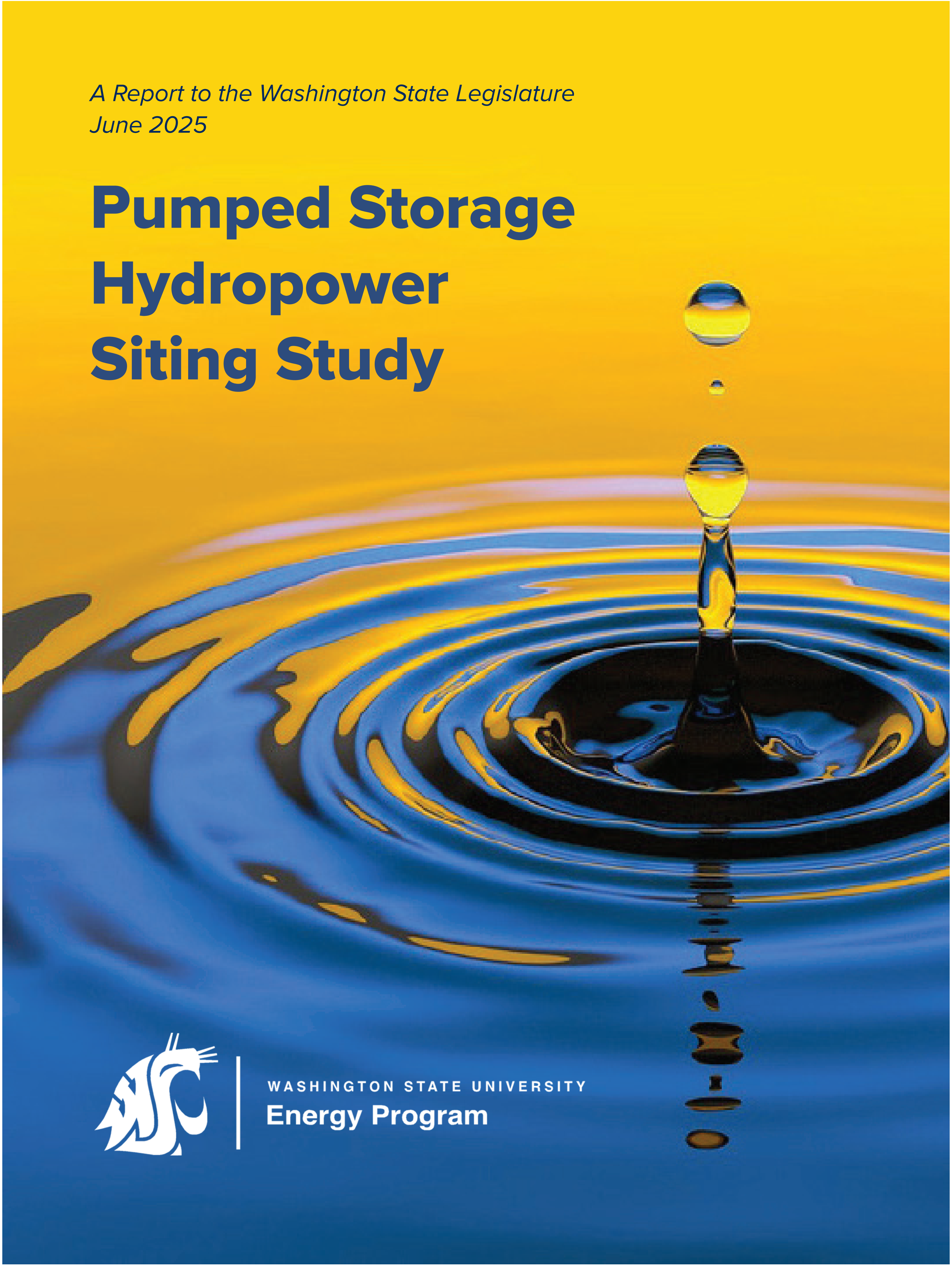
A Report to the Washington State Legislature
June 2025

Pumped Storage Hydropower Siting Study



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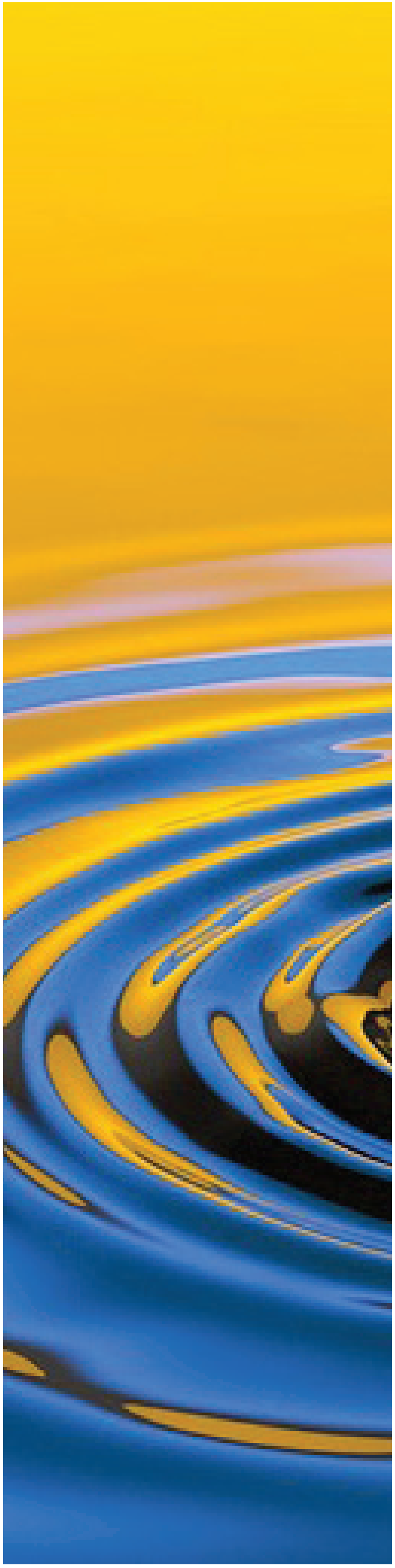

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Pumped Storage Hydropower Siting Study

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Visit the Study's website at

https://www.energy.wsu.edu/CleanFuelsAltEnergy/PSHSiting.aspx

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Acknowledgements

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Executive Summary

Pumped storage, or pumped storage hydropower (PSH), is a proven, existing, grid-scale, long-duration energy storage technology that currently provides over 90% of the utility-scale energy storage capacity in the United States.[1] Sometimes considered a “water battery,” PSH uses two reservoirs at different elevations, storing water as potential energy in the upper reservoir, and releasing water to the lower reservoir through turbines to create electricity for the grid when needed. When demand for energy is low and there is excess energy on the grid, water is pumped from the lower reservoir back to the upper reservoir to be stored until again needed. PSH can provide eight or more hours of electricity before needing to be “recharged” (water pumped back to the upper reservoir for storage).

Washington state is committed to an electricity supply free of greenhouse gas emissions by 2045.[2] As the state shifts to fossil-free energy sources such as utility-scale solar and wind, increased capacity of energy storage systems such as PSH will be needed to store the intermittently produced renewable energy, satisfying energy demands and balancing out the grid.[3]

Depending in part on where PSH facilities are sited, however, their construction and operation could potentially impact Tribal cultural resources, wildlife and habitat, water availability, and more. To identify these impacts, as well as other issues and interests, and provide that information to potential developers and agencies, the Washington State Legislature directed the Washington State University Energy Program (WSU) to carry out a process which WSU calls the PSH Siting Study.[4]

As part of the WSU PSH Siting Study, a team convened statewide online meetings, met with Tribes and individuals, and attended conferences to engage Tribes, agencies, local governments, special-purpose districts, and others to provide their views and thoughts about PSH. The statewide meetings provided technical information from subject matter experts about the PSH technology, and potential impacts from and mitigations for PSH construction and operations. This provided a foundation of knowledge for participants to engage in discussions and share insights.

The siting study team made it clear throughout the process that the study is not proposing or promoting any specific pumped storage hydropower projects. It is also not intended to substitute for project-specific environmental review and consideration of project-specific adverse effects on indigenous resources.

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1 Uria Martinez, R., & Johnson, M. 2023. US Hydropower Market Report 2023 (No. ORNL/SPR-2023/3076). Oak Ridge National Laboratory (ORNL), Oak Ridge, TN. *https://www.energy.gov/sites/default/files/2023-09/U.S.%20Hydropower%20Market%20Report%202023%20Edition.pdf*

2 Washington’s Clean Energy Transformation Act (CETA) (SB 5116, 2019) commits the state to an electricity supply that is fossil-free by 2045. *https://www.commerce.wa.gov/energy-policy/electricity-policy/ceta/*

3 Ramos, H., J. Sintong, and A. Kuriqi. 2024. Optimal Integration of Hybrid Pumped Storage Hydropower Toward Energy Transition. Renewable Energy 221: 119732. *https://doi.org/10.1016/j.renene.2023.119732*.

4 ESSHB 1216, 2023, Sec. 306 *https://lawfilesext.leg.wa.gov/biennium/2023-24/Pdf/Bills/Session%20Laws/House/1216-S2.SL.pdf?q=20240327114612*

This report is not a full research report on PSH technology, nor does it contain an exhaustive list of impacts; it is intended primarily to provide information gathered from participants. Citations for reports with more information on PSH are provided as footnotes throughout this paper.

The study focused primarily, but not exclusively, on closed-loop, or “off-river”, PSH systems, which have greater siting flexibility and tend to have fewer environmental impacts relative to open-loop systems, which are created by damming a naturally flowing water body and have greater impacts on aquatic ecology. While open-loop PSH has greater impacts to fish and other aquatic species, a disadvantage of closed-loop PSH is its need for a water source to fill the reservoirs. There are currently more preliminary permit applications for closed-loop PSH than open-loop, yet there are also many license applications for a subset of open-loop called add-on, which uses an existing reservoir so that only the upper reservoir needs to be constructed.

Participant comments

Four overarching themes surfaced from participant comments and discussion: concerns about Tribal cultural resources, water availability, impacts to terrestrial habitat, and impacts to aquatic ecosystems and fish from open-loop PSH. Avoiding areas with Tribal cultural resources was often stated to be the best way to protect them, especially because many impacts cannot be adequately mitigated. Other major Tribal concerns included the cumulative impacts from multiple projects, and that Tribes are often brought into the site identification, licensing, and environmental review processes too late. Participants suggested that developers and agencies engage early with Tribes, not develop where Tribal cultural resources would be impacted, continue monitoring PSH impacts after sites are developed, and continue engaging with Tribes over time.

Many participants expressed concern that water was needed to fill reservoirs in closed-loop PSH systems. Since water in Washington state is already mostly allocated and water for closed-loop is considered consumptive use, the need for water rights for PSH facilities could affect future water availability for other uses such as river flows and agriculture. The effect of climate change also brings uncertainty to future water availability. While suggestions from participants on this issue were few, they included investigating how to minimize the consumptive use of water.

Both open-loop and closed-loop systems have impacts on wildlife and terrestrial habitats, though the construction impacts are greater with closed-loop since two reservoirs are built, not one. Participant concerns ranged from wildlife and habitat disturbance and loss to disruption of migration routes and the introduction of invasive plant species. Most concerns about open-loop PSH were focused on impacts to fish. Suggestions made by participants to prevent or mitigate these impacts included establishing baseline habitat conditions with continuous monitoring, avoiding areas with the most listed species and important habitat, and establishing native vegetation after construction.

Mapping

In addition to the siting process, the legislature also required WSU to develop a map with GIS data layers highlighting areas identified through the process. The National Renewable Energy Laboratory (NREL) identified sites of theoretical pairs of reservoirs (which essentially create one closed-loop PSH) in the U.S. from digital elevation data.[5] The reservoir pairs have parameters such as minimum surface area, a specified height distance between reservoirs, and avoidance of critical habitats and federal protected lands.[6] The siting study team used the NREL map as a base to create four Washington state study-specific maps. It must be noted, however, that the objective of NREL was to assess the pumped storage resource capacity for the U.S. It is not the intent of the PSH Siting Study that these maps be used for actual siting of PSH.

Two maps highlight site proximity to rivers. The team learned from the Director of the Washington Department of Archaeology and Historical Preservation and from Tribal participants that important traditional cultural sites may sometimes lie within ½ mile from rivers and often up to the ridgeline. One map includes this ½-mile buffer but does not exclude reservoir pairs within the buffer, while another map excludes pairs within the buffer. It must be noted that working beyond a pre-determined buffer distance is not a substitute for consultation or vigorous cultural surveys.

Considering colocation of PSH with utility-scale solar and wind projects, another map plots utility-scale wind and solar facilities as well as transmission lines. Given that utility-scale solar is generally developed on relatively flat land while PSH needs elevation for one of its reservoirs, NREL's theoretical PSH reservoir pairs generally occur in locations away from existing solar. As for wind, concerns were voiced by participants that reservoirs could attract small mammals and birds, which in turn could attract raptors, which would be at risk of colliding with wind turbines. Finally, a fourth map shows land ownership along with the reservoir pairs.

Recommendations

From subject matter experts, research in published reports, and participant comments and discussion, WSU identified some suggested recommendations for the legislature, as well as for agencies and potential developers, to consider and explore in regards to siting PSH with the fewest negative impacts. While the WSU study leads were informed by the study process and participants, these recommendations were not developed or affirmed by project participants. The following suggestions reflect the views of only the WSU study leads.

Prioritize early contact with Tribes and the local community, although the preliminary permit process does not mandate it. Developing relationships and engaging with Tribes before extensive planning resources are expended can help guide development to appropriate sites and prevent project siting on important cultural areas.

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5 Rosenlieb, E., D. Heimiller, and S. Cohen. 2022. Closed-Loop Pumped Storage Hydropower Resource Assessment for the United States. National Renewable Energy Laboratory. Golden, CO. NREL/TP-6A20-81277. *https://www.nrel.gov/docs/fy22osti/81277.pdf*

6 It is important to note that the NREL data has never been assessed on the ground.

Research water availability and future constraints. Water availability issues might not easily be overcome for closed-loop systems, especially given the unknown changes in future climate scenarios. It is advised that early consideration and research go into any closed-loop facility in the state to ensure that the extraction of reservoir water from local sources does not eventually cause hardships for aquatic wildlife, domestic water supplies, agriculture, irrigation, and other users.

Consider other approaches to PSH. Other approaches to PSH may be worth exploring, with the goal of limiting negative impacts. One such approach is add-on PSH, for which an upper reservoir is constructed and connected to an existing reservoir to create a PSH facility. However, add-on PSH is an open-loop system and has the associated aquatic resource impacts once operations begin. Figure 8 shows relative locations of three theoretical add-on sites from the NREL data. Connecting two existing reservoirs with an added tunnel and powerhouse is another approach that some in the industry are currently considering.

Develop and utilize resources that can guide developers to areas where there will be less impact on wildlife and habitat. Tools exist, and more are being developed by Washington state agencies, to guide developers away from critical habitat for protected and other important species. Guidelines, such as the Washington Department of Fish and Wildlife's newly published ***Guidelines for Utility-Scale Solar & Onshore Wind Energy,***[7] can and should be used for PSH projects as well, as the purpose of the guidelines is to avoid and minimize impacts to the state's wildlife and habitat resources.

Consider utilizing criteria for low-impact PSH when available. Low-impact criteria and certification processes may be developed through external organizations, similar to the Low Impact Hydropower Institute's (LIHI)[8] certification program for conventional hydropower. This type of certification may be one way to identify PSH as low impact. Low-impact criteria aim to avoid, minimize, or reduce impacts to the environment, Tribal cultural properties, and Tribal trust resources. Investigation of such programs by Washington state agencies may provide guidance that can be incorporated into state guidelines, recommendations, regulations, and/or procedures.

Potential PSH projects that follow some of the recommendations above, and that demonstrate understanding of and compliance with the issues and needs expressed by Tribes, local communities, agencies, local governments, NGOs, and others, may find that their projects have fewer obstacles and can advance in a more efficient manner to help the state reach its goal of fossil-free electricity.

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7 Due to be published June 2025
8 *https://lowimpacthydro.org/*

Table of Contents and Figures

Figures

Acronyms

ACHP	Advisory Council on Historic Preservation
ALP	Alternative Licensing Process
APE	Area of Potential Effect
ARES	Advanced Rail Energy System
CBA	Community Benefit Agreement
Commerce	Washington State Department of Commerce
DES	Washington State Department of Enterprise Services
DAHP	Department of Archaeology and Historical Preservation
DOE	US Department of Energy
Ecology	Department of Ecology
EFSEC	Energy Facility Site Evaluation Council
FERC	Federal Energy Regulatory Commission
FPIC	Free, prior, and informed consent
GHG	Greenhouse gases
GIS	Geographic Information System
GIS	Geographic Information Systems
GMA	Growth Management Act
GW	gigawatt
GWh	gigawatt hours
ILP	Integrated Licensing Process
LIHI	Low Impact Hydropower Institute
m	meter
MOA	Memorandum of Agreement
MW	megawatt
MWh	megawatt hours
NEPA	National Environmental Policy Act
NHPA	National Historic Policy Act
NREL	National Renewable Energy Laboratory
ORIA	Washington State Governor's Office for Regulatory Innovation and Assistance
PNNL	Pacific Northwest National Laboratory
PSH	Pumped Storage Hydropower
PUSH	Pumped underground storage hydropower
SEPA	State Environmental Protection Act
TCP	Traditional Cultural Properties
THPO	Tribal Historic Preservation Officer
TLP	Traditional Licensing Process
U&A	Usual and accustomed territories
WDFW	Washington Department of Fish and Wildlife
WPTO	US Department of Energy Water Power Technologies Office
WSRRI	Washington Shrubsteppe Restoration and Resiliency Initiative
WSU	Washington State University Energy Program

Introduction

Legislative Directive

Pursuant to Section 306 of House Bill 1216 (2023), The Washington State Legislature directed the Washington State University Energy Program (WSU) to carry out a process to identify issues and interests related to siting pumped storage projects in Washington state.[9] The intent of the bill is to support expanded capacity to store intermittently produced renewable energy as part of the state's transition from fossil fuel to one hundred percent clean energy.[10]

The goal of the process is to identify and understand the issues and interest of various stakeholders and federally recognized Tribes related to areas where pumped storage might be sited, providing useful information to developers of potential projects, and for subsequent environmental reviews under the State Environmental Policy Act. It was specified that ample opportunities be given to engage Tribes, local governments, special purpose districts, land use and environmental organizations, and others interested in the process. The study is not a substitute for project-specific environmental review or consideration of project-specific adverse effects on indigenous resources. WSU was also required to develop a map and associated GIS data layers that highlight areas identified through the process.

While the House Bill language alluded only to pumped storage, and not pumped storage hydropower, any deep Internet search of 'pumped storage' will result in the inclusion of hydropower. Pumped storage hydropower is commonly abbreviated to PSH, and these are the terms most frequently used in the study and report.

This report (including maps) is a deliverable to the legislature for work done under Section 306 of House Bill 1216.

House Bill 1216 concerns clean energy siting, with legislation for the creation of: an Interagency Clean Energy Siting Coordinating Council; a clean energy coordinated permitting process; an application process for Clean Energy Projects of Statewide Significance; new provisions for clean energy projects added to the State Environmental Policy Act; non-project environmental impact statements for utility-scale solar energy projects, onshore utility-scale wind projects, and renewable hydrogen or green electrolytic projects. These items are under the purview of the Washington State Department of Ecology (Ecology) and/or the Washington State Department of Commerce (Commerce).

