Technical Memorandum

GEI Consultants

To: Mr. David Kepler

CC: Mr. Ron Hansen, P.E., P.S., Mr. Adam Heinrich

From: Paul D. Drew, P.E., CFM, Ellen Faulkner, P.E. (Ayres Associates Inc.)

Date: April 15, 2022

Re: Summary of Flood Routing Downstream of Sanford Dam
Four Lakes Task Force (FLTF)
Midland, Michigan
GEI Project No. 2002879

Introduction and Project Background

This technical memorandum (TM) presents a summary of the Tittabawassee River, and Salt River flood study performed by the project team of Ayres Associates Inc. (Ayres), GEI Consultants of Michigan, P.C., (GEI), and Applied Weather Associates (AWA) on behalf of the Four Lakes Task Force (FLTF). The results of the flood study are being used to select the Inflow Design Flood (IDF) in accordance with the guidelines in the Federal Emergency Management Agency (FEMA) P-94 – Selecting and Accommodating Inflow Design Floods for Dams (Ref. FEMA-P-94, 2013). The goal of selecting the IDF will be to balance the risks of a hydrologic failure of a dam with the potential downstream consequences and the benefits derived from reconstructing the Secord, Smallwood, Edenville and Sanford Dams.

In July 2021 Ayres published a flood study for the Tittabawassee and Tobacco Rivers titled, *Design Flood Hydrologic Analysis – Secord, Smallwood, Edenville and Sanford Dams* dated July 2021 (Ref. Ayres, 2021a) and supplemental report titled *Inflow Frequency Estimates at Secord, Smallwood, Edenville and Sanford Dams*, dated August 9, 2021 (Ref. Ayres, 2021b). The reports were prepared using a site specific Probable Maximum Precipitation (PMP) and extreme precipitation probability study by Applied Weather Associates (Ref. AWA, 2021) to determine the probabilistic (2- to 5,000-year) flood magnitudes and deterministic design floods (PMP and fractional PMPs).

As a follow up to this work, Ayres extended the flood study of the Upper Tittabawassee River watershed to include the Salt River watershed near Sanford Michigan. This TM summarizes the results of the updated flood study that is intended to be used by the United States Army Corps of Engineers (USACE) as part of the Midland County flood study to understand how the Tittabawassee River interacts with downstream rivers (Sturgeon Creek, Snake Creek, Chippewa River, Pine River) and the total watershed at Midland, Michigan. We understand the USACE will use the Sanford Dam and Salt River hydrographs as upstream inputs into the hydrologic model of the larger watershed to create a flood map library of the National Weather Service's Advanced Hydrologic Prediction Service (AHPS) flood categories and USGS flood stages of the Tittabawassee River at Midland added to the USGS Flood Inundation Mapper (FIM) program. The USACE flood study intends to have better models, flood prediction, and risk assessment to determine future projects to mitigate flood in Midland County.

10501 West Research Drive, Suite G100
Milwaukee, WI 53226
414.930.7534

Tittabawassee and Salt River Watersheds

The newly added Salt River Watershed is comprised of 230 square miles and was added to the Upper Tittabawassee River basin (Secord Dam through Sanford Dam) of 945 square miles for a total watershed study area of approximately 1,175 square miles. The Salt River confluence is located immediately downstream of Sanford Dam and functions as part of the same system as flows from the Salt River affect Tittabawassee River tailwater elevations at Sanford Dam and potentially hydraulic performance of the proposed spillway configuration. Downstream of the confluence with the Salt River, the Tittabawassee River extends downstream approximately 11.5 river miles southeast toward Midland, Michigan before combining with the Chippewa and Pine Rivers for a total watershed area of 2,400 square miles at the United States Geological Survey (USGS) Gage *04156000 TITTABAWASSEE RIVER AT MIDLAND, MI.* Based on this information, the outflows from Sanford Dam account for approximately 40% of the total contributing watershed in Midland. The HEC-HMS watershed delineation map is provided in **Exhibit 1**.

Spillway Configurations

Ayres performed U.S. Army Corps of Engineers (USACE) Hydrologic Engineer Center Hydrologic Modeling System (HEC-HMS) flood routing for the following configurations of Secord, Smallwood, Edenville and Sanford Dams to evaluate the impacts of the dam configurations on the downstream watershed:

- Dams Absent – All four dams and their impoundments were removed for the “dam absent” model, and previously impervious areas representing the reservoirs were converted to low-permeability areas. This configuration represents the Tittabawassee and Tobacco Rivers prior to the original construction of the FLTF dams in 1924.

- Post-Reconstruction – Represents the proposed spillway configurations of Secord, Smallwood, Edenville and Sanford Dam following the dam reconstruction projects and restoration of the legal lake levels. These are considered the most relevant dam configurations to evaluate the long-term flooding impacts downstream of Sanford Dam.

Interim Stabilization

Following the May 19, 2020, storm event that resulted in minor downstream erosion damage to Secord Dam, severe downstream erosion to Smallwood Dam and catastrophic failure of Edenville and Sanford Dam, the FLTF implanted interim stabilization repairs to safely pass base and flood flows (up to the 200-year event). The intent of the interim stabilization is to restore the Tittabawassee River back into the natural flow path of the river, prevent further head cutting erosion, transport of riverbed materials downstream, while also improving dam safety prior to the future reconstruction of the dams and restoration of the legal lake levels.

