A Strategy to Reduce the Risks and Impacts of Dams on Floodplains

JULY 2013

This report includes an analysis of the relationship of dams to the floodplain and recommendations on how to better integrate dams into floodplain management and risk reduction activities.

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STAFF

The primary authors of this report are Dave Carlton, DKCarlton & Associates and Heidi Kandathil, H.A.Kandathil Planning Services. Samuel Johnson provided editorial assistance.

The Project Manager was Alan Lulloff, Association of State Floodplain Managers.

ADVISORY COMMITTEE MEMBERS

- Mustafa Altinakar, *University of Mississippi*
- Glen Austin, *National Hydrologic Warning Council*
- Jill Butler, *River Science, LLC*
- James Demby, *Federal Emergency Management Agency*
- Victor Hom, *National Oceanic and Atmospheric Administration, National Weather Service*
- Martha Juch, *Texas Section, American Society of Civil Engineers*
- Byron Lane, *Michigan Department of Natural Resources*
- Stephanie Lindoff, *American Rivers*
- Enrique Matheu, *Department of Homeland Security*
- Jim Murphy, *URS Corporation*
- Mark Ogden, *Association of State Dam Safety Officials*
- Bronwyn Quinlan, *Federal Emergency Management Agency*
- Cleighton Smith, *Bergmann Associates*
- Robert Webb, *United States Geological Survey*
- Laura Wildman, *Princeton Hydro*

PREFACE

ASFPM WORKING GROUP ON DAMS – IMPACT OF DAMS ON FLOODPLAIN MANAGEMENT

In 2008, ASFPM developed a working group of floodplain experts to address floodplain management issues related to dams. The objectives of this group were to:

- Educate themselves on all aspects of dams and dam issues related to floodplain management;
- Identify dam-related issues that relate to floodplain management;
- Quantify, categorize and/or prioritize aspects of these issues to make them easier for ASFPM members and ASFPM Board members to understand;
- Draft a white paper on dam-related issues for consideration by the ASFPM Board; and
- Suggest policies and policy statements for adoption by ASFPM.

The working group developed several documents that serve as the basis of this report. These include:

1. Modeling Tools for Dam Break Analysis
2. Environmental Issues Related to Dams
3. Risk Communication about Dams Relative to Floodplain Management

After creating these draft documents, the volunteer group suggested an outline structure for a future comprehensive paper on dam risk reduction and completed their work. FEMA desired to create a strategy utilizing the knowledge of the volunteers and decided to fund ASFPM to build on the efforts of the working group to explore the topic.

PROJECT BACKGROUND

During the past several years, the Federal Emergency Management Agency (FEMA) has worked to modernize its inventory of Flood Insurance Rate Maps (FIRMs) and has recently implemented the Flood Risk Mapping, Assessment and Planning (Risk MAP) strategy to reduce flood risks in the nation. This initiative includes risks associated with levees such as those areas behind levees that do not provide protection from at least the 100-year event. While this initiative estimates the risks associated with

levees, there has been no comparable effort by FEMA to assess the residual risk associated with dams. It is known that dams affect floodplains and the communities, in which they are located in a number of ways, including public safety, flood risk and the environment.

The purpose of this document is to help floodplain management officials and communities better understand how dams affect floodplains, and the impacts dams may have on those communities. Information on dams that may have a bearing on a state's or community's responsibility to protect its citizens must be made accessible to ensure citizens are aware of their risks and are prepared to deal with them. This report includes an analysis of the relationship of dams to the floodplain and recommendations on how to better integrate dams into floodplain management and risk reduction activities.

Much of the public believes that *every* dam provides them some level of flood protection, but fails to recognize that less than a fifth of all dams were built primarily to provide flood protection. While many others provide some limited degree of flood protection, that is not their primary purpose. There are many small dams, old mill dams for instance, that provide no flood protection, but do present a risk to the community should they fail. Many believe that the Flood Insurance Rate Maps produced by FEMA's National Flood Insurance Program include areas subject to dam failure. Unfortunately, they do not. Likewise, the NFIP does not require or address the need for any special construction or land use standards below dams, no matter their condition. This is at odds with its policy on levees, where the potential for their failure is considered in both the mapping and the minimum land use and construction standards. This was an important consideration in the development of this report, since there is the potential for a dam failure to inundate areas far beyond the mapped Special Flood Hazard Area.

PROJECT OBJECTIVE

The objective of this project was to develop a national risk reduction strategy for communities affected by dams, especially those not designed for flood protection, keeping in mind the wide range of issues associated with ownership, purpose, and the environment. This strategy provides suggestions on:

- *How to improve community understanding of the effects of dams on floodplains and floodplain management,*
- *How communities can find information on dams from their states that may impact their responsibilities, and*
- *Steps that can be taken to ensure that communities and states are aware of the hazards associated with dams and are prepared to deal with them through appropriate mitigation strategies.*

When communities consider the impacts of dams on their community they most often think only of the consequences of the failure of a dam. However, there can be severe consequences to a community even when a dam does not fail, and in some instances, operates exactly as planned. The following

examples from locations throughout the United States illustrate a few of the issues dam owners and communities face.

DESIGN CAPACITY – NASHVILLE, TENNESSEE – MAY 2010 FLOOD EVENT

In early May 2010, Nashville and Davidson County, Tennessee were impacted by destructive floods in the aftermath of a major precipitation event across the region. Record rainfall amounts of 10-20 inches fell over a 36-hour period from May 1st to 2nd across the Cumberland River Basin, which stretches across north-central Tennessee down to the Ohio River in southeastern Kentucky. The runoff from this rainfall resulted in significant floodwaters on the Cumberland and its main tributaries, including the Harpeth, Red, Stones, Caney Fork, and Obey Rivers. Unfortunately, the heaviest rains fell primarily in the unregulated portions of the Cumberland River Basin outside of the flood control reservoirs behind Wolf Creek, Dale Hollow, Center Hill, and J. Percy Priest Dams. These four dams control floodwaters from the tributaries flowing into the mainstem of the Cumberland River, but are not located on the Cumberland itself. As a result, Nashville and Davidson County became vulnerable to the May 2010 floods. Portions of Nashville were inundated soon after the rains and remained so for weeks.

The three locks and dams (L&D) nearest to Nashville, namely the U.S. Army Corps of Engineers' Cordell Hull, Old Hickory, and Cheatham L&D, reached record elevations in the days after the rainfall subsided. Barkley L&D, located on the Cumberland River downstream of Nashville, set a record maximum water flow release. Old Hickory L&D came within 6.6 inches of overtopping the upstream lock wall.

With some degree of flooding at Nashville inevitable and to the maximum extent possible, the Corps of Engineers reverted to a damage control strategy of passing floodwaters between the three locks and dams, lowering the Cheatham L&D water level to reduce the backwater in Nashville, while slowly drawing down the upstream flood control reservoirs to regain flood control capacity without increasing the flooding in Nashville downstream of Old Hickory L&D. Thus, Cheatham L&D below Nashville remained in free-flow with all gates removed from its spillway throughout the week after the rains. Barkley L&D continued to pass the flows from Cheatham L&D and the flood control reservoirs slowly released the stored floodwaters for several months before regaining their designed flood storage capacity.

To prevent a flood event similar to that at Nashville from occurring elsewhere in the country, it may be worthwhile to note the following:

- Heavy rains will cause flooding on tributary and river channels where the channel capacities are inadequate to contain the runoff.
- When excessive rainfall occurs in areas with inadequate off-channel storage, stormwater runoff cannot be stored to prevent flooding in the tributary and river channels.
- If excessive rains fall downstream of flood control reservoirs, they cannot store the floodwaters to alleviate flooding.

- A federal flood control dam is normally regulated to alleviate downstream flooding by holding back floodwaters to the maximum extent possible without exceeding its design capacity.
- Downstream channel capacities and floodplain development can hamper upstream flood control reservoirs from making reservoir releases and optimally regulating for subsequent flooding.
- When a flood control dam is unable to release floodwaters, it will continue to store water, which results in a reduction of reservoir storage capacity for future flood events.
- Since dams are designed for specific purposes and operated to achieve their design function, not all dams can effectively reduce downstream flooding downstream.

In summary, in the spring of 2010, heavy rains fell across the large watershed draining to several of the Cumberland River's Locks and Dams (L&D), in particular around Nashville's Cordell Hull, Old Hickory, and Cheatham L&D. These three facilities were primarily designed for navigation and hydropower. Locks and dams that are operated for maintaining navigable waters and generating hydropower have limited flood storage capacities. The flooding associated with this record event was more than these three projects and Nashville could handle.

In addition, the Nashville floods illustrate the effects of the development within the floodplain on the dams' ability to safely regulate the passage of flood, hydropower, and navigational releases. Therefore, communities could benefit from a better understanding of the strategies and precise sequence of dam operations used to coordinate releases between various dams, in order to determine more effective operational sequences, and to make a set of alternate plans to account for all possible future high water scenarios. (ASFPM, 2012)

RISK COMMUNICATION – MINOT, NORTH DAKOTA – JUNE 2011 FLOOD EVENT

The Souris River floods of 2011 necessitated the evacuation of approximately 12,000 residents from Minot, North Dakota and caused an estimated $600 million in damage to property and infrastructure. In the upper headwaters of the Souris River in Saskatchewan, Canada, states of emergency were declared in the cities of Weyburn and Estevan, where over 400 residents were evacuated from their homes; almost every home in the Village of Roche Percee was inundated. In the lower Souris River Basin in Manitoba, approximately 140 people were evacuated, either by mandatory order or voluntary request. Numerous road closures, undermined roads, and damaged river crossings occurred throughout the Souris River Basin.

The Souris River originates in the Yellow Grass Marshes of semiarid southern Saskatchewan, flows 358 miles through north-central North Dakota, and then flows back into Canada in southern Manitoba. The basin has historically been subject to the extreme variations of drought and high water. The Souris River valley is flat, shallow, and has been extensively cultivated.

Major reservoirs within the Souris River Basin include Boundary, Rafferty, and Alameda reservoirs in Saskatchewan and Lake Darling in North Dakota. International agreements exist to manage water in the Souris Basin (see HERE). The Saskatchewan Watershed Authority owns, operates and maintains the Rafferty and Alameda Dams. Lake Darling Dam is owned and normally operated by the United States Fish and Wildlife Service (USFWS), but its flood control operation is regulated by the U.S. Army Corps of Engineers. These three dams are critical in protecting Minot from flooding.

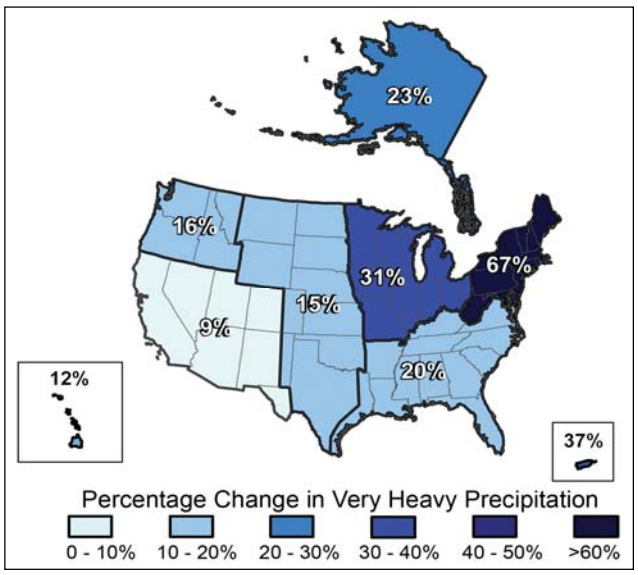
In 2011, high soil moisture content, above average snowpack, and persistent moderate spring rainfall and moderate to heavy summer rainfall combined to produce multiple flood peaks and record flooding throughout the Souris River Basin. Reservoir operations were in compliance with the 1989 International Agreement until inflows became too high and the reservoirs became too full due to a series of precipitation events, culminating with the very heavy rainfall of June 17th to 21st. The Souris Basin in the vicinity of Rafferty Dam received four to seven inches of rain from Monday, June 20 into Tuesday, June 21.

To avoid overtopping, the reservoirs released flows in excess of the 1989 International Agreement. The spillway gates at Rafferty Reservoir were fully opened on Monday, June 20th at 8 AM due to concerns for the spillway capacity and dam safety. On June 21st the Saskatchewan Watershed Authority passed flows in excess of 27,000 cfs through Rafferty and Boundary Dams and surpassed the previous record flood height by two feet. This large pulse of water proved to be about three times more than Lake Darling could hold back; as a result, a peak outflow of 26,000 cfs had to be passed downstream into Minot. Lying just 15 miles downstream of Lake Darling, Minot bore the brunt of the floodwaters and became the focus of one of the final episodes of an unusually severe flood season in the Missouri and Mississippi basins in 2011.

The eventual flooding in Minot and surrounding Ward County was apparently caused by cross-border miscommunications concerning plans for water releases from the dams in Saskatchewan. The USACE 2011 Post Flood Report for the Souris River Basin cited that differing interpretations of the 1989 International Agreement added to the complexity of operating the Souris Basin project. It noted that the inability to attain and hold target flows for Sherwood Crossing and Minot seemed in conflict with the requirement to evacuate the floodwaters in an "orderly and timely" manner.

