REPORT OF THE MINNESOTA LEGISLATURE

As required by Minnesota Session Laws, 2023 Regular Session, Chapter 62, Article 1, Section 47

Report Title:
St. Anthony Falls Study

Submitted by:
University of Minnesota Board of Regents

Prepared by:
The report was prepared by a team based at University of Minnesota, St. Anthony Falls Laboratory; University of Minnesota, Minnesota Geological Survey; Hennepin County Emergency Management; and the Freshwater Society.

Report Preparation Costs:
Per the requirements set forth in Minnesota Statute 3.197, the cost to prepare this report was $1,000,000.

St. Anthony Falls Study

Investigation Team:

Jeff Marr[1], John Anfinson[1], Richard Christopher[1], Aaron Hirsch[2], Carrie Jennings[3], Madigan Rios[1], Anthony Runkel[2], Eric Waage[4], John Walton[1]

[1] St. Anthony Falls Laboratory, University of Minnesota, 2 Third Ave SE, Minneapolis, MN 55414
[2] Minnesota Geological Survey, University of Minnesota
[3] Freshwater Society
[4] Hennepin County Emergency Management

Prepared for:

Minnesota State Legislature

July 1, 2026

Minneapolis, Minnesota

Final Report

St. Anthony Falls Study: Preliminary Risk and Hazard Assessment of the St. Anthony Falls Cutoff Wall and Subsurface Infrastructure

1. Introduction

This preliminary risk assessment study did not find any evidence of impending or immediate failure of the St. Anthony Falls region related to the cutoff wall or other subsurface infrastructure. There are periodic inspections performed on key assets including bridges, damming surfaces, lock and spillway infrastructure, and underground tunnels. The US Army Corps of Engineers (USACE), Xcel Energy, and the Minnesota Department of Transportation (MnDOT) have made large investments in repair and replacement of existing infrastructure, and these inspections and repair activities continue today through established processes. We identify opportunities to add additional monitoring and increase frequency of inspections.

The project determined, however, **that this site is very complex with many unknowns**. The geological characteristics of the bedrock that make up the falls, drastic anthropogenic changes that occurred over the last 150 years, and decay and erosion of old infrastructure create **plausible failure modes**. The **likelihood of any of these failures occurring is low**; however, the project team believes they are plausible scenarios given the unique geologic characteristics of the site and the aging and unknown condition of subsurface infrastructure. These failure modes and impacts to the upstream and downstream Mississippi River are discussed in the sections below.

The project also found that **connectivity and coordination among the many stakeholders at St. Anthony Falls can be improved**, and this includes within a single organization and between organizations. Some of the subsurface infrastructure is more than 150 years old, and the study revealed that many stakeholders were unfamiliar with some of the history, existing historic infrastructure, and its possible impact on modern infrastructure.

The most pressing issue for the region is the lack of determination of what organizations share ownership and responsibility for the cutoff wall and subsurface tunnels on Hennepin Island. It is imperative that ownership be determined for the cutoff wall as well as the West Branch Tunnel, Eastman Tunnel, and Hennepin Island Utility Tunnel. Owners and other stakeholders can then work together to monitor, maintain, and coordinate necessary actions for the region.

There is an opportunity to implement monitoring systems throughout the site to detect conditional changes that would indicate progression toward a failure scenario. Relatively inexpensive technologies are available for monitoring. Monitoring devices could

provide owners and stakeholders with notification of changes, helping prevent a catastrophic failure situation well before an event fully unravels. Monitoring needs to be implemented quickly and should not wait for the likely lengthy processes of determining ownership.

Finally, the project reveals a **need for emergency action plans to be developed around various failure modes and processes.** Determining ownership and the key stakeholder groups that should be involved in monitoring, preparations, and failure response is prudent, achievable, and would further safeguard this important region into the future.

Enabling Legislation

This study summarizes detailed investigations into historic subsurface infrastructure located at St. Anthony Falls and provides a preliminary assessment of associated risks and recommended actions. This report was prepared at the request of the Minnesota State Legislature to investigate the condition of the subsurface cutoff wall constructed by the United States Army Corps of Engineers (USACE) from 1874 to 1876 and located immediately upstream of St. Anthony Falls in Minneapolis, Minnesota, USA.

During the 2023 Minnesota legislative session, the Minnesota State Legislature requested that the University of Minnesota assemble a team to conduct a preliminary risk assessment of the St. Anthony Falls cutoff wall and nearby subsurface infrastructure (SF2994/HF2744). The state allocated funds to complete this assessment by July 1, 2026, including geophysical surveys of the site and other tasks. The appropriation language, amended in April of 2025, states the following:

$1,000,000 in fiscal year 2024 is appropriated from the general fund to the Board of Regents of the University of Minnesota for a geophysical study and hazard assessment of the St. Anthony Falls area and St. Anthony Falls cutoff wall. The study must include a field-based investigation of the cutoff wall and other subsurface structures, modeling of the surrounding area, examination of public safety and infrastructure risks posed by potential failure of the cutoff wall or surrounding area, and emergency response plan for identified risks. By conducting this study, the Board of Regents does not consent to accepting liability for the current condition or risks posed by a potential failure of the cutoff wall. By July 1, 2026, the Board of Regents must submit a report to the legislative committees with jurisdiction over state and local government policy and finance. This appropriation is available until June 30, 2026.

Study Approach

This study involved the following investigations:

A. Discovery and review of important historic documents and site history
B. Field-based geophysical investigation
C. Field-based inspections of subsurface infrastructure
D. Stakeholder consultations

E. Literature review of how rivers respond to dam failure and dam removal
F. Identification of possible failure modes
G. Hazard assessment of failure and emergency planning
H. Development of recommendations for the state legislature

2. Purpose

This study aimed to verify and quantify the hazard posed to Minneapolis and the surrounding Twin Cities region from a failure at St. Anthony Falls and particularly the cutoff wall, a 150-year-old technology built to protect it. Recently, St. Anthony Falls could be considered as a regional "black swan" hazard, which Taleb (2007) describes as a rare and unpredictable event that is unimagined; an event with rapid and cascading consequences worsened by an unprepared response trying to catch up; and a tendency to be only seen clearly in hindsight as a litany of 'missed signals'. This assessment was the first step in addressing a hazard that posed an existential economic threat to Minneapolis generations ago but has since been long forgotten. This study should be useful in reducing surprise, at least among responders and stakeholders, if a failure event were to occur.

The data revealed in this work has measurably reduced (but not eliminated) the unknowns regarding St. Anthony Falls as a hazard. It has removed some barriers that made it difficult to imagine its failure. The authors developed several plausible failure modes, offering a chance to reduce surprise and foster advance planning. Describing St. Anthony Falls as an interconnected natural-human system provides a rationale for forming stronger ties across agencies and disciplines so that existing monitoring can be better coordinated and so that systemic response plans can be developed.

It is important to state that this assessment did not discover an imminent threat of catastrophic failure of the falls. Some features of the fall's environment remain stubbornly resistant to observation because of their inaccessibility and the limitations of available technology. Many questions remain unanswered. Because of these knowledge gaps it is not currently possible to develop a statistical probability regarding the loss of St. Anthony Falls. The investigation team agrees that in the abstract the likelihood of failure is low (but not zero). The failure modes developed during this study indicate that the consequences of failure would be high. Losses in the vicinity of the falls would be driven by the speed, intensity, and extent of destruction that each failure mode could produce. Cascading impacts beyond the immediate area of physical destruction would create disruptions that ripple across the region.

