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W-P Project No. 13843A

Mr. Dana Little, President
Taylor Pond Association
585 Garfield Road
Auburn, ME 04210

Subject: Taylor Pond Flood Mitigation Assessment
Findings and Recommendations

Dear Mr. Little:

For the past year, Wright-Pierce has been working with the Taylor Pond Association to assess options for flood mitigation at Taylor Pond. These options have focused on some combination of improvements to infrastructure along Taylor Brook, as this infrastructure limits discharge and flow capacity during large storm events. The following sections of this letter outline the findings of our assessment.

WP Modeled Flood Elevations versus Flood Elevations published by FEMA

A primary finding our assessment was the difference between the flood elevations modeled by Wright-Pierce versus the flood elevations published by the Federal Emergency Management Agency (FEMA) in their Flood Insurance Study (FIS) for Androscoggin County (FIS# 23001CV001). The most recent FEMA FIS (dated July 8, 2013) indicates that the 100-year flood hazard elevation in Taylor Pond is 245.5 (NAVD88). Wright-Pierce modeling estimates the 100-year flood hazard elevation to be as much as two feet less than FEMA (approximately 243.6 feet NAVD88).

The principle difference between the Wright-Pierce modeling and the FEMA modeling relates to hydrologic estimation methods. The FEMA FIS states that the methods for determining flow rates (hydrologic conditions) in Taylor brook were determined by a regression technique developed by the USGS. While regression techniques can be quite accurate in undeveloped and unregulated drainage basins, there are some limitations. In particular, regression analysis predicts a single peak flow rate, which can be useful in steady-state modeling efforts. However, to estimate water surface elevations in large waterbodies with substantive storage volumes and outlet structures that regulate discharge, it is important to incorporate modeling methods that incorporate time and volume. The regression methodology does not effectively account for the flow regulation at the outlet of Taylor Pond, nor the storage volume of Taylor Pond.

Wright-Pierce utilized the United States Department of Agriculture (USDA) Soil Conservation Services (SCS) TR-20 methodology to develop flow hydrographs for Taylor Pond and associated tributary streams to Taylor Brook. The flow hydrographs were then routed through an unsteady (time based) HEC-RAS hydraulic model that accurately incorporated the specific stage-storage-discharge relationships of Taylor Pond and the infrastructure along Taylor Brook. This methodology more accurately reflects the relationship of the detention capacity of Taylor Pond and the associated flood elevation that results from a 100-year event.

It appears that the FEMA analysis is substantively overestimating the flood hazard elevation in Taylor Pond. Utilizing more a more detailed and volume based hydrologic modeling approach, we anticipate that the FEMA flood hazard mapping could be revised below its currently published elevation. While this reduction in flood elevations would be mainly a "paper" improvement (would not make an actual change to the flood levels in Taylor Pond), it may provide substantive financial relief to residents around the pond via reducing flood insurance requirements.

If the Taylor Pond Association is interested in revising the FEMA Flood Hazard mapping, it will be necessary to file an application for a LOMR (Letter of Map Revision) with FEMA. The LOMR process will take time as substantive technical information will accompany the application for review by FEMA. The modeling prepared by Wright-Peirce for this exercise would also require further refinement and additional detail prior to being acceptable for submission to FEMA for review. We would be happy to discuss this process with further with the Taylor Pond Association, however it was outside of the scope of this study.

<u>Taylor Brook Infrastructure and Stream Summary</u>

Discharge from Taylor Pond forms Taylor Brook, which flows through twin culverts under Hotel Road prior to crossing under a bridge structure and over a dam (Upper Kendall Dam). One of the focal points of this study was to quantify actual flood elevation improvements in Taylor Pond by improvement and/or modification to the infrastructure along Taylor Brook.

Wright-Pierce focused data collection, stream assessment, and hydraulic modeling efforts on the segment of Taylor Stream from the outlet of Taylor Pond to the point just downstream of the Upper Kendall Dam. The data review included the collection of available plans for the associated infrastructure, limited topographic survey in the area of infrastructure (particularly in the area of hotel road), and a paddling survey of the brook segment. Wright-Pierce also constructed an unsteady HEC-RAS computer model of the Taylor Pond and Brook system to calculate hydraulic characteristics in the system and determine the associated effects of modifying the infrastructure.

