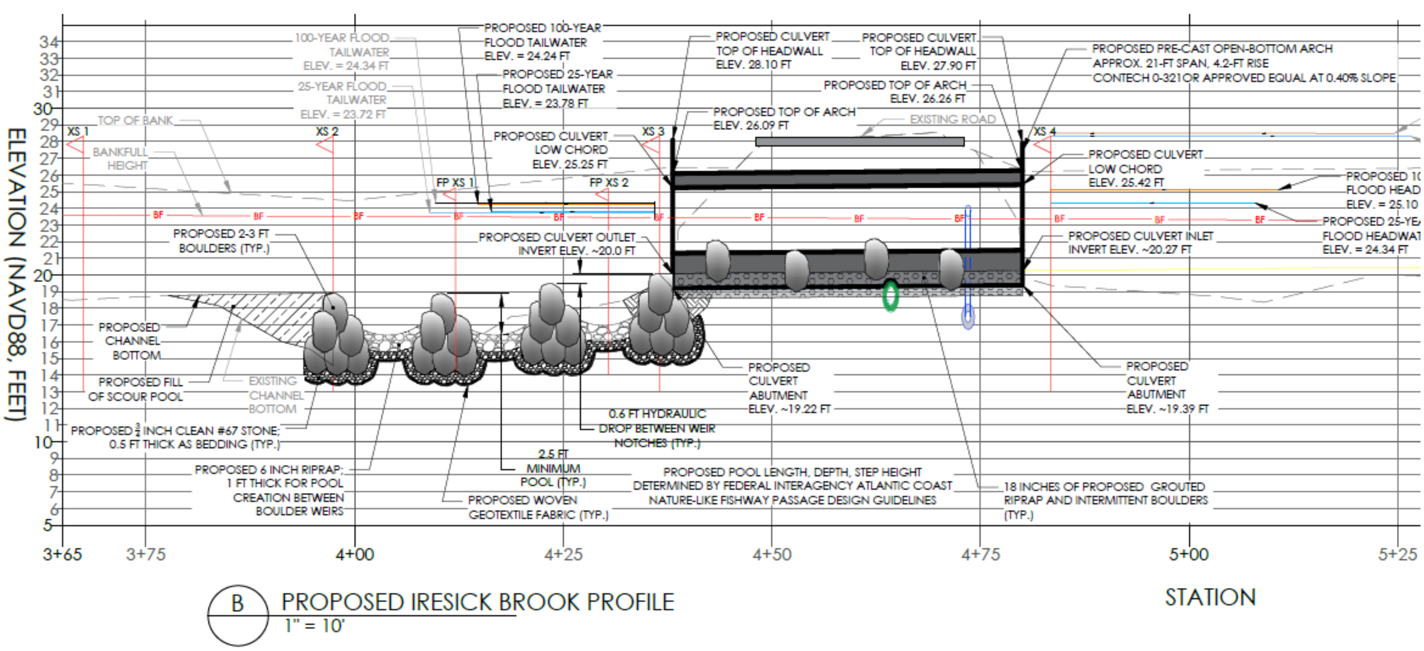

FIGURE 4: PROPOSED STEP-POOL FISHWAY IN PROFILE VIEW (HEP DESIGN DRAFT, PAGE 4)

REPRESENTATIVE CROSS SECTION

Princeton Hydro used two cross sections outside the areas of hydraulic influence of the culvert, v-notch weir, riprap, scour hole, or other unrepresentative features to develop a representative cross-section. The representative cross-section was produced by averaging the bank characteristics of "XS A" (not shown on plans) and "XS B" (corresponding to "Cross Section 5" shown on engineering plans). Table 1 displays the bank characteristics measured and averaged to generate the representative geometry.

