DIRTY WATER: THE FAILURE OF THE CLEAN WATER ACT'S TMDLS

BY

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Nonpoint source water pollution is the largest cause of water pollution in the United States today. From harmful algal blooms to acid rain to red tide, the impacts of nonpoint source pollution are devastating for human and environmental health. In the last several decades, states and the Environmental Protection Agency have spent billions of dollars trying to address this pollution through the Clean Water Act's TMDL program. TMDLs have been derided for their lack of a coherent regulatory driver, but many academics have come to argue for their value as an example of information regulation: a regulation that requires the disclosure of information but does not impose significant regulatory burdens or requirements on the basis of this information. While information regulation is a favorite approach to environmental management, little evidence exists on whether it is an effective regulatory strategy.

This Article provides a critical assessment of the Total Maximum Daily Load (TMDL) program to concretely evaluate whether such information regulations lead to measurable improvements in water quality. Despite significant resources allocated to TMDL implementation, robust analyses evaluating its success have been lacking. For the first time, this Article presents a comprehensive quantitative analysis using nationwide data. The findings reveal that impaired waters with TMDLs in place have not shown marked improvements in quality over time, suggesting the ineffectiveness of this type of information regulation in environmental law. Based on these insights, the Article argues for several reforms to nonpoint source pollution and TMDL regulations, highlighting key aspects that undermine the effectiveness of information regulation more generally.

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I. INTRODUCTION

Fifty years after the passage of the Clean Water Act,[1] which aimed to create fishable, swimmable waters throughout the nation by 1985, the water quality in over 50% of waters in the United States remains impaired.[2] The cause of this impairment is not a mystery: nonpoint source pollution drives most water pollution problems in the United States, accounting for up to 93% of pollution loads in waters nationwide.[3] Driven by a complex group of sources, from agricultural

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[1] Federal Water Pollution Control Act Amendments (Clean Water Act) of 1972, 33 U.S.C. §§ 1251–1388 (2018).

[2] *Id.* § 1251(a); U.S. ENV'T PROT. AGENCY, EPA 841-R-16-011, NATIONAL WATER QUALITY INVENTORY: REPORT TO CONGRESS 8 (2017), https://perma.cc/36RM-HER8.

[3] *See, e.g.*, LARRY J. PUCKETT, U.S. GEOLOGICAL SURV., WRIR 94-4001, NONPOINT AND POINT SOURCES OF NITROGEN IN MAJOR WATERSHEDS OF THE UNITED STATES 4 (1994) (reporting that nonpoint sources account for 93.5% of nitrogen pollution); James S. Shortle et al., *Nutrient Control in Water Bodies: A Systems Approach*, 49 J. ENV'T QUALITY 517,

runoff to stormwater drainage, nonpoint sources can send pollution to water bodies hundreds of miles distant, making effective regulatory controls challenging.[4]

The Clean Water Act (CWA) has been strikingly successful in regulating point sources of pollution, such as factories and other industrial uses.[5] The strength of this program led to rapid increases in nationwide water quality after the Act was passed in 1972.[6] Today that progress has stalled and in many cases begun to reverse.[7] While point

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518 (2020) (discussing the impacts of nutrient loading on water systems and proposing a systems approach for controlling nonpoint source pollution).

[4] Nonpoint source pollution is generally caused by runoff carrying pollution from one area to another. This is contrasted with point source pollution, which originates in specific, identifiable sources like factories or wastewater treatment facilities. For discussion of the sources of nonpoint pollution and the consequent regulatory challenges, see generally Robin Kundis Craig & Anna M. Roberts, *When Will Governments Regulate Nonpoint Source Pollution? A Comparative Perspective*, 42 B.C. ENV'T AFFS. L. REV. 1 (2015) (comparing sources and regulatory approaches in the U.S. and Australia); David Zaring, *Agriculture, Nonpoint Source Pollution, and Regulatory Control: The Clean Water Act's Bleak Present and Future*, 20 HARV. ENV'T L. REV. 515 (1996) (evaluating challenges of agricultural nonpoint source pollution); Anastasios Xepapadeas, *The Economics of Non-Point-Source Pollution*, 3 ANN. REV. RES. ECON. 355 (2011) (discussing economic challenges to effective regulation of nonpoint source pollution); Richard Cabe & Joseph A. Herriges, *The Regulation of Non-Point-Source Pollution Under Imperfect and Asymmetric Information*, 22 J. ENV'T ECON. & MGMT. 134 (1992) (evaluating information challenges); Marc O. Ribaudo, *Non-Point Pollution Regulation Approaches in the US*, *in* THE MANAGEMENT OF WATER QUALITY AND IRRIGATION TECHNOLOGIES 83, 83–99 (Jose Albiac & Ariel Dinar eds., 2009) (comparing different regulatory approaches and their limitations); Robin Kundis Craig, *Local or National? The Increasing Federalization of Nonpoint Source Pollution Regulation*, 15 J. ENV'T L. & LITIG. 179 (2000) (discussing the federalism implications of nonpoint source control); Paula J. Lebowitz, Note, *Land Use, Land Abuse and Land Re-Use: A Framework for the Implementation of TMDLs for Nonpoint Source Polluted Waterbodies*, 19 PACE ENV'T L. REV. 97 (2001) (focusing on land-use approaches to nonpoint source regulation).

[5] Success that is effectively unquestioned by legal academics. *See, e.g.*, Oliver A. Houck, *TMDLs IV: The Final Frontier*, 29 ENV'T L. REP. 10469, 10469 (1999) [hereinafter Houck, *TMDLs IV*] (describing the CWA's NPDES technology controls as the foundation of the CWA's overall success).

[6] *See* Oliver A. Houck, *TMDLs: The Resurrection of Water Quality Standards-Based Regulation Under the Clean Water Act*, 27 ENV'T L. REP. 10329, 10329–30 (1997) [Houck, *TMDLs*] ("By any measure, the technology approach has produced significant results. Industrial pollution has plummeted; municipal loadings have dropped, despite the doubling and more of the populations they serve."); ROBERT W. ADLER ET AL., THE CLEAN WATER ACT 20 YEARS LATER 18 tbl.2.3 (1993) (finding for instance, that in the 3 years following 1987's implementation of toxic waste standards, toxic discharges dropped from 412 to 197 million pounds annually, and discharges into municipal sewage systems from 610 to 447 million pounds.).

[7] *Compare* U.S. ENV'T PROT. AGENCY, 841-R-16-011, NATIONAL WATER QUALITY INVENTORY: REPORT TO CONGRESS 7–10 (2017) *with* U.S. ENV'T PROT. AGENCY, 841-R-23-001, NATIONAL WATER QUALITY INVENTORY: REPORT TO CONGRESS 10–14 (2024) (showing stagnation and decreases in water quality nationally); *see* Oliver A. Houck, *The Clean Water Act Returns (Again): Part I, TMDLs and the Chesapeake Bay*, 41 ENV'T L. REP. 10208, 10212 (2011) [Houck, *The Clean Water Act Returns*] ("[T]he fact is that impairment is not going *down*. It is going *up*. The impaired category for rivers and streams has increased to nearly half a million segments and to almost 50% of all monitored waters over

sources continue to be well-regulated, nonpoint source pollution lacks strong regulatory oversight under the CWA.

The CWA targets nonpoint source pollution using water quality monitoring requirements and the Total Maximum Daily Load (TMDL) program. Unlike the strong command-and-control model of the rest of the CWA, and the majority of canonical environmental law,[8] TMDLs rely on an information-driven approach: states are mandated to determine detailed total maximum daily pollutant loads (thus the TMDL moniker) for any waters within their boundaries that have impaired water quality.[9] Creating these TMDLs is a technically complex process that requires water quality and hydrogeologic modeling to determine the sources of nonpoint pollution and how they will impact a given water.[10] Once a TMDL is implemented, however, there are limited regulatory requirements that nonpoint sources comply with these daily pollutant limitations, creating a model that is effectively command (water quality targets) without control (any enforcement mechanisms).[11] Instead, the TMDL program relies on the theoretical belief that simply providing scientific information on what nonpoint sources could (and arguably should) do to reduce pollution will result in behavior change without the need for any regulatory penalties or incentives.[12]

the past decade. The picture for lakes is even bleaker, rising to 11 million acres and a whopping two-thirds of all lakes measured.").

[8] *See generally* Todd Aagaard, *Environmental Law Outside the Canon*, 89 IND. L.J. 1239 (2014) (surveying the major environmental laws of the 1970s).

[9] Clean Water Act § 303(d), 33 U.S.C. § 1313(d) (2018).

[10] *See* ALICE MILLER KEYES & DAVID RADCLIFFE, A PROTOCOL FOR ESTABLISHING SEDIMENT TMDLS 1–2 (2002), https://perma.cc/9NYQ-A749 (describing specifically the difficulty in establishing TMDLs for sediment pollution and the complex methodologies needed to evaluate the impacts and best responses to pollution that form the basis of TMDLs); KENNETH H. RECKHOW ET AL., NAT'L RSCH. COUNCIL, ASSESSING THE TMDL APPROACH TO WATER QUALITY MANAGEMENT 2–3 (2001) (describing TMDL development and finding widespread technical barriers to development); Bethany T. Neilson & David K. Stevens, *Issues Related to the Success of the TMDL Program* 122 J. CONTEMP. WATER RSCH. & EDUC., 2002, at 57, 58 (describing the technical methods needed for TMDL development and variation in these methods between states).

[11] The regulatory controls that TMDLs create interestingly apply easily to point sources, whose permits will be altered to comply with the TMDL, but not nonpoint sources, who are under no regulatory control from the CWA. It is worth noting here though that some states may impose additional legal requirements on certain nonpoint sources, which may provide a mechanism for forcing TMDL compliance. *See Overview of Total Maximum Daily Loads (TMDLs)*, U.S. ENV'T PROT. AGENCY, hhttps://perma.cc/FW6C-UWZT (Oct. 25, 2024) (noting that "non-point source load reduction actions" are implemented through programs at the state, local, and federal level and may be "regulatory, non-regulatory, or incentive based"; also noting that states can develop TMDL implementation plans that provide additional guidance on non-point source pollution control).

[12] This is an approach characteristic of information disclosure strategies. *See generally* Bradley C. Karkkainen, *Information-Forcing Environmental Regulation*, 33 FLA. STATE U. L. REV. 861, 891, 902 (2006) (explaining that regulatory penalty defaults, such as those in the TMDL program, can indirectly trigger state action); William F. Pedersen, *Regulation and Information Disclosure: Parallel Universes and Beyond*, 25 HARV. ENV'T L. REV. 151

Academics have shown widespread skepticism toward the TMDL program largely due to the regulatory design choices that were made during the program's creation.[13] While the Environmental Protection Agency (EPA) and states have begun developing TMDLs with vigor,[14] initial reports show the limitations of the TMDL program's reach. Government analysis from EPA and the Government Accountability Office (GAO) details how TMDL implementation lags due to insufficient resources and political will for states to keep up with the demands of creating and enforcing TMDLs.[15] All is not bleak, though: TMDLs have led to major water quality improvements in several very important waters, for instance Chesapeake Bay.[16] Academics have shown how a combination of innovative approaches at the local level can lead to successful water quality outcomes.[17]

(2001) (advocating for adoption of social cost disclosure programs); Paula J. Dalley, *The Use and Misuse of Disclosure as a Regulatory System*, 34 FLA. STATE U. L. REV. 1089 (2007) (discussing the deficiencies of disclosure programs).

13 *See, e.g.*, Houck, *The Clean Water Act Returns*, *supra* note 7, at 10212 ("We are not catching our tail. Why would this be? The obvious answer, which is also a correct one, is that the dominant causes of pollution today are not regulated at any level: they are nonpoint sources and they believe they are God, for good reasons."); Dave Owen, *After the TMDLs*, 17 VT. J. ENV'T L. 845, 855 (2016) ("[E]vidence of success is sparse because successes have been few and far between. That would not be entirely surprising, for section 303 of the Clean Water Act was not constructed particularly well in the first place."); James Boyd, *The New Face of the Clean Water Act: A Critical Review of the EPA's New TMDL Rules*, 11 DUKE ENV'T L. & POL'Y F. 39, 41 (2000) ("Federal authority to mandate nonpoint source controls remains weak. Implementation of the analytic tools required by the TMDL process will be costly and difficult. And conflicts are almost certain to arise due to the geographically interrelated nature of pollution sources and legal jurisdictions."). Some instead point to the scientific issues at the heart of the TMDL program as a reason for skepticism. *See, e.g.*, David S. Caudill & Donald E. Curley, *Strategic Idealizations of Science to Oppose Environmental Regulation: A Case Study of Five TMDL Controversies*, 57 KAN. L. REV. 251, 256 (2009) ("[T]he issues of the 'soundness' of TMDL science, the challenge of scientific uncertainties, and the effect of political and economic interests on science have been part of the national TMDL controversy.").

14 Houck, *The Clean Water Act Returns*, *supra* note 7, at 10211 ("The results of the TMDL process to date depend largely on whether one counts by beans or clean water. . . . As the smoke clears, we have over 41,000 completed documents for some 44,000 listed impaired waters, pretty much a whole deck.").

15 U.S. ENV'T PROT. AGENCY, EPA 100-R-98-006, REPORT OF THE FEDERAL ADVISORY COMMITTEE ON THE TOTAL MAXIMUM DAILY LOAD (TMDL) PROGRAM 6–7 (1998); U.S. GOV'T ACCOUNTABILITY OFF., GAO-14-80, CLEAN WATER ACT: CHANGES NEEDED IF KEY EPA PROGRAM IS TO HELP FULFILL THE NATION'S WATER QUALITY GOALS 49–62 (2013).

16 Houck, *The Clean Water Act Returns*, *supra* note 7, at 10223; *Water Quality Standards Attainment and Monitoring*, CHESAPEAKE PROGRESS, https://perma.cc/JYK2-F2VG (last visited May 29, 2025) (reporting improvements in Chesapeake Bay water quality and progress towards achieving TMDL targets).

17 *See* William V. Luneburg, *Where the Three Rivers Converge: Unassessed Waters and the Future of EPA's Total Maximum Daily Load Program—A Case Study*, 24 J.L. & COM. 57, 85 (2004); RECKHOW ET AL., *supra* note 10, at 39.

In 1998, renowned TMDL scholar Oliver Houck noted that the jury was still out on the question of whether the TMDLs are worth it.[18] This question remains unanswered. Whether positive or negative, the discussion of TMDL efficacy to date is largely anecdotal. A comprehensive understanding of whether the TMDL program is helping to achieve water quality goals is needed before drawing conclusions about the relative costs and benefits of this approach to nonpoint source pollution. This Article combines existing quantitative studies with a novel empirical analysis of TMDLs implemented from 1997–2017 to address how effective these water quality measures have been. It answers the key question of whether the over 75,000 TMDLs currently in place in the United States are leading to reductions in pollution and improvements in water quality in the 50 years since the CWA was implemented. Unfortunately the answer is a resounding no.

In answering this question, this Article provides insight not only into the future of water quality in the United States but also into the efficacy of the CWA's regulatory design. The TMDL program illustrates the dangers of creating legislation without adequate mechanistic attention to how the regulation will achieve its goals.[19] In the case of TMDLs, academics, the EPA, and Congress have highlighted its information-forcing role but also point to a state-first, land-use based approach and ambient monitoring as theoretical mechanisms underlying its design.[20] Unfortunately, TMDLs fail to exhibit the key characteristics of each of these types of regulation, helping to explain why it has not been a successful approach to environmental regulation. Identifying the critical features that prevent TMDLs from achieving water quality goals illustrates important lessons for other regulations seeking to use information-based approaches to regulation and for potential efforts to improve the TMDL program in the future.

This Article begins in Part II with background on the history of the TMDL program. It details how TMDLs have been implemented in different states, noting that while the program has evolved significantly in the last two decades, implementation remains fragmented. It characterizes the development of TMDLs, showing how this process was

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[18] Houck, *TMDLs IV*, *supra* note 5, at 10485 (1999) ("Which leaves us with the ultimate question: Are TMDLs worth it?").