The suddenness of the rain event in combination with the existing snowpack exacerbated the problem. As a result, Lake Darling was challenged by a flood event with an approximate annual exceedance frequency of 0.2 percent (500-year return interval). The frequency of extreme rain events like this one is increasing nationwide (see Figure 1) due to changing climatic conditions.

Figure 1 - – Increases in Amounts of Very Heavy Precipitation (1958 to 2007)



The map shows the percent increases in the amount falling in very heavy precipitation events (defined as the heaviest one percent of all daily events) from 1958 to 2007 for each region. There are clear trends toward more very heavy precipitation for the nation as a whole, and particularly in the Northeast and Midwest. Source: U.S. Global Change Research Program (Karl et al, 2009)

Better communication between the U.S. Army Corps of Engineers and the Saskatchewan Watershed Authority, including detailed plans and notice, could have allowed for more effective releases from Lake Darling Dam and reduced the excess flows crossing the U.S.-Canada border. Enhanced reservoir operations to reduce flooding are possible, but when dams are pushed to the edge of their design capacity it will not prevent extreme flooding. The decision to safeguard a dam's safety is the top priority for preventing a mass catastrophe and is the proper decision when there are minimal alternatives.

Enhanced cooperation and planning between USACE, Saskatchewan Watershed Authority, and city and county officials could minimize the impacts of flooding. If extreme flooding is the "new normal" and dams are being pushed to the brink of their design capacity, then risk communication and the understanding of the residual risk for living below a dam is paramount. (ASFPM, 2012) (Corps of Engineers, 2012)

EVOLVING CONDITIONS & RISK MAPS – PACIFIC, WASHINGTON – JANUARY 2009 FLOOD EVENT

The City of Pacific, Washington, a community of over 6,600 people (2010) in the greater Tacoma metropolitan area, experienced severe flooding in January 2009. The USACE Seattle District's Pacific Flooding After Action Review (AAR) noted "*[on] the evening of 8 January, 11,700 cubic feet per second (cfs) peak outflow releases from US Army Corps of Engineers' (USACE) Mud Mountain Dam (MMD) on the White River, combined with downstream inflows, caused flooding in downstream residences and businesses in the City of Pacific. The apparent cause of the increased flooding is a substantial change in channel capacity. US Geological Survey (USGS) channel measurements at the river gage location in January 2009 compared with those taken in November 2008 indicate an approximate 30% loss of channel capacity at the gage location*."

Mud Mountain Dam, built in 1948, is a flood control dam that protects the lower White and Puyallup River valleys from flooding by storing water from heavy rains and melting snow in its reservoir. Prior to its construction, annual floods from the White River severely impacted Pierce and King Counties. Water released from the dam flows between the cities of Buckley and Enumclaw, around Lake Tapps, past the City of Pacific, and into the Puyallup River at Sumner. Mud Mountain Dam is 23 miles upstream of the City of Pacific; releases from the dam take approximately four hours to reach the city.

Mud Mountain Dam is authorized to release a maximum discharge of 17,600 cfs. In recent years, USACE has tried to keep MMD outflows below 12,000 cfs to limit downstream flooding along the White River. Releases exceeding 10,000 cfs from MMD have occurred at least 11 times since 1974. Prior to the January 2009 event, comparable dam releases were made in November 2006 without flooding homes or businesses. The USACE AAR noted that during the 2006 flooding, there were observations of a two-foot change in the elevation of the channel bottom over a short period of time. This change was significantly greater than the expected gradual aggradation of the channel at a rate of approximately six feet over a 20-year period. Increases in channel debris and bed deposition will reduce the channel capacity in the White River and inhibit the passage of USACE authorized flood releases.

A 2010 USGS study of the Puyallup River system, which includes the White River, indicated that increases in average channel bed elevations were significant between 1984 and 2009, particularly in the vicinity of Pacific. It noted that the largest net volume of deposited sediment in the White River for one particular area was approximately 547,000 cubic yards of sediment, or 21,900 CY per year (Pierce County, 2012). The report reinforces that the White River is highly dynamic, with the potential for abrupt changes to the riverbed and the movement of large amounts of sediment. Consequently, its flows are very difficult to measure using the traditional USGS gaging methods.

The January 2009 event exposed the hazards of living in the floodplain below Mud Mountain Dam. MMD is no longer able to operate in the manner for which it was originally designed. The changes in the lower floodplain illustrate the need to address residual risks of living in the floodplain below a dam – the essential topic of this ASFPM report. In addition, understanding residual risks should take into account the potential impacts of geomorphology, climate change and extreme weather. The January 2009 flood event at Pacific was a result of a version of the meteorological phenomenon known as an *atmospheric river*. At the time of this event, the National Weather Service was prepared for the phenomenon commonly known as the *Pineapple Express*. The *Pineapple Express* is an example of atmospheric river, in which there is a strong persistent flow of high atmospheric moisture content streaming onto the U.S. Pacific coast from the Hawaiian Islands. At the 2012 Western States Water Council Conference in San Diego, Larry Schick of the USACE Water Management Section provided a presentation on atmospheric rivers and their effects on Washington State. Specifically, he explained that an atmospheric river is a long, narrow plume of water vapor originating in the tropics and attached to mid-latitude storms. Such a plume was associated with the November 2006 and January 2009 events and affected USACE operations of MMD by causing the accumulation of significant floodwaters behind it. During the 2009 event, the flood control pool behind the dam filled from empty to 65% full in two days. If MMD had not been constructed, there was the potential for an additional 30,000 cfs in the White River from the storm and the damage in Pacific would have been much greater. There were 112 residential and 10

commercial properties affected by the January 2009 event, with damages of $5 million and $10 million, respectively.

Many residents impacted by the flooding in Pacific did not have flood insurance because they were unaware their homes were within a Special Flood Hazard Area, largely due to the inadequacy of the existing effective FEMA Flood Insurance Rate Maps (FIRMs) for predicting where flooding would occur. The inadequacy of the effective maps—dating to the 1980s—and recently prepared preliminary maps appears to be due to the volatile, fast-changing nature of the White River. Misunderstanding or ignorance of the flood hazard, owing largely to outdated and ineffective flood mapping, was thus another contributor to the severity of the flooding in Pacific (ASFPM, 2012). FEMA is working to develop Risk MAP products, including non-regulatory maps, which show the residual risks for those living below a dam. ASFPM believes this will help in communicating the flood risks and allow those potentially impacted to implement measures to reduce their risk.

THE LESSONS LEARNED

The three case studies show that flood control dams are frequently operated beyond their design capacity during a flood event. Flooding is inevitable, whether due to manmade degradations in a floodplain, natural changes in the stream channel, excessive rainfall, a combination of rainfall and snowmelt, or competing riverine interests. Therefore an understanding of the residual risk of those living below a dam becomes paramount.

Some dams are built to reduce flooding, but they do not prevent flooding. The federal government constructed numerous dams in the mid- to late- 20th century to reduce flooding. The Corps of Engineers and Bureau of Reclamation have worked diligently to maintain their dams to ensure their integrity in the face of dwindling federal resources. If dams are not adequately maintained, the risk associated with catastrophic dam failure increases dramatically. Most importantly, these risks should be disclosed to the segment of the public living below the dam, for which the risks are the greatest. FEMA's strategy to encourage the development of Emergency Action Plans (EAPs) for high-hazard-potential dams, which show the residual risks where hazards are greatest, should be universally adopted.

The Corps of Engineers' *After Action Reports* and *After Action Reviews* highlight the best intentions in coming up with mitigation strategies to reduce future flood risks. It should not be overlooked that flooding is inevitable and exactly when, where, and to what extent cannot be answered. Further, enhanced communication can increase awareness, but the awareness should acknowledge that damages will inevitably occur for inhabitants living too close to the water's edge.

With continued losses of channel capacity, inhabitants should respect and "make way" for the river. This is a central theme of ASFPM and is recommended to modify human behaviors to reduce flood risk. The six critical actions stated in the ASFPM Foundation Forum 2050 Report include:

1. Make room for rivers, oceans, and adjacent lands.

2. Reverse perverse incentives in government programs.

3. Restore and enhance the natural, beneficial functions of riverine and coastal areas.
4. Generate a renaissance in water resources governance.
5. Identify risks and resources and communicate at public and individual levels.
6. Assume personal and public responsibility.

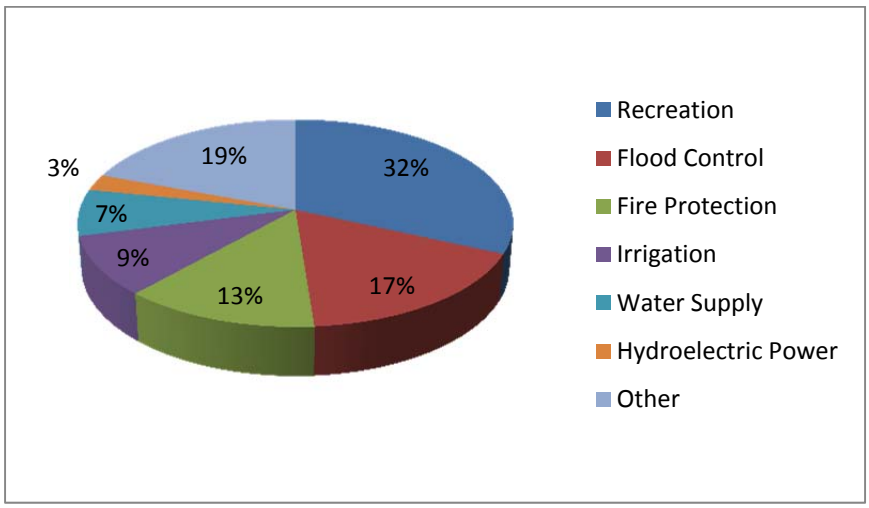
The guiding principles of the ASFPM Foundation Forum 2050 Report align well in crafting a strategy to better integrate the understanding of dams' impacts on floodplains and flood risk. The report (see here) should be consulted for the specific "calls to action." The ASFPM Foundation Forum 2050 Report and this dam working group report provide specific programmatic recommendations which FEMA's National Dam Safety Program could consider. Their guiding principles capture new ways of thinking and operating that will be needed to achieve safe and sustainable relationships with our water resources. If decision-makers, professionals in floodplain management, households, businesses, and others keep these guiding principles in mind, our individual and collective actions will serve to move the United States toward a safer and more sustainable future.

DAMS IN THE UNITED STATES

Dams are barriers that are designed to impound or retain water for a variety of purposes, including water supply, irrigation, power generation, flood control, recreation and pollution control. Further, dams have great variation in size, ownership and operating rules. They can be as small as a neighborhood detention facility to as large as a hydropower structure like the Hoover Dam. Many small private dams have no operating rules, have spillways that are not regulated, and provide limited to no flood protection. The use of dams can be traced through history on many different river systems throughout the world. The first dam is believed to be the Jawa dam system in modern-day Jordan, constructed about 3000 BC. Throughout history, many different materials have been used to construct dams. Most dams in the United States are either embankment or concrete dams (Association of State Dam Safety Officials, 2012). Embankment dams are made of earthen materials such as soil, rock, or waste from mining or milling.

The United States Congress authorized the U.S. Army Corps of Engineers to inventory the nation's dams with passage of the National Dam Inspection Act (Public Law 92-367) of 1972. The National Inventory of Dams (NID) was first published in 1975 and has been periodically updated since (Federal Emergency Manangement Agency, 2009). According to the 2013 NID there are over 87,000 dams in the 50 states and Puerto Rico. In addition to this, there are a significant number of dams in the U.S. that are too small to be included in the NID. Of the 87,000, the top six purposes for which they were constructed are as follows: 27,733 are primarily for recreation, 14,883 are primarily for flood control, 11,253 were designed for fire protection, 8,133 are for irrigation, 6,307 dams are for water supply and 2,209 are for hydroelectric power (Army Corps of Engineers, 2013). See Figure 2 for distribution.

Figure 2 -Uses of Dams in the United States



Other primary uses of dams in the United States include debris control, grade stabilization, navigation and fish and wildlife uses. Most dams are considered multi-purpose.

USES OF DAMS

FLOOD CONTROL

The Federal Emergency Management Agency defines a dam as an artificial barrier that has the ability to impound water, wastewater or any liquid-borne material for the purpose of storage or control. Flood control dams are used to temporarily hold floodwaters, which are then either released at a controlled rate to the river below or diverted for other uses (Federal Emergency Management Agency, 2012). As mentioned, flood control is and has been one of the primary purposes of dams in the United States. According to the NID, approximately 17 percent of all dams were constructed for the primary purpose of flood control.

A series of flood control legislation was passed by the federal government in the early- and mid-20th century for the primary purpose of dam construction for flood control. The Flood Control Act of 1928 authorized the U.S. Army Corps of Engineers to design and construct flood control projects on the Mississippi River and Sacramento River systems. Its significance is difficult to assess, but three aspects are worth noting. First, the 1928 act greatly increased public awareness of the major advances in flood control theory and practice. Second, it put flood control on a par with other major projects of its time by authorizing an expenditure of $325 million, the largest appropriation for a public works project authorized by the federal government up to this time. Finally, the act brought to the forefront the issue of how much money local communities should contribute to the cost of a project. The issue became one of the central questions surrounding future flood control acts (Arnold, 1988). The Flood Control Act of 1944 and the Watershed Protection and Flood Control Act of 1954 delegated to the Natural Resources Conservation Service the responsibility to assist in the construction of 11,000 flood control dams in 2,000 different watersheds in 47 states (Federal Emergency Management Agency, 2004). These dams

effectively provide an estimated $1.7 billion in flood damage protection to downstream structures (Federal Emergency Manangement Agency, 2009). Additionally, the dams of the Tennessee Valley Authority prevent an average of $280 million in structural flood damages each year (Federal Emergency Management Agency, 2004).

