Sanford Lake Restoration - Fishery Scoping Report

NOTE: Following the May 2020 flood event, Sanford Lake was dewatered with impacts to the fish community likely to be catastrophic. The following discussion presumes that Sanford dam will be repaired and the impoundment refilled. Ultimately, Fisheries Division of the Department of Natural Resources is the management agency charged with overseeing the management of the fishery resources in the Tittabawassee River and its' impoundments. We expect any management activities such as fish stocking, habitat improvement, or fish passage at the dams would be led by or endorsed by DNR Fisheries Division.

A. Fishing Economic Activity – Sanford Lake vs. Tittabawassee River Segment

Fishing generates economic activity. Fishing activity differs between different aquatic habitats, such as lakes and rivers. The purpose of this section is to evaluate the relative economic impact of restoring the fishery in the fully restored Sanford Lake against the fishery that could be expected in the Tittabawassee River if the impoundment remained dewatered.

Fisheries management agencies use creel or angler surveys to measure the amount of fishing activity that takes place on a given body of water. Estimated fishing activity is generally measured in hours of fishing per angler or fishing trips to the water body. The economic impact of a fishing trip is estimated regularly by the United States Department of the Interior including estimates for freshwater and saltwater fishing activities. By applying the estimated economic impact of a fishing trip to the fishing pressure measured at a water body, it is possible to estimate the economic activity generated by the fishery.

Streamside Ecological Services (SES) staff searched for creel survey data from the impoundments on the Tittabawassee River collected during the past 20 years. We found that the fishery at Sanford Lake was creel surveyed in 2015. To provide additional data, we expanded our data search to include other similar-sized southern Michigan impoundments. This resulted in seven additional datasets for impoundment fisheries measured in the last 20 years. We found that the estimated angler fishing trips per acre for the seven impoundments ranged from 2.5 to 17.2 trips per acre (Table 1), and an average of 7.7 trips per acre.

Table 1. Angler fishing trips for seven southern Michigan impoundments.

Waterbody	Area (acres)	Year	Time period	Total angler trips	Angler Trips per acre
Sanford Lake	1,250	2015	June to August	6,261	5.0
Hardy Pond	3,971	2006	April to October	23,111	5.8
Kent Lake	1,200	2007	April to September	8,532	7.1
Hamlin Lake	5,350	2008	April to September	28,968	5.4
Hamlin Lake	5,350	2019	April to September	13,135	2.5
Belleville Lake	1,270	2005	April to October	21,901	17.2
Ford Lake	975	2006	April to October	9,008	9.2
Croton Impoundment	1,380	2007	April to October	13,133	9.5
Average					7.7

We then used the average number of angler boat trips per acre to generate estimated annual fishing trips for all four of the Tittabawassee River impoundments (Table 2). Using the estimated $36 expenditure per trip for freshwater non-Great Lake fishing (USDI et al. 2016), estimated annual expenditures for the Sanford Lake fishery was $346,500.

It's noteworthy that these estimates are conservative. Night fishing, ice fishing, early and late season open water fishing, shore fishing and fishing from private docks were not measured or included in the data used for Table 1. However, ice fishing and shore fishing at Kent Lake were also measured in 2007. When those components of the fishery are included, the estimated angler trips increased 2.4 times from 8,532 trips to 20,468 trips. Based on this dataset, we submit it would be reasonable to estimate total economic expenditures for fishing activity on Sanford Lake would be approximately $831,600 annually ($346,500 X 2.4).

Table 2. Annual angler boat fishing trips and expenditures estimated for the four Tittabawassee River impoundments.

Lake	Surface Area	Est. Trips per acre	Trips	Est. Expenditures
Sanford	1,250	7.7	9,625	$346,500
Wixom	2,600	7.7	20,020	$720,720
Smallwood	402	7.7	3,095	$111,434
Secord	895	7.7	6,892	$248,094
Total			39,632	$1,426,748

Non-fishing or "recreational" boating also contributes to the local economy. We have not attempted to estimate the amount of recreational boating that takes place on the impoundments when they are at full pool. However, all four impoundments are multi-use waters with large numbers and a wide variety of power and non-powered watercraft. We suspect the local economic impact of recreational boating on these waters is substantial.

To facilitate comparison of the estimated economic activity generated by the restored impoundments versus economic activity that could be expected from the fishery on the Tittabawassee River segments lying between Sanford Dam and Edenville Dam, SES staff sought creel survey data for comparable river fisheries in Southern Michigan. Specifically, we looked for warm or cool water river creel surveys from sections of rivers without dams and impoundments. We also filtered out any river segments that were open to fish movements from waters of the Great Lakes which generally result in increased angling effort during seasons when anadromous salmonids or walleye are present. We found creel survey data for Michigan river fisheries are limited and data for warm water, inland (no Great Lakes fish access), un-impounded reaches are even rarer. We were able to find creel survey data including estimated trips for segments of the Huron River near Ann Arbor, the Muskegon River near Temple, and the Grand River near Grand Ledge. For the Grand River, fish passage from Lake Michigan upstream to Lansing is possible, but we only used the summer data when no Lake Michigan salmonids (and probably salmonid targeting anglers) were present, for this analysis.

