HYDROLOGIC ALTERATION AND WATER QUALITY: OPPORTUNITIES AND CHALLENGES

LISA PERRAS GORDON, US EPA
KEVIN O'DONNELL, FDEP

May 28, 2020

Content

- Scope of the Issue
- Hydrologic alteration & natural infrastructure under the CWA, AWIA, WIIA.
- Framing it under the CWA/Assessment-Listing Program
- Opportunities & Challenges for Restoration
  - Barriers – Dams/Causeways
  - Large Hydro
  - Withdrawals
  - Stream Crossings
  - Stormwater

Discussion

- What are you doing/what do you know or do that would help others on this topic?
- Is your assessment methodology working well to accurately identify waters impaired due to hydrologic alteration?
- Are you able to make linkages between alteration and biological impairment? Alteration and water quality impacts?
- Have you partnered to work on restoration of hydrologically altered waters?

Discussion

- What do you need to better understand this topic? We have training on multiple topics that can be modified to get you the information you need.
- What additional information would be beneficial to states and tribes on this topic? Case studies? Data or information?
- Would additional training on the state-of-the-science be helpful on this topic?

USGS Assessments Define National Scope of the Issue

"Human influence on watershed hydrology is extensive and…

…may be the primary cause of ecological impairment in river and stream ecosystems."

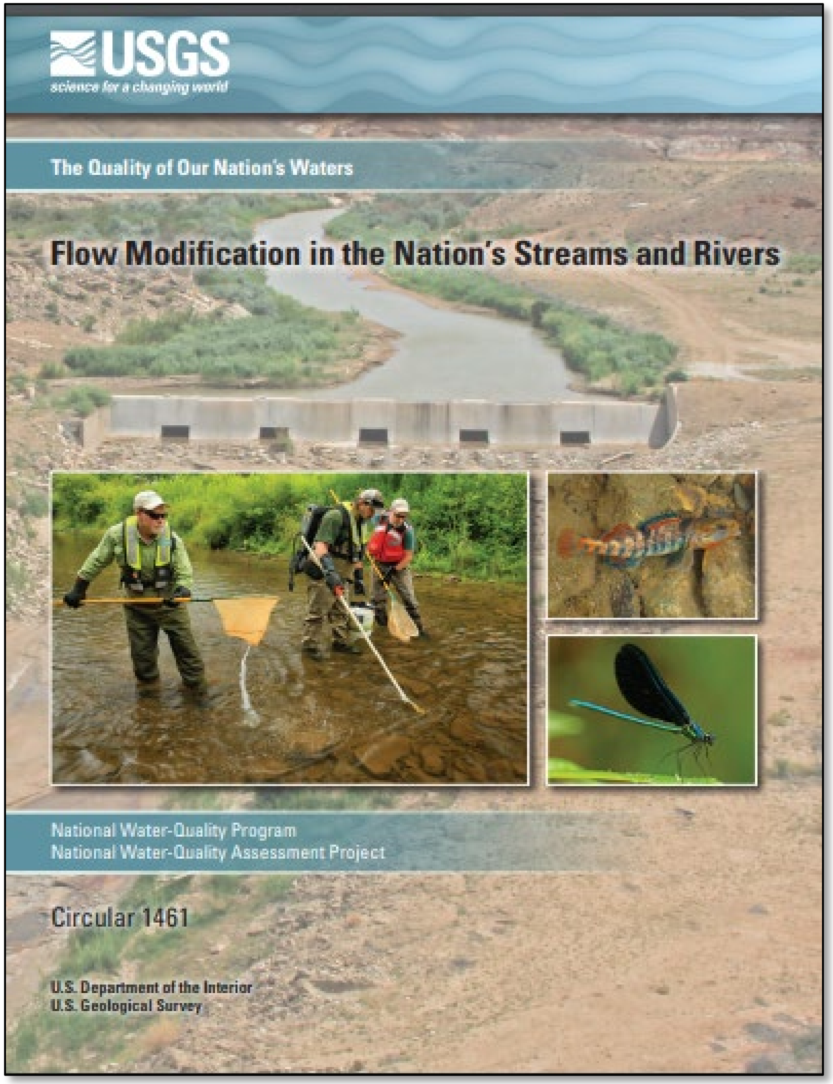
- Carlisle, Wolock and Meador, USGS, 2010

USGS Assessment 2020

Human activities have altered flow in 1.2 million stream miles of the Nation's rivers and streams.

Dams, diversions, water withdrawals, impervious cover alter water in predicatable yet sometimes unintentional ways.

In every Region assess, these changes associated with loss of native fish, invertebrates and the ability of aquatic life to survive and reproduce.



Hydrologic Alteration

- Dams/Impoundments
- Withdrawals
  - Surface Water
  - Ground Water
- Channelization/ Canalization
- Culverts/Stream Crossings
- Impervious Cover/ Storm Water
- Diversions/Inter Basin Transfers
- Valley Fill
- Loss of riparian
- Rate of change, timing and delivery of flows

Clean Water Act
Section 101(a) Goals and Policy

The objective of this chapter is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters

CWA and Hydrology

- CWA 502(19) definition of "pollution" is " …the man-made or **man-induced alteration** of the chemical, **physical**, biological, and radiological **integrity of water.**"
- EPA should publish information on pollution caused by…
  - "changes in the movement, flow, or circulation of any navigable waters . . . including changes caused by the construction of dams, levees . . . or flow diversion facilities."
  - "salt water intrusion resulting from reductions of fresh water flow from any cause, including extraction of ground water, irrigation, obstruction, and diversion…. CWA 304(f).

Section 305(b) Guidelines (1997)

- Causes/stressors are those pollutants or other stressors (e.g. flow and other habitat alterations..) *that contribute to the actual or threatened impairment of designated uses in a waterbody.*

- ***Flow alteration*** refers to frequent changes in flow or chronic reductions in flow that impact aquatic life (e.g., as flow regulated rivers or a stream with excessive irrigation withdrawals.)

2006 IR Guidance

Which segments should states include in Category 4c?

- Segments should be placed in Category 4c when the states demonstrates that the failure to meet an applicable water quality standard is not caused by a pollutant, but instead is **caused by** other types of **pollution**.

- Pollution, as defined by the CWA is "the man-made or man-induced alteration of the chemical, physical, biological, and radiological integrity of water" (section 502(19)).

- **Examples of circumstances where an impaired segment may be placed in Category 4c include segments impaired solely due to lack of adequate flow or to stream channelization.**

July 29, 2005 (page 56)

(See also July 31, 2004, page 8, 2004 IR Guidance)

R4 Rivers and Streams EPA HQ counts

http://ofmpub.epa.gov/waters10/attains_index.control

Cause of Impairment Group	Miles Threatened or Impaired
Pathogens	20,655
Organic Enrichment/Oxygen Depletion	11,005
Sediment	10,844
Cause Unknown - Impaired Biota	7,128
Mercury	6,810
Habitat Alterations	6,695
Nutrients	5,488
Metals (other than Mercury)	2,098
Turbidity	1,655
Salinity/Total Dissolved Solids/Chlorides/Sulfates	1,511
Algal Growth	1,451
pH/Acidity/Caustic Conditions	1,204
Polychlorinated Biphenyls (PCBs)	988
Cause Unknown	802
Flow Alteration(s)	**653**
Ammonia	558
Pesticides	475
Dioxins	300
Nuisance Native Species	30
Radiation	24
Noxious Aquatic Plants	22
Taste, Color and Odor	12

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

WASHINGTON, D.C. 20460

OFFICE OF WATER

August 13, 2015

MEMORANDUM

SUBJECT: Information Concerning 2016 Clean Water Act Sections 303(d), 305(b), and 314 Integrated Reporting and Listing Decisions

FROM: Benita Best-Wong, Director /s/
Office of Wetlands, Oceans, and Watersheds

TO: Water Division Directors, Regions 1 – 10
Robert Maxfield, Director, Office of Environmental Measurement and Evaluation, Region 1

I am pleased to provide you with information to assist you and your States as you prepare and review the 2016 Integrated Reports (IR), in accordance with Clean Water Action (CWA) Sections 303(d), 305(b), and 314. This memorandum focuses on the following topics: 1) implementing the CWA 303(d) Program Vision; 2) identifying nutrient-impaired waters based on narrative nutrient water quality criteria and direct evidence of failure to support designated uses; 3) implementing the Water Quality Framework, including the Assessment and Total Maximum Daily Load (TMDL) Tracking and Implementation System (ATTAINS) redesign and reporting of statewide statistical survey data; 4) providing information about the update to the data in the variable portion of the Fiscal Year 2017 Clean Water Act Section 106 grant allocation formula; and 5) clarifying how to assess and assign waters impaired by "pollution" not caused by a "pollutant" to Category 4C.

This memorandum is not regulation and does not impose legally binding requirements on EPA or the States. EPA recommends that the States prepare their 2016 IRs consistent with previous IR guidance including EPA's 2006 IR Guidance, which is supplemented by EPA's 2008, 2010, 2012, and 2014 IR memos and this memorandum available at: http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/guidance.cfm.

I would like to thank the Regions and our State partners for their input on the information in this enclosure. I particularly appreciate the continued hard work and dedication in developing the IRs so that we can report to the public on the status of the nation's waters. If you have any questions or comments concerning this memorandum, please contact me or have your staff contact Shera Reems at 202-566-1264 or reems.shera@epa.gov.

