A History of Pollution and Pollution Controls in the Scioto River with Corresponding Changes in Water Quality and Biological Integrity

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Background

This article describes the results of a 37 year (1979-2015) series of biological and water quality assessments in the middle Scioto River, a 40 mile reach of the Scioto River mainstem from Columbus to Circleville, coupled with historical information to document the recovery of the aquatic biota from severely polluted conditions that existed for more than 150 years. The results show remarkable improvements in biological and water quality conditions in response to water pollution controls by the City of Columbus in the 1970s and 1980s. Historical information before that time period include the observations of pioneer naturalists to the first treatises of fishes and other aquatic biota in Franklin Co. and Ohio at the turn of the 19th century (Williamson and Osburn 1898; Osburn 1901) in the Ohio State University Museum of Biodiversity (OSUMB) fish collections database.

The Scioto River basin drains 6517 mi.[2] and is the second largest contained entirely within Ohio (16% of all land). The mainstem is 231 mi. in length (Ohio DNR 1960) originating in north central Ohio in Auglaize Co. and entering the Ohio River at Portsmouth, OH in Scioto Co. It has the longest reach of unimpounded free-flowing riverine habitat in Ohio being open from the Greenlawn Dam in Columbus, OH to the confluence with the Ohio River, a distance of 129.5 mi. The Scioto River valley was originally home to several Native American cultures and the name Scioto is derived from the Wyandot word sk•n•·t•' (deer). European settlement after the American Revolution in the late 1700s and early 1800s displaced the native populations. Of the 11 major cities that now border the mainstem, Columbus is the largest in terms of population. When Columbus was chartered in 1834 the population was 3500 with rapid growth after 1900 through the latter half of the 20th century reaching over 2 million in 2015.

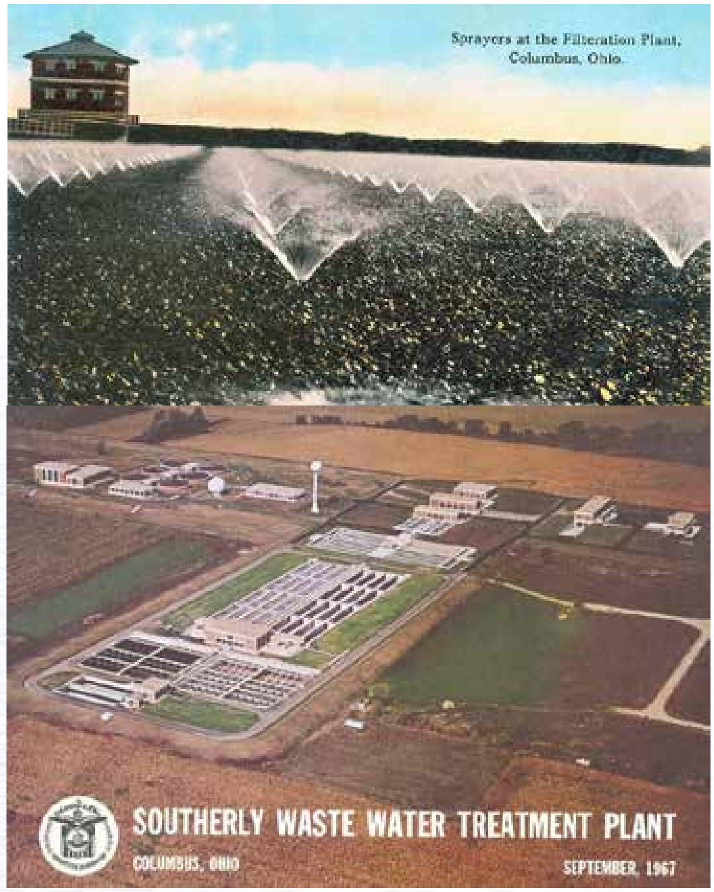

Figure 1. Sprayers at the first Columbus sewage treatment works in 1904 (upper panel) and the newly constructed Columbus Southerly wastewater treatment plant (WWTP; lower panel) in 1967.