3. High Impact Low Probability (HILP) Hazard

St. Anthony Falls presents a high impact low probability (HILP) hazard at a regional scale. The loss of the falls would be a tipping point in the disruption of vital interconnected systems. Lee (2012) describes three variants of HILPs. First are 'black swans' which are unanticipated surprise events. Next are 'known but unprepared for' disasters, where preparation was

ignored due to the low likelihood of occurrence. Finally, there are 'known and prepared for' events. The authors of this report urge that actions be taken to place the hazard at St. Anthony Falls into the 'known and prepared for' category.

Traditional hazard assessment, especially for natural hazards, is employed at all levels of emergency management using a two-dimensional matrix where consequences are plotted along with likelihood. This method usually leaves HILP hazards off hazard assessments because their low probability does not meet the threshold required. In some cases, hazard lists are further ranked and narrowed to a top five or ten. These methods are used to maximize limited resources but almost always leave HILPs as 'known but unprepared for' hazards. As is the case for safety in general, many effective measures can be taken to address HILPs by employing imaginative foresight and a modest investment of time and resources.

While the falls itself is no longer the epicenter of the regional economy, the infrastructure surrounding it remains vital to the Twin Cities region. Many works describing black swans and HILPs feature the resulting calamity on a global or national scale. A HILP can also create a serious impact in a specific region. A regional impact is the scale that the loss of St. Anthony Falls would produce. A rough regional analog could be the 2024 loss of the Francis Scott Key Bridge in Baltimore, an event with cascading regional impacts far beyond the interruption of highway traffic that used the yet to be rebuilt bridge.

4. Study Area

The section of the Mississippi River assessed for consequences of the failure of St. Anthony Falls (river mile 854.0) extends upstream a distance of 12.2 miles to the Coon Rapids Dam (river mile 866.2). Downstream it extends 6.3 miles south to Lock and Dam No. 1 (river mile 847.7). The study revealed that the area of immediate and short-term impact is restricted to around one mile upstream and a similar length downstream.

5. Brief Description of St. Anthony Falls

From the outset, it is essential to recognize that St. Anthony Falls is a natural feature. It is a waterfall. Despite the many engineered structures built in and around it, to protect it, utilize it for power, or navigate past it, St. Anthony Falls is a naturally occurring hydrologic knickpoint in the flow of the Mississippi River. It is the only major waterfall along the river's entire length.

St. Anthony Falls is (or more accurately, was) a migrating waterfall, traveling upstream from its point of origin in St. Paul around 12,000 years ago. Limestone forms the hard caprock of the falls. Its vertical headwall or limestone "lip" was clearly visible in early paintings and photographs of the natural St. Anthony Falls. As the flow of the Mississippi River poured down into the plunge pool below the falls, it carved out the soft sandstone layer underneath and caused the overlying limestone to overhang. Natural fractures, partings, and apertures in the limestone bed also allowed water to flow downward into the sandstone, further

compromising the strength of the ledge. Regularly, large blocks of limestone would fall into the plunge pool creating additional turbulence and further eroding the sandstone. In this way the falls retreated at a natural rate of around 4 feet per year (Carroll, 2015; Wright et al. 1998, Winchell 1878, Wright 1972,). The migration of the falls left behind the only gorge on the Mississippi River, extending from the mouth of the Minnesota River to St. Anthony Falls in Minneapolis.

St. Anthony Falls shares many traits with Niagara Falls in New York. Both are migrating falls with hard caprock and soft erodible rock underneath. Both formed around 12,000 years ago in rivers swollen with glacial meltwater. The retreat of St. Anthony Falls began around ten miles downstream in St. Paul and averaged around 4 feet of travel per year once it separated from what is now the Minnesota River. Niagara Falls retreated about six miles upstream at an estimated rate of three to five feet per year. If left to nature, both falls would have eventually retreated to their extinction when their hard caprock ended. Niagara Falls will run out of caprock and encounter a soft shale layer four miles upstream, transforming it into a rapids some 15,000 years from now (NYSM, 2026). St. Anthony Falls, on the other hand, loses its limestone caprock only 1,200 feet upstream as it encounters a buried glacial river valley. If this had been allowed to happen it would have taken only a few hundred years for St. Anthony Falls to be lost.

In both falls, humans have intervened to slow or stop the retreat process. The importance of these waterfalls to regional economies resulted in efforts to stabilize them against further erosion. At Niagara Falls, industry slowed erosion because it diverted significant flow away from the brink of the falls, mostly for hydropower. Occasional suspension of flow has allowed close inspection of loose rock, installation of sensors, rock bolts, and other measures to further mitigate erosive forces.

At St. Anthony Falls, in contrast, industry significantly accelerated erosion due to tunneling in the sandstone, impacts of logs on the limestone, and other physical impacts to the integrity of the rock forming the falls. The erosive forces of industry reached a crisis point when the Eastman Tunnel collapsed in 1869, presenting an existential threat to the economy of Minneapolis. This spurred a drive to save the falls which was marked by several unsuccessful attempts to stem rampant flow through pipes and channels in the sandstone under the falls. Eventually, stability was achieved by the installation of the subterranean cutoff wall in the sandstone (to block piping), as well as the roll dams (to prevent impact damage), and the apron (to prevent undercutting). This arrangement has prevented further falls migration since 1877.

6. Risk Assessment Methodology

St. Anthony Falls is not a dam, so using dam risk assessment methodology is not a perfect fit. The threat of dam failure produces the most impact downstream. The threat of waterfall failure produces the greatest impact upstream. Dam safety risk assessments emphasize such

events as incidents triggered by an unusual load that would stress a dam (such as a flood or earthquake). Then the structural response of the dam to such a load is assessed, including the potential release of large volumes of impounded water. The few waterfall failure examples show that rapid upstream erosion is the greatest threat to people and structures. It seems prudent therefore, to not simply adopt a structural engineering risk assessment for a dam as a template for assessing St. Anthony Falls.

St. Anthony Falls is a waterfall, but it is also not sufficient to assess it as a natural hazard. The statistical probabilities produced when the falls are viewed as a natural hazard are no longer applicable. This is because St. Anthony Falls is an interconnected system - neither exclusively a natural feature nor a work of human engineering. It is both.

Probability

As a natural feature, St. Anthony Falls had an easily calculable probability of failure. The falls maintained an average rate of retreat of 4 feet per year established in the geological record since the time it began to form the Gorge upstream from the Minnesota River. The falls require a hard limestone bed underlain by a soft sandstone layer for its characteristic headward erosion-driven travel. However, the limestone layer ends about 1,200 feet above the falls' current location which would spell the demise of the falls. These factors mean that a reliable estimate of the time of natural extinction of the falls could be calculated, but since the falls are no longer a fully natural feature that statistic is of no value to a hazard assessment.

Plausibility

Human intervention in the natural migration of the falls means that a statistical probability of failure is no longer possible. St. Anthony Falls is now a compound hazard where natural and technological factors are intertwined, and which presents a cascading threat to nearby infrastructure if a failure event is left unchecked. A key component of human technology protecting the falls is the cutoff wall which has been performing its role in ensuring sandstone stability under the falls for 150 years. It has remained almost entirely unseen since its completion, raising questions about its condition. The engineering practices of the 1870s, along with the lack of detailed design data, and the novelty of its role, contribute additional uncertainty. Finally, the response of natural systems such as groundwater flow, to the intrusion of the cutoff wall is not well understood, leading to more uncertainty. Because of this cumulative uncertainty, combined with the likely consequences of a failure, it is reasonable to conclude that St. Anthony Falls poses a plausible significant hazard. Plausibility is a determination of credibility based on available evidence and knowledge in alignment with established scientific principles.

