2008

The Gilboa Dam and its possible failure: what it means for NYC and Upstate New York

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THE GILBOA DAM AND ITS POSSIBLE FAILURE: WHAT IT MEANS FOR NYC AND UPSTATE NEW YORK

By

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Submitted in partial fulfillment

of the requirements for

Honors in the Department of Environmental Studies

UNION COLLEGE

June, 2008

ABSTRACT

The majority of the NYC water supply is provided by a system of dams and reservoirs that have been created in upstate New York. As the owner of this water supply system, NYC is responsible for managing each of the dams and reservoirs within the system. This responsibility includes upholding dam regulations in order to ensure the safety of the citizens of the surrounding area and to lesson any environmental impacts that may occur due to the water supply system. Of the 30 dams owned by NYC, however, 25 of them have been identified at a high-hazard level according the National Inventory of Dams. The Gilboa Dam, which is located in Schoharie County along the Schoharie Creek, is part of the Catskill water supply system of NYC and is one of the NYC dams that has recently been classified at a high-hazard level. The possibility of the Gilboa Dam failing is just one of many problems NYC has had to mitigate with regard to its water supply system. While this thesis will focus primarily on the Gilboa Dam crisis, it will also examine the management of dams at a national level in order to recommend future policies in dam projects.

ACKNOWLEDGEMENTS

Firstly, I would like to thank the members of the DCC for welcoming me to their meetings and allowing me to learn about an issue that they have all worked so hard on to improve. In particular, however, two members of the DCC, Sherrie and Howard Bartholomew, have been an extreme help to me in the writing of my thesis. Their enthusiasm for my project was instantly apparent and with their support, working on my thesis has been that much more of an enjoyable process. Besides the DCC, I want to acknowledge my advisor Jaclyn Cockburn for guiding me through the completion of my thesis, Dr. John Garver, who introduced me to my project topic in the first place, and Amanda Kern, who allowed me to use the results from her own research in my thesis.

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1. INTRODUCTION

In the United States, there are approximately 79,000 dams currently listed on the National Inventory of Dams, a collection of information produced by the United States Army Corps of Engineers (United States Army Corps of Engineers, 2005). 3,361 of these listed dams have been labeled as deficient, or have hydrological or structural faults that make them susceptible to a failure triggered by a large storm event, an earthquake, progressive deterioration, or simply inadequate maintenance. This is an 85% increase from the number of dams identified as deficient in 1998. Even more noteworthy, is the fact that the majority of these deficient dams are also categorized as high or significant-hazard potential dams, meaning that significant property damage and/or loss of life would be expected in the event that one of these dam's failed (Association of State Dam Safety 21, 2007).

Of the total number of dams listed on the inventory, 1,971 of them are located in the state of New York. 789 of these New York dams have been classified as a significant-hazard, while 378 of them are considered a high-hazard (United States Army Corps of Engineers, 2005). The state of high-hazard and significant-hazard dams is not much better in New York than it is at a national level. Recently, 133 significant and high-hazard dams were also identified as having high-priority deficiencies by Dam Safety officials of the New York state Department of Environmental Conservation (DEC) (Office of the New York State Comptroller, 2008).

Such high-hazard potential dams should be inspected every year according to the *Model State Dam Safety Program* published by the Federal Emergency Management Agency (FEMA) in 1998 and yet, many dam owners do not follow this precaution. Based

on the information given to the National Inventory of Dams only about half of state-regulated high-hazard potential dams follow this suggestion. Due to these problems and the resulting risk to human life, local economies, and the surrounding environment, the American Society of Civil Engineers gave dams in the United States a grade of “D” in its 2005 Report Card for America’s Infrastructure. Recent extreme weather events in the past couple years have also triggered greater concern over the likelihood of the dams classified as deficient failing (Association of State Dam Safety Officials, 2007). With the occurrence of these extreme events only being predicted to increase and the number of aging or non-compliant dams on the rise as well, stricter regulations as well as substantial funding for dam repairs is a necessity (Northeast Climate Impact Assessments Team, 2007).

As is apparent from the large number of dams presently classified as deficient in the United States, there are many examples of structures that need repairing, but this paper focuses on the Gilboa Dam, a dam that engineers declared in 2005 would collapse under extreme weather conditions. The Gilboa Dam is located in upstate New York in the town of Gilboa within Schoharie County and was put into service in 1926. It impounds the waters of the Schoharie Creek to form the Schoharie Reservoir that has a capacity of 19.5 billions of gallons of water (NYC DEP 6, 2007). The Schoharie Creek drains part of the northern slopes of the Catskill Mountains and acts as a tributary to the Mohawk River, which eventually flows into the Hudson River just north of Albany, New York (Lumia, 1996). The Schoharie’s watershed drainage basin is 316 square miles and encompasses 15 towns (NYC DEP 6, 2007).

Both the Gilboa Dam and the Schoharie Reservoir are owned by New York City and are part of the Catskill water supply system that provides the City’s nine million residents with drinking water (NYC DEP 4, 2006). While so many people do depend on this portion of the Catskill system for their drinking water, the neglect in the upkeep of the Gilboa Dam has put others at serious risk if a collapse was to occur. If the dam was to fail, downstream residents would have only minutes to evacuate as it has been estimated that the villages of Schoharie and Middleburgh would be submerged beneath 30 to 40 feet of water (Association of State Dam Safety Officials, 2007). With populations of 1,004 and 1,600 respectively, such flooding would result in the displacement of many families (United States Census Bureau, 2006).The floodwaters would not just be destructive in the immediate area either, but instead, could create havoc in places as far away as 96.56 kilometers (Association of State Dam Safety Officials, 2007).

Besides the Gilboa Dam not meeting New York State’s standards for newly-constructed dams, the Schoharie Reservoir has its own set of problems as well. In part of its journey to NYC, the water from the Schoharie Reservoir travels through the Shandanken Tunnel before emptying into Esopus Creek, but a build-up of sediment within the reservoir has caused increasing levels of turbidity in the creek, affecting the balance of the ecosystem within Esopus Creek. Proposed changes to fix this turbidity problem, which have included a dredging process and a smaller flow of water through the Shandanken Tunnel, will, in turn, affect both the ecosystems of the Esopus Creek and the Schoharie Creek (Cornell Cooperative Extension et al., 2007). Even without the turbidity problem, however, the Gilboa Dam and the Schoharie Reservoir have already changed the ecosystem in both Schoharie and Esopus Creek by affecting the rate of discharge in

each of these rivers. In fact, the impact of dams on the environment has even been compared to the consequences that global warming is now having on our world. Daniel Beard, a recently retired commissioner of the United States Bureau of Reclamation (an agency responsible for the construction of thousands of dams in America), believes that, "Except for global warming, there has been no more drastic human alteration of the landscape in the last fifty years than the damming, regulation, and diversion of the world's rivers (in Pearce, 2006)." Even though many of these modifications have already occurred within both river systems because the Gilboa Dam is now over eighty years old, the effects of global warming, like the more extreme weather patterns that were briefly mentioned earlier, could severely affect the Gilboa Dam and the Schoharie Reservoir's ability to cope with an increased flow, which, in turn, will make a collapse of the dam more likely and will effect the balance in the rivers themselves as well.

Fixing any or all of these problems within this portion of the Catskill system comes with a whole new set of issues to be addressed. Environmentally, the repairs to the Gilboa Dam and the Schoharie Reservoir could have a negative impact on rivers and the organisms that live there. At a social level, maintaining the quality of the drinking water that is being provided to NYC while doing these repairs could prove difficult, while ensuring the safety of the surrounding citizens of the area at the same time. In an economic sense, the funds for the renovation plans to bring the Gilboa Dam up to an acceptable standard may be lacking as well (Cornell Cooperative Extension et al. 8, 2007). According to the United States Bureau of Reclamation, the primary objective of dam owners and regulators should be to guarantee that aging dams "don't create unacceptable risks to public safety and welfare, property, the environment and cultural

resources" (in Bowles et al., 1999). What makes achieving this goal with the Gilboa Dam even more difficult than it would be with any other dam, is the fact that as the dam owner, New York City must keep this objective in mind for both the people living in the City and the people actually living where the Gilboa Dam is located. Competing interests between the population of upstate New York and the population of the City has really politicized the issues that come along with repairing the Gilboa Dam. Thus, while the Gilboa Dam problem is unique because of these differing priorities between NYC and Schoharie watershed communities, NYC's experience in solving the issues will be one that could set a precedent for other dam owners to consider when addressing their own concerns.

As detailed above, the renovation plans for the Gilboa Dam and the Schoharie Reservoir will result in many different outcomes, all of which, however, will have a lasting impact on both the NYC and upstate communities and the ecosystems of the Schoharie Creek and the Esopus Creek. Uncertainty about future environmental conditions only increases the challenge of managing this portion of the Catskill water supply. Furthermore, the population of NYC is expected to increase in the coming years and global warming could affect the availability of water in the northeast, leading to an increase in demand for NYC water from other areas (Commission on Geosciences, Environment, and Resources, 2000). With all these considerations in mind, the purpose of this paper will be to address NYC's management of the Gilboa Dam and Schoharie Reservoir in both a scientific and political manner. This paper will examine previous literature and examples, to analyze whether the NYC Department of Environmental Protection's management plan will be sufficient enough to keep the Gilboa Dam from

failing and what kind of an impact this plan will have on the ecosystem of the affected rivers. In addition, I will attempt to use NYC's experience with the Gilboa Dam to make suggestions for future policies when dealing with dam projects. With the failing state of so many of our current dams in the United States, answering such questions is crucial for avoiding future catastrophes and mitigating the effects our changing environment will have on our dams of today.

2. THE NYC WATER SUPPLY

2.1 The History of the Creation of the NYC Water Supply

As the most populous city in the United States since the 1800s, the demand for drinking water in NYC has been growing steadily as NYC's population has grown as well. Because of this expanded need, NYC has had to explore water supply options past its own wells in the area. For this reason, rivers in upstate New York, like the Schoharie Creek, have been developed by NYC with its own water interests in mind. The Gilboa Dam and the Schoharie Reservoir, the focus of this paper, are products of this increased need for water by NYC residents. In order to understand the complexities and controversy surrounding this part of the particular NYC water supply system, it is essential to know the history behind it (Table 1).

Table 1.Chronology of the NYC population, water supply, and related events (Commission on Geosciences, Environment, and Resources, 2000, NYC DEP 1, 2008, United States Geological Survey, 2008)

NYC Population	Year	Event
250,000	1832	Cholera epidemic strikes NYC
	1835	Great Fire burns much of NYC
312,710	1840	
	1842	Old Croton Reservoir and Old Croton Aqueduct were placed into service. First outside source of water used by NYC
	1873	Boyds Corner reservoir put into service
1,000,000	1878	Middle Branch reservoir put into service
	1890	New Croton Aqueduct placed into service, completing Croton watershed system
	1898	Consolidation of "Greater New York City" – five boroughs
3,500,000	1905	Board of Water Supply created
4,600,000	1911	
	1915	The Ashokan Reservoir and the Catskill Aqueduct were completed.
	1928	The Schoharie Reservoir, the Shandaken Tunnel, and the Gilboa Dam constructed, complete the water supply system in the Catskill watershed
		NYC's plan approved to expand water supply system into the Delaware River watershed
		Lawsuit over the right to use water from the Delaware River, New

		Jersey vs. NYC
	1931	United States Supreme Court authorizes NYC to withdraw up to 1665.58 millions of liters per day from Delaware River headwaters
7,500,000	1936	
	1937	Construction of Delaware system begins
	1944	Delaware Aqueduct is completed
	1950	Rondout Reservoir is finished
	1954	Neversink Reservoir is completed
	1955	Pepaction Reservoir is finished
	1955	100 – year flood hits the Schoharie Valley with a peak discharge of 19,812 cubic meters per second at the Gilboa, NY station on Oct. 16th
7,700,000	1961	
	1964	Cannonsville Reservoir is finished, also completing the Delaware water supply system
7,900,000	1970	
	1975	New York State Pollutant Discharge Elimination System is approved and passed
	1977	Title 6, Part 670 of New York Codes, Rules, and Regulations is implemented
	1987	100 – year flood hits Schoharie Valley again with a peak discharge of 17,190.72 cubic meters per second at the Gilboa, NY station on Apr. 4th
7,300,000	1990	
	1996	National Dam Safety Program created
		Another 100 – year flood hits the Schoharie Valley with a peak discharge of 21,579.84 cubic meters per second at the Gilboa, NY station on Jan. 19th
	1997	Watershed Management Agreement signed
8,008,278	2000	Catskill Mt. Chapter of Trout Unlimited wins a citizen suit against NYC for high turbidity levels in Esopus Creek
	2001	NYC appeals court’s decision in the case against the Catskill Mt. Chapter of Trout Unlimited and loses again
		NYC applies for SPDES permit
	2005	100 – year flood hits the Schoharie Valley with a peak discharge of 14,264.64 cubic meters per second at the Gilboa, NY station on Apr. 3rd
		NYC announced that the Gilboa Dam was below the required standards for dam safety of the DEC
		NYC proposes a plan to deal with fixing the dam and the possibility of a failure in the meantime
	2006	NYC makes several stabilization improvements to the Gilboa Dam, including the installation of and anchoring cables
8,250,567	2007	NYC announces the full scale plan for the complete renovation of the Gilboa Dam

For nearly two centuries, since the founding of NYC in 1625, the NYC relied on local water sources like ponds and wells (Gandy, 1997). By the early 1800s, nearly all of these local sources for water had become scarce and polluted. Wells had become brackish due to saltwater intrusion from the Atlantic Ocean and even the water table was contaminated from surface wastes. Finally, after two major fires in 1828 and 1835, which the City lacked the necessary amount of water to extinguish, and an outbreak of cholera in 1832, NYC decided the development of a better water supply system was crucial to its continued prosperity (Commission on Geosciences, Environment, and Resources, 2000).

Initially, there were attempts by private entrepreneurs to provide water to the city with their own piped supply system, but this system only managed to provide poor quality water to a limited amount of homes. Even with the failure of this private system, NYC residents intensely debated whether the water supply system should remain private or turn public (Gandy, 1997). Eventually, after a proposal was made to dam the Croton River, located in what is now Westchester County, the public became more willing to allow the City government to take charge, because such an endeavor was deemed to be too expensive to be done privately (Commission on Geosciences, Environment, and Resources, 2000). With a majority of the public's consent, the New York State legislature finally passed an act in 1834 that gave NYC the right to build its first municipally owned waterworks (Gandy, 1997).

Based on this approval, the City began its construction of what is now known as the Old Croton Reservoir and the Old Croton Aqueduct in 1837 (Commission on Geosciences, Environment, and Resources, 2000). By the time the system was completed and placed into service in 1842, the NYC population, based on the most recent census,

was the highest of any city in the United States at 312, 710 people (Bureau of the Census 26, 1998). The Croton River dam was approximately 15.5 meters high and 82 meters long, which produced the 2271.25 million gallon storage capacity in the Croton Reservoir. The 35 acre receiving reservoir in NYC was built within the future cite of Central Park (Commission on Geosciences, Environment, and Resources, 2000). When the first supplies of water reached Manhattan, the people of NYC celebrated in a way that had not been matched since America declared its own independence. From that day forward, NYC has always prided itself on having one of the highest quality water supplies of any major city in the world (Gandy, 1997). NYC's Croton River system marked the beginning of the City's development of its own water supply system, an integral part to facilitating urban growth and development according to Gandy (1997), a researcher of the NYC water supply's history. This urban growth continued to occur within NYC as in subsequent decades, the city was forced enlarge the Croton system to meet the rising demand for drinking water. Approximately thirty years later, two more reservoirs, Boyds Corner and Middle Branch Reservoirs, were put into service in what is now Putnam County. By 1890, with the NYC population already breaking the 1 million mark, the New Croton Aqueduct and New Croton River dam (Figure 1) had already been constructed and had begun serving the city population (NYC DEP 1, 2008).

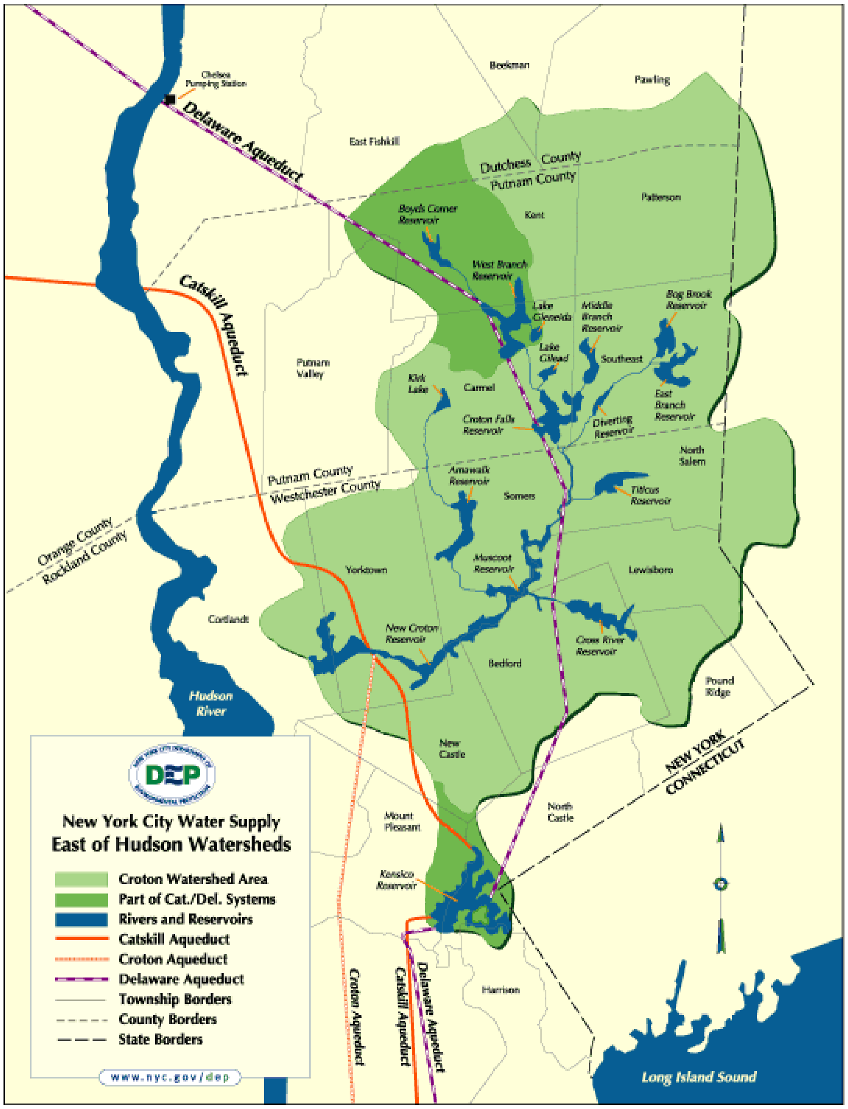

Figure 1. Croton Watershed Map (NYC DEP 2, 2008)

Soon, the Croton system was not enough to meet the needs of the rapidly expanding city. The Board of Water Supply, created by the New York state legislature in 1905, decided to address this growing demand by developing the Catskill region (Figure 2) as an additional water source for NYC (NYC DEP 1, 2008).