[19] The focus at the time of the TMDL program's inclusion in the CWA was more on how to resolve federalism concerns between states and the federal government and how to assuage the concerns of industry lobbies, such as agriculture, than how to create a robust and effective regulatory system for mitigating nonpoint source pollution problems. *See id.* at 10474 (discussing the history of the TMDL program).

[20] *See, e.g.*, Sarah Birkeland, *EPA's TMDL Program*, 28 ECOLOGY L.Q. 297, 303 (2001) (explaining TMDLs main mechanistic driver was the need for a state-centered approach to deter federalism concerns); Boyd, *supra* note 13, at 40–41 (explaining TMDLs' ambient monitoring approach as a new and untried mechanism underlying TMDLs); Houck, *TMDLs IV*, *supra* note 5, at 10473 (describing conception that states have a better understanding of local conditions and water quality models as the basis for the state-led approach of TMDLs).

originally driven by litigation from environmental non-profits but has not followed up with an emphasis on effective implementation.[21] It then describes the theoretical basis for TMDLs, showing how TMDLs are primarily an example of information forcing regulation though they also employ some elements of command-and-control and adaptive regulation.

Part III addresses the question of how the TMDL program is faring 50 years after the passage of the CWA and 25 years after EPA turned its attention to implementing TMDLs in earnest. It presents empirical results, showing on several different dimensions how the TMDL program is failing to produce meaningful water quality improvements. In waters where TMDLs have been implemented, less than 1% have seen significant increases in water quality.[22]

Part IV builds on this empirical evidence to discuss the impact of the TMDL program both as a substantive regulation that limits pollution outputs and also as an information regulation that increases knowledge of water quality issues. It argues that neither of these goals are being met under the current implementation of the TMDL program. It points to several existing proposals for modifying the TMDL program to lead to better nonpoint source pollution outcomes, leveraging both local action as well as updates to the TMDL regulatory mandates. It argues that no progress can be made on TMDLs without fixing existing mechanistic gaps, and that even with this it may be desirable to put aside attempts at reinvigoration and reimagine our approach to nonpoint source pollution.

II. THE CLEAN WATER ACT'S APPROACH TO NONPOINT SOURCE POLLUTION

Nonpoint source pollution is unquestionably the largest source of water pollution in the United States today.[23] Nonpoint source pollution is anything that does not originate from a "discernable, defined, or discrete conveyance," which the CWA labels a point source.[24] Nonpoint source pollution most frequently comes from runoff: precipitation falling onto the surface of the Earth picks up pollutants in the form of

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[21] *See generally* Owen, *supra* note 13 (explaining the motivating forces and subsequent failures of the TMDL program).

[22] *See* discussion *infra* Section III.B.2 (relying on a study extrapolating data from water samples of TMDL de-listed water bodies).

[23] *See, e.g.*, Linda A. Malone, *What Do Snowmobiles, Mercury Emissions, Greenhouse Gases, and Runoff Have in Common?: The Controversy over 'Junk Science'*, 9 CHAP. L. REV. 365, 389 (2006) ("Today, nonpoint source pollution remains the nation's largest source of water quality problems. It is the main reason that approximately forty percent of our surveyed rivers, lakes, and estuaries are not clean enough to meet basic uses such as fishing and swimming.").

[24] Clean Water Act § 502(14), 33 U.S.C. § 1362(14) (2018) ("The term 'point source' means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural stormwater discharges and return flows from irrigated agriculture.").

fertilizers, oils, sediment, and myriad other chemicals and washes it into nearby waterbodies.[25] Agricultural and urban stormwater runoff are the biggest contributors to nonpoint source pollution problems, driving some of the most visible and economically catastrophic water pollution problems we have today.[26]

This section describes in detail the entwined history and theoretical foundations of the CWA's approach to regulating nonpoint source pollution in the TMDL program. It shows how scientific constraints and historical inertia at the time of the CWA's enactment dictated the regulatory approach currently enshrined in the TMDL program. It argues that three main mechanistic theories can be used to understand the TMDL approach to water quality regulation: command-and-control, information forcing, and adaptive regulation.

A. Overview of the TMDL Program

The Clean Water Act provides tools to address nonpoint source pollution through the Total Maximum Daily Load (TMDL) program.[27] The TMDL program is tied to the CWA's ambient monitoring requirements in Section 303 and 305.[28] These portions of the CWA require states to monitor all of the waters within their boundaries to determine which waters are not meeting state water quality standards.[29] States are given considerable latitude to define what quality standards will apply to a given waterbody depending on the desired uses for that water, from fishing and recreation to purely aesthetic values.[30] States must then report biannually on the status of

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[25] Craig, *supra* note 4, at 180.

[26] *See* Houck, *The Clean Water Act Returns*, *supra* note 7 (describing how water pollution drove to ecosystem collapse in Chesapeake Bay); Jacob Ogles, *Algal Blooms Cost Florida $17.3 Million in Emergency Funding Last Year*, FLA. POL. (Jan. 23, 2019), https://perma.cc/ZK9X-ZNN6 (describing water pollution driven algal blooms off Florida's beaches).

[27] 33 U.S.C. § 1313(d); 40 CFR § 130.7 (2025).

[28] Section 303 of the CWA requires that states establish water quality standards and determine waters where existing point source controls are not sufficient to ensure that the water is meeting water quality standards, while Section 305 requires that states prepare and submit reports on water quality biannually to Congress. Clean Water Act § 303(d), 33 U.S.C. § 1313(d); Clean Water Act §305(b), 33 U.S.C. §1315(b).

[29] Clean Water Act § 303(d), 33 U.S.C. §1313(d).

[30] These water quality standards are intended both to protect human health and aquatic life, with designated uses falling into five major categories: CLASS I Potable Water Supplies; CLASS II Shellfish Propagation or Harvesting; CLASS III Fish Consumption; Recreation, Propagation and Maintenance of a Healthy, Well-Balanced Population of Fish and Wildlife; CLASS III-Limited Fish Consumption; Recreation or Limited Recreation; and/or Propagation and Maintenance of a Limited Population of Fish and Wildlife; CLASS IV Agricultural Water Supplies; CLASS V Navigation, Utility and Industrial Use. Clean Water Act § 303(c), 33 U.S.C. § 1313(c); U.S. ENV'T PROT. AGENCY, CHAPTER 62-302: WATER QUALITY STANDARDS (2018), https://perma.cc/5A8F-CUVE (documenting Florida's surface water quality standards).

these waters to Congress.[31] If waters are deemed impaired, or are not meeting appropriate water quality standards for the specified designated use, they are listed separately on the CWA's required 303(d) list of impaired waters.[32] This listing triggers mandatory TMDL development, with the goal of limiting pollution inputs into these waters and returning them to an unimpaired state.[33]

Creating TMDLs is a lengthy and resource intensive process at all stages. Even the first stage of water quality monitoring to identify impaired waters has been a hurdle for states to achieve: despite the CWA's mandate that states monitor all of the waters within their boundaries, only about one third of the waters in the United States are actually monitored. [34] For waters that are actually monitored and determined to be impaired, states must create a priority ranking of waters for TMDL development.[35] Only then can states proceed with developing a TMDL, a process that requires states to determine the causes of water quality impairment and understand the local hydrology and human uses at a detailed level.[36] With this information, states create nutrient allocations, or Total Maximum Daily Loads, that limit how much pollution can be put into a water each day.[37] TMDLs often take years to create, resulting in detailed document filings that can be hundreds of pages long.[38] Once created, TMDLs are often the subject of litigation over the accuracy and validity of their scientific foundations.[39]

While resource-intensive, the TMDL process up to this point makes scientific sense. Water quality monitoring to determine which waters are impaired provides important baseline information to guide regulatory efforts and target resources toward the most threatened waters.[40] Likewise, while creating TMDLs themselves is resource

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[31] 33 U.S.C. § 1315(b).

[32] 33 U.S.C. § 1313(d).

[33] *Id.*

[34] *See* U.S. ENV'T PROT. AGENCY, *National Summary of State Information* (2022), https://perma.cc/BD8C-SPSE.

[35] 33 U.S.C. § 1313(d)(1)(A).

[36] See RECKHOW ET AL., *supra* note 10, at 14–15, for a description of this process. *See also* Matthew DeGioia, *Overboard? The Complexity of Traditional TMDL Calculations Under the Clean Water Act*, 49 ENV'T L. REP. 11150, 11153–58 (2019) (detailing the scientific difficulties inherent in TMDL development).

[37] For an overview of EPA's recommended TMDL development process, see *Overview of Total Maximum Daily Loads (TMDLs)*, *supra* note 11.

[38] *See generally* Houck, *TMDLs*, *supra* note 6 (discussing the nature of water quality standards and the positions of states, industry, and other stakeholders on the TMDL program); U.S. ENV'T PROT. AGENCY, 2007-P-00036, TOTAL MAXIMUM DAILY LOAD PROGRAM NEEDS BETTER DATA AND MEASURES TO DEMONSTRATE ENVIRONMENTAL RESULTS 3 (2007), https://perma.cc/UF2V-EPSY ("In 2001, EPA estimated that the total average annual costs to EPA and States of developing about 36,000 TMDLs over 15 years would be between $63 to $69 million per year . . . .").

[39] Malone, *supra* note 23, at 393 n.201 (citing lawsuits brought against unfounded state TMDL listing and subsequent EPA approvals).

[40] Eric Biber, *The Problem of Environmental Monitoring*, 83 U. COLO. L. REV. 1, 5 (2011).

intensive, the process recognizes the complexity inherent in addressing nonpoint source pollution. Nonpoint source pollution is notoriously difficult to understand, with interacting sources of pollution that can originate hundreds or thousands of miles away from where water quality impacts are ultimately seen.[41] Requiring states to carry out the hydrogeological modeling and pollution load analyses that form the basis of TMDLs provides essential information for addressing point and nonpoint sources of water quality impairment.[42]

However, after TMDLs are developed, the regulatory process created by the Clean Water Act is less laudable.[43] While the CWA's provisions with regard to point sources mandate comprehensive and binding restrictions on pollution outflows, the provisions governing nonpoint sources are essentially voluntary.[44] TMDLs create clear numerical targets for nonpoint sources but no legal requirements that force nonpoint sources to comply with these targets.[45] Much of the discretion over if and how TMDL compliance is incentivized is driven by non-regulatory state and local programs.[46] The result is a largely voluntary program that few, if any, nonpoint sources ultimately comply with.[47]

The TMDL program is not completely without teeth: while TMDLs do not place any enforceable controls on nonpoint sources, they do create enforceable standards that point sources must meet.[48] Waters that are impaired primarily by point sources are thus relatively well-controlled under the TMDL program.[49] Unfortunately, after the success of the NPDES portions of the CWA very few, if any, waters today are impaired primarily because of point source pollution.[50] The TMDL program thus

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41 *See* Houck, *TMDLs IV*, *supra* note 5, at 10476–77 (discussing the difficulty of identifying causes of impairment from nonpoint sources).

42 *See* Nina Bell, *TMDLs at a Crossroads: Driven by Litigation, Derailed by Controversy?*, 22 PUB. LAND & RES. L. REV. 61, 65–68 (2001) (describing the importance of the EPA's rulemaking in the 1990s that required these changes).

43 *See, e.g.*, K.A. McConnell, *Limits of* American Farm Bureau Federation v. EPA *and the Clean Water Act's TMDL Provision in the Mississippi River Basin*, 44 ECOLOGY L.Q. 469, 477 (2017) ("[T]he TMDL program—designed to address nonpoint source pollution—is inherently flawed, as it leaves the federal government no way to hold a state's nonpoint source polluters accountable for their respective contribution to an interstate water's water quality violations.").

44 Clean Water Act § 303(d), 33 U.S.C. § 1313(d) (2018) (requiring states establish TMDLs but not requiring their enforcement against nonpoint sources).

45 *See Overview of Total Maximum Daily Loads (TMDLs)*, *supra* note 11.

46 *Id.*

47 Houck, *TMDLs*, *supra* note 6, at 10342–43.

48 Houck, *The Clean Water Act Returns*, *supra* note 7, at 10210 ("[Courts] required EPA to ensure that *point* sources discharging into TMDL waters ensure controls over *nonpoint* sources sufficient to meet the attainment of water quality standards. This latter case, limited as it is to point source permits, is to date the only enforceable federal abatement requirement for agriculture, timber, and the nonpoint world.").

49 *Id.*

50 *See* Houck, *TMDLs IV*, *supra* note 5, at 10470.

provides unnecessary additional regulatory oversight over point sources while ignoring the nonpoint sources that it most needs to address.

Despite its lack of binding regulatory requirements for nonpoint sources, the TMDL program may work through additional mechanisms to promote the CWA's goals of improved water quality. The TMDL program, for instance, serves an important and undertheorized information-forcing function.[51] Requiring that states develop TMDLs for impaired waters creates a scientific process that identifies impaired waters and bolsters understanding of the cumulative pollution impacts on those waters for both government managers and the public.[52] In other areas of environmental law, this type of information-forcing regulation may play an important role in achieving regulatory goals.[53]

The potential information on the water quality benefits of TMDLs is weighed against significant costs. EPA reports on the exact costs of developing and implementing the TMDL program are hard to come by, but early estimates were on the order of $30 billion in implementation costs in 2000.[54] State agencies devote significant resources to the project of implementing the nonpoint source provisions of the CWA.[55] Developing TMDLs is a lengthy process, requiring significant scientific expertise in addition to public input.[56] Many states have attempted to avoid creating new TMDLs, instead waiting until litigation forces them to act.[57]

B. History of TMDLs

Understanding why the TMDL program was framed the way it is requires understanding the political and scientific constraints present at

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[51] *See* discussion *infra* Section II.C. The Theory Behind TMDLs1.

[52] *See* Houck, *TMDLs IV*, *supra* note 5, at 10470, 10474–75.

[53] *See, e.g.*, Wendy E. Wagner, *The Science Charade in Toxic Risk Regulation*, 95 COLUM. L. REV. 1613 (1995); Karkkainen, *supra* note 12 at 869; Katrina Fischer Kuh, *Informational Regulation, the Environment, and the Public*, 105 MARQ. L. REV. 603, 606–07 (2022).

[54] Dave Owen, *After the TMDLs*, 17 VT. J. ENV'T L. 845, 853 & n.53 (2016) ("Current aggregate data on those costs are not easy to find; EPA's last comprehensive estimate of the cost of TMDL development comes from a 2001 draft report, which predicts that aggregate state costs would level off at between 68 and 75 million dollars per year. EPA's cost estimates for implementing TMDLs are much higher. But given the uneven implementation of TMDLs, those estimates may not correspond to anything actually occurring in the real world. They also may be far lower than the direct costs of developing some alternative program that effectively regulates the pollution sources that TMDLs might target. The financial benefits of such a program also might be quite large, but that is a question for another analysis." (citation omitted)).

[55] *See* U.S. ENV'T PROT. AGENCY, NATIONAL COSTS TO IMPLEMENT TMDLS (DRAFT REPORT): SUPPORT DOCUMENT # 2, at 3 (2001), https://perma.cc/8SB5-9FXE (estimating costs of TMDL development).

[56] *See generally* Matthew DeGioia, *Overboard? The Complexity of Traditional TMDL Calculations Under the Clean Water Act*, 49 ENV'T L. REP. 11150 (2019) (breaking down the complexities and imprecision of TMDL calculation into six categories).

