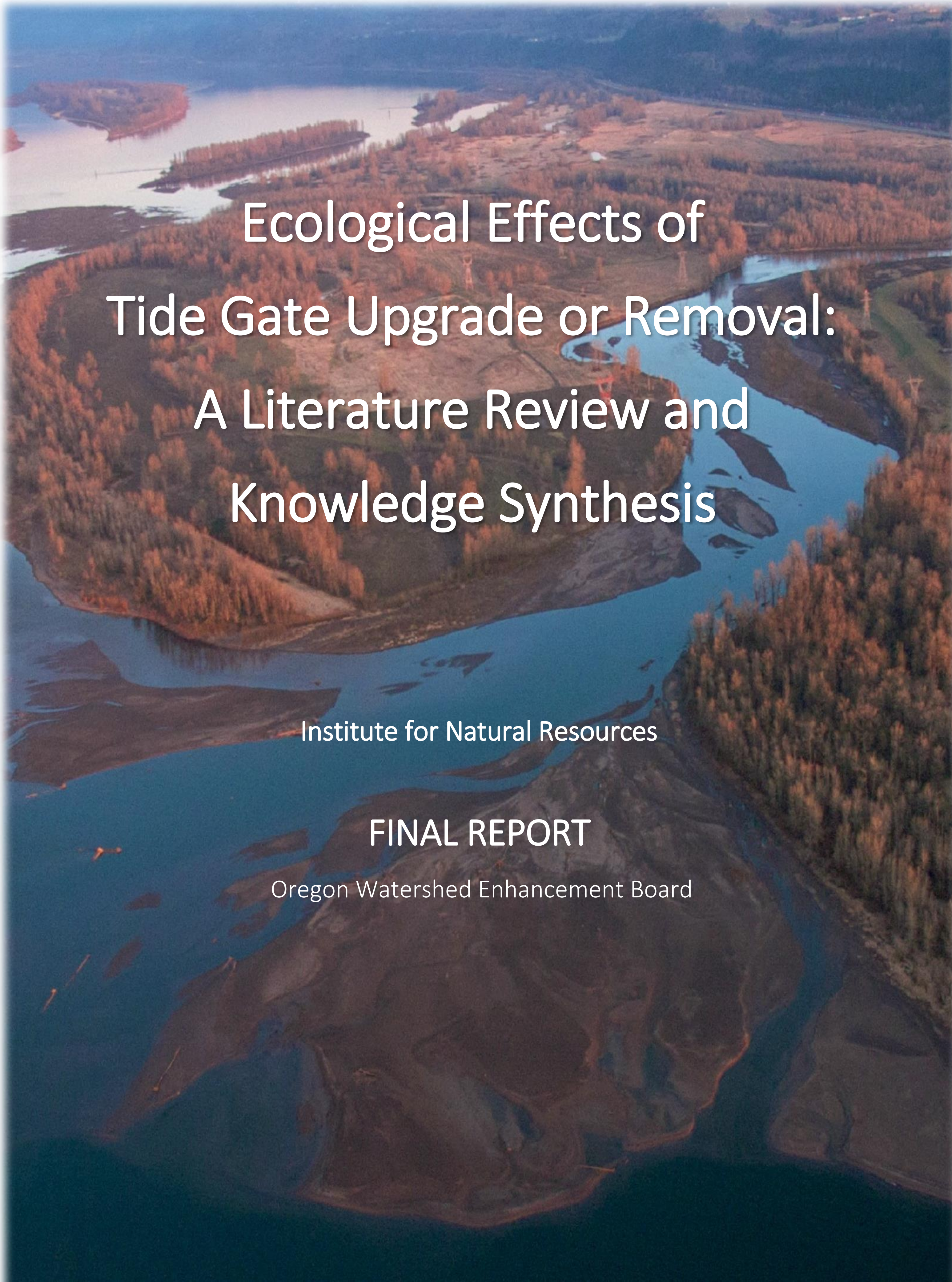

Ecological Effects of Tide Gate Upgrade or Removal: A Literature Review and Knowledge Synthesis

Institute for Natural Resources

FINAL REPORT

Oregon Watershed Enhancement Board

Ecological Effects of Tide Gate Upgrade or Removal: A Literature Review and Knowledge Synthesis

Final Report: Executive Summary

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Disclaimer

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The contents of this report reflect the views of the authors who are solely responsible for the facts and accuracy of the material presented. This report does not constitute a standard, specification, or regulation.