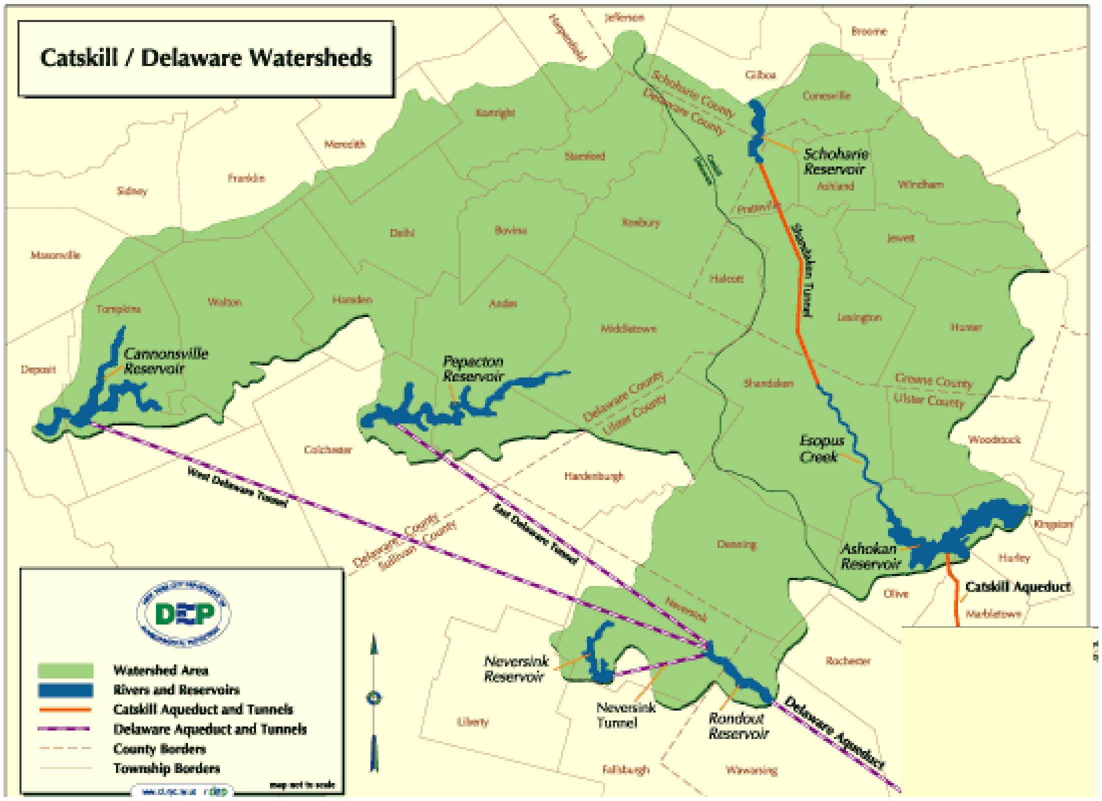

Figure 2. Catskill/Delaware Watershed Map (NYC DEP 2, 2008)

Through the beginning of the 20th century, NYC extended its water supply system into the far larger and much more distant Catskill region using state-of-the-art technologies and the expertise of engineers in the management of urban space (Gandy, 1997). Located in Ulster County, the Ashokan Reservoir and the Catskill Aqueduct were the first developments within the Catskill system and make up part of the of the Esopus Creek drainage area. In 1928, NYC furthered this development, with the completion of the Gilboa Dam, the Schoharie Reservoir, and the Shandaken tunnel. The Gilboa Dam is located in Schoharie County, while the Schoharie Reservoir and the Shandaken Tunnel are both in Greene County.

Before long, the NYC Board of Water Supply began considering another area to expand its sources for water even further. This time, NYC looked to the Rondout

watershed and the tributaries of the Delaware River within New York State as the next best option for capturing water. The project was approved in 1928, but construction of the Delaware Aqueduct was delayed after a lawsuit was brought to the United States Supreme Court by the state of New Jersey, challenging the right of New York State and NYC to use the water from the Delaware River (NYC DEP 1, 2008). The lawsuit was the first time ever that local citizens had disputed the right of NYC to construct its dams and reservoirs in areas outside of NYC. With the Delaware River Basin located almost 100 miles away from NYC, the state of New Jersey questioned the legitimacy of NYC undertaking a project such as this (Delaware River Basin Commission 2, 2004). In its natural flow, the Delaware River drains into Pennsylvania, the state of New York, and New Jersey, but its course does not naturally run into NYC (Figure 3).

Figure 3. The Delaware River watershed (Pennsylvania Sea Grant et al., 2008)

At this time, and even still today, Philadelphia and parts of New Jersey depend on the river for their water supply and the entire length of the river is a valuable habitat and source of recreation for many people. With such multiple demands, the competition for the use of water from the Delaware River is very high (Delaware River Basin Commission 2, 2004). For this reason, New Jersey insisted to the United States Supreme Court that in this case of water rights, the same rules should be applied that govern stream owners who are from the same state (Simsarian, 1938).

Even with such intense competition for water use and New Jersey's request for a strict adherence to the common water laws already in place, the United States Supreme Court ruled in favor of NYC, issuing a decree that authorized NYC to divert up to 1666 million liters of water per day from the Delaware River basin to its own water supply system. The decree also stated that NYC must maintain a specified flow in the Delaware River at Port Jervis, New York by releasing a sufficient amount of water from the reservoirs it constructed. The states of New Jersey and Pennsylvania were given the right to inspect any of the dams, reservoirs, or other structures built by NYC on the Delaware River as well (Supreme Court of the United States, 1931). The decree was the result of the United States Supreme Court's belief that a more liberal rule could be applied to this case than in one where the neighbors were members of a single state. According to the United States Supreme Court, different considerations must be taken into account when dealing with independent states having to deal with the general welfare of an entire population and when the alternative to settlement is war. The navigability of the tributaries was also taken into account by the United States Supreme Court and it was

found that the proposed water diversion by NYC would not impair the navigable capacity of the tributaries at all (Simsarian, 1938).

With the United States Supreme Court's decision, NYC was allowed to continue the construction of the Delaware Aqueduct, completing it in 1944. Within 10 years, NYC built two more reservoirs in the area, the Rondout Reservoir, located in Ulster County, and the Neversink Reservoir, located in Sullivan County (Figure 2; NYC DEP 1, 2008). Within the next decade, also came an amendment to the Supreme Court's first decree on diverting the waters of the Delaware River. Created in 1954, the new amendment allowed NYC to divert an average of up to 3028 million liters of water per day, providing that NYC would also release enough water from its reservoirs to retain a basic flow rate of about 50,000 liters per second in the Delaware River at Montague, New Jersey. Another change in the decree was the establishment of a River Master (Delaware River Basin Commission 1, 2004). While appointed by the United States Supreme Court, the River Master was employed by the United States Geological Survey (United States Geological Survey, 2008) Part of this person's duties as the River Master was ensuring that the measures of the 1954 decree were being met (Delaware River Basin Commission 1, 2004). Eventually, to finish the Delaware River system, two more reservoirs were built in Delaware County, the Pepaction and Cannonsville Reservoirs (Figure 2; NYC DEP 1, 2008).

2.2 The NYC Water Supply System Today

When the NYC water supply system was finally completed in 1967, it consisted of the largest watershed in the United States, spanning nearly 5180 km^2. It now connects a total of 19 up-state reservoirs, two down-state reservoirs, two city water tunnels, and

two in-city balancing reservoirs, which have a total storage capacity of 2196 billion liters (Gandy, 1997). Normally, ten percent of New York City's water is provided by the Croton River System, while the other ninety percent comes from the Delaware and Catskill System (Murphy et al., 1995). In 2006, however, the Croton System was not used as part of the City's water supply because a new filtration plant was being constructed to bring the system up to the standards for drinking water quality (NYC DEP 4, 2006).

2.3 The History of NYC's Water Supply Management

After NYC decided to expand its water supply system beyond its own local sources, its management of water became increasingly centralized and supply oriented. NYC also took on much more of a state-coordinated approach to public policy as the area of its water supply system increased. This "municipal managerialism", as researcher Matthew Gandy (1997) describes it, lasted until the 1970s because the primary concern of water policy at the time was to meet the increasing demands of the public. By leasing the city's water to a central authority, the NYC Water Board, meeting these demands was much easier to accomplish. In fact, it was not until the mid-1970s that the NYC attitude began to change with regard to water policy. During this time, the public, with an increased environmental awareness, shifted its primary concerns from simply wanting its water demands met, to wanting the guarantee of a clean and healthy water supply. As the areas within NYC's upstate watersheds continued to develop after World War II, the water quality within these areas became a serious issue due to its associated risk with public health. The public interest in the environmental aspect of its water supply is

apparent when examining the trend in NYC's water consumption over time (Figure 4; Gandy, 1997).

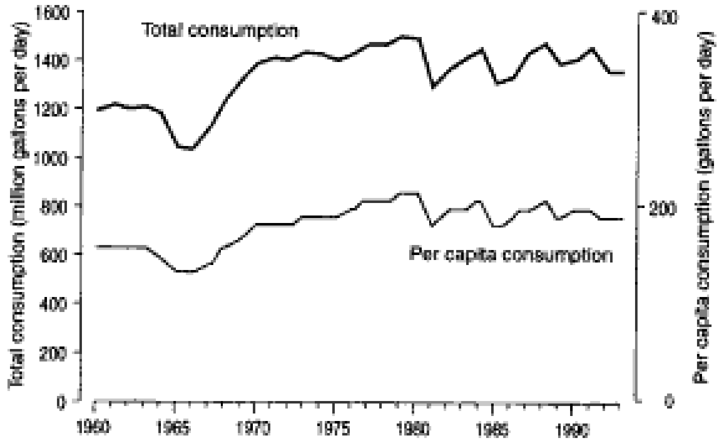

Figure 4. Changing levels of city-wide and per capita water consumption in NYC from 1960 to 1993 (Gandy, 1997).

The period up until the 1980s shows a steady rise in the total consumption of NYC residents and the per capita consumption of NYC residents. This trend begins to change as agencies like the Department of Environmental Protection were created to take control of regulating the water supply system and new polices on water conservation were adopted (Gandy, 1997).

Beyond environmental issues, economic pressures have also influenced NYC's management of its water supply system. In 1995, the mayor of NYC at the time, Rudolph W. Giuliani, proposed a plan to sell NYC's entire water system to the NYC Water Board, in order to help with the city's growing budget deficit. While the selling of the water system may be an economically viable solution for NYC in the short term, it actually could have hurt NYC in the long run, which is why Giuliani's plan was never followed.

Opponents of the idea felt that selling the water system would make it easier for the New York State governor to change the composition of the Water Board's members to favor upstate interests (Gandy, 1997). The primary difference between upstate and NYC interests with concern to the NYC water supply is that as upstate New York continues to develop, this suburbanization increasingly becomes a threat to the safety of NYC's water. This is because the watershed where NYC's drinking water originates is in these developing areas in upstate New York and the quality of drinking water depends on its source. For this reason, it is of utmost importance for NYC to protect its watershed (Commission on Geosciences, Environment, and Resources, 2000). Thus, a change in control of the NYC Water Board could make the construction of water filtration plants in the Catskill-Delaware systems much more likely because of the city's need to comply with the Safe Drinking Water Federal Act of 1989. Constructing these water filtration plants, however, would be financially detrimental to NYC, costing an estimated $8 billion (USAID Water Team, 2006). Since this conflict, there has been an increased polarization between the interests of upstate communities and the interests of NYC residents, creating a lot of resentment between the two.

To avoid the cost of building these filtration plants, however, NYC proposed a long-range watershed protection plan to the United States Environmental Protection Agency (EPA) as a way to comply with the Safe Drinking Water Act without a large expense. Although these talks began in 1993, it was not until January 21, 1997 that an agreement was actually signed by NYC and upstate watershed communities. This agreement, called the Watershed Memorandum of Agreement (MOA), commits NYC to a long term watershed management program in exchange for an EPA waiver from

filtration. There are a number of different provisions within the MOA that NYC must also follow. One of these provisions is the Land Acquisition and Stewardship program, which lets the city buy undeveloped land near its own reservoirs or other water quality sensitive areas. Not only does this ensure greater control over the water quality within NYC's supply system, but it also enhances the recreational value of this land as in many cases the city keeps the land open for recreational purposes (USAID Water Team, 2006). Another provision in the agreement is that NYC must make payments to watershed communities in order to support local economic development, while promoting watershed protection at the same time (Commission on Geosciences, Environment, and Resources, 2000) If necessary, NYC is also required to give supplies of drinking water to municipalities and water districts in the counties where its water supply facilities and watersheds are located (NYC DEP 6, 2007). The final provision of the MOA involves ongoing regulations on activities within the watershed, which have emerged through the creation of a Watershed Council that represents both city and upstate interests in overseeing the protection of water quality. This new institution is a shift from the former centralized regulatory system, and instead is a forum composed of many different participating groups with varying interests from around the entire region (Gandy, 1997).

Still, even with the creation of the MOA, NYC has, for the most part, maintained primary control over its own water supply system. Other cities, like Boston for example, have not retained this kind of control. Boston began conveying its system to separate entities beginning with the Metropolitan Water District in 1896 and then a state agency called the Metropolitan District Commission in 1919. Since 1985, however, a new regional agency, the Massachusetts Water Resources Authority has been in control of

Boston's water supply. According to the Commission on Geosciences, Environment, and Resources, it may be these differences that account for why NYC has encountered such hostility from the communities where its watersheds are located, while cities like Boston have not (Commission on Geosciences, Environment, and Resources, 2000).

2.4 The Gilboa Dam and Schoharie Reservoir System

Today, these varying interests between NYC and upstate New York communities are most evident when examining the Gilboa Dam and the Schoharie Reservoir System. As mentioned above, the Gilboa Dam and the Schoharie Reservoir are both located on the Schoharie Creek, a river that drains part of the northern slopes of the Catskill Mountains. The primary tributaries that drain into the Schoharie Creek are the East Kill, West Kill, Little West Kill, Batavia Kill, Huntersfield Creek, and the Johnson Hollow Brook (Catskill Streams, 2008). The Schoharie Creek is itself a tributary and flows into the Mohawk River, which also is a tributary, flowing into the Hudson River. The Schoharie runs a total of 133.575 kilometers and makes up a 1485 km^2 drainage area (Figure 5; Lumia, 1996). This drainage area includes parts of fifteen different towns: Ashland, Cairo, Durham, Halcott, Hunter, Jewett, Lexington, Prattsville, and Windham in Greene County, Broome, Conesville, Gilboa, and Sullivan in Schoharie County, and Roxbury and Stamford in Delaware County (Figure 6; NYC Water Supply Watersheds).