As referenced in a June 30, 2021, letter from State of Michigan EGLE it was understood that the Edenville and Sanford dams will either be fully restored or removed, and the interim stabilization was not a long-term feasible solution. “*However, if FLTF determines that reconstruction of Sanford [or Edenville], isn’t feasible in a reasonable timeframe, a plan to address remaining concerns with long-term dam safety and stability ongoing natural resource impacts will need to be developed and implemented. The plan would need to consider such alternatives as additional stabilization and restoration measures or removal of the dam and restoration of impacted reaches of the river channel.*

Based on the intent of the interim stabilization design, we do not consider the flood routing results provided below relevant to the USACE flood study for evaluating the long-term flooding impacts downstream of Sanford Dam for the following reasons:

- The interim stabilization measures were designed to pass base, and flood flows up to the 200-year event. The interim stabilization does not provide the same level of dam safety protection as compared to the post reconstruction configuration (5,000-year or greater).

- Storage and attenuation of flood peaks in the FLTF lakes has the greatest impact for the interim stabilization condition, which begins with drawn-down lakes and requires a rise in the lake level for any increase in outflow. This condition will not be feasible in the post-reconstruction configuration as the proposed spillway gates will be operated to minimize pond surcharging during frequent and infrequent storm events.

- The interim stabilization construction will be complete by Summer 2022 and remain intact until the dams are reconstructed, and legal lake levels restored by 2025 (Sanford) 2026 (Wixom).

- As stated by EGLE, the interim measures were not designed for the long-term operation of the lakes and additional restoration measures, or removal of the dams would be needed if the reconstruction efforts weren't completed in a reasonable time frame.

Flood Routing Results

Table 1 summarizes the peak outflows from the Sanford Dam for return periods ranging from the 2- to 5,000-year flood events for the Dams Absent and Post-Restoration configurations. The post reconstruction hydrographs were developed using the most up-to-date spillway configurations for the Secord, Smallwood, Edenville and Sanford Dam design projects. Changes in the final spillway configurations will have an impact on the storage-outflow relationships and could result in minor changes to the routed hydrographs throughout the system. The comparison of peak flow generally matches between the two configurations for flows up to the 50-year flood event. Floods having return periods of 100-years and above are affected by the storage in Secord, Smallwood, Wixom and Sanford Lakes and peak outflows are generally less when compared to the dams-absent condition which provides no flood attenuation (storage) during any storm event.

Table 1: Peak Outflows from Sanford Dam

Storm Recurrence Interval (year)	Dams Absent (cfs)	Post-Restoration (cfs)	Interim Stabilization (cfs)
2-	5,690	5,750	5,300
5-	9,040	9,100	8,200
10-	11,700	11,800	10,500
25-	16,000	16,000	14,200
50-	19,600	19,700	17,000
100-	23,800	22,800	20,100
200	28,600	25,400	23,700
500-	36,600	30,900	N/A
1,000-	42,700	37,000	N/A
5,000-	59,900	53,000	N/A

Note: Drainage Area (945 square miles)

Table 2 summarizes the concurrent peak flows in the Salt River at the confluence with the Tittabawassee River (downstream of Sanford Dam). These were modeled assuming that the same storm that affects the watershed above Sanford Dam occurs over the Salt River watershed. Since the

Salt River watershed is approximately 1/4th the size of the upstream Tittabawassee River watershed, it is unlikely that both watersheds will experience the same recurrence interval storm concurrently. For example, a 100-year storm in the Upper Tittabawassee River watershed could result in either a lower or higher recurrence interval storm in the Salt River watershed depending on the storm positioning, rainfall distribution, duration, and intensity (inch-hour). Considering the size of these separate watersheds, we recommend that the USACE perform a sensitivity analysis of storm combinations of each watershed to evaluate the relative the long-term flooding impacts downstream of Sanford Dam. Salt River flood hydrographs are provided in **Attachment 2**.

Table 2: Peak Flows from Salt River

Storm Recurrence Interval (year)	Dams Absent / Post Restoration (cfs)
2-	2,730
5-	4,120
10-	5,230
25-	7,000
50-	8,380
100-	9,930
200	11,600
500-	14,200
1,000-	16,400
5,000-	22,000

Note: Drainage Area (230 square miles)

Next Steps

The intention of this TM is to provide updated flood hydrographs downstream of the Sanford Dam for direct input into the USACE flood study. The results are considered DRAFT until the final restoration design is complete for the FLTF dams. The FLTF will provide the following information when available:

- Flood hydrographs downstream of Sanford Dam following the completion of FINAL Restoration Design of Secord, Smallwood, Edenville and Sanford Dams in Summer 2023.

- Inundation Mapping downstream of Sanford Dam – GEI and Spicer Group Inc. (SGI) are currently developing one-dimensional (1D) and two-dimensional (2D) USACE Hydrologic Engineering Center – River Analysis System (HEC-RAS) computer models to delineate the flood inundation limits downstream of Sanford Dam for the 100-, 500-year and IDF to evaluate the downstream impacts of the proposed spillway configurations. The floodplain inundation mapping will be used by the FLTF to communicate the incremental impacts of the proposed spillway capacity improvements of Secord, Smallwood, Edenville and Sanford Dams. GEI and SGI will develop floodplain inundation mapping compatible with ESRI ArcGIS standards.

References

(Ayres, 2021a) "Design Flood Hydrologic Analysis – Secord, Smallwood, Edenville and Sanford Dams." July 2021.

(Ayres, 2021b) “Inflow Frequency Estimates at Secord, Smallwood, Edenville, and Sanford Dams.” August 9, 2021.