Executive Summary

This document reports on findings, conclusions and recommendations derived from scientific literature and knowledge regarding the effectiveness of tide gate removal or upgrade in improving conditions for Oregon's native migratory fish species, particularly salmonids, and other plant and animal species that utilize estuarine ecosystems. The project was commissioned by the Oregon Watershed Enhancement Board (OWEB) to foster better understanding of the effectiveness of their past investments in estuary habitat restoration involving tide gates, and to aid in targeting future investments. This will be especially important because many less-complicated projects (e.g. those on public land, smaller, single-action projects, those with consensus on land use) have already been completed, and restoration efforts are becoming increasingly complex and resource intensive. Additionally, restoration actions and benefits can vary considerably according to local conditions. Thus, key questions going forward involve project prioritization and design to achieve maximum return on investments in an environment where demand for projects exceeds available resources. Users of this information may include applicants submitting tide gate and estuary restoration proposals to OWEB, reviewers of these proposals, other OWEB staff, and the OWEB Board of Directors.

The project is premised on the assumption that the ecological effects of existing tide gates are understood well enough to make estuary restoration involving removal or upgrades of aging tide gates generally worthwhile in terms of improved fish passage and estuarine habitat conditions. However, the data on tide gate restoration (removal or upgrade) was not cohesively synthesized. To address this information gap we focused our work around the following four tasks.

Task 1: A review of literature pertaining to tide gate removals and upgrades;

Task 2: Summary and review of completed, primarily OWEB-funded tide gate removal and/or upgrade projects and associated effectiveness monitoring;

Task 3: Summary and review of completed tide gate removal and/or upgrade projects and associated effectiveness monitoring not funded primarily by OWEB; and

Task 4: Summary and synthesis, including findings and recommendations.

We used a multi-faceted approach to knowledge synthesis, including review of relevant scientific literature, OWEB and non-OWEB agency reports on tide gate projects, and inquiries to state and federal agency staff working on estuary restoration in the Pacific Northwest region. The work was completed by a team based at Oregon State University. The report is organized into seven chapters, described below, with significant findings and recommendations at the conclusion of this Executive Summary.

Chapter 1: Introduction provides an overview of tide gates and tide gate hydraulics to help understand their effects. Various types of tide gates are described, including modifications intended to reduce adverse effects on fish passage and water quality. Because tide gate operations are controlled by tidal cycles, we are using an example from the upgraded Willanch Creek tide gates in the Coos Bay estuary to explain how tidal hydraulics govern the timing of gate openings and closing, the degree of opening, and resulting water velocities. The chapter concludes with a discussion of recent OWEB investments in tide gate removals and upgrades, and the desire to have a review of literature and knowledge to lay the foundation for future programs. Throughout our investigations, we were asked to identify data gaps and areas for future study, as well as major uncertainties or topics of concern that should be considered in grant application reviews for tide gate removal and upgrade projects.

Chapter 2: Methods describes the process we used to conduct the literature search and our examination of completed restoration projects and monitoring. This review focused on four questions:

1. Does tide gate *upgrade* affect salmonid abundance, distribution, growth, survival or habitat availability in the Pacific Northwest (PNW)?
2. Does tide gate *removal* affect salmonid abundance, distribution, growth, survival or habitat availability in the PNW?
3. Does tide gate *upgrade* affect water temperature, salinity, dissolved oxygen and tidal exchange in the PNW?
4. Does tide gate *removal* affect water temperature, salinity, dissolved oxygen and tidal exchange in the PNW?

To conduct our search for relevant literature we utilized systematic review methods (which enhance objectivity and transparency) in conjunction with traditional literature searches. Systematic searches were conducted using Google Scholar and Web of Science. About 350 search results from twelve individual searches were assessed in this manner, producing an initial list of approximately 65 pieces of provisionally included literature, with an additional 15 found through other means. These 80 articles were evaluated and categorized in an Excel spreadsheet, with 32 ultimately considered pertinent for the literature review (although others were used for the ecological context discussion).