The estimated angler trips were summed across the creel surveyed months (April to September) to generate a total number of trips per season for each river section. The linear distance of river included in each surveyed section was then used to divide the total number of estimated angler trips to arrive at a number of angler trips per mile of river. We then averaged the angler trips per mile across the 5 sections of river to arrive at the average of 280 angler trips per river mile (Table 3).

Table 3. Annual angler fishing trips from creel surveys on southern Michigan river segments.

River	Section	Year	Angler trips	Distance (mi)	Angler trips/mile
Muskegon	Temple Dr. to M115	2008	1,728	9.0	191
Muskegon	Reedsburg Dam to Dolph Rd	2008	4,619	21.3	217
Grand	Moores Park to Grand Ledge	2004	6,237	15.4	405
Huron	Bell to Mast Road	1993	1,770	5.7	311
Huron	Mast to Delhi	1993	1,296	4.7	276
Average					280

The number of annual angler trips for the dewatered Sanford dam river segment was estimated by multiplying the estimated linear distance of river within the section by 280 angler trips per mile. For Sanford Dam, we calculated 10.94 miles of Tittabawassee River and 1.36 miles of Tobacco River for a total of 12.3 river miles. Multiplying 12.3 river miles by an estimated 280 angler trips per mile, results in a total of 3,444 trips and an annual estimated expenditure of $123,984 for fishing activity on the river segment.

These estimates were based on seasonal fishing trip totals summed across the months of April thru September. Unlike the impoundments, where ice fishing contributes substantially to the fishery, we would not expect much additional fishing activity on the river segments during the late fall or winter. However, if upstream fish passage from Saginaw Bay is re-established and seasonal walleye (*Sander vitreus*) or salmonid spawning runs occur, a considerably higher level of fishing effort and associated expenditures would be expected.

In summary, leaving Sanford Lake dewatered would result in an expected $123,984 of fishery economic activity. Restoring the impoundment and lake fishery would generate an estimated $831,600 of fishery based economic activity annually. Thus, restoration of the impoundment fishery results in 6.7 times more economic activity, with benefits for the local economy.

<u>B. Restocking Sanford Impoundment</u>

The Tittabawassee River Assessment (Schrouder et al. 2009) describes the fish community of Sanford impoundment as dominated by cool- to warm-water fishes that are indicative of lake rather than riverine environments. A Status of the Fishery report for Sanford Lake (Schrouder 2016) provides a more recent snapshot of the fish community in that impoundment and includes details on growth rates and age distribution for the fish species important in the recreational fishery.

Sunfishes, including black (*Pomoxis nigromaculatus*) and white crappie (*Pomoxis annularis*), bluegill (*Lepomis macrochirus*), pumpkinseed (*Lepomis gibbosus*), green sunfish (*Lepomis cyanellus*) and rock bass (*Ambloplites rupestris*) dominated the fish community and fishery prior to May 2020. Top predators in these systems were black bass [largemouth bass, (*Micropterus salmoides*) and smallmouth bass (*Micropterus dolomieu*)], northern pike (*Esox Lucius*), muskellunge (*Esox masquinongy*), walleye and channel catfish (*Ictalurus punctatus*). Sanford Lake also supported a resident white bass (*Morone chrysops*) population. Additionally, the impoundment also had sizable populations of a variety of redhorse sucker species (*Moxostoma* spp.), white sucker (*Catostomus commersonii*), common carp (*Cyprinus carpio*), and black bullhead (*Ameiurus melas*), brown bullhead (*Ameiurus nebulosus*), and yellow bullhead (*Ameiurus natalis*).

The pre-flood fish community in Sanford Lake supported excellent fishing opportunities for black bass, northern pike, muskellunge, walleye, channel catfish, bluegill, black and white crappie, and other sunfish (Schrouder et al. 2009). White bass were also part of the fishery. Age distributions for the predator species were balanced with good survival to older ages, resulting in desirable numbers of large individuals to attract fishing activity. Periodic stocking of walleye and muskellunge by MDNR supported the fisheries for those predatory species (Table 4).

Table 4. Michigan DNR fish stocking records for Sanford Lake from 2006 to 2020.

Year	Muskellunge fingerlings	Walleye fingerlings
2006		66,288
2007	3,228	
2008		
2009		
2010	4,800	
2011		107,737
2012		
2013	1,875	149,304
2014		
2015	1,875	95,072
2016		
2017		58,780
2018	1,223	104,095
2019	2,500	48,339
2020	0	0
Grand Total	15,501	629,615

Since restoration of the impoundment will result in ecological aquatic conditions that approximate those conditions existing in the impoundment prior to the May 2020 dam failures, a restoration target of fish community similar to that present before May 2020 appears logical and reasonable.

Attempts to improve the fish community when the impoundment is refilled could include reduction of nuisance species or introduction of additional species of angler interest. Use of a piscicide to remove undesirable species such as common carp, prior to impoundment re-filling is an option, but also results in total fish kill, so all surviving desirable fish are lost as well. Additionally, history has documented that chemical removal of fish in large dewatered impoundments with numerous small tributaries is difficult and complete mortality of nuisance target species such as common carp, goldfish (*Carassius auratus*) or gizzard shad (*Dorosoma cepedianum*) is rarely achieved. As a result, this option does not appear worthwhile.