(Ayres, 2022) “Flood Hydrograph Development for the Salt and Tittabawassee Rivers, Upper Tittabawassee River HEC-HMS Model Extension. April 2022.

Exhibits

Exhibit 1 – Tittabawassee River Watershed

Attachments

Attachment 1 – Sanford Dam Outflow Hydrographs

- Tittabawassee River Below Sanford Dam (Dams Absent 2- through 50-year)
- Tittabawassee River Below Sanford Dam (Dams Absent 100- through 5,000-year)
- Tittabawassee River Below Sanford Dam (Post Restoration 2- through 50-year)
- Tittabawassee River Below Sanford Dam (Post Restoration 100- through 5,000-year)
- Tittabawassee River Below Sanford Dam (Dams Absent and Post Restoration 50-year)
- Tittabawassee River Below Sanford Dam (Dams Absent and Post Restoration 100-year)
- Tittabawassee River Below Sanford Dam (Dams Absent and Post Restoration 500-year)
- Tittabawassee River Below Sanford Dam (Dams Absent and Post Restoration 5,000-year)

Attachment 2 – Salt River Flood Hydrographs

- Salt River (2- through 50-year)
- Salt River (100- through 5,000-year)

Exhibit 1 – Tittabawassee River Watershed

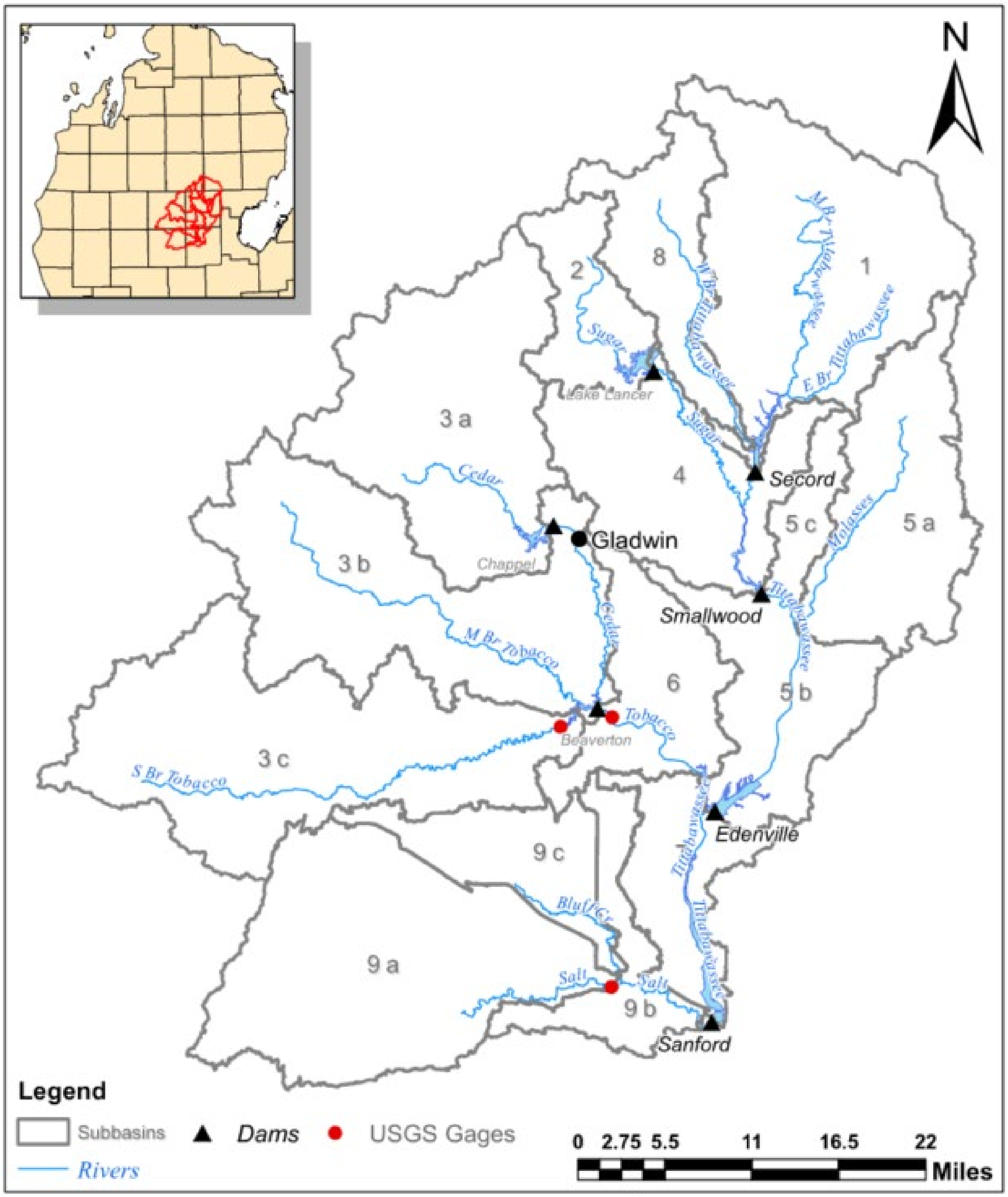


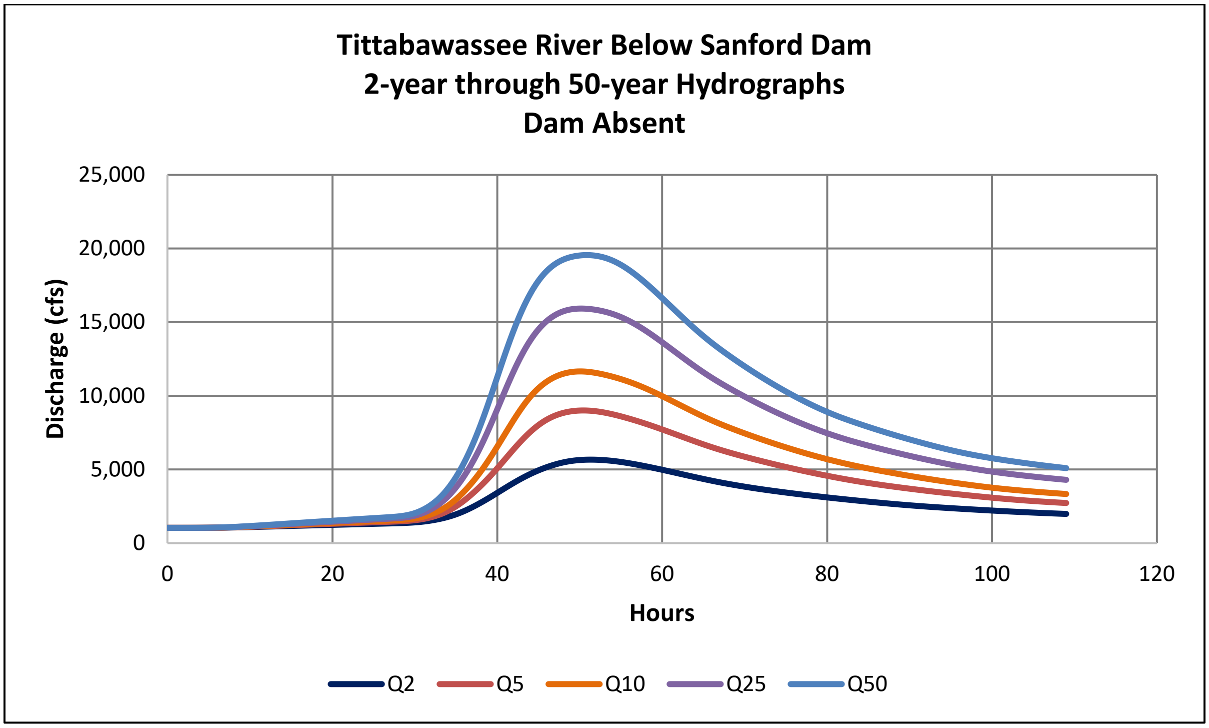
Exhibit 1: Tittabawassee River Watershed
Tittabawassee River Dams
Gladwin and Midland Counties, Michigan
March, 2022

AYRES RIVER ENGINEERING+ WATER RESOURCES

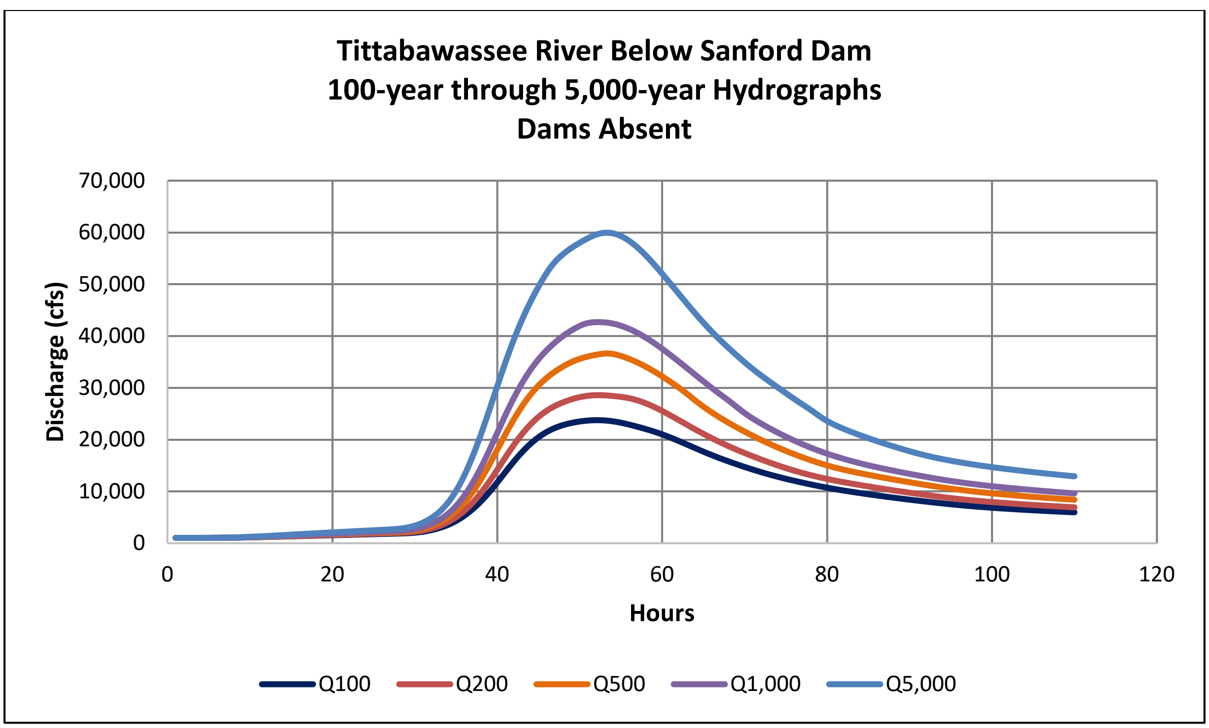
Attachments

Attachment 1 – Sanford Dam Outflow Hydrographs

Tittabawassee River Below Sanford Dam (Dams Absent 2- through 50-year)

