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Hydraulic Study of Fish Creek for *The Saratoga Lake Association*

Saratoga County, New York

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HYDRAULIC STUDY OF FISH CREEK
FOR
THE SARATOGA LAKE ASSOCIATION

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1.0 INTRODUCTION

In early September, 2008, CT Male Associates, PC was retained by the Saratoga Lake Association (SLA) to conduct a hydraulic analysis of Fish Creek, the lake's outlet. The Saratoga Lake Protection and Improvement District (SLPID) also supported the study financially beginning in October, 2008. The study was prompted by frequent complaints to the SLA about lake levels being too high or too low. SLA representatives identified the following items for possible consideration/resolution by the study.

- It takes longer than expected for lake water levels to drop following large runoff events in the lake's watershed, and high water levels in particular are a major problem for lakeside property owners.
- There is a water level control structure across Fish Creek at Winnies Reef 6.5 miles downstream of the lake. Water is released through the structure using removable wooden stop-logs and mechanically operated sluice gates.
- At times, the control structures at Winnie's Reef are fully open and the lake level remains elevated for an extended period of time.
- Obstacles/ restrictions in Fish Creek are believed by some to impede the release of water from the lake. Aquatic plants and hydraulic restrictions in the Fish Creek channel sides and bottom are most often suspected causes.

The purpose of the study was to develop a better understanding of the hydraulics of Fish Creek and to provide insight into possible improved water level management of Saratoga Lake. This report summarizes the results of the study.

1.1 Elevation Datum

Elevations in the United States are typically given in one of two datums: the National Geodetic Vertical Datum of 1929 (NGVD 29), or the North American Vertical Datum of 1988 (NAVD 88). NAVD 88 was introduced because of refinements to our understanding of sea levels and the shape of the planet which had taken place since 1929; and because of improvements in survey accuracy over the same period.

Unless otherwise indicated, all elevations presented in this report, and in the associated figures, are based on NAVD 88.

2.0 STUDY AREA LOCATION

Saratoga Lake is located in Saratoga County, New York and comprises approximately 4,147 surface acres at the normal summer pool elevation of 202.9′ MSL. The lake is located in parts of 4 municipalities, namely the Towns of Malta, Saratoga, and Stillwater, and the City of Saratoga Springs. A location map is included in Figure 1, "Location Map". The lake is relatively shallow and supports a warm-water fish population. Game fish species include largemouth and smallmouth bass, northern pike, chain pickerel, and walleye. Rooted aquatic plants are abundant. A copy of a bathymetric survey of Saratoga Lake is included in Appendix F.

The watershed above Winnie's Reef (including Saratoga Lake) is approximately 226 square miles, 81% of which is contained in the drainage basin of Kayaderosseras Creek, the lake's principal inlet. Refer to Figure 1, "Location Map".

Water drains from the lake via the outlet, Fish Creek, which eventually discharges into the Hudson River at Schuylerville. Traditionally, the boundary between Saratoga Lake and the start of Fish Creek has been the NYS Route 9P Bridge over the lake, thereby resulting in a total length of Fish Creek from Route 9P to its mouth, of 12.5 miles. Refer to Figure 1, "Location Map".

There are three (3) dams/impoundments that affect water levels and flows in Fish Creek. Refer to Figure 1, "Location Map". The upstream-most impoundment is at Winnie's Reef, 6.4 miles downstream from the 9P Bridge. Next in line, approximately 4.9 miles downstream of Winnie's Reef, is the hydroelectric dam at Victory Mills (FERC project #7153). These two (2) facilities are currently owned and operated by Enel, N.A.Inc. The downstream-most dam, also a hydropower facility, is located in the Village of Schuylerville and is operated by Consolidated Hydro of New York, Inc. (FERC project #9606). The impoundment at Winnie's Reef, because of its location and elevation, is the only one of the three dams/impoundments that has a direct effect on Saratoga Lake water levels and flows draining out of the lake via Fish Creek.