New fish species to consider for introduction to the impoundments once they are refilled, could include sauger (*Sander canadensis*) and flathead catfish (*Pylodictis olivaris*). However, both species are currently not available within the state hatchery system. Further, both prefer turbid water conditions, and the recent trend in Sanford Lake has been towards clearer water conditions due to colonization by zebra mussels. Therefore, both species are unlikely to be feasible or ecologically appropriate.

Streamside Ecological Services used the following approach to estimate the approximate cost to replace the fish community in Sanford Lake when the dam is repaired and the impoundment restored. Typical southern Michigan warm-water lakes generally support a fish biomass standing stock of about 100 pounds per acre. Due to the high productivity of the Tittabawassee River watershed and the shallow nature of both impoundments, we doubled the target biomass standing stock to 200 pounds per acre. We then used the description of the fish communities in the impoundments from Schrouder et al. (2009) and Schrouder (2016) to generate a list of fish species and approximate biomass per species per acre based on the typical balance found in southern Michigan warm-water fish communities. Based on the surface area of each impoundment, the target number of mature adults needed to re-establish a self-sustaining fish community similar in species diversity and abundance to that occurring pre-flood was estimated. Monetary estimates for stocking mature-sized fish of each species based on the AFS monetary values found in Southwick and Loftus (2017) were used to estimate the cost by species.

Using the above methodology, the estimated cost to restore the adult fish population of Sanford Lake is $2,862,219 (Table 5). However, we must note that some of the recreationally important fish species, and nearly all of the non-recreationally important species are not available from commercial or state hatcheries at any size. We should further note that mature sized individuals of most species are not routinely available from any hatchery source. Therefore, the estimates generated here should be considered very conservative. Further, it will take years to rebuild the balanced age structure of the fish community through stocking of fingering or juvenile fish.

A few other caveats should be mentioned here. First, fish movement downstream out of impoundments occurs universally and can be dependent on characteristics of the dam, dam operations, the fish species involved, and hydrodynamics of the river system. Further, high flow events can result in greatly increased downstream fish movement. Finally, installation of fish passage may help mitigate downstream losses by allowing upstream migration to occur (fish passage will be further discussed in that section of the report).

Sources of fish for stocking include private, state and federal hatcheries. However, as noted above, adult sized fish for many species are available in very limited numbers or not at all. The state hatchery system is heavily focused on producing fingerling-sized walleye and muskellunge. Generally, warmwater species such as bluegill, black and white crappie, and smallmouth and largemouth bass are not raised in the state hatchery system and must be purchased from private sources. Stocking of fish from private sources into public waters of the state of Michigan requires a fish stocking permit from the DNR Fisheries Division.

Table 5. Estimated fish restocking needed to promote recovery of the fish community in Sanford Lake.

Recreationally valuable species	pounds per acre	# per pound	# per acre	Total number	Value per indiv.	Total
Black crappie	10	4	40	50,000	$4.50	$225,000
Bluegill	30	4	120	150,000	$3.16	$474,000
Largemouth bass	10	1	10	12,500	$14.00	$175,000
Muskellunge Great Lakes	5	0.1	0.5	625	$506.00	$316,250
Northern pike	10	0.5	5	6,250	$38.56	$241,000
Pumpkinseed	2.5	5	12.5	15,625	$3.16	$49,375
Rock bass	5	5	25	31,250	$3.16	$98,750
Smallmouth bass	10	1	10	12,500	$33.46	$418,250
Walleye	5	0.5	2.5	3,125	$15.00	$46,875
Yellow Perch	2.5	5	12.5	15,625	$3.57	$55,781
White bass	10	1	10	12,500	$2.83	$35,375
Total	100					$2,135,656

Other species	pounds per acre	# per pound	# per acre	Total number	Value per indiv.	Total
Banded killifish	2	50	100	125,000	$0.07	$8,750
Bluntnose minnow	4	50	200	250,000	$0.07	$17,500
Bowfin	5	0.5	2.5	3,125	$0.90	$2,813
Brown bullhead	5	2	10	12,500	$3.98	$49,750
Brook silverside	2	50	100	125,000	$0.12	$15,000
Golden shiner	3	25	75	93,750	$0.81	$75,938
Greater redhorse	26	0.5	13	16,250	$3.75	$60,938
Green sunfish	2	5	10	12,500	$3.16	$39,500
Logperch	2	50	100	125,000	$1.24	$155,000
Spotfin shiner	3	25	75	93,750	$0.81	$75,938
Stonecat	5	2	10	12,500	$2.16	$27,000
White sucker	26	1	26	32,500	$3.75	$121,875
Yellow bullhead	5	2	10	12,500	$3.98	$49,750
Channel catfish	10	0.5	5	6,250	$4.29	$26,813
Total	100					$726,563
Grand Total						$2,862,219

In summary, the fish community of Sanford Lake has likely been dramatically changed by the lake dewatering. Restoring the fish community will be costly and slow. Quality size individuals of most recreationally important warmwater fish species are not routinely available from fish hatcheries (private or public). Stocking juvenile fish will provide improvements in the fish community in future years as those fish grow and mature.