[57] *See* Houck, *TMDLs IV*, *supra* note 5, at 10477–78.

the time the CWA was enacted. The TMDL portion of the CWA derives directly from earlier federal attempts to regulate water quality. In 1965, Congress passed the Water Quality Act (WQA),[58] which required states to determine intended uses for water bodies and then monitor water quality and create remediation plans for those waters not meeting water quality goals.[59] This provided the foundation for the TMDL sections of the CWA, which in essence require the same things.[60] However, the first decade of the WQA did not show the desired improvements in water quality throughout the United States, so the federal government went about creating a stronger, more enforceable water quality law: the Clean Water Act.[61]

The scope of the CWA went far beyond that of the WQA, most notably by creating a robust program of controls for point source pollution through the National Pollutant Discharge Elimination System (NPDES).[62] This was the meat of the CWA and the focus for the congressional discussions that led to its passage.[63] However, legislative history shows that Congress also knew of the potential wide-reaching impacts of nonpoint source pollution when the CWA was drafted.[64]

To address nonpoint source pollution concerns, the solution was to import the WQA into the CWA, creating the TMDL program.[65] Congress was resistant to the idea of water quality standards, due to the clear evidence that these were not working in the WQA.[66] However, states and industry insisted on their continued inclusion in the CWA, largely not due to concerns about nonpoint source pollution, but instead as a mechanism for pushing back on federal intervention.[67] Adopting the WQA approach was an expedient and relatively easy way to address a

58 Water Quality Act of 1965, Pub. L. No. 89-234, 79 Stat. 903 (codified as amended in scattered sections of 33 U.S.C.).

59 Robert L. Glicksman & Matthew R. Batzel, *Science, Politics, Law, and the Arc of the Clean Water Act: The Role of Assumptions in the Adoption of a Pollution Control Landmark*, 32 WASH. U. J.L. & POL'Y 99, 102 (2010).

60 *See* Houck, *TMDLs*, *supra* note 6, at 10331–37 (describing the origination of a water quality standards based approach to water pollution in the Water Quality Act and how this approach was later incorporated into the Clean Water Act through water quality standards and TMDLs).

61 Houck, *TMDLs IV*, *supra* note 5, at 10471–72.

62 *See generally id.* at 10475 (chronicling EPA's 1984 in-house assessment, which analyzed the need for technical assistance for states in NPDES permitting).

63 Oliver A. Houck, *TMDLs III: A New Framework for the Clean Water Act's Ambient Standards Program*, 28 ENV'T L. REP. 10415, 10424 (1998) [hereinafter Houck, *TMDLs III*].

64 Glicksman & Batzel, *supra* note 59, at 115 ("A House committee report refers to 'extensive testimony' during oversight hearings 'that nonpoint sources of pollutants could and would, in many cases, preclude the meeting of water quality standards. . . .'").

65 Houck, *TMDLs IV*, *supra* note 5, at 10473.

66 In fact, it was failing so noticeably that it led to the creation of the CWA. *See id.* at 10472 (quoting congressional attitudes towards the WQA's ambient standards).

67 Houck, *The Clean Water Act Returns*, *supra* note 7, at 10209.

problem for which creating realistic regulation would have taken a good deal more time and political motivation than Congress had available.[68]

The CWA did not directly regulate nonpoint sources like it did point sources in part because Congress could not come up with a way to easily regulate nonpoint sources at the time.[69] Nonpoint sources are inherently difficult to regulate, so this outcome is not particularly surprising.[70] The diffuse nature of these sources makes targeting nonpoint source controls extremely difficult.[71] Runoff from hundreds of nonpoint sources can combine before flowing into a water at a level sufficient to cause water quality issues.[72] Once water quality issues are identified, how should regulation be used to effectively target these many diffuse sources? Under the TMDL program, overall nonpoint source pollutant loads for a water are created, but there is no responsibility assigned to any individual nonpoint source for altering their pollutant discharge to help meet these daily load standards.[73]

Beyond the difficulty of regulating diffuse nonpoint sources, linking water quality problems to specific causes was scientifically infeasible at the time the CWA was passed.[74] This was particularly true given that scientific understanding of water quality was limited at the time.[75] Congress may not have fully recognized the dynamism inherent in water quality, relying instead on the equilibrium model of ecology that was then widely accepted.[76] This was not a problem for regulation of point sources, as EPA could rely on technology-based controls to ensure that point sources were minimizing pollutant discharges.[77] In the case of nonpoint sources, though, a reliance on technology-based controls would have required that these controls be applied to an incredibly wide range of activities in order to be effective in combatting pollution issues.[78] From agriculture to logging to stormwater runoff, EPA would have needed to come up with technology standards for a dizzying array of

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[68] *See* Houck, *TMDLs IV*, *supra* note 5, at 10474 (describing the lack of political will to create strong enforcement requirements for nonpoint source pollution).

[69] Glicksman & Batzel, *supra* note 59, at 115.

[70] *See* Houck, *TMDLs IV*, *supra* note 5, at 10474–75 (describing the scientific hurdles to addressing nonpoint source pollution).

[71] *Id.*

[72] *See* DeGioia, *supra* note 56, at 11155.

[73] Notably, TMDLs do apply to already well-regulated NPDES point sources. Houck, *The Clean Water Act Returns*, *supra* note 7, at 10210–11.

[74] If not impossible. *See* Houck, *TMDLs IV*, *supra* note 5, at 10475 ("[T]he science of these programs foundered every step of the way, from accurate assessment of existing conditions, to accurate predication of the effects of particular emissions, to the establishment of limits, to the proof of causation when ambient standards were violated. . . . The requirements of science also make ambient-based systems far more resource intensive than their proponents are willing to acknowledge.").

[75] *See id.* (highlighting various agency findings reflecting only limited data was available regarding key, scientific points for achieving and maintaining successful water quality standards).

[76] Glicksman & Batzel, *supra* note 59, at 108–10.

[77] *Id.* at 120–21.

[78] *See*, Craig, *supra* note 4, at 180 (describing the diverse range of nonpoint sources).

different industries. The logistical and resource requirements of this were outside the realm of possibility.[79]

TMDLs thus seemed like a reasonable approach, particularly in light of the fact that Congress saw the CWA as the first version of an iterative approach to water pollution control.[80] While a robust regulatory approach to nonpoint sources was both technically and politically infeasible, Congress created extensive information gathering requirements that ultimately were intended to provide the basis for a new approach to regulating nonpoint source pollution in the future.[81]

Unfortunately, the hope that the CWA would be iterative and dynamic has largely not borne out. While there have been some amendments and improvements to the CWA in the ensuing fifty years, these have been neither of the scope nor import that congressional drafters likely envisioned.[82] Despite efforts to revitalize the TMDL portions of the CWA from EPA and outside groups, Congress itself has done little to change or improve the CWA's TMDL provisions.[83] While EPA's 2000-era rule changes made critical updates without which the TMDL program would be a regulatory backwater, in the absence of congressional action to add enforcement provisions or broaden the scope of covered sources to include additional nonpoint actors, it is perhaps no surprise that skepticism towards the TMDL program continues to run high.[84]

Not only have few changes been made in the intervening years, the degree to which the CWA was overly ambitious has only become more obvious. Some of this was apparent from the get-go, most notably the no-discharge goal, which may have been intended to serve as a placeholder until Congress had the information necessary to create more realistic targets.[85] In other cases, the unrealistic assumptions of the CWA did not become clear until decades after the CWA was passed.[86] Requirements that states monitor their waters and submit biannual reports to Congress, for instance, were a scientific stretch at the time

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[79] *See* Houck, *TMDLs IV*, *supra* note 5, at 10474 ("[The ambient water quality] approach failed in the 1950s and 1960s for basically the same reasons that it went dormant in the 1970s and 1980s and is proving so difficult to effectuate today. We are short on science.").

[80] Glicksman & Batzel, *supra* note 59, at 116.

[81] *Id.*

[82] *See* Houck, *TMDLs IV*, *supra* note 5, at 10473–74 (describing the history of TMDLs and EPA efforts in the 1990s to update the program).

[83] *Id.*

[84] For discussion of the EPA's late 1990 rulemaking efforts and the limited nature of these updates, see generally Birkeland, *supra* note 20, at 321; RECKHOW ET AL., *supra* note 10, at 15; Houck, *TMDLs IV*, *supra* note 5, at 10473.

[85] *See* Glicksman & Batzel, *supra* note 59, at 105–08 (discussing the rationale behind the no-discharge goal).

[86] Something that is often a feature of regulation in the face of uncertainty. *See* Justin R. Pidot, *Governance and Uncertainty*, 37 CARDOZO L. REV. 113, 115 (2015) ("Indeed, advances in knowledge often serve to unmask the extent of uncertainty, rather than to resolve it.").

the CWA was passed but certainly did not seem infeasible.[87] Fifty years later, the resources required to achieve this goal remain out of reach for all states, with only one-third of waters in the United States being monitored at all, and far fewer monitored frequently enough to yield robust water quality data.[88]

In the decades after the CWA was passed, TMDLs were neglected while EPA focused on implementing the point source NPDES portions of the law.[89] This was a resource-intensive process requiring EPA to create technology standards for many different types of point sources around the country.[90] However, it yielded immediate results: in some cases, water pollution levels dropped to less than half of what they had been prior to the CWA.[91]

Meanwhile, the TMDL portions of the CWA remained largely ignored until the 1990s.[92] A wave of environmental litigation brought by nonprofits and citizen groups spurred EPA to begin preparing 303(d) lists of impaired waters and TMDLs for those waters.[93] This was one of the most significant litigation campaigns in environmental history, as it moved TMDLs from their position as an ignored backwater of the CWA to a central focus of EPA's CWA implementation.[94] Early litigation focused on forcing states to monitor their waters, list impaired ones, and create TMDLs for them on scheduled timelines.[95]

EPA signaled its commitment to the TMDL program in a 2000 rulemaking, formalizing what had become increasingly detailed informal guidance on TMDL implementation.[96] The process of creating these rules was extremely contentious, with over 33,000 comments submitted in the notice and comment process.[97] In making these rules, there was significant disagreement between environmental and industry groups about whether TMDL implementation plans, including limits on nonpoint sources, should be construed as part of the

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87 *See* Houck, *TMDLs IV*, *supra* note 5, at 10473.

88 *See* discussion *supra* Section II. The Clean Water Act's Approach to Nonpoint Source PollutionA.

89 Houck, *TMDLs*, *supra* note 6, at 10329.

90 Houck, *The Clean Water Act Returns*, *supra* note 7, at 10209.

91 Houck, *TMDLs*, *supra* note 6, at 10329–30 & n.6 ("Between 1987 and 1990 alone . . . direct toxic discharges dropped from 417 to 197 million pounds per year . . . .").

92 *Id.* at 10330.

93 Owen, *supra* note 13, at 849–50 (describing the role of citizen litigation generally); Bell, *supra* note 42, 62–63 (listing the TMDL lawsuits brought in key states).

94 Houck, *TMDLs III*, *supra* note 63, at 10416 ("Against a background of federal environmental programs in which litigation has played a central role, it is hard to think of any program more precipitously driven by citizen suits from absolute zero toward its statutory destiny than TMDLs.").

95 *Id.* at 10417.

96 65 Fed. Reg. 43586 (July 13, 2000) (codified at 40 C.F.R. pts. 122–24, 130); Houck, *TMDLs III*, *supra* note 63, at 10421.

97 *See* Bell, *supra* note 42, at 65. Somewhat ironic given that TMDLs today have faded into obscurity for most.

mandatory § 303(d) process or voluntary § 319 planning.[98] While EPA may initially have split the difference, it has become clear in subsequent years that EPA's interpretation is more in line with industry groups arguing that TMDL implementation plans should essentially be voluntary.[99] Section 319's provisions on voluntary funding still drives the majority of action on TMDLs.[100] The implementation of the 2000 rules, following on the heels of successful litigation, spurred optimism that TMDLs could be the new heart of the Clean Water Act.[101]

In the next decade, over 69,000 TMDLs were prepared.[102] Some have argued that EPA made an intentional choice to ignore the TMDL program prior to the 1990s not just because of EPA's resource constraints but also because they did not believe the program would be effective.[103] The concerns about the TMDL program were not limited to EPA; many academics at the time and well after expressed similar views that the TMDL program was unlikely to be effective.[104] These misgivings stemmed largely from the seeming issues with the regulatory design of the TMDL program.

C. The Theory Behind TMDLs

The energy devoted by EPA and the states to implementing TMDLs reflected a bet that an essentially voluntary, information-based approach to water pollution management would be effective. This Article asks whether that bet paid off, but first it looks to the theoretical basis for this approach. While political and logistical constraints were the largest factors driving the shape of the TMDL program, the solutions that were drawn upon are popular regulatory strategies throughout environmental law.[105] TMDLs thus provide insight into the efficacy of these approaches to environmental management.

The problem that Congress was faced with when creating the TMDLs, and EPA when drafting the rules to implement them, reads like a canon of classic environmental management challenges: diffuse actors

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98 Houck, *TMDLs III*, *supra* note 63, at 10422.

99 Houck, *The Clean Water Act Returns*, *supra* note 7, at 10210.

100 *See, e.g.*, U.S. GOV'T ACCOUNTABILITY OFF., GAO-12-335, NONPOINT SOURCE WATER POLLUTION: GREATER OVERSIGHT AND ADDITIONAL DATA NEEDED FOR KEY EPA WATER PROGRAM (2012) (evaluating only the impacts of § 319 as EPA's primary approach to managing nonpoint source pollution).

101 *See generally* Birkeland, *supra* note 20.

102 Owen, *supra* note 13, at 850.

103 *Id.* at 848 ("States did not even publish lists of impaired waterways, let alone write TMDLs, and EPA did not step into the void. The agency had decided its efforts were better spent elsewhere.").

104 *Id.* at 850 ("From the get-go, TMDL litigation had its skeptics; many commentators registered concerns about how efficacious Clean Water Act section 303 would ever really be.").

105 And similarly to TMDLs, these approaches are generally used as a second-based approach when more intensive regulatory strategies are off the table.

that are difficult to regulate,[106] scientific uncertainty about the sources and impacts of pollutants,[107] technological hurdles to pollution control technology,[108] lack of political motivation to enact strong enforcement mechanisms,[109] and strong industry pressure to prevent costly regulatory measures.[110] In the face of these challenges, traditional command-and-control regulation is rarely successful.[111] Instead, two other solutions have surfaced as particularly popular approaches: information forcing and adaptive regulations. Each have their own benefits. Adaptive regulation can, in theory, respond and change over time as more scientific information is available or technological capabilities change. Information regulation, meanwhile, can help to close data gaps necessary to inform better management and in general is a politically palatable approach for both industry and environmental groups. TMDLs, in one way or another, have characteristics of each of these approaches to environmental regulation.

1. Information Forcing

Some have argued that TMDLs primarily serve an information forcing function.[112] This view aligns with the congressional record;

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[106] *See, e.g.*, Neil Gunningham & Cameron Holley, *Next-Generation Environmental Regulation: Law, Regulation, and Governance*, 12 ANN. REV. L. & SOC. SCI. 273, 276 (2016) (discussing the economic difficulties of regulating diffuse, heterogenous sources generally); J.B. Ruhl, *Farms, Their Environmental Harms, and Environmental Law*, 27 ECOLOGY L.Q. 263 (2000) (describing the specific issues inherent in regulating agricultural sources of pollution).

[107] *See, e.g.*, Daniel Kim et al., *Judicial Review of Scientific Uncertainty in Climate Change Lawsuits: Deferential and Nondeferential Evaluation of Agency Factual and Policy Determinations*, 46 HARV. ENV'T L. REV. 367 (2022) (describing scientific uncertainty in climate change litigation); Melanie E. Kleiss, *NEPA and Scientific Uncertainty: Using the Precautionary Principle to Bridge the Gap*, 87 MINN. L. REV. 1215, 1216 (2003) (describing scientific uncertainty in environmental impact assessments); Wagner, *supra* note 53, at 1616 (describing scientific uncertainty in toxic risk regulation); Eric Biber, *Which Science? Whose Science? How Scientific Disciplines Can Shape Environmental Law*, 79 U. CHI. L. REV. 471 (2012) (describing scientific uncertainty across different environmental science relevant disciplines).

[108] *See* OLIVER A. HOUCK, THE CLEAN WATER ACT TMDL PROGRAM: LAW, POLICY, AND IMPLEMENTATION 136 (2d ed. 2002) ("Pollution control systems based on ambient standards have always relied more on science than science can deliver.").

[109] *See, e.g.*, Houck, *TMDLs IV*, *supra* note 5, at 10479–80 (explaining how lack of political will shaped the development of TMDL regulation).

[110] *Id.* at 10472; Malone, *supra* note 23, at 388 (describing the contentious nature of TMDL development).

[111] Gunningham & Holley, *supra* note 106, at 276 (describing the difficulty with "direct regulation" in the face of many environmental challenges).

