Conservation Design Project

Due Dates:

Draft report Thursday November 10
Final report Tuesday November 30

Recommended Length

Project Report: up to 10 pages, including any maps, tables, or figures.

Group Project: 6 options

(1) Restoring climate resilience, risk reduction, and riparian conservation in the Nooksack River floodplain

(2) Restoring climate resilience in Chuckanut Community Forest/Hundred Acre Wood.

(3) Restoring wildlife connectivity in Bellingham

(4) Dam Retention-Removal Decision Framework

(5) Grizzly Bear restoration in North Cascades Ecosystem

(1) Restoring climate resilience, risk reduction, and riparian conservation in the Nooksack River floodplain

In the Pacific Northwest, hydrologic extremes are among the greatest forecasted impacts of climate change (Mantua et al. 2010, Snover et al. 2019). Warmer winters are shifting precipitation from snow to rain, leading to rapid stormwater runoff and more frequent river flooding. Stronger atmospheric rivers are expected to increase severity of winter flooding. Reduced snowpacks are melting earlier in warmer springs, resulting in lower summer flows. Warmer air and water temperatures are exacerbating low flow water quality issues, which further impact vulnerable salmonid populations.

Both kinds of hydrologic extremes occurred in 2021. On the South Fork of the Nooksack River, warm summer weather, low summer river flows, and low riparian canopy cover raised river water temperatures to levels that were stressful to salmonid fishes. Warm water also supported growth and spread of fish pathogens. Warm water and disease caused mortality of 89% of the critically endangered South Fork Chinook salmon population (Northwest Treaty Tribes 2021). Several months later, a series of atmospheric rivers drenched the Nooksack basin and generated multiple flood events. The most severe event in mid-November raised the river 1.7 meters above flood stage in a 50-year flood event that caused record damage on both sides of the international border (VanderKlippe 2021).

Climate change forecasts suggest events at both hydrologic extremes will become more frequent and severe (Snover et al. 2019). Low flows on the Nooksack are exacerbated by overallocation of water and unpermitted withdrawls (Hirst 2015). Summer water withdrawls have reduced river flow minimum environmental flow requirements throughout most of the summer since requirements were established in 1985 (Loranger 2016). The length and depth of this water deficit have increased in recent years (McLaughlin 2018). Ongoing climate change is expected to further increase the deficit markedly in coming decades (Murphy 2016). Similarly, flood frequency and magnitude are expected to increase as climate change shifts winter precipitation from snow to rain (Mantua et al. 2010). Expanding development and forest clearing will compound climate impacts to further increase flood risk, frequency, and magnitude (Booth et al. 2002, Battin et al. 2009, WCPDS 2015, McLaughlin 2018).

Some advocates address flood risk mitigation as a plumbing issue, in which rivers are viewed as pipes that need to be expanded (build higher levees) or cleared (dredge river sediment) to increase capacity for transporting water from headwaters to the sea. Geomorphological analyses have shown this approach to be ineffective or counterproductive (Applied Geomorphology, Inc. et al. 2019, WCPW 2022).

Greater promise lies in approaches scaled to the problems and their drivers. These recognize rivers as dynamic systems that function in four dimensions: longitudinal, lateral, vertical, and temporal. Climate change and land development alter river dynamics in all four dimensions. The approaches seek to achieve climate resilience by adapting human infrastructure and land use to become compatible with river extent and variability in each dimension. The approach with broadest recognition is "Floodplains by Design."

Originally promoted by The Nature Conservancy (TNC) and implemented by TNC and government agencies at several levels, Floodplains by Design seeks to resolve floodplain issues by realigning human land use and infrastructure to configurations that reduce risk of flood damage and restore ecological functions of floodplains (TNC 2019, WDOE 2023). The program includes the following strategies: remove constructed infrastructure from active river floodplains, set back levees to allow floodwater access to more floodplain area and slow downstream flow of floodwater, restore floodplain wetlands, and establish flood overflow regions. The program provides grant funding and advisory support to achieve the following goals.

1. Reduce risk of flood damage to built infrastructure.

2. Restore floodplain habitats and floodplain ecosystem functions, including habitats and functions that support restoration of wild salmon.

3. Improve water quality, including reducing summer water temperatures, maintaining or increasing summer baseflows, reducing sediment erosion, and reducing inputs of agricultural nutrients.

4. Improve conditions for agricultural production, including reducing flooding risk, reducing drainage problems, and consolidating agricultural land use.

5. Improve public access and recreational opportunities associated with the river and floodplain.

Additional strategies can further enhance climate resilience. These strategies include the following.

1. Restore floodplain forests, to reduce and slow stormwater transit into rivers and streams.
2. Restore upland forests, to buffer streams from winter storms and augment summer low flows (Morgan and Krosby 2020, Grah 2022).
3. Install engineered log jams (ELJs), to store water in scour pools, increase alluvial water storage, and increase connections between surface water and groundwater. (Abbe et al. 2019).
4. Restore beavers, to increase water storage in tributaries and side channels (Beechie et al. 2010).

The capacity of strategy (3) to store floodwater and augment low flows was evaluated by Abbe et al. (2019). They found extensive restoration of ELJs could increase water storage by 21,800 m^3/km to 57,600 m^3/km in tributary streams and by 151,000 m^3/km to 695,000 m^3/km in intermediate-sized valleys. The Nooksack basin contains 2132 linear kilometers of streams, including 233 km in the three forks and main stem. For comparison, the summer deficit between minimum required environmental flows and actual flows in the Nooksack river amounts to 152 Million m^3/km in a typical year. In brief, extensive implementation of strategy (3) could fill the entire summer low water deficit and store considerable volumes of winter floodwater.

While Floodplains by Design and other strategies described above have the capacity to provide climate resilience in the form of flood mitigation and summer low flow augmentation, basin-scale designs for implementing them are lacking. Spatially explicit designs are needed because opportunities and obstacles for strategy implementation vary throughout the basin. For example, levees may be desired to protect existing urban development, but flood overflow basins are more appropriate for locations with little infrastructure or human habitation. For this design project option, the following steps are recommended.

1. Define climate resilience, risk reduction, and riparian conservation objectives the design should achieve.
2. Determine which strategies to include, and whether each would address resilience in winter, summer, or both.
3. Determine locations where each selected strategy would be appropriate.
4. Identify locations where your design would implement each strategy.
5. Create a map(s) illustrating strategy locations identified in step (4).
6. Estimate how well the design would achieve objectives defined in step (1).

References

Abbe T, S Dickerson-Lange, M Kane, P Cruickshank, M Kaputa, and J Soden. 2019. Can wood placement in degraded channel networks result in large-scale water retention? Natural Systems Design, Seattle, WA. [online] https://naturaldes.com/resources/can-wood-placement-in-degraded-channel-networks-result-in-large-scale-water-retention-2/

Applied Geomorphology, Inc, Element Solutions, Northwest Hydraulic Consultants, DTM Consulting. 2019. Lower Nooksack River Geomorphic Assessment, Final Report. Prepared for Whatcom County Flood Control Zone District, Bellingham, WA. [online] https://www.whatcomcounty.us/DocumentCenter/View/39545/Lower-Nooksack-Geomorphic-Assessment-Final-Report-02112019

Battin, J, MW Wiley, MH Ruckelshaus, RN Palmer, E Korb, KK Bartz, and H Imaki. 2007. Projected impacts of climate change on salmon habitat restoration. *Proc.Nat.Acad.Sci*. 104:6720-6725. doi: 10.1073/pnas.0701685104

Beechie TJ, DA Sear, JD Olden, GR Pess, JM Buffington, H Moir, P Roni, and MM Pollock. 2010. Process-based principles for restoring river ecosystems. *BioScience* 60:209-222. doi: 10.1525/bio.2010.60.3.7

Booth DB., D Hartley, and R Jackson. 2002. Forest cover, impervious-surface area, and the mitigation of stormwater impacts. *J. American Water Resources Association* 38:835-845. doi: 10.1111/j.1752-1688.2002.tb01000.x

DeWeerdt S. 2022. Rethinking flood control for the Nooksack River. *Encyclopedia of Puget Sound* 22 March 2022. [online] https://www.eopugetsound.org/magazine/nooksack-river

Grah O. 2022. Watershed Restoration: The Rest of the Story - Bringing Land Use and Upper Watershed Processes into Focus. Presentation to WWU College of the Environment Speaker Series, Bellingham, WA. 24 February 2022. [online] https://cenv.wwu.edu/speaker-series/grah

Hirst E. 2015. Water use in Whatcom County: 2010 data, estimates, assumptions. *Whatcom Watch* 24(5). [online] http://www.whatcomwatch.org/php/WW_open.php?id=1857

Loranger T. 2016. Whatcom County Council Agenda Bill [ruling in Whatcom County v. Western Washington Growth Management Hearings Board]. Washington Department of Ecology, Olympia, Washington, USA. [online] http://www.whatcomcounty.us/DocumentCenter/View/24098

Mantua N, I Tohver, A Hamlet. 2010. Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State. *Climatic Change* 102:187-223. doi: 10.1007/s10584-010-9845-2

McLaughlin JF. 2018. Safe operating space for humanity at a regional scale. *Ecology and Society* 23(2):43. doi: 10.5751/ES-10171-230243

Morgan H, and M Krosby. 2020. Nooksack Indian Tribe Climate Change Adaptation Plan. A collaboration of University of Washington Climate Impacts Group and Nooksack Indian Tribe Natural and Cultural Resource Department. University of Washington, Seattle, WA. [online] https://cig.uw.edu/wp-content/uploads/sites/2/2021/11/Nooksack-Adaptaiton-Plan-FINAL_errata_11.24.21_v2.pdf