Natural Factors

There are three main natural factors involved in the St. Anthony Falls system. These are 1) geology, which includes both bedrock and unconsolidated materials, 2) surface water flow, and 3) groundwater movement.

The bedrock of most importance to St. Anthony Falls is the Platteville Formation. Specifically, it is the Mifflin and Pecatonica members which form the 8 to 12 feet of hard limestone remaining near the crest of the falls. These are the units that give the falls strength and structure. The Platteville Formation should not be viewed as simply a durable and resistant mass, however. There are naturally occurring fractures, partings, and apertures within the limestone which allow some water to travel through the unit. This rock was also the object of considerable human activity in the area as well. Owing to its strength and availability, Platteville was heavily used for construction, and it was quarried just upstream of the falls on Nicollet Island. In other places, the Platteville had to be removed to access the soft sandstone underneath for tunneling. The industrial period left the Platteville pockmarked with various excavations in the vicinity of the falls.

Under the Platteville Formation is the Glenwood Formation between 2 and 4 feet thick. It is mostly shale and as such is not an effective conveyor of water, but there are vertical fractures present. Industry was not interested in the Glenwood Shale because it had no properties that produced economic reward. However, the unit is interesting for this report because the contact between it and the next lower unit, the St. Peter Sandstone is the location of much of the tunnelling and piping in the St. Anthony Falls Area.

The final bedrock unit of interest in the St. Anthony Falls system is the St. Peter Sandstone which is a very thick unit ranging from 150-175 feet. The uppermost portion, called the Tonti member, is the unit involved with St. Anthony Falls. The erodibility of the sandstone is the critical factor in St. Anthony Falls' journey of retreat upstream to Minneapolis. To an industrial complex dependent upon stabilizing the falls at one location, stopping further erosion of the St. Peter Sandstone was paramount. This is the purpose of the cutoff wall. Beyond its erosional threat, however, the sandstone's properties appealed to industry because of its ease of excavation. The St. Peter was used for conduits, cold storage, and particularly at the falls, to direct water for industrial uses. Similar to the Platteville, the St. Peter has been extensively excavated around the falls by industry.

It is important to note that eastern Hennepin County is a karst area, meaning that the area hosts naturally formed voids and caves. Unlike in most karst areas, chemical action dissolving limestone is not the cause of cave formation here. Instead, the St. Peter Sandstone is prone to forming voids and cavities due to the physical action of running water. Frizzell (1883) noted that "the softest stratum at the falls is 16 to 22 feet below the bottom of the limestone. The attempt to excavate in this stratum and to keep excavations clear by pumping has resulted in extensive and dangerous cavities." Mazzullo and Ehrlich (1987) named this

layer the "Cave Unit" of the St. Peter Sandstone. Several caves are hosted within the St. Peter across the Twin Cities including a few near St. Anthony Falls. This includes Schieks Cave underneath downtown Minneapolis. Across the river, Chute's Cave lies underneath Main Street just below the Pillsbury A Mill. These caves, like most across the Twin Cities, were excavated and expanded and made to work in some way. These alterations resulted in the collapse of Chute's Cave in 1880, which swallowed a portion of Main Street along the river front. The possibility of additional natural voids remains an important unanswered question in the assessment of failure modes for St. Anthony Falls. Detecting buried bedrock voids is not realistic given current resources. The situation is made more complicated by the potential of ancient caves and voids created along now-filled ancient river valleys.

St. Anthony Falls is only 1,200 feet from such a buried ancient river valley. Besides the potential for voids and sinkholes compromising the sandstone and undermining the last remnants of limestone, the other hazard at the upstream limit of limestone is unconsolidated material. Once the limestone is gone, so are the falls. The soft sandstone and loose river gravels would be quickly removed by the Mississippi River, leading to rapid downward cutting upstream. There would be an initial burst of erosion (perhaps one or two miles upstream) before the river settles in for a slower erosive pace.

Much of that pace will be determined by the volume of surface river flow. The historical mean flow of the Mississippi upstream of Minneapolis near Anoka is 15,700 cubic feet per second (cfs). The flood of record at that location was 91,000 cfs in May of 1965. More recent high flows were 55,600 cfs in May of 2001, and 39,300 cfs in April 2023. Flooding events produce high velocity flows, often with considerable flow turbulence resulting from debris. Ice, vegetation and other debris are carried by these flows, increasing the ability of the river to abrade and erode the riverbed and banks. Floods can accelerate scour damage on bridges and other structures as well.

Historically, floods played an ongoing role in speeding the collapse and retreat of the limestone that formed the falls. Floods impacted structures at the falls and destroyed initial attempts to repair the damage from the collapse of the Eastman Tunnel. As late as 1952, an April flood caused considerable damage to the spillway surface and rock filled crib support structure at the falls (Straub, 1952). At the spillway, two concrete panels were dislodged by floodwaters exposing the limestone escarpment "for the first time in decades" (MNR&RA, 2019).

The river may also shift to low flow based on long-term rainfall trends. Drought plan "watch" conditions begin at 2000 cfs above Minneapolis (MN DNR, 2015). The effects of high and low flow on the integrity of the St. Anthony Falls system is complex. Surface flow, or load, is not the overarching factor at St. Anthony Falls that it is in other engineered structures. Surface flow is presumably an important variable, and it seems intuitive that flood conditions would

make a failure more likely, but significant events such as the 1987 Lower Dam Hydro Plant failure caused by a sandstone piping blowout occurred during a period of low flow.

Since the key vulnerability to the St. Anthony Falls system is the St. Peter Sandstone, and since this bedrock unit is located deep underground, far from surface water flow, it seems important to acknowledge that subterranean water activity is also a critical factor in the hazard. This situation presents many unanswered questions because of the difficulty in observing such activity, especially detecting the small pipes and flows that could be building conditions for a failure. This is where natural factors interact with the technological ones.

Technological Factors

Several technological components have kept the natural forces at St. Anthony Falls in check to maintain a stable position of the waterfall for 150 years. These engineered components include the Horseshoe Dam, Main Spillway, cutoff wall and others. The accessible portions of the protective system holding St. Anthony Falls in place can be regularly inspected. These structures have been occasionally updated over the years with newer materials using more advanced techniques. The replacement of the timber apron with a concrete one in the 1950s is one such example.

In contrast, the cutoff wall has remained almost entirely unseen since its construction. The number of tunnels that allow a peek at little parts of the wall has been shrinking. The original surface shaft used to build the wall was filled-in and capped decades ago. The remnants of tunnels that once facilitated access are no longer safe for human entry and instead must be observed with remotely piloted devices. What can be inspected is limited by challenging obstacles such as standing water and fallen timbers. Image quality and signal range vary inside the rock. Only a few square feet can be remotely seen today, and it is not possible to adequately assess structural integrity from this tiny view.

Not only is the cutoff wall almost entirely obscured from view, it also has remained untouched since 1877. No upgrades or repairs have been possible. It appears to be a novel structure, with no equivalent elsewhere. It is, perhaps, one-of-a-kind. This means that lessons from the experience of others are not available to help understand its potential lifespan, or the behavior of its materials in similar environments, or its potential failure modes.

Engineering in the 1870s was markedly different than profession known today. A very small percentage of engineers were school-trained. Most learned on the job under other engineers. Engineering standards, methods, and techniques were being developed in this era. “Trial and error” was a typical method of improvement, and so-called “overbuilding” was used to mitigate uncertainty.

