Confronting America's dam problems

Maria Teresa Freeman

Iowa State University

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Confronting America's dam problems

by

Maria Freeman

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Community and Regional Planning; Public Policy

Program of Study Committee:
Carlton Basmajian, Co-major Professor
Mack Shelley, Co-major Professor
Steffen Schmidt

The student author, whose presentation of the scholarship herein was approved by the program of study committee, is solely responsible for the content of this thesis. The Graduate College will ensure this thesis is globally accessible and will not permit alterations after a degree is conferred.

Iowa State University
Ames, Iowa
2020

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## NOMENCLATURE

<table>
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<th>Abbreviation</th>
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<tr>
<td>ASCE</td>
<td>American Society of Civil Engineers</td>
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<td>ASDSO</td>
<td>Association of State Dam Safety Officials</td>
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<tr>
<td>FEMA</td>
<td>Federal Emergency Management Agency</td>
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<td>NDNR</td>
<td>Nebraska Department of Natural Resources</td>
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<td>NPPD</td>
<td>Nebraska Public Power District</td>
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<td>PPP</td>
<td>Public-Private Partnership</td>
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ABSTRACT

The United States is facing a nexus of deteriorating infrastructure, single-purpose infrastructure, and a changing climate. As these forces collide and interact, infrastructure systems are pushed to the edge of their capacity and begin to collapse. The Spencer Dam failure in March of 2019 is an example of what can happen when these competing forces go unchecked. The Spencer Dam was 40 years past its life expectancy, was designed for hydroelectricity, and collapsed in the midst of a nation-wide storm event that produced large amounts of rain and ice which flooded the river.

Spencer Dam is not the only dam to fail in recent years and it will not be the last. The United States infrastructure is in disarray and Spencer Dam presents a case study through which it is possible to identify several specific weakness afflicting the country’s dam infrastructure. There are over 90,000 dams in the United States and many of them have passed their predicted life expectancy of 50 years. Repairs to this system will cost billions of dollars, but waiting for the dams to collapse and repairing the resulting damage will cost much more.

This paper identifies defects in the United States’ dam infrastructure, how these defects play out as seen by examining Spencer Dam, and what these defects mean for the future of the United States.
CHAPTER 1. INTRODUCTION TO POLICY PAPER

In March 2019, the Spencer Dam in Nebraska failed. The specific conditions that led to this dam failure are unique, but the underlying vulnerabilities afflict countless dams across the United States. No dam is completely protected from failure and the dam in Spencer, Nebraska illustrates what happens on a small scale when dam failures occur (Federal Emergency Management Agency (FEMA), 2012A). There are two primary questions this report aims to answer. First, how did planning and policy decisions about Spencer Dam lead to the dam’s collapse? On a larger scale, to what extent are these decisions and resulting deficiencies seen throughout the United States’ dam infrastructure? Second, how do planning and policy need to change in order to overcome the current issues? What could have prevented - or at least mitigated - Spencer Dam’s collapse? What needs to be done to reduce future dam failures throughout the country?

These questions desperately need to be answered as 15,500 of the 90,000 dams included in the United States’ National Inventory of Dams (NID) (Association of State Dam Safety Officials (ASDSO), n.d. A), are deemed to be of high-hazard concern to their surroundings (American Society of Civil Engineers (ASCE), n.d.). With over 17% of all dams in the United States considered highly dangerous – a number that climbs every year for reasons that will be explored more fully later on – immediate attention is required to combat and shore up these vulnerabilities. Unlike many other natural hazards, local communities cannot build up experiential knowledge with dams. Dam failures usually only occur once as dams are either not rebuilt, or built to higher standards, thus preventing a repeat of the disaster. It is thus crucial for communities to learn from dam failure events elsewhere in order to increase their readiness and resiliency. With so many dams spread across the country, “many communities find themselves
in the vicinity of at least one dam,” albeit likely unknowingly (FEMA, 2013D). For now, it will be sufficient to allocate rising dam hazard risks to three main factors: age, purpose, and dangerous development.

Dams constructed throughout the 20th century were built to last around half a century. The average age of dams in the United States has now reached 56 years. Averages can be misleading, with outliers pulling the average either up or down. It is thus helpful to look at the distribution of dam ages. This form of analysis shows that 7 out of 10 dams will have reached their half-century mark by the year 2025 (ASCE, n.d.). The map below examines the percentage of dams in each stage that will be 50 years or older by 2020. Adding to this, dams are built for many different reasons and thus according to different standards and construction requirements (Associated Press, 2019). Regardless of their initial or intended purposes, many dams are now playing a part in flood control, regardless of how well-suited they are to that role. Their de facto role in the United States’ flood control infrastructure is due to the fact that dams can gather and hold water, preventing the water adding to potential flood conditions downstream (United States Society on Dams (USSD), n.d.). However, while dams can initially catch water in reservoirs, they can be overwhelmed by the amount or quick onset of rain, especially if the dams and their reservoirs were not built with the role of flood catchment in mind. These two stressors, aging structures and changing roles, increase the likelihood of dam failure, while construction downstream of dams has increased the costs that will occur should a dam fail (Lane, 2006).

This paper begins with an overview of infrastructure in the United States, the role of the federal government in dams and water policy, and the changes in the planning and policy approaches to dams over the years. Having set the stage, the paper moves onto an analysis of Spencer Dam, it’s characteristics prior to collapse, what happened the night of the failure, and
the damage inflicted by the dam’s collapse. This account of events is followed by an examination of the four stages of emergency management as it applies to this case study: the mitigation of hazards or dam preparedness pre-event, the immediate response, and the long-term recovery efforts. Often, reduction and readiness occur simultaneously while response and recovery tend to overlap. Once Spencer Dam has been sufficiently covered, the identified problems will be examined in the context of dam infrastructure across the country to determine if these vulnerabilities are specific to Spencer Dam alone, or if they are systemic. As will be seen, Spencer Dam is an apt case study to draw general conclusions from when studying the nation’s dam infrastructure. Spencer Dam did not fail from any unique weakness but rather was affected by a myriad of issues that chipped away its protective qualities unnoticed and these issues are common throughout the country. This paper contains a literature review, case study overview, systemic dam infrastructure analysis, a brief section on potential policy solutions, and concludes by summarizing the lessons learned through this research project.
CHAPTER 2. LITERATURE REVIEW

Infrastructure Preconceptions

Infrastructure within the United States is defined by contradictory worldviews, at once necessary but dismissed. Infrastructure can be defined as “a subset of public works, comprising the permanent physical installations and facilities supporting socioeconomic activities in a community, region, or nation,” (Kaufman & Snape, 1997). Another common definition refers to infrastructure as “the ‘backbone’ of the economy, connecting people and business to jobs, goods, services, information, and customers (both) in and outside of the U.S.,” (Committee for Economic Development of the Conference Board, n.d.). Amenities such as electricity and water as well as services such as transportation systems and emergency services are all considered critical infrastructure networks. Despite having a general conception of what makes up infrastructure, the exact boundaries of different infrastructure networks are often indistinct. How large or important does something need to be to be included in the inventory of national infrastructure? Are trails or dirt roads considered part of the larger transportation network? Should small locks and dams used only for water control of a particular field be part of the National Dam Inventory? If not, what are they? Every list has its own cutoffs, its own standards of criticality or importance required for inclusion and it is important to be aware of what is included or overlooked (Edwards et al., 2009).

One of the reasons it is important to consider critically the question of what infrastructure means and encompasses is because infrastructure in general is too often dismissed. Over the last two centuries, there has been an inflow of people into urban settings. Large cities struggled to build adequate infrastructure to keep up with their growing populaces and the result is that today 55% of all people live in urban areas, supported by vast infrastructure systems that are either
hidden or unnoticed (Kaufman, 2006). The most common explanation for individual indifference and ignorance towards these complex systems providing residents with daily services is that their presence by this point is simply taken for granted (Graham, 2012). It is expected that cities in the United States will handle the distribution of water and energy, the maintenance of transport and communication systems, the removal of waste, and the encouragement of businesses. These infrastructure systems are so ingrained with our definition of ‘city’ and ‘modern urban life’ that they are rarely considered separately (Graham & Thrift, 2007). A common argument is that infrastructure has been made invisible, hidden away, and is thus out of sight, out of mind. But there are other ways to render something ‘invisible.’ As Kaufman and Snape argue, “public indifference is bred by familiarity,” (Kaufman & Snape, 1997). In short, invisibility is not invisible strictly referring to whether something is hidden away, but rather that its mundanity has fostered public indifference or boredom which has created the impression of invisibility based on lack of active contemplation (Ugarte, 2017). Thus, despite “its centrality in maintaining and enhancing the quality of the natural and urban environment” (Kaufman & Snape, 1997), infrastructure is rarely discussed or contemplated, resulting in negligible policy debate.

This normalized support system is not necessarily negative. It is indicative of a high living standard if such services are expected. Infrastructure is also often designed to be overlooked, to be in the background. As designer Bruce Mau argues, “The secret ambition of design is to become invisible, to be taken up into a culture, absorbed into the background,” (Graham, 2012). He argues that “the highest order of success in design is to achieve ubiquity, to become banal,” (Graham, 2012). This argument has also been taken up by anthropologists Geoffrey Bowker and Susan Leigh-Star. They argue that “good, usable (infrastructure) systems
disappear almost by definition. The easier they are to use the harder they are to see. As well, most of the time, the bigger they are, the harder they are to see” (Bowker & Leigh-Star, 2000). In other words, if one wants to see infrastructure, it must first cease being usable.

Public debate around infrastructure arises after a malfunction when the services provided by it is no longer guaranteed (Little, 2002). Public, and thus political, concerns center around returning the infrastructure to working condition as soon as possible. As Felbinger wryly put it, “public works do not become issues until they do not work,” (Kaufman & Snape, 1997). As most of the infrastructure we use has been around for decades, it is hard to fully conceptualize how much people rely on these networks. The breakdown of infrastructure is helpful to determine how ‘critical’ critical infrastructure actually is. Breakdown also helps illustrate the complexity of the systems people rely on. What are the base components of an infrastructure network? How are different networks interconnected? Disruptions to infrastructure provide opportunities for critical policy and planning analysis. What went wrong? What needs to change to reduce the chance of this happening again?

Unfortunately, the general indifference to infrastructure, broken occasionally by short term demands, has resulted in little public debate and the outcome of any debate being of little political concern. The presumption that infrastructure will continue working is supplemented by cognitive barriers that also reduce the likelihood of intense public scrutiny and debate (Kaufman & Snape, 1997). These include the normal challenges accompanied by long term planning and the basic scientific – often engineering-based – knowledge required for infrastructure maintenance activities. There are numerous studies illustrating that people often choose short-term gains over long-term benefits. There is also a rising mistrust in, and disinterest of, scientific information within this country. The resulting lack of general public information about
infrastructure systems dissuades the public from becoming more involved. The projects that do get attention tend to be short and involve relatively easy fixes. Complex infrastructure – such as replacing water pipes, building railroads – are sometimes expanded upon but rarely replaced or revamped (Deloitte Insights, 2016).

Long term planning of public services falls to elected officials in all levels of planning. Unfortunately, long-term planning is unlikely to help individuals secure re-election and thus these issues are often pushed to the side (Kaufman & Snape, 1997). The lack of public interest in the mechanics behind maintaining and restoring critical infrastructure systems has also allowed those in charge of infrastructure networks to remain faceless and unaccountable for the actions they choose, or choose not, to take (Ugarte, 2017).

Infrastructure underpins economic activity and “transforms natural, social, and urban life,” (Graham, 2012). There is increasing frustration in the United States with the current state of aging infrastructure systems but this frustration has yet to produce meaningful political changes.

**Public vs. Private Ownership**

Unlike other types of infrastructure within the United States, dams are primarily privately owned rather than public entities managed by the government (Kriley, 2019). Around 65% of dams belong to private owners, 20% are controlled by local governments, 7% controlled by state governments, and 8% by the federal government, as seen in Figure 1 (ASDSO, n.d. C). This unique distribution of dam ownership leads to numerous problems that are not present in solely publicly owned infrastructure.
The first problem is that of regulation. Dams can be highly dangerous if not properly maintained and can affect wide swaths of land. However, dam owners are the ones responsible for inspections, maintenance, and general upkeep (White, 2019). Government agencies and groups do exist to help private dam owners manage their dams, but ultimately the dam owners are responsible for initiating the process.

The second problem is that since maintenance and improvements are the responsibility of the owner, the owner must foot the bill (ASDSO, n.d. C). Maintenance and dam rehabilitation projects can be inordinately expensive, beyond the means of many people, resulting in dam maintenance often being overlooked (Bass, 2003). The dearth of sufficient funds to help owners complete regular maintenance increases the risk of dam failure and often results in a problem becoming more expensive to fix over time.

