COLORADO
Colorado Water Conservation Board
Department of Natural Resources

Last Updated: July 2019

Colorado Water Conservation Board

Water Plan Grant Application

Instructions

To receive funding for a Water Plan Grant, applicant must demonstrate how the project, activity, or process (collectively referred to as "project") funded by the CWCB will help meet the measurable objectives and critical actions in the Water Plan. Grant guidelines are available on the CWCB website.

If you have questions, please contact CWCB at (303) 866-3441 or email the following staff to assist you with applications in the following areas:

Water Storage Projects	Anna.Mauss@state.co.us
Conservation, Land Use Planning	Kevin.Reidy@state.co.us
Engagement & Innovation Activities	Ben.Wade@state.co.us
Agricultural Projects	Alexander.Funk@state.co.us
Environmental & Recreation Projects	Chris.Sturm@state.co.us

FINAL SUBMISSION: Submit all application materials in one email to *waterplan.grants@state.co.us* in the original file formats [Application (word); Statement of Work (word); Budget/Schedule (excel)]. Please do not combine documents. In the subject line, please include the funding category and name of the project.

Water Project Summary

Name of Applicant	DNR Low Head Dam Steering Committee Bill McCormick, Colorado Division of Water Resources 1313 Sherman Street Denver, CO 80203 303-866-3581 Ext 8262 bill.mccormick@state.co.us
Name of Water Project	Colorado Low Head Dam - Public Safety Initiative 2020

CWP Grant Request Amount	$35,000
Other Funding Sources - FEMA NDSP	$20,000
Other Funding Sources - Wright Water Engineers (in-kind funding)	$15,000
Other Funding Sources _____	$
Applicant Funding Contribution	$

Last Updated: July 2019

Total Project Cost	$70,000

Applicant & Grantee Information
Name of Grantee(s): DNR Low Head Dam Steering Committee Bill McCormick, Division of Water Resources (DWR) Alex Alma, Department of Natural Resources (DNR) Amy Moyer, Department of Natural Resources (DNR) Doug Vilsack, Department of Natural Resources (DNR) Kevin Houck, Colorado Water Conservation Board (CWCB) Brad Henley, Colorado Parks and Wildlife (CPW) Steve Boand, Division of Homeland Security and Emergency Management (DHSEM) Nathan Fey, Colorado Outdoor Recreation Industry Office (OREC) Kevin Stewart, Mile High Flood District (MHFD) Andrew Earles, Wright Water Engineers (WWE) Ruth Wright, Citizen
Mailing Address: 1313 Sherman Street, Denver, CO 80203
FEIN: N/A
Organization Contact: Bill McCormick
Position/Title: Chief of Dam Safety
Email: bill.mccormick@state.co.us
Phone: 303-866-3581 Ext 8262
Grant Management Contact: same as above
Position/Title
Email
Phone
Name of Applicant (if different than grantee)
Mailing Address
Position/Title
Email
Phone
Description of Grantee/Applicant
Provide a brief description of the grantee's organization (100 words or less).

Last Updated: July 2019

In 2019, the Colorado Department of Natural Resources (DNR) Executive Director's Office (EDO) formed a steering committee to advise and inform on the issue of low head dam safety. The first goal of this ad hoc committee was to gather information and create an inventory of low head dams statewide. Armed with that information, the committee is outlining a path forward toward increasing public safety at low head dams. This ad hoc group includes representatives from EDO, DWR, CPW, CWCB, DHSEM, OREC, MHFD, engineering consultants (WWE) and the general public. This group is applying for this water plan grant.

Type of Eligible Entity (check one)	
X	**Public (Government):** Municipalities, enterprises, counties, and State of Colorado agencies. Federal agencies are encouraged to work with local entities. Federal agencies are eligible, but only if they can make a compelling case for why a local partner cannot be the grant recipient.
	Public (Districts): Authorities, Title 32/special districts (conservancy, conservation, and irrigation districts), and water activity enterprises.
	Private Incorporated: Mutual ditch companies, homeowners associations, corporations.
	Private Individuals, Partnerships, and Sole Proprietors: Private parties may be eligible for funding.
	Non-governmental organizations (NGO): Organization that is not part of the government and is non-profit in nature.
	Covered Entity: As defined in Section 37-60-126 Colorado Revised Statutes.

Type of Water Project (check all that apply)	
	Study
	Construction
	Identified Projects and Processes (IPP)
X	Other: Multi-faceted project to improve public safety at low head dams in Colorado.

Category of Water Project (check the primary category that applies and include relevant tasks)	

Last Updated: July 2019

	Water Storage - Projects that facilitate the development of additional storage, artificial aquifer recharge, and dredging existing reservoirs to restore the reservoirs' full decreed capacity and Multi-beneficial projects and those projects identified in basin implementation plans to address the water supply and demand gap.. *Applicable Exhibit A Task(s):*	
	Conservation and Land Use Planning - Activities and projects that implement long-term strategies for conservation, land use, and drought planning. *Applicable Exhibit A Task(s):*	
X	Engagement & Innovation - Activities and projects that support water education, outreach, and innovation efforts. Please fill out the Supplemental Application on the website. *Applicable Exhibit A Task(s):*	
	Agricultural - Projects that provide technical assistance and improve agricultural efficiency. *Applicable Exhibit A Task(s):*	
X	Environmental & Recreation - Projects that promote watershed health, environmental health, and recreation. *Applicable Exhibit A Task(s):*	
	Other	Explain:

Location of Water Project

Please provide the general county and coordinates of the proposed project below in **decimal degrees**. The Applicant shall also provide, in Exhibit C, a site map if applicable.

County/Counties	Entire State of Colorado
Latitude	
Longitude	

Water Project Overview

Please provide a summary of the proposed water project (200 words or less). Include a description of the project and what the CWP Grant funding will be used for specifically (e.g., studies, permitting process, construction). Provide a description of the water supply source to be utilized or the water body affected by the project, where applicable. Include details such as acres under irrigation, types of crops irrigated, number of residential and commercial taps, length of ditch improvements, length of pipe installed, and area of habitat improvements, where applicable. If this project addresses multiple purposes or spans multiple basins, please explain.
The Applicant shall also provide, in Exhibit A, a detailed Statement of Work, Budget, Other Funding Sources/Amounts and Schedule.

Last Updated: July 2019

1. Create a Website
    a. Build a website to share information on Colorado low head dams
    b. House the low head dam inventory
    c. House content related to education about low head dams
    d. House content regarding best practices for dam owners, recreators, and first responders to avoid, mitigate, manage low head dam hazards
    e. Host content on the other parts of this project (described below)
2. Stakeholder Engagement
    a. Develop printed materials for use at stakeholder meetings and distribution to the public.
    b. Plan and execute a series of Stakeholder Meetings statewide (locations TBD, potential sites include: Denver, Ft Collins, Salida, Alamosa, Montrose, Glenwood Springs, Steamboat Springs, Durango)
    c. A Stakeholder Survey will be developed, distributed across the state and the results analyzed to help the steering committee inform and prioritize future activities.
3. Signage
    a. Develop standards for signage at low head dams.
    b. Fabricate a small number of signs.
    c. Install signs at selected, prioritized low head dam sites.
4. Emergency Responder Education
    a. Deliver six to eight training sessions at key, prioritized locations around the state.
    b. Utilize existing program of study for emergency responders developed by WWE.
    c. Enhance training as necessary based on survey results.

Last Updated: July 2019

Measurable Results	
To catalog measurable results achieved with the CWP Grant funds, please provide any of the following values as applicable:	
2.1 Million	Number of Coloradans Impacted by Engagement Activity - About 2.1 million people participate in water-based recreation in Colorado annually, which includes boating (both motorized and non-motorized), fishing, and other water contact sports. Source: CSU - Colorado Water Center
70+	Number of emergency responders to be trained at workshops around the state. Explanation: Number of attendees at presentations for emergency responder awareness of low head dam hazards, based on past experience, typical attendance is 10 participants per training. We anticipate 6 - 8 training sessions during the grant period.
3-4	# of signs installed - based on overall printing and installation costs.
8	# of stakeholder meetings planned. Final engagement numbers will depend on attendance (possible locations include: Denver, Ft Collins, Salida, Alamosa, Montrose, Glenwood Springs, Steamboat Springs, Durango). Attendance will be tracked and number of attendees collected.
# of stakeholder surveys completed	The more surveys we can get completed, the better understanding we'll have on the public's knowledge about these structures.

Last Updated: July 2019

# of website visits	Measuring “hits” to various pages of our website will ensure the public and other stakeholders are seeing our low head dam inventory data and education.
Reduce average # of deaths and injuries from low head dams over the next 5 years	We will collect baseline data through stakeholder engagement surveys. This is a one year grant so we will only be able to establish a baseline that we can compare against in future years.

Water Project Justification

Provide a description of how this water project supports the goals of Colorado’s Water Plan, the most recent Statewide Water Supply Initiative, and the applicable Roundtable Basin Implementation Plan and Education Action Plan. The Applicant is required to reference specific needs, goals, themes, or Identified Projects and Processes (IPPs), including citations (e.g. document, chapters, sections, or page numbers).

The proposed water project shall be evaluated based upon how well the proposal conforms to Colorado’s Water Plan Framework for State of Colorado Support for a Water Project (CWP, Section 9.4, pp. 9-43 to 9-44;)

The components of this grant application support the goals of the plans identified above in a variety of ways:

Colorado Water Plan

Supporting recreation is identified as one of Colorado’s Water Values: A productive economy that supports vibrant and sustainable cities, viable and productive agriculture, and a robust skiing, recreation, and tourism industry (CWP, Chapter 1, pp. 1-6). This hits at the core of our grant which is to reduce the number of deaths and injuries around low head dams in Colorado.

Additionally, our approach to provide education around these features and best practices for signage supports one of the main goals for the Water Plan, which is to Outreach, Education, and Public engagement around water issues in Colorado (CWP, Chapter 9, pp. 9-53).

Many, if not all of the Basin Implementation Plans reference the preference to develop and fund projects that are multi-use and/or ones that benefit multiple partners. The project we are putting forth will benefit the recreating public, agriculture interests, and other private landowners. Additionally, through our stakeholder process, any low head dams that are flagged for infrastructure improvements may benefit fish populations via new passage systems as part of their improvement plan.

Statewide Water Supply Initiative

Recommendations from the State Water Supply Initiative include: “Actively encourage projects to address multiple purposes, including municipal, industrial, environmental, recreational, agricultural, risk management, and compact compliance needs.” (SWSI ES, pp ES-40) Low head dam projects fit into many of these categories as they help reduce the risk to the recreating public while ensuring continued beneficial uses for agricultural, municipal, industrial and other stakeholder uses.

Additionally, another recommendation from the initiative encourages work with Colorado’s water stakeholders to help “Protect or enhance environmental and recreational values that benefit local and statewide economies.” (SWSI ES, pp ES-41). This strikes at the core of what we’re doing, which is to increase safety around low head dams which benefit landowners, the recreating public and the environment.

This project will help identify multi-objective projects. An example would be the case of a low head dam still in use, but in need of repair. A project that rehabilitates the structure could also be designed to include safety features for boat passage, fish ladders to connect trout habitat, and features to reduce environmental degradation.

Related Studies

Last Updated: July 2019

Please provide a list of any related studies, including if the water project is complementary to or assists in the implementation of other CWCB programs.
An overview of our inventory and report, including a study of low head dam activities in other states is attached as Exhibit C.

Previous CWCB Grants, Loans or Other Funding
List all previous or current CWCB grants (including WSRF) awarded to both the Applicant and Grantee. Include: 1) Applicant name; 2) Water activity name; 3) Approving RT(s); 4) CWCB board meeting date; 5) Contract number or purchase order; 6) Percentage of other CWCB funding for your overall project.
DNR EDO and CWBD partnered 50/50 to pay for an intern to create the low head dam inventory and produce the final report included as Attachment C. This intern was paid from a Severance tax fund set-aside from CWCB and the EDO staff budget.

Taxpayer Bill of Rights
The Taxpayer Bill of Rights (TABOR) may limit the amount of grant money an entity can receive. Please describe any relevant TABOR issues that may affect your application.
N/A

Last Updated: July 2019

Submittal Checklist	
X	I acknowledge the Grantee will be able to contract with CWCB using the Standard Contract.
Exhibit A	
X	Statement of Work(1)
X	Budget & Schedule(1)
N/A	Engineer's statement of probable cost (projects over $100,000)
X	Letters of Matching and/or Pending 3rd Party Commitments(1)
Exhibit C	
X	Map (if applicable)(1)
X	Photos/Drawings/Reports
X	Letters of Support (Optional)
N/A	Certificate of Insurance (General, Auto, & Workers' Comp.) (2)
N/A	Certificate of Good Standing with Colorado Secretary of State(2)
N/A	W-9(2)
N/A	Independent Contractor Form(2) (If applicant is individual, not company/organization)
Engagement & Innovation Grant Applicants ONLY	
X	Engagement & Innovation Supplemental Application(1)

(1) Required with application.
(2) Required for contracting. While optional at the time of this application, submission can expedite contracting upon CWCB Board approval.

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

Last Updated: July 2019

ENGAGEMENT & INNOVATION GRANT FUND SUPPLEMENTAL APPLICATION

Introduction & Purpose

Colorado's Water Plan calls for an outreach, education, public engagement, and innovation grant fund in Chapter 9.5.

The overall goal of the Engagement & Innovation Grant Fund is to enhance Colorado's water communication, outreach, education, and public engagement efforts; advance Colorado's water supply planning process; and support a statewide water innovation ecosystem.

The grant fund aims to engage the public to promote well-informed community discourse regarding balanced water solutions statewide. The grant fund aims to support water innovation in Colorado. The grant fund prioritizes measuring and evaluating the success of programs, projects, and initiatives. The grant fund prioritizes efforts designed using research, data, and best practices. The grant fund prioritizes a commitment to collaboration and community engagement. The grant fund will support local and statewide efforts.

The grant fund is divided into two tracks: engagement and innovation. The Engagement Track supports education, outreach, communication, and public participation efforts related to water. The Innovation Track supports efforts that advance the water innovation ecosystem in Colorado.

Application Questions

*The grant fund request is referred to as "project" in this application.

Overview (answer for both tracks)
In a few sentences, what is the overall goal of this project? How does it achieve the stated purpose of this grant fund (above)?
The overall goal of this project is to prevent injury and loss of life at low head dams across Colorado. We plan to achieve this goal through a multi-pronged approach. Our grant is innovative in that we are using lessons learned from other states and a collaborative approach with our steering committee to take action on key risk mitigation activities simultaneously.
Who is/are the target audience(s)? How will you reach them? How will you involve the community?
The target audiences include the recreating public, emergency responders, the agricultural community, private landowners, and M+I water users. The recreating community includes all those who participate in recreational activities on rivers including; tubing, rafting, kayaking, stand-up paddle boarding, and fishing. We will reach these groups through our website, our statewide stakeholder engagement meetings and surveys, our installed signage, and our emergency responder trainings. The community will be involved in stakeholder meetings around the state as well as stakeholder surveys. We also plan to use local volunteers where feasible to help install signage at high priority low head dam locations across the state.
Describe how the project is collaborative or engages a diverse group of stakeholders. Who are the partners in the project? Do you have other funding partners or sources?

Last Updated: July 2019

Overview (answer for both tracks)
DNR Low Head Dam Steering Committee Bill McCormick, Division of Water Resources (DWR) Alex Alma, Department of Natural Resources (DNR) Amy Moyer, Department of Natural Resources (DNR) Doug Vilsack, Department of Natural Resources (DNR) Kevin Houck, Colorado Water Conservation Board (CWCB) Brad Henley, Colorado Parks and Wildlife (CPW) Steve Boand, Division of Homeland Security and Emergency Management (DHSEM) Nathan Fey, Colorado Outdoor Recreation Industry Office (OREC) Kevin Stewart, Mile High Flood District (MHFD) Andrew Earles, Wright Water Engineers (WWE) Ruth Wright, Citizen In-kind Support: Wright Water Engineers (WWE)
Describe how you plan to measure and evaluate the success and impact of the project?
We plan to measure success by tracking the number of: • Emergency responders that complete trainings specific to low head dams • New signs installed around the state • Public and stakeholder attendees at our stakeholders meetings • Completed stakeholder surveys • Website “hits” The overall goal is to reduce the average number of deaths and injuries from low head dams over the next 5 years. We will collect baseline data through our stakeholder engagement surveys.
What research, evidence, and data support your project?
As determined by the low head dam inventory project, there are approximately 793 structures in Colorado rivers that are considered diversion dams. The safety around these water features is a serious concern as we’ve had about one fatality annually in recent years. Please refer to our low head dam inventory report for our full research, evidence, and data to support the need for our project.
Describe potential short- and long-term challenges with this project.
Short and long-term challenges with this project include conflicting interests within stakeholder communities, resistance to potential change (dam configurations and access), perception of liability, funding mechanisms for retrofits, lack of statutory authority over low head dams, and determining methods of prioritization of future risk reduction activities.