TABLE 1: BANKFULL CHARACTERISTICS

Cross-Sectional Characteristic	XS A	XS B	Average
Bankfull Width (ft)	18.1	14.1	16.1
Max Bankfull Depth (ft)	1.45	1.81	1.63
Bankfull Area (sq ft)	16.5	16.6	16.5
Width at Flood Prone Stage (ft)	28.7	20.6	24.1

Princeton Hydro drew from the representative bankfull characteristics table to propose a culvert opening width that at least 1.2x bankfull width in accordance with guidance provided by USACE Stream Crossing Best Management Practices for the New England District and the Forest Service Stream-Simulation Working Group.

The representative cross section was overlaid on the culvert inlet and outlet cross sections to illustrate the proposed conditions. Princeton Hydro proposes the representative cross-sectional geometry to be continued, downstream of the step-pool fishway, through the scour hole. Material excavated or imported for the placement of the proposed culvert will be used to fill in the downstream scour hole and create a local floodplain.

Typical streams have an approximately parabolic cross section. However, true parabolic channels are not practical to construct; Instead, an approximately triangular cross section can be built and allowed to adjust and naturalize over time. Shown in Figure 5, the representative cross section features an approximately parabolic cross-section with side slopes at about 5:1 (Horizontal: Vertical) (H:V). 4-foot floodplain benches were included on either side of the proposed geometry to match the average flood prone width (see Table 1). Proposed grade is to be tied into the existing grade of the channel banks at 10:1 slopes unless otherwise specified. Upper banks and floodplain benches can be wrapped or populated with vegetation for stabilization at a later design phase.

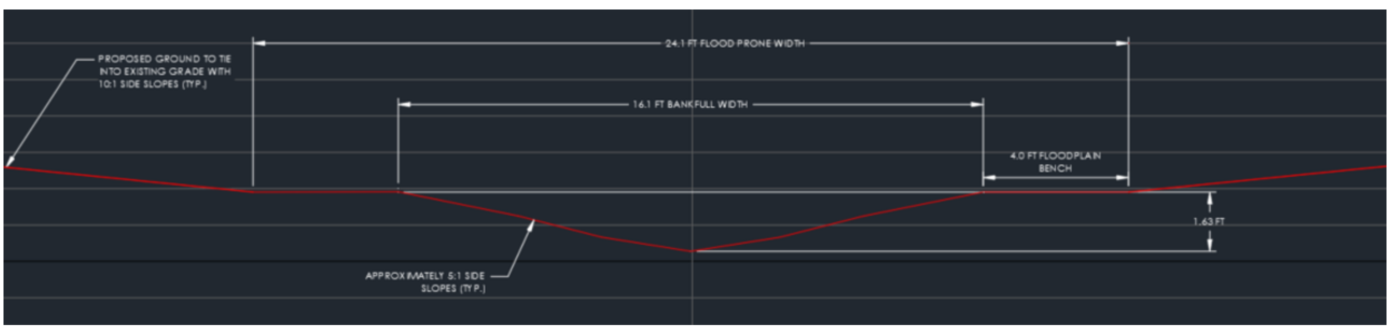

FIGURE 5: REPRESENTATIVE CROSS-SECTIONAL GEOMETRY

Several locations in the design required deviation from the representative cross-sectional geometry.

- XS 3 and XS 4: Princeton Hydro proposes a 2-foot floodplain bench be created on either side of the channel throughout the culvert. This floodplain will be composed of large boulder to protect the culvert from scour. Princeton Hydro proposes a 4-foot floodplain bench be created upstream of the culvert and tied into existing ground to replicate representative channel geometry.
- FP XS 2: The cross-section through a typical fishway pool displays side slopes altered from 5:1 to 3:1 to accommodate the minimum pool bottom width outlined by Federal Interagency Guidance for the Sea Run Brook Trout. Bankfull, flood prone, and floodplain bench widths and maximum depths remain consistent with all other proposed cross sections.

Existing and proposed cross-sections can be found on pages 5, 6, and 7 of the Plan Set.