Enclosure

cc: Julia Anastasio, Association of Clean Water Administrators

State Methodologies Summary

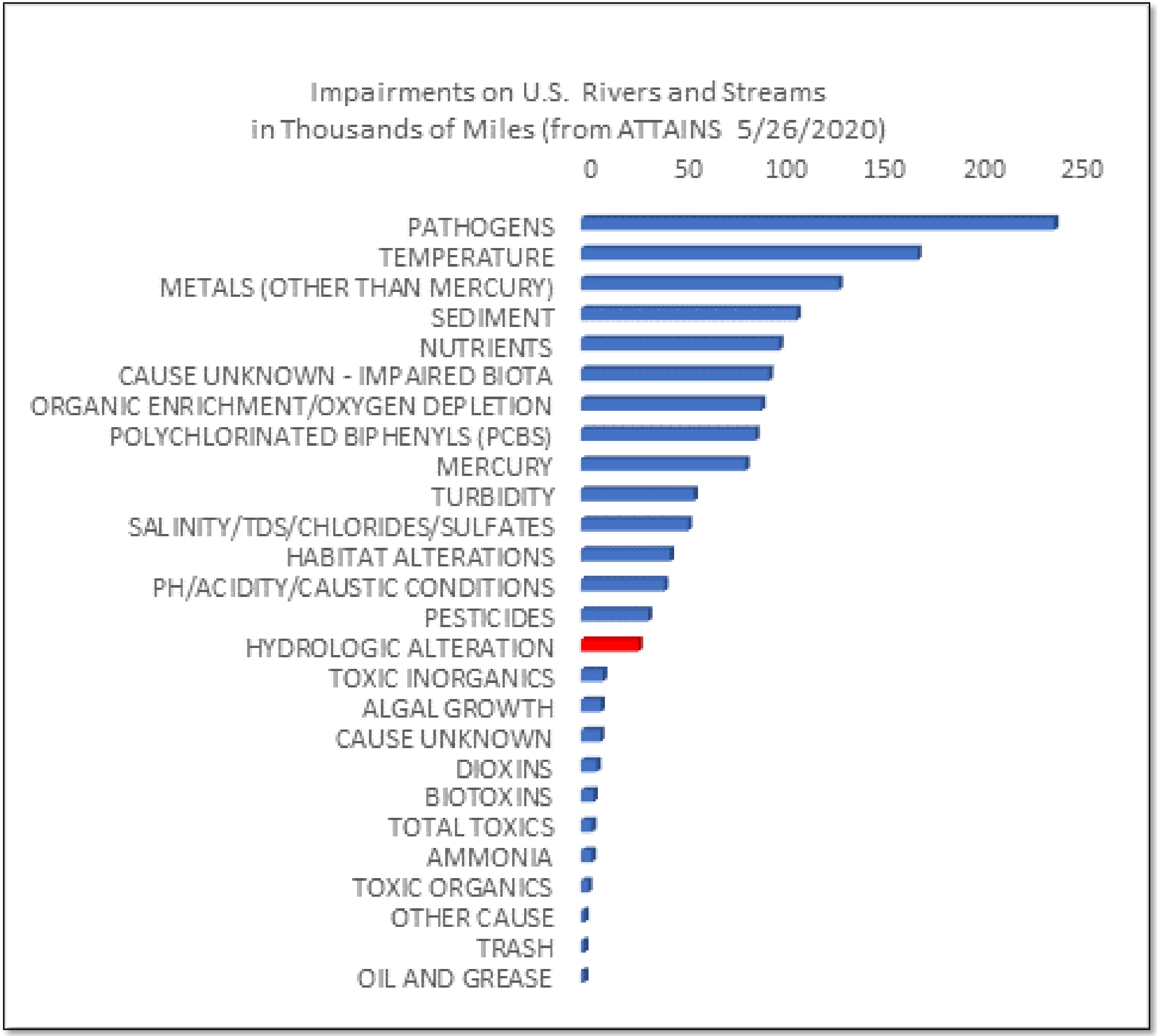
“Water bodies affected by these forms of pollution are not overlooked or ignored; they are identified in Category 4C of the Integrated Report.” - **Idaho**

“The assessor considers all of the information related to the segment, including…the existence of potential pollution sources…and whether the impairment is explained by the presence of degraded habitat or other non-pollutant causes.” – **Illinois**

“The majority of the river miles that are not supporting one or more designated uses indicated by poor biological communities have been highly modified by channel maintenance…(including channel straightening, dredging, riparian vegetation removal, and snag removal)…therefore, these river miles are placed in Category 4C.” **-Michigan**

State Methodologies

“Rhode Island is concerned that excessive withdrawals of water from certain streams of adjacent aquifers could severely impact the quantity and quality of stream water available during low flows….Impacts to the aquatic habitat occur due to loss of riverbed area covered by water, receding wetlands, loss of vernal pools and inadequate instream water depth for a healthy, reproducing fish population.” **– Rhode Island.**


Impairments on U.S. Rivers and Streams
in Thousands of Miles (from ATTAINS 5/26/2020)
0
50
100
150
200
250
PATHOGENS
TEMPERATURE
METALS (OTHER THAN MERCURY)
SEDIMENT
NUTRIENTS
CAUSE UNKNOWN - IMPAIRED BIOTA
ORGANIC ENRICHMENT/OXYGEN DEPLETION
POLYCHLORINATED BIPHENYLS (PCBS)
MERCURY
TURBIDITY
SALINITY/TDS/CHLORIDES/SULFATES
HABITAT ALTERATIONS
PH/ACIDITY/CAUSTIC CONDITIONS
PESTICIDES
HYDROLOGIC ALTERATION
TOXIC INORGANICS
ALGAL GROWTH
CAUSE UNKNOWN
DIOXINS
BIOTOXINS
TOTAL TOXICS
AMMONIA
TOXIC ORGANICS
OTHER CAUSE
TRASH
OIL AND GREASE

Aging Infrastructure
& Extreme Weather Events

America's Water Infrastructure Act (AWIA) (Oct 2018)

Authorizes the construction of various **water-related infrastructure projects,** requires **analysis of existing projects,** provides guidance and authorizes funding for drinking water system improvements, and provides guidance and authorizes funding for **other miscellaneous programs related to improving water quality.**

EPA National Water Program Guidance (FY 20-21)"The Office of Water looks forward to working in partnership with states and tribes to integrate the implementation of AWIA into the national water program." (David Ross)

AWIA Excerpt

Section 1149. Inclusion of Alternative Measures for Aquatic Ecosystem Restoration. Use of natural and nature-based features in carrying out a project to restore and protect aquatic ecosystem or estuary. Natural infrastructure for flood risk management or hurricane and storm damage risk reduction.

Water Infrastructure Improvement Act (WIIA) of 2019

- Amends the Clean Water Act to define and promote green infrastructure and EPA's integrated planning framework in enforcement and permitting. It also provides increased technical support through a new Municipal Ombudsman position.

- **Section 502** of the Clean Water Act defines green infrastructure as "...the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters."

Water Infrastructure Improvement Act (WIIA) of 2019

- **Section 402(s) (33 U.S.C. § 1342).** Allow NPDES to incorporate integrated plans to address compliance with Clean Water Act; such integrated plans can include innovative projects to reclaim, recycle, or reuse water and include green infrastructure

- **Section 519 (33 U.S.C. § 1379).** Green Infrastructure should be promoted into permitting, enforcement and other regulatory programs; EPA should promote GI throughout the public and private sectors.

Restoration of Hydrologically Altered Waters

Impact: Marine and Coastal Waters

Impact: Altered Flows in Coastal Areas

As early as 1953, the vital importance of flows to the fisheries of Texas bays and estuaries was recognized (Hildebrand and Gunter, 1953, Powell et al 2002)

- *Effects of Decreased River Flow on Estuary Ecology (Copeland 1966) noted: Impacts to* ***sea grass, salinity, oyster beds, mangroves, marsh lands and soft bottom un-vegetated habitats*** *can all degrade due to changes to timing and delivery of freshwater flows.*
- Instream flow has been identified as a major factor for healthy ecological systems in estuaries, affecting all levels of physical, chemical and biological functions. (Poff et al 1997).
- H. Dickson Hoese's ended his 1967 paper in a plea to address the **"pressure of rising salinities (due to decreased freshwater inflow]".**
- *Conceptional Model of Estuarine Freshwater Inflow Management* **"estuarine ecologists have been bemoaning the lack of attention paid to [decreased freshwater flows]" for a very long time.** (Albers 2002)

National Estuary Programs

Every NEP in Region 4 identifies hydrologic alteration as a critical factor in estuary health or impairment.

Every NEP in Region 4 has identified goals/objectives related to restoration of hydrologic alteration.

Impact: Freshwater Low Head Dams

PROBABILISTIC MONITORING OF STREAMS BELOW SMALL IMPOUNDMENTS IN TENNESSEE

Tennessee Department of Environment and Conservation
Division of Water Pollution Control
7th Floor L&C Annex
401 Church Street
Nashville, TN 37243-1534

Assessing Impacts Due to Small Impoundments in North Carolina to Support 401 Certification Policies

Prepared by Department of Environment and Natural Resources

North Carolina Division of Water Quality

February 28, 2013

Project funded by

U.S. Environmental Protection Agency

Wetland Program Development Grant Cooperative Agreement CD 95471111

Water Quality Impact of Dams:

Physical/Biological Impacts

- Significant biological impacts, for instance TN has found macros adversely affected in most of the streams sampled with only 4 out of 75 passing biocriteria. NC noted sharp increase in tolerant taxa.
- Lack of flow or no flow
- Adverse affects on habitat
- Alteration of sediment transport.
- Fragmentation
- Loss of fish passage
- Increased evaporation

Chemical Impacts

- Altered temperature
- Elevated iron
- Elevated manganese.
- Increased nutrients. (Ammonia was the most frequently elevated nutrient in the TN study, chlorophyll a increases and increased periphyton biomass also noted in the NC study.)
- Low DO

(Arwine, et al. 2006, NC DWR, 2011, Stallins & Ignatius, 2011)