Water level elevations in Saratoga Lake are monitored continuously at a gauging station on a concrete pier at the Route 9P Bridge crossing. This gauging station includes a pressure transducer connected to a telemetry system such that the water level can be obtained any time via telephone. There is also a staff gauge on the pier adjacent to where the transducer is mounted. There is generally good agreement between the two devices on the bridge. Lake elevations are recorded daily by Mr. Joseph Finn, a SLPID commissioner. There is also a staff gauge on a concrete pier at Winnie's Reef to determine water levels there. All of the above gauges are reportedly owned and operated by Enel, N.A. Inc. Currently there is very limited gauging of stream flows in the Kayaderosseras Creek watershed that could be used to estimate inflow into the Lake. The only continuous monitoring gauge is located in the headwater area of Glowegee Creek, and only covers approximately 10 percent of the Lake's watershed.

Winnie's Reef - The water level control structures at Winnie's Reef are located near the upstream end of an island 6.4 miles downstream of the Route 9P Bridge. On the north side of the island (left side looking downstream) are three (3) sluice gates, each 10.5 'W x 8'H, that can be lifted mechanically to allow water to pass underneath the gates. The sill plate for these gates is at elevation 196.2' MSL. On the south side of the island (right side looking downstream) is another water level control structure consisting of eight (8) stop-log bays. Each bay consists of two (2) slotted concrete piers that can hold up to four (4), 11.5'L x 12"H x 6"W stop-logs. Because the ends of the stop-logs are recessed into the slots the actual width of the opening in each bay is only approximately 11.0 feet. The sill elevation for the stop-log bays is 198.9' MSL, about 2.7 feet higher than the sill for the sluice gates. With all logs in place, the elevation across the top of the uppermost row of logs is approximately 202.9' MSL. Refer to Figure 2, "Impoundment at Winnie's Reef".

3.0 NORMAL OPERATING CONDITIONS

Historically, the water level control structures at Winnie's Reef have been used to manage the water level in Saratoga Lake. Pursuant to an agreement first developed between the former dam owner and SLPID in 1987, the gates/stop-logs were opened/removed in the fall to drop the lake level and closed/reinstalled in the spring to restore the summer pool elevation for the summer recreation season. In the agreement the dam owner agreed that, consistent with the goal of power generation, it would strive to operate the dam in a manner that was consistent with the goals of weed control and water level management on Saratoga Lake. A copy of this agreement is included as Appendix G.

As the operating agreement has evolved over time, the current operating goals for Saratoga Lake are to maintain a level of between 202.6' and 203.0' MSL[1] during the summer recreational season. After Columbus Day in mid-October, an attempt is made to lower the lake to 201.3' MSL, where it is maintained until after the "Head of the Fish" rowing regatta held on the last weekend in October. After the regatta, the lake is lowered as much as possible for the winter season in an effort to kill aquatic plants near the shoreline and to reduce property damage from ice and spring flooding. The lowest possible lake level is approximately 199.3' MSL, but it rarely drops below 200.3' MSL. A minimum downstream conservation release of 36 cubic feet per second (cfs) is reportedly required by the NYS Department of Environmental Conservation (DEC) to protect aquatic life downstream of the dam, but there are no lake level requirements except via agreement between Enel and SLPID.

[1] The existing lake level gauge at the Route 9P bridge reads 0.67 feet higher than MSL. See discussion in Section 4.1.

During normal summer conditions the flow in Fish Creek is generally low, all the stop-logs are in place, and at least one sluice gate is closed. This operation scenario generally provides a regulated flow for hydroelectric power generation at Victory Mills, and maintains an adequate water depth upstream to allow motorboat access up Fish Creek to the lake. Sometimes however, within a day or two of heavy rain during summer conditions, the lake water level may rise as much as two feet. It has been reported by Enel that even when fully opening the sluice gates and removing several of the stop-logs during these events, it takes many days if not weeks for the lake level to drop back to pre-storm conditions.

4.0 DATA GATHERING / METHODOLOGY

The focus of this study was to determine what factor(s) are primarily responsible for the sustained water levels in Saratoga Lake after a runoff event. Therefore, to gain a better understanding of the hydraulics in the upper reaches of Fish Creek, six (6) water level monitoring stations were established in the uppermost 6.7 miles of Fish Creek.