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9 ESSHB 1216, Sec. 306. *https://lawfilesext.leg.wa.gov/biennium/2023-24/Pdf/Bills/Session%20Laws/House/1216-S2.SL.pdf?q=20240327114612*

10 Washington State Clean Energy Transformation Act (CETA). *https://www.commerce.wa.gov/energy-policy/electricity-policy/ceta/*

Pumped Storage

Pumped storage, or pumped storage hydropower (PSH), is a proven, existing, grid-scale, long-duration energy storage technology that currently provides over 90% of the utility-scale energy storage capacity in the United States.[11] Sometimes considered a "water battery," PSH uses two reservoirs at different elevations, storing water as potential energy in the upper reservoir, and releasing water to the lower reservoir through turbines to create electricity for the grid when needed. When demand for energy on the grid is low and there is excess and lower-cost energy on the grid, water is pumped from the lower reservoir back to the upper reservoir.

There are generally two approaches to PSH – open-loop and closed-loop. The lower reservoir of open-loop PSH is dammed and connected to a continuously flowing waterbody such as a river or lake, while neither reservoir in a closed-loop system is connected to a waterbody. Each approach has potential impacts – to environmental and cultural resources, as well as other systems – that arise from the construction of the project and/or daily operations. Add-on PSH is a type of open-loop where the lower reservoir already exists; this approach appears to have fewer impacts during construction.

PSH can play an important role in balancing energy needs with the increase of utility-scale solar and wind energy sources, as these resources are intermittent, depending on whether the sun is shining or the wind is blowing.

A full description of pumped storage hydropower can be found in the next chapter.

PSH Siting Study

This paper reports on the work done by WSU to carry out the legislative directive, and includes the study's approach, engagement, findings, and recommendations. A review of PSH technology, benefits, potential impacts, and more is provided to allow readers to understand the study findings. A separate section discusses the maps developed by the study team.

Siting can be defined as "to exist or be built in a particular place".[12] One of the PSH Siting Study's goals was to gather information from people potentially affected by, and/or interested in, the siting, construction, and operation of PSH.

It was important to call this process a study and not a project, as the word project could be mistakenly interpreted as promoting or proposing an actual PSH facility.

11 Uria Martinez, R., & Johnson, M. 2023. US Hydropower Market Report 2023 (No. ORNL/SPR-2023/3076). Oak Ridge National Laboratory (ORNL), Oak Ridge, TN. *https://www.energy.gov/sites/default/files/2023-09/U.S.%20Hydropower%20Market%20Report%202023%20Edition.pdf*

12 *https://dictionary.cambridge.org/us/dictionary/english/siting*

Note that this study is limited in scope; what it includes and does not include are as follows:

- **The siting study includes:**
  - Synthesis and summary of comments and questions provided by participants
  - Information about the study process
  - Basic overview of PSH technology, including potential impacts and potential mitigations
- **The siting study does NOT**
  - Propose, or advocate for or against, pumped storage hydropower projects
  - Identify least-conflict PSH sites
  - Intend any of the maps to be used for identification of locations for PSH development
  - Provide a full research report on the technology
  - Report on the economics or market outlook of PSH

Goldendale Pumped Storage Hydropower Plant

It would be remiss of this report to not mention the proposed Goldendale Pumped Storage Hydropower plant, as it has sparked controversy about PSH in Washington state and elsewhere. If built, the Goldendale Energy Storage Project would be a 1200 megawatt (MW) closed-loop PSH facility located close to the Columbia River in Klickitat County eight miles southeast of the City of Goldendale, Washington. The lower reservoir would be built on a brownfield site previously occupied by an aluminum smelter, while the upper reservoir would be built on a clifftop about 2400 feet upslope.[13]

The proposed upper reservoir would be built in an area held sacred by the Confederated Tribes and Bands of the Yakama Nation.[14] They are part of a coalition of other Tribes and environmental groups who have contested the proposed project that they say will harm a site that they consider culturally and spiritually important, and also because they believe the consultation process was inadequate.

The controversy surrounding the proposed Goldendale project brought attention to PSH in the state, which in part led to the PSH Siting Study. However, it is not an isolated incident concerning hydropower development and Tribes. *Historic and Ongoing Impacts of Federal Dams on the Columbia River Basin Tribes*, published June 2024 by the U.S. Department of the Interior, documents the historic, ongoing, and cumulative effects of dams on the Columbia River to Columbia River Tribes.[15]

As of June 2025, the Goldendale project is still pending final licensing.

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13 Washington State Department of Ecology. 2022. Proposed Goldendale Energy Storage Project: State Environmental Policy Act Draft Environmental Impact Statement—Summary. *https://apps.ecology.wa.gov/publications/parts/2206015part2.pdf*

14 Sax, S. 2022. Cultural resources are not a renewable thing for us. High Country News. *https://www.hcn.org/issues/54.1/north-renewable-energy-cultural-resources-are-not-a-renewable-thing-for-us*

15 United States Department of the Interior. 2024. Historic and Ongoing Impacts of Federal Dams on the Columbia River Basin Tribes. *https://eelp.law.harvard.edu/wp-content/uploads/2024/06/tribal-circumstances-analysis.pdf*

Pumped Storage Hydropower

This section provides a short, non-exhaustive description of PSH, including capacity, land and water requirements, existing PSH systems, and comparisons of closed-loop and open-loop designs. The information comes from subject matter experts and published literature.

How PSH Works

Pumped storage hydropower typically is comprised of two reservoirs at different elevations that store and release water to absorb or provide electricity when called upon to maintain a reliable electric grid. Potential energy, stored as water in the upper reservoir, is released to the lower reservoir through tunnels or pipes, and through a turbine that produces electricity when demand for energy is high. When the demand for energy is low and electricity prices are low, or there is a need to absorb excess energy from the grid, water is pumped back to the upper reservoir, where it is stored as potential energy until needed again. The system can be described as a "water battery" because its energy storage and electricity producing capabilities allow it to store and discharge electricity in a similar manner to a battery. See Figure 1.

The total amount of energy that can be stored in the upper reservoir is the energy storage capacity, measured in watts per hour, [most commonly megawatt-hours (MWh) or gigawatt-hours (GWh)]. Power capacity is the maximum instantaneous amount of electricity produced, or output, measured in watts (commonly MW or GW). The capacity depends on the size of the reservoirs and the elevation difference (called head) between the two. A larger head increases capacity, as does increased size of reservoirs.[16]

PSH is considered a long-duration energy storage system, meaning it can deliver electricity for approximately eight hours or more.[17,18] Current U.S. PSH systems, based on their reservoir size and plant capacity, are able to provide their maximum designed output capacity of electricity for between 4 and 20 hours a day. The median time that U.S. utility-scale battery installations, such as lithium-ion batteries, can operate on full output capacity is approximately two hours.[19] The large MW-hours of storage capacity and flexibility of the pump-turbine equipment also enable PSH systems to provide electricity for a significantly longer duration (hours) when their generation

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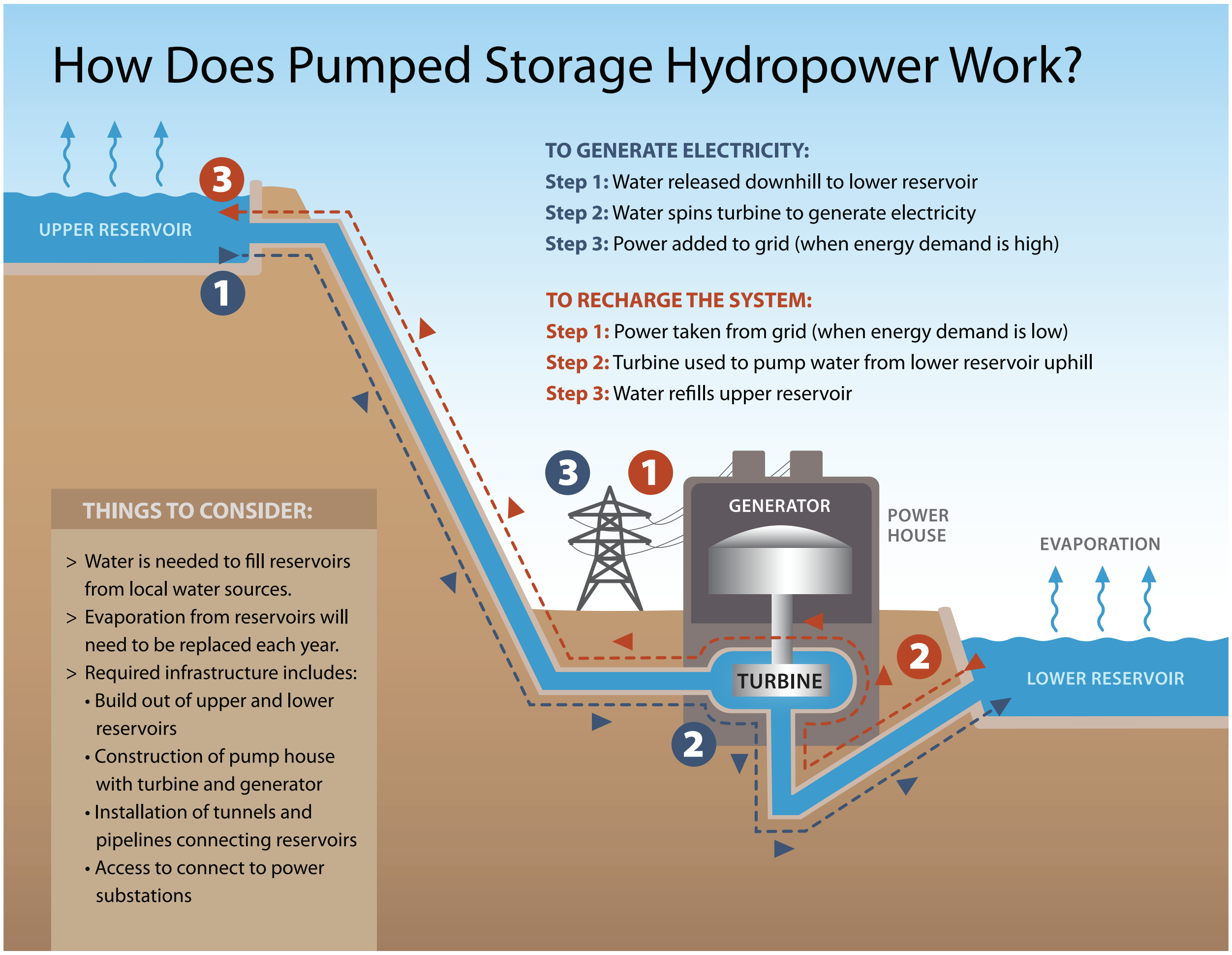
16 United States Energy Information Administration. Electricity Explained. 2023. *https://www.eia.gov/energyexplained/electricity/energy-storage-for-electricity-generation.php*

17 United Stated Department of Energy. 2024. Long-Duration Energy Storage. Office of Clean Energy Demonstrations. *https://www.energy.gov/oced/long-duration-energy-storage#:~:text=Long%2Dduration%20energy%20storage%20(LDES,or%20more%20hours%20in%20duration.*

18 There is no universal agreement on the definition of long duration energy storage. It can refer to the amount of stored energy in the upper reservoir or how long the system can provide electricity at the maximum rate. Denholm, P. W. Cole, A. Frazier, K. Podkaminer, and N. Blair. 2021. The Challenge of Defining Long-Duration Energy Storage. Golden, CO. National Renewable Energy Laboratory. NREL/TP-6A40-80583. *https://www.nrel.gov/docs/fy22osti/80583.pdf*

19 Simon, T. R., D. Inman, R. Hanes, G. Avery, D. Hettinger, and G. Heath. 2023. Life Cycle Assessment of Closed-Loop Pumped Storage Hydropower in the United States. Environmental Science & Technology 57, no. 33: 12251–12258. *https://doi.org/10.1021/acs.est.2c09189*

Figure 1.
A Model of a Pumped Storage Hydropower Plant, Showing Electricity Generation and System Recharge



Graphic courtesy of Joan Carstensen, Grand Canyon Trust
https://www.grandcanyontrust.org/resources/pumped-storage-hydropower-101/

(power capacity) output is reduced (less than maximum MWs). For example, a reservoir with 100 MWh of storage could operate with full generation output of 10 MW for 10 hours, but also operate at 5 MW for 20 hours. In addition, unlike the current electro-chemical battery systems, such as lithium-ion, PSH shows minimal degradation over time of use in terms of performance, with continued operation.

In addition, PSH has one of the lowest life-cycle greenhouse gas (GHG) emissions of any energy storage technology.[20] Life cycle assessments (LCA) generally include embodied energy and materials used – for PSH this includes construction, operation, and maintenance. Because PSH facilities can operate from 50 to 100 years, life-cycle GHG is lower than other energy storage

20 Simon, T. R., D. Inman, R. Hanes, G. Avery, D. Hettinger, and G. Heath. 2023. Life Cycle Assessment of Closed-Loop Pumped Storage Hydropower in the United States. Environmental Science & Technology 57, no. 33: 12251–12258. *https://doi.org/10.1021/acs.est.2c09189*

systems. Studies have also shown almost no GHG emissions result from the operation of closed-loop PSH. The potential for increased or decreased GHG is commonly part of the early studies for project licensing.

In general, PSH is a net consumer of electricity, meaning it takes more energy to pump uphill to store water than is generated. However, the systems are highly efficient, with a round-trip efficiency of modern projects of about 80%, meaning that only about 20% of the energy is lost during operations.[21]

Although transmission is necessary for new generation and storage facilities, and transmission congestion is a known issue, this study focuses on just PSH, although the topic was commented on by participants.

Benefits

PSH benefits the U.S. electricity grid by balancing the bulk of regional electricity supply and demand, integrating renewable energy resources, supporting grid reliability, and providing large-scale electrical system reserve capacity. With its fast ramping capability, PSH can respond to load changes in seconds, turning on and starting to produce electricity quicker than most other energy storage systems. Its “black start” capability enables PSH facilities to provide electricity needed to restart power after grid failure.[22]

Advantages of PSH over other energy storage technologies are many. Although the initial construction cost may be high, PSH facilities last from 50 to 100 years, which makes their life cycle cost one of the lowest of all energy storage systems.[23]

Land and Water Requirements

The area of land and volume of water required for a closed-loop PSH facility can be illustrated using the example of a system with a storage capacity of 1000 MWh. Approximately 30 acres would be needed for both reservoirs combined, at an average depth of 66 feet and with a head of 1312 feet. The volume of water needed would be approximately 264 million gallons. By doubling the head, the volume of water could be halved for the same storage capacity, and conversely by halving the height of the head, water volume would be doubled. This estimate does not include any of the land needed for water conveyance pipes, above ground facilities, roads, and transmission line connectors.[24]

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21 Blakers, A., M. Stocks, B. Lu, and C. Cheng. 2021. A Review of Pumped Hydro Energy Storage. Progress in Energy 3, no. 2: 022003. *https://doi.org/10.1088/2516-1083/abeb5b*

22 Coleman, L. 2021. Black Start: Hydropower is the Guardian of the Grid. National Hydropower Association. *https://www.hydro.org/powerhouse/article/black-start-hydropower-is-the-guardian-of-the-grid/*

23 National Hydropower Association. 2021. 2021 Pumped Storage Report. *https://www.hydro.org/wp-content/uploads/2021/09/2021-Pumped-Storage-Report-NHA.pdf*

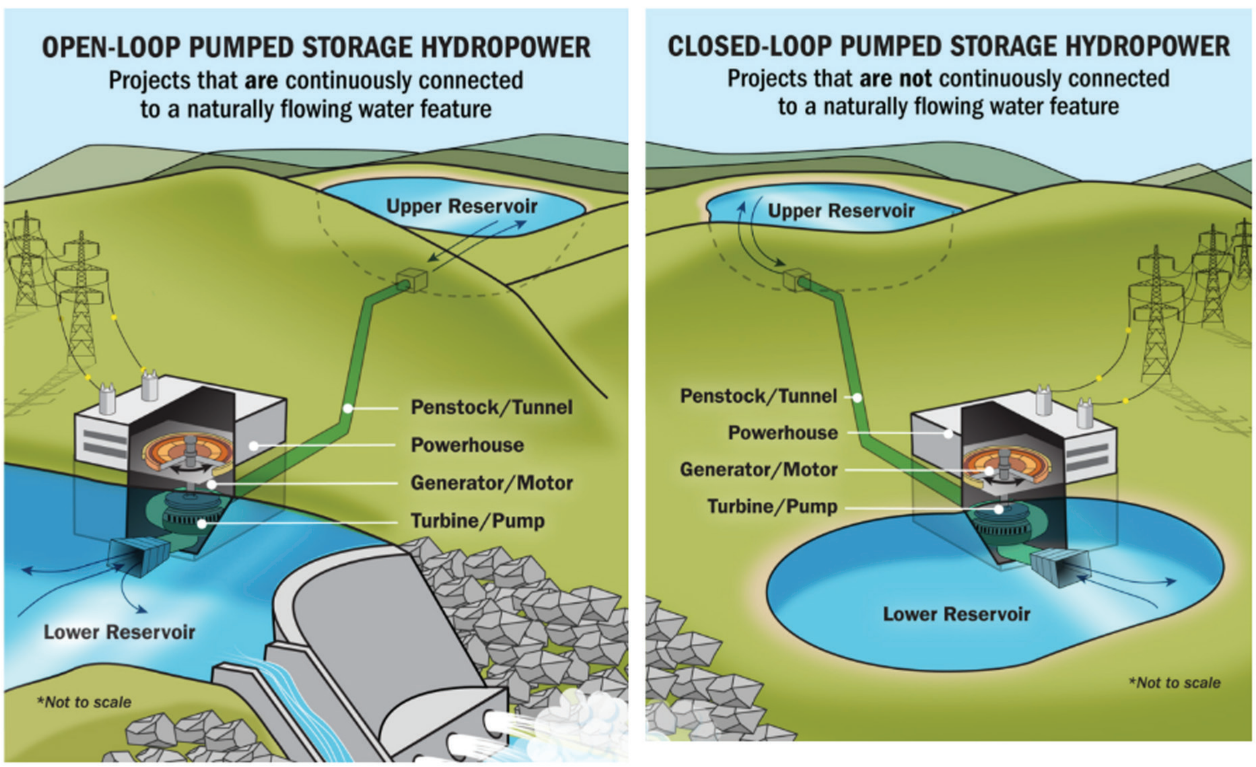
24 Blakers, A., M. Stocks, B. Lu, and C. Cheng. 2021. A Review of Pumped Hydro Energy Storage. Progress in Energy 3, no. 2: 022003. *https://doi.org/10.1088/2516-1083/abeb5b*

Closed-Loop and Open-Loop PSH

The two major configurations of PSH are closed-loop systems and open-loop systems. Closed-loop PSH systems, sometimes called "off-river" systems, have no connection to a naturally occurring waterbody. The lower reservoir in an open-loop PSH system is dammed and continuously connected to a naturally occurring waterbody. Figure 2 shows a closed-loop PSH system and an open-loop PSH system, side by side. The types of impacts from these systems differ to some extent, but as discussed below, closed-loop projects generally, though not always, have lower environmental impacts from construction and operations relative to open-loop systems.[25]

Figure 2.

Open-Loop and Closed-Loop Pumped Storage Hydropower



Courtesy of the U.S. Department of Energy. https://www.energy.gov/eere/water/pumped-storage-hydropower

25 Saulsbury, J. W. 2020. A comparison of the environmental effects of open-loop and closed-loop pumped storage hydropower (No. PNNL-29157). Pacific Northwest National Lab.(PNNL), Richland, WA. *https://www.energy.gov/sites/prod/files/2020/04/f73/comparison-of-environmental-effects-open-loop-closed-loop-psh-1.pdf*

Closed-Loop PSH

Closed-loop systems have two main advantages over open-loop systems. One is that closed-loop has the greatest flexibility in siting, since it is not dependent on an existing waterbody and can therefore be sited closer to built environments, brownfields, and transmission lines. The other advantage of closed-loop over open-loop is that it has very few impacts to the aquatic ecosystem. One of the operational benefits of a closed-loop system is its rapid ramping rate.