The storage provided by large flood control dams enables the reduction of high peak flows in rivers. As shown in Figure 2 however, most of the dams in the country were not built for flood control and provide limited or no flood control benefit. Floodwaters stored behind flood control dams can be released downstream at a lower flow rate, thereby reducing flood risk to downstream communities. However, residual flood risk still exists downstream of these structures. *Residual risk* is defined as the portion of risk that remains after a dam has been built. Risk remains because of the chance of the design capacity being exceeded or the structural failure of the dam (Library of Congress, 2005).

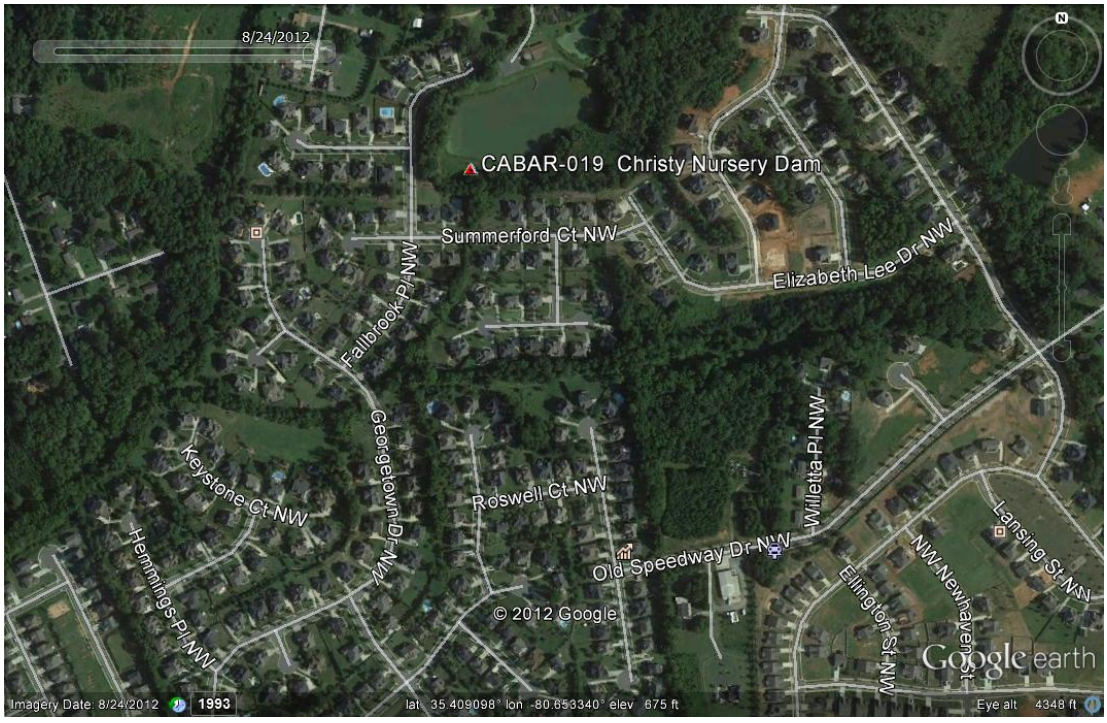
While providing some flood reduction for millions of people under most scenarios, the risk of dam failure remains for communities below dams. According to the 2013 data for the NID, of the approximately 87,000 dams in the United States, over 14,000 are considered *high-hazard-potential* – meaning they pose a high or significant hazard to life and property in the event of failure or breach (Army Corps of Engineers, 2013) (National Dam Safety Review Board, 2006).

While some flood control dams were constructed as *high-hazard-potential* dams, with an awareness of the risk to downstream communities, many were not. Instead they were constructed as *low-hazard-potential*' dams in rural areas to provide flood control for agricultural lands or downstream communities. As the building and development of homes, industry and road networks occurred in areas that would be subject to inundation in the event of a dam failure, these dams have been reclassified as high-hazard-potential (Oklahoma Conservation Commission, 2012). This phenomenon is commonly referred to as *hazard creep*.

The National Resources and Conservation Service (NRCS) constructed 2,042 dams in Texas as part of the Texas Watershed Program. Of these dams, 372 are now classified as high-hazard-potential. However, only 113 of the high-hazard-potential dams were originally constructed as high-hazard-potential. The other 259 were constructed in rural areas and became high-hazard-potential due to development downstream. These dams were built to a lower standard and must do extensive rehabilitation to meet current state standards. The NRCS has very limited funds for assisting local sponsors with dam rehabilitation projects. More dams can be expected to become high hazard as the population and associated development continues to expand in the state. Another example of hazard creep is illustrated below in the photographs of development around the Christy Nursery Dam, a private dam near Concord, North Carolina. The first photograph was taken in 1998 (see Figure 3) and the second in 2012 (see Figure 4) showing the impact of recent residential development.

Figure 3 - Development near Christy Nursery Dam in 1988

Figure 4 - Development near Christy Nursery Dam in 2012



HYDROPOWER

The technology to generate power using water has existed in some form for more than a century. The hydropower turbine was first developed in the mid-1700s by the French engineer Bernard Forest de Bélidor. Hydropower was introduced in the United States in the late 19th century. In 1882 the world's first hydroelectric dam began operation on the Fox River in Appleton, Wisconsin (see Figure 5) (U.S. Department of Energy, 2011).

Figure 5 – Fox River Dam, Appleton, WI. (Source: Library of Congress)

The United States is one the world's leading producers of hydropower, providing more than 103,800 megawatts of electricity and meeting up to 12% of the nation's electricity needs (Federal Emergency Management Agency, 2004). Hydropower is considered a renewable, clean energy source because it does not contribute to air pollution or global warming. Hydropower facilities in the United States have the capacity to supply 28 million homes with electricity (U.S. Environmental Protection Agency, 2007). Without hydropower, it is estimated that the United States would have to utilize an additional 77 million metric tons of coal, 27 million barrels of oil, and 741 billion cubic feet of natural gas to meet the nation's energy resource needs annually (Federal Emergency Management Agency, 2004). Impoundments behind hydropower dams often also offer recreational opportunities, flood control, irrigation and water supply benefits.

WATER SUPPLY

STORING WATER

The reservoirs created by dams supply water to a variety of different users throughout the country. Approximately 10 percent of American croplands are irrigated by water stored behind dams, while reservoirs supply water to more than 31 million people (Federal Emergency Management Agency, 2004). Water is captured behind dams during wet seasons and is then released during dryer parts of the year. Water can also be moved to watersheds that need supplemental or primary water supply. The Bureau of Reclamation is the nation's largest wholesale water supplier, operating a total of 348 reservoirs with a storage capacity of 245 million acre feet of water[1]. (U.S. Department of the Interior, 2011).

IRRIGATION

Forty percent of the nation's water supply is used for irrigation purposes. Dams provide one out of every five Western farmers with irrigation water for 10 million acres of farmland that produce 60 percent of the nation's vegetables and 25 percent of its fruits and nuts (Federal Emergency Management Agency, 2004). Worldwide, irrigation is the largest use of the waters withdrawn from dams. However, irrigation is not necessarily the biggest user of the storage capacity behind dams.

SEDIMENT CONTROL

Dams have also been constructed to prevent pollution from sediment. For example, the dams on the Susquehanna River in Pennsylvania have helped prevent large-scale pollution of Chesapeake Bay by sediment (Federal Emergency Management Agency, 2004). The primary purpose of debris dams is to capture high loads of sediment at a location where it can be easily removed before it clogs a downstream channel. Tailing dams are constructed at many mines to contain the pollutants generated by mining and prevent their entry into streams and rivers.

RECREATION

Dams provide recreational opportunities for boating, fishing, swimming, hiking and camping. Recreation is one of the primary uses of reservoirs in the United States, and approximately one-tenth of the population visits a Corps of Engineers dam facility each year for that purpose. According to the NID, dams constructed for the primary purpose of recreation make up close to 40 percent of the total dam inventory. The Bureau of Reclamation (BoR) reports over 90 million visitors annually to 289 recreation

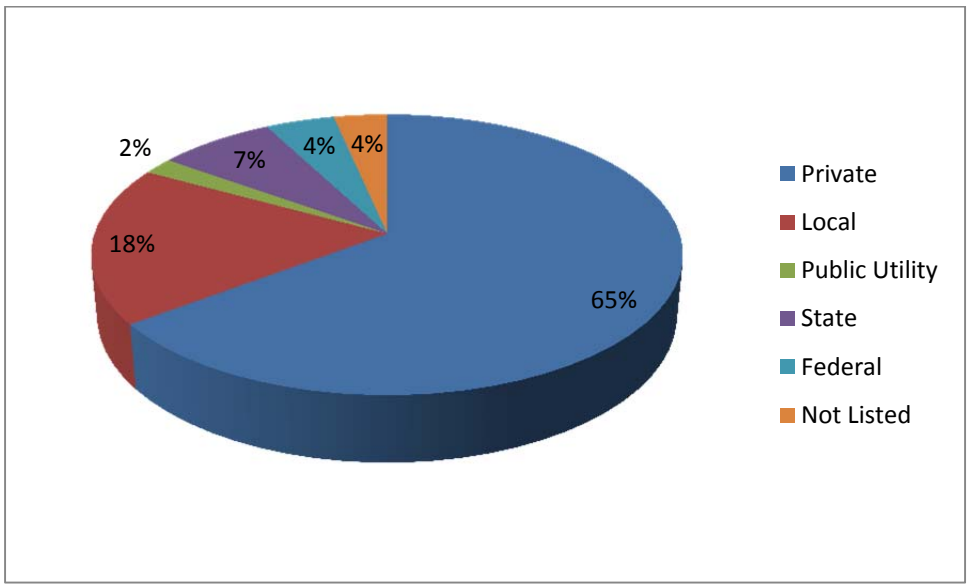
[1] One acre foot of water is enough to provide water for a family of four for one year.

areas developed as part of its dam and reservoir projects. Eleven national wildlife refuges have been developed as a result of a BoR water project (U.S. Department of the Interior, 2011).

OWNERSHIP

Dams in the U.S. have a variety of owners. Unlike other major infrastructure, most are privately owned. Of the approximately 87,000 dams listed in the NID, 3,808 dams are owned by the federal government; 15,938 are owned by a local government; 56,541 are privately owned; 1,686 are owned by a public utility; 6,435 are state owned; and the ownership of the other 2,951 dams is not listed (see Figure 6) (Federal Emergency Manangement Agency, 2009). Dam owners are responsible for operations, maintenance and inspections of dams and are liable for problems related to the dam. The extent of liability depends on many factors including but not limited to the downstream consequences, causes of the problem, existing state statutes and safety requirements.

Figure 6 - U.S. Dam Ownership



REGULATION

In the U.S. dams are the responsibility of many different entities including private organizations and governments. However, the majority (over 80 percent) of these are regulated by state governments. Dams in the U.S. fall under the principle of the Public Trust Doctrine as well as the inherent duty of government for public safety. The essence of the Public Trust Doctrine observed today is that the waters of the United States belong to the public. It is the Public Trust Doctrine that, as a corollary, establishes the states' regulatory authority over dams. The principle as we know it dates back to English common law, but has its roots in the Institutes of Justinian, the code of Roman civil law assembled under the direction of the Roman Emperor Justinian in 530 AD, which stated: "*By the law of nature these*

things are common to all mankind, the air, running water, the sea and consequently the shores of the sea."

At the end of the 19th century the U.S. Supreme Court firmly established the Public Trust Doctrine in American jurisprudence, finding that *"the ownership of and dominion and sovereignty over lands covered by tide waters, within the limits of the several States, belong to the respective States within which they are found."* (*Illinois Central Railroad Co. v. Illinois,* 146 U.S. 387, 435 (1892))

Under the Public Trust Doctrine, the states have an affirmative duty to take the public trust into account in the planning and allocation of land and water resources. They also must protect public trust uses for the common good, including the protection of recreational and ecological values.

Under the U.S. Constitution, the states authorized the federal government to address issues associated with interstate commerce. At the time, rivers were the primary mode of transportation, hence streams navigable for transportation of goods fell under federal sovereign authority. This sovereign authority associated with the Public Trust Doctrine allows the federal government to erect and regulate dams on navigable streams. In addition to the Public Trust Doctrine, the primary reason state entities began to regulate dams is to protect public safety. Dams represent one of the greatest risks to public safety, local and regional economies and the environment. Historically, some of the largest disasters in the United States have resulted from dam failures (Association of State Dam Safety Officials, 2013). As an example, the Johnstown flood which killed 2,200 people in Johnstown, Pennsylvania in May 1889 was caused by the failure of the South Fork Dam – a recreational dam nine miles above the city.