Please fill out the applicable questions for either the Engagement Track or Innovation Track, unless your project contains elements in both tracks. If a question does not relate to your project, just leave it blank. Please answer each question that relates to your project. Please reference the relevant documents and use chapters and page numbers (Colorado’s Water Plan, Basin Implementation Plan, PEPO Education Action Plan, etc.).

Last Updated: July 2019

Engagement Track
Describe how the project achieves the education, outreach, and public engagement measurable objective set forth in Colorado's Water Plan to "significantly improve the level of public awareness and engagement regarding water issues statewide by 2020, as determined by water awareness surveys."
Existence and dangers associated with low head dams are unknown to many recreational water users. The number of recreational water users is on the rise as the population of Colorado's rivers continues to grow. This sets up a high likelihood for increases in occurrence of loss of life due to drowning at low head dams. Our plan uses awareness building through website development, providing educational materials and training classes tailored to avoidance of these hazards and tools for emergency responders to stay safe during rescues and safety incidents. Our stakeholder meetings and survey will be designed to engage local communities to increase awareness of our team's activities and inform local citizens on a topic they may not have engaged in previously.
Describe how the project achieves the other measurable objectives and critical goals and actions laid out in Colorado's Water Plan around the supply and demand gap; conservation; land use; agriculture; storage; watershed health, environment, and recreation; funding; and additional.
Supporting recreation is identified as one of Colorado's Water Values: A productive economy that supports vibrant and sustainable cities, viable and productive agriculture, and a robust skiing, recreation, and tourism industry (CWP, Chapter 1, pp. 1-6). This hits at the core of our grant which is to reduce the number of deaths and injuries around low head dams in Colorado. Additionally, our approach to provide outreach and education around these features and incorporate best practices for signage supports one of the main goals for the Water Plan, which is to Outreach, Education, and Public engagement around water issues in Colorado (CWP, Chapter 9, pp. 9-53). Many, if not all of the Basin Implementation Plans reference the preference to develop and fund projects that are multi-use and/or ones that benefit multiple partners. The project we are putting forth will benefit the recreating public, agriculture interests, and other private landowners. Additionally, through our stakeholder process, low head dams flagged for infrastructure improvements may also provide for benefits to wildlife habitat via new fish and sediment passage systems.
Describe how the project achieves the education, outreach, and public engagement goals set forth in the applicable Basin Implementation Plan(s).
"Outreach creates public awareness of policies and processes, whereas education promotes a deeper understanding of these topics. Both are prerequisites to public engagement." This quote is straight from the Colorado Water Plan (CWP) and the work plan elements for this project speak to each of the CWP objectives/directives. Having a website to house the low head dam inventory provides for awareness of the scope of this issue at the state and local level. Our plans for emergency responder training speak to education. Our plans for stakeholder meetings and surveys provide for engagement. Since this is truly a statewide issue, our plans include meeting in all Water Division within the state. The team will make efforts to engage the basin roundtable leadership in the planning process for these stakeholder meetings. We will strive to work collaboratively with the Basin Implementation Plan authors where our common objectives intersect with the topic of Low Head Dams.
Describe how the project achieves the basin roundtable's PEPO Education Action Plans.

As discussed above, our stakeholder outreach activities will be coordinated with the leadership on each of the basin roundtables statewide, to promote collaboration. This will ensure these outreach activities are effective and for the benefit of as many stakeholders as possible. We will seek out and rely on the local information provided by the basin roundtables to achieve this goal.

Innovation Track
Describe how the project enhances water innovation efforts and supports a water innovation ecosystem in Colorado.
We have compiled a large diverse steering committee to ensure that mitigation and education strategies work for a variety of perspectives and needs. The challenge of low head dams is a relatively new topic for states to be tackling. While the dangers of these water features have long been recognized, solutions have been difficult to implement because there is no one-size fits all approach. Innovative approaches are required to have measurable impacts. This grant proposal provides a multi-pronged approach in order to test and identify which approaches are most successful for improving safety around low head dams. Those successful approaches will be documented and repeated around the state.
Describe how the project engages/leverages Colorado's innovation community to help solve our state's water challenges.
An innovative and "outside the box" element of our proposal is our training of first responders. What is too often mistaken as a normal water feature to perform rescues on, is far from normal. As WWE travels the state and educating first responders, they are ensuring that first responders are more effective at saving lives and reducing injuries and at the same time not putting themselves at risk. Additionally, we are looking forward to our public stakeholder meetings to hear new perspectives and innovative ways that we can help to reduce the dangers around low head dams in Colorado. Often times some of the best ideas come from the local people who are closest to the issues.
Describe how the project helps advance or develop a solution to a water need identified through TAP-IN and other water innovation challenges. What is the problem/need/challenge?
TAP-IN's mission is to convene Coloradans around water challenges to bring fresh voices and new approaches to the conversation and build a collaborative network across communities. Low head dams present a leadership challenge in Colorado. No one entity has authority or responsibility over regulation or public safety at low head dams. And all the while, we watch as unknowing individuals parish needlessly. Our grant proposal is to provide leadership to identify, educate and empower stakeholder groups to work together to find creative solutions that enhance public safety and reduce the number of needless deaths.

Last Updated: July 2019

Innovation Track
Describe how this project impacts current or emerging trends; technologies; clusters, sectors, or groups in water innovation.
Recreation trends and technologies are growing fast. While these technologies and trends get more people outside, improving their mental and physical health, some trends like increasing water recreation are creating more interactions with low head dams across the state. This upward trend emphasizes the need for the multi-pronged approach to reduce the number of injuries and deaths around low head dams in Colorado. Such an approach is outlined in this grant proposal. Additionally, we hope this project leads to advancements in multi-objective low head dam hazard mitigation designs. We hope our project creates opportunities for diverse stakeholder group interactions that lead to new and creative solutions to the challenges we are facing in Colorado.

Last Updated: July 2019

Colorado Water Conservation Board
Water Plan Grant - Exhibit A

Statement Of Work	
Date:	**1/31/20**
Name of Grantee:	**DNR Low Head Dam Steering Committee**
Name of Water Project:	**Colorado Low Head Dam - Public Safety Initiative 2020**
Funding Source:	**FEMA though the Division of Water Resources, Dam Safety, Colorado Water Conservation Board, In-kind from Wright Water Engineers**

Water Project Overview:

Discussion

As previously discussed, the goal of this project is to create a framework for risk reduction activities to increase public safety at and around low head dams in Colorado. Figure 1 below shows a graphic depiction of the situations that lead to fatalities at these structures.

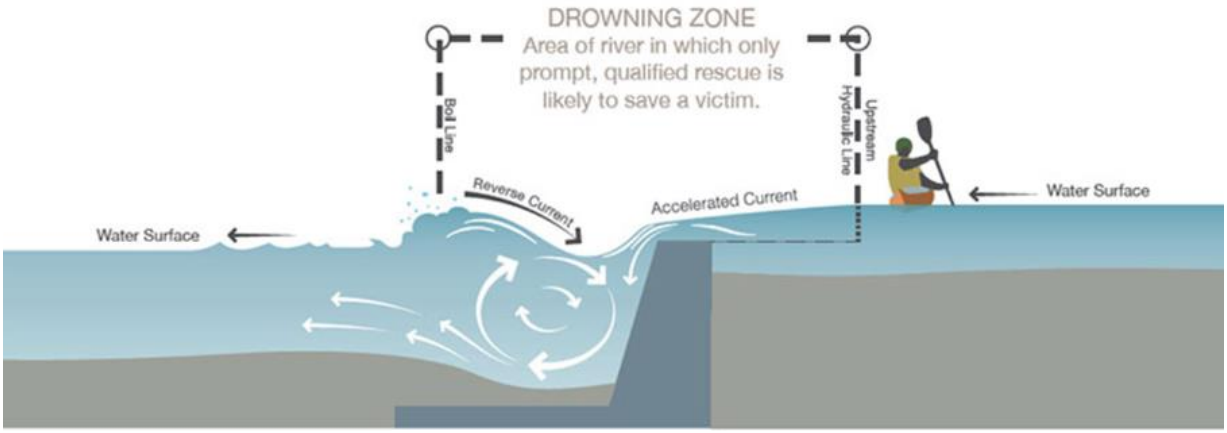


Figure 1- Graphic depiction hydraulic action of water flowing over low head dams that can lead to fatal accidents.

Exhibit C of this application contains the report of the 2019 project that established an inventory of these structures. This project is intended to build on that inventory work and begin to take steps to reduce risks. As described in the inventory report and shown in Figure 2, there are five action areas upon which to build a risk reduction program.

Figure 2 - Depiction of the five action areas utilized to reduce risk at Low Head Dams

The work plan developed for this project includes the Steering Committee hiring and managing a consultant to perform and/or facilitate the work tasks described herein. The proposed tasks each have ties to the five risk mitigation action areas.

Project Objectives:

The overall goal of this grant is to reduce the average number of injuries and deaths around low head dams across Colorado. We will achieve this by advancing the following elements:

1. Create a Website
    a. Build a website to share information on Colorado low head dams
    b. House the low head dam inventory
    c. House content related to education about low head dams
    d. House content regarding best practices for dam owners, recreators, and first responders to avoid, mitigate, manage low head dam hazards
    e. Host content on the other parts of this project (described below)
2. Stakeholder Engagement
    a. Develop printed materials for use at stakeholder meetings and distribution to the public.
    b. Plan and execute a series of Stakeholder Meetings statewide (locations TBD, potential sites include: Denver, Ft Collins, Salida, Alamosa, Montrose, Glenwood Springs, Steamboat Springs, Durango)
    c. A Stakeholder Survey will be developed, distributed across the state and the results analyzed to help the steering committee inform and prioritize future activities.
3. Signage
    a. Develop standards for signage at low head dams.
    b. Fabricate a small number of signs.
    c. Install signs at selected, prioritized low head dam sites.
4. Emergency Responder Education
    a. Deliver six to eight training sessions at key, prioritized locations around the state.
    b. Utilize existing program of study for emergency responders developed by WWE.
    c. Enhance training as necessary based on survey results.

Tasks
Task 1 – Website
Description of Task:
The first risk mitigation tool is 'Warn and Educate'. This entails the development, distribution and use of public educational, outreach and awareness programs. These programs seek to identify user groups and develop materials targeted to them. Printed materials, public service announcements, websites and digital platforms (APPS) are commonly used tools. We will create a website that houses this information, in order to increase awareness of the risks of low head dams while at the same time creating educational materials that can be shared across stakeholder communities.
Method/Procedure:
• Build a website as a clearing house for information on Colorado low head dams • House the low head dam inventory • House content related to education about low head dams • House content regarding best practices for dam owners, recreators, and first responders to avoid, mitigate, manage low head dam hazards • House content on the other parts of this project (described below)
Deliverable:

Last Updated: July 2019

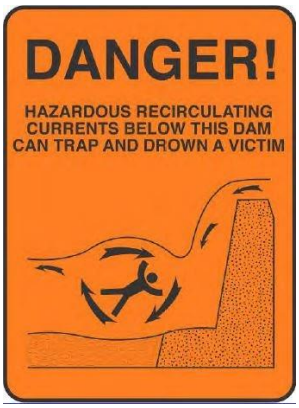
Tasks
Launch website and share with our stakeholders and other partners.

Tasks
Task 2 – Stakeholder + Public Engagement
Description of Task:
There are two elements to this task. One, a series of stakeholder meetings around the state will be used to provide foundational data for the development of educational materials and will also be used to identify structures of local concern. With input from user groups and local communities, actions toward eliminating local hazard will be identified. This activity would build toward the "mitigation and elimination of hazards" area of risk reduction. Secondly, developing a survey to collect information of community understanding and values around low head dams. This will help ensure marketing materials are relevant and local structures of concern are highlighted in our data inventory.
Method/Procedure:

Tasks
• Stakeholder Surveys will be developed, distributed, and assessed across the state. Survey information will help the steering committee inform and prioritize future activities to increase public safety at low head dams. • Plan and execute a series of Stakeholder Meetings statewide (possible stakeholder meeting locations include; Denver, Ft Collins, Salida, Alamosa, Montrose, Glenwood Springs, Steamboat Springs, Durango)
Deliverable:
Six to eight stakeholder meetings and a stakeholder survey.

Tasks
Task 3 – Signage
Description of Task:
Create guidelines and best management practices for signage based on emerging guidance from national professional associations and other states. Prioritize locations for installation of signage. Identify 3-4 locations around the state where fatalities have occurred and install signage. Encourage public and volunteer participation as a way to raise awareness and promote stakeholder engagement.
Method/Procedure:

Last Updated: July 2019

Tasks
• Develop standards for signage at low head dams. • Fabricate a small number of signs. • Install signs at selected, prioritized low head dam sites.
Deliverable:
One guideline establishing signage standards. The standards will be utilized to fabricate a small number of signs (3-4). Through this process survey data and local stakeholder input will be used to identify and prioritize the installation of these signs. Local stakeholder and user groups will be engaged as volunteers to participate in sign location and installation.    (example signage)

Tasks
Task 4 – Emergency Responder Education and Training
Description of Task:

Last Updated: July 2019

Tasks
Provide education and training to emergency responder organizations (fire departments, swift water rescue, etc.) to raise awareness of the hazards of low head dams (most recent version attached). During the grant period, WWE will reach out to firehouses and other emergency response organizations to offer to provide a "brown bag" presentation on safety hazards at low head dams. WWE senior staff including Kenneth Wright, P.E. or Dr. Andrew Earles, P.E., who have evaluated drownings at low head dams across the country will provide the presentation, supported by one of WWE's staff hydraulic engineers. Presentations typically run from 60 to 90 minutes including a question and answer period. WWE will travel to the location of the first responders to provide the presentation. We expect to conduct six to eight sessions with an average of approximately ten attendees per session.
Method/Procedure:
The method for training is to use an existing educational presentation developed by WWE. This presentation has been given to emergency responders in the past, and the feedback from trainees based on this presentation has been positive. WWE will take the results of stakeholder surveys into consideration, and may update the presentation based on issues and concerns identified by stakeholders.    Ken Wright and Karl Kingery of WWE with Technician Ben Soderfelt and Lieutenant Kurt Buhler of Denver Fire Department Engine 1—Water Rescue.
Deliverable:

Last Updated: July 2019

Tasks

The deliverable will be education and training materials on recognition and methods to avoid hazards to the public as well as first responders' safety at low head dams. Materials will target aspects relevant to first responders. Each presentation conducted will be a deliverable in itself, and we will document names, positions, and contact information for attendees to quantify the number of attendees and their background. Educational materials will be archived for future use.

Budget and Schedule

This Statement of Work shall be accompanied by a combined Budget and Schedule that reflects the Tasks identified in the Statement of Work and shall be submitted to CWCB in excel format.

Reporting Requirements

Progress Reports: The applicant shall provide the CWCB a progress report every 6 months, beginning from the date of issuance of a purchase order, or the execution of a contract. The progress report shall describe the status of the tasks identified in the statement of work, including a description of any major issues that have occurred and any corrective action taken to address these issues.

Final Report: At completion of the project, the applicant shall provide the CWCB a Final Report on the applicant's letterhead that:

- Summarizes the project and how the project was completed.
- Describes any obstacles encountered, and how these obstacles were overcome.
- Confirms that all matching commitments have been fulfilled.
- Includes photographs, summaries of meetings and engineering reports/designs.

The CWCB will pay out the last 10% of the budget when the Final Report is completed to the satisfaction of CWCB staff. Once the Final Report has been accepted, and final payment has been issued, the purchase order or grant will be closed without any further payment.

Last Updated: July 2019

Payment

Payment will be made based on actual expenditures and must include invoices for all work completed. The request for payment must include a description of the work accomplished by task, an estimate of the percent completion for individual tasks and the entire Project in relation to the percentage of budget spent, identification of any major issues, and proposed or implemented corrective actions.

Costs incurred prior to the effective date of this contract are not reimbursable. The last 10% of the entire grant will be paid out when the final deliverable has been received. All products, data and information developed as a result of this contract must be provided to CWCB in hard copy and electronic format as part of the project documentation.

Performance Measures

Performance measures for this contract shall include the following:
(a) Performance standards and evaluation: Grantee will produce detailed deliverables for each task as specified. Grantee shall maintain receipts for all project expenses and documentation of the minimum in-kind contributions (if applicable) per the budget in Exhibit B. Per Water Plan Grant Guidelines, the CWCB will pay out the last 10% of the budget when the Final Report is completed to the satisfaction of CWCB staff. Once the Final Report has been accepted, and final payment has been issued, the purchase order or grant will be closed without any further payment.
(b) Accountability: Per Water Plan Grant Guidelines full documentation of project progress must be submitted with each invoice for reimbursement. Grantee must confirm that all grant conditions have been complied with on each invoice. In addition, per Water Plan Grant Guidelines, Progress Reports must be submitted at least once every 6 months. A Final Report must be submitted and approved before final project payment.
(c) Monitoring Requirements: Grantee is responsible for ongoing monitoring of project progress per Exhibit A. Progress shall be detailed in each invoice and in each Progress Report, as detailed above. Additional inspections or field consultations will be arranged as may be necessary.
(d) Noncompliance Resolution: Payment will be withheld if grantee is not current on all grant conditions. Flagrant disregard for grant conditions will result in a stop work order and cancellation of the Grant Agreement.