It was in this environment that the cutoff wall was designed and built. Extensive archival research revealed only brief insights into the thinking of the cutoff wall designers. For

instance, USACE 3rd District Engineer, Major Francis U. Farquhar was careful regarding his selection of cement for the project, citing a comparison of five different varieties. Farquhar also determined how deep the wall should descend into the sandstone based on the hardness and absence of water flowing through seams in the sandstone at that level. Farquhar's successor, USACE 4th District Engineer, Major Charles Allen, understood the cutoff wall to be a diaphragm that required the support of the sandstone around it for strength. Finally, the Corps of Engineers had initially planned for a second wall to be constructed upstream near the upper edge of the limestone, likely intended to prevent the undermining of the limestone from above. However, Major Farquhar decided that a separate upstream defense was not needed. These few bits are the extent of knowledge about the design concept for the cutoff wall. Other key questions about original design decisions remain. A particularly crucial one is how long the cutoff wall was expected to function – an intended service life. Unless more historical documents emerge, it is probable that many original design questions will stay unanswered. There are risk implications for lack of design intent and data. Specifically, it makes lifespan risk assessment much more difficult. In systems engineering, failure analysis can be plotted along a curve called the bathtub model (Figure 1). An unanswered question is where the St. Anthony Falls system, and particularly the cutoff wall component, should be placed along a bathtub plot.

What is clear is that 150 years ago a vast subterranean cement wall was inserted into an excavated cavity in the St. Peter Sandstone, some 15 to 20 feet below the riverbed at St. Anthony Falls. It was intended to attach at the top to the lowest layer of the Platteville Formation and from there drop 40 feet through the Glenwood Formation and into the uppermost layer of the St. Peter. There is some evidence that the connection between the top of the cutoff wall and the bottom of the limestone is not as tight today as was intended during construction. The base of the cutoff wall is six feet thick, tapering toward the top to four feet. The total length of the structure is 1,850 feet.

Beyond the intended effect of preventing further undermining of the limestone caprock, there are probably other (and likely unanticipated) effects resulting from the insertion of a hard and heavy linear mass of cement into a soft bedrock aquifer formation. Redirection of natural groundwater flow seems very likely. A central question is whether this redirection of subsurface flow has channelized flow to produce weaknesses that have increased the chance of failure. Another question is whether the concrete mass has produced other unanticipated effects on the natural environment.

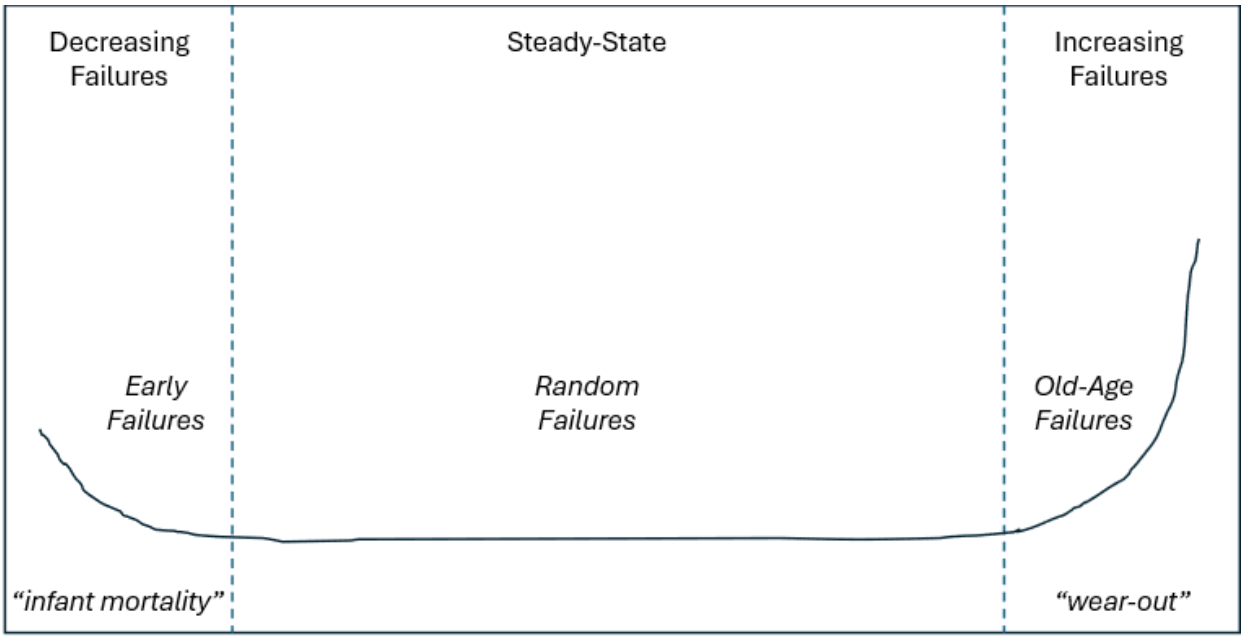

Figure 1. Bathtub curve. Adapted from Ostrom, L. and Wilhelmsen, C. (2012). Risk Assessment: Tools, Techniques, and Their Applications. Wiley.

7. Failure Modes

Failure is defined as a rapid change in the steady-state conditions found at the site, leading to negative consequences. If not stopped by an intervention, each failure mode results in the destruction of the falls – the replacement of the near vertical drop (now encased by the protective apron) with a more horizontal flow through the limestone block remnants of the falls. In each failure mode the East Channel along Nicollet Island is left abandoned, perhaps as a perched lake or marsh. The Main Channel assumes the full surface flow above the falls.

Failure modes also progress in two stages. During Stage 1, the limestone caprock is still able to provide grade control for the upstream river, and if stopped at this point, the falls could survive. If the event progresses to Stage 2, the limestone caprock is no longer able to provide grade control for the river. The exposed sandstone and loose river gravels are rapidly removed upstream as the riverbed adjusts to the loss of St. Anthony Falls. Once Stage 2 is triggered, emergency stabilization efforts will be substantially more difficult. Significant riverbed grade adjustment would likely occur for a mile or more upstream from the falls in as little as one year. Downstream a wave of sediment would eventually work its way down to Lock and Dam No. 1.

8. Exposure

The exposure of population and infrastructure to impacts from a failure of St. Anthony Falls is high. The portion of the Mississippi River affected runs through the heart of Minneapolis, the largest city in Minnesota and the core of the Twin Cities metropolitan area. Historically, the river has been the central thread running through the region's social and economic fabric.

The human geography of the Twin Cities has been shaped by the river. Its largest cities are alongside it. Its busiest highways and rail lines cross it. Networks of supporting electrical, gas, petroleum, steam, communications, water and sewer infrastructure run along, over and under it. In some places industry is tied to the river. In other places, recreation. Spread along its length are sites of deep spiritual, cultural, and historical significance. The failure of St. Anthony Falls would likely produce immediate disruptions to critical lifeline services in Twin Cities and lasting social and economic disruption across the entire region.

It is important to note, however, that the direct life-safety threat of a failure at St. Anthony Falls is low (but not zero). This is because St. Anthony Falls does not control a significant reservoir upstream that would be suddenly released. It is also because the river immediately downstream from the falls flows through a Gorge with very few human structures or activities present. Finally, most failure modes contain enough warning time to potentially evacuate and block access of people to high-threat areas.

9. Monitoring

Hazard monitoring, forecasting, and prediction are the tools needed to provide timely and accurate early warning to save lives and mitigate property loss. These are used effectively across many kinds of hazards. However, in a St. Anthony Falls failure scenario, few reliable methods exist for hazard monitoring. The deeply buried cutoff wall itself is now unmonitored. Its inaccessibility renders it essentially unmonitorable without a very large investment in technology and resources. Further, the legal matter of what organizations are responsible for the cutoff wall and subsurface tunnels (and therefore the monitoring) also has yet to be determined. At the surface, a patchwork of organizations already monitor for isolated hazards which might impact their particular specialized activity, but a comprehensive and wholistic approach to St. Anthony Falls' integrity is not currently part of hazard monitoring at the falls.

