

# Dam and Reservoir Safety

## Water May Save Us - Water May Drown Us

### June 27, 2023

#### SUMMARY

Atmospheric rivers are deluges. Such pronounced weather events may replenish dwindling water levels in dams and reservoirs (this report collectively refers to these as dams). In light of protracted droughts, *this water may save us*. However, scientists worry that future deluges may bring these structures to the brink of failure and potentially major downstream floods. *This water may drown us*.

Atmospheric rivers are long regions in the atmosphere that carry vast amounts of water vapor that eventually falls in the form of very large rainstorms. Scientists warn us that climate change is already causing increases in size and frequency of atmospheric rivers, which may contribute to dam and reservoir failures. From October 1, 2022 through March 31, 2023, there were over 30 atmospheric rivers across the West Coast. This exceeds the average for this period, which is nine.

Marin Municipal Water District (MMWD, also known as Marin Water) and North Marin Water District (NMWD) are the owners of the only eight dams in Marin requiring regulation by the California Division of Safety of Dams (DOSD). This report, completed on April 30, 2023, focuses on the fact that the latest science on changing climate's atmospheric weather events is not incorporated in these two districts' dam hazard mitigation plans.

The average age of dams in the U.S. is 50 years. The average age of dams in Marin County is 87 years, or 37 years older than the national average. In the event of dam failure, risks to life, property, and the economy increase because populations downstream have grown significantly since dams were built.

*We ask readers of this report to carefully note a very important distinction: the Grand Jury does not question regulatory compliance by either water district, including having current risk mitigation plans in place, and evaluating their dams as prescribed by the law. They do comply.*

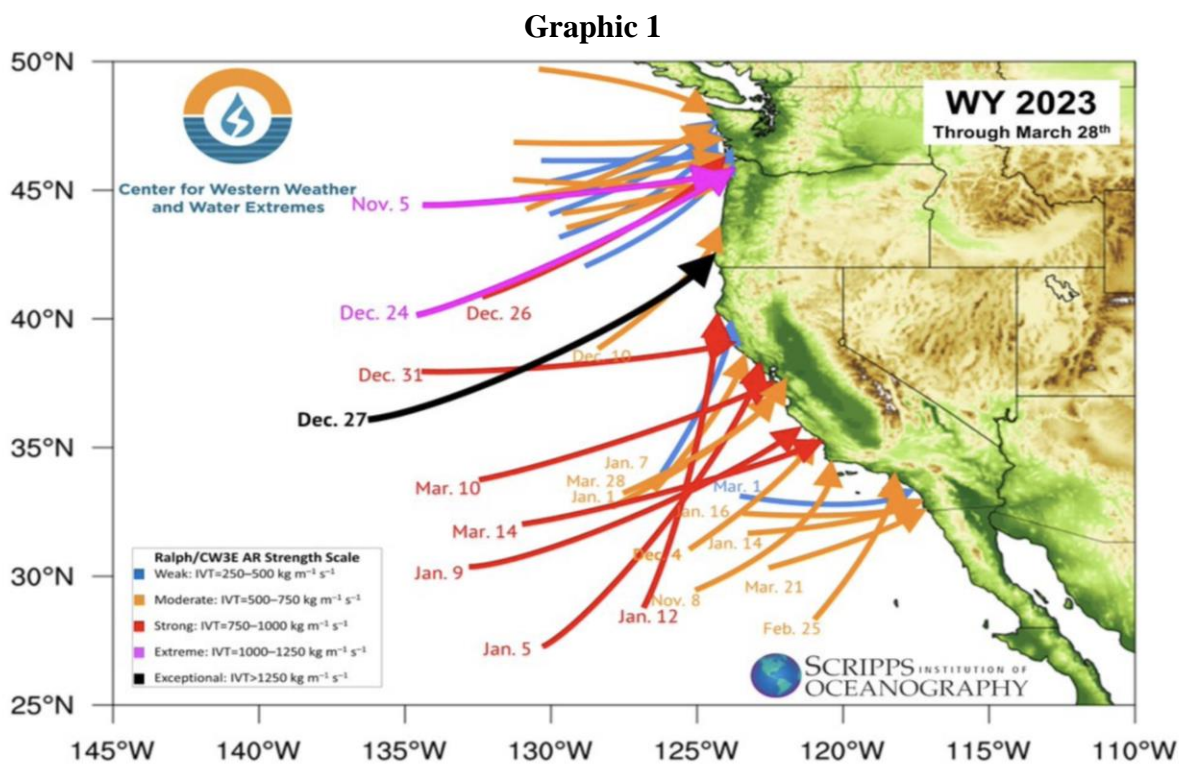
However, regulatory agencies' requirements for dam safety do not incorporate the latest scientific information on climate change. These agencies do not require specific approaches or methodologies to define dam safety assessment and risk mitigation plans to be employed by dam owners. Further, they require that the *dam owners be solely responsible for their dams' safety*. Therefore, the two Marin water districts should include new, state-of-the-art hazard mitigation strategies. Additionally, access to dam failure inundation maps (maps showing areas likely to flood), and Federal Emergency Management Agency (FEMA) information regarding flood insurance (the only flood insurance available in the United States) must be easily accessible by the public.

## BACKGROUND

Why is this report relevant now?

Current climate change models show that storms will likely be bigger.<sup>1</sup> More specifically, scientists warn us about climate change, and how warming temperatures are causing significant increases in size, duration, and frequency of atmospheric rivers. These weather events are potentially catastrophic.<sup>2</sup>

Graphic 1 shows that the current weather year (WY), which runs from October 1st through September 30th, has already produced over 30 atmospheric rivers. An average year has less than nine. The potential for flooding remains high.



Source: Atmospheric River Storm Tracks (Oct 1 - March 28th, 2023) (Center for Western Weather and Water Extremes, Scripps Institution of Oceanography at UC San Diego, <https://cw3e.ucsd.edu/real-time-observations/>)

Columbia University scientists and other scientific experts argue that as rains increase, floods from failed dams could damage critical infrastructure, and pose threats to populations

<sup>1</sup> Climate change basics, (California Department of Water Resources), <https://water.ca.gov/Water-Basics/Climate-Change-Basics>. Accessed on February 1, 2023

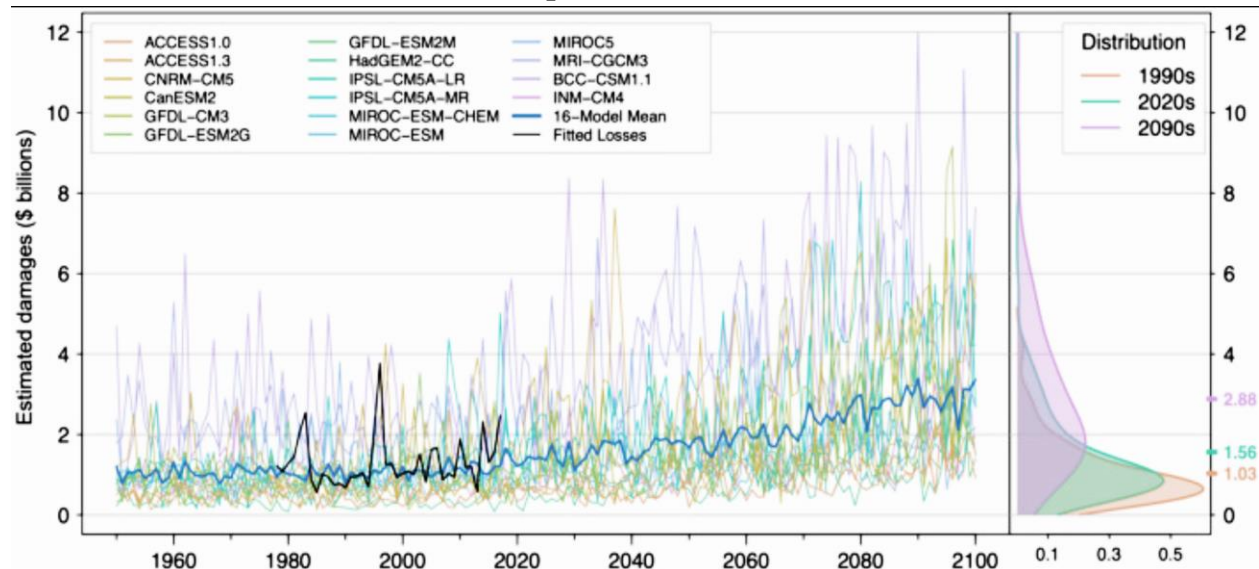
<sup>2</sup> Henry Fountain, “Expect more: climate change raises the risk of dam failure.” (*The New York Times*, May 20, 2022), <https://www.nytimes.com/2020/05/21/climate/dam-failure-michigan-climate-change.html> Accessed on April 21, 2023

downstream.<sup>3</sup> Such circumstances could also negatively impact water availability and the economies of affected communities.