Federal regulations apply to federally owned dams and are expressed through the specific department the dam falls under. For example, a dam under the Army Corps of Engineers gets its
rules from the military whereas one owned by the Department of Agriculture would look to the agriculture department for guidance. Private ownership largely moves dams outside of the sphere of federal regulation. States are far more exacting with the standards they desire dams to meet, although the stringency of these standards vary greatly between states. But there is only so much regulatory pressure a state government can apply to privately owned dams. Private dams have regulations issued by states which they are supposed to meet but lack of knowledge, lack of funding, and lack of oversight can reduce the ability of dams to meet state regulations. Should a dam fail, the owner can be held liable for the failure, but again to what extent they are held accountable and in which circumstances varies greatly between states such that no conclusive statement can be made in regards private liability for dam failure to the country as a whole. The general rule of thumb is that owners are “required to use ‘reasonable care’ in the operation and maintenance of a dam and reservoir” and successfully pleading their case in court can absolve owners of accountability in the event that their dam fails (ASDSO, n.d. C).

**Federal & State Involvement**

Federal involvement in dam management across the United States is disjointed and composed of a dozen different organizations. The Army Corps of Engineers is one of the older participants in dam creation and management of dams in the United States but it is joined by the Department of Agriculture, Department of Defense, Department of Energy, Department of the Interior, the Department of Labor and State, the Federal Energy Regulatory Commission, etc (ASDSO, n.d. A). With each agency applying their own priorities and standards, who supervises dams at the federal level is not a clear cut matter. The Federal Emergency Management Agency (FEMA) helps coordinate these separate organizations and administers the National Dam Safety Program (ASDSO, n.d. A). FEMA neither owns nor regulates dams but coordinates,
implements, and evaluates disaster management and reduction at key dams as well as overseeing financial grants and research.

While the federal government through FEMA encourages a minimum standard of dam safety that varies on a state-by-state basis, federal government involvement with dams is limited. States are the main legislative body dictating rules, standards, and regulations with local governments stepping up to help plan around individual dams (Bass, 2003).

In Nebraska, the state’s interest in dams manifests in several key activities. New dam creation and significant changes to existing dams require state approval. The state maintains an active inventory of dams in Nebraska organizes periodic inspections of all dams listed in the inventory. Beyond ensuring standards for the physical dam, the state also offers training to dam operators and owners and can help create emergency action plans and preparations (Nebraska Department of Natural Resources (NDNR), n.d.).

**Dam Upkeep and Inspection Process**

Regular inspection has been determined to be necessary to ensure the safe operation and maintenance of dams (ASDSO, n.d. C). Of the 90,000 dams within the United States, state governments have been charged with the task of inspecting 70% of these dams at regular intervals (ASDSO, n.d. A). Unfortunately, inspection is only useful if maintenance recommendations are actually undertaken but high costs often prevent owners from fulfilling all the necessary dam improvements. Because dams have wide reaching effects if they should fail, after failures the state often takes dam owners to court to examine whether the dam owner was negligent in mitigating dam risks or if they kept up with inspections and regular maintenance (ASDSO, n.d. B). It has been estimated that dam improvements in the United States, excluding those dams owned by the federal government, now exceed $70 billion in expected maintenance costs according to the Association of State Dam Safety Officials (ASDSO, n.d. B) (Kriley,
At some point, the expense becomes large enough that problems identified through inspection are left unaddressed. Congress provides little help in covering these costs (Bliss, 2017). Multiple breakdowns and bottlenecks occur annually and are likely to increase in number over time as more dams fall into disrepair. The disruption of transport of goods along with costs from potential disasters due to dam failure “cost the United States economy millions annually,” (Bliss, 2017).

How Has Understanding of Dams Changed Over Time?

Government

Many conditions came together to act as an impetus for the United States’ era of dam building in the first half of the 20th century. To begin with, the southern plain region of the United States was ravaged first by the dust bowl and then by severe floods throughout the 1930s and 1940s (Kelley, 2019). Something needed to change: the landscape needed to be manipulated and rearranged to mediate both the lack of water and the overabundance of it. Dams had been built prior to this era, primarily by the Army Corps of Engineers in their efforts to control the Mississippi and other eastern river networks (Arnold, 1989). But the economic advantage and population increase following World War II meant that the United States’ government found itself with an abundance of resources they could and did invest in infrastructure improvements across the country (FEMA, 2012B).

However, with the increase in dams, there was also an increase in dam failures. While increased understanding in engineering and environmental studies has decreased the total number of dam failures over time, many dams currently in existence are not built to modern standards. With increased dam failures, the government realized that some regulation and oversight would be necessary to ensure the safety of people living downstream of dams (ASDSO, n.d. A). California was “one of the earliest state (dam safety) programs enacted during
the 1920s,” (ASDSO, n.d. A). In 2020, every state except Alabama has a dam safety program that they developed to hold their local dams accountable and increase resident safety (ASDSO, n.d. A).

While there has been significant improvement in the last century, most of the changes in dam safety regulations have occurred in the last 50 years. The 1970s were marked by “a string of significant dam failures,” (ASDSO, n.d. A). In 1971, the Lower Van Norman Dam in California failed (FEMA, 2013C). This, along with a the failure of the Baldwin Hills Dam in California a few years earlier, helped popularize dam breach inundation mapping (FEMA, 2013C). In 1972, congress enacted the National Dam Inspection Act which “authorized the Secretary of the Army to inspect non-federal dams” of a certain hazard risk level, an important step to take considering most dams within the United States are non-federal (FEMA, 2013C) (FEMA, 2016B). The Secretary of the Army issued an order for an updated National Inventory of Dams and helped organize the inspections of high-hazard dams across the country (Cornell Law School, n.d.). 1977 saw a presidential memorandum directing the numerous and varied agencies involved with dam oversight to review and update their safety programs (FEMA, 2013C). The Reclamation Safety of Dams Act of 1978 increased the federal government’s oversight and maintenance abilities of their own dams (FEMA, 2013C). In the same year, a dam break in West Virginia inspired Kai Erikson to write *Everything in Its Path*, one of the foundational books regarding dam failures but that also explored the aftermath of disasters in general (Erikson, 1978). The 1970s concluded with FEMA adopting the *Federal Guidelines for Dam Safety* (FEMA, 2016B).

The National Dam Safety Program was created in 1996 (FEMA, 2013C). This program was intended to bring various stakeholders together to create a coordinated mitigation effort and
an organized disaster response (FEMA, 2016B). Through the various efforts of the latter half of the 20\textsuperscript{th} century, the United States has managed to reduce the number of fatalities that occur when a dam fails but there is still room for improvement and the reduction of economic costs inflicted by these disasters.

**Environment and Climate Concerns**

Infrastructure and climatic concerns are often treated as competing points of importance (Cassidy & DeGood, 2019). Infrastructure is deeply linked with the economy and in a culture where economic growth and success are promoted as a necessity, infrastructure benefits from this association (Cassidy & DeGood, 2019). Until recently the environment and, even more recently, climatic concerns and planning were seen as bonuses; that is to say, something that’s nice to have but not essential (Cassidy & DeGood, 2019). Changing attitudes towards the natural world have increased attention paid to the environment. As the importance of the environment has been reassessed, its connection with infrastructure has become apparent. Infrastructure may improve economic growth, but it is also often at fault, directly or indirectly, for greenhouse gas emissions (Cassidy & DeGood, 2019). For example, a good road network facilitates if not encourages a large amount of greenhouse gas emissions from personal automobiles that consolidated public transportation systems would not.

In regards to dams, environmental consequences are complex. Richard White in his 1995 book, *The Organic Machine*, examines how dams and other activities on the Columbia River have severely altered the river’s ecosystem, including the complex relationship of native salmon in the river and for the surrounding populace (White, 1996). The popularization of the impacts of dams on local fish populations and the resulting efforts of people to save these populations have led to dam removal along the northwest coast of the United States (Gan, 2020). In southeastern United States, dams and the resulting accumulation of pollutants has led to species
extinction throughout the river ecosystem (Hossain et al., 2012). In addition to changes in the ecological life of dammed rivers, studies indicate that the presence of dams spurs a change in local human activity (Hossain et al., 2012). Dams have been found to encourage different land-use decisions, increasing irrigation of fields, urbanization, deforestation, and afforestation or commercial tree farms (Hossain et al., 2012). While the climatic impacts of dams themselves, excluding all other changes that occur in nearby land use or local human populations, has been understudied, there is evidence of localized feedback systems along dams (Hossain et al., 2012). The observed changes indicated that dams affect temperature and precipitation along the affected river.

There is an increased understanding that dams have effects on local ecosystems and this should be taken into account when making decisions regarding dams (Gan, 2020). Most dams in the United States built in earlier years did not include the environment in their cost analysis and the impacts of this are still affecting the United States.

The Twenty-First Century

The era of dam building in the United States has come to an end. This is not limited to the “big dams” from the first few decades of the 1900s but encompasses the country’s opinion on dams of all sizes. This sentiment is captured in Hossain’s and colleagues’ statement: “In the United States, statistics suggest that building dams is outdated and considered a twentieth-century construct by the civil engineering profession,” (Hossain et al., 2012).

This sentiment is echoed throughout the government. The head of the United States Bureau of Reclamation, one of the departments in charge of dams in the United States, stated at an international conference in 1994 that “the dam building era in the United States is over” and that “the United States would be finding alternative ways to solve its water problems,” (Gan, 2020). The reasoning was twofold: dam construction almost always exceeded the allotted budget
and the expected benefits did not appear upon completion, leaving the builders with large deficits (Gan, 2020).

**The Problem of Our Time: Climate Change**

The effects of climate change must be considered in every project, plan, and policy the world moves forward. The impact of climate change is particularly relevant when discussing dams and dam failures. Because climate change is inextricably tied with water, both droughts and inundation are expected in parts of the United States.

Figure 2 shows the changes in rainfall across the United States between 1901-2015. This data, colored by the National Oceanic and Atmospheric Administration, shows trends of increasing rainfall in the Midwest and Northeast with decreasing rainfall in the Southwest. Dams can help control and collect water for drought-stricken areas, but it is inundation that overwhelms dams and increases the risk of dam failures (Leslie, 2019). Threats to dams are more likely in places where the increase of rain occurs in a few extreme weather events rather than spread more evenly throughout the year.

Additionally, when extreme weather events affect large portions of the country, cities and states...
downriver will be flooded. For example, increased rainfall in the Dakotas, Minnesota, and Iowa, increases the chance of flooding in Missouri.

Risk assessment looks to the past to determine what type of hazards have affected a region and are likely to occur again. Risk assessment is a critical component of building design and policy formation. However the risk assessments of the past no longer work in times of largescale change. How, then, should planners and builder prepare for the future? What information should be drawn upon when conducting risk analysis for a region? Climate change is a concept that scientists are still studying but general trends, such as changes in rainfall, have been uncovered and can be taken into account when planning for the future. However there is now a greater uncertainty that accompanies all plans for the future, thus a greater potential for future disasters that planers and builders must face when helping physically create the future.

Cost Analysis of Dams

Benefits: Why Were Dams Built in the First Place?

Dams can serve numerous purposes and often serve multiple purposes at once. Perhaps somewhat surprisingly, over 40% of the dams listed in the National Inventory of Dams (NID) were built for recreational purposes (Lane, 2006). Just examining those dams maintained by the Army Corps of Engineers, it is estimated that 10% of the United States’ population visits at least one dam or connected reservoir every year (ASDSO, n.d. A).

Historically, another important role dams were built to fulfill was the creation of a guaranteed water source (Hossain et al., 2012). Water can then either be earmarked for municipal, agriculture, or industrial needs. Of the water used in farming across the country, 10% comes from dams (ASDSO, n.d. A). Dams can also be used to generate hydropower. The United States is the second-largest producer of hydroelectricity in the world, Canada being the first (ASDSO, n.d. A).
Dams are often associated with flood control and “18% of dams in the national inventory serve as flood control,” (ASCE, n.d.). By reducing flooding, dams can also help reduce erosion. Lastly, dams are crucial to the United States’ economy as they maintain inland water routes for commerce. It is estimated that tens of billions of dollars’ worth of commodities traverse the United States’ rivers each year (Bliss, 2017).

**Costs: When Dams Fail in the United States**

Regardless of the numerous benefits dams provide, there is constant risk surrounding dams. As Lane stated in a Congressional Research Service Paper, “(dam) risk stems from two sources: the likelihood of a dam failure and the damage it would cause,” (Lane, 2006). Dam failures and the resulting floods are more like floods that accompany tsunamis rather than typical river or coastal floods. This is due to the fact that “when dams fail, they don’t fail with warning,” (Associated Press, 2019). The damage resulting from dam failures is wide-ranging, often inflicts death or injury, damages physical structures and farms, and results in a loss of key infrastructure services, large amounts of debris, and road closures (FEMA, 2012A). Such impacts have been displayed and documented in the hundreds of dam failures the United States has experienced (FEMA, 2012A).