C. Fish Passage at Sanford Dam

Dams have four basic negative effects on rivers. First, they prevent fish migration. For some species, this limits access to spawning habitat. Second, dams slow the flow of the river and can alter the timing of peak and low flows. The natural seasonal flow variations that trigger growth and reproductive cycles in many fish species can be altered. Third, dams alter habitat and change the way rivers function. They trap sediment and woody debris with negative impacts on downstream river habitat complexity. Finally, dams can result in abnormal physical and chemical changes such as water temperature fluctuations and abnormal dissolved oxygen levels in downstream waters.

Additionally, dams directly impact fish populations through mortality caused by entrainment and impingement. Entrainment is the unwanted passage of fish through a water intake, which is generally caused by an absent or inadequate screen surrounding the water intake. Impingement is the physical contact of a fish with such a barrier structure (screen) due to intake velocities which are too high to allow the fish to escape. Sources of entrainment or impingement-related injury or mortality include the following: (1) fish passage through hydroelectric facilities (i.e., turbines, spillways, sluiceways, and other passage routes) during downstream migration for migratory fish; (2) the entrainment of resident fish; and (3) the impingement of adult or large fish (migratory or resident) against screens/trash racks (Rytwinski et al. 2017).

Schrouder et al. (2009) summarized the results of fish entrainment and impingement assessment studies at the 4 FERC licensed dams on the Tittabawassee as follows: "*Environmental assessments were conducted for several years (Freshwater Physicians 1988) in conjunction with the relicensing of the hydroelectric dams on the main stem Tittabawassee River (FERC 1998). The estimated total annual mortality rate for all species of larval fish was 8 million at Sanford Dam. Highest mortality occurred in spring during high flows. In 1998, annual monetary replacement costs were estimated to be $3,830 at Sanford Dam.*"

According to Schrouder et al. (2009), there are 143 dams in the Tittabawassee River watershed and many have significant negative effects on aquatic resources. Most of the larger dams in the Tittabawassee River basin were built on the higher gradient habitats to create the highest hydraulic head possible for the lowest cost. These areas were probably fast riffles to small waterfalls. Historically, these areas provided spawning habitat for a wide variety of species including lake sturgeon (*Acipenser fulvescens*) and walleye from Lake Huron. These areas are no longer accessible and quality riverine habitat has been lost.

However, Schrouder et al. (2009) also recognize that dams do provide benefits. These can include recreational opportunities (boating, swimming, fishing, hunting) that differ from those on free-flowing reaches. Dams also create barriers blocking upstream migration of undesired species such as sea lamprey (*Petromyzon marinus*) and carp. Finally, contaminated sediments are sometimes trapped behind dams which prevents their downstream transport.

Fish passage technology has been used to try and mitigate some of the negative impacts of dams on fish populations. Fish passage structures can help enable some fish to pass around or over a dam, but their effectiveness largely depends on the species of fish and the physical properties of the dam, such as hydraulic head and dam design. Upstream movement can be facilitated with nature-like constructed channels (pool/riffle or rock ramp), technical fishways (vertical slot, pool and weir, Denil), and special-purpose structures (eel ladders, fish locks and fish lifts). Downstream movement can be facilitated by engineering that minimizes fish entrainment and impingement. However, fish passage is far from a proven technology, and successful fish passage at a particular site can be impeded by numerous knowledge and information gaps (Silva et al. 2017) that can include both biological and physical factors. Zielinski and Freiburger (2020) reviewed the current state of fish passage technologies in the Laurentian Great Lakes basin, and highlight the challenges resource managers face when making decisions about barriers and fish passage that are critical for invasive species control and fishery restoration.

The most downstream barrier to fish passage on the Tittabawassee River is the Dow Dam in Midland. Dow dam has a normal hydraulic head of 4 feet with a height of 7 feet and a crest width of 325 feet. Schrouder et al. (2009) provided a detailed history of the efforts to create effective fish passage at Dow Dam and modifications to the dam. At present, fish passage at Dow Dam is limited to high water periods, but includes the invasive sea lamprey, necessitating sea lamprey control in the mainstem of the Tittabawassee River up to Sanford Dam, and the major tributaries including the Chippewa and Pine Rivers. Recently, a proposal to construct fish passage at Dow Dam has been connected to the Tittabawassee River Natural Resources Damage Assessment. This proposal targets walleye, suckers, white bass, and lake sturgeon as the primary species of interest. A nature-like design, such as a rock ramp, has been suggested for this low hydraulic head site.

There are major challenges associated with constructing effective fish passage at the 4 Tittabawassee River dams upstream from Midland. First, all four dams have hydraulic head much higher than the Dow Dam (26 foot at Sanford, 44 foot at Edenville, 28 foot at Smallwood, and 46 foot at Secord). In general, the higher the hydraulic head, the more difficult and expensive it becomes to successfully design an effective fishway. Second, the primary species of interest for upstream fish passage in the Tittabawassee River are walleye, suckers, and lake sturgeon. All of which are poor jumpers, relative to trout and salmon, and are notoriously difficult species to pass upstream through technical fishways. Third, creating passage for those desired species, while blocking upstream movement of invasive spawning sea lamprey, nuisance common carp, and potential future invasive species such as silver carp (*Hypophthalmichthys molitrix*) or bighead carp (*Hypophthalmichthys nobilis*), would be difficult or impossible. This is a dilemma for fisheries managers across the Great Lakes basin (Zielinski and Freiburger 2020).

