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Memorandum

To: Scott Tucker, Superintendent, Sleeping Bear Dunes National Lakeshore (SLBE)

Through: Forrest “Ed” Harvey, Chief, Water Resources Division (WRD)

From: Derek Schook, Hydrologist, WRD
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Subject: Shalda Creek flow modeling, including how beaver dams and the West Traverse Lake Road culvert affect Little Traverse Lake water levels, Sleeping Bear Dunes National Lakeshore

Executive Summary

We investigated how existing and hypothetical beaver dams could impact water levels in Shalda Creek and Little Traverse Lake (LTL) using a standard one-dimensional hydraulic model (HEC-RAS). In November 2021, we conducted a topographic survey of Shalda Creek beginning at LTL and continuing 1.34 mi downstream. The reach had a sinuous channel with one small arch culvert crossing, one large box-culvert crossing, and two intact beaver dams. The creek was very flat, with a 0.02% slope and 2.40 ft of water level drop throughout the reach. Through the modeling effort we draw two primary conclusions: 1) A sizable beaver dam located anywhere in the study reach could raise the base water level in LTL, with the effect being most influential at low flows, and 2) the culvert at West Traverse Lake Road always restricts flow, with this impact increasing during wet periods when inflows to LTL and Shalda Creek streamflow are high.

Introduction

As part of a continued investigation of Shalda Creek water levels, this report summarizes hydraulic modeling that was undertaken to see if high water in Little Traverse Lake (LTL) could be caused by downstream flow obstructions in Shalda Creek. The low-gradient meandering creek flows 2.9 mi from LTL to Lake Michigan. Beavers, a natural part of river ecosystems in northern Michigan and across the continent, were widely removed through trapping during the fur trade and by early settlers. The resulting diminished beaver population lessened their influence on the ecosystem when humans expanded across and developed the modern landscape. Recently beavers have reoccupied Shalda Creek

and have built dams downstream of LTL, leading to the questions: 1) To what degree can beaver dams of different sizes and locations along Shalda Creek raise water levels upstream at LTL? 2) Under what conditions would lowering dams on Shalda Creek relieve the flooding of private property on LTL? We used a standard hydraulic model to investigate.

Field and Modeling Methods

From November 9-13, 2021, we conducted a topographic survey of Shalda Creek (Figure 1). The upstream extent of the study reach was east of West Traverse Lake Road (WTL Rd) at the outlet of LTL, so water levels at this location represent those of LTL. We used two Trimble R12i RTK GPS units differentially corrected using SLBE's new NTRIP base station. The survey included 22 channel cross-sections, 46 channel thalweg (lowest point) locations, 83 water surface locations, and infrastructure including West Traverse Lake Road (WTL Rd) and its culvert, County Road 669 (CR669, or Bohemian Rd) and its box culvert, staff plates, and water level monitoring wells located in Shalda Creek. The surveyed points averaged 0.12 ft vertical and 0.09 ft horizontal error, verifying a high-precision survey.

We used HEC-RAS, a standard water surface profile model developed by the U.S. Army Corps of Engineers (USACE 2019), to estimate stream and lake levels in the Shalda Creek system at a range of discharge values. The 1.34 mi study reach was modeled using one-dimensional, steady-state flows with normal flow as boundary conditions. Discharge measurements at the time of the field survey were about 20 cubic feet per second (cfs), which served as an initial model calibration. Manning's roughness values were 0.06 in-channel and 0.18 overbank, relatively high values but appropriate for this sinuous and densely vegetated stream. Four discharges were used to characterize conditions across the spectrum of flows: 10 cfs for low-flow, 20 cfs for average flow (Steinburg et al 1994, Canale and Neilson 1997, Leelanau Conservancy, unpub), 70 cfs to represent a May 2014 flow event measured by Gosling Czubak Engineering Sciences, Inc. (GCES) (GCES 2014) and considered a "typical flow rate" for 2014 (GCES 2015a; note that 2014 mean discharge was 19% above the long-term average at the nearby Platte River USGS gage 04126740), and 120 cfs previously modeled by GCES as the 10-year flood as estimated by the Michigan Department of Environmental Quality (GCES 2014).