Future atmospheric rivers are predicted to have the catastrophic power of the megastorms impacting California 160 years ago. Then, vast portions of the state effectively drowned due to a forty-five day sequence of atmospheric storms from late December 1861 into January 1862.<sup>4</sup> Researchers at UCLA, among others, argue that such storms typically occur every 100 to 200 years.<sup>5</sup> Scientists are issuing warnings because such large floods could have much more catastrophic impacts today due to increases in population and infrastructure. These megastorms would produce rain levels never experienced by anyone alive today. Further, just one of these storms could result in one trillion dollars in damages.<sup>6</sup>

At the national level, Graphic 2 shows that estimated damages from atmospheric rivers are projected to reach \$6 billion per year this decade, \$8 billion by 2040, and will surpass \$10 billion annually by the end of the 21st century.

Graphic 2



Graph showing various models of increasing Atmospheric River Damages (\$B) projected out to 2100.

Source: <https://pubmed.ncbi.nlm.nih.gov/35961991/>

<sup>3</sup> “Assessing the risk of dam failure in the United States,” (Columbia Climate School, Water Center), <https://water.columbia.edu/content/assessing-risks-dam-failure-united-states>, Accessed on February 9, 2023

<sup>4</sup>“An incredible 45 day storm turned California into a 300 mile sea, and it could happen again,” (Science Alert, February 17, 2016), <https://www.sciencealert.com/an-incredible-45-day-storm-turned-california-into-a-300-mile-long-sea-and-it-could-happen-again>

<sup>5</sup> “Scientists point to the great megaflood of 1862 in study about California megaflood possibilities,” (Nature World News, August 16, 2022), <https://www.natureworldnews.com/articles/52557/20220816/scientists-point-great-flood-1862-study-california-megaflood-possibilities.htm>

<sup>6</sup> “Scientists point to the great megaflood of 1862 in study about California megaflood possibilities,” (Nature World News, August 16, 2022).

Scientific investigations of climate change in general, and atmospheric rivers in particular, have accelerated over the past 20 years. In comparison, dam regulations are decades old and have been slow to be updated.

Dam failure is extremely rare, but when it happens it can have catastrophic consequences. In California, the 1928 failure of the newly constructed St. Francis Dam “...sent a 70-foot wall of water, mud, trees, and boulders crashing down the San Francisquito Canyon into the Santa Clara River Valley, and out to the Pacific Ocean near Oxnard. This cleared a two-mile-wide swath of land, 70 miles long. The 5½-hour event killed more than 450 people, left hundreds more homeless, destroyed 900 houses, many bridges and roads, and swept away 24,000 acres of farmland. This disaster was one of the deadliest in California history, second only to the 1906 San Francisco earthquake.”<sup>7</sup> As a direct result of this event, the Division of Safety of Dams (DOSD) was created to regulate dam safety.

**Table 1 - Dam Failures and Resulting Regulatory Actions**

Dam Failure Dates	Dam’s Name	Resulting Action
1928	St. Francis Dam	Creation of DOSD in 1929
1963	Baldwin Hills Reservoir	Included off-stream due to subsidence in 1965
1967	Lower San Fernando Dam Incident	Water level lowered due to the owner’s inspection report, but the 1971 earthquake resulted in liquefaction and evacuations. Revised liquefaction and seismic regulations
2017	Oroville Spillway	Approximately 200,000 people evacuated. California was the only state without an emergency management plan. Resulted in new legislation providing for dam inspections, mitigation plans, and inundation maps delineating potential flooding under the Governor’s Office of Emergency Services 2018

*Source: Large Dam Failures and Subsequent Legislative Actions (created by the Grand Jury)*

Table 1 above shows that historic actions to improve dam safety have been reactive to dam failures. That is, actions have not proactively addressed new issues or concerns to prevent crises such as recent information on climate change. Could the latest scientific progress made with the understanding of atmospheric rivers and climate change be the next catalyst for action?

The regulation of dams in the United States has a long history, and is now consolidated under the National Dam Safety Program, which is administered by FEMA.<sup>8</sup> The Interagency Committee on Dam Safety (ICODS) consolidates all of the regulations into a series of guidelines, which are

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<sup>7</sup> History of Division of Dam Safety, <https://water.ca.gov/Programs/All-Programs/Division-of-Safety-of-Dams/History>, Accessed on April 18, 2023

<sup>8</sup> FEMA National Dam Safety Program Outline, <https://www.fema.gov/emergency-managers/risk-management/dam-safety>, Accessed on April 18, 2023

published under FEMA.<sup>9</sup> California DOSD has adopted those guidelines for its dam safety program for regulated dams in California. Note that not all dams in California are regulated.<sup>10</sup>

However, DOSD does not require dam owners, or their engineering consultants, to apply any specific dam safety approach. “DOSD generally does not require specific approaches or methodologies to be employed by dam owners or their engineering consultants. ...ultimately, the dam owner bears the legal responsibility and associated consequences related to the failure of a dam.”<sup>11</sup>

The most significant update to California dam regulations in decades has been the issuance of the DOSD guideline, “Inspection and Reevaluation of Protocols,” dated September 18, 2018.<sup>12</sup> DOSD, in a 2016 peer review report conducted by the Association of State Dam Safety Officials, was named the “leading dam safety program in the Nation.”<sup>13</sup> The subsequent failure of the Oroville spillway in February 2017 was due to atmospheric rivers and laid bare that California was the only state in the country that did *not* have an emergency dam management plan in place. Nearly 200,000 people were evacuated due to the Oroville event. Legislation was quickly enacted, designating the California Governor’s Office of Emergency Services (CalOES) as a coordinating agency, along with DOSD, for new dam regulations that require additional inspections, mitigation plans, regular inspections, and inundation flood mapping, as well as additional inspections.

In Marin County, mitigation and inundation maps have recently been completed by both MMWD and NMWD (as well as all other regulated dam owners in California). The dam owners were required to complete a new dam inspection and detailed engineering reports as to the failure risks of each dam and inundation flood maps detailing the consequences should a dam fail.

Today, DOSD administers oversight of eight dams in Marin County, and each is assigned a hazard designation of failure. Six of the seven MMWD-owned structures are in the high risk hazard category. The NMWD Seegar Dam (Nicasio Reservoir) has a high hazard risk. Of the eight dams, the oldest was built in 1872, and the newest in 1979. Overall, the average age is 87, which is 37 years older than the national average. Age is a consideration when evaluating risks because of downstream population growth and infrastructure. Construction standards have

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<sup>9</sup> FEMA, Dam Safety Federal Guidelines, <https://www.fema.gov/emergency-managers/risk-management/dam-safety/federal-guidelines>, Accessed on April 18, 2023

<sup>10</sup> DOSD Dam Jurisdictional Requirement, <https://water.ca.gov/Programs/All-Programs/Division-of-Safety-of-Dams/Jurisdictional-Sized-Dams>, Accessed on April 18, 2023

<sup>11</sup> [https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/All-Programs/Division-of-Safety-of-Dams/Files/Publications/DSOD-Inspection-and-Reevaluation-Protocols\\_a\\_y19.pdf](https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/All-Programs/Division-of-Safety-of-Dams/Files/Publications/DSOD-Inspection-and-Reevaluation-Protocols_a_y19.pdf), (California Natural Resources Agency, Department of Water Resources, 2018, page 1), Accessed on March 14, 2023.

