Sediment Surge: Predicting the Downstream Effects of Water Injection Dredging at Tuttle Creek on the Big Blue River

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Research Report

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1. Introduction

The U.S. Army Corps of Engineers (USACE) is addressing the build-up of sediment in lakes and reservoirs caused by dams, a common issue that reduces water capacity. With over 400 dams and reservoirs under its management, USACE faces the need for sustainable sediment management strategies. Currently, many reservoirs are at or beyond their 50-year mark, experiencing displacement of beneficial pool capacity and sedimentation impacts not considered by original designs. One innovative approach being explored by USACE researchers is water injection dredging, a method historically used in the past in Europe for dredging ports. This technique involves injecting large volumes of water into sediment, creating a density current capable of traveling far within a reservoir and out through the dam. The first project is set at Tuttle Creek Lake in Kansas (shown in Figure 1), chosen for its environmental suitability and will be assisted by both facilities of Kansas State University and the University of Kansas. The project involves injecting water into sediment in front of the dam to create a density current that moves towards the dam, venting downstream. The success of this project could provide a less expensive alternative to traditional dredging. The significance of this research extends beyond sediment management to downstream impacts. Our team recognizes the importance of evaluating how water injection dredging affects water quality for fish and channel

Figure 1: Tuttle Creek Lake Reservoir (Manhattan CVB)

morphology downstream of Tuttle Creek Reservoir. The study aims to collect data on the turbidity current generated, its flow, and potential effects on physical habitat, water quality, and organisms downstream. By understanding these effects, researchers can develop tools to model and inform decision-making processes, adaptive management, and environmental impact studies for future USACE lakes and reservoirs. As sediment release may have both positive and negative impacts, the project emphasizes the need for comprehensive research to guide sustainable sediment management strategies. The effort involves ecologists, engineers, and researchers working collaboratively to learn from the effects of water injection dredging in the specific habitats downstream of Tuttle Creek. The ultimate goal is to provide valuable insight that can inform decisions and potentially assist and provide additional information for USACE and other projects, ensuring longevity and efficiency within critical water infrastructure projects.

As the sediment is released it will have the potential to impact the biological and physical components downstream on the Big Blue River, which includes fish communities, sediment quality, water quality, geomorphic channel shifts, and changes in the overall ecosystem, which will undoubtedly affect human activities as well (Coleman, 2023). River channels are changing constantly as a result of flow rates, sediment transport, and other natural events. Because this dredging method is unexplored in freshwater settings, it is important to monitor how the channel may change as they are hoping for water injection dredging to be applicable to more than just Tuttle Creek Reservoir (Coleman, 2023). Obtaining an understanding of the historical and current channel morphology will aid in analyzing the post-dredging effects to be able to grasp if water injection dredging will be successful in Tuttle Creek Lake Reservoir, and at the end of the study, be able to evaluate if the Big Blue River was ready for the events imposed upon it.

2. Background

The Tuttle Creek Dam began construction in 1952 and became completely operational by 1962. Construction of the dam was highly opposed by locals and ended up displacing 3000 people in nearby towns (Kansas Memory, 1954-1956). Despite this opposition, the great flood of 1951 had detrimental economic effects on the city of Manhattan and surrounding areas, calling for a solution. A 1950 study concluded that a single dam would be the most effective in controlling floods on the Big Blue River (U.S. Army Corps of Engineers). Over the years, sediment has been accumulating at the bottom of Tuttle Creek Reservoir, and consequently, lowering its capacity (Figure 2). Before the dam was constructed, the transported sediment load was 44 million tons per year, and post-construction, the transported sediment load is 13 million tons, a 70% reduction. That 70% now sits in Tuttle Creek Reservoir, where it is quickly reducing the depth of the lake (Olson, 2022). Tuttle Creek falls within the Big Blue River Basin, where 75% of the land is cultivated cropland (Barnes and Kalita, 2001). Cropland erosion is a major source of sediment deposition within lakes and rivers, especially Tuttle Creek Reservoir (Smith et al., 2013). Much of the sediment load that is deposited from the Big Blue River is deposited near the river's basin, with about 5-10% of that load being carried throughout the lake (Schwartz and Marzolf, 1971).

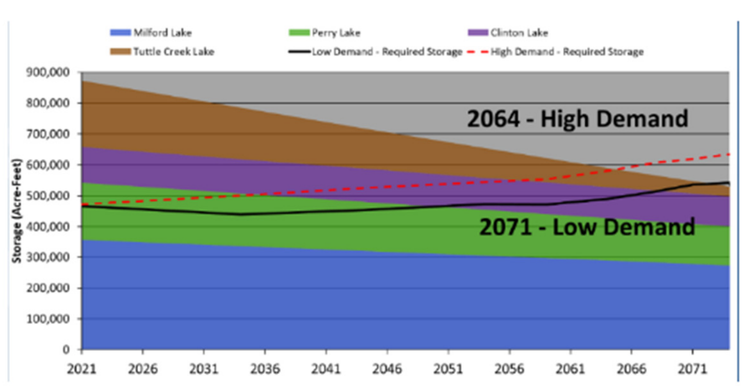

Figure 2: Kansas River Basin Projected Water Supply (Olson, 2022)