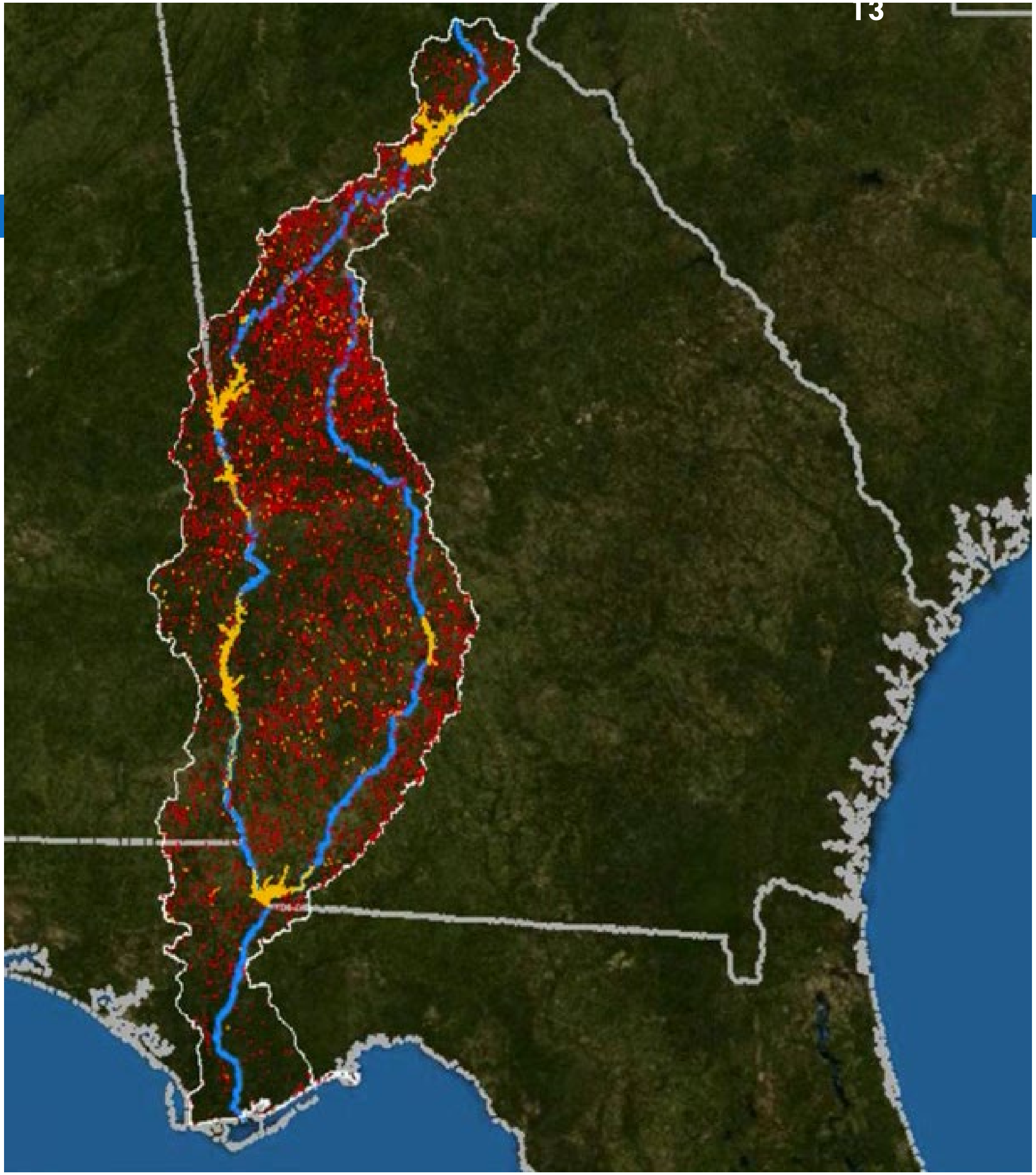
Dams

Estimated 2 – 2.5 million dams in the US

Estimates range that as high as 75-90% may not longer be used for any purpose.

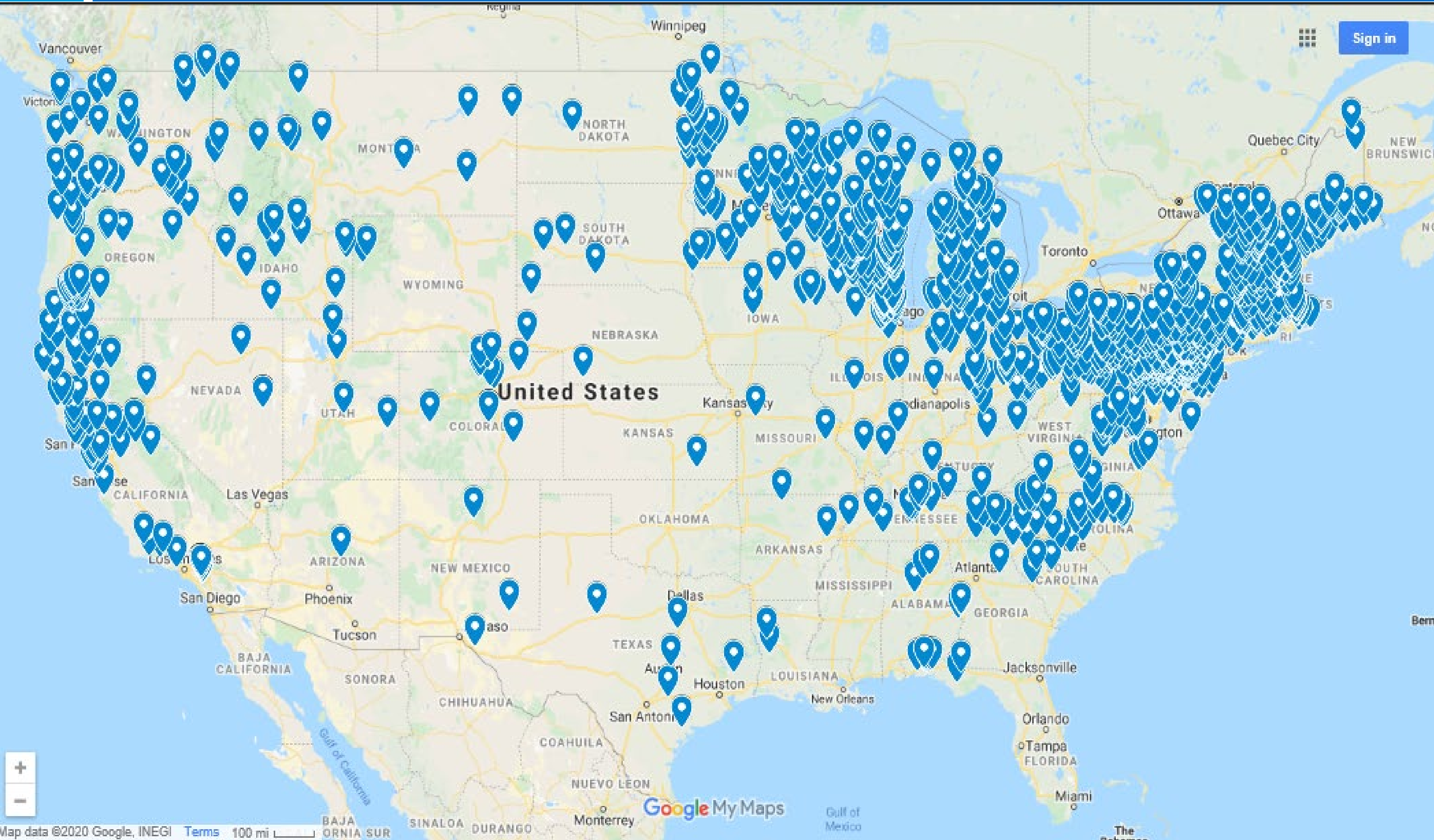
Only around 90,000 are including in the ACOE National Inventory of Dams.

(Graf 1993, Stallins & Ignatius, 2011, EPA 2016)



Restoration: Dam Removal

Rivers, American (2019): American Rivers Dam Removal Database. figshare. Dataset. https://doi.org/10.6084/m9.figshare.5234068.v6



NEUSE RIVER FLOWS FREELY AFTER MILBURNIE DAM REMOVED

A deadly dam along the Neuse River in Raleigh, NC is being removed. Once Milburnie dam is removed, shad will be able to return to historic spawning grounds.

Erin Singer McCombs | November 10, 2017

Maine's Penobscot opens up 1,000 river miles restoring shad, > 2 million alewives, baby eels, sea lamphrey, perch and brook trout.

When Dams Come Down, Salmon and Sand Can Prosper

The mouth of the Elwha River in Washington in March 2014 as the dam removal project sent sediment its way. Andy Ritchie/National Park Service

By Cornelia Dean

Aug. 10, 2015

When people urge the removal of dams they say are strangling rivers in the West, it's usually fish they're worried about. Studies of dam-removal projects show that migratory species like salmon respond quickly to improved conditions once a dam is removed.

The Anniston Star
A home-owned newspaper Anniston, Alabama - Since 1883

Dam on Tallapoosa River being removed this week

Demolition will clear waterway for fish, kayakers and more to move up and down the stream

By Bill Wilson, Star Staff Writer, wwilson@annistonstar.com Jun 4, 2019

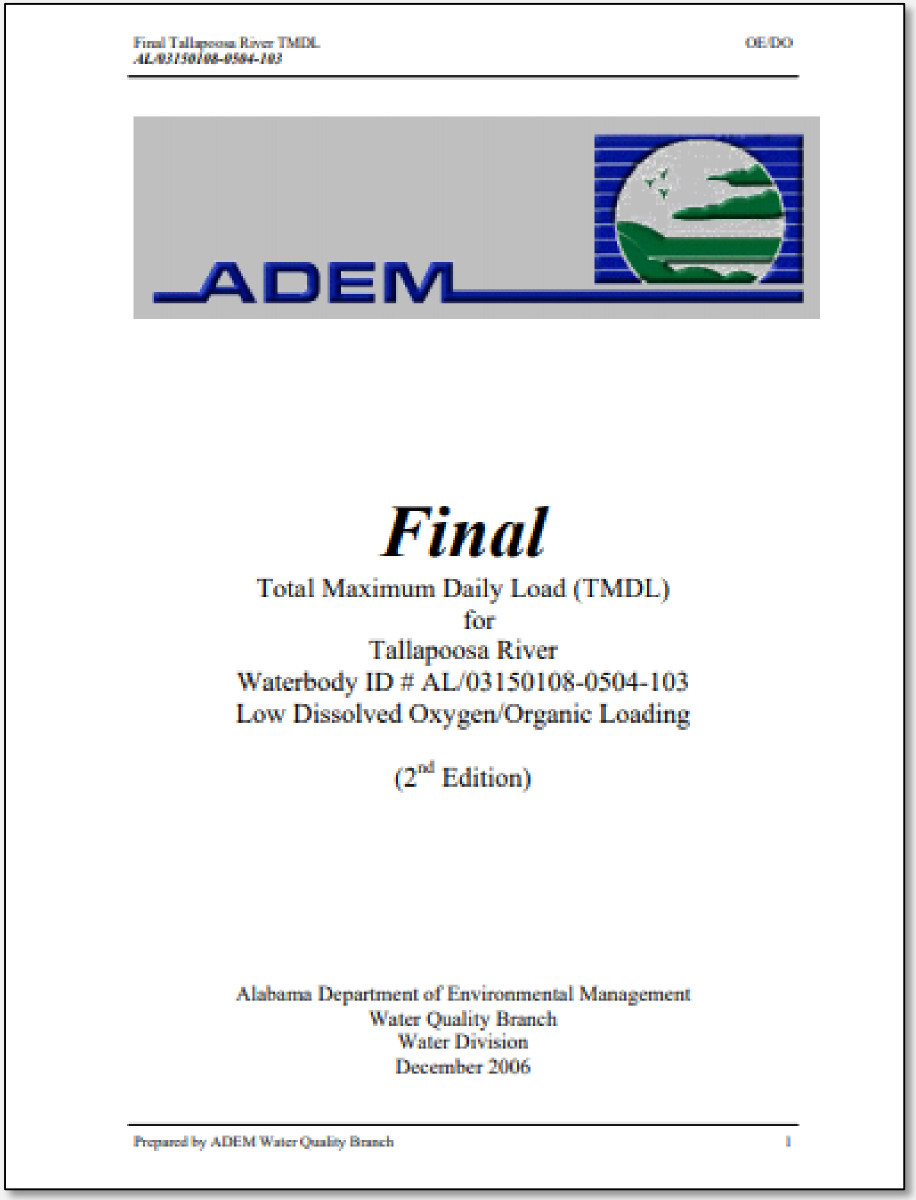
Howle & Turner Dam

Dam originally part of the Mill economy in the early 1900s. Short period of hydropower in the 1980's. Obsolete by 1990.