Murphy, R. D. 2016. Modeling the effects of forecasted climate change and glacier recession on late summer streamflow in the upper Nooksack River basin. Thesis. Western Washington University, Geology Department, Bellingham, Washington, USA. [online] https://cedar.wwu.edu/wwuet/461/

Northwest Treaty Tribes. 2021. Until we restore habitat, we can’t prevent future fish die-offs. Northwest Indian Fisheries Commission, Olympia, WA. [online] https://nwtreatytribes.org/until-we-restore-habitat-we-cant-prevent-future-fish-die-offs/

Northwest Treaty Tribes. 2022. Forest acquisition could preserve water for summer streamflows. Northwest Indian Fisheries Commission, Olympia, WA. [online] https://nwtreatytribes.org/forest-acquisition-could-preserve-water-for-summer-streamflows/

Snover AK, CL Raymond, HA Roop, H Morgan. 2019. No Time to Waste. The Intergovernmental Panel on Climate Change's Special Report on Global Warming of 1.5C and Implications for Washington State. Briefing paper prepared by the Climate Impacts Group, Univ. Washington, Seattle. Updated 02/2019. [online] https://cig.uw.edu/resources/special-reports/no-time-to-waste/

TNC (The Nature Conservancy). 2019. Floodplains by design. The Nature Conservancy, Seattle, WA. https://www.floodplainsbydesign.org/

VanderKlippe N. 2021. U.S. rebuffed B.C.’s pleas to shore up dike for $29-million. Now, flood damage will hit $1-billion. *The Globe and Mail* 3 December 2021. Toronto, Ontario, Canada. [online] https://www.theglobeandmail.com/world/article-bc-flooding-marks-most-severe-consequence-of-dike-dispute-between/

WDOE (Washington Department of Ecology). 2023. Floodplains by design. Washington Department of Ecology, Lacey, WA. [online] https://ecology.wa.gov/Water-Shorelines/Shoreline-coastal-management/Hazards/Floods-floodplain-planning/Floodplains-by-Design

WCPDS (Whatcom County Planning and Development Services). 2015. Final EIS: Whatcom County 2016 comprehensive plan and development regulations update and urban growth areas review. Whatcom County Planning and Development Services, Bellingham, Washington, USA. [online] http://www.whatcomcounty.us/1178/Environmental-Impact-Statement

WCPW (Whatcom County Public Works Department) 2022. Nooksack River Gravel Removal FAQs. Bellingham, WA. [online] https://co.whatcom.wa.us/4040/Nooksack-River-Gravel-Removal-FAQs

(2) Restoring climate resilience in Chuckanut Community Forest/Hundred Acre Wood.

This project will give you experience with conservation planning and design to mitigate local impacts of climate change while also achieving habitat and salmonid restoration goals. If successful, the approach could serve as a model for climate impact mitigation throughout the region.

The Hundred Acre Wood (HAW) Master Plan (COB 2022) includes climate resiliency as one of four primary goals. Unfortunately, actions proposed in the Master Plan overlook most opportunities to increase climate resiliency in the park and adjacent areas. These opportunities focus on restoring hydrologic processes, which are among the ecological functions most sensitive to climate change in the Pacific Northwest (Mantua et al. 2010, Beechie et al. 2012, Krosby et al. 2018). Restoring climate resiliency would include mitigating flood risk to adjacent areas during winter storms and mitigating summer drought impacts to wetlands within the park and to creeks downstream of the park. Restored resiliency could lead to restored salmonid spawning and rearing within the park and improved riparian habitat conditions in Padden, Hoag, and Chuckanut Creeks downstream.

Option 2 Context

Ongoing climate change is impacting riparian systems in our region, and those impacts are projected to increase in coming decades (Snover et al. 2019). Increasing hydrologic impacts to wetlands, creeks, and fish will occur as temperatures warm and precipitation regimes shift (Mantua et al. 2010). Although these impacts have become increasingly certain, they are ignored in local comprehensive plans (City of Bellingham 2016, Whatcom County PDS 2016) and its supporting environmental review (BERK Consulting, et al. 2015). Local comprehensive plans also lack measures to mitigate climate impacts on the environment and biodiversity. In this project option provides an opportunity to address these gaps.

Chuckanut Community Forest (CCF) was acquired as public open space due to its outstanding environmental values, desirable natural aesthetic character, and strong potential for outdoor recreational uses (Eissinger 2017). Among the most important environmental attributes in CCF is a network of wetlands. In recent years, extent and condition of those wetlands have degraded, due to impacts of recreational activities, a warming and drying climate, and loss of beavers.

Restoring beavers to Chuckanut Community Forest (CCF) could enhance diverse wetland functions and mitigate climate change impacts (Dittbrenner et al. 2018). Beaver reintroduction increasingly is being applied as a restoration tool (Pollock et al. 2018a). Restoration functions performed by beavers include wetland creation and maintenance, water storage, streamflow regulation, aquifer recharge, water filtration, and fish and wildlife habitat creation (Goldfarb 2018a,b). In some cases, these functions can be performed more effectively and inexpensively by beavers than by other restoration methods.

Quality and quantity of these functions in CCF decreased substantially when beavers disappeared from the area about 20 years ago. A beaver dam near the outlet of wetland JJ maintained permanent flow from Hoag Creek to Chuckanut Creek. Without beavers, Hoag Creek flow now ceases during the summer-autumn dry season. Loss of summer flow also decreases discharges of clear and cold water into Chuckanut Creek, when those discharges are most important. The water table in wetland JJ has fallen substantially in the absence of beavers. Sea-run cutthroat trout formerly spawned in wetland JJ (Jim Johnson, personal communication), but spawning ceased after the water table dropped and creek flow decreased. Coho salmon (*Oncorhynchus kisutch*) also spawned in Hoag Creek and reared in wetland JJ before a culvert blocked passage under Chuckanut Drive (Highway 11; Figure 1). That culvert was replaced in August 2020 by a structure allowing fish passage (WSDOT 2020). Benefits of restored coho access will not be realized unless the wetland water table and creek flow also are restored.

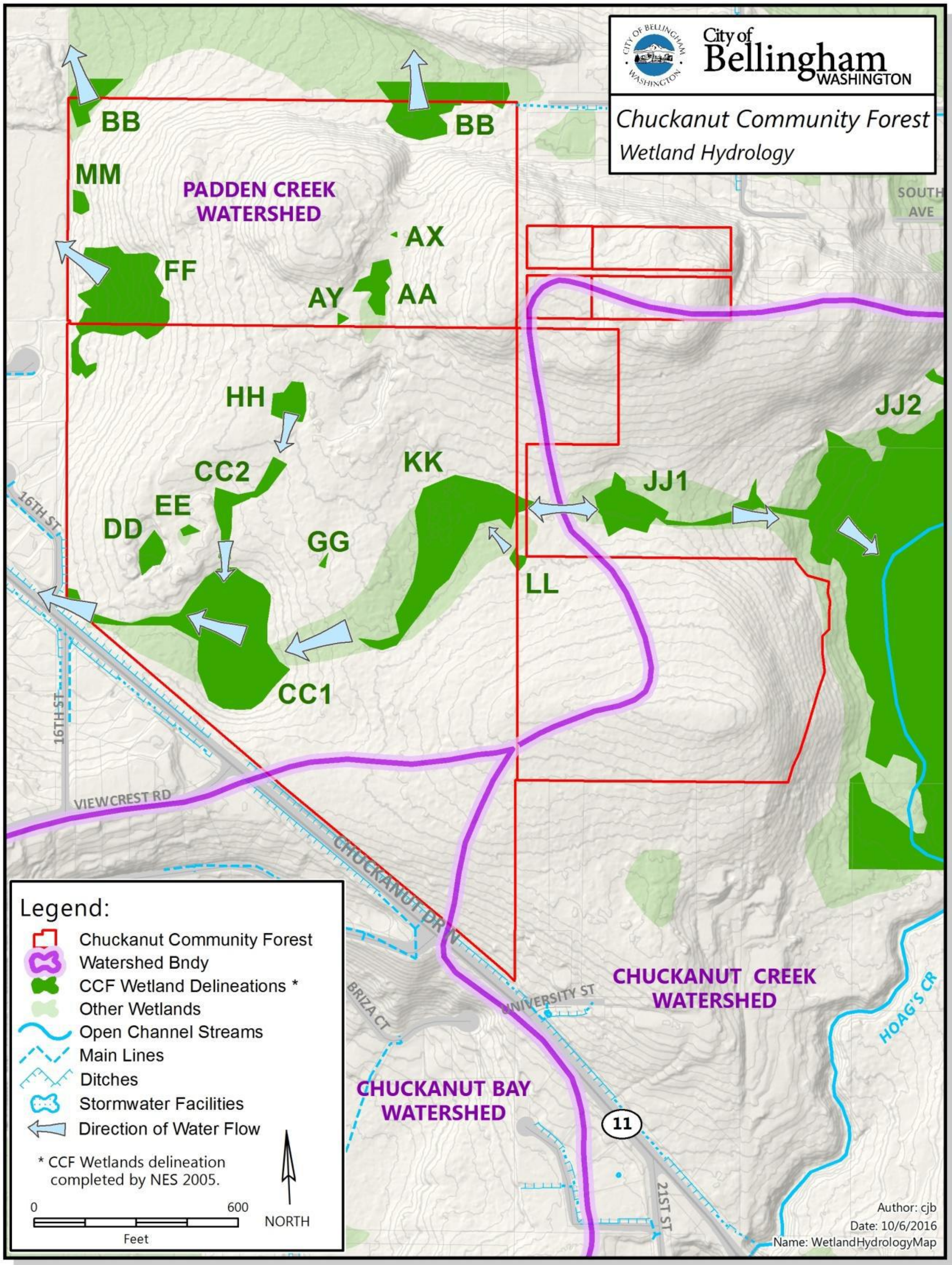


Figure 1. Hydrological flows in Chuckanut Community Forest and vicinity. From Eissinger (2017), map by Chris Behee, City of Bellingham.