2.1 Water Injection Dredging (WID)

Water Injection Dredging (WID) is defined as the technique that injects high volumes of water through a series of nozzles with low pressure pumps, which are positioned on a horizontal bar, to pump water into the sediment. The water then fluidizes the sediment to flow with a gravity current. The fluidized sediment has a higher density than surrounding water, allowing it to flow with the current (PIANC Report No. 120, 2013). Water at Tuttle Creek will be injected about 3-5 km in front of the dam, depending on the water level at the time of dredging. The dredge that has been chosen for water injection dredging at Tuttle Creek is 120 feet in length by 32 feet wide which can create a larger density current that can then produce an even larger sediment plume to travel further towards the gate to be released. Pipes are placed along the side of the barge that pump the water into the sediment as seen in Figure 3.This will be the first time in world history that WID will be performed in a lake setting (Ingram, 2023). WID falls under the category of hydrodynamic dredging, a fairly new method of dredging patented in the 1980s (Spencer et al., 2006). It's important to understand the texture of the sediment before WID can be conducted. Sediments with more sand and larger grained sands are not very compatible with WID because they cannot travel very far when suspended due to their weight (PIANC Report No. 120, 2013). WID is growing in popularity because it is often more cost effective than other dredging methods, while also maintaining the sediment balance within the water body. Some downsides of the WID process are that it poses threat to the aquatic biological community by spreading sediment that is potentially contaminated with organic and inorganic compounds, as well as heavy metals (PIANC Report No. 120, 2013). Research Ecologist, Darixa Hernandez-Abrams, with USACE-ERDC, said "We need to know the duration, magnitude and timing of the release sediments and the relationship between the ecological processes and the physical processes that come into play. Not only are you releasing sediment, but you're probably also changing the hydraulics downstream, and that in turn can have different effects on the downstream biota." (Ingram, 2023). The long-term ecological effects of WID have yet to be studied (Spencer et al., 2006).

2.2 Sediment

One main problem WID poses for the Tuttle Creek Project is the potential for the sediment to carry harmful contaminants downstream. Sediment samples from Tuttle Creek show a high percentage of silt and clay, along with little sand, making it a good contender for WID (Olson, 2022). However, a higher percentage of silt and clay could result in more contaminants being transported downstream, as these smaller particles are what will be kicked up into the water column. The use of pesticides in agriculture has increased 40-fold within the last 3 decades (Willis and McDowell, 1982). Many of these pesticides have been known to cause adverse effects on humans and wildlife if they are consumed. With the majority of the land surrounding the Big Blue Basin

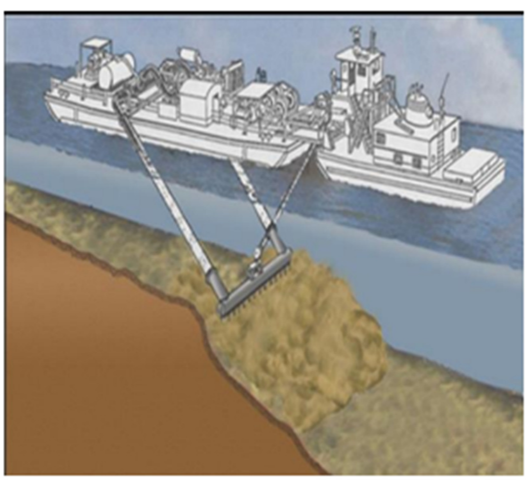

Figure 3: Dredge (Welp et al., 2017)

being cropland, a high amount of pesticides and herbicides are making their way into the aquatic systems.

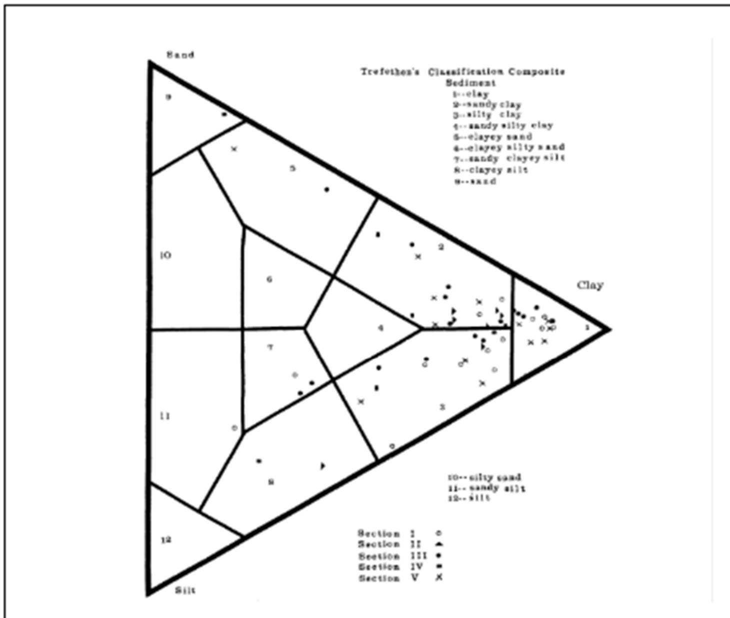

Figure 4: Sediment texture throughout the 5 strata (Schwartz and Marzolf, 1971)

A study performed in 1968 determined the particle size and organic matter concentration within 65 sediment core samples taken from Tuttle Creek. The lake was divided into 5 strata for sampling purposes, with strata 1 being closest to the dam, and strata 5 being the furthest (north). They found no statistical differences between particle sizes within the lake (Figure 4). This is interesting when compared to other studies, because others have found much higher amounts of clay in Tuttle. This could be due to differences in farming practices as the years go on. Practices that control erosion would have more resistance to larger sized particles, allowing more clay particles to runoff with precipitation events. Organic matter was statistically insignificant in limiting or enhancing benthic abundance within Tuttle Creek Reservoir (Schwartz and Marzolf, 1971).