Hotel Road Crossing and the Upstream Reach of Taylor Brook

The segment of Taylor Brook between Hotel Road and the Pond contains dense woody vegetation and a rather non-descript braided channel. Much of the substrate in this reach area is a sandy gravel, which appears to be general aggradation of sediment transported from the adjacent beach areas and sandy shoreline near the outlet of the Pond. Anecdotal accounts of beach nourishment practices indicate that excessive artificial sand and gravel sediment loads have been supplied to the Pond for many decades since the early 1900s. While these sands loadings have improved the beach conditions for recreational purposes, substantive amounts of sand and gravel have been transported into the mouth of Taylor Brook at the outlet of the Pond.

As shown on a plan from 1935 on file with the Maine DOT, a small bridge existed at the crossing of Hotel Road and Taylor Brook in the early 1900s. The plan depicted the existence of a "Fish Screen" just upstream of the bridge location prior to 1935. While not specifically defined as a "dam", the existing conditions survey identified that a water surface elevation step of over two feet (>2') existed at the crossing. The combined effect of the "fish screen" and bridge created a damming effect at hotel road.

In 1935, the Maine DOT replaced the prior bridge with an new sixteen foot (16') span concrete structure. This bridge existed until 1978, until it was replaced with the set of twin corrugated metal arch culverts that exist today. Each of these structures creates a hydraulic "constriction" of the Taylor Brook channel, which limits its hydraulic capacity.

It is likely that prior to the construction of infrastructure along Taylor Brook, the reach upstream of Hotel Road had similar channel form, floodplain, and vegetative qualities as the segment downstream of Hotel Road. However, these two reaches are substantively different at this time. The difference is obvious and evident by standing on Hotel Road and comparing the general visual observation of these reaches from upstream to downstream.

It appears that the damming effects of historic structures on the Brook combined with the excessive sediment loading from upstream recreational beach nourishment, has severely altered the segment of Taylor Brook upstream of Hotel Road. The sedimentation appears to have effectively raised the elevation of the channel bed and adjacent flood plain (filled with sand and gravel sediments). The higher channel and flood plain elevations, combined with altered soils has promoted the growth of dense woody vegetation with an aggressive root structure throughout the upper reach.

Taylor Brook below the Hotel Road Crossing

Downstream of Hotel Road the Taylor Brook channel is notably different. The channel bed material is generally a fine silty-clay. The channel is well defined and meanders through a wide floodplain covered in emergent marsh grass. This downstream reach is reflective of the a more natural condition of Taylor Brook prior to the influences of infrastructure that have altered the upper reach.

The presence of beaver and their associated dams are evident throughout Taylor Brook between the Upper Kendall Dam and the Hotel Road Crossing. Based upon a review of prior studies and historic aerial photographs, it is evident that the beaver dam structures regularly breach and reform in different locations throughout the system. The relatively wide floodplain, flat channel gradient, fine/erodible bed materials and presence of Beaver Dams combine to cause a reasonable level of channel movement and migration over time. The aerial photo depicts several historic channel alignments and thalweag locations, indicating that the channel can fully utilize the flood plain as it meanders and may shift substantively during high flow events.

The Taylor Brook Channel form is substantively impacted by the Upper Kendall Dam for approximately 3,200 feet upstream from the dam. In this area, the channel is impounded during normal flow conditions. Channel velocities are reduced and water depths are increased. These effects are more pronounced with closer proximity to the dam location.

Just upstream from the Upper Kendal Dam is a bridge structure. This bridge structure carries a single lane road/driveway over Taylor Brook. The road/driveway appears to only serve a single residential property.

Taylor Brook Infrastructure Improvement Analysis

Wright-Pierce constructed a hydrologic and hydraulic model to evaluate the performance of Taylor Brook (and the corresponding effect to water surface elevations in Taylor Pond) during a variety of infrastructure improvement scenarios.