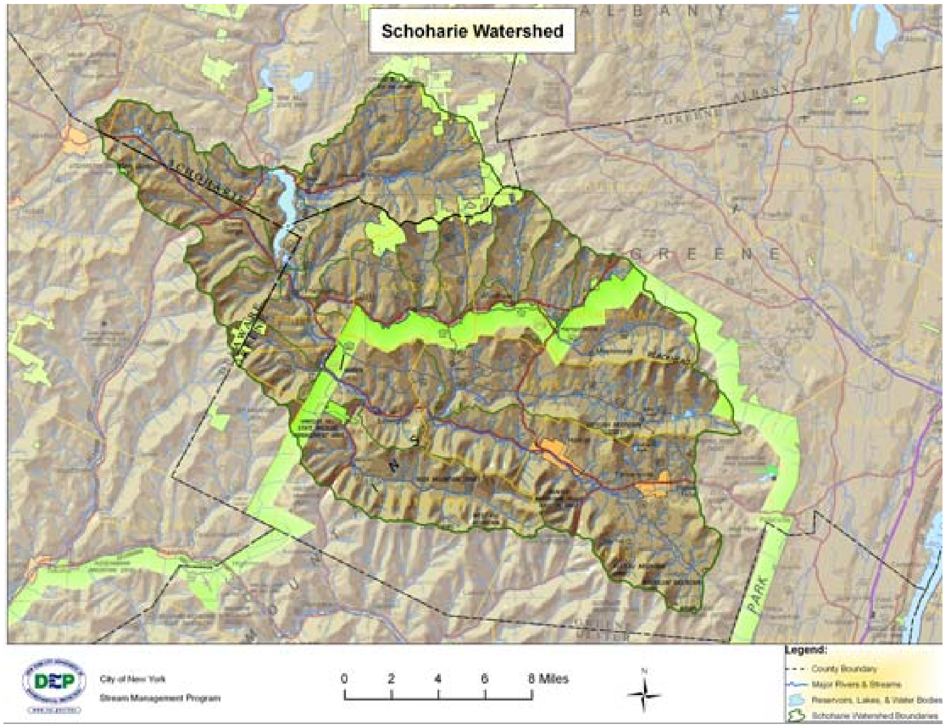

Figure 5. Map of the Schoharie Creek Drainage Basin (Catskill Streams, 2008)

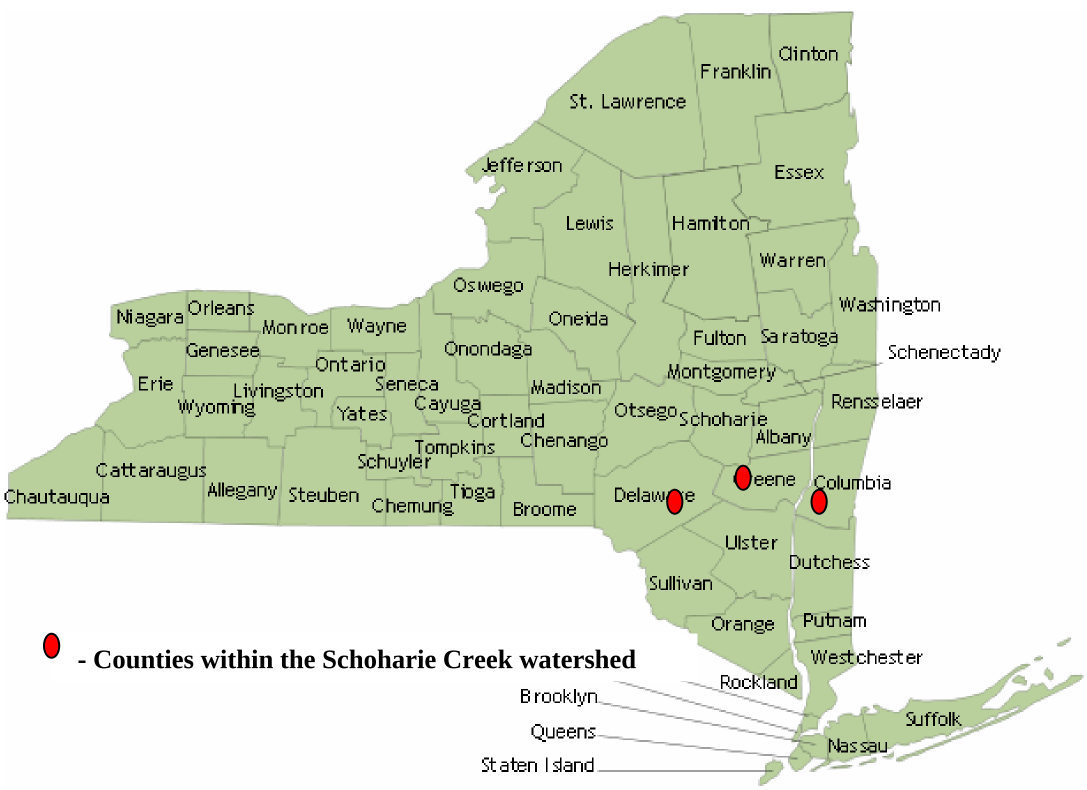

Figure 6. Counties within the Schoharie Creek watershed (NYS Department of Health, 2006)

While the natural course of the water in the Schoharie Creek's is to empty into the Mohawk River, there are currently two dams along the Schoharie Creek that alter the water's path. One of these dams is the Blenheim-Gilboa Pumped Storage Power Project, a hydroelectric facility owned by the New York Power Authority. Located in Schoharie County, the Belnheim-Gilboa draws water from the Schoharie Creek, which will then either be used to generate power or will be stored in one of the two reservoirs within the system. If necessary, it can generate more than 1,000,000 Kw of electricity during peak periods and helps provide New York consumers with cheaper and environmentally-friendlier electricity (New York Power Authority, 2008).

Farther upstream on the Schoharie Creek, however, is the focus of this paper, the Gilboa Dam. The now 81 year old dam impounds the water of the Schoharie Creek to form the Schoharie Reservoir (Kelly 1, 2008). It is 55 m high and 585 m long (DePalma, 2005). The dam is composed of an earthen embankment and a concrete spillway, but it has been the deterioration of its stone facing over the past twenty-five years that has led to concern over its possible failure (NYC DEP 7, 2005).

The water that will eventually travel to NYC is first collected in the Schoharie Reservoir, providing 16 percent of the City's water supply (NYC DEP 3, 2007). The majority of this water is from the Schoharie Creek, 75% of it, but two smaller streams also flow directly into the reservoir, the Manor Kill and the Bear Kill, providing the remainder of the water within the reservoir (NYC DEP 8, 2007). From the Schoharie Reservoir, the water is then withdrawn via an intake chamber in the north end of the reservoir into the Shandaken Tunnel, where the water is transported 28.9681 kilometers and released into the upper portion of the Esopus Creek. The Esopus Creek drains into

the Ashokan Reservoir, which is part of the Catskill Aqueduct System that then travels on to the Kenisco Reservoir. Ultimately, this system drains from the Croton Aqueduct into the Hillview Reservoir in Westchester County, which is the final storage point before the water is distributed within the NYC water supply (Figure 7; Cornell Cooperative Extension et al., 2007).

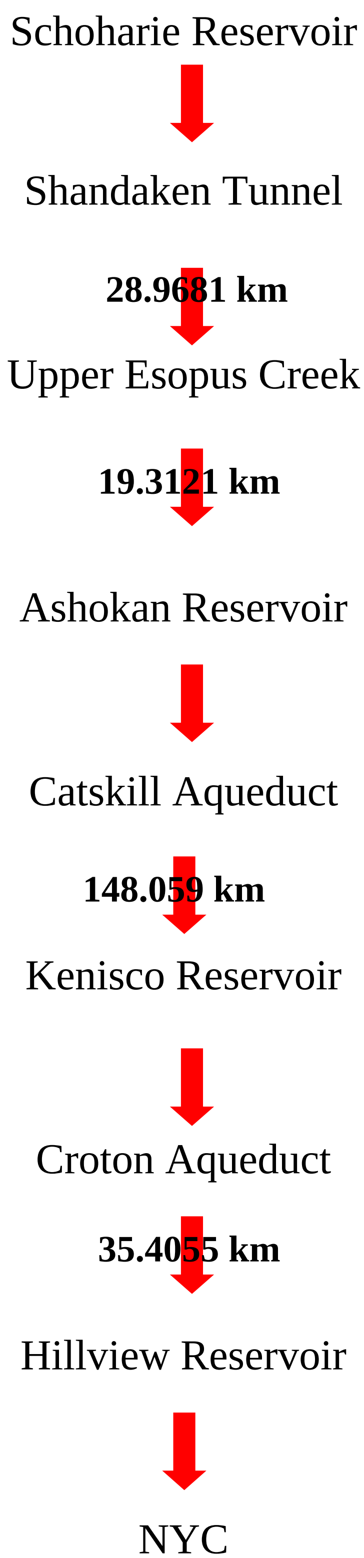

Figure 7. Course of water from the Schoharie Reservoir to NYC (Catskill Watershed Corporation, 2005; Cornell Cooperative Extension et al., 2007)

3. THE MANAGEMENT AND IMPACT OF DAMS IN GENERAL

3.1 The Characteristics of the Gilboa Dam

The Gilboa Dam is composed of an earthen embankment and a concrete spillway (NYC DEP 7, 2007; Figure 8). Embankment dams are completely made of natural materials, typically either earthfill or rockfill. This type of dam is the most common throughout the United States. It relies solely on its weight to resist the force of the water and it also has a waterproof core that prevents any water seepage from occurring through the structure (PBS, 2001). In the case of the Gilboa Dam, it is comprised of earthfill, but also has a concrete spillway (NYC DEP 7, 2007). A spillway is an overflow channel that allows the release of water when it gets high enough to threaten the safety of the dam (PBS, 2001).

Figure 8. Gilboa Dam and the Schoharie Reservoir (Pytlovany, 2006)

3.2 The Environmental Impacts of Dams

Much of the controversy surrounding the Gilboa Dam not only centers upon its social impacts, but upon its environmental effects as well. The impacts a dam can have on a river system are numerous and many of them are just becoming evident today. The reason that these environmental costs have only recently been recognized is because most of the dams built in the United States were constructed between the 1950s and 1970s, meaning that many of the effects of these dams have not matriculated until now (Graf, 1999). The environmental effects of dams, however, are wide-ranging, with some of them simply due to the existence of the dam and the reservoir, while others occur because of the way the dam has been managed.

As soon as a dam is built, for example, a large area of the river valley is flooded, resulting in a loss of habitat for many different species, both terrestrial and aquatic. The river valley is filled by the resulting reservoir, which for the most part is a very uniform environment where a smaller variety of species will be able to live (Bocking, 1998). The construction of dams also impacts species living within the actual river the dam is being built upon. Many of these impacts are due to a change in sediment load. Because dams store much of the sediment that enters their reservoirs, the movement of these materials is disrupted and does not integrate through the river system as it once would have (Graf, 1999). A smaller sediment load can change the morphology of the riverbed and banks, which in turn affects the type of organisms that can live in the river under these new environmental circumstances (Bocking, 1998).

One of the largest ways, however, that dams have altered the river ecosystems upon which they are built is through changes in river flow patterns. In fact, William L. Graf, a researcher of dams, states that because of the storage capacity of dams, they can change river discharges to a much greater degree than any anticipated alterations due to climate change. Graf also states that some scientists have predicted a 15% to 20% change in annual water yield because of climate change, but that dams in many regions already have storage capacities larger than the area's natural runoff and have reduced downstream flow by almost 100% (Graf, 1999). These changes are not just in total annual stream flow either, but also in seasonal timing and even in hourly fluctuations in discharge (Bocking, 1998). Because many times dams release water at times and rates that are different from the river's natural rhythms, the ecosystem of the river can be greatly affected (Graf, 1999). A shift in peak discharge from the spring to winter months, for example, can have a substantial impact on migration and breeding patterns of species with a river. Changes in flow can also affect the water quality within the river. When water is held within a reservoir for long periods of time, its temperature can change, its nutrient load may increase, and its turbidity may increase as well (Bocking, 1998).

Ultimately, each of these impacts, the flooding of river valleys, changes in sediment load, and changes in discharge, combined with the fact that dams serve to segment and fragment watersheds, results in a reduction in the overall biodiversity of the affected areas. With the impact of dams spreading so far and reaching such a variety of organisms within the food chain, understanding these effects is crucial. Interestingly enough, as more and more people become concerned over the effect that climate change will eventually have on our rivers, the hydrologic effects of this still remain speculative.

The impacts of dams are happening now and are measurable as well, which means that correctly managing dams to mitigate these effects is a necessary and achievable goal (Graf, 1999).

3.3 Dam Management in the United States

Based on a history given by the Association of Dam Safety Officials, the United States did not begin to recognize the need to address the failing state of thousands of dams across the nation until the 1970s (Table 2).

Table 2. Chronology of Dam Management in the U.S. (National Performance of Dams Program 2, 2004; Gardner, 2007)

Date	Event
1970	USCOLD publishes *Model Law for State Supervision of Safety of Dams and Reservoirs*
Feb 26, 1972	Dam failure on Buffalo Creek in West Virginia
Aug 8, 1972	Enactment of National Dam Inspection Act
May, 1975	USACE completes and presents the National Inventory of Dams as required by the National Dam Inspection Act
Jun 5, 1976	Failure of Teton Dam in Idaho due to internal erosion
Nov 6, 1977	Failure of the Kelly Barnes Lake Dam in Toccoa, Georgia
1979	Federal Guidelines for Dam Safety published
1980	Interagency Committee for Dam Safety created
1983	*A Report on Review of State Non-Federal Dam Safety* published, showing the lack dam safety programs in individual states
June 20, 1984	Formation of the Association of State Dam Safety Officials
October 12, 1996	The Water Resources Development Act passes, establishing the creation of the National Dam Safety Program Act
2002	National Dam Safety Program Act is reauthorized through the Dam Safety and Security Act.
2005	U.S. infrastructure receives a grade of “D” by the American Society of Civil Engineers NYC DEP announces the possibility of the Gilboa Dam failing
2006	National Dam Safety Act passes, granting greater assistance to states

Feb 15, 2007	H.R. 1098 National Dam Rehabilitation and Repair Program is introduced

During this time, a number of catastrophic dam failures occurred, finally bringing the nation's dam problem to the attention of not only the United States government, but the public as well (Gardner, 2008). In particular, it was the failure of a dam along Buffalo Creek in West Virginia in February of 1972 that led to the federal government passing the National Dam Inspection Act (Public Law 92-367) that same year (Table 2, National Performance of Dams Program 2, 1994). This act appointed the USACE with the responsibility of inspecting all of the dams within the United States in order to discover any hazardous conditions that might harm human life or property. Based on each of these inspections, the act also required the USACE to give a full report to Congress which included an inventory of all the dams in the United States, a review of each inspection made and the recommendations given after these inspections, and a proposal for a national program for the inspection and regulation of dams (National Performance of Dams Program 1, 1994). The inventory which the USACE eventually completed has become known as the National Inventory of Dams. Open to the public, it provides the location, owner name, owner type, drainage area, and hazard level of every dam in the United States (United States Army Corps of Engineers, 2005). Building on these improvements, the government published Federal Guidelines for dam safety in 1979 (National Performance of Dams Program 2, 1994). In 1980, also came the creation of the Interagency Committee for Dam Safety. This agency was established to encourage the creation and maintenance of federal programs, policies, and guidelines for dam safety and security. While FEMA chairs the organization, a number of different agencies are involved in the group including, the Department of Agriculture, the Department of

Defense, the Department of Energy, the Department of the Interior, the Department of State, International Boundary and Water Commission, and the Tennessee Valley Authority (FEMA, 2007).

As dam safety regulations continued to improve and become a focus at the federal level, the importance of addressing some sort of state dam safety program became more and more apparent since only 4.7% of all the dams in the National Dam Inventory are federally owned (Figure 9).

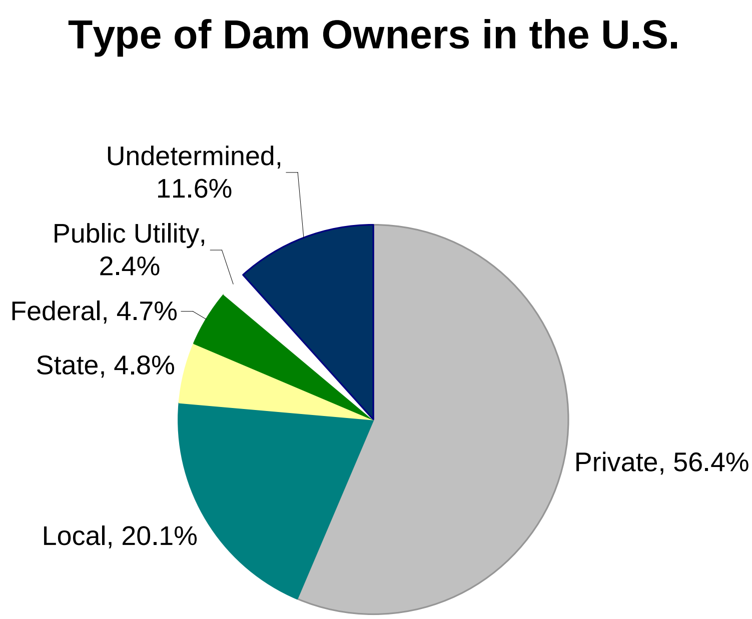

Figure 9. Percentage of each type of dam owner in the U.S. (FEMA, 2007)

Dam ownership in the United States varies greatly (Figure 9), with the most dams by far being privately owned and the next greatest percentage being locally owned, as is the case with the Gilboa Dam. Because there are so many different types of owners, creating regulations pertaining to dam safety has been a difficult task for the American government outside of managing its own federal dams. For this reason, the government must coordinate the activities of dam management at a federal, state, and local level in

order to fully ensure the safety of the citizens living near a dam (FEMA, 2007). The United States Committee on Large Dams (USCOLD) was one of the first organizations to recognize the need of a state dam safety program with its publication of a *Model Law for State Supervision of Safety of Dams and Reservoirs* in 1970. The model established guidelines that states would follow when trying to implement their own regulations and management criteria for dams (Gardner, 2008).