Another study, done in 1999, took bottom-sediment cores from 22 sites within Tuttle Creek. These cores were tested for 44 metals and trace elements, 15 organochlorine compounds, and 1 radionuclide. 40 of the 44 metals and trace elements were found in all of the sediment samples. Au, Bi, S and Tl were detected in little to none of the samples. The U.S. EPA has certain criteria determining dangerous levels of contaminants within sediment. Two of these concern guidelines are TELs (threshold-effects level), and PELs (probable-effects level). TEL is the level below which toxic biological effects rarely occur. Between the TEL and PEL toxic effects can occasionally occur, and above the PEL is when toxic effects frequently occur. Cd, Pb, and Hg concentrations were generally below the TELs. Ag, As, Cr, Cu, Ni, and Zn all typically exceeded the TELs. Ar, As, Cu, and Ni were between TEL and PEL. Of the 15 organochlorines examined, only aldrin, DDD, DDE, and dieldrin were detected. Generally, DDD, DDE, and dieldrin were all below TEL. Aldrin doesn't have any sediment quality guidelines established. DDE, which is a degradation product of DDT, was present in most of the sediment samples (Figure 5) (Juracek and Mau, 2003).

Constituent (unit of measurement)	Number of detections/ number of analyses	Concentration			Sediment-quality guidelines[1]	
		Minimum	Median	Maximum	TEL	PEL
Metals and trace elements						
Ag ($\mu g\ g^{-1}$)	41/41	0.4	0.73	1.2	0.733	1.77
As ($\mu g\ g^{-1}$)	41/41	6.9	14	18	7.24	41.6
Cd ($\mu g\ g^{-1}$)	41/41	0.26	0.44	0.61	0.676	4.21
Cr ($\mu g\ g^{-1}$)	41/41	48	81	120	52.3	160
Cu ($\mu g\ g^{-1}$)	41/41	20	34	44	18.7	108
Hg ($\mu g\ g^{-1}$)	40/41	<0.02	0.04	1.4	0.13	0.696
Ni ($\mu g\ g^{-1}$)	41/41	19	38	77	15.9	42.8
Pb ($\mu g\ g^{-1}$)	41/41	16	25	160	30.2	112
Zn ($\mu g\ g^{-1}$)	41/41	65	120	150	124	271
Organochlorine compounds						
Chlordane ($\mu g\ kg^{-1}$)	0/34	<3	<3	<3	2.26	4.79
DDD ($\mu g\ kg^{-1}$)	10/34	<0.5	<0.5	1.4	1.22	7.81
DDE ($\mu g\ kg^{-1}$)	30/34	<0.2	0.36	5.2	2.07	374
DDT ($\mu g\ kg^{-1}$)	0/34	<0.5	<0.5	<0.5	1.19	4.77
Dieldrin ($\mu g\ kg^{-1}$)	10/34	<0.2	<0.2	0.39	0.715	4.3
PCBs ($\mu g\ kg^{-1}$)	0/34	<5	<5	<5	21.6	189

[1]Guidelines from U.S. Environmental Protection Agency (1997). TEL and PEL values for organochlorine compounds converted from mg kg^{-1} to $\mu g\ kg^{-1}$.
[TEL, threshold-effects level; PEL, probable-effects level; <, less than].

Figure 5: Concentrations of metals, trace elements, and organochlorine compounds in bottom-sediment samples from Tuttle Creek Lake (Juracek and Mau, 2003)

Past use of organochlorine pesticides (OCPs), like DDT, had detrimental effects on the environment, and these chemicals still persist in soils, water, and sediments. OCPs are dangerous because they can bioaccumulate and have been found in wildlife, drinking water, human adipose tissue, and human milk (Barlas et al., 2006). DDT was a commonly used pesticide, especially in the United States, where it was initially used by the military in WWII to control malaria, typhus, and the bubonic plague. It was banned in 1972 by the U.S. EPA because it had adverse effects on wildlife (National Pesticide Information Center, 1999). Although use of DDT has ceased, a degradation product of it, DDE, still persists. DDE tends to stay in the body longer than DDT. Low exposure to these chemicals has unknown effects on the human body, but high exposure results in vomiting, shaking, and seizures (DDT Factsheet, 2009). The half life of DDT in an aquatic ecosystem is 150 years. It is highly toxic to aquatic animals and amphibians, and has been labeled as a B2 carcinogen (National Pesticide Information Center, 1999).

2.3 Water Quality

Atrazine is an increasingly popular herbicide, commonly used in Kansas and Nebraska, that kills almost any plant it comes into contact with. It's the active ingredient in many popular herbicides used worldwide. In 1992, the EPA established a new drinking water standard for atrazine called the maximum contaminant level (MCL), and set it to 3 g/L. Limited monitoring in Kansas resulted in a majority of surface waters to be above the MCL. The majority of the Big Blue River Basin is in Nebraska, and it ends at the Tuttle Creek dam. The section of the Big Blue River that passes through Marysville, Kansas represents 49% of the drainage area, but produces 80% of atrazine loading. The station in Marysville exceeds the upper stations by as much as 1.5 times. The total inflow of atrazine to Tuttle Creek Reservoir is 11,509 kg, while the outflow is 4506 kg, indicating the reservoir reduces atrazine loading by 61%. Water samples routinely collected from 10 stream sites consistently exceeded the drinking water standard for atrazine (Barnes and Kalita, 2001).

A study conducted in China examined 6 lakes for atrazine behavior in aquatic environments. The 6 lakes sampled had differing runoff from urban wastewater, to aquatic wastewater, to agricultural pollution. Interestingly, the highest concentrations of atrazine were found in the center of each lake. This indicates high mobility of atrazine in water, and could be because it is more soluble in water than organochlorine pesticides. Several studies have shown atrazine to be rapidly biodegradable in surface soils, but persistent in anaerobic or denitrifying conditions in subsurface soils and sediments (Qu et al., 2017). Through this study, they found that atrazine can adsorb to lake sediments 6 times faster than surface soils. It seems to persist in lake sediments, as it adheres strongly through hydrogen bonds (Qu et al., 2017). One of the biggest threats of pesticides and herbicides in runoff is the effect on aquatic organisms. Aquatic organisms concentrate pesticides in their tissues more readily than terrestrial organisms. Once a pesticide or herbicide enters an aquatic system, it is rapidly transported and dispersed throughout. It then remains in the water, adsorbs to sediment, or is absorbed by aquatic organisms. Through many different processes within the organisms, pesticides can reduce their population and alter ecosystems through decreased food and oxygen supply (Willis and McDowell, 1982).