We paid particular attention to the effects of flow obstructions such as the culvert at LTL, the large box culvert at CR669, and the two existing beaver dams surveyed in the field (Figures 1 & 2). Some model runs removed the dams to simulate undammed conditions, and other runs included them using the inline weir function. The model runs with dams also included two additional constrictions that represented relict dams like one that was found downstream of CR669 during the field survey.

Modeling Results and Discussion

Flow modeling provided two primary insights. The first is that in this very low gradient stream (0.02% slope), sizable beaver dams that are at least 3.7 ft high from base that are located anywhere in the study reach could affect LTL water levels. Results indicate that the downstream-most dam in the study reach (previously called "Dam 1" (GCES 2015b; Martin and Kim 2018)), which was surveyed and modeled at an elevation of 593.24 ft in the NAVD88 datum (note: this datum differs from the WTL Rd staff plate elevations¹), is capable of creating backwater that extends to the upstream dam (previously the focus of

¹ The staff plate upstream of WTL Rd (at our well 1) was previously reported to be 0.8 ft below the NAVD88 elevation (GCES 2014). Our RTK data agreed, showing the staff plate to be 0.83 ft below NAVD88. For example, an elevation of 593.24 ft would read 592.41 ft on the staff plate.

GCES (2020) and called “Dam 0” (Martin and Kim 2018)). The upstream dam was surveyed and modeled at an elevation of 594.42 ft. Modeling showed that while the upstream dam increased water levels at LTL, the increase was greatest at low flow and smallest during high flow. Compared to no-dam conditions, the dam raised water at LTL by 1.18 ft (to 594.72 ft) during low flow, but the rise was essentially nothing (0.03 ft, likely a modeling artifact and equivalent to 0) at the highest flow, when conveyance through the WTL Rd culvert was fully under “inlet control” conditions (GCES 2014). These results are consistent with a peer-reviewed modeling study that showed beaver dams “have no considerable impact on the peak discharge attenuation for flood events with return periods of 2 or more years in terms of flood mitigation measures” (Neumayer et al. 2020). This means that flood conditions occur without dams adding water to storage or slowing down the runoff, and the degree to which water levels rises diminishes with dams because of increasing channel cross-sectional area.

To further investigate, a hypothetical dam was placed at the downstream extent of the modeling reach, which was 280 ft downstream from the existing downstream dam. During average flow conditions (20 cfs), the dam would have to be at least 3.7 ft high to increase water surface at LTL by just 0.07 ft. A slightly larger dam of 4.0 ft is needed to increase water by 0.13 ft. These sizeable dams had no effect on water levels at LTL at the higher flows of 70 and 120 cfs. If located further upstream, slightly smaller dams could have similar effects on LTL.

The Shalda Creek channel bed rises and falls within its general downstream slope (Figure 3). The two dams encountered during field survey looked small, but they rose approximately 3.9 ft above nearby deep parts of the streambed. Additionally, because dams are a mixture of sticks and sediment often without a readily identifiable base, accurately quantifying the dam height and location combinations that could impact LTL is not a feasible approach to prescribing a management framework.

Our second major finding is that the existing culvert at WTL Rd restricts flow and raises LTL water levels under all discharges, and these effects increase with increasing discharge (Figures 4 & 5). During low and average flows, the culvert constriction causes LTL water level to increase up to 0.23 ft (depending on flow rate and presence of dams), while for the two highest modeled flows the culvert backs up water by 1.08-1.28 ft (Table 1). These findings are similar to those reported by GCES (2015a), although their models simultaneously investigated culverts at both WTL Rd and CR669. They found the culverts to raise water levels by 0.4 ft during average flows of 20 cfs, 0.7 ft at 60 cfs, and 2.5 ft at 120 cfs. Thus, both studies showed that flow constrictions imposed by small round culverts cause higher water in LTL, and this effect is greatest during higher flows when human property is most susceptible to flooding. Considering that there is a threshold stage where flooding becomes problematic for property owners (previously reported as 596.48 ft in NAVD88, or 595.65 ft on the staff plate), the culvert constriction exacerbates whatever water level has been established by beaver activity and other naturally dynamic ecosystem processes.