There are human-based monitoring efforts among the organizations that could detect changing conditions at the cutoff wall, such as the detection of new "clean sand" deposits downstream that might indicate active scour into the sandstone. However, human-based efforts are, by nature, difficult because of the impact of situational variability on human observers. Hours of darkness, high water, or winter ice cover can render visual observation difficult. Also, inconsistency of changing work shifts, schedules, and seasonality can disrupt the opportunities for human observation throughout the days, weeks, and seasons

Automated monitoring offers more consistent observation than human methods, however both rely on indirect evidence to deduce that a failure scenario may have begun.

10. Warning Time

Warning time is defined as the time elapsed between the issuance of a specific warning and the arrival of dangerous conditions. Previous major incidents involving rapid erosion of the

St. Peter Sandstone in the St. Anthony Falls area imply that dramatic failure effects can occur within only a few hours of detection. Therefore, in a worst-case scenario, warning time for a St. Anthony Falls failure scenario is likely to be low (1 to 3 hours) but not analogous to earthquake warning time (seconds) nor to tornado warning time (minutes). This warning time allows for potential evacuation and access restrictions if preplanned and well executed.

On October 4, 1869, when Eastman Tunnel excavation workers returned after a weekend break, they found water running through the sandstone tunnel and chunks of sandstone wall falling into the running water. By nightfall a 100-foot section over the downstream end of the tunnel had collapsed, while at the upper end the original 6 by 6-foot tunnel had become a cavern ranging from 10 to 90 feet wide and nearly 17 feet deep in some places. The next morning, another 100-foot section near the tunnel outlet collapsed, and a riverbed collapse on the upstream side created the infamous "whirlpool" which swallowed and spit out nearly all the materials that workers attempted to use to stop the flow.

At 6:35 p.m. on November 9, 1987, an automatic sensor at the Lower Dam Hydro Power Plant activated a low pool alarm at the Northern States Power control room in Minneapolis. When a foreman arrived at the plant at 7:00 pm, they observed the pool level to be 6 feet below normal. While shutting down the generators, the foreman noticed a large boil immediately downstream of the powerhouse that bulged several feet above the rest of the tailrace. By 7:30 pm the upstream reservoir was completely drained and the flow of water underneath the powerhouse had caused massive erosion in the sandstone bedrock upstream of the powerhouse. Despite the Corps of Engineers opening the gates of the dam to relieve pressure, the river continued to erode the sandstone causing a collapse of the powerhouse superstructure by 4:15 pm on November 10, 1987 (Barr Engineering, 1988).

These incidents, as well as others in the falls area, illustrate the fragility of the sandstone when faced with the eroding effects of running water. It is likely that once indications are detected of an exposure of the sandstone to moving water, physical damage and destruction is imminent. Therefore, unless monitoring capabilities significantly improve, warning time is likely to remain in the 1 to 3 hours timeframe. As mentioned previously, warning authority, messages, and response actions should be established in advance to save time in a crisis situation.

11. First Day Impact - Life Safety

The priority of any emergency response plan is life safety. Eliminating loss of life and injuries is imperative and all other actions are subordinate to this objective. In some environments, effective notification and warning means the difference between success and failure of life-safety efforts. St. Anthony Falls is one such hazard. The authors believe that the risk of a failure occurring without prior indications is remote. Even a few hours of indications (as the case for the 1987 Lower Dam Hydro failure) should be enough for the execution of planned evacuation and exclusion operations within at-risk areas in the immediate vicinity of the

falls. In an ideal situation there might be days or more of indications. However, all failure modes have life-safety implications. The settling or collapse of limestone supporting piers of the 3rd Avenue Bridge, is a particular life-safety hazard. Planning design scenarios should be based on the operational challenge of having only a few hours to evacuate and exclude access to areas of human activity so that life-safety factors are considered.

To be effective, multi-agency plans must be created well in advance with broad participation. Responsibilities must be clearly assigned and acknowledged by those agencies. Monitoring activities must be coordinated across functions and alert procedures developed. Notification chains must be developed and maintained, including primary, alternate, and contingency contacts. Public warning criteria and procedures should also be designed including tool selection, such as wireless emergency alerts. Plans should be exercised periodically. Effectiveness is reached when responsible agencies are able to quickly carry out pre-arranged assignments upon notification of imminent failure. A modest investment in interagency coordination and planning could significantly reduce life-safety threats of a St. Anthony Falls failure.

12. First Year Impact – Community Lifelines

The most significant disruptions of a failure of St. Anthony Falls (one that attains Stage 2) would occur in the first year. This first year would see rapid and significant riverbed lowering upstream for one mile or more. Literature on dam failures and removals suggest that the riverbed upstream of the headward-moving knickpoint would remain largely unaffected. In other words, it would likely take many years for riverbed effects to be detected as far as I-694 or the Coon Rapids Dam. However, for the one or perhaps two miles upstream from the falls, the effects would be significant and swift. Nearly all infrastructure that crosses the river in this stretch would be impacted. This would cause disruption and destruction for many kinds of infrastructure. The Federal Emergency Management Agency uses the Community Lifeline concept to describe the critical functions required to support the continuous operation of government and business, as well as provide health, safety and security services.

Hydraulic modeling and study of historical analogs suggest that the loss of St. Anthony Falls (at Stage 2 level) would produce a rapid headward erosion of the riverbed in the first year. Analysis suggests that around one mile upstream is a reasonable distance to consider for first year bed adjustments. This assumes normal streamflow. As a hazard analysis contingency in a scenario where a failure occurs coincident with or due to a major flood, this assessment also provides for a two-mile incision of the upstream riverbed. For details of infrastructure along the entire length of the study area, refer to Figure 2.

One reason that first year impacts are important to consider in this assessment is the rapid disruption of many different types of infrastructure in a relatively small area. This presents a significant challenge for response and restoration in terms of complexity, interim

adaptation, and cost. Recent emergency reconstruction of collapsed bridges provides an example of restoration timelines. For example, under ideal political and budgetary circumstances the replacement of the I-35W bridge took 13 months from collapse in 2007 to ribbon-cutting in 2008. Another longer emergency bridge replacement example is provided by the 2024 collapse of the Francis Scott Key Bridge in Baltimore which is projected to be completed in 2030. In the case of a Stage 2 failure at St. Anthony Falls, it is likely that multiple bridges would require replacement or major stabilization efforts. Not only would bridges be impacted in a failure scenario, but a wide variety of utilities would also be disrupted, including communications, energy and water. While some costs would be borne by private industry and insurance companies, a largest portion would come from government and especially state and federal disaster assistance. Recovery would be a long and complicated process.