A large impact from closed-loop PSH results from their reliance on water sources to initially fill reservoirs and the need to continue to refill to make up for water lost through evaporation and possible leakage, although leakage can be greatly decreased with the use of reservoir liners. Evaporation rates highly depend on the climate and the size of the reservoirs. If the water source is groundwater, there may be a higher impact to groundwater quality and quantity than with open-loop PSH.

Closed loop PSH systems may have a greater potential impact on terrestrial ecology, cultural resources, and land use since two reservoirs must be constructed on upland (not aquatic) locations. This also increases potential impacts on geology and soils.[26]

Open-Loop PSH

The lower reservoir of an open-loop PSH is connected to a flowing waterbody, separated and created by a dam. This can cause a greater negative impact on aquatic ecology and fish than closed-loop, both during construction and operations. It also may have a greater operational impact on surface water quantity and water quality, affecting the naturally flowing water that was dammed to make the lower reservoir. Nearly all of the existing PSH facilities in the U.S., all built decades ago, are open-loop.

While the meetings for the PSH Siting Study focused on closed-loop, further research and subject matter experts provided additional information on all PSH approaches, including open-loop.

Add-on PSH

A third approach, add-on PSH, is a subset of open-loop systems. Using an existing reservoir, an upper reservoir, conveyance tunnels, turbines, and other structures are built to create a PSH system. The existing reservoir can be originally built for reasons other than electricity generation, such as for municipal water use, irrigation, and flood control.[27] This approach tends to have the least environmental impacts during construction because only one reservoir is built, and it is less costly for the developer. However, once built, operational impacts are the same as with an open-loop system.[28] The NREL data identified three theoretical add-on PSH sites in Washington.

26 Pracheil, B. M., Duffy, K. P., Zeng, L., & Saulsbury, J. W. 2025. Environmental Impacts of Closed-Loop Pumped Storage Hydropower (No. PNNL-36322). Pacific Northwest National Laboratory (PNNL), Richland, WA. *https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-36322.pdf*

27 National Hydropower Association. 2021. 2021 Pumped Storage Report. *https://www.hydro.org/wp-content/uploads/2021/09/2021-Pumped-Storage-Report-NHA.pdf*

28 Saulsbury, J. W. 2020. A comparison of the environmental effects of open-loop and closed-loop pumped storage hydropower (No. PNNL-29157). Pacific Northwest National Lab.(PNNL), Richland, WA. *https://www.energy.gov/sites/prod/files/2020/04/f73/comparison-of-environmental-effects-open-loop-closed-loop-psh-1.pdf*

Other PSH Design and Configuration Approaches:

There are ways to increase the capacity of existing PSH or create new PSH energy capacity without constructing two new reservoirs. There are, and continue to be, technological advances in power generation equipment, fish screens, dam safety, and other technologies that can improve energy generation and environmental protection at new and existing plants.[29]

An additional approach that is getting more attention is using former or abandoned underground mines or open pit mines to develop pumped storage. The obvious advantage to this is the use of already impaired land. Potential issues of water quality from these mines must be researched to assure no contamination of nearby watersheds or habitat, but several projects in early development show promise. These PSH systems are considered closed-loop.

Existing and Proposed PSH

PSH has been providing energy storage for about 100 years and is the largest contributor to U.S. energy storage. As of 2022, the 42 existing PSH projects provided over 90% of the total energy storage capacity in the U.S. This is about 22 gigawatts of generating capacity, and over 550 GWh of energy storage capacity.[30]

In Washington state, besides the proposed Goldendale Energy Storage Project, there are no other PSH facilities that are close to licensing, as can be seen in Figure 3. However, two in the state have been given preliminary permits by the Federal Energy Regulatory Commission (FERC) – Badger Mountain PSH and Saddle Mountains PSH (see Figure 4).

Another project of note in Washington state is the Banks Lake Pumped Storage Project, which has been proposed by Columbia Basin Hydropower, an organization consisting of three irrigation districts.[31] The project is not under the FERC's jurisdiction because it would utilize resources owned by the U.S. Bureau of Reclamation, an agency not subject to FERC's regulatory authority.[32] This project is not to be confused with the John W. Keys III Pump-Generating Plant, which has pumped capabilities, but is not a pumped storage plant.[33] More information on FERC and non-FERC projects can be found in the Topics section on State and Federal Permitting and Licensing Processes.

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29 Koritarov, V., Q. Ploussard, J. Kwon, and P. Balducci. 2022. A Review of Technology Innovations for Pumped Storage Hydropower. Argonne National Laboratory. ANL-22/08. *https://publications.anl.gov/anlpubs/2022/05/175341.pdf*

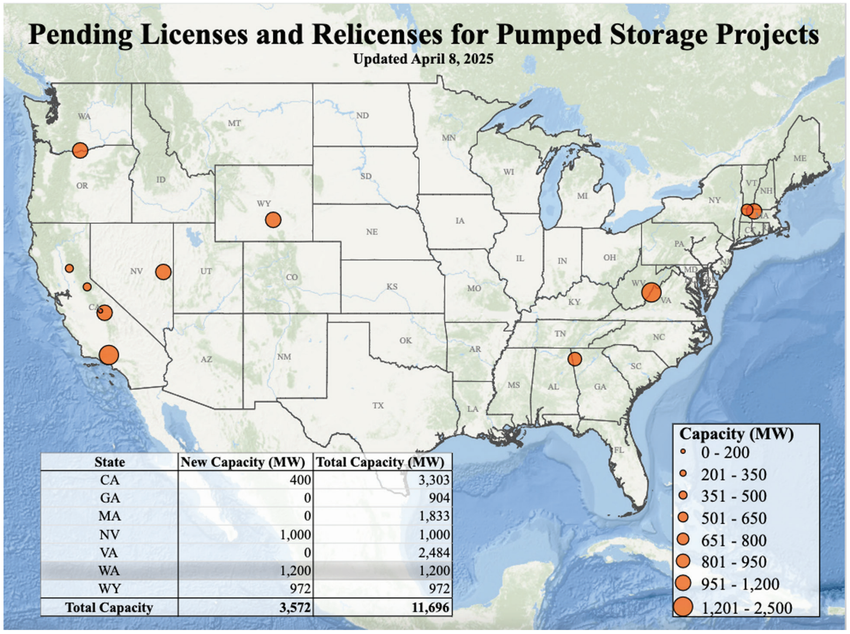
30 Uría-Martinez, R., and M.M. Johnson. 2023. U.S. Hydropower Market Report Data (2023 edition). Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA. doi.org/10.21951/HMR Data/1994511. *https://www.energy.gov/sites/default/files/2023-09/U.S.%20Hydropower%20Market%20Report%202023%20Edition.pdf.*

31 Columbia Basin Hydropower Banks Lake Pumped Storage Project. *http://www.cbhydropower.org/proposed-banks-lake-project.html*

32 Bureau of Reclamation. 2023. Interior Region 9, Columbia-Pacific Northwest Region, Lease of Power Privilege – Banks Lake Pump Storage Project. *https://www.usbr.gov/pn/programs/lopp/bankslake/index.html*

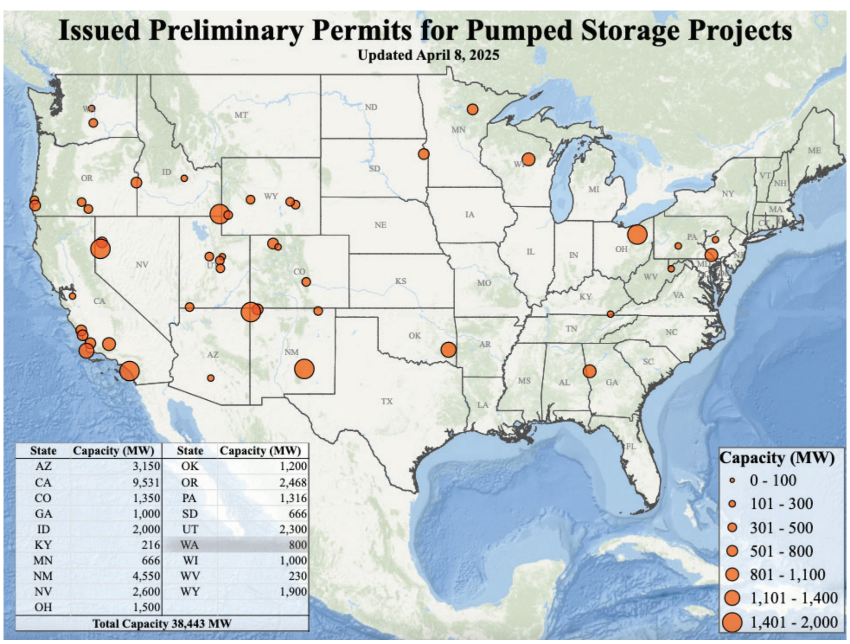
33 The John W. Keys III Pump-Generating Plant. *https://clui.org/ludb/site/john-w-keys-iii-pump-generating-plant*

Figure 3.
Pending Licenses and Relicenses for Pumped Storage Projects Map, as of April 8, 2025



Courtesy of the Federal Regulatory Energy Commission
https://www.ferc.gov/media/pending-licenses-and-relicenses-pumped-storage-projects-map-0

Figure 4.
Issued Preliminary Permits for Pumped Storage Projects by FERC as of April 8, 2025



Courtesy of the Federal Regulatory Energy Commission
https://www.ferc.gov/media/issued-preliminary-permits-pumped-storage-projects-map

PSH Siting Study Approach

An important decision early in the study design was to call this process a study, or information study, and not a project. The term "project" may be suggestive of an actual proposal or on-the-ground development of a PSH system. Given the opposition to PSH that already exists among some Tribes, environmental NGOs, and others, use of the more accurate term of "study" was adopted to hopefully encourage more open participation and avoid negative assumptions about the study.

Another decision made at the beginning was to focus primarily on closed-loop PSH facilities. Based on research on PSH systems and conversations with Washington state agency staff and others, it appeared that any development that could potentially harm fish and the aquatic ecosystem in Washington state, with its strong environmental regulations and values, could be difficult to achieve. This shift in focus is evident across the U.S. PSH industry, as most of the current proposals are for closed-loop systems. In addition, the National Renewable Energy Laboratory (NREL) recently published the ***Closed-Loop Pumped Storage Hydropower Resource Assessment for the United States***.[34] This report used data to identify theoretical pairs of reservoirs for closed-loop systems across the U.S.,[35] and that data has been used as the basis for the mapping deliverable requested by the legislature.

Although the focus, at least initially, was on closed-loop PSH, the siting study team was open to all information from subject matter experts and participant comments heard throughout the process. Expert presentations at meetings, along with research, revealed aquatic ecosystem effects from open-loop PSH, and the lower impacts from construction of add-on PSH projects. All information was used to develop the final key points and suggested recommendations.

PSH Siting Study Team

WSU contracted with professionals to form the PSH Siting Study Team to carry out the siting study. Terri Parr, WSU Tribal Liaison for Special Projects, worked as part of the team to facilitate contact with Tribal partners and review Tribal communications, as well as to facilitate connections with the Affiliated Tribes of Northwest Indians (ATNI) for conferences and conventions. Staff from Ross Strategic provided meeting support and facilitation, as well as outreach to Tribes and agencies. Mapping, GIS support, and technical support came from Meridian Environmental.

Outreach and Engagement

The PSH Siting Study Team developed communication and engagement plans to reach interested Tribes, agencies, and stakeholders. The first outreach was to the chairs, natural

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34 Rosenlieb, E., D. Heimiller, and S. Cohen. 2022. Closed-Loop Pumped Storage Hydropower Resource Assessment for the United States. National Renewable Energy Laboratory. Golden, CO. NREL/TP-6A20-81277. *https://www.nrel.gov/docs/fy22osti/81277.pdf*

35 A "theoretical pair of reservoirs" in the NREL report is a modeled (not real) pumped storage hydropower site consisting of two reservoirs.

resources directors, and cultural resources directors or Tribal Historic Preservation Officers (THPOs) of Washington state federally recognized Tribes, as well as those Tribes who have usual and accustomed areas in Washington.

To decide what form engagement should take – in person meetings across the state and/or online meetings, for example – the team solicited feedback from attendees at the PSH Siting Study introductory webinar on June 13, 2024. Participants preferred statewide online meetings focusing on different PSH siting topics. This viewpoint was further confirmed by an industry developer who said that developers would most likely not attend meetings in a location that was not near their project, so online meetings would be better.

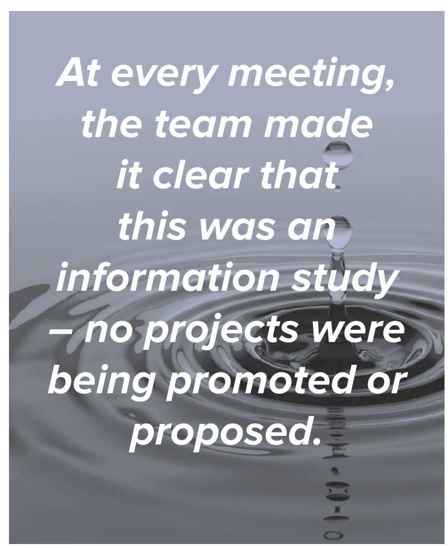
Using lists of previous and current contacts, including Tribes, agencies, local government, environmental NGOs, associations, and developers, the team contacted nearly 800 people throughout the course of the study to invite them to meetings and to provide information.

Tribal Engagement

The PSH Siting Study Team drafted a Tribal engagement plan to frame communications with Tribes for the study period. In addition to communications going out to all 29 federally recognized Tribes in Washington state and Tribes in neighboring states who have rights in Washington, study team members attended and occasionally gave presentations at ATNI conventions and summits, and they also met with some Tribes separately from the main meetings.

A Tribal Forum was held in January 2025 with the intent to listen to concerns and interests without public or government agencies present. While the Forum was very useful and offered new viewpoints, Forum participants, and other Tribal partners as well, made clear that they appreciated attending the public meetings with the agencies, developers, and other public participants so that these other entities could hear from the Tribes directly. Concerns and suggestions from the Tribal Forum are included under the appropriate subheading in the Topics section.

Over the course of the meetings and Tribal Forum, 13 Tribes (including 11 of the 29 federally-recognized Washington state Tribes) were represented, as well as staff from the ATNI and the Columbia River Inter-Tribal Fish Commission (CRITFC).



Meetings

Five public statewide online meetings on various topics relevant to PSH siting were held between September 2024 and January 2025, after the introductory webinar held in June 2024. The term “public” does not apply to Tribes as they are sovereign governments. However, Tribal partners were encouraged to attend. We chose to use the term “public” to distinguish these meetings from other individual or small group meetings. Many Tribal members attended the public meetings, and we heard from Tribes that this was important so that agencies, developers, and others could hear Tribal viewpoints.

The statewide meetings provided technical information from subject matter experts about PSH technology, and potential impacts of and mitigations for PSH construction and operations. This provided a foundation of knowledge that allowed participants to engage in discussions and share insights. The meetings usually followed a typical pattern of a quick recap of PSH technology, presentations on topics, question-and-answer time, and audience participation with breakout sessions. Smaller breakout sessions and poll questions gave participants the opportunity to further discuss topics, and voice their concerns, questions, and suggestions.

At every meeting, the team made it clear that this was an information study – no projects were being promoted or proposed.

Below are the statewide meeting dates, topics, numbers of attendees, and presenters. Meeting summaries, video-recordings, and meeting slides can be found at *https://www.energy.wsu.edu/CleanFuelsAltEnergy/PSHSiting/Meetings.aspx.* The information from the meeting presentations is provided under the topics section of this report, as are participant comments. Detailed information of comments is in the appendix.

Introductory Webinar
June 12, 2024, 93 attendees

- Introduction of PSH siting study and PSH technology – WSU Study Lead Karen Janowitz
- NREL Resource Assessment Theoretical PSH Reservoir Pairs – Jeff Boyce, GIS Analyst, Meridian Environmental

PSH Basics and Tribal Cultural Resources
September 11, 2024, 90 attendees

- Pumped Storage Hydropower Basics – James Saulsbury, Energy & Water Systems Analysis, Idaho National Laboratory
- Tribal Cultural Resources – Karen Capuder, Senior Archaeologist, Confederated Tribes of the Colville Reservation

Aquatic Ecosystems, Water Quality, and Water Quantity
October 9, 2024, 57 attendees

- Aquatic Ecology Impacts of PSH – Brenda Pracheil, Fisheries Biologist, Pacific Northwest National Laboratory (PNNL)
- Water Availability and PSH – Megan Kernan, Energy, Water, and Major Projects Division, WA Dept. of Fish & Wildlife

Wildlife & Habitat, Geology, Access
October 31, 2024, 60 attendees

- PSH Impacts to Wildlife & Habitat – Emily Grabowsky, Solar & Wind Energy Biologist, WA Dept. of Fish & Wildlife
- Geology & Soil Considerations for PSH – Mike Manwaring, Regional & Sector Lead, Stantec
- Land Use Considerations: Air, Aesthetics, & Access – Maryalice Fischer, Certification Program Director, Low Impact Hydropower Institute

PSH State & Federal Permitting and Licensing Processes
December 4, 2024, 52 attendees

- Overview of Federal Energy Regulatory Commission (FERC) Hydropower Licensing Process – Aaron Levine, Senior Legal & Regulatory Analyst, National Renewable Energy Laboratory (NREL)
- Washington State Environmental Policy Act (SEPA) – Fran Sant, Clean Energy SEPA Review Lead, WA Dept. of Ecology
- Section 106 of the National Historic Preservation Act – Rob Whitlam, State Archaeologist, WA Dept. of Archaeology & Historic Preservation

Other Gravity Energy Storage – Rail and Abandoned Mines
January 23, 2025, 47 attendees

- Advanced Rail Energy Storage (ARES) – Ray Wiseman, General Manager, Yakama Power
- Pumped Storage Using Abandoned Mines – Tim Scarlett, Associate Professor, Michigan Technological University

Summaries from the meetings and the introductory webinar, video recordings, and meeting slides are available for viewing at *https://www.energy.wsu.edu/CleanFuelsAltEnergy/PSHSiting/Meetings.aspx.*

Over 250 individuals attended the introductory webinar and five public meetings, many of them attending more than once, so that total attendance was over 400 appearances. Sectors with the most participants are listed below.

- State agencies..................19%
- Tribes..................................15%
- County government.........12%
- Industry...............................12%
- NGOs..................................10%

Utilities (collectively) had participation that was under 10%, as did the federal government and other sectors including citizens and landowners, universities, associations, media, city government, and conservation districts.

PSH Topics

The siting of PSH facilities, which includes both construction and operations, changes the land and environment, and can potentially cause effects on elements such as wildlife and habitat, traditional cultural resources, water quality, noise levels, and more.

Through presentations from subject matter experts, the PSH meetings provided information on various topics related to the elements listed above, and their possible impacts and mitigations. Further information for this report on impacts and mitigations was gathered from published reports on a variety of PSH siting topics.

While a body of information and research on impacts of and accompanying mitigations for PSH systems has been assembled for this siting study, it is not extensive, especially given that some PSH systems have been operating for decades. Most of the current PSH facilities were built before the existence of the Endangered Species Act, the Clean Water Act, and state regulations, and there is scarcely any information synthesizing the impacts from these plants, such as those related to drought mitigation, carbon sequestration, and environmental impacts. However, when these projects come up for relicensing, the facilities must be assessed for environmental impacts and meet the requirements.