OWEB provided project completion and post-implementation reports for restoration and monitoring projects for which they were the primary funder (Task 2). Identifying and accurately describing primarily non-OWEB tide gate projects (Task 3) was not straightforward, due the complex, multi-phase nature of estuary restoration; diversity in participants, funders and project goals; and associated inconsistencies and gaps in project naming, reporting, and monitoring. We identified some primarily non-OWEB projects during systematic searching, and additional projects using variants of project and location names, publication lists, keyword searches within synthesis documents, bibliographies, and queries to estuary restoration entities. We faced similar issues in identifying primarily non-OWEB monitoring efforts. Monitoring was sometimes linked with a particular tide gate removal or upgrade, but was usually focused on watershed-level restoration with multiple components. This limited our ability to distinguish results associated with tide gates from broader watershed-level findings. We included projects from British Columbia, Canada to Humboldt Bay in northern California. Some were well documented while others were not, so the level of detail provided for each project varies.

Our searches to identify and review primarily non-OWEB tide gate projects were extensive but not exhaustive. A “deeper dive” into projects already identified would likely reveal additional information.

Chapter 3: Ecological Context of Tide Gates in Streams and Estuaries examines the effects of existing tide gates, salmon life history diversity, and the importance of coastal marsh habitats for juvenile salmonids. We began with the assumption that ecological effects of tide gates were well understood and accepted. During our investigation we found additional evidence of effects resulting from existing tide gates. We also found new information on early migrating estuary-rearing coho salmon life histories contributing to the spawning population and highlighting the importance of estuarine habitats to a broader range of juvenile salmonids than previously recognized. We include this information as context for our discussion of tide gate removals and upgrades, and as evidence for the value of such projects.

Chapter 4: Effects of Tide Gate Upgrades and Removal on Aquatic Organisms and Estuarine Environments is a review of findings on this subject reported in the scientific literature (i.e., peer-reviewed journal articles and graduate student theses) and various project reports identified via literature searching. Our review was focused on the Pacific Northwest but included studies from other regions. Documentation and availability of monitoring data—even in cases where we found evidence that monitoring was done—varied significantly from project to project, and by region. Where monitoring data were available, interpretation and synthesis were often insufficient to allow for robust conclusions. Summaries and findings are drawn from peer-reviewed literature and M.S. theses where available, but are also informed by a significant amount of information from non-peer reviewed agency reports and monitoring data. Very few studies only examined the effects of tide gate upgrades or removal independently of other restoration actions. Thus, for most studies we could not distinguish the confounding effects of different actions. As a result, we were not able to answer the guiding questions separately. Instead, we identified two main themes related to tide gate upgrades and removals- 1) effects on salmonids and other aquatic organisms and, 2) effects on water quality- that we used to organize our synthesis of 32 publications. Only a few of these publications were directly relevant to addressing the four guiding questions. The rest provided valuable information to better understand the general context of how and why tide gate upgrade and removal projects benefit salmonids and other aquatic organisms as well as their estuarine habitats. Individual summaries of these publications are included in Appendix A.

Chapter 5: Regional Project Summaries complements the literature review by showing the extent and diversity of estuarine restoration projects in Oregon, Washington, and northern California, extracting information from the detailed project descriptions found in Appendix B (primarily OWEB-funded) and Appendix C (primarily non-OWEB funded). Forty-seven restoration projects in five different regions are highlighted, including 14 in Oregon where OWEB was the primary funder (and another eight primarily funded by others). These projects highlight the diversity of tide gate related estuarine restoration, ranging from single tributary stream tide gates to complex projects involving multiple tide gates, levee setbacks, habitat restoration, and infrastructure improvement. Chapter 5 also discusses monitoring efforts that evaluate these projects. This monitoring includes implementation (whether the project was implemented according to designs), effectiveness (whether the project was likely to meet its goals), and validation (how do these projects fit into the larger status and trend, and salmon life cycles). Thirteen OWEB-funded monitoring projects are discussed, along with an additional 21 funded by others.

Chapter 6: Thinking Systematically about Tide Gates synthesizes the work described in Chapters 3, 4, and 5 into a framework that can be used for program development. We identify four types of project goals (developing estuarine rearing habitat, improving fish passage, providing flood control, and protecting infrastructure) that typically guide tide gate related restoration projects. We also identify three general tide gate geographies (river/stream mouths, tributary mouths, and field drains) and discuss their features as they relate to restoration opportunities. Through our analysis of projects in the previous chapter, four common types of tide gate related restoration projects were distinguished (complete tidal reconnection, partial tidal reconnection, tide gate upgrades for fish passage, and tide gate upgrades to improve rearing habitat). Chapter 6 also provides a number of "lessons learned" by restoration practitioners related to fish ecology, project implementation, and monitoring. The final section discusses regional frameworks for collaboration, project prioritization, and reducing regulatory uncertainty. Washington's extensive experience in restoring its estuaries offers potential models, Oregon's land use planning for estuary management provides a framework to develop a coast-wide programmatic strategy, and there are recent examples of cooperation and collaboration that could provide a structure.