<sup>12</sup> [https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/All-Programs/Division-of-Safety-of-Dams/Files/Publications/DSOD-Inspection-and-Reevaluation-Protocols\\_a\\_y19.pdf](https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/All-Programs/Division-of-Safety-of-Dams/Files/Publications/DSOD-Inspection-and-Reevaluation-Protocols_a_y19.pdf), (California Natural Resources Agency, Department of Water Resources, 2018), Accessed on April 18, 2023.

<sup>13</sup> [https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/All-Programs/Division-of-Safety-of-Dams/Files/Publications/DSOD-Inspection-and-Reevaluation-Protocols\\_a\\_y19.pdf](https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/All-Programs/Division-of-Safety-of-Dams/Files/Publications/DSOD-Inspection-and-Reevaluation-Protocols_a_y19.pdf), (California Natural Resources Agency, Department of Water Resources, 2018, page 1), Accessed on April 18, 2023.

changed considerably over the years and older dams usually do not have good construction records.

The Grand Jury finds the issue of dam safety is relevant in light of climate change and increasing strength and number of atmospheric rivers. This now requires a critical review to proactively mitigate future potential hazards.

## **APPROACH**

The jurisdiction of the Marin County Civil Grand Jury encompasses government agencies in the county. It does not encompass private entities or agencies outside of the county. Thus, recommendations pertaining to dam and reservoir safety in relation to atmospheric rivers focus on those managed by MMWD and NMWD (the dam owners). This report excludes any other dams managed privately or federally in Marin.

Our investigative effort, which was concluded on April 30, 2023, included a multi-pronged approach that consisted of primary and secondary information gathering techniques and analysis. For primary information gathering, our research included in-person stakeholder interviews and follow-up correspondence and telephonic communication with interviewees. In addition, the Grand Jury reviewed the following categories of materials for secondary governmental, scientific, and journalistic information gathering:

- Federal and state dam and safety regulations (FEMA, DOSD, CalOES - Dam Safety and others)
- FEMA - National Flood Insurance Program
- Safety guidelines and risk classifications for Marin County's dams and managed by the MMWD and NMWD
- The hazard mitigation plan of MMWD
- The multi-jurisdiction mitigation plan for Marin County, in which NMWD participates
- Demographic data (population totals) from the U.S. Census
- Newspaper articles and publications by climate change expert reporters, scientists and academic institutions



## DISCUSSION

### Atmospheric Rivers

California experienced nine nearly back-to-back atmospheric rivers between late December 2022 and early January 2023.<sup>14</sup> These heavy rains drenched the state with more than thirty-two trillion gallons of water and snow. In fact, for the San Francisco Bay Area, a deluge of this magnitude over the course of three consecutive weeks had not happened in the last 160 years.<sup>15</sup> Across the state, these rains took twenty one lives, caused catastrophic flooding, severely damaged property, and resulted in an estimated one billion dollars in losses in this two-month period.<sup>16</sup> Further, during the rainy season beginning October 2022, and until March 2023 there were 31 atmospheric rivers in California.<sup>17</sup> The average number of atmospheric rivers during this period was nine. This weather year has greatly exceeded the average. Of note, no failures took place thus far, in part because water levels in dams were low due to the prolonged drought. However, with stronger atmospheric rivers happening in greater numbers, and perhaps higher water levels in the dams, the situation could be different.

What are scientists saying about atmospheric rivers, dams and safety?

1. Scripps Institution of Oceanography: “We know that atmospheric rivers are already boosted by the changing climate.”<sup>18</sup>
2. The president of the U.S. Society on Dams, who is an engineer, said: “All of a sudden you’ve got older dams with a lower design criterion that now can potentially cause loss of life if they fail.”<sup>19</sup>
3. “Climate impacts are becoming increasingly common and increasingly complicated, piling on top of each other in both time and space — and disaster resilience, preparedness, and response need to adapt accordingly.”<sup>20</sup>

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<sup>14</sup> *Atmospheric rivers hit west coast.*” (National Environmental Satellite Data and Information Service), <https://www.nesdis.noaa.gov/news/atmospheric-rivers-hit-west-coast>, Accessed on February 23, 2023

<sup>15</sup> *Atmospheric rivers hit west coast.*” (National Environmental Satellite Data and Information Service), <https://www.nesdis.noaa.gov/news/atmospheric-rivers-hit-west-coast>, Accessed on February 23, 2023

<sup>16</sup> Bob Henson, “Taking stock of California’s three week deluge.” (Yale Climate Connections. January 19, 2023), <https://yaleclimateconnections.org/2023/01/taking-stock-of-californias-three-week-deluge/> Accessed on April 21, 2023

<sup>17</sup> Grace Toohey, “Volcano? Climate Change? Bad luck? Why California was hit with 31 atmospheric river storms,” (Los Angeles Times, April 11, 2023), <https://www.latimes.com/california/story/2023-04-11/californias-wild-winter-of-atmospheric-rivers> Accessed on April 21, 2023

<sup>18</sup> Climate change projected to increase atmospheric river flood damage in the United States, (Scripps Institution of Oceanography, August 22, 2022), <https://scripps.ucsd.edu/news/climate-change-projected-increase-atmospheric-river-flood-damages-united-states> Accessed on April 21, 2023

<sup>19</sup> David A. Lieb, Michael Casey, and Michelle Minkoff, “A whole lot of dams in the U.S. are at risk of failure,” (Huffington Post, May 6, 2022), [https://www.huffpost.com/entry/high-hazard-dams-united-states\\_n\\_627545cbe4b009a811c319fa](https://www.huffpost.com/entry/high-hazard-dams-united-states_n_627545cbe4b009a811c319fa) Accessed on April 21, 2023

<sup>20</sup> Sarah Fetch, “Climate in California: What went wrong and what comes next,” (Columbia Climate School, January 12, 2023), <https://news.climate.columbia.edu/2023/01/12/flooding-in-california-what-went-wrong-and-what-comes-next/> Accessed on April 21, 2023

4. Data show that the intensity of precipitation will significantly increase as the atmosphere warms. NOAA’s National Climate Center states “...given the potential catastrophic consequences of dam failure, these findings should be considered carefully.”<sup>21</sup>
5. The recent spate of atmospheric river events is a shadow of what’s possible — actually inevitable.<sup>22</sup>
6. “In just December and January, nine atmospheric rivers hammered western United States and Canada relentlessly, dumping record rain and snow across the region. Over 121 billion metric tons of water fell on California alone, according to the U.S. National Environmental Satellite Data and Information Service.”<sup>23</sup>
7. In 2016, at the first Atmospheric Rivers Conference, held at the Scripps Institution of Oceanography, 100 experts in this field gathered to advance the science of these weather events. This signifies increased scientific interest and concern about atmospheric rivers, and related impacts.
8. A panel discussion of experts in hydrology, climate change, and atmospheric rivers, “...focused on how atmospheric river (AR) information is affecting decision-making in water management and flood risk mitigation. These included perspectives from local, state, and federal water management experts who described how the development of AR science, monitoring, and forecasting tools offer opportunities to refine decision-making strategies related to reservoir operations.”<sup>24</sup>

### **Federal and state dam and reservoir guidelines**

FEMA provides Federal Guidelines for Dam Safety Risk Management. The most recent version on FEMA’s website dates back to 2015. The guidelines indicate that since the 1980s, many entities in the dam safety industry incorporated risk assessment to better inform their decisions.<sup>25</sup> “Risk analysis and risk estimation are qualitative or quantitative procedures that identify potential modes of failure and the conditions and events that must take place for failure to occur.”<sup>26</sup>

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<sup>21</sup> Selecting and accommodating inflow design floods for dams, (FEMA P-94, August 2013), [https://www.fema.gov/sites/default/files/2020-08/fema\\_dam-safety\\_inflow-designs\\_P-94.pdf](https://www.fema.gov/sites/default/files/2020-08/fema_dam-safety_inflow-designs_P-94.pdf), Accessed on March 30, 2023