Of the 87,000 dams identified in the 2013 National Inventory of Dams, 14,726 are considered high-hazard-potential, meaning there is a significant risk to life and property in the event of failure. The American Society of Civil Engineers (ASCE) graded the nations dams a "D" in the 2013 Report Card for America's Infrastructure based on the large numbers of dams with structural deficiencies and the lack of available funding for inspections, repairs and rehabilitation projects. ASDSO estimated that an investment of $21 billion would be needed to repair the nation's high-hazard dams (American Society of Civil Engineers, 2013). As dams age, especially without proper maintenance, the risk of failure increases significantly. Dam failures have occurred in every U.S. state. From January 1, 2005 to January 1, 2009 state dam safety programs reported *at least* 132 dam failures and 434 incidents (Association of State Dam Safety Officials, 2012). This number is probably low due to unreported incidents and is known to be increasing. An *incident* is defined as an event that without intervention would have resulted in dam failure. A series of dam failures in the 1970s began to raise awareness of the issues related to dam safety and led to increased state and federal regulation of dams. In the wake of these failures, then-President Jimmy Carter directed the Corps of Engineers to begin inspecting all non-federal high-hazard-potential dams. The findings of the inspection led to the development of dam safety programs in most states and ultimately to the development of the National Dam Safety Program (Association of State Dam Safety Officials, 2012).

The National Dam Inspection Act of 1972 (Public Law 92-367) first authorized the Corps to inventory the nation's dams. The Water Resources Development Act of 1986 (Public Law 99-662) authorized the Corps to maintain and periodically publish an updated dam inventory. As discussed previously, the goal of the NID is to inventory all dams that meet the following criteria:

1. High-hazard-potential classification – loss of at least one human life is likely if the dam fails.
2. Significant-hazard-potential classification – possible loss of human life and likely significant property or environmental destruction.
3. Equal or exceed 25 feet in height and exceed 15 acre-feet in storage.
4. Equal or exceed 50 acre-feet in storage and exceed six feet in height. (Army Corps of Engineers, 2013)

While the goal is to inventory all dams meeting the above characteristics, the database only contains the information that can be gathered and interpreted easily. Incomplete and unreported information remains to be added. Therefore, the inventory may not include all dams meeting a given criteria. Additionally, there are many significant- and low-hazard-potential dams for which states have information but that are not currently in the NID because they do not meet size criteria. More complete dam safety information is available from the state dam safety programs. The NID was not intended to be the ultimate source for information on dams. The states have the most complete information.

Another significant law supporting dam safety is the National Dam Safety Program Act, which was signed into law as part of the Water Resources Development Act of 1996. Its purpose is to reduce the risks to life and property from dam failure in the United States through the establishment and maintenance of an effective national dam safety program to bring together the expertise and resources of the Federal and non-Federal communities in achieving national dam safety hazard reduction. In 2006, Public Law 109–460 reauthorized the National Dam Safety Program Act. This legislation formally established the National Dam Safety Program (NDSP), which is administered by FEMA and designed as a partnership between federal and state governments and other stakeholders to encourage community responsibility for dam safety (Federal Emergency Management Agency, 2012). The act further reauthorized the Corps to continue to maintain and update an inventory of dams in the United States, and required that the inventory include an assessment of each dam based on an inspection performed by a federal or state dam safety agency. It also required that the strategic plan prepared by FEMA establish performance measures to improve dam safety (Northwest Hydroelectric Association, 2012). The NDSP expired in September in 2011 and to date Congress has yet to reauthorize it. In May 2013, The Senate passed the Water Resources Development Act, which includes reauthorization of the National Dam Safety Program Act. However, the House of Representatives has not yet passed comparable legislation.

STATE & LOCAL STATUTES AND GUIDELINES

States have permitting, inspection and enforcement authority for approximately 80% of the dams listed in the 2010 NID database (Association of State Dam Safety Officials, 2012). With the exception of Alabama—which lacks a dam safety program—all states (plus Puerto Rico) have legislative authority to administer dam safety programs. The programs vary by state, but most include the following components: means to provide safety evaluations of existing dams; review of plans and specifications for dam construction and major repair work; periodic inspections of construction work on new and existing dams; and review and approval of Emergency Action Plans (Association of State Dam Safety Officials, 2012).

The Association of State Dam Safety Officials (ASDSO) is a national non-profit organization whose main purpose is to advance and improve the safety of dams by increasing awareness of dam safety issues. The association is a partnership of local, state, federal, and private industry officials working toward improving the safety of the nation's dams. Together with FEMA through the National Dam Safety Program, the ASDSO developed the Model State Dam Safety Program. The model program was designed to be used by state officials to initiate or improve state dam safety programs and provides the key components of a successful dam safety program. The model includes chapters on legislative authority, inspection, enforcement, permitting, emergency action planning and response, education, training, and public relations. Its goal is to provide guidance for the development of effective, sustainable programs that reduce the risks associated with unsafe dams. In 2011 over 90% of the existing state programs had incorporated at least some aspects of the model program, and over 70% had incorporated most of the program (Association of State Dam Safety Officials, 2012).

Although most states have assumed the authority to create and implement dam safety programs, many states have not incorporated all of the elements recommended in the Model State Dam Safety Program. According to the Association of State Dam Safety Officials, because of specific language in their laws some states have exempted certain types and sizes of dams from state regulations. For instance, mining dams are sometimes regulated under other state programs whereby the dam safety program might not

In 2011, the Texas Legislature amended the Texas Water Code to make changes to the Dam Safety Program in a reaction to requests from owners of small dams in rural areas. The legislation added an exempt status for any dam which is: 1) privately owned, 2) has a maximum capacity at the top of the dam of less than 500 acre-feet, 3) has a low or significant hazard classification, 4) is located in a county with a population of less than 215,000, and 5) is located outside of a city limits. Effectively, the Program reduced regular (every five years) inspections to include only high and significant hazard dams and large low hazard dams, and focuses the Program's review of emergency action plans and hydrologic and hydraulic adequacy to only high and significant hazard dams which are not exempt. Dams which are exempt under the new rules are still required to be operated and maintained in a safe manner and to have an operations and maintenance plan; however, they will not be included on the Program's inspection schedule, will not be required to submit an Emergency Action Plan to the State, and will not be hydrological or hydraulically evaluated for safety by the Program. The exemption expires in 2015.

have the jurisdiction to enforce related laws. In some cases state legislation exempts certain activities from regulations, for example, cranberry operations in Wisconsin. In addition, for many states the financial resources are not available to maintain the type of program that is seen as critical for maintaining dam safety (Association of State Dam Safety Officials, 2012).

FEDERAL GUIDELINES AND OPERATING RULES

Only about four percent of the dams in the United States are federally owned and operated, and only about 14 percent of dams are federally regulated. There are several federal agencies that hold responsibilities for dam operation, construction and maintenance. These include: the Departments of Agriculture, Defense, Interior, Labor and State, the Federal Energy Regulatory Commission, Nuclear Regulatory Commission, and the Tennessee Valley Authority. The National Dam Safety Program is administered by FEMA. FEMA is charged with assisting state dam safety programs by providing financial grants, funding research and training, and facilitating technology transfer (Association of State Dam Safety Officials, 2012).

The safety of federally owned dams is generally overseen by the agency that owns the dam although this is not always the case. States typically hold the regulatory authority for non-power producing dams or for dams that are not owned by the federal government. State authority and the extent of regulation regarding dams and dam safety vary significantly by state (Northwest Hydroelectric Association, 2012). In additional to variances in regulation by states, there are also dams that are exempted from regulation based on size or purpose. These dams, which potentially could be high-hazard-potential dams, often fall through gaps in regulation.

According to the 2012 NID there are approximately 5,266 non-federally-owned dams on federal lands. About 1,149 of the dams are high-hazard-potential; 914 are significant-hazard-potential; and the remaining 3,203 are low-hazard-potential. (Interagency Committee on Dam Safety, 2012)

This subset of dams, known as “non-federal dams on federal land,” is unregulated or inconsistently regulated. These are non-federal dams that were constructed on federal land or dams constructed on land which was later acquired by federal land management agencies. Many of the dams were permitted by federal agencies many years ago without permit conditions for addressing dam safety. The dams may be owned by state and local government agencies or may be privately owned dams necessary to maintain water rights or mining rights.

Non-federal dams located on federal lands pose a unique and longstanding challenge to federal land management agencies. In many cases, the responsibility for these dams is not clear and regulatory authority is either lacking or inconsistent. Moreover, a significant number of these dams are high-hazard-potential, meaning that their failure could result in loss of life.

Many federal land management agencies, including the Bureau of Land Management (BLM), the National Park Service (NPS), the Bureau of Indian Affairs (BIA), the U.S. Fish and Wildlife Service (FWS), and the U.S. Forest Service (FS), have expressed concerns regarding their responsibilities for these dams located on their lands. Many of the federal agencies do not have regulatory authority over these dams

or the resources to address the safety of them. In the case of some federal agencies, there is no policy direction from headquarters; policy is often created at their state offices.

The policy for addressing these dams at the state level also varies. Findings from a survey of state dam safety programs conducted by the ASDSO in 2009 indicate that some states lack the authority and/or resources to enter federal lands while some states (California, Colorado, and Oregon) are aggressively assuming regulatory authority over these dams, often through Memorandum of Agreements (MOAs) with federal agencies. (Interagency Committee on Dam Safety, 2012)

REGULATIONS RELATED TO HYDROPOWER DAMS (NON-FEDERALLY OPERATED)

Non-federal dams that produce hydroelectric power are actively regulated by the Federal Energy Regulatory Commission (FERC). FERC reviews and approves their design, plans and specifications prior to construction. Construction progress is closely monitored and when complete, FERC engineers continue to provide regular inspection of the facilities. Additionally, 18 CFR (Code of Federal Regulations) Part 12, Safety of Water Power Projects and Project Works, requires periodic inspection by an independent consultant to ensure that the project is operating in compliance with FERC regulations. Licensees of hydropower dams are required to develop and maintain an Emergency Action Plan (EAP) in association with the overseeing federal agency, which is designed to provide early warning to upstream and downstream residents and communities. 18 CFR Part 12, Safety of Water Power Projects and Project Works, sets the requirements for safety, monitoring, recordkeeping and emergency action plans for hydropower dams (Northwest Hydroelectric Association, 2012).

The Indian Dams Safety Act of 1994 directs authorizes the Secretary of the Interior to establish maintenance and repair programs for dams within the Bureau of Indian Affairs in order to monitor the condition of all dams on Indian lands and maintain them in a satisfactory condition on a long-term basis.

FEMA MAPPING STANDARDS

As a part of the National Flood Insurance Program (NFIP), FEMA provides participating communities with a Flood Insurance Rate Map (FIRM), the official map delineating flood hazard areas in the community. Depending on its use, a FIRM may consider a dam as part of the flood control system. If a dam provides flood control, the mapped Special Flood Hazard Area is developed based upon the reduced flood flows provided. However, information on the residual risk associated with dam failure or flood flow releases to prevent dam failure is not provided to communities downstream. FIRMs do not include partial or full dam break inundation areas. Therefore, downstream residents are often not aware of the extent of the flooding that could result from a dam failure. While FIRMs are not the only means of informing residents of the risks associated with dams, they are the map most commonly available to the public. Most high-hazard-potential dams now have Emergency Action Plans in place, so community emergency management officials should already be informed of the potential risk from dam failure. However, in most cases officials have not shared this information with their residents. It is also important to understand that coordination of information and resources between state agencies which house the Dam Safety Program and those that administer the National Flood Insurance Program varies widely

between states. In a little over half of the states, the two programs are part of the same agency. The remaining states house the two programs in different agencies. A lack of communication between the programs may adversely impact the information available to the public on the relationship between dams and flood risk.

The Biggert-Waters Flood Insurance Reform Act of 2012 reformed the NFIP and reauthorized it through 2017. One of the provisions of the act requires that FIRMs include a depiction of the residual risk for areas that are protected by levees, dams, and other flood control structures. (U.S. Government Printing Office, 2012)

EMERGENCY ACTION PLANS

An Emergency Action Plan (EAP) is a document that "identifies potential emergency conditions at a dam and specifies preplanned actions to be followed to minimize property damage and the loss of life" (Federal Emergency Management Agency, 2004). Nationally, in 2012, 69% of dams identified as high-hazard had an Emergency Action Plan in place, compared to 35% in 1999 (Association of State Dam Safety Officials, 2012).

FEMA provides resources and guidelines to dam owners, operators and local governments to aid in the development of an EAP. FEMA states that an EAP is designed to provide the dam owner with procedures and information relating to early warnings and notification messages to downstream emergency management agencies in the event of an incident or failure. An EAP should generally contain six elements:

1. Notification flowchart – to identify who is to be notified, by whom, and in what priority.
2. Emergency Detection, Evaluation, and Emergency Level Determination – an essential section, it establishes the procedures for reliable and timely determination of an emergency situation, and is critical to ensuring that the appropriate course of action is taken.
3. Responsibilities – this section will delegate the responsibilities for EAP-related tasks.
4. Preparedness – actions to be taken in advance of an emergency. This section will identify the actions to take to alleviate the effects of a failure later.
5. Inundation Maps – to show the areas that would be flooded as a result of a dam failure. The maps will be used to facilitate emergency notification and evacuation for at-risk communities.
6. Appendices – include any and all materials that supplement the plan. (Federal Emergency Management Agency, 2004)

Federally regulated hydropower dams are required by FERC to adopt an EAP in conformance with the "Guidelines for Preparation of Emergency Action Plans". Established by Congress in 1979 and updated periodically since their initial adoption, these guidelines establish a specific format to assist in preparing an effective EAP. They were revised in 1998 as the result of an initiative of the Interagency Committee

on Dam Safety to provide national consistency in the content of EAPs. The FEMA 64 publication "Federal Guidelines for Dam Safety: Emergency Action Planning for Dam Owners" sets the current standard framework for EAP planning throughout the U.S. This document is intended for use by dam owners and operators, but is not required for dams not regulated by FERC unless the state in which a dam is located requires the adoption of an EAP. This document is being updated with a scheduled release during the summer of 2013.