Chapter 7: Findings and Recommendations concludes the report. "Findings" are used to identify key insights of the review team, organized into five themes: physical and ecological effects of tide gates; project scoping, prioritization, and planning; project implementation and effectiveness; future monitoring and information needs; and potential components of a Phase II follow-on project. Each of the findings provides some elaboration, as well as recommendations that OWEB can consider as they move forward with program development.

A subset of the findings and recommendations from Chapter 7, representing the key findings, are summarized below, divided into five categories.

Physical and ecological effects of tide gates

Finding 1: Limited or nonexistent connectivity significantly affects fish community composition and water quality.

Recommendation: The science is clear that for salmonid fish habitat and passage, the absence of tide gates is preferred, if possible. However, this does not take into consideration current land uses and other factors associated with the use of tide gates. Improved tide gates and their active management have the potential to ameliorate many adverse impacts to fish passage and water quality, especially when seasonal passage needs and habitat utilization are incorporated.

Finding 2: Life-history diversity of juvenile coho salmon is greater than previously realized.

Recommendation: The clear implication of this body of literature is that, besides Chinook salmon, coastal populations of coho salmon will benefit significantly from increased connectivity and fish passage opportunities in the freshwater/estuarine ecotones of rivers and this should be incorporated into tide gate design, installation, upgrades or removal projects.

Recommendation: Additional research into juvenile coho salmon rearing life histories and their habitat use would benefit practitioners if targeted to potential restoration strategies and project site selection and implementation.

Finding 3: Estuary rearing provides increased growth opportunities for juvenile coho salmon.

Recommendation: Plan restoration actions with the expectation that all beneficial ecological effects, such as increased prey productivity creating improved foraging opportunities for juvenile salmon, may not occur for several years after project completion.

Project scoping, prioritization, and planning

Finding 4: Oregon's Statewide Land Use planning framework includes detailed requirements for the planning and management of Oregon's estuaries that need to be recognized in project scoping, design, and implementation.

[illegible] potential types, places, and methods for tide gate related restoration in Oregon's estuaries. Local conservation organizations should work with local county planners in developing future program strategies. The collaborative process for revising the Coos Bay Estuary Management Plan by Coos County and the Partnership for Coastal Watersheds (South Slough National Estuarine Research Reserve and Coos Watershed Association) can serve as a model and pilot for revising other coastal estuary management plans.

[illegible] Development to identify processes that facilitate incorporation of restoration considerations associated with both tide gate upgrades and removals as estuary management plans are revised.

Finding 5: Estuary restoration projects increasingly have multiple goals providing joint benefits.

[illegible] quality, fish recovery, agricultural conservation, flood protection, climate change resilience, and/or recreation benefits are more likely to be locally acceptable and fundable, but are also more complex and require coordinated project management.

Finding 6: Oregon lacks a comprehensive framework for estuary restoration.

[illegible] acknowledges diverse stakeholder goals and benefits, while articulating a common vision for human uses of estuaries, floodplains, and coastal wetlands.

Finding 7: Estuary restoration projects increasingly include acquisition of the lands to be restored, a trend that is likely to continue.

[illegible] for identifying lands that are suitable for acquisition as part of a comprehensive estuarine restoration strategy.

Finding 8: Oregon has a system of watershed councils and soil and water conservation districts that work to coordinate and support local restoration efforts.

[illegible] councils and districts for partnership building, promoting social learning regarding the multiple benefits of estuary restoration, generating support and helping to coordinate locally-acceptable restoration projects.

Finding 9: Mitigation and environmental damage funds are underutilized for estuary restoration in Oregon.

[illegible] other estuary restoration actions. This may involve administrative rule-making (or statutory changes) to better coordinate mitigation and restoration.

Finding 10: **Benefits and effects of tide gates are related to their geographic location: stream/river mouth and tributaries allow tide gate upgrades to meet multiple goals.**

[illegible] flood mitigation) prioritize projects where the tide gate(s) are located at stream/river mouths, or tributary creeks.