Hotel Road Crossing

As described above, the constriction created by the Hotel Road crossing and its impact to the upstream channel area is notable. Alleviation of this constriction by increasing the span and capacity of the Hotel Road crossing structure can aid Taylor Brook in reforming to a more natural (pre-impact) channel morphology. The U.S. Army Corps of Engineers' Programmatic General Permit for the State of Maine includes standards for the crossing of streams and brooks. A primary criterion of these standards is that a road crossing structure provides a span of 1.2 times (120%) of the stream's bank-full width. By providing a structure with a 1.2 bank-full width, the stream can maintain a more natural geomorphologic function.

There are limited locations to reference the appropriate bank-full width of Taylor Brook for the Hotel Road Crossing. As noted, the channel above the crossing is already severely altered. Downstream of the crossing, several tributary streams converge with Taylor Brook approximately 900 feet downstream. Beaver dam activity has also impounded the channel and there is some channel braiding within the remaining representative areas. During our in-stream survey in the Spring of 2017, Wright-Pierce measured the bank width of the stream to be in the range of 22 to 27 feet. For the purposes of design, we suggest the use of a bank-full width of 24 feet. Based upon this bank-full width, the structure at Hotel Road should be improved to a span of at least 29 feet.

Upper Kendal Dam and Bridge Crossing

The Upper Kendal Dam and Bridge Crossing are located in close proximity to each other. During normal monthly flow conditions, these two structure do not have a direct impact on Taylor Pond. However during high flow events (i.e. 100-year storm) both of these structure have a substantive impact on the flood level in Taylor Pond.

The Upper Kendal Dam sits on natural bedrock and has a simple overflow style spillway crest that spans the entire Taylor Book Channel. The bridge is located approximately 30 feet upstream and has a span of approximately 13.5 feet. Each structure has its own individual impacts to Taylor Brook, however their combined impact is more substantial.

Improvement Scenarios

To quantify the associated impact to Taylor Pond, our hydraulic modeling evaluated a variety of infrastructure improvement scenario combinations. Specifically, the following list of scenarios was evaluated:

SCENARIO EX – No improvements to infrastructure. This represents the existing conditions.

SCENARIO 1 – Improvement to Hotel Road Crossing: 20' wide Arch Culvert, Crown Elevation:241.5'
No Improvement to Steven's Mill Bridge Crossing
No Improvement to Upper Kendal Dam

SCENARIO 2 – Improvement to Hotel Road Crossing: 20' wide Arch Culvert, Crown Elevation:241.5'
Improvement to Steven's Mill Bridge Crossing: 23' wide Bridge, Deck Elevation Retained.
No Improvement to Upper Kendal Dam

SCENARIO 3 – Improvement to Hotel Road Crossing: 20' wide Arch Culvert, Crown Elevation:241.5'
Improvement to Steven's Mill Bridge Crossing: 23' wide Bridge, Deck Elevation Retained.
Removal of Upper Kendal Dam

SCENARIO 4 – Improvement to Hotel Road Crossing: 20' wide Arch Culvert, Crown Elevation:241.5'
No Improvement to Steven's Mill Crossing
Removal of Upper Kendal Dam

SCENARIO 5 – Improvement to Hotel Road Crossing: 29' wide Bridge, Crown Elevation: 246'
No Improvement to Steven's Mill Bridge Crossing
No Improvement to Upper Kendal Dam

SCENARIO 6 – Improvement to Hotel Road Crossing: 29' wide Bridge, Crown Elevation: 246'
Improvement to Steven's Mill Crossing: 35' wide Bridge, Bridge Deck Elevation Retained.
No Improvement to Upper Kendal Dam

SCENARIO 7 – Improvement to Hotel Road Crossing: 29' wide Bridge, Crown Elevation: 246'
Improvement to Steven's Mill Crossing: 35' wide Bridge, Bridge Deck Elevation Retained.
Removal of Upper Kendal Dam