DAM FAILURES

Dams fail for many reasons. Dam failure or breaches occur most often when a dam has been overtopped. Thirty-four percent of dam failures in the U.S. occurred following an initial overtopping. Overtopping is usually due to inadequate spillway design, debris blockage, or settling of the dam crest. Foundation defects accounted for 30% of all dam failures, while 20% were caused by *piping*, which is internal erosion caused by seepage. Another cause is the structural failure of materials used in dam construction (Association of State Dam Safety Officials, 2012).

Some significant historic dam failures include the following[2]:

- Mill River Dam (May 16, 1874) – the Mill River Dam above Williamsburg, Massachusetts failed, killing 139 people.
- South Fork Dam (May 31, 1889) – the failure of the South Fork Dam, nine miles above the town of Johnstown, Pennsylvania, killed 2,200 people; one in five residents died.
- Buffalo Creek Valley (February 26, 1972) – A West Virginia coal-waste impoundment failed, killing 125 people and causing $400 million in damages.
- Canyon Lake Dam (June 9, 1972) – Canyon Lake Dam at Rapid City, South Dakota failed, taking 33 lives and destroying 1,335 homes, with total damages of more than $60 million.
- Teton Dam (June 5, 1976) – the failure of the Teton Dam (Madison County, Idaho) resulted in 11 deaths and caused over $1 billion in property damage.
- Laurel Run Dam (June 19-20, 1977) – the Laurel Run Dam near Johnstown, Pennsylvania failed, killing 40 people and causing $5.3 million in damages.
- Kelly Barnes Dam (November 5, 1977) – 39 Toccoa Falls College students and staff died when the Kelly Barnes Dam in Stephens County, Georgia failed. The breach caused $2.5 million in damages. (Association of State Dam Safety Officials, 2012)

[2] Damage costs prior to 1900 were not available to include in this report.

- Kaloko Reservoir Dam (March 14, 2006) – the failure of this dam at Kilauea, Hawaii resulted in seven deaths and the destruction of several homes. (Center for American Progress, 2012)

DAM REMOVALS

In recent years, many communities and dam owners have begun to remove dams, particularly those that have deteriorated. While dams serve many beneficial purposes, they also can cause negative impacts to rivers, wildlife, and local communities. Some dams no longer provide any of their intended benefits and continue to harm the river. Others have significant negative impacts that outweigh the aggregate benefits. Others still are simply so old and/or unsafe that maintenance costs are prohibitive and not worth the effort. For these cases, dam removal has proved to be a reasonable option to eliminate negative impacts and safety concerns (American Rivers, Friends of the Earth, & Trout Unlimited, 1999).

The publication ***Dam Removal Success Stories*** states that over 465 dams have been removed in the United States since 1912. A clear history of many dam removals is difficult to find due to the lack of documentation available from the various agencies that have been involved with them. Many removals of smaller dams (i.e. less than six feet high) often are not documented at all (American Rivers, Friends of the Earth, & Trout Unlimited, 1999). There is no database like the NID available for these small dams.

REASONS FOR DAM REMOVAL

The main reasons for removal of existing dams are their considerable negative impacts to the river or the community or to costs of operation and maintenance that outweigh their benefits. Many dam owners choose to remove dams that are deteriorating, no longer provide a quantifiable benefit, or are deemed unsafe instead of repairing them. Removal is often the most reasonable and cost-effective alternative.

> *"Many of these older dams have outlived their intended purpose and now serve no official use. Thousands of dams in the United States were built generations ago, powering mills that fueled this country's leap into the Industrial Age. Although these dams served an important purpose in their day, today many of them have outlived that purpose. These dams often are abandoned by the original owner, which requires the state to take over the obligation of safety repairs and other maintenance, thus placing large economic burdens on taxpayers."* (American Rivers, Friends of the Earth, & Trout Unlimited, 1999)

Moreover, *"Dams change the chemical, physical, and biological processes of rivers and related fish and wildlife"* (American Rivers, Friends of the Earth, & Trout Unlimited, 1999). Dam removals resulting from obsolescence and deleterious impacts are beneficial to the environment.

DAM REMOVAL EXAMPLES

ELWHA RIVER, WASHINGTON

Two large dams have been dismantled in this dam removal project. The Elwha River flows north out of Olympic National Park to the Strait of Juan de Fuca in Puget Sound. The purpose of the Elwha dam removals is to help restore the natural ecosystem and reopen over 70 miles of the river to native salmon. Removal began September 17, 2011. Originally anticipated to be a two- to three-year process, removal proceeded quickly and by late spring 2012, the Elwha Dam was completely gone. The Glines Canyon Dam will be completely removed in the summer of 2013 and Lake Mills, its impoundment, will return to its natural state as the free-flowing Elwha River. At 210 feet high, the Glines Canyon Dam will be the tallest ever removed in the United States (National Park Service, 2013).

PENOBSCOT RIVER, MAINE

The Penobscot River Restoration Project is one of the largest river restoration projects in the country. It is New England's second longest river after the Connecticut and is known for having the largest Atlantic salmon run remaining in the United States (American Rivers, 2012). The Penobscot River project includes the purchase and removal of the two lowermost dams on the river, Veazie and Great Works, and the purchase and decommissioning of a third dam, Howland Dam, where a fish bypass will be constructed (American Rivers, 2012).

A key aspect of the Penobscot River Restoration Project includes continued hydropower generation. Considerable investments in local hydropower generation will at least maintain and possibly increase the amount of energy that was generated when the project began (American Rivers, 2012). Removal of Great Works Dam began in June 2012 and was largely completed by the end of November, with Veazie Dam to follow within two field seasons, by 2014.

CURRENT INITIATIVES, PARTNERSHIPS AND COLLABORATIONS

NATIONAL DAM SAFETY PROGRAM

The National Dam Safety Program (NDSP) has been in existence for over 30 years but was formally established by the Water Resources Development Act of 1996. Led by FEMA, the NDSP is a partnership of states, federal agencies, and other stakeholders to encourage and implement programs to promote dam safety (Federal Emergency Managment Agency, 2012). In 2006, the NDSP was reauthorized as Public Law (P.L.) 109-460. Included in the NDSP are two groups that provide direction on dam safety. These are:

1. The National Dam Safety Review Board (NDSRB), and
2. Interagency Committee on Dam Safety (ICODS).

NATIONAL DAM SAFETY REVIEW BOARD

Under the National Dam Safety Act of 2006, the NDSRB is responsible for monitoring the safety of dams in the United States, overseeing state implementation of the NDSP, and advising the Director of FEMA on national dam safety policy. The Board consists of diverse representation from state and federal agencies plus a private sector representative. Its main duties are to encourage the establishment and maintenance of effective programs, policies, and guidelines to enhance dam safety for the protection of human life and property throughout the nation.

INTERAGENCY COMMITTEE ON DAM SAFETY

The Interagency Committee on Dam Safety created a formal charter and operating rules in 1985 and was reauthorized under the National Dam Safety Act of 2006. Representation on this committee comes from ten federal agencies and departments. The goal of ICODS is to encourage the establishment and maintenance of effective federal programs, policies, and guidelines to enhance dam safety for the protection of human life and property. This is accomplished through coordination and information exchange between federal agencies concerning implementation of the Federal Guidelines for Dam Safety.

STATE ASSISTANCE GRANTS

A key element of the National Dam Safety Program is to provide financial assistance to states to improve their dam safety programs (Federal Emergency Management Agency, 2012). States use this financial assistance for a number of dam safety-related activities, including the following:

- Dam safety training for state personnel
- Increasing the number of dam inspections
- Increasing the submittal and testing of Emergency Action Plans
- More timely review and issuance of permits
- Improved coordination with state emergency preparedness officials
- Identification of dams to be repaired or removed, and
- Conducting dam safety awareness workshops and creating dam safety videos and other outreach materials. (Federal Emergency Management Agency, 2012)

ASSOCIATION OF STATE DAM SAFETY OFFICIALS

The Association of State Dam Safety Officials (ASDSO) is a national non-profit organization serving state dam safety programs and the broader dam safety community. Its mission is to advance and improve the safety of dams by supporting these groups, raising awareness of dam safety issues, facilitating cooperation, providing a forum for the exchange of information, representing dam safety interests before governments, providing outreach programs, and fostering a unified community of dam safety advocates. Representatives from each state make up the voting membership of ASDSO; its governing board is chosen from these 50 individuals.

One of the committees in ASDSO is the Dam Owner Outreach Advisory Committee, which collaborates to develop educational materials related to owner responsibilities including dam maintenance and the development of Emergency Action Plans.

Recently ASDSO, together with FEMA, completed an electronic book called ***Living Near Dams*** (see HERE). In addition, ASDSO's website (HERE) houses information about each state's dam safety program and details the projects or programs each currently has in progress.

ASDSO also has a program for providing independent expert reviews of state dam safety programs and policies. The objective of the Peer Review Program is to provide professional guidance to state agencies to help improve the management of their dam safety programs. The Peer Review Program seeks to raise the level of dam safety program practice by evaluating an agency's mission, objectives, and policies and procedures, then examining its compliance with those policies and procedures. The peer review

evaluates the competence of the program relative to the generally accepted standards of dam safety practice. (Association of State Dam Safety Officials, 2012)

RISK ASSESSMENT TOOLS

DAMS SECTOR ANALYSIS TOOL

The Dams Sector Analysis Tool (DSAT) is a Web-based application that is intended to be is a one-stop shop where dam owners and operators have secure access to state-of-the-art analytical capabilities within a user-friendly graphical user interface.

DSAT consolidates analysis tools and data collection mechanisms supporting the screening, prioritization, and characterization of critical assets. It provides Dams Sector partners with secure access to a series of modules and applications covering a wide range of analytical capabilities. Users employ algorithms in DSAT to identify and prioritize the most critical dams within their purviews. DSAT also incorporates an advanced geospatial viewer that provides query capabilities as well as access to real-time information such as meteorological data, seismic activity, and so on. This tool was developed by the Dams Sector-Specific Agency of the Department of Homeland Security (DHS) in collaboration with the USACE Headquarters Office of Homeland Security.

DAM FAILURE INUNDATION MAPPING AND EAP DEVELOPMENT TOOLS (FEMA)

Developing dam breach inundation maps is an inexact science dependent upon numerous assumptions, such as flow conditions in the river when the dam fails, how it fails, and even where it fails. Conservative estimates of dam breach inundation limits can be used for emergency and evacuation planning purposes. Simplified inundation maps (SIMS) produce conservative inundation limits at a much lower cost than performing more detailed studies. These studies may result in a more precise representation of potential flooding for a given set of circumstances, but not necessarily a more accurate representation of actual flooding should dam failure occur. A number of states routinely accept simplified inundation maps for use in Emergency Action Plans, but not for classifying hazard potential or establishing in-flow design floods. Commonly used methods for generating SIMS fall into two categories:

1. Simplified Engineering Analyses, and
2. Photo-Based Mapping.

SIMS are most applicable for small- and intermediate-sized dams with a limited number of homes downstream and for areas where local emergency management officials agree that adequate evacuation procedures can be developed without more detailed inundation mapping. More detailed surveying or modeling may be warranted for large dams, those with a large population in the evacuation area, or with significant downstream hydraulic complexities such as major diversion structures, split flows, or the potential for cascading dam failures. (Association of State Dam Safety Officials, 2012)

In 2012 FEMA released its Geospatial Dam Break, Rapid EAP, Consequences, and Hazards (GeoDam-BREACH) tool, which is based on the simplified dam breach method (SMPDBK) developed by the National Weather Service. FEMA specifically developed the tool to reduce the high cost of dam breach inundation studies and Emergency Action Plans. The tool produces datasets and maps that allow communities to define the dangerous reaches downstream of dams and the potential loss of life. These datasets can link with the Risk MAP products FEMA produces for local governments so that these governments can conduct dam breach consequence studies and develop hazard mitigation plans.

FEMA COMMUNITY RATING SYSTEM

The National Flood Insurance Program was established in 1968 to address the increasing demand on the federal treasury for disaster assistance. Since then, the program has insured individuals against the risk of flooding. For many structures the insurance has been highly subsidized, in return for communities adopting construction standards for all development within the Special Flood Hazard Area, as identified by FEMA on its Flood Insurance Rate Maps (FIRMs). These standards include elevating or floodproofing all new structures to at least the elevation predicted to have a one-percent probability of occurring in a given year. By 1990 FEMA had recognized that the minimum standards were not sufficient to protect people and property from flooding, and so created the Community Rating System. The Community Rating System (CRS) is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements. Flood insurance premium rates are discounted to reflect the reduced flood risk consequent of community actions that meet the three goals of the CRS, which are:

- To reduce flood damage to insurable property,
- Support and strengthen the insurance aspects of the NFIP, and
- Encourage a comprehensive approach to floodplain management. (Federal Emergency Management Agency, 2012)

Activity Number 630 of the CRS Manual describes activities related to dam safety that are credited. Its objectives are to encourage states to provide dam safety information to communities and to encourage communities to provide timely identification of an impending dam failure, disseminate warnings to those potentially impacted, and coordinate emergency response activities to reduce the threat to life and property.