This section contains the bulk of the report. Each category of impact is further divided into:

- Background information on the topic from subject matter experts and published literature, including potential impacts and mitigations
- Participant issues and suggestions from meetings, conversations, and conferences

> Appendices A and B contain more detailed information on the participant comments regarding issues and suggestions, as well as potential impacts and potential mitigations.

The term mitigation is used in this report to signify actions, or non-actions, taken to avoid, minimize or lessen, or compensate for an impact. The following mitigation sequence is a concept used by the Washington Department of Ecology SEPA rules.[36]

- Avoid the impact (site specific)
- Minimize impacts (site specific)
- Repair, rehabilitate, or restore affected environment
- Reduce impact over time
- Monitor impact

36 Washington State Legislature. WAC 197-11-768. Mitigation. *https://app.leg.wa.gov/wac/default.aspx?cite=197-11-768*

Tribal Cultural Resources and Tribal Rights

Background

This section discusses Tribal sovereignty, Tribal rights, and traditional or Tribal cultural resources. Much of this information is from the presentation provided by Karen Capuder, a senior archaeologist for the Confederated Tribes of the Colville Reservation, during the September 11, 2024 PSH Siting Study meeting.

Most federal, state, and local cultural resource mandates and policies define cultural resources to consist of property types such as objects, buildings, structures, districts, and sites, which include Traditional Cultural Properties (TCP). These are determined eligible for listing or formally listed on the National Register of Historic Places.

However, the term “resources” can be problematic because it often relates to property and commodification, which is not congruent with the way collective cultural resources are conceived by many indigenous people. As stated by a participant, “For Tribal nations, cultural resources include not only sacred sites and burial grounds, but also rivers, fisheries, wildlife, native plants, clean water, and functioning ecosystems. These are not just cultural features, they are treaty-protected resources and central components of Tribal sovereignty.” Different Tribal communities have different definitions of what constitutes a cultural resource.

Furthermore, disclosure of culturally and spiritually sensitive information could violate Tribes’ ancestral laws and traditional teachings, which is part of the reason why Tribes may not want their cultural resources mapped or shared with developers and agencies.

Tribes have inherent sovereignty (defined as the power to make one’s laws and be governed by them). As stated by a participant, “Any discussion of impacts to Tribal cultural resources must include the role of Tribes as co-managers and decision-makers. Tribal consent and participation should be central to project planning, not an afterthought or procedural step.”

As independent sovereigns, Tribes have government to government relationships with federal, state, and local government entities. States have no inherent jurisdiction over reservations.

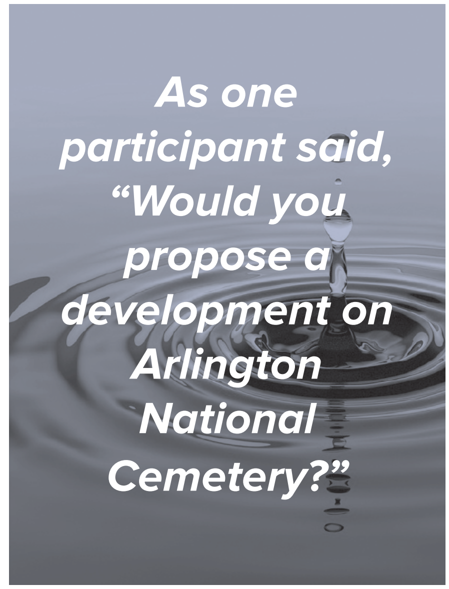
In Washington state there are treaty Tribes, as well as executive order Tribes, and Tribes whose reservations were created by statute or who have subsequently been recognized by the federal government as Tribes. These instruments other than treaties also reserve Tribal rights with equally binding effect. Treaties are grants of rights from Tribes to the United States, because these sovereign rights are inherent and predate the formation of the United States. Tribes that are not signatories to treaties and Tribes whose treaties have been abrogated have legally ceded none of their homelands and none of their inherent sovereignty.

Potential Impacts and Potential Mitigations

Invited experts and published literature provided the information about potential impacts to and avoidance of, or mitigations for, cultural resources with regard to PSH.

Important sites could potentially be disturbed or destroyed if PSH were to be sited on or near them. This includes sites related to indigenous settlement, human burial, food gathering, natural resources, and sacred sites. The visual landscape may also be impacted if siting occurs adjacent to culturally significant sites used by local Tribes for traditional cultural practices.

A first step in mitigating impacts to culturally important sites is to avoid siting PSH projects where they are located. Many sites are regarded as irreplaceable, and cannot be repaired or compensated for. Conducting Tribal consultation and community engagement before extensive planning resources are expended, and before developers and regulators become attached to a particular outcome, can help identify where culturally significant sites are located in order to avoid them.



Participant Issues and Suggestions

The following are major issues, concerns, and suggestions from participants at PSH Siting Study meetings, as well as those at separate meetings with Tribal partners. Appendix A provides complete comments.

The harm or destruction to traditional cultural resources and how this harm cannot be mitigated, only avoided, was the concern that stood out the most among those voiced about Tribal cultural resources. Meeting participants expressed the cultural and ecological connection and relationship to these sites that cannot be interrupted and that such sites carry individual and family identities. As one participant said, *"Would you propose a development on Arlington National Cemetery?"*

Tribes are constantly asked to compromise. Tribal rights and resources keep getting chipped away. The constant pressure for Tribes to compromise is considered a social injustice. If "no" is not an acceptable answer from the Tribes then it is not consultation.

Tribes take on disproportionate burdens of adverse effects while not benefiting environmentally or economically. Also, it was stated that cumulative impacts from many projects add up – they affect the shrubsteppe area, and impact access to sacred areas.

Cultural resources are often ignored and/or not valued when clean energy facilities are being sited. Tribal participants said that Tribes generally support clean energy projects, but not at the expense of cultural resources. Constant training of non-Tribal staff on basics of Tribal sovereignty and cultural resources is exhausting to Tribes, but they want to make it clear that talking to Tribes is not just 'checking the box'. The current siting laws work such that they reduce everything to a monetary value; tribal resources don't get considered and will be lost if a developer can save money by building right next to a transmission line. Past experience of Tribes has shown that industry has not honored or acknowledged that tribal rights can be exercised in or near the facilities.

Tribes are often brought in too late to proactively identify cultural resources and suggest alternative locations or approaches. It was said that traditional cultural resources such as traditional food gathering and viewsheds may be impacted because their locations are often not known to non-Tribal stakeholders until a project is well on the way to development.

Information about cultural resources is very sensitive to Tribes and cannot be disclosed. Disclosure of spiritually sensitive information is of extreme concern and can violate Tribal ancestral laws and traditional teachings.

Impact on the local community from construction is a concern. This includes “man camps” with workers from out of the region, which can promote apprehension given the prevalence of native women’s disappearances.

Do not develop areas that will impact Tribal cultural resources or other Tribal interests was the main suggestion by participants. While avoidance all together should be the goal, one participant said that if important Tribal areas cannot be avoided, work with folks to decide if the project needs to be done or not.

Developers and agencies should engage early with Tribes about cultural resources. One participant said that interacting with Tribes early in the process will greatly benefit Tribes and require that federal agencies uphold their trust responsibilities; together, these steps will make the siting process more meaningful going forward.

Proactively analyze impacts on cultural resources that seem particularly likely for PSH. Ridges above rivers are important spiritually.

Monitor sites over time for impacts on cultural resources and continue to engage Tribes. Implement sustained consultation and observational data collection.

Aquatic Ecology

Background

Impacts to aquatic ecology occur mostly with open-loop PSH since such systems are connected to streams or other waterbodies. While these impacts are relatively low for closed-loop systems, they can still occur from the construction process and from withdrawing surface water or groundwater to fill reservoirs.

Potential Impacts and Potential Mitigations

According to subject matter experts and published literature, the greatest impacts from open-loop PSH on aquatic ecology are the loss of aquatic habitat through damming and inundation, fish entrainment (harm to or loss of fish when they are diverted to or pulled into the equipment), and barriers to fish migration created by dams, which can also change the composition of fish species. Natural river processes could also be inhibited and river fluctuations could occur from the PSH operation.[37]

One instance where the impact of closed-loop is similar to that of open-loop is when surface water is used to fill the reservoirs, and entrainment can also occur, causing mortality. Surface water withdrawal could also affect species located elsewhere due to hydraulic connectivity. Groundwater withdrawal may affect species as well, if the source is connected to groundwater-dependent streams.

37 Saulsbury, B. 2020. “A Comparison of the Environmental Effects of Open-Loop and Closed-Loop Pumped Storage Hydropower.” Pacific Northwest National Laboratory. PNNL-29157. *https://www.energy.gov/sites/prod/files/2020/04/f73/comparison-of-environmental-effects-open-loop-closed-loop-psh-1.pdf*

Minimizing impacts includes proper screening to prevent impingement and entrainment, and implementing studies and monitoring along with a control plan. If avoiding the critical area is not possible, then mitigation may be to replace wetlands, and establish two ponds and stock to provide warm water fish habitat.

Participant Issues and Suggestions

The loss of fish from open-loop reservoir construction, drawdown in reservoirs with hydrologic connectivity that can affect fish and other aquatic biota, and invasive species in ponds were among the impacts that participants were most concerned about, regarding aquatic ecology. One participant stated: "Having worked previously in the permitting of salmon habitat restoration, I find it incredulous that any of these potential projects would ever actually happen because of the major impact it would have on any of our regional watersheds."

Create requirements for mitigation steps to avoid or reduce the loss of riparian habitat and/or aquatic habitat conditions and functions were some suggestions.

Water Quality

Background

Water quality of PSH reservoirs, and that of groundwater and other surface waters can be impacted by the operation and construction of PSH facilities, both open-loop and closed-loop. Surface water quality tends to be impacted more with open-loop, while groundwater quality is impacted more with closed-loop.

In open-loop PSH systems, water quality impacts can occur when warmer upper reservoir water flows into the lower reservoir that is hydrologically connected to a river or stream. A water quality impairment of warmer temperature can be of particular concern for fisheries.

Potential Impacts and Potential Mitigations

Potential water quality impacts are many and tend to differ between surface water and groundwater, and they also differ in magnitude between closed-loop and open-loop. Changes in sediment transport, surface water temperature, reduced dissolved oxygen, and increased concentration of dissolved solids, nutrients, and heavy metals are some of the impacts that occur to a greater degree in surface water with open-loop systems.[38]

Groundwater quality impacts occur more with closed-loop systems, and include changes in groundwater circulation and flow patterns, as well as in temperature. Seepage from the reservoir into the groundwater can also transfer contaminants to hydraulically connected surface waters.

Ways to mitigate these impacts include creating evaporation ponds or water treatment facilities and not operating in areas that contain legacy groundwater contamination. Installing impermeable liners in reservoirs and all water conveyance structures can prevent leakage to groundwater. And finally, continuous monitoring and developing water quality plans are recommended by experts and the literature.

38 Saulsbury, B. 2020. "A Comparison of the Environmental Effects of Open-Loop and Closed-Loop Pumped Storage Hydropower." Pacific Northwest National Laboratory. PNNL-29157. *https://www.energy.gov/sites/prod/files/2020/04/f73/comparison-of-environmental-effects-open-loop-closed-loop-psh-1.pdf*

Participant Issues and Suggestions

Algal blooms and water temperature fluctuations, which could affect cooler river water, were a few of the specific concerns, though participants expressed many general water quality concerns as well.

In open-loop systems, there was concern that smolts (young salmon) could be impacted by water temperature as they migrate out to the ocean or circulate in the system before they migrate out. A Tribal member expressed the importance of not increasing salmon mortality due to PSH, especially at this time when Tribes are moving toward full reintroduction of anadromous fish.

Water Quantity and Water Availability

Background

Two distinct concepts affect water availability in Washington state – the physical availability of water, and the legal availability to acquire water. Surface waters have low flow during dry summers and depend on groundwater or melted snowpack. The lowest flow periods are when water is needed most. Groundwater, including aquifers, and surface water are often hydrologically connected, so what affects one may affect the other.

According to the presenter from WDFW, Megan Kernan, water law is a complicated subject in Washington state. In simple terms, water law is about the allocation of water, which is determined by the seniority of a water right. This is then complicated by instream flow rules, which are unique to Washington state. These are administrative code rules that specify a minimum instream flow, or minimum level of water for certain streams and rivers, for the purpose of protecting habitat and fish.

Most water rights in the state are already allocated. Although, technically, there are ways to acquire water, such as purchasing or leasing a water right from another entity, or purchasing mitigation credits from a water bank, this is a far more complicated process given the level of legal complexity of water rights along with Washington's hydrological landscape, cumulative pressures of Tribal rights, instream protections, and climate change.

> In one of the meetings, a county commissioner mentioned that counties will be updating comprehensive plans in 2025 and need to be aware of the potential for these types of projects so they can understand how to accommodate them within new planning documents.

Potential Impacts and Potential Mitigations

Potential impacts of using water to fill PSH reservoirs, as gathered from invited experts and published literature, include loss of groundwater and surface water. Wetlands, water supplies for wells, and agricultural irrigation could be affected if they are hydrologically connected to the water source.

Timing when the initial reservoir fills and refills occur, as well as how often and the quantity of water, can avoid or reduce many of these impacts. If the water source is connected to irrigation water, schedule filling of the reservoir during the non-irrigation season.

An impact concerning water quantity is that precipitation runoff collected in reservoirs could potentially overflow and impact dam safety and wetland drainage patterns. Runoff collected in reservoirs could also make that water less available to nearby ephemeral streams and wetlands.

Participant Issues and Suggestions

The use of water for filling reservoirs impacting future water availability, reducing groundwater, and affecting wildlife were the major concerns expressed by participants. A recurring issue was the continued need to refill reservoirs to make up for evaporation loss, while climate change and increased populations could change where and how much water is needed. One participant asked "Who will do without water to satisfy the PSH need for this limited resource, which is under increasing pressure from development and a changing climate?" As for wildlife, if groundwater loss reduces recharge of wetlands systems, wildlife that use the wetlands, especially during the breeding season, could be affected.

Investigating ways to minimize reservoir evaporation losses, which include adding floating solar to the reservoirs, and documenting possible groundwater withdrawal effects were a few participant suggestions.

Wildlife & Habitat / Terrestrial

Background

One of the larger potential impacts from PSH, especially in closed-loop systems because of the construction of two reservoirs, is to the terrestrial ecosystem.[39] Construction of facilities, which may include transmission line construction, converts land to industrial use and potentially removes wildlife habitat.

Potential Impacts and Potential Mitigations

According to Emily Grabowsky, biologist at WDFW, as well as other experts, common impacts to wildlife habitat from large-scale projects are loss of habitat, habitat fragmentation, and loss of connectivity, especially for wildlife whose migration routes are blocked. The species most likely to be impacted by PSH projects are those that need upland habitat or shrubsteppe to survive. Shrubsteppe habitat is already imperiled and highly fragmented, and is important to numerous plant species as well as to wildlife.[40]

Loss of habitat and fragmentation can lead to the spread of diseases among animals living closer together, as well as to a loss of genetic diversity due to decreasing populations. Noise and vehicle emissions can lead to disruptions of critical portions of species' life cycles, including nest abandonment. Vehicles and traffic can also lead to direct mortality.

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39 Saulsbury, B. 2020. "A Comparison of the Environmental Effects of Open-Loop and Closed-Loop Pumped Storage Hydropower." Pacific Northwest National Laboratory. PNNL-29157. *https://www.energy.gov/sites/prod/files/2020/04/f73/comparison-of-environmental-effects-open-loop-closed-loop-psh-1.pdf*

40 Washington Shrubsteppe Restoration and Resiliency Initiative. https://wdfw.wa.gov/species-habitats/habitat-recovery/shrubsteppe

There are also impacts from reservoirs on terrestrial species. Reservoirs can be a drowning hazard by attracting wildlife that fall in and cannot get out, and water level fluctuations can increase the potential for invasive species. Terrestrial species dependent in part on wetlands or streams, for example, may be impacted if water withdrawal for closed-loop PSH affects those water bodies through hydraulic connectivity.

Using tools and resources that identify priority habitats, as well as field surveys, can reduce or prevent harm to habitat and wildlife. Developing protection plans and ongoing monitoring is also important. There are many other mitigations, including restoring and enhancing habitat, decommissioning unnecessary roads after construction, and timing disruptive activities to avoid critical life cycle periods. Appendix A includes more impacts to terrestrial wildlife and habitat and possible mitigations.

Participant Issues and Suggestions

The effects on habitat and habitat loss together made a large topic of discussion, including the impact on species dependent on shrubsteppe habitat and interdependent species. An example of this is that badgers, whose numbers are declining, dig holes and burrowing owls then use those holes for their nesting burrows. Also mentioned was the disruption of movement corridors due to the placement of facilities and safety controls such as fences.

Facility construction can bring in invasive and non-native plant species, which create a domino effect through the spread of unwanted seeds and pollen.

Monitoring and establishing baseline habitat conditions were suggested by participants. Avoiding areas that have high quality native habitat and listed species was also important, and someone mentioned including habitat connectivity in project design.

Avoid locating PSH next to wind energy projects. Open reservoirs can create beneficial habitat for small mammals, bats, and migratory birds. The increase of these populations attracts birds of prey, which increases the risk of collision between these birds and the wind turbine blades.

Geology and Soils

Background

According to a presentation by Mike Manwaring, regional and sector lead for an engineering consultant firm, understanding the site-specific surface and subsurface geology, and the hydrology of projects is crucial to determining potential project impacts from development and operations, managing risk, estimating potential costs, and ultimately designing PSH facilities appropriately. These are the goals of onsite geologic and geotechnical studies, which include site suitability investigations such as geotechnical studies and mapping.

Understanding baseline conditions and the associated potential for shoreline erosion and landslides is essential. The most suitable sites are those with stable slopes and low-permeability soils. Most sites need reservoir liners to prevent water from leaking into the groundwater.

Typically, vegetation is removed when the hole is dug for a reservoir to prevent dead vegetation in the reservoir from potentially creating methane. Replanting slopes or shoreline is almost always done with the native species that were there before. Non-native vegetation is usually not planted, even if it could help reduce evaporation. It is important for the developer to partner with those who know the vegetation in the area, such as local Tribal or environmental partners.

Engineers study, upfront, the potential to induce seismic activity that might not otherwise occur without the presence of a PSH project. If there is a failure, it is not caused by the weight of the water – it is caused by the fairly rapid removal of the water. A smaller reservoir that completely empties or fills over a day has more potential for failure. Analysis must be done to determine the locations of potential faults.

Potential Impacts and Potential Mitigations

Potential impacts related to geology and soil that can occur due to PSH include subsidence (the sinking of an area), increased seismic risk and erosion, and seepage or leakage from the reservoir. Excavating reservoirs could potentially impact aquitards (confining layers above aquifers), springs, seeps, and wetlands, and excavation of a reservoir more than 60 feet deep could potentially change the way that groundwater flows.

Mitigations for these potential impacts are incorporated mostly in the design and construction stages of a PSH facility. Engineering studies are done on every site, as every site has a unique geology and structure. The studies are used to design the facility for the maximum critical credible earthquake in the area. Potential mitigations also includes stabilizing soils, timing construction to not occur during wet periods, and installing impermeable liners in the reservoir.

Participant Issues and Suggestions

Participants expressed concern about ground disturbance and induced seismicity. A Tribal member pointed to the fires in eastern Washington that have burned off vegetation and roots, which along with increased rain events can create the risk of slope failures and landslides during earthquakes. Structural failures could also cause water quality problems by releasing water into rivers, impacting salmon. Though engineers and developers plan to prevent failure, unforeseen failure events do happen.