Colorado Low Head Dam - Public Safety Initiative 2020 - Budget Estimate

1	**Work Item #1 - Website Development**				
	Item	**Unit**	**Unit Cost**	**Qauntity**	**Total Cost**
a	**Website Design Services**	Lump sum	$7,500	1	$7,500
				Subtotal	**$7,500**
2	**Work Item #2 - Stakeholder Engagement**				
	Item	**Unit**	**Unit Cost**	**Quantity**	**Total Cost**
a	**Printed Eduational/Awareness Information**				
	Design	Each	$675	2	$1,350
	Reproduction	Each	$0.25	680	$170
b	**Stakeholders Meetings**				
	Planning	Lump sum	$1,500	7	$10,500
	Execution	Lump sum	$2,500	7	$17,500
c	**Stakeholder Surveys**				
	Survey Development	Lump sum	$1,500	1	$1,500
	Survey Distribution	Lump sum	$2,500	1	$2,500
	Survey Data Reduction and analysis	Lump sum	$2,500	1	$2,500
				Subtotal	**$36,020**
3	**Work Item #3 - Signage**				
	Item	**Unit**	**Unit Cost**	**Quantity**	**Total Cost**
a	**Signage Standards Development**	Lump sum	1,500	1	$1,500
b	**Signage Design and Fabrication**	Each	500	4	$2,000
c	**Signage Installation**	Each	2,000	4	$8,000
				Subtotal	**$11,500**
4	**Work Item #4 - Low Head Dam Safety Training for Emergency Responders (60 min. presentation)**				
	Item	**Unit**	**Unit Cost**	**Quantity**	**Total Cost**
a	**Preparation and Logistics**	Lump sum	$670	7	$4,690
b	**Travel Time**	Lump sum	$735	7	$5,145
c	**Presentation Time**	Lump sum	$735	7	$5,145
				Subtotal	**$14,980**
				Total Estimated Cost	**$70,000**

Colorado Low Head Dam - Public Safety Initiative 2020 - Schedule Estimate

1	**Work Item #1 - Website Development**		
	Contracting	July 2020 - Sept 2020	
	Website Development	Sept 2020 - March 2021	
2	**Work Item #2 - Stakeholder Engagement**		
	Contracting	July 2020- Sept 2021	
	Printed Educational Materials	Nov 2020 - Jan 2021	
	Stakeholder Surveys	Sept 2020 - Jan 2021	
	Stakeholder Meetings	Nov 2020 - June 2021	
3	**Work Item #3 - Signage**		
	Contracting	July 2020- Sept 2021	
	Signage Standards Development	Nov 2020 - Jan 2021	
	Signage Design and Fabrication	Jan 2021 - March 2021	
	Signage Installation	April 2021 - May 2021	
4	**Work Item #4 - Low Head Dam Safety Training for Emergency Responders**		
	Contracting	July 2020- Sept 2021	In-kind contracting required
	Preparation and Logistics	Nov 2020 - Jan 2021	
	Presentations	Jan 2021 - June 2021	

LOW HEAD DAM RESCUES AND WATER SAFETY

Kenneth Wright, P.E.
Karl Kingery, P.E.

Wright Water Engineers, Inc.
Denver, Colorado

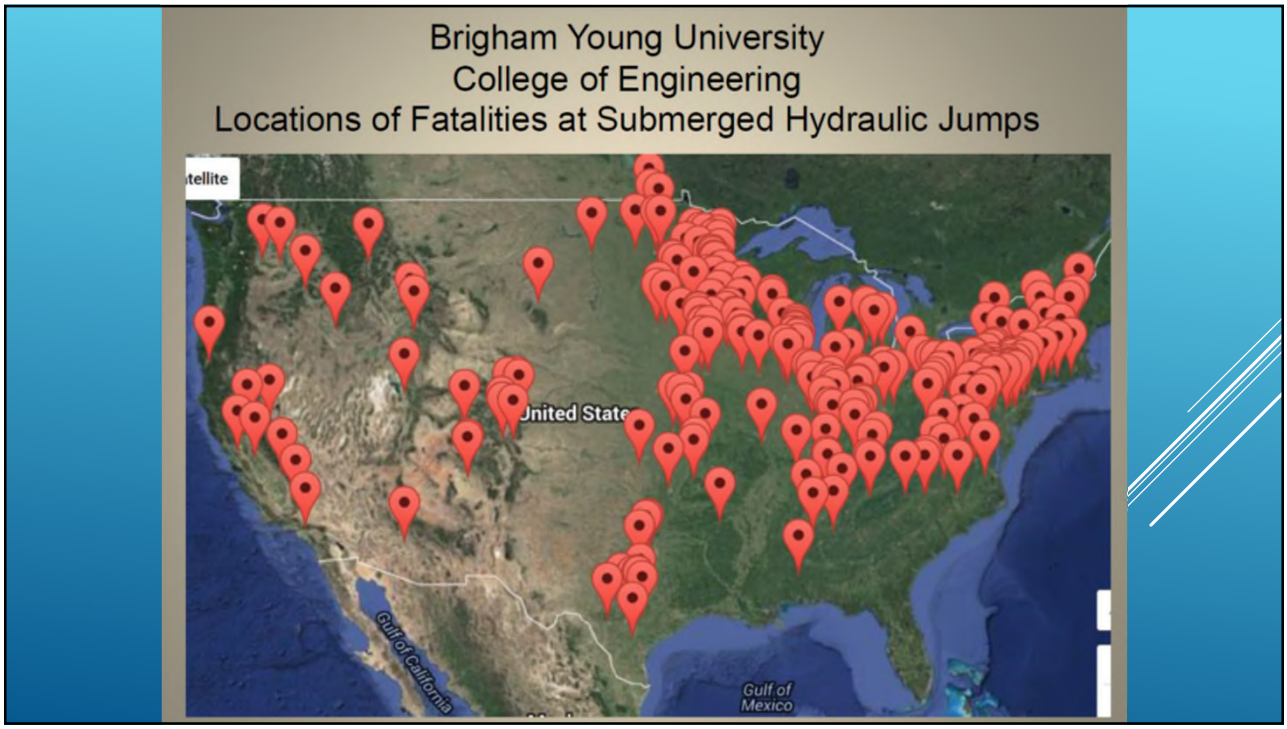
WWE
WRIGHT WATER ENGINEERS, INC.

R:\Resources\Library\Tech Reference\LHD\LHD for DFD.pptx

1

Attractive Nuisance

2



3

SALT RIVER, TEMPE, ARIZONA

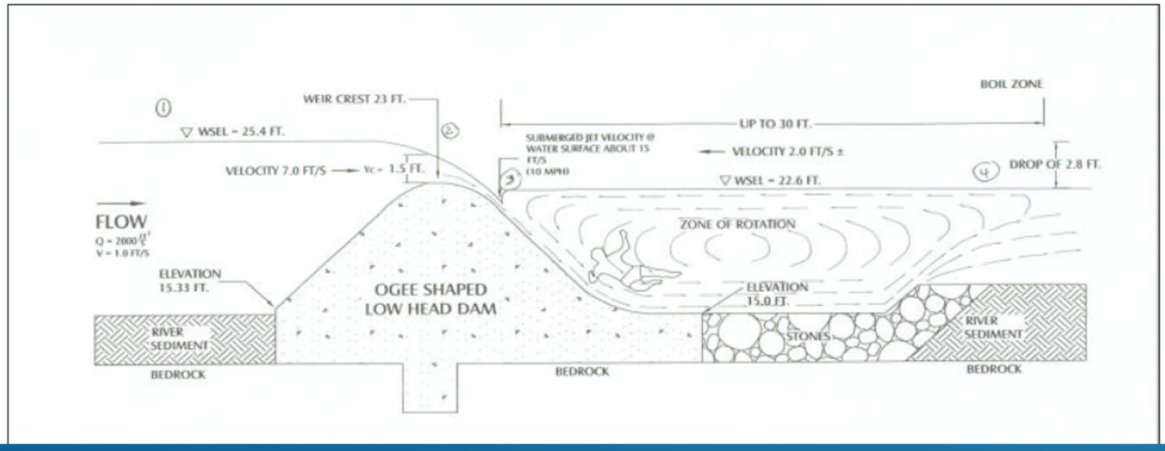
4

5


ISLAND FARM DAM ON RARITAN RIVER, NJ
(MODIFIED IN 1998 AFTER 4 DROWNINGS IN 3 YEARS AFTER CONSTRUCTED)
Before
Constructed 1995
After
Helpless TV crew records tragedy as canoeist is lost in Raritan River
IN MEMORY OF
ROBERT A. KOERNER (1954 – 1996)
IN FRIEND, A FATHER, A HERO DWELT
NO GREATER SORROW HAVE WE FELT
THE BEST OF MEN, NATURES BOAST
PRECIOUS MEMORIES, A SILENT TOAST
A RELUCTANT FAREWELL. THE SEASONS TOO FEW
MANY LIVES WERE ENRICHED
BY THE LIKES OF YOU
6

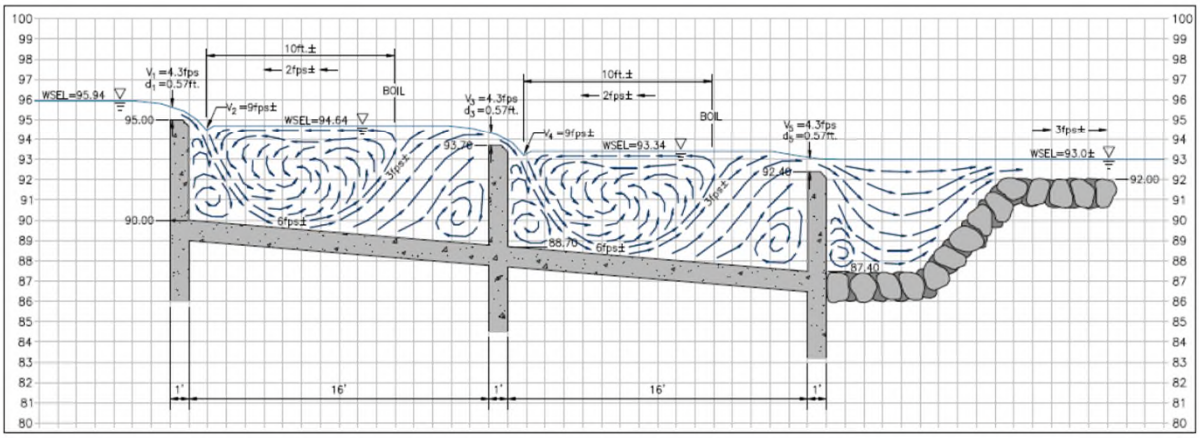
6

Figure 3 – Island Farm Weir Hydraulic Conditions on April 12, 1996



7

Figure 2 – Swackhammer Dam on Catherine Creek Near Union, Oregon



8

MCDONALD STEEL MILL DAM GIRARD, OHIO

9

DES MOINES RIVER AT CENTER STREET, DES MOINES, IOWA, LOOKING DOWNSTREAM, THE RED ARROWS POINT TO THE LOW HEAD DAM

10

RESCUE BOAT AND WOMAN TRAPPED BY HYDRAULIC CAUSED BY A LOW HEAD DAM IN THE DES MOINES RIVER, DES MOINES, IOWA

11

Rescue, Center St. Dam, Des Moines, Iowa

12

DES MOINES RIVER, BOONE, IOWA

13

LIME KILN DAM NEAR NEOSHO, MISSOURI

14

LIME KILN DAM NEAR NEOSHO, MISSOURI

15

THOMPSON MILL DAM, EDINBURGH, INDIANA

16

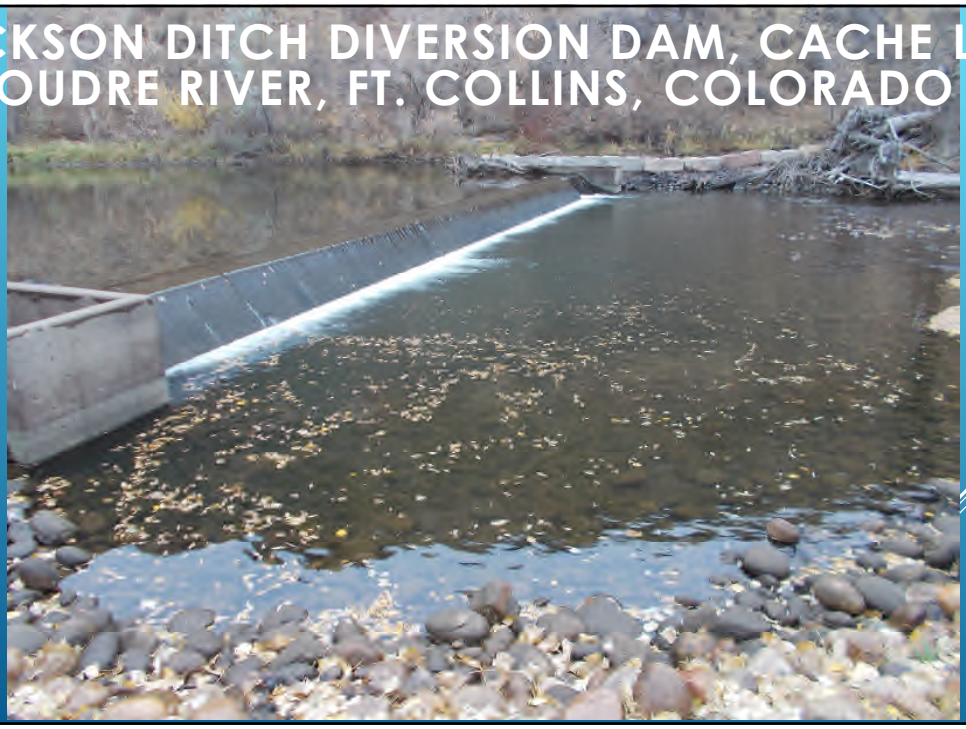
WATERWORKS DAM, NEAR UPPER SANDUSKY, OHIO