PROPOSED CHANNEL MATERIALS

Princeton Hydro proposes a makeup of grouted riprap (D50=6 inches) for the channel through the culvert, with intermittent boulders throughout to dissipate flow. The grouted riprap will be a minimum of 18 inches thick throughout the culvert, excluding the area of the sanitary sewer line where the thickness will decrease to 6 inches. The grouted riprap will follow the representative cross-section and slope up at 5:1 side slopes on either side of the channel until the edge of the proposed floodplain bench at bankfull width. This channel geometry will create a low-flow channel to support aquatic organism passage when upstream and downstream depths are sufficient.

The pools and weirs of the proposed step-pool fishway structure are designed with specific substrate. The pools of the fishway will consist of 1 foot of non-grouted riprap (D50 = 6 inches) set on a six-inch layer of #67 (¾ inch) clean stone set on woven geotextile fabric. The weirs of the fishway will utilize at least three vertically stacked rows of boulders (D50=2.5 feet) embedded into existing ground. The profile of the weir structures will likely take on a triangular prism structure in order to retain stability. Beneath the boulder weirs will be 6 inches of #67 ¾ inch clean stone once again followed by woven geotextile fabric at the bottom of the proposed substrate mixture.

Excavated earthen material obtained during the removal and installation of the proposed culvert will be used to fill the existing scour hole downstream of the culvert. This reach is designed to create a new channel with floodplain benches and representative cross-sectional geometry. Earthen material obtained on-site will also supplement imported materials used for fishway construction. Further details regarding quantities of earth to be moved are outlined in the Cut/Fill Analysis discussion.

The existing substrate upstream of the culvert will remain unchanged.

CUT/FILL ANALYSIS

Aside from 2-3-foot boulders and materials for the step-pool fishway (see Figure 4), proposed regrading will be accomplished with material sourced on-site to be more sustainable and reduce material and transportation costs. An estimated 230 CY of material will be cut from the culvert location and approximately 124 CY will be cut directly downstream of the culvert to allow for step-pool creation and boulder, riprap, and stone installation. As designed, an estimated 221 CY of material will be required to regrade the area around the existing scour hole, create a floodplain bench, and fill in gaps between the proposed weirs of the step-pool fishway. The 133 CY of excess material will be used on-site to provide additional bank stabilization and update the grades of the floodplain. This will be addressed in the final design phase.

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STRUCTURE SELECTION

Princeton Hydro considered a variety of factors when determining the optimal structure type for the existing road, stream, and structural limitations. Specific factors included bankfull channel width, minimum boulder size and bank width, bed features, channel slope, vertical adjustment potential, bank stability, overbank topography, road-stream alignment (skew), structure length / road width, road cover, road slope, road shoulder width, geotechnical stability, constructability, material costs, construction costs, etc. The structure selection process was iterative and involved coordination with culvert manufacturers (Contech, Inc.). Ultimately, Princeton Hydro recommends replacing the existing culvert with a Contech Precast O-321 culvert, or similar alternative. This culvert has the potential to reduce local flood risk and restore aquatic organism passage to the reach of Iresick Brook.

To accommodate the design requirement of 1.2x bankfull width, the minimum span applicable on site was 20 feet. To avoid additional material cost and a conflict with the water line, it was determined that the span could be a maximum of 23 feet. Alternatives assessed were limited to precast culverts spanning 20 to 23 feet.

RISE

Contech suggested Princeton Hydro provide approximately 18" above proposed culvert arches for a combination of an aggregate base and sufficient asphalt thickness to provide optimal road performance. Including the standard strip foundation dimensions provided by the Contech Design Center, the span of the alternatives considered was constrained to a maximum of 5 feet.