[112] *See, e.g.*, Mandi M. Hale, Comment, Pronsolino v. Marcus, *the New TMDL Regulation, and Nonpoint Source Pollution: Will the Clean Water Act's Murky TMDL Provision Ever Clear the Waters?*, 31 ENV'T L. 981, 1007 (2001) (noting the purely informational function of TMDLs for nonpoint sources); Malone, *supra* note 23, at 392 ("[T]he TMDL process has provided valuable monitoring information of pollution in water bodies, allowing greater public awareness and leading to technically sound and legally defensible decisions for attaining and maintaining water quality standards.").

Congress believed that the TMDL program was an important step in gathering the information necessary to inform future nonpoint source pollution regulation.[113] While there is an argument that Congress in the 1970s may have imagined purposes for TMDLs beyond just information gathering, e.g. in creating actual mandatory regulatory burdens, in the decades following the CWA's creation, EPA's interpretations have placed TMDLs squarely in the category of information regulation.[114]

As a category, information regulation requires regulated entities to disclose information but does not attach any regulatory penalties or requirements to that information.[115] The key purpose of this approach is the information itself, with the process of providing this information theoretically leading to increased transparency, both internally within firms and externally to stakeholders, incentivizing pro-environment behavioral changes.[116]

The baseline monitoring requirements of 305(b) lists are a relatively typical example of information regulation. Information disclosure generally requires regulated entities, in this case states, to collect information and then make that information available to regulators or the public.[117] Information forcing is distinguished from other types of regulation by the feature that information disclosed is not linked to any regulatory penalties.[118] TMDLs arguably stray slightly from this model by requiring additional regulatory work (the creation of a TMDL) based on the outcomes of monitoring (if monitoring reveals that a water is impaired). However, these burdens are not typically considered penalties such that regulations would no longer be considered information forcing.[119]

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113 Glicksman & Batzel, *supra* note 59, at 116.

114 *See id.* ("[The House committee report noted that] the information-gathering provision concerning nonpoint sources was 'among the most important in the 1972 Amendments.'").

115 *See generally* David W. Case, *The Law and Economics of Environmental Information as Regulation*, 31 ENV'T L. REP. 10773 (2001). Information regulation is also called, variously, information forcing regulation or disclosure regulation. Karkkainen, *supra* note 12; Kuh, *supra* note 53; Cass R. Sunstein, *Informational Regulation and Informational Standing:* Akins *and Beyond*, 147 U. PA. L. REV. 613 (1999).

116 *See, e.g.*, Bradley C. Karkkainen, *Information as Environmental Regulation: TRI and Performance Benchmarking, Precursor to a New Paradigm?*, 89 GEO. L. J. 257, 261 (2001) (describing the mechanisms driving information forcing).

117 *See, e.g.*, Madhu Khanna et al., *Toxics Release Information: A Policy Tool for Environmental Protection*, 36 J. ENV'T ECON. & MGMT. 243 (1998) (discussing toxics disclosures under TRI); Claudia Polsky & Megan Schwarzman, *The Hidden Success of a Conspicuous Law: Proposition 65 and the Reduction of Toxic Chemical Exposures*, 47 ECOLOGY L.Q. 823 (2021) (discussing chemical disclosures under Prop 65); Claude E. Walker, *The Lead-Based Paint Real Estate Notification and Disclosure Rule*, 8 BUFF. ENV'T L. J. 65 (2000) (explaining home-buyer lead paint disclosures); Amanda M. Rose, *A Response to Calls for SEC-Mandated ESG Disclosure*, 98 WASH. U. L. REV. 1821 (2021) (explaining proposal for SEC climate disclosures).

118 Karkkainen, *supra* note 12.

119 Notably though the presence of regulatory burdens may be an important feature dictating the efficacy of information forcing regulation. Both TMDLs and NEPA share

The mandate to create full TMDLs is on the more onerous end of information forcing requirements. Many laws present relatively simple disclosure mandates, for instance the Toxics Release Inventory (TRI), perhaps the most paradigmatic example of environmental disclosure regulation, or Proposition 65.[120] Under the TRI, firms are simply required to submit an annual list of what toxic chemicals they released and in what quantity, a process EPA has estimated costs firms only $1,100.[121] TMDLs fall on the opposite end of the spectrum, along with other notoriously burdensome environmental information laws like the National Environmental Policy Act (NEPA).[122] These laws require something beyond simple checkbox disclosure, instead requiring that regulated entities complete extensive scientific research and analysis in order to fulfill their information mandates.[123]

In many ways, NEPA is the closest information forcing analog to TMDLs. While NEPA is traditionally categorized as a procedural environmental law and the CWA a substantive one, in practice the TMDL provisions fulfill more of a procedural function. Both laws require not only extensive data collection but also significant analysis of this data, something that is rare in other information disclosure laws.[124] In the case of NEPA, this analysis involves turning environmental data into Environmental Impact Statements, which can run into the thousands of pages.[125] TMDLs similarly require states to turn baseline water quality data into complete TMDL reports, a process that requires extensive hydrogeologic modeling to understand where pollution is coming from and what its impacts likely are.[126] Once these extensive reports are created, both NEPA and TMDLs have no requirements for

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these regulatory burdens. *See* Annie Brett, *Rethinking Environmental Disclosure*, 112 CAL. L. REV. 1535, 1565 (2024) (describing regulatory burdens associated with NEPA assessments).

[120] Karkkainen, *supra* note 12, at 871–75 (discussing disclosure as regulatory penalty under Proposition 65); *see generally* Clifford Rechtschaffen, *The Warning Game: Evaluating Warnings Under California's Proposition 65*, 23 ECOLOGY L. Q. 303 (1996) (discussing Proposition 65 requirements and implementation).

[121] *See* Andrew Schatz, *Regulating Greenhouse Gases by Mandatory Information Disclosure*, 26 VA. ENV'T. L. J. 335, 336 n.3 (2008) (finding that each TRI response costs an average of only $1,156 and just under 20 person-hours to create, according to EPA estimates).

[122] National Environmental Policy Act of 1969, 42 U.S.C. §§ 4321–4347. NEPA's information disclosure is so burdensome that some have argued it could function as a carbon tax to incentivize agency behavioral change. *See generally* Sarah E. Light, *NEPA's Footprint: Information Disclosure as a Quasi-Carbon Tax on Agencies*, 87 TUL. L. REV. 511 (2013).

[123] *See, e.g.*, Bradley C. Karkkainen, *Toward a Smarter NEPA: Monitoring and Managing Government's Environmental Performance*, 102 COLUM. L. REV. 903, 909–16 (2002) (describing NEPA's information disclosure requirements).

[124] *See* Karkkainen, *supra* note 116, at 286–87 (describing TRI as an information disclosure law that only requires reporting of basic toxic releases with minimal attendant analytical effort).

[125] Karkkainen, *supra* note 123, at 918 & n.64.

[126] *See* discussion *supra* Section II.A.

action.[127] In the case of NEPA, the hope is that the mere act of evaluating the environmental impacts will cause entities to change behavior.[128] With TMDLs, the hope is also that water quality will improve simply by having water quality targets in place, even though there are no comprehensive regulatory mandates to comply with these targets.

Theoretically, the information created by TMDLs could be extremely useful.[129] Given the general dearth of water quality data TMDLs could play an important role in filling data gaps.[130] This is particularly true given that the majority of water quality data is very basic and not temporally or geographically robust.[131] TMDLs require detailed analysis and modeling to understand water quality conditions on a systemic level, an endeavor that drives additional data collection and could generate important new synthetic information.

2. Other Mechanisms

While TMDLs are primarily framed as information forcing provisions, they also embody aspects of other approaches to environmental regulation. Understanding how, and if, these approaches can complement information disclosure provisions provides important lessons into structuring nonpoint source regulation. Specifically, TMDLs adopt provisions that echo the mechanisms and outcomes of command-and-control and adaptive regulation. This section considers the theoretical foundations of each of these provisions in the nonpoint source pollution context in turn. It is worth noting that much of the current discussion of TMDL design is largely *post hoc* justifications—a desire to make something make sense that simply does not and did not at the time it was enacted. Nonetheless, better understanding the mechanistic basis, even if those mechanisms were relied on unintentionally, can point the way towards future improvements in regulation of nonpoint source pollution.

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[127] Or at least requirements for action in any significant way: TMDLs do, of course, require updates to NPDES load allocations for point sources, but fail to extend these to any other sources.

[128] *See, e.g.*, Kirk Emerson & Elizabeth Baldwin, *Effectiveness in NEPA Decision Making: In Search of Evidence and Theory*, 21 J. ENV'T POL'Y & PLAN. 427, 440 (2019); John Ruple & Mark Capone, *NEPA—Substantive Effectiveness Under a Procedural Mandate: Assessment of Oil and Gas EISs in the Mountain West*, 7 GEO. WASH. J. ENERGY & ENV'T L. 39, 39–40 (2016).

[129] *See* Houck, *The Clean Water Act Returns*, *supra* note 7, at 10211 ("[W]hat we have succeeded in doing here is produce a great number of [TMDL] documents that could be useful, depending upon what implementation, if any, comes next.").

[130] *See id.* at 10211–12 (describing the gaps in water quality data).

[131] *Id.*

a. Command and Control

Parts of the Clean Water Act, namely the NPDES point source controls, are a canonical example of command-and-control regulation. The CWA water quality standards and TMDLs, on the other hand, are not generally considered command-and-control. But not analyzing them under this framework is an oversight: the driving logic at the time of their creation was that of command-and-control, and many of the features of the resulting TMDL regulations share the foundational building blocks of command-and-control approaches.

Under the traditional model, command-and-control regulations require that regulated entities apply certain pollution-curbing technologies (technology standards) or remain below certain quantitative pollution thresholds (performance standards).[132] These standards are enforced with both civil and criminal penalties if they are violated.[133] The government is thus commanding that regulated entities comply with environmental standards and controlling this outcome through ongoing monitoring and enforcement mechanisms.

The water quality approach and TMDLs exhibit many of the command features of command-and-control without the attendant control measures.[134] TMDLs set out specific standards both in the form of water quality targets for all waters and more granular load allocations as part of TMDLs themselves.[135] What sets TMDLs apart is the lack of enforcement mechanisms tied to these standards. While point sources are subject to enforcement, nonpoint sources are not.[136] As a result, TMDLs in many cases are essentially empty commands to comply with standards that will never be enforced.

The choice to frame TMDLs with only half of the features needed to make successful command-and-control regulation work was not only due to the political and scientific constraints at the time the CWA was passed. To many, the attraction of TMDLs lay in the flexibility they allowed: unlike the NPDES portions of the CWA, water quality standards and TMDLs gave additional control to the states to set water quality standards.[137]

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[132] *See, e.g.*, Eric W. Orts, *Reflexive Environmental Law*, 89 NW. U. L. REV. 1227, 1235 (1995) (discussing command-and-control techniques).

[133] *Id.*

[134] Though point sources are subject to controls, making TMDLs in their application to point sources a clear example of command-and-control regulation.

[135] Clean Water Act, 33 U.S.C. §§ 1315(b), 1313(d) (2018).

[136] Houck, *TMDLs*, *supra* note 6, at 10474 (noting that TMDLs are merely informational as applied to nonpoint sources).

[137] *See* Glicksman & Batzel, *supra* note 59, at 101 ("The statute's failure to perform even more admirably than it has is due largely to a lack of legislative clarity in addressing the role of wetlands in preserving the integrity of aquatic ecosystems and to Congress's unwillingness to adopt, or force the states to adopt, measures to control nonpoint source pollution."); Houck, *TMDLs IV*, *supra* note 5, at 10472–74 ("State and local agencies were

In the intervening decades since the heyday of command-and-control in the 1970s, scholars, managers, and environmentalists have increasingly called for movement away from the command-and-control model.[138] Critics of command-and-control point to the lack of flexibility in the system,[139] the high economic costs of compliance,[140] and the coercive nature of the state[141] as some of the major consequences of adopting this approach. Traditional quantitative command-and-control regulations stifle creativity and incentivize short-term thinking.[142]

Unfortunately, these issues are also prevalent in the TMDL program, which exhibits many of the flaws of command-and-control without the benefits. TMDLs create quantitative targets for water pollution goals (command) without the complementary requirement that polluters abide by these targets (control). The regulatory backbone of TMDLs thus looks very similar to traditional environmental laws while lacking any of the features that many commenters argue are needed to make for better, more adaptive regulation. TMDLs fit neither the model of flexible adaptive or market-based regulation nor the model of true, quantitative command-and-control regulation.

b. Adaptive Regulation

Other theoretical support for the structure of TMDLs can be found in the literature of adaptive regulation, one of the more recent darlings of environmental law.[143] In situations rife with uncertainty, either over the underlying environmental conditions or the appropriate legal mechanisms for tackling them, adaptive regulation can be a particularly appealing strategy.[144] In these circumstances, passing laws that are intended to evolve over time allows Congress to begin to address a

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said to be in a far better position to know the numerous 'local and natural variables' for pollution control.").

138 *See, e.g.*, J.B. Ruhl, *Thinking of Environmental Law as a Complex Adaptive System: How to Clean Up the Environment by Making a Mess of Environmental Law*, 34 HOUS. L. REV. 933, 940 (1997) ("[T]he coercive, regulatory, command-and-control state has produced some admirable results in terms of environmental protection, but the underlying reductionist premises of that approach have exhausted their usefulness and will never allow us to tackle the significant environmental challenges ahead.").

139 *Id.* at 988.

140 *See generally* Orts, *supra* note 132 (discussing and exemplifying how economic studies show that command-and-control methods are often inefficient and irrational).

141 *See generally* Jodi L. Short, *The Paranoid Style in Regulatory Reform*, 63 HASTINGS L. J. 633 (2012) (analyzing the coercive nature of administrative government).

142 Ruhl, *supra* note 138, at 988.

143 *See* Eric Biber, *Adaptive Management and the Future of Environmental Law*, 46 AKRON L. R. 933, 935 (2013) ("Adaptive management has become a dominant theme in the scholarship and practice of environmental law, so dominant that many scholars and managers assert that the *only* feasible option for environmental law is adaptive management.").

144 *See generally id.* (framing adaptive regulation as a response to uncertainty).

problem while ensuring that regulation can be changed over time as new information or technological capabilities emerge.[145]

In the case of the TMDL program, uncertainty over the significance of nonpoint source pollution and doubts about how to go about addressing this problem drove Congress's choice to structure the program with more focus on information gathering than strong regulatory enforcement.[146] While the theory of adaptive regulation was not the wunderkind in 1972 that it is today, the idea that TMDLs were a first step in what would be an evolving regulatory process aligns with current ideas about how regulation can be designed to tackle uncertainty and evolve over time.

The theoretical foundations for the appeal of adaptive regulation hinge on the recognition that current "static laws" are unable to adequately address new and emerging challenges or take advantage of scientific and technological advances.[147] This is particularly true in environmental law, where major pollution control regulations were passed in the 1970s and have received relatively few updates in the intervening fifty years.[148] These fifty-year-old laws are being asked to tackle entirely new environmental problems from climate change to invasive species. In a purely theoretical world, the best way to tackle these emerging challenges would be with new laws. However, political realities suggest that it is highly unlikely that any significant new environmental laws will be passed in the near future.

Adaptive regulation, then, provides a potential answer by creating structures that allow, and in some cases require, regulations to change to address new circumstances. Adaptive regulation integrates mechanisms that allow managers to test different management approaches, and such experimentation can trigger regulatory change.[149] A key feature that distinguishes static law from adaptive law is whether there are structural mechanisms built into the law that force its evolution over time.[150] In some cases, this takes the form of durational regulation, time bound regulations with sunset provisions that must be revisited at certain points.[151] Other adaptive regulation instead focuses on internal procedural mechanisms that require reconsideration of

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145 *See, e.g.*, Holly Doremus, *Adaptive Management as an Information Problem*, 89 N.C. L. REV. 1455, 1464 (2011) ("Adaptive management has been touted as a way to deal with the information deficit, allowing action in the face of uncertainty in the short run while information gaps are filled in over the longer term.").