Pollution History of the Scioto River

Official documentation of water pollution in the Scioto River dates to 1886 by the Ohio State Board of Health (Sharp 1886) serious enough to elicit numerous complaints by the public in nearly every city along the mainstem. Wastewater from municipalities and industries were discharged without treatment during that time period. Leighton (1903) commented ". . . The river is little more than a dumping ground for refuse and its misuse affords a good example of the wanton destruction of a valuable resource . . .". The description of polluted conditions by Trautman (1933, 1977, 1981) tracks that of Sharp and Leighton and includes pollution caused by extensive changes to the landscape beginning with the deforestation of Ohio in the latter 19th century and conversion to agricultural and urban land uses into the 20th century. Despite the inherent richness of the pre-settlement fish fauna, the Scioto River downstream from Columbus was so polluted in the summer of 1897 that only a "few species of fish" could be obtained by seining (Williamson and Osburn 1898). These changes intensified in the latter half of the 20th century which resulted in further changes to the hydrological and chemical aspects of water quality. The accumulation of these changes with a rapidly increasing population dramatically changed the fish fauna throughout Ohio by reducing or eliminating altogether many species of fish from entire regions of the state (Trautman 1981). Trautman (1977) observed that the general littering and exploitation of natural resources had reached its climax in the 1960s and that such polluted conditions could no longer be ignored.

Water Pollution Control in the 20th Century: Incremental Progress

Sharp (1886) and Leighton (1903) both referenced that the pollution observed in the 1800s was being addressed by the Ohio State Board of Health, which would constitute one of the earliest references to governmental intervention in water pollution. A Federal Water Pollution Control Act (FWPCA) was not forthcoming until 1948, and as amended in 1956 and 1968, it contributed little to real pollution reductions. In the intervening time frame new studies of water pollution advanced the science incrementally. The U.S. Public Health Service A Study of the Pollution and Natural Purification of the Scioto River (Kehr et al. 1941) focused on oxygen demanding wastes discharged by cities along the mainstem. This followed the landmark study by Ellis (1937) of water pollution and its effects on aquatic biota throughout the U.S. which also helped focus on the need to limit discharges of polluting substances. The Ohio Department of Health (ODH, 1961) produced one of the first studies on discharges of wastewater to the Scioto River using an early water quality model, an important prerequisite for limiting pollution at the source. Still, meaningful actions to reduce water pollution to levels that were needed to restore degraded aquatic assemblages were not forthcoming. Finally, the 1972 FWPCA amendments (aka the Clean Water Act, CWA) forced such actions via NPDES permits[2] which have since been issued to all major point source discharges of wastewater to the Scioto River by the Ohio Environmental Protection Agency (Ohio EPA).

The first public sewer in Columbus was constructed in 1841 and in 1872 the first "waterworks" came into service for delivering potable water to homes and businesses and for building and maintaining sanitary sewers[3]. By 1880 nearly 2.2 million gallons/day (MGD) of water was supplied with the majority collected by sewers and discharged without treatment to nearby receiving streams all of which were tributaries to the Scioto River. The first treatment of sewage was proposed in 1898, but was rejected by the Ohio Department of Health (ODH) as inadequate to resolve the problems posed by raw sewage. The first treatment works consisting of septic tanks and spray filtration was initiated in 1908 (Figure 1). Known first as the "Improved Sewerage Works", what later became the Jackson Pike WWTP was constructed in 1908 as the first dedicated sewage treatment facility located 5 mi. from downtown Columbus. It transitioned from primary to secondary treatment in the late 1950s with flows of nearly 82 MGD. In 1967, the Southerly treatment plant (Figure 1) was constructed to handle the rapid growth in sewage flows, discharging to the mainstem 12 miles downstream from Columbus. Over that time period, population growth caused sewage flows to exceed the capacity of the treatment system such that a nearly continual process of latent treatment upgrades occurred. Biological degradation occurred over a distance of 60-75 miles downstream and fish kills of more than 1,000 to 10,000 fish were common and one kill of more than 300,000 fish occurred in 1967 (FWQA 1970). Bypasses of partially treated and raw sewage were commonplace and at Southerly they comprised nearly 80 % of the BOD5 loadings in the late 1970s. It was during this time period that Trautman (1977) described visual evidence of gross pollution below Columbus in the form of "globs of suds" that were more than 5 feet high that completely enveloped the boat he was using to navigate the Scioto mainstem.