Land use – Air Quality, Aesthetics, Access, Lighting, Noise

Background

All large-scale developments have land use impacts. Clearing and changing large pieces of land to construct and operate PSH facilities can generate loud noise, create emissions from vehicles and equipment, limit access and recreational use, change the look of an area, and light an area that was previously dark. In addition to some of the impacts cited in topics above, such as those on traditional lands and sensitive protected lands, impacts can also include increased fire risk from transmission lines; potential conflicts with compatibility of management or development plans at local, regional, or state levels; and the potential for unanticipated land changes due to faulty design, dam failure, overtopping, and flooding.

Siting considerations for avoiding or minimizing these impacts include:

- Engage early and often with Tribes, local communities and government at multiple levels
- Avoid sensitive sacred areas

- Utilize already developed sites if possible
  - Add-on projects: Add pump storage or reversible turbines between two existing reservoirs.
  - Repurpose old mine sites
- Site and design to minimize footprint and accommodate pre-existing uses
- Enhance existing conditions if possible
- Conduct wildfire risk assessment and develop mitigation plans
- Conduct risk assessments and develop avoidance/minimization plans for other identified impacts

Potential Impacts and Potential Mitigations

Subject matter experts and published literature provided information about potential impacts and possible mitigations from air emissions, noise, lighting, and other elements of land use regarding PSH plants.

Dust, emissions, and noise from vehicles can impact wildlife, as well as the local community members who live nearby. Other air quality problems can occur if the site of a future reservoir is not cleared of vegetation; for example, dead vegetation in water can produce methane. Lights used in construction, and during plant operations may disturb nocturnal species, and if near outdoor activity areas, can disturb campers.

Some of the many possible mitigation measures include a “no idling” policy for vehicles, restricting timing of loud activities, creating buffers out of vegetation or fences, and using lighting products that minimize visibility from long distances. Directional lighting and lighting hoods are also options.

As views can be impacted, a “Photoshop trial” can be performed by modifying a photograph of the pre-construction reservoir site to visualize what it would look like filled with water; such trials can provide information needed to possibly alter designs.

Other possible impacts are listed in Appendix A.

Participant Issues and Suggestions

Issues expressed by participants included air quality, lights, noise, and ground vibrations changing the migration of birds, bees, and other wildlife. New recreational opportunities may be possible near open-loop systems, but safety concerns prohibit recreational opportunities for closed-loop PSH.

Socioeconomics

Background

PSH facilities are usually located in rural areas with low population density and often few services. When large facilities are constructed, there is an increase in the number of construction and other workers, as well as vehicles and large equipment. Workers may be unable to find sufficient housing, capacity in local schools if they bring their families, or services such as food stores, fuel stations, banks, and the like. Pollution from vehicle exhaust may increase, and increased traffic could disrupt school traffic. Safety becomes an issue.

Potential Impacts and Potential Mitigations

Invited experts and published literature point to potential socioeconomic impacts such as increased traffic from workers and construction vehicles on local roads, leading to school traffic disruption. As stated above there may be housing or service shortages that stress the local resources of small communities.

Mitigation strategies to help remedy the impact of increased traffic include monitoring traffic conditions, implementing shuttle bus use, using staggered work shifts, and avoiding travel when local schools begin and end their day. If possible, constructing more housing and essential service would be useful, although this solution may become a problem once PSH construction is completed and the workforce departs.

Engaging with the local community and nearby Tribes to determine mitigation strategies could help decrease impacts. Furthermore, a community benefit agreement (CBA) can be a powerful tool for local residents to ensure they receive benefits from a development, such as improved community infrastructure or other investments. A CBA is a legally binding contract between a developer and a coalition of local groups.[41]

Participant Issues and Suggestions

Some Tribal members expressed strong concern about the safety of indigenous women given the influx of out-of-town workers, and possible "man camps."

Participants also had questions about whether such projects provided economic, social, and other benefits to local communities, and if the facilities would have an impact on local property taxes.

State and Federal Permitting and Licensing Processes

This section provides basic information about some of the processes for permitting and licensing a PSH facility. The information is from three subject matter experts who gave presentations at the December 4, 2024 PSH Siting Study meeting: Aaron Levine, Senior Legal & Regulatory Analyst with NREL; Fran Sant, Clean Energy SEPA Review Lead, Ecology, and; Rob Whitlam, State Archaeologist with DAHP.

A longer description of state and federal permitting, licensing, and environmental review processes can be found in Appendix B.

The permitting and licensing processes for a PSH facility through federal and state agencies can be a lengthy process. Although these processes do not directly create impacts such as those that occur during construction or operation, they are just as crucial because the decisions made at this stage and the process structure itself can diminish or multiply future siting issues, or even determine if a facility is licensed at all. For example, early and meaningful communication – with Tribes, the local community, and others in the vicinity as well as with local government and state and federal agencies – about a proposed facility can help ensure that PSH facilities are sited responsibly.

41 United States Department of Energy. FAQ: Community Benefit Agreements. *https://www.energy.gov/sites/default/files/2024-12/CBA%20Guidance%20FAQ.pdf*

Background

Federal Permitting and Licensing

The permitting and licensing processes for PSH can be complicated with different paths and a multitude of involved agencies.[42] If a PSH project is owned and/or developed by a non-federal entity, it is considered a non-federal project, although the Federal Energy Regulatory Commission (FERC) is the agency that issues most of the required permits and licenses. Projects developed and owned by federal agencies such as the Bureau of Reclamation or Tennessee Valley Authority do not have licensing processes but do have to meet certain federal requirements such as compliance with the Endangered Species Act and the National Environmental Policy Act (NEPA).

Based on discussions at PSH Siting Study meetings, it appears that PSH development companies sometimes apply for and obtain a preliminary permit without first contacting local Tribes or others who might be affected by the project. They do this to prevent the word getting out to competitors about a potential site. Consequently, preliminary assessment work is done by the developer before contacting the Tribe and determining if there are sites to be avoided. Obtaining a preliminary permit is not actually mandatory, but it does protect first right.

The FERC process for PSH facility licensing involves a preliminary permit (which is not mandatory), and then pre-filing for a license which includes the Notice of Intent, when the pre-application document process starts. Many permits and certifications of regulatory compliance are gathered and submitted with the final license application. The issuance of final FERC license order may include mandatory terms and conditions.

There are two other processes for certain closed-loop non-federal PSH projects:

- Within FERC jurisdiction, there is a reduced licensing process for qualifying closed-loop PSH, which usually shortens the process by about one year. This reduced process is a two-year post-filing licensing process that starts after the filing of the Notice of Intent and preliminary application documents.
- Outside FERC jurisdiction, a closed-loop project may be licensed by a state or local jurisdiction if it is not on federal public land or a federal reservation; does not use surplus water or waterpower from a government dam; is not located on a non-navigable commerce clause stream; has no associated interstate or foreign commerce (that is, not connected to the grid); has undergone construction or modification since 8/26/1935; only uses groundwater to fill the system.

Washington State Environmental Policy Act (SEPA)

The purpose of SEPA, the State Environmental Policy Act Is to inform decision-making by identifying and disclosing environmental impacts before a public agency makes a decision. SEPA focuses on the adverse effects to both the natural environment (e.g., air, water, plants, animals) and the built environment (e.g., land use, transportation, public services).

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42 Levine, A., Pracheil, B., Curtis, T., Smith, L., Cruce, J., Aldrovandi, M. Brelsford, C., Buchanan, H., Fekete, E., Parish, E., Uria-Martinez, R., Johnson, M., & Singh, D. 2021. An examination of the hydropower licensing and federal authorization process (No. NREL/TP-6A20-79242). *National Renewable Energy Lab.(NREL), Golden, CO. https://docs.nrel.gov/docs/fy22osti/79242.pdf*

The SEPA process is intended to inform decisions made by public agencies, but **it is not a permit decision**. The lead agency seeking SEPA assessment can be Ecology, the Energy Facility Site Evaluation Council (EFSEC), or a local government.

To enable early and meaningful engagement with stakeholders, Tribes, and interested parties, a robust public involvement process should be conducted by the lead agency. Early and meaningful engagement includes consideration of all phases of a project, from construction and operation to decommissioning.

The National Environmental Policy Act (NEPA) is similar to SEPA. SEPA has the flexibility to adopt NEPA if the documentation is adequate, but there is not a reciprocal flexibility.

Section 106 of the National Historic Preservation Act

The National Historic Preservation Act (NHPA) mandates certain roles and responsibilities for a federal historic preservation program, authorizing certain tools, resources, and processes, including the Advisory Council on Historic Preservation (ACHP) and the Section 106 review processes.

Section 106 requires federal agencies to take into account the effects of their undertakings on historic properties, which include historic, archaeological, and significant cultural places. Physical alteration of the built or natural landscape is the main focus. The definition of an undertaking is:

> *A project, activity, or program funded in whole or in part under direct or indirect jurisdiction of a federal agency; those carried out with federal money; those requiring a federal permit, license, or approval; those subject to state or local regulation administered pursuant to delegation or approval by a federal agency*

FERC licensing is an example of a project that uses federal money.

Complying with Section 106 is the responsibility of the federal agency and is a consultative process that involves multiple parties; the federal agency must reach out to states, Tribal governments, and other affected parties.[43]

The process includes four overarching steps: initiate the process; identify the sites and conduct background and on-the-ground research; assess the effects and determine if there is no effect, no adverse (non-damaging) effect, or adverse effect; and resolution of adverse effect, which could be failure to resolve.

Participant Issues and Suggestions

Since the state and federal processes are entwined with each other, the highlights of comments from participants are combined below. Appendix B has a more complete list of comments.

43 Consultation is defined by the ACHP as "the process of seeking, discussing, and considering the views of other participants, and, where feasible, seeking agreement with them regarding matters arising in the Section 106 process". *https://www.achp.gov/Section_106_Archaeology_Guidance/Questions%20and%20Answers/Section%20106%20consultation%20about%20archaeology*

Developers and others need to understand the differences between engagement and government-to-government consultation with Tribes in the FERC process; early engagement does not satisfy the required government-to-government consultation.

Tribal engagement often happens too late in the process, and project developers seem to underestimate the amount of Tribal engagement that is necessary to work through the process. Developing relationships with Tribes is important – it is not just a process requirement.

It is important to understand that Section 106 is a process and not a protection. The lead federal agency can decide to go ahead with a project as long as they follow the process to the letter. Lack of proper coordination between state and federal agencies can mean that cultural resource studies have not yet been conducted, yet a determination is made by SEPA.

The length of the permitting process was criticized by some participants because it takes too long, and there are too many regulations that new projects must comply with.

Include all Tribes that may be affected by a project as all Tribes are different. It is important to recognize the individuality and uniqueness of each Tribe.

Suggestions to help developers work through the processes included reaching out directly to the SEPA lead agency and permitting agencies, as well as contacting the Governor's Office for Regulatory Innovation and Assistance (ORIA). ORIA has a service to help developers perform an early analysis of environmental characteristics and constraints, and they can connect developers with Tribal or stakeholder contacts relevant to their projects.

SEPA should consider sufficiency of environmental review in the interest of expediting permitting for pumped storage hydropower; it should also consider alternative actions that would reduce disruption to the natural and cultural environment.

Washington state counties will be updating their comprehensive plans in 2025 as part of Growth Management Act (GMA) requirements, so county officials need to be aware of the potential for these types of projects to accommodate them within their local planning efforts.

Other Gravity Energy Storage Systems

Background

While pumped storage hydropower was the focus of the siting study, the siting study team felt it was important to look at other promising energy storage options that are also gravity-based. These are also classified as mechanical energy storage. The team considered the legislative directive to include mechanical energy storage technologies, but not electrochemical (such as lithium-ion batteries), thermal, or chemical (such as hydrogen).

The information below was provided by presentations at the January 23, 2025 PSH Siting Study meeting. It must be noted that these technologies are still in the very early stages of development.

Advanced Rail Energy Storage (ARES)
Yakama Power, which provides electric power to the Yakama Reservation, is exploring the use of Advanced Railway Energy Storage (ARES) systems on the reservation. This gravity-based energy storage technology uses a rotating motor to move rail cars loaded with cement up a slope, creating potential energy. The potential energy is released when the rail cars move down the slope, to create electricity.[44]

The strengths of ARES are that it is a mechanical gravity system that is also flexible, and that has less environmental impact in part because it does not use water. Participants from the Yakama Tribe expressed the importance of ARES not needing water, as PSH does. Ray Wiseman, General Manager of Yakama Power stated: "[ARES] allows us to place a battery storage facility on the reservation in which we could work with what the landscape would give us and not impose a project on the landscape."

Pumped Storage Using Abandoned Mines
The use of abandoned mines to site PSH is a way to minimize impacts because the land is already impacted. This type of PSH facility would be considered closed-loop. Students at the Michigan Technological University have been studying this approach, called Pumped Underground Storage Hydropower (PUSH), which uses abandoned mines as the locations for PSH reservoirs; this repurposing of abandoned mines can lower the impact of PSH by reusing existing infrastructure.

No PUSH projects are operating in the U.S., but there is a proposal for a PSH in an abandoned Kentucky coal mine.[45] There is an operating project in an abandoned slate quarry in Wales, United Kingdom.

A problem that the students are finding is that assessing possible locations in the U.S. is difficult because data and maps on mines and abandoned mines are very inadequate. Mines are also very site-specific and differ greatly, so much work is yet to be done. A couple of FERC documents provide more information about PSH in abandoned mines: *Guidance for Applicants Seeking Licenses or Preliminary Permits for Closed-Loop Pumped Storage Projects at Abandoned Mine Sites*;[46] and *Notice of Workshop: Closed-Loop Pumped Storage Projects at Abandoned Mine Sites*,[47] which poses research questions that could help further this approach.

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44 Advanced Rail Energy Storage. https://aresnorthamerica.com/

45 Business Wire. October 22, 2024. U.S. Department of Energy Finalizes $81 Milion Award for Lewis Ridge Long-Duration Energy Storage Project. *https://www.businesswire.com/news/home/20241007919327/en/U.S.-Department-of-Energy-Finalizes-%2481-Million-Award-for-Lewis-Ridge-Long-Duration-Energy-Storage-Project*

46 FERC (Federal Energy Regulatory Commission). 2019. Guidance for Applicants Seeking Licenses or Preliminary Permits for Closed-Loop Pumped Storage Projects at Abandoned Mine Sites (Docket No. AD19-8-000). *https://elibrary.ferc.gov/idmws/file_list.asp?accession_num=20191017-3004*

47 FERC (Federal Energy Regulatory Commission). 2019a. Notice of Workshop: Closed-Loop Pumped Storage Projects at Abandoned Mine Sites. April 4, 2019. *https://elibrary.ferc.gov/idmws/file_list.asp?accession_num=20190305-3005*

Water quality can be an issue in ways that are very site (mine) specific. Since the mines are contaminated already, perhaps PSH would provide an opportunity to clean them up.

There are also some projects experimenting with using mines with solid mass to produce energy.

Participant Issues and Suggestions

A few comments were provided by participants for this section. However, as the technologies are in the very early stages of exploration and development, there is not enough information to provide published literature impacts and mitigations on ARES and PUSH.

One participant mentioned that underground pumped storage could possibly prevent the use of surface water in PSH, but care would be needed regarding hydrological connectivity. It is good to use brownfields such as abandoned mines for redevelopment so that no additional habitat is removed. It appears, as least initially, that a closed loop system has fewer impacts if located entirely below ground.

General Observations – Participant Comments

Some participant comments were too general to belong to any one topic section, yet the study team felt they were important to include. These comments are included below.

One participant noted: "*My assumption is that the WSU study is neutral with regard to what the project is used for. The fact is that a key driver of interest in new storage is a way of managing wind and solar on the grid, but pumped storage certainly is a 'Swiss army knife' that can be used with any kind of pumping energy and grid support system.*"

Energy demands fluctuate during the day, so no matter the energy source, storage lowers the overall cost of energy for ALL customers. That is the value provided by any form of storage, including pumped storage.

The Colville Tribes have two of the biggest dams in the state on their reservation, so they know the impacts of green energy. Speaking from experience, a Tribal member stated that the Tribe wants to make sure that any PSH project is done well and intelligently, and does not make the same mistakes that occurred with hydropower dams, which everyone thought was the greatest thing at the time.

Participants were curious about what trade-offs are acceptable between what we want to protect versus achieving clean energy goals.

> According to a participant, utilities are looking for solutions to meet the green energy goals for the state – other options don't provide the long-duration storage that PSH can achieve.

Mapping

In the House Bill calling for the siting study, the legislature mandated that WSU develop a map with geographic information system (GIS) data layers that highlight areas identified through the process. WSU approached this task using, as a first step, information and data from the ***Closed-Loop Pumped Storage Hydropower Resource Assessment for the United States*** from the National Renewable Energy Laboratory (NREL).[48]

> The NREL report uses the term "**theoretical**" in describing the reservoir sites that they identified. The PSH Siting Study uses this term as well. However, the reservoir sites on the maps are not intended to be used for the actual siting of PSH.

NREL Report

Released in May 2022 by the U.S. Department of Energy Water Power Technologies Office (WPTO) as part of their HydroWIRES initiative,[49] *Closed-Loop Pumped Storage Hydropower Resource Assessment for the United States*, produced by the National Renewable Energy Laboratory, provides a "GIS-based analysis of potential new closed-loop PSH systems in the U.S." The objective of the report is to help identity sites that could be further assessed – both economically and environmentally – for potential PSH development, and to quantify the potential PSH storage capacity for the country. This work was based in part on previous work done by the Australian National University, which created a global atlas of mostly off-river theoretical sites for PSH.[50]

An interactive map with the geospatial data that is described in NREL's report can be found at *https://maps.nrel.gov/psh*.

Using 30-meter resolution digital elevation data, NREL identified the geographic locations and elevations of theoretical sites. The data presented is the third-generation dataset.[51]

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48 Rosenlieb, E., D. Heimiller, and S. Cohen. 2022. *Closed-Loop Pumped Storage Hydropower Resource Assessment for the United States*. National Renewable Energy Laboratory. Golden, CO. NREL/TP-6A20-81277. *https://www.nrel.gov/docs/fy22osti/81277.pdf*

49 United States Department of Energy. 2024. *Hydropower and Water Innovation of for a Resilient Electricity System* (Hydro WIRES) *https://www.energy.gov/eere/water/hydrowires-initiative*

50 Australian National University. 2024. Pumped Hydro Energy Storage Atlases. *https://re100.eng.anu.edu.au/pumped_hydro_atlas/*

51 National Renewable Energy Laboratory. 2025. Pumped Storage Hydropower Supply Curves. *https://www2.nrel.gov/gis/psh-supply-curves*

The following design specifications were used:

- Storage duration for 8, 10, or 12 hours
- Reservoirs sized with dam heights of 40, 60, 80, and 100 meters (131, 197, 262, and 328 feet, respectively)
- Minimum reservoir surface area; 10 hectares (25 acres).
- Minimum head height (elevation difference between reservoirs) of 200 meters (656 feet)
- Maximum head height of 750 meters (2461 feet).
- Maximum conveyance length distance to head ratio of 12:1.
- Capacity of each reservoir is within 10% of the other in the pair.

Using federal data, sites that were excluded include:

- Sites located within 1000 feet of a wetland
- Critical habitats for endangered species
- Pairs of reservoirs that intersect existing water bodies and waterways
- Federal protected lands such as national parks
- Urban areas

The NREL resource assessment did not, however, exclude theoretical pairs from Tribal reservations. The NREL team said that by leaving the information in the reservation areas, Tribes could have the information and choose for themselves if they wanted to pursue PSH.[52]

An economic valuation model, *A Component-Level Bottom-Up Cost Model for Pumped Storage Hydropower,*[53] was used to identify the pairs with the lowest estimated capital cost, which contributed to identifying the final theoretical pairs. As the PSH Siting Study report does not discuss PSH economics or valuation, refer to the valuation report for more information.