Warmer summer stream temperatures and lower flows in Hoag and Chuckanut creeks could be mitigated in part by restoring beavers to wetland JJ. Although beavers formerly lived there, the wetland currently is not suitable for beavers because it contains little ponded water. Installing one or more beaver dam analogs (BDAs) could restore ponded water and attract beavers (Figure 2; Goldfarb 2018a,b).

Your design should consider the following goal and objective.
Goal: Restore suitable beaver habitat to wetland JJ. Beavers can maintain ponded wetland habitat, but they are more likely to establish and persist in the area if it contains sufficient escape habitat.
Objectives: install beaver dam analogs (BDAs) at the outlet of wetland JJ, restore the wetland water table, and provide escape habitat to beavers. The restored wetland would discharge clean cold water into Hoag and Chuckanut Creeks during the dry season, when Hoag Creek currently runs dry and Chuckanut Creek flow is low. This strategy has demonstrated efficacy (Goldfarb 2018a,b; Pollock et al. 2018), and could serve as a regional climate resiliency model.

Design Steps

1 BDA design goals. For your project, use the following BDA design goals.
- (1) Restore permanent flow throughout the year to Hoag Creek.
- (2) Maintain areas of ponded water in wetland JJ at least one meter deep.
- (3) Minimize risk of BDA failure due to downstream scour and end cutting.

2 BDA siting decision. After considering wetland JJ conditions and topography, your design could include one or more BDA structures. Determine the number of BDAs to be installed, including the location(s). Information in Pollock et al. (2018b) should be useful siting considerations. Please indicate BDA location(s) on a map, such as Figure 1 or other CCF maps in Eissinger (2017).

3 BDA structure design. For each location in (4), determine the BDA structural design. Information in Pollock et al. (2018b) should be helpful in informing your designs.

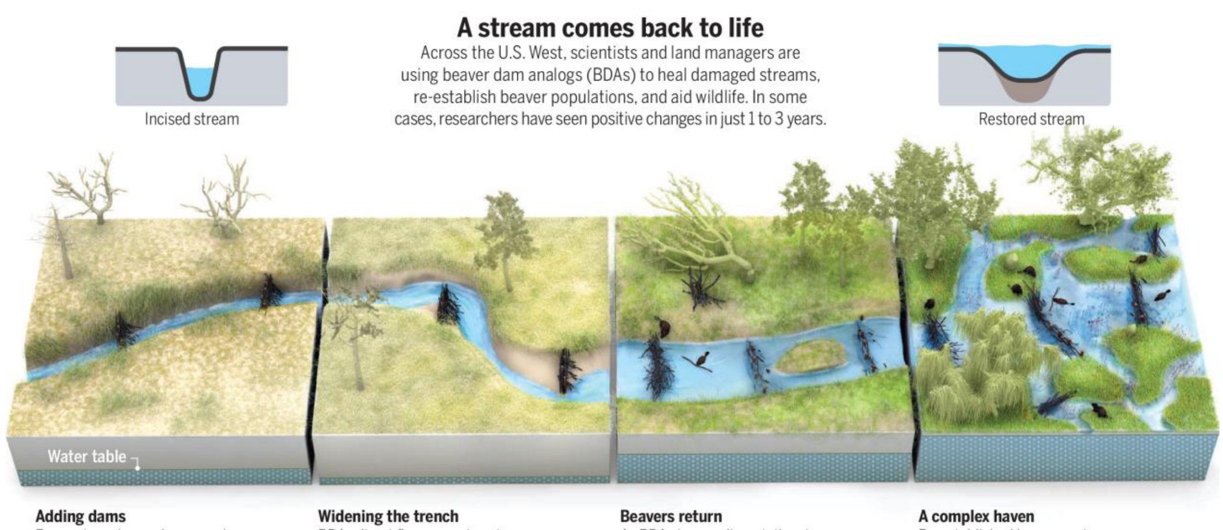


Figure 2. Desired restoration sequence following BDA installation. From Goldfarb (2018).

References

Beechie T, H Imaki, J Greene, A Wade, H Wu, G Pess, R Roni, J Kimball, J Stanford, P Kiffney, N Mantua. 2012. Restoring salmon habitat for a changing climate. *River Research Applications* 29:939-960. doi: 10.1002/rra.2590

BERK Consulting, et al. 2015. Whatcom County 2016 Comprehensive Plan Development Regulations Update and Urban Growth Areas Review Final Environmental Impact Statement. Whatcom County Planning and Development Services, Bellingham, WA. [online] https://www.whatcomcounty.us/1178/Environmental-Impact-Statement

COB (City of Bellingham). 2016. Bellingham Comprehensive Plan. Bellingham, WA. [online] https://cob.org/services/planning/comprehensive-plan

COB (City of Bellingham) 2022. Hundred Acre Wood draft Master Plan. Dept. of Parks and Recreation, Bellingham, WA. [online] https://cob.org/wp-content/uploads/HundredAcre-Master-Plan-Final-9-12-22.pdf

Dittbrenner BJ, MM Pollock, JW Schilling, JD Olden, JJ Lawler, CE Torgersen. 2018. Modeling intrinsic potential for beaver (Castor canadensis) habitat to inform restoration and climate change adaptation. *PLOS One* 13: e0192538 [online] doi: 10.1371/journal.pone.0192538

Eissinger A. 2017. Chuckanut Community Forest Baseline Documentation Report. prepared for Chuckanut Community Forest Park District, Bellingham, WA. [online] https://chuckanutcommunityforest.com//files/CCF-Baseline-Documentation-Report-Final-5-8-17.pdf

Goldfarb, B. 2018a. Beavers, rebooted. *Science* 360:1058-1061. doi: 10.1126/science.360.6393.1058

Goldfarb B. 2018b. *Eager: The Surprising, Secret Life of Beavers and Why They Matter*. Chelsea Green Pub. Co., White River Junction, VT.

Krosby M, DM Theobald, Norheim R, BH McRae. 2018. Identifying riparian climate corridors to inform climate adaptation planning. *PLoS ONE* 13(11): e0205156. doi: 10.1371/journal.pone.0205156

Mantua N, I Tohver, A Hamlet. 2010. Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State. *Climatic Change* 102:187-223. doi: 10.1007/s10584-010-9845-2

Pollock MM., GM Lewallen, K Woodruff, CE Jordan, JM Castro (eds.) 2018a. The Beaver Restoration Guidebook: Working with Beaver to Restore Streams, Wetlands, and Floodplains. Version 2.01. United States Fish and Wildlife Service, Portland, Oregon. 189 pp. [online] http://www.fws.gov/oregonfwo/ToolsForLandowners/RiverScience/Beaver.asp

Pollock MM, N Weber, G Lewallen. 2018b. Chapter 6 – Beaver Dam Analogues (BDAs), pp. 85-99 in: Pollock MM., GM Lewallen, K Woodruff, CE Jordan, JM Castro (eds.) 2018. The Beaver Restoration Guidebook: Working with Beaver to Restore Streams, Wetlands, and Floodplains. Version 2.01. United States Fish and Wildlife Service, Portland, Oregon. 189 pp. [online] http://www.fws.gov/oregonfwo/ToolsForLandowners/RiverScience/Beaver.asp

Snover AK, CL Raymond, HA Roop, H Morgan. 2019. No Time to Waste. The Intergovernmental Panel on Climate Change's Special Report on Global Warming of 1.5C and Implications for Washington State. Briefing paper prepared by the Climate Impacts Group, Univ. Washington, Seattle. Updated 02/2019. [online] https://cig.uw.edu/resources/special-reports/no-time-to-waste/

Whatcom County PDS. 2016. Whatcom County Comprehensive Plan. Whatcom County Planning & Development Services, Bellingham, WA. [online] https://www.whatcomcounty.us/1171/Current-Comprehensive-Plan

WSDOT (Washington State Department of Transportation) 2020. SR 11 – Hoag's Creek – Fish Passage – Complete October 2020. Northwest Region, WSDOT, Seattle, WA. [online] https://wsdot.wa.gov/projects/sr11/hoags-creek/home (accessed 6 November 2020)

(3) Restoring wildlife connectivity in Bellingham

Habitat connectivity serves several functions in wildlife conservation. Connectivity facilitates movement of individual animals during seasonal migration or dispersal from natal habitats. Connectivity allows individuals with large area requirements to persist in a region by aggregating habitat patches into an adequate home range, when single patches are insufficient to meet the species' requirements. Connectivity permits wildlife to return to habitats following disturbance or habitat restoration. Connectivity facilitates gene flow to prevent loss of genetic diversity. Connectivity enables range shifts, as species adapt to climate change and other coarse scale stressors.

The City of Bellingham recognized the importance of wildlife habitat connectivity by including a wildlife corridor analysis to inform ongoing development of an Urban Forest Management Plan (COB 2022). The City contracted a consultant to conduct a wildlife corridor analysis to "identify important terrestrial habitat hubs, wildlife corridors and breaks within the City limits and urban growth area" (Diamond Head Consulting 2021a). The analysis was based on connectivity modeling results for three focal vertebrate species.