FWPCA of 1972 – "The Clean Water Act"

Spurred on by the grossly polluted condition of rivers, streams, and lakes the passage of the FWPCA amendments of 1972 by Congress was the first federal legislation that required permits that limited the amount of pollution that could be discharged to waters of the U.S. NPDES[4] permits were eventually issued to discharges of municipal and industrial wastewater including the two

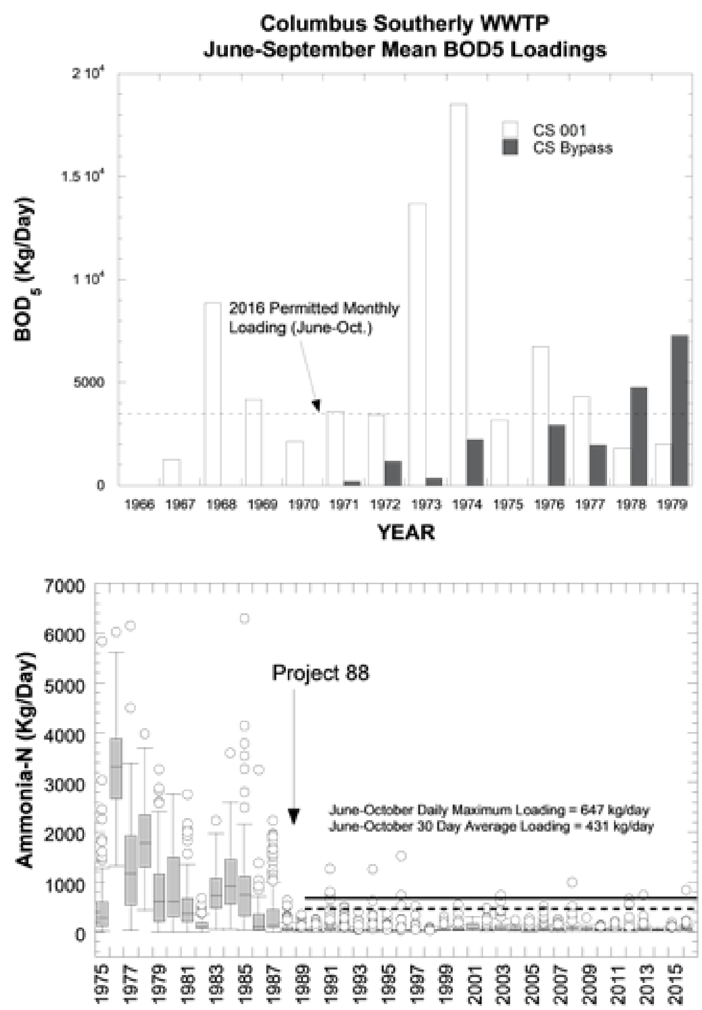

Figure 2. Loadings of BOD5 (Kg/day) discharged by the Columbus Southerly WWTP 1967-1979 (upper panel) from the 001 outfall (open bars) and as raw or untreated bypasses (filled bars) and loadings of NH3-N (Kg/day) discharged July 1-September 30 during 1975-2015 (lower panel). The most recent NPDES permit limitations are shown on each.

City of Columbus facilities. It was the first to state the principal objective of the CWA is to “restore and maintain the chemical, physical, and biological integrity of the Nation’s waters.” It also set forth seven national policies including Section 101[a][2] that stated . . . “wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water . . .” which promoted the concept of designated uses of water and criteria to protect those uses.

Water Quality Standards

Water Quality Standards (WQS) consist of two parts, a designated use and criteria to support that use. “Uses” include the value of water to the society as a resource for water supply, recreation, and aquatic life. “Criteria” are chemical, physical, and biological properties and attributes of water that support the quality intended by the designated uses. Criteria are also used to determine the amount of pollution that a waterbody may receive and fully support the designated uses. WQS were initially adopted by Ohio EPA in 1974 and underwent major revisions in 1978, 1985, and 1990 that essentially define the WQS of today. For aquatic life, Ohio uses a concept of habitat for aquatic life segregated into tiers depending on the level of biological quality that a river or stream can potentially support. Termed “tiered aquatic life uses” (TALUs) the concept was first adopted in 1978 with chemical criteria only and the addition of biological criteria following in 1990. The implementation of TALUs is dependent on information about the aquatic biota and habitat of a stream or river, thus it is dependent on data and information provided by a systematic monitoring and assessment program.