It must be noted that the NREL model is just that – a model. The information used to find the theoretical reservoir pairs came from publicly available national and global geospatial data layers – no one reviewed any of these sites on the ground. The model gives an indication of where sites might theoretically and potentially be located. However, there is a lot of assessment work that goes into finding appropriate locations. It must be noted that the objective of NREL was to assess the pumped storage resource capacity for the U.S. It is not the intent of the PSH Siting Study that these maps be used for actual siting of PSH.

WSU PSH Siting Study Mapping

To begin developing a map that highlights areas identified through the siting process, which was the charge given by the state legislature, a map of Washington state showing the NREL theoretical pairings of closed-loop reservoirs was produced. Each reservoir pair is portrayed on the maps as a “barbell” – a short line with dots at both ends. On each barbell, the centers of the dots are the two reservoir locations and the line shows the tunnels or penstocks (whether above or below ground) that would connect them.

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52 Online communication with Stuart Cohen and Evan Rosenlieb, NREL, March 28, 2025.

53 Cohen, S., V. Ramasamy, and D. Inman. 2024. A Component-Level Bottom-Up Cost Model for Pumped Storage Hydropower. National Renewable Energy Laboratory. NREL/TP-6A40-84875. *https://www.nrel.gov/docs/fy23osti/84875.pdf*

NREL's resource assessment identified 408 theoretical pairs of reservoirs that are entirely within Washington state. Of these pairs, 91 have one or both reservoirs situated within a Tribal reservation. The study team decided to remove from the map the theoretical reservoir pairs situated within Tribal reservations – Tribes may choose for themselves if and how to use NREL's information. That leaves 317 sites (pairs) that are entirely outside of Tribal reservations. Figure 5, at the end of this chapter, shows these theoretical pairs in Washington state, as well as predominant public land ownership.

The most frequently mentioned issues voiced by siting study participants involved traditional cultural resources, water availability, and terrestrial habitat, all of which are difficult to portray on a map, especially across the entire state.

In the end, the siting study process identified only a very few factors from which to create map layers. These layers were:

- Buffers along rivers
- Wind and solar projects in the state
- Transmission lines and substations

Tribes do not share their information about the locations of important cultural resources areas. However, during conversations with Tribes, they said that areas extending from rivers or streams up to ridges hold great spiritual importance. The Director of DAHP suggested that all land a half mile from rivers could be important traditional cultural areas. The team therefore decided to show a half mile buffer on both sides of major streams and rivers on two maps. Figure 6 shows major rivers with ½ mile buffers and all 317 theoretical PSH sites. Theoretical PSH sites which had at least one reservoir touching the ½ mile buffer were removed from the map in Figure 7. Some reservoirs (dots) appear to be within a buffer on Figure 7, but that is a result of the map scale and the size needed to make the barbells visible.

Forty-one pairs of reservoirs had at least one reservoir with the 1/2 mile buffer of the Columbia, Snake, Okanogan, and Grande Ronde Rivers. Removing these leaves 276 theoretical pairs of PSH closed-loop reservoirs in Washington state, as identified by NREL.

It must be stressed that removing the NREL sites from within river buffers does not mean that the remaining theoretical sites do not have any traditional cultural sites or are not important areas to Tribes. Tribes do not make their cultural resource areas public. Developers must perform due diligence in contracting Tribes early and reviewing proposed sites with them.

The legislation suggested that WSU could choose to look at colocating PSH sites near solar and wind projects. Participants expressed concern that PSH should not be placed near wind turbines because of the risk of raptors seeking prey over the reservoirs being injured by wind turbines. NREL's sites generally occur in locations away from existing solar, although floating photovoltaic solar on reservoirs could be an option. Figure 8 shows 317 theoretical PSH sites, along with existing utility-scale wind turbines and photovoltaic solar installations, and transmission lines greater than 220 volts.

Figure 8 also shows the general locations of three theoretical add-on PSH sites, circled in red, which are next to existing waterbodies. Swift Reservoir is the site in SW Washington, Tolt Reservoir is just east of Seattle, and Osoyoos Lake is at the Canadian border.

Figure 5.
Washington State Land Ownership Map with Theoretical PSH Reservoirs

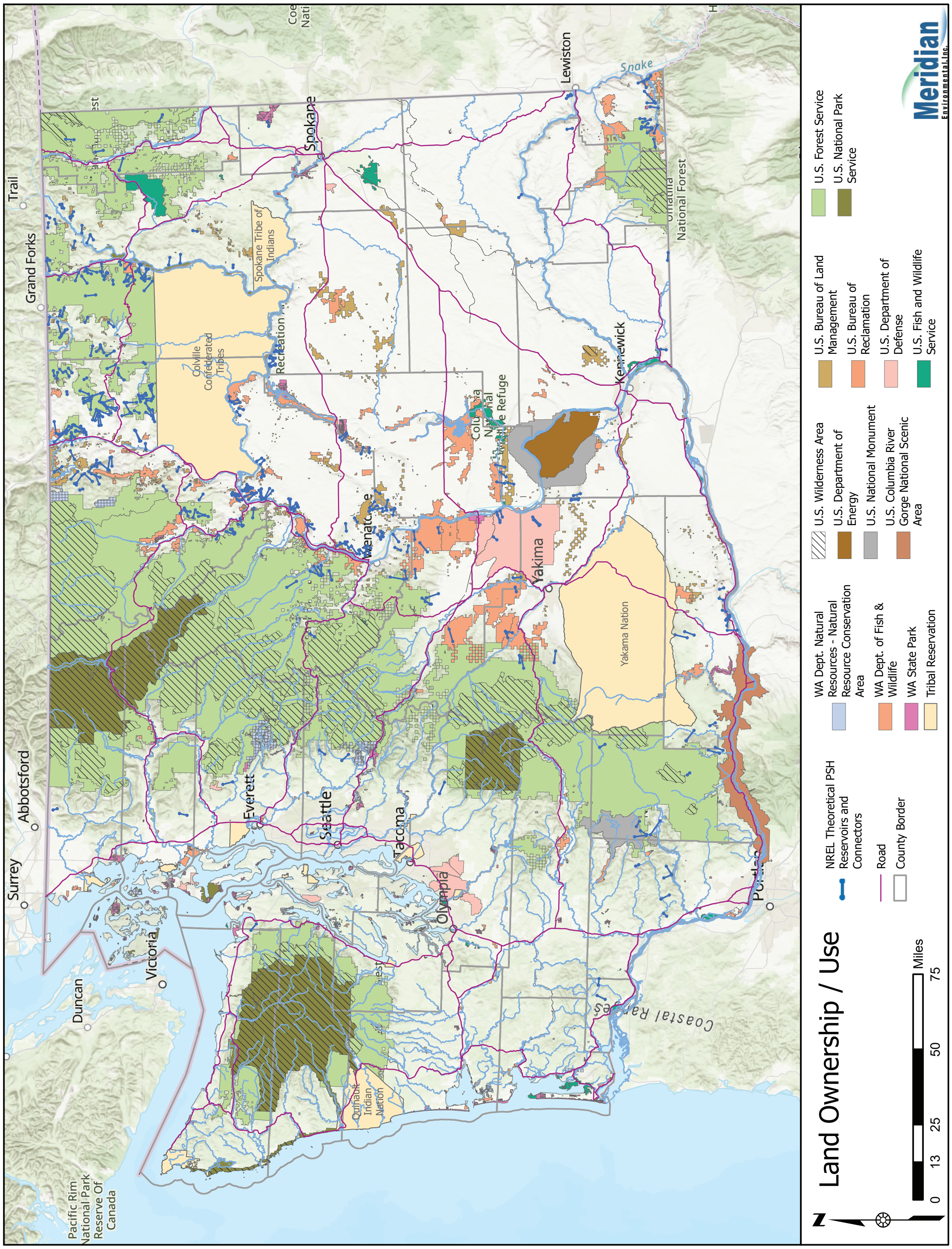


Figure 6.
Washington State Map with Theoretical PSH Reservoirs and ½ Mile Major River Buffers

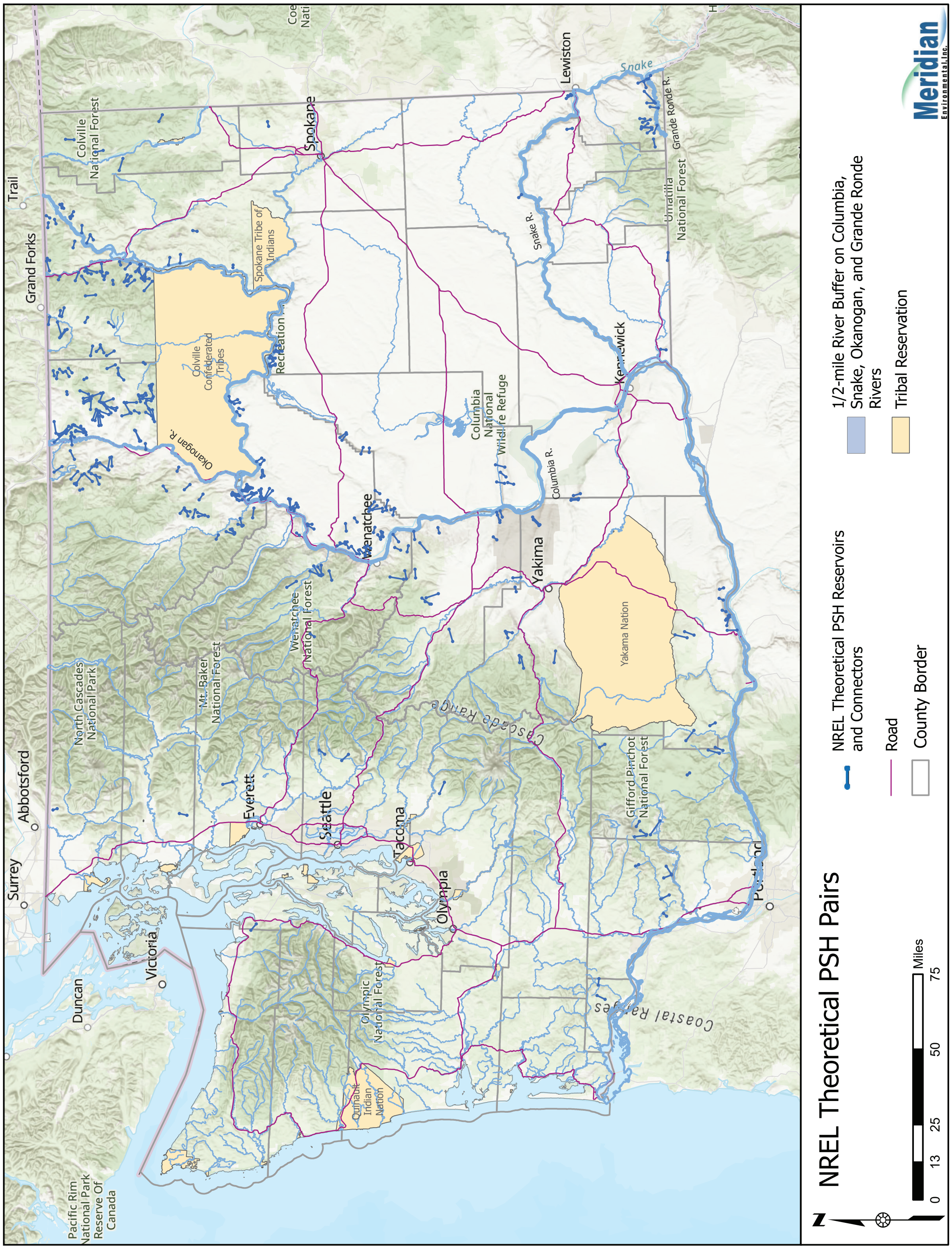


Figure 7.

Washington State Map with Theoretical PSH Reservoirs NOT Within the ½ Mile Major River Buffers

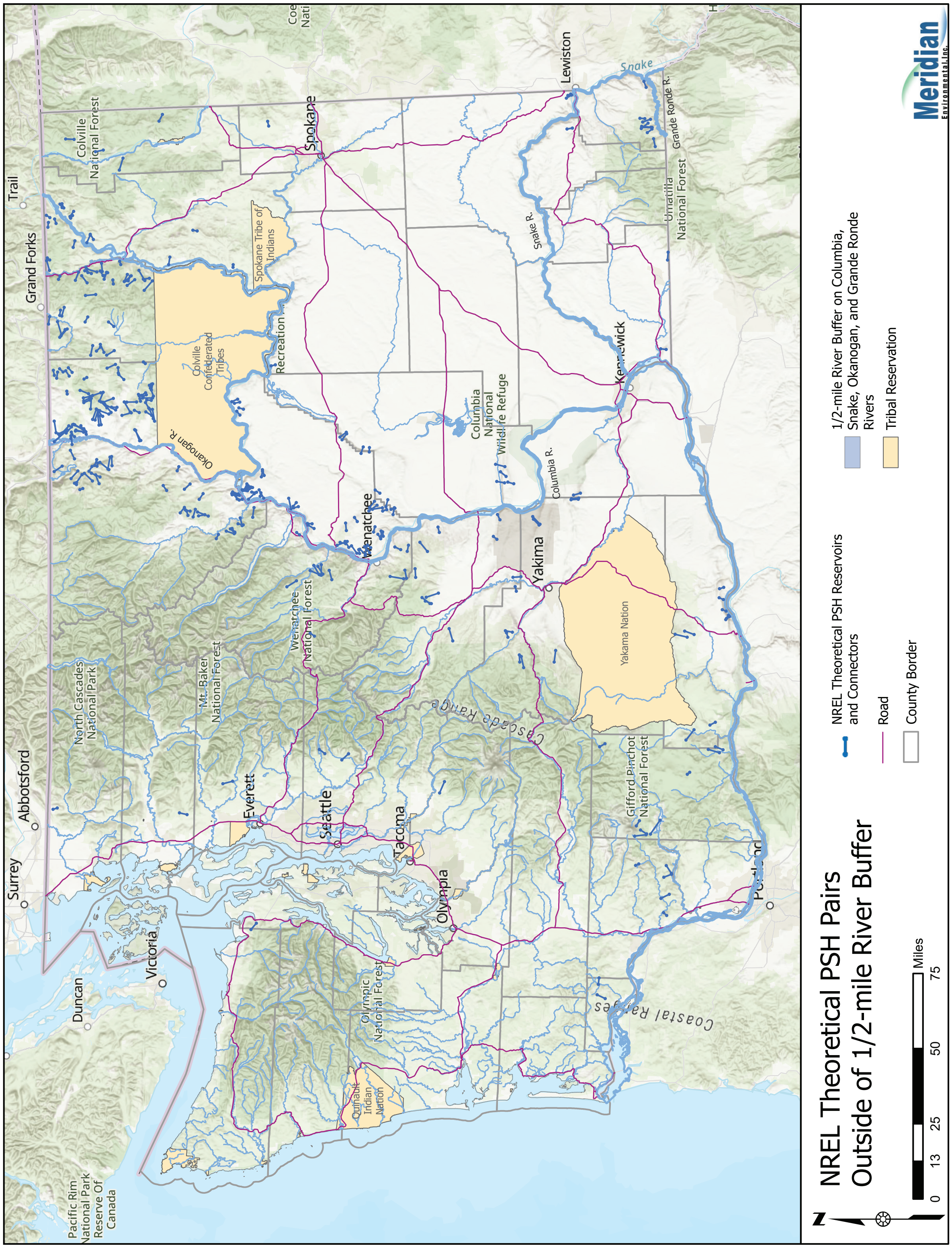
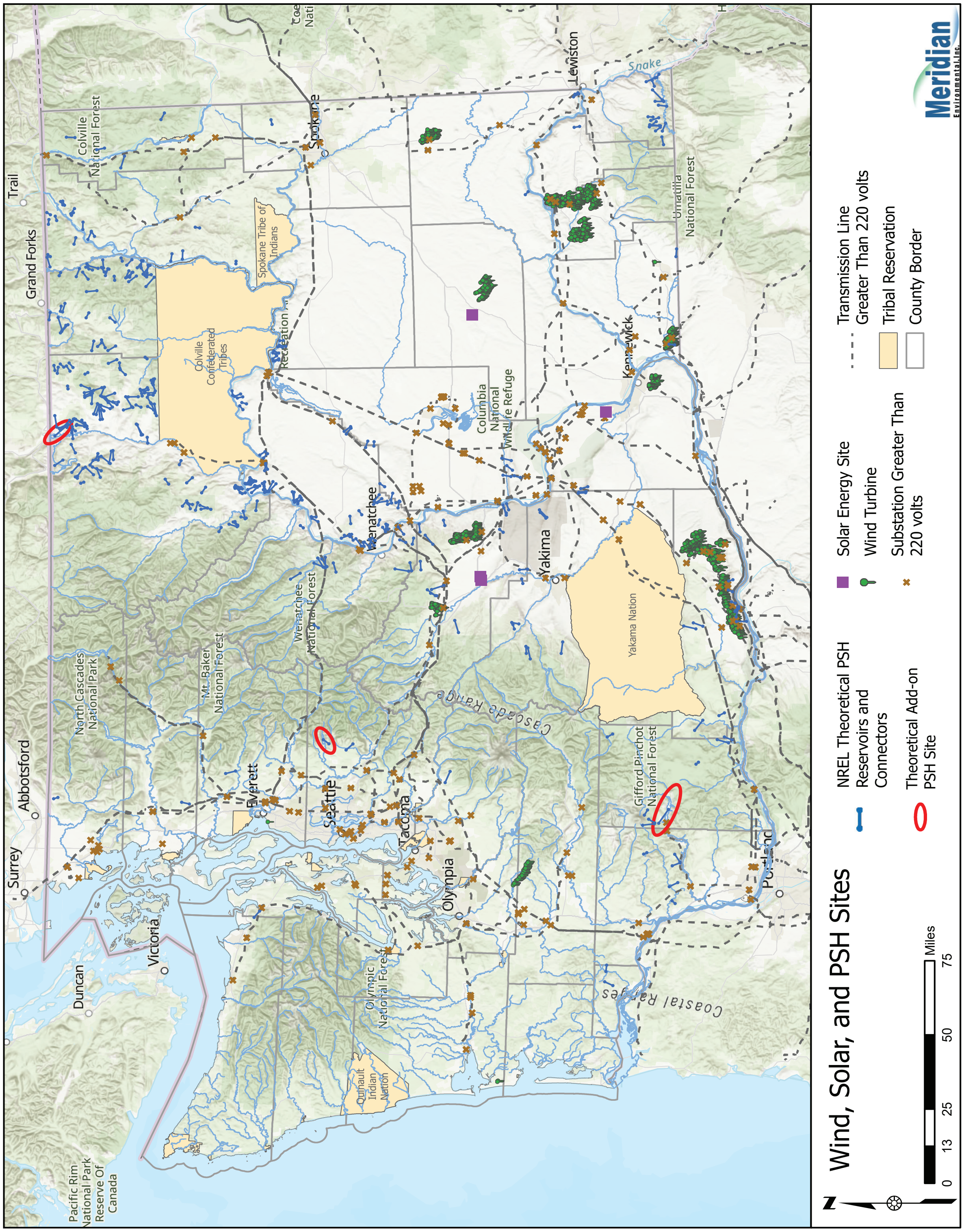


Figure 8.

Washington State Map with Theoretical PSH Reservoirs (including Add-ons), Utility-Scale Wind and Solar Installations, and Transmission Lines



Key Points

Throughout the PSH Siting Study, at meetings and in other discussions, a few themes stood out as major concerns – Tribal cultural resources, water availability, terrestrial habitat, and aquatic habitat.