McLaughlin et al. (2013) directly address this dilemma: "*Trade-offs arise when fish passage decisions intended to benefit native species interfere with management decisions intended to control the unwanted spread of non-native fishes and aquatic invertebrates, or genes, diseases and contaminants carried by hatchery and wild fishes. These consequences and trade-offs will vary in importance from system to system and can result in large economic and environmental costs.*" These difficult decisions may benefit from a formal, structured process such as decision analysis, that is transparent, objective, and can incorporate quantitative evaluation of risk (McLaughlin et al. 2013). Experts at the Quantitative Fisheries Research Center at Michigan State University have been leaders in decision analysis approaches to addressing these types of difficult resource management questions in recent years.

In summary, creation of effective upstream fish passage at the Sanford dam on the Tittabawassee River for walleye, lake sturgeon, and suckers would be challenging at best. Major trade-offs related to unwanted spread of invasive species need to be rigorously evaluated. These decisions will require a collaborative and comprehensive process that involves stakeholders as well as resource management agencies and probably academia.

D. Fish Habitat Enhancement in Sanford Impoundment

For the purposes of this document, we will define fish habitat as all the required physical factors (temperature, water depth, current, waves, bottom types, cover or structure, etc.) and chemical factors (oxygen levels, dissolved minerals, and other substances) that permit fish to survive. It should also be noted that habitat requirements for different fish species, and for different life stages for a given species, may also be quite different within the same water body. Fish habitat in rivers and impoundments is always a function of the conditions found in the watershed. Human activities on the landscape of the watershed directly affect the habitat for fish in the rivers and impoundments of that watershed. Miranda and Krogman (2015) found that shallower reservoirs with higher percentage of agricultural land use in the watershed show accelerated senescence. Reservoir habitat impairments include point source pollution, nonpoint source pollution, excessive nutrients, algae blooms, siltation, limited nutrients, mudflats and shallowness, limited connectivity to adjacent habitats, limited littoral structure, nuisance species, anomalous water regimes, and large water level fluctuations (Krogman and Miranda 2016).

Reservoir habitat improvement efforts have been common in southern and western states where impoundments are the most abundant form of waterbodies. Addition of structure such as large woody debris, boulders and rocks, and even engineered fish structures has been common. However, the results have been varied and in many cases research efforts have not been able to clearly demonstrate increased fish production. In general, the question of whether adding structure actually increases fish production or simply concentrates the fish increasing their availability for anglers, remains unanswered (Arlinghaus et al. 2016). In either case, anglers can benefit from increased structure, particularly if the location of structure is known.

The impoundments on the Tittabawassee River are nearly 100 years old. The dams were constructed just a few decades after the lumber era when virgin coniferous and deciduous forests throughout the watershed were logged off and much of the landscape was converted to agricultural use. This massive change in the landscape was accompanied by aquatic habitat degradation from erosion and siltation. Modern agricultural practices have resulted in further degradation of aquatic habitat from non-point source pollution and excessive nutrients. Schrouder et al. 2009 reported that only 34.8% of the watershed was forested, while 44.8% was agricultural with cash crop production (corn, soybeans, wheat) predominant.

General habitat conditions in the Tittabawassee River impoundments have been measured sporadically and incompletely. Based on measures of nutrients, productivity, and water clarity, Schrouder (2016) found that Sanford Lake was mesotrophic, indicating moderate biological productivity. Schrouder et al. (2009) also noted that zebra mussels (*Dreissena polymorpha*) had colonized Sanford Lake by the early 2000's and that increased water clarity and light penetration has promoted increasing abundance of submergent aquatic vegetation, including milfoil. Coincidentally, property owners Sanford have expressed increased desire for management or control of excessive submerged aquatic vegetation in recent years (Schrouder 2013, Schrouder 2016).

Prior to any habitat enhancement efforts targeting structure in Sanford Lake, we recommend a mapping project of the dewatered lake to record the quantity and location of existing structure. Specifically, documentation of the spatial distribution of large woody debris (both vertical and horizontal), boulder/rock areas, and bare sand flats. Also, we expect it would likely prove useful to delineate those areas with dense growth of new woody plants. Such a mapping effort may be best conducted by GPS equipped drone video. The resulting structure map would facilitate identification of zones with limited structure for possible enhancement efforts. Conducting this mapping effort before additional growth seasons for terrestrial and wetland plants on the dewatered lake bottom lands would probably produce best results. SES found many recent publications in peer-reviewed literature that provide relevant examples of drone-based habitat mapping (Flynn and Chapra 2014, Marcaccio et al. 2015, Husson et al. 2016, Ventura et al. 2018). Table 6 below provides cost estimates for a drone-based habitat mapping project on both of the drained impoundment basins. The total cost is estimated at $37,250.

Table 6. Estimated cost for drone mapping habitat in drained Sanford and Wixom basins.