Changed the physical, biological and chemical characteristics of the river.

Impacted T&E species.

- Data from 1992 resulted in listing this section of the Tallapoosa River for organic enrichment/DO on AL's 1996 303(d) list.
- TMDL completed and approved by EPA in 2002
- Segment moved to Category 4a.



Final Tallapoosa River TMDL
AL/03150108-0504-103

OE/DO

ADEM

Final

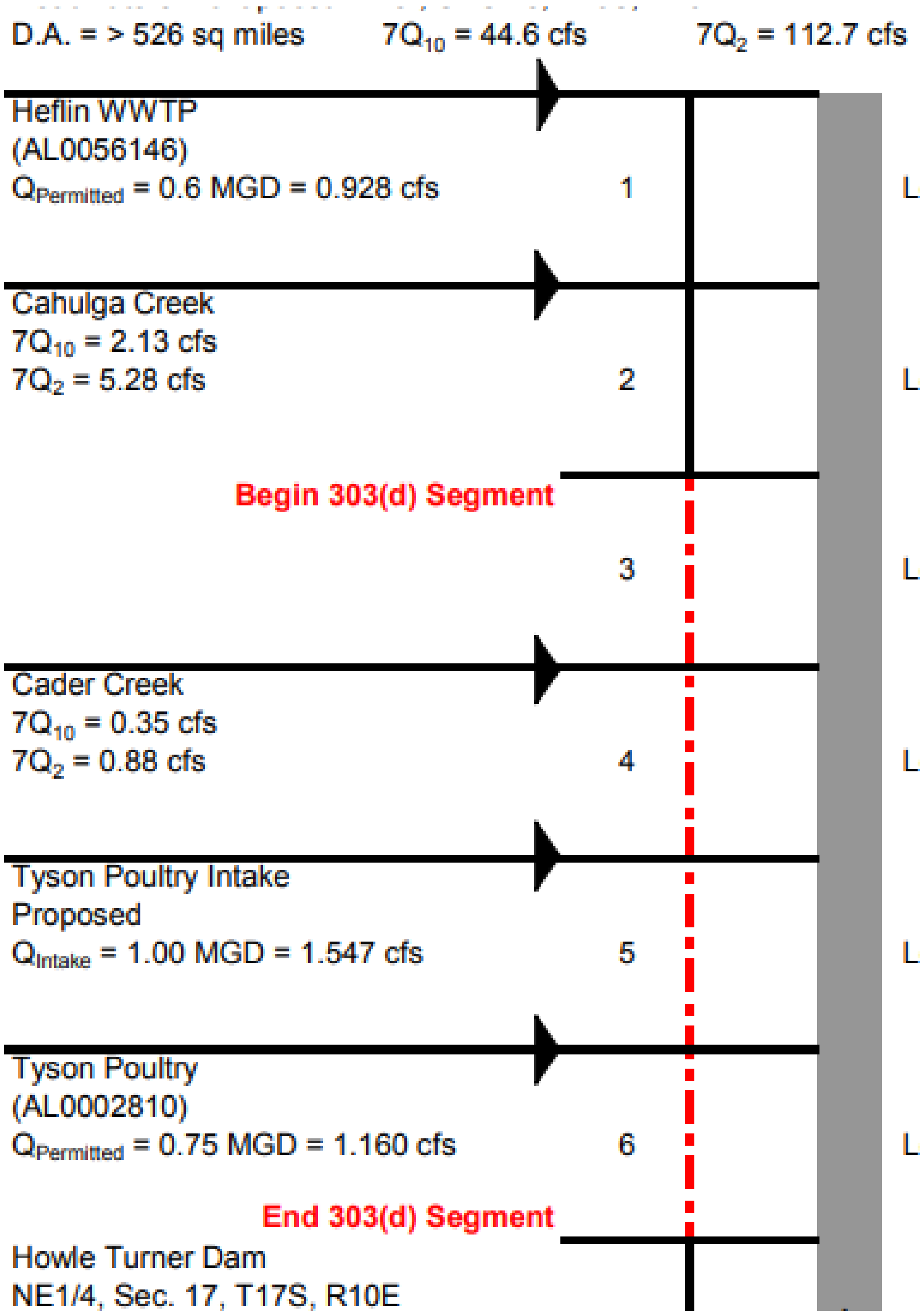
Total Maximum Daily Load (TMDL)
for
Tallapoosa River
Waterbody ID # AL/03150108-0504-103
Low Dissolved Oxygen/Organic Loading

(2nd Edition)

Alabama Department of Environmental Management
Water Quality Branch
Water Division
December 2006

Prepared by ADEM Water Quality Branch

1



- In July 2006, waterbody still in 4a.
- Models run with gates closed, gates open and with dam removed.
- TMDL revised after agreement with dam owner to continuously keep gates open.
- Flowing water allowed for less stringent limits for Heflin WWTP & Tyson Poultry.

Howle & Turner Removal

Partners:

- AL Rivers & Streams Network
- US FWS Partners for F&W Program.
- US FWS Aquatic Habitat Restoration Team.
- ADEM

Dam Removed June 2019.

Photo: Bill Wilson/The Anniston Star

Photo: Eric Spadgenske, US FWS

"Before the dam was completely removed from the river, fish of at least four species could be seen straining against the flow in salmon-like runs over the rubble and past the century-old barrier to migration." US FWS

US FWS

The U.S. Fish and Wildlife Service, National Fish Passage Program (NFPP) is a federal program which provides financial and technical assistance to reconnect aquatic habitats through the removal of barriers.

Photo Credit: Lisa Perras Gordon, EPA

Sediment filled in pond behind dam

→Stagnant & shallow

→Low DO

Reduced upstream sediment sources

DAM REMOVED

Once the water was free-flowing:

DO rebounded

Aquatic life use was met

Removed from 303(d) list

https://www.epa.gov/sites/production/files/2015-10/documents/nh_maxwell.pdf

Section 319

NONPOINT SOURCE PROGRAM SUCCESS STORY

New Hampshire

Stakeholders Cooperate to Remove Dam and Restore Stream Hydrology

Waterbody Improved A century-old dam across Black Brook created an impoundment called Maxwell Pond, which was a site for ice harvesting, fishing, swimming and other recreation. Over time, sediment from poorly managed industrial sites accumulated in the pond, which became stagnant and shallow. As a result, the New Hampshire Department of Environmental Services (NHDES) added Maxwell Pond to the 2002 Clean Water Act (CWA) section 303(d) list of impaired waters. Stakeholders restored the pond's water quality by reducing upstream sediment sources and removing the dam. Once Black Brook returned to its free-flowing condition (and Maxwell Pond ceased to exist and was reclaimed as a segment of Black Brook), the dissolved oxygen level rebounded and the brook could once again support its aquatic life designated use. As a result of the improvements, in 2010 NHDES removed the former Maxwell Pond portion of Black Brook from the state's CWA section 303(d) list of impaired waters for dissolved oxygen.

Problem

New Hampshire's Black Brook flows approximately seven miles from its headwaters in the town of Dunbarton to the city of Manchester, where it empties into the Merrimack River. More than 100 years ago (circa 1900), Maxwell Pond Dam was constructed across Black Brook in northwest Manchester to create an ice-harvesting pond (Figure1). When first created, Maxwell Pond included 5.5 acres of open water and had a maximum depth of 12 feet.

In the late 1950s, a cement processing plant/sand and gravel company began operating in the Black Brook watershed upstream of Maxwell Pond. Historically, the company stockpiled materials next to the brook, had poor on-site stormwater controls, and built undersized culverts at road crossings, which caused flooding and exacerbated erosion during storm events. The excessive sediment load from within the watershed was transported in the swift flow of Black Brook and then deposited in Maxwell Pond as the flow decreased within the impoundment.

By 2002 the pond that had once hosted ice harvesting, skating, swimming, fishing and other uses had become severely impaired by sediment accumulation. The maximum water depth had diminished to three feet. Maxwell Pond was warm, supported excessive aquatic plant growth, and had low dissolved oxygen levels. The applicable New Hampshire water quality standard for dissolved oxygen requires that Class B waters achieve a 75 percent minimum

Figure 1. Maxwell Pond Dam on Black Brook in September 2008.

daily average dissolved oxygen saturation and meet a minimum instantaneous concentration of 5.0 milligrams per liter (mg/L). Maxwell Pond data showed that dissolved oxygen levels violated both the dissolved oxygen saturation standard (in 10 of 19 samples) and the dissolved oxygen concentration standard (in 6 of 19 samples). Because the waterbody did not support its aquatic life designated use, NHDES added Maxwell Pond to the state's 2002 CWA section 303(d) list of impaired waters for low dissolved oxygen concentration and dissolved oxygen saturation. As a result of those impairments, along with additional environmental concerns, recent flooding, and other public safety issues, the city of Manchester was compelled to repair or remove the dam.

Impact: Functional Dams

Hydropower, Recreation, Flood Control, etc.

Alteration: Hydropower

Changes to the:

- Natural flow regime.
- Timing and delivery of flows. Lower high flows. Higher low flows. Removal of natural variability of flows.
- Temperature.
- Chemical composition of water.
- Natural rate-of-change of water levels/scouring.

Excerpt from NatureServ: **Coldwater releases** from Wolf Creek, Dale Hollow, and Center Hill **Dams** continue to degrade Spectaclecase habitat in the Cumberland River system. The scouring effects caused by **40 years of operation of the Center Hill Dam for hydroelectric power generation has dramatically altered the river morphology for 7 miles** (12 km) downstream of the dam (Layzer *et al.* 1993, p. 69). Layzer *et al.* (1993, p. 68) reported that **37 of the 60 pre-impoundment mussel species of the Caney Fork River have been extirpated.** (Watters 2000, pp. 262–263) summarizes the **tremendous loss of mussel species from various portions of the Tennessee and Cumberland River systems.**

Freshwater Biology

Freshwater Biology (2010) **55**, 86–107 doi:10.1111/j.1365-2427.2009.0217

Incorporating thermal regimes into environmental flows assessments: modifying dam operations to restore freshwater ecosystem integrity

JULIAN D. OLDEN AND ROBERT J. NAIMAN
School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, U.S.A.