Unfortunately, results of the consultant's wildlife corridor analysis do not fulfill the stated goal and cannot provide a reliable basis for analyzing, managing, or restoring wildlife connectivity. The analysis was undermined by fundamental flaws in focal species selection. The consultants selected the three focal species using 'professional judgement,' an approach that was discredited several decades ago (Landres et al. 1988). In addition, species selection and corridor analysis were conducted without consideration of objectives for habitat management, protection, or restoration nor decisions or actions to achieve objectives. Extensive work in recent decades developed more objective and reliable methods for selecting and applying more relevant focal species. A scientific journal dedicated to the topic has been publishing some of this work for 20 years (Jørgensen et al. 2013), which also has appeared in many other journals. One of the most effective approaches embeds focal species selection in a decision framework (Bal et al. 2018), based on structured decision-making (Gregory et al. 2012). This approach would substantially improve wildlife and habitat conservation in the City.

For this project option, use the template in Bal et al. (2018) to create a decision framework for protecting, maintaining, and restoring wildlife habitat connectivity in Bellingham. An expanded version of the template is in Figure 4, below. Because implementing conservation actions would exceed your legal authority and resources available, you should focus on steps 1-3 in the framework. You should feel empowered to develop your own ideas, but you might consider options below for steps 1 and 2.

1(a) Define problem:
- Wildlife habitat loss, fragmentation, and degradation. Degradation includes removal of important
  habitat structures such as snags ("hazard" trees).
- Wildlife mortality due to vehicle collisions.

(b) Define management objectives:
- Protect existing forested, riparian, and wetland habitat.
- Restore riparian forest cover.
- Restore important habitat links.
- Install connectivity structures, e.g., road overpasses or underpasses for wildlife.

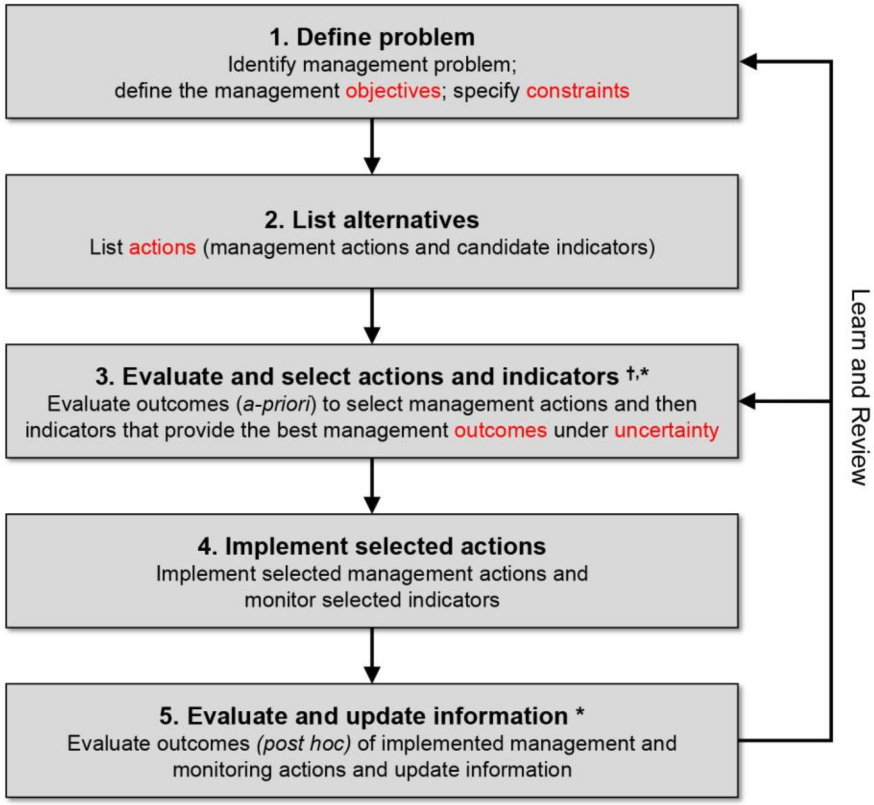
(c) Specify constraints:
- Limited funding.
- Private land ownership and landowner (lack of) cooperation.
- Limited legal protections for wildlife and habitats.
- Inadequate enforcement of environmental laws.

2 List alternative management actions

- Public acquisition of properties in strategic locations.
- Changes in public land management to protect or restore wildlife and habitat.
- Increased enforcement of environmental laws.
- Construction of wildlife connectivity structures, or improvement of existing structures.
- Partnerships between NGOs (e.g., NSEA) and private landowners.
- Public education.
- Wildlife monitoring.
- Roadkill monitoring and identification of hazard sites.

You might find the City's forest canopy height map (Figure 5, Diamond Head Consulting 2021b) helpful to visualize habitat distributions, connectivity, and barriers. The map was created by the same consultant that analyzed wildlife connectivity. Although the forest canopy report contains errors in forest structure and height, your analysis should be less impacted by those errors because many wildlife are less sensitive to habitat features during migration or dispersal than during use or selection of home range habitats (Keeley et al. 2017).

Your primary results from this project should be step 3 in the framework: a set of actions to protect, maintain, and restore wildlife connectivity; and a set of focal species to inform selection of those actions and monitor results of their implementation.



Step 1	Specify the decision context, primarily the management objectives against which the indicators will be evaluated, e.g. reduce number of species declining. Monitoring objectives may also be specified. Constraints such as resources, time or logistics that bind the decision are also specified here.
Step 2	List alternative actions or choices (management actions and candidate indicators) that the decision-maker can choose from to address the problem.
Step 3	Evaluate the expected consequences of management alternatives (based on *a-priori* beliefs regarding system dynamics and responses to management), select management actions to be implemented and indicators to evaluate management outcomes. In doing so, management actions and indicators are linked to outcomes using qualitative or quantitative approaches (e.g. conceptual models, decision trees, optimization) to explicitly account for the decision constraints and uncertainty in the decision process.
Step 4	Implement the selected management actions and indicator monitoring.
Step 5	Evaluate management actions and indicators to update estimates on the effectiveness of chosen management actions and indicator performance (*post hoc* evaluation). The adaptive component of the framework comes into play if the decision is recurrent and the structured decision process incorporates feedback loops to improve management and indicator choices in the next time step.

WebFigure 4. Detailed decision framework for indicator selection and evaluation based on the structured decision-making approach (Gregory *et al*. 2012). Decision factors are highlighted in red (see Table 1 for definitions). The dagger (†) denotes steps where indicators are selected (Step 3), whereas the asterisk (*) denotes steps where indicators are used to evaluate management outcomes (Steps 3 and 5).

Figure 4. Decision framework for indicator selection and evaluation. From Bal et al. (2018), Supplementary Information.

For step 3, a conceptual ecological model (CEM) can facilitate focal species selection (Lindenmayer et al. 2015). A CEM should include factors or processes that affect wildlife and links between potential focal species and those factors or processes. Below is an example of a CEM for restoration of drained reservoirs following dam removal, from Bellmore et al. (2019).

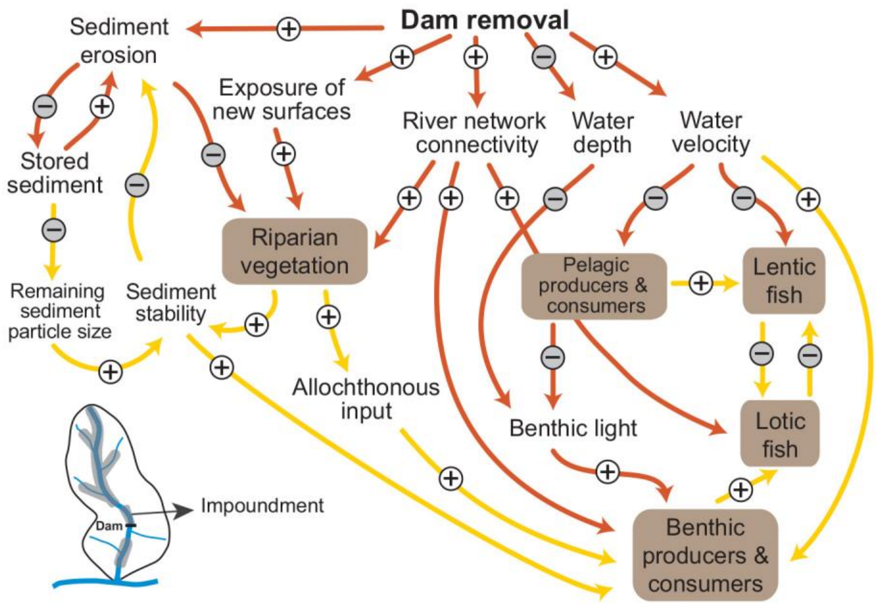


Figure 3. Causal-loop diagram depicting the cause-and-effect links and associated feedback loops influencing dam removal responses within the former reservoir. Sediment erosion and changes in channel hydraulics alter the environment from one that favors pelagic production and lentic fish assemblages to one that favors benthic production and lotic fish assemblages. The shaded shapes indicate key ecological parameters. The arrows indicate the direction of influence, and the plus and minus signs indicate whether the influence is positive or negative. When they are positive, the variables change in the same direction (when causal variable increases the effected variable also increases or vice versa). When they are negative, the variables change in the opposite direction (when causal variable increases the effected variable decreases or vice versa). Causal links that control responses at short time scales (hours to years) and long time scales (years to decades) are shown in orange and yellow, respectively.