By the mid-1970s, two more major dam failures led to an even greater review of the United States policy towards dams. The failure of the Teton Dam in Idaho in 1976 and the failure of the Kelly Barnes Lake Dam in Toccoa, Georgia in 1977 both resulted in another widespread review by the United States government of its own management and policies towards dams (National Performance of Dams Program 2, 1994). FEMA was one federal agency in particular that was becoming increasingly concerned about the lack of state dam safety laws. Because of this concern, FEMA decided to fund a National Research Council Committee on Safety of Non-Federal Dams. The committee's report, which was published in 1982, confirmed what many organizations had been saying for the past decade. There was a great need for better state dam safety programs, and better interstate dam safety communication as well. One year later, a follow-up report was published by a National Research Council called *Safety of Existing Dams*, which focused more on the technical aspects of dam safety and what sort of remediation was available. FEMA also sponsored dam research for another group headed by Dr. Bruce A. Tschantz that published its landmark assessment in 1983 too. Titled, *A Report on Review of State Non-Federal Dam Safety*, the findings were based on a questionnaire sent out to all 50 states and showed that over half of them had no dam safety laws and no dam safety

programs. The report also expressed many of the states' desire to share information with other states in order to create the best dam safety program possible. As the necessity of interstate communication about dam safety became more and more obvious, several meetings were held between FEMA employees and members of the Council of State Governments, an already existing entity focused upon the sharing of ideas between states. The purpose of these meetings was to create some sort of association to help with increasing communication between states about dam safety. The result was the creation of the Association of State Dam Safety Officials (ASDSO), forming officially in 1984 (Gardner, 2008).

With the formation of the ASDSO, states were finally working together towards the common goal of developing and improving dam safety programs. As the national focus on dam safety became greater and greater, many states, including New York where the Gilboa Dam is located, finally began to make their own improvements in the management of dams. In the state of New York, the Department of Conservation (DEC) has been in charge of the inspection and maintenance of dams (New York State Department of Environmental Conservation 1, 2008). The New York State DEC, however, did not officially begin implementing its own dam safety regulations until the year 1985 when it first passed Part 673 – Dam Safety Regulations of Title 6 of the Official Compilation of Codes, Rules, and Regulations of the state of New York. Part 673 created a hazard classification system and a condition rating for New York dams, while also establishing the investigation procedure the DEC would follow to assign these ratings. (New York State Department of Environmental Conservation 2, 2008). Each dam was classified as a low, medium, or high hazard not based on its condition, but on its

threat to downstream communities and infrastructure in the event of a failure (New York State Department of Environmental Conservation 3, 2008). The owner of any dam that was found unsafe would then be notified by the DEC, which would then provide the owner with a recommended action to bring the dam to a satisfactory safety level (New York State Department of Environmental Conservation 2, 2008).

Building upon this legislation, the New York State DEC furthered its improvements in dam management by publishing its own manual on dam safety in 1987. This manual was the first time that the state of New York had officially recognized that a plan was necessary to mitigate the risk that dams pose to surrounding communities. Made with the help of funding from FEMA, the plan consists of several different guidelines including how to create a dam safety program, proper inspection of dams, the instrumentation and monitoring of dams, the maintenance of dams, and an emergency action plan in case of a dam failure. The manual also directly cites that the legal and moral responsibility of dam safety rests with the dam owners. This fact is essential to understanding dam safety because it shows that it is up to the owners of dams to be sure that their dams are within compliance of state and federal regulations regarding dam safety (DEC, 1987).

Even with accomplishments like the New York state manual for dam inspection and maintenance that was produced with the help of FEMA and the New York state DEC, there was still the need for even greater coordination between federal agencies, states, and other dam owners in order to promote responsibility in dam management (FEMA, 2007). Under the Water Resources Development Act of 1996, the National Dam Safety Program was able to serve this purpose (National Performance of Dams Program

2, 2004). This program is administered primarily by FEMA, but also by the Department of Homeland Security and is made up of three different components (Association of State Dam Safety Officials, 2007). It grants assistance to state dam safety programs, providing extra support to these programs which regulate a majority of the dams in the United States (FEMA, 2007). States can use this grant money in any way they deem best suited for their area (Association of State Dam Safety Officials, 2007). Besides allotting money to every state, the National Dam Safety Program also set up a program for dam safety research and for dam safety training, which is provided to all state inspectors and staff (FEMA, 2007). Since the programs creation, it has been reauthorized twice, once through the Dam Safety and Security Act of 2002 and then again in 2006 with the passing of the National Dam Safety Act. After its most recent reauthorization, the program's funds were given modest increases providing $38.7 million over 5 years in grant assistance to states, $3.25 million over 5 years for dam safety training, and $9 million over five years for research.

The latest dam legislation that has been introduced to Congress is the National Dam Rehabilitation and Repair Program. Vigorously supported by the ASDSO, the program would be federally administered, but the funding from it would be a shared cost between local, state, and federal governments, with the federal government providing 65% of funding and state and local governments providing 35% (Association of State Dam Safety Officials, 2007). The program would actually be apart of the National Dam Safety Program and all of the funding would used as grants to assist states in the repair and rehabilitation of dams (GovTrack.us, 2007).

While no new legislation has actually been passed at the federal level for some time, the New York state DEC just recently repealed all of Part 673 – Dam Safety Regulations in order to incorporate certain amendments to the regulations. The biggest change to Part 673 comes in the form of a new section that outlines stricter and greater responsibilities for dam owners in the state of New York. Some of the new regulations that dam owners must comply with include: new requirements for record keeping, inspection and maintenance plans, scheduled inspections by a professional engineer hired by the dam owner, requirements to develop and submit an emergency action plan annually, and the issuing of annual certifications in order to ensure that all dams are up to standards with the new regulations. The hazard classification system for dams was slightly changed as well, with new labels for high, intermediate, and low hazard dams. If the proposed amendments passed, low hazard dams would become known as Class A dams, intermediate dams would become Class B dams, and high hazard dams would become Class C dams. After the changes to Part 673 had been released, the Commissioner of the New York state DEC, Alexander B. Grannis, declared, "These draft regulations increase DEC's enforcement authority, bring New York's program in line with federal standards and make clear that dam safety is foremost the responsibility of the owner (New York State Department of Environmental Conservation 3, 2008)." While the more stringent regulations show that the New York state DEC is taking the risk associated with dams more seriously, some members of local New York communities argue that the DEC has still not gone far enough to ensure the safety of everyone living near a dam (Dam Concerned Citizens Inc. 80, 2008).

In addition to this revamping of the state's dam safety regulations, the New York state DEC has been putting forth a newfound effort to enhance its dam safety program in general. The number of dam safety staff members has increased from just three people to twenty and the number of inspections being completed has risen as well, with more than 250 dam inspections being completed last year. The DEC has also taken a role in the educational and training aspect of dam management by offering seminars about dam safety to dam owners and those with an invested interest in maintaining dam safety guidelines (NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION 3, 2008).

Even with so many breakthroughs in the management of dams in the United States, however, neither the legislation in place today at the state level nor at the federal level comes close to ensuring dam safety at an adequate level. One instance of the limitations of the current laws is the amount of funding given to the National Dam Safety Program. After its reauthorization, the program was set to receive a moderate increase in its budget, and yet this increase has not yet been included in FEMA's latest budget. In fact, the funding levels for the State Grant Assistance Program have been steadily decreasing over the past five years. New York, for example, was supposed to receive an annual grant of $149,295 between 2003 and 2006 if FEMA fully funded the National Dam Safety Program. Instead, New York only received $87,074 in 2003 and even less, $77,844 in 2004. According to the ASDSO, full funding of these grants is very important for states to be able to hire more dam safety inspectors for better enforcement of regulations that prevent dams from becoming unsafe structures (Association of State Dam Safety Officials, 2007). With all of the legislation that has been passed, dam safety

inspections are still rare occurrences. A report by Environmental Advocates of New York found that just 10% of New York's low hazard dams had been examined during the last decade, while high hazard dams are inspected about every two years (Bruno, 2007). As is apparent then, just creating the legislation to enact dam safety programs is not enough. Funding is and will continue to be a key issue in ensuring that all of the dams in the United States will eventually meet the requirements for dam safety. The American Society of Civil Engineers expressed the necessity of this idea in their 2005 Report Card for America's Infrastructure saying, "The combined effect of rapid downstream development, aging/non-compliant structures, and inadequate past design practices, coupled with a predicted increase in extreme events demands fully funded and staffed dam safety programs, as well as substantial and proactive funding for dam repairs (Association of State Dam Safety Officials, 2007)."

4. THE ISSUES SURROUNDING THE GILBOA DAM AND ITS POSSIBLE FAILURE

4.1 The Possible Failure of the Gilboa Dam

In November of 2005, NYC announced that the Gilboa Dam was well below the standards for dam safety required by the New York state DEC. While NYC officials tried to calm locals after the announcement was made by saying that the chance of the Gilboa Dam failing was remote and would only occur in the event of a record storm and snow melt, residents of the area still felt the safety of their homes and lives were at too much of a risk of being destroyed. In the wake of the Hurricane Katrina disaster in New Orleans, the mood of local citizens was especially distrusting of the NYC DEP's assurance that the likelihood of failure was slim. However, according to Emily Lloyd, the commissioner of the NYC DEP, the dam was safe under normal conditions, and only if a 10,000 year flood was to occur would the dam not have enough strength to cope with the excess water pressure. A 10,000 year flood would be the result of 63.5 centimeters of rain in 72 hours and would push the water of the Schoharie Creek over the Schoharie Reservoir at a historic flood elevation level (DePalma, 2005). This historic flood level would mean the water of the Schoharie would have to rise 2.01 meters over the current spillway of the Schoharie Reservoir, which is at a height of 344 m. Based on an assessment done by the NYC DEP, 1.52 m over the spillway would constitute a major flood stage, while 0.91 m over would be a moderate flood stage, and 0.61 m would be classified as a minor flood stage (NYC DEP 7, 2007).

For most citizens, however, it has been questionable whether the deteriorating conditions of the Gilboa Dam would be able to withstand the extreme weather conditions that have become more and more common in the area. One resident of Schoharie, Howard Bartholomew, who has lived downstream from the dam his entire life, cited the deterioration of the dam as "appalling", while another nearby resident, Gail S. Schaffer called NYC's lack of maintenance and upkeep of the dam "borderline negligence". When NYC announced the possibility of the dam failing, its hazardous conditions were apparent. Thick bluestone blocks, once about 1 meter thick, on the downstream side of the dam had been washed away, steel reinforcing bars had been exposed, and much of the concrete part of the dam had been pockmarked with holes as well. Even with these small holes in the concrete, Rodney E. Holderbaulm, a consulting engineer that was hired by NYC to inspect the dam, believed that the main concern with regard to the dam failing was not the erosion of the concrete, but the weak bedrock underneath the dam that could cause it to slide out of place if a major storm was to occur (DePalma, 2005).

According to the ASDSO, if the Gilboa Dam ever was to collapse, residents in the area would have mere minutes to escape. Schoharie and the nearby village of Middleburgh would be underneath 9.14 to 12.19 meters of water and areas as far away as 95.56 kilometers would be affected by the flooding as well (Association of State Dam Safety Officials, 2007). This means that even Schenectady and Scotia would be affected by the failure of the Gilboa Dam, experiencing some amount of flooding (Pytlovany, 2006).

4.2 Changing Climatic Conditions

The NYC DEP has emphasized time and time again that the possibility of the Gilboa Dam failing has been more a result of a shift in weather patterns than a sudden deterioration of the dam. These changes in the climate of Schoharie can almost certainly be attributed to global warming according to the *Northeast Climate Impact Assessment* (*NCIA*), a report developed by collaboration between the Union of Concerned Scientists and a team of more than fifty independent experts on climate change. According to the *NCIA*, the warming that has been occurring across the Northeast can also be correlated with several other climate-related changes including, less precipitation falling as snow and more as rain, an earlier breakup of winter ice on lakes and rivers, and an earlier spring snowmelt. The *NCIA* also specifically cites an 8% rise by the mid-century in the number of heavy-precipitation events, which is defined as more than 5.1 cm falling in 48 hours. In addition to these extreme precipitation events, there is expected to be increases in precipitation intensity by 8% to 9% as well, meaning that wet days will become wetter. Furthermore, more rain is being projected to fall during the wettest five-day periods of each year (NCIA, 2007).

The effects of climate change that the NCIA has cited are actually already evident in the Schoharie Valley. Based on discharge data gathered from the Schoharie Creek over a period of 66 years, it does appear as if the total discharge of the Schoharie has been increasing in the most recent decades (Figure 10).

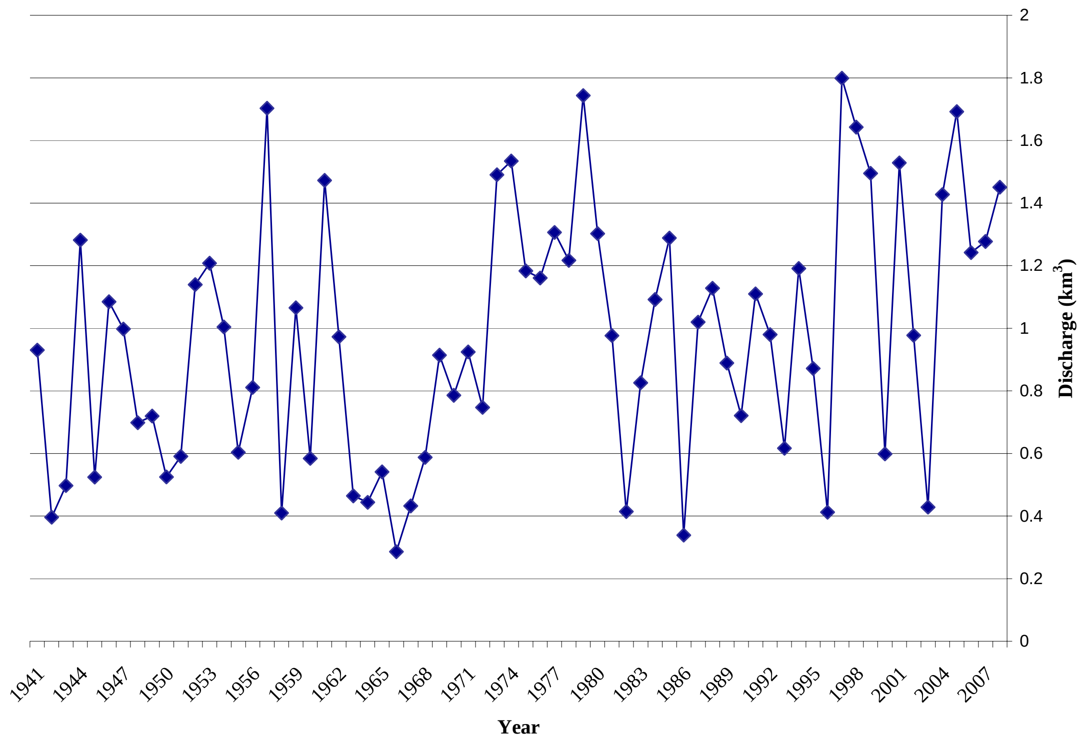

Figure 10. Average yearly discharge of Schoharie Creek, 1941 to 2007 (Kern, 2008)

Since 1970, there have been 10 average yearly discharge levels in the Schoharie Creek above 1.4 km^3, while before 1970 there were only 2 years where the average discharge was above this amount (Figure 10; Kern, 2008). Such a change could be due to the increase in the number of heavy precipitation events and the increase in precipitation intensity predicted by the *NCIA*. Thus, an overall greater amount of precipitation in the Schoharie Valley could be causing these higher levels of discharge in Schoharie Creek (NCIA, 2007).

A comparison graph between the average daily discharge of Schoharie Creek during an earlier period and a later period also provides evidence for the types of changes the *NCIA* claims are happening in the Northeast because of climate change (Figure 11).

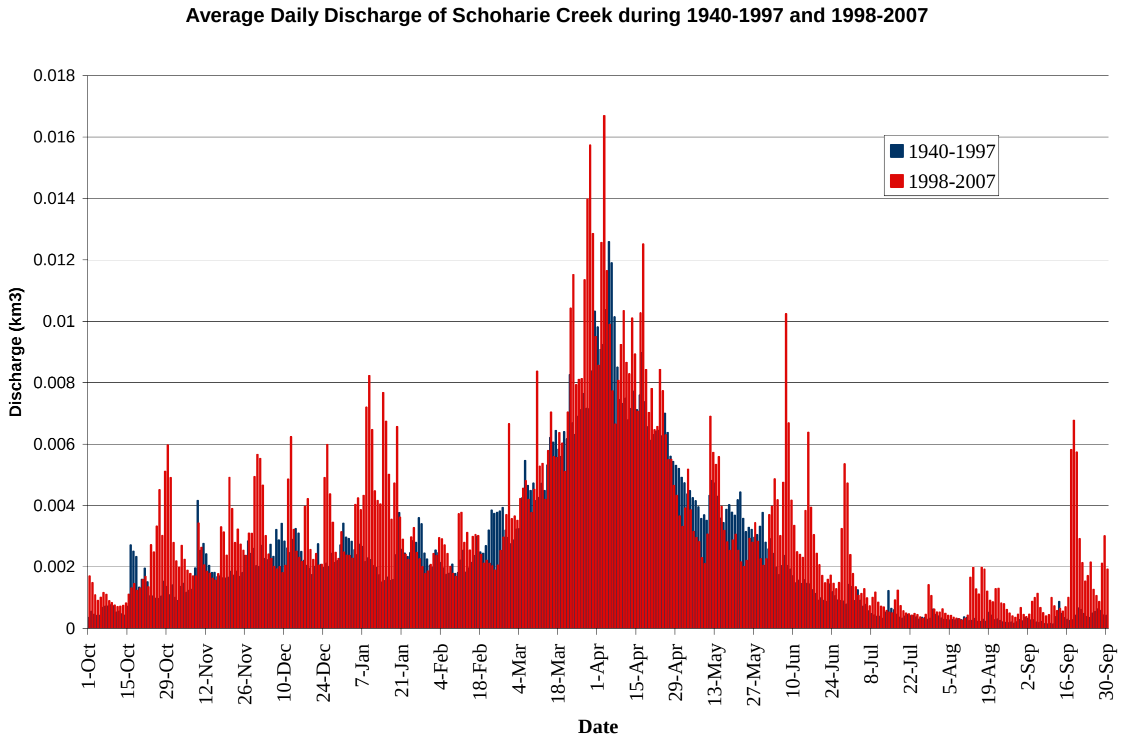

Figure 11. Average daily discharges in the Schoharie Creek during the period of 1940 to 1997 and the period of 1998 to 2007 (Kern, 2008).