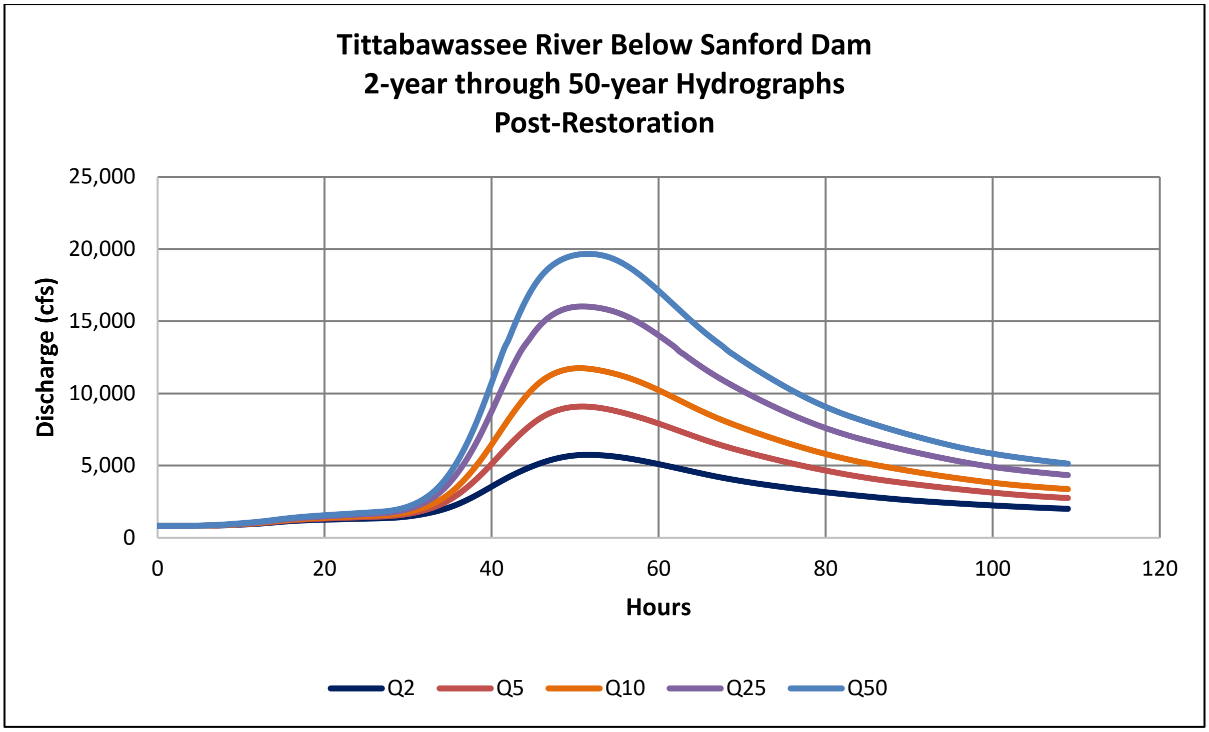


Tittabawassee River Below Sanford Dam (Dams Absent 100- through 5,000-year)