Costs can be divided into human, economic, and environmental categories, although the boundaries between these are fluid rather than rigid. Humans can experience injuries or death. Sudden dam failures can inflict long-lasting trauma on a population. It is also not uncommon for dam failures to “cause significant and long-term social effects, resulting in changes to the quality of life in the affected communities,” (FEMA, 2012A)(Erikson, 1976). Economic impacts can be either direct or indirect (FEMA, 2012A). Direct impacts occur in the immediate aftermath of the failure while indirect consequences become apparent in the months and years following the event. Standard homeowners’ insurance does not include floods caused by dams nor is flood
insurance required for those living in the inundation zone (FEMA, 2013D). Purchasing extra insurance is encouraged by the government but many do not realize they live in a dam inundation zone or they underestimate the risk a dam presents. Environmentally, the release of large amounts of water in a short period of time scours downstream environments, often contaminates the water, and heavily impacts downstream ecosystems – be they crops and livestock or forests.

There are however costs beyond that of potential dam failure. There is constant tension within the United States over possible unequal benefits delivered by dams. There is a political aspect regarding where dams are built and why, where water is redirected and prioritized, as well as when and why controlled releases of water occur (Congressional Record, 1994). With numerous demands for water from different sectors in the United States, contention over the management of water via dams is likely to be present as long as dams exist.

There are also environmental consequences of dams while they stand as well as when they fail. As more research is undertaken, it is becoming apparent that dams create secondary impacts that were not expected or planned for. The disruption on local ecosystems is increasingly well documented and is now consistently part of the conversation regarding dams (Congressional Record, 1994).
CHAPTER 3. SPENCER DAM: A HISTORY

Lifespan

When attempting to understand what happened to the Spencer Dam on the Niobrara River in Nebraska, it is important to begin with a discussion of design. Figure 3 shows the location of Spencer Dam in relation to the rest of the state of Nebraska. Spencer Dam was designed as a hydroelectric dam (ASDSO, 2020). It was not designed to play an active part in flood control in the region but nonetheless that is a role it assumed. The dam continued being able to produce hydroelectricity as needed until its demise in a flood event in 2019.

Figure 3: Map of Nebraska, (Lee Enterprises Graphic, 2019)

The dam was a 3,700-foot dam of earthen construction with a 400-foot gated spillway and powerhouse section, and a 3,300-foot earthen dam embankment (Hammel, 2019C). The reservoir the dam created was estimated to hold up to 16,500 acre-feet (Yoders, 2019). The other
important element of the dam’s design was that when it was built in the 1920s, it had a predicted lifespan of 50 to 60 years. The Spencer Dam was 92 years old when it failed, and had thus long since surpassed its original predicted age of retirement. Not only was the dam long past its age of best use, so to speak, but the water levels a century ago were considerably below what the dam has had to deal with in recent years (Pollock, 2019).

Due to its creation almost a century ago, the Spencer Dam, whilst capable of generating electricity, pre-dated the Federal Energy Regulatory Commission (FERC) and thus was not under FERC control (ASDSO, 2020). Instead, the dam was owned and regulated by the state, with the Nebraska Public Power District (NPPD) having bought the structure in the 1970s (ASDSO, 2020).

**Risk Classification**

Across the United States, dams are classified based on their hazard potential. Hazard potential correlates to the predicted consequences should the dam fail. Dam failures can result in many types of damage and loss, but risk classification or hazard potential focuses on the possible loss of human life (FEMA, 2015). High-risk classification thus indicates that should a dam fail, it is probable that at least one person will die. FEMA’s classification of hazard potential can be seen in Table 1. In most places of the United States, dams are inspected regularly and one of the inspection outcomes is the reclassification of risk based on current hazard potential. The National Dam Safety Program’s purpose statement indicates the paramountcy of human life

<table>
<thead>
<tr>
<th>Hazard Potential</th>
<th>Loss of Human Life</th>
<th>Economic, Environmental, Lifeline Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>None expected</td>
<td>Low and generally limited to owner</td>
</tr>
<tr>
<td>Significant</td>
<td>None expected</td>
<td>Yes</td>
</tr>
<tr>
<td>High</td>
<td>Probable. One or more expected</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Source: FEMA 333 (2004a)
followed by property or economic damage; “(purpose is) to reduce the risks to life and property from dam failure in the United States through the establishment and maintenance of an effective national dam safety program to bring together the expertise and resources of the federal and non-federal communities in achieving national dam safety hazard reduction,” (FEMA, 2016B).

The most recent inspection of Spencer Dam occurred in 2018, a year before the dam’s failure. At the time, the dam was earmarked as possessing significant risk towards the homes and their inhabitants located downriver (Hammel, 2019A).

**Dam Condition**

Whilst risk classification centers on what should happen if a dam were to fail, it has nothing to do with the physical conditions of the dam or if the dam is likely to fail in the first place. The classification of dam condition is not exact, with more variance between states and individual inspectors than that experienced in risk classification (Associated Press, 2019).

In the 2018 inspection, Spencer Dam was determined to be in “fair condition.” Breaking this classification down, Spencer Dam was considered well maintained, with “acceptable performance expected under most conditions,” (Associated Press, 2019). With the aid of hindsight, the warning that “deficiencies exist which could lead to dam failure during rare, extreme storm events,” is particularly ominous (Hammel, 2019A). Nonetheless, as the Associated Press at the New York Post points out, until the Spencer Dam failed, it was “indistinguishable from thousands of dams across the United States,” (Associated Press, 2019). While the first statement is worrisome in regards to Spencer Dam, this latter statement is worrisome in regards to the entire dam infrastructure network across the United States.

**Natural Environment, Built Environment, & Past Failures**

Prior to the dam being built, the Niobrara River was surrounded by floodplains. After engineers modified and controlled the river, 522,000 acres of the surrounding floodplain turned
into farmland (Pollock, 2019). Thus human habitation moved closer to the newly contained river as the farms transformed the landscape. With humans living closer to the river, engineers were forced to increase the protections around the river as any flood became more likely to affect humans (Pollock, 2019).

The landscape immediately upriver of the Spencer Dam increased the likelihood of incidents occurring at the dam. The Niobrara River has easily eroded sand beds which have created a braided morphology within the riverbed, resulting in multiple shallow streams of water with high surface area to volume ratio (ASDSO, 2020). This becomes problematic when paired with Nebraska’s rapidly changing weather patterns and cold winters which result in ice formation. Due to the increased surface level of the water, the amount of ice that can form on the river in the right conditions is considerable. Upriver there are also a series of bridges that confine the river to a specific width, often causing the ice to get stuck, condense into a more streamlined form, and eventually gather enough pressure to push past the bridges (ASDSO, 2020).

While the event that occurred in the spring of 2019 resulted in the total destruction of the Spencer Dam, it is not the first time the dam experienced trouble. The dam was breached, although to a lesser, actually fixable extent, in 1935 due to ice flows (Miles, 2019). This incident left the dam inoperable until repairs were made in the 1940s. The dam was also overtopped in 1960. While water overran the dam, ice slammed into it, creating a puncture wound that had to be repaired after the incident. The dam was banged up a bit more in 1966 during another ice event although the dam this time was not completely disabled. The events that were witnessed in the 1966 incident are presumed to be identical to what occurred in 2019, the difference being that the operators were aware of changing conditions and drained the reservoir somewhat so that the
dam was less likely to be overtopped (ASDSO, 2020). The operator on duty in 1966 described the event as “a wall of water and ice entering the reservoir,” (ASDSO, 2020). The high water mark inside the dam control room and eyewitness accounts downstream verify that a large, powerful wave struck the dam and surrounding region.

**Question of Ownership**

Complicating the Spencer Dam failure is the fact that the dam was in the process of changing owners when it collapsed. The NPPD had sold the structure and water rights to a “coalition of natural resources districts in the area for $9 million,” (Hammel, 2019C). This sale was the end result of a Nebraska Supreme Court decision (Hendee, 2019). The state of Nebraska experienced a drought in 2009. The NPPD requested its allotment of water from the state, resulting in the state turning off farming irrigation pumps due to the shortage of water. The resulting series of court cases stretched over 7 years. Natural resource districts in the surrounding areas ended up banding together and forming the Niobrara River Basin Alliance. The result of the court cases was the valuation that the “water rights and electricity generated by the dam was worth around $12 million” of which the NPPD would receive $9 million in exchange for giving up their control of the dam and the water rights that went with it (Hendee, 2019).

With the dam gone and the transfer incomplete, the NPPD is left in charge of a now-defunct dam and its associated water rights. Should the dam be replaced, the NPPD would have to foot the bill and the damage is so extensive that builders would have to start from scratch. Rebuilding is an unlikely outcome as the NPPD was in the process of getting rid of the dam and is unlikely to invest the amount of money needed to recreate Spencer Dam.
CHAPTER 4. SPENCER DAM: HOW IT FAILED

Incident Report

In March 2019, a bomb cyclone was predicted to hit Nebraska and the rest of the Midwest. The forecast warned of anticipated rainfall of 2-3 inches delivered in mere hours (Genoways, 2019). The investigation of the dam failure initiated after the event says that nothing could have been done to keep the dam standing (ASDSO, 2020). The water and ice simply overwhelmed Spencer Dam’s capabilities.

Facing high waters and ice chunks the size of cars, the 92-year-old dam was in trouble (Belsie, 2019). The two operators working at Spencer Dam the night of March 13th were besieged with wind, freezing rain, snow, and rapidly changing conditions during the dark, early hours of the morning (ASDSO, 2020). Attempting to control the increasingly dangerous conditions, the operators opted for a controlled release of water from the dam to relieve the building pressure. Unfortunately, one of the gates had frozen shut, leading to the operators abandoning the structure (Belsie, 2019).

Despite the problems faced at the gateway and the eventual failure that occurred there, the main breach actually “occurred towards the south end of the earthen dam embankment,” (Yoders, 2019). By the time the sun had risen the entire riverbed of the Niobrara River had shifted to run through this new opening. With the dam failure came a rush of water and large chunks of ice that battered nearby buildings and fields. The ice chunks, a common characteristic on the Niobrara, were 1-2 feet thick and reached pickup-truck weights. In the moments after the break the water gauge, which had rested around a height of 5-6 feet, soared to the maximum height of 17.5 feet (Salter, 2000). In terms of water flow measured in cubic feet per second, the dam experienced a flow of approximately 40,000 cubic feet per second (Hammel, 2019A). In
normal circumstances, the average flow is 1,500 cubic feet per second or 27 times smaller than the peak flow following the collapse.

Following the collapse, NPPD officials argued that the dam was not at fault. Rather, it was a victim of the “unprecedented combination of high (water) flows from the Niobrara River mixed with massive chunks of ice,” (Hammel, 2019C). Indeed, in the immediate aftermath there was discussion across news sources that this dam failure due in large part to battering-ram-shaped-ice chunks might indeed be the first of its kind in the United States. However, the Spencer Dam failure in 2019 was not the first of its kind. There have been other ice-impacted dams prior to last year, in fact, there had even been previous ice-impacted occurrences in Spencer Dam’s own history. Ice was at fault for the 1935 breach as well as the 1960 overtopping (Miles, 2019). Despite not being “unprecedented,” the Spencer Dam 2019 collapse has underlined the need for more research on the risks associated with the combination of snow, ice, and rain (White, 2019).

**Event In Context**

Handling an isolated incident is one thing, handling a rare extreme event that stretches across half the Midwest is exponentially more difficult. States across the Upper Midwest, from Colorado through Minnesota, were hammered with a bomb cyclone that occurred in March of 2019 (Erdman, 2020). Figure 4 includes an image of the 2019 bomb cyclone from space, showing its wide ranging effects. A bomb cyclone is generated by “the atmospheric expressway formed by the Plains in the transition from winter to spring (which) create(s) fast-moving weather systems,” (ASDSO, 2020). One symptom of these cyclones is rapid and extreme fluctuations of temperature in the affected region. In the spring of 2019, this led to the ground freezing while the atmosphere warmed sufficiently to produce large amounts of (rain rather than snow). When the rain fell it could not percolate into the frozen ground and thus ran off into
rivers and streams (Kelley, 2019). The situation was not helped by the fact that the area received large amounts of rain the previous fall, which had left the ground saturated throughout the winter (Bloch, 2019). “It is difficult to know,” Emily Pollock wrote, “what the Army Corps of Engineers could have done differently. A decades-old flood control system coupled with recent extreme weather meant that it was difficult for the agency to make any better choices,” (Pollock, 2019).

Across the Midwest, the storm killed four people and caused billions of dollars of damage (Pollock, 2019). The National Oceanic and Atmospheric Administration (NOAA) estimated that this bomb-cyclone was “one of the nation’s costliest inland flood events on record,” (Erdman, 2020). In Nebraska alone 65 of the state’s 93 countries declared a state of emergency (Belsie, 2019). The state’s governor referred to the March storm as “the most widespread destruction we have ever seen in our state’s history,” (Belsie, 2019).

Damage

Human Loss of Life

Dam risk levels are classified based on the potential of human death associated with failure and thus damage assessment must first begin with this measure of hazard-turned-disaster.
Kenneth Angel owned and occupied a house immediately downstream of the dam. When officials decided to evacuate the dam, they stopped at his house and told him he had to leave immediately (ASDSO, 2020). It is unclear, and likely will remain so, why Angel either did not or could not leave before he and his house were swept away. Angel was the first person in the United States to die due to a dam since 2006 (Associated Press, 2019).