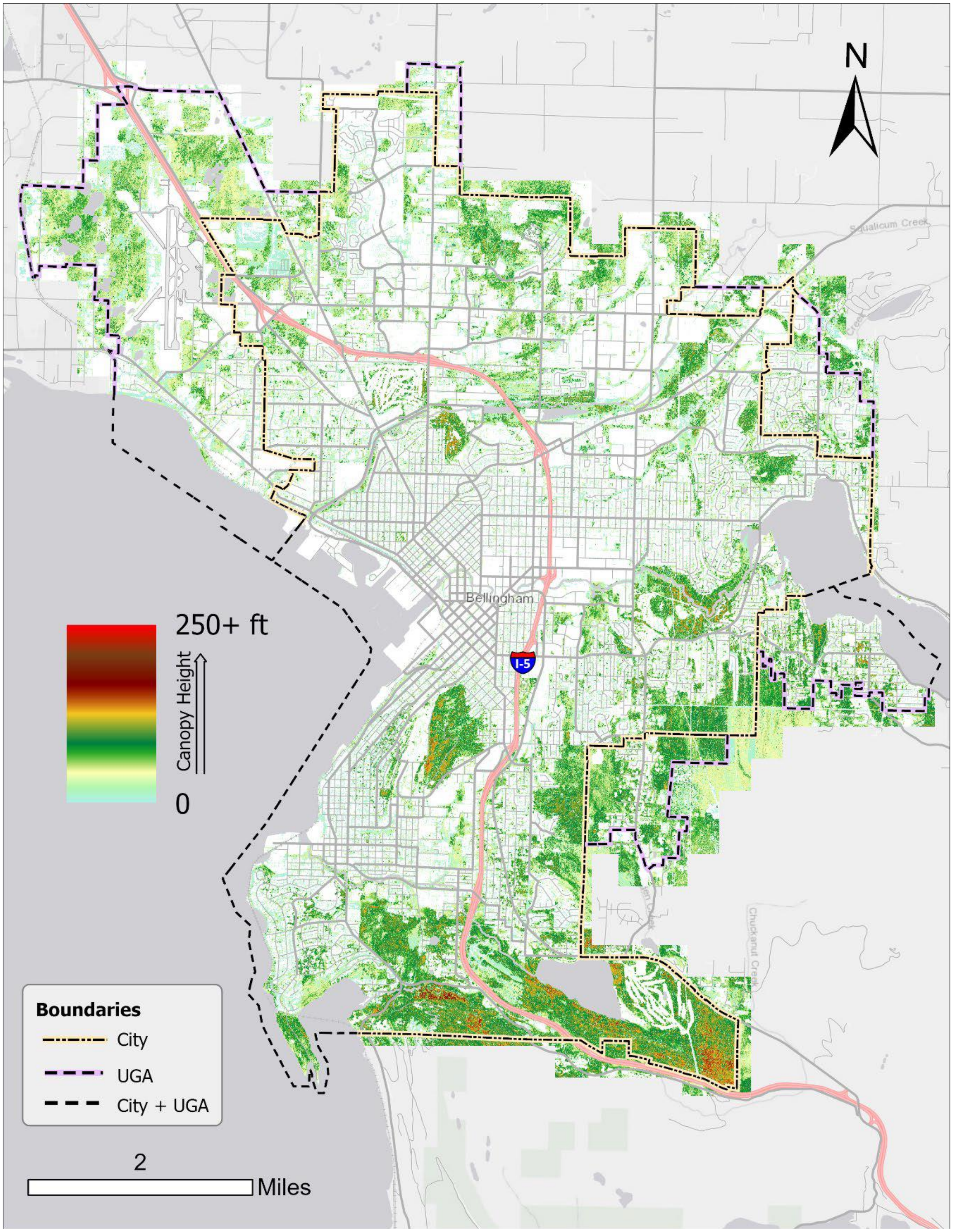


Figure 5. Canopy Height Model (CHM), derived from 2013 LiDAR data. From Diamond Head Consulting (2021b), Figure 20.

References

Bal P, AIT Tulloch, PFE Addison, E McDonald-Madden, and JR Rhodes. 2018. Selecting indicator species for biodiversity management. *Frontiers in Ecology and Environment* 16(1):589-598. doi: 10.1002/fee.1972

Bellmore, JR, GR Pess, JJ Duda, J O'Connor, AE East, MM Foley, A Wilcox, J Major, P Shafroth, S.A. Morley, C Magirl, C Anderson, J Evans, CE Torgersen, and LS Craig. 2019. Conceptualizing ecological responses to dam removal: if you remove it, what's to come? *BioScience* 69:26-39. doi: 10.1093/biosci/biy152

COB (City of Bellingham) 2022. Urban Forestry Management Plan. Natural Resources, Public Works Department, Bellingham, WA. [online] https://cob.org/services/planning/environmental/ufmp#:~:text=The%20City%20of%20Bellingham%20is,long%2Dterm%20urban%20forest%20management.

Diamond Head Consulting. 2021. 2021 Wildlife and Corridor Analysis: Methods Summary and Results. Prepared for City of Bellingham, Public Works Natural Resources Division, by Diamond Head Consulting, Vancouver BC. [online] https://cob.org/services/environment/restoration/wildlife-corridor-analysis

Diamond Head Consulting. 2021. Urban Forestry Management Plan – Canopy and Forest Structure Analysis Summary report. Prepared for City of Bellingham, Public Works Natural Resources Division, by Diamond Head Consulting, Vancouver BC. [online] https://bhamprod.wpenginepowered.com/wp-content/uploads/210823-Bellingham-Canopy-and-Forest-Structure-Report-1acd.pdf

Gregory R, Failing L, Harstone M, G Long, T McDaniels, and D Ohlson. 2012. *Structured Decision Making: A Practical Guide to Environmental Management Choices*. Chichester, UK: Wiley-Blackwell.

Jørgensen SE, B Burkhard, and F Müller. 2013. Twenty volumes of ecological indicators – An accounting short review. *Ecological Indicators* 28:4-9. doi: 10.1016/j.ecolind.2012.12.018

Keeley ATH, P Beier, BW Keeley, and ME Fagan. 2017. Habitat suitability is a poor proxy for landscape connectivity during dispersal and mating movements. *Landscape and Urban Planning* 161:90-102. doi: 10.1016/j.landurbplan.2017.01.007

Landres PB, J Verner, and JW Thomas. 1988. Ecological uses of indicator species: A critique. *Conservation Biology* 2(4):316-328.

(4) Dam Retention-Removal Decision Framework

Rivers are exceptionally important to humanity and biodiversity (Lynch et al. 2023). Rivers are the primary terrestrial conduit in the hydrologic cycle, essential components of freshwater ecosystems, and the largest source of renewable water for societal use (Vorosmarty et al. 2000, Vorosmarty et al. 2010). The economic value of rivers and other freshwater systems may exceed the combined value of all other non-marine environments (Costanza et al. 1997). Rivers and riparian habitats account for more than 50% of species globally (Sabo et al. 2005) and support more than 75% of terrestrial animals in the western U.S. (Chaney et al. 1990).

Despite the importance of rivers, or perhaps because of it, they are among the most imperiled systems on Earth (Dudgeon et al. 2006, Reid et al. 2019). Threats and impacts to rivers are diverse, synergistic, and escalating. These include floodplain development, channelization, development of adjacent land, anthropogenic water withdrawls and diversions, hydropower development, introduction of non-native organisms and pathogens, overfishing, contaminant inputs, nutrient enrichment, and climate change (Allan and Castillo 2007). Collectively, freshwater organisms have declined in abundance more than 80% since 1975, a rate far greater than declines in marine and terrestrial systems (WWF 2018, Reid et al. 2019).

Hydropower development is among the most pervasive threats to rivers. Dams impact 60 percent of large rivers on Earth (World Commission on Dams 2000) and all large river basins in the contiguous U.S. (Graf 1999). Conversely, dam removal has proven to be one of the most effective strategies in river restoration. More than 1700 dams have been removed in the last 100 years (Thomas-Blate 2020), with the vast majority of removals occurring since 2000 (Bellmore et al. 2016). The pace of dam removals in the US is expected to increase, because 85% of US dams now are approaching the end of their useful lives (Doyle et al. 2003). Society is not prepared to cope with aging dams, in part because we lack policies (Doyle et al. 2003) or an objective framework for making dam retention-remediation-removal decisions.

In the film *DamNation*, renowned geomorphologist David Montgomery stated the need to evaluate dams for retention or removal as follows (slightly modified):

> Like all constructed things, dams have a finite lifetime. It is not time to pull out every dam in the country; that would be economically foolish. It would be just as foolish not to rethink every dam in the country, and try to decide which are the ones that actually still make sense in the 21st century and which are those that we can get more value economically, culturally, aesthetically, morally, and ecologically out of a river system by sending it part way back to a state that it was in naturally.

Although the need to make decisions about dams is clear, the process for doing so is not. O'Connor et al. (2015) provided some guidance:

> "Decisions regarding these dams will require balancing risks, continued economic function, and the potential for ecologic restoration"

Advocates for retention or removal of individual dams have presented arguments specific to those dams, but generally applicable decision criteria are lacking. Your task in this project is to develop those criteria and a framework for applying them. You should use the following steps.

Dam Decision Framework

(1) Determine factors that should be considered in dam retention/removal decisions.

(2) Translate those factors into objective criteria that each dam could be evaluated against.

(3) Determine which (range in) values for each criterion would support the three following decisions. Values may be quantitative or qualitative.

(3.1) dam retention
(3.2) dam retention with mitigation
(3.3) dam removal

(4) Develop a method to combine criteria scores to reach retention-removal decisions when some criteria support retention and others support removal. Your method should achieve the “balance” described by O’Connor et al. (2015). Your method need not weight all factors equally. For example, an unrepairable safety hazard could dictate dam removal regardless of other factors. In that case, you could elevate safety to a requirement that supersedes other criteria.

(5) Demonstrate your decision framework (1-4) by applying it to the Middle Fork Nooksack diversion dam that was removed in summer 2020. Information resources for that dam removal are listed below. Alternatively, you may demonstrate your framework on another existing or removed dam.