Water Quality Based Permitting

Water quality based permitting involves the development of limitations for discharges of pollution based on meeting instream WQS under critical conditions. While the 1972 CWA specified technology based limits that all discharges must meet, it was understood that technology based limitations may not be sufficient meet WQS in all rivers and streams. Such was the case with the City of Columbus WWTPs which can dominate the flow of the Scioto River during critical periods. Wasteload allocations were developed that essentially achieved a mass balance between the amount of pollution a receiving river could receive and not exceed instream criteria for selected chemical constituents such as dissolved oxygen (D.O.) and ammonia-nitrogen (NH3-N). However, this meant that additional removal of oxygen demanding wastes and NH3-N had to be accomplished which in turn raised the costs and efficiencies of wastewater treatment. When water quality based permitting was first proposed, serious doubts were raised about achieving wastewater treatment efficiency beyond the secondary treatment technology standard. This concern was compounded further by skepticism about the attainability of CWA mandated WQS under the extant philosophy of dilution

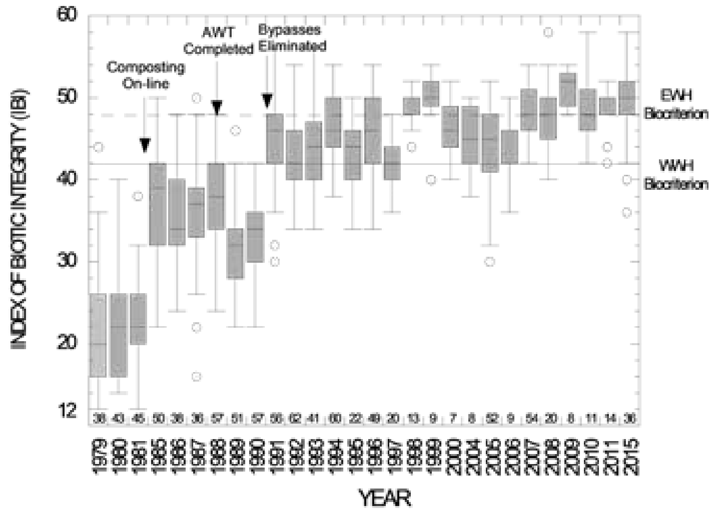

Figure 3. Box-and-whisker plot of the Ohio Index of Biotic Integrity (IBI) by year of sampling between 1979 and 2015 in the middle Scioto River mainstem between the Greenlawn Dam and Circleville, OH by Ohio EPA and MBI.

oriented thinking.

Attainment of WQS and Full Biological Restoration – It Almost Didn’t Happen

As part of the 1978 Ohio WQS revisions, discharges to many segments of Ohio rivers and streams could not meet newly adopted water quality criteria without additional treatment and certainly not by the 1977 compliance deadline (later extended to 1983) set forth by the 1972 CWA. To preclude the impending conflict between the existing levels of wastewater discharge and the new water quality criteria, a Limited Warmwater Habitat (LWH) use designation was added to the suite of Warmwater Habitat Uses (e.g., WWH minimally met the CWA) that comprised the first set of TALUs for Ohio rivers and streams. The water quality criteria for each LWH segment was varied to accommodate the existing levels of wastewater discharges with all being less stringent than the WWH criteria. U.S. EPA, acting in their oversight role over the states, disapproved the LWH designations as being incompatible with the intent of the CWA and placed Ohio on a schedule to upgrade each segment to WWH at a minimum. This event and the funding made available via the construction grants program eventually resulted in water quality based permits being issued for all major WWTPs including the Jackson Pike and Southerly WWTPs. U.S. EPA issued the National Municipal Policy and Implementation in 1979 which required that major WWTPs meet water quality based limitations by July 1, 1988.

“Project 88”

What became known as “Project 88” was the City of Columbus response to meeting the water quality based requirements of the Ohio WQS and the intent of the National Municipal Policy. Project 88 was a $208 million wastewater treatment plant expansion plan that would become the largest capital improvement program in the history of Columbus. The eventual success of Project 88 was evident in the reduction in loadings of common wastewater constituents such as 5-day biochemical oxygen demand (BOD5), suspended solids, and NH3-N (Figure 2). The reductions in NH3-N loadings resulted in lower instream concentrations and reduced ammonia toxicity (Figure 2) which was also paralleled by improved instream D.O. levels in response to reductions in BOD5 loadings. In terms of the primary "currency" of the NPDES program, water quality based permitting and the completion of Project 88 were each indicators of success. However, questions remained about the eventual showing of that success in terms of the recovery of the resident biota and meeting the biological criteria components of the Ohio WQS.