SUMMARY

1. Despite escalating conflict over fresh water, recent years have witnessed a growing realisation that human society must modify its behaviour to ensure long-term ecologica vitality of riverine ecosystems. In response, ecologists have been increasingly asked to guide instream flow management by providing 'environmental flow' prescriptions for sustaining the ecological integrity of riverine systems.
2. Environmental flows are typically discussed in the context of water releases from dam and water allocation for extraction (such as for urban use or irrigation), where there is general agreement that rivers need to exhibit some resemblance of natural flow variabilit necessary to support a functioning ecosystem. Although productive dialogue continues o how best to define environmental flows, these discussions have been focused primarily o water quantity without explicit consideration of many components of water quality, including water temperature – a fundamental ecological variable.
3. Many human activities on the landscape have modified riverine thermal regimes. In particular, many dams have modified thermal regimes by selectively releasing hypolimnetic (cold) or epilimnetic (warm) water from thermally stratified reservoirs to the detriment of entire assemblages of native organisms. Despite the global scope of therma alteration by dams, the prevention or mitigation of thermal degradation has not entere the conversation when environmental flows are discussed.
4. Here, we propose that a river's thermal regime is a key, yet poorly acknowledged, component of environmental flows. This study explores the concept of the natural therm regime, reviews how dam operations modify thermal regimes, and discusses the ecologic implications of thermal alteration for freshwater ecosystems. We identify five major challenges for incorporating water temperatures into environmental flow assessments, an describe future research opportunities and some alternative approaches for confronting those challenges.
5. We encourage ecologists and water managers to broaden their perspective on environmental flows to include both water quantity and quality with respect to restorin natural thermal regimes. We suggest that scientific research should focus on the comprehensive characterisation of seasonality and variability in stream temperatures, quantification of the temporal and spatial impacts of dam operations on thermal regime and clearer elucidation of the relative roles of altered flow and temperature in shaping ecological patterns and processes in riverine ecosystems. Future investigations should als concentrate on using this acquired knowledge to identify the 'manageable' components of the thermal regime, and develop optimisation models that evaluate management

Correspondence: Julian Olden, School of Aquatic and Fishery Sciences, Box 355020, University of Washington, Seattle, WA 98195, U.S.A. E-mail: olden@u.washington.edu

Richter, B. D., and G. A. Thomas. 2007. Restoring environmental flows by modifying dam operations. *Ecology and Society* **12**(1): 12. [online] URL: http://www.ecologyandsociety.org/vol12/iss1/art12/

E&S

Synthesis, part of a Special Feature on Restoring Riverine Landscapes

Restoring Environmental Flows by Modifying Dam Operations

Brian D. Richter[1] and *Gregory A. Thomas*[2]

ABSTRACT. The construction of new dams has become one of the most controversial issues in global efforts to alleviate poverty, improve human health, and strengthen regional economies. Unfortunately, this controversy has overshadowed the tremendous opportunity that exists for modifying the operations of existing dams to recover many of the environmental and social benefits of healthy ecosystems that have been compromised by present modes of dam operation. The potential benefits of dam "re-operation" include recovery of fish, shellfish, and other wildlife populations valued both commercially and recreationally, including estuarine species; reactivation of the flood storage and water purification benefits that occur when floods are allowed to flow into floodplain forests and wetlands; regaining some semblance of the naturally dynamic balance between river erosion and sedimentation that shapes physical habitat complexity, and arresting problems associated with geomorphic imbalances; cultural and spiritual uses of rivers; and many other socially valued products and services. This paper describes an assessment framework that can be used to evaluate the benefits that might be restored through dam re-operation. Assessing the potential benefits of dam re-operation begins by characterizing the dam's effects on the river flow regime, and formulating hypotheses about the ecological and social benefits that might be restored by releasing water from the dam in a manner that more closely resembles natural flow patterns. These hypotheses can be tested by implementing a re-operation plan, tracking the response of the ecosystem, and continually refining dam operations through adaptive management. The paper highlights a number of land and water management strategies useful in implementing a dam re-operation plan, with reference to a variety of management contexts ranging from individual dams to cascades of dams along a river to regional energy grids. Because many of the suggested strategies for dam re-operation are predicated on changes in the end-use of the water, such as reductions in urban or agricultural water use during droughts, a systemic perspective of entire water management systems will be required to attain the fullest possible benefits of dam re-operations.

Key Words: *dams; dam re-operation; environmental flows; flood control dams; flow restoration; hydrologic alteration; hydropower dams; irrigation dams.*

INTRODUCTION

During the latter half of the 20th century, two large dams were built each day, on average (WCD 2000). By 2000, the number of large dams had climbed to more than 47,000, and an additional 800,000 smaller dams now block the flow of the world's rivers (McCully 1996, Rosenberg et al. 2000, WCD 2000). Globally, over half of the 292 large river systems have been affected by dams (Nilsson et al. 2005). Most of these dams provide substantial benefits to human societies and their economies. Hydroelectric power dams currently provide 19% of the world's electricity supply; one in three nations depends on hydropower to meet at least half of its electricity demands (WCD 2000). By capturing and storing river flows for later use, dams and reservoirs have contributed to the global supply of water for urban, industrial, and agricultural uses. Worldwide, water demands have roughly tripled since 1950, and dams have helped satisfy that demand. About half of the world's large dams were built solely or primarily for irrigation. Today, large dams are estimated to contribute directly to 12–16% of global food production (WCD 2000).

However, damming of the world's rivers has come at great cost to their ecological health and ecosystem services valued by society (WCD 2000, Postel and Richter 2003, WWF 2004, MEA 2005). Dams have

[1]The Nature Conservancy, [2]Natural Heritage Institute

Successful Reoperation: Green River, KY

- Changes to filling schedule and downstream releases.
- Improved release schedules
- Improved mussel population/aquatic life.
- Significant decrease to turbidity.
- Decrease drinking water treatment downstream.
- Increased revenue to marina operators, lake recreation, downstream outfitters.
- Benefits to Mammoth Cave Tourism.

- Partners: State and Federal Agencies, ACOE, TNC.
- AWIA improvements continue to restore natural infrastructure on the Green through removal of locks and dams.

https://www.youtube.com/watch?v=_1RUizLermM

Successful Reoperation: Saluda in SC

- Partners: South Carolina Gas & Electric Utility, NGOs, State and Federal agencies.

- Seasonally variable flows included as articles in the FERC license.
- Spring flow releases to improve spawning.
- Enhanced flows to meet WQS.
- Restoration of rare species.
- Less fluctuation in reservoir levels.
- Earlier filling of reservoir for recreation
- Public safety improvements.

Impact: Withdrawals

Alteration: Surface and Ground Water Withdrawals

Restoration/Prevention: Improved Irrigation Techniques

Restoration/ Prevention

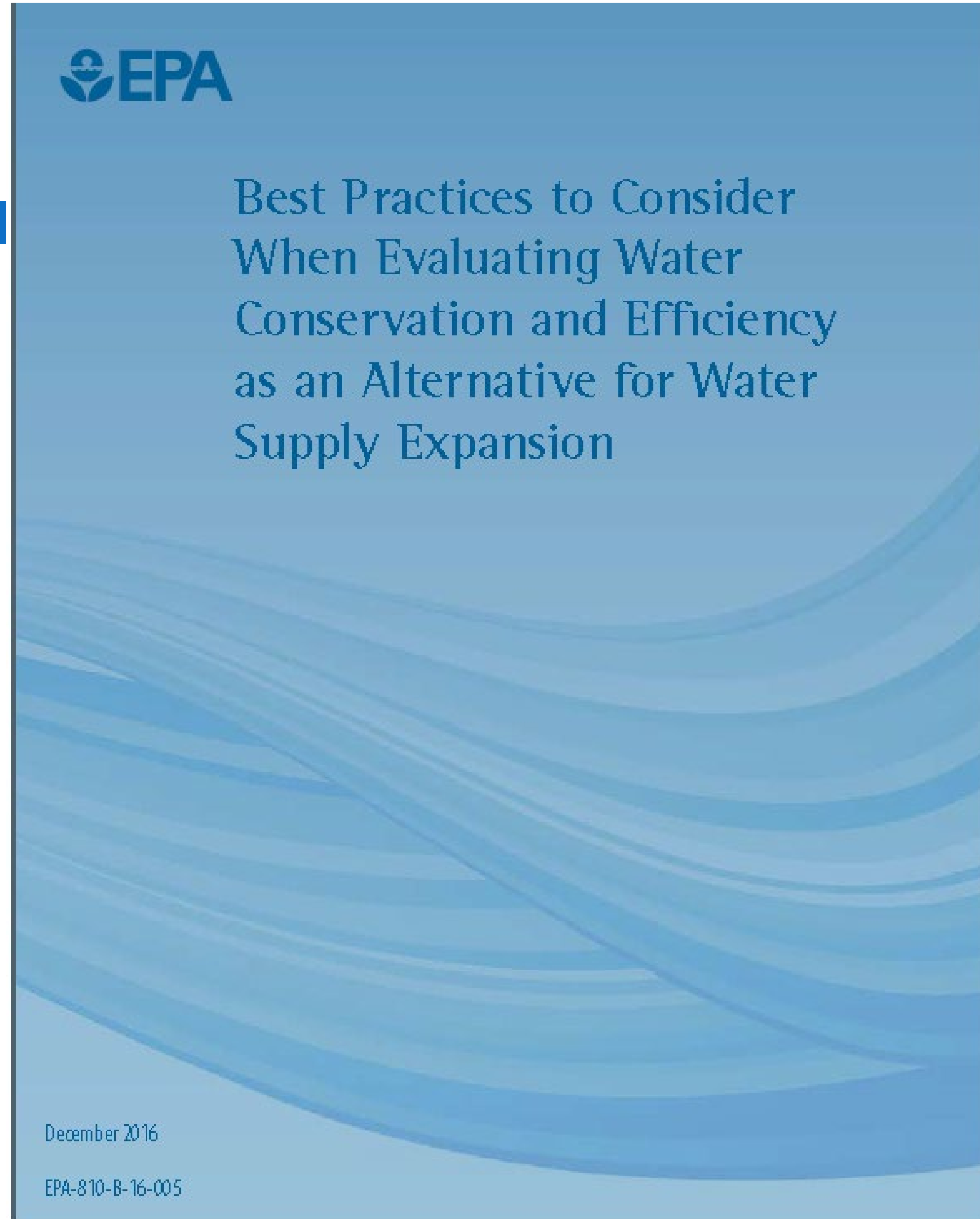
Published in December 2016

Hosted on the under the Office of Water web.

Excellent discussion on the impacts of impoundments and withdrawals.

Lots of case studies.

Originally published in Region 4 as the Water Efficiency Guidelines for use in the Section 404 program.