SCENARIO 8 – Improvement to Hotel Road Crossing: 29' wide Bridge, Crown Elevation: 246'
No Improvement to Steven's Mill Crossing
Removal of Upper Kendal Dam

SCENARIO 9 – No Improvement to Hotel Road Crossing
Improvement to Steven's Mill Crossing: 23' wide Bridge, Deck Elevation Retained.
No Improvement to Upper Kendal Dam

SCENARIO 10 – No Improvement to Hotel Road Crossing
Improvement to Steven's Mill Crossing: 35' wide Bridge, Bridge Deck Elevation Retained.
No Improvement to Upper Kendal Dam

Based upon these scenarios, we determined the following performance (shown in Table 1). It is important to note that the reported existing condition differs from the FEMA published information. As discussed in prior sections, this is due to a difference in hydrologic modeling techniques and pond routing methods.

Table 1 – Taylor Brook Hydraulic Performance Summary (100-year event)
No Channel Adjustment/Response

Scenario	Taylor Pond Outlet		Upstream of Hotel Road		Downstream of Hotel Road	
	Elevation (Feet)	Shear Stress (Ft-lbs)	Elevation (Feet)	Shear Stress (Ft-lbs)	Elevation (Feet)	Shear Stress (Ft-lbs)
EX	243.57	0.12	243.43	0.13	242.31	0.05
#1	243.30	0.15	243.11	0.16	242.32	0.05
#2	243.26	0.19	243.02	0.20	242.01	0.08
#3	243.17	0.27	242.78	0.32	241.17	0.20
#4	243.19	0.23	242.88	0.26	241.61	0.12
#5	243.23	0.19	242.99	0.20	242.62	0.05
#6	243.17	0.27	242.80	0.31	242.16	0.09
#7	243.09	0.36	242.53	0.47	241.32	0.22
#8	243.13	0.29	242.71	0.34	241.99	0.11
#9	243.32	0.15	243.13	0.15	241.93	0.06
#10	243.32	0.15	243.13	0.16	241.87	0.07

Note: Elevations are in reference to NGVD88 and reflect the modeled maximum water surface of the brook at the noted location. Shear stress is the average shear stress in the channel at the noted location.

As shown in Table 1, there is only approximately six inches (6") of flood reduction associated with the most aggressive improvement scenario (Scenario #7). Considering these water surface elevations on their own, one would conclude that there is little benefit to improvements to any of the infrastructure along Taylor Brook. However, considering the overall modeling results more closely (particularly the associated shear stress at each location), it becomes apparent that some level of channel geometry adjustment and response would also occur during large storm events.

As noted in prior sections of this report, the channel bed material in Taylor Brook is a uniform sand in the reach upstream of Hotel Road. Downstream of Hotel Road the channel bed material is a finer silt/clay. To determine the potential for channel response and adjustment, a representative sample of the channel bed material (sandy material upstream of hotel road) was collected and analyzed.

The laboratory analysis of the material identified it as a relatively uniform sand. The test indicated that 99% of the material had a particle size smaller than 12.5 millimeters (1/2") and about 10% of the material was less than 0.15 millimeters (No. 100 sieve). The average size of the sand particles is approximately 1.0 to 1.5 millimeters in size.

Based upon the analysis of this sample, Wright-Pierce performed calculations relating to the potential for mobilization of this sand during various conditions. Our calculations indicate that the smaller (finer) particles of sand will begin to mobilize when shear stress in the channel reaches approximately 0.04 foot-pounds (ft-lbs). Once a shear stress of 0.16 foot-pounds develops in the channel, all particles in this sandy material will mobilize. As such, the sandy material that forms the Taylor Brook Channel around the outlet of the Pond will begin to mobilize during storm events that create shear stress in the channel of 0.04 ft-lbs. It should be expected that the channel will begin to meaningfully reform once shear stress reaches 0.16 ft-lbs.

As shown in Table 1, shear stress in the Taylor Brook study area does not exceed 0.12 ft-lbs in the existing conditions. This result is to be expected, as the geometry of the Taylor Brook Channel has developed around this existing hydraulic condition. However, improvements to infrastructure along Taylor Brook will increase shear stress on the channel, which will trigger changes to the existing channel geometry. As identified in Table 1, a shear stress of as much as 0.36 ft-lbs could develop in the most aggressive improvement scenario (Scenario #7).