146 Glicksman & Batzel, *supra* note 59, at 116.

147 Ruhl, *supra* note 138, at 938–40.

148 *See generally* Richard Lazarus & Sara Zdeb, *Environmental Law & Politics,* AM. BAR ASS'N (Jan. 5, 2021), https://perma.cc/LT9Y-FWUQ (highlighting the evolution of environmental law in the political context from 1970's to present day).

149 *See* discussion *supra* Section I.B.

150 *See generally* Pidot, *supra* note 86, at 113 ("'Static law' is a legal rule initially intended to last in perpetuity. 'Dynamic law' which is intended to change, and includes [distinguishable features].").

151 *Id.*

substantive regulation in light of new information or changing conditions.[152] It is important to note that many discussions of adaptive regulation focus on adaption as it relates to the nitty-gritty implementation options of a regulatory program, not adaptation of entire regulations themselves.[153]

TMDLs are potentially a ripe candidate for adaptive regulation.[154] Large, complex systems like watersheds are difficult to understand and information gaps are pervasive.[155] Making fixed regulatory decisions at early stages can prevent the uptake of needed information later in the process. It seems that Congress realized this when they passed the Clean Water Act, but unfortunately the TMDL program was written not as a true adaptive regulation but as a static law.[156] While Congress may have hoped that the TMDL program would be the first step towards additional regulation,[157] they built none of the features of adaptive regulation into TMDLs or the CWA more generally. Because of its framing as a static law, it is unsurprising that there have been relatively few changes to the program since it was initially enacted.

Under information forcing or adaptive regulatory theories, it may be not a bug but a feature that TMDLs were structured without any regulatory penalties. In some ways, TMDLs represent a more modern approach to environmental management given that the command-and-control model is seen increasingly as a flawed approach.[158] TMDLs are instead an example of an "ambient" approach to environmental regulation.[159] Under this ambient approach, the goal is to understand the baseline conditions of an ecosystem first and then put in place the necessary controls to achieve healthy ecosystem functioning.

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[152] *Id.* at 151.

[153] *Id.* at 113.

[154] *Id.* at 154 ("For example, a state agency attempting to reduce nonpoint source water pollution from road construction projects might require silt fences along one stream, a vegetative buffer along another, and a storm water management system along a third. Over time, the agency would assess the efficacy of each management regime and use comparative information to formulate new policies.").

[155] *See* Houck, *The Clean Water Act Returns*, *supra* note 7, at 10227 (describing the information challenges in watershed management through ambient quality standards).

[156] CLAUDIA COPELAND, CONG. RSCH. SERV., 97-831, CLEAN WATER ACT AND TOTAL MAXIMUM DAILY LOADS (TMDLS) OF POLLUTANTS, at CRS-2 (2008) ("The TMDL itself does not establish new regulatory controls on sources of pollution.").

[157] Glicksman & Batzel, *supra* note 59 ("[T]he CWA as initially adopted was an experiment whose impact and sufficiency would be reassessed as implementation proceeded.").

[158] Richard B. Stewart, *A New Generation of Environmental Regulation?*, 29 CAP. U. L. REV. 21, 21 (2001).

[159] Birkeland, *supra* note 20, at 316–17.

III. EVALUATING THE EFFICACY OF TMDLS

The CWA's stated goal is to provide fishable, swimmable waters throughout the nation.[160] Fifty years after its passage, whether it is achieving its goal of improving water quality in impaired waters remains unclear. When EPA made efforts to begin real implementation of TMDLs in the late 1990s, there was a good deal of academic debate about the merits of the program, with scholars taking turns evaluating aspects of the TMDL program and making predictions about whether it was likely to be effective.[161] However, in the twenty years since, this discussion has dropped off. The scale of implementing the TMDL program has made it a relatively slow process, further impeded by a sense of confusion among state water managers and others charged with on the ground implementation of TMDLs.[162] As a result, the majority of EPA data collection efforts and subsequent academic analysis have focused on whether TMDLs were being implemented at all.[163] The question of whether TMDLs were effective once they were in place was not yet ripe for the asking. Now, twenty years later, enough time has passed to begin take stock of whether or not TMDLs have actually been successful in improving national water quality.

While some have looked at specific case studies of TMDL implementation, few have attempted to answer the broad question of just how successful TMDLs have been in improving water quality on a programmatic level. Professor Dave Owen began to address this in 2016, noting that early evidence suggests that TMDLs have been far from effective but that truly answering that question is impossible without more robust quantitative data.[164] The EPA itself has likewise made some quantitative efforts, but these have largely been stymied by incomplete data sets.[165] Some recent scientific literature begins to also address this question, showing how various aspects of EPA's approach to nonpoint source pollution, from grant spending to water quality

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[160] Clean Water Act § 101(a)(2), 33 U.S.C. § 1251(a)(2) (2018).

[161] *See, e.g.*, Houck, *TMDLs III*, *supra* note 63; Birkeland, *supra* note 20; Boyd, *supra* note 13, at 39; Linda A. Malone, *The Myths and Truths That Ended the 2000 TMDL Program*, 20 PACE ENV'T L. REV. 63, 63 (2002).

[162] Owen, *supra* note 13, at 851 ("EPA has surveyed its regional TMDL staff to find out about levels of awareness of, and interest in, TMDLs among staff at state and local planning offices, agricultural agencies, and other governmental entities that might partner in TMDL implementation. Those surveys revealed a widespread perception that the very people who ought to be implementing TMDLs instead lack understanding of, and commitment to, the TMDL program.").

[163] *See id.* at 850–51 (describing recent academic scholarship on TMDL efficacy).

[164] *Id.* at 851.

[165] U.S. ENV'T PROT. AGENCY, *supra* note 38 ("The TMDL and surface water quality performance measures we reviewed do not provide clear and complete metrics of the program's accomplishments. . . . All of these measures are unclear, and some are inconsistently reported in EPA's publications.").

monitoring frequency, have failed to improve water pollution outcomes.[166]

This Article steps into this arena, adding to the discussion with new quantitative evidence that uses nationwide data on TMDL implementation to understand whether the TMDL program has led to any appreciable improvements in water quality over time. To understand whether the TMDL program is leading to high-level water quality improvements, this analysis looks at whether waters with TMDLs in place are moving from an impaired status to an attaining status over time.[167] If TMDLs are working, we would expect to see that water quality in waters with TMDLs improves over time so that these waters are no longer listed as impaired.[168]

Addressing the question of TMDL success requires working with widespread data gaps and a lack of systematic data collection, making this analysis both difficult and inherently limited.[169] Unfortunately, this is true not only with TMDLs but also with many types of environmental regulation. The ways that Congress structured required data collection and submission under the CWA have led to rampant inaccuracies, and as some have convincingly argued, an overstatement of what we know about waterbody health across the United States.[170] While well-intentioned, CWA required data submissions reveal relatively little important information about water quality.[171] In looking to understand whether TMDL implementation has an appreciable impact on water quality, this Article presents a first round of quantitative analysis. Future work following this will focus specifically on mitigating

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166 *See, e.g.*, Nathan Tomczyk et al., *Nonpoint Source Pollution Measures in the Clean Water Act Have No Detectable Impact on Decadal Trends in Nutrient Concentrations in U.S. Inland Waters*, 52 AMBIO 1475, 1475 (2023); Andrea L. Crumpacker et al., *A National Assessment of TMDL Effectiveness Monitoring Approaches*, PROC. OF THE WATER ENV'T FED'N, 2007, at 238, 243; JOHN HOORNBEEK ET AL., IMPLEMENTING TOTAL MAXIMUM DAILY LOADS: UNDERSTANDING AND FOSTERING SUCCESSFUL RESULTS 11–12 (2008), https:// https://perma.cc/4Z7U-WK6C; *see also* Craig A. Stow & Mark E. Borsuk, *Assessing TMDL Effectiveness Using Flow-Adjusted Concentrations: A Case Study of the Neuse River, North Carolina*, 37 ENV'T SCI. & TECH. 2043, 2050 (2003).

167 *See* discussion *infra* Part III (discussing future work on a more granular analysis of water quality changes over time).

168 Note that looking at whether a water has a TMDL in place is not an accurate indicator of whether or not the water quality in that water is impaired: EPA encourages states to keep TMDLs in place, even once water quality standards are met in an attempt to protect this water in the future and ensure that water quality remains acceptable in the long term.

169 *See, e.g.*, U.S. GOV'T ACCOUNTABILITY OFF., *supra* note 100, at 49 (describing the data gaps at issue in nonpoint source pollution management).

170 William L. Andreen, *Water Quality Today—Has the Clean Water Act Been a Success?*, 55 ALA. L. REV. 537, 567 (2004).

171 *Id.* at 566 ("EPA, in turn, is directed to transmit these reports to Congress along with the agency's analysis of the state results. While these reports could have yielded, in theory at least, significant data on overall trends, they have not.").

confounding variables, such as environmental change over time, and improving overall coverage given existing data gaps.[172]

A. Methodology

There are several different metrics that may characterize the success of the TMDL program. Many of these metrics focus on the process of TMDL implementation: the number of waters identified as impaired or the number of TMDLs developed and approved. These are useful first steps, however the goal of the TMDL program is ultimately to improve water quality so that waters are able to support their designated uses.[173] This study specifically addresses this question, looking not just at whether TMDLs are being developed but whether they lead to appreciable improvements in water quality after implementation.

The hypothesis of this study reflects the regulatory hypothesis of the TMDL program: implementing a TMDL in waters that are listed as "impaired," i.e. too polluted to be able to support their designated uses, should over time lead to improvements in water quality. If the TMDL is successful, those improvements should be sufficient to move the water out of the "impaired" classification and into the "attaining" classification, denoting that waterbody health has been improved sufficiently to meet state selected water quality goals.

The easiest way to determine whether water quality in waters with approved TMDLs in place has improved is to look at whether these waters have been moved off the 303(d) impaired waters list onto the attaining list. However, a lack of data standardization limits the effectiveness of this approach. Due to discrepancies in how states manage their 303(d) lists, some TMDLs are moved off the impaired list simply when an approved TMDL is put in place, regardless of whether or not the water remains impaired.[174] In other cases, the water remains on the impaired list when a TMDL is implemented so long as the water is still impaired. These reporting differences mean that any analysis must look independently at each of these categories of waters to determine whether there have been improvements in water quality.

The TMDL process is pollutant-specific. When a water is deemed impaired it is because it exceeds healthy thresholds in one of the established monitoring categories.[175] When the water is then listed as

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[172] Forthcoming work for publication in scientific journals specifically compares waterbodies with TMDLs in place with "control" waters from the same watersheds without TMDLs in place to attempt to understand whether TMDLs are making any appreciable difference in water quality once natural variation and other factors are accounted for.

[173] RECKHOW ET AL., *supra* note 10, at 3.

[174] Arturo A. Keller & Lindsey Cavallaro, *Assessing the US Clean Water Act 303(d) Listing Process for Determining Impairment of a Waterbody*, 86 J. ENV'T MGMT. 699, 700 (2008).

[175] *See generally Overview of Total Maximum Daily Loads (TMDLs)*, *supra* note 11 (providing an overview of TMDLs and how impaired waters are identified).

impaired, a TMDL is created for that specific pollutant.[176] As a result, impairments and TMDLs are linked to remedying specific pollution issues. When this study considers whether water quality of a water body has improved, it looks specifically at whether the TMDL has worked to remedy impairment in a given pollution category.

B. Data

1. Overall U.S. Water Quality and TMDLs

There has been a dramatic rise in the number of TMDLs in place in the last two decades. Before diving into TMDLs specifically, overall data on water quality across the United States shows several critical trends. The first is that roughly half the waters in the United States are currently listed as impaired.[177] While the CWA may have been a success in its first decades of implementation, that success rate has clearly slowed and in many instances reversed.

	Size of Water							
	Rivers and Streams (Miles)	Lakes, Reservoirs, and Ponds (Acres)	Bays and Estuaries (Square Miles)	Coastal Shoreline (Miles)	Ocean and Near Coastal (Square Miles)	Wetlands (Acres)	Great Lakes Shoreline (Miles)	Great Lakes Open Water (Square Miles)
Good Waters	518,293	5,390,570	11,516	1,298	726	569,328	106	1
Threatened Waters	4,495	30,309						
Impaired Waters	588,173	13,208,917	44,625	3,329	6,218	672,924	4,354	39,230

Figure 1: Number of waters in the United States listed as good, impaired, and threatened as of 2022, from *National Summary of State Information,* U.S. ENV'T PROT. AGENCY (2022), https://perma.cc/8Z3Y-B8VZ. Note that these waters are classified not on the *number* of waters listed in any given category, but on the *overall* size of waters (in miles or acres respectively) in these categories.

Water quality data also shows widespread gaps in baseline water quality information. Over fifty years after Congress passed the CWA, which included a clear regulatory mandate that states biannually submit water quality data to Congress on *all* the waters in their states,[178] states are nowhere near close to achieving this goal. Nationwide only roughly one-third of waters are monitored at all (see Figure 1). And of course, what this data does not reveal is that many of the approximately 1/3 of waters that are currently monitored are monitored infrequently or poorly, leading to data that is unrepresentative at best and misleading and inaccurate at worst.[179]

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[176] *Id.*

[177] Depending on the type of water, this percentage varies. *See* Figure 1.

[178] *See* Clean Water Act, 33 U.S.C. § 1315(b)(1), (2) (2018).

[179] *See* Andreen, *supra* note 170, at 566–67.

2. Delisting Impaired Waters

The first question of this study is how many impaired waters are being moved off the 303(d) impaired list annually and why. TMDLs are one mechanism that might cause water quality improvements and lead to delisting, but there are also potential improvements in water quality that are not driven by regulation and may also lead to impaired water delisting.

Of the 73,951 impaired waters in the United States,[180] over 35,000 were removed from the impaired list between 1997 and 2017 (*see* Figure 2). This delisting could be an indicator of water quality improvements over time if impaired waters are being delisted because they begin attaining water quality standards.

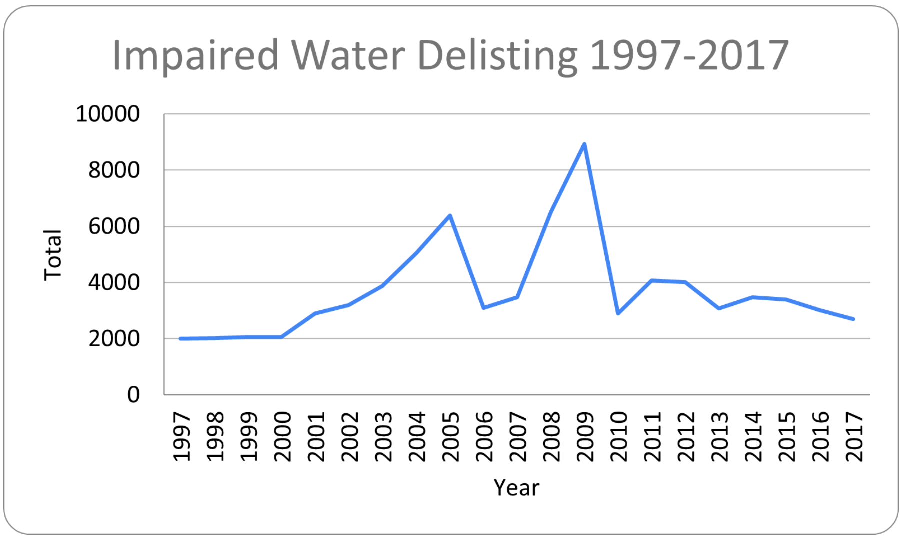

Figure 2: Number of impaired waters moved off of the impaired list annually between 1997 and 2017. Cumulatively, 35,550 impaired waters were delisted in this two-decade period.

However, this data reveals that the reason for impaired water delisting is generally not that waters are now meeting water quality standards. The vast majority of waters (74%) that are delisted are delisted after an approved TMDL is put in place (*see* Figure 3). While some states keep impaired waters on the 303(d) list after TMDLs are implemented, others remove them from the impaired list at this point.[181] Delisting in those states represents the bulk of impaired water delisting. Other waters are being delisted because of administrative changes—either changes in water quality standards (16%) or changes in the

[180] Note that this is a numerical count by water, not by length or area of water as displayed in Figure 1.