Overall criteria for this activity are described in Section 631.b of the 2013 CRS Manual and include:

- The community must have a description of the dam failure threat and a dam failure inundation map.
- To receive any Activity 630 credit, the community must implement a dam failure threat recognition and warning system, be prepared to carry out dam failure response operations, and must account for critical facilities in dam failure planning.

- There must be a dam failure warning and response plan in place.
- There must be one or more outreach projects in progress on the warning and safety precautions.
- There must be an annual exercise of the plan with a concluding report on lessons learned.

Additionally, these criteria have detail specific to each:

- State dam safety program (SDS): Up to 45 points credit for membership in the state's program.
- Dam failure threat recognition system (DFR): Up to 30 points for having a system to advise the emergency manager when there is a threat of a dam failure.
- Dam failure warning (DFW): Up to 35 points for disseminating the warning to the public.
- Dam failure response operations (DFO): Up to 30 points for planning and practicing specific tasks to be undertaken to reduce or prevent threats to health, safety, and property.
- Dam failure critical facilities planning (DCF): Up to 20 points for coordination of dam failure warning and response activities with operators of critical facilities. (Federal Emergency Management Agency, 2012)

NATIONAL HYDROLOGIC WARNING COUNCIL

The National Hydrologic Warning Council (NHWC) is a non-profit organization with membership across the United States and around the world that is dedicated to assisting emergency and environmental management officials by providing expert advice on the use of real-time, high-quality hydrologic information from automated remote data systems, with the goal of protecting lives, property, and the environment. NHWC has a Dam and Levee Safety Technical Warning Group, whose goal is to promote the development of sound monitoring techniques and specific decision criteria implementation to provide the best detection, decision making, and notification of an event at a dam or levee that would warrant warning and evacuation of the affected populace. (National Hydrologic Warning Council, 2012)

AMERICAN RIVERS

The national non-profit American Rivers plays a leadership role in the Hydropower Reform Coalition, which works to reform dam operations to more closely approximate natural river flows and benefit fish, wildlife and communities. It also works with agencies to remove outdated dams and other stream barriers. American Rivers has contributed to the removal of over 150 dams in the United States, and is currently developing a map of the locations of dam removals throughout the country.

ONGOING MONITORING AND WARNING SYSTEM FOR ALL DAMS

As a risk reduction measure for dams classified as high- or significant-hazard-potential, the Department of the Interior Bureau of Reclamation has been implementing flood warning systems for over 20 years. Existing flood warning system designs for dams make use of current technology to remotely monitor water levels, rainfall and other conditions in real-time, then contact and notify key emergency management staff of hazardous flooding conditions.

Additionally, the Bureau of Reclamation's support of the Bureau of Indian Affairs (BIA) Safety of Dams Program has resulted in unique data monitoring and communication solutions for dams located in rural, mountainous areas with challenging access, power and telemetry issues. As a result of this work, a real-time data collection network has been developed that utilizes commercial satellite telemetry and is monitored 24/7 to provide timely warnings for populations deemed at-risk.

There are also many state specific initiatives that have been undertaken and continue to be expanded upon.

ISSUES AND RECOMMENDATIONS

A. RESIDUAL RISK, HAZARD CREEP & MAPPING GUIDELINES

The operation and existence of dams can have significant effects on floodplains above and below the structures themselves (Federal Emergency Management Agency, 2011)**. Most dams have minimal impact and were not built for flood protection; flood control is the primary purpose of only 19% of dams. However, changes in land use downstream can result in an increase in risk due to the presence of additional structures and people. Historically, dam safety programs have primarily been helping to ensure that dams do not fail. Their focus has been on inspections, operation and maintenance, rehabilitation, repairs, construction and training of owners rather than on impacts on adjacent floodplains. More recently there has been significant attention given to the preparation of Emergency Action Plans, with over 69% of high-hazard-potential dams now having plans.**

RECOMMENDATIONS

1. Dam safety and dam hazard risk management should be part of a comprehensive flood risk management strategy for all communities. Floodplain management programs should be aware of and closely aligned with dam safety programs so that floodplain managers understand how dams operate and how they can affect both upstream and downstream land use management issues. FEMA should integrate dam safety information into every aspect of Risk Mapping, Assessment, and Planning (Risk MAP) and similar programs. Efforts to integrate land use planning with floodplain management below dams similar to those being carried out in Wisconsin and Virginia and described below should be encouraged in all states. (Federal Emergency Management Agency, 2011)

2. Recent FEMA-hosted summits have broadened the scope of research interests to appropriately include upstream and downstream factors; however, no additional resources are available to cover these topics. The National Dam Safety Program (NDSP) should develop and implement a new strategy and management model to address expanded needs such as upstream and downstream factors. (Federal Emergency Management Agency, 2011)

3. FEMA Risk MAP procedures should require development of A) a map that assumes the dam operates as planned (current practice), B) a map that assumes the dam is no longer there (highlights potential for removal), and C) a map that assumes the dam fails. Outreach to communities downstream of flood control dams concerning their residual risk should occur during the Risk MAP process. Risk assessment runs should be provided to each community as requested for the purposes of mitigation planning and long-term land use planning.

4. Communities should be encouraged to tie land use planning to failure zones to prevent low-hazard-potential dams from becoming high-hazard-potential dams. If all development cannot be prevented, then it should be minimized to the extent practicable. These standards can be credited in the CRS.

5. If flood insurance is provided within a dam failure inundation zone, premiums should reflect the residual risk.

6. FEMA should work with states to create more uniform standards that address the potential downstream impacts of a failure, such as land use standards that could be implemented at the local level.

BEST PRACTICE

The State of Wisconsin has addressed the issue of hazard creep in its floodplain management regulations. Wisconsin NR116 states: "Areas downstream of dams shall be zoned and regulated by municipalities with floodplain zoning ordinances in compliance with the standards in section, to reduce potential loss of life and property located downstream of the dam." Dams without downstream zoning in place are designated high-hazard-potential dams. This designation can result in additional costs for the dam owner since high-hazard-potential dams are required to have increased spillway capacity. In addition, in 2011 the Virginia General Assembly passed the authorization to offer a low-cost, simplified inundation mapping directly to dam owners (Virginia Code 10.1-604.1). This mapping is intended to prevent downstream new development and keep low-hazard-potential dams as low-hazard.

B. CHANGING HYDROLOGIC CONDITIONS

Hydrologic conditions in the watershed where a dam is located often change, impacting the channel and floodplain downstream of the dam. For instance, changes in the elevation of the channel bed will influence the interaction between the river and its floodplain. If channel depth decreases, flooding becomes more frequent. Changing conditions can result in hazard creep, downstream physical changes that impact life, safety, and property, and significant environmental impacts. With climate change there is also a potential for increased frequency of severe rainfall cycles and increased severity of rainfall events that may impact dam safety and floodplain management. Dam owners and public agencies need to take these changing conditions into consideration when following and updating the operating rules for their flood protection dams.

RECOMMENDATIONS

1. Dam owners and regulatory agencies must understand changing hydrologic conditions and build flexibility into the operating rules for dams that provide flood protection to ensure these conditions are accounted for.

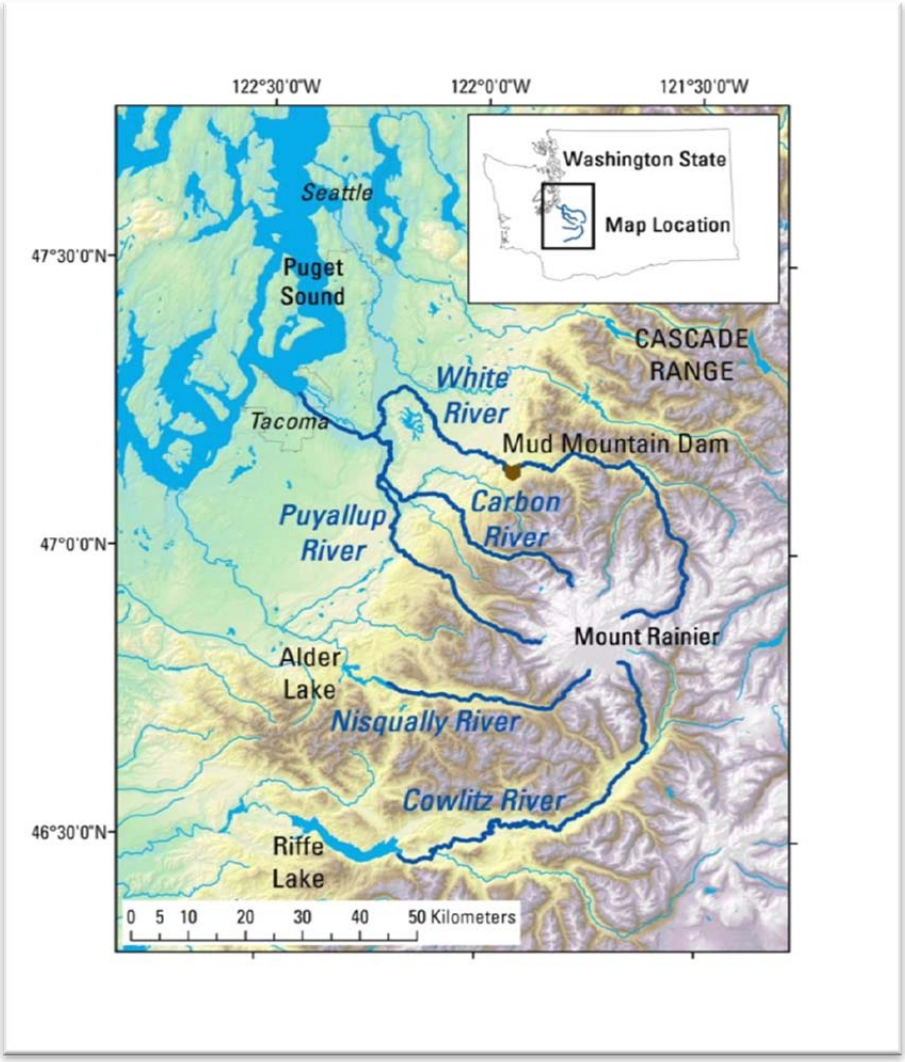
2. FEMA, in cooperation with the National Weather Service (NWS) and dam safety officials, should lead the effort to provide information about changing hydrologic conditions. State and local governments traditionally have jurisdiction over land use regulations. FEMA and the NWS should

provide guidance related to climate change that can be applied at the local level. This can include a report that addresses climate change and its relation to hydrologic conditions, with recommendations on methods to assess and incorporate these changing conditions. FEMA should develop guidelines for states to update the hydrology every ten years and then analyze the impacts of any changes on the safety of a given dam, its capacity, how it should operate, and any change in the threat downstream.

BEST PRACTICE

After recent flooding events, Pierce County, Washington and the U.S. Army Corps of Engineers are working together closely to assess the changing conditions of the Puyallup River system and identify resulting impacts on operations of Mud Mountain Dam on the White River. The White River flows about 75 miles from its source at the Emmons and Winthrop glaciers on Mount Rainier's northeast side to its confluence with the Puyallup River in the City of Sumner. Mud Mountain Dam (MMD) influences the hydrology of the White River during flood events (see Figure 7). (Pierce County, Washington, 2012)

Figure 7 - White River. (Source: Pierce County Water Programs)



Releases from MMD are based on maintaining a maximum flow of 45,000 cfs at the Puyallup River gage, located near Milroy Bridge in the City of Puyallup. Detention at the dam typically delays peak flows of the White River by one to two days behind Puyallup River peak flows. In the original Corps of Engineers MMD 1948 Water Control Plan, water stored in Mud Mountain Reservoir was to be discharged to the White River at up to 17,600 cfs because the river channel capacity downstream was estimated to be at least 20,000 cfs. Field observations in the 1970s noted that the threshold for flooding on the White River had declined to 12,000 cfs. The reduction of flood conveyance capacity was attributed to multiple factors including the encroachment of development into the floodplain, vegetation along the channel, sedimentation in the channel, and restrictions on channel dredging. (Pierce County, Washington, 2012)

Flows on the White River can be better controlled in average storms than in major ones in which the reservoir nears capacity and local inflows increase. In recent years, discharge from Mud Mountain Dam

was limited to 12,000 cfs when operations allow. Further reductions in target discharge for moderate events—to between 6,000 and 8,000 cfs—were planned for 2010 and beyond. The change in carrying conveyance capacity since a 1984 USGS study has been significant. Table 1 presents flood frequency flows from the 1987 and 2009 Flood Insurance Studies. Flows reflect operating policy changes and peak lag time due to detention at MMD. (Pierce County, Washington, 2012)

Table 1 - Lower White River flood frequency flows at the USGS Auburn Gage. (Source: 1987 and 2009 FEMA Flood Insurance Studies, based on USGS data)

Location	Discharge (cfs)				
	10-yr	50-yr	100-yr	500-yr	Method
Mouth of the White River (Puyallup R. Confluence)	16,400	18,300	19,100	21,600	1987 FEMA Flood Insurance Study (Log Pearson Type III)
Mouth of the White River (Puyallup R. Confluence)	14,000	15,300	15,500	19,000	2009 FEMA Flood Insurance Study for Pierce County (NHC 2006)