17

PARIS, KENTUCKY, SPEARS MILL IMPOUNDMENT DAM

18

JACKSON DITCH DIVERSION DAM, CACHE LA POUDRE RIVER, FT. COLLINS, COLORADO

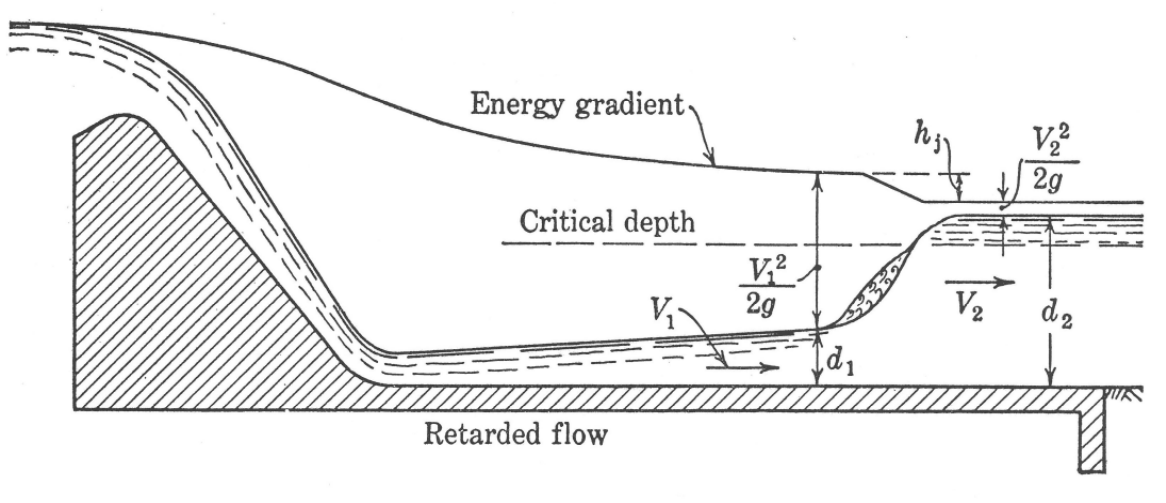


19

JACKSON DITCH DIVERSION DAM, CACHE LA POUDRE RIVER, FT. COLLINS, COLORADO

20

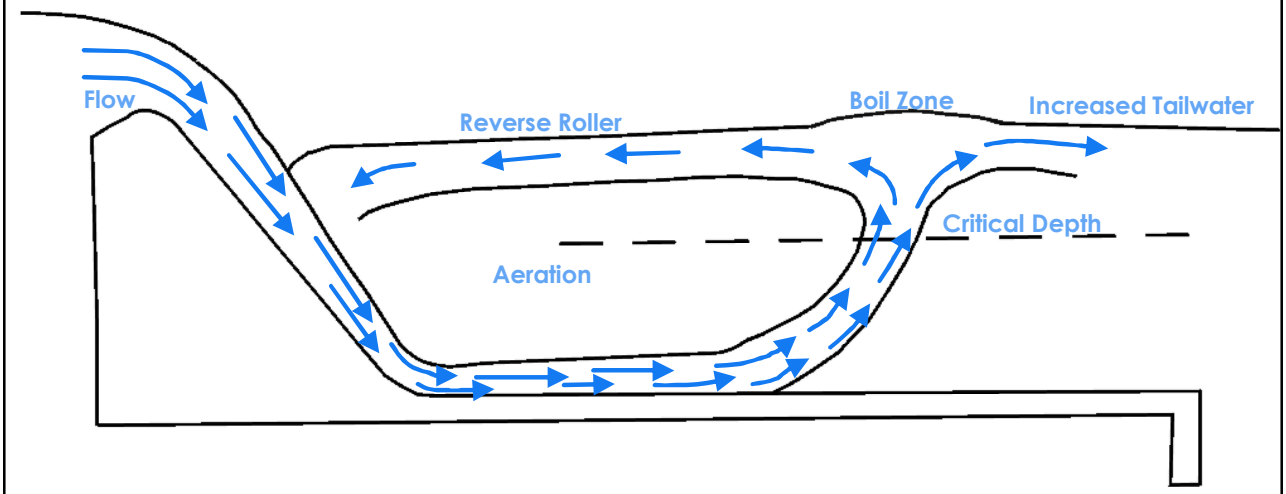
Hydraulic Jump



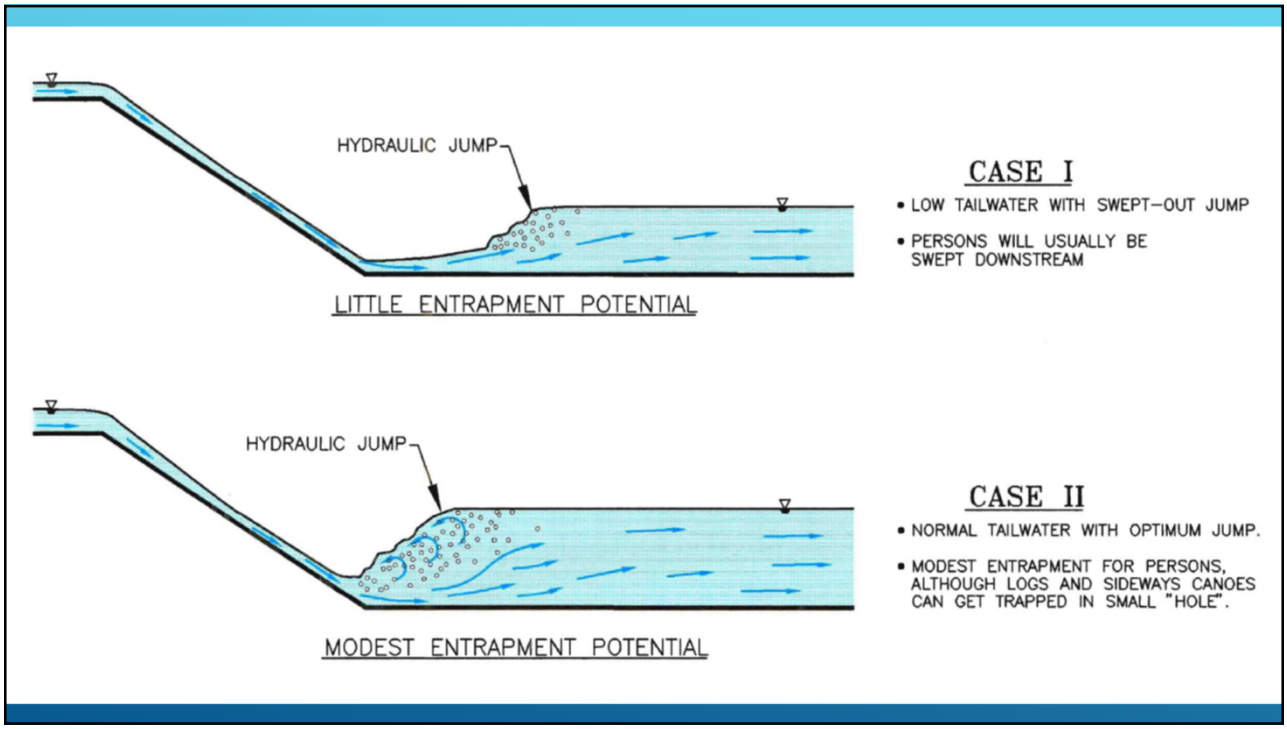
King, H.W., Wisler, C.O., Woodburn, J.G. 1948. *Hydraulics*. 5th edition. New York: John Wiley & Sons. Page 278.

21

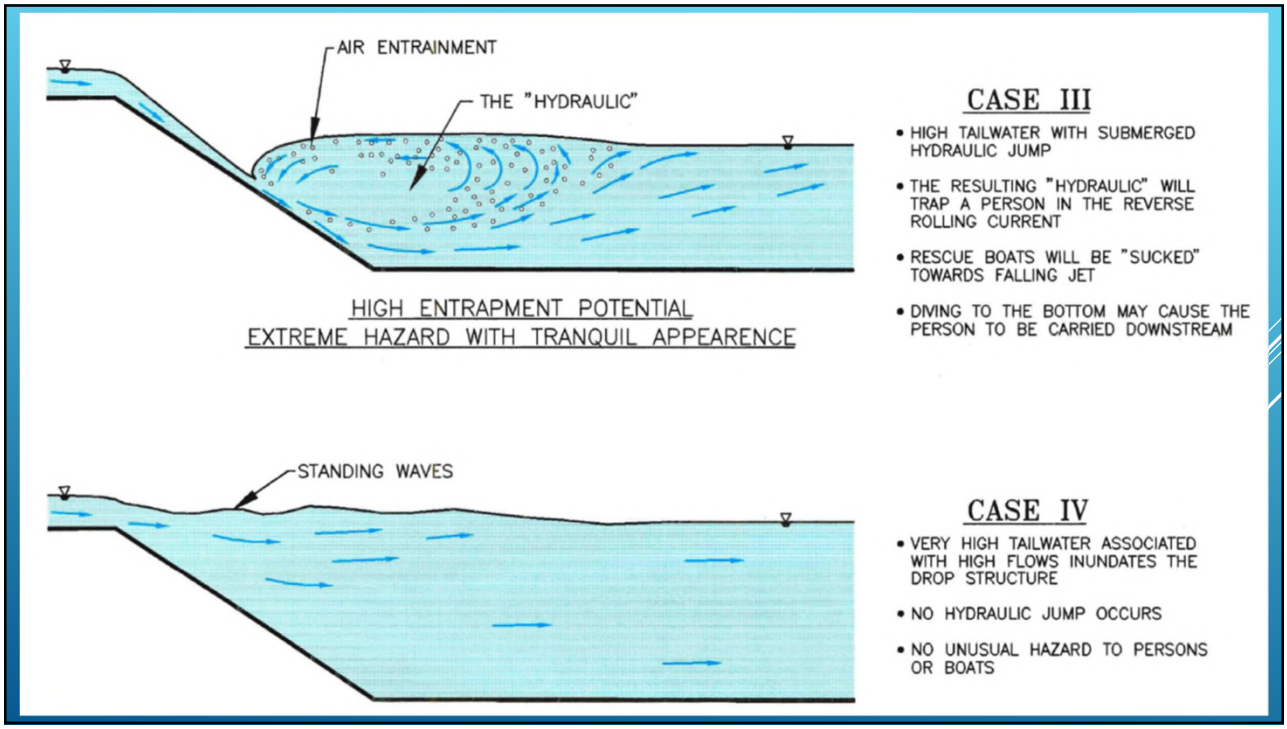
Submerged Hydraulic Jump



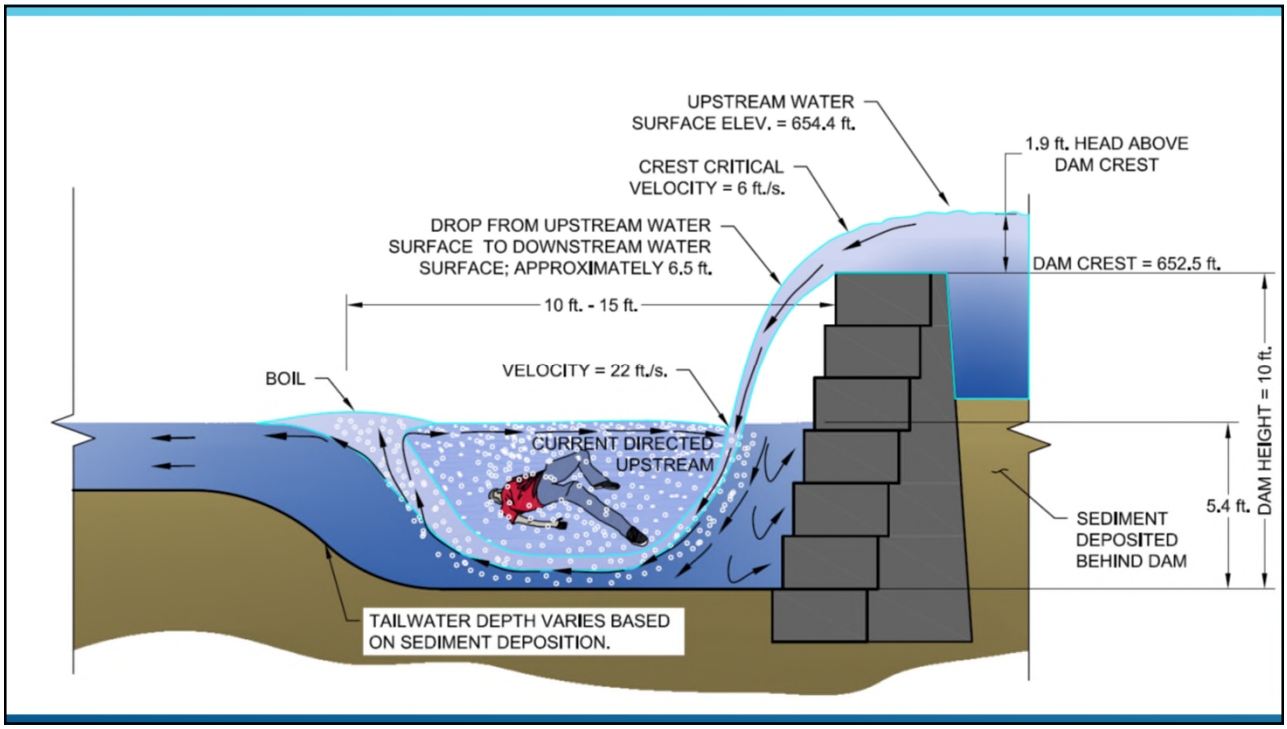
22


HYDRAULIC JUMP
LITTLE ENTRAPMENT POTENTIAL
CASE I
• LOW TAILWATER WITH SWEPT–OUT JUMP
• PERSONS WILL USUALLY BE SWEPT DOWNSTREAM
HYDRAULIC JUMP
MODEST ENTRAPMENT POTENTIAL
CASE II
• NORMAL TAILWATER WITH OPTIMUM JUMP.
• MODEST ENTRAPMENT FOR PERSONS, ALTHOUGH LOGS AND SIDEWAYS CANOES CAN GET TRAPPED IN SMALL "HOLE".

23


AIR ENTRAINMENT
THE "HYDRAULIC"
HIGH ENTRAPMENT POTENTIAL
EXTREME HAZARD WITH TRANQUIL APPEARENCE
CASE III
• HIGH TAILWATER WITH SUBMERGED HYDRAULIC JUMP
• THE RESULTING "HYDRAULIC" WILL TRAP A PERSON IN THE REVERSE ROLLING CURRENT
• RESCUE BOATS WILL BE "SUCKED" TOWARDS FALLING JET
• DIVING TO THE BOTTOM MAY CAUSE THE PERSON TO BE CARRIED DOWNSTREAM
STANDING WAVES
CASE IV
• VERY HIGH TAILWATER ASSOCIATED WITH HIGH FLOWS INUNDATES THE DROP STRUCTURE
• NO HYDRAULIC JUMP OCCURS
• NO UNUSUAL HAZARD TO PERSONS OR BOATS

24


UPSTREAM WATER
SURFACE ELEV. = 654.4 ft.
1.9 ft. HEAD ABOVE
DAM CREST
CREST CRITICAL
VELOCITY = 6 ft./s.
DROP FROM UPSTREAM WATER
SURFACE TO DOWNSTREAM WATER
SURFACE; APPROXIMATELY 6.5 ft.
DAM CREST = 652.5 ft.
10 ft. - 15 ft.
BOIL
VELOCITY = 22 ft./s.
CURRENT DIRECTED
UPSTREAM
DAM HEIGHT = 10 ft.
5.4 ft.
SEDIMENT
DEPOSITED
BEHIND DAM
TAILWATER DEPTH VARIES BASED
ON SEDIMENT DEPOSITION.