4.1 Water Surface Profile

A licensed land surveyor, using high resolution GPS equipment, set bench marks (BM) at 6 locations and tied them to a common datum, i.e. NAVD 88. The locations were: (1) Route 9P Bridge, (2) Stafford's Bridge, (3) former railroad (RR) crossing, (4) Bryant's Bridge, (5) Winnie's Reef, and (6) just downstream of Winnie's Reef. Refer to Figure 3, "Gauge Locations". Information about and photos of the gauges is presented in Appendix A, "Gauge Information". Benchmark numbers 1-5 were established in September 2008 and benchmark 6 was established in April 2009.

A licensed land surveyor, using high accuracy GPS equipment, determined that readings at the existing gauges at the Route 9P Bridge and Winnie's Reef required adjustment to conform to the NAVD 88 datum. The 9P gauge read 0.67 feet too high, and the Winnie's Reef gauge read 0.20 feet too high. Spreadsheet software automatically corrected elevations at these two sites when raw data were entered. Corrected values were used to develop the Fish Creek water surface profiles presented in this report.

The benchmarks were used to set the staff gauges so that it would be relatively quick and easy to compare recorded water levels at the various gauges relative to the same datum. (Note: Water surface elevations at benchmark site 6 were obtained using survey equipment – no staff gauge was set). Surveyed elevations and benchmarks tied to the NAVD 88 datum were used to adjust the existing staff gauge readings at the Route 9P Bridge and Winnie's Reef and to correctly install and tie the new staff gauges at Stafford's Bridge, the RR crossing and Bryant's Bridge. A licensed surveyor obtained planimetric and topographic information for the water control structures at Winnie's Reef.

Water elevations at sites 1,2,3,4 and 6 were obtained and recorded by trained volunteers from the Saratoga Lake Association and Skidmore College, while elevations at Winnie's Reef were obtained and supplied by Enel employees. Volunteers were trained by CTM survey personnel. Water surface elevations were recorded during periods of relatively high flow, generally after a runoff event as water level in the lake was near peak or just starting to drop. Water elevation data at each gauge site was recorded once daily as the runoff subsided and flows dropped to normal levels. The elevation data from each gauge were compiled and used to develop a water surface profile for upper Fish Creek during each runoff event. The water surface profile was expected to become steeper in areas that were obstructed during periods of high flow.

Between the period of October 5, 2008 and August 9, 2009, water surface elevation data were collected on 34 separate days at the five gauges between the Route 9P Bridge and Winnie's Reef control structures. During periods of stable water levels, measurements were taken once weekly. During high runoff events, measurements were taken daily. Four major high runoff events were monitored during the study period: October 28-November 3, 2008; March 13-23, 2009; April 28-30, 2009; and August 6-9, 2009.

4.2 Creek Bottom Profile

A profile of the creek bottom in the deepest part of the channel or thalweg, was needed to determine if there were areas where the river bottom elevation was high enough to restrict the flow.

The profile was obtained using a calibrated fathometer attached to the stern of a motorized boat. The unit was also connected to GPS equipment so that the surveyors were able to simultaneously record location and elevation of the unit and the elevation of the creek bottom at a periodic, preset time interval. As with all other elevations, these data were correlated to the NAVD 88 datum. Readings from the sinuous path taken by the boat were used to locate the path of the thalweg and the elevations therein between the Route 9P Bridge and Winnie's Reef. Maps showing the path of the boat and the associated creek bottom elevations are included in Appendix B, "Bathymetric Maps of Fish Creek".

4.3 Stream Cross Sections and Hydraulic Analysis

As part of the scope of work for the hydraulic study of Fish Creek, it was originally proposed that cross-section elevation information at crossing locations along Fish Creek would be collected. Data from these cross sections, along with information on the Winnie's Reef dam, were then to be incorporated into a HEC-RAS hydraulic model to simulate flow in Fish Creek in the study area.

This part of the study was not completed however because the morphology of Fish Creek was too variable to select adequate sites for cross sections without generating more extensive mapping of the Fish Creek bottom profile than was originally planned. Therefore, an extensive mapping of Fish Creek's bottom profile was undertaken as described in the previous sections of this report. The data collected in this effort allowed the siting and development of stream cross-sections that could be incorporated into a hydraulic simulation model.

The bathymetric survey was limited to the central portion of Fish Creek that was deep enough to navigate by boat. The bathymetric survey was supplemented by using aerial photos and USGS topographic maps to estimate channel width where the cross sections were taken.

