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MEMO

To: Gianna Petito, District Manager, Winooski Natural Resources Conservation District

From: Gabe Bolin, PE, Meghan Arpino, Stone Environmental, Inc.

Stone Project No. 20-007
Subject: Hands Mill Dam Removal – H&H Analysis Memo

Stone Environmental, Inc. (Stone) had completed hydrologic and hydraulic analysis as part of the Hands Mill Dam Removal 30% design effort. This memo provides a summary of the analysis completed.

1. Selected Alternative

Based on field work, modeling and concept design development, Stone developed four project alternatives that were evaluated via an Alternatives Analysis. Alternative 4 (A4) was selected as the final alternative, which includes removal of the entire visible portion of the dam (165 linear feet) plus a portion of the dam that is buried along river right. The removal extents include the embankment section and principal concrete spillway, 67 linear feet of the concrete/stone wall, 70 linear feet of the visible portion of the concrete training wall and 30 linear feet of the buried portion of the concrete training wall.

Alternative 4 was selected over other alternatives due to the depth of sediment removal directly behind the dam (approximately 14' deep) and the need to remove the majority of the concrete training wall due to potential undermining of the wall by the excavation, if the wall were to remain in place. Besides the length and extent of dam removal, all other project components were the same across each alternative.

2. Hydrologic and Hydraulic Modeling

Hydrologic Peak Flow Analysis

Stone staff delineated the geographical region contributing flow to the site and determined the watershed size to be 6.65 mi^2. Streamflow data from nearby USGS gauges were then used to determine peak flow rates using a gauge transfer technique. Stone located 3 gauges within 50 miles of the site and chose 2 of those 3 gauges for further analysis based on watershed size relative to the Jail Branch watershed, geology and surficial soils, length of period of record, and presence of obstructions to flow (ex. dam or withdrawal). At each gauge, a Log-Pearson Type III distribution was used to determine the 2-, 5-, 10-, 25-, 50- and 100-yr recurrence interval design flows. For each gauge, an additional hydrologic analysis was performed that compared records to data collected after 1970, to identify if the hydrology at each site was impacted by a recent shift in hydrologic regimes as a result of climate change. The resulting distributions were plotted and compared to the StreamStats distribution.

The East Orange Branch, near East Orange, Vermont gauge (#01139800) was selected to determine peak flows at the site due to its long period of record (61 years), its comparable watershed size (8.8 mi^2), proximity to the site, location along an unregulated stream and current status as an active gauge. Because the post-1970 flows were higher than those corresponding to the entire record at this particular gauge, the post-1970 flows were used for our analyses.

The USGS gauge transfer technique was used to relate the calculated peak flows at the East Orange Branch gauge to the site using the following equation:

$$Q_u = \left(\frac{A_u}{A_g}\right)^b Q_g$$

where Q_u is the estimated flow statistic for the ungauged site, A_u is the drainage area for the ungauged site, A_g is the drainage area for the stream gauging station, Q_g is the flow statistic for the stream gauging station, and $_b$, depending on the state, may be the exponent of drainage area from the appropriate regression equation, a value determined by the author of the state report, or 1 where not defined in the state report (for this project a value of 1 was used).

The resulting peak storm flows for Jail Branch are provided in Table 1.

Table 1: Summary of Peak Flows at Jail Branch

Recurrence Interval	Flow (ft^3/s)
2	215
5	336
10	433
25	576
50	701
100	839

Abbreviations: ft = feet; s = second
Date and Author: 09-14-2020 / MRA
Pathname: O:\PROJ-20\WRM\20-007 Hands Mill Dam\Data\Hydrology\HandsMill_FPF_and_Summary.xlsx

Fish Passage Flows Analysis

High and low fish passage flows were estimated to assess potential fish passage conditions at the site following dam removal. Daily streamflow data was downloaded from the East Orange Branch gauge and used to calculate the 5% and 95% exceedance flows (seasonal high and low flow) during September to November, when brook trout migration is likely. The 5% and 95% exceedance flows were also calculated using daily streamflow data from the entire year. The fish passage flows calculated for both time intervals are provided in Table 2.

Table 2: Fish Passage Flows at Jail Branch

Flow	Sept – Nov Fish Passage Flow (ft^3/s)	All Months Fish Passage Flow (ft^3/s)
High	15.6	31.7
Base	4.0	6.7
Low	1.2	1.3

Abbreviations: ft = feet; s = second
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The flow scenarios above were simulated using a hydraulic model described below.

Hydraulic Model Development

Stone used the US Army Corps of Engineers (USACE) Hydrologic Engineering Center's River Analysis System model (HEC-RAS; http://www.hec.usace.army.mil/software/hec-ras/) to develop a one-dimensional, steady flow hydraulic model of Jail Branch, the dam and its floodplains. This model was used to simulate the peak flows and fish passage flows calculated above for existing and proposed conditions.

The basemap developed as part of Stone's assessment of the existing conditions at the site was the source of the topography and bathymetry for the existing conditions hydraulic model. The basemap was developed in a relative datum and will be tied to NAVD88 datum during 100% design. Stone staff exported the TIN surface as a digital elevation model (DEM) and then imported the DEM into HEC-RAS Mapper to create a terrain model, which supported the development of the geometry file in HEC-RAS.

Once the geometry file was created, the dam structure and features such as natural levees, ineffective flow areas, stream bank stations, distances between cross-sections, Manning's roughness coefficient at each cross-section were more fully defined. Survey data collected by Stone staff were used to specify the dam locations and dimensions in the existing conditions model. Manning's n values were selected based on channel surface roughness, vegetation, and channel features such as pools.