25

26

27

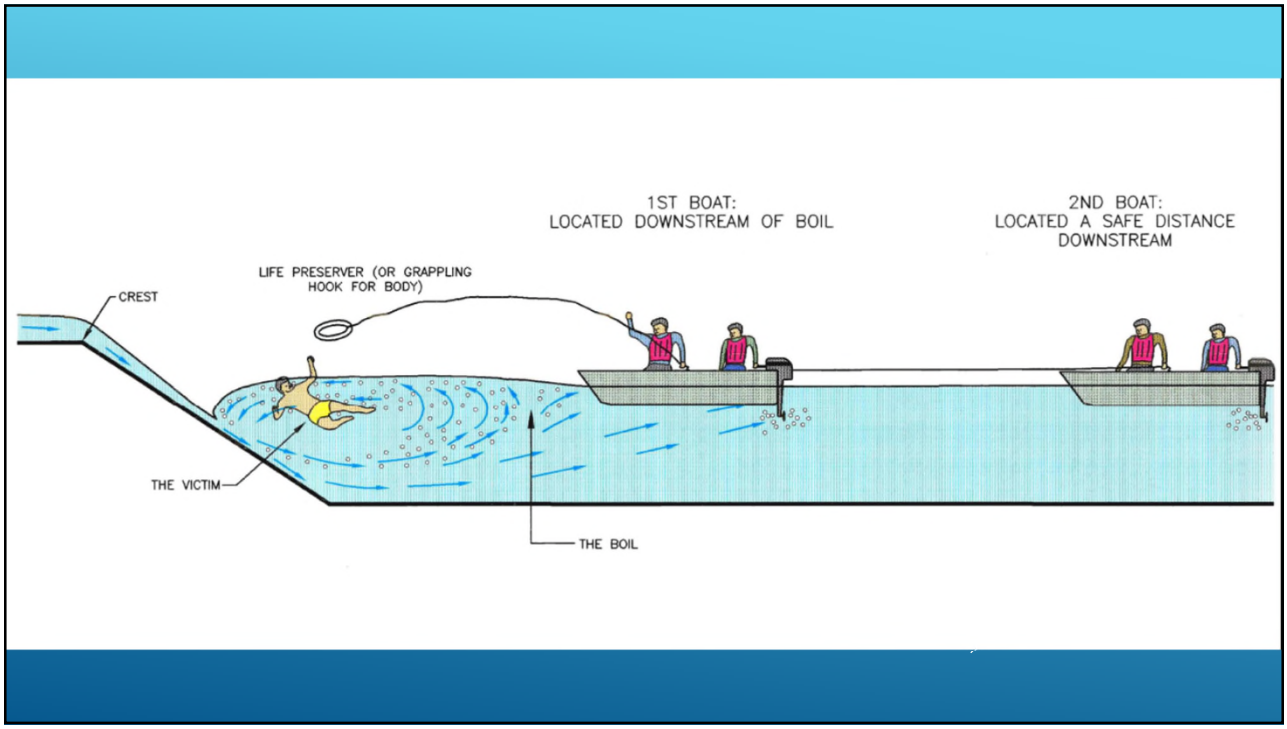
28

29

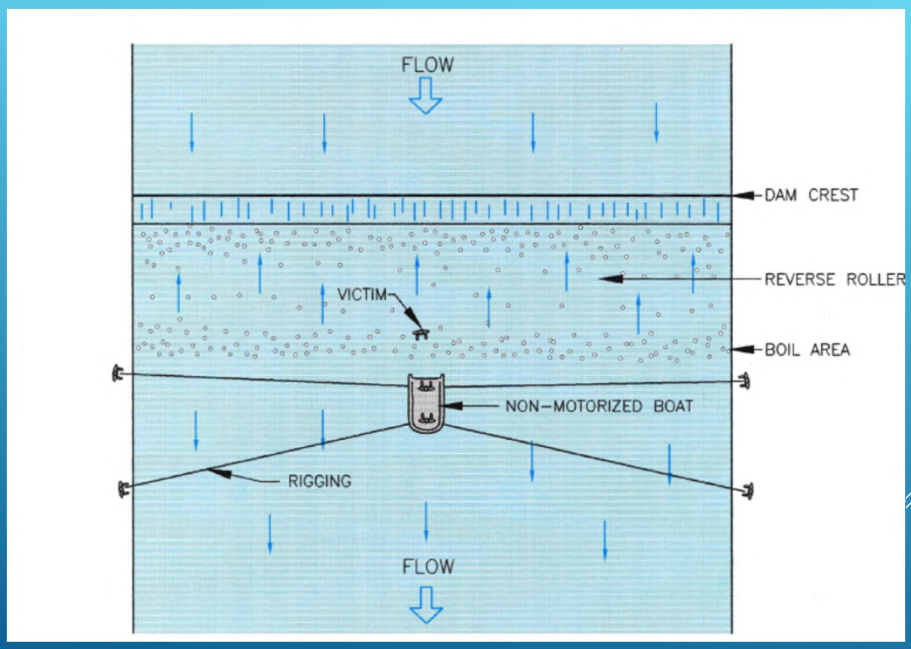
30

Binghamton New York Video

31



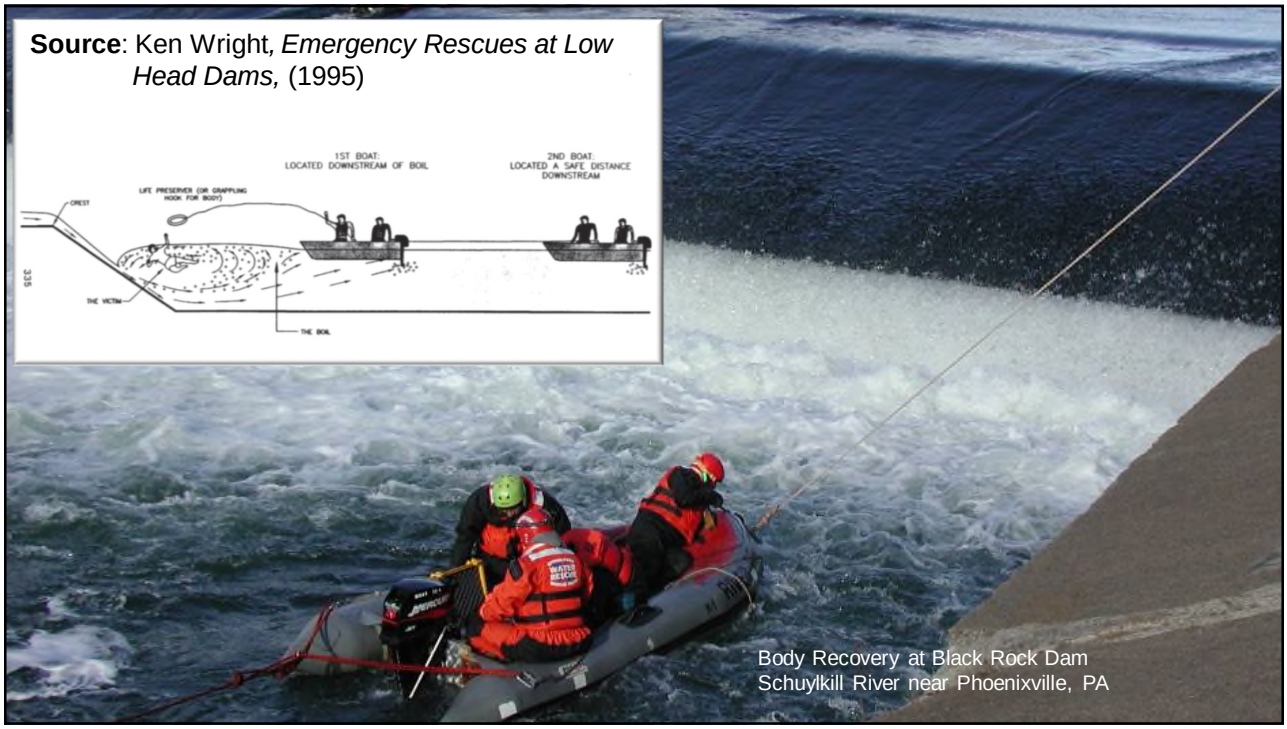
32


FLOW
DAM CREST
REVERSE ROLLER
VICTIM
BOIL AREA
NON-MOTORIZED BOAT
RIGGING
FLOW

33

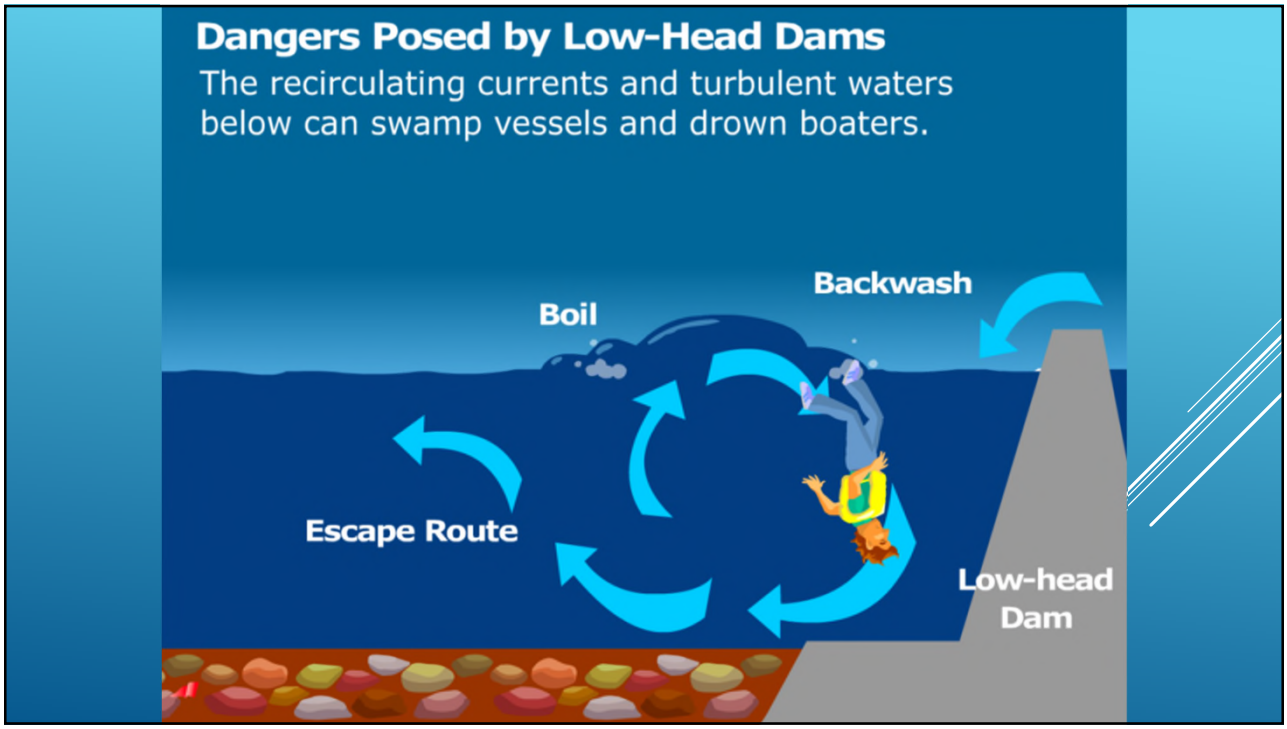

Over, Under, Gone: The Killer in Our Rivers. PBS, 2016

34

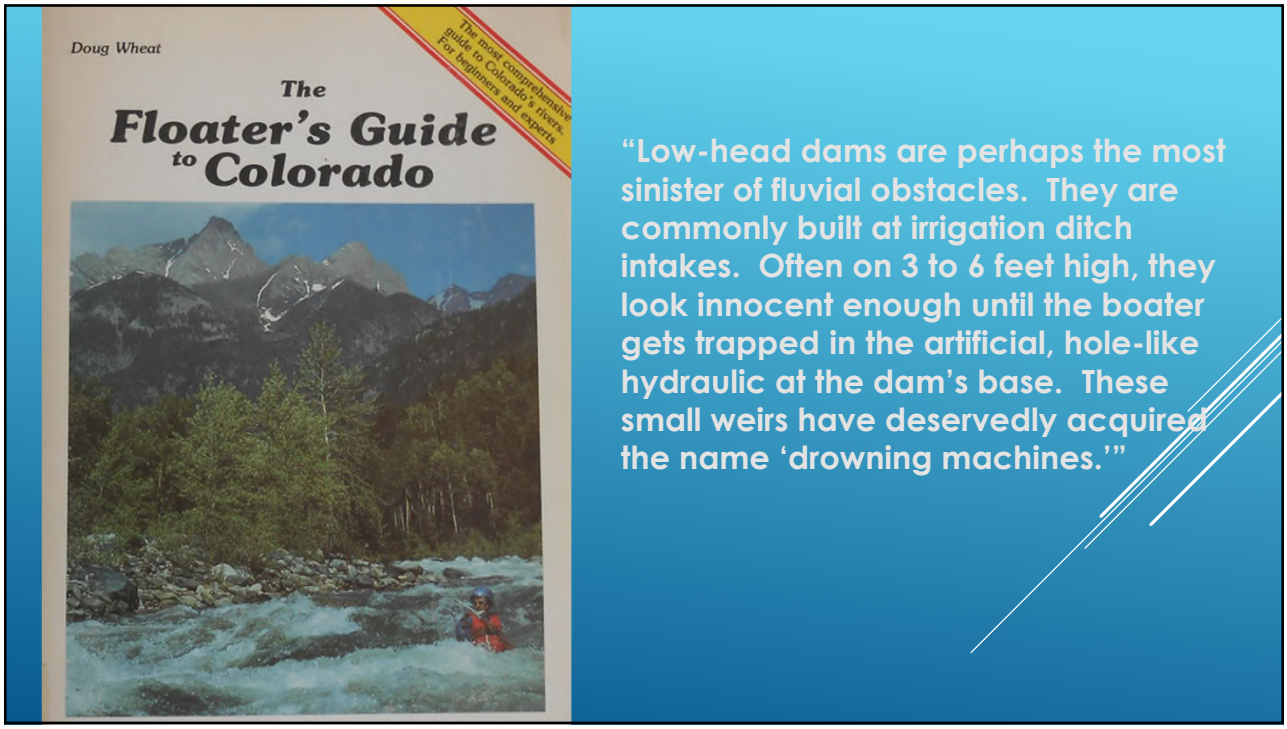

Source: Ken Wright, Emergency Rescues at Low Head Dams, (1995)
1ST BOAT: LOCATED DOWNSTREAM OF BOIL
2ND BOAT: LOCATED A SAFE DISTANCE DOWNSTREAM
LIFE PRESERVER (OR GRAPPLING HOOK FOR BODY)
CREST
THE VICTIM
THE BOIL
Body Recovery at Black Rock Dam
Schuylkill River near Phoenixville, PA

35

36


Dangers Posed by Low-Head Dams
The recirculating currents and turbulent waters below can swamp vessels and drown boaters.
Boil
Backwash
Escape Route
Low-head Dam

37


Doug Wheat
The most comprehensive guide to Colorado's rivers. For beginners and experts
The
Floater's Guide to Colorado
"Low-head dams are perhaps the most sinister of fluvial obstacles. They are commonly built at irrigation ditch intakes. Often on 3 to 6 feet high, they look innocent enough until the boater gets trapped in the artificial, hole-like hydraulic at the dam's base. These small weirs have deservedly acquired the name 'drowning machines.'"

38

Wright Water Engineers, Inc.
2490 West 26th Ave., Suite 100A
Denver, Colorado 80211
(303) 480-1700 TEL
(303) 480-1020 FAX

www.wrightwater.com
e-mail: krw@wrightwater.com

January 29, 2020

Via email: bill.mccormick@state.co.us

Bill McCormick, P.E., P.G.
Chief, Colorado Dam Safety
Colorado Division of Water Resources
1313 Sherman Street, Rm 821
Denver, CO 80203

Re: Wright Water Engineers, Inc. In-kind Contribution to Department of Natural Resources Low Head Dam Safety Proposal

Dear Mr. McCormick:

Wright Water Engineers, Inc. (WWE) has prepared this letter to express our support for the grant that the Colorado Department of Natural Resources (DNR) is preparing related to improving public safety at low head dams. WWE has worked on evaluating drownings at low head dams across the country, and we are very pleased to see the state of Colorado taking on this important issue. WWE has been working as a part of DNR's low head dam advisory committee over the past year, and we look forward to continuing to support these efforts.

One of the things that we have done to raise awareness of the hazards around low head dams is to provide presentations to emergency responders such as firefighters, swift water rescue units, and other organizations involved in responding to incidents at low head dams. If the DNR is awarded the grant that is being requested, we will reach out to emergency response organizations in areas where the DNR mapping indicates there are dams that pose a high risk. We will work to line up six to eight sessions for emergency responders over the course of the grant period. Based on past experience, we estimate that approximately 10 people will attend each of the sessions. WWE also will participate in ongoing work group meetings, and we will assist the DNR with grant tasks related to signage and stakeholder input where needed.

Based on the typical cost of putting on these training sessions and our standard hourly rates, we estimate that our in-kind input for this grant would be at least $15,000. We sincerely look forward to working with you on this grant, and we hope that the application will be successful. Thank you for involving us in this effort.

Sincerely,

WRIGHT WATER ENGINEERS, INC.

By _____
Kenneth R. Wright

Colorado Low Head Dam Inventory Project 2019

Jackson Ditch Diversion Dam on the Cache La Poudre River, Ft Collins, Colorado
(Photo Courtesy of Wright Water Engineers)

By Sarah L. Zimmer
University of Colorado Denver
October, 2019

Table of Contents

1. Executive Summary

Low Head Dams exist on main stem rivers and tributaries in all of Colorado's' seven water divisions and on the eastern and westerns slopes of the continental divide. During the months of April through August Colorado experiences periods of seasonally high snowmelt runoff and monsoonal rain-driven high water conditions. Heightened water levels increase the frequency of fatal incidents involving recreational water users at low head dams. In recent years, Colorado has experienced at least one fatality annually. This is consistent with low head dam fatality statistics nationally. As Colorado's population increases so does the number of residents recreating on our rivers these factors increase the potential for fatal incidents. Other states in the nation have initiated programs to address the issue of public safety at low head dams. In 2019, the Colorado Department of Natural Resources (DNR) initiated a project to inventory low head dams across the state as a means to begin to assess the risk and examine viable means to mitigate these risks in Colorado.

Over a period of four months, a comprehensive inventory of potentially hazardous structures in Colorado's mainstem rivers and major tributaries was created using satellite imagery, data from the Colorado Division of Water Resources (DWR) water rights database, and ArcMap 10.4. A total of 1,103 structures were identified and georeferenced into the inventory. There were multiple tasks identified for including structures into the inventory. These included visually scanning the rivers and tributaries in Google Earth to identify potential structures, comparing the identified locations with water rights database information, capturing the geographic location and unique identifier information for structures to be included in the inventory and assigning each structure to a classification system based on physical attributes and purpose. A series of maps were created to visually convey the locations of the structure within each of the state's seven water divisions. The inventory includes information for structures on mainstem rivers and their major tributaries. The data collection focused on those rivers and streams most heavily recreated and utilized by the public.

The objective of this project was to create a statewide inventory of low head dams, detailing the extent and distribution of these structures in Colorado's waterways. In addition, research was conducted on what other states in the nation have done toward reducing risks and fatalities at low head dams. Actions range from developing statutes to create programs for administration of low head dams, statutes for signage and warnings, developing inventories of low head dams, and education and outreach activities including displaying location information and education and awareness materials on public websites.

Armed with the inventory and research materials included in this report, DNR leadership can outline a possible framework for additional discussion. This will provide policy makers sufficient information to make decisions regarding how to further define the issues and develop strategies toward improving public safety at Colorado's low head dams.

2. Overview

Low head dams are commonly referred to as the quintessential "drowning machines" (Kelly, Earles, Wright, 2006). This is due to the physical characteristics of the structures themselves. Because of their height and location within the river channel, they can be quite difficult to detect by upstream water recreators, who may have a narrow window of reaction time depending on the flow velocity of the water. Low head dam vertical drops range in height from 1-15 feet on average, and produce circulating water conditions under the water's surface. This phenomenon is known as a 'hydraulic'. The abrupt change in flow velocity caused by the drop allow for the falling water to gain additional speed, and it pushes aerated water to trap debris, animals, and people against the face of the dam's wall as the water continues to circulate. Escaping is extremely difficult if not impossible, even with a personal flotation device such as a lifejacket. Tree branches, sediment, and other trapped debris create further hazardous variables because they can entangle victims and knock them unconscious.