Considering the potential for the channel bed to mobilize upon improvement of infrastructure, it is important to consider the associated affects of restoring the natural channel form to Taylor Brook. In addition to collecting the aforementioned sample of bed material, several explorations were performed via excavation and probes in the channel (with hand tools). Throughout the most confined channel sections (constricted horizontally and vertically) there is multiple feet sandy bed material. Hand probes were advanced at least four feet without reaching refusal. Generally, a fine grey silt/clay material was found underlying the sand bed. The underlying silt/clay was similar to the composition of the bed material downstream of Hotel Road. Overall, it appears that mobilization of the sand bed material would be generally unrestricted within the extent of the flood plain.

The precise channel adjustments that would occur during large storm events are dynamic and complicated to predict. It is also likely that the channel would take time to respond and the mobilization of materials would occur gradually over a series of high flow events. However, it is reasonable to expect that the channel form and grade associated with Taylor Brook downstream of Hotel Road, would continue through Hotel Road and up to Taylor Pond. Utilizing the Taylor Brook Channel downstream of Hotel Road as a proxy for the restored condition of the upstream reach, the HEC-RAS model was revisited for several key scenarios to consider hydraulic performance of Taylor Brook that would include channel response and restoration of channel form. The associated results are shown below in Table 2.

Table 2 – Taylor Brook Hydraulic Performance Summary (100-year event)
Includes Channel Adjustment/Response

Scenario	Taylor Pond Outlet Water Surface Elevation (Feet)
EX	243.6
#1	243.3
#5	243.2
#6 or #8	242.4
#7	241.8

As shown in Table 2, there are minimal impacts to the water level in Taylor Pond by improvement only to the Hotel Road structure. However, a combination of improvements to the Hotel Road crossing and one of the other structures (either the Upper Kendal Dam or the Bridge) will result in approximately one foot of reduction to the flood level in Taylor Pond during the 100-year event. If the most aggressive infrastructure improvement strategy is employed (under scenario #7), it may be possible to reduce flood levels (100-year event) in Taylor pond by as much as 1.5 feet or more.

Reccomendations and Considerations

Based upon this analysis, we have the following basic recommendations:

- Improve the Hotel Road crossing structure to at least a 29 foot span with a crown at or above elevation 244.0 feet (NGVD88)
- Coordinate with the Owner of the Upper Kendall Dam and Bridge to improve/modify at least one of those structures
- Coordinate with the City of Auburn and FEMA to revise the FEMA mapping for the 100-year flood levels.

There are several additional points to consider if these recommendations are acted upon. This includes, the associated effect of channel restoration to the normal water levels in Taylor Pond. During our in-stream survey in the Spring of 2017, the water level in Taylor Brook was controlled principally by a beaver dam located approximately 1,200 feet downstream of Hotel Road. Based upon our review of prior studies, it seems that other beaver dams and/or temporary "berms" have controlled water levels over-time. The restoration of the Taylor Brook Channel will result in the potential for increased mobility of these structures and, perhaps impact (lower) normal water surfaces in Taylor Pond. This could be mitigated for by the construction of a new grade control structure at the pond outlet (such as a "nature-like" stone weir structure).

It is also likely that the woody vegetative growth that has encroached the Taylor Pond channel upstream of Hotel road will inhibit channel restoration. The root structure of those woody species is much more aggressive than the root structure of the marsh grasses and floodplain vegetation located in downstream reaches. As such, further consideration may be warranted to proactively cutting vegetation and/or dredging of portions of the channel upstream of Hotel Road to accelerate the channel restoration. This would only be recommended if it was happening after or in conjunction with the recommended improvements.

We appreciate this opportunity to work with the Taylor Pond Association. Please feel free to contact me with any additional questions or if you need further information.

Sincerely,
WRIGHT-PIERCE

Joseph M. McLean, PE
Senior Project Manager

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