<sup>22</sup> Andrew Revkin, “California’s atmospheric rivers warn of future climate calamity, (Columbia Climate School, January 9, 2023), <https://news.climate.columbia.edu/2023/01/09/californias-atmospheric-rivers-warn-of-future-climatic-calamity/> Accessed on April 21, 2023

<sup>23</sup> Carolyn Gramling, “By flying over atmospheric rivers, scientists aim to improve forecasts (Science News, March 19, 2023), <https://www.sciencenews.org/article/atmospheric-river-forecast-storm> Accessed on April 21, 2023

<sup>24</sup> F. M. Ralph, M. Dettinger, D. Lavers, I. V. Gorodetskaya, A. Martin, M. Viale, A. B. White, N. Oakley, J. Rutz, J. R. Spackman, H. Wernli, and J. Cordeira, “Atmospheric rivers emerge as a global science and applications focus,” (University of California San Diego), Accessed on April 18, 2023

<sup>25</sup> FEMA, Dam safety federal guidelines, 2015. <https://www.fema.gov/emergency-managers/risk-management/dam-safety/federal-guidelines> Accessed on April 18, 2023

<sup>26</sup> FEMA, Dam safety federal guidelines P-1025, 2015, page 5. [https://www.fema.gov/sites/default/files/2020-08/fema\\_dam-safety\\_risk-management\\_P-1025.pdf](https://www.fema.gov/sites/default/files/2020-08/fema_dam-safety_risk-management_P-1025.pdf) Accessed on April 22, 2023



In California, DOSD operates under the California Department of Water Resources, which provides guidelines for dam owners and managers in the state. DOSD, as do nearly all regulatory dam agencies in the United States, adopted the FEMA standards as the base for dam safety regulations.

It is common at both the Federal and State levels (including DOSD) to not require specific approaches or methodologies in the regulation of dam safety. It is also common to require dam owners to be solely responsible for their dam safety and liability. The reason is that each dam is unique in age, construction, location, and potential risks and hazards. Instead, the regulations are broad-based engineering strategies, developed over decades, with the assistance of national entities such as the Corps of Engineers and ICODS. These regulations provide dam owners with guidance in “best practices” for dam construction, operations, maintenance and, most importantly, safety and identification of risk hazards.

In eight of the highest risk dams in Marin, the Grand Jury examined how recent advances in climate change science and the understanding and forecasting of atmospheric rivers could be incorporated to reduce risk.

Both DOSD and FEMA utilize similar, but not identical Safety and Risk Hazard models, which is why the numbers of dams and their risks vary. For example, the most recent Dam Safety Report from DOSD in 2022 shows that the National Inventory of Dams (FEMA) lists 1,526 dams, 832 of which are classified as High Hazard. Whereas DOSD lists its regulated dam count as 1,239 dams, 724 are classified as High Hazard dams.<sup>27</sup>

The basis for these classifications is the potential for dam failure, which can include earthquakes, faulty construction or operation, increases in water (flooding), etc. Dam owners do not self-classify either the safety category or the risk hazard categories that are reported by the State (DOSD) or the Federal (FEMA). The dam owners’ responsibility rests in providing engineering reports, inspection reports; and now in California inundation maps and mitigation plans that identify their dams’ specific potential for failure. For flooding, engineers use a set of calculations to determine how much water a dam will hold, and how quickly it will enter and exit the dam.

FEMA has been aware of the consequences of climate change for some time, noting in its most recent FEMA P-94 guideline, dated August 2013, that “Others have also concluded that due to likely changes to maximum moisture and maximum storm efficiency, PMP [Probable Maximum Precipitation], estimates would increase under a warming climate (Jakob et. al., 2009). This would lead directly to substantial increases in PMP values. Given the potential catastrophic consequences of dam failure, these findings should be considered carefully in future design activities.”<sup>28</sup>

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<sup>27</sup> DOSD, “Dam Safety Performance Report - 2022”, <https://damsafety-prod.s3.amazonaws.com/s3fs-public/files/California%20Dam%20Safety%20Performance%20Report%202022.pdf> , Accessed on April 21, 2023

<sup>28</sup> FEMA Selecting and Accommodating Inflow Design Floods for Dams FEMA P-94 /August 2013, [https://www.fema.gov/sites/default/files/2020-08/fema\\_dam-safety\\_inflow-designs\\_P-94.pdf](https://www.fema.gov/sites/default/files/2020-08/fema_dam-safety_inflow-designs_P-94.pdf), Accessed on April 18, 2023

PMP is used in the determination of dam failure analysis, as it is the key metric in calculating water flow into a dam. Climate change is recognized by the PMP number. However, the FEMA P-94 regulations still refer dam owners back to the National Oceanographic and Atmospheric Administration (NOAA) data from 1999. This was only updated through 2012, and it does not incorporate current climate science.<sup>29</sup>

The key point is that dam guidelines should be considered as minimum regulatory standards. Each dam and geographic location has unique characteristics which impact failure risk analysis.

This investigation has shown that climate change and atmospheric rivers have not been thoroughly incorporated in the risk assessment as noted in the current mitigation plans. Yet, dam owners have the ability to do so because they have the independence to conduct assessments and develop hazard mitigation plans on their own.

### **Dam and reservoir safety: MMWD and NMWD**

MMWD serves the central and southern areas of the county, and it has its own hazard mitigation plan. NMWD participates in the Marin County Multi-Jurisdiction Local Hazard Mitigation Plan (MCM LHMP). This water district serves Novato and surrounding areas. Each of these entities is required to define and communicate potential risks of dam failure in their hazard mitigation plans. These plans are also submitted to the Marin County Office of Emergency Management (OES). FEMA specifies: "...hazard mitigation means any cost effective measure which will reduce the potential for damage to a facility from a disaster event."<sup>30</sup>

Table 2 below demonstrates the official dam failure risk hazard classification for Marin's publicly managed dams. This classification is based on FEMA. In Marin, the majority of publicly managed dams are in the high and significant risk hazard classification (this classification shown in Map 1 is made by DOSD ( "The definitions for downstream hazard are borrowed from the Federal Guidelines for Inundation Mapping of Flood Risks Associated with Dam Incidents and Failures (FEMA P-946, July 2013). FEMA categorizes the downstream hazard potential into three categories in increasing severity: Low, Significant, and High. DSOD adds a fourth category of "Extremely High").<sup>31</sup>

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<sup>29</sup> FEMA, National Flood Safety Publications P-94, <https://www.fema.gov/media-collection/dam-safety-publications> NOAA. (1999). Hydrometeorological Report No. 59 – Probable Maximum Precipitation for California. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, U.S. Department of the Army Corps of Engineers. NOAA. (2011). Current NWS Probable Maximum Precipitation (PMP) Documents and Related Studies. Retrieved May 5, 2011, from NOAA Hydrometeorological Design Studies Center: <http://www.weather.gov/oh/hdsc/studies/pmp.html> NOAA. (2012). NOAA Atlas 14: Precipitation-Frequency Atlas of the United States. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service.

<sup>30</sup> Title 44 of the Code of Federal Regulations (CFR), Section 206.401, <https://www.ecfr.gov/current/title-44/chapter-I/subchapter-D/part-206>, Accessed on March 30, 2023

<sup>31</sup> See <https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/All-Programs/Division-of-Safety-of-Dams/Files/Publications/Division-of-Safety-of-Dams-Definitions-for-Downstream-Hazard-and-Condition-Assessment.pdf> for definitions.

