PROGRESS REPORT
OF THE
MARYLAND HYDRAULICS PANEL

CULVERTS, CHANNEL STABILITY AND AQUATIC ORGANISM PASSAGE IN MARYLAND

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ACRONYMS AND ABBREVIATIONS

AOP	Aquatic Organism Passage
CMP	Corrugated Metal Pipe
DNR	(Maryland) Department of Natural Resources
MDE	Maryland Department of the Environment
MDOT SHA	Maryland Department of Transportation State Highway Administration
MDSPGP–5	Maryland State Programmatic General Permit–5
TMDL	Total Maximum Daily Load
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
WIP	Watershed Implementation Plan

EXECUTIVE SUMMARY

This document reports on the work of the Maryland Hydraulics Panel ("the Panel") during the period 2017-2018. The Maryland Department of Transportation State Highway Administration (MDOT SHA) and the Maryland Department of the Environment (MDE) appointed the Panel in July 2018 to explore the development of improved procedures to ensure that Maryland policies and processes leading to construction in floodplains are efficient, while also providing accurate assessments of hydraulic performance of highway waterway crossings. The Panel has worked closely with the staff of MDOT SHA and MDE; reviewed MDE regulations, policies and design approaches; and provided input on a variety of issues.

This report presents brief summaries of the Panel's consideration of several hydraulic concerns: culvert repair issues, channel stability, and aquatic organism passage. Guidance on culvert repair and replacement was ultimately delegated to a group other than the Panel. The Panel continues to discuss these topics and to consider potential recommendations, possibly including suggested revisions to relevant sections of the Code of Maryland Regulations (COMAR).

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1. INTRODUCTION

Since its establishment in 2015, the Maryland Hydraulics Panel ("the Panel") has discussed topics of concern to the state's waterways and aquatic resources. Maryland currently faces a number of challenges and opportunities requiring the application of hydraulics, including Watershed Implementation Plans (WIPs) in response to Total Maximum Daily Load (TMDL) requirements; stream restoration; and aging infrastructure (such as culverts and bridges). Maryland regulations promulgated several decades ago are not necessarily up to date with current environmental concerns, scientific understanding, and technical practice. Furthermore, it is desirable to coordinate among various state and federal agencies that have overlapping responsibilities for these resources. To date, Panel discussions have not resulted in recommendations on these topics. This Progress Report provides an overview of the Panel's work on three general topics: Culvert Lining, Channel Stability, and Aquatic Organism Passage. One chapter is devoted to each topic.

2. CULVERT LINING ISSUES

Some culverts within the MDOT SHA system are deteriorating, as identified through periodic inspection leading to repair and maintenance. MDOT SHA currently has a large inventory of inspected culverts needing repair of corrugated metal pipes (CMP) due to material deterioration at the culvert invert. Failure of these compromised culverts may result in road collapse at the stream crossing leading to increased potential of flooding and public safety issues.

Culvert repair could include invert paving, inserts, linings and other similar methods. Considering replacement may be cost prohibitive, the most effective and cost-efficient MDOT SHA invert repair is steel reinforced concrete paving of the culvert's lower half. MDOT SHA's goal for compromised culverts is to retain structural and hydraulic functions of the crossing to preserve public safety.

Since most culvert repair activities will occur in Waters of the United States (WOTUS), authorization is required prior to commencing construction (if not an emergency). All Maryland state laws and codes pertaining to waterway construction are mainly a result of the Clean Water Act of 1972. COMAR Title 26 "Department of the Environment, Subtitle 17 Water Management," (Maryland Division of State Documents, 2018) governs waterway construction throughout the state. Operational Policy 93-1 dated July 1, 1993 for "In-Kind Replacement of Bridges and Culverts" provided a guideline for the regulatory review process of "in-kind" replacement and repair of culverts. Hydrologic and hydraulic evaluation is typically provided to state regulators in quantifying post-repair benefits or consequences on the receiving waters. Increased upstream headwaters and downstream velocities are customarily a focus of regulatory review.