Biological Restoration – The Best Evidence of Success

The increase in water quality monitoring spurred by the rapid proliferation of government agencies tasked with environmental protection and management in the early 1970s eventually included biological monitoring of aquatic assemblages such as macroinvertebrates and fish. While water quality monitoring had previously been focused on selected chemical parameters, the biological integrity and protection and propagation of fish, shellfish, and wildlife provisions[5] of the 1972 CWA spurred an increased emphasis on biological monitoring and assessment (Davis and Simon 1995). Ohio EPA initiated a statewide program of intensive mainstem river and watershed surveys of fish and macroinvertebrate assemblages in combination with chemical/physical monitoring in 1979 (Yoder and Rankin 1995a, 1998; Ohio EPA 2011). The mainstem of the Scioto River between Columbus and Circleville was monitored annually beginning in 1979 with the goal of providing detailed information about year-to-year variations in the biological assemblages and about the need for and responses to increasingly stringent controls for wastewater discharges, especially addressing the serious doubts about meeting aquatic life restoration goals in an effluent dominated river. Providing badly needed clarity for these issues and the close proximity to the Ohio EPA facilities in Columbus made the middle Scioto River mainstem an ideal place for long term monitoring. The Ohio EPA program was designed at the outset to provide biological end points as the measures of pollution control success thus the monitoring and assessment program was fully integrated with the WQS and permitting programs (Yoder and Rankin 1998).

Early Biological Assessments of the Scioto River

The earliest biological assessments of the Scioto River in the 1960s by Olive and Smith (1975) and the FWPCA in 1965-68 (FWQA 1970) were focused on macroinvertebrates sampled with qualitative methods and their pioneering use as indexes of water quality. Each study concluded that ". . . the primary cause of water quality degradation was the excessive amount of oxygen demanding material introduced by municipalities and industries . . . which was particularly true of that portion of the Scioto River downstream from Columbus where the benthos reflected significant degradation of the Scioto River for a distance of 60-75 miles (97-120 km)." During that period bypasses of untreated or partially treated sewage were commonplace as the treatment plants did not yet have the capacity to treat all sewage flows (Yoder et al. 1981). The initial Ohio EPA biological assessments added to three decades of a singular focus on chemical measures of the quality of receiving rivers that were focused solely on oxygen demanding wastes as the awareness and technology to measure and assess the effects of toxicants lagged in their development.

While the awareness of water pollution raised by these early assessments helped spur water pollution controls, alone they were inadequate to understand and address the needs for fully restoring aquatic assemblages to levels expected by the 1972 CWA. The Ohio WQS eventually filled this void by adding an initial list of toxic chemical parameters in 1978 and expanding it in both coverage and scientific adequacy by 1990. The advent of biological criteria consisting of direct measures of the fish and macroinvertebrate assemblages (Ohio EPA 1987a,b, 1989a,b; 2015) and a process for determining the attainment and attainability of tiered aquatic life uses (Yoder 1995; Yoder and Rankin 1995a, 1998) filled gaps left by chemical assessments and criteria alone. Taken together the integration of WQS and monitoring and assessment provided a firmer basis for requiring advanced wastewater treatment via NPDES permitting resulting in the eventual attainment of CWA goals in the Scioto River mainstem.

Scioto River Fish Assemblage: 1979-2015

The historical record in Trautman (1981) and the Ohio EPA/MBI and OSUMB databases of 1979-2015 reveals the Scioto River to have one of the most species rich fish assemblages of any river in Ohio. Trautman (1981) lists 100 fish species in the middle Scioto River study area and with 8 new species added by Ohio EPA and MBI during 1979-2015, the current total is 108 species recorded. The effect of the Greenlawn Dam located in south Columbus as the downstream-most barrier to upstream fish movement is noteworthy in that 26 native fish species that occur downstream from the dam were not recorded upstream during 1979-2015.