Zone of Initial Impact

The initial one-mile impact area is from Upper St. Anthoy Falls (river mile 854) to the Plymouth Avenue Bridge (river mile 855). Infrastructure within this stretch includes the St. Anthony Falls Lock and Dam, as well as associated energy facilities at the falls. The bridges in order from the falls are:

- 3rd Avenue Bridge
- Merriam Street Bridge
- Hennepin Avenue East Channel Bridge
- Hennepin Avenue Main Channel Bridge
- 1st Avenue Bridge
- BNSF East Channel Railroad Bridge
- BNSF Main Channel Bridge
- Boom Island Pedestrian Bridge
- Plymouth Avenue Bridge

Zone of Subsequent Impact

The subsequent one-mile impact area is from the Plymouth Avenue Bridge (river mile 855) to river mile 856 just upstream from the BNSF rail bridge. The bridges in this section are:

- Plymouth Avenue
- Broadway Avenue
- BNSF Bridge

Utilities

Many utility lines run across the river in the study area and particularly in the few miles both up and downstream from the falls. Overhead lines, usually electric transmission lines, would largely be unaffected by significant riverbed erosion. Utilities attached to bridges would share the fate of their bridge hosts. Bridges in this area carry a wide range of utilities

including fiber-optic cables, electrical power, gas lines, steam pipes, and water mains. This report does not specify which bridges carry which utility lines. Finally, some utilities are buried in the riverbed. The most important of these are large diameter water mains and sewer connectors. Again, this report does not specifically locate such infrastructure, though they are known to be present in both the primary and secondary impacts areas.

Downstream Impacts

Downstream impacts would be less severe than those occurring upstream. Unlike dam failure, there would be no large impoundment of water released if St. Anthony Falls were to fail. The fact that the stretch downstream of St. Anthony Falls to the Minnesota River is a gorge also limits potential impacts. Models suggest that a wave of sediment would be released by the loss of St. Anthony Falls. This wave would slowly move its way downriver until it reached Lock and Dam No.1 (Ford Dam).

13. Lifeline Assessments

According to the Federal Emergency Management Agency (FEMA), Community Lifelines enable the continuous operation of critical business and government functions and is essential to human health and safety or economic security; “Lifelines are the most fundamental services in a community, that when stabilized, allow all other aspects of a society to function” (FEMA, 2026).

Safety and Security

The impact of a Stage 2 failure of St. Anthony Falls would result in major transportation disruptions from blocked routes, reduced access options, and increased burdens on remaining routes. Gridlock is a likely result. This impacts safety and security by impeding the movement of police, fire, and emergency medical services. Response times would increase. Further, impacts on utility lines could present challenges requiring workarounds. Reliable water service, which could be disrupted by the loss of buried watermains under river gravel, is needed for firefighting. Lost fiber optic lines could also present short-term disruptions to monitoring and alarm services until fixes are applied.

Food, Water and Shelter

The loss of St. Anthony Falls would not impact residential units directly and thus would not produce a sheltering crisis. However, other essential life-sustainment commodities such as food and water would be impacted due to supply chain disruption. The retail supply chain system in the immediate area of the falls would likely be impacted. Area retailers (which in urban settings tend to be smaller, more numerous, and require more frequent resupply than their suburban counterparts) could be subjected to logistical challenges until adaptation to new transportation realities is made by suppliers.

Health and Medical

Physical accessibility to medical services is a major factor in effective healthcare. Emergency medical services would have to adjust to significant congestion and loss of access routes into sections of the area. Patients and staff would have to adjust to mobility issues affecting their movement to care facilities. Medical facilities also require reliable connectivity to data, energy, and water, any of which might be impacted by disruptions caused by the loss of St. Anthony Falls.

Energy

Energy in many forms is moving constantly in and around the falls area. Hydroelectric generators now produce electricity at St. Anthony Falls. However, generation there is modest and there would be minimal impact to the overall grid if it were lost due to a failure of the falls. The larger Excel Riverside Generating Plant is located three miles upstream from the falls. The most significant exposure for this plant in scenarios considered is the water intake. However, the distance of the intake upstream means that there is likely adequate time for adaptation measures to be constructed negating any negative impact. Beyond power generation, many electric transmission lines are in the study area, some of which cross the river. Overhead lines are generally not at risk. Buried lines, or those attached to bridges require individual study to determine risk. It is likely, however, that there are opportunities to redirect energy flow to minimize negative impacts while longer-term fixes are developed. Electricity is not the only energy to flow in the area. Gas transmission and distribution lines also are in place, almost always buried underground. Some gas lines cross the river attached to bridges. In some places, steam lines for district heating systems cross the river attached to bridges. Finally, energy is transported along rail lines that cross the river including crude oil and refined products. The ability to shift to alternate routes for gas transmission or district steam may be more difficult and therefore may present opportunities for more impactful and lengthy disruption. Finally, energy also moves in bulk form along the rail lines that cross the Mississippi River in the study area. These shipments include crude oil as well as refined petroleum-based products.

Communications

Line-based communications systems, such as fiber optic and other cables cross the river at many locations, often attached to bridges. Loss of such lines could create an interruption in data and communications flow for some users. It is likely that such disruptions would be relatively short-lived and that areas of physical impact can be re-routed.

Transportation and Mobility

The most significant impact of a St. Anthony Falls failure scenario is to transportation and mobility. In both Stage 1 and Stage 2 scenarios, the 3rd Avenue Bridge is at risk of failure. In the Stage 2 scenario, many other bridges upstream also are at risk. Several bridges in the study area are already considered to have “scour critical” risk, requiring frequent

monitoring. Many other bridges have some "limited" risk of scour today (Figure 2). A significant reduction in the grade of the riverbed following a Stage 2 level failure of St. Anthony Falls would imperil many bridges upstream. Again, it would be the bridges in the first two miles upstream that faced the greatest risk. The river would continue to have head-cutting erosion upstream beyond two miles, but by then sufficient time may have elapsed to determine and execute a response that could mitigate the erosion. Contingency plans should anticipate significant impacts on road traffic and rail movement. All but one of the bridges in the first two miles are minor arterials or major collectors, meaning that there would be significant consequences if lost. The study area contains some of the most heavily used bridges in Minnesota, but fortunately their positions relative to St. Anthony Falls reduces (but does not eliminate) their exposure to hazardous conditions. Other bridges are significant for bicycle and pedestrian traffic, an important alternative way to move people in an urban environment.

Loss of transportation routes without efficient replacement has economic costs. Added travel time and loss of productivity due to congestion can be measured. Analogies with other incidents are not necessarily reflective of a St. Anthony Falls scenario. The Minnesota Department of Transportation for instance, estimated the cost of the loss of the I-35W bridge to the Minnesota economy was $60 million dollars, with effects concentrated in the Twin Cities metro area. The impact hit personal auto travel in increased time on the road and increased fuel costs. Increased costs also hit the commercial vehicle sector as well (MnDOT, 2026). This cost estimate did not include the cost of improvements that had to be made along detour routes to handle the increased traffic.