MF Nooksack dam removal fact sheet:
https://cob.org/wp-content/uploads/middle-fork-project-factsheet.pdf

MF Nooksack dam removal project documents and media coverage:
https://cob.org/services/environment/restoration/middlefork/Project-Documents

MF Nooksack dam removal storymap:
https://fws.maps.arcgis.com/apps/Cascade/index.html?appid=d3e2066004e74e95bf4b8c4382a51771

MF Nooksack dam removal benefits:
https://cob.org/services/environment/restoration/middlefork/middle-fork-benefits

To develop your list of decision criteria, you might find a list of benefits and impacts of dams useful. One list is available at the following URL:

https://www.wwu.edu/faculty/jmcl/Conservation/dam_CBA.pdf

References

Allan JD, MM Castillo. 2007. *Stream Ecology: Structure and Function of Running Waters, 2nd ed.* Springer.

Bellmore JR, JJ Duda, LS Craig, SL Greene, CE Torgerson, MJ Collins, K Vittum. 2016. Status and trends of dam removal research in the United States. *WIREs Water* 2017(4):e1164. doi: 10.1002/wat2.1164. [online] https://www.fs.fed.us/pnw/pubs/journals/pnw_2016_bellmore001.pdf

Chaney E, W Elmore, WS Platts. 1990. Livestock Grazing on Western Riparian Areas.U.S. Environmental Protection Agency, Washington D.C.

Costanza R, R d'Arge, R De Groot, S Farber, M Grasso, B Hannon, K Limburg, S Naeem, RV O'Neill, J Paruelo, RG Raskin. 1997. The value of the world's ecosystem services and natural capital. *Nature*, 387:253-260.

Doyle MW, EH Stanley, JM Harbor, GS Grant. 2003. Dam removal in the United States: Emerging needs for science and policy. *EOS* 84:29–36.

Dudgeon D, AH Arthington, MO Gessner, Z-I Kawabata, DJ Knowler, C. L´evˆeque, RJ Naiman, A-H Prieur-Richard, D Soto, MLJ Stiassny, CA Sullivan. 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews* 81:163–182.

Graf WL. 1999. Dam nation: A geographic census of American dams and their large-scale hydrologic impacts. *Water Resources Research* 35:1305–1311.

Lynch AJ, et al. 2023. People need freshwater biodiversity. *WIREs Water* 10(3):e1633. doi: 10.1002/wat2.1633

O'Connor JE, JJ Duda, GE Grant. 2015. 1000 dams down and counting. *Science* 348:496-497.

Reid AJ, AK Carlson, IF Creed, EJ Eliason, PA Gell, PT Johnson, KA Kidd, TJ MacCormack, JD Olden, SJ Ormerod, JP Smol, WW Taylor, K Tockner, JC Vermaire, D Dudgeon, SJ Cooke. 2019. Emerging threats and persistent conservation challenges for freshwater biodiversity. *Biological Reviews* 94:849–873.

Sabo, J. L., Sponseller R., Dixon M., Gade K., Harms, T., Heffernan, J., Jani, A., Katz, G., Soykan, C., Watts, J., and Welter, J. 2005. Riparian zones increase regional species richness by harboring different, not more, species. *Ecology* 86:56-62.

Thomas-Blate J. 2020. Record number of states (26!) remove dams in 2019. American Rivers, Washington D.C. [online] https://www.americanrivers.org/2020/02/record-number-of-states-26-remove-dams-in-2019/

Vörösmarty CJ, P Green, J Salisbury, RB Lammers. 2000. Global water resources: vulnerability from climate change and population growth. *Science* 289:284-288.

Vorosmarty CJ, PB McIntyre, MO Gessner, D Dudgeon, A Prusevich, P Green, S Glidden, SE Bunn, CA Sullivan, CR Liermann, PM Davies. 2010. Global threats to human water security and river biodiversity. *Nature* 467:555–561.

World Commission on Dams. 2000. Dams and Development: A New Framework for Decision-Making. Earthscan Publications, London, UK.

WWF. 2018. Living Planet Report - 2018: Aiming Higher. Grooten, M. and Almond, REA (Eds). World Wildlife Fund International, Gland, Switzerland.

(5) Grizzly Bear restoration in the North Cascades Ecosystem

The North Cascades ecosystem (NCE) is one of six grizzly bear "recovery" zones designated in the contiguous states (Servheen 1997). Grizzly bears have been exceptionally rare or absent in the region for decades (Romain-Bondi et al. 2004). Despite their perilous conservation status, the Interagency Grizzly Bear Committee (IGBC) gave low priority to the NCE for many years; IGBC research, planning, and funding emphasized other recovery zones. In at least one case, funding dedicated to grizzly conservation in NCE was redirected to another recovery zone.

The North Cascades rose in priority regarding grizzly restoration in 2014, when the USFWS and National Park Service (NPS) announced planning for NCE grizzly restoration and an associated environmental impact statement (USFWS and NPS 2015). The draft EIS was completed and released two years later (USFWS and NPS 2017). Project review was suspended during transition to a new presidential administration. A year later, Interior Secretary Zinke announced that review of the project and its draft EIS would resume (US DOI 2018). The public review and comment process was re-opened. Before public review concluded, Secretary Zinke resigned under pressure from investigations about ethics breaches. Zinke's successor, David Bernhardt, suspended planning for grizzly bear restoration in North Cascades (Flatt 2020). The project was restarted almost two years into the current presidential administration (NPS 2022). The agencies solicited public comment during a scoping period, and then prepared a draft environmental impact statement. The DEIS was released for public review on 28 September 2023, and comment will be accepted through 13 November 2023 (NPS 2023).

The DEIS concludes NCE grizzly restoration will fail without intervention: the "No Action Alternative" would not restore a grizzly population (USFWS and NPS 2023). Two action alternatives propose translocating 25 grizzly bears into NCE over 5-10 years. Both alternatives anticipate grizzly bear abundance in NCE would increase to 200 bears, nearly to habitat capacity (Lyons et al. 2018), within 200 years (USFWS and NPS 2023). These outcomes were developed from simplistic projections of exponential population growth at rates that would be high for most grizzly populations. The DEIS apparently was not informed by population viability analysis or similar population modeling, as recommended (Traill et al. 2007, Perez et al. 2012).

For this project, you will conduct analyses to inform a grizzly restoration strategy for the NCE. A complete grizzly restoration plan would exceed time available in this course. Instead, you should derive distribution and abundance criteria required for grizzly population viability. (Alternatively, you may choose criteria to meet the higher ESA mandate to "restore populations to all or a significant portion of the species' range." For this project, you may restrict "range" to habitat that is suitable currently, although you also may consider restoration of unsuitable habitat.)

Grizzly bears will be considered "recovered" in the North Cascades when two criteria are met (USFWS and NPS 2017):

(1) The population size reaches at least 200 bears,

(2) Reproducing bears are distributed throughout the recovery area.

The restoration plan further specifies a time horizon of 100 years to achieve these criteria.

You will need to conduct a population viability analysis (PVA) to derive the first criterion. You can use PVA both to determine minimum grizzly abundances required for viability and to evaluate alternative grizzly restoration scenarios. Population viability analysis is the standard approach to evaluating extinction risk, conservation prospects, and likely outcomes of various management alternatives in the context of population and environmental uncertainty (Traill et al. 2007).

The foundation of any population viability analysis is a model describing how a population changes over time. The model description consists of population change functions and their associated demographic parameter estimates. Because we lack demographic data for grizzly bears in WA, you will need to use values from grizzly populations in other regions (Pease and Mattson 1999; Wielgus 2002). Next, uncertainty in model parameters is included in forms relevant to the population and its environment, which results in a stochastic population model. In most cases, the stochastic model is used to conduct numerical simulations of the population over a time period scaled appropriately to the species' generation time. (In principle, PVA could be conducted analytically, but in practice models for most PVAs are too complex for analytical solutions in closed form.) PVA results often are sensitive to qualitative and quantitative forms of uncertainty, so care must be taken to represent uncertainty in population and environmental factors appropriately. The following example applies the model and parameter estimates developed by Pease and Mattson (1999) for the most intensively studied grizzly population (Craighead et al. 1995). Wielgus (2002) provides parameter estimates for four other grizzly populations.

Pease and Mattson (1999) analyzed data collected from 1975 to 1992 on radio-collared bears and estimated age-specific survival and fecundity rates for Yellowstone grizzlies. They organized those rates in a population matrix with the following structure, in which F_i denotes the annual average number of cubs produced by a female in the i^{th} age class and P_i is the average annual survival rate of bears in the i^{th} age class.

Age	Age class
0	1
1	2
2	3
3	4
≥ 4	5

$$\begin{pmatrix} 0 & 0 & 0 & F_4 & F_5 \\ P_1 & 0 & 0 & 0 & 0 \\ 0 & P_2 & 0 & 0 & 0 \\ 0 & 0 & P_3 & 0 & 0 \\ 0 & 0 & 0 & P_4 & P_5 \end{pmatrix}$$

Pease and Mattson (1999) derived the following matrix for wary (backcountry) female bears. This population subset functions as a "source" when food is plentiful, i.e., during mast years for whitebark pines, the most important grizzly food in GYE.

Age	Age class
0	1
1	2
2	3
3	4
≥ 4	5

$$\begin{pmatrix} 0 & 0 & 0 & F_4 & F_5 \\ P_1 & 0 & 0 & 0 & 0 \\ 0 & P_2 & 0 & 0 & 0 \\ 0 & 0 & P_3 & 0 & 0 \\ 0 & 0 & 0 & P_4 & P_5 \end{pmatrix} \quad \begin{pmatrix} 0 & 0 & 0 & 0.40 & 0.41 \\ 0.78 & 0 & 0 & 0 & 0 \\ 0 & 0.87 & 0 & 0 & 0 \\ 0 & 0 & 0.87 & 0 & 0 \\ 0 & 0 & 0 & 0.87 & 0.89 \end{pmatrix}$$

They also derived the following matrix for wary female bears in nonmast years for whitebark pines. During the 20 years represented in their data, mast and nonmast years occurred with nearly equal frequencies.