In general, there has been a greater average daily discharge of the Schoharie Creek in the last ten years during the months of October, November, December, and January than there has been in the 1940-1997 period (Figure 11). During the month of May, however, when the discharge of any river is typically higher due to spring snowmelt, the 1998-2007 period does not have as high of average daily discharges as the earlier period does (Kern, 2008). Both of these trends could be the result of an earlier breakup of winter ice and an earlier spring snowmelt occurring, as the *NCIA* also mentioned in its statement of climate change impacts. The higher discharges occurring during the winter months in the modern period could be due to the fact that less precipitation is falling as snow now as well (NCIA, 2007).

In addition to the changes in discharge of Schoharie Creek (Figures 10 and 11) storms that were once rare are now much more common in the Schoharie Valley, another change that the *NCIA* also focused upon in its report. In fact, the area has been hit with 100-year floods in 1955, 1987, 1996, and again in 2005. In reaction to the increase of these major flood occurrences, one local farmer named Fred Risse said, “Seems like we’ve got 100-year floods coming every 9 years now. What happens when we get another?” Concerns of locals seem valid when many of the *NCIA’s* predictions of changes in weather patterns are already coming true in places like Schoharie (DePalma, 2005). The 1996 flood, for example, that occurred in New York on January 18th through January 19th clearly demonstrates the effects that these new precipitation patterns could have on local communities. The extensive flooding was the result of heavy rain combined with unseasonably warm temperatures, the exact scenario the *NCIA* had predicted to occur more and more during the winters of the coming years. Leading up to the flooding event, temperatures statewide reached 15 degrees Celsius, setting the stage for a major snow melt to occur as parts of New York were covered in as much as 114 cm of snow, like the Catskill Region where the Gilboa Dam is located. The majority of the rain fell on January 19th, with the most falling in the Catskills, where 12.2 cm was recorded in one area. Maximum river discharges, however, were recorded at 15 different sites, primarily within the Schoharie Creek and Delaware River basins. For example, the extremeness of the 1996 flood event in comparison to past flood events along the Schoharie Creek demonstrates these changes (Figure 12).

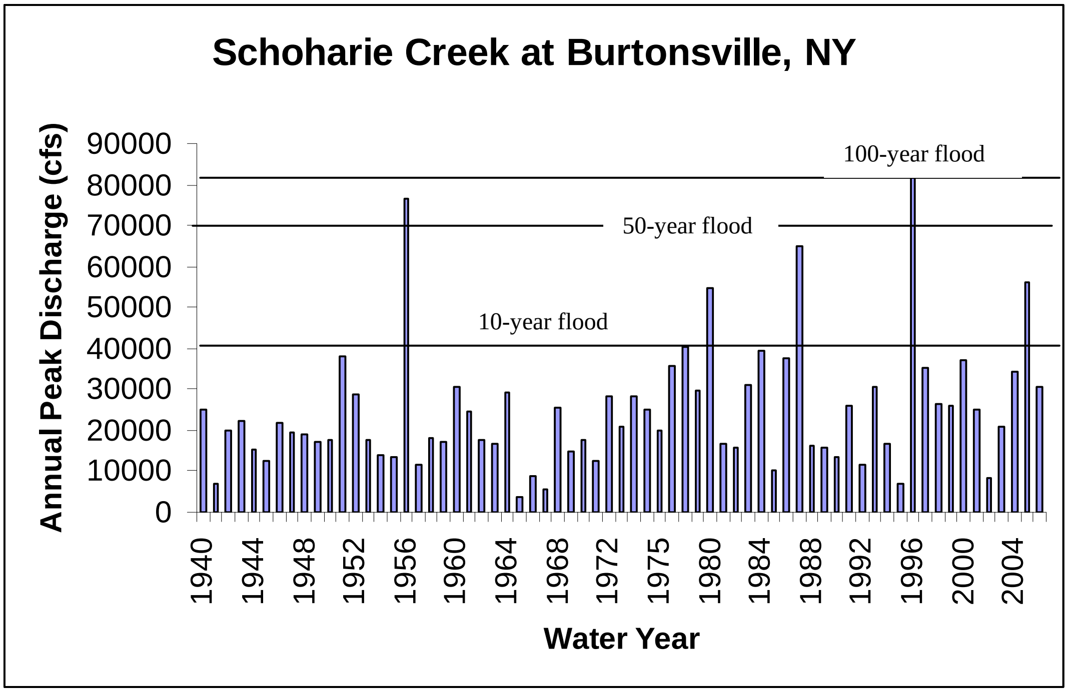

Figure 12. Annual peak discharge recorded on the Schoharie Creek at Burtonsville, NY (Lumia, 1996).

At this particular stream gauge system in Burtonsville, NY, the peak discharge in 1996 was the only time the stream flow had reached a level high enough for a 100-year flood to occur. The result of this 100-year flood was a major flow of water into surrounding towns within Schoharie County. In the town of Breakabeen, floodwaters rose 18 feet and 10 feet in a 24 hour period in the town of Esperance.

During the flood, the NYC reservoirs actually had a mitigating effect on the flooding that occurred because most of them were well below their normal capacity levels, which is around 50% (Table 3). The Schoharie Reservoir, on the other hand, was at nearly full capacity before the storm hit and thus, may have been part of the reason the Schoharie area was hit hardest by the flooding (Lumia, 1996). In fact, the highest crest elevation ever was reached at the Schoharie Reservoir in this 1996 flood at an elevation of 346.44 meters (National Weather Service, 2007). Still, the total amount of floodwater

that was stored in the Catskill Mountain part of the NYC reservoir system from January 18th to January 23rd of 1996 was enough to supply 6.9 million NYC residents with water for 3 and a half months. Without the added storage from these reservoirs, the effects of the flooding would have been even more detrimental.

Table 3. Percentage of full capacity of each NYC reservoir in the days preceding and following the 1996 flood event (Lumia, 1996)

Reservoir	10/1/1995	11/1/1995	12/1/1995	1/16/1996	2/1/1996
Schoharie	21.8	101	101	98.5	101
Ashokan	56.7	62.5	76.2	71	101
Croton System	73.2	79.2	91.5	86.6	98.3
Rondout	85.6	87.8	87.7	82	88.4
Neversink	25.3	42.7	63.5	54.3	87.8
Pepacton	46.3	46.6	59.8	57.6	91.1
Cannonsville	25.1	39.5	63.5	65.4	103
System Total	51	59.3	73.2	N/A	96.6
System Normal	75	68.8	70.8	N/A	81.7

Even with the added help from the reservoirs, the damages from the 1996 flood were far-reaching and devastating to communities across the state of New York. Overall the flooding caused damages to highways, bridges, and private property that amounted to over $100 million and 10 lives were lost in total as well. The Catskill region, however, fared the worst by far with Schoharie County experiencing the majority of the flood's disastrous effects. In Schoharie, two people died, several houses were damaged severely or were completely destroyed, hundreds of acres of farmland were damaged, and more than a hundred farm animals died. The amount of disaster assistance received by Schoharie County from FEMA after the flood was more than $2 million, one of the highest amounts received by any county in New York State (Lumia, 1996, Table 4).

Table 4. Amount of individual and public assistance each country of New York received following the 1996 flooding event (Lumia, 1996)

County	Individual Assistance	Public Assistance	County	Individual Assistance	Public Assistance
Albany	$344,692	$4,275,852	Onondoga	N/A	$1,080,049
Allegheny	639, 703	3,852,852	Ontario	N/A	1,027,244
Broome	694, 033	3,204,820	Otsego	$230,359	2,146,718
Cattaraugus	897,839	1,926,839	Orange	1,295,374	3,700,640
Cayuga	177,715	461,846	Putnam	313,995	1,517,966
Chemung	970,257	3,598,677	Rensselaer	288,803	4,600,449
Chenango	385,699	1,437,151	Saratoga	328,494	1,336,113
Clinton	210,916	498,824	Schenectady	303,655	2,069,700
Columbia	169,960	3,109,401	Schoharie	1,161,161,	2,122,731
Cortland	611,343	1,511,746	Schulyer	N/A	504,936
Delaware	2,196,575	18,926,212	St. Lawrence	N/A	288,916
Dutchess	741,321	2,690,079	Steuben	936,896	5,166,423
Essex	245,288	1,075,742	Sullivan	460,402	5,695,752
Franklin	N/A	522,439	Tioga	957,662	4,526,105
Greene	916,839	4,446,055	Tompkins	260,554	1,258,344
Herkimer	N/A	1,605,615	Ulster	823,163	5,703,246
Jefferson	N/A	481,392	Warren	N/A	1,009,564
Lewis	N/A	610,555	Washington	N/A	2,996,427
Livingston	N/A	715,493	Wyoming	N/A	104,307
Madison	69,052	603,085	Yates	N/A	941,792
Montgomery	65,682	375,150			
			Total	**$16,697,432**	**$103,727,247**

The most recent example in New York of the changing precipitation patterns cited by the *NCIA*, however, occurred between April 2nd and April 3rd of 2005, according to a

United States Geological Survey report written by Gary D. Firda and Thomas P Suro. While the report states that the most extensive flooding took place along the Esopus Creek, which receives water from the Schoharie Creek via the Shandaken Tunnel, the Schoharie Creek also experienced a fair amount of flooding during the event as well. The days preceding this flood event were very wet too, with 2.5 to 5.1 cm falling on March 28th and 29th of that year, leaving the stream flow of the Esopus Creek well above the norm. Although the actual rainfall that did occur on April 2nd and 3rd did not reach record rates of intensity, it was the preexisting conditions that made the flooding happen. Most of the New York terrain was still covered in snow, with as much as 104 cm of snow being reported at the headwaters of the Esopus Creek. This snow, combined with the rain beforehand and the 10 degrees Celsius temperatures, made the conditions prime for the 5.1 to 7.6 centimeters cm of rain to have a major effect on the discharge of the area's rivers.

In comparison to the 1996 flood, the flooding in 2005 along the Schoharie Creek did not have nearly as large of an effect, but as stated before, the discharge of the river was still very high. At all four of the United States Geological Survey stream-gaging stations located along the Schoharie Creek, one at Gilboa, one at North-Blenheim, one at Breakabeen, and one at Burtonsville, the discharge of the creek was high enough to reach a 25 year recurrence interval, meaning that such a flood happens once every 25 years. At the Gilboa station on Schoharie Creek, the peak discharge of the river during the storm was 1399 $m^3 \cdot s^{-1}$, almost 75 percent of what the Schoharie's discharge was at this station during the 1996 flood. On the other hand, the result of the rain on the Esopus Creek was much more severe. At the Mount Marion station along the Esopus Creek, the peak

discharge was 864 m3·s^{-1}, giving it a recurrence interval of 80 years. At Allaben on the Esopus, the recurrence interval was 60 years and at Coldbrook on the Esopus it was 30 years. Except at Coldbrook, the peak discharges at the other two stations on Esopus Creek were higher during the 2005 flooding than the peak discharges recorded during the1996 flooding. Thus, overall the flooding in 2005 was more extreme than in 1996 along the Esopus Creek.

Just as with the 1996 flood, the 2005 flood also caused extensive damage to private property and public infrastructure as well. 20 counties, including Ulster County of New York, were declared Federal disaster areas, 11 of which were eligible for individual assistance. As a result of the flooding, 40 water rescues had to be performed to save people either stranded in their homes or cars from the rising water, over 100 homes were destroyed, and several major roadways had to be closed as well. Ulster County alone estimated that it would cost $23 million to restore the area to its state before the storm hit. In total, however, FEMA provided almost $35 million in assistance to recovering areas because of the flooding (Firda and Suro, 2007).

4.3 The Implications of the Shandaken Tunnel and its Threat to the Stability of the Gilboa Dam

Beyond any expected changes in the climate of New York and the Gilboa Dam's already deteriorating status, the operation of the Shandaken Tunnel provides a second challenge and concern to the vulnerability of the Gilboa Dam failing. As the aqueduct which connects the Schoharie Reservoir to the Upper Esopus Creek, the Shandaken Tunnel plays a crucial role in determining the total amount of water flowing through the

Schoharie Creek. The discharge of the Schoharie is important because an increase in discharge will only add pressure to an already fragile Gilboa Dam.

The amount of water which the Shandaken Tunnel can receive from the Schoharie Reservoir is regulated by two different documents, the New York State Pollution Discharge Elimination System (SPDES) permit and Title 6, Part 670 of the New York Codes, Rules, and Regulations, both of which are administered by the New York State DEC (Upper Esopus Creek Management Plan, 2007). The SPDES permit is actually New York's implementation of the National Pollution Discharge Elimination System (NPDES) permit, which is apart of the Clean Water Act of 1972. NPDES permits regulate the discharge of pollutants into water and are issued to industrial, municipal, and other point source discharges by either the EPA or an authorized state, as is the case with the Shandaken Tunnel (U.S. EPA, 2001). For the Shandaken Tunnel, the SPDES permit must correspond with Title 6, Part 670 of the New York Codes, Rules, and Regulations. This regulation was implemented in 1977 with the purpose of protecting and enhancing the recreational use of the waters within Esopus Creek while ensuring an adequate supply of water for power production and drinking. Its implementation was the result of efforts by state resource protection managers who wished to protect the wildlife in Esopus Creek and recreational users who wanted a certain amount of water released for whitewater rafting. Thus, these regulations have been imposed with multiple uses of Esopus Creek in mind.

The NYC DEP's compliance with these two documents came under scrutiny in the year 2000 when the Catskill Mountain Chapter of Trout Unlimited brought a citizen suit under the federal Clean Water Act against NYC. According to the Trout Unlimited

group, the elevated level of turbidity in Esopus Creek was having a detrimental impact on the recreational fishing of the area and was caused by the water being diverted from the Shandaken Tunnel into Esopus Creek (Upper Esopus Creek Management Plan, 2007). Turbidity, the measure of water clarity related to the amount of suspended matter present in the water, has been linked to a decreased growth rate and reactive distance in rainbow trout and a decreased feeding rate in Lahontan trout, according to one study conducted by scientists through the National Institute of Water and Atmospheric Research Limited. In fact, the feeding rate of the Lahontan trout was decreased by 50 percent in water with a turbidity level at 15 Nephelometric Turbidity Units (NTUs). The study also cited the reduced ability of trout to select large prey and reject smaller ones in turbid waters, proving that visual cues are important for efficient size selection in trout (Rowe et al., 2003). Such reduced rates of growth, feeding, and reactive distance could have serious implications for trout populations, which is one of the most prevalent types of fish living in Esopus Creek, causing a decrease in the overall amount of trout located in the area or the living trout to be smaller in general as well. These kinds of effects are the reason groups like Trout Unlimited have had concerns with regard to the turbidity issue in Esopus Creek and eventually are what eventually caused the group to bring NYC to court.

The Shandaken Tunnel has been a chronic source of turbidity in Esopus creek since the aqueduct's creation. It has the highest mean turbidity value of any of the other New York City water sources at 8.8 NTUs. While the source of the turbidity in Esopus Creek may appear to be the Shandaken Tunnel, in reality all of this suspended sediment originates in the Schoharie Creek and the Schoharie Reservoir. The sediment being

transported from the Schoharie Reservoir into the Shandaken Tunnel is a combination of fine silt and clay that comes from the glacial deposits in the riverbed upon which the Schoharie Creek runs. Thus, the turbidity levels in Esopus Creek can be controlled by modifications in the operation of the Schoharie Reservoir. Currently, there are 5 operable gates that manage the amount of water entering into the Shandaken Tunnel from the Schoharie Reservoir (Upper Esopus Creek Management Plan, 2007).

Finally, in October of 2001, the United States Court of Appeals decided in favor of the Trout Unlimited group after the group's original citizen suit had been dismissed by the United States District Court (NYC DEP 59, 2005). While the NYC DEP continues to dispute this ruling, NYC now has applied for a SPDES permit that corresponds with Title 6, Part 670 of New York Codes, Rules, and Regulations, which sets its own standards for the volume and the rate of change in discharge of water from the Shandaken Tunnel into Esopus Creek. Under the SPDES permit, which became effective in September of 2006, NYC must follow a number of different standards for discharge, turbidity, temperature, and phosphorous levels in the Shandaken Tunnel's diversions to Esopus Creek. Determining the standard for the amount of discharge permitted from the Shandaken Tunnel to Esopus Creek was especially difficult for the NYC DEC because while too much discharge may be contributing to the elevated turbidity levels in Esopus Creek, too little of a discharge could also have a negative impact on the trout and other organisms living in the river. Many of the organisms located in the Esopus depend on the discharge from the Shandaken Tunnel to provide a cold water habitat that is necessary for their survival. With these different discharge dependencies in mind, the NYC DEC established a set of maximum and minimum discharge rates in the SPDES permit that also correlate

with Title 6, Part 670 of New York Codes, Rules, and Regulations. The minimum discharge rate put into place was 227.12 million liters per day, while the maximum discharge rate was 1135.62 million liters per day. Both documents also determined the maximum increase and maximum decrease in discharge that could occur from the Shandaken Tunnel in order to ensure that habitat conditions in Esopus Creek could adapt slowly to changes in discharge. The maximum increase in discharge was set at 151.42 million liters per day and the maximum decrease in discharge was set at 75.71 million liters per day. However, these provisions do not apply in the instance of a threat to the safety of the operation of the Schoharie Reservoir, Shandaken Tunnel, or the Ashokan Reservoir.