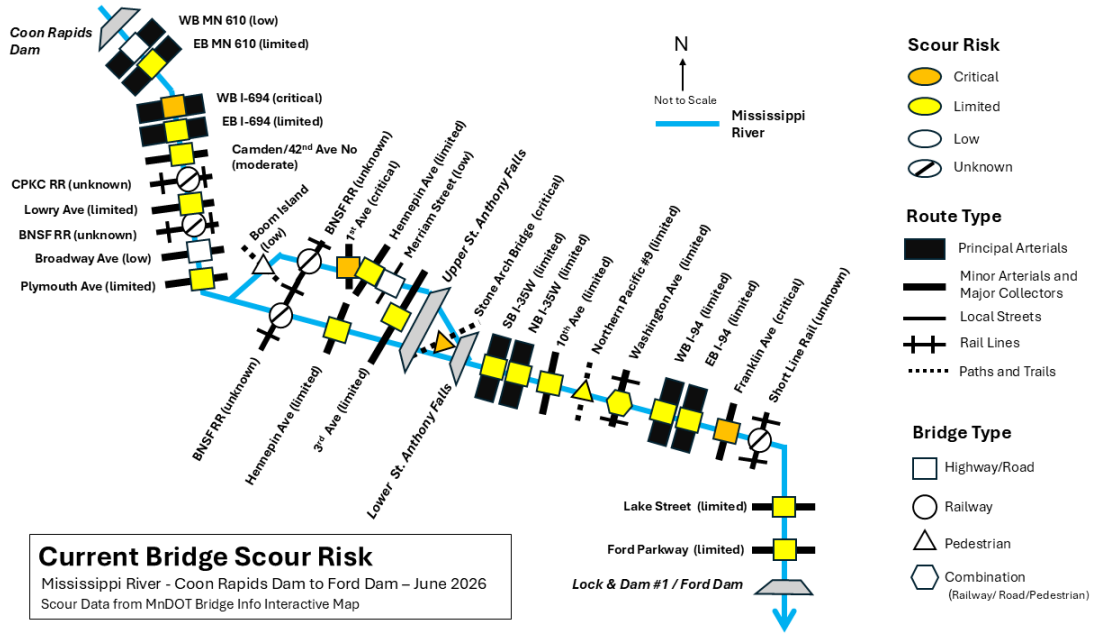

Figure 2. Map of bridges across the Mississippi River between the Coon Rapids Dam and the Lock and Dam No. 1 with the scour risk indicated for each bridge.

Hazardous materials

The failure of St. Anthony Falls has the potential to release toxic industrial materials. This potential has significantly decreased as industrial activities upstream from the falls have relocated to other parts of the Twin Cities. There do not appear to be fixed sites immediately along the two-mile stretch of initial and subsequent impacts that store amounts of toxic compounds that are reportable. This leaves only transient opportunities for contamination that come from rail or highway transportation incidents on the bridges. Response protocols for these incidents in a waterfall-failure scenario are no different than for an incident today.

Water Systems

There are two major water systems that operate within the study area.

The City of St Paul has a water supply intake nine miles upstream of falls. This distance places the intake outside of immediate or near-term danger of a significant riverbed adjustment from the loss of St. Anthony Falls. St. Paul also has adequate groundwater backup to replace lost surface water supplies and it does not provide any water distribution in the impacted area. In short, St. Paul is well positioned to continue uninterrupted service despite a failure at the falls. The time expected before the riverbed cutting arrives to the St. Paul intake and the alternate groundwater supplies means that there will be adequate time available to take adaptive action before impact.

Minneapolis (and cities connected to Minneapolis water) is more impacted. The Minneapolis water intake is located about four miles upstream of the falls, but still well beyond the zones of expected immediate and subsequent impact. Therefore, Minneapolis would likely have adequate time to adapt the intake to the changing river level. More challenging is the delivery mission of the Minneapolis water system to serve its residents. The water treatment plant is located on the east side of the Mississippi River while the bulk of the customers are located on the west side. The delivery of water from the plant to users is facilitated by five water mains that cross the Mississippi, all in the study area. A few cross in areas of increased risk. Most river-crossing mains are buried in the river gravel which will present issues if the riverbed changes elevation due to the loss of St. Anthony Falls. Contingency planning for the loss of one or more water mains seems prudent in order to ensure uninterrupted service across the cities that use Minneapolis water.

14. Extended Impacts

Economic

A failure at St. Anthony Falls that attains Stage 2 would be expected to produce significant economic impact across the Twin Cities region. Fast-moving disruption for a year or more that destroys or disrupts cross-river transportation infrastructure and a wide spectrum of utilities for a mile or more upstream from the falls would certainly add widespread delay

and disruptions to normal flows and processes in the metro. Direct costs of response and recovery to government and industry could combine with strains on small business and households. After the first several years of upstream erosion, the crisis nature of the situation will fade and transition into a predictable upstream riverbed adjustment. Rather than short emergency timespans that require tactical decisions, this new period offers adequate time to make strategic decisions about infrastructure protection, reinforcement, or replacement as the river slowly carves its way upstream.

Environmental

Environmental consequences of the loss of St. Anthony Falls will be apparent downstream. A 10-foot vertical drop in the river elevation could yield an estimated 1.8 million cubic yards of sediment eroded and moved downstream over several years. Increased turbidity would last for decades. Much of the sediment load would come to rest in Pool 2 and require increased dredging (USACE, 2025). Depending on the thickness of the sediment depositing wave, drain outlets may become buried requiring intervention. Another concern is the industrial nature of the sediment immediately above the falls raises the possibility of contaminated sediment being released through riverbed erosion and sediment transportation.

15. Summary of Hazards

General

A statistical probability of failure of St. Anthony Falls cannot be calculated due to inadequate data. The authors of this report consider that failure is plausible based on consideration of the natural setting and forces acting on the falls, the history of previous failures there, and the difficulty in observing key aspects of the St. Anthony Falls system. The authors also agree a failure at the falls is not imminent. **No reader of this report should draw the conclusion that either the falls itself or the infrastructure around it are unsafe.** Many other hazards in the Twin Cities offer a more significant ongoing danger to the public such tornadoes, severe weather and flooding and more. The threat posed by St. Anthony Falls should be placed in perspective with all other hazards in Hennepin County and the wider metro area. From this perspective, the threat to area residents is very low. However, enough significant consequences can come from failure at St. Anthony Falls that preparatory planning and increased monitoring are justified. This preparation is not needed at the household level. Instead, the small group of government and private entities that operate in and around the falls are responsible for addressing this hazard.

Several key findings came from this report that will assist St. Anthony Falls stakeholders in efforts to prepare. These findings indicate important limitations on the progression of any failure. They also indicate critical time periods in life-safety operations, as well as identifying

the period where engineering interventions have the best chances of stabilizing a failure scenario.

Life Safety

Because of the geography of the falls and Gorge, and because of the authors' conclusion that there would be some indications preceding a failure, the overall life-safety risk of a failure event at the falls is low (but not zero). The life-safety phase is also relatively brief once a warning is issued. At that point, further messaging, evacuation, and exclusion operations begin. Once people have left and access has been blocked, efforts at security can be reduced to sustainment levels.

Stabilization

Another important finding is that failure at St. Anthony Falls can be separated into two stages. A Stage 1 failure happens when the limestone caprock is compromised above the falls, but not enough to remove the grade control function of the limestone. At this point, the falls are at risk but are still present. Limestone continues to protect most of the sandstone below it and the 50-foot drop of the falls remains intact. The collapse of the Eastman Tunnel in 1869 was a Stage 1 failure. The dramatic upstream whirlpool from a widening hole in the limestone; the rapid widening of the sandstone tunnel; and the headward collapse of the tunnel's lower exit all imperiled the integrity of the falls itself. Early efforts to stabilize the incident were either entirely unsuccessful or provided short-term relief until they were destroyed by seasonal floods. Eventually, the cutoff wall provided a long-term solution needed to stabilize the falls. The importance of this finding is that interventions to stabilize the falls may be successful if conducted in Stage 1. Stage 2 is when the limestone no longer can provide grade control for the riverbed, and the falls cease to exist. At that point, the river is free to rapidly erode the loose river gravels upstream. Emergency stabilization would require a well-designed approach.