EPA

Best Practices to Consider When Evaluating Water Conservation and Efficiency as an Alternative for Water Supply Expansion

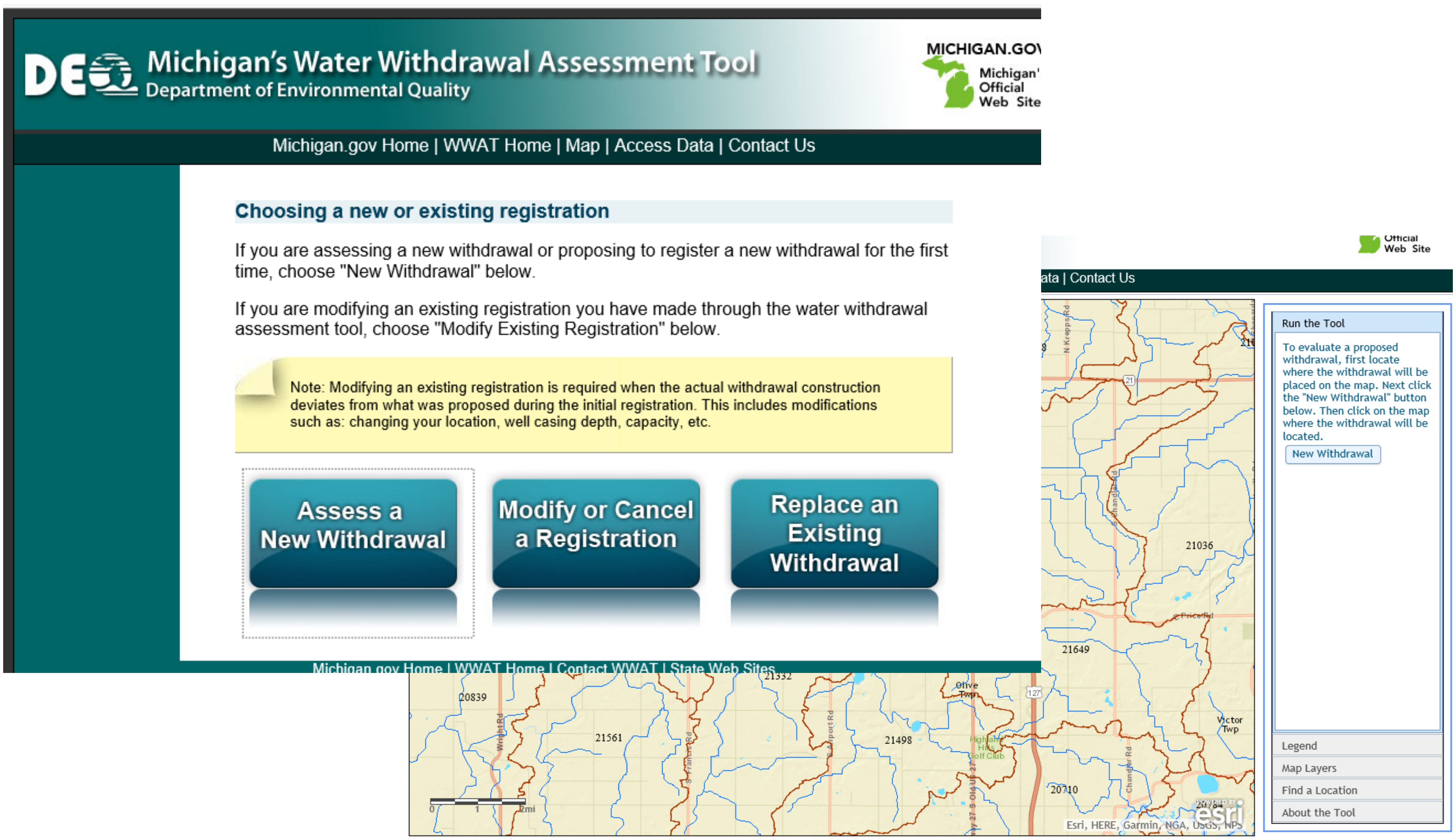
December 2016

EPA-810-B-16-005

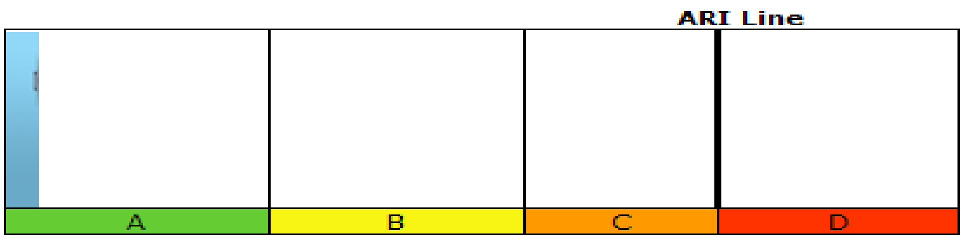
6 Elements of Best C & E Practices

- System Accounting: Audit to define water balance with free AWWA software
  - Data Validity Score
  - Non-revenue water
- Loss Minimization: Leak Management
  - Infrastructure Leakage Index (ILI) , Economic Level of Leakage (ELL) , plan
- Metering: Meter all users and inputs, maintain & calibrate
- Conservation Rate Structure
  - Full-cost pricing for system viability
  - Rate structure that incentivizes conservation
- End User Profile & Practices
  - Customer classes, seasonal use, plumbing age…
  - Programs, ordinances, incentives
- Water Conservation & Efficiency Plan

Restoration/Prevention: Improved ground water permitting in Michigan



Adverse Resource Impact (ARI) Graph



The ARI graph above illustrates the estimated removal of water from a nearby stream and its potential for causing an adverse resource impact (ARI).

The proposed withdrawal has passed in Zone A.

Screening Results - PASSED

STREAM CLASSIFICATION: Warm stream

Learn More..

RESULTS:
The proposed withdrawal has passed the screening process. The projected impact of the withdrawal lies within 'Zone A' and is not likely to cause an adverse resource impact.

REGISTRATION:
A large quantity withdrawal (LQW) with a capacity of 70 GPM or greater must be registered with the Michigan Department of Environmental Quality, or with the Michigan Department of Agriculture if the LQW is for an agricultural purpose, before the withdrawal can begin. A registration is valid for 18 months. The withdrawal capacity must be installed within this time period or the registration becomes void. Registration may be done at this time through the button at the right.

You may register at this time, or come back to this site at a later time, or you may obtain a form to register the withdrawal by contacting Andrew LeBaron at 517-241-1435, or on-line at: www.michigan.gov/deqwateruse

Actions:

- Help
- Rerun
- Register Now
- Feedback
- Print Report
- Administrator
- Exit

DISCLAIMER:
The Water Withdrawal Assessment Tool is designed to estimate the likely impact of a proposed water withdrawal on nearby streams. It is not an indication of how much groundwater may be available for your use. The quantity and quality of groundwater varies greatly with depth and location. You should consult with a water resources professional or a local well driller about groundwater availability at your location.

Prevention: Planning for Ecological Needs in New Projects

Stream Flow : The Next Two Decades Balancing Human Use and Ecological Health (Connecticut, 2009)

Table 4 Maximum Flow Reduction Rule

Bioperiod	Class 1	Class 2	Class 3
Overwinter	0.05 x Q99	0.25 x Q99 x F	0.50 x Q99 x F
Habitat Forming	0.05 x Q99	0.25 x Q99 x F	0.50 x Q99 x F
Cluepied Spawning	0.05 x Q99	0.25 x Q99 x F	0.50 x Q99 x F
Resident Spawning	0.05 x Q99	0.25 x Q99 x F	0.50 x Q99 x F
Rearing and Growth	0.05 x Q99	0.25 x Q99	0.50 x Q99
Salmonid Spawning	0.05 x Q99	0.25 x Q99 x F	0.50 x Q99 x F

"F" represents the ratio of bioperiod Q99 to Rearing and growth bioperiod Q99 at site

Prevention/Restoration: *De Minimus* for Antidegradation

Tennessee and Vermont WQS:

- Antideg *DeMinimis* –5% of 7Q10 or 10% cumulative removal.
- Water withdrawals will be considered de minimis if less than 5% of the 7Q10 flow of the stream is removed
- If more than one activity is authorized in a segment and the total of the impacts uses no more than 10% of the assimilative capacity, available capacity, available habitat, or 7Q10 low flow, they are presumed to be *de minimus*.

Stream Crossings

Alteration: Stream Crossings

Multiple entries clog, scour out the streambed, cause flooding of roadway. No Aquatic Organism Passage (AOP)

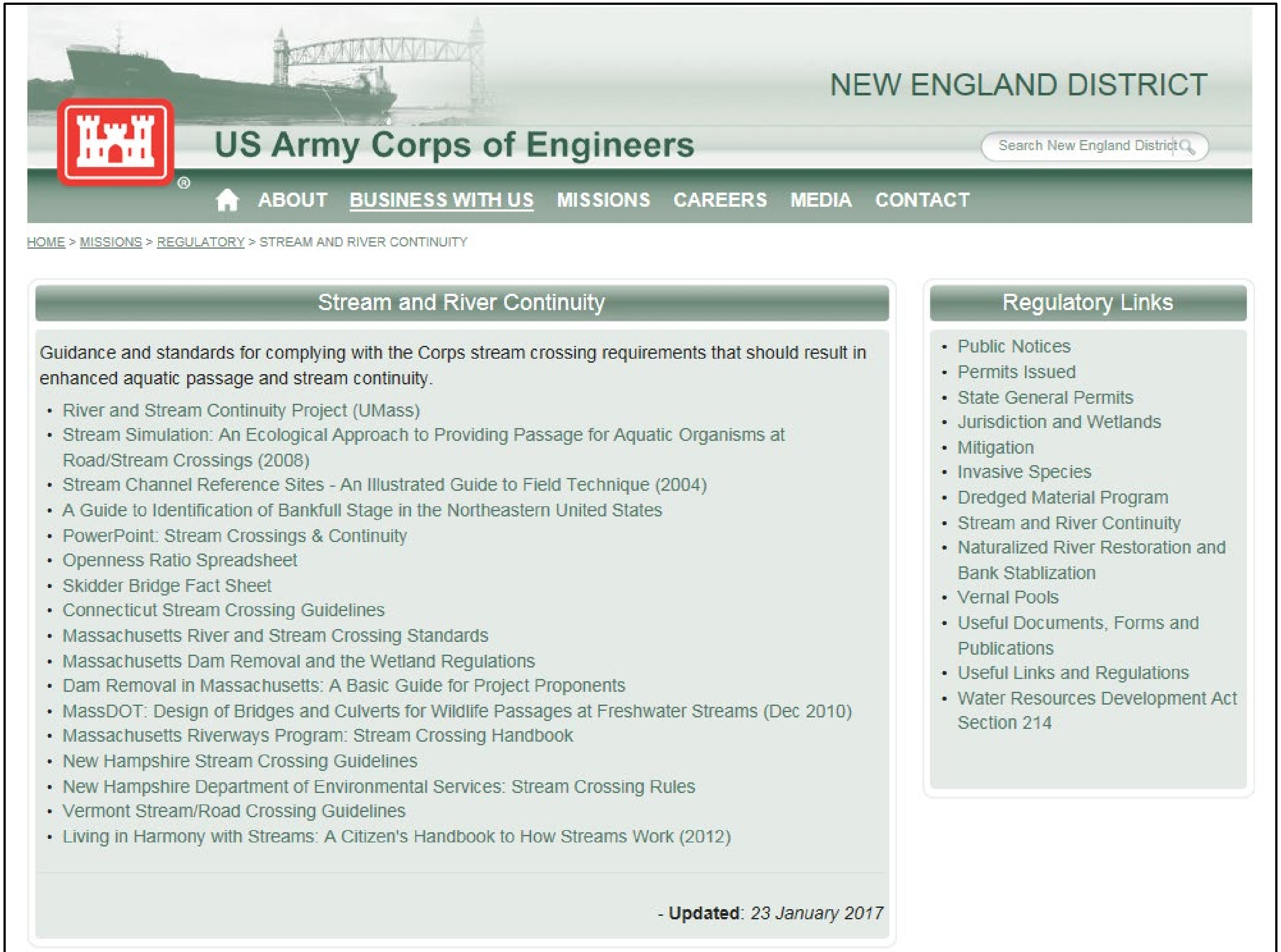
Undersized perched culverts restrict flow, cause scouring, erosion. Restricts woody debris from being transported. No AOP.