Agriculture

The flooding the bomb cyclone inflicted on Midwest states overlaps with the United States’ main agriculture hubs: Nebraska, South Dakota, Wisconsin, and Iowa. Within these states, the bomb cyclone hit Nebraska the hardest with an early estimate of around $1 billion in agriculture loss (Bloch, 2019). Nebraska is the second-largest cattle state with 6.4 million head of cattle along with other types of livestock also being raised. Nebraska is also the third-largest corn producer in the country. The livestock sector lost $500 million worth in damage, with the impacts to be felt for years. The agricultural sectors within the state lost $400 million (Bloch, 2019).

This event is predicted to be the final straw for many local farmers (Bloch, 2019). The country was already at a ten year high of the number of farmers filing for bankruptcy. The trade wars with China, the reduction in federal government crop buying, disastrous weather and dam failures do not paint a pretty picture. The Spencer Dam failure also occurred right before planting season which requires dry ground, or at least dryer ground, in order to be successful (Bloch, 2019). Melissa Bell, a commercial agronomist for Mycogen Seeds, urged farmers to delay planting, and consequently have a shorter growing season rather than attempt to plant early and possibly having no growing season at all (Sents, 2019).

Drowned land not only makes planting complicated but also “brings rot, mold, and other challenges” to these regions. Additionally, floodwater is often also polluted and so any crops
already started must be destroyed (Sents, 2019). In the case of the Spencer Dam failure, the floodwater was likely polluted as the Nebraska Farmers Union determined that it took out gas stations, farm shops, and fuel barrels (Bloch, 2019).

Once a dam fails, farmland is inundated and there is nothing farmers and planters can do but wait to begin the cleanup phase. This is not the case with livestock. It is possible to move livestock to safety, and that potential makes the losses more devastating as circumstances of dam collapse work against farmers (Genoways, 2019). In the case of the Spencer Dam failure, it was in the midst of blizzard-like conditions, dangerous conditions developed rapidly, and it failed in the early hours of the morning when getting word to locals and getting just humans out of danger was difficult (Reiley, 2019).

Most farms lost their calves (next year’s income) and their bulls (the animals with the highest genetic value), if not their entire herds (Reiley, 2019). Nebraska is known for being relatively flat, with few high areas where herds could gather. Those in pens were trapped. Those not in pens were hit by a strong, fast-moving wave. Figure 5 shows a lone cow walking through flooded fields in the aftermath of the bomb cyclone. Food stores were destroyed and the National Guard was required to step in and

![A cow walking through a flooded field in Nebraska, (Hammel, 2019B)](image-url)
use helicopters to drop food near the livestock who survived the initial flood (Bloch, 2019). For those who were able to access and move their herds, the state turned the fairgrounds in Lincoln to temporary shelters (Reiley, 2019). Those animals who survived might be injured, traumatized, and unlikely to return to optimal productivity anytime soon (Reiley, 2019).

While agriculture is often considered as its own infrastructure sector, it is also interconnected with and relies on other infrastructure systems. Notably, functioning transportation systems are critical to functioning agriculture systems (Bloch, 2019). In regards to crops, roads and railroads that are used to get produce to markets and supplies to farms were flooded or washed away. In regards to livestock, many ranchers found themselves cut off, unable to reach their animals, unable to bring supplies to help them, and unable to move them to safer regions (Reiley, 2019). Hence the reason that the National Guard resorted to helicopters to get food to animals. Across the state, over 40 federal and state highways were closed not numerous county roads were inundated (Bloch, 2019).

**Transportation**

Taking a step back and moving away from agriculture, the damage to transportation infrastructure affected the entire region. While water and debris clogged roads in the aftermath, the initial ice and flood pressure took down bridges. The entirety of Boyd County, Nebraska, bordered by the Niobrara River, was stranded, accessible only via South Dakota or a small westward route into Keya Paha County, Nebraska (Salter, 2000). Two main bridges that usually connected the county to the rest of the state were destroyed: a Highway 281 bridge and a Highway 12 bridge (Foster, 2020). The U.S. Highway 281 bridge located downstream of Spencer Dam was destroyed in the moments after the dam failure and the resulting surge of ice and water. Bridge replacements often take months to repair and in this case the bridge failure required an hour-long detour for commuters (Foster, 2020).
When roads flood, people are stranded. When bridges disappear, communities are separated, the economy is disrupted, and it is hard for aid to enter the region and reach hard-hit areas. Figure 6 shows one of the bridge failures in Nebraska. This further exacerbates the challenges locals face in their recovery process.

**Water Infrastructure**

The interconnectedness of infrastructure networks means that the failure of one can lead to the collapse of another. Water infrastructure often follows roads and is affected by the same hazards. Additionally, water infrastructure into Boyd County to the north of the river was connected to the rest of the state in the south via pipes under the Niobrara River. The pressure created by water and ice building up at the Spencer Dam when released by the dam failure was strong enough to destroy not just the aboveground bridges but also the underground pipes (Larson, 2019). Local water storage tanks also were slammed into and destroyed in the
aftermath of the dam failure (Yoders, 2019). Following the disaster, the majority of the population who relied on the Boyd Country Rural Water District therefore found themselves without water for up to several months (Lindberg, 2020).

Disasters exacerbate existing weaknesses. The region’s water infrastructure was already stressed. Prior to the Spencer Dam collapse, the Boyd County Rural Water District already “owned approximately $1 million in loans from their last expansion,” (Schurman, 2014). The flood added another $2 million in damage costs, a high burden for a local government to bear but help from the state and national government is limited due to the widespread destruction the bomb cyclone caused.

Other Physical Damage

Throughout Boyd County, in addition to flooded roads and no usable water, towns and rural residents found themselves faced with many damaged buildings, both residential and commercial (Hammel, 2019B). Figure 7 shows an aerial view of the damage caused by the dam failure in surrounding regions. The ice released from the dam and propelled by the built-up water pressure stripped trees in the region of their bark up to ten feet high (Genoways, 2019). Whether these trees survive this treatment can only be determined with time.

Figure 7: Debris from Spencer Dam Collapse, (Grecket, 2020)
While many of the structures and farms in the region downstream of the dam were affected, this cannot be blamed solely on the failure of Spencer Dam. Buildings built not just in the dam inundation zone but in the natural flood plain would have been affected by the bomb cyclone even if the dam had not existed (ASDSO, 2020). The type of flood onset may have differed, perhaps giving locals more warning that a flood was building up, but the entire Midwest, dams or not, struggled with floods caused by this storm system.
CHAPTER 5. SPENCER DAM: DISASTER PLANNING

Emergency Management: An Overview

A natural hazard and a natural disaster are not synonymous. If a flood occurred in a region where there was no human settlements or activity, it would not be considered a disaster. Hazards exist in nature and it is only when humans interact with nature that hazards are turned into potential disasters. In other words, the flood or earthquake is not the disaster, it is merely a hazard and how humans are affected, react, and cope determines if the event becomes a disaster (FEMA, 2016B). For this reason, it has also been argued that there is no such thing as a “natural” disaster as by definition disasters are determined based on human activity and thus to some extent can be considered “man-made.” After all, humans do not have to build in a flood zone or attempt to control a river with the addition of dams and other management techniques. Nonetheless, for the remainder of this paper the collapse of the Spencer Dam will be referred to as a natural disaster since the hazard was actualized and floods are commonly thought of and understood to be “natural” in contrast to the more traditional manmade disasters of terrorism and war. “Emergency,” “emergency planning or management,” or simply “disaster management” is a neutral way to avoid the confusion between what is considered “natural” or not. The National Incident Management System (NIMS) defines an emergency as “any incident, whether natural or manmade, that requires responsive action to protect life or property,” (FEMA, 2013B).

Emergency management monitors all types of hazards and has three main stages. The first in pre-event monitoring, planning, and readiness. The second stage is the immediate post-disaster response. The last phase focuses on long term recovery and is tied into the first stage as the community plans for and attempts to mitigate the next event. In reality, all of these
components of the recovery process often overlap and are interconnected, with the actions in one stage affecting those in the next.

**Pre-Disaster Plans and Hazard Beliefs**

The roots of a successful recovery begin with pre-disaster preparedness and planning (FEMA, 2011). There is a common idiom that states ‘an ounce of prevention is worth a pound of cure.’ In the given circumstances this argument is twofold. If a community is able to successfully mitigate and manage hazards and prevent them from turning into disasters, past experience in the United States shows that the incurred cost of mitigation measures is, in the long run, more cost-efficient compared to the costs inflicted by many disasters. But even if a disaster occurs and inflicts high levels of damage, pre-planning can help speed recovery and reduce wasted resources in the process, thereby reducing the cost of disasters to a community. The ability to recover quickly after the disastrous is called resiliency and is what all disaster planning aims to achieve.

The first step in pre-disaster planning is risk analysis (FEMA, 2015). What threatens a community? How bad is the hazard-turned disaster likely to be? Are there multiple hazards threatening a community? With hazards such as dams, which tend to be located outside of communities, threatening multiple communities at once, are locals even aware of the threat of dam failure? Who controls these structures caught between communities or beyond urban boundaries? Throughout the United States, when questioned most people answer that they have no personal awareness of threats posed by dams in their communities.

Risk analysis and recognition feed into the policies and plans created prior to disasters. In regards to dams, the main three components are inspections, upkeep, and the creation and renewal of emergency plans of action (EPA). These vary widely between states because while the federal government encourages high standards and regular inspection, there is little actual
federal guidance on the matter. While dam owners are responsible for initiating and completing inspections, the state often provides help (White, 2019). Nebraska had regular inspections, led by the Nebraska Department of Natural Resources (NDNR or DNR). The NDNR has just shy of 3,000 dams they regularly inspect, averaging visits to 700 dams a year, resulting in these dams being inspected every few years (Yoders, 2019). The most recent inspection Spencer Dam went through was in 2018, a year before its collapse. Upkeep and renovations based on these inspections is far more varied. With costs of maintenance falling to dam owners rather than government authorities, the ability or willingness to make repairs is left to the owner’s discretion. Spencer Dam was considered to be in “acceptable” condition at its last inspection.

While Spencer Dam was in good standing regarding the first two components of pre-dam-disaster planning, the dam did not have an emergency plan of action (EPA). The EPA helps coordinate agencies across the region, creates communication networks, and provides clear steps and protocols to follow ahead of the often panicked disaster event (FEMA, 2011).

**Response**

Response refers to the immediate action taking during and after an incident. Response is often confused with recovery and chronologically the two often overlap and blend together. The main difference is that recovery is focused on long-term gains and goals whereas response is centered around immediate dangers (Library of Congress, n.d.).

Response can best be seen by going through a timeline of the disaster. The night of March 13 and the morning of March 14 saw the workers of the Nebraska Public Power District, the dam’s owner, fighting to weather the storm and attempting to keep the dam afloat, so to speak (Genoways, 2019). Around 5:30 A.M. on March 14th one of the dam’s retention gates frozen close and the dam began to fail. The workers determined that the dam was unsafe and unlikely to survive the storm, issued an emergency warning, and evacuated. On their way out
they stopped at the house of Kenneth Angel at the base of the dam and yelled that he had to leave immediately (Genoways, 2019). For whatever reason, he did not leave his house and was killed by the inundation following the dam collapse. During this time, Becker, the Nebraska Public Power District’s media supervisor, was alerted that the dam had failed due to ice and increased water load. By 10:30 A.M. “volunteer firefighters from Lynch and neighboring communities” arrived with large trackers able to breach the high waters that had inundated surrounding regions and began the rescue and evacuation process of rural residents (Hammel, 2019B).

The response to the Spencer Dam failure was complicated by the fact that it was not an isolated event. The state of Nebraska was fighting floods across the state, resulting in strained state as well as federal responses. “Officials from the U.S. Army Corps of Engineers, the Nebraska Department of Natural Resources, the state’s biggest public power utility, and local fire departments were all overwhelmed by a combination of frozen ground, rain, and snow in mid-March,” (Yoders, 2019). An initial needs assessment reported that the region surrounding the Spencer Dam required debris removal, the assessment of personal property for insurance purposes as well as the repair of said property, fencing and feed for the livestock that survived the storm, and veterinary services to help these animals, farm equipment replacement, temporary portable water delivery, and severe damage to the local transportation network (Lindberg, 2020). Along with the evacuation of humans, in the immediate aftermath the Nebraska National Guard flew feed to the herds they could see as normal food sources were either washed away or underwater (Genoways, 2019).
During the response phase, a call was issued by the Nebraska Department of Natural Resources, the regulatory authority of Spencer Dam, for an official investigation of the Spencer Dam failure. Figure 8 compares before and after photos of the dam’s structure, capturing the level of destruction the dam suffered. The investigation was handed off to the Federal Emergency Management Association (FEMA) and the Association of State Dam Safety Officials (ASDSO) (Larson, 2019). The group eventually selected to investigate the disaster was comprised of “retired members of the U.S. Corps of Engineers with a combined experience of 500 years,” with specialists of “hydrology, mechanical, electrical, and civil engineering” coming together to provide a thorough assessment of the dam (Miles, 2019). The investigation is intended to determine and learn from what went wrong to improve future dam management (Staff and Wire, 2019).