C. IMPACTS ON THE NATURAL & BENEFICIAL FUNCTIONS OF FLOODPLAINS

Dams have a significant environmental impact on the functions of rivers and their floodplains. At minimum, dams block a river's flow and can harm clean water, fish and wildlife, and recreational opportunities (American Rivers, 2012)**. The impacts range from disruption of ordinary riverine processes such as sedimentation, channel changes and evolution, floodplain and coastal delta morphology, and water quantity, temperature and flow, to impacts on river ecosystems and riparian habitat and vegetation.**

The impacts dams can have on natural sediment transport processes in rivers is substantial. Sediment transport in the river is blocked by the dam so that sediment builds up within the reservoir behind the dam while creating sediment-starved conditions below it that lead to channel bed degradation, channel narrowing and bank erosion. This disruption of sediment processes often disconnects a river from its natural floodplain downstream and submerges riverine floodplains upstream of a dam. These impacts are compounded when there are multiple dams along a river. The decrease in sediment supply downstream means that natural processes like deposition of sediment on floodplains and the creation of deltas and coastal beaches are all negatively impacted by dams. In some cases this leads to river systems that are no longer naturally self-sustaining. (ASFPM Working Group on Dams, 2008)

Dams disrupt not only sediment processes but critical debris and nutrient processes as well. Dams prevent these building blocks of riverine habitat from reaching downstream locations, while upstream

riverine habitat is submerged by the reservoir itself. Dams are often built in high-gradient reaches of the river, which are prime spawning habitat for many coldwater fish species. Many high-gradient riffles, rapids and even waterfalls have been submerged by dams and their impoundments. Both the river channel itself and the floodplain are fragmented by many barriers such as bridges (road and rail crossings) and levees. Dams of all sizes further fragment riverine corridors. Impacts of these barriers can be significant for many aquatic species, and they may also impact terrestrial wildlife passage. Open riverine corridors play a significant role in the ability of many species to migrate, whether due to life cycle requirements, habitat disturbances, or changing climate. In the United States it is nearly impossible to find river systems that are not fragmented by numerous manmade barriers. (ASFPM Working Group on Dams, 2008)

RECOMMENDATIONS

1. Federal agencies that administer programs related to protection and enhancement of natural resources (Natural Resources Conservation Service, U.S. Geological Survey, National Oceanic and Atmospheric Administration, National Park Service, Bureau of Land Management, and U.S. Forest Service) should work with states and organizations involved with dam removal to develop a tiered approach to identify dams whose removal would result in the restoration of natural and beneficial functions of floodplains and river systems. This process should begin by prioritizing high-hazard-potential dams that have been abandoned.

2. When considering dam removal, the environmental services that could be restored should be included in any benefit-cost analysis. Methodologies to account for natural capital are being developed. One recent study monetizes the natural capital of the Middle Cedar Watershed of the Mississippi River system. This includes showing the economic benefits of flood risk reduction, fish and wildlife habitat, and other environmental services. (Earth Economics, 2012)

3. Federal and State dam safety programs and natural resource agencies should work with partners to define how operations could be improved so that dams could be operated to help reduce impacts on the river and its riparian areas. Current flood insurance studies take into account dam operations. (American Rivers, 2012)

4. As a potential flood risk reduction measure, communities should consider the negative impacts as well as the flood-control benefits when examining a dam. The benefit-cost analysis of a new dam should include the lost environmental services, life-cycle operation and maintenance cost, capital reinvestment costs, and the cost of decommissioning the dam.

BEST PRACTICE

As discussed earlier, the Penobscot River Restoration Project is one of the largest river restoration projects in the country. Located in Maine, the Penobscot is the second largest river in New England and is known for having the largest remaining Atlantic salmon run in the United States (American Rivers, 2012). The Penobscot River Restoration Trust was created as a collaboration between private and public partners to implement the core aspects of the Penobscot River Restoration Project. The project will

remove the two dams lowest on the river and, bypassing a third, will open up nearly 1,000 miles of habitat for endangered Atlantic salmon, sturgeon, river herring and eight other species of sea-run fish in Maine. As fish passage is improved at four remaining dams and current flow energy is increased at others, these ecological benefits will be realized while maintaining or even increasing hydroelectric energy production. By reconnecting the natural river to the sea, the Penobscot project promises large-scale ecological, cultural, recreational and economic benefits throughout this large watershed. (Penobscot River Restoration Trust, 2012)

D. FEDERAL AND STATE GOVERNANCE

Under the National Dam Safety Program Act, dealing with nonfederal dams is fundamentally a state function and states are expected take the lead. Not all states have fully incorporated these responsibilities, however, and state legislation is sometimes lacking. The federal role is to encourage the development of state programs, provide funding, technical assistance and training, facilitate knowledge sharing, and support states in ensuring that communities below dams are adequately prepared for potential emergency activities. In addition, state dam safety programs vary in their robustness and authority. (Federal Emergency Management Agency, 2011)

RECOMMENDATIONS

1. A national strategy should be developed that leverages federal agency programs and dam authorities to incentivize appropriate dam hazard mitigation, preparedness and risk management actions. Incentive programs will help state and local governments undertake actions that will discourage the increase in dam hazard risks to human life, property and the environment. There are many federal programs and activities that may influence or impact dam safety and dam and flood hazard risk management activities. These include but are not limited to: National Dam Safety Program, FEMA's National Flood Insurance Program, Community Rating System, Risk MAP, Hazard Mitigation Assistance, Hazard Mitigation Planning, the NRCS Watershed Rehabilitation Program, USGS stream gage monitoring, NWS forecasts and flood warnings, and the USACE Silver Jackets program. There is a strong need for these numerous federal programs and initiatives to integrate and form a coordinated national framework to address flood risks. FEMA should then lead the development of an internal working committee to ensure that all of these programs are working in concert for dam safety.

2. Although responsibility for deteriorating infrastructure does not fall directly under the National Dam Safety Act, FEMA is the agency most cognizant of national conditions and should become an advocate for addressing the infrastructure problem.

3. Abandoned dams, and high-hazard-potential dams whose condition threatens the public safety and welfare, as well as any dams that no longer provide a quantifiable benefit, should be targeted for removal. Dams that need rehabilitation to meet current safety standards should be identified. A funding mechanism for rehabilitating these is recommended.

4. Metrics to measure the progress in improving the safety of the nation's dams are currently in place. ASDSO and FEMA are partnering to collect data in conjunction with the USACE National Inventory of Dams Administrator. These include A) counts of the current Emergency Action Plans for dams and downstream communities, B) annually updated numbers of dams inspected, C) an annual update on the conditions of all dams, D) an inventory of actions taken by communities downstream of dams to prepare themselves in case of a failure, and E) the availability of the information that communities need to properly plan. Based on these metrics, it is recommended that the process on how to determine success at a state and national level should be determined. For example, what percent of dams having an EAP is required to determine success at a state and national level?

5. State policy makers should work closely with local officials to ensure there is a strong dam safety program. All states should provide oversight and inspection of dams, regardless of size, hazard or use through adoption of the model standards.

6. A consistent nationwide definition of a regulated dam needs to be developed as part of creating minimum nationwide standards.

BEST PRACTICE

In 2008 the Virginia Dam Safety Act was amended to require mapping of dam break inundation zones for all regulated dams (10.1-606.2) and also added the requirements for development in dam break inundation zones (10.1-606.3) and payment by developer (15.2-2243.1). In addition, it required disclosures to purchasers of property in dam break inundation zones (55-519).

As a result of these amendments, Virginia has inundation maps for all regulated dams. Because dam engineers are required in Virginia to provide hazard classification analyses, inundation maps, inspections, and Emergency Action Plans, the most significant barrier to generating inundation mapping for all dams has been the high cost to dam owners. (Bennett, 2012)

In 2011 the Virginia General Assembly passed the authorization to offer a low cost, simplified inundation mapping solution directly to dam owners (10.1-604.1). This mapping is intended to help communities prevent downstream development and keep low-hazard-potential dams as low-hazard. If a map indicates a dam is low-hazard-potential, the owner is eligible for a General Permit with minimal requirements as long as the dam maintains that classification. If a map shows a dam as significant- or high-hazard-potential, the owner's engineer shall provide the full inundation analysis and mapping. The revised regulations authorize Virginia to offer low-cost (about $2,000) simplified inundation mapping to dam owners.

Additionally, a Web-based Virginia Flood Risk Information System became operational in late 2012 to provide access to digital flood maps and eventually risk information and dam break inundation maps as more data is collected.

Another best practice occurs where states create a dam rehabilitation fund that includes a provision for dam removals. Wisconsin has such a program that is funded intermittently. It is difficult to get a state

legislature to fund dam removal solely, but if it is part of a dam rehabilitation fund it is usually more palatable.

E. COMMUNICATION

Success in reducing human losses and property damages in a dam failure is largely dependent on the strength of the collaboration between dam safety officials, dam owners, and the emergency management personnel who on a day-to-day basis must deal with disastrous events. The linkage between these three groups must be maintained and in some cases improved through joint exercises, collaborative planning, and continuous association (Federal Emergency Management Agency, 2011). **This is reiterated in as Finding # 1: *Communication and Coordination between Dam Safety Officials, Dam Owners, and Emergency Responders Can Be Improved in FEMA's report titled Emergency Action Planning for State Regulated High-Hazard Potential Dams, commonly referred to as FEMA 608*** (Federal Emergency Management Agency, 2007)**.**

RECOMMENDATIONS

1. The National Dam Safety Program should continue to bring the dam owner and local, state and federal communities together to deal collectively with common issues, with the Association of State Dam Safety Officials as facilitators. (Federal Emergency Management Agency, 2011)

2. The Risk MAP process can be used to map the residual risk downstream of dams. Risk MAP is based on a model of collaboration between different groups that are involved in flood risk. Dam owners should be one of the groups included. FEMA should also help facilitate collaboration by including all relevant federal agencies during a Risk MAP project. For instance, the USACE Silver Jackets Program could be used to facilitate watershed-based discussions on mitigation strategy.

3. Current FEMA efforts to more closely link dam safety and emergency management are moving in the correct direction. However, dam safety activities, particularly Emergency Action Plans (EAPs), should be better aligned with the National Incident Management System (NIMS) and the National Preparedness Goal.

4. FEMA should establish internal experts on dam safety subject matter to act as liaisons between itself and federal, state, local and private partners to work with them to develop community and regional preparedness, mitigation, response and recovery strategies.

5. FEMA 608, Page 5 states that watershed/floodplain managers should be included as stakeholders. Additionally, FEMA should maintain an active list of the names of these managers and assist in coordination of all stakeholders during an exercise. (Federal Emergency Management Agency, 2007)

6. All state, regional, and local watershed/floodplain managers should have log-in access to the NID and be able to check the following fields: Dam Name, State, River Name, River Basin, Dam Condition Assessment, Hazard Potential Classification, Nearest Downstream Community, Agency with Jurisdiction, and Date of Last Functional Exercise. The NID data is updated every few years so it is

important that in conjunction with the NID data, more accurate data in the state's dam offices should be accessible.

7. FEMA should tally the number of publications related to dam failures it has developed and maintain a website with links to these publications so that others can benefit. (Federal Emergency Management Agency, 2004). FEMA should work with ASDSO and DHS Dams Sector Specific Agency who are currently doing this.

8. Communities should annually remind their residents of the potential impacts of a dam failure and what they should do if a dam fails. (Federal Emergency Management Agency, 2012)

9. Communities should create their own EAP for what to do when a failure is imminent or underway. This plan should be coordinated with the dam owner and all impacted or potentially impacted agencies, critical facilities, residents, and other interested parties. (Federal Emergency Management Agency, 2012)

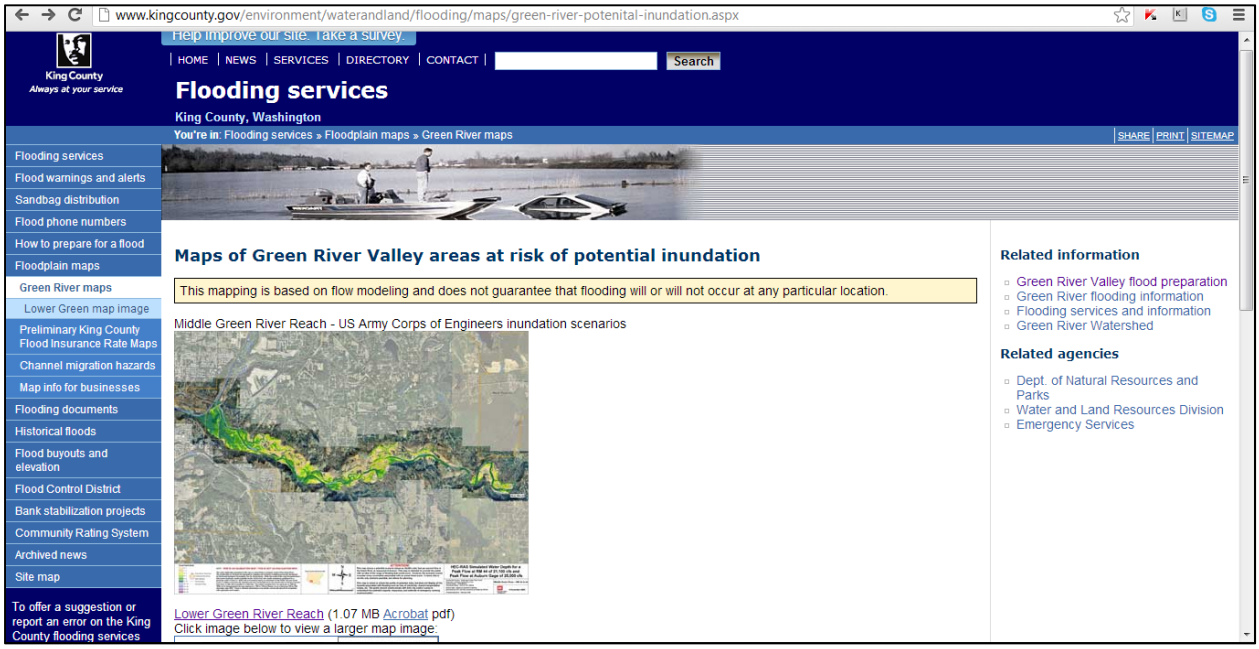
BEST PRACTICE

Howard Hanson Dam in King County, Washington underwent $40 million in repairs by the Army Corps of Engineers in 2011. These repairs were done as a result of seepage issues discovered during a flood in 2009. A flood event in February 2012 was among the most severe events in the dam's history, but the impact was minimized because the dam functioned according to design.