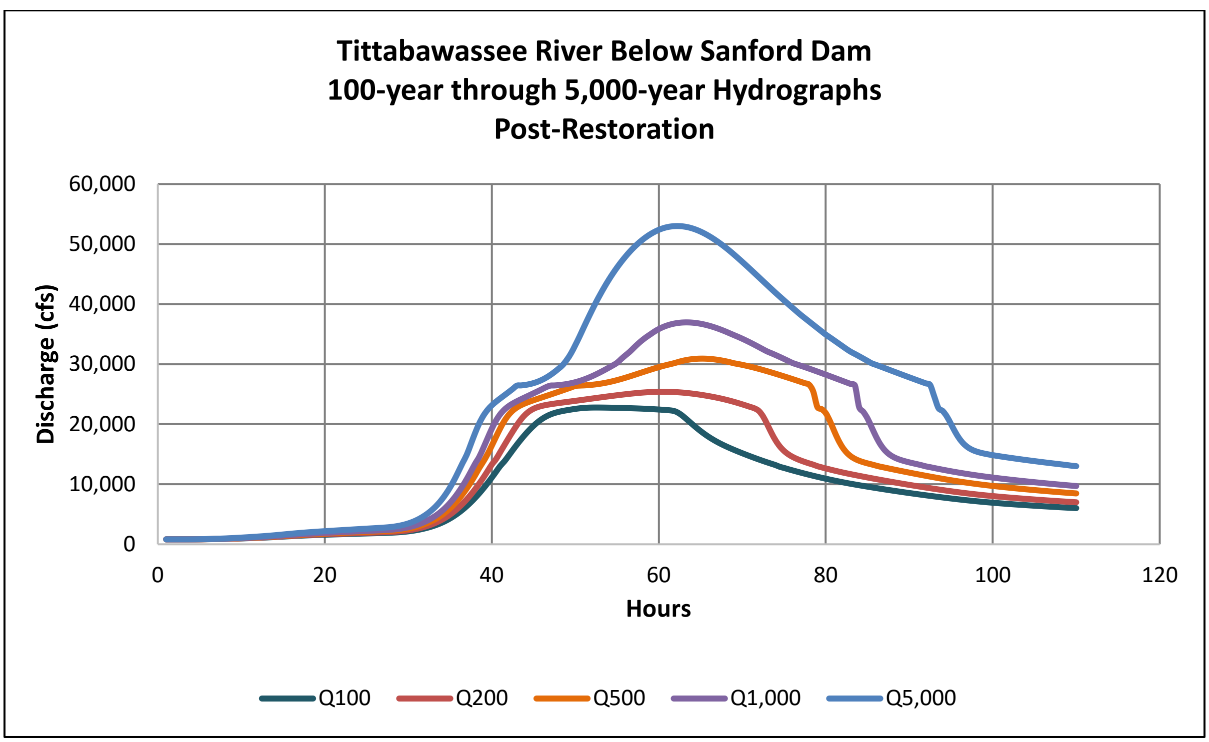


Attachment 1 – Sanford Dam Outflow Hydrographs

Tittabawassee River Below Sanford Dam (Post Restoration 2- through 50-year)

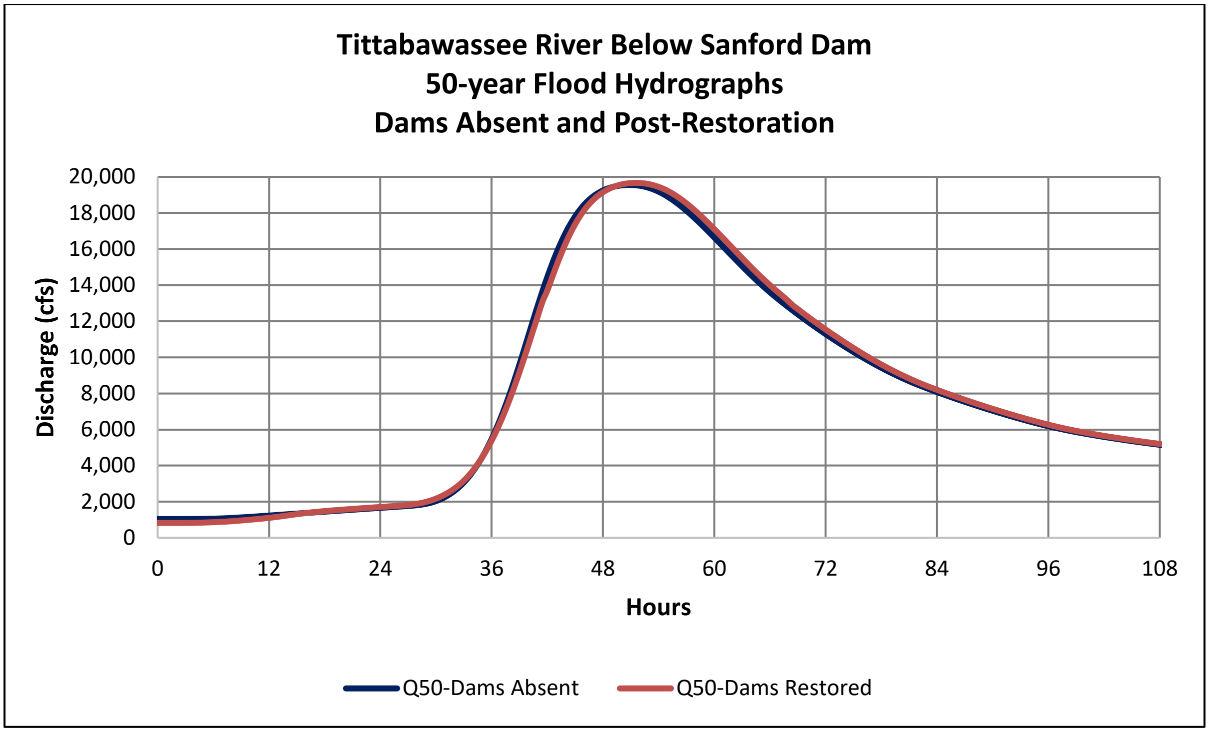


Tittabawassee River Below Sanford Dam (Post Restoration 100- through 5,000-year)