In lieu of conducting a detailed field survey, the creek bottom survey (bathymetric survey) and the creek channel width were used to generate cross sections that were entered into a computer simulation program known as HEC-RAS. This program was developed by the US Army Corps of Engineers to calculate water surface profiles in river systems.

The HEC-RAS model thus obtained was calibrated by adjusting the Manning roughness coefficient (a.k.a. Manning "n") at each cross-section, so as to replicate the observed water surface elevations. Manning "n" values ranging from 0.024 to 0.055 were applied to the cross sections. This range of values is typical for this type of stream. The calibration effort resulted in a model that fits well with the data from August 6 through 9 of 2009. Output from the HEC-RAS model is included in Appendix D.

It should be noted that the model does not fit as well with data gathered during the winter months of December 2008 and March 2009. Specifically, an unusually low Manning's "n" would need to be used in the model in order to fit the observed data for those months. The reasons for this lack of a good winter fit are unknown. However, because the lake drainage issues are experienced during the summer months, the lack of a good correlation between the model and winter-observed data should not be a significant issue for the purposes of this study.

The calibrated HEC-RAS model was used to create a series of stage-discharge tables for the Lake for various configurations of the Winnie's Reef flow control structures. Discharge through Winnie's Reef was estimated using rating curves prepared by others (see Appendix C). The stage-discharge relationships were then used in conjunction with a simplified stage-storage table of the lake to evaluate the length of time required to lower the water surface elevation in the lake by one foot (from elevation 204' to 203' MSL) under each of seven possible configurations (scenarios) of the Winnie's Reef flow control structures. The seven scenarios are described in the table below:

Table 1: Description of Winnie's Reef scenarios

Scenario	Status of Gates at Winnie's Reef	Status of Stop-logs at Winnie's Reef
1	3 gates: wide open	8 bays: 0 logs in each
2	3 gates: closed	8 bays: 0 logs in each
3	3 gates: wide open	8 bays: 4 logs in each
4	2 gates: wide open 1 gate: closed	8 bays: 4 logs in each
5	1 gate: wide open 2 gates: closed	8 bays: 4 logs in each
6	3 gates: closed	8 bays: 4 logs in each
7	1 gate: wide open 2 gates: closed	4 bays: 0 logs in each 4 bays: 4 logs in each

The HydroCAD computer program was used to perform the unsteady flow lake discharge calculations under each of the seven scenarios. Under each scenario, the HydroCAD model was started with a Lake elevation of 204' MSL, and was run to determine the time required for the water surface elevation to drop to 203' MSL. Output from the HydroCAD program is included in Appendix E. For purposes of comparing the impacts of various gate/stop-log openings on reducing lake levels, it was assumed there was no inflow to the lake.

5.0 RESULTS AND DISCUSSION

Water surface profiles from August 6-9, 2009 are shown graphically in Figure 4, “Water Surface Profiles”. Note that each profile represents water level readings that were taken on a given day. Data collected in December 2008 and March 2009 has not been plotted. A Fish Creek bottom profile which includes photographs of the bridge locations and the structures at Winnie’s Reef is also included in Appendix H.

Analysis of the water surface profiles reveals that the water surface is nearly level between the Route 9P gauge and the Stafford’s Bridge gauge. From Stafford’s Bridge to the RR crossing, the slope of the profile is 0.3 feet per mile, from the RR to Bryant’s Bridge, the slope is 0.5 feet per mile, from Bryant’s Bridge to Winnie’s Reef 0.7 feet per mile, from Winnie’s to the downstream gauge about 7.1 feet per mile. Refer to Figure 4, “Water Surface Profiles”. A flat profile generally indicates little flow resistance whereas a steeper water profile typically indicates increased flow resistance and/or a steeper channel slope. The profile slope between Stafford’s Bridge gauge and the Railroad gauge indicates that there is only a slight impediment to the flow in this section of the creek. This finding refutes the contention that aquatic plants in this section of the creek are a significant hindrance to flow.

The steeper water surface profile from the RR to Winnie’s Reef indicates that there is a flow restriction in this section of the creek and/or the channel bottom is steeper. However, the very steep aspect of the profile below Winnies Reef indicates that the dam at Winnie’s Reef is the single, most important factor acting to retard flow at the time the readings were taken.