From 1960 to 2016, there have been 377 documented fatalities nationwide, with the majority occurring during the months of April to August. In Colorado, there have been 13 recorded fatalities involving low head dams since 1986 (Brigham Young University, 2014). The most recent tragedy involved a young woman tubing with her friends on the South Platte River near Fort Morgan over the Fourth of July weekend 2019. Further, the average ages of those involved with low head dam-related incidents are between 13 and 30 years of age. The increased prevalence of incidents in Colorado directly correlates to increased recreational water usage by out-of-state tourists, new residents, and long-term residents. The victims include kayakers, boaters, swimmers, tubers, rafters and anglers. Unfortunately, first responders and law enforcement are also at risk because accidents involving low head dams create very dangerous situations for rescue efforts and body retrieval. The turbulent water conditions created by low head dams can impede the use of motorized water craft during rescue attempts, as the aerated water will inhibit the proper function of the propellers. Victims with years of recreational water experience have been known to succumb to the hazardous conditions.

The potentially hazardous conditions generated by low head dams are the result of historical and current industrial, municipal, and agricultural water usage. Some of the structures actively divert water for irrigation, mining, pumping and storage, while others are in place to prevent erosion of embankments, and to slow the velocity to further control the direction of a river's flow. Increased popularity for activities such as whitewater rafting, tubing, kayaking, and fishing has given rise to increased incidents (Tschantz, 2014).

Throughout time and across the nation low head dams were built to serve industries such as mining, power generation for industry, and irrigation for agricultural. However, many low head dams no longer serve their originally intended beneficial purposes and remain only as hazards to life and public safety. While some states have opted for removal of unnecessary structures, others have turned to mitigating the hazards through retrofitting and structural modification methods. Some states have also engaged in non-structural risk reduction activities that include development of strong education, outreach and awareness programs. It should be noted that not every structure is necessarily life-threatening all of the time. A dam can go from being relatively safe to extremely hazardous with a single rainfall episode. This can occur overnight, or within a matter of a few hours.

3. Steering Committee

A steering committee was also assembled to advise and inform the inventory. Members of the steering committee include representatives from DNR, DWR, Colorado Parks and Wildlife (CPW), Colorado Water Conservation Board (CWCB), Colorado Division of Homeland Security and Emergency Management (DHSEM), Colorado Office of Outdoor Recreation, the Mile High Flood District, the engineering consulting industry and the general public. The steering committee met several times over the course of the four months to establish objectives and goals. These meetings provided valuable feedback, and assisted in narrowing the focus of the project toward the collection, organization and display of the quantitative information in a relevant and logical way. A listing of steering committee members and their affiliations is included in Appendix A.

4. Methodology

The low head dam inventory project lasted from June until the end of September, 2019. During this time geographic data were collected and input it into a geodatabase within ArcMap. Data on structures observed within the rivers were organized into three categories based on physical attributes and intended purpose. Categories include: Diversion structures (for water diversion), grade control structures (for stream stabilization) and recreational structures. Some of the structures identified in this project have multiple uses. Some initial quality control through ground-truthing at several of the structures was conducted, primarily in the Denver metro area. The steps in the inventory development process are shown below in Figure 1

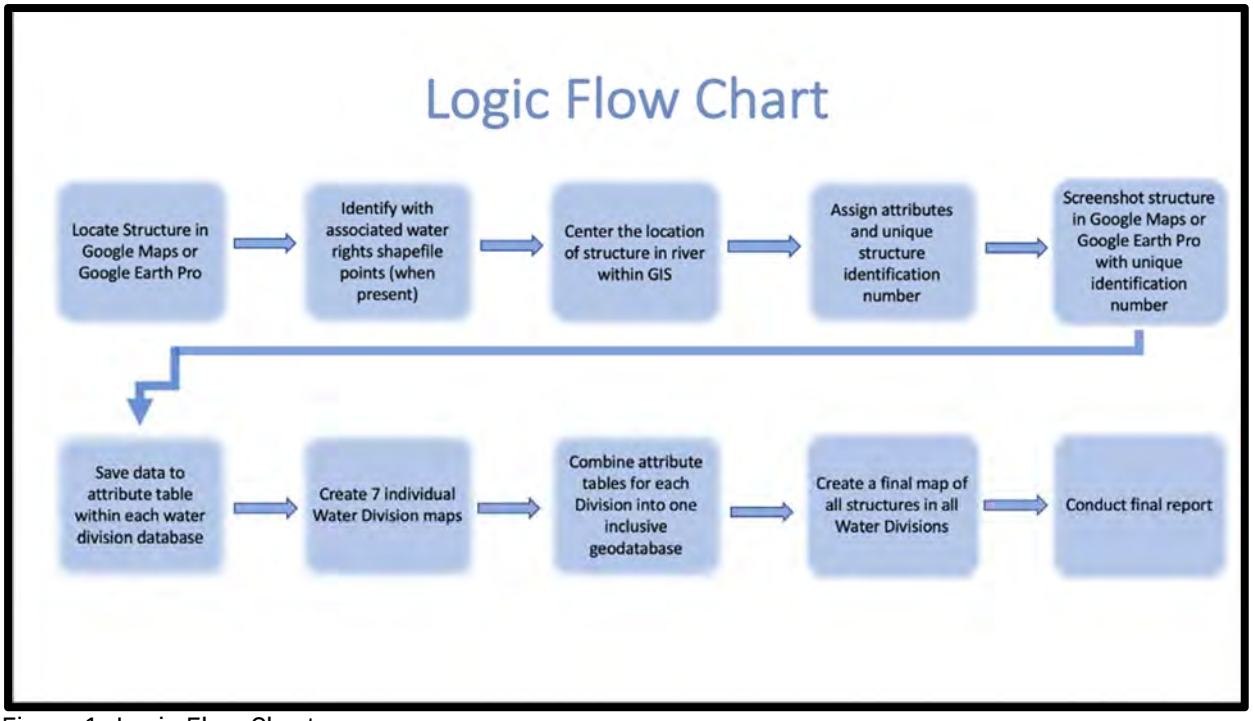


Figure 1: Logic Flow Chart

Identification of structures on rivers and streams was accomplished through the use of Google Maps (or Google Earth Pro when the quality of the imagery in Google Maps was inadequate) from which the latitudinal and longitudinal points were collected, and then added into the GIS. Manual scrolling over each major river or stream in Google Maps with the satellite view turned on was utilized to locate potential structures, and then referenced to the maps created in ArcGIS 10.4. 2017 NAIP imagery for all of the counties within Colorado were downloaded, extracted then overlaid the images of each county into the map. Shapefiles of water rights information provided by he Division of Water Resources database were used and detailed the locations where water rights points of diversion originated, often times at the location of a low head dam diversion structure. Next, each dam was combined with latitudinal and longitudinal points within the GIS using a unique identifier. Screenshots were collected for each structure in Google Maps, attached a unique number identifier to each image that correlated with the structure's assigned identifier in each divisional attribute table, and then placed the point onto the base map of the NAIP imagery. All shapefiles within the database for each water division map and the map of the entire state were projected into Universal Transverse Mercator Zone 13 North, as this is better suited for displaying information for the state of Colorado. Inventory maps are shown in Appendix B.

5. Structure Categories

Each dam was organized into one of three categories based on structural characteristics. The first category was "Diversion Dams". Diversion dams typically divert the flow of water to a side ditch or canal for municipal, agricultural, or industrial usage. Additionally, the attached ditches can divert water in various directions off the side of the main diversion structure. These were the most common structures identified in the inventory project and are historically the most hazardous and represent the "drowning machine". Two examples of diversion structures are shown below in Figure 2.

Figure 2: Examples of Diversion Dams. Photo Credit Google Maps

The next category is called "Grade Control Structures". The primary purpose of grade control structures is stream stabilization on highly developed rivers and streams. Increases in development have increased runoff over natural conditions which contributes to degradation of the stream beds. The resulting erosion can destabilize structures constructed near the channel. Some passage has generally been provided on these structures in the form of gradual rock ramps or concrete slopes. Some grade control structures have chutes for the passage of boats and debris through the center or off to the side. Although the dangerous hydraulic conditions have typically been mitigated through the design of these structures, they are not usually intended for recreation and present hazards due to their rough nature. Two examples of grade control structures are shown below in Figure 3.

Figure 3: Examples of Grade Control Structures. Photo Credit Google Maps

The third category of structures inventories those used for recreational purposes including stream restoration for fish habitat and also areas developed as "play holes" and whitewater parks. These structures are considered generally non-hazardous, although hazardous conditions may exist at certain water flow levels and rates. Each point within the inventory for structures in this category represents a reach of the waterway with multiple structures per reach. Examples of river habitat and whitewater park structures as seen from Google Earth are shown in Figure 4.

Figure 4: Example of Habitat Improvement structures (left) and Whitewater playpark structure (right). Photo Credit Google Maps

A total of 1,103 structures from all categories were identified and included in the inventory. Table 1 below shows a compilation of the categories across all water divisions within the state.

Table 1: Structure Totals by Category and Water Division

Water Division	Number of Diversion Dams	Number of Grade Control Structures	Areas of Recreation/ Habitat Improvement
1	149	146	4
2	78	46	10
3	103	23	11
4	103	14	12
5	137	15	19
6	92	2	5
7	131	2	14
Totals	**793**	**248**	**62**

6. Quality Control Procedures

Quality control activities utilized during the study included careful checking of information as it was entered through the attribute table and into the GIS database. Using GIS platforms of Google Earth, Google Maps and NAIP imagery allowed a visual cross check of the location information entered. At the time of report writing those activities represent the only quality control measures undertaken. Prior to providing the inventory for public review, additional quality control activities are planned. The geodatabase of information will be divided among water districts containing categorized structures (nearly all 78). Maps of each water district and tabular data on each structure shown on the maps will

be provided to the water commissioners along with a brief questionnaire. The questionnaire will ask for information including verification of the existence and correct categorization of each structure, current use, and current condition. A final inventory suitable for release to stakeholders and for further uses is the goal of the water commissioner provided quality control activity.

7. Low Head Dam Risk Mitigation Strategies

Over the course of the project, five "Risk Management Tools" that are commonly used by states to address public safety issues at low head dams were identified. States that are most effective utilize portions of all these tools at the same time.

The first tool is '**Warn and Educate**'. This entails the development, distribution and use of public educational, outreach and awareness programs. These programs seek to identify user groups and develop materials targeted to them. Printed materials, public service announcements, websites and digital platforms (APPS) are commonly used tools. Education could involve visiting schools throughout the state to teach children and young adults about the dangers around low head dams and how to recognize and avoid them. Education programs for first responders have been developed and could be institutionalized. Working with river outfitters and guides is another opportunity to educate potential river users and warn them of the risks.

The second risk management tool is '**Control Exposure**' and entails the deployment and use of proper signage, buoys, and other safety measures upstream of low head dams. As many of Colorado's low head dams are located on private property, the question of how to encourage safe portage without encouraging trespassing persists. Legally allowing recreational water usage only in designated public areas might not be enough to deter people. However, by creating incentive for landowners to post proper signage and allow safe portage in highly trafficked areas the risks and frequency of incidents might be reduced.

'**Mitigating Hazards**' can be effectively accomplished through structural changes to existing low head dams. This can be accomplished by retrofitting dangerous structures with modifications such as rock ramps, stepped spillways, and others physical modifications. "The purpose of a structural modification is to disrupt or completely eliminate the submerged jump while maintaining the original functionality of the dam" (McGhin, Hotchkiss and Kern, 2018). Mitigation projects can almost always be combined with other stream restoration, habitat improvement or recreation-based project to increase the number of enthusiastic participants.

Another risk management tool, '**Eliminate Hazards**,' includes the removal of hazardous dams. As with mitigation projects multiple benefits of dam removal can often be found to increase stakeholder interest and participation. In areas of the country many older dams are no longer serving their intended purposes and may have fallen into disrepair after being abandoned (Tschantz and Wright, 2011) and are good candidates for removal.

The final tool we used in assessing risks with low head dams is '**Prepare for Emergency Response**'. This is an education and training activity focused on those in the community tasked with emergency response to low head dam incidents. Various tools are available to educate public safety and law enforcement officials at the local and state level and provide proper training and access to advanced rescue technology in order to prepare for responses at the same time as other mitigation tools are begin engaged.

8. Other States Low Head Dam Activities

Most sates around the nation also contend with the issue of low head dams. In an effort to explore other avenues, research of the status of other states' inventories and dam safety programs was conducted. States exemplifying a high regard for initiating safety programs and public outreach include

Iowa, Minnesota, Montana, South Dakota, Ohio, and Indiana. States with statutory authority to regulate public safety around low head dams include Pennsylvania, Illinois and Virginia. The following section will focus on the public safety at dams programs in Iowa and Indiana, as well as the signage efforts of Virginia, Pennsylvania, and Illinois.

Iowa's Department of Natural Resources is well known for its avid promotion of public education through outreach programs. A 2009 survey conducted by Iowa State University's Center for Agriculture and Rural Development determined that about half of Iowans use rivers for recreational purposes (Iowa's Water Trails and Low-head Dam Mitigation, 2010). The state also provides support to landowners by creating incentive to post proper signage to warn about dangerous structures. In some cases, the removal of a dam has led to repurposing the area for whitewater parks. Additionally, the Iowa Department of Natural Resources was legislated to create and regularly the "Dam Mitigation Manual". In 2010, the River Dam Inventory was released. It details the status of various mitigation and removal projects throughout the state. The 2010 Plan for Dam Mitigation provides a comprehensive analysis of mitigation strategies and hazard reduction alternatives. Iowa's "Water Trails: Connecting People with Water and Resources" and the "Developing Water Trails in Iowa" are included within the plan. These publications highlight restoration projects, and begin to address the needs of various stakeholders, including landowners and recreational water users.

Another state with a considerably involved dam safety program is **Indiana**, which maintains a comprehensive Low Head Dam inventory. Some of the initiatives included in the state's dam safety programs are the promotion of public safety at and around dams. Indiana has contributed to PSA videos such as "Over, Under, Gone: the Killer in Our Rivers". Indiana Department of Natural Resources (IDNR) has also promoted proper training for safe water practices that includes the utilization of new rescue technology for first responders. Proper signage posting efforts, retrofitting, and removal of dams that no longer serve a necessary purpose are all ways that Indiana addresses its low head dam issue.

Virginia maintains a Duty of Care and Liability Code designed to address damages incurred on private property to hunters, anglers and outdoor recreators. 29.1- 509 states that a private landowner with a low head dam located on their property has the option to post signage and buoys adjacent to the areas both above and below the structure in order to give adequate warnings of the associated potential hazards. Although not mandatory, by properly marking areas of low head dams on private property in accordance to the requirements of subsection 29.1- 509, a landowner is "deemed to have met the duty of care for warning the public of the hazards posed by the dam. Any owner of a low head dam who fails to mark a low head dam in accordance with this subsection shall be presumed not to have met the duty of care for warning the public of the hazards posed by the dam" (Virginia Code § 29.1-509, 2008). Virginia's Game and Inland Fisheries adopted a Uniform State Waterway Marking System. Similar to the federal marking system, it details the uniform placement and upkeep of warning signs where they can be easily viewed by boaters recreating in areas within close proximity of low head dams.

Pennsylvania has focused on proper signage and buoy placement. Code 3510- "Marking of Dams", requests the owners of dams to purchase, place, and upkeep two sets of "exclusion zone" signs on each side of a structure, with one pair positioned to be legible to upstream recreators, and the other to be positioned facing downstream. This ensures that warnings are posted in clear sight regardless of which direction a person is moving along the river. Should a person trespass in the marked "exclusion zone", they are subject to penalties in the form of fines. In dams less that 200 feet in length, warning signs can be posted instead of exclusion zone warning signs. Similarly, the owners of the dam must purchase and install the signage themselves. However, exclusion zone and warning signage may not be used in conjunction with each other (Pennsylvania Act of 1998). Apart from posting proper signage, Pennsylvania's Fish and Boat Commission mandates that low head dams longer than 200 feet need to have buoys upstream and downstream. This is primarily focused on areas where water levels are at or above 3 feet of water. The buoys must be uniformly spaced about 150 feet or less from each other.

In 2007, Public Act 095-0020 was created as an amendment to the Rivers, Lakes and Streams Act in **Illinois**. The act promotes posting adequate signage, the use of buoys along waterways, and the maintenance of exclusion zones. As with Pennsylvania, trespassers caught in exclusion zones are found guilty of a Class A misdemeanor. Section 23b. states "The Department of Natural Resources shall establish specifications for signs and devices that provide warnings of the presence of dams for persons using the public waters of the State. The Departments shall establish such specifications pursuant to administrative rule" (Illinois Public Act 095-0020). The Illinois DNR retains the authority to determine and enforce exclusion zone areas around dams, and the Department is not held liable for any damages or injuries incurred by structures in public waters, including death. Further, owners and operators of dams in public waters are not free from liability in the event of personal injury, damage, and death. Illinois conducted a study in 2007 and titled it "Safety at Dams". The report was almost 300 pages long and included examples of options for posting signage along rivers containing low head dams.