Zones of Impact

The study also pointed to limits on the rapid upstream movement of headward erosion. This data came from studies of various dam removals and some much rarer instances of waterfall failures. Previous reports envisioned a St. Anthony Falls failure impact felt far upstream. "It is conceivable that degradation could extend 30 miles upstream, somewhere between Elk River and Monticello" (USACE, 2025, p.23). Other reports specified the failure impacts would be felt to the next major feature that changed the riverbed grade. The latter formed the basis for the study area for this report. However, reports of riverbed behavior after dam removal, waterfall failure, and hydrological modeling of St. Anthony Falls all point to a rapid headward incision upstream in a Stage 2 scenario. The authors of this report believe that once the failure moves beyond the limestone (Stage 2), the upstream riverbed adjustment would require about one year to reach the first mile. Thus, this report describes a Zone of Initial Impact being one mile upstream from the falls. A Zone of Subsequent Impact continues for

an additional mile, which allows for contingency planning adjustment for aberrations of headward erosion. If the rate were faster than presumed or there was a flood event inserted into the failure scenario, then adjustments would already be factored into emergency plans. To be sure, streambed adjustment will continue beyond two miles of St. Anthony Falls. But the rate should slow significantly upstream, which will increase the opportunity for timely and infrastructure protections. Above two miles, the task of emergency continuity of infrastructure and critical services fades and is replaced by deliberate accommodations to the anticipated new river environment.

16. Response Prioritization

General

In response prioritization it is important to understand that the most significant impacts are upstream in a waterfall failure scenario, in contrast to dam failures, which focus their effects downstream. St. Anthony Falls is a waterfall failure scenario. The rapid riverbed cutting in a falls failure (which reaches Stage 2) will quickly threaten bridges and critical utilities for a mile or more upstream. There are four phases that can be identified when considering the failure of St. Anthony Falls. The first phase is the baseline, termed routine or steady state. Next is the first response phase; warning and life safety. Once life-safety priorities have been met, the next two response phases are centered on the physical progression of the failure of the falls. Stage 1 response is needed when the limestone is still able to control the grade of the riverbed and intervention might save the falls. A Stage 2 response happens when the limestone has been compromised to the point that it no longer can maintain the grade of the riverbed, and rapid upstream erosion has begun. Each phase has a set of priority actions dealing with the most important functions required at that point in the crisis. Throughout all phases, the criticality of interagency collaboration and public-private coordination is paramount. Another crucial function needed across all phases is public information. Refer to Figure 3 -for details on each phase of response.

Routine / Steady State

This is not a response phase. Instead, it is a preparatory one, designed to continue to seek answers to the remaining unknowns about the hazard posed by St. Anthony Falls. It is a time to prepare comprehensive interagency plans together with private partners and then test those plans with drills and exercises. Another key aspect is the development of a holistic monitoring program at the falls that can accurately detect, assess, and act on hazard indications in a timely manner. Finally, when feasible, measures to lessen the risk presented by the falls should be undertaken.

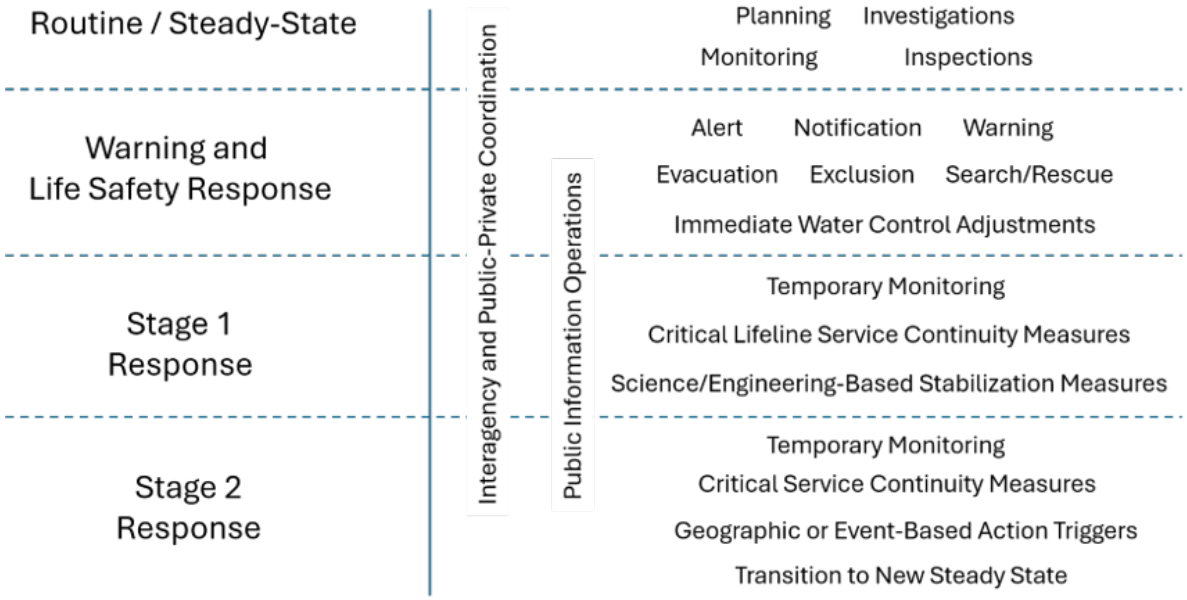

Figure 3. St. Anthony Falls Failure Response Phases

Warning and Life-Safety Response

This is the first response phase. The life-safety phase almost certainly will be brief. Perhaps no more than one day. An expected few hours of failure indications should provide sufficient time for warning, evacuation, and exclusion of at-risk areas (only if they have been pre-planned and coordinated in advance). Of course, since key parts of St. Anthony Falls infrastructure are unable to be inspected there is a small chance that a failure could occur without warning. In that case, search and rescue would be the first task of the life-safety phase.

Stage 1 Response

In a Stage 1 failure, after life-safety requirements have been met there would then be two simultaneous tasks to accomplish. Both relate to incident stabilization. One task is the adaptation of critical community lifeline services to ensure that water, energy, communications, and transportation can continue to serve residents in the area and to limit regional impacts. The other task is a science and engineering-based assessment to determine

if any measures could stop the progression of the failure while it remains contained in the limestone.

Stage 2 Response

If the incident deteriorates into a Stage 2 failure, plans should anticipate risk rapidly moving upstream, threatening an expanding list of bridges and utilities. Plans should remain flexible on the timing of this movement because differences in surface flow will impact expected rates. Geographic or event-based decision points could trigger actions in this phase in which weeks or even months of time may be available before some infrastructure is impacted. It is likely that Stage 2 response will have a unified command due to the many agencies with primary responsibilities. Coordination may also benefit from the establishment of functional task forces in areas such as transportation, energy, water, public health and safety, etc. which report through the incident command structure. Unless incident modeling suggests otherwise, above two miles from St. Anthony Falls, infrastructure operators can step back from crisis measures and begin to settle in for an ongoing adaptation to the new river environment as it slowly adjusts upriver.

17. Recommendations

Based on the findings of the study, a number of recommendations were identified, they are summarized below:

- Install near real-time monitoring sensors within subsurface tunnels and conduct annual drone-based LiDAR and visual surveys of subsurface tunnels
- Determine ownership of cutoff wall and subsurface tunnels
- Perform inspection of the riverbed in the region of the 3rd Ave Bridge and historic failure areas associated with the Eastman Tunnel Collapse
- Perform a detailed evaluation of the integrity of the West Branch and Eastman Tunnels
- Evaluate the subsurface flow through the East Bank Falls/Hennepin Island region of the falls

18. Protection of Information

This report provides extensive information regarding the conditions and hazards posed by a failure of St. Anthony Falls. The bulk of this information is releasable to the public with the intention that all may understand the extensive work that was performed and the concepts, opinions and recommendations that resulted from this study. There are, however, some specific pieces of information that could enable people to trespass and endanger themselves or others, creating difficult search and rescue challenges for emergency responders. These details are considered under Minnesota Statutes Chapter 13 (Government Data Practices) to be security information. Security information means government data the disclosure of which would be likely to substantially jeopardize security, aid in trespass, and result in

physical injuries. Security information is nonpublic data and therefore it will not be released to the public.

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