Recovery

The concept of what recovery consists of and when communities have officially ‘recovered’ is a matter of debate and opinion. With many disasters, there is a conflict between
quick recovery and the return to a sense of normalcy for those affected vs. building back better, reducing future vulnerability while also potentially solving long-standing issues in the community despite the increased time frame this requires. However, realistically, the biggest problem for disaster recovery is the sheer economic cost involved. By April 1, 2019, a few weeks after the bomb cyclone that battered the region, the state of Nebraska’s damage cost was $1.3 billion (Yoders, 2019). President Trump made some federal recovery funds available and different federal and state departments and programs also provided aid for the sections of the country relevant to their mandate (Yoders, 2019). For example, the Nebraska Farm Bureau Disaster Relief Fund allocated $3.4 million for damage relief (Lindberg, 2020). However, donations and aid are hard-pressed to meet the entirety of the billion-dollar damage Nebraska alone incurred, with surrounding states taking similar damages in the storm.

The destruction of Spencer Dam became a symbolic photograph of the 2019 bomb cyclone, as seen in Figure 9 (Hammel, 2019A). The areas around the dam were slammed by ice, water, and debris such as sand that rivers normally carry along, creating a muddy, desolated background for these pictures. The current owner of the Spencer Dam, the NPPD, had to decide if they were going to rebuild the dam. Such a project would have to start from scratch, with the demolition of the remaining structure and meeting newer building standards that were developed over the last century. Edward Sloan, the program delivery manager for FEMA, stated that the acquisition of completely new materials and implementation of current construction procedures would have to be followed if the owners wanted any aid from FEMA for the project (Larson, 2019). The other option would be to leave the river undammed, allowing it to return to its natural flow. This option becomes more attractive when one considers that the path of the river actually shifted in the storm and its aftermath and moved 3,000 feet south which would require
the movement of secondary infrastructure such as roads and electrical equipment in order for the
dam to function as it did previously (Larson, 2019) (Miles, 2019). On top of this, this is a dam
that the owners didn’t want, that they were in the process of selling and thus unlikely to spend
the needed money rebuilding would require. A year after the failure, Spencer Dam looks much
the same as it did immediately after the bomb cyclone with the exception that “the highway just
downriver now has a temporary bridge in place,” allowing for resumed movement between Boyd
County and the rest of Nebraska (Foster, 2020).

Despite the dearth of an Emergency Action Plan prior to the disaster, the common
conclusion is that given the storm and the then capacity of Spencer Dam, the dam didn’t stand a
chance and would have failed regardless (Pollock, 2019). The questions that arise then are what
components of planning and policy led to the dam failure? What policies and plans were at fault and what worked as expected? The next section will assess these questions and answer how planning and policy can adapt to counter these risks.
CHAPTER 6.  ZOOMING OUT

Spencer is not the only dam failure in the United States in recent years. Press states that in the past four decades, 1,000 dams have failed, an average of 25 dam failures a year (Associated Press, 2019). The year before the Spencer Dam failed, 2017, California’s Oroville dam broke (Leslie, 2019). The report that came out at the time underlined the problem dam infrastructure across the country is facing and argued that change of some sort is necessary in order to avoid future disasters. In regards to Oroville, “the fact that this incident happened to the owner of the tallest dam in the United States, under regulation of a federal agency, with repeated evaluation by reputable outside consultants, in a state with a leading dam safety regulatory program, is a wake-up call for everyone involved in dam safety,” (Leslie, 2019). This is a hard argument to counter and raises concerns for the safety of dams with fewer resources and less stringent regulation. There is a need to reassess how dams are measured, evaluated, and managed.

Spencer Dam Overview

The failure of Spencer Dam was decidedly not unexpected. The collapse was not caused by negligence in yearly reviews and subsequent upkeep and improvements. Indeed, the investigation report concluded that “there was nothing the operators at the dam could have done… that would have kept the dam from failing given the magnitude of the flood and ice run,” (ASDSO, 2020). It was not due to human error such as complacency or overconfidence (ASDSO, 2020). It was not due to lack of maintenance as for the previous 25 years inspections came back listing Spencer Dam as “well-maintained” (Hammel, 2019A). So what went wrong?

There is another idiom that goes “those who do not learn from history are doomed to repeat it.” Spencer Dam lacked compiled historical data, leaving the owners and operators
unaware of the fact that ice can very much affect the dam’s operation. (ASDSO, 2020). This ignorance was reemphasized by the fact that inspections often occurred in normal or best weather, not during the storms and ice season, thus failing to adjust the risk portfolio of the dam to include ice with these extreme winter weather events.

Spencer Dam, like many dams across the United States, had a hazard potential classification rating assigned several decades ago. More specifically, the U.S. Army Corps of Engineers’ National Dam Inspection Program in the early 1970s surveyed the dam, its surroundings, the risks associated with possible dam failure, and assigned the hazard rating accordingly (ASDSO, 2020). Since this assessment, significant downstream development occurred but no new assessment was undergone. This is because ordering a new assessment within the system is cumbersome and would require significant justification. Instead, it is normal for “state regulator(s) to treat that classification as one that needs no review or update, or to simply defer to the prior classification” (ASDSO, 2020). The problems the Spencer Dam faced are endemic of the dams across the nation.

**Systemic Issues**

Nothing truly out of the normal policy or planning wise brought down the Spencer Dam, and this is worrying. There was not some obvious problem such as lack of maintenance or structural damage. The dam underwent regular inspection, acted to correct identified problems, and according to the Nebraska Department of Natural Resources was not in a location that the state was particularly worried about. The state dam safety inspector, Tim Gokie, argued that the structure’s old age was not the reason for failure, at least not the primary reason. Specifically, Gokie’s statement was:“with age comes problems with any infrastructure – steel corrodes, concrete deteriorates over time. But there’s no indication that any of that led to the failure of the (Spencer) dam,” (Hammel, 2019A). He followed up this comment by adding “I would definitely
say that we (Nebraska) have dams that are not well-maintained, but this was not one of them,” (Hammel, 2019A). The review panel inspecting the dam’s collapse concluded: “that nothing they (the dam managers) could have done at the dam as configured at the time would have kept the dam from failing given the magnitude of the combined flood and ice run,” (ASDSO, 2020). However, there are common faults in the management of dam infrastructure within the United States that can be seen in the case study of the Spencer Dam failure and which are vital to begin taking into account for planning and policy.

**Historical Ignorance**

The inspection of Spencer Dam revealed that the dam operators knew that ice formed along the Niobrara River and these formations could impinge on a dam’s operations (ASDSO, 2020). But they knew nothing more than that. Information about the interaction of ice and dams is rarely researched or communicated between dams, leading to a gap in operator knowledge (ASDSO, 2020). However, it is not just that ice can impact dams but, more to the point, ice has impacted the Spencer Dam itself in the past and the current managers did not know this. It was not until after the 2019 dam failure and the subsequent investigation that the Nebraska Dam Safety Program (NebDSP) gathered information on the 1935 Spencer Dam failure due to an ice run nor the later dam ice inflicted in 1960 and 1966 (ASDSO, 2020). Prior to 2019, not even the dam’s owner – the Nebraska Public Power District – had a consolidated history of the Spencer Dam (ASDSO, 2020). Thus the owners did not remember that not only were ice runs a plausible turn of events but a probable one in the current location. While infrequent, this mode of failure was “foreseeable given the dam’s history,” (ASDSO, 2020). This adds to the irony that in the immediate aftermath of the failure in 2019, Gokie, chief engineer of the state’s dam safety program, suggested that this “may be the first dam failure in the nation related to ice floes,” (Hammel, 2019A).
Technically, Spencer Dam followed regulations and took necessary actions. What this indicates is that “dam inspections, while valuable, are not adequate dam safety evaluations in themselves,” (ASDSO, 2020). Knowledge of local dam history is invaluable when preparing and planning for the future. The records that survived from the 1966 ice incident describe “a wall of water and ice entering the reservoir,” a description that fits the events that occurred over 50 years later in 2019 (ASDSO, 2020). No comprehensive history of Spencer Dam was prepared until the 2019 failure investigation. It is postulated that one of the causes behind this ignorance was that the current owner, the NPPD, took over the dam in 1970 may have forgone historical analysis of their new possession (ASDSO, 2020). Past dam failures and damages are also known to destroy or damage records which also could have resulted in limited historic information.

Inadequate Design & Project Life Expectancy

Civil engineering projects, including dams, come with predicted life expectancies; anticipating when a structure will become unsafe as the materials used age and weather. These life expectancies tend to be determined in decades rather than years. However, when examining a structure that has been part of a community or landscape for 40 or 50 years, it is easy to assume the structure to be invulnerable, to assign it a description of an everlasting entity. This is one of the reasons why dam failures so often come as complete surprises to communities, a hazard many had never thought about before as dams so often blend into the background, into the everyday and mundane.

“By 2025, seven out of ten dams in the United States will be over 50 years old,” (ASCE, n.d.). Even now, the average age of dams in the United States is 56 years (ASDSO, n.d. C). Considering that “many dams were designed with a 50-year design life” (emphasis added), these are not reassuring statistics (Yoders, 2019). Figure 10 shows a map of the United States with the
percentage of dams over 50 years old broken down by state. With risk increasing as these structures age, the potential disasters associated with dams over the next few decades has skyrocketed. Especially for those dams that now have large downstream communities where before few lived. Adding to this is the fact that the surrounding environment changes over time as well. Large swaths of the United States are grappling with increasing rain loads, often experienced in several extreme events rather than multiple smaller storms (FEMA, 2012B). Attempting to improve existing dams to measure up to these increased challenges is prohibitively expensive, especially for the majority of dams owned by private individuals rather than government agencies.

Figure 10: Map of dams more than 50 years old, (Hossain et al, 2009)
In Nebraska alone, there are 1,200 dams over the age of 50 years old (Yoders, 2019). Spencer Dam was built in the 1920s. That a dam designed to last 50-60 years made it to 92 years old before it finally failed actually conveys a favorable message about the engineering skills that kept it afloat and also speaks loudly of the neglect dams have received within the United States. Ultimately, the storm that spelled its downfall did so because it was completely out of possibilities the dam was built for (Hammel, 2019A). A spokesman for the Nebraska Public Power District, Mark Becker, stated: “There needs to be a better understanding of what this facility was intended to be. A lot of people, their thought was: ‘Wasn’t this supposed to control the flooding?’ When it was built in the ’20s, it was never ever designed to do that. It’s a run-of-the-river hydroelectric facility, and not a flood control operation,” (White, 2019). In the introduction of this paper, the different uses of dams were discussed. What was not mentioned is that most dams in the United States, regardless of original purpose or intended use, have now reverted to being, by default, part of the nation’s flood control management, regardless of matters of design. Spencer Dam, a hydroelectric dam 30-40 years past its expected replacement date, failed in an extreme storm event. When examined that way, the collapse was just a matter of ‘when,’ not ‘if.’

Beyond life-span expiration date, there is the matter of inadequate design. The 20th century was characterized by improved scientific understanding across all fields, an understanding that continues to improve in the 21st century. Dams built today must meet new standards based on the scientific lessons learnt over the last several decades (FEMA, 2012B). Dams built a century ago can only hope to be lucky enough to have been built to withstand today’s challenges even when built based on less sophisticated science. For example, understanding of ecosystems, their complexity, and the cycles and feedback mechanisms in
existence has radically changed since the beginning of the 1900s, meaning the understanding of precipitation and floods has changed as well (Leslie, 2019). Safety standards have also increased over the decades. Dams built today have much higher standards to meet than those considered acceptable a hundred years ago and are sometimes ignored by modern regulations (source). For example, the Spencer Dam was a hydroelectric dam but it outdated the Federal Energy Regulation Commission (FERC) and thus went unexamined by the commission (ASDSO, 2020).

While some of the inadequacies dams possess can be attributed to limited scientific knowledge in the past, changing circumstances also leave dams blindsided and unable to cope. Climate change has played havoc with local environments, increasing extremes ecosystems and the infrastructure built within must face. According to Gokie, head of the NDNR’s dam safety program, “the flood exceeded what the dam was designed to handle,” (Hammel, 2019A). In other words, “the dam as configured was incapable of passing the flood and subsequently failed” (ASDSO, 2020). If needed, the dam could pass large amounts of water, but ice floes and substantial amounts of river sediment pushed the hydroelectric dam too far (ASDSO, 2020). The fact that Spencer Dam has a history of problems due to both ice and sediment returns to the earlier issue of historical ignorance by dam owners and operators which exaggerates the challenges of aging structures and changing circumstances.