**Table 2 - Dams and year built, classifications, and distance in miles to nearest towns (Includes MMWD and NMWD district-owned dams)**

Name	Year built	Safety classification	Risk hazard classification	Miles to closest towns
Alpine	1917	Satisfactory	High	Point Reyes Station 9
Bon Tempe	1949	Satisfactory	High	Point Reyes Station 6
Kent/Peters	1954	Satisfactory	High	Point Reyes Station 9
Lagunitas	1872	Satisfactory	Significant	Point Reyes Station 7
Seeger (Nicasio Reservoir)	1961	Satisfactory	High	Point Reyes Station 4
Novato Creek	1951	Satisfactory	High	Novato 2
Phoenix	1907	Satisfactory	High	Ross 1
Soulajule	1979	Satisfactory	High	Tomales 15

*Source: National Inventory of Dams and IndyStar, Marin County Dam Safety Inspection  
(table created by the Grand Jury) <https://data.indystar.com/dam/california/marin-county/06041/>*

According to the DOSD, dam failure and downstream hazard potential is classified as high, significant, or low risk (Risk Hazard Classification). High risk may likely cause loss of human life. Significant risk can cause property damage, environmental, and economic loss, as well as disruption of lifeline facilities. Low risk dams pose no threat to life, and present low economic and environmental risks. Rather, losses in the low risk classification may mostly impact dam owners.<sup>32</sup> The DOSD also has a Safety Classification, according to a dam’s current physical condition, as satisfactory, fair, poor, and unsatisfactory. *There is an important distinction between the two separate classifications; safety is the current condition, and the other is potential for risk.*

Of all eight structures shown above, seven are at high and one at significant risk hazard. Six of the seven MMWD-owned structures are in the high risk hazard category.

Due to the direction in which downstream floods would occur, Novato, Point Reyes Station, and Ross are at the greatest risk of flooding. Combined, these three towns represent nearly 20 percent of the total population of Marin County.

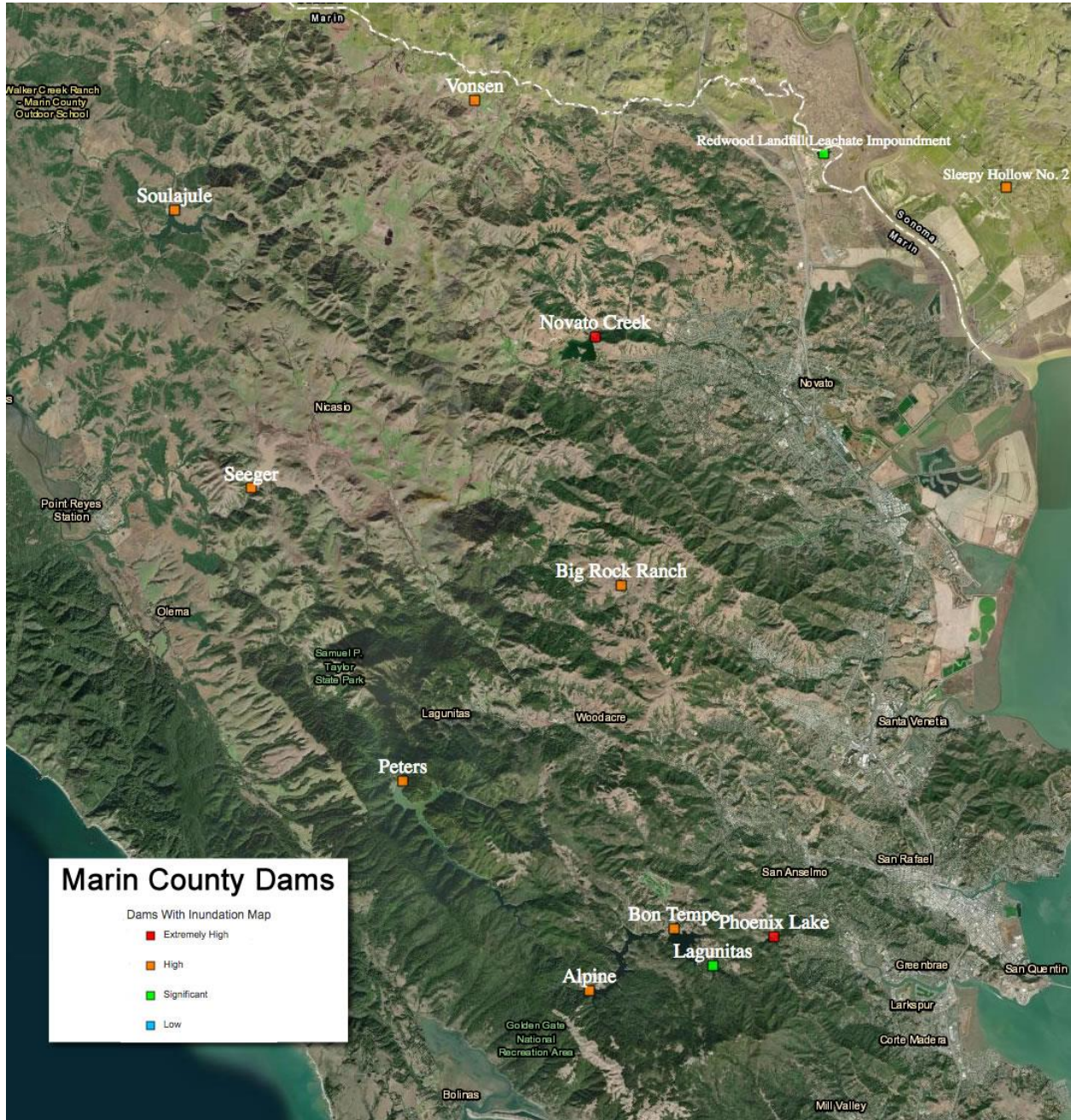
Dam failure risk reduction is of utmost importance. Atmospheric rivers should be front and center as a growing threat in the risk mitigation plans of MMWD and NMWD.

To illustrate, the Map 1 shows the dams mentioned in the table above: Alpine, Bon Tempe, Kent/Peters, Lagunitas, Seeger (Nicasio Reservoir), Novato Creek, Phoenix, and Soulajule.

<sup>32</sup> California dam safety, (National inventory of dams), <https://damsafety-prod.s3.amazonaws.com/s3fs-public/files/California%20Dam%20Safety%20Performance%20Report%202022.pdf>, Accessed on March 17, 2023



### Map 1 - Satellite photo of the 8 regulated dams in Marin County



Screenshot from [https://fnds.water.ca.gov/webgis/?appid=dam\\_prototype\\_v2](https://fnds.water.ca.gov/webgis/?appid=dam_prototype_v2) (title block by Grand Jury),  
Accessed on March 14, 2023

### Inundation Maps

DOSD now requires dam owners to prepare Mitigation Plans based on new (and in the future, ongoing) dam inspections and engineering reports. These engineering reports must detail information that the state can use to determine the dams’ safety classification as well as the dam risk hazard classification. In order to best show the risk classification, flood inundation maps are created for each dam showing the worst case scenario for flooding should the dam fail.

These flood inundation maps form the core of the Mitigation Plan, which is publicly available, and is used by both the Governor's OES and Marin County's Office of Emergency Services to create detailed plans of action should a catastrophic event occur.

FEMA maps are used by the National Flood Insurance program to predict and advise residents of their likelihood of potential flooding. The National Flood Insurance Program (NFIP) is the only one in the U.S. providing flood insurance to property owners, and it is usually required to be noted as part of any property listing. NFIP provides flood information and maps so that residents can assess whether they are in a flood zone and determine if pursuing FEMA flood insurance is a step for them to consider.

Unfortunately, these maps are not easily accessible on the internet. Even when located, the scales and information are difficult to compare and understand. The Grand Jury created the maps below from the available referenced sources. This is intended to provide examples of what publicly available information can look like and be accessed by communities at risk of floods. Readers who want more information about their specific area and risk are encouraged to utilize the links below and zoom into their respective neighborhood. We expect this will demonstrate the need for better access to this information.