Examination of aerial imagery also reveals that the width of Fish Creek narrows rather significantly from 270′ to 100′ feet starting just downstream of the RR gauge and remains at about 100′ feet all the way to Winnie's Reef. Refer to Figure 6, "Aerial Imagery". The narrow width of the stream channel in this corridor likely contributes to greater hydraulic loss, in part contributing to the steeper water surface profile.

Analysis of the creek bottom profile is best accomplished by examining Figure 5, "Water Surface and Creek Bottom Profiles", which shows the water surface profile on August 6, 2009 along with the creek bottom profile from the Route 9P Bridge gauge down to the Backyard Bench Mark location (Gauge 6). Due to the vertical scale required to show the bottom of the lake at the Route 9P Bridge it is not possible to distinguish between the multiple profiles that comprise the plot of the water surface profile.

Figure 5 shows the presence of high spots in the creek bottom at 10,000', 15,000', 17,000-20,000', 24,000-29,000', and at 34,000' (Winnie's Reef), downstream of the Route 9P bridge crossing. Since the sill invert elevation for the sluice gates at Winnie's Reef is 196.2′, any streambed elevation higher than 196.2′ feet that is upstream of the dam would act to control the release of water from the lake hindering the flow reaching the sluice gates at Winnie's Reef.

Examination of Figure 5, "Water Surface and Creek Bottom Profile" indicates that Fish Creek is deepest between the Route 9P bridge and Stafford's bridge with an average depth of 15′ – 30′. The depth of the creek decreases between Stafford's bridge and the RR crossing to depths averaging between 10' and 15'. Downstream of the RR gauge, at a distance of 17, 000' downstream from the Route 9P bridge, the depth decreases significantly to less than 5' for a section approximately 275' in length. This shallow spot occurs in an area of the creek where the surface width of the creek also decreases abruptly from 270′ to 190′. Downstream of this pronounced shallow section the depth of the creek stays relatively shallow most of the way down to Winnie's Reef.

The abrupt shallowing and narrowing of the channel in the section of the creek downstream from the railroad gauge creates a key hydraulic feature in Fish Creek between Saratoga Lake and Winnie's Reef. However, this creek feature would have the most impact on water levels and flows when water is passed through Winnie's Reef via the sluice gates because of their low sill elevation.

Field observations and the review of aerial imagery and topographic mapping, indicate there are two natural features that are unique to the shallow stretch of the creek: a gravel deposit on the north (left) side of the creek, and the discharge of Sucker Brook on the south side of the creek. Small tributary streams, like Sucker Brook, can deposit gravel deltas where they join larger rivers such as Fish Creek. However, examination of Sucker Brook reveals that its bottom profile is gently sloped for several hundred feet upstream of it's confluence with Fish Creek, indicating that it is not likely capable of carrying and discharging large diameter rocks that could obstruct the flow in Fish Creek. The smaller particles that Sucker Brook is capable of depositing into Fish Creek will likely be transported downstream in the flow in Fish Creek. These observations, plus an old gravel pit on the north side of Fish Creek opposite Sucker Brook, tend to support the theory that there is a natural deposit of compacted gravel or rocks in this stretch of the creek that obstructs flow leaving Saratoga Lake in Fish Creek.

The stage-discharge relationship for the Lake was applied to seven possible configurations (scenarios) of the Winnie's Reef flow control structures. Under each scenario, the HydroCAD model starts with a lake elevation of 204' MSL. The models were run to determine the time required for the water surface elevation to reach 203' MSL. Table 2 below presents the results of this analysis:

Table 2: Time required for modeled lake level to drop 1 foot under seven different Winnie's Reef scenarios.

Scenario	Status of Gates at Winnie's Reef	Status of Stop-logs at Winnie's Reef	Time required for modeled lake level to drop from elevation 204' to 203' MSL *
1	3 gates: wide open	8 bays: 0 logs in each	45 hours
2	3 gates: closed	8 bays: 0 logs in each	48 hours
3	3 gates: wide open	8 bays: 4 logs in each	46 hours
4	2 gates: wide open 1 gate: closed	8 bays: 4 logs in each	52 hours
5	1 gate: wide open 2 gates: closed	8 bays: 4 logs in each	75 hours
6	3 gates: closed	8 bays: 4 logs in each	23 days
7	1 gate: wide open 2 gates: closed	4 bays: 0 logs in each 4 bays: 4 logs in each	49 hours

* Please note that the times presented in this table are only intended to allow a comparison between the various gate and stop-log configurations at Winnie's Reef. Due to the simplifying assumptions made (most notably: the assumption of no inflows into the lake), the times presented in the table are not an accurate representation of the actual times required for the lake level to be lowered.