Modeling crucially avoided a complication associated with field data investigations in that field data are confounded by rainfall-runoff events, time lags related to flood wave attenuation, and beavers dam deconstruction and rebuilding. This study shows that dams and culverts can have extensive upstream effects, if given enough time. Notably, the steady-state approach modeled an unchanging flow rate until equilibrium conditions were reached, meaning that the time it takes to fill and drain storage reservoirs (e.g., the channel, floodplain, near-channel groundwater, and LTL) were not addressed in this study.

Conclusions and Next Steps

- Modeling revealed that during *low flow* periods beaver dams are the more influential obstruction determining the water level at LTL. During *high flow* periods the WTL Rd culvert is the much more influential obstruction (Table 1); removing dams during high flow would be ineffective at reducing LTL water levels because the culvert dictates lake drainage.
- The WTL Rd culvert exerts a constant effect on LTL water levels, and impacts are greater with increasing discharge. The culvert raises water by 0.23-1.28 ft for flows of 20-120 cfs when beaver dams are not present.
- Beaver dams such as those existing during the field survey increase the base water level in LTL. Beaver dams greater than 3.7 ft above the channel bed located anywhere in the study reach can affect LTL water levels. The upstream dam would need to be 1.4 ft higher to cause LTL to reach the previously identified critical flood elevation. The exact height of impactful dams depends on their position relative to channel bed undulations, so measuring their height does not offer a clear management approach.
- Constructing an expanded WTL Rd culvert would almost fully negate its impact on LTL water levels. For example, a 20 ft wide box culvert (similar to the 30 ft one at CR669) would increase the water level in LTL by just 0.1 ft at 120 cfs, its most influential modeled flow. Thus, enlarging the road underpass would be the most effective way to prevent LTL flooding.
- A relatively straight-forward management approach to identify the presence of beaver dam-driven backwater near LTL would be to measure water level at well 2 (Figure 1). This location can be affected by dam backwaters, but its position just downstream of WTL Rd removes the complicating effects from the culvert constriction.
- If there is interest in future dam manipulation events, a decision framework could include an action stage measured at well 2 that would trigger additional protocols. For example, a staff plate stage of 595.65 ft at well 1 was the stated level for crawl space flooding (GCES 2014); this or a slightly lower stage could be the action stage at the nearby well 2 (assuming the staff plates are level, and recognizing their offset from the NAVD88 datum). Note that the existing upstream dam would need to be 1.4 ft higher for water to reach this stage, which would be a massive dam given that this height would need to extend across the channel and overbank.
- Colorado State University is producing a report that characterizes Shalda Creek from a watershed perspective. The report will synthesize past data from the creek itself, and also scale-up to describe the interacting processes affecting flows in the broader landscape context.

The NPS Water Resources Division is available to continue conversations concerning this river ecosystem. If you have any questions, please contact Derek Schook (derek_schook@nps.gov).



Figure 1. The Shalda Creek modeled reach (blue). Inset map at top-right shows West Traverse Lake Rd, its small arch culvert (white line), and wells 1 and 2. Flow is from right to left. Google Earth image 2018.



Figure 2. Photos of (top) the downstream view of the existing small arch culvert under West Traverse Lake Road, and (bottom) upstream view of the downstream beaver dam, showing both the dam that backs up water by 0.7 ft and adjacent spoils piles from past breaching events (NPS, 2021).