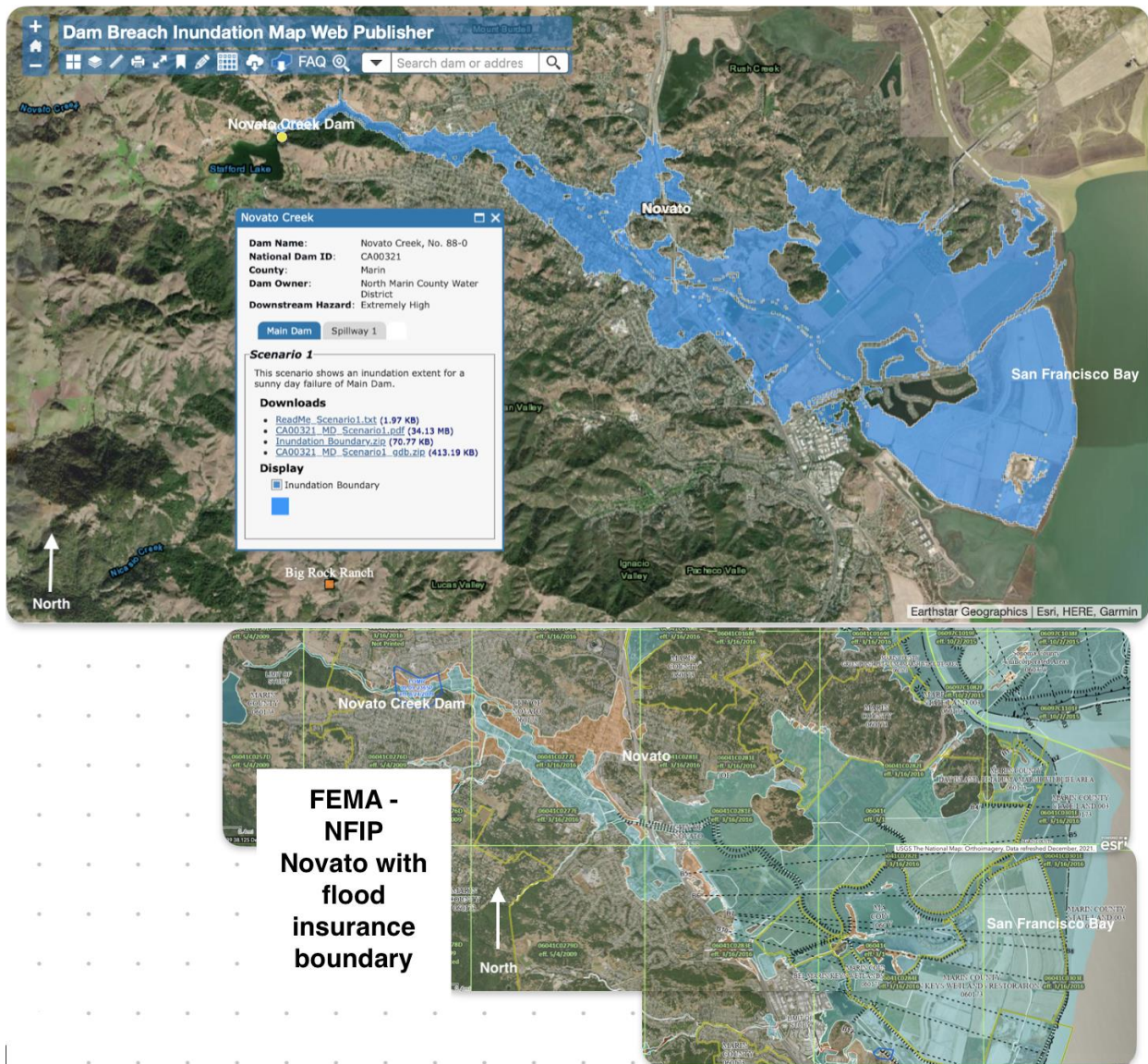
The top part of Map 2 shows the Novato Creek Dam Inundation map which illustrates the predicted flood boundary of a catastrophic dam failure. The lower part of Map 2, is the FEMA National Flood Insurance flood map, which shows flooding from all occurrences, including dams, reservoirs, sea level rise, etc. These two maps are similar in scale and orientation. However, some differences between the two show that the FEMA Dam Inundation map may not demonstrate the entire scope of the dam flood area. When combined, they illustrate what the dam inundation zone (flooding) could be.

The Inundation Map is based on an engineering analysis as required by FEMA P-94 guidelines issued in 2013, which rely upon weather data generated prior to 1999 and updated through 2012. *The main point of this report is that these weather models are not reflective of current climate change patterns and should be updated.*

What does a failure of the Novato Creek mean downstream in terms of flood scale? A vast proportion of Novato's infrastructure, including housing, commerce, and facilities of vital importance for community safety and wellbeing, could be underwater if the Novato Creek dam were to fail.



## Map 2 - Dam Flood Inundation Map (NMWD Novato Creek Dam) and FEMA National Flood Insurance Map for the town of Novato



Novato Creek Dam Flood Inundation Map, source: [https://fnds.water.ca.gov/webgis/?appid=dam\\_prototype\\_v2](https://fnds.water.ca.gov/webgis/?appid=dam_prototype_v2)  
 FEMA National Flood Insurance Program (NFIP) Map, Novato, California source: <https://hazards-fema.maps.arcgis.com/apps/webappviewer/index.html?id=8b0adb51996444d4879338b5529aa9cd&extent=-122.71020728149391,38.038546733259224,-122.425592718506,38.17362176438635>

Focusing on West Marin, the top map in Map 3 shows the scale of the inundation that may occur should the Seeger Dam (Nicasio Reservoir, marked by a yellow dot) fail. Nicasio reservoir is in the high risk hazard classification category. The meandering blue lines represent the water inundation that would ensue, and thus flood downstream to Pt. Reyes Station, and then spread onto sensitive and protected wildlife property. This failure would impact Point Reyes Station, a popular tourist destination locale with a population just shy of 1,000, where tourists visit almost year-round, and shops are plentiful. Additionally, impacts would be felt at the 482 acre Tomales Bay Ecological Reserve. This popular site includes a salt marsh and tidal flats where pickleweed, arrow grass, and salt grass abound. Birds rely on this marshy area for habitat, nesting, and food