Although both King County and the Army Corps of Engineers have confidence in the repairs completed, the county has made a concerted effort to inform the downstream communities of the potential risks of a flood event. King County has published a link on its website to a USACE fact sheet that provides the public with information about Howard Hanson Dam and the potential for flooding events.

In addition, while inundation as a result of complete failure of Howard Hanson Dam is not shown, King County's website provides maps that show potential inundation areas at double the stream flow that can pass without compromising the levee's intended to protect downstream development (see Figure 8). A map showing evacuation routes for use during a flood event is also provided. This is a good example of risk communication between the dam owner, government agency, and the impacted community. (King County, Washington, 2012)

Figure 8- Potential inundation areas on the Green River. (Source: King County website)



Lastly, FEMA completed a study that utilized the HAZUS modeling tool to look at the social and economic impacts of three different scenarios, one of which was complete failure of the levee system downstream of Howard Hanson Dam. While this is not the same as showing complete failure of the dam, it provides an example of effective communication of risk to the public.

F. ACCESS TO DATA & INFORMATION SECURITY

For outreach and emergency management activities to be successful, both the public and public officials must have open access to information concerning the location and condition of dams and the potential flood inundation that affects them. The present limitations within the NID and in some federal and state programs on public access to dam condition information are an obstacle to public safety and must be addressed.

RECOMMENDATIONS

1. Dam officials should work with FEMA-Department of Homeland Security to create a system under which both public officials and private citizens have access to information. For outreach and emergency management activities to be successful, both groups must have open access to information concerning the location and condition of structures that affect them. (Federal Emergency Management Agency, 2011)

2. Information on inundation and the operations and maintenance of dams should be made available to anyone potentially impacted by a failure in order to ensure that future development considers the associated risk properly. (National Research Council, 2012)

3. Communities should work with state and federal officials to ensure they have the most current information available concerning the status of dams affecting them.

BEST PRACTICE

Inundation maps and information on the integrity of a given dam must be publicly available to ensure that communities can prepare for emergency situations. The New York State Department of Environmental Conservation (DEC) has a dataset available to the public via Google Earth (see HERE) that depicts the locations of dams in the New York State Inventory of Dams. This inventory contains the locations of dams in New York State and provides information about the condition and characteristics of each. (New York State Department of Environmental Conservation, 2012)

The State of California Department of Water Resources, Division of Safety of Dams provides a listing of dams on its website (see HERE) that is available to the public. This information was obtained from applications and plans submitted by owners and from surveys and supplementary information acquired during inspections and special studies of these dams. The listing also includes federal dams and reservoirs within the State of California that are not under state jurisdiction. The information provided includes: dam name, dam number, name of owner, county, national ID, location, stream, year completed, reservoir capacity, reservoir area, drainage area, crest elevation, freeboard, dam height, crest width, dam type, and volume for each dam under the jurisdiction of the State of California. (California Department of Water Resources, 2010)

Emergency Action Plans offer a good opportunity to provide detailed information about dams to the public. The San Joaquin County, California Office of Emergency Services has a dam failure plan covering the 16 dams whose failure could impact the community, and also includes failure inundation maps for each dam. This EAP is published on the county's website for public viewing.

G. TRAINING AND TECHNICAL ASSISTANCE

Greater training opportunities and technical assistance for dam safety officials, floodplain managers, hazard mitigation officers and emergency managers are needed. A comprehensive approach to training professionals with a role and responsibility in dam hazard risk reduction and management is needed. Training land use managers, planners, and emergency managers on hazard creep and the dynamics of dam-related flooding and evacuation planning and execution is an effort that goes beyond the traditional "dam safety program" training activities.

RECOMMENDATIONS

1. The National Dam Safety Program should support efforts for the training of professionals within the dam safety profession and provide specialized training related to dam programs at the state level (Federal Emergency Management Agency, 2011). FEMA and ASDSO have a long-standing partnership on training where FEMA provides funding to ASDSO to provide the "Program of Study" in which state dam offices participate. It should continue in its current direction to further cement

its complementary relationship with ASDSO. (Federal Emergency Management Agency, 2011) Funding from FEMA should support the following: 1) the national training program at ASDSO and; 2) small grants to states to train state and local dam safety staff.

2. The NDSP should leverage other components within FEMA such as Preparedness, Response, and the Federal Insurance and Mitigation Administration. Partnering with organizations like ASFPM, the National Emergency Management Agency, and the International Association of Emergency Managers would be necessary to provide training opportunities to these other professionals who have critical stakes in dam hazard risk management.

BEST PRACTICE

The State of Michigan has used federal grant funds to hire, train and equip an adequate staff of dam safety engineers to administer its program, resulting in a drop in dam failures since the 1970s (54) and 1980s (72) to only 7 in the 2000s. (Association of State Dam Safety officials, 2012)

H. EDUCATION AND OUTREACH

The public is generally unaware of the potential risks they face in living below a dam and what actions have been taken to mitigate these risks. They and public officials are also generally unaware of the existence of and reasons for dam safety programs and as a result express little concern about and little support for these programs. (Federal Emergency Management Agency, 2011)

RECOMMENDATIONS

1. The National Dam Safety Program needs to continue, in conjunction with other FEMA activities and related federal and state activities, an outreach strategy that would work in a collaborative manner to remedy these challenges. (Federal Emergency Management Agency, 2011)

2. FEMA should include dam failure inundation maps as part of all Risk MAP projects. Communities should receive training to ensure they are capable of including this information in their land use plans, comprehensive plans, and emergency management activities. This information is required to ensure that inappropriate development does not occur in these inundation areas.

3. States should require that notification be provided to prospective property owners when buying a piece of property with a dam on it. This notification should include the responsibilities associated with ownership transfer. Those buying property within a dam breach inundation zone should also be notified of the fact and the potential risk. States should require realtors to disclose this information.

BEST PRACTICE

The public must have access to dam failure inundation maps downstream of dams and information concerning the integrity of the dams. The Virginia Dam Safety Act has specific requirements for any development proposed within the boundaries of dam break inundations zones in the State of Virginia.

> ***§ 10.1-606.3. Requirement for development in dam break inundation zones. (2008)***
>
> ***A. For any development proposed within the boundaries of a dam break inundation zone that has been mapped in accordance with § 10.1-606.2, the locality shall, as part of a preliminary plan review pursuant to § 15.2-2260, or as part of a plan review pursuant to § 15.2-2259 if no preliminary review has been conducted, (i) review the dam break inundation zone map on file with the locality for the affected impounding structure, (ii) notify the dam owner, and (iii) within 10 days forward a request to the Department of Conservation and Recreation to make a determination of the potential impacts of the proposed development on the spillway design flood standards required of the dam. The Department shall notify the dam owner and the locality of its determination within 45 days of the receipt of the request. Upon receipt of the Department's determination, the locality shall complete the review in accordance with § 15.2-2259 or 15.2-2260. If a locality has not received a determination within 45 days of the Department's receipt of the request, the Department shall be deemed to have no comments, and the locality shall complete its review. Such inaction by the Department shall not affect the Board's authority to regulate the impounding structure in accordance with this article.***
>
> ***If the Department determines that the plan of development would change the spillway design flood standards of the impounding structure, the locality shall not permit development as defined in § 15.2-2201 or redevelopment in the dam break inundation zone unless the developer or subdivider agrees to alter the plan of development so that it does not alter the spillway design flood standard required of the impounding structure or he contributes payment to the necessary upgrades to the affected impounding structure pursuant to § 15.2-2243.1.*** *(Bennett, 2012)*

I. INSUFFICIENT FUNDING

National program resourcing is marginal even if funded at FY 2012 levels, which was a historical high. Given its purpose, federal support of state activities is just enough to provide some flexibility to the states. Additionally, hydrologic challenges will increase and dam structure conditions will continue to deteriorate without a new infusion of funding. These conditions will create significant challenges for states and their dam safety programs. There is a potential for abandonment by dam owners if the costs of repairs are significant. (Federal Emergency Management Agency, 2011)

RECOMMENDATIONS

1. FEMA should provide more information on grants and how grant money is spent, and provide a discussion on the topic at ASFPM, ASDSO, and Association of State Wetland Managers (ASWM) conferences.

2. Any changes in national program scope to accommodate expansion of research and development efforts or to deal with emergency and floodplain management activities that cannot be accomplished within other FEMA programs will require increases in funding. The National Dam Safety Program should not only be focused on minimizing dam failures but should also consider a broad range of risk reduction measures including, but not limited to, interim risk reduction, land use policy development, advancements in early warning system, dam removal, improved emergency planning and consequence assessments. In addition, the federal government should work to leverage federal agencies research resources and activities and engage and collaborate with the private sector. (Federal Emergency Management Agency, 2011).

BEST PRACTICE

There are many different creative approaches for funding flood mitigation projects in the nation. In 2007 the King County (Washington) Flood Control District was established to provide a proactive, regional approach to flooding as well as the funding to improve the county's nearly 500 aging and inadequate flood protection facilities.

Funding for the Flood Control District comes from a county-wide property levy of 10 cents per $1,000 of assessed value. This amounts to $40 per year on a $400,000 home, for example. The levy raises roughly $36 million a year. This funding dramatically increases the number of projects that can be completed each year. The additional local funding also enhances King County's ability to receive federal and state matching funds. (King County Flood Control District, Washington, 2012)

Such funds can be targeted at maintenance and upgrades when a low-hazard-potential dam becomes high- hazard. In addition, they can be utilized for flood warning systems and the development of evacuation routes.

Via its Division of Water, the State of Kentucky was able to procure over $1 million in grants from FEMA to implement an effort to create potential inundation mapping for about 200 state-owned high-hazard-potential dams.

J. EMERGENCY ACTION PLAN DEVELOPMENT

An Emergency Action Plan (EAP) is a formal document that identifies potential emergency conditions at a dam and specifies preplanned actions to be followed to minimize property damage and loss of life (Federal Emergency Management Agency, 2007)**. Nationally, in 2011, 69% of dams identified as 'high hazard' had an EAP in place** (Association of State Dam Safety Officials, 2012)**. There are still a**

significant number of high hazard dams that lack coordinated EAPs. EAPs are not required unless the state authority under which a dam is regulated requires the adoption of one.

RECOMMENDATION

FEMA should work with states to ensure that they all require high-hazard-potential dams to have an Emergency Action Plan and that impacted communities are included in development of the plan. Emergency response plans must adequately address dam-related flooding, and the development of EAPs must involve the active participation of local emergency management and response officials.

BEST PRACTICE

Federally regulated hydropower dams are required by the Federal Energy Regulatory Commission to adopt an EAP in conformance with the "Guidelines for Preparation of Emergency Action Plans" (Federal Emergency Management Agency, 2004). The EAPs should be developed by the dam owner in coordination with all impacted communities. The public must be made aware of its role in the implementation of any plan, especially in relation to evacuation routes, refuge locations, and warning methods.

CONCLUSION

1) The FEMA Risk MAP process is intended to provide communities with information associated with all natural hazards in the community. Therefore, in addition to the flood hazards traditionally identified on Flood Insurance Rate Maps, the Risk MAP process should be used to map the hazards posed by dams to downstream communities. Sufficient funding should be provided to develop these maps. Risk MAP is based on a model of collaboration between different groups that are involved in flood risk management. Dam owners should be included in this model.

2) Communities should be encouraged to tie land use planning to failure zones to prevent low-hazard dams from becoming high-hazard-potential dams.

3) FEMA should work with states to create more uniform safety standards that address the potential downstream impacts of a dam failure, such as land use standards that could be implemented at the local level. This could be modeled on the National Flood Insurance Program and include minimum state standards.

4) A national strategy should be developed that leverages federal agency programs and dam authorities to incentivize appropriate dam hazard mitigation, preparedness, and risk management actions.

5) A funding mechanism should be established that addresses abandoned and high-hazard-potential dams whose condition threatens the public safety and welfare. The funding should give preference to removal of abandoned dams and rehabilitation of deteriorated dams in order to avoid recurring maintenance costs and eliminate risks associated with the long-term operation of the dam.

6) Communities should create their own Emergency Action Plan (EAP) for what to do when a dam failure is imminent or underway. This plan should be coordinated with the dam owner and all impacted or potentially impacted agencies, critical facilities, and residents.

7) Information on inundation and the adequacy of maintenance and operations of dams should be made available to anyone potentially impacted by a failure or releases of floodwaters in order to ensure future development properly considers the associated risk.

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