[181] This lack of standardization is just one representative example of the data quality and standardization issues inherent in CWA reporting.

geographic boundaries of a water (5%). Most importantly, only 2 out of the 35,550 impaired waters delisted in the last two decades were delisted because they had attained water quality standards.[182]

Reason for Delisting	Number of Waters
TMDL Approved	26402
Change in Terminology	5978
Other	1149
Re-Segmented	2019
Applicable WQS attained; Reason for recovery unspecified	2
Total Impaired Waters Delisted	**35550**

Figure 3: Reasons that impaired waters were delisted and removed from the impaired water list between 1997 and 2017. Listed reasons reflect the available EPA classifications for this category.

This data is useful in evaluating TMDL success for states that keep waters on the impaired list once a TMDL is implemented (so long as the water is still impaired). In these states, if TMDLs are effective we should see waters move off of the impaired list if they are improving in water quality over time. Practically, there is no significant movement of waters off of the impaired list, suggesting that TMDLs in these states are not leading to significant improvements in water quality.[183]

However, in states where impaired waters are removed from the impaired list once TMDLs have been implemented, regardless of their water quality, additional analysis is necessary to determine whether these waters are improving over time. There are no other categorical methods that make this simple. Instead, understanding water quality improvements for these waters requires looking at water quality data for each water individually. Given that there are over 26,000 waters in this category—waters that have been delisted for impairment as a result of TMDL implementation—analysis of the water quality of each of them is currently outside the scope of this study. Instead, this study used a random sample of these waters to understand whether there are trends toward water quality improvement in waters with active TMDLs.

Looking at this nationwide random sample (n=1,993),[184] approximately 3% of waters with TMDLs in place that have been

[182] This is all drawn from state reporting data, so it is important to note that it is very possible that more waters than this may have attained water quality standards but that states have not been reporting them as such.

[183] *See supra* Figure 3 (showing that only two waters moved off the impaired lists because the "applicable water quality standards" had been attained).

[184] Waters were drawn from each state in rough proportion to the total number of TMDLs in each state. Detailed breakdowns of this data are on file with the author and can be shared upon request.

removed from the impaired list (n=59) show sustained water quality improvements.[185] Assuming this 3% is roughly representative of the sample ($p<0.001$), when extrapolated out to cover the full set of waters with TMDLs in place, less than 1% of waters overall that have been delisted show sustained water quality improvements over time.[186]

It is worth noting that this is a relatively coarse analysis: there may be improvements in water quality in waterbodies with active TMDLs that are not large enough to move the water from one classification category to another (i.e. impaired to attaining). Understanding whether these changes are occurring would require looking at granular water quality from each water to understand whether there are trends indicating robust improvement over time and may be an area for future research.

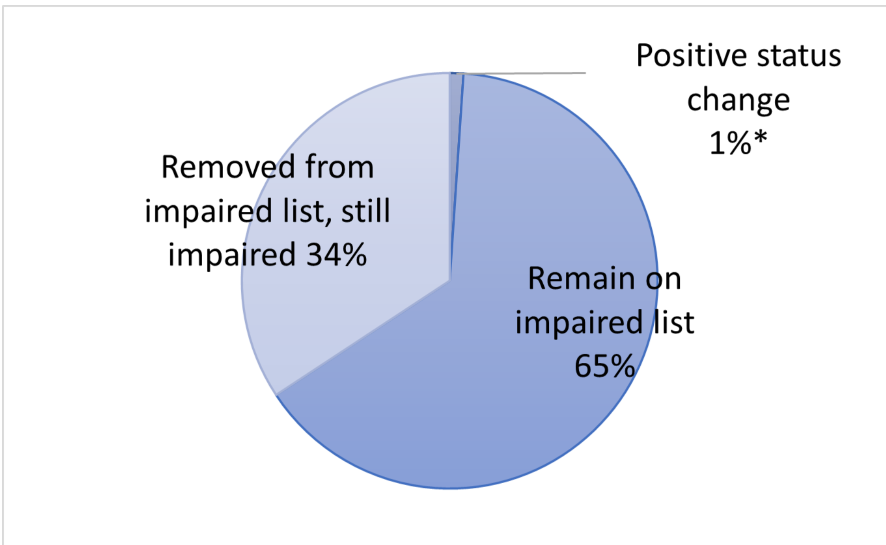

Figure 4: 34% of waters with TMDLs in place have been removed from the impaired list because of this TMDL implementation. 65% of waters with TMDLs in place remain on the impaired list. Of both of these, only approximately 1% of waters with TMDLs in place see sustained water quality improvements that would be sufficient to lead to them "attaining" water quality standards.

One other mechanism of identifying whether TMDLs are effective would theoretically be to look at whether there are waters which once had TMDLs in place and then had those TMDLs removed after the water began attaining water quality goals. EPA historically has

[185] Measured as water quality improvements that would be sufficient enough to move the water from the impaired list to the category of attaining water quality standards.

[186] In addition to this statistical analysis, this study looked at whether there was any correlation between improvements in water quality over time and size of waters, geographic location of water, type of waterbody, and type of pollution. No significant relationships were found for any of these variables.

discouraged states from removing TMDLs once water quality has improved, noting that keeping these TMDLs in place is likely necessary to continue to maintain good water quality.[187] However, new trends have seen states setting increasingly clear, quantitative TMDL endpoints.[188] These endpoints are created as part of TMDL documentation and set thresholds for when TMDLs will no longer be needed for that water.

Overall, this analysis provides important insights into whether the CWA's TMDL program is achieving its goal of improving water quality and moving waters off the impaired list over time. This data suggests clearly that only a very small proportion of impaired waters have seen significantly improved water quality after the implementation of a TMDL. This is nonetheless a relatively rough measure of TMDL efficacy: a more in-depth analysis would look not just at whether waters are being moved from impaired status to attaining status, but whether more granular improvements in water quality are occurring in these waters regardless of status. Understanding whether non-point source efforts like TMDLs are working also requires not just looking at these regulatory mechanisms but also separating out natural changes to ecosystems that are occurring independent of regulatory interventions. Teasing out these natural changes is extremely difficult, and without robust long-term data from a given water body it is effectively impossible.

This Article sets the stage for future work that will address these questions, focusing not just on whether the waters have moved from the impaired category to the attaining water quality standards category but using more granular analysis of water quality indicators to track smaller changes in water quality. Additionally, analyzing a sample of paired waters from the same watershed where one water has an approved TMDL and the other does not will be used to control for additional factors, like nationwide increase in nonpoint water pollution that may confound a simpler analysis.

IV. REMEDYING NONPOINT SOURCE POLLUTION REGULATION

This is the first time nationwide data has shown that TMDLs are not working to improve water quality in a meaningful way. Less than 1% of waters with TMDLs in place have seen positive status improvements in the past two decades.[189] Given concerns raised when the TMDL program was reinvigorated, this result is perhaps

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[187] Of course, this advice seems largely theoretical given the lack of evidence of significant numbers of waters with TMDLs that have shown water quality improvements over time.

[188] *See, e.g.*, D.C. DEP'T OF ENERGY AND THE ENV'T, CONSOLIDATED TOTAL MAXIMUM DAILY LOAD (TMDL) IMPLEMENTATION REPORT 116 (2022), https://perma.cc/GZ2N-H6J9 ("The endpoint of the TMDL is DC's tidal Anacostia water clarity criterion.").

[189] *See* discussion *supra* Section III.B.2.

unsurprising.[190] What is surprising is the degree of the failure and the resources that are currently being invested in achieving what is arguably very little environmental progress. Twenty years of data on TMDL implementation show that it is time to rethink our approach to nonpoint source pollution. Over half of the waters nationwide are impaired.[191] There is no doubt that nonpoint source pollution is the major cause of these issues; the CWA's point source oriented NPDES controls have by all accounts been a resounding success.[192] The TMDL program, however, is not working to remedy nonpoint source pollution issues.

The party line is that the easy work of environmental protection has already been done: the command-and-control regulations of the 1970s targeted pollution's low-hanging fruit and making further advances will require significant additional investments for much lower returns.[193] However, it is not entirely true that "major sources of pollution and wastes are already tightly controlled."[194] Nonpoint source pollution is certainly major but not at all tightly controlled. Remedying this issue is the next great challenge of water pollution management.

Despite the scope of the challenge, nonpoint source pollution is not an unsolvable problem. Countless scholars over the past three decades have proposed solutions to nonpoint source pollution.[195] Individual examples in states and other countries demonstrate myriad different

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[190] *See, e.g.*, Houck, *TMDLs*, *supra* note 6, at 10330 ("At the bottom of these developments is an approach to pollution control—regulating dischargers by their impact on receiving water quality—that never really worked in the first place and is back for another try. One could have legitimate doubts about it this time as well.").

[191] *See* discussion *supra* Section III.B.1.

[192] *See* Houck, *TMDLs IV*, *supra* note 5, at 10469 ("The federal Clean Water Act (CWA) could lay claim to being the most successful environmental program in America. . . . [T]he ineludible fact is that the Act's fixed deadlines, technology standards, permits, and enforcement mechanisms have stimulated measurable compliance, new and improved technologies, source reduction, waste recycling, and a growing number of voluntary, quasi-voluntary, and alternative abatement schemes.").

[193] Stewart, *supra* note 158, at 28 ("Further reductions will be quite costly and require significant advances in technologies and the organization of production, distribution, consumption, and treatment of post-consumer residuals.").

[194] *Id.*

[195] *See generally, e.g.*, *id.* at 108 (proposing effluent trading as an alternative approach to reduce nonpoint source pollution); Birkeland, *supra* note 20, at 297 (explaining that the TMDL provisions of the Clean Water Act presents "[t]he most promising and controversial tool" for addressing nonpoint source pollution); Bell, *supra* note 42; Lebowitz, *supra* note 4; Luneburg, *supra* note 17, at 59 ("[D]ealing effectively with the many and diverse sources of pollution, both point and nonpoint, presents immense challenges, including the need to think and act on a watershed basis . . . . [S]uccess . . . requires inclusive, rather than exclusive, and collaborative information-gathering, decision-making, and implementation."); Owen, *supra* note 13, at 860–61, 869 (providing examples of successful TMDL policies that have led to "significant controls on nonpoint source pollution"); RECKHOW ET AL., *supra* note 10; Kelly Seaburg, *Murky Waters: Courts Should Hold That the "Any-Progress-Is-Sufficient-Progress" Approach to TMDL Development Under Section 303(d) of the Clean Water Act Is Arbitrary and Capricious*, 82 WASH. L. REV. 767, 772 (2007).

ways that this can be done effectively.[196] However, doing anything about nonpoint source pollution must start from the place of accepting that our current regulatory approach is not working. Continued piecemeal improvements to and attempted reinvigoration of the TMDL program often only serve to waste resources and delay meaningful change.[197] This Article does not intend to present an exhaustive analysis of nonpoint source remedies. Instead, it points to several methods that could be used to refashion how TMDLs are implemented.

Rethinking TMDLs requires looking back to the mechanisms that form the foundation of this approach and identifying if and how these can be improved to allow TMDLs to achieve their purpose. At its core, the TMDL program is trying to be many things and failing at all of them.[198] It is a command-and-control regulation without adequate (or arguably any) regulatory controls. It is an information forcing regulation that generates data that is inaccurate and inaccessible. It is an adaptive regulation that lacks any regulatory features to require iteration or adaptation over time. Whatever regulatory box you put the TMDL program into, it is at best a pale shadow of what a fully realized approach to regulation would look like. Despite efforts to continue to pour money and resources into TMDLs, without attention to fixing its regulatory foundation this program will continue to be a costly and unsuccessful endeavor.[199]

This Part analyzes the three major regulatory design approaches that TMDLs arguably adopt: command-and-control, adaptive regulation, and information forcing. For each of these mechanisms, it asks how well the TMDL program is embodying its regulatory goals. It points to the gaps in design that prevent TMDLs from being a true example of any of these approaches, and having identified these gaps, makes specific arguments for how new provisions could be added to the TMDL program to make it a fully realized and more effective example of each of these different approaches to regulation. Lastly, it recognizes that while all of these fixes have the potential to improve the TMDL program, ultimately it may be time to move beyond TMDLs and approach nonpoint source regulation from an entirely new starting point.

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[196] *See, e.g.*, Craig & Roberts, *supra* note 4, at 63–64 (discussing Australian approaches); Jussi Lankoski & Markku Ollikainen, *Innovations in Nonpoint Source Pollution Policy—European Perspectives*, 28 CHOICES, No. 3, 2013, at 1 (discussing European approaches).

[197] *See generally* Ruhl, *supra* note 139, at 936. Some have called this desire to try to improve regulations that are not working the "mirage of reinvention rhetoric." *Id.* at 976.

[198] It is unclear whether Congress intended it to be many things or if academics and the EPA in the years since its passage have tried to justify it and reshape it into many different forms.

[199] And one that diverts energy and resources away from other regulatory action. Owen, *supra* note 13, at 854 ("Those expenses also bring opportunity costs. To the extent that money for TMDLs comes out of lump sum allocations to state or federal environmental agencies, it could have been spent on environmental protection in some other form.").

A. TMDLs as an Information Forcing Problem

Even those who have voiced concerns about the effectiveness of TMDLs fall back on the importance of 303(d) lists and TMDLs in driving improved water quality data: if TMDLs are not working to improve water quality, they are at least forcing states to monitor water quality and provide critical water quality information. Some have gone so far as to argue that this information forcing function is the primary purpose of TMDLs.[200] Congress certainly seemed to think that generating new information was a critical purpose of these provisions; when Congress passed the CWA, it was with the explicit hope that the monitoring requirements would generate enough new information to be able to understand and effectively regulate nonpoint source pollution in the future.[201]

The information generated by 305(b) monitoring requirements and the TMDLs that follow them has two main pathways for potentially leading to better water quality outcomes. The first is internally focused: by generating new information, federal and state managers may be able to better understand water quality and nonpoint source pollution and implement more effective management strategies. The second mechanism for change relies on the theory that providing information on water quality to the general public can motivate environmental change by increasing political and economic pressure on government and regulated entities.

In either case, information forcing relies first on the generation of robust, accurate data. It is true that TMDLs have undoubtedly generated vast volumes of new information on water quality that would otherwise not exist. The problem is that much of this data is incomplete and inaccurate. Some, like Professor William Andreen, have argued that water quality data generated by the TMDL program is so unscientific and unreliable as to be actively misleading, giving the impression that we know something about water quality when in fact we do not.[202]

This problem is particularly acute in regard to the monitoring data prepared for 305(b) and 303(d) lists. This baseline monitoring data is rarely sampled at sufficient geographic or temporal scales to give robust results.[203] It is not uncommon for states to rely on just one or two data points per year to reach the conclusion about whether a water is

200 *See* discussion *supra* Section II.B.2.

201 Glicksman & Batzel, *supra* note 59, at 116.

202 Andreen, *supra* note 170 ("In addition to being a moving target, the state section 305(b) surveys actually overstate our actual knowledge about water quality. While some of the state estimates are based upon actual monitoring data, other estimates are subjective and based upon best professional judgments, or as two recent observers have phrased it, 'best guesses' as to water quality.").

203 This does not even get into questions about the validity of the methods used to sample water quality. States frequently rely on volunteer non-scientists to collect this data, some of whom are able to produce excellent quality data while others are less reliable. No concrete practices exist to differentiate the later samples from the former.

impaired or not.[204] If either of those sampling days is done in unusual conditions, for instance right after a storm, it can dramatically alter the resulting sample quality.[205] Moreover, sampling stations are often not at the geographic densities necessary to effectively extrapolate and draw conclusions about water quality throughout an entire water.[206] In some cases, one location's water sample may be used to determine the water quality for substantial distances around it.[207] The resulting data presents a vision of water quality in the United States that is far from accurate.[208] While Congress may have hoped that the additional data provided by regular monitoring would help create the guideposts necessary to drive implementation and iterative improvements to TMDL regulations, in practice water quality data is far from meeting the standard necessary to achieve those goals.