Georgia's Stream Crossing Handbook, US FWS, 2012

Tied US Supreme Court decision means Washington must remove barriers to salmon migration

Originally published June 11, 2018 at 12:19 pm | *Updated June 12, 2018 at 10:22 pm*

Adequate AOP Support ACOE New England


NEW ENGLAND DISTRICT

US Army Corps of Engineers

Search New England District

ABOUT | BUSINESS WITH US | MISSIONS | CAREERS | MEDIA | CONTACT

HOME > MISSIONS > REGULATORY > STREAM AND RIVER CONTINUITY

Stream and River Continuity

Guidance and standards for complying with the Corps stream crossing requirements that should result in enhanced aquatic passage and stream continuity.

- River and Stream Continuity Project (UMass)
- Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road/Stream Crossings (2008)
- Stream Channel Reference Sites - An Illustrated Guide to Field Technique (2004)
- A Guide to Identification of Bankfull Stage in the Northeastern United States
- PowerPoint: Stream Crossings & Continuity
- Openness Ratio Spreadsheet
- Skidder Bridge Fact Sheet
- Connecticut Stream Crossing Guidelines
- Massachusetts River and Stream Crossing Standards
- Massachusetts Dam Removal and the Wetland Regulations
- Dam Removal in Massachusetts: A Basic Guide for Project Proponents
- MassDOT: Design of Bridges and Culverts for Wildlife Passages at Freshwater Streams (Dec 2010)
- Massachusetts Riverways Program: Stream Crossing Handbook
- New Hampshire Stream Crossing Guidelines
- New Hampshire Department of Environmental Services: Stream Crossing Rules
- Vermont Stream/Road Crossing Guidelines
- Living in Harmony with Streams: A Citizen's Handbook to How Streams Work (2012)

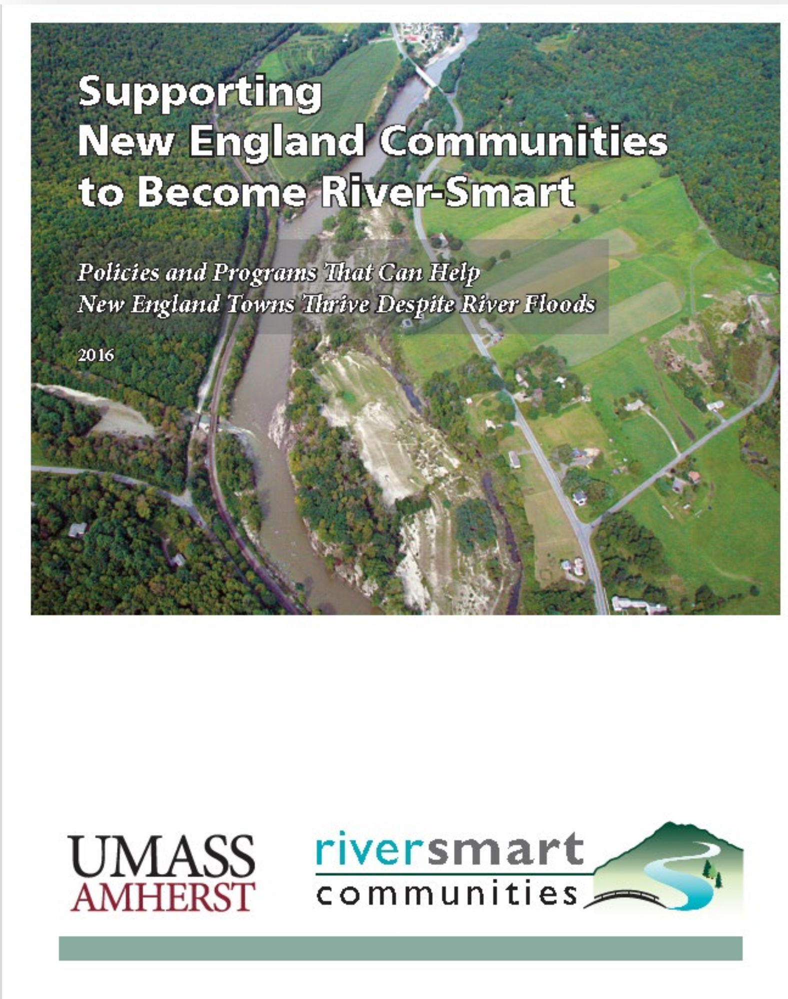
- **Updated**: *23 January 2017*

Regulatory Links

- Public Notices
- Permits Issued
- State General Permits
- Jurisdiction and Wetlands
- Mitigation
- Invasive Species
- Dredged Material Program
- Stream and River Continuity
- Naturalized River Restoration and Bank Stablization
- Vernal Pools
- Useful Documents, Forms and Publications
- Useful Links and Regulations
- Water Resources Development Act Section 214

Webpage contains information on importance of connectivity, resources to understand impacts and permitting guidelines for properly designed sustainable culverts.

Restoration: State and Local Support



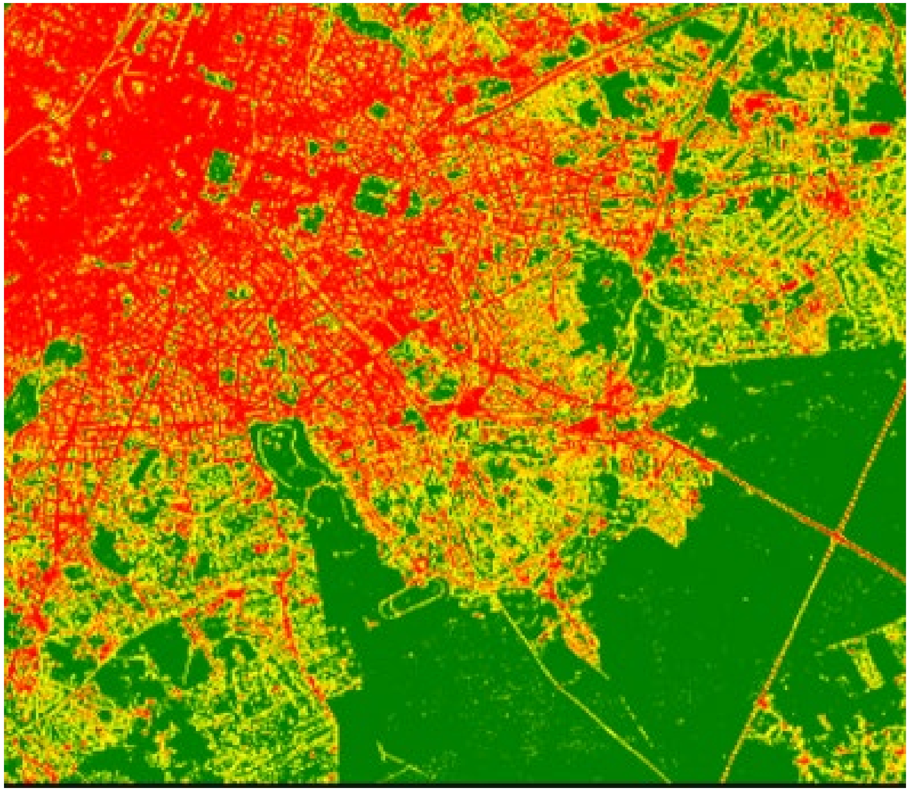
Recommendation #2: Upgrade Vulnerable Stream Crossing Infrastructure.

- Supports upgrades across all 6 New England states.
- Develop easy-to-follow design templates that will readily go through permitting.
- Acknowledges higher short-term cost but notes significant long term savings over 50 years.

Supporting New England Communities to Become River-Smart (page 41)

Impact: High Flows/Stormwater

Alteration:
Impervious Cover & Storm Water



Sediment, turbidity, nutrients, loss of base flow, altered timing and delivery of flow.