Prior to establishment of the Panel in July 2015, MDOT SHA reviewed and hydraulically evaluated 12 of their previously invert-paved culverts. These culverts were randomly selected considering proximity to Baltimore City for timely field measurements and observations. Up- and downstream conditions of each culvert were field observed and photo documented. The intent was to note any impacts to downstream conditions that could be attributed to the culvert invert paving. Of the original 12 culverts visited, three were disregarded because varying tailwater conditions severely limited any degradation from the subject culvert. The remaining nine field-visited Baltimore-area culverts and three additional Western Maryland culverts (giving a total of 12) were hydraulically evaluated using Federal Highway Administration's HY-8 Culvert Hydraulic Analysis Program (USDOT 2018). Geometry input was based on field measurements (9 Baltimore area culverts) and surveyed data (Western Maryland culverts).

The culvert lining issue was presented to the Panel in July 2015 with the intent to address regulatory review and authorization of these repairs on a programmatic scale rather than an individual review basis. The results of the HY-8 analyses for the 12 culverts were discussed at four meetings of the Panel from July to December 2015. The Panel discussions focused on the following issues: (1) the 100-year headwater flood elevation relative to elevations of improved structures upstream of the culvert, (2) reduction in cross sectional area of the culvert and increased downstream velocities, (3) the impact of the culvert diameter and slope on channel stability, and (4) the impact of culvert lining on Aquatic Organism Passage. The Panel also discussed the guidance given in the COMAR and Operational Policy 93-1. The objective of the Panel discussions was to develop criteria to determine when detailed hydrologic and hydraulic analyses were needed in "in-kind" replacement. A decision flow chart was developed but never finalized. In early 2016, MDOT SHA management assigned the task of addressing issues related to culvert lining to another group and the Panel stopped discussing this issue.

3. Channel Stability

The Panel's objective was to review and provide recommendations for modification or replacement of COMAR 26.17.04.07, Changes in Stream Channels or Floodplains (Maryland Division of State Documents, 2018)

3.1. ACTIVITIES

3.1.1. Review of Documents and Regulations

The panel explored stream stability issues and project permitting concerns related to COMAR 26.17.04.07.B.3: "Proposed floodplain encroachments may not increase the tractive force by more than 10 percent during the passage of the 2-year and 10-year frequency flood events unless it can be demonstrated that the channel will remain stable."

The following items were discussed:

- Significant increases in modeled shear stress (tractive force) in roadway crossing replacement projects. Most often increases in shear stresses are associated with increasing the size of a waterway crossing and a reduction in upstream water surface elevations (backwater).
- Increases in local shear stresses associated with removal of legacy sediments
- Acceptable magnitudes of tractive force
- Application of 2D models and the difference between local and cross section average value of shear stress
- Rosgen approaches for stream projects and stream stability
- Channel and waterway crossing costs associated with stream stability
- Waiver applicability based upon drainage areas

3.1.2. Presentations

The Panel reviewed a number of example projects and considered the implications of COMAR 26.17.04.07.

Presentation 1: MD 5 over St. Mary's River (September 28, 2017; Drew Altland, Jason Coleman)

A significant increase (733%) in modeled shear stress was found upstream of the proposed replacement bridge because the backwater was reduced in the proposed conditions. The proposed upstream stresses, however, were shown to be lower than existing downstream stresses. The justification provided for this project made it eligible for a waiver. The Panel discussed cost of stream stability improvements, safety issues at crossings, and the use of absolute or threshold magnitudes of shear stress instead of a percentage change in the COMAR,

Presentation 2: MD 223 over Piscataway Creek (December 5, 2017; Ward Oberholtzer, SHA)

Modeling showed that the MD 223 bridge replacement reduced upstream backwater and water surface and significantly increased the upstream boundary stresses. Downstream stresses were lower than the increased proposed stresses. A permit was granted; however, the cost of modeling and other associated work to show that the project would not increase that potential instability was significant. Environmental agencies limited channel work due to wooded upstream reaches. This prevented management of sediment upstream away from the bridge.

Presentation 3: MD 25 over Georges Run (December 5, 2017; Ward Oberholtzer, SHA)

The Project objective was to stabilize roadway and bridge from lateral migration that caused embankment erosion with the existing bridge. A 400-ft reach of channel upstream and a 300-ft reach downstream from the bridge was realigned. The floodplain upstream and

downstream of the bridge was graded as part of the realignment. The approach embankments were modified and armored to align flow with the bridge and to prevent future lateral migration damage to the crossing. Shear stress increases were mitigated by stabilization upstream and downstream reaches with rock riffle and buried rock structures. A 2D model was used to guide the design of the embankment modifications, the extent of rock protection, the floodplain grading, and the channel stabilization. Channel bank heights were well below bankfull elevations. Stabilization of an additional 300 feet upstream would have reduced the potential for significant lateral migration. Environmental agencies limited channel work due to the wooded riparian zone upstream and downstream. Wetlands and wetland vegetation is extensive and excellent habitat has developed in the project area only a year after construction.