Age Age class

$$
\begin{matrix} 0 & 1 \\ 1 & 2 \\ 2 & 3 \\ 3 & 4 \\ \geq 4 & 5 \end{matrix}
\qquad
\begin{pmatrix} 0 & 0 & 0 & F_4 & F_5 \\ P_1 & 0 & 0 & 0 & 0 \\ 0 & P_2 & 0 & 0 & 0 \\ 0 & 0 & P_3 & 0 & 0 \\ 0 & 0 & 0 & P_4 & P_5 \end{pmatrix}
\qquad
\begin{pmatrix} 0 & 0 & 0 & 0.35 & 0.37 \\ 0.60 & 0 & 0 & 0 & 0 \\ 0 & 0.77 & 0 & 0 & 0 \\ 0 & 0 & 0.77 & 0 & 0 \\ 0 & 0 & 0 & 0.77 & 0.80 \end{pmatrix}
$$

In any region where grizzly bears and humans or anthropogenic food sources interact, some wary bears learn to use foods derived from humans. This process, or habituation, often leads to premature death of bears, and survival rates of habituated bears tend to be lower than those of wary bears of the same age. Wary bears occasionally become habituated, but habituated bears almost never regain wariness. Hence, habituation is an irreversible transfer from increasing to decreasing population segments, and overall grizzly population growth rate decreases with habituation rates. Pease and Mattson (1999) studied this issue by combining matricies for wary and habituated bears. The source-sink relationship between wary and habituated subpopulations can be studied using an expanded 10x10 population matrix. This matrix, shown below, contains four sub-matrices: the upper left for wary bears, the lower right for habituated bears, the lower left for transition of wary bears to habituated bears, and the upper right for transition of habituated bears to wary bears. All matrix elements in the upper right quadrant are zeros, because habituated bears almost never become wary. The matrix contains the same five age classes shown above. The notation is as follows: F is fecundity; P is survival probability; and subscripts w, h, and t represent wary, habituated, and transitional bears respectively. For example, F_{w5} is the average annual number of wary cubs produced by a wary adult (≥4 year) female, and P_{t5} is the probability that a wary adult female bear will become habituated in the next year.

$$
\begin{pmatrix}
F_{w1} & F_{w2} & F_{w3} & F_{w4} & F_{w5} & 0 & 0 & 0 & 0 & 0 \\
P_{w1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & P_{w2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & P_{w3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & P_{w4} & P_{w5} & 0 & 0 & 0 & 0 & 0 \\
F_{t1} & F_{t2} & F_{t3} & F_{t4} & F_{t5} & F_{h1} & F_{h2} & F_{h3} & F_{h4} & F_{h5} \\
P_{t1} & 0 & 0 & 0 & 0 & P_{h1} & 0 & 0 & 0 & 0 \\
0 & P_{t2} & 0 & 0 & 0 & 0 & P_{h2} & 0 & 0 & 0 \\
0 & 0 & P_{t3} & 0 & 0 & 0 & 0 & P_{h3} & 0 & 0 \\
0 & 0 & 0 & P_{t4} & P_{t5} & 0 & 0 & 0 & P_{h4} & P_{h5}
\end{pmatrix}
$$

Pease and Mattson (1999) developed the following matrix for Yellowstone grizzlies during whitebark pine mast years.

$$\begin{pmatrix} 0 & 0 & 0 & 0.40 & 0.41 & 0 & 0 & 0 & 0 & 0 \\ 0.78 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.87 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.87 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.87 & 0.89 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.02 & 0.01 & 0 & 0 & 0 & 0.39 & 0.39 \\ 0.10 & 0 & 0 & 0 & 0 & 0.79 & 0 & 0 & 0 & 0 \\ 0 & 0.04 & 0 & 0 & 0 & 0 & 0.84 & 0 & 0 & 0 \\ 0 & 0 & 0.04 & 0 & 0 & 0 & 0 & 0.84 & 0 & 0 \\ 0 & 0 & 0 & 0.04 & 0.03 & 0 & 0 & 0 & 0.84 & 0.84 \end{pmatrix}$$

During years when whitebark pines produce mast crops, wary bears remain in backcountry areas and rarely habituate. Bear movement rates increase during non-mast years, resulting in a two-fold increase in habituation rates and reductions in survival and reproduction for all bears. Pease and Mattson (1999) developed the following matrix for Yellowstone grizzlies during non-mast years.

$$\begin{pmatrix} 0 & 0 & 0 & 0.35 & 0.37 & 0 & 0 & 0 & 0 & 0 \\ 0.60 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.77 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.77 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.77 & 0.80 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.04 & 0.04 & 0 & 0 & 0 & 0.35 & 0.35 \\ 0.19 & 0 & 0 & 0 & 0 & 0.68 & 0 & 0 & 0 & 0 \\ 0 & 0.09 & 0 & 0 & 0 & 0 & 0.76 & 0 & 0 & 0 \\ 0 & 0 & 0.09 & 0 & 0 & 0 & 0 & 0.76 & 0 & 0 \\ 0 & 0 & 0 & 0.02 & 0.02 & 0 & 0 & 0 & 0.76 & 0.76 \end{pmatrix}$$

Much uncertainty obscures prospects for grizzly restoration in NCE because we lack information from NCE on grizzly demographic rates, habitat use, and food sources. In the absence of such information, we can apply matrices from Pease and Mattson (1999) as surrogates for “good” and “bad” years in NCE. Although white pine blister rust largely has eliminated whitebark pine as a potential grizzly food source in NCE, other food sources fluctuate in abundance and distribution. The severity in those fluctuations is expected to increase as climate variability increases. Warmer winter temperatures are expected to reduce snowpacks, which also will affect the timing and abundance of NCE food sources. The USFWS, NPS, and USFS may have little influence on climate change or its causal factors, but the agencies can mitigate grizzly mortality by controlling roads and trails that provide human access to grizzly habitat.

In your alternative designs for this project, you may want to consider some version of the following three scenarios for grizzly restoration in NCE. You will need to apply PVA to evaluate probabilities of various outcomes for each scenario.

(1) Current conditions: NCE grizzly abundance estimated at six (Romain-Bondi et al. 2004). Assume (optimistically) that all six are adult females and that “good” and “bad” years occur with equal probability.

(2) Grizzly augmentation: adult female bears (and some adult males) are released in NCE. (Augmentation by translocating bears from other ecosystems is being considered in the EIS, but some authors urge caution and comprehensive contextual review prior to adopting this approach, e.g., Perez et al. 2012). The viability criterion would require enough bears to achieve a high probability of sustaining a grizzly population size of at least 200 (100 females) within 100 years. You might assume crudely that "good" and "bad" years occur with equal probability.

(3) Grizzly augmentation with access restriction. As in scenario (2), adult females are released in NCE with a goal of sustaining a grizzly population size of at least 200 (100 females) within 100 years. You could assume that education, changes in management policies, and restrictions on road and trail access reduce human-caused grizzly mortality in ways that increase the frequency of "good" years and decrease the frequency of "bad."

References

Craighead JJ, Sumner JS, Mitchell JA. 1995. *The Grizzly Bears of Yellowstone*. Island Press, Washington, D.C.

Flatt C. 2020. Interior Secretary: Grizzlies will not be brought back to Washington's North Cascades. Northwest Public Broadcasting. Washington State University, Pullman, WA. [online] https://www.nwpb.org/2020/07/07/interior-secretary-grizzlies-will-not-be-brought-back-to-washingtons-north-cascades/

Lyons AL, WL Gaines, PH Singelton, WF Kasworm, MF Proctor, J Begley. 2018. Spatially explicit carrying capacity estimates to inform species specific recovery objectives: Grizzly bear (*Ursos arctos*) recovery in the North Cascades. *Biological Conservation* 222:21-32.

National Park Service 2015. North Cascades Ecosystem Grizzly Bear Restoration Plan/Environmental Impact Statement: Document List. [online] http://parkplanning.nps.gov/documentsList.cfm?projectID=44144 (accessed 30 Jan.2016)

National Park Service 2017. North Cascades Ecosystem Draft Grizzly Bear Restoration Plan/Environmental Impact Statement. [online] https://parkplanning.nps.gov/document.cfm?parkID=327&projectID=44144&documentID=77025 (accessed 13 January 2017)

National Park Service 2019. North Cascades Ecosystem Grizzly Bear Restoration Plan/Environmental Impact Statement. [online] https://parkplanning.nps.gov/projectHome.cfm?projectID=44144 (accessed 15 October 2019)

National Park Service. 2022. National Park Service, U.S. Fish & Wildlife Service to evaluate options for restoring grizzly bears to the North Cascades. North Cascades National Park, Sedro-Woolley, WA. [online] https://www.nps.gov/noca/learn/news/national-park-service-u-s-fish-wildlife-service-to-evaluate-options-for-restoring-grizzly-bears-to-the-north-cascades.htm

National Park Service. 2023. 2022 North Cascades Ecosystem Grizzly Bear Restoration Plan/Environmental Impact Statement. North Cascades National Park, Sedro-Woolley, WA. [online] https://parkplanning.nps.gov/projectHome.cfm?projectId=112008

Pease CM and Mattson DJ. 1999. Demography of Yellowstone grizzly bears. *Ecology* 80(3):957-975.