By itself, however, the SPDES permit also limits directly the amount of additional turbidity that the Shandaken Tunnel can deliver to Esopus Creek. This limit has been placed at 15 NTUs. The SPDES permit establishes a maximum temperature of the water that the Shandaken Tunnel can divert into Esopus Creek as well. When the water reaches a temperature higher than 21.11 degrees Celsius, the Shandaken Tunnel must be shut off (Upper Esopus Creek Management Plan, 2007). Limiting the temperature of the discharge from the Shandaken Tunnel is important with respect to maintaining the necessary temperature for many of the organisms in Esopus Creek to live, especially the trout. According to the New York State DEC, brown and rainbow trout generally do best in areas where water temperatures rarely exceed 22.11 degrees Celsius. The New York State DEC also sites the importance of temperature drop-off overnight as being important to the survival of wild trout. Thus, keeping the maximum temperature of water discharge

from the Shandaken Tunnel at 21.11 degrees Celsius helps guarantee a healthy environment for the abundance of trout living in Esopus Creek (NYC DEP 60, 2007).

4.4 Examples of Notable Dam Failures in the United States and their Impacts

With all of the controversy surrounding the possible failure of the Gilboa Dam and the factors which may lead to this breakdown, it is important to understand what the consequences of such a failure would be. In order to do this, I will examine several other examples of rivers where dams have failed and what the impacts of these failures were. In general, dam failures pose a severe threat to life and property and can result in millions of dollars in damage. Human lives can be lost in the event of a dam failure, with as many as 125 people having died due to a dam failing, as was the case in Buffalo Creek, West Virginia. Houses and businesses have been damaged and even completely destroyed because of a dam failure as well (Table 5)

Table 5. Loss of life and property damage from various U.S. dam failures (New York State Department of Environmental Conservation, 1987)

Name and Location of Dam	Date of Failure	Number of Lives Lost	Damages
Mohegan Park, CT	Mar 1963	6	$3 Million
Little Deer Creek, UT	Jun 1963	1	Summer Cabins damaged
Baldwin Hills, CA	Dec 1963	5	41 houses destroyed, 986 houses damaged, 100 apartment buildings damaged.
Lee Lake, MA	Mar 1968	2	6 houses destroyed, 20 houses damaged, 1 manufacturing plant destroyed
Buffalo Creek, WV	Feb 1972	125	546 houses destroyed, 538 houses damaged
Canyon Lake, SD	Jun 1972	33	Unable to assess damage
Bear Wallow, NC	Feb 1976	4	1 house destroyed
Teton, Idaho	Jun 1976	11	771 houses destroyed, 3,002 houses damaged, 246 businesses damaged or destroyed
Laurel Run, PA	Jul 1977	39	6 houses destroyed, 19 houses damaged
Kelly Barnes, GA	Nov 1979	39	9 houses, 18 house trailers, and 2 college buildings destroyed. 6 houses and 5 college buildings damaged
Lawn Lake, CO	Jul 1982	3	18 bridges destroyed, 117 businesses, 108 houses, campgrounds, fisheries, and power plant damaged

Even more people and property at placed at risk when a dam fails as a result of a flood, which is one of the most serious threats to the Gilboa Dam. The flooding that occurs after a dam failing is much more sudden than a natural flood and exceeds the maximum flood expected to happen naturally. Thus, residents and businesses that would not normally be at risk during a natural flood may not be able to escape the flooding that happened as a result of a dam failure. This should be a great cause of concern for locals living near the Gilboa Dam as even natural flooding has caused extensive damage to the area, as was the case in 1996 and 2005 for example. One dam failure can also result in another dam failing farther downstream, almost like a snowball effect. In the case of the Gilboa Dam, this kind of disaster could apply, as the Blenheim-Gilboa Pumped Storage Power Project is located downstream from the Gilboa Dam and provides electricity to thousands of New Yorkers (NYS DEP 52, 1987).

One of the most tragic examples of a dam failure that resulted in widespread property loss and many lost lives was the Buffalo Creek flood (Table 5). Three dams had been built on Buffalo Creek by the Buffalo Creek Mining Company starting in 1960 in order to impound the waste that the company was dumping from their strip mining operations. The third impoundment dam and the one which would eventually break in 1972 was the farthest upstream of all three dams. Each of the dams was approximately 182.88 meters away from the other. The preexisting conditions of Dam No. 3 and the surrounding environment were right for such a failure to occur as this particular dam actually had already failed once before in 1971, but the effects were not as disastrous because Dam No. 2 did not then proceed to fail as well. Instead, Dam No. 2 halted the

water, protecting the downstream communities. While the Buffalo Mining Company was cited by the state for violations, the company never followed through with inspections.

Thus, leading into the days before the disaster the stability of Dam No. 3 was already not up to standards and combined with a continuous amount of rainfall beforehand, the collapse of Dam No. 3 was almost imminent. After the failure of Dam No. 3, the two other dams also collapsed under the weight of almost 499.67 million liters of waste water from the Buffalo Mining Company (West Virginia Archives and History, 2008). In just an hour, the floodwaters had traveled 17 miles until coming to rest at the confluence with the Guyandotte River and had destroyed 17 towns in the process. The impacts of the Buffalo Creek flood were disastrous. 125 people lost their lives and a total of 4000 people were left homeless. 30 businesses and 1000 automobiles and trucks were destroyed, along with 10 bridges and power, water, and telephone lines. Estimates of property damage amounted to $50 million, while highway damage amount to more than $15 million (West Virginia Ad Hoc Commission of Inquiry into the Buffalo Creek Flood, 1972).

In the aftermath of the failure, three separate commissions which were created to analyze and study the disaster, concluded that the Buffalo Mining Company had completely disregarded standard safety practices and that this was the primary reason the failure of Dam No. 3 occurred in the first place. With this in mind, the Buffalo Mining Company was sued not only by the state of West Virginia, but by survivors as well. The rebuilding process for the communities that had been destroyed in the flood was a long one and many of the redevelopment projects proposed by the state never even materialized. Even after more than 10 years had past, most of the towns that had been

affected by the Buffalo Creek disaster had not recovered to their status before the flood had occurred (West Virginia Archives and History, 2008).

Another example of a dam failing because it did not meet proper safety standards and because of preexisting weather conditions is the Kelly Barnes Dam failure on November 6th of 1979. Just like the Gilboa Dam, the Kelly Barnes Dam, located on the Toccoa Creek in Georgia, was an earth fill dam, but was at first constructed to create a reservoir for a small hydroelectric plant along Toccoa Creek. At the time of the collapse, however, the reservoir of the Kelly Barnes Dam was only being used for recreational purposes (Federal Investigative Board, 1977).

One of the primary factors which appears to have contributed to the failure of the Kelly Barnes Dam was the impact of the heavy rainfall that occurred in the days leading up to the dam's collapse. Even before the rainfall began on November 2nd and continued on until November 5th, the ground was already saturated from a heavy rain event that had occurred from October 25th to October 26th. The estimated amount of rainfall, however, during the four day period leading up to the failure was about 17.78 cm for the entire basin area and 8.89 cm fell within a 6 hour period on November 5th.

This type of weather combined with the already poor condition in which the Kelly Barnes dam was in created just the right circumstances for the failure to occur. The dam was heavily vegetated and plant roots extended deep into the dam's embankment. Furthermore, in the area where the outlet pipe of the dam was located that at one time supplied water to the hydroelectric plant, the embankment had been experiencing seepage from the large amounts of rain and the possibility of the slope failing around this vicinity appeared imminent. Local slope failures near the dam had actually already occurred,

adding pressure to the dam. Piping, or tunnels created by water through the soil, had occurred within the dam embankment as well, making the structure that much weaker. Even the basic design of the dam, with three outlet pipes concentrated in one area, probably contributed the dam's eventual failure according to the report created by the Federal Investigative Board after the collapse occurred (Federal Investigative Board, 1977).

Eventually, under these strenuous circumstances, the Kelly Barnes dam failed on November 6, 1977 at approximately 1:30 AM, 39 people lost their lives due to the failure and extensive property damage occurred as well (Table 5).The water-supply pipe for the city of Toccoa was also broken and because of this, the city's water was contaminated for several days following the collapse (Sanders and Sauer, 1979). In total, the damages cost an estimated 2.5 million dollars (Association of State Dam Safety Officials, 2008).

5. NYC'S RESPONSE TO THE POSSIBLE FAILURE OF THE GILBOA DAM

5.1 The NYC DEP's Reconstruction Project for the Gilboa Dam

Immediately following NYC's announcement that the Gilboa Dam did not meet the New York state DEC's safety requirements for modern-day dams, the NYC DEP presented the City's proposed plan of action to the Schoharie County Board of Supervisors on November 18, 2005 (NYC DEP 10, 2007). According to the NYC DEP, the Gilboa Dam Reconstruction Project had been created with two separate goals in mind, one of which was to ensure public safety and the other of which was to sustain the public water supply (NYC DEP 9, 2007). The plan of action was divided chronologically into three different types of response to the risk: an immediate, short term, and long term response to the danger posed by the possible failure of the Gilboa Dam (Figure 13)

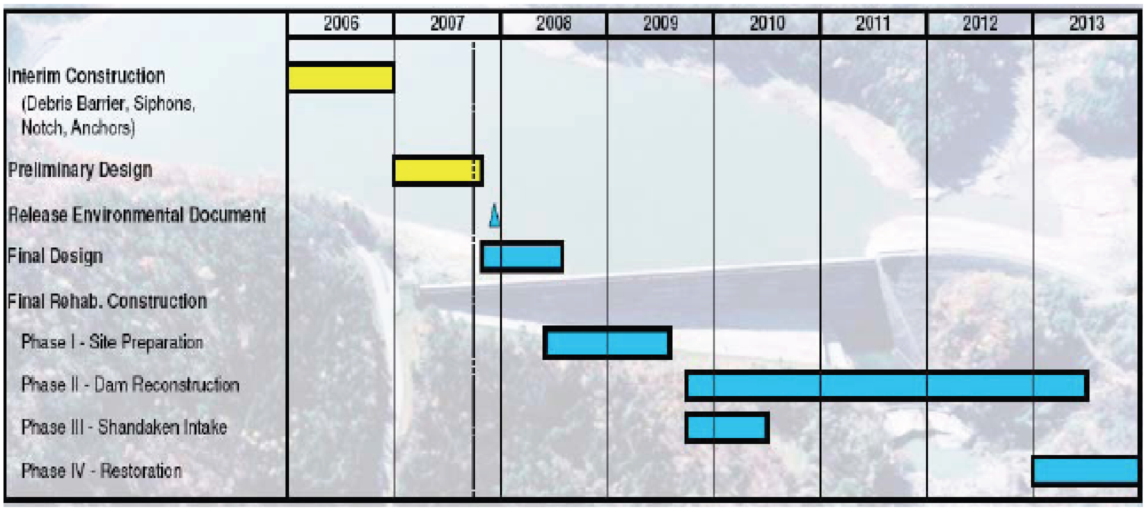

Figure 13. Timeline of the NYC DEP's Gilboa Dam reconstruction project (NYC DEP 9, 2007).

The reconstruction plans had been made by the NYC DEP after a thorough review of all of the dams owned by NYC between 1998 and 2003. In 2005, however, the NYC DEP reviewed the safety factors that should be considered with regard to the Gilboa Dam, including historical floods and the current trend in climatic events, and began to see that the safety level of the Gilboa Dam was less than satisfactory (NYC DEP 7, 2005).

5.2 The Immediate Response

Part of the NYC DEP's immediate response to the possible failure of the Gilboa Dam was to reduce the level of water in the Schoharie Reservoir by 4.88 meters in order to relieve pressure on the dam structure (DePalma, 2005). To make this reduction possible, the NYC DEP increased the flow of water running through the Shandaken Tunnel to 2044.12 million liters per day, a number much higher than normally allowed under Title 6, Part 670 of New York Codes, Rules, and Regulations, but because of the emergency situation surrounding the Gilboa Dam, this flow was acceptable (NYC DEP 10, 2007). The NYC DEP also greatly improved the monitoring of the Gilboa Dam with the use of the National Weather Service's Advanced Hydrologic Prediction Service (AHPS) (NYC DEP 7, 2005). Using the best science and technology available, AHPS provides forecasts of river levels and river discharge based on many different time intervals from changes by the hour to changes by season. Some examples of the kind of river forecast information AHPS can supply include how high a river will rise, when the river will reach its peak, what areas flooding will reach, and how long flooding will last. With such information, the NYC DEP will better able to predict where and when to evacuate people from potential flood areas and will be more likely to know how to use reservoir storage capacity and release in a way that will reduce flood impacts (National

Weather Service, 2008). To further improve the monitoring of the Gilboa Dam, the NYC DEP also called for heightened policing of the dam by NYC DEP officials every two hours. The final aspect of the NYC DEP's immediate plans for the Gilboa Dam includes mobilizing the borings of the dam within 10 weeks, which helped to stabilize the structure (NYC DEP 7, 2005).

5.3 The Short Term Response

The NYC DEP's short term plan for the dam involved monitoring and several stabilization improvements. The majority of this short term plan was completed in 2006 and was a $24 million project (NYC DEP 4, 2006). The first step toward the completion of this project was the installation of a debris boom across the top of the Gilboa Dam. The purpose of the debris boom was to keep outside material off of the dam in order to make sure no extra fragments were adding pressure to the structure and the work site for reconstruction would be clean as well (NYC DEP 10, 2007). The next progression of the NYC DEP's plan was the removal of a notch from the western end of the dam that was 67 m long and 1.68 m high (Figure 14) (Michaels, 2006).

Figure 14. Placement of the notch (arrows) that was removed from the Gilboa Dam (NYC DEP 9, 2007).

With the Gilboa Dam's old spillway system, before the notch was added, peak inflow behind the dam was 1133 $m^3 \cdot s^{-1}$ and peak outflow over the dam spillway was 1019 $m^3 \cdot s^{-1}$, which would only mitigate a ten year flood by 10 percent. After the notch was installed, however, the NYC DEP reported peak inflows of 566 $m^3 \cdot s^{-1}$ and 680 $m^3 \cdot s^{-1}$ being reduced to 255 $m^3 \cdot s^{-1}$ and 510 $m^3 \cdot s^{-1}$, which is a mitigation of 55 and 25 percent respectively. Thus, just the installation of the notch has resulted in a significant improvement of the Gilboa Dam's flood mitigation ability (DCC 72, 2007). The installation of this notch also lowered the capacity of the Schoharie Reservoir, which in turn decreased the amount of pressure occurring behind the Gilboa Dam and ensured a dry area upon which further renovations could take place (Michaels, 2006).

To lower the Schoharie Reservoir level even further in preparation for the full-scale reconstruction of the Gilboa Dam, part of the NYC DEP's short term plan was to also install four large siphons, which could potentially remove up to 472.18 million liters of water per day (Figure 15). With the combined effect of the 4 siphons and the notch, enough water was being released from the Schoharie Reservoir to allow the final stage of the interim reconstruction to take place. In this final stage, 79 anchoring cables were installed in parts of the Gilboa Dam thought to be the most unstable, which included areas along the top of the dam and some farther downstream as well (Michaels, 2006). In order to set up these cables, workers had to drill holes into the dam, some straight into the bedrock and some at an angle, for each cable (DePalma, 2005). Each cable was then anchored to both the dam and the bedrock at the bottom of each drilled hole and tightened to create tension that would help keep the dam in place (Michaels, 2006). According to Paul Rush, the deputy commissioner of the Bureau of Water Supply, this kind of a repair

has worked on thousands of other dams and is a step in the right direction to stabilizing the Gilboa Dam (DePalma, 2005). In fact, the anchoring work brought the Gilboa Dam within the safety standards required for existing dams by the New York state DEC (Michaels, 2006).

Figure 15. Gilboa Dam after the siphons were installed as part of the NYC DEP's short term reconstruction (NYC DEP 9, 2007).

In addition to these improvements to the actual structure of the Gilboa Dam, part of the stabilization project has involved major advances in the monitoring of the dam. As early as December of 2005, a trailer was put on site at the Gilboa Dam by the NYC DEP in order to electrically monitor the dam 24 hours a day. To help with this monitoring, surveillance lighting was also established to make the process easier for NYC DEP officials during the night. By February of 2006, video monitoring of the dam was also established, along with automated monitoring of the snow pack in the Schoharie Reservoir watershed (NYC DEP 10, 2007). Only a month later, the NYC DEP committed to using a snow pack-based flood management program, which it already uses at the Pepaction and Neversink reservoirs that are parts of the Delaware River portion of the

NYC water supply system (Canty, 2006). This increased snow pack management could potentially be very beneficial for the communities surrounding the Gilboa Dam in the event of another storm occurring that could cause a 100 year food. In that case, a snow pack management program could be the difference in whether as many as 144 structures flood in the surrounding area or not (NYC DEP 9, 2007). Within the next month, the NYC DEP had put remote computer monitoring of the Gilboa Dam and of the Gilboa and Prattsville stream gages into place as well.