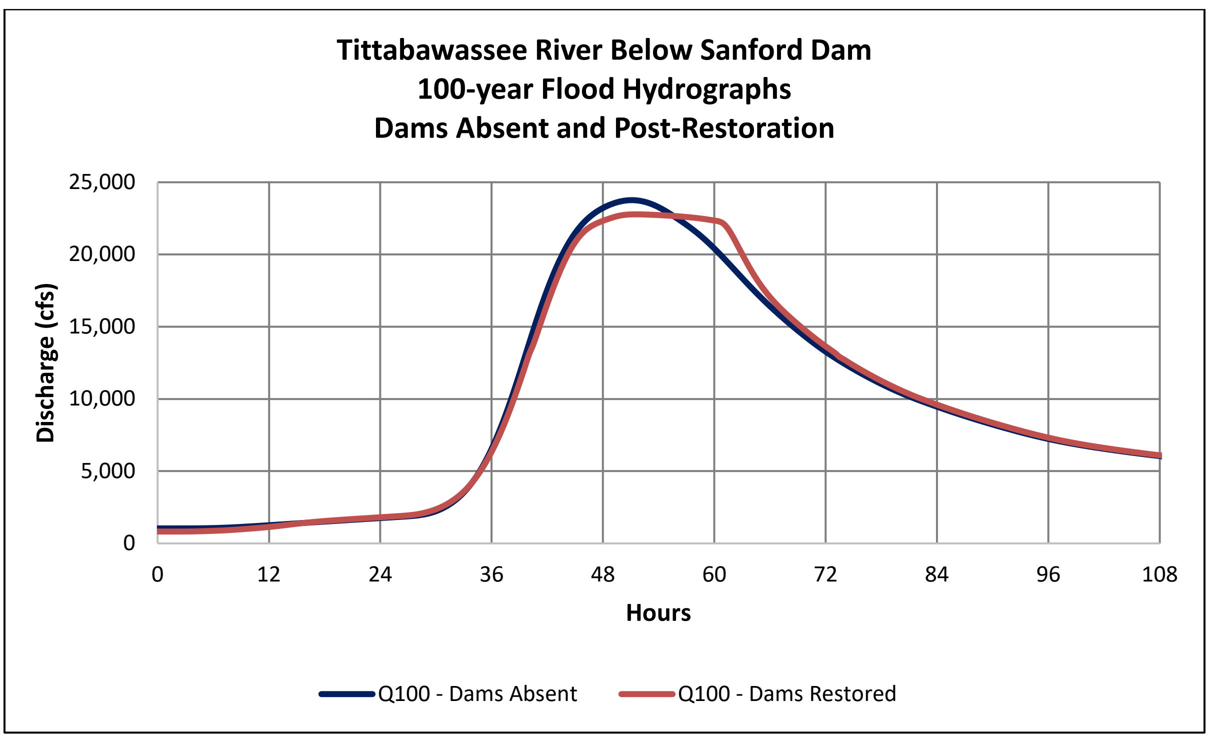


Attachment 1 – Sanford Dam Outflow Hydrographs

Tittabawassee River Below Sanford Dam (Dams Absent and Post Restoration 50-year)

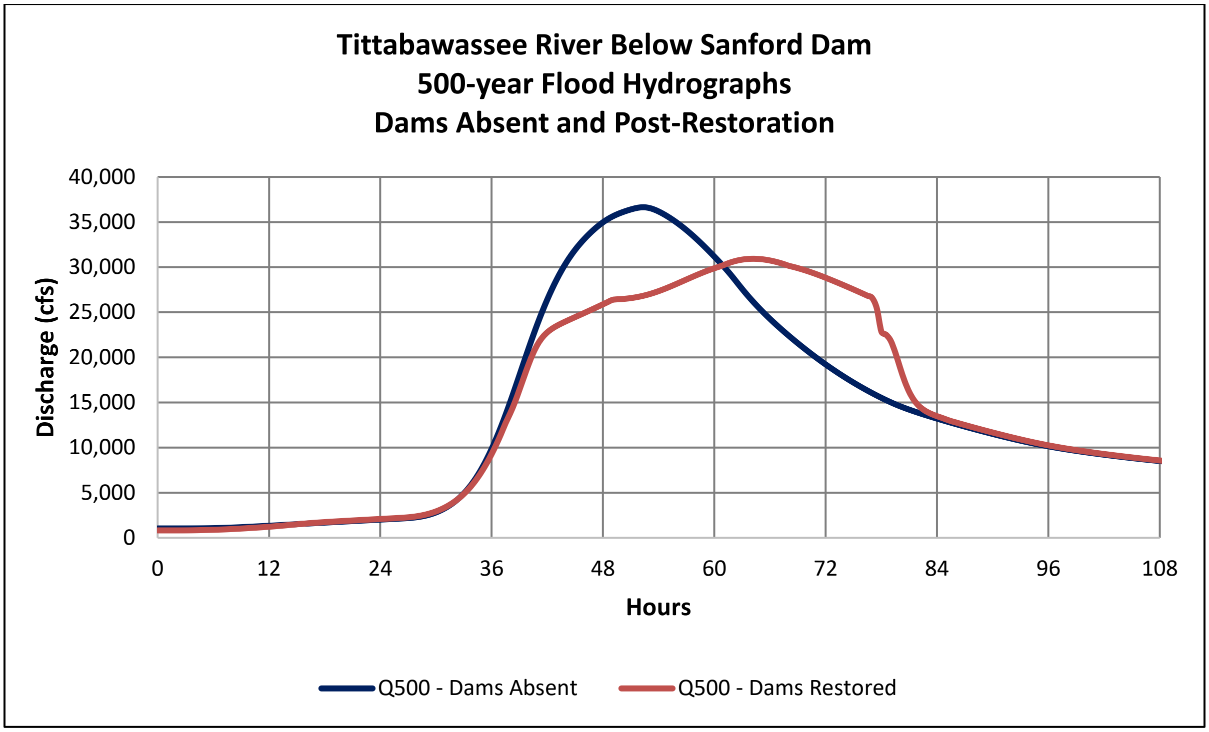


Tittabawassee River Below Sanford Dam (Dams Absent and Post Restoration 100-year)