OPENNESS RATIO

Openness ratio is calculated as the ratio of cross-sectional area of a culvert to its length. An openness ratio of 0.82 is more likely to attract and pass small and medium-sized riverine wildlife that would otherwise avoid constricted structures. USACE Stream Crossing BMPs for the New England District outlines a cross-sectional open area of 34.44 ft^2 to meet the openness ratio requirements for a culvert 42 feet long.

$$Opening\ Ratio > 0.82\ ft = Waterway\ Area\ /\ Culvert\ Length$$
$$0.82\ ft = 34.44\ ft^2\ /\ 42\ ft$$

Neither of the existing twin culverts meet the minimum recommend USACE standards for openness ratio that require at least 34.44 ft^2 of open area. Princeton Hydro used the openness ratio to refine the alternatives assessment, selecting the culvert with the highest cross-sectional waterway area to maximize the openness ratio and safe passage for all sizes of migratory wildlife. Princeton Hydro selected the Contech CONSPAN O-300 Series Model O-321 with a 21-foot span, 4.2-foot rise, and 69 ft^2 waterway area for the proposed design. The design will maximize cross-sectional open area and minimize embedded depths.

FOUNDATION

3.5-foot-wide by 2-foot-tall by 42-foot-long strip foundations would be poured in place for the proposed culvert design. The sanitary sewer line and the proposed 21-inch steel encasement would be located approximately 16 feet downstream of the upstream face of the culvert. An approximate of a 4.5-inch-tall by 18-inch-wide area must be reserved from the foundation pour at this station along either side of the culvert foundation to accommodate the utility. Contech stated that small gaps in foundation pours have been catered for in previous projects and that lay length arrangements of the culvert can be configured to avoid conflicts between the proposed gap location.

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HYDROLOGY AND HYDRAULICS

Qualitatively, in comparing the culvert diameter to the bankfull width of the stream, it is clear the culvert attenuates high flows. This leads to localized flooding during high flow events. To quantify this backwater effect, Princeton Hydro conducted a preliminary hydrology and hydraulic assessment used to inform the engineering design using the US Federal Highway Administration (US FHWA) HY-8 Culvert Hydraulic Analysis Program. Changes in discharge, outlet velocity, and water depth, including changes in water depth to the 25-year and 100-year event water surface elevations have been assessed and detailed below.

HYDROLOGIC ANALYSIS

Given the lack of sufficient regional USGS gage data, Princeton Hydro concluded that USGS StreamStats was the most accurate, cost-effective option to determine the stream flows relevant to the culvert replacement project. Princeton Hydro compared the Cornell WRI Hydrology Model to StreamStats peak flow statistics at this project location and five additional locations in Middlesex County, NJ to understand the level of agreement between the two models.

The Cornell WRI Hydrologic Model calculates the peak discharge calculation module utilizes the USDA Natural Resources Conservation Service (NRCS) Technical Release 55 (TR-55) graphical method. The USGS StreamStats provides an estimate for peak discharge based on a regression analysis described in the 2009 USGS publication *Methodology for Estimation of Flood Magnitude and Frequency for New Jersey Streams* (https://pubs.usgs.gov/sir/2009/5167/pdf/sir2009-5167.pdf). This methodology breaks the state of New Jersey up into four physiographic regions and analyses USGS streamflow gaging stations within each physiographic region. Table 2 shows the percent difference between the USGS Streamstats peak flow estimate and that of the Cornell WRI Hydrology model – calculated by diving the StreamStats flow by the average of the StreamStats and Cornell flow.

TABLE 2: PERCENT DIFFERENCE BETWEEN THE USGS STREAMSTATS AND CORNELL WRI MODEL

Recurrence Interval	IB1	IB5	BB1	MBK1	MBKT1	MBKT3
2-Yr	195%	198%	11%	94%	56%	74%
5-Yr	166%	170%	1%	88%	46%	71%
10-Yr	134%	140%	-13%	83%	35%	66%
25-Yr	88%	93%	-36%	73%	18%	59%
100-Yr	19%	24%	-81%	55%	-15%	47%

Overall, it appears that the StreamStats flow is relatively higher than the Cornell model at lower flows, and that the trend reverses as the flows get larger. However, with these six sites, a clear trend was not able to be observed. However, there was enough of a difference between the two models that the Cornell Model does not perfectly match StreamStats. Since the StreamStats methodology is more robust for the state of New Jersey, Princeton Hydro utilized its peak flows for the hydraulic analysis.