In order to prepare for the full-scale reconstruction of the Gilboa Dam, the NYC DEP was also forced to make a number of changes in the operation of its reservoirs throughout its water supply system. As already mentioned, the discharge rate through the Shandaken Tunnel had been operating at an emergency level since the fall of 2005 when the risk of the Gilboa Dam failing was announced. In January of 2006, however, new equipment allowed the Shandaken Tunnel intake to be widened to increase the discharge through the tunnel even more. Currently, the discharge rate of the Shandaken Tunnel is operating at 2233.39 million liters per day, the maximum discharge allowed under the emergency provisions of Title 6, Part 670 of New York Codes, Rules, and Regulations (NYC DEP 10, 2007). Besides maximizing the amount of water diverted from the Shandaken Tunnel, the NYC DEP also decided to maximize its diversions from the Ashokan Reservoir as well. To keep the water level of the Ashokan Reservoir low, the NYC DEP began maintaining the discharge of the Catskill Aqueduct at 2195.54 million liters per day, instead of the normal 1135.62 to 1324.89 million liters of water per day that flows through the aqueduct. In March of 2006, the NYC DEP took measures even farther to ensure that a maximum amount of water was being diverted from the Ashokan

Reservoir by re-activating the Ashokan Waste Channel, which eventually empties into the lower Esopus below the Ashokan's spillway channel. The Ashokan Waste Channel will allow the NYC DEP to release as much as 2271.25 million liters of water per day from the Ashokan Reservoir if necessary (Michaels, 2006). Thus, the rebuilding of the Gilboa Dam is a process that will affect all parts of the NYC water supply system.

5.4 The NYC DEP's Emergency Action Plan

During these interim construction repairs, the NYC DEP, specifically the West of Hudson Divison (WHO), was also responsible for designing and completing an emergency action plan (EAP) in case the Gilboa Dam was to fail (NYC DEP 5, 2007). An EAP, according to the NYC DEP, states the basic procedures, duties, and responsibilities that should be implemented in the event of an emergency condition at the Gilboa Dam. To even further define an EAP, the NYC DEP also has stated that an emergency condition at the dam would entail an impending or sudden uncontrolled release of water from the dam caused by the failure of the structure, the result of an accident, or an incident that occurred at the Gilboa Dam. With this outline in mind, the NYC DEP has developed a 2 part EAP, with one part, "Situation A", focused upon the actions that should be taken if the failure of the Gilboa Dam is imminent or has already occurred, and the other part, "Situation B", focused on the actions that should be taken if the situation developing at the Gilboa Dam is potentially harmful and destructive (NYC DEP 7, 2005).

In "Situation B", part of the procedure includes notifying the NYC DEP WOH director of operations along with the NYC DEP WOH Control Center and the NYC DEP Emergency Operations Center (EOC). The NYC DEP WOH director of operations

supervises the activities of both the NYC DEP WOH Control Center and the EOC, which are both organizations in charge of handling emergency response situations. The NYC DEP WHO Control Center is specifically in charge of assessing any problem that may occur at the Gilboa Dam and thus, must also inform outside NYC DEP personnel and any outside parties which may be affected as well. The next step in the EAP is to appoint staff members of the WOH division to begin emergency repairs on the Gilboa Dam if possible, while also contacting the East of Hudson district to begin emergency operation of the NYC water supply system as a whole. The WOH Control Center must also be in contact with the New York Power Authority (NYPA) staff at the Blenheim-Gilboa Power Project in order to warn them of a potential emergency. Furthermore, the WOH Control Center will coordinate action with local geotechnical engineers as consultants for repair guidance and will work with locals to provide the necessary resources to make these repairs happen. To keep concerned citizens informed, the WOH Control Center would also provide updated reports on the emergency situation to the Schoharie County Emergency Management Office through microwave or teletype systems.

In the event of “Situation A”, however, the WOH Control Center would order the immediate evacuation of all emergency personnel from the area and all repairs to the Gilboa Dam would cease. The WOH Control Center would also contact the NYC DEP Police (Croton Command Center), the Schoharie County Emergency Management Office, the NYPA staff at Blenheim-Gilboa, and all major utilities located downstream from the Gilboa to warn them of the emergency situation. After informing these organizations, the WOH Control Center would continue to give periodic updates concerning the condition of the dam and the surrounding area. As a whole, the NYC DEP

would still be operating the water supply system under emergency conditions as well (NYC DEP 5, 2005).

In addition to the NYC DEP's EAP, the DEP commissioner Emily Lloyd announced on September 18, 2006 that the NYC DEP had just recently committed to buying a siren system for Schoharie County that would alert surrounding residents of any possible threat occurring at the Gilboa Dam. All 20 sirens cost about $370,000, which will be funded primarily by NYC, but some maintenance costs will also be covered by the NYPA as well (NYC DEP 10, 2007 and County of Schoharie, 2006). While the location of these sirens was planned to be spread throughout the Schoharie Valley in places such as the Gilboa Highway Garage, Mine Kill State Park, the Schoharie Fire Department, the Middleburgh Pharmacy, the Esperance Fire Department, and Priddle Camp by January of 2007, the NYC DEP encountered several issues when attempting to buy the sirens (County of Schoharie, 2006). Due to an order by the Federal Government Homeland Security for the same type of sirens, the NYC DEP was unable to purchase as many of the sirens as they initially had planned to buy. Because the federal government's need for the sirens superseded the NYC DEP's need, the delivery of the sirens that the NYC DEP did buy was delayed as well. Thus, as of February, 2007, only 4 of the 8 sirens that the NYC DEP had bought had been delivered and none of them had been installed yet (The Dam Concerned Citizens Inc. 10, 2007).

5.5 The Long Term Response

The NYC DEP's long term response to the risk posed by the aging Gilboa Dam was the complete reconstruction of the dam. While this full-scale reconstruction was not scheduled to begin until 2010, the NYC DEP announced at the end of 2007 that the

project would begin much earlier, starting now in 2008 and will be finished by 2011.The reconstruction will cost more than $200 million for the NYC DEP to complete and will allow the Gilboa Dam to meet the standards required by the New York state DEC for newly constructed dams (Michaels, 2006). Before beginning the project, the NYC DEP released an environmental assessment of what impact the reconstruction of the Gilboa Dam would have on the surrounding area, the Schoharie Creek, and other affected bodies of water as well. This assessment permitted the NYC DEP to go ahead with the project through a permit received by the New York state DEC and the United States Army Corps of Engineers and was incorporated into the last step of the reconstruction plan as part of the site restoration phase. In all, there are actually 4 phases of the NYC DEP's reconstruction project which include, site preparation in Phase I, Gilboa Dam reconstruction in Phase II, Shandaken Tunnel intake improvements in Phase III, and as mentioned, site restoration in Phase IV.

As part of Phase I, there are number of measures the NYC DEP must take in order to prepare the Gilboa Dam and the surrounding area for the increased pressure that will result because of the reconstruction process. Firstly, the site of the Gilboa Dam must be cleared in order to provide a clean and safe environment for the reconstruction process to begin. Part of ensuring the site will be ready for construction includes grading and drainage improvements and utility upgrades as well. The NYC DEP plans to construct a new road leading to the Gilboa Dam to make access to the construction site easier and also plans to construct of a staging area where parts of the new dam can be built in a safe and efficient manner. One of the most important aspects of Phase I of the reconstruction process, however, is the construction of a spillway crest gate (NYC DEP 9, 2007). This

crest gate will allow controlled releases of water to occur behind the dam, thus contributing to the mitigation of possible floods that could happen along Schoharie Creek. It will also enhance the notch that the NYC DEP already built during the interim construction of the Gilboa Dam (The Dam Concerned Citizens Inc. 72, 2007).

The next phase of the project, Phase II, is the actual reconstruction of the Gilboa Dam. There are several aspects which the NYC DEP plans to improve upon in the new design of the Gilboa Dam and one of these is the dam's spillway system (NYC DEP 9, 2007). The Gilboa Dam's current spillway system is very inefficient at mitigating floods because it is so broad at 404 m (The Dam Concerned Citizens Inc. 72, 2007). The new spillway system modeled for the reconstruction project, however, is not so broad and consists of many more steps, which will help to better control the flow of water entering the spillway and passing from the upstream side of the dam to the downstream side (Figure 16).

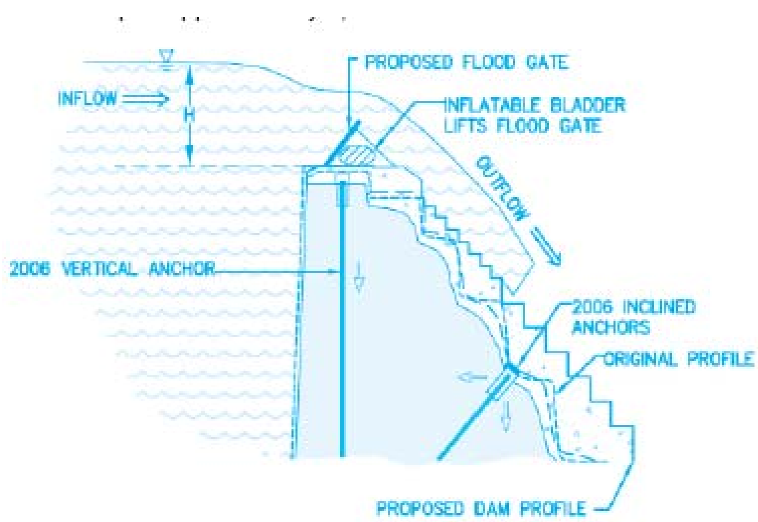

Figure 16. The NYC DEP's final flood gate and spillway design for the reconstruction of the Gilboa Dam (The Dam Concerned Citizen Inc. 72, 1007).

The size of the steps in the new spillway design also vary from smaller to larger in order to control the flow of water more efficiently (Figure 16). Other renovations to the Gilboa Dam include a complete wall reconstruction, along with embankment improvements as well.

The creation of a low level outlet works is yet another essential part of Phase II of the NYC DEP's reconstruction plan (NYC DEP 9, 2007). Currently, the low level outlet system of the Gilboa Dam is inoperable and has been a major reason why flooding cannot be controlled as easily at the Gilboa Dam (The Dam Concerned Citizens Inc. 72, 2007). The NYC DEP is set to construct a low level outlet that is 4.27 m in diameter and will release water downstream in Schoharie Creek from the Schoharie Reservoir for the first time ever (Kelly 1, 2008). It will provide more than double the release capacity of the existing four siphons that were installed on the Gilboa Dam in 2006. This greater outflow will allow the low level outlet system to decrease the level of the Schoharie Reservoir during normal inflow conditions by 0.30 to 0.61 m/day. Such capability is extremely important when it comes to creating storage for the snowmelt management recently put into place or for the possible influx of water discharge in the event of a large storm. Another advantage of the low level outlet is the fact that it will be placed underground, running through bedrock. This means there will be no possibility of the outlet freezing, as has happened with the siphons in the past 2 years (The Dam Concerned Citizens Inc. 72, 2007). Determining a location in which to construct this low level outlet, however, has proven more difficult than imagined for the NYC DEP. In October of 2007 when the NYC DEP released its final design plans for the reconstruction of the Gilboa Dam, 6 different areas had been considered for placement of the tunnel, with only one of these

areas being rejected outright (NYC DEP 9, 2007). Unfortunately, as work on the Gilboa Dam has progressed, workers have still been unable to find a suitable location for the low level outlet. According to city officials, the rock in the area under consideration is too deep and thus will make the construction of the tunnel that much more difficult. Such difficulties have actually resulted in the NYC DEP announcing a rise in the cost of the reconstruction project to $583 million and a longer length of time, 3 more years, to complete the renovations (Kelly 1, 2008).

Phase III, which has partly already begun, is the improvement of the Shandaken Tunnel intake gate. As discussed in Chapter 4, one of the major issues surrounding the Gilboa Dam has been the increased turbidity of the water released from the Shandaken Tunnel into the Upper Esopus Creek. The source of this problem is the bedrock of the Schoharie Creek and because of this, there is a large amount of sediment that has accumulated where the water from the Schoharie Reservoir is transferred into the Shandaken Tunnel. While the NYC DEP has acknowledged that the improvement plans for the Shandaken Tunnel will not fix the turbidity problem, the changes will allow the tunnel's release gates to fully operate. In order to help ensure that the tunnel is operating at full capacity, the NYC DEP plans to replace the intake gate of the Shandaken Tunnel (NYC DEP 9, 2007). Before this replacement will be able to take place, however, the NYC DEP began removing the sediment that had collected in front of the mouth of the Shandaken Tunnel this past spring in 2007 (The Dam Concerned Citizens Inc. 10, 2007). The dredging was to be a short term fix until the full renovations of the intake gates could be finished. It was estimated that 4,572 m^3 of silt and mud were removed from the mouth of the Shandaken Tunnel (*Times Union*, 2007). Now, with the dredging process complete,

the NYC DEP will begin to make utility upgrades and site improvements to prepare for the replacement of the Shandaken intake gates. Bettering the operation of the Shandaken Tunnel will contribute greatly to the flood mitigation ability of the Gilboa Dam.

The final and fourth phase of the NYC DEP reconstruction project involves actions taken after the construction process is already complete. In Phase IV, the NYC DEP has planned out a site restoration process that will include mitigating any environmental damage that was done during reconstruction. Much of this site restoration will be based on the environmental assessment that was already completed by the NYC DEP in 2007. By including this final phase, the NYC DEP is making an effort to be conscious of the impact the reconstruction process will have on the surrounding environment (NYC DEP 9, 2007).

6. THE SUFFICIENCY OF NYC'S RECONSTRUCTION PLAN AND FUTURE CONSIDERATIONS

6.1 The Role of the Dam Concerned Citizens, Inc.

While the NYC DEP has created a reconstruction plan to bring the Gilboa Dam up to standards for newly constructed dams required by the New York state DEC, concerns are still being raised today about whether this plan is sufficient enough to ensure the safety of the citizens living in the surrounding area. One group of local community members, the Dam Concerned Citizens, Inc. (DCC), has actually been at the forefront of making sure that the NYC DEP is held accountable for its responsibility to repair the Gilboa Dam and that it does so in a way which will guarantee safety for everyone. The DCC formed as a non-profit group just after the NYC DEP revealed there was a possibility of the Gilboa Dam failing and since then has played a crucial role in representing the concerns of the people who would be affected by the dam's failure. By spreading critical information about the vulnerabilities of the Gilboa Dam to the public, the DCC has helped to increase awareness of the risks posed by the dam, which in turn has led to greater public participation in solving the problem. In particular, the DCC has utilized their own website to inform the public of the problem itself, water level data of the Schoharie Creek, and of weather conditions that could threaten the stability of the Gilboa Dam. Besides the group's website, the DCC has also published articles pertaining to issues surrounding the dam in local newspapers (Dam Concerned Citizens, Inc. 1,

2006). Without such a lobbying effort by the DCC, it is questionable whether many of the repairs and additions that have been made to the Gilboa Dam would have ever happened.

This essential role of the DCC is evident at all stages of the solution process. For example, in NYC DEP's short term plan for the Gilboa Dam, four siphons were installed as part of the interim construction done to the Gilboa Dam, but these siphons would not have been part of the plan if it was not for the DCC's insistence that they were added to the dam. Another major feature of NYC's interim reconstruction was the installation of 80 anchoring cables, each of which is made up of 58 braided steel cables. Originally, however, only 79 anchoring cables were installed and shortly after the installation process, several cable strands broke from one of anchors, compromising its strength. In order to not make this an issue later and to help strengthen the dam further, the DCC asked that the NYC DEP add an additional anchoring cable to the dam, increasing the total number of anchors to 80. With regard to the NYC DEP's emergency evacuation plans that it has developed, the DCC was also critical in ensuring that NYC would fully reimburse Schoharie County for the cost of the sirens that are going to be installed throughout the area.

Now, as the full-scale renovations of the Gilboa Dam begin, the DCC's additions to the NYC DEP's long term plan can also be seen. To guarantee the highest possible safety standard for the Gilboa Dam, the DCC has maintained that the dam must be repaired at a Factor of Safety (FOS) level of 1.5/2.0, which is higher than originally proposed by the NYC DEP. FOS is an engineering formula that labels the strength of a dam in the event of a flood or other disasters. In the case of the Gilboa Dam, a 1.5/2 FOS level means that the dam will be 50 percent stronger than the heaviest anticipated flood

event and 100 percent stronger than a normal flooding event. In addition to asking and receiving a higher FOS level for the Gilboa Dam, the DCC has also been persistent in its requests to ensure better flood mitigation for the dam. The siphons installed as part of the interim construction have been vital to the flood mitigation process, but at times, as previously mentioned, have been rendered useless due to freezing. In October of 2007, the DCC asked that the NYC DEP use some sort of means to prevent the siphons from freezing and this request was met in December when the NYC DEP built a deicing mechanism within the siphons. Eventually, however, after the final construction phase is complete, these siphons will not be needed anymore because the NYC DEP has committed to incorporating a low level outworks systems to its renovations of the dam. The DCC helped make sure this low level outworks system was included in the plan because such an addition will give the NYC DEP the ability to drain 90 percent of the Schoharie Reservoir in just 10 days if necessary. Until the completion of the entire renovation project, however, the DCC has also demanded that the siphons and notch remain in place. The NYC DEP wanted to remove these features after the anchoring cables had been installed, but the DCC believed both the siphons and the notch should continued to be used until the end of construction as a way to release water when needed. NYC has complied with this demand as well and both the siphons and notch are still in place (Dam Concerned Citizens Inc. 2, 2006).

6.2 Is NYC's Final Reconstruction Plan Sufficient?

Even though the NYC DEP has incorporated many of the DCC's suggestions into its overall renovation plans for the Gilboa Dam, the DCC still feels that more could be done to make the final reconstruction of the dam as complete as possible. For this reason

the DCC has listed several future challenges they face in trying to further strengthen the Gilboa Dam in an article that was published in the local newspaper. As already discussed, the DCC has done a lot to provide residents living near the Gilboa Dam with better flood control options, but, in the end, the DCC would like the NYC DEP to do even more with its flood mitigation plans. As of now, the reconstruction plans of the Gilboa Dam only include the creation of one flood gate as part of its spillway system. According to the DCC, however, a two gate system would be a more effective design in dealing with the changing climatic conditions we face today and is necessary to prevent destructive and catastrophic flooding from happening, no matter what the initial cost may be. This two gate system would provide a controlled release of 566.34 cubic meters per second and 1.68 meters to 2.74 meters of storage behind the dam, which would improve the flood mitigation ability of the Gilboa Dam even more.