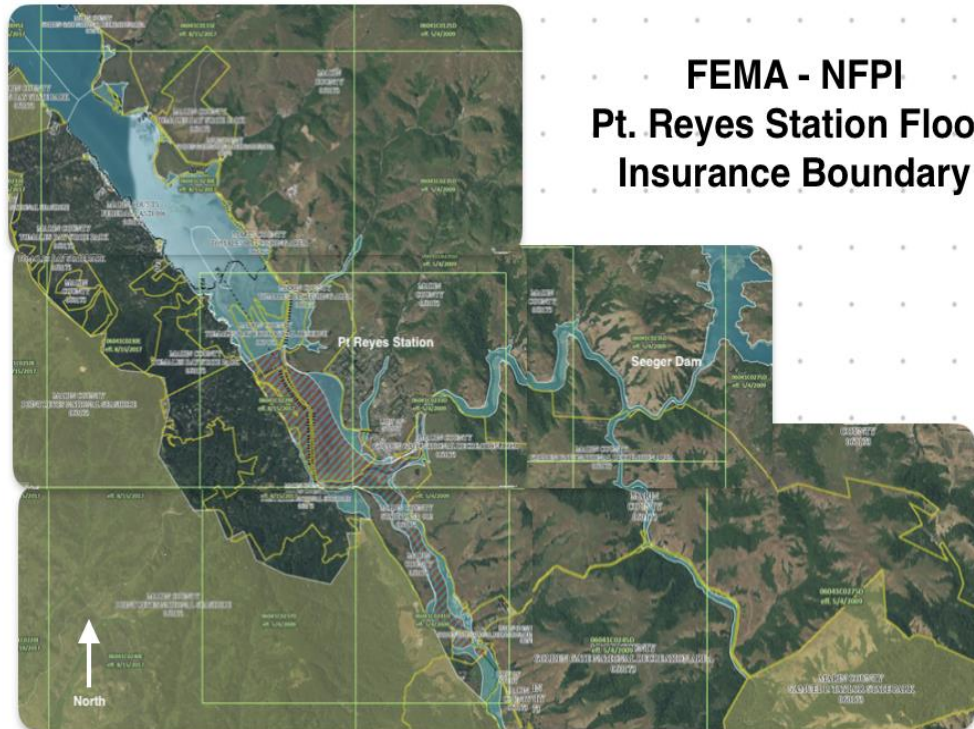
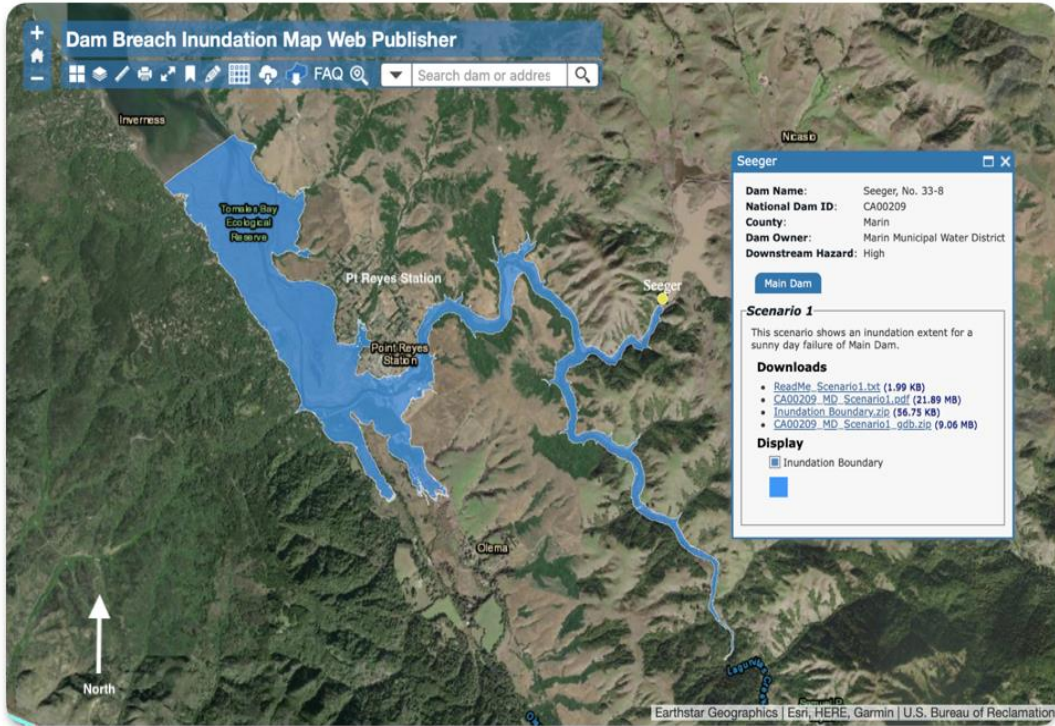
for waterfowl, shorebirds, brown pelican, California clapper, and black rail.<sup>33</sup> This is an example of how a local economy could be imperiled by a dam-caused flood.

At the bottom is the FEMA flood map, showing flooding from all possible occurrences (including the failure of Seeger Dam). While the two maps are similar, it appears that not all of the dam inundation mapping has been taken into account by FEMA. Between the two maps, however, residents can assess their flood risks and make decisions about flood insurance accordingly.

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<sup>33</sup> California Department of Fish and Wildlife, Tomales Bay Ecological Reserve, <https://wildlife.ca.gov/Lands/Places-to-Visit/Tomales-Bay-ER>, Accessed on March 9, 2023

### Map 3 - Dam Flood Inundation Map (MMWD Seeger Dam (Nicasio Reservoir)) and FEMA National Flood Insurance Map for the town of Pt. Reyes Station



Seeger Dam (Nicasio Reservoir) Flood Inundation Map, source:

[https://fnds.water.ca.gov/webgis/?appid=dam\\_prototype\\_v2](https://fnds.water.ca.gov/webgis/?appid=dam_prototype_v2)

FEMA National Flood Map, Novato, California, source: <https://hazards-fema.maps.arcgis.com/apps/webappviewer/index.html?id=8b0adb51996444d4879338b5529aa9cd&extent=-122.71020728149391,38.038546733259224,-122.425592718506,38.17362176438635>

## **Marin Municipal Water District**

The MMWD hazard mitigation plan offers actions related to climate change, such as changing chemical treatments in a couple of the plants for green purposes, and other actions that may mitigate dam failure, centering in detail on seismic issues. This plan was finalized in 2022. At that time, the scientific community (as noted above) was already elevating warnings about growing atmospheric river risks. In its plan, MMWD demonstrates great concern about earthquakes. Of course, these pose serious risks to dam and reservoir safety, and require mitigation strategies. But the district does not analyze the current science regarding atmospheric rivers, or incorporate associated hazard risk mitigation strategies, to the extent that it considers earthquakes in its plan.

The MMWD mitigation plan reflects the belief that most dam failure considerations by the federal government require a determination of the biggest floods that could occur (probable maximum flood). In the case of MMWD, this measure has been considered to “represent a worst-case-flood-scenario, and thought of as the event with the lowest probability of taking place.”<sup>34</sup> Further, the MMWD plan considers that the less extreme probable flood cases are much more likely to occur.<sup>35</sup> Scientists, however, are now expressing significant concerns because they believe probable maximum floods are becoming more and more likely to occur than in the past. As a result, scientists argue that dam owners and managers have to seriously consider the probability of the worst floods happening. Thus, the practice of defaulting to the assumption that only the lowest flood levels should be considered is becoming outdated. Additionally, in its 2022 plan, MMWD indicates that this document will be reviewed every five years.

Again, as Table 2 above shows, six of the seven dams managed by MMWD have been classified as having a high risk hazard. Although the dams have been classified as having a satisfactory safety rating, a high risk classification means that loss of human life downstream from failing dams is likely to happen.

## **North Marin Water District**

Turning to NMWD, the multi-jurisdictional plan, created in 2018, addresses risks of dam failure, with an emphasis on earthquakes. This hazard plan also states: “*A future hazard* that poses a threat to the County is climate change. Climate change is not considered as a separate hazard in this multi-jurisdiction plan. Climate change is expected to cause or contribute to numerous other hazards that are already addressed in this and related documents, including wildfires, flooding, severe winter storms, and coastal erosion.”<sup>36</sup> The issue with this position is that threats due to climate change have grown significantly. Although wildfires, coastal erosion, etc. are partly due

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<sup>34</sup> Hazard Mitigation Plan, (Marin Municipal Water District, March 2022), [https://www.marinwater.org/sites/default/files/2022-04/2022-03-23\\_MMWD\\_Hazard\\_Mitigation\\_Plan\\_Final.pdf](https://www.marinwater.org/sites/default/files/2022-04/2022-03-23_MMWD_Hazard_Mitigation_Plan_Final.pdf), Accessed on April 30, 2023

<sup>35</sup> Hazard Mitigation Plan, (Marin Municipal Water District, March 2022)

<sup>36</sup> Marin County Multi-Jurisdiction Local Hazard Mitigation Plan, (Marin County Flood Control District, 2018), <https://marinflooddistrict.org/documents/marin-county-multi-jurisdiction-local-hazard-mitigation-plan-2018/> Accessed on March 25, 2023

to climate change, this report believes that the multi-jurisdiction plan should include a separate category specifically dedicated to climate change and the escalation of atmospheric rivers. This is exactly what is also pointed out about the MMWD plan.

The current multi-jurisdiction plan, (through which NMWD addresses its dam safety strategies), asserts that “hazard mitigation is any action taken to reduce or eliminate the long-term risk to human life and property from natural hazards.”<sup>37</sup> This plan further indicates: “It is a process in which hazards are identified and profiled, the people and facilities at risk are analyzed, and mitigation actions to reduce or eliminate hazard risk are developed.”<sup>38</sup> In other words, the drafters of the multi-jurisdiction plan understand that hazards need to be identified and addressed. What this plan lacks is the recognition that high risks posed by current and growing climate change and atmospheric rivers already threaten the safety of its reservoir, and those downstream from it, just as earthquakes do.