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HYDRAULIC ANALYSIS

Princeton Hydro input surveyed channel geometry, road-stream crossing dimensions, and StreamStats recurrence flow data into HY-8 to gather existing hydraulic data displayed below in Table 3.

TABLE 3: EXISTING CROSSING HYDRAULIC DATA – GENERATED WITH HY-8

Discharge Names	**Culvert Discharges (cfs) (Total, Left, Right)**			**Headwater Elevation (ft)**	**Tailwater Elevation (ft)**	**Outlet Velocity (fps) (Left, Right)**	
2-Year	113	55.65	57.37	23.89	22.04	10.29	9.06
5-Year	185	91.99	93.01	27.32	22.83	13.01	13.16
Overtopping	196.08	97.55	98.53	28	22.91	13.81	13.95
10-Year	238	98.8	99.76	28.16	23.25	13.98	14.11
25-Year	310	99.99	100.61	28.31	23.72	14.15	14.23
50-Year	364	98.34	98.35	28.41	24.02	13.91	13.91
100-Year	423	95.82	95.82	28.5	24.34	13.56	13.56
500-Year	556	91.06	91.05	28.69	24.94	12.88	12.88

Princeton Hydro's proposed design will increase the culvert opening area and allow for significant increases in capacity. Table 4 below displays hydraulic data for the design proposed by Princeton Hydro. Using HY-8, Princeton Hydro estimates that the proposed roadway will have less than a 0.2% chance of overtopping in any given year. Assuming a 500-year recurrence event discharges a total of 556 cfs, HY-8 estimates that the proposed crossing will have the capacity to convey 40% more flow than a 500-year flood for a total of more than 780 cfs.

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TABLE 4: PROPOSED CROSSING HYDRAULIC DATA – GENERATED WITH HY-8

Discharge Names	Total Discharge (cfs)	Headwater Elevation (ft)	Tailwater Elevation (ft)	Outlet Velocity (fps)
2-Year	113	22.79	22.62	2.28
5-Year	185	23.43	23.14	3.13
10-Year	238	23.84	23.44	3.7
25-Year	310	24.34	23.78	4.42
50-Year	364	24.71	24.01	4.95
100-Year	423	25.1	24.24	5.53
500-Year	556	25.98	24.69	6.84
Overtopping	781.13	28	25.31	9.38

HY-8 is a relatively simple program that uses empirical formulas to calculate flow capacity and water surface elevations based on the culvert dimensions and cross sections at the upstream and downstream faces of the culvert. However, a final design would require a more detailed hydraulic analysis using the USACE HEC-RAS program. HEC-RAS includes the impact from more complicated hydraulic scenarios, including the hydraulic impact of cross sections further upstream and downstream from the culvert itself and interaction with the floodplain.

WATER SURFACE ELEVATIONS

According to HY-8, the design proposed by Princeton Hydro will lower headwater elevations during the 25-year flood from 28.31 ft to 24.34 ft and during the 100-year flood from 28.50 to 25.10 feet. As shown in Table 3 and Table 4, the increased capacity of the proposed road-stream crossing will ensure that headwater elevations during future 500-year floods will be lower than elevations during current 5-year flood events.

FLOW VELOCITIES

HY-8 estimates current outlet velocities during a 2-year flood to be 9.06-10.29 fps, which approach the maximum swim speeds of the strongest swimming fish in the region such as Atlantic Salmon. Princeton Hydro does not believe Iresick Brook services any larger migratory fish species able to withstand the current elevated velocities. As discussed, the target species of the culvert and fishway design is the medium-sized Sea Run Brook Trout. Proposed designs are in accordance with Interagency Guidance, and the proposed culvert will remain passable for the Brook Trout up to about the 10-year storm event. HY-8 analysis of the proposed design yields outlet velocities of 2.28 fps during a 2-year flood and 5.53 fps during a 100-year flood. The reduction in average water velocities will increase the range of aquatic species that can pass beneath the crossing.