**Downstream Construction**

The number of dams considered to be high-hazard is increasing in the United States. This despite the fact that few dams are still being built. The weaknesses inherent in aging structures is worrisome but is not involved in this increase in numbers of high-hazard dams. As hazard level is associated with the consequences of failure rather than the likelihood of failure, what matters is what is located within dam inundation zones. Dams ‘tame’ the landscape downriver and can provide benefits such as cheap electricity and easily accessible water sources.
Building around dams thus makes sense for developers. Developers often “know nothing about the potential devastation an upstream dam could cause should it ever fail,” (ASDSO, n.d. C). In other words, when considering where to live, people see the benefits but not the risks associated with these areas downstream of dams. In 1999, there were 9,300 high-hazard dams spread across the United States. By 2017, this number had grown to over 12,500 (Leslie, 2019).

The new construction responsible for the increasing number of high-hazard dams does not happen all at once. Often it occurs slowly, forming what is known as a ‘hazard creep’ as changes over years and decades add up and dams (or other structures) are “being relied upon to protect more and more people” in a particular area (Leslie, 2019) (Associated Press, 2019). Changes in nearby development mean that dam safety regulators should “periodically (re)assess the areas downstream of low and significant hazard dams,” (ASDSO, 2020). Inundation maps, maps showing those areas predicted to be at risk should a dam fail, are useful ways to conceptualize risk and spread information to communities (FEMA, 2012A). Spencer Dam did not have an inundation map (ASDSO, 2020). This is in part because the last assessment of hazard risk for the dam was also the first, i.e. the initial one that occurred when the dam was built a century ago.

The investigation of Spencer Dam’s failure found that the owner as well as state regulatory agencies “underestimated the potential of the life-threatening flooding to downstream houses and properties in the event of dam failure,” (ASDSO, 2020). On record, Spencer Dam was considered to be a ‘significant hazard’ to the surroundings prior to the failure. Taking into account downstream construction, the investigation panel determined that the dam was actually high-hazard, a difference emphasized by the fact that the dam collapse did result in death and significant economic loss (ASDSO, 2020). The nation has an increasing number of dams
considered to be high-hazard and the case study of Spencer Dam underlines the fact that even this increased number is not yet representative of reality. How many dams in the United States would be added to the high-hazard list if there was widespread risk re-assessment? Assessment does not change reality, these dams are still dangerous regardless, but assessment does affect how much evaluation and maintenance a dam receives.

**Externalities & Preparation for Worst Case Scenarios**

When a dam begins to fail in the middle of the night, in a blizzard, what actions might save the structure? Who should be informed and in what order to get the most people to safety as possible? Who begins the cleanup process? A prepared document containing this information would be very helpful.

Emergency Action Plans (EAPs) are detailed plans of action that should be taken should the worst happen. EAPs are designed to “minimize the loss of life and property damage,” (FEMA, 2013B). EAPs are complex, living documents and are only of use if regularly reviewed, updated, and practiced (FEMA, 2013B). The average EAP has six components to be effective. The first lists pre-disaster mitigation efforts. The second covers coordinated, regional responses to emergencies. If a dam does fail, it is not just the dam owner that will be affected. Creating networks with nearby authorities and first responders prior to actually needing them is crucial to a quick response. The third component of an EAP outlines the actions owners will take to notify the surrounding populations should an incident occur. To help coordinate and communicate risk, the fourth component of an EAP is an inundation map that visualizes risks and helps identify critical infrastructure in the danger zone. The fifth section is the division of responsibilities between actors to provide an efficient, synchronized response. Lastly, as emergency action plans are living documents, there needs to be planned reviews meant to ensure the rest of the document is still up to date and covers all risks in the case of a disaster (FEMA, 2013B).
The National Dam Safety Program would prefer for all dams to have an EAP, but in a country with 90,000 dams, choices of priority must be made (FEMA, 2013C). High-hazard dams receive the brunt of focus as far as EAP planning is concerned as these are the dams that, if they failed, would likely result in death. Unfortunately, dams are not always in the right hazard classifications and dams marked “significant risk” rather than “high hazard risk” are not required by regulation to have a working EAP. Some dams create EAPs even if not required to do so, and Figure 11 shows the distribution of EAPs across hazard levels. However, even if dams are not earmarked as “high hazard risk,” it is important to remember that there is no such thing as an infallible dam and where there’s a risk, appropriate planning and preparation needs to occur. With changing climatic conditions especially, the chances of dams being overwhelmed and going under is only increasing as time passes.

Figure 11: Graph of EAPs for each hazard-potential categories of dams, (USACE, 2009)
Within the state of Nebraska, regulation dictates that 145 dams of high hazard classification must have an EAP prepared (White, 2019). Of these dams, 97% have complied and now have a working EAP (White, 2019). Nationally, Nebraska is ahead of the game as the country-wide average is only 77%, as of 2015 (ASCE, n.d.). But when considering all dams within the state of Nebraska, not just the high-risk ones, only 80% have EAPs according to the most recent records collected by the U.S. Army Corps of Engineers (Associated Press, 2019). Hence why Spencer Dam did not have an EAP prepared that they could fall back on, although, had its hazard classification increased the state would have mandated the dam to create one.

One final benefit provided by EAPs resides in the types of policy actors that it brings together (FEMA, 2013B). The federal government can promote resiliency, provide funding, and allot economic disaster aid, but their role is limited when it comes to the immediate disaster (FEMA, 2013A). The EAP forces dams to identify and form relationships with local authorities and critical first responders, relationships that usually do not exist, not in a sufficient form, without the trigger of an EAP.

Emergency Action Plans prepare for worst-case scenarios, but they should not be the only preparatory action dams take regarding worst-case scenario planning. It is important that dams correctly assess risks in order to take appropriate actions and know when the EAP might need to be used. Spencer Dam ignored one crucial externality in their preparation and planning stage: the weather. As the investigation puts it, “The location of Spencer Dam is subject to some of the most dynamic fluctuating weather patterns in North America. This presents challenges for design and operation of infrastructure, such as the (Spencer) dam,” (ASDSO, 2020).

The Niobrara River apparently has ice every winter, some winters are just more severe than others (ASDSO, 2020). The operators of Spencer Dam are not alone to blame for
overlooking the threat of ice as this is apparently a common oversight in dams across the country, according to the Spencer investigation, but that does not make it less damning (ASDSO, 2020). The dam, as its managers correctly identified, was in good condition before the bomb cyclone. It merely didn’t have any method at all to handle ice and keep it from building up upstream of the structure (ASDSO, 2020). No person or technical system was monitoring ice conditions upriver (ASDSO, 2020). The dam merely acted as if ice were not of its concern. How could the inspections every couple of years miss this threat? Even without historical data to underscore how damaging ice could be, the threat should have been spotted. Worst-case scenario planning, in this case, was undermined by one important fact – inspections at Spencer Dam occurred in warm weather, out of season with the river’s ice formations (ASDSO, 2020). Out of sight, out of mind.

Giving the inspectors and operators a reprieve, it is worthwhile to note that before 2019, very few people knew what a bomb cyclone was, let alone how to prepare for it. A common question asked when examining events such as the polar vortex, bomb cyclone, and derecho that have hit the Midwest one after the other is, “Is this the new normal?” (Genoways, 2019). With predictions of future conditions often based on past accounts, how does one plan around change? Additionally, how does the United States prepare for climate change and the extremes in brings when the federal government, as often as not, denies the effects of climate change? The worst-case scenario is becoming more extreme and less predictable, but planners nonetheless need to recognize this fact and increase the robustness of their disaster plans.

False Confidence

There is a commonly held belief that infrastructure is invulnerable and infallible. This preconception is one of the reasons developers build in dam inundation zones. An employee of the Army Corps of Engineers adds that the United States in general is also arrogantly
overconfident in the human ability to control and remake the environment (Kelley, 2019). Even should locals be aware of dams and the potential disaster they embody, it is easy to “be overly confident in the infallibility of these manmade structures,” as a dam that lasts decades, as most dams do, can take on the attributes of immortality (ASDSO, n.d. C). As FEMA warns, “the most important steps someone can take to protect themselves from dam failure is to know their (own) risks,” (emphasis added) (FEMA, 2016A). Figure 12 shows the distribution of high, significant, and low-risk dams across the United States.

![Dams Across the United States](image)

**Figure 12: Map of dams across the United States (FEMA, 2016A)**

There are many culprits for this overconfidence and ignorance, but in the last two decades there has been a systematic concealment of information by the federal government (Leslie, 2019). After September 11, 2001, the government located the country’s key infrastructure, which includes the dam network spanning the nation, and retrieved and hid public information regarding these critical infrastructure structures (Associated Press, 2019). Considering that this information included not just the locations of dams but the hazard
classifications of dams, based on the predicted death toll failure could create, and the years of heightened fear following 9/11, it is perhaps not surprising that the federal government classified such information. Over the years, as the threat of terrorism on the scale seen in 2001 decreases, information regarding dams has slowly been made public again.

Even so, the aftershocks of 9/11 continue to affect dam infrastructure. While it is unclear how many developers and citizens knew of the dams in their area prior to 2001, today, after years where this information was not accessible, the number of people unknowingly living in inundation zones is considerable. But in addition, on a national level rather than an individual scale, the policy conversation shifted. The increased interest in dam safety and related regulations that began in the 1970s and lasted through the 1990s has lessened, with Congress instead focusing on “securing and protecting” dams and the water sources connected to them (Lane, 2006). Incidents like New Orleans’ levees failing in Hurricane Katrina are reminders that the physical condition of these structures are important and the country is now attempting to figure out a balance between security and maintenance when it comes to dams (Lane, 2006).

In regards to Spencer Dam, the investigation panel identified two main faults regarding the dams fostering of community knowledge of potential risks. The weaknesses of dams bleed into each other and inaction in one circumstance can result in cascading effects. Without an emergency action plan, the operators on duty the night of the disaster did not know how to contact the community effectively during a time-sensitive crisis (ASDSO, 2020). This lack of communication efforts was present before the failure as well. Dams ideally should have community engagement and education sessions so that locals can prepare for dams breaks like they prepare for tornadoes or fires (ASDSO, 2020). Not doing so leads to an inaccurate portrayal of risk and this creates an atmosphere of false confidence regarding the potential of dam failures.
Ignorance, false confidence, and poor planning combine to create a dangerous situation. Even with the establishment of better warning systems, there is only so much one can hope for when people don’t know how they are supposed to respond to dam failures. Mistakes and poor decisions are almost guaranteed. The economic loss will also be higher in those communities that are blindsided by the dam collapse compared to those who knew beforehand and took actions to mitigate damages from possible disasters (FEMA, 2012A). Risk communication is the key ingredient to counter false confidence and prepare locals to react appropriately when dams fail (FEMA, 2018).

**Lack of Resources**

Dams in the United States experience a trifecta of resource shortages: aging infrastructure, little governmental funding for upkeep or upgrades, and overworked and insufficient dam inspection boards. Of these, aging infrastructure has already been discussed. Overworked dam safety staff is related to the lack of government funding and so will be examined first.

There are 90,000 dams in the United States that need to be overseen, reviewed, and managed. These dams are aging and facing greater climatic stress making oversight crucial. “State dam safety programs need to balance workload with quality of work” in order to inspect as many dams as possible (ASDSO, 2020). But even though inspections have improved and the review progress has been streamlined, the final step, fixing the actual issue rather than merely identifying it, is where the progress falls short. At this point, Congress would need to allocate billions of dollars to rectify the problems that safety staff have identified, and so far Congress does not seem interested (Leslie, 2019).

The review process varies state by state as there is no federal standard that must be met (Associated Press, 2019). The state government has instead stepped up and taken on the
responsibility of inspecting dams, with some states creating more stringent requirements than others. On average, in the United States dam inspectors are each charged with 200 dams to keep track of (Leslie, 2019). Each state has around 8 employees dedicated to dam inspection and the average number of regulated dams is 1,600 (ASDSO, n.d. C). Some states are better than others, increasing the number of employees working on dam safety. Who becomes a dam inspector also varies. While it is not necessary for inspectors to have a background in engineering to review normal dams, it would certainly be helpful. Dams classified as possessing a ‘high hazard risk’ must be reviewed by engineers, but states can find it hard to attract and keep engineers (ASDSO, 2020).

One of the reasons is that state dam safety programs lack funds. This is another metric that varies greatly between states, “ranging from less than $50 per state-regulated dam to more than $16,000 per dam,” (Lane, 2006). Assessing dams cost money. Fixing problems cost money. Improving policy and planning costs money (ASDSO, n.d. C). With the majority of dams owned by private individuals, who are in charge of organizing inspections and repairs, the amount the owners can contribute is limited which limits the activities available at that particular dam (ASCE, n.d.).

Lack of investment on a wider scale has resulted in disrepair accumulating. Over time, repeated failure to solve issues while they are small has resulted in the issues growing, placing the dam in a precarious place (Genoways, 2019). This neglect is one of the reasons why the number of high hazard dams is increasing. Jacques Leslie referred to the current situation as being caused by “a huge backlog of rehabilitation (of) needs regarding dams in our country,” (Leslie, 2019). Not only do dams cease to function properly, impacting their ability to fulfill their original purpose, but they also become infinitely more dangerous to their surroundings.
With each delay in investment, the need for increased funding grows (Kriley, 2019). The Association of State Dam Safety Officials “estimates (that at this point) it would take more than $70 billion to repair and modernize our dam infrastructure” (Associated Press, 201). The need for increased resources plagues every state (Associated Press, 2019).