2.4 Channel Morphology

The Big Blue River has seen many changes to its channel in the past hundred years. The event that brought the most change to the channel was the flood of 1951 which shortened the river channel length and greatly reduced the sinuosity (Weatherly, 1994). Shortly after. and as a result of the constant flooding, in 1962 the Big Blue River became Tuttle Creek dam and reservoir, halting the steady flow of the river into its downstream counterpart. Barclay and his team worked to analyze the results of installing the Tuttle Creek dam, they looked at daily discharge, pulse count, pulse duration, hydrography rise rate, peak flow date, peak discharge, and return interval which are all summarized pre-dam construction and post-dam construction in the image. Up until the late nineties the elevation of the Big Blue river was declining post dam construction (decreasing by a total of 1.6 meters). Soon after the bed stabilized and remained degrading at a steady rate, seen in Figure 6.(Barclay et al., 2023). Degrading is typical of a sediment starved river as there is less sediment to deposit which makes the bed unable to accumulate which makes the elevation raise.

Discharging the sediment downstream into the channel can reduce channel incision and start aggradation, which can restore habitat for fish and bird species that they depend on for survival (Kondolf et al., 2014). However, the sediment would eventually settle, helping to aggrade and build back up the river bank. It is thought there has been less cases of sediment fleshing in the United States due to the mindset that sediment is a pollutant and discharging it to our river should be avoided at all costs (EPA, 1994). Sediment concentration transport and floodwater level along a river gradually decrease in a river as you go downstream (Lee et al., 2022). Flushing sediment would be able to restore both in-reservoir and downstream channel environments to resemble what they were before man intervention (Shelley et al., 2016). There are many ways that sediment has been flushed downstream in the past, and the results have varied, here are some examples:

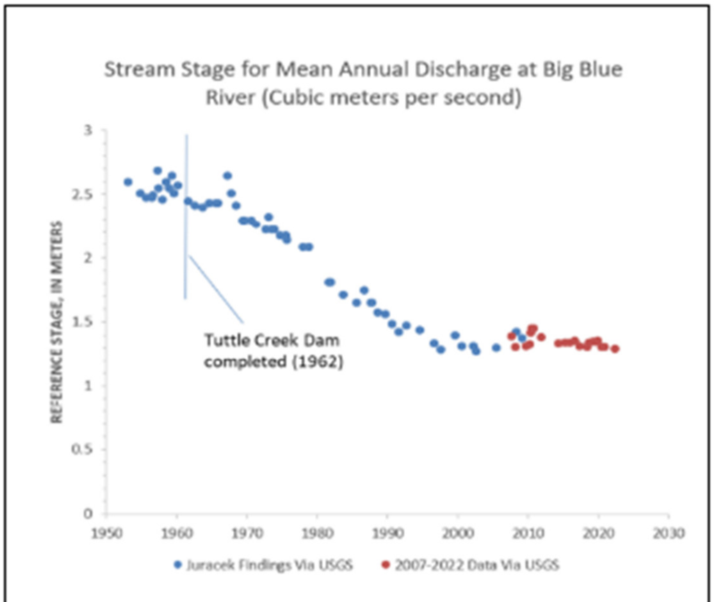

Figure 6: Change in channel morphology of the Big Blue through time (Barclay et al., 2023)

Since water injection dredging has never been done before in this context it is important to look at the effects of other dredging methods on downstream channel morphology. Bypassing tunnels redirect sediment so it never even enters the reservoir. This process has less of an impact on the environment as there is no need for the sediment to be flushed and it enters the channel at a natural rate. Strategies such as managing the sediment quantity and quality, making sure the sediment and flow regime is adjusted for the current water level (Kantoush et al., 2010). A sediment pulse can create a sediment wave which can move as a unit or disperse as it moves down the stream. Either of these can result in morphology changes. Channel braiding started to become apparent and gravel bars started to emerge. It is concluded that a supply of sediment to a fluvial network can incise and create coarse grained terraces or the sediment acts as a bedload trap and causes large scale aggregation of fine sediment which results in raises the elevation of the stream bed and creates braided rivers, which can be seen in Figure 7 (Hoffman & Gabet, 2007).

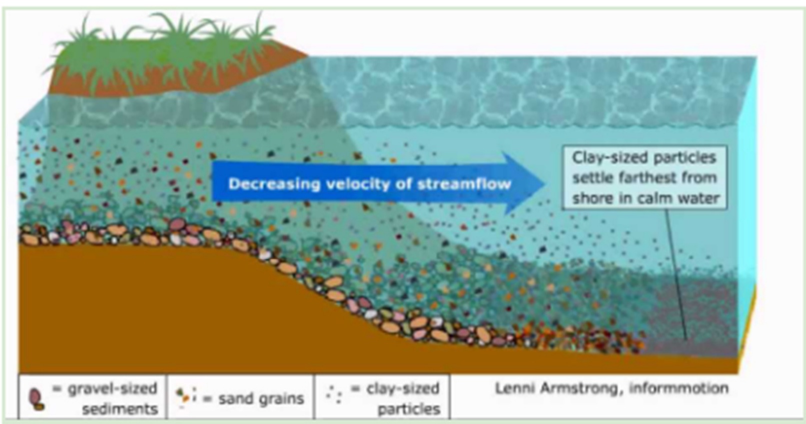

Figure 7: How sediment can lead to aggradation and degradation (Shailendra Kumar, Youtube)