The series of biological surveys in the Scioto River during 1979-2015 revealed poor biological conditions through 1981 followed by increments of improvement that corresponded to intermediate steps taken to reduce the bypassing of untreated sewage. Further improvements corresponded to the installation of advance wastewater treatment by Project 88 and substantially reduced loadings and improved water quality. The fish Index of Biotic Integrity (IBI), one of the three indices that comprise the Ohio biocriteria, exemplifies these improvements with full attainment of the Warmwater Habitat aquatic life use following shortly after in the early 1990s (Figure 3). The results of the 2015 survey by MBI showed attainment of the Exceptional Warmwater Habitat biocriteria by both the fish and macroinvertebrates downstream from Columbus Southerly. An analysis of changes in the occurrence of individual fish species during 1979-2015 show that 69 species exhibited increases while only five species on one hybrid showed significant declines. Consistent with the IBI, the majority of the increasing species are classified as intolerant or moderately intolerant to pollution while to declining species are classified as highly or moderately tolerant. Some of the increased species have used the Scioto River mainstem as an avenue of ingress to tributaries from which they have been absent for more than 100 years. Among the longer lived species, individual fish have markedly increased in size through the same time period.

Conclusions and Lesson Learned

All of the fish assemblage indicators showed clear trends of improvement through time that correspond to the decreased loadings of sewage pollution discharged the Columbus WWTPs after 1988. Both the fish and macroinvertebrate assemblage indices showed a steady improvement some of which have exceeded the minimum expectations of CWA mandated WQS and effluent limitations. Species level analyses likewise showed an increase in occurrence of formerly extirpated or reduced species that comprise nearly two-thirds of the fish fauna. In turn, only five tolerant species and one hybrid showed significant declines. All of these indicators of improvement coincide with the reduction of water pollution from Columbus wastewater treatment plants and the sewer system in general and commensurate improvement in instream water quality. The improved biological quality has provided for better recreational opportunities including fishing, hunting, and canoeing as evidenced by the addition of liveries and public access sites.

Perhaps the most important lesson learned is that the CWA mandated reductions in loadings of sewage pollutants from the Columbus sewer system via water quality based permitting resulted in water quality that was good enough to allow for a biological recovery that meets and in some places exceeds the goals of the CWA. This happened despite serious doubts about the treatability of sewage and the attainability of then poorly understood biological goals of the CWA when they were first introduced in the 1970s. From the first reported evidence of serious water pollution in the Scioto River dating to the 1880s to the installation and operation of advanced wastewater treatment after 1988, it took more than a century before sufficient actions to reduce pollution took place. Part of the delay was due to the perception of the costs of wastewater treatment, but also was largely due to the almost constant pursuit of the engineering technology that was actually required to consistently and reliably reduce pollutants to the levels necessary to meet CWA goals. These achievements did not come easily nor without a significant expenditure of public funds at the federal, state, and local levels. The serious doubts about the efficacy of advanced wastewater treatment and the attainability of Clean Water Act mandated WQS in an effluent dominated river first surfaced in the form designating the Scioto River as a Limited Warmwater Habitat (LWH) in 1978 that had lower water quality goals than that prescribed by the CWA, an action that was eventually disapproved by U.S. EPA illustrating the important role of federal agency oversight early in the process. Had the LWH designation not been reversed the improvements witnessed since 1988 would probably not have occurred, an illustration of the critical importance of getting the WQS "right" before developing regulatory or abatement actions. Hopefully this is an important example of why not giving up on difficult to attain water quality goals will eventually produce tangible environmental results.

This remarkable story of success is the result of the cumulative efforts by the many individuals at the federal, state, local, and private levels who labored through the difficulties of navigating the challenges of setting WQS, water quality based permitting, and achieving advanced wastewater treatment in an economically sustainable manner. It would be a challenge to name them all and some probably do not realize the important role they played in this success story – the real credit goes to those unnamed persons who worked in the City, County, State, Federal, and private domains to make all of this a reality.

Footnotes

[1]Midwest Biodiversity Institute, P.O. Box 21561, Columbus, OH 43221-0561

[2]NPDES – National Pollution Discharge Elimination System (NPDES): a CWA provision that prohibits the discharge of pollutants into waters of the U.S. without a permit issued by U.S. EPA or a delegated state.

[3]https://www.columbus.gov/utilities/about/Historical-Milestones-for-Wastewater-Treatment-in-Columbus/.

[4]NPDES – National Pollution Discharge Elimination System (NPDES) required by Section 402 of the FWPCA.

[5] Section 101(a) for biological integrity and 101(a)(2) for protection and propagation provisions.

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