The question then becomes: how can the funds be acquired to meet dam infrastructure demands? Policy and finance are inextricably entwined. Private owners cannot shoulder the burden alone when the costs can range from a few thousand to several million. Local governments do not have the budget to meet these needs, especially for those dams outside city limits. Even state governments, those responsible for dam oversight and inspections, struggle to allocate funds for dam maintenance. A dozen states have experienced decreases in spending on dam programs over the last decade, despite no decrease in responsibilities (Associated Press, 2019). “Many states are simply under-resourced for carrying out the letter of the law,” (ASDSO, n.d. C). In 2018, Alabama allocated no funds towards dam safety, California designated $21.3 million towards safety initiatives, and the other states fell somewhere between these extremes, many tending more towards Alabama than California (ASDSO, n.d. C).

It is therefore up to the federal government who has the budget needed to address the state of disrepair dam infrastructure is slowly succumbing to (ASDSO, 2019). A Congressional Research Service report examines what motivates Congress when it comes to dam safety and consolidated the considerations into three categories: “(1) dam security and the potential for acts of terrorism at major U.S. dam sites; (2) prevention of potential dam failures due to structural deficiencies; and (3) recovery from dam failures,” (Lane, 2006). The federal government is one of the main actors in building large infrastructure projects and funding their general upkeep, although not to the extent they once did. But while airports and highways may receive federal
funding, there “exists no federal funding to rehabilitate most dams in the U.S.” (ASDSO, 2019). Until Congress puts needed funds into the system, addressing the current repair problems, major policy changes and safety regulations improvements will not occur (Leslie, 2019). It is important to note that while it is easy to refer to federal level involvement as “Congress” since Congress is the one who controls the final federal budget and passes national legislation, the federal level involvement with dams is highly fractured. Some dams are overseen by the Department of Agriculture, some by the Department of Energy, some by the Department of Water Resources, some by the National Parks Service. Even dividing by sectors such as this oversimplifies the mess of confusion that is federal oversight of dams. Funding dam improvements would be considerably easier if there were only one or two national-level departments or agencies that oversaw dams.

As events such as the Spencer Dam failure in 2019 become more common, public pressure is likely to mount and eventually Congress will act (Lane, 2006). At some point, the short term repair costs will become cheaper than the otherwise short and long term disaster costs.

**Changing Environment**

The last overarching problem facing dams today is climate change. Climate change is intimately connected to water, with the geographical location determining if areas experience these changes either as droughts or as floods. One of the principal concerns for the 21st century is the threat of freshwater shortages. As such, many inventions have been made to increase water efficiency and these concepts and designs are spreading across not just the United States but the world at large. But drought, water shortages, is only part of the current dilemma. After the failure of Spencer Dam, John Mitchell, the director of alternative delivery at the engineering firm Burns & McDonnell, summarized the current policy issue: “When we talk about water resiliency west of the Missouri River, we always talk about not enough water, right? We’re
focused so much on water resiliency being drought resiliency,” (Yoders, 2019). But climate change has a way of normalizing extreme weather, consolidating a region’s yearly rainfall into a handful of extreme events (Leslie, 2019). This concentration of rainfall leads to mass flooding and water infrastructure, such as dams, having to handle increased flow load potentials. The United States Bureau of Reclamation only predicts future difficulties when it comes to increased flow loads across the nation. The average increase of upper-basin runoff is a “6% average annual increase, with the number rising to 10% increase in runoff,” (Pollock, 2019). These enlarged flow loads aid in weathering and stressing water infrastructure, reducing its lifespan (DeGood et al., 2016).

If the increase in rainfall occurred steadily throughout the year, with only minute changes noticeable at any given time, increased loads might not be a problem. However often this change in rainfall is experienced through extreme weather events that deposit large amounts of rain in short periods of time, overloading the region’s drainage system, including dams. FEMA has warned the country that “even if kept in good condition, thousands of dams could be at risk because of extreme rainstorms,” (Associated Press, 2019). An example of the increasing frequency of extreme events can be seen across the country as communities experience ‘100-year’ and ‘500-year’ floods, events that, based on historical inferences, were thought to have a 1% or a .05% chance of occurring each year, now hit communities every decade or two (Genoways, 2019). The Midwest or Northern Great Plains area is repeatedly hit by storms which, depending on local temperature, can either bury communities in snow or drown them with rain (ASDSO, 2020). With such varied weather possibilities, planners need to be prepared for anything. This includes highly regulating infrastructure to ensure it is strong enough to
“stand the test of time, which increasingly will include the worst impacts of climate change,” (Cassidy & DeGood, 2019).

The presence of ice, specifically, has strong connections to changing temperatures. The investigation carried out at Spencer Dam after its failure found next to no research or knowledge regarding how ice formed on the Niobrara River, with a dearth of information both in regards to braided river formations and in regards to rivers in general facing these weather conditions in the center of the country (ASDSO, 2020). Similar conditions have been known to create ice jams on rivers, but the incident at Spencer Dam, with the following investigation, is now the most well-documented instance and can help other dams prepare for similar conditions in the future (ASDSO, 2020).

Spencer Dam, located on the Niobrara River, is part of the larger Missouri River watershed. A map of the Missouri Water Basin has been included in Figure 13. John Remus, the person in charge of the Army Corps of Engineers’ Missouri River Basin division, has already seen the impacts of climate change and predicts more frequent disasters in the future, be it “longer and more severe floods” or “longer and more severe droughts” as the region is expected to alternate between the two extremes.

Figure 13: Map of Missouri Water Basin (American Rivers, 2019)
(Kelley, 2019). To put this into perspective, the Missouri River watershed drains 10 states and two Canadian provinces. The controls and engineering manipulations humans installed to regulate the river are now outdated, built for different conditions based on different, now outdated, science concepts. The system is struggling and in 2019, Mr. Remus had “nothing but bad options” when faced with the weather events afflicting the river system that year (Kelley, 2019). When faced with only bad options, it is time for significant infrastructure change in how water is managed.

**Spencer Dam Revisited**

Damage to dams via ice has occurred before, albeit rarely, but the complete collapse of Spencer Dam to ice was an eyeopener for the country. There are environmental lessons that need to be carried over from this incident to other dams in ice prone areas of the country. Especially as state dam safety inspector Gokie has stated that “ice jams and floes are rarely considered in safety assessments,” (Hammel, 2019A). Despite this important identification of future environmental hazards, the main lessons from Spencer Dam are not climate-related but rather center around policy and planning concerns. More comprehensive planning needs to be undertaken at dams, planning that looks into not just the dam’s past but also current and future developments, making note of and acting to reduce newly identified risks. An easy method of trying to solve these problems is to throw money at it and hope the concerns disappear. While money is generally lacking and very much needed to keep the system running, alone it is not enough. More thoughtful answers are needed for long term solutions. In order to simply keep the current infrastructure network running, more funds are needed for basic maintenance and improvement. Local planning also needs to help develop local awareness and education of populace about the hazards they face.
CHAPTER 7. DISCUSSION & ACTION PLAN

Future Problems

There are three main problems facing the United States’ current dam infrastructure network: 1) the high financial cost resulting in policy deficit and thus increased risk, 2) the risk presented in interconnected systems, and 3) dangerous development.

Future Problem #1: High Financial Cost and Resulting Policy Deficit Accompanied by Increased Risk

According to Press, “1,000 dams have failed over the past four decades,” (Associated Press, 2019). In 2019, when the Spencer Dam failed, there were 1,688 high-hazard dams in dangerously poor condition, and this was just the number from states who actually turned in documentation to the federal government (Associated Press, 2019). Dams have been left to their own devices mainly due to the economic cost of actually beginning the improvement process. There are around 87,500 non-federal dams in the United States, 14,000 of which are considered high-hazard. An additional 4,000 dams are federally owned. Together, the cost of rehabilitation is around $70 billion (ASDSO, 2019). “The question is, how much money are we willing to spend to make sure that any river in the state is flood proof? I’m not sure you could even come up with that kind of money and I think that would be a very difficult thing to do,” (Gordon & Schleicher, 2015). It is a question that is at the root of every discussion regarding flooding and infrastructure: how much are we willing to spend? Even focusing on high-hazard dams alone, the United States would still need to locate around $22 billion, an estimate that continues to increase as disrepair builds up (Kriley, 2019). But despite their names, high-hazard dams are only part of the problem. Spencer Dam was not of high-hazard and it still failed and killed somebody. So, in this case, what counts as ‘high hazard?’ Approaching the problem using a different classification system, by manager rather than risk classification, the Army Corps of
Engineers has stated their maintenance bill alone has reached $25 billion (ASCE, n.d.). At current rates of spending, the expected finish date for improvements required by army dams is 50 years away.

Programs such as the Water Infrastructure Improvements for the Nation Act (WIIN) may be developing a structure for future governmental actions, but with a lack of funding this act remains more of a thought exercise than a working plan of action from the federal government (ASCE, n.d.). 2015 saw a 10% increase in state dam program spending from 2011, adding $50 million to their dam regulatory programs but as the need is measured now in billions rather than millions the effects of these funds has been minimal (ASCE, n.d.).

It is hard to get the public interested in dam infrastructure and well-being. This in turn makes it difficult to create the pressure necessary for policy improvements to be created. As federal spending comes from the head of government rather than from states, public pressure leading to public policy is the main trigger for money to be added to the system and improvements to be made. This challenge merges into the invisibility of infrastructure by the general public unless it fails. Ideally, it will not have to reach such a dangerous precipice before officials start paying attention.

**Future Problem #2: Interconnected Systems**

Dam failures and the resulting flood events tend to trigger cascading secondary disasters. Infrastructure systems in the United States are intertwined and when one comes down it tends to bring others with it (ASCE, n.d.). Floodwaters can take out bridges and inundate roads, thereby temporarily taking nearby transportation infrastructure out of commission. Power lines can be taken down, water sources polluted, and washed up garbage and chemicals spread throughout the community. These secondary side-effects, those that were caused by the primary disaster,
considerably increase recovery costs. This is one of the reasons why failure is significantly more expensive than continuous dam improvements.

Beyond financial strain, secondary infrastructure failures severely hamper the logistics involved in response and recovery efforts as areas often become stranded. This affects supplies into communities and the ability for travel within communities. Disruptions to transportation networks also derail local economies and the repercussions of this are felt far into the future. “Many supply chains rely on multiple modes of transportation, and no single mode has enough redundancy to accommodate the goods of another,” (Kelley, 2016). Considering that the local economy is one of the most important factors for successful long term recovery, repairing infrastructure systems beyond the dam itself is crucial.

Even in cases where there are no causalities, the initial rapid flood wave that radiates out after a dam’s collapse combines with lack of power and often water, and this double hit brings a community to its knees. Planning ahead of time to identify likely cascading infrastructure failures and creating action-plans for how to get them running as soon as possible needs to be part of community emergency action plans when examining possible dam failure.

**Future Problem #3: Dangerous Development**

There is an increasing number of high-hazard dams in the United States. Surprisingly, this is not necessarily due to aging infrastructure or changing climates. Instead, dam hazard increases based on the number of people downstream who will be affected by dam failure. Thus the trend of increasing development in flood zones in general, not just dam inundation areas, is greatly increasing the risks that the inhabitants must live with every day. For example, the investigation in Spencer Dam noted that, “if the dam were not there (never built or removed), the highway and local buildings would likely have been washed downstream” anyway as they were built in flood zones that would have been affected by the bomb cyclone regardless of the
(temporary) impediment of Spencer Dam (ASDSO, 2020). But in the actual circumstances, the presence of the dam and the automatic risk that it might one day fail should have been enough of a threat that nearby building would occur in safer areas. The investigation’s exact statement was “it would be difficult to conclude that the area between the dam and Highway 281 was a safe place for a permanent residence,” (ASDSO, 2020).

The problem of dangerous development occurs across the United States, be it building along river flood plains or in coastal communities faced with sea level rise and increased frequency of large storms. Water based disasters, flood disasters, are going to continue occurring in the United States unless these reckless development practices are curbed. Building in flood zones occurs in part because federal flood insurances mitigates the potential costs of an actual flood at the individual level. It is not uncommon, in the wake of disasters, for development to occur in the same location that is identical to what was there prior to the disaster and thus has all the same vulnerabilities and will thus be impacted similarly in the next disaster. Even though currently there are no plans to rebuild Spencer Dam, the area around is still a flood plain and recovery needs to build back better, build back smarter, for recovery to be deemed a success. Relocation is a valid part of recovery and needs to receive more recognition as a possible solution for future hazard risk reduction.