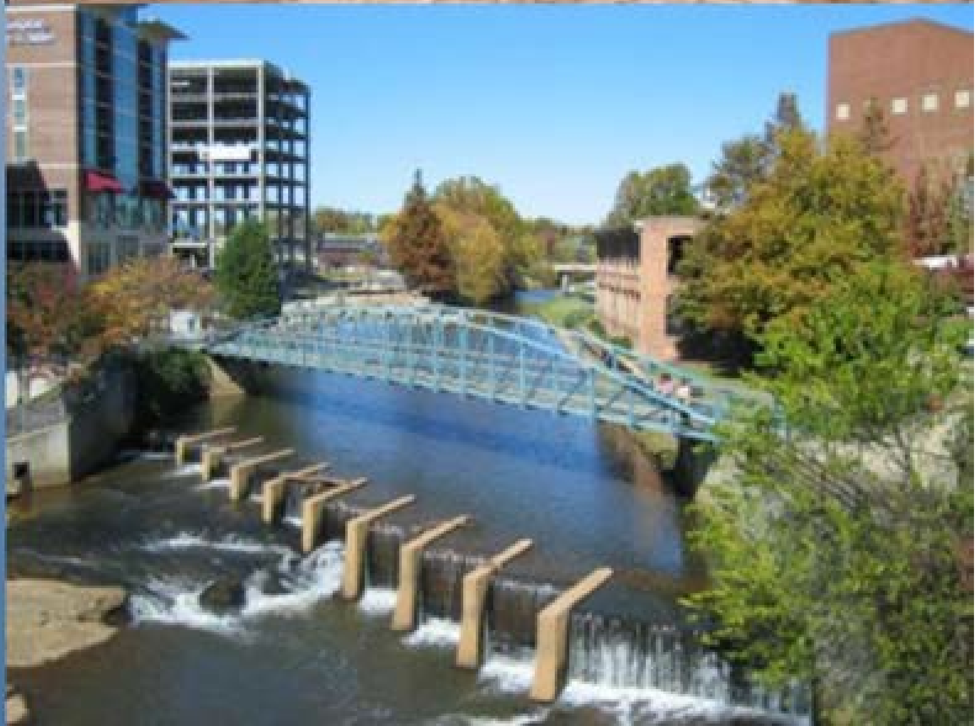
Watershed Hydrology

Increase

- Runoff rate/velocity/volume
- Peak streamflow levels
- Flooding frequency

Decrease

- Lag time to peak flow
- Baseflow
- Subsurface storage



GI Approaches - Mitigate Urbanization Impacts

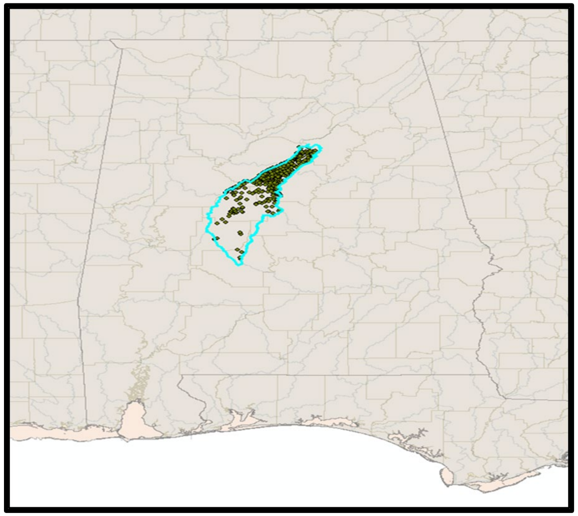
Site Scale

Atlanta City Hall
Atlanta, GA

Neighborhood Scale

Historic Forth Ward
Atlanta, GA

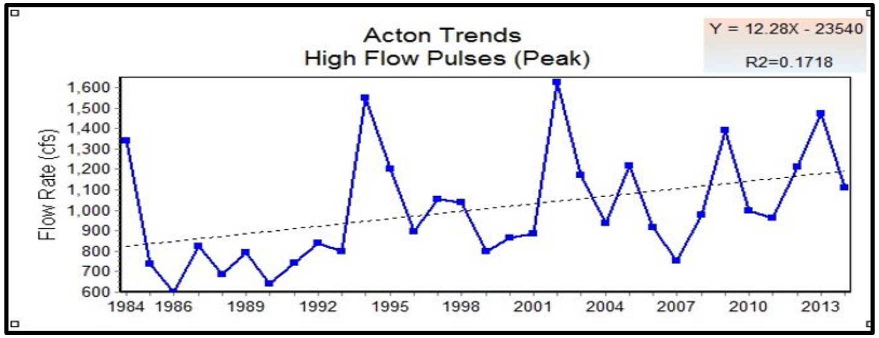
Watershed Scale

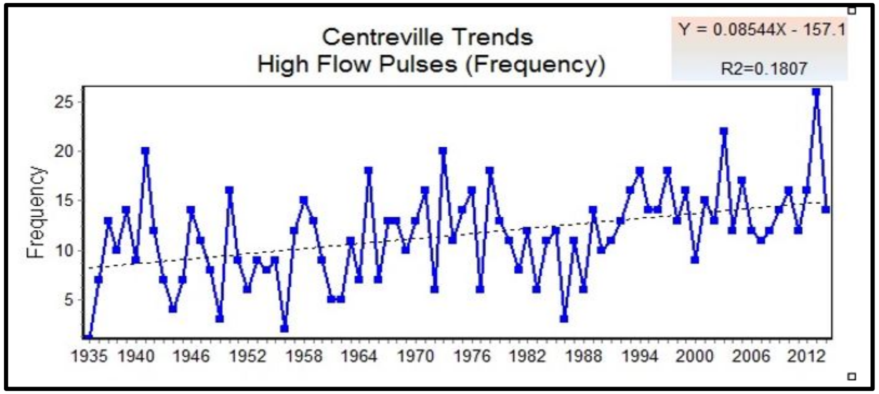


Cahaba River
Watershed, AL

AL Flow Study - Urbanization Impacts

Watershed Scale

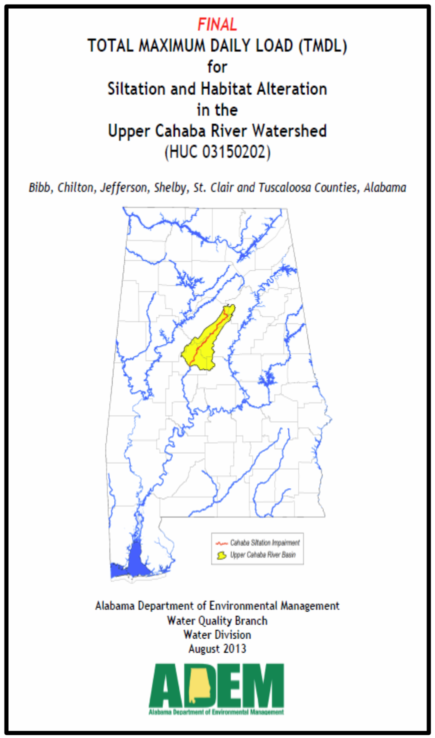




- Study identified significant increases in flashy flows over time
- Significant base flow reduction over time
  - Increased erosion due to bank instability and morphological alteration
  - Increased flooding, turbidity, sedimentation and habitat alteration

AL Flow Study – Associated TMDLs

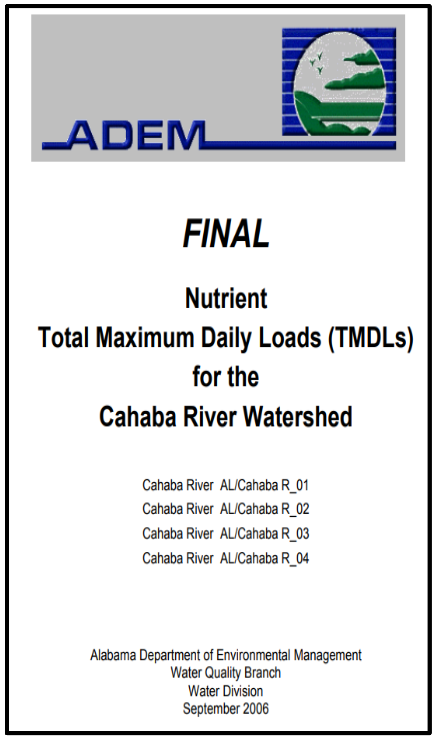
Watershed Scale


FINAL
TOTAL MAXIMUM DAILY LOAD (TMDL)
for
Siltation and Habitat Alteration
in the
Upper Cahaba River Watershed
(HUC 03150202)

Bibb, Chilton, Jefferson, Shelby, St. Clair and Tuscaloosa Counties, Alabama

Alabama Department of Environmental Management
Water Quality Branch
Water Division
August 2013

ADEM
Alabama Department of Environmental Management


ADEM

FINAL

Nutrient
Total Maximum Daily Loads (TMDLs)
for the
Cahaba River Watershed

Cahaba River AL/Cahaba R_01
Cahaba River AL/Cahaba R_02
Cahaba River AL/Cahaba R_03
Cahaba River AL/Cahaba R_04

Alabama Department of Environmental Management
Water Quality Branch
Water Division
September 2006

- Siltation/habitat alteration
  - 6 counties and 8 segments
  - TSS/SSC
  - Freshwater sp. diversity
  - 11 threatend or endangered sp.
- Nutrients
  - Entire watershed impaired (1,027 mi^2) TP
  - MS4s/NPS 65% TP reduction
  - Majors 43 µg/l TP (ma/gs)
  - Minors 300 µg/l TP (ma/gs)

Although considered voluntary, the Cahaba River Society and partners are planning GI throughout the watershed.

Green Infrastructure

Enforcement

Examples of settled Clean Water Act enforcement cases that include green infrastructure.

Chicago, Illinois

Consent Decree 2014

The Metropolitan Water Reclamation District of Greater Chicago (MWRD) is required to implement a detailed Green Infrastructure Program. Where feasible, MWRD will prioritize GI projects where they: (1) will help reduce flooding and basement backups; (2) can be readily accommodated as permanent stormwater control measures, vacant parcels that can be retrofitted into "stormwater parks," which would store and infiltrate or reuse rainfall and runoff and also be an amenity for local residents; and (3) can improve socio-economic conditions in the MWRD service area where the need is greatest, specifically by improving conditions in areas impacted by environmental justice concerns.

EPA's Metropolitan Water Reclamation District of Greater Chicago Settlement

MWRD background EXIT

Restoration Success Story Co-Benefits

- Healthy bays and estuaries support 1,000's of jobs and generate billions in revenue.
- Healthy aquatic ecosystems support outdoor tourism and recreation
  - 6.1 million American jobs (that cannot be outsourced)
  - $646 billion in outdoor recreation spending
  - $39.7 billion in state/local tax revenue
- Economic benefits to rural communities
- Safe Recreation
- Minimizes drinking water costs
- Minimizes damage from natural disasters (hazard mitigation)
- Improved public safety

Thank you

- Ralph Abele, R1, Flow Guru & Mentor
- Rosemary Calli, R4
- Leah Ettema, R3
- Chris Johnson, Alabama DEM
- Marion Hopkins, R4
- Kevin O'Donnell, Florida DEP
- Bill Richardson, R3
- Kacy Sable, R4
- Margaret Stebbins, R4
- Dwayne Young, HQ

References available for all slides.

Follow-Up

We encourage you to share challenges, restoration approaches, examples, case studies or any other information you have on this topic.

Lisa Perras Gordon, EPA Region 4

gordon.lisa-perras@epa.gov

Marion Hopkins, EPA Region 4

hopkins.marion@epa.gov

Margaret Stebbins, EPA Region 4

stebbins.Margaret@epa.gov

Discussion

- What are you doing/what do you know or do that would help others on this topic?
- Is your assessment methodology working well to accurately identify waters impaired due to hydrologic alteration?
- Are you able to make linkages between alteration and biological impairment? Alteration and water quality impacts?
- Have you partnered to work on restoration of hydrologically altered waters?

Discussion

- What do you need to better understand this topic? We have training on multiple topics that can be modified to get you the information you need.
- What additional information would be beneficial to states and tribes on this topic? Case studies? Data or information?
- Would additional training on the state-of-the-science be helpful on this topic?