The concern about traditional cultural resources and siting clean energy facilities such as PSH is multi-faceted. Essentially, however, Tribes desire that no harm be done to these resources. The best way to guarantee such protection was stated again and again: avoid areas with cultural resources that Tribes identify and consider important.

Two related concerns voiced by Tribal partners and others are the toll taken by the cumulative effect of damage done to resources from different projects, and that Tribes feel that they are always asked to compromise. A major barrier that prevents the full inclusion of Tribes in siting processes is that preliminary permits are typically requested and issued before Tribes are made aware of the proposed project.

Water availability is of great concern, especially given the unknown future with climate change. Since Washington state freshwater resources are mostly already allocated, there is concern that water rights leased or bought from elsewhere to initially fill closed-loop pumped storage systems could possibly create a deficit in agricultural water, domestic supplies, or a future need.

There is also a thought-provoking tension between the impacts of open-loop and closed-loop systems. Originally, pumped storage systems were all open-loop, which had, and have, harmful effects on aquatic habitats and fish. The shift toward closed-loop systems may seem to result in fewer impacts, yet more land is impacted when two reservoirs are constructed, and some of this land may be culturally important to Tribes or other community members. Groundwater quality and quantity also may be more impacted by closed-loop systems.

As one subject matter expert participant put it: the move away from open-loop PSH to closed-loop PSH is a paradigm shift for the development community because of the differences in the greatest impacts from the different systems. Open-loop systems have impacts on aquatics, specifically salmon and other fish, while closed-loop systems seem to be more of a land-based development, creating reservoirs on landscapes. Instead of the greatest impact being to the aquatic ecosystem, development of closed-loop systems now affects people and communities and those who have been living on these landscapes, due to land impacts and potential water availability issues.

Bridging this gap somewhat are add-on PSH facilities. Using an existing waterbody as the lower reservoir reduces environmental impacts from construction activities and removes the need for surface water or groundwater to fill the reservoirs. However, operationally, there are still great impacts to the aquatic ecosystem.

Recommendations

From subject matter experts, research in published reports, and participant comments and discussion, WSU identified some suggested recommendations for the legislature, as well as for agencies and potential developers, to consider and explore in regards to siting PSH with the least number of negative impacts. These suggestions reflect the views of the WSU study leads only. While they were informed by the study process and participants, these recommendations were not developed or affirmed by project participants.

Prioritize early contact with Tribes and the local community. Although the preliminary permit process does not mandate it, engaging at the earliest opportunity with an open mind and without an assumed outcome and developing relationships with Tribes can help guide development to appropriate sites as well as prevent project siting on important cultural areas.

Research water availability and future constraints. Water availability issues might not easily be overcome for closed-loop systems, especially given the unknown changes in future climate scenarios. It is advised that early consideration and research go into any closed-loop facility in the state to make sure that the extraction of reservoir water from local sources does not eventually cause hardships for aquatic wildlife, domestic water supplies, agriculture, irrigation, and other water users.

Consider other approaches to PSH. Other approaches to PSH may be worth exploring, with the goal of limiting negative impacts. One such approach is add-on PSH, for which an upper reservoir is constructed and connected to an existing reservoir to create a PSH facility. Minimal additional impacts would be expected to the aquatic ecology during construction, yet during operations there could be many impacts. Connecting two existing reservoirs with an added tunnel and powerhouse is another approach that is currently being considered.

Develop and utilize resources that can guide developers to areas where there will be fewer impacts on wildlife and habitat. Tools exist, and more are being developed by Washington state agencies and others, to guide developers away from critical habitat for protected and other important species. Guidelines such as WDFW's *Guidelines for Utility-Scale Solar & Onshore Wind Energy*[54] and tools such as WDFW's *WSRRI Spatial Priorities Xeric and Mesic Habitat* model[55] and WSU's *Least-Conflict Solar Siting on the Columbia Plateau*,[56] which although created for other large-scale clean energy projects, should be used for PSH projects as well.

Consider utilizing criteria for low impact PSH when available. The Low Impact Hydropower Institute (LIHI)[57] is an NGO that has developed rigorous science-based criteria to certify hydropower generation projects (not PSH) as low impact. Their certification process is voluntary. If similar voluntary certification programs are developed by organizations for PSH, with criteria that aim to avoid, minimize, or reduce impacts on the environment, Tribal cultural properties, and Tribal trust resources, to name a few, Washington state agencies may want to investigate these criteria to obtain guidance that can be incorporated into state guidelines, recommendations, regulations, and/or procedures.

Potential PSH projects that follow some of the recommendations above, and that demonstrate understanding of and compliance with the issues and needs expressed by Tribes, local communities, agencies, local governments, NGOs, and others, may find that their projects have fewer obstacles and can advance in a more efficient manner to help the state reach its goal of fossil-free electricity.

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54 Due to be published June 2025

55 Washington Shrubsteppe Restoration and Resiliency Initiative. https://wdfw.wa.gov/species-habitats/habitat-recovery/shrubsteppe

56 Washington State University Energy Program. 2023. Least-Conflict Solar Siting on the Columbia Plateau. WSUEEP23-004. Olympia, WA *https://www.energy.wsu.edu/documents/Least-Conflict_Solar_Siting_Report-WSUEP23-04--6-29.pdf*

57 Low Impact Hydropower Institute *https://lowimpacthydro.org/*

Appendix A

Topics – Potential Impacts/Mitigations and Participant Issues/Suggestions

The following lists contain information that is additional to what is written in this report's Topic chapter. Separated by individual topics, the lists include potential impacts and potential mitigations, as provided by subject matter experts and published literature, and comments from participants about issues and suggestions.

The Background sections of the individual topics in the report may help readers to better understand some of the information and comments below.

Tribal Cultural Resources and Tribal Rights

Potential impacts and potential mitigations

Potential impacts

- Disturbance or destruction of culturally important sites, including but not limited to:
    - Indigenous settlement sites
    - Human burial sites and/or sacred sites
    - Previously unknown sites in project areas or sites not mapped to maintain confidentiality
- Impacted views from adjacent culturally significant sites used by local tribes for traditional cultural practices

Potential mitigations

- Avoid culturally important sites because many sites are regarded as irreplaceable and therefore cannot be mitigated
- Track cumulative impacts of energy infrastructure on traditional cultural properties
- Hire a cultural resource monitor during ground-disturbing activities
- Conduct Tribal consultation and community engagement in advance of preliminary permit application filing to understand, early on, where culturally significant sites are to avoid them, while maintaining confidentiality
- If sites are disturbed, erect signs describing what was disturbed within project boundaries
- Develop and implement historic properties management plan

Participant issues and suggestions

Participant issues

- Cultural resources including traditional foods, gathering areas, wildlife, water, and other natural resources, need to be protected
  - Impacts to cultural resources cannot be mitigated
  - Tribes generally support clean energy, but not at the expense of cultural resources
  - Cultural and ecological connection/relationship must not be interrupted
  - These sites carry individual and family identities
  - "Would you propose a development on Arlington National Cemetery?"; Tribes' sacred landscapes are just as sacred
  - Tribes have been in the area for tens of thousands of years, while a PSH site can exist for 100 years; don't desecrate the landscape for only 100 years of benefits
- Tribes are constantly asked to compromise
  - Tribal rights and resources keep getting chipped away
  - Constant pressure for Tribes to compromise is a social injustice – Tribes are always asked to make a deal
  - If "no" is not an acceptable answer from the Tribes than it is not consultation
- Tribes take on disproportionate burdens of adverse effects and inequitable consequences
  - Projects like PSH don't benefit Tribes environmentally or economically
  - These projects are often sited in more rural areas that always contain unceded homelands, and/or ceded territory/U&A
- Tribal rights include concern about wildlife migration routes that could be blocked by new projects and fencing
- Cumulative impacts from many projects add up
  - Concern about impacts from all existing and proposed projects in the Colville shrubsteppe area and on state sensitive and federally listed species overall
  - Cumulative impacts on access to sacred areas and areas important to local communities
- Cultural resources are often ignored and/or not valued when clean energy facilities are being sited
  - Constant training of non-tribal staff on basics of Tribal sovereignty and cultural resources is exhausting and contributes to continuation of so many injustices
  - Tribes must always remind the state that they have trust responsibilities
  - Talking to Tribes is not just "checking the box"
  - The current siting laws work such that they reduce everything to a monetary value; Tribal resources don't get considered and will be lost if a developer can save money by building right next to a transmission line
  - Some state agencies, such as the DAHP, have culturally sensitive confidential Tribal information, but that information is not used to keep possible projects from Tribal areas
  - There is no mandate to protect cultural resources – they are just given consideration in planning, which is a failure at the federal and state level
  - Concerning access, past experience has shown that industry has not honored or acknowledged that tribal rights can be exercised in or near these facilities or areas

- Tribes are often brought in too late to proactively identify cultural resources and suggest alternative locations/approaches for development
    - Traditional cultural resources such as traditional food gathering sites and viewsheds may be impacted because their locations are often not known to non-tribal stakeholders until a project is well on the way to development
    - Studies are often done for the purpose of expedited permitting, and that puts Tribes on a faster deadline to advocate for resources that are under-considered by the structure of the siting process
- Information about cultural resources is very sensitive to Tribes and can't be disclosed
    - Disclosure of spiritually sensitive information is of extreme concern and can violate Tribal ancestral laws and traditional teachings
    - Mapping exercises might ignore the importance of cultural resources and can mistakenly identify locations as appropriate for development
- Concern about impact on the local community from construction
    - There are many missing native women – "man camps" with workers from out of the region may contribute to their disappearance
    - General concern about safety impacts to local indigenous communities
- Tribes' concerns about clean energy siting are based on bad experiences with actual projects

Participant suggestions:

- Do not develop areas that will impact Tribal cultural resources or other Tribal interests
    - Avoidance all together should be the goal
    - Avoid cultural resources that interact with or relate to water
    - Do not take existing agricultural lands out of production or utilize areas where there are cultural resources
    - If important Tribal areas cannot be avoided, work with folks to decide if the project needs to be done or not
- Proactively analyze the impacts that PSH seems particularly likely to have on cultural resources
    - Steep slopes seem critical for PSH, so find out if steep slopes are critical cultural resource land
    - Ridges above rivers are important spiritually – assess these areas carefully for cultural resources
- Developers and agencies should engage early with Tribes about cultural resources
    - One of the first steps for PSH projects should be to get input from the Tribes whose cultural sites and/or regularly used foraging grounds would be eradicated
    - Make sure to interact with Tribes early in the process, which will greatly benefit Tribes, and require that federal agencies uphold their trust responsibilities; together, these steps will make the siting process more meaningful going forward
    - Conduct the required studies but also engage tribal partners and local agencies early and often in the siting process to understand potential impacts
    - Create a good communications framework
- Require free, prior, and informed consent[58]
    - Respect and honor Tribal sovereignty along with free and informed prior consent

58 Obtaining consent from indigenous peoples for any activity taken on the land

- Look for ways to develop PSH while also limiting impacts to cultural resources
    - Tribes have a history of working with developers to develop energy sources; we can find areas to develop without having impacts on cultural resources
    - Green energy must be done in a responsible manner that respects Tribes' traditional foods, properties, and cultural resources
    - Give Tribes the opportunity to have keyed access to fenced areas surrounding cultural resources
- Monitor sites over time for impacts on cultural resources and continue to engage Tribes
    - Implement sustained consultation and observational data collection
- Consider reparations based on the history of issues concerning habitat, treaty rights, displacement from development, and other histories of harm to Tribes
- Incorporate lessons learned from Goldendale

Aquatic Ecology

Potential impacts and potential mitigations

Potential impacts

- Aquatic habitat loss and barriers to fish migration due to dams
- Increased invasive plant species from a higher reservoir nutrient content due to water loss
- Fluctuations in the river connected to the lower reservoir
- Inhibition of natural river processes
- Changes in fish species composition due to habitat alteration

Potential mitigation

- Implement additional studies and monitoring along with a control plan
- Plant natives along diversion channel
- Manage invasive plant species
- Replace wetlands by creating them in the same ratio elsewhere
- Establish two ponds and stock them to provide warm water fish habitat

Participant issues and suggestions

Participant issues

- Impacts on aquatic and riparian species
- Fish entrainment – the loss of fish from open-loop reservoir construction
    - Need to determine impacts of fish screens in open-loop systems
- Drawdown in reservoir with hydrologic connectivity can affect fish and other aquatic biota
- "Having worked previously in the permitting of salmon habitat restoration, I find it incredulous that any of these potential projects would ever actually happen because of the major impact it would have on any of our regional watersheds."
- Invasive species in ponds

Participant suggestions

- Create avoidance or mitigation requirements for impacts and loss of riparian habitat and/or aquatic habitat conditions and functions

Water Quality

Potential impacts and potential mitigations

Potential impacts

- Evaporative losses, which can lead to increased concentrations of dissolved solids such as metals and other contaminants used during construction and operation
- Temperature changes
- Biofouling (accumulation of microorganisms, algae, and plants)
- Seepage or leakage from the reservoir to groundwater
  - Contaminants concentrated from evaporation seeping into groundwater

Potential mitigation

- Develop a water quality standard and perform continuous monitoring
  - Monitor against unintended consequences for other surface water users, since many waters are hydrologically connected
  - Create evaporation ponds or water treatment facilities
  - Provide water treatment to control algal growth as needed
  - Operate in areas that do not impact any legacy groundwater contamination
  - Install impermeable liners in reservoirs, power tunnels and all water conveyance structures

Participant issues and suggestions

Participant issues

- General water quality concerns
- Water quality issues related to algal blooms
- Water temperature fluctuations and warmer water released down into cooler river water
- Water released back into the river could attract smolts; smolts could be impacted by water temperature as they migrate out or circulate in the system before they migrate out

Participant suggestions

- Consider installing screening; as Tribes move toward full reintroduction of anadromous fish, it's important that there is not additional mortality because of PSH

Water Quantity and Water Availability

Potential impacts and potential mitigations

Potential impacts

- Groundwater loss from withdrawals from aquifers and surface water loss for initial filling and for makeup water
  - Can impact connected wetlands, water supplies for wells, and minimum water supplies, along with potential impacts to agriculture/irrigation

- Precipitation runoff collected in reservoirs and not natural watersheds, causing overflow and impacting dam safety and wetland drainage patterns
- Water movement between reservoirs when such movement affects naturally flowing lakes and rivers
- Connection between groundwater and surface waters

Potential mitigations

- Prescribed timing, quantity, and frequency of initial reservoir fill and refill
- Restrictions on water withdrawals during wildlife and plant critical life events
- Set minimum flow requirements or maximum limits for pumping from nearby water to fill reservoir
    - Time withdrawals during higher flows
- Water right buyout or compensation for use of water rights, with restrictions on rate and timing
- Construct diversion channels along with flood control structures and measures
- Schedule irrigation interconnection during non-irrigation season so endangered fish species aren't accidentally harmed

Participant issues and suggestions

Participant issues:

- Using groundwater to fill reservoirs can have impacts on groundwater and groundwater dependent ecosystems, including downstream effect on native wetlands
    - Can reduce groundwater recharge of wetlands down slope that are important breeding areas for amphibian species
    - It may not be easy to discern that the groundwater withdrawals for the PSH project are affecting wetlands because of spatial separation
- Water will be a long-term issue due to the length of PSH operations
- Water loss/evaporation
    - Water source locations and need for water to replenish PSH over time
    - Groundwater reduction
- Water availability
    - Regulators need to consider what effect designating water for these projects may have on future water availability for the residential usage and agricultural production that will be necessary for an increased population
    - "Who will do without water to satisfy the PSH need for this limited resource, which is under increasing pressure from development and a changing climate?"
- Impacts on future water availability by phenomena such as climate change
- Consider that suitable locations for PSH may have less water availability over time, and how that relates to water quality and ecosystems
- Water rights could be an issue
    - If initial water is diverted from the Columbia River, a water right is needed. If it's a closed system, need to purchase water right – will that water be taken from agricultural irrigation or upstream or somewhere else? In Central and eastern WA, basins are closed to new water rights. Given changing climates in eastern, central WA, this could be an issue.
- The water levels of some waterbodies need to meet certain requirements and regulations; this may be the case with the proposed Banks Lake and Lake Roosevelt PSH

Participant suggestions

- Reflect possible effects of groundwater withdrawals in environmental documentation for permitting
- Investigate ways to minimize consumptive use of water (evaporation)
- Use cover systems such as floating balls, flexible covers to minimize water loss
    - Floating balls are often more effective in reservoirs that do not see a lot of fluctuations

Wildlife & Habitat / Terrestrial

Potential impacts and potential mitigations

Potential impacts

- Land disturbed, inundated, or removed due to construction of PSH and transmission lines can cause:
    - Loss of habitat, habitat fragmentation, and loss of connectivity, including land needed for life cycle events such as foraging, hunting, nesting, breeding, and overwintering
    - Higher risk of disease from living closer together due to decreased habitat
    - Loss of genetic diversity due to decreasing populations
- Disturbance and disruption from construction and operations, such as from noise and vehicle emissions, can cause:
    - Abandoned nests, avoidance of habitat, mortality
    - Disruption of species' critical life cycle events
- Construction vehicles & traffic causing direct mortality and habitat loss
- Establishment of invasive species
- Fire risk from slash cut to prepare for construction
- Entrapment within pipes, fencing, netting, holes, etc.
- Transmission lines
    - Transmission structures provide perches for predatory birds
    - Transmission lines can be electrical hazards
    - Reservoirs attract wildlife and can be a drowning hazard (attractive nuisance)
    - Brine ponds used in water quality maintenance can be a health hazard to birds attracted to them
    - Water level fluctuations could increase potential for invasive species
        - Impacts to amphibians
    - Elimination of wetlands/riparian habitat

Potential mitigations

- Develop protection plans and establish ongoing monitoring
- Restore and enhance habitat
- Fence reservoirs to prevent risk of drowning
- Decommission unnecessary roads after construction
- Create wildlife crossings under penstocks
- Remove slash piles that were cut for construction to prevent the risk of fires
- Time disruptive construction activities to avoid critical life cycle events
- Manage noxious weeds, reseed with native mixes, manage vegetation during operations
- Seal up anything that can be a hazard for small and large animals
- Map areas that are important to protect habitat in order to prevent cumulative fragmentation effects

Participant issues and suggestions

Participant issues

- Effects on habitat and wildlife
  - Habitat disturbance and loss
    - Impact on species dependent on shrubsteppe during life cycle events. This includes sharp-tailed grouse, sage grouse, and other federal and state-listed species. An example of an interspecies relationship that could be impacted is that of badgers (whose numbers are already declining) that dig holes that burrowing owls subsequently utilize for nesting burrows.
  - Fluctuating water levels might impact amphibians and nesting birds on shorelines
  - Reservoirs are attractive to certain nuisance species
  - Amphibians are the terrestrial species most adversely impacted
- Wildlife displacement and disruption to migration routes
  - Wildlife displacement from former habitat on which PSH facilities are sited
  - Disruption and fracturing of wildlife migration routes, movement corridors and habitat connectivity routes due to placement of facilities and safety controls such as fences
- Invasive and non-native species
  - Creating a domino effect through the spread of unwanted seeds, pollen, etc., during facility construction
  - Non-native vegetation brought in on tires and other equipment

Participant suggestions:

- Establish baseline habitat conditions and monitoring plans
- Avoid construction in high quality native habitat
- Avoid areas that are habitat for species of greatest conservation, such as state and federal listed species
  - Use tools such as the Washington Shrubsteppe Restoration and Resiliency Initiative (WSRRI) Spatial Priorities Xeric and Mesic Habitat models to identify high quality native habitat within proposed project areas
- Avoid locating PSH adjacent to wind energy projects
  - Creating open reservoirs near existing wind energy projects increases beneficial habitat for some terrestrial and avian species and can increase the population of small mammals, bats, and migratory birds, all of which attract birds of prey (raptors); this can increase collisions of migratory species and birds of prey (raptors) with wind turbine blades
- Include habitat connectivity in project design
- Bring in and establish vegetation that is native to the surrounding areas to help mitigate the noise, block out some light, and absorb some of the vibration, while helping to establish nutrients
- Create and maintain new habitat such as mud flats for migratory birds