9. National Inventory of Low Head Dams

To date, the most comprehensive national database of fatalities attributed to low head dams is the Low-Head Dam Fatality Database, which was created in 2014 by Brigham Young University (BYU) Professor Rollin Hotchkiss, Associate Professor Daniel P. Ames, and Edward Kern. The database was designed with an interactive map and a web-based user interphase to allow the public to submit incidents and view the current list of fatalities in each state (Kern, Hotchkiss, Ames 2015). There is work currently underway to enable compilation of individual state inventories into a true national database. The BYU model provides an avenue for such a repository.

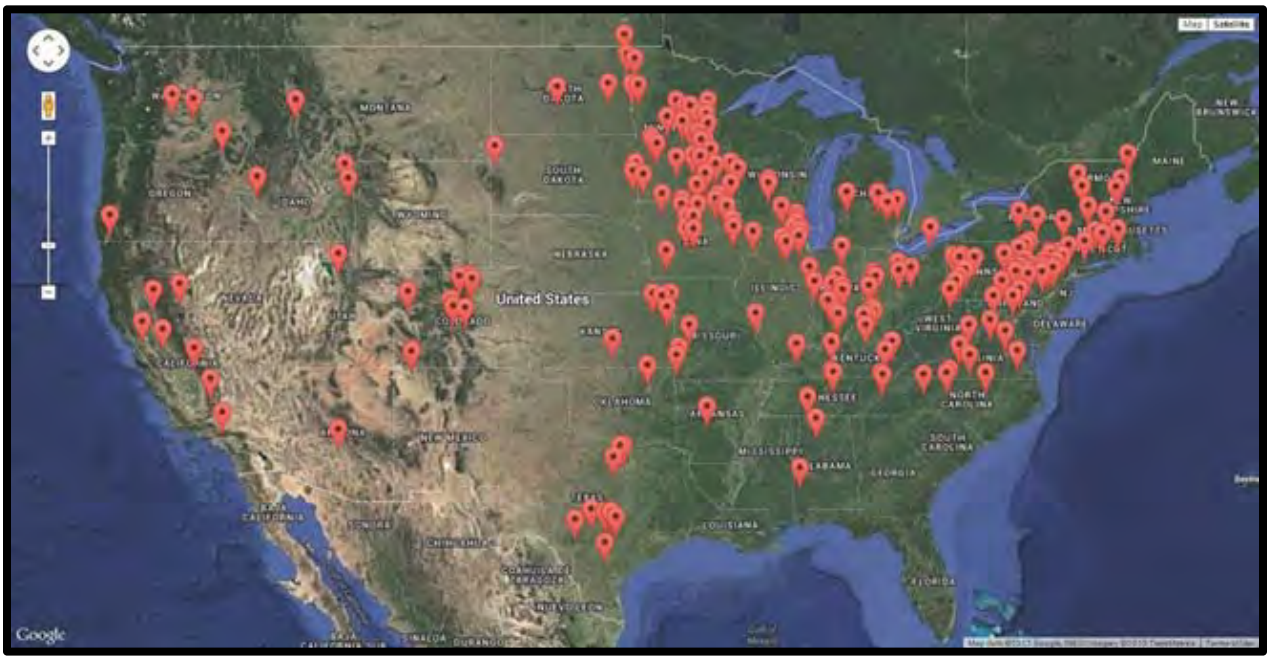


Figure 5: Image of interactive map national inventory of low head dam fatalities and incidents in the United States. Photo Credit Brigham Young University. The database can be access via the following web link: https://krcproject.groups.et.byu.net/browse.php

10. Conclusion

Low head dams are a prevalent hazard located throughout the nation. In Colorado, approximately 793 potentially hazardous in-stream structures (diversion dams) have been identified and inventoried into a geodatabase using satellite imagery from Google Maps and Google Earth Pro. The inventory demonstrates a high frequency of low head dams on heavily recreated waterways. Multiple hazard

mitigation strategies and tools have been identified and other states have instituted programs to address the hazard associated with low head dams. The inventory created and research conducted by through this project provides shows the prevalence of low head dams in Colorado and demonstrates the potential tools available to reduce low head dam risks. These tools can be used to engage and support policy makers.

11. Recommendation

Quality control of the existing inventory should be completed. The next phases of the project should involve gathering local knowledge from the recreational water community, as well as the continued exploration of other low head dam safety programs throughout the United States and Canada. Integration of a final inventory with other Colorado datasets from different agencies and further analysis methods using GIS should be completed.

12. Acknowledgements and Appreciation

Special thanks to Wright Water Engineers, the Governor's Office of Outdoor Recreation Industry, American Whitewater, Google Earth, Google Maps, the USGS, the Colorado Department of Natural Resources, the Colorado Division of Water Resources, and the Colorado Water Conservation Board.

13. Appendix A – Steering Committee Membership

Colorado Department of Natural Resources, Assistant Director for Water- Amy Moyer
Colorado Department of Natural Resources, Assistant Director for CPW - Doug Vilsack
Colorado Division of Water Resources, Chief of Dam Safety - Bill McCormick
Colorado Parks & Wildlife, SE Region Assistant Regional Manager - Brad Henley
Colorado Water Conservation Board – Chief of Flood and Stream protection - Kevin Houck
Colorado Office of Outdoor Recreation Industry, Director - Nathan Fey
Colorado Division of Homeland Security and Emergency Management, State Hazard Mitigation Officer - Steven Boand
Mile High Flood District- Kevin Stewart
Wright Water Engineers- Andrew Earles
General public - Ruth Wright

14. Appendix B – Low Head Dam Inventory Maps

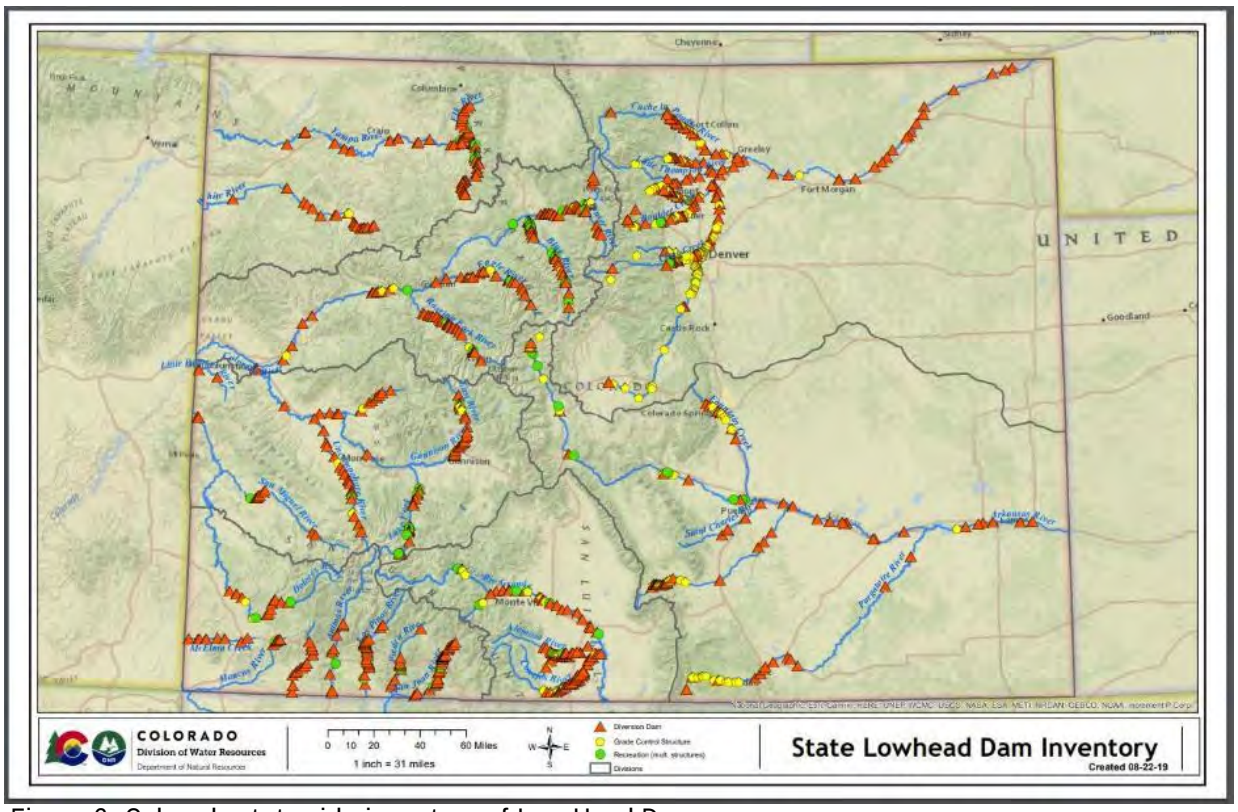


Figure 6: Colorado statewide inventory of Low Head Dams

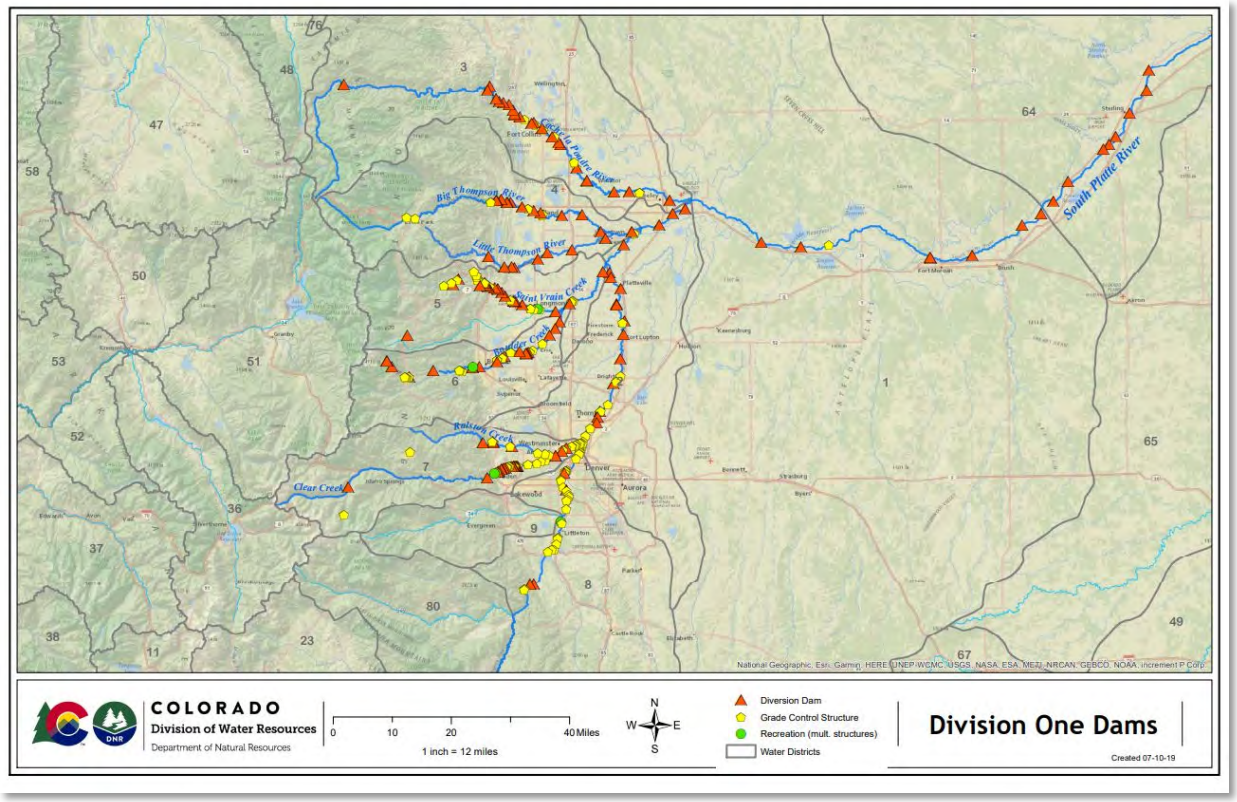


Figure 7: Low head dams in water division one

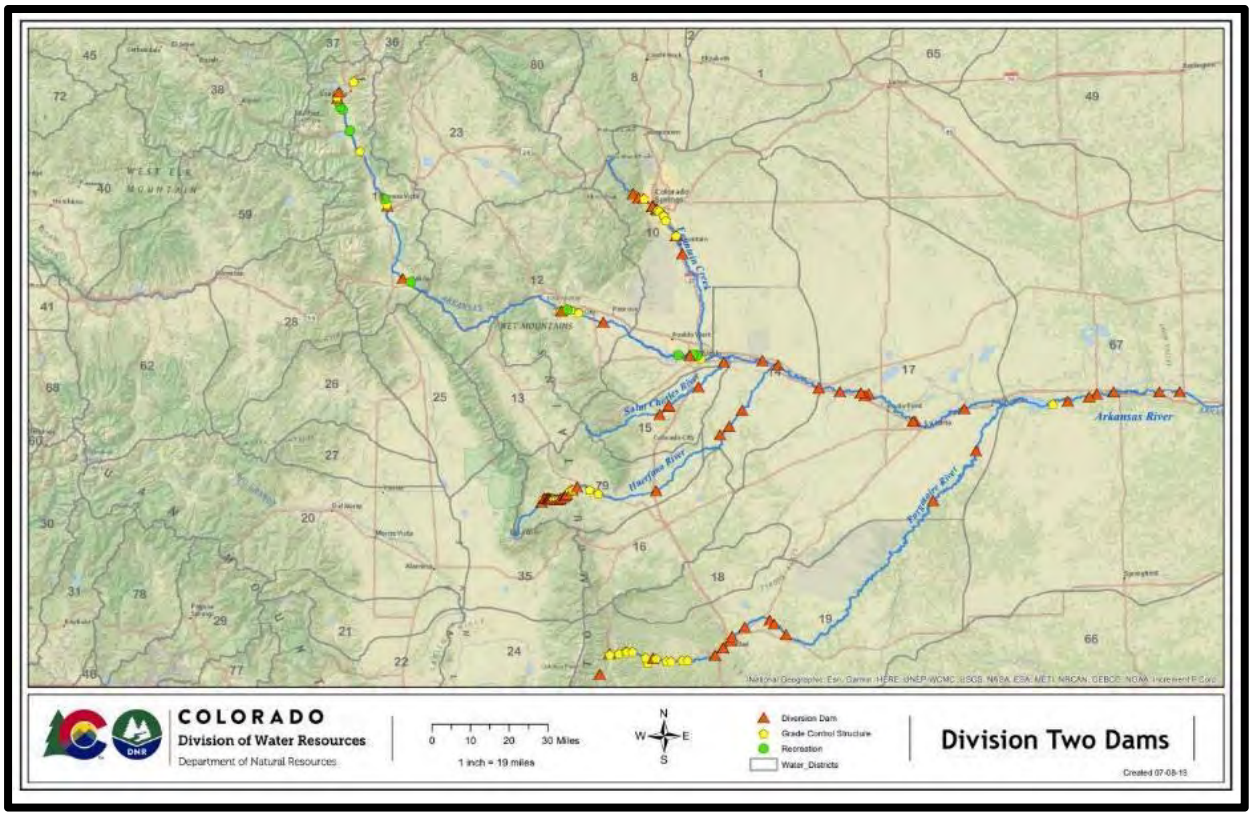


Figure 8: Low head dams in water division two

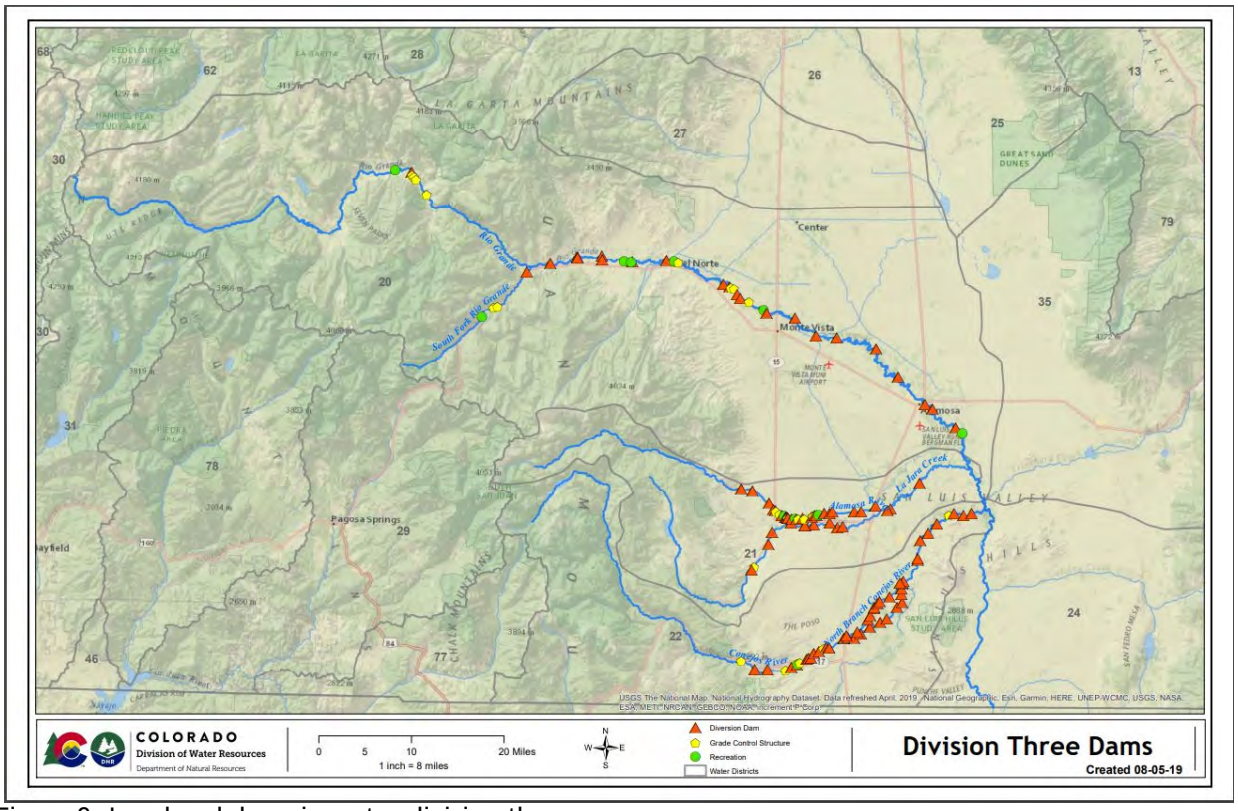


Figure 9: Low head dams in water division three.