3.2. FINDINGS

MDE will be opening the regulations for revisions and welcomes any input regarding regulations. The regulations are from the 1970's and need updating. All meeting participants agreed that the current COMAR 10% rule should be considered for revision. The current MDE administration is in favor of adding a stream restoration section in the COMAR.

Under current regulations, bridge projects are not subject to COMAR 26.17.04.07 unless channel work upstream or downstream is included as part of the project.

3.3. FUTURE WORK

Personnel from the USACE and other environmental regulatory agencies should be included in discussions regarding regulation changes to obtain their perspectives and knowledge, so that all agencies are in agreement. The Panel will continue to review projects and will consider developing metrics for assessing restoration and other projects that affect stream stability.

4. Aquatic Organism Passage

The Panel formed a subcommittee of several of its members who routinely work on aquatic organism passage (AOP) projects. The objectives of the subcommittee were to identify regulations that should be updated and policies and procedures that should be developed to reflect advances in applied science and practices. The subcommittee anticipates that modifications of the regulations, policies and procedures will increase the effectiveness of AOP practices, decrease ambiguity of what is required to permit highway crossings, and allow AOP to be integrated into the water crossing design with other waterway crossing objectives, including scour, reduction in flood levels, and stream stability.

4.1. ACTIVITIES

The activities of the subcommittee focused on the review of existing policy and evolving applied science and practice in the design of water crossings for AOP. Before initiating the reviews, the subcommittee expanded Panel and subcommittee membership to include two new members from resource agencies: Joseph DaVia (Chief, Maryland Section Northern, Regulatory Branch, USACE) and Mark Secrist (USFWS biologist). The members were added to ensure inclusion of environmental agency perspectives. The subcommittee has worked on two tasks:

- Review relevant documents and regulations regarding AOP practices.
- Share presentations from subcommittee and panel members with experience in AOP and resource agencies involved in permitting.

4.1.1. Review of Documents and Regulations

The subcommittee reviewed research reports and manuals of practice to identify those that were the most relevant to Maryland AOP issues:

- Barnard (2013): *Water Crossing Design Guidelines [for Washington state]*.
- Hotchkiss and Frei (2007): *Design for Fish Passage at Roadway-Stream Crossings: Synthesis Report.*
- Kenney et al. (1992): *Blockage to Fish Passage Caused by the Installation/Maintenance of Highway Culverts.*
- Kilgore et al. (2010): *HEC-26: Culvert Design for Aquatic Organism Passage.*
- Martin and Apse (2013): *Chesapeake Fish Passage Prioritization: An Assessment of Dams in the Chesapeake Bay Watershed.*
- US Forest Service Stream-Simulation Working Group. (2008): *Stream simulation: an ecological approach to providing passage for aquatic organisms at road-stream crossings.*
- *Factors Considered for Conducting a Fish Crossing Analysis for Culvert Maintenance.* Poster from Coastal Resources, Inc. Not publicly available.
- *North Atlantic Aquatic Connectivity Collaborative (NAACC) roadway crossing assessment protocols and database: https://www.streamcontinuity.org/index.htm.*

The subcommittee also reviewed the Code of Maryland Regulations (COMAR), state permit requirements, and federal permit requirements.

4.1.2. Presentations

Members of the panel experienced in the design and implementation of AOP practices presented lessons learned from previously implemented AOP projects. Individuals from state and federal agencies presented information on current regulations and policies of their agency.