[illegible]

Finding 11: **A recently recognized ecosystem service of coastal wetlands is their extraordinary capacity to capture and sequester atmospheric carbon (known as "blue carbon").**

[illegible] to quantify potential carbon benefits of coastal wetland restoration. Explore the potential for investment in tidal wetland restoration efforts by considering the interplay of such efforts with carbon sequestration.

Project implementation and effectiveness

Finding 12: **The best restoration results have been reported for large scale and comprehensive restoration projects, and not solely tide gate upgrades.**

[illegible] reestablishing connectivity and ecosystem level processes over those that focus on changing one single factor (e.g., number of fish that pass, water quality above tide gates, etc.).

Finding 13: **Upgrading a tide gate is only the first step in the process of improving ecological conditions and fish migration corridors.**

[illegible] post restoration management plans should explicitly provide for active and adaptive management of the gates in order to incorporate knowledge gained from research and monitoring, and to account for unforeseen effects or outcomes.

[illegible] requires a balancing of: 1) gate opening time and width, 2) culvert width, 3) invert elevation, and 4) upstream pool depth at high tide.

[illegible] requirements, water temperatures and dissolved oxygen are suitable for juvenile salmonids when they are present in the system. Additionally, any maintenance that requires a tide gate to be closed should be conducted when salmonids are not present.

Future monitoring

Finding 14: **The information base on the effects of tide gate upgrades is very limited. Project practitioners lack support to publish monitoring results in peer-reviewed journals.**

wŜŏ2ΥΥŜyŘl·ű/2y/ Provide funding support, incentives, and technical assistance to allow entities conducting monitoring of OWEB estuary restoration projects to develop publications of their findings for submission to peer-reviewed journals.

wŜŏ2ΥΥŜyŘl·ű/2y/ Continue and expand partnering with research universities to recruit graduate students to test hypotheses regarding tide gates, conduct in-depth monitoring, and publish results.

Finding 15: **Long-term monitoring is critical, but this is resource and time-intensive and support for it is usually limited. There is no comprehensive estuary restoration project monitoring strategy.**

wŜŏ2ΥΥŜyŘl·ű/2y/ Develop a more integrated and cohesive monitoring strategy for OWEB estuary restoration projects, starting with rigorous analysis of what questions the monitoring should be designed to inform or answer. Explicitly consider how monitoring results would be used to inform adaptive management of tide gates. To the extent possible, institutionalize and standardize existing OWEB monitoring protocols, so existing data can be compared to new data.

wŜŏ2ΥΥŜyŘl·ű/2y/ Review monitoring protocols used by other programs in the PNW (e.g. the Columbia Estuary Ecosystem Restoration Program) to inform development of a more standardized and cohesive approach for monitoring OWEB-funded estuary projects.

wŜŏ2ΥΥŜyŘl·ű/2y/ Carefully consider which projects to monitor, who will be using the resulting knowledge, and how it will be used. Focus tightly on a carefully selected subset of potential sites or projects to track through time, i.e., 10-20 years.

Phase II project opportunities

Finding 16: **There is considerable potential for additional qualitative learning and quantitative data synthesis regarding the effectiveness of estuary restoration actions that involve tide gates in Washington and northern California.**

wŜŏ2ΥΥŜyŘl·ű/2y/ Develop a scope of work to continue knowledge synthesis and development of tools to support restoration and infrastructure modernization in Oregon's estuaries. Potential components include gathering and analyzing additional documentation and data sets, developing a monitoring framework, reviewing and synthesizing frameworks for collaborative restoration, and exploring the potential for development and application of a coast wide approach to hydrodynamic modeling to support project prioritization and alternatives analysis.

Finding 17: **There is a lack of clear guidance or reports on the likely costs and benefits of various types of tide gate and estuary restoration projects.**

wŜŏžƳƳŜyŘI·ŭžyľ Work with the INR review team and others to further develop this concept for use in a programmatic strategy and to support restoration grant reviews.

Conclusion

We believe there is an opportunity to expand and utilize the data sources and leads identified in this project for use in more robust analyses and syntheses, and generate new knowledge regarding the effectiveness of tide gate upgrades or removal. The information and recommendations contained in this report, coupled with additional efforts in the same vein, could foster a more holistic and integrated approach to estuary restoration projects in Oregon that involve tide gates.