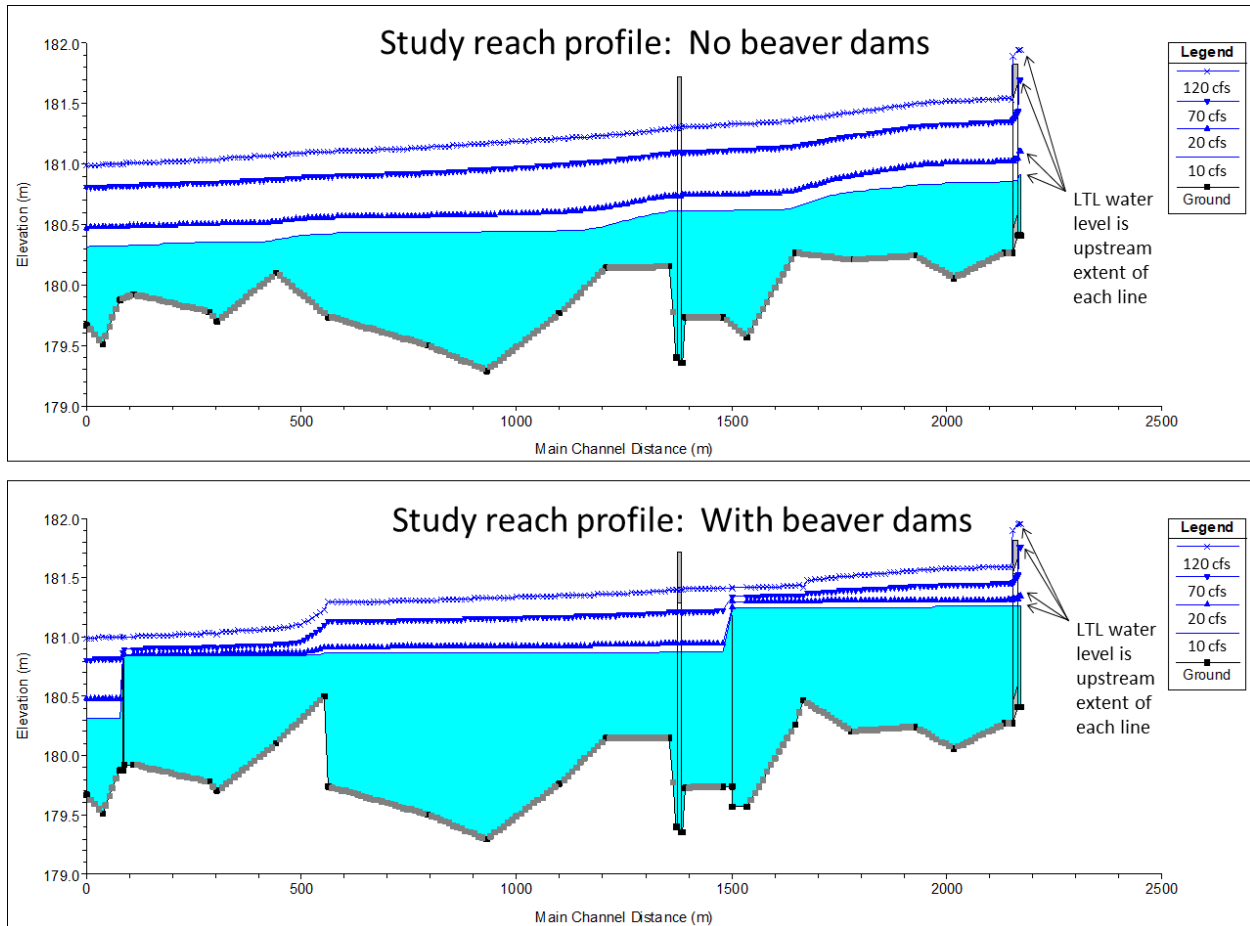


Figure 3. Shalda Creek longitudinal profiles of water surface throughout the study reach for flows of 10, 20, 70, and 120 cfs for both dam-free (top) and beaver dammed (bottom) conditions. Note that axes are in metric units. For dammed conditions, existing dams are shown as vertical lines at 90 and 1500 m on x-axis, and two relict dam constrictions were included as seen in bed elevation at 550 and 1670 m. Downstream is at left, and the large box culvert (center) and small arch culvert (right) are shown as vertical rectangles. A zoomed-in view of the small arch culvert is shown in Figure 4.