Presentation 1: MDOT SHA/RK&K Report on Assessment of Fish Passage Measures. Drew Altland and Jason Coleman presented results of their study (Altland et al. 2017) on the effectiveness of fish passage retrofits at six locations:

- Indian Creek at MD 193
- Paint Branch at I-495 (inner and outer beltway loops)
- Indian Creek at Old Baltimore Pike
- Muddy Bridge Branch (Tributary to Sawmill Creek) at I-97
- Jones Falls at Ruxton Road/MD 25
- White Marsh Run at US 40

Presentation 2: Evolution of fish passage design in MDOT SHA Office of Bridge Development / Office of Structures (OBD / OOS) projects. Andy Kosicki discussed the evolution of MDOT SHA design processes concerning waterway crossing and fish passage.

Presentation 3: Hollywood Branch Retrofit. Ward Oberholtzer described the Hollywood Branch project, which included a riffle grade control structure used as an AOP retrofit.

Presentation 4: Department of Natural Resources (DNR). Greg Golden (Senior Environmental Review Manager) and Nancy Butowski (Program Manager, Fishery Management Planning & Fish Passage) participated in a discussion of AOP issues that centered on questions generated by the panel.

Presentation 5: USFWS Fish Passage Guidance. Mark Secrist presented guidance used by USFWS.

Presentation 6: USACE Policy and Guidance. Joe DaVia (Chief, Maryland Section Northern, Regulatory Branch) discussed Section 404 of the Clean Water Act (USEPA, 2018) and USACE's Maryland State Programmatic General Permit–5 (MDSPGP–5) (USACE Baltimore District, 2018), which require avoiding and minimizing impacts to WOTUS.

4.2. FINDINGS

Presentation 1: MDOT SHA/RK&K Report on Assessment of Fish Passage Measures. The presentation included the following findings and conclusions:

- Riffle grade controls
    - They were effective at several of the sites to provide fish passage at culverts that had developed downstream drops up to 4 feet.
    - They were most effective where they created backwater into the culverts, providing passage into and through the culverts.
    - They were ineffective in providing sufficient flow depth in the culvert outlet invert where they did not provide backwater into the culvert.
    - They appeared to be scoured by the concentrated culvert discharge when they were placed too close to the outlet. The high stresses from the discharge

caused the riffle crest to degrade to an elevation below the outlet invert elevation, which results in the loss of baseflow backwater to the culvert. The grade control riffles appeared to be less prone to erosion when placed downstream of a pool that allowed the culvert discharge to diffuse before flowing over the grade control riffle.
    - They may cause upstream sediment deposition and debris accumulation and may increase floodwater elevations.
- Concrete walls and weirs placed at culvert entrances and outlets to pond and concentrate water, small concrete channels with culverts intended to provide a low-flow fish passage pathway, and structures such as an Alaskan steeppass fishway can be effective where debris and sediment loads are low. These structures and devices, however, are prone to failure where debris and sediment may fill or divert low flow away from the intended structures or block access to them. Frequent maintenance is required to ensure effectiveness of these structural measures. In some instances, these structures were constructed or are now located in hydraulically ineffective culvert cells. Hydraulically ineffective cells are those (e.g., a cell located on the inside of a channel bend) where flood flow velocity is much lower than in other cells or where flow is recirculating at the entrance, causing sediment deposition or debris accumulation.
- Herringbone pattern baffles
    - They provide increased flow depth in box culverts that may be sufficient for fish passage.
    - Overlapping baffles appear to be more effective in providing higher flow depths than non-overlapping.
    - They may not be effective where sediment and debris loads are significant.

Presentation 2: Evolution of fish passage design in MDOT SHA Office of Bridge Development / Office of Structures (OBD/OOS) projects. The presentation had several main points:

- For AOP design to be reliable, effective, and sustainable, it must consider stream morphology.
- Fish ladders will not be the preferred MDOT SHA practice for AOP retrofits.
- Riffle grade control structures will be the main practice for retrofits.
- Latest designs for replacement structures prefer creating a pool in and through a culvert and/or embedment of one of the culvert cells in a multi-cell structure.
- The ecological effectiveness of AOP projects depends on the degrees of floodplain and channel connectivity and the ability of the waterway to convey sediment, debris and floodwaters (Hotchkiss and Frei 2007).

Presentation 3: Hollywood Branch Retrofit. The main points of the presentation were:

- Floodplain excavation downstream could be used to mitigate the effect of riffle grade controls on upstream 100-year flood elevations.
- Resource agencies were concerned that the size of the pool created by the grade control structure was so large that it would affect the temperature of the water to the extent that it could affect aquatic organisms.