Although this is the first time water injection dredging will be conducted in a reservoir, analyzing the impacts of how sediment reacts in other water bodies can give information that can be used to hypothesize the results we will see in the Big Blue River. The Parrett River is characterized by fine gravel and coarse sand. Dredging was conducted within the thalweg zone during high tides in an upstream direction. Their key findings were that water injection dredging was effective at removing the sediment but the results were short lived, meaning dredging would have to occur annually. WID did not significantly alter the sediment grain size distributions in the study area. The area of the study had relatively turbid waters, therefore the alterations in water quality were minimal but they expect less turbid waters to see an increase in water quality changes (Pledger et al., 2020). Unlike the Parrett River, the Big Blue River is not currently extremely turbid, so it is more likely it will experience more changes in water quality based on these findings. The average cubic feet per second (csf) of discharge out of Tuttle in the past decade was 2,253 csf (USGS, 2023). The proposed discharge during WID will be around 3,000 csf. This discharge will be within the rate that the channel has experienced before, making it not extreme and is not much higher than the average. Considering this, I believe the channel will aggrade, filling with sediment as the flow enters at a slightly higher than average speed. This aggradation will raise the channel bed, especially in the Rocky Ford area, mirroring conditions similar to before the reservoir was built as seen in Figure 8.

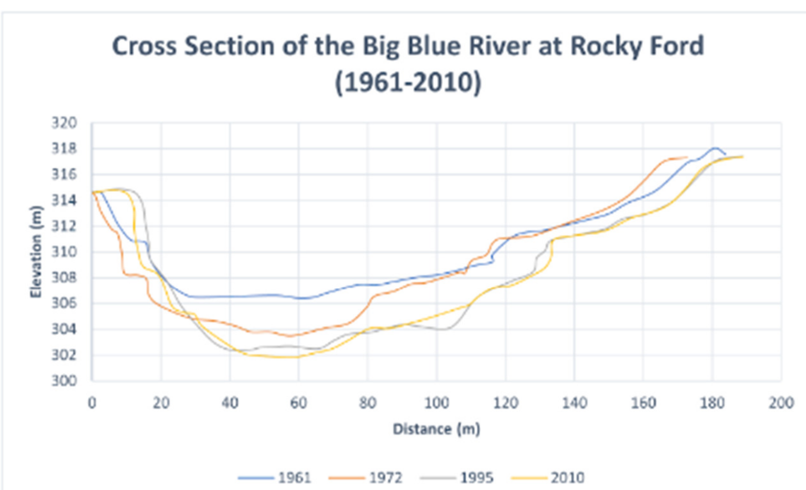

Figure 8: Rocky Ford cross sections (Carrie Bigham, 2023)

2.5 Fish Health

2.5.1 Sediment Effects on Fish Health

The research on fish health, sedimentation, and water quality provides a comprehensive understanding of how these factors interact and impact aquatic life. Dredging, a process crucial for maintaining waterways and supporting construction, can disturb fish habitats by stirring up sediment and altering the shape of river or lake beds. The noise and vibrations associated with dredging can further disrupt fish behavior and well-being, affecting their ability to find food, lay eggs, and go about their daily lives. Water quality can become a key concern during dredging, as changes in sediment levels can introduce pollutants, impacting the health of fish populations. Sediment, consisting of tiny particles in the water, plays a significant role in water quality and aquatic ecosystems. The study by Putnam and Pope (2003) emphasizes the detrimental effects of sediment on water quality, acting as a carrier for pollutants and reducing water usability. The impact of sediment on fish populations is further explored in studies focusing on specific fish species. Kawanishi et al. (2015) investigate how sedimentation affects the endangered benthic fish species, Cobitis shikokuensis, revealing a clear preference for sediment-free substrates. The study emphasizes the negative effects of fine sediment deposition on the health and well-being of fish, and provides valuable insights into the habitat requirements of the species. Consideration of the long-term consequences of dredging on fish habitats is crucial. The work of Pasternack, Bounrisavong, and Parikh (2008) emphasizes that alterations in habitat structure, vegetation, and substrate composition may persist beyond the immediate dredging period. These lasting effects can significantly influence fish communities, affecting their abundance and diversity over time.

2.5.2 Water Quality Effects on Fish Health

Some may think that fish do not need oxygen, they only need water because we all know, fish cannot live outside of water. On the contrary, fish do need oxygen, but in a form that is called Dissolved oxygen (D.O). Dissolved oxygen is oxygen that is dissolved in the water. Fish filter D.O. through their gills, which allows them to breathe underwater. The reason fish cannot breathe outside of water is because the fish cannot filter the oxygen through their gills, which then causes them to suffocate. “Fish extract oxygen from the water by passive diffusion through the gills. An adequate concentration of DO in the water is required to facilitate passive diffusion down a concentration gradient from the water into the blood [**7**]. If DO concentrations fall below the requirements of the fish, then fish cannot convert energy as efficiently into a usable form, resulting in reduced growth rate, feed efficiency and swimming ability,” (Yildiz, 2017). Low D.O. is one of the most common stressors for fish. Low levels of D.O. can cause reductions in feeding, feed conversion, and growth. Low D. O. is often associated with elevated levels of carbon dioxide (CO2) and unionized ammonia (NH3), which are both toxic to fish. “Combination of low D.O. with high C02 and NH3 dramatically increases the susceptibility of fish to diseases,” (Water Quality, 2020). Low oxygen is most common during July-September when fish weights and feed rates are increasing. High levels of nutrients cause phytoplankton growth and oxygen is often nearly depleted from high rates of respiration. Low D.O. may begin to occur in late summer or early fall when the first cold fronts begin to occur. If large amounts of decayed waste, feed, or plant material are present on the bottom of a waterway, more oxygen demand will occur when the water layers mix. Oxygen can then be completely depleted within 15-30 minutes. “Oxygen may also be depleted if silt-laden runoff from heavy storms causes die-offs of algae or rooted aquatic vegetation,” (Water Quality, 2020). Water quality is important for fish health. If water quality is poor than D.O. will begin to drop, causing fish to become more susceptible to diseases and death. Water quality can be characterized by concentration ranges of nitrogen, phosphorus, and D.O. Each of these characteristics promote appropriate ecosystem functioning. “Sudden changes in the fish stocking density, growth rate, feeding rate or water volume can elicit rapid changes in water quality; hence, regular measurement of those critical water quality parameters is essential. The deterioration of water quality parameters affects fish physiology, growth rate, and feed efficiency, leading to pathological changes and even mortality under extreme conditions," (Yildiz, 2017). Water quality parameters for fish are in the same range of plants except water temperature and pH in the aquaponic system, as shown in Table 1. Fish species with a high tolerance of pH and temperature should be taken into account. It is obvious that pH and temperature are the parameters that have an impact on fish welfare, fish health issues, and plant needs.