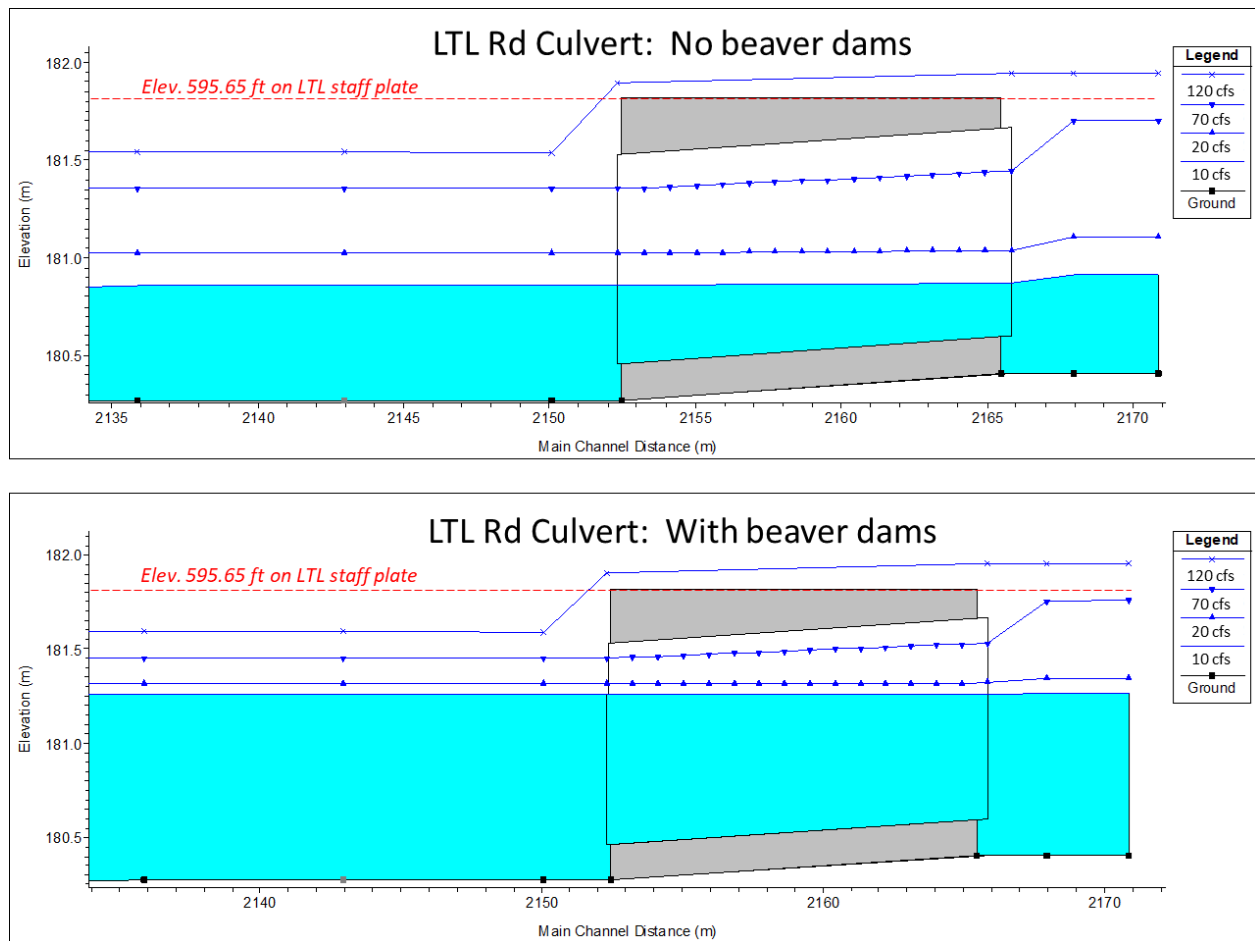


Figure 4. Water level effects of the WTL Rd culvert at 10, 20, 70, and 120 cfs during dam-free (top) and beaver dam (bottom) conditions. Note that axes are in metric units, and flow overtops the road at 120 cfs. The impact of beaver dams is much less than that of the culvert during high flows (70 and 120 cfs) when lake drainage is under culvert inlet control.

