

# DAM RISKS IN DISASTERS: A PUERTO RICO CASE STUDY FOR HURRICANE FIONA

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## ABSTRACT

As the impact of climate change is felt across the world, it's important that communities take steps to increase their resilience against extreme weather events, such as hurricanes. Doing so involves maintaining and improving key dam infrastructure, which are particularly susceptible to the excessive precipitation and flooding associated with these events.

In September 2021, the FEMA National Dam Safety Program (NDSP) and National Integration Center (NIC) Technical Assistance Branch began a "Planning for Dam-Related Emergencies" Collaborative Technical Assistance (CTA) project in Puerto Rico. The CTA assisted communities at risk for flooding due to operational discharge or dam-related infrastructure failure gain a better understanding of the consequences of dam-related emergencies. Throughout the process, the CTA engaged emergency managers and dam owners and operators, along with federal, regional, and local governmental partners, in a facilitated process to build relationships, develop risk-informed plans, and collaborate with community partners to achieve the goal of increased preparedness to dam-related hazards. The Puerto Rico CTA concluded in August 2022, just prior to the devastation caused by Hurricane Fiona, which dumped more than 20 inches of rain across much of the island and resulted in widespread flooding and storm-related damages.

In response, and as a follow-up to the CTA, FEMA deployed an Incident Specific Technical Assistance (ISTA) in Puerto Rico. Through a robust post-event data collection process, done in collaboration with CTA partners and stakeholders, the ISTA team conducted more than 30 interviews and site visits to better understand the actions taken by emergency managers and dam owners/operators before, during, and after Hurricane Fiona. The ISTA team also developed detailed models, performed spatial mapping, and created illustrative graphics to represent hurricane-related flooding and help understand dams' influence on flooding.

## THE CURRENT STATE OF DAMS

- 91,807 Total dams in the National Inventory of Dams (NID)
- 16,577 High-hazard potential dams in NID

All 36 dams in Puerto Rico are high hazard potential



- 2,300 Deficient high-hazard potential dams\*
- 71% State Regulated
- 5% Federally Regulated
- 61 years Average Dam Age

High Hazard Potential is a classification standard for any dam whose failure or mis-operation will cause loss of human life and significant property destruction.

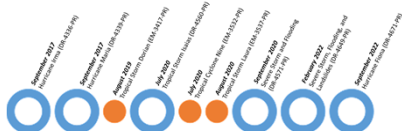
\*According to the US Army Corps of Engineers (USACE)

## IMPACTS OF HURRICANE FIONA: NATURAL & INFRASTRUCTURE

- River Systems:** Multiple rivers rose above moderate or major flood stage
- Dams:** No reported dam failures; numerous dams activated spillways or opened gates to release water and lower reservoir levels, both in advance of and during the storms
- Flooding & Mudslides:** Widespread flooding and numerous mudslides, plus significant to catastrophic coastal flooding due to the sharp rises along rivers combined with storm surge
- Power:** All of the island's nearly 1.5 million electrical customers were without power, some for more than two weeks
- Water:** Nearly two-thirds of the island's almost 800,000 homes and businesses had no drinking water
- Telecommunications:** 23.5% of cellular sites in the impacted area were reported out of service
- Transportation:** Numerous roads, bridges, causeways, and access routes were washed out or rendered impassable



## EMERGENCY & MAJOR DISASTER DECLARATIONS

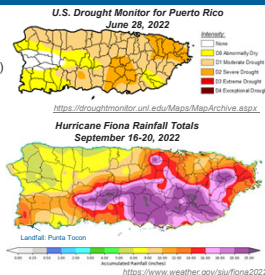


## FEMA NATIONAL DAM SAFETY PROGRAM SUPPORT

- Planning for Dam-Related Emergencies CTA (Dec 2020 – Aug 2022)
  - GOAL: Help communities at risk of dam-related flooding better understand their risk landscape and potential consequences of dam-related emergencies
- Incident Specific Technical Assistance (Nov 2022 – Ongoing)
  - GOAL: Understand the influence of dams on flooding during Hurricane Fiona and how key stakeholders in Puerto Rico responded to and dealt with the impacts

## HURRICANE FIONA & MORE

- Summer:** Moderate to severe drought
- Early-September:** Hurricane Earl
  - East/north/interior: 3-5 inches (peaks >7.5 inches)
- September 14-17:** Hurricane Fiona
- October:** Above average rainfall
- Late-October:** Unnamed storm event
  - East/southeast/southwest: 5-10 inches
- Early-November:** Precursor Event to Hurricane Nicole
  - Southeast: 6-10 inches
  - Southwest/north: 2-4 inches
- Mid-November:** Unnamed storm event
  - Far southeast: 5-10 inches