There are many factors that can affect fish health such as organic materials, excessive nutrition and phosphorus, suspended solids, and toxic chemicals. When nutrients wash into waterways through storm runoff, they deplete oxygen in the water that fish need to survive. Nitrogen and phosphorus enter streams and lakes from fertilizers, waste, and other sources. These nutrients then build up in the water and create more algae and water plant growth. Once they begin to decay oxygen levels begin to drop in the water. Algal blooms can be harmful to fish. As they eat the algae toxins will begin to accumulate within the fish and when a predator fish consumes that fish, they are then consuming higher toxin levels. This leads to a constant cycle of toxin poisoning in fish. (Alan et. al), discusses that "silt suspended in the water column is probably the most prevalent of the suspended solids. It generally results from runoff where land has been disturbed by plowing or excavation. Ground up

Table 1. General water quality tolerances for fish (warm or coldwater), hydroponic plants and nitrifying bacteria (from Somerville et al. [32]).

Organism Type	Temperature (°C)	pH	Ammonia (ppm)	Nitrite (ppm)	Nitrate (ppm)	Dissolved Oxygen (ppm)
Warmwater fishes	22–32	6–8.5	<3	<1	<400	4–6
Coldwater fishes	10–18	6–8.5	<1	<0.1	<400	6–8
Plants	16–30	5.5–7.5	<30	<1	-	>3
Bacteria	14–34	6–8.5	<3	<1	-	4–8

Table 1: Water quality parameters (Yildiz, 2017)

wood fibers can also be a significant form of suspended solid pollution."

2.6 Cultural Services

Based on a comprehensive synthesis of the diverse studies reviewed for this project, we found there to be a complex and multifaceted nature of influences impacting river ecosystems. Delving into sediment dynamics, water quality, habitat modifications, and the extensive repercussions of climate change, these collective findings underscored the imperative need for continued research, innovation, and a greater perspective in water resource management. A deeper comprehension of the interplay between these complex factors is essential in effectively managing the intricacies of river ecosystems and riparian areas.

Furthermore, the presence of pesticides and contaminants in water bodies necessitates a multifaceted strategy. Combining ongoing research, comprehensive monitoring, and the integration of advanced water treatment technologies represents a critical approach that will likely continue on into future years. Collaborative endeavors and stringent regulatory frameworks are essential not only to protect ecosystems but also to safeguard public health, ensuring access to safe water for consumption and recreational activities. The need for a comprehensive approach to managing and minimizing these contaminants during the proposed 2025 water injection dredging project is clear, necessitating a concerted effort from various stakeholders.

The urgency to adapt and cultivate sustainable practices in the face of evolving environmental conditions cannot be said enough. The interconnectedness of these challenges emphasizes the importance of a holistic approach that considers the intricate relationships between human activities, environmental changes, and the health of these vital ecosystems. This collective understanding reinforces the critical significance of preserving and managing river ecosystems for the benefit of both current and future generations. It calls for a shared responsibility and concerted action to guarantee the resilience and vitality of these natural systems, which play an integral part in the well-being of our planet and its inhabitants.

3. Study Area

The water injection dredging will be occurring in Tuttle Creek Lake Reservoir five miles north of Manhattan, Kansas and covers 10,900 acres and is surrounded by 20,000 acres of park land. The surrounding area consists of many recreational activities such as campgrounds, hiking trails, ORV trails, picnic areas, fishing, hunting, and even a marina (USACE, 2023). After the great flood in 1951 that flooded the streets of Manhattan, the United States Army Corp of Engineers set out to construct Tuttle Creek Dam. When the dam was built it submerged four towns: Cleburne, Randolph, Garrison Cross and Stockdale. Initially, the dam was intended to be a dry dam, passing the flow below the dam without considering water conservation or recreational advantages (USACE, 2023). The water that flows through Tuttle Creek is a drinking water resource for towns such as Topeka and Lawrence all the way up to the Kansas City area, so it was important to consider the environmental impacts, water quality, and flow rates (Kansas Department of Water, 2017). After these considerations the dry dam was removed in 1957 and replaced with the dam we have today consisting of spillway chutes. These chutes discharge into the Big Blue River, where it flows for nine miles through Manhattan before intersecting with the Kansas River and flowing east (USGS, 2023). The Big Blue River water that flows from Tuttle contributes up to 50% of the water in the Kansas River (Kansas Department of Water, 2017). Along the Big Blue, just one and half miles downstream of Tuttle lies Rocky Ford. Rocky Ford is also a dam, once used for milling and power as seen in Figure 9 (KDWP, 2023). Today, the milling foundation still stands and the area is largely used for fishing. At the time of our data collection the water was low and many sand bars were found throughout the area and vegetation and wildlife were abundant. Further downstream on the Big Blue, Dyer Road crosses overhead, this is where our second set of collections were taken. Water injection dredging poses unknown effects to the downstream area, therefore a year from now, the area may look starkly different. The geographic relationship of our study area can be seen in Figure 10.