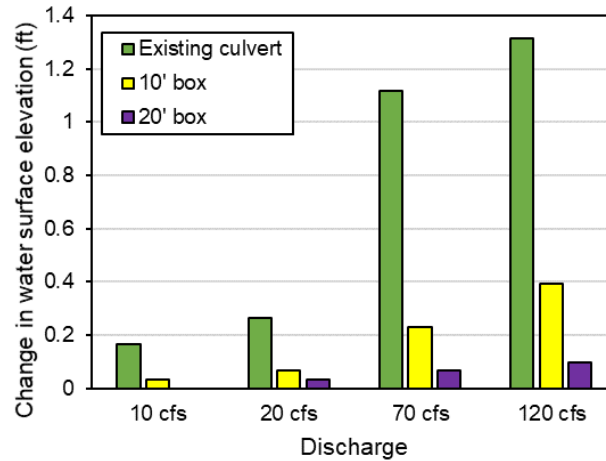


Figure 5. Modeled change in water surface elevation upstream and downstream of WTL Rd. In the three scenarios, the road underpass is modeled as 1) the existing culvert (green), 2) a 10 ft box culvert (yellow), and 3) a 20 ft box culvert (purple). Note that increasingly larger underpasses back up less water. For clarity, all scenarios are shown without beaver dams; removing dams reduced the effect by 0.10-0.16 ft.

Table 1. Little Traverse Lake water levels under different modeling scenarios. Columns represent the four possible present/absent combinations of the WTL Rd culvert and the beaver dams. Values in the top half of the table are LTL water level in feet above sea level (NAVD88), with the deeper shades of red highlighting higher water. Values in the bottom half of the table are water level changes relative to the “no culvert, no dams” scenario for each flow, with the deeper shades of yellow highlighting larger changes. Note that 1) the highest LTL water levels occur at high flows when the culvert is present, and 2) the largest *changes* occur from dams at low flow and from the culvert at high flow.

Flow	No Culvert, No Dams	No Culvert, With Dams	Culvert, No Dams	Culvert, Dams
<i>in feet above sea level (NAVD88)</i>				
10 cfs	593.41	594.72	593.54	594.72
20 cfs	593.93	594.88	594.16	594.98
70 cfs	595.05	595.34	596.13	596.33
120 cfs	595.64	595.83	596.92	596.95
<i>in feet relative to the "No Culvert, No Dams" condition</i>				
10 cfs	N/A	+ 1.31	+ 0.13	+ 1.31
20 cfs	N/A	+ 0.95	+ 0.23	+ 1.05
70 cfs	N/A	+ 0.30	+ 1.08	+ 1.28
120 cfs	N/A	+ 0.20	+ 1.28	+ 1.31

References

- Canale, R. P., and W. H. Nielsen. 1997. Report of the Leelanau Watershed Council: nutrient data and budgets for Leelanau County streams and lakes, 1990-1996. Leelanau Conservancy Report 97-2.
- Gosling Czubak Engineering Sciences, Inc. (GCES). July 15, 2014. Little Travers Lake Water Level Investigation.
- Gosling Czubak Engineering Sciences, Inc. (GCES). March 18, 2015a. Culvert Replacement Preliminary Engineering Report.
- Gosling Czubak Engineering Sciences, Inc. (GCES). May 13, 2015b. Shalda Creek Beaver Dam Study.
- Gosling Czubak Engineering Sciences, Inc. (GCES). December 15, 2020. Report of Shalda Creek Water Level Study 2017-2020.
- Leelanau Conservancy. 2022. Water quality information. <https://leelanauconservancy.org/our-work/water/water-quality-information/>.
- Martin, M. and T. W. Kim. May 9, 2018. Graphical analysis of water level data from Shalda Creek and West Traverse Lake, Aug-Oct 2017. National Park Service Report.
- Neumayer, M., S. Teschemacher, S. Schloemer, V. Zahner, and W. Rieger. 2020. Hydraulic modeling of beaver dams and evaluation of their impacts on flood events. *Water*: 12(1), 300.
- Steinburg et al. 1994. Leelanau County Inland Lakes Project-A Study of Development and Water Quality Within the Little Traverse and Lime Lake Watersheds. Completed in partial fulfillment of the requirements for the degree of Master of Science and Master of Landscape Architecture. University of Michigan School of Natural Resources and Environment.
- United States Army Corps of Engineers (USACE). March 2019. Hydrologic Engineering Center's River Analysis System (HEC-RAS). Davis, CA.

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