Data used in the preparation of TMDLs themselves is much more robust than baseline monitoring data. While there are routinely legal disputes over the scientific basis for TMDLs, the TMDL process requires data collection and analysis that goes well beyond what states undertake in the process of creating 305(b) lists.[209] TMDLs can run to hundreds of pages long, detailing biological, chemical, physical and hydrological conditions of a waterbody.[210] This data is potentially useful

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[204] Houck, *TMDLs*, *supra* note 6, at 10212.

[205] *See, e.g.*, James M. Rand et al., *The Human Factor: Weather Bias in Manual Lake Water Quality Monitoring*, 20 LIMNOLOGY & OCEANOGRAPHY METHODS 288, 300 (2022) ("[M]anual sampling, typically subject to weather bias, will tend to record higher lake water temperatures on average than the 'true' average lake water temperature.").

[206] *See, e.g.*, U.S. ENV'T PROT. AGENCY, EPA-823-R-10-005, SAMPLING AND CONSIDERATION OF VARIABILITY (TEMPORAL AND SPATIAL) FOR MONITORING OF RECREATIONAL WATERS 9 (2010) (comparing studies demonstrating how variability in indicator density can result in misclassification of water quality).

[207] JOHN B. STEPHENSON, U.S. GOV'T ACCOUNTABILITY OFF., GAO-02-186, INCONSISTENT STATE APPROACHES COMPLICATE NATION'S EFFORTS TO IDENTIFY ITS MOST POLLUTED WATERS 11 n.6 (2002) ("[M]any states use a targeted approach to monitor their waters, which means that monitoring points are selected judgmentally or for a purpose. . . . With targeted sampling, unless complete coverage can be achieved, the data cannot be used to draw conclusions about the extent to which the state's entire inventory of waters is attaining water quality standards.").

[208] And this is of course setting aside the issues that only one-third of waters in the United States are sampled *at all*.

[209] *See generally* Caudill & Curley, *supra* note 13 (discussing the scientific basis of TMDLs and how this is contested in litigation).

[210] For example, the Chesapeake Bay TMDL is over 200 pages, while the Lake Tahoe TMDL is 380. *See Chesapeake Bay TMDL Document*, U.S. ENV'T PROT. AGENCY, https://perma.cc/3QBM-DNY6 (Oct. 1, 2024) (hosting multiple PDFs making up the full TMDL); LAHONTAN REG'L WATER QUALITY CONTROL BD., FINAL LAKE TAHOE TOTAL MAXIMUM DAILY LOAD REPORT (2010), https://perma.cc/3EU8-CJYT. Note however that the length of TMDL documentation is not inherently linked to the underlying complexity of the environment: the TMDL for Lake Okeechobee, which is roughly four times the area and of similar ecological complexity to Lake Tahoe is only 53 pages long, perhaps reflecting divergent state approaches to TMDL development and resulting differences in information quality. *See* FLA. DEP'T OF ENV'T PROT., TOTAL MAXIMUM DAILY LOAD FOR TOTAL PHOSPHORUS: LAKE OKEECHOBEE, FLORIDA (2001).

and arguably is the meat behind the information forcing functions of TMDLs. In an effort to prevent issues in litigation, states go to great lengths to ensure that TMDL data and analysis is scientifically sound, even including measures such as peer review to ensure that the science underlying TMDL formulation represents accepted methodologies and reaches defensible conclusions.[211]

However, TMDL data is generally not made available to interested stakeholders in ways that promote access and understanding. Recent research has shown how rarely information created by disclosure regulations is actually made available to interested parties in accessible ways.[212] Instead, information forcing often leads to volumes of information that are stored in disparate locations and formats, reducing the usability of the data. Additionally, information is often not translated in ways that are sufficiently accessible to members of the general public.[213]

In the case of TMDLs, there are no clear public education goals of the statute, so it is perhaps less concerning that data is not translated in ways that the public might understand.[214] It is, however, important that TMDL data be able to be used and accessed by both industry (who are potentially generating water pollution and may be seeking information on desirable alterations to their operations to help achieve environmental goals) and by water managers (who may be making water quality plans at the local or regional level). Unfortunately, TMDL documentation generally takes the form of lengthy PDF documents where key data is buried and often presented only in summary form.[215] This significantly undermines the potential utility of this data, though new natural language processing tools may soon be able to scrape this data in more effective ways.

The focus on ensuring TMDLs can withstand attacks in litigation at the creation stage also results in different incentives than exist in regulations where litigation is more likely at the implementation or enforcement stages. In the case of TMDLs, this means that EPA and states focus on creating TMDLs that are scientifically defensible, which involves gathering large volumes of data and carrying out extensive analysis in the very early stages of the process. However, because there

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[211] *See, e.g.*, *Peer Review of the Lake Tahoe TMDL*, LAHONTAN REG'L WATER QUALITY CONTROL BD., https://perma.cc/G3M8-FGDD (Sept. 28, 2009).

[212] *See generally* Kuh, *supra* note 53.

[213] *Id.* at 655–58.

[214] Though of course, Congress is the recipient of biannual 305(b) and 303(d) lists and they generally do not hold any special expertise in water quality. As a target audience then, some interpretation of results is likely necessary to appropriately inform Congress. In practice EPA does this by providing summary statistics and other high-level data overviews to Congress. The same information is provided publicly on EPA's websites, but it contains little specific or insightful information on detailed water quality parameters at a more localized level.

[215] In this way TMDL reports end up looking very similar to NEPA Environmental Assessments and Environmental Impact Statements.

is virtually no litigation after this stage, ongoing monitoring is not prioritized.[216] As such, TMDL data represents a detailed snapshot of water quality during the window of time while a TMDL is being prepared. This provides critical information that would otherwise not be available on the water quality and dynamics in given areas, but it notably does not help to answer long-term questions about how these waters are faring over time.

In practice, the information forcing elements of the 303(d) listing process and the creation of TMDLs seem to be failing to effect any meaningful change. While the data in this study does not attempt to quantitatively isolate the information forcing mechanism of TMDLs from any others, qualitative evidence suggests that information forcing as a mechanism is failing to effect behavior change through TMDLs, and there is little evidence that this information is improving water quality outcomes outside of the TMDL process.

1. Improving TMDLs' Information Function

The first step towards improving the information mechanisms of TMDLs lies in improving baseline water quality data across the United States. This is not a new goal, but with technological improvements in low-cost sensors and analysis tools, it is increasingly feasible. There are over 3.5 million miles of streams and rivers and 43 million acres of lakes in the United States that need monitoring.[217] This is an enormous task for any monitoring agency and has to date been largely insurmountable.[218] Using new technological solutions can help to increase the number of waters that are monitored and increase the robustness of datasets if monitoring occurs not just once annually but continuously at more frequent time intervals. Increasing monitoring capacity is an important first step in improving the informational functions of TMDLs.

In addition to sampling more waters, changes should also be made to EPA and state monitoring protocols so that waters that are sampled at scientifically indefensible frequencies and scales are not considered actively monitored and reporting data is not included in 305(b) submissions. The current CWA 305(b) mandate that states sample all of the waters within their boundaries biannually[219] may drive states to make incomplete and inaccurate submissions in trying to comply with this requirement. It would be better at this stage that states only report temporally and geographically robust monitoring data, even if it means that fewer waters are deemed monitored. Putting robust accuracy and

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[216] Even more concerning than deficits in ongoing monitoring is of course the fact that implementation of these plans is not prioritized. *See* discussion *supra* Part IV.

[217] *See supra* Figure 1.

[218] *See* discussion *supra* Section III.B.1 (noting that only approximately one-third of U.S. waters are currently monitored for water quality).

[219] 40 C.F.R. § 130.8(a).

validity measures in place would ensure that there is a more representative understanding of what water quality actually looks like across the nation.[220]

Coupled with improving the accuracy of data, an improved information approach to TMDLs should ensure that data is accessible to multiple audiences. The main information mechanism behind TMDLs lies in educating managers on local conditions. There may also be some transparency value in providing this information to the public and to regulated entities. In any case, placing data in summary form into lengthy pdf documents and not making underlying data available undermines the effectiveness of information sharing.[221] EPA has made recent efforts to improve the data on water quality available to the public and these efforts have vastly improved the data products they use.[222] Continued efforts on this score are needed to ensure that data meets current open and FAIR data standards that are now the norm for environmental data.[223]

Lastly, and perhaps most importantly, it is time to recognize that information disclosure on its own is unlikely to be an effective regulatory strategy. Other recent studies have shown as much, and the TMDL case study at hand only serves to reinforce this outcome.[224] This is not to say that environmental information is not important or useful; it forms the critical foundation for all environmental management decisions. However, information disclosure regulations must be combined with other regulatory approaches if managers wish it to be successful.

B. Other Approaches to Nonpoint Source Pollution

1. Adaptive Approaches

Congress knew when the CWA was passed that the nonpoint source provisions were likely inadequate to achieve their goals.[225] However, the hope was that the additional information generated under the monitoring mandates of 305(b) and 303(d) would provide necessary guidance to improve nonpoint source controls with amendments in the

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220 And would address Professor Andreen's concern that current water quality monitoring in fact obscures how little we know about nationwide water quality. *See* Andreen, *supra* note 170, at 567.

221 *Cf.* Kuh, *supra* note 53, at 617–22 (discussing formatting difficulties with disclosing and explaining Toxic Release Inventory data to the public so as to advance their understanding of toxic substances in their communities).

222 *E.g.*, *How's My Waterway? – About*, ENV'T PROT AGENCY, https://perma.cc/E4GC-7R5J (last visited June 4, 2025) (describing "How's My Waterway," a web-based tool designed by EPA to inform the public about the water quality of waterways in their area).

223 *See generally, e.g.*, Toste Tanhua et al., *Ocean FAIR Data Services*, FRONTIERS MARINE SCI., Aug. 2019, No. 440, at 1 (discussing FAIR data principles in ocean data).

224 *See, e.g.*, Kuh, *supra* note 53, at 667; Brett, *supra* note 119, at 1565.

225 *See* discussion *supra* Part I.

future. This strategy shares a foundational approach with the popular idea of adaptive regulation.

Adaptive regulation is the antithesis of the fixed controls of much 1970s-era environmental regulation, building experimentation and opportunity for change into regulation. The adaptive model is particularly attractive in environmental contexts, where regulations that can evolve better reflect the dynamism of the regulated ecosystems. Adaptative regulation can also be used to address scenarios of scientific uncertainty: as more information becomes available, adaptive models integrate this information and update regulatory procedures.

Despite language from Congress and the EPA that tout an adaptive approach to nonpoint source pollution, TMDLs do not exhibit the key characteristics of adaptive regulation. There is a difference between regulations that are explicitly built to be adaptive, with parameters, responsive actions, and timelines for review built into the regulations themselves, and regulations that are passed lacking any of these features with the hope that someday a future Congress may improve them. The TMDL program falls into the latter category.

At the time the CWA was passed, hoping that Congress would continue to iterate and improve on the TMDL program may have made sense. The Water Quality Act had been passed less than a decade before, and Congress was already working to remedy the issues it exhibited. In the case of TMDLs though, kicking the can down the road in the hope that further scientific information would help motivate action did not pay off. The political roadblocks to creating strong enforcement mechanisms for TMDLs or ensuring that nonpoint sources like agriculture could be regulated under the NPDES programs remained unchanged over time.[226] And like in many other cases, gathering more scientific information did serve to somewhat clarify the problem by illustrating the extent of nonpoint source pollution, but it did nothing to drive political action.[227] TMDLs serve as a warning of what can happen when Congress passes a law knowing it is inadequate but hoping that it could be the foundation of stronger regulation in the future.

Despite the enthusiasm for adaptive management, it has seen relatively few real-world success stories, and academics and managers are beginning to show skepticism towards this approach.[228] The failure

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[226] *See* Houck, *TMDLs III*, *supra* note 63, at 10436–37 (describing these political challenges).

[227] Climate change is of course the glaring example of other cases where political action has been delayed in the interest of reaching more scientific certainty on the causes and impact of environmental problems. Much has been written about the use of scientific uncertainty as a scapegoat to delay or avoid making difficult political choices.

[228] Biber, *supra* note 143, at 936 ("[C]alls for the widespread adoption of adaptive management have been matched by the observations that adaptive management has had few real-world successes to date."); Doremus, *supra* note 145, at 1457 ("Enthusiasm has spilled over to the policy arena, where adaptive management is now routinely endorsed, and even mandated. When it comes to implementation, however, skepticism becomes the

of TMDLs may provide some insight into some of the circumstances why adaptive management is challenging. TMDLs reflect the reality that many so-called "adaptive" regulations are that in name only and fail to exhibit the features needed to achieve active adaptive management. In the context of adaptive management scholarship, TMDLs can be characterized as an example of "passive" adaptive management.[229] Managers use underlying data on water quality conditions to implement a TMDL plan that they then monitor (in theory) and evaluate over time. Passive adaptive management is generally regarded as a less successful approach than active adaptation strategies, something that the TMDL experience bears out.

a. Improving TMDLs' Adaptive Approach

Despite concerns about adaptive regulation as a strategy, it is a potentially sound approach to managing nonpoint source pollution if implemented correctly and in combination with improved information forcing mechanisms. Adaptive management is applicable to situations involving a series of sequential decisions, uncertainty, and the opportunity to make changes based on actual outcomes and new information.[230] The TMDL program has all of these characteristics. Academics have recognized that this is a viable approach, specifically pointing to the need for adaptive implementation in the TMDL program along with a process of regular review and iteration to ensure that TMDLs are working to improve water quality standards over time.[231] To move from the current version of TMDLs to a version that is a better example of adaptive regulation would ideally be done through Congressional action to modify the TMDL program. However, recognizing that that is unlikely, several rule-based updates to the

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rule. Documented instances of successful adaptive management are rare, and many touted examples diverge significantly from the theoretical ideal. Furthermore, adaptive management can create a new type of accountability problem, providing cover that allows resource management agencies to put off imposing politically controversial limits on economic activity.").

229 Biber, *supra* note 143, at 934 ("[M]anagers, instead of consciously or actively creating differences in management across multiple sites in order to produce information, might rely on historical data to produce rigorous models about how environmental systems function, use those models to identify a single best-practice for management, and implement that practice. Managers would also use monitoring to observe whether results diverge from predictions from the model, and use those divergences to update the model and the management system. This option gained the moniker of 'passive adaptive management' because managers were not using active experimentation to reduce uncertainty.").

230 *See* Doremus, *supra* note 148, at 1465 (listing specifically nonpoint source watersheds as examples of complex systems with sequential decision points); James E. Lyons et al., *Monitoring in the Context of Structured Decision-Making and Adaptive Management*, 72 J. WILDLIFE MGMT. 1683, 1691 (2008) (describing the key characteristics of systems ripe for adaptive management).

231 RECKHOW ET AL., *supra* note 10, at 5.

TMDL program could help it become a more effective example of adaptive regulation. For instance, water quality monitoring and TMDLs already exhibit regulatorily mandated sequential decisions. However, these mandates effectively stop at the implementation stage. Taking the TMDL program to a more effective version of adaptive management would require creating new decision points later in the process, namely in the form of ongoing monitoring and evaluation requirements. EPA is not precluded from extending TMDL rules to require regular reporting and additional opportunities for managers to update existing TMDLs. Doing so would be a critical step towards improving our understanding of, and hopefully the effectiveness of, the TMDL approach.

Beyond this, adaptive management requires vast volumes of information.[232] A cornerstone of any successful approach to nonpoint source pollution will be ongoing monitoring and adaptation over time. Currently, mechanisms for the collection of this information do not exist.[233] In the case of TMDLs and most other environmental regulation, the monitoring systems that are set up are intended to provide insight into environmental conditions, not whether regulatory programs are working as they should to improve them. Of course, monitoring environmental conditions over time is an essential piece of data for evaluating the success of regulatory programs, but it alone is not enough. Future TMDL efforts should put in place clear requirements for efficacy data collection and evaluation, a critical basis for adaptive management. If TMDLs are failing, as current evidence suggests they are, it should not take twenty years to discover this and begin to consider opportunities for change. Adaptive management relies on consistent and timely feedback on the efficacy of regulatory programs, allowing managers the opportunity to iterate and improve on these programs in real time.