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PRELIMINARY IMPACT ASSESSMENT

SEDIMENT RELEASE ISSUES

Following the installation of the proposed culvert the hydraulic constriction and backwater effect upstream of the road-stream crossing will be limited to large storm events. Therefore, this project will retore natural transport of bedload and woody material downstream. Reestablishment of natural sediment transport will increase the complexity of the floodplain and provide ecological uplift and promote biodiversity. Due to the small volume of sediment upstream of the culvert, Princeton Hydro does not foresee sediment release to present significant challenges for the project.

HABITAT BENEFIT

AQUATIC AND TERRESTRIAL SPECIES

The quality of the John A. Phillips Open Preserve and surrounding riparian habitat will be improved by replacing the existing undersized road-stream crossing. The reduction in water surface levels, velocities, and erosive forces will allow a wider range of aquatic and terrestrial species to migrate through the road-stream crossing. The proposed step-pool fishway has been designed targeting favorable conditions for the medium-sized Sea Run Brook Trout. The step-pool dimensions and configuration will likely be passable for smaller and larger migratory fish species as well due to the moderate proportions and swimming velocities of the target species.

LARGE WOODY DEBRIS

The increased culvert opening area will allow less opportunity for impounded woody debris and more movement of woody debris to benefit downstream habitat, a critical element of healthy riparian ecosystem. Fallen logs, sticks, branches, and other organic material typically collect in jams that can serve to decrease erosive forces by deflecting flow paths, activating side channels, and increasing floodplain connectivity. Woody debris jams also create pools that provide necessary refugia for fish breeding and rearing habitat.

FINAL DESIGN CONSIDERATIONS

NEXT STEPS

Additional steps should be accomplished to achieve an appropriate level of detail and meet professional engineering design standards in the final engineering design phase. A professional survey should be completed of the site to affirm elevations and coordinates in appropriate coordinate systems and vertical and horizontal datums (i.e. NAVD88, NAD83, State Plane, Feet). Parcel boundaries have been added to the planset, but all adjoining property owners should be informed of the potential project. Although utilities were considered during this design phase, plans for the gas line were unable to be obtained. Additionally, the presence of below-ground utilities must be confirmed through professional survey and/or Call Before You Dig. A formal hydrologic and hydraulic model in HEC-RAS will be required to ensure there is no significant increase in water surface elevation. As part of final engineering design, some form of subsurface investigation, such as mechanical geotechnical borings should be completed to determine appropriate foundation design. Geotechnical data, including competence of subsurface materials (Atterberg limits), depth to bedrock, and soil pH (which affects material corrosion), may be necessary alternate materials for the culvert structure are under consideration (i.e. steel, aluminum or HDPE). The height and configuration of headwalls will need to be finalized based on a professional survey. In addition, hydraulic modeling should be reviewed and confirmed, particularly if any modifications are made to the structure that is proposed herein. Municipal Plans of Conservation and Development, municipal officials, and certain municipal planning boards should be consulted to understand any future road improvement plans that may include, for example, pedestrian sidewalks, bike lanes, road upgrades/widening, guide rails, traffic pattern improvements, traffic calming features, or other transit infrastructure enhancements.

REGULATORY APPROVAL

The following regulatory approvals are anticipated to be required:

1. NJ Division of Land Resource Protection – Freshwater Wetlands Permit:
    a. Freshwater Wetlands General Permit 16 application in compliance with N.J.A.C. 7:7A-7.16 for submission to the New Jersey Department of Environmental Protection's Division of Land Resource Protection Program (NJDEP-DLRP).
2. NJDEP Division of Land Resource Protection - Flood Hazard Area Approvals
    a. General Permit if hydraulics (span size) is not changed (not the case with this design)
    b. Individual Permit (in conjunction with additional hydrologic and hydraulic modeling to ensure there is no increase in water surface elevation)
3. Public Notification for Flood Hazard Area and Freshwater Wetlands Submission
4. Soil Erosion and Sediment Control Certification
5. NJPDES Request for Authorization (RFA)