Comparing scenarios 1 and 2 reveals that, with zero logs in each of the log bays, closing all three gates extends the time required to lower the lake level by three hours. In contrast, comparing scenarios 1 and 3 reveals that, with all gates wide open, adding four logs to each of the log bays extends the time required to lower the lake level by only one hour. This shows that the gates have a larger impact on the lake level than the stop logs.

The other notable result can be found by comparing scenarios 1 and 4. This comparison reveals that, as long as two gates are kept wide open, the configurations of the other gate and of the stop logs have a relatively small impact on the time required to lower the lake level. From scenario 1 to scenario 4, one gate has been closed and four stop logs have been added to each of the eight log bays, and yet the time required to lower the lake level has increased by only 16 percent. In contrast, when comparing scenario 1 to scenario 5 (in which only one gate remains open), the time required to lower the lake level increases by 67 percent.

6.0 CONCLUSIONS

1. The flow control structures at Winnie's Reef and their operational regime are major controlling factors affecting flows in Fish Creek, and ultimately, water elevations in Fish Creek and Saratoga Lake.

2. Even with the full opening of the sluice gates and removal of the stop-logs at Winnie's Reef, significant water rise will continue to occur on the Lake during extreme rainfall events in the summer recreation season. The duration and extent of these rises can be mitigated to some extent by the timely opening of the sluice gates in anticipation of and during these events. The removal of stop-logs during these periods appears to produce little additional benefit.

3. A natural deposit of gravel and rocks between the railroad grade crossing and Bryant's Bridge partially obstructs flow in Fish Creek between Saratoga Lake and Winnie's Reef; the elevation of the creek bottom at this obstruction is slightly higher than the elevation of the sill plate elevation of the Winnie's Reef sluice gates, but lower than the sill plate elevation of the stop-log section. This natural deposit may be important to maintaining minimum lake levels during the non-recreational season when all of the sluice gates are open and the stop-logs are removed.

4. The existing water level gauges at the Route 9P Bridge and Winnie's Reef dam are not correlated to the NAVD 88 datum; the 9P bridge gauge reads 0.67 feet too high and the Winnie's Reef gauge reads 0.20 feet too high.

5. Because the Winnie's Reef structures control the upstream water surface elevations as far up as Saratoga Lake, aquatic plant growth does not

appear to be a major factor in the hydraulic capacity or water level elevations in Fish Creek.

7.0 RECOMMENDATIONS

1. SLA, SLPID, Enel and other agencies and interests should collaborate in reviewing and revising as appropriate the existing Water Level Management Agreement for the purpose of achieving mutually agreeable improvements in water level and flow management in Fish Creek and on Saratoga Lake.

2. Gauges at Route 9P and Winnie's Reef should be reset to be correlated to the NAVD88 datum. Historical lake elevation data should be corrected accordingly.

3. Using information collected as part of this Fish Creek study, a calibrated, hydraulic model for Fish Creek between the Route 9P bridge and Winnie's Reef dam was developed. This model should be used as a tool in evaluating improved water level and flow management options for Fish Creek and Saratoga Lake and in making revisions to the Water Level Management Agreement.

4. Evaluate the feasibility of operational changes at Winnie's Reef during high flow periods to increase flows in Fish Creek and reduce high waters in Saratoga Lake. In particular, the timely raising of at least two of the three sluice gates prior to and during high flow events should be evaluated. If at least two sluice gates are fully raised, then removal of stop-logs is of little additional benefit.

5. Evaluate the benefits and feasibility of installing precipitation stations and/or flow monitoring devices in the Kayaderosseras Creek watershed for use in monitoring and predicting inflows to the lake to help improve lake level management.

6. If satisfactory lake level management cannot be achieved with other measures described previously, evaluate the feasibility and effects of removing existing obstructions in Fish Creek (just downstream of the Railroad gauge) to increase the hydraulic efficiency of the creek.

Respectfully submitted,

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