### **Newest dam failure mitigation actions for now and the future**

There are other jurisdictions whose mitigation plans align with today’s knowledge regarding risks posed by atmospheric rivers. Sonoma County’s Forecast Informed Reservoir Operations (FIRO) is a water management practice that offers flexibility by using data from watershed monitoring, coupled with enhanced weather forecasting. FIRO utilizes state-of-the-art airborne data collection approaches ranging from flights over the Pacific Ocean to detect warming temperatures and possible atmospheric rivers, to weather balloons launched during storms to assess their force and direction. FIRO enables water managers to keep or release water when floods or dam failure could occur due to megastorms. FIRO, of course, can help better manage droughts.<sup>39</sup> Yuba County has also been developing its own FIRO implementation in collaboration with the Scripps Center for Oceanography.<sup>40</sup>

Marin County does not have high resolution (C-Band) radar that is required to track atmospheric storm cells.<sup>41</sup> However, a new radar station in West Marin, spearheaded by Sonoma County, will provide more detailed weather predictions for mitigating flood damage risk.

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<sup>37</sup> Marin County Multi-Jurisdiction Local Hazard Mitigation Plan, (Marin County Flood Control District, 2018)

<sup>38</sup> Marin County Multi-Jurisdiction Local Hazard Mitigation Plan, (Marin County Flood Control District, 2018)

<sup>39</sup> Forecast informed reservoir operations - A flexible and adaptive water management approach, (Sonoma Water), <https://www.sonomawater.org/firo>, Accessed on February 13, 2023

<sup>40</sup> John James, Adapting to California’s ‘Weather Whiplash’ with Forecast-Informed Reservoir Operations (North California Water Association, November 22, 2022), <https://norcalwater.org/2022/11/22/californias-weather-whiplash-with-forecast-informed-reservoir-operations/> Accessed on April 28, 2023

<sup>41</sup> “New Weather Radar to Sit on Barnabe”, Pt Reyes Light, Sam Mondos, Feb 22, 2023, <https://www.ptreyeslight.com/news/new-weather-radar-to-sit-on-barnabe> Accessed on April 21, 2023



## **Marin Municipal Water District and North Marin Water District are not alone**

The Grand Jury offers the following comparison with the goal of illustrating that MMWD and NMWD are not alone. The Grand Jury has chosen to look at a similar county in California in terms of population, as well as dam and reservoir risk hazard classification. Specifically, populations greater than 250,000 and lower than 300,000 were considered. We compared Marin and a County in Central California. Marin has a population of 265,294, and eight publicly run dams, all of which are in satisfactory condition, and seven of which pose high hazard risks. The comparable County, with a population of 286,216, has a total of thirteen dams. Five of these dams are operated by the local government and/or a public utility. All five dams have a satisfactory current condition, and all are classified as posing high hazard risks.<sup>42</sup> In essence, these two counties, similar in population numbers, have the vast majority of their publicly run dams classified at high hazard levels. This comparison shows that Marin County is not alone in dam and reservoir hazard risk classification.

At the state level, California-wide numbers show that more than half of all dams are categorized as having some risk of failure. Specifically: California has 1,239 dams. Of these, 58 percent are classified as high hazard risk.<sup>43</sup> It should be noted that this is not an apples-to-apples comparison because each dam is unique in terms of construction, susceptibility to atmospheric rivers, risk assessments, and ownership/operational status (private, public, local or federal). Nonetheless, this provides an illustration at the state level.

Many agencies are looking at dam safety in different ways, which is not necessarily inappropriate. Rather, this points out age and scope varying regulations and guidance documents can be somewhat arbitrary. This could be improved by incorporating a process to speed up review and updates that would incorporate the rapidly changing science of risk factors (the most important of which is PMP and flood risk to dam failure). This report focuses on this issue, as this has not been done yet.

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<sup>42</sup> National Inventory of Dams and IndyStar, Marin County and San Luis Obispo County Dam Safety Inspection, Accessed on February 9, 2023 <https://data.indystar.com/dam/california/marin-county/06041/>  
Accessed on April 28, 2023

<sup>43</sup> DOSD, "Dam Safety and Performance Report - 2022," <https://damsafety-prod.s3.amazonaws.com/s3fs-public/files/California%20Dam%20Safety%20Performance%20Report%202022.pdf>, Accessed on April 21, 2023

## **FINDINGS**

- F1. Climate change is increasing the atmospheric rivers' strength and frequency which impacts communities across Marin County. Failure to include and recognize these growing threats underestimates current dam safety risks and possible preventive strategies.
- F2. MMWD and NMWD are in full compliance with both state DOSD, as well as all federal regulations. However, dam safety analysis and reporting would be enhanced by including current data on probable maximum precipitation (basis for risk analysis) numbers.
- F3. MMWD and NMWD hazard mitigation plans fail to incorporate the latest scientific studies on climate change. They use DOSD and FEMA climate models that were last updated in 2012. This eleven-year gap may lead to an underestimation of current and future risks.
- F4. FEMA and National Flood Insurance maps may not have entirely incorporated the most recent dam inundation maps and are not available on the MMWD and NMWD websites.
- F5. The advancement of dam safety is greatly enhanced with the expertise of scientific institutions. They use a range of tools and practices such as FIRO, flyovers, weather balloons, radar along the coast, and collaborations between dam owners and scientific institutions. These practices, used by other water districts, serve as an example from which MMWD and NMWD can benefit.



## **RECOMMENDATIONS**

- R1. By March 15, 2024, MMWD and NMWD should establish a Climate Change and atmospheric rivers working group to consider, and begin to develop, new hazard mitigation actions. These should be based on the current scientific projections regarding atmospheric rivers and other extreme precipitation events.
- R2. By December 31, 2023, the two water districts should begin work to expand their respective hazard mitigation plans, which should include a new section dedicated to climate change, and a discussion of atmospheric rivers and their accelerating potential threats to dam and reservoir safety.
- R3. By January 1, 2026, the water districts (at the time of their next dam inspections, and when their hazard mitigation plans are revised) should provide the public with new information about the updated plans. This information needs to ensure that they effectively consider flood risks in light of the new science, thus ensuring that the public is aware of this.
- R4. By September 30, 2023, both water districts should update their websites to include links to the inundation and FEMA maps. They should also provide links to the National Flood Insurance Program.
- R5. By December 31, 2023, dam owners should provide the public with easily accessible information on flood risks, as FEMA and National Flood Insurance may not have entirely incorporated the most recent dam inundation maps.
- R6. By December 2023, both water districts should begin to explore collaborations with scientific institutions to learn from, expand their toolkit of mitigation strategies, and thus augment the safety of their dams in light of growing risks posed by atmospheric rivers.

## **REQUIRED RESPONSES**

The following responses are required pursuant to Penal Code Sections 933 and 933.05 from the following elected county officials within 90 days:

From the following governing bodies:

- Marin Municipal Water District (F1-F5, R1-R6)
- North Marin Water District (F1-F5, R1-R6)

The governing bodies indicated above should be aware that the comment or response of the governing body must be conducted in accordance with Penal Code section 933 (c) and subject to the notice, agenda and open meeting requirements of the Brown Act.

## **INVITED RESPONSES**

The following responses are invited pursuant to Penal Code Sections 933 and 933.05 from the following within 90 days:

- Marin County Board of Supervisors

### **Emergency Services:**

- Marin County Fire Department Office of Emergency Management

### **Communities at risk of damage to life and property:**

- Town of Ross
- City of Novato

Note: At the time this report was prepared information was available at the websites listed.
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Reports issued by the Civil Grand Jury do not identify individuals interviewed. Penal Code Section 929 requires that reports of the Grand Jury <u>not</u> contain the name of any person or facts leading to the identity of any person who provides information to the Civil Grand Jury. The California State Legislature has stated that it intends the provisions of Penal Code Section 929 prohibiting disclosure of witness identities to encourage full candor in testimony in Grand Jury investigations by protecting the privacy and confidentiality of those who participate in any Civil Grand Jury investigation.
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