	Drone Tech and Drone*	Post processing/GIS mapping	Ground truth data and map	Total hours by lake	Est. cost by lake
Est. cost per hour	$150	$150	$150		
Est. hours Wixom (2600 acres)	87	40	40	167	$25,000
Est. hours Sanford (1250 acres)	42	20	20	82	$12,250
Cost by task for both lakes	$19,250	$9,000	$9,000		$37,250

*Assumes 2 minute per acre for mapping

Sanford Lake was created in 1925. When the impoundment was originally filled, standing timber in some areas of the basin was cut off at varying heights above what was to become the lake bed. Since the lake was dewatered in May 2020, it is easy to identify the areas where standing timber and stumps remain. These are a testament to the durability of large woody debris as fish habitat in the impoundment. Addition of more large woody material to the impoundment could benefit anglers by attracting and concentrating fish in areas where existing structure is sparse. However, large woody materials must be firmly anchored to prevent movement during periods of increased flow. It can also create problems for motorized navigation if located in areas that are too shallow. Paradoxically, shallow shoreline areas in impoundments tend to be lacking for large woody materials (Miranda et al. 2020), and woody structure in shallow waters that is partially exposed is typically heavily utilized by reptiles and amphibians, in addition to fish. It should also be noted that hard surfaces, like woody material, provide more habitat for the invasive zebra mussels, which promote clearer water and subsequently more submerged aquatic vegetation.

Boulders and rocks are visible in some areas of the dewatered Tittabawassee impoundments, but much less common than standing timber and stumps. Addition of boulders and large rocks to areas with sparse structure could benefit anglers by attracting and holding fish. While boulders and large rocks are less prone to movement during high flow events, like large woody material, they can be hazardous for motorized navigation if located in shallow waters. Like wood, boulder and rocks also provide more habitat for invasive zebra mussel attachment.

A variety of structures made of natural materials have been used for fish habitat enhancement in impoundments and reservoirs. Miranda (2017) provides an extensive overview of the rationale for habitat management in reservoirs. Jones et al. (2015) provides a detailed listing of various types of habitat structures and designs including both woody and stone or rock structures. Some examples of woody structures that might be appropriate for Sanford Lake include tree clusters, root wads, brush piles, and wood cribs. Rock or stone humps or reefs may also be an option. We estimate the cost of construction and installation of log cribs at approximately $1,000 per crib. Construction of 1 crib per 100 acres would cost an estimated $13,000 for Sanford Lake (1,250 acres). Construction of rock reef type habitat is more expensive, with an estimated cost of approximately $100 per ton of stone. For example, construction of a 100 foot by 100 foot by 5-foot-high rock hump would cost an estimated $277,000. Smaller rock piles, 10 foot by 10 foot by 5 foot high could be constructed for roughly $2,770 each.

Another fish habitat enhancement option could be to add walleye spawning habitat to the tailrace sections below each of the dams on the Tittabawassee, if such habitat is found to be absent or limited. An assessment effort that includes mapping the substrate characteristics below each dam would provide the information necessary to determine if addition of cobble or rock could potentially improve wild spawning success by walleye migrating upstream from the impoundments. At a cost of $100 per ton for stone, a spawning bed of 50 feet width, by 500 feet length and 1 foot high would cost an estimated $138,500.

Fishing in the impoundments can also be improved in other ways besides fish habitat enhancement. For example, public access for anglers (both boat and shore) can be increased or improved to accommodate physically challenged anglers. Safe kayak/canoe portages and access around the dams can increase safe recreational use of the riverine areas as well as increase fishing opportunities around the dam sites. New public shore fishing sites can be enhanced by adding fish attracting structures near the fishing sites to help increase opportunities for success for anglers using the sites. Finally, a detailed bathymetric map showing structural habitat features like standing timber and stump fields, boulder and rock areas, and any new structural enhancements would also serve to increase angler success.

In summary, the dewatering of Sanford Lake has created an opportunity for mapping the structural component of fish habitat found in the basin. Depending upon the mapping results, habitat enhancement by adding large woody material such as log cribs, or rock structures would be feasible while the lakebeds is exposed. Such habitat enhancement efforts could improve fish habitat and benefit anglers with improved fishing success.

E. Riverine fish community losses by Sanford Lake Restoration

Sanford Dam began operating as a hydroelectric facility in 1925 (Schrouder et al., 2009). There are no historical fisheries or macroinvertebrate data for the Tittabawassee and Tobacco Rivers in the vicinity of the former impoundments that predate the construction of the impoundments. The purpose of this section of the scoping document is to identify an approach and cost estimate to survey the Tittabawassee and Tobacco Rivers and their associated tributaries in the vicinity of the former impoundments. These survey data would be used to identify the prevailing fish and macroinvertebrate communities associated with the riverine environment. The primary intent of these survey plans is to use the survey data to assess impacts to the riverine fish and macroinvertebrate communities resulting from the restoration of the impoundments back to operational conditions.

Although no pre-impoundment fishery survey data exist for Sanford Lake, the Tittabawassee River system downstream of Sanford Lake has maintained components of predominantly warmwater and coolwater fisheries, along with seasonal migratory potadromous species (Schrouder et al. 2009). Lake sturgeon, longnose gar (*Lepisosteus osseus*), bowfin (*Amia calva*), longnose sucker (*Catostomus catostomus*), white sucker, silver redhorse (*Moxostoma anisurum*), golden redhorse (*Moxostoma erythrurum*), shorthead redhorse (*Moxostoma macrolepidotum*), yellow bullhead, brown bullhead, channel catfish, northern pike, lake trout (*Salvelinus namaycush*), white bass, rock bass, smallmouth bass, largemouth bass, yellow perch (*Perca flavescens*), walleye, and freshwater drum (*Aplodinotus grunniens*) have been identified within the downstream portion of the Tittabawassee River. These species were described as having access to the Tittabawassee River watershed and likely used the main stem and its tributaries to complete a portion of their lifecycle (Schrouder et al. 2009). Although the remnants of the failed Sanford Dam may create physical barriers to upstream migration, many of the species identified in the Tittabawassee River Assessment were also previously identified in Sanford Lake during periodic fisheries assessments (Schrouder 2007).