Presentation 4: DNR. The main points that came from the subcommittee's discussion are as follows:

- The foundation of DNR environmental review for culverts is the MDE regulation that requires setting the pipe invert a minimum of 1 foot below the stream invert, so that a natural channel bottom is provided.
- Long-term bed degradation is not considered as part of the 1-foot embedment requirement.
- The DNR preference for crossings is (1) bridge, (2) large bottomless arch culvert, and (3) conventional culvert/depressed pipe. The applicant has to prove that a lower priority is acceptable.
- Retrofits are viewed differently than new and replacement structures, with more consideration to cost and ecological benefits.
- DNR considers the best approach for AOP to be mimicking upstream and downstream conditions.
- The Chesapeake Fish Passage Prioritization tool uses metrics to evaluate passage barriers that may be applicable to culvert assessment (http://maps.freshwaternetwork.org/chesapeake).
- The USFWS approach to AOP is a broader "reference reach" approach rather than design of specifics for a certain species (i.e., velocity and depth requirements related to a specific fish).
- Baseflow and high springtime flows should be the priority flow conditions for assessing passage.
- Flow in the fall is important for spawning brook trout.
- Requirements are the same for streams with anadromous, catadromous, and potamodromous fish generally; but spring flows are important for anadromous fish. Connectivity is important for all species.
- Three areas for improvement were noted: improving communication, education of policy makers, and demonstration projects.
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Presentation 5: USFWS Fish Passage Guidance. Secrist emphasized that this is only guidance and not policy. The presentation included the following main points:

- The 2016 USFWS Mitigation Policy (USFWS 2016b), which is still in review and is a revision of the 1981 policy; and fishway prescriptions (under Section 18 of the Federal Power Act (FPA)), which minimize, rectify, or reduce over time through management the impacts of non-federal hydropower facilities on fish passage.

- The 2016 USFWS Endangered Species Act Compensatory Mitigation Policy (USFWS 2016a): Incorporating a landscape-scale approach to development and conservation planning, including mitigation, that ensures a "net gain" or, at a minimum, "no net loss" in the status of affected resources, as directed by presidential memorandum (80 FR 68743, November 6, 2015).
- USFWS's preference that fish (and non-fish) passage be a consideration for all road crossing projects: new crossings, replacement crossings, roadway widening, and maintenance projects.
- Overall USFWS policy to prevent the spread of invasive species
    - Susquehanna Anadromous Fish Restoration Committee (SRAFRC) is working on a policy for Conowingo regarding passage of snakeheads and other invasive fish like flathead and blue catfish.
    - Prevention of brown trout from moving into brook trout streams.

Presentation 6: USACE Policy and Guidance. The Nationwide 27 permit and the MDSPGP–5 include conditions to avoid and/or limit AOP blockage issues. Pre-permit application meetings are important to increase the chance that AOP issues and practices are identified and discussed early in projects. The preferred prioritization for waterway crossings: (1) bridge, (2) bottomless pipe, and (3) culvert with partial depression.

4.2.1. Existing State and Federal Regulations

General statements addressing fish habitat and passage are provided within Maryland COMAR Title 26: "Administration shall consider blockage of free passage of fish to be contrary to the public interest" and "projects that eliminate or significantly and adversely affect aquatic or terrestrial habitat and their related flora and fauna are not in the public interest."

COMAR subtitles related to waterway crossings that currently address fish habitat and fish passage include 26.17.04.06 Bridges and Culverts, 26.17.04.11 Criteria for Evaluating Applications, and 26.17.04.04 Permit Applications – General Requirements. Two specifications are provided in the COMAR subtitles:

- 26.17.04.06 B(3): "The length of culverts shall be limited to a maximum of 150 feet unless it can be demonstrated through an environmental study that any adverse impacts will be adequately mitigated."
- 26.17.04.06 B(6): "Culverts shall have at least one cell placed at least 1 foot below the invert of the stream. In the case of bedrock foundations, culverts shall be designed without a concrete invert unless measures are incorporated into the design to ensure that fish habitat or migration patterns are not adversely affected."