Perez I, Anadon JD, Diaz M, Nicola GG, Tella JL, Gimenez A. 2012. What is wrong with current translocations? A review and a decision-making proposal. *Front.Ecol.Environ.* 10(9):494-501.

Romain-Bondi KA, Weilgus RB, Waits L, Kasworm WF, Austin M, Wakkinen W. 2004. Density and population estimates for North Cascades grizzly bears using DNA sampling techniques. *Biol.Cons.* 117:417-428.

Servheen C. 1997. Grizzly Bear Recovery Plan Supplement: North Cascades Recovery Plan Chapter. US Fish & Wildlife Service. Missoula, MT.

Soulé ME, Estes JE, Berger J, Martinez del Rio C. 2003. Ecological effectiveness: Conservation goals for interactive species. *Cons.Biol.* 17:1238-1250.

Traill LW, Bradshaw CJA, Brook BW. 2007. Minimum viable population size: A meta-analysis of 30 years of published estimates. *Biol.Cons.* 139:159-166.

US Department of the Interior. 2018. Secretary Zinke supports grizzly bear restoration in North Cascades ecosystem. USDOI press release, 23 March 2018. [online] https://www.doi.gov/pressreleases/secretary-zinke-supports-grizzly-bear-restoration-north-cascades-ecosystem (accessed 31 October 2018).

US Fish & Wildlife Service, National Park Service. 2015. North Cascades Ecosystem Grizzly Bear Restoration Plan/Environmental Impact Statement, Washington. *Federal Register* 80(33): 8894-8895.

US Fish & Wildlife Service and National Park Service. 2017. North Cascades Ecosystem Draft Grizzly Bear Restoration Plan / Environmental Impact Statement, Sedro-Woolley, Washington. [online] https://parkplanning.nps.gov/document.cfm?parkID=327&projectID=44144&documentID=77025 (accessed 13 January 2017)

US Fish & Wildlife Service. 1993. Grizzly bear recovery plan. Missoula, MT. 181pp.

US Fish & Wildlife Service, National Park Service. 2015. North Cascades Ecosystem Grizzly Bear Restoration Plan/Environmental Impact Statement, Washington. *Federal Register* 2015-03504: 8894-8895.

Wielgus RB. 2002. Minimum viable population and reserve sizes for naturally regulated grizzly bears in British Columbia. *Biol.Cons.* 106:381-388.

Evaluation: Maximum 100 points possible. Blank evaluation forms are shown below.

ESCI 439/539 Conservation of Biological Diversity

(1) Restoring climate resilience … Nooksack River floodplain

Step 1 Define climate resilience, risk reduction, cons. objectives (15 pts)	______
Step 2 Strategies to include (15 pts)	______
Step 3 Appropriate locations for each strategy (15 pts)	______
Step 4 Locations for strategy implementation (15 pts)	______
Step 5 Map(s) illustrating strategy locations (15 pts)	______
Step 6 Estimate design achievement of objectives (15 pts)	______
Writing and Presentation (10 pts)	______
Total (100 pts)	________

Evaluation rubric: Descriptions that fully meet the following criteria will earn full credit.

Step 1 Resilience defined appropriately and relevant to the Nooksack system. Objectives are clear, measurable, and would achieve effective climate resilience in the region.

Step 2 Strategies are described clearly, practicable, and capable of achieving objectives.

Step 3 Locations are appropriate to each strategy, are described clearly, and located precisely.

Step 4 Locations are logistically practicable, identified precisely, acceptable for (most) stakeholders (perhaps with stakeholder engagement), and conducive to objective achievement.

Step 6 Evaluation is realistic, and as precise as possible.

Writing and Presentation: ideas are clearly and effectively presented using written and visual elements. Paragraphs use transitions where appropriate, sentences are well-formed, language is precise, spelling is correct. Maps illustrate design effectively, easy to interpret, conforms to standard cartographic conventions (e.g., includes legend, scale bar, and directional arrow).

(2) Restoring climate resilience in CCF/HAW

Step 1 BDA design goals (0 points -- provided)	
Step 2(a) BDA siting decision (30 pts) Number of BDA structures Structure location(s)	______
Step 2(b) BDA siting map (20 pts)	______
Step 3 BDA structure design (40 pts)	______
Writing and Presentation (10 pts)	______
Total (100 pts)	________

Evaluation rubric: Descriptions that fully meet the following criteria will earn full credit.

Step 2 BDA number and siting locations(s) stated or mapped clearly and justified using successful programs reported in published sources.

Map illustrates design effectively, easy to interpret, conforms to standard cartographic conventions (e.g., includes legend, scale bar, and directional arrow).

Step 3 BDA design(s) is(are) described or illustrated clearly. Structural features are appropriate for the site and apply design elements with efficacy demonstrated in other BDA projects.

Writing and Presentation: ideas are clearly and effectively presented using written and visual elements. Paragraphs use transitions where appropriate, sentences are well-formed, language is precise, spelling is correct. Maps illustrate design effectively, easy to interpret, conforms to standard cartographic conventions (e.g., includes legend, scale bar, and directional arrow).

(3) Restoring wildlife connectivity in Bellingham

Step 1 Define the problem (mostly provided) (10 pts)	______
Step 2 Define management objectives (mostly provided) (10 pts)	______
Step 3 Actions to protect, maintain, restore connectivity (30 pts)	______
Step 4 Focal species selected to inform and monitor (3) (30 pts)	______
Step 5 Monitoring plan (10 pts)	______
Writing and Presentation (10 pts)	______
Total (100 pts)	________

Evaluation rubric: Descriptions that fully meet the following criteria will earn full credit.

Step 1 Problem defined appropriately and relevant to Bellingham region.

Step 2 Objectives are clear, measurable, and would restore wildlife connectivity in Bellingham.

Step 3 Actions are described clearly, practicable, and capable of achieving objectives. Actions are located clearly and precisely, at appropriate sites where actions would be effective. Actions, if implemented as described, would achieve objectives (2) fully.

Step 4 Focal species were selected using an appropriate CEM and linked clearly to actions in (3). Focal species would provide effective assessment of performance of actions in (3).

Step 5 Monitoring plan addresses all objectives and includes all focal species, but does not include extraneous measurements. Plan is feasible within budget and staffing constraints. Plan is described clearly and succinctly.

Writing and Presentation: ideas are clearly and effectively presented using written and visual elements. Paragraphs use transitions where appropriate, sentences are well-formed, language is precise, spelling is correct. Maps illustrate design effectively, easy to interpret, conforms to standard cartographic conventions (e.g., includes legend, scale bar, and directional arrow).

(4) Dam decision framework

(1) Factors to be considered in dam decisions (20 pts)	______
(2) Evaluation criteria (20 pts)	______
(3) Criterion values for decision alternatives (20 pts)	______
(4) Method to combine criteria scores (15 pts)	______
(5) Application to Middle Fork Nooksack dam or another dam (15 pts)	______
Writing and Presentation (10 pts)	______
Total (100 pts)	________

Evaluation rubric: Reports that fully meet the following criteria will earn full credit.

(1) Factors to be considered. Factors are relevant to dam decisions. Include important societal and conservation interests. Factors are described clearly and well-justified.

(2) Evaluation criteria. Criteria follow logically from factors described in (1). Criteria are relevant to dam decisions. Criteria can be measured objectively. Criteria statements are clear and concise.

(3) Criterion values. Values (or ranges) are appropriate to criteria stated in (2). Values are appropriate to decision alternatives. Values are stated clearly.

(4) Method to combine criteria. Method includes all criteria stated in (2). Method reflects relative importance of each criterion. Method is practical and easy to implement. Method is described clearly.

(5) Application to MF Nooksack dam. Application includes steps (1-4) as described. Application assesses MF Nooksack dam accurately. Results are stated clearly.

Writing and Presentation: ideas are clearly and effectively presented using written and visual elements. Paragraphs use transitions where appropriate, sentences are well-formed, language is precise, spelling is correct. Figures or tables present ideas clearly and are easy to interpret.

(5) Grizzly bear restoration in NCE

(1) Grizzly distribution criteria for viability (5 pts) ______
(2) Grizzly abundance criteria for viability (15 pts) ______
(3) Number of translocated bears needed to achieve restoration goals (15 pts) ______
(4) Population viability analysis to support above items (20 pts) ______
(5) Figures illustrating PVA results (10 pts) ______
(6) PVA interpretation and recommendations for grizzly restoration (25 pts) ______
Writing and Presentation (10 pts) ______
Total (100 pts) ________

Evaluation rubric: Descriptions that fully meet the following criteria will earn full credit.

(1) Distribution criteria would support viable population in NCE. (Do not obsess over; spatial analysis largely beyond scope of this project.)

(2) Abundance criteria sufficient for viable grizzly population in NCE, clearly justified.

(3) Translocation cohort size sufficient to achieve population size of 200 by year 2100. Result supported by PVA or other appropriate analysis.

(4) PVA appropriate for NCE grizzly restoration, conducted appropriately, and documented clearly.

(5) Figures illustrate PVA results clearly. Axes labeled clearly. All graphical elements defined in figure captions. Figures meet standards for scientific graphic design.

(6) PVA results interpreted appropriately and applied to inform grizzly restoration in NCE. Interpretation supports results in (1)-(3) and consistent with (4)-(5). Interpretation supports utility of PVA to inform restoration planning; demonstrates how PVA influences restoration design.

Writing and Presentation: ideas are clearly and effectively presented using written and visual elements. Paragraphs use transitions where appropriate, sentences are well-formed, language is precise, spelling is correct. Maps illustrate design effectively, easy to interpret, conforms to standard cartographic conventions (e.g., includes legend, scale bar, and directional arrow).