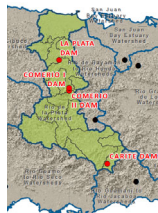
## CLIMATE IMPACTS & WATERSHED PLANNING

### Challenges

- Increased storm frequency & extreme precipitation; drought impacts
- Watershed-level threat detection: Rainfall vs. river flow

### Best Practices

- Continue to enhance rainfall, streamflow monitoring network
  - NWS uses hydrologic forecasting that take into account both rainfall and watershed topography
- FEMA is helping Puerto Rico Electric Power Authority (PREPA) expand hydrologic & hydraulic (H&H) modeling for more recent storm event
- Puerto Rico Aqueduct and Sewer Authority (PRASA) is developing an early detection, "citizen sensing" monitoring network that will use visual observations, crowd-sourced social media information, and NWS/USGS tools



## PUBLIC EDUCATION & COMMUNITY OUTREACH

### Challenges

- Public education and outreach is being done (or planned) across the island; however, there is little coordination between the various agencies/organizations leading the different efforts

### Best Practices

- FEMA is working with the U.S. Army Corps of Engineers Silver Jackets, Caribbean Area Office, and PREMB on an FY24 proposal to develop:
  - Outreach and messaging toolkit, with presentation materials, handouts, and communications templates, that can be easily customized to meet the specific needs of each Zone or municipalities
  - Train-the-trainer program to educate those with a role in local emergency planning and preparedness on the use and promotion of developed materials, so that they can be integrated into relevant and existing education and outreach efforts



## DECISION MAKING CONFLICTS/PRIORITIES

### Challenges

- Balancing drinking water supply vs. flood storage/infrastructure protection
- Different dam owners have different priorities and capabilities
- Balancing benefits vs. risk
  - Use: water supply vs. recreation; Security: access vs. safety/protection

### Best Practices

- Watershed-level operations and planning
- Dam owners must communicate and coordinate operations to reduce flooding and increase community resilience
- Close working relationships give decision makers and dam owners the confidence in forecasts needed to support operational decisions



## PRIOR & REPETITIVE DAMAGE

### Challenges

- Residual damage from previous storm events (e.g., Hurricane Maria in 2017)
- Storm debris can:
  - Compromise spillway function/gate operation and clog outlet works
  - Block drainage in sewers, culverts, and ditches

### Best Practices

- Interim mitigation measures are needed until full projects are completed
- Debris management plans establish procedures and guidelines for managing storm debris in a coordinated way and facilitates response/recovery efforts
  - Needed at the dam and municipality level



## COMPOUNDING FACTORS FOR FLOOD RISK

### Challenges

- Sedimentation reduces storage capacity and impacts drinking water facilities
- Overgrown/fast growing vegetation
- Island topography

### Best Practices

- Both NRCS and PRASA are planning major dredging projects to restore and increase storage capacity to withstand changing rainfall patterns and allow for greater water reserves
- Department of Natural & Environmental Resources (DNER) maintenance brigades provide continual preventative vegetation control



## PLANS, PROTOCOLS, & PROCEDURES

### Challenges

- High flow operational events are not typically included in dam emergency action plans (EAPs) and EMs do not usually have response procedures for these events
  - Communities are frequently flooded with no notice
- Geography and topography makes response hard
- EAPs are commonly shared with only local emergency management personnel and not Zone EMs who also have responsibilities during in incident response

### Best Practices

- Dam-Incident Annex included in jurisdictional emergency operations plans (EOPs)
- Emergency plan alignment and integration with defined triggers at the dam that link directly to EM response
- EAPs shared and exercised with emergency management



## CTA OUTCOME

### NWS San Juan Weather Forecast Office

- CTA participation – Played an active role
  - Attended multiple sessions
  - Presented at sessions: Risk & Crisis Communications and Alerts & Warning
  - Leveraged existing relationships with local EMs to increase attendance
- Follow-on activities:
  - Developed processes to speed the San Juan WFO staff's ability to issue a dam emergency WEA message
  - Ensured all staff were trained on how to issue alerts using the NOAA weather radio
  - Recommended that dam owners/operators review where the San Juan WFO was on their EAP phone tree and time how long this call would take in a dam emergency scenario