**Potential Solutions**

The last decade of federal politics has been characterized by gridlock, increasing party divides, and ineffectiveness. Fortunately, infrastructure improvement is one of the few popular issues that enjoys a bipartisan consensus that improvements are needed (Committee for Economic Development of the Conference Board, n.d). On the other hand, this consensus has been around for numerous election cycles and congressional seasons, and the initiatives that
managed to be passed have not been able to measure up to the actual demand from the various infrastructure sectors.

In 2016, a Gallup Poll found that 75% of respondents favored increased federal spending on infrastructure (Newport, 2020). Many polls have shown similar results. It is impossible to talk solely about one type of infrastructure without taking into account the other, interconnected systems. Infrastructure networks in the United States are all facing the same lack of funding and dearth of policy. With the systems as entwined as they are, this section will lump all networks under the general term of ‘infrastructure.’ Infrastructure improvements and investments would affect the daily life of people, it provides “tangible results” that would have long lasting benefits (Newport, 2020), but infrastructure policy is hindered by one crucial factor: construction projects take years and significant progress will likely not be noticed until years down the road, beyond the next election cycle. And so “infrastructure today (remains) both an all-encompassing solution and an omnipresent problem, indispensable yet unsatisfactory, always already there yet always an unfinished work in progress,” and thus it remains a topic discussed but rarely acted upon (Edwards et al., 2009). This could always change, for example in 2019 President Trump and House Speaker Pelosi with Senate Minority Leader Schumer verbally agreed to allocate $2 trillion to infrastructure improvements (Newport, 2020). This is not a plan nor anywhere close to a policy, but an agreement on importance is at least a beginning.

The problem is that a final dollar amount alone does not actually fix the issue. To be sure financial aid is needed, but throwing money towards infrastructure only gets the country so far. The conversation needs to be refocused from total spending to questions about “how much infrastructure do we get for our money?” (Gordon & Schleicher, 2015). Infrastructure is incredibly expensive in the United States, unreasonably so. There are multiple theories about
why this is so and no conclusive answer, but the effectiveness of government spending and the
efficiency of infrastructure improvements needs to be considered when making relevant policy
decisions (Gordon & Schleicher, 2015). However, despite the high cost of infrastructure the
United States is wealthy enough that the cost is immaterial if the political will for action is strong
enough (Cassidy & DeGood, 2019). And the political will needs to be strong - a general
consensus that change is needed is not enough - because the American Society of Civil
Engineers predicts that in the next decade, government spending at current levels will fall short
of infrastructure needs by $2 trillion (Cassidy & DeGood, 2019). This is an intimidatingly large
amount of money but when examined at a nation-level scale it is more manageable, for example
the Tax Cuts and Jobs Act (TCIA) passed in 2017 resulted in a tax cut of $1.9 trillion (Cassidy &
DeGood, 2019). Clearly this amount of money can be allocated by the United States government
towards specific endeavors, be it the TCIA or a policy to revamp national infrastructure systems.

A concern that arises when countries move this amount of money around is that the
money must be allocated with equity and inclusiveness in mind from the start (Cassidy &
DeGood, 2019). Improving infrastructure of only specific regions of the country has lasting
impacts on overlooked communities and makes the country as a whole weaker. Many
infrastructure systems currently require or will soon require a large systemic overhaul to
continue being functional and this presents the perfect opportunity to reexamine current planning
procedures (Nellenbach et al., 2019). “The needs to reverse years of this underinvestment in
infrastructure, despite tighter budgets at every level of government, calls for us to rethink how
we pay for and manage infrastructure,” (Department of the Treasury, 2014). What priorities are
to be emphasized? What should the country look like going forward? Are there ideas that
should be copied from other countries? Are there components that are no longer relevant? For
example, the United States has decided to stop building new dams so planning needs to focus on the end of a dam’s lifespan rather than its beginnings.

There are many different options for how the government can go forward from here, different steps they can take to help alleviate the problem of aging infrastructure. The problem of infrastructure improvement is complex and each of the options listed below only chip away at the problem, attempting to make it more manageable. None of the options listed below are exclusive and since they can easily be combined.

An initial step, one that ought to be taken before any major decisions are made, is to improve the data collection and analysis of information regarding infrastructure in order to make informed decisions. From a disaster management point of view, “better data is needed to evaluate risk and develop new insurance products,” (Kunreuther et al., 2018). From a planning point of view, it is important to know what works and what does not work. Collecting data also allows researchers to develop better infrastructure models for future investments.

A second decision that could be made is the choice to stop deferring maintenance. There are many reasons why crumbling infrastructure is undesirable. From a disaster management perspective, it is preferred if basic amenities such as bridges or dams do not collapse. There are also economic considerations to take into account when discussing infrastructure failures. Failures are often accompanied by delays in services and with the mindset that “time is money,” the costs of these delays begin to add up (Nellenbach et al., 2019). Additionally, older infrastructure also often is not only environmentally unfriendly but is more prone to problems and delays (Nellenbach et al., 2019). Slowly phasing these older structures out of use and replacing them with newer, more efficient versions is both cost friendly but also less damaging than allowing structures to continue until they fail completely, often creating significant damage
as they go. On a national scale, reducing deferments in favor of continuous maintenance is expensive and will require federal funding as city and even state governments do not have access to a sufficient amount of resources to handle the current backlog of problems. However, there are actions that can be taken on the local level that would help the situation. As seen when looking at the history of Spencer Dam, many communities do not require comprehensive reports of the infrastructure assets near them, sometimes missing assets completely, other times, like with Spencer Dam, missing crucial information about infrastructural risks. As the Bipartisan Policy Center explains, “This inhibits the ability of public agencies to make strategic decisions about how and where to deploy their limited funds, and masks potential opportunities for innovative solutions,” (Nellenbach et al., 2019).

These first few options act as preventative measures meant to limit further problems from developing. The next option examines a method of addressing the current problems, focusing on the main roadblock created by current and future funding demands. With individual owners lacking the means to act independently, city and state governments stretched for resources, and the federal government unable to find political motivation to act, communities have started looking for other sources of funding. One method of securing funding for infrastructure projects that has become increasingly widespread over the years and which is garnering considerable attention from the research community is the adoption of public-private partnerships (PPPs). These partnerships are “not a substitution for government spending on infrastructure” but rather meant to aid governments by providing funding and helping ensure the funds are used efficiently (Department of the Treasury, 2014). By splitting the risk that accompanies any large project, private firms help reduce the pressure on governments, reduce the amount of money required for infrastructure projects, and can often speed project timelines along and increase end-result
quality (Department of the Treasury, 2014). While PPPs are still relatively rare in the United States, they are common in Australia, Canada, and the United Kingdom. In other words, the countries most similar to the United States are all making use of PPPs to help finance infrastructure roles.

In regards to utilizing these partnerships, Australia is only about a decade further down the road than the United States. In 2008, faced with the threat that “inadequate infrastructure could limit (their) economic growth,” the country reorganized how infrastructure was handled and began national level planning (Tan, 2017). The country “brought together the public and private sectors to devise a long-term strategy and prioritize key projects for funding,” (Tan, 2017). As important as the tangible results have been since then, equally important was that in having had these discussions, planning could adjust and better satisfy current infrastructure needs. The United States is in a similar position now to Australia in 2008. The United States, however, has the advantage that both political parties already agree that infrastructure improvement is important. Now there just needs to be discussion and agreement on how to achieve these improvements and where to start. With many debates in the United States government being split along economic lines – i.e., how should government projects be funded and where should the money come from – appealing to private firms for partnerships and reducing the amount of funding required from the government might alleviate some of the current debate differences. Australia found that changing how infrastructure was understood, purchased, and funded helped them modernize their infrastructure systems and the mechanism they chose to utilize to achieve this was private-public partnerships (Tan, 2017). Considering its
success in Australia as well as its presence in the United Kingdom and Canada, these partnerships are worth considering as the United States begins to address mounting infrastructure needs.

While public-private partnerships have the potential to alleviate or delay the need for government spending on infrastructure improvements, there are drawbacks to this type of proposal as well. Currently, the United States is overwhelmed with infrastructure projects requiring attention and resources. Splitting the cost with private firms can lessen the financial burden the government faces today and help achieve needed infrastructure improvements, but eventually private firms will expect to be reimbursed, either by the government or by the project’s consumers (Whitmore Schanzenbach et al., 2017). Like other forms of loans, there is “a cost attached to debt” that will eventually have to be paid (World Bank Group, 2016). In other words, PPPs are a possible solution for spreading infrastructure costs over time to make it more manageable.

Other drawbacks include the fact that any contract with private companies requires detailed contracts outlining expectations and reimbursements prior to the project beginning. This rigidity can be challenging should unexpected situations occur over the course of construction (World Bank Group, 2016). While private firms have incentives to be as efficient as possible, government oversight would be required to ensure honesty and high standards (Whitmore Schanzenbach et al., 2017). By entering into a PPP, the government is signing its name to the end product and thus taking responsibility for its success or failure.

PPPs are also only applicable to certain types of projects. When the United States government finally begins large scale work on infrastructure improvements, it will likely start with high priority, high risks projects. Even if the government had begun major overhauls
several years ago years, Spencer Dam likely would not have received attention or funds due to its risk classification as well as its relatively small stature (World Bank Group, 2016). However, logically it can be assumed that any method that can make the government’s funds stretch further increases the likelihood that smaller dams and other infrastructure edifices will be attended to and improved.

**Saving Today in Order to Build Tomorrow**

Infrastructure maintenance and planning create results that last years if not decades. Infrastructure, the base of current lifestyles, shapes how people act and will act going forward. As the Center for American Progress argues, infrastructure “represent(s) the direction the country should take,” (Cassidy & DeGood, 2019). For example, at the beginning of the 1900s the United States decided to build roads. To this day, the United States is dominated by automobiles rather than trains or bicycles. The decision to invest in roads rather than alternative infrastructure changed cities and changed human habits. Lifestyle, living standards, as well as equity and social mobility are all heavily dependent on the ubiquity of quality infrastructure (Cassidy & DeGood, 2019). Infrastructure and the connected services can draw people to countries or repulse them. Beyond individual experience, infrastructure systems are also essential for modern economies (Committee for Economic Development of the Conference Board, n.d).

Failing infrastructure is not just a safety hazard. Crumbling infrastructure has effects on a nation’s economy. “Deteriorating infrastructure… has a cascading impact on the nation’s economy, negatively affecting business productivity, gross domestic product (GDP, employment, personal income, and international competitiveness,” (ASCE, 2013). Current infrastructure deficiencies need to be addressed in order to fix current safety hazards and future economic potential. Another source, the Center for American Progress, argues that national
infrastructure investment is uniquely suited to fix modern problems such as “increasing wages, rebuilding struggling communities, and decarbonizing the economy,” (Cassidy & DeGood, 2019). The decisions the United States makes today will play out in the future of how the country functions and what issues continue to affect the nation.

**Moving Forward From Spencer Dam**

Dam failures occur only once, meaning that communities cannot build experiential learning for the next incident. It is therefore crucial for communities to learn from dam failures elsewhere. While dam failures are rare, each dam is at risk of one day collapsing and the consequences of the collapse can be severe (Office of the New York State Comptroller, 2018). Thus dam failures are “low probability but high consequence,” which presents unique planning challenges (FEMA, 2013D).

Planning and policy decisions contributed to the failure of the Spencer Dam in Nebraska in 2019, but this failure was characteristic of systemic weaknesses across the country. Ignorance, false confidence, erroneous risk perceptions and predictions, and lack of resources have worked together to create an unacknowledged vulnerability throughout the dam infrastructure in the United States. Infrastructure vulnerabilities are often only realized when the infrastructure system stops working, but when dams stop working it is too late to realize the existence of unnoticed risks, such as ice buildups, that can cause a dam to fail in extreme weather.

Planning needs to evolve to adopt revised risk analysis procedures that include a changing environment and extreme weather events in the predictions of the future. Policy needs to act on the public desire for improved infrastructure and begin allotting time and money to fix dilapidated infrastructure systems. The cost is high, but the federal government can afford it by changing its priorities, and improving the systems and networks that keep the country functioning will result in economic gains in the long run.
Future research needs to be conducted on how climate change is impacting dams. The United States is not the only country to have built dams in the last century and research on how countries across the world are handling dam aging and deterioration can provide clues for how the United States might proceed. Innovative solutions to reduce the economic costs of repairing the national dam infrastructure network are required as in recent years Congress has avoided making any concrete moves to address infrastructure defects when it seems that Congress will be the main, if not only, funder for these improvements.

The United States’ infrastructure construction slowed down as the 20th century came to an end. As with construction, maintenance has also been lackadaisical over the last few decades and this oversight is beginning to make itself felt. Every year more dams are reclassified as ‘high-risk’ and every year dam failures happen somewhere in the United States. In 2019, Spencer Dam, in Nebraska, was one of the ones that failed. Other communities should look at Spencer Dam for lessons about the dangers of ice and underestimation of. For planners and policy makers, changes need to be made addressing lack of resources, changing environments, and where new development is allowed to occur. It’s time to fix America's dam problems.
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