To further help with flood control at the Gilboa Dam, the DCC has recommended that the NYC DEP install compressed air bubbling units in the 4 siphons until the low level outworks system has been completed. The compressed air bubbling units are the surest way to guarantee that the siphons do not freeze during the winter as has happened in the past, even after the NYC DEP installed a deicing mechanism within the siphons. Keeping the siphons in working condition is of utmost importance to the DCC as they are essential to accommodating excess water from snowmelt and spring runoff. Even after knowing this and the DCC’s recommendation, the NYC DEP has refused to install the compressed air bubbling units, citing cost as a major issue. Still, the DCC has continued to lobby for this addition to the NYC DEP’s construction plans, but whether NYC

decides to include the idea in its project is questionable and unlikely to happen at this time.

In addition to flood control issues, the DCC is also trying to get the NYC DEP to commit to a continuous release of 2.12 $m^3 \cdot s^{-1}$ from the base of the Gilboa Dam after the low level outworks system has been constructed. This constant release of water will help to diminish many of the environmental impacts the Gilboa Dam has had on the area since its construction. Because Schoharie Creek no longer flows naturally and so much of its water is diverted from the Schoharie Reservoir to the Shandaken Tunnel and finally into Esopus Creek, the river basin has become very dry and as a result, has affected many organisms living in the area (DCC 72, 2007). Such a release would have many benefits for the local area and NYC at the same time. For the surrounding region, the continuous release would enrich agricultural lands located in the Schoharie Valley, restore fish habitats, and increase the availability of water for recreational use, which in turn would be economically stimulating for the area as well. In the case of NYC, the release would have benefits as well, allowing the NYC DEP to more easily comply with the SPDES permit it is required to follow due to turbidity issues through the Shandaken Tunnel. Because the SPDES permit sets a maximum discharge that can be emitted from the Shandaken Tunnel, a continuous release downstream from the dam will decrease the amount of water needing to be diverted into the tunnel in the first place.

With regard to the NYC DEP’s emergency evacuation plan, the DCC has been keeping a close watch on the emergency sirens that have been installed to ensure that they are fully operating. The DCC hopes to act as a means of communication between the public, the Schoharie County emergency management personnel, the manufacturer of the

sirens, and the NYC DEP in order to voice any concerns or problems that local citizens may have come across in the installation of these sirens. The successful operation of the sirens is a main priority for the DCC as it is critical to public safety.

In general, the DCC has also referred to how essential the need for an independent dam inspector is at the construction site of the Gilboa Dam. By having an independent dam inspector present at the Gilboa Dam for the duration of the reconstruction project, the DCC feels it will be easier to provide non-biased and current information to community members. Such an inspector will be important to help the public receive the facts about the reconstruction process rather than simply rumors or hearsay. An inspector would also be useful in the event of any problems that could occur during the renovations (Dam Concerned Citizens, Inc.3, 2006).

6.3 Future Constraints and Concerns Pertaining to the Gilboa Dam

As already mentioned in Chapter 4, climate change is already increasing the risk of the Gilboa Dam failing. These shifts in weather patterns will continue to put the Gilboa Dam at risk and will affect the NYC water supply as a whole as well. The fact that the *NCIA* has cited a predicted increase in the number of heavy-precipitation events, earlier snowmelts happening, and more precipitation falling as rain instead of snow is especially important because rain falling on snow and snowmelt tend to be the largest and most destructive flow events. If these kinds of weather patterns are occurring more frequently, not only will the Gilboa Dam be in greater danger of failing, but flooding of the dam will be more likely to happen as well (Commission on Geosciences, Environment, and Resources, 2000). As has been true with the entire solution process regarding the repair the Gilboa Dam, however, the NYC DEP has a responsibility to the citizens living in

NYC and the citizens living in the areas where it owns dams and reservoirs. In *The NYC DEP Climate Change Program Assessment and Action Plan*, the NYC DEP addresses the idea that in the case of climate change, NYC interests may differ from upstate New York interests greatly. On the demand side, the NYC DEP has projected that climate change will likely exaggerate seasonal and peak period usage. Especially in the summer, longer dry periods between rain events and more frequent extreme temperatures could lead to additional outdoor water usage. With that said, the NYC DEP has also stated clearly in this report that with the uncertainty of the weather and the possible increase in the number of droughts, the City cannot commit to regular releases of water from its reservoirs as a way to mitigate floods. According to the NYC DEP, it has no duty to engage in flood control and that the reservoir were not built with this job in mind, but only as means to provide water to citizens of NYC. Thus, while the NYC DEP has agreed to make some controlled releases from its reservoirs, NYC's primary concern is to meet the water demands of its people. These releases being called for may limit the NYC DEP's ability to meet such demands in the case of more frequent droughts due to climate change. For this reason, the NYC DEP has cited the need to work with other agencies and local parties to ensure public health and safety with extra dam stabilization efforts if such a conflict of interest was to arise (NYC DEP 11, 2008).

Another stress that will most likely be added to the NYC water supply in the future is an increase in the NYC population, which in turn will cause a further increase in demand. NYC's population is projected to reach almost 9.5 million by 2025, which is over a million people more than are living in NYC today (Figure 17; Roberts, 2006). Currently, the demand for water within the city is at 4046.61 millions of liters per day,

but the NYC DEP has projected that this demand could increase to 4682.55 millions of liters per day by 2030. While NYC appears confident that the mandated use of low water use fixtures will significantly help to moderate the overall future demand for water, the NYC DEP has begun to look to develop its water supply in other areas if necessary. As of now, possible places where NYC could receive its water from in the future include Long Island, northern New Jersey, or NYC could further develop its supply in Westchester or Putnam County (Commission on Geosciences, Environment, and Resources, 2000).

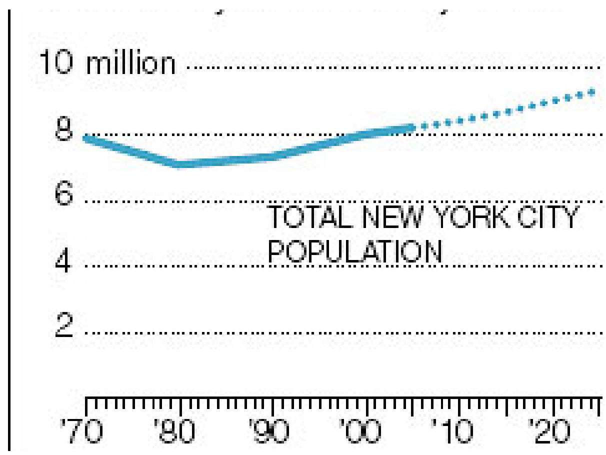

Figure 16. Past and predicted population of NYC (Roberts, 2006)

6.4 Future Suggestions in Dam Management

The Gilboa Dam crisis demonstrates there are many aspects of dam management in the United States that are lacking and in dire need of improvement. Through this analysis of the situation surrounding the Gilboa Dam, the following are suggestions for future policy, maintenance, and building of dams in the U.S.. One of the most obvious areas that must be improved upon if the all the dams of the United States are ever going to be up to the standards required by the DEC is the amount of funding given to help with dam management. As mentioned previously, the National Dam Safety Program, which

was established to give greater support to state dam safety programs, has not been fully funded in the past five years and even if it was fully funded, the amount of money being allotted to the program would not be nearly enough to ensure a satisfactory level of safety for the dams present in the United States. In 2003 and 2004, for example, New York state was set to receive $149,295 through the National Dam Safety Program, but instead received $87,074 in 2003 and $77,844 in 2004 (Association of State Dam Safety Officials, 2007). In comparison to the $583 million budget for the complete reconstruction of the Gilboa Dam, this amount of money is very little even when it is fully funded, especially if it is to be distributed throughout the entire state of New York (Kelly 1, 2008).

At a public hearing held on May 2, 2008 to discuss the proposed amendments to the Dam Safety Rules and Regulations, 6 NYCRR Part 673, the DCC recommended that all dam owners should contribute to a state-administered fund to provide for independent engineers to inspect dams periodically and make engineering assessments as well. The amount contributed would then be matched by the State. The DCC also stated that the amount paid by each dam owner should be directly related to the conditions of the dam, the dam's classification and rating under the dam rating system established in the 6 NYCRR Part 673 (Dam Concerned Citizens Inc. 80, 2008). Small dam owners, however, were quick to protest that such proposals would be too costly for them to follow. Mother Raphaela, a nun who directs Holy Myrrhbearers Monastery near Oneonta, said that her monastery already had spent $20,000 on inspections for the 5.18-meter high dam located at their pond, but the DEC found these inspections unacceptable. Another representative for small dam owners, the Mariaville Lake manager, Sandra Scott, expressed similar

concerns as the Mariaville Civic Association had spent $7,000 trying to put its dam into a lower risk category. With such high costs and no way to pay for the further expenses, which would be caused by the tighter regulations, more and more people at the meeting called the proposals another “unfunded mandate” by the state.

Such concerns bring another issue to light with regard to dam management and that is the limitations of the present dam hazard classification system. Should, for example, the small dam on the 3.96m deep Mariaville Lake be listed under the same “high-hazard” classification that the Gilboa Dam is listed as according to the DEC? It seems unreasonable that the risk posed by these small dams would be at the same level as that posed by a dam like Gilboa and that the owners of these small dams should be spending as much money as NYC without any help from the state or an outside source. Cynthia Beer, a representative of the Garnet Lake Civic Association present at the recent public hearing, voiced her own complaints about this discrepancy in dam regulation. Beer criticized the current classification system, “You’re putting these little country dams and ponds and the millions of gallons reservoirs in the same category. I feel like we’re being punished for individuals or municipalities that have not maintained their lakes.” In response to hearing the concerns of the small dam owners, the DCC was quick to say that there should be two sets of regulations in place, one for smaller dams and one for larger dams like the Gilboa Dam (Kelly 2, 2008).

Even beyond the differences in the hazard classifications which should be set in place for small dams versus large dams, the condition rating system used by the DEC also appears to be lacking. In a recent audit by State Comptroller Thomas P. DiNapoli, 133 high and intermediate hazard level dams were identified as having high priority

deficiencies and 24 of the dams labeled as deficient remained so for between 2 to 36 years, while 2 others were classified as deficient for an unknown period of time. Some of the deficiencies which may have been assigned to these dams include inadequate spillway capacity, inadequate stability, no spillway capacity analysis, or no dam stability analysis. By having just one of these deficiencies, the DEC requires that the dam receive further engineering study or remedial work. If these kinds of problems have been present in some of the dams for 2 years or even as long as 36 years and the condition of the dam has not progressed to an “unsound” or “unsafe” status, the labeling of these structures as deficient may not be appropriate. Not identifying the seriousness of the deficiency within a dam correctly only makes dam owners less likely to follow the recommended policy given by the DEC with regard to dam repairs. If a dam can be labeled as having high-priority deficiencies and these deficiencies have still not resulted in a negative impact after 20 or 30 years of ignoring the problem, how can dam owners and community members be expected to take these condition ratings seriously (Office of the New York State Comptroller, 2008)? For this reason, the DEC should consider updating the criteria used to classify a dam as safe. Currently, the proposed amendments to Part 673 - Dam Safety Regulations of Title 6 of the Official Compilation of Codes, Rules, and Regulations of the state of New York only require that all dams be kept in “safe condition”, but do not define the provisions that make a dam classified as safe. Mike Quinn, a dam engineer and member of the DCC, has proposed that the DEC replace the old criteria with a USACE standard (Bartholomew, 2008). As with the Gilboa Dam, each dam could also be set against a FOS standard to ensure its stability in withstanding flood pressures.

In the event that a failure of a dam did occur, the DCC also pointed out the need for the New York state DEC to take greater responsibility when it comes to who is liable for the costs associated with this failure. The new provisions to Part 673 clearly attempt to avoid the New York state DEC's accountability to guarantee dams are operated and maintained at a safe level. The proposed regulations state:

No action shall be brought against the department or its agents for the recovery of damages caused by the partial or total failure of any dam or through the operation of any dam upon the ground that the department is liable by virtue of any of the following:

(1) the approval of the application, plans, or specifications for any dam project;

(2) issuance or enforcement of any administrative or judicial orders relative to maintenance or operation of a dam;

(3) control, regulation, and/or inspection of a dam;

(4) measures taken to protect against dam failure during an emergency; or

(5) measures taken to address a dam failure during or immediately after an emergency.

With this addition to the new regulations, the New York state DEC is trying to shift the responsibility of maintaining dams through periodic inspections to solely the dam owner, when the reality is that the DEC is also responsible for ensuring that the upkeep of these dams happens (Dam Concerned Citizens Inc. 80, 2008). As one can see from the situation with the Gilboa Dam, the NYC DEP has taken on the burden of completely reconstructing the dam to meet DEC standards, but part of the blame must also be placed on the New York state DEC for allowing the NYC DEP to neglect the Gilboa Dam for so many years that its failure was imminent. If the policies regarding dams set forth by the

New York state DEC were sufficient and being properly followed, the Gilboa Dam crisis most likely would never have occurred.

For the DCC, taking a greater responsibility for the effects of dams also includes assisting in flood mitigation, which the group included in its suggestions for the proposed amendments to Part 673. In fact, the DCC has already been successful in incorporating this aspect in the reconstruction plans for the Gilboa Dam, even though NYC has denied that it is accountable for flood control as is shown in *The NYC DEP Climate Change Program Assessment and Action Plan*. The NYC DEP is not the only agency that has resisted such a responsibility, as the New York State Power Authority has also stated in the past that its sole purpose is to provide power using the Blenheim-Gilboa Pumped Storage Power Project, not to help with the mitigating of floods. However, due to the uncertainty of the weather because of climate change, dam owners can no longer deny the responsibility to help with flood control, especially when the construction of a dam alters the flow of the river so much in the first place. Thus, the DCC has asked that the New York state DEC require that whenever a Class C dam undergoes renovations, its owner must add features to the dam that will enhance its flood mitigation abilities

Besides extensively reforming the current regulations set in place for dams, another area which the Gilboa Dam crisis has highlighted the need for improvement upon is greater coordination among counties downstream from dams, local governments, the NYC DEP and other dam owners, and the New York state DEC. The most obvious solution to increasing the amount of communication between each of these entities is the creation of a Watershed Commission. Such a commission would allow public participation as well, in order to address the ongoing concerns of the community with

respect to dams and water issues in general. By creating such a forum, each group's interests and goals could be examined in a more organized fashion and challenges can be met more efficiently too (Dam Concerned Citizens, Inc. 78, 2008). The success of the Delaware River Basin Commission (DRBC) demonstrates how separate governmental bodies and individuals can unite to better the management of a common resource like water. The commission consists of four state governors, one from Pennsylvania, Delaware, New Jersey and New York and one federal representative appoints by the President of the United States. Its creation was the first time that a group of states and the federal government joined together as equals to plan river basin management and development. Today, there are many programs created by the DRBC in place including water quality protection, water supply allocation, regulatory review, water conservation initiatives, watershed planning, drought management, and flood loss reduction (Delaware River Basin Commission 2, 2004). These are the kind of issues a Watershed Commission for New York could address at the state level.

While the establishment of a Watershed Commission would be the first step towards involving local citizens in issues surrounding dam management, allowing the concerns of individuals who would actually be affected by a dam failure to be heard is crucial to improving the state of dams across the United States. As the accomplishments of the DCC show, the participation of local community members can greatly impact the amount of progress that can be made in enhancing the safety standards of a dam. Too often, the government, governmental agencies, corporations, or other organizations leave the public uninformed about their plans, whether it comes to the construction of a new dam or the repair of an old one. This is the case not only here in the United States, but in

other countries as well, like Canada. Many dam projects have been built in Canada without the input of the natives to the area, as was the case with the James Bay Project constructed in northern Quebec. Because the dam was believed to only negatively affect the interests of about 2,000 people, the company building the dam chose to ignore these impacts and go ahead with the construction of the dam (Quinn, 1991). No matter what the amount of people, however, all the residents living near a dam or living near the site of a proposed dam should be informed of dam regulations, dam deficiencies, dam inspection reports, and construction or reconstruction plans. The DCC recognizes the importance of its role in the developments of the Gilboa Dam reconstruction plan and because of this has requested that the New York state DEC include in its regulation reforms the requirement that the full record of safety inspections for a dam be disclosed to the public in a timely fashion. The public's right to such information will allow local community members to ensure that their interests are being represented by the dam owners and the government. While the residents of the Schoharie Valley have been able to depend upon the DCC as their informants and representatives to guarantee their safety, future communities at risk should be able to rely on the government to provide them with a full account of the problem at hand (Dam Concerned Citizens, Inc. 80, 2008). Still, however, once a local community is given the necessary information, it is then their responsibility to make sure their concerns are heard.

In a much broader sense, each of my suggestions comes down to the fact that there is simply a greater need for the integration of science, engineering, and policy when managing dams. As is the case with many environmental issues we are facing today, the policy cannot be created without first understanding the science behind an issue and with

respect to dams, the engineering of a problem as well. Once the science and engineering is understood, however, one cannot forget the social impact that the construction of dams and the upkeep of dams can have on a community. The state of all the dams in the United States being at a satisfactory level is thus dependent upon this combination of contributions from scientists, engineers, and policy-makers and only with this combining can dams be managed successfully.

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