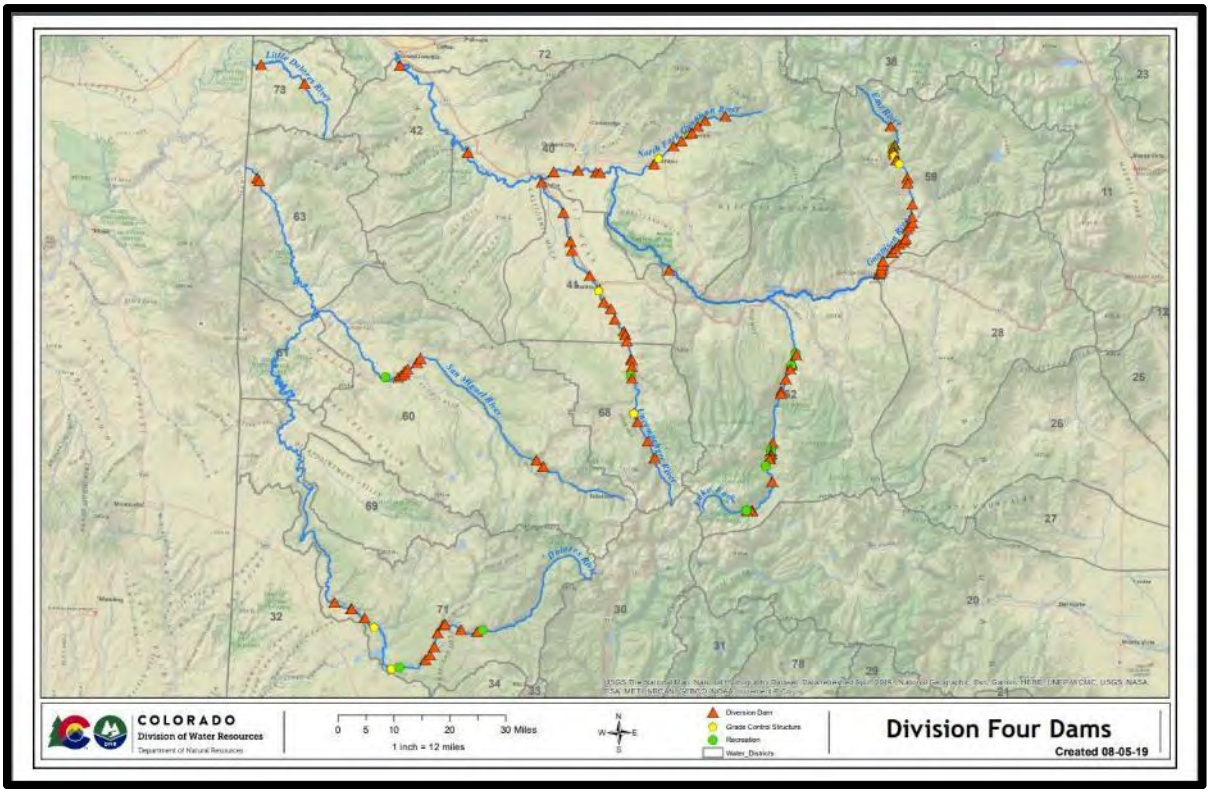


Figure 10: Low head dams in water division Four

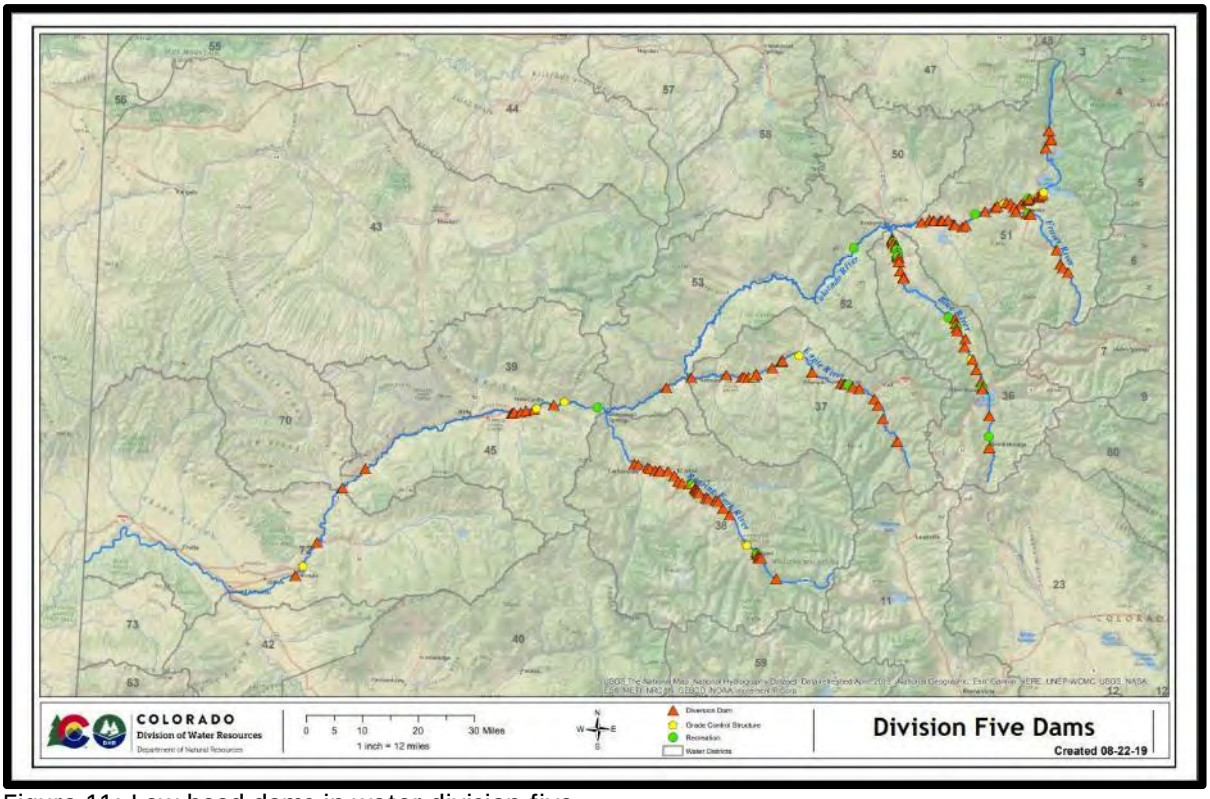


Figure 11: Low head dams in water division five.

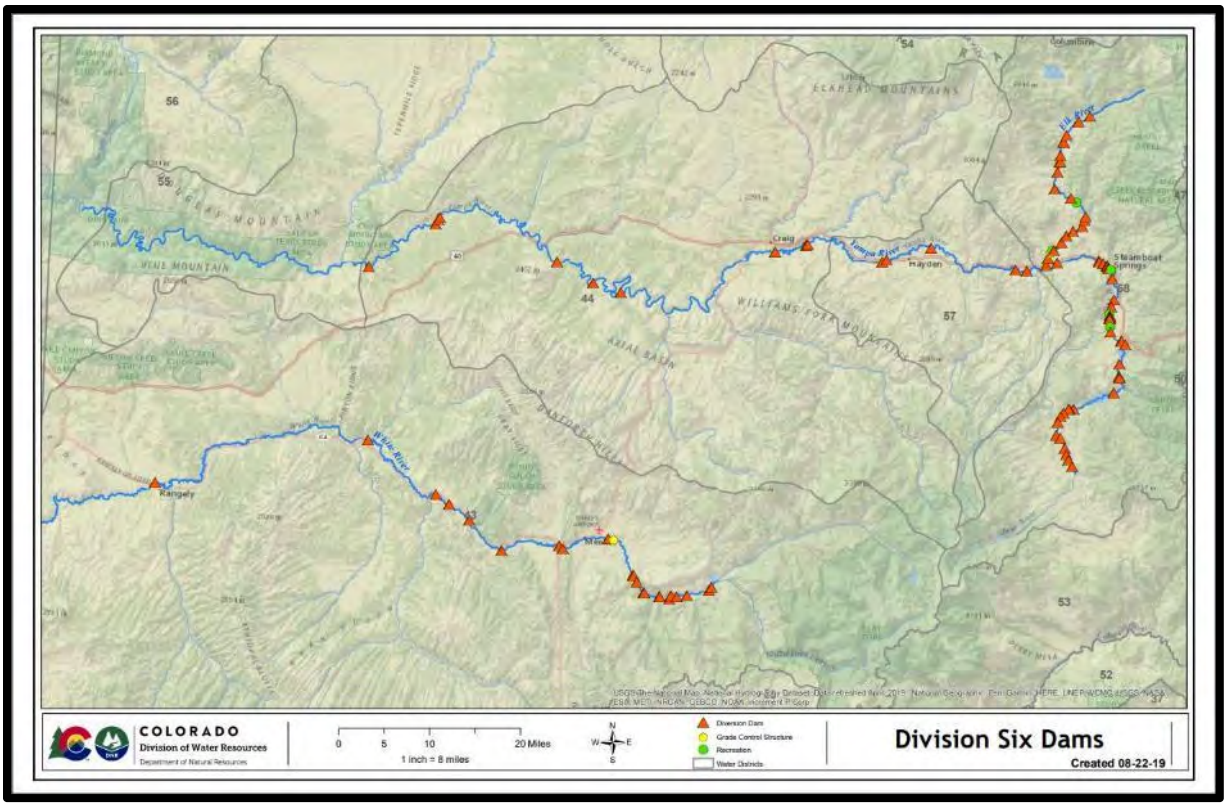


Figure 12: Low head dams in water division six.

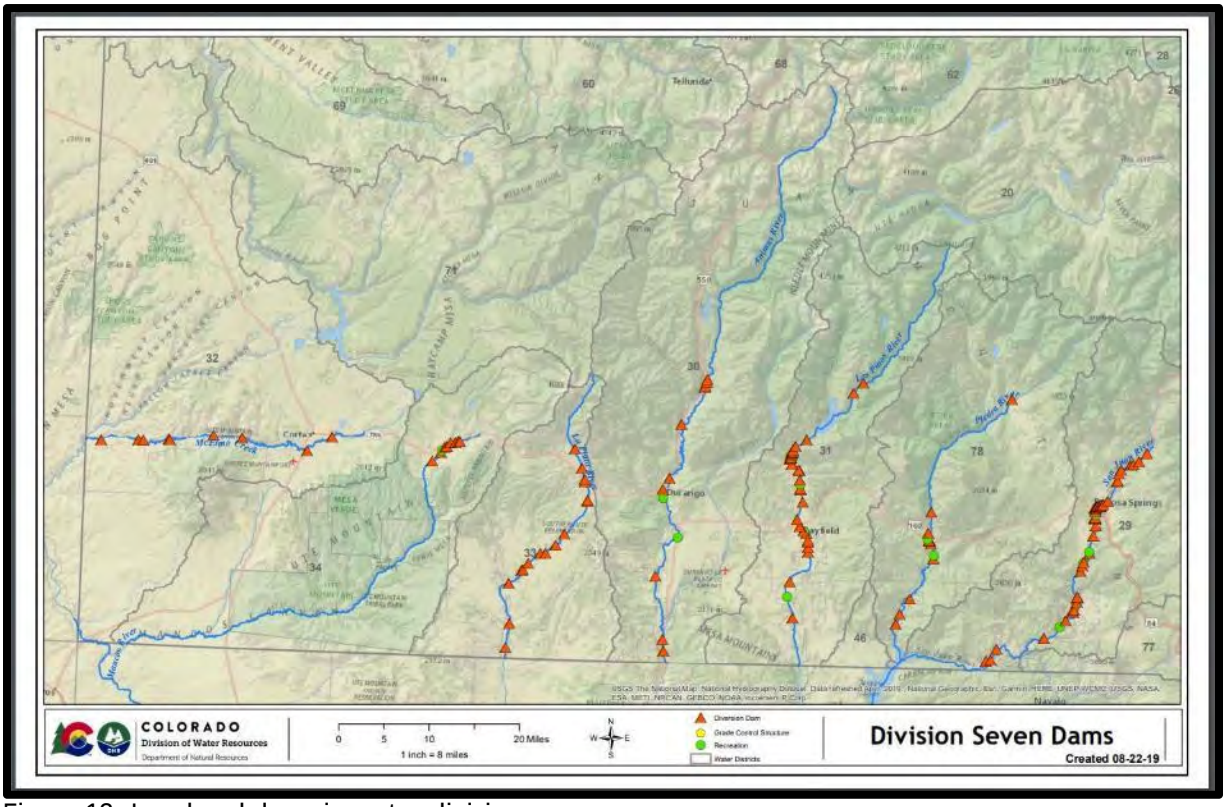


Figure 13: Low head dams in water division seven.

15. Works Cited

Brigham Young University. 2014. “Locations of fatalities at submerged hydraulic jumps.” Accessed September 27, 2019. https://krcproject.groups.et.byu.net/browse.php

Illinois Public Act 095-0020, Section 23b (615ILCS 5/23b new, Dams Signs and Buoys) Accessed September 27, 2019. http://www.ilga.gov/legislation/publicacts/fulltext.asp?Name=095-0020 Amendment to The Rivers Lakes and Streams Act, Aug. 2, 2007.

Indiana Department of Natural Resources. "Over, Under, Gone: The Killer in Our Rivers." PBS. 21 Nov. 2016. Public Broadcasting Service. 30 Sept. 2019 https://www.pbs.org/video/over-under-gone-killer-our-rivers/.

Iowa Water Trails and Low-head Dam Mitigation, 2010, 40 pp Accessed September 27, 2019. https://www.iowadnr.gov/things-to-do/canoeing-kayaking/low-head-dams

Kern, Edward W., Hotchkiss, Rollin H., and Ames, Daniel P., 2015. Introducing a Low-Head Dam Fatality Database and Internet Information Portal. Journal of the American Water Resources Association (JAWRA) 51 (5): 1453-1459.

McGhin, Ronald F., Rollin H. Hotchkiss Ph.D., and Ed Kern P.E. 2018. Submerged Hydraulic Jump Remediation at Low-Head Dams: Partial Width Deflector Design Journal of Hydraulic Engineers 144 (12).

Pennsylvania Act of 1998, No 1998-91, (P.L. 702, 91) Run-of-River Dams: Marking of Dams, eff Jan. 1, 1999; Sign and Buoy Guidelines for Run-of-the-River Dams, Accessed September 26th, 2019. https://www.fishandboat.com/Boat/WaterandIceSafety/Documents/HazardsWater/DamMarkingGuidelines.pdf

Tschantz, B.A., 2014. What we know (and don’t know) about low-head dams., Journal of Dam Safety, ASDSO 12 (4): 37- 42.

Tschantz, B.A. and K.R. Wright, 2011. Hidden Dangers and Public Safety at Low Head Dams., Journal of Dam Safety, ASDSO 9 (1): 8- 17.

Virginia Code § 29.1-509. Duty of Care and Liability for Damages of Landowners to Hunters, Fishermen, Sightseers, etc. (Sect. F) eff. Jan. 8, 2008 Accessed September 26, 2019. https://law.lis.virginia.gov/vacode/title29.1/chapter5/section29.1-509/

Wright, K.R., T.A. Earles and J.M. Kelly, 2006. Public Safety at Low-Head Dams., Journal of Dam Safety, ASDSO 2-7.