Federal requirements related to aquatic organism passage in WOTUS are primarily contained within the MDSPGP–5. The permit language addresses aquatic life movement and is not

restricted to passage of fish. Below are excerpts from sections of the MDSPGP–5 that pertain to AOP:

- "Activities must not block or impede the movements of anadromous or resident fish species."
- "Culverts placed in streams must be installed to maintain low flow conditions."
- "A low flow channel must be maintained through any discharges placed for armoring across the channel so as to not impede flow in the waterway and/or not to block or impede the movements of anadromous, estuarine, and resident fish."
- "Permanent culverts or pipes placed in streams must be depressed in accordance with the State of Maryland regulations."
- "If countersinking of the culvert or footer is not practicable in accordance with condition (1) above (except those placed in streams on bedrock or over buried utility lines), the applicant must submit a narrative, along with their application, documenting measures evaluated to minimize disruption of the movement of aquatic life, as well as specific documentation concerning site conditions and limitations on depressing the culvert/footer, cost, and engineering factors that prohibit depressing the culvert/footer."
- "Options that need to be considered include the use of a bridge, bottomless pipe, partial depression, or other measures to provide for the movement of aquatic organisms."

4.3. FUTURE WORK

The subcommittee is still in the early stages of gathering and synthesizing information on innovations in AOP practices. Based on discussions and findings to date, the subcommittee has identified several issues that it intends to pursue.

Maryland state regulation is focused on fish passage with limited criteria related to culvert embedment and culvert length. Advances in the state of practice of AOP may allow for more specific regulation that includes channel morphological assessment and more advanced AOP practices. The 1-foot embedment criteria and the 150-foot length limitations are appropriate for some culvert installations; at many sites, however, they are inadequate. Specifications that include factors such as bed degradation, debris load, and sediment load may be beneficial.

The general statements in the regulations provide for broad interpretation of potential AOP requirements. However, more regulatory language regarding several specific issues may be beneficial:

- Emphasis on AOP instead of fish passage.
- Distinction in some regulations regarding anadromous fish that are entirely dependent on passage at specific times of the year for spawning and other fish species that may be less dependent on passage for survival.

- Variation in requirements for retrofits, replacement structures, and new structures.
- Emphasis on policy that specifies creating flow passage conditions in the waterway crossing similar to those upstream and downstream of the crossing rather than the use of generic flow depth and velocity criteria.
- Integrate AOP into water crossing design together with other objectives including scour, flooding, and stream stability
- Guidance for culverts in tidally affected waters

Currently, state regulations are broad, allowing for flexibility by resource agencies to permit a variety of types of AOP practices; however, the broad nature of the regulatory language causes uncertainty and inefficiency in the permitting process. Project reviews are case-by-case and inconsistent, with some conflicting comments between agencies. Permit review agencies sometimes disagree about specific practices and requirements. Interpretation of current regulations by resource agencies excludes practices that may be beneficial or allows practices that may be unsustainable and detrimental to AOP.

A guidance document that includes interagency agreement on AOP practices and requirements could improve the permitting process. A few states have developed AOP manuals of practice that may be useful in development of policies and procedures in Maryland.

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APPENDIX A: DEFINITIONS

Code of Maryland Regulations (COMAR) – The official compilation of all administrative regulations issued by agencies of the state of Maryland.

Floodplain – Any land area susceptible to being inundated by floodwaters from any source.

Maryland Department of the Environment (MDE) — Created in 1987 to protect and preserve the state's air, water and land resources and safeguard the environmental health of Maryland's citizens. MDE's duties also encompass enforcement of environmental laws and regulations, long-term planning and research. MDE provides technical assistance to Maryland industry and communities for pollution and growth issues and environmental emergencies.

Maryland Department of Transportation State Highway Administration (MDOT SHA) — A business unit of the Maryland Department of Transportation, responsible for planning, design, engineering, maintenance and operation of state-owned roads and bridges.

United States Army Corps of Engineers (USACE) — a U.S. federal agency under the Department of Defense and a major Army command made up of some 37,000 civilian and military personnel. USACE permits are necessary for any work, including construction and dredging, in the Nation's navigable waters.

United States Fish and Wildlife Service (USFWS) — a U.S. federal agency within the Department of the Interior dedicated to the management of fish, wildlife, and natural habitats. Among its responsibilities are enforcing federal wildlife laws, protecting endangered species, managing migratory birds, restoring nationally significant fisheries, and conserving and restoring wildlife habitat, such as wetlands.