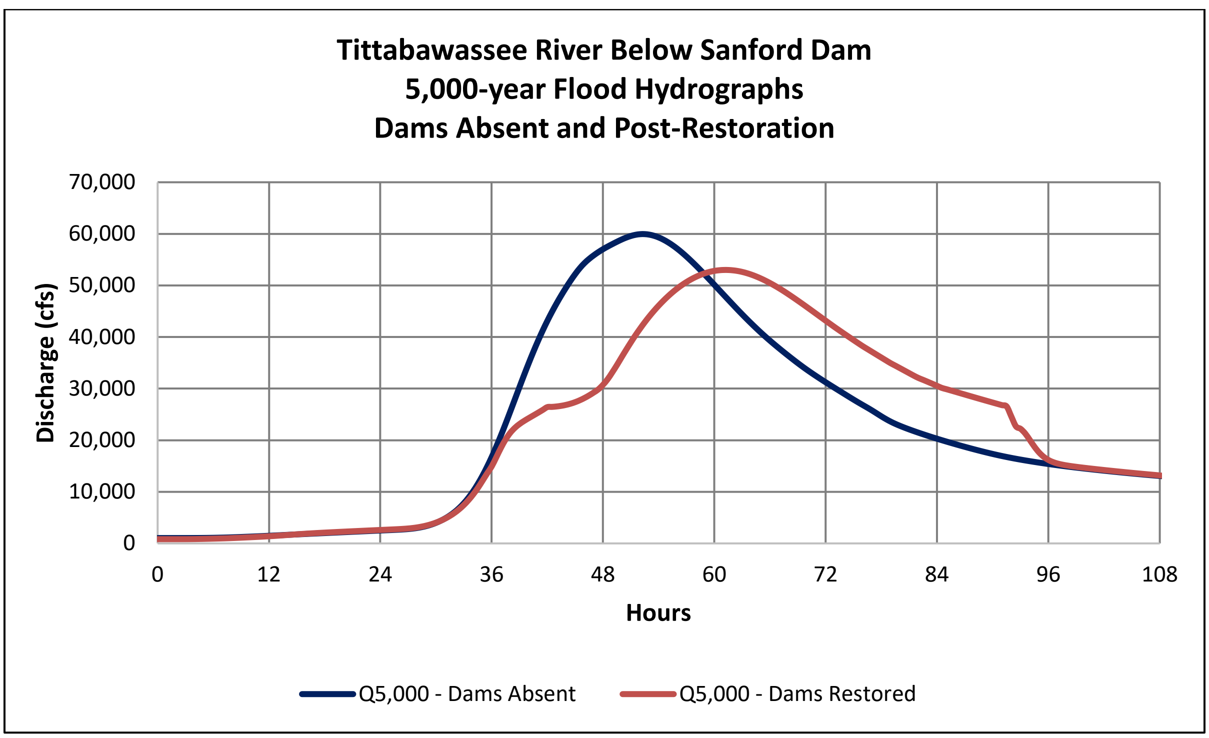


Attachment 1 – Sanford Dam Outflow Hydrographs

Tittabawassee River Below Sanford Dam (Dams Absent and Post Restoration 500-year)

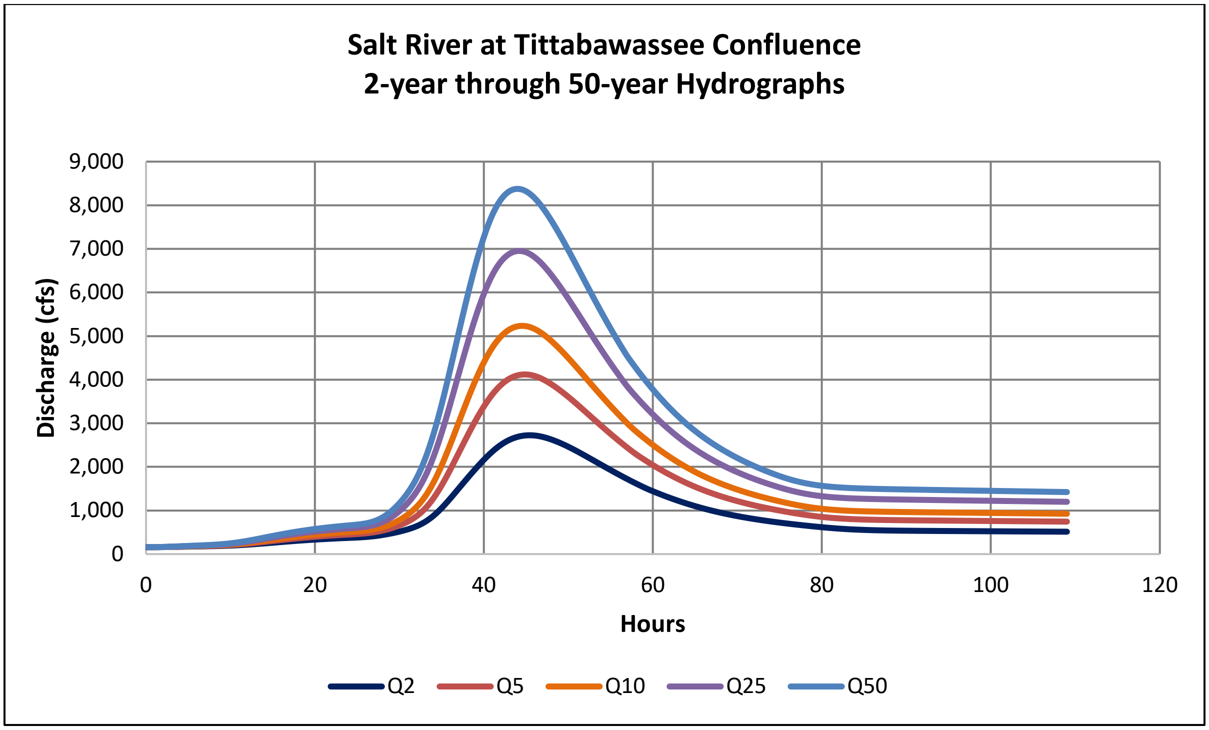


Tittabawassee River Below Sanford Dam (Dams Absent and Post Restoration 5,000-year)



Attachment 2 – Salt River Flood Hydrographs

Salt River (2- through 50-year)



Salt River (100- through 5,000-year)