HES-RAS requires boundary conditions to set the starting water surface elevation at the upstream and/or downstream ends of the river system being modeled. Additionally, a flow regime (subcritical, supercritical, or mixed) must be selected for each analysis. For this 30% design, each steady flow analysis was completed using a subcritical flow regime, which is well suited for preliminary dam removal evaluations. Since the subcritical flow regime was used, only a downstream boundary condition was specified. The downstream boundary condition was set to normal depth with an energy slope of 0.0055, for all flow profiles. The energy slope was estimated based on the channel slope in the vicinity of the downstream cross sections. The boundary condition was set at cross-sections sufficiently far away from the area of interest as to minimize errors due to estimating the starting water surface elevation.

The peak flow and fish passage flow values calculated using gauge transfer and statistical techniques were entered into the HEC-RAS flow file that was used for both the existing conditions and the proposed conditions model. For this final 30% design deliverable, the model included the tributary junction at Jail Branch and the Unnamed Tributary and incoming flows were apportioned to each tributary based on tributary watershed size. Table 1 lists the peak flow conditions simulated and Table 2 lists the fish passage flow simulated.

Existing Conditions Hydraulic Analysis

The hydraulic analysis completed for the existing conditions provides insight into the expected water surface elevations, water velocities, flood inundation limits, and barriers to fish passage for the flow scenarios analyzed. A longitudinal profile for existing conditions, including water surface elevations for specific flow scenarios, is provided as Figure 1.

Proposed Conditions Hydraulic Analysis for the Selected Alternative

Stone developed a one-dimensional hydraulic model to simulate flow conditions for the selected alternative (Alternative A4). The model for Alternative A4 was developed based on approximately 195 total linear feet of dam removal, the extents of which are shown on Sheets 5 and 6 of the plans. The model also incorporates the removal of approximately 11,100 CY of impounded sediment behind the dam; which is simulated in the model via a revised pilot channel slope as shown on Sheet 7 (see dashed blue line in the profile at top of sheet) and the dimensions of the Typical Channel Cross Section also provided on Sheet 7, which includes bank stabilization measures and incorporation of a 30' wide floodplain bench along river left (green shaded area on Sheet 6).

Table 3 below provides a comparison of the 100-year recurrence interval flood water surface elevations at the dam for the existing condition and Alternative A4. Figure 1 provides a plot of water surface elevations for the existing condition and proposed condition, for Alternative A4.

Table 3: Water Surface Elevation Comparison for the 100-Year Recurrence Interval Flow

Scenario	100-yr WSE[1] (ft)	Linear Feet of Dam Removed
Existing	1279.79	0
Alternative A4	1265.15	195

Abbreviations: ft = feet; WSE = water surface elevation
[1]WSE presented references a relative datum and will be tied to NAVD88 during 100% design development
Date and Author: 1-5-2021 / MRA/GMB

It is evident that Alternative A4 provides significant reduction in water surface elevations compared to those of the existing conditions, with a peak water surface reduction of 14.64 feet for the 100-year recurrence interval storm event. Similar reductions apply for other significant recurrence intervals (i.e. 10-, 25- and 50-year intervals). In addition to these peak water surface elevation reductions and mitigation of flooding, the dam removal also improves public safety by removing a high hazard dam that has been deteriorating over the past few decades.

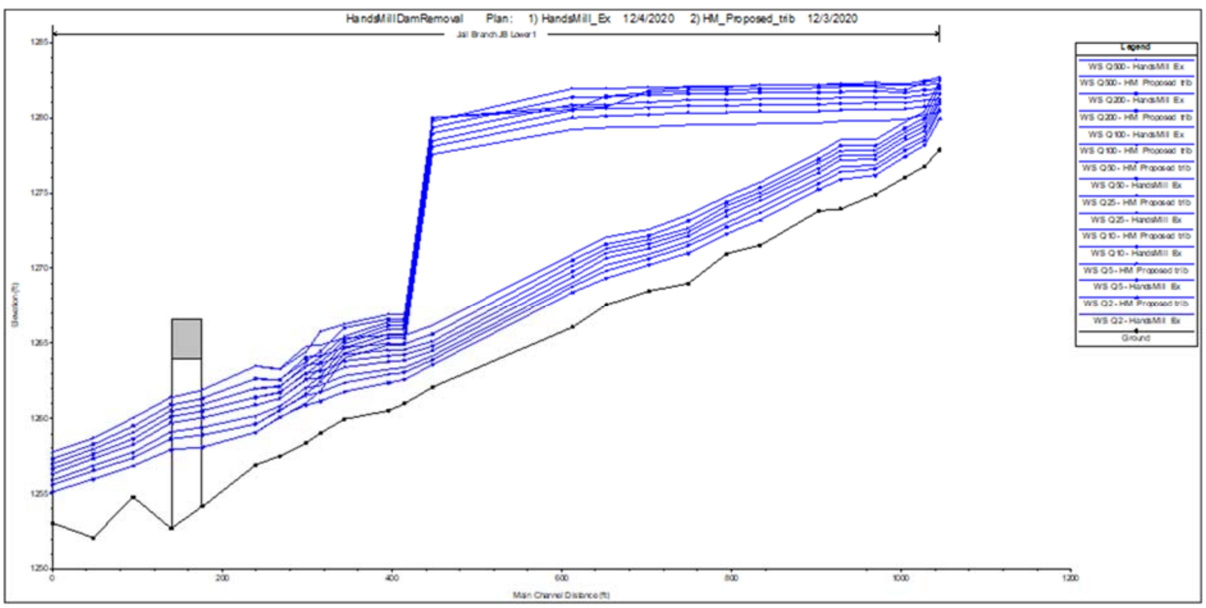

Figure 1. Profile of HEC-RAS output showing water surface elevations for existing and proposed conditions. Water surface elevations (blue lines) that follow pilot channel thalweg (black line) are storm peak flow water surfaces following dam removal.