Although no historical macroinvertebrate data exist for the Tittabawassee and Tobacco Rivers prior to the construction of the Edenville and Sanford Lake dams, macroinvertebrate surveys have been conducted within tributaries to each river in 1997 as part of a Procedure 51 assessment conducted by the Michigan Department of Environmental Quality (now referred to as Michigan Department of Environment, Great Lakes, and Energy – EGLE; Schrouder et al. 2009). Tributaries to the middle portion of the Tittabawassee River, which includes Wixom and Sanford Lakes were surveyed during 1997 and observed a diversity of taxa ranging from a minimum of 18 to a maximum of 36 different taxa among the five survey locations (Schrouder et al. 2009). The tributaries to Tobacco River that were surveyed as part of the Procedure 51 assessment observed diversities ranging from a minimum of 11 taxa to a maximum of 32 different taxa in one survey location (Schrouder et al. 2009).

We recommend using Procedure 51 (MDEQ's Surface Water Quality Division *Procedure #51 Survey Protocols for Wadable Rivers* P-51; MDEQ 1990) as a means to survey fish and aquatic macroinvertebrates in the wadable tributaries to the Tittabawassee and Tobacco Rivers. We also recommend using Procedure 22 (MDEQ's Surface Water Quality Division *Procedure #22 Qualitative Biological and Habitat Survey Protocol for Non-Wadable Rivers* P-22; MDEQ, 2013) as a means to survey fish and macroinvertebrates in the Tittabawassee and Tobacco Rivers, which are expected to be too deep for a wading P-51 survey. Both of these survey protocols provide a description of fish community composition and relative abundance and these fisheries data can be used to estimate a qualitative rating of the fish community that could be used as a resource evaluation tool. The macroinvertebrate portion of these survey protocols also provides community composition and relative abundance data, along with a community rating, which includes a determination of tolerant versus intolerant species.

A total of 14 streams, creeks, and drains, including the Tittabawassee River, have been identified that could potentially be impacted by the restoration of the Sanford Lake Dam (Table 7).

Table 7. Waterways observed in impounded portions of Sanford Dam.

Sanford Lake Dam streams and tributaries

Stream Name	Impact Area (ft)
Tittabawassee River	23,760
Unnamed 5 (W. Adams)	150
Unnamed 6 (Baker)	280
Unnamed 7 (Campbell Ct)	1,100
Unnamed 8 (Blakely)	150
Ditmar Drain	1,000
Mason Drain	650
Meridian Drain	650
Varity Creek	4,300
Black Creek	2,900
Unnamed 9 (Dague)	1,200
Unnamed 10 (Shaffer)	3,000
Unnamed 11 (Clarence Ct)	680
Unnamed 12 (Branscomb)	120

A total of 13 tributaries to the Sanford Lake Dam are expected to be wadable and could likely be surveyed using the Procedure 51 assessment for wadable streams. The Tittabawassee River and Tobacco River within the Sanford Lake Dam former impoundment area are expected to be surveyed using the Procedure 22 assessment for non-wadable streams and rivers. It is likely that some of these tributaries may be found to be intermittent during the growing season, or may be impounded from the remnants of perched culverts that were likely placed while each impoundment was in place and was impounding water.

The length of a survey reach using the Procedure 51 method is dependent upon the stream width (MDEQ 1990). Based on visual reconnaissance of many of the tributaries of each impoundment, we assumed that most of the Procedure 51 survey reaches would be no longer than 300 feet.

We estimated the cost to conduct the Procedure 51 surveys in all the wadable tributaries to Sanford Lake basin. Our estimate was based upon a three-person crew surveying a total of three wadable streams each day. The total estimated cost to survey the wadable streams within the Sanford Lake basin is $42,600, which could be completed within approximately 4.3 days (Table 8).

We estimated the cost to conduct the Procedure 22 surveys in non-wadable portion of the Tittabawassee River segment within the former Sanford Lake basin. Our estimate was based upon a three-person crew surveying a total of three large stream segments (approximately 2,000 feet in each segment) within the Tittabawassee River using electrofishing and nets to survey the fish communities. We also anticipate collecting macroinvertebrates within those stream segments. The total estimated cost to survey the non-wadable river segments within the drawn down Sanford impoundment is $18,700, which could be completed within approximately 1.5 days (Table 8).

Table 8. Cost estimate to survey fish and macroinvertebrate communities prior to restoration of impoundments.