4. Methods

4.1 Establish Existing Conditions

Our group's research began with individual studies related to the effects of water injection dredging on varying aspects of river/riparian zone health such as, channel morphology, wildlife populations, fish health, sediment and water quality, and general ecosystem services. Each area of study was delegated out to a group member who then found a variety of research articles focusing on topics related to the issue. Each student compiled roughly 10 articles into an annotated bibliography summarizing the findings of each research article. Using the research articles, each group member predicted some baseline estimates regarding the implications

Figure 9: Rocky Ford Recreation Area downstream of Tuttle (Raja Brockenberry)

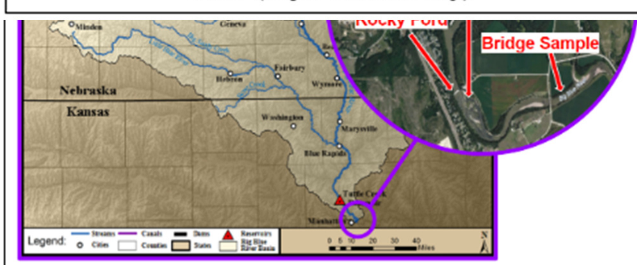

Figure 10: Our Study Site (Nebraska Dept. of Natural Resources, Palmer Bowles 2023)

of the Water Injection Dredging project on the Blue River downstream regarding their respective areas of focus.

4.2 Study Site Selection

To determine our study set, we looked at a variety of predicted variables, first of which was establishing an estimated discharge from the Tuttle Creek Reservoir. For this, we referred to the USGS gauge at Big Blue River NR Manhattan, KS (06887000) which approximates the average at roughly 3,000 CFS though it can greatly vary depending on the time of year and the annual precipitation. Based on this data we inferred that most of the sediment released via water injection dredging would bypass the River Pond area commonly referred to as the, “Tuttle Puddle" and ultimately be discharged through the rocky ford reservoir. At Rocky Ford, the sediment would then be released back into the Blue River’s natural current. Based on that information, we chose study sites 1 and 2 to be 100 yards south of the discharge area and about 1 mile downstream near Dyer Rd. Bridge.

4.3 Data Collection

At our research sites, our groups conducted multiple water and sediment tests in order to establish baseline conditions (as seen in Figures 11 and 12). These tests were conducted on October 5th of 2023 at a discharge of 581 ft3/s. It is worth noting that this was an extremely low water year for the Blue River watershed and therefore it is predicted that these results would vary in a more precipitous year. Our data collection/river sampling equipment consisted of a YSI multi parameter sonde (EXO3) with sensors for dissolved oxygen, temperature, conductivity, pH, turbidity, chlorophyll-a and phycocyanin pigments. Additionally, we used a soil corer in order to gather reliable and consistent soil samples. These samples were then sorted and transported back to the Kansas-State University labs where they were refrigerated for further testing.

4.4 Lab Testing

Back at Kansas-State University, we began analyzing the results via a variety of lab test equipment such as a vacuum pump and HACH test kit. We conducted this research twice a week over a period of four weeks until all 8 samples had been analyzed in each test.

Our suspended solids testing began by measuring the weights of the unused filters to establish a baseline weight for all samples. We then shook the 100 mL water samples for 20-30 seconds in order to evenly disperse suspended solids throughout the sample. Next, we placed the

Figure 11: Group Sampling at a Small Pond adjacent to Rocky Ford (Palmer Bowles)

Figure 12: Sample Collection below Rocky Ford (Palmer Bowles)

unused filters on a vacuum pump attached to a filter bottle with a 0.45 micron filter mesh to separate the solids from liquids. From there, we poured the 100 mL sample over the 0.45 micron filter. After distributing the water sample on the filter, we then removed it from the vacuum pump and placed it on a tin plate to be dried at 105 degrees Celcius for 24 hours before re-weighing it (as seen in Figure 13). We then repeated this for all 8 samples in addition to a “Blank” sample to serve as a control variable. After thoroughly drying the samples, we then reweighed the dry filters and subtracted the weight from the initial weight/control variable weight in order to determine the sediment weight.

For the water sample analysis portion of our study, we extracted 8 small 2 oz. samples of water from our four different sampling locations and ran them through a series of tests, in order to acquire data of potential concern. These tests consisted of total suspended solids (mg/L), Ammonia Nitrogen (mg/L NH_3-N), Phosphate (mg/L PO_4-P), and Nitrate (mg/L NO_3-N) level tests. For each of these tests we extracted one sample of water as a control variable and an additional sample of water for testing. We then combined the testing sample with a mixture of various chemicals in order to change the solution's coloring. From there we placed the solution into a HACH surface water test kit and compared it to the coloration of the control sample of water (without the solution). In order to acquire our results we'd then hold the two solutions up to the light and adjust the dial so that the colors matched thereby giving us a numerical reading telling us the concentration of various chemicals in the solution.