Geology and Soils

Potential impacts and potential mitigations

Potential impacts

- Subsidence (sinking of an area)
- Increased seismic risks
- Increased erosion
- Seepage or leakage

Potential mitigations

- Site specific engineering studies
- Design for maximum critical credible earthquake in the area
- Stabilize soils, time construction, create erosion plan
- Install impermeable liners in reservoirs, power tunnels and all water conveyance structures

Participant issues and suggestions

Participant issues:

- Concern about ground disturbance
- Concern about induced seismicity
- Concern about structural failure
  - Eastern Washington has had many fires that burned off vegetation and roots, and significantly more rain events than normal, both of which increase the risk of slope failures and landslides during earthquakes
  - Structural failures causing water quality problems by releasing water into the river and impacting salmon
  - Though engineers and developers plan to prevent failure, unforeseen failure events do happen

Land use – Air Quality, Aesthetics, Access, Lighting, Noise

Potential impacts and potential mitigations

Potential impacts

- Air emissions
  - Dust and vehicle exhaust impact wildlife and the local community
  - Methane gas emissions from reservoirs that were not cleared of vegetation before being filled
- Noise from construction activities and operation of pumping generation cycle
  - Impact on wildlife
- Visual access to the viewshed
  - The look of reservoirs, buildings, and roads not matching the character of an area
- Lighting
  - Light pollution disturbing nocturnal species
  - Light pollution and noise disturbing campers

- Lack of irrigation payments to irrigation districts if irrigated land taken out of production
- Recreation and other land uses disturbed and/or unavailable because of project construction, project facilities, and land required for transmission line that crosses large areas

Potential mitigations

- Conduct additional studies and monitor impacts
- Create a "no idling" policy and site-specific measures to limit noise, exhaust, and dust
- Clear vegetation before constructing reservoir to prevent methane production
- Restrict timing of loud activities so as not to interfere with sensitive wildlife life cycle events
    - Use noise mufflers and intake silencers
- Create buffers and fencing, and use vegetation for fence rows
- Use lighting products that minimize visibility from long distances
    - Use directional lighting and light hoods, and use lighting only when needed
- Use attractive or natural design
    - Do a "Photoshop trial" – Modify a photograph of the pre-construction reservoir site to visualize what it would look like with the reservoir
- Create new or improved recreational opportunities
    - Fund off-site recreation
    - Add new signage to new or existing trails
    - Purchase land for new recreation
- Keep livestock watering and salt licks away from project and transmission corridor
- Provide payments to irrigation districts to compensate for loss of income from land taken out of irrigated production
    - Time construction to avoid conflict with irrigation needs
- Use brownfield sites, preserve greenfield sites
- Create marketplace for utilizing lands already compromised
    - Get funding from government for adaptive reuse
    - Communicate interest to generate taxes from those properties again
    - Create economic viability

Participant issues and suggestions

Participant issues

- Air quality, lights, noise, and ground vibrations changing the migration of birds, bees, and other wildlife
- Concern about the disturbances of noise and light generated by ongoing maintenance
- Concern about higher GHG emissions associated with the PSH reservoir, and about emission sources
- Onsite recreational opportunities may be possible for open-loop systems; safety concerns prohibit recreational opportunities for closed-loop PSH

Socioeconomics

Potential impacts and potential mitigations

Potential impacts

- Increase in traffic on local roads, leading to school traffic disruption
- Increase in constructions vehicles
- Safety issues
- Release of contaminants
- Potential housing shortages
- Influx of workers from elsewhere that stresses local resources of small community
- Safety of indigenous women given influx of out-of-town workers

Potential mitigations

- Monitor traffic conditions; implement shuttle bus use, carpooling, staggered work shifts, traffic management plan
- Time deliveries
- Construct more housing and essential businesses and services
- Engage with local community to determine appropriate mitigation strategies

Participant issues and suggestions

Participant issues

- Concern about impacts these facilities have on local property taxes
- Questions about whether such projects provide economic, social, etc. benefits to local communities

General Observations

- Participant: “My assumption is that the WSU study is neutral with regard to what the project is used for. The fact is that a key driver of interest in new storage is a way of managing wind and solar on the grid, but pumped storage certainly is a ‘Swiss army knife’ that can be used with any kind of pumping energy and grid support system.”
- Energy demands fluctuate during the day
- No matter what the energy source, storage lowers the overall cost of energy for ALL customers
- Reduced cost is the value provided by any form of storage, including pumped storage
- The Colville Tribes have two of the biggest dams on their reservation, so they know the impacts of green energy
- The Tribe wants to make sure that any PSH projects are done well and intelligently, and don’t repeat the same mistakes that were made with hydropower dams, which everyone thought was the greatest thing at the time
- The Banks Lake and Roosevelt Lake PSH project in Grant County, if done correctly, could be good for consistent additional power
- Utilities are looking for solutions to meet the green energy goals for the state
- Other options don’t provide the long-duration storage that PSH can achieve
- Curious about what trade-offs are acceptable between what we want to protect versus achieving clean energy goals

Appendix B

State and Federal Permitting and Licensing Processes

This appendix provides a more detailed look at some of the federal and state processes for permitting and licensing, including environmental reviews, for PSH in Washington state. Participant issues and suggestions for these processes follow the background information.

Background

Federal Permitting and Licensing

The permitting and licensing processes for PSH can be complicated, involving different paths and a multitude of agencies. If a PSH project is owned and/or developed by a non-federal entity, it is considered a non-federal project, although the Federal Energy Regulatory Commission (FERC) is the agency that issues most of the required permits and licenses. Projects developed and owned by federal agencies such as the Bureau of Reclamation or Tennessee Valley Authority have different licensing processes, which are not discussed in this report.

It is important to note that PSH development companies often apply for and obtain a preliminary permit without first contacting local Tribes or others who might be affected by the project. They do this to prevent the word getting out to competitors about a potential site. Consequently, a lot of preliminary assessment work is done by the developer before contacting the Tribes and determining if there are sites to be avoided. Obtaining a preliminary permit is not mandatory, but it does protect first right.

A simplistic outline of the permitting and licensing process by FERC is presented below.

FERC process

- Preliminary permits
  - Give the permit holder priority for a site over other applicants
    - Permit holders can then conduct feasibility and environmental studies, and pre-file stakeholder consultations without competition for the site
  - Are not technically necessary but are preferred because they protect first-in-line status for a particular site
- Licenses
  - Pre-filing – Notice of intent and pre-application document process starts
    - Steps and timelines vary between 3 processes – ILP, ALP, CLP – see below
  - Post-filing phase – Begins after submission of final license application
    - Permits/certifications of regulatory compliance that need approval at this time include the National Environmental Policy Act (NEPA), Clean Water Act section 401 water quality certification, Endangered Species Act, Coastal Zone Management Consistency, and state and federal agency submissions

- The issuance of final FERC license order may include mandatory terms and conditions

- Three types of FERC licensing processes a developer can choose from are:
    - Integrated Licensing Process (ILP) – default
        - The most structured and most suitable for sites with complex issues
        - FERC involved from outset
        - Ex Parte communications – prohibits interactions between one party and the decision-making authority without the presence of all other parties involved
            - Developer comment: ILP has a more scheduled process with consultation occurring earlier, resulting in fewer delays late in the process
    - Traditional Licensing Process (TLP) – most commonly used
        - Most flexible and most suitable for sites with no complex issues
        - FERC involved after final license application
            - Developer comment: TLP can result in complications that arise late in the process and result in licensing delays
    - Alternative Licensing Process (ALP) – least commonly used
        - Most cooperative – Stakeholders/developer agreement upfront

There are two other processes for certain closed-loop non-federal PSH projects:

- Reduced licensing process for closed-loop PSH
    - FERC has a two-year post-filing licensing process for qualifying closed-loop PSH, which usually shortens the process by about one year
- Outside FERC jurisdiction, that is, under only state and local jurisdiction if a closed-loop project:
    - Is not on federal public land or a federal reservation; however, if a transmission line from the PSH crosses federal land, the project must go under FERC
    - Does not use surplus water or waterpower from a government dam
    - Is not located on a non-navigable commerce clause stream, interstate or foreign commerce (that is, not connected to the grid), and has undergone construction or modification since 8/26/1935
    - Only uses groundwater to fill the system

Washington State Environmental Policy Act (SEPA)

The purpose of SEPA, the State Environmental Policy Act is to inform decision-making by identifying and disclosing environmental impacts before a public agency makes a decision. SEPA covers the assessment of impacts (both negative and positive) on both the natural environment (e.g., air, water, plants, animals) and the built environment (e.g., land use, transportation, public services).

The SEPA process is intended to inform decisions made by public agencies, but it is not a permit decision. The lead agency seeking SEPA assessment can be Ecology, the Energy Facility Site Evaluation Council (EFSEC), or a local government.

To enable early and meaningful engagement with stakeholders, Tribes, and interested parties, lead agencies should conduct a robust public involvement process. Early and meaningful engagement includes consideration of all phases of a project, including construction, operation, and decommissioning.

- Key features of SEPA include:
    - Identifying and evaluating probable impacts (both negative and positive) for elements of the environment
    - Applying a condition or denying government actions
    - Supplementing existing authority of all branches of state government
- No project actions can be taken until after SEPA completion
- Considerations when evaluating the proposal include
    - Existing conditions
    - Direct and indirect impacts
    - Short- and long-term impacts
    - Sensitive areas and species
    - Both probable and significant impacts are defined by SEPA rules
- Tribal engagement best practices
    - SEPA requires notification of Tribes
    - Tribal governments are sovereign nations with their own priorities and government-to-government relationship with the state and federal governments
    - Usual and accustomed lands extend well beyond tribal reservation boundaries
    - State has a 1-day government-to-government training available at the Washington Department of Enterprise Services (DES) to aid understanding of unique role of tribes in WA and agency responsibilities
- National Environmental Policy Act (NEPA)
    - Federal projects, permits, or funding may trigger NEPA review
    - Both SEPA and NEPA could be required on same proposal
    - SEPA has flexibility to allow adoption of NEPA documents if they are adequate though NEPA does not have reciprocal flexibility; federal and state agencies can work together to align timing

Section 106 of the National Historic Preservation Act

The National Historic Preservation Act (NHPA) mandates certain roles and responsibilities for a federal historic preservation program, authorizing certain tools, resources, and processes, including the Advisory Council on Historic Preservation (ACHP) and the Section 106 review processes.

Section 106 requires federal agencies to take into account the effects of their undertakings on historic properties, which include historic, archaeological, and significant cultural places. Physical alteration of the built or natural landscape is the main focus. The definition of an undertaking is:

> *A project, activity, or program funded in whole or in part under direct or indirect jurisdiction of a federal agency; those carried out with federal money; those requiring a federal permit, license, or approval; those subject to state or local regulation administered pursuant to delegation or approval by a federal agency*

Complying with Section 106 is the responsibility of the federal agency and is a consultative process that involves multiple parties; the federal agency must reach out to states, Tribal government, and other affected parties. FERC licensing is an example of a project that uses federal money.

- Parties of a Section 106 process may include:
    - Lead federal agency or agencies
    - Advisory council on historic preservation (ACHP)
    - Consulting parties which may include:
        - Tribal historic preservation officer (THPO)
            - Tribal governments can assume duties of state historic preservation offices within the boundaries of their reservation and on off-reservation trust lands
        - Tribal cultural staff
        - The State Historic Preservation office (SHPO) (which in Washington is within the Department of Archaeology and Historical Preservation)
    - Applicants for funding or license
    - Members of the general public
    - Consultants, etc.

The process includes four overarching steps: initiation, identification, assessment of effect (or adverse effect), and resolution of adverse effect (which can include a failure to resolve). Below is an outline of the process.

1: Initiate the process by Identifying the area of potential effect (APE) and the involved parties

2: Identify the sites
- Acquire background, historic, and cultural archaeological information
- Conduct on-the-ground survey and consult with parties on findings
- Develop methodology and consult with SHPO and THPO to do actual on-the-ground inspections

3: Assess the effects and determine one of the following categories
- No historic properties affected
- No adverse effect
    - There will be a change, but one that is not damaging to qualities
- Adverse effect
    - Impact will alter, damage, destroy, or change characteristics that make property significant and eligible for listing in the national register (NR)
    - Create a Memorandum of Agreement (MOA) for formalized actions the federal lead will take to minimize, avoid, or mitigate adverse effect
        - Must notify ACHP, invite participants, consult with THPO and SHPO

4: Final step
- Implement MOA
- Report back to assure MOA requirements were met
- If agreement not reached, notify ACHP for formal comment
- If conditions change, notify parties of need for amendment

Participant issues and suggestions

Participant issues

- General
    - Getting through the permitting process takes too long
    - The number of regulations that new projects must comply with
- Federal permitting and licensing
    - Developers and others need to understand the differences between engagement and government-to-government consultation; early engagement does not satisfy the required government-to-government consultation
    - Inadequate amounts of time that organizations or Tribal governments have to engage with developers about issues is a barrier that needs to be overcome
        - Project developers seem to under-estimate the amount of tribal engagement that is necessary to work through the process
    - Tribal engagement in project development processes often happens too late, putting Tribes in a reactive and adversarial stance
        - Delayed engagement can drive the perception that Tribes and others bring up issues "late" in the process, when they may only just be hearing about the projects at that time
    - It is important to develop relationships with the Tribes, not just consider Tribal engagement to be a process requirement
    - Just following the "letter" of the FERC process is insufficient
- SEPA and NEPA
    - The requirements for an adequate SEPA and NEPA process are ad hoc and subject to excessive litigation (the legal system allows excessive "what about…." lawsuits)
- Section 106
    - It is important to understand that Section 106 is a process and not a protection
    - The lead federal agency can decide to go ahead with a project as long as they follow the process to the letter
    - NHPA needs to inform NEPA; but sometimes NEPA comes out before the NHPA
    - For state projects, the failure to properly coordinate NEPA and NHPA has even more pronounced consequences
        - When following the SEPA checklist, if cultural resource studies have not yet been conducted, often they go ahead with the threshold determination without knowing the cultural resource impacts
- A proposed PSH near the Colville reservation, the Pearl Hill Pump Storage project, failed because the proponents failed to consider alternative locations after very sensitive cultural resources had been identified
    - FERC unilaterally crafted programmatic agreement without input
    - Because of Colville objection and DAHP support of the Colville position, FERC terminated the project because it was determined that consultation would not be productive
    - At that point, FERC could have licensed Pearl Hill because they followed the 106 process, but they did not

Participant suggestions

- Include all Tribes that may be affected and recognize that Tribes are different
  - Developers should emphasize active collaboration with Tribes and communities
  - Having facilitation support can help
  - The Governor's Office for Regulatory Innovation and Assistance (ORIA) provides a service to help developers perform an early analysis of environmental characteristics and constraints, which can include an analysis of archeological issues
  - ORIA can also help developers connect with Tribal or stakeholder contacts relevant to their projects
- In the interest of expediting permitting for pumped storage hydropower, it is suggested that SEPA consider sufficiency of environmental review
- Consider alternative actions (SEPA requires identifying alternative actions) that would reduce disruption to the natural and cultural environment
- Local planning
  - County officials will be updating comprehensive plans in 2025 as part of Growth Management Act (GMA) requirements
    - Counties need to be aware of the potential for these types of projects so they can understand how to accommodate them within new planning documents
  - It is important to be aware of and engaged in local planning efforts at the county level or other local government levels around land preservation, whether the impact would be positive or negative; the same is true for other kinds of planning where pump storage hydropower might be sited
  - Work within or consider local efforts to preserve critical lands and other planning requirements
- Expand upon how historic properties are discussed and include language like cultural landscapes, riverscapes, soundscapes, viewsheds
  - Tribes must take a larger landscape approach to the identification of historic properties within the Section 106 process

Appendix C

GIS Data Source Documents for Washington State Maps

(Figures 5 through 8)

Dataset	Description	Publisher / Owner	Source / Link
Potential PSH Sites	Potential pump storage reservoir locations within Washington from NREL study of potential PSH sites within the U.S.	National Renewable Energy Laboratory (NREL)	*https://maps.nrel.gov/psh*
Washington State Boundary	Detailed boundary for the State of Washington	ESRI, ArcGIS Pro Living Atlas	*ArcGIS Pro License*
County Boundaries	Detailed boundaries of all counties within Washington State	Washington Geospatial Open Data Portal, Department of Natural Resources	*https://geo.wa.gov/datasets/12712f465fc44fb58328c6e0255ca27e_11/explore*
Roads	Transportation routes within Washington State	Washington Geospatial Open Data Portal, Department of Transportation	*https://geo.wa.gov/datasets/8e92b0368a6747f0845d9990c109519b_6/explore*
Tribal Reservations	Detailed boundaries of Tribal Reservations within Washington State	Washington Geospatial Open Data Portal, Department of Ecology	*https://geo.wa.gov/datasets/waecy::trib-al-lands/about*
Electrical Transmission Lines	Transmission lines within the U.S.	Homeland Infrastructure Foundation-Level Data	*https://hifld-geoplatform.hub.arcgis.com/*
Electrical Substations	Substations within the U.S.	Homeland Infrastructure Foundation-Level Data	*https://hifld-geoplatform.hub.arcgis.com/*
Federal Land	Federally administered land within the U.S.		
Bureau of Land Management, Bureau of Reclamation, Department of Defense, Fish and Wildlife Service, Forest Service, National Parks	ESRI, ArcGIS Pro Living Atlas	ArcGIS Pro License	

Dataset	Description	Publisher / Owner	Source / Link
State DNR Land	Detailed boundary for all land administered by the DNR	Washington Geospatial Open Data Portal, Department of Natural Resources	*https://geo.wa.gov/datasets/f0419317aee24072846efb73e75b0755_6/explore?location=47.189559%2C-120.735050%2C7.44*
State Parks	Detailed boundary of all Parks administered by the State of Washington	Washington Geospatial Open Data Portal, Washington State Parks and Recreation Commission	*https://geo.wa.gov/datasets/wa-state-parks::parks-land-classification-1/about*
Wilderness Areas	Designated Wilderness Area boundaries within the U.S.	ESRI, ArcGIS Pro Living Atlas	
Original Source: Wilderness Institute, University of Montana	ArcGIS Pro License		
Columbia River Gorge National Scenic Area	Federal administrative boundary of the National Scenic Area	US Forest Service Geospatial Data Clearinghouse	*https://data.fs.usda.gov/geodata/edw/datasets.php*
Wind Turbines	Individual wind turbine locations within the U.S.	US Geological Survey	*https://eerscmap.usgs.gov/uswtdb/data/*
Solar Photovoltaic Sites	Areas encompassing solar sites within the U.S.	US Geological Survey	*https://eerscmap.usgs.gov/uspvdb/data/*
Rivers	Rivers within the U.S.	National Hydrography Dataset	*https://www.usgs.gov/national-hydrography/national-hydrography-dataset*
Mount St. Helens National Monument	Detailed boundary of the Mount St. Helens National Monument	US Geological Survey, Protected Areas Database	*https://www.usgs.gov/programs/gap-analysis-project/science/pad-us-data-overview*
Hanford Reach National Monument	Detailed boundary of the Hanford Reach National Monument	US Geological Survey, Protected Areas Database	*https://www.usgs.gov/programs/gap-analysis-project/science/pad-us-data-overview*


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