Sanford Lake Dam streams and tributaries	
Task	Cost
P-51 Survey of 13 wadable streams	$42,600
P-22 Survey of Tittabawassee River	$18,700
Total	$61,300

Literature cited

Arlinghaus, R., K. Lorenzen, B. Johnson, S. Cooke, and I. Cowx. 2016. Management of freshwater fisheries: addressing habitat, people, and fishes. Pages 557-579 In Freshwater Fisheries Ecology, First edition, J. Craig editor. John Wiley & Sons Publishers.

FERC (Federal Energy Regulatory Commission). 1998. Multiple project environmental assessment for hydropower license. Tittabawassee River projects. FERC Project Nos. 10808, 10809, and 10810. Washington D.C.

Flynn, K. and S. Chapra. 2014. Remote sensing of submerged aquatic vegetation in a shallow non-turbid river using an unmanned aerial vehicle. Remote Sens. 6, 12815-12836; doi:10.3390/rs61212815

Freshwater Physicians, Inc. 1988. Hydroelectric facilities in the Tittabawassee River basin: potential impacts of operation. Brighton, Michigan.

Husson, E., F. Ecke, and H. Reese. 2016. Comparison of manual mapping and automated object-based image analysis of non-submerged aquatic vegetation from very-high-resolution UAS images. Remote Sens. 8:724; doi:10.3390/rs8090724

Jones, A., D. Weedman, C. Gill, and B. Dickens. 2015. A catalog of reservoir fish habitat structures 2015 (Version 2.0). Arizona Game and Fish Department. Phoenix AZ.

Krogman, R. and L. E. Miranda. 2016. Rating US reservoirs relative to fish habitat condition, Lake and Reservoir Management, 32:1, 51-60, DOI: 10.1080/10402381.2015.1121307.

MDEQ (Michigan Department of Environmental Quality). 2013. SWAS Procedure 22 Qualitative Biological and Habitat Survey Protocols for Non-Wadable Rivers, February 6, 2013.

MDEQ (Michigan Department of Environmental Quality). 1990. SWAS Procedure 51 Qualitative Biological and Habitat Survey Protocols for Wadable Streams and Rivers, April 24, 1990. Revised June 1991, August 1996, January 1997, May 2002, and December 2008.

Marcaccio, J., C. Markle, and P. Chow-Fraser. 2015. Unmanned aerial vehicles produce high-resolution, seasonally-relevant imagery for classifying wetland vegetation. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-1/W4, International Conference on Unmanned Aerial Vehicles in Geomatics, Toronto, Canada.

McLaughlin, R., E. Smyth, T. Castro-Santos, M. Jones, M. Koops, T. Pratt, L-A. Espino. 2013. Unintended consequences and trade-offs of fish passage. Fish and Fisheries 14:580-604.

Miranda, L.E. 2017. Reservoir fish habitat management. Lightning Press, Totowa, New Jersey. 306 pp.

Miranda L., and R. Krogman. 2015. Functional age as an indicator of reservoir senescence. Fisheries. 40:170–176.

Miranda, L., G. Coppola, and J. Boxrucker. 2020. Reservoir fish habitats: a perspective on coping with climate change. Reviews in Fisheries Science and Aquaculture 28(4):478-498.

Rytwinski, T., D. Algera, J. Taylor, K. Smokorowski, J. Bennett, P. Harrison, and S. Cooke . 2017. What are the consequences of fish entrainment and impingement associated with hydroelectric dams on fish productivity? A systematic review protocol. Environ Evid 6, 8. https://doi.org/10.1186/s13750-017-0087-x.

Schrouder, K.S. 2016. Sanford Lake Status of the Fishery Resource Report 2016-216. Michigan Department of Natural Resources, Ann Arbor.

Schrouder, K.S. 2013. Smallwood Impoundment Status of the Fishery Resource Report 2013-157. Michigan Department of Natural Resources, Ann Arbor.

Schrouder, K.S., R.N. Lockwood, and J.P. Baker. 2009. Tittabawassee River assessment. Michigan Department of Natural Resources, Fisheries Special Report 52, Ann Arbor.

Schrouder, K. 2007. Michigan Department of Natural Resources Status of the Fishery Resource Report – Sanford Lake. 2007-40. 17 pages.

Silva, A., M. Lucas, T. Castro-Santos, C. Katopodis, L. Baumgartner, J. Thiem, K. Aarestrup, P. Pompeu, G. O'Brien, D. Braun, N. Burnett, D. Zhu, H-P. Fjeldstad, T. Forseth, N. Rajaratnam, J. Williams, S. Cooke. 2018. The future of fish passage science, engineering, and practice. Fish and Fisheries 19:340-362.

Southwick, R.I, and A.J. Loftus, editors. 2017. Investigation and Monetary Values of Fish and Freshwater Mollusk Kills. American Fisheries Society, Special Publications 35, Bethesda, Maryland. 165pp.

U.S. Department of the Interior (USDI), U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. 2016 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.

Ventura, D., A. Bonifazi, M. Gravina, A. Belluscio, and G. Ardizzone. 2018. Mapping and classification of ecologically sensitive marine habitats using unmanned aerial vehicle (UAV) imagery and object-based image analysis (OBIA). Remote Sens. 10, 1331; doi:10.3390/rs10091331

Zielinski, D.P. and C. Freiburger, 2020. Advances in fish passage in the Great Lakes basin. Journal of Great Lakes Research, https://doi.org/10.1016/j.jglr.2020.03.008