2. Command-and-Control

Some good news regarding nonpoint source pollution is that the founding logic behind TMDLs—that the methods needed to regulate nonpoint source pollution do not exist or are unrealistically difficult to implement—is no longer true.[234] The bad news, of course, is that the simplest ways of implementing these methods require overcoming political barriers that may be insurmountable. Creating additional provisions that move the TMDL program out of its quasi-command-and-control approach to having real and robust regulatory command-and-

[232] Ruhl, *supra* note 138, at 997.

[233] Stewart, *supra* note 158, at 35 ("No federal mechanism or program exists to systematically monitor and evaluate the performance of the existing environmental regulatory system.").

[234] Houck, *TMDLs III*, *supra* note 63, at 10424–25 (describing the belief that at the time the CWA was passed, nonpoint source pollution was too diverse and technologically complex to regulate).

control over nonpoint sources, for instance, would be far and away the most efficient method of tackling nonpoint source pollution nationally.

Interestingly, despite the repeated criticism of command-and-control as a model, evidence from the CWA suggests that command-and-control, in the form of the NPDES program, is a much more effective strategy than the CWA's more flexible forms of regulation (e.g. water quality standards and the TMDLs).[235] This comports with recent scholarship questioning the negative accounts of command-and-control and arguing that command-and-control is not an inherently inefficient, either economically or environmentally, approach to regulation.[236] Command-and-control is appealing because of the relative ease and initially low cost of implementation.[237]

a. Improving TMDLs' Command-and-Control Foundations

Many have argued that the lack of any regulatory teeth is the fatal flaw of the TMDL program.[238] The evidence of this paper certainly supports that conclusion. We have reached a stage where controlling nonpoint sources may arguably be easier and more economical than controlling point sources. While point sources require technology controls that are costly and intensive to maintain, nonpoint source pollution can often be decreased in ways that are relatively cheap and low effort.[239] In the realm of agriculture, for instance, nonpoint source pollution generally occurs from overfertilization.[240] Changing fertilizer application timing and methods, for instance, can drive dramatic decreases in nonpoint source nutrient loading.[241] It can also reduce

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[235] *See* Houck, *TMDLs IV*, *supra* note 5, at 10469, 10471 (describing how, while the CWA is "[o]ft-criticized" for its "'command-and-control' mechanisms," it is nonetheless one of the "most successful environmental program[s] in America," and how historically, "ambient-based regulation . . . has never really worked in pollution control.").

[236] *See, e.g.*, Daniel H. Cole & Peter Z. Grossman, *When Is Command-and-Control Efficient? Institutions, Technology, and the Comparative Efficiency of Alternative Regulatory Regimes for Environmental Protection*, 1999 WIS. L. REV. 887, 889 (1999) (using empirical evidence to demonstrate when command-and-control may be efficient regulatory approaches).

[237] Stewart, *supra* note 158, at 28.

[238] *See generally* Houck, *TMDLs IV*, *supra* note 5; Birkeland, *supra* note 20 (summarizing challenges the TMDL program faces); Andreen, *supra* note 170.

[239] *See, e.g.*, Houck, *The Clean Water Act Returns*, *supra* note 7, at 10212–13 (noting that in 2008 the cost to implement BMPs for nonpoint pollution reduction on farmland in Maryland farmland was $45 per acre). While not negligible when aggregated widely, this is still a much more cost-effective option than other approaches.

[240] *See* Zaring, *supra* note 4, at 519–20 ("American ranches and farms produce approximately 1.8 billion metric tons of wet manure per year, much of which reaches surface water supplies after being applied to fields, as do fertilizers and pesticides. . . . Nitrates attributable to fertilizers have been found in the groundwater of every agricultural region of the United States.").

[241] Houck, *TMDLs IV*, *supra* note 5, at 10480 ("In the state of Florida, years of struggle, litigation, legislation, and compromise recently yielded an agreement to reverse the trend

decreases in nonpoint source nutrient loading.[241] It can also reduce farming costs: while fertilizers have historically been relatively cheap, precision application methods available today can decrease both water pollution and the amount of fertilizer used by farmers.[242] Similar, relatively minor, changes can help to decrease pollution runoff from logging, stormwater, and other major nonpoint pollution sources.

Comparable approaches are being used by other countries to try to target non-point source pollution. Whereas the United States has focused (largely unsuccessfully) on trying to reduce pollution at the individual water level, Europe instead has focused on encouraging more sustainable and less polluting practices in non-point sources like agriculture.[243] This focus on decreasing nonpoint source pollution at its origin has been widely successful.[244] While this may have been a promising avenue for the United States, the outsized efforts of agricultural and other lobbyists to exclude their industries from regulation made this approach politically infeasible when the CWA was passed.[245]

Unfortunately, this political reality remains true. While the scientific tools are available to both better monitor water quality and implement relatively low-cost solutions to nonpoint pollution through command-and-control, political impediments remain the major stumbling block to extending the reach of TMDLs to nonpoint sources.[246] Amending the CWA is likely not an option, despite the fact that this would be the most expedient and effective way at fixing the problem of nonpoint source pollution. Congress has not been amenable to amending the CWA for the last several decades, and even environmental groups have focused on pursuing incremental regulatory gains through

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241 Houck, *TMDLs IV*, *supra* note 5, at 10480 ("In the state of Florida, years of struggle, litigation, legislation, and compromise recently yielded an agreement to reverse the trend of deterioration of water quality in Everglades National Park by, inter alia, restricting the use of fertilizers in the adjacent agricultural areas: fertilizers would be applied in specific amounts and in specific ways. Within a year, with the sugar crop still flourishing, nutrient loading from the agricultural areas dropped 40 percent.").

242 The low cost of fertilizer arguably is one of the main reasons why nonpoint source pollution from farms is as high as it is: if it were more expensive, greater efforts would have been taken to decrease fertilizer waste historically.

243 *See* Lankoski & Ollikainen, *supra* note 196, at 1.

244 *See id.* at 2 (explaining that the European Union's Common Agricultural Policy (CAP) addressing agricultural nonpoint source pollution has "increased the coherence of agricultural policies with overall water policies in the EU" and resulted in "a decline in nutrient surpluses for EU15 from 1990 to 2009.").

245 *See* Houck, *TMDLs*, *supra* note 6, at 10332–35 (explaining that the Federal Water Pollution Control amendments of 1972 "were resisted strongly by most states, by a widespread spectrum of industry, and by high-level members of the administration up to and including the President").

246 Linda A. Malone, *The Myths and Truths That Ended the 2000 TMDL Program*, 20 PACE ENV'T L. REV. 63, 63 (2002).

legislation rather than advocating for full-scale legislative overhaul of the program.[247]

Outside of political amendments to the CWA, legal options do exist that could help to expand the scope of nonpoint source regulation. Some have argued that new Supreme Court precedent after *County of Maui v. Hawaii Wildlife Fund*[248] might place some particularly large nonpoint sources into the category of indirect discharges, allowing them to be regulated under the command-and-control point source provisions of the CWA.[249] Others agree that the key to meaningful CWA regulation of agricultural nonpoint sources can be found by interpreting the CWA in such a way as to establish them as point sources.[250]

As with other TMDL solutions, federal Congressional action could improve the command-and-control function of TMDLs through either treating certain nonpoint sources as point sources or by amending the TMDL provisions to create enforcement mechanisms for EPA. These solutions have been discussed extensively; however, they remain unlikely in the near term. In the absence of federal action, state efforts may be the most important area for improving TMDL outcomes.

Cooperative federalism is a cornerstone of the TMDL program. While TMDL structuring was framed by Congress at the time as a well-informed decision based on sound consideration of regulatory design—a feature that has also been justified *post hoc* by many academics—in practice the structure of TMDL program was heavily driven by historical approaches to water quality control and political compromise.[251] The historical approaches were grounded in the idea of state supremacy in the area of land use decisions.[252] States were some of the strongest interests lobbying for the use of a water quality standards approach in the Clean Water Act.[253] Attempts over time to increase federal control over these standards or additional point sources were

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[247] *See generally* Dave Owen, *After the TMDLs*, 17 VERMONT JOURNAL OF ENVIRONMENTAL LAW 845 (2016) (discussing the strategic use of litigation by environmental NGOs to spur regulatory strengthening of the TMDL program).

[248] County of Maui, Hawaii v. Hawaii Wildlife Fund, 590 U.S. 165 (2020).

[249] *See generally* Anthony B. Schutz, *Agricultural Discharges Under the CWA: Old Questions and New Insights*, 52 U. PAC. L. REV. 567 (2021) (looking specifically at Concentrated Agricultural Feeding Operations (CAFOs) as potential indirect discharges under the CWA).

[250] *See generally* Jan G. Laitos & Heidi Ruckriegle, *The Clean Water Act and the Challenge of Agricultural Pollution*, 37 VT. L. REV. 1033 (2013).

[251] Houck, *TMDLs*, *supra* note 6, at 10331 ("The TMDL process represents, in the short life of environmental law, an ancient approach to pollution control. . . . From the very first hint of federal involvement in water pollution control fifty years ago, states and pollution dischargers have fought a running battle to defend and, where lost, return to the local primacy and utilitarianism of regulation by water quality standards.").

[252] *See* Houck, *TMDLs*, *supra* note 6, at 10415–16 (highlighting the deference given to states in developing and implementing TMDLs).

[253] *See* Houck, *TMDLs*, *supra* note 6, at 10332–33 (summarizing state governors' statements of support for water quality standards during hearings in advance of passing the Clean Water Act).

met with virulent resistance, with opponents emphasizing the importance of maintaining flexibility as the chief reason for avoiding top-down control.[254]

In practice, it appears to some extent that states were correct. EPA's top-down control efforts have largely failed, and there is increasing evidence that states or regions that are able to come up with new and more robust approaches to TMDLs are the only places where positive progress on TMDLs is occurring. The most successful TMDL stories have come in areas with strong collaboration, often extending beyond local or state jurisdictions to include many cooperating partners.[255] The majority of these stories happen when motivated community groups are able to work together outside of the traditional TMDL process.[256]

Working at the state and local levels also allows greater utilization of land use tools that are traditionally the province of state governments. Land use approaches, for instance new approaches to zoning and development planning, may be critical in addressing nonpoint source pollution.[257] Likewise, many have noted that watersheds by their nature are inherently regional.[258] Regulating waters on a regional watershed level thus can be much more effective than trying to isolate an individual water without addressing the systemic issues.[259] The success of these collaborative efforts is in line with ideas that environmental law requires more organizational control at the regional level.[260]

In an ideal world, these approaches to regulation are not mutually exclusive. The TMDL program could be a command-and-control law that is both adaptive and information forcing.[261] Working on a concerted level

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[254] *Id.* at 10343 ("[In the 1990s,] [s]tates [argued they] needed 'flexibility to develop WQS, tailored to meet individual hydrology, geology, topography, ecosystem and climate considerations.' A top-down approach 'inhibits innovation and thwarts aggressive and/or creative approaches' which would lead to national improvements.").

[255] *See, e.g.*, Houck, *The Clean Water Act Returns*, *supra* note 7, at 10215–16 (discussing collaboration in Chesapeake Bay).

[256] *Id.* at 10214–16.

[257] *See* Laitos & Ruckriegle, *supra* note 250, at 1067–69.

[258] *Id.*

[259] *Id.* at 1069–70.

[260] For a discussion of the need for this specifically in the context of watersheds, see Ruhl, *supra* note 138, at 982 ("[E]ntirely new forms of organizational structures are needed in order to match environmental law with the complexity of its subject matter. Watersheds, for example, exist in a nested hierarchy, open system form: small-scale watersheds (a drainage ditch fed intermittently by runoff from several farms) feed into local watersheds (a perennial stream) that feed into larger regional watersheds (a river tributary) that feed into enormous multistate and multinational watersheds (the Colorado River). Protection of ecological and economic interests associated with watersheds, therefore, will require greater reliance on interlocal organizations, interstate compacts, regionally-oriented autonomous federal agencies, and partnerships between all of those as well as nongovernmental organizations and landowners.").

[261] Not that it should, given existing concerns about any and all of these approaches to environmental regulation.

to remedy the failure points for these different mechanistic approaches could create a more robust and possibly more effective TMDL program. Understanding how these regulatory mechanisms have failed also provides insight into future use of these strategies in environmental law.

C. Jettisoning TMDLs

Rethinking and fixing the mechanisms that drive the TMDL approach has the potential to remedy ongoing issues with the TMDL program and improve nonpoint source outcomes. Nonetheless, this may not be the best approach. Doubling down on TMDLs may simply serve to put further emphasis on a broken regulation, as opposed to pursuing more creative approaches to nonpoint source pollution.[262] Getting rid of the TMDL program and starting from a blank slate may ultimately be necessary to make meaningful progress on nonpoint source pollution.

Others have illustrated how typical "reductionist" approaches to environmental law have failed to remedy environmental problems.[263] Solutions to this typically include a revisionist approach, which reinterprets and reinvigorates existing environmental regulation to try and address ongoing problems.[264] The reinvigoration of TMDLs in the late 1990s and early 2000s is a classic example of this approach. This approach has been both costly and likely ineffective.[265] Now, twenty years later, is the optimal time to reevaluate whether the benefits of additional revisionist attempts are likely to outweigh the considerable direct and opportunity costs of continuing to try to band-aid the TMDL program. This reflects a broader lesson for environmental law.[266] Doubling down on regulations that are flawed from their inception often has limited effectiveness. While environmental litigators and others are happy to breathe new life into old laws, in practice this strategy can be costly and ineffective.[267]

This article does not attempt to answer the question of what nonpoint regulation beyond the TMDLs could look like, though other scholars have begun to try to address this question. It does though provide additional quantitative evidence that suggests that now is the time we must truly grapple with answering this question, as opposed to

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[262] Ruhl, *supra* note 141, at 988 ("[Improvements to] the environmental law system will not come until we are released (that is, release ourselves) from the quantitative-based command-and-control model—not simply able to deviate from it at the margins, but rather able to operate outside its sphere of influence altogether. Problems such as non-point source water pollution and mobile source air pollution cry out for approaches based on experimentation, rapid modification as needed, and variability of performance standards over small and large scales of time and landscape.").

[263] *Id.* at 937–40.

[264] *Id.*

[265] *See* discussion *supra* Part III (describing the lack of success of the TMDL program).

[266] Probably not a new one either.

[267] Ruhl, *supra* note 138, at 976.

continuing to waste resources supporting or revising a program that is simply not working.

V. CONCLUSION

Nonpoint source pollution remains the largest water quality challenge facing the United States today. It is so significant that over half of the waters of the United States are impaired and not meeting water quality standards for their designated uses.[268] The TMDL program that the CWA created to try and address these issues is also not working: new data shows here that only 1% of waters with TMDLs in place have shown substantial water quality improvements in the last two decades.[269]

This evidence illustrates the problems with a solely information-based approach to environmental law. While this has become a popular strategy for addressing environmental problems in a relatively politically uncontroversial manner, it is a regulatory approach that is ultimately leading to very few, if any, meaningful results. Paying attention to how information forcing interacts with other regulatory mechanisms underlying TMDLs allows for identifying and remedying the failure points that have prevented these approaches from working. While addressing these mechanistic failures may provide critical avenues to improve nonpoint source regulation in the TMDL program, in the end the best-case scenario for the future of nonpoint source pollution and water quality may be to start from scratch and develop entirely new approaches to nonpoint source regulation. This is not an easy task, but academics have been skeptical of the TMDL approach for decades. This study clearly supports such skepticism.

In any case, it is clear that simply implementing the nonpoint source controls we currently have and hoping for the best will not lead to the needed improvements in national water quality. Nonpoint source pollution issues are getting worse year by year, exacerbated by climate change, increased development, and biodiversity changes.[270] Now is the time to move beyond questions of whether the TMDL program is working to concretely consider what comes next. Without concentrated efforts to address nonpoint source pollution, the many successes of the CWA's point source provisions are at risk.

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268 *See* discussion *supra* Section III.B.2 (noting that 65% of waters with TMDLs in place are water quality impaired).

269 *Id.*

270 *See generally* Zi-jian Xie et al., *The Global Progress on the Non-Point Source Pollution Research from 2012 to 2021: A Bibliometric Analysis*, 34 ENV'T SCI. EUR. 121 (2022).