Figure 13: The Eight Samples on the Micron Filters (Palmer Bowles)

5. Results and Discussion

Water Sample Analysis				
Site	Total Suspended Solids (mg/L)	Ammonia Nitrogen (mg/L NH3-N)	Phosphate (mg/L P)	Nitrate (mg/L N)
Rocky Ford Site 1	62.5	0.1	0.125	0.675
Rocky Ford Site 2	26.5	0.9	0.185	0.655
Rocky Ford Site 3	23	0.2	0.26	0.75
Bridge Site	112	0.4	0.24	0.75

Table 2: Water sample analysis from Rocky Ford and Bridge sites

Each site is an average of two samples taken from the same general area. According to the USGS, TSS is a measure of both sediment and organic material in the water. A high TSS can be a problem for fish because it creates the potential to clog their gills and suffocate them. High TSS can also block out sunlight which limits plant growth, which in turn, lowers dissolved oxygen. Water quality standards are set in each state. The benchmark maximum TSS in Cheney Reservoir is 100 mg/L (USGS, 2010) . The results show only one sampling site that exceeds the maximum TSS, yet the rest were within normal range (as seen in Table 2). It is expected that TSS will be higher than the maximum amount during the WID process, because of the high volume of sediment in the water column. Ammonia nitrogen and nitrate are within normal levels. All sample phosphate levels are higher than normal.

The YSI sonde is a multiparameter tool used to analyze several aspects of water quality from a single sample. While sampling at Rocky Ford, our team recorded two samples from different sites. The YSI sonde conducted the temperature in degrees Celsius, the % saturation of dissolved oxygen, specific conductivity, turbidity, chlorophyll, and phycocyanin readings. Turbidity was higher than usual (1-5 NTU) at the two sites. The chlorophyll readings were within normal range. Summarized results can be seen in Table 3.

Although Tuttle Creek has a high amount of nutrient-rich runoff from agriculture, it doesn't tend to have algal blooms. Even with the addition of nitrogen and phosphorus, the high amount of suspended solids blocks out sunlight, which is needed for the algae to form. From this research, we infer that the WID project will eventually aggrade downstream in the Big Blue River and/or the Kansas River. We are especially concerned with the Rocky Ford area, as this is where a good amount of the sediment could settle after the initial release. Although the sediment studies performed in Tuttle Creek are 25+ years old, there don't seem to be any specific concerns

Results From YSI Sonde		
	Rocky Ford Site 1	Rocky Ford Site 3
Temperature (C)	21.825	22.22
DO (% saturation)	107.5	93.8
Specific Conductivity (uS/cm)	553	556
Turbidity (NTU)	11.34	13.16
Chlorophyll-a (RFU)	1.43	2.15
Phycocyanin (RFU)	0.12	0.16

Table 3: YSI Sonde results from two sites at Rocky Ford

with contaminants attached to them. As these particles are transferred downstream, they may become concentrated, which would cause issues, especially where the Kansas River is used for drinking water. The atrazine studies showed that atrazine is typically in the middle of lakes, which in this case, would not make its way downstream, as the dredging project is close to the dam. Something that may cause issues would be the downstream effects on wildlife. Since the lake already has a high amount of TSS, the addition of even more sediment in the water could block out light for aquatic organisms and deplete them of oxygen. This study was mainly conducted to establish baseline conditions and potential threats that WID may pose. To improve this study, we need measurements of river cross-sections in several downstream areas, which are being conducted by other teams, but we did not have the data for. Repeated measurements over the years will give us accurate data as to whether or not the WID process is beneficial in a lake setting.

6. Conclusions and Future Research

The study aimed to assess the potential impacts of a Water Infrastructure Dredging (WID) project on the water quality of Tuttle Creek, specifically in the Rocky Ford area. Our findings indicate that TSS levels, while generally consistent, were below the normal range, with only one sampling site exceeding the benchmark maximum of 100 mg/L in Cheney Reservoir. The YSI sonde measurements revealed elevated turbidity levels at two sites, while other parameters such as chlorophyll were within normal ranges. Notably, phosphate levels were consistently higher than normal. Tuttle Creek, despite having nutrient-rich runoff, does not experience algal blooms due to the high amount of suspended solids blocking sunlight, which is essential for algae formation. From our research, we infer that the WID project may lead to downstream aggradation in the Big Blue River and/or the Kansas River, with particular concern for the Rocky Ford area. Sediment studies in Tuttle Creek, even though dated, did not raise specific contaminant concerns. However, the potential downstream effects on aquatic life, particularly due to increased sediment and TSS, could adversely affect aquatic organisms by blocking light and depleting oxygen. The study acknowledges limitations, including the need for river cross-section measurements in downstream areas, which other teams are conducting. The inconclusive nature of our data may suggest the importance of repeated measurements over time to assess the long-term impact of the WID process. In conclusion, our study suggests that while current water quality parameters are generally within acceptable limits (summarized in Table 4), the WID project may have downstream consequences on fish populations, channel morphology, sediment quality, and cultural services. The hypothesized results anticipate degradation in water quality, diminished fish populations, channel aggradation, and potential negative effects on recreational activities. The findings emphasize the need for continued monitoring and further research to fully understand and mitigate the potential impacts of the WID project on Tuttle Creek and its downstream areas. The Future project will be conducted by The U.S. Army Corps of Engineers (USACE) that will involve the implementation of a water injection dredging method at Tuttle Creek Lake, Kansas, as a novel approach to address sediment accumulation. The hypothesized results are summarized in Table 5. In summary, our research assists the USACE project at Tuttle Creek Lake by providing crucial baseline information, highlighting concerns and potential threats, recommending long-term monitoring, and contributing to the overall understanding of sedimentation processes and potential challenges associated with dredging.

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Objective	Hypothesized Result
Water Quality	The water will begin to degrade causing fish populations to diminish over time.
Channel Morphology	The channel will begin to aggrade, filling with sediment.
Sediment Quality	Harmful contaminants, like metals and pesticides, that are attached to sediment particles could cause adverse effects on downstream aquatic life and water quality
Cultural Services	As the hydraulic water dredging increases, then the beneficial ecosystem services will diminish. Fish populations will decrease in number, increased sedimentation will make recreational activities such as kayaking and hunting more difficult, and water quality will degrade.

Table 5: Hypothesized results of the four phenomena we were analyzing

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