Conservation Design Project

Due Dates:

Draft report Thursday November 3
Final report Tuesday November 22

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) Chuckanut Community Forest/Hundred Acre Wood trail map and assessment

(4) Restoring wildlife connectivity in Bellingham

(5) Pollinator Pathway design

(6) Dam Retention-Removal Decision Framework

(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 clearing (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 2022). 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.
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).

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(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.

Your design should consider the following three elements, and additional elements you may devise.

1. Restore surface and subsurface hydrologic flows among wetlands in the park. Flow paths are indicated in Figure 1 below, from Eissinger (2017). Currently, many of these flows are impeded by soil compaction caused by trails and forest roads developed for timber harvest in the early 20th century (Eissinger 2017). Many of those roads and trails are mapped in Figure 3, although additional unmapped trails also impact hydrologic flows in the park – see project option 3.
2. Fill the drainage ditch that was excavated north of the western extension of wetland JJ. This ditch hastens surface water flow during the wet season, which reduces wetland area and exacerbates summer drought. The ditch serves no useful function; filling it would support the Master Plan’s climate resiliency goal.
3. 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. Beavers could be restored to the wetland by installing beaver dam analogs (BDAs) at the outlet of wetland JJ. BDAs would restore the wetland water table, providing escape habitat to beavers while they construct their own dam(s) to replace the BDA(s). 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.

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.

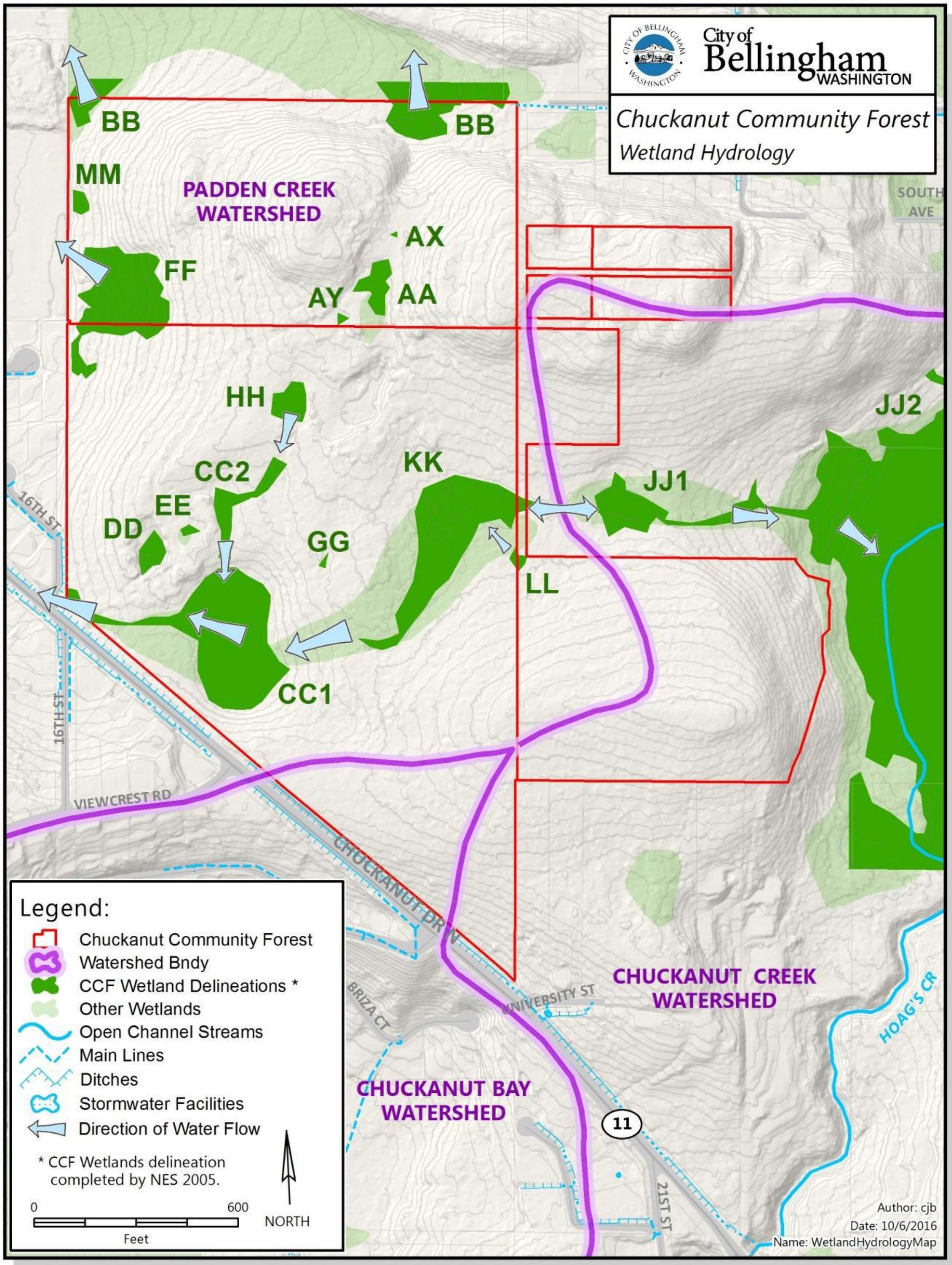

Figure 1. Hydrological flows in Chuckanut Community Forest and vicinity. From Eissinger (2017), map by Chris Behee, City of Bellingham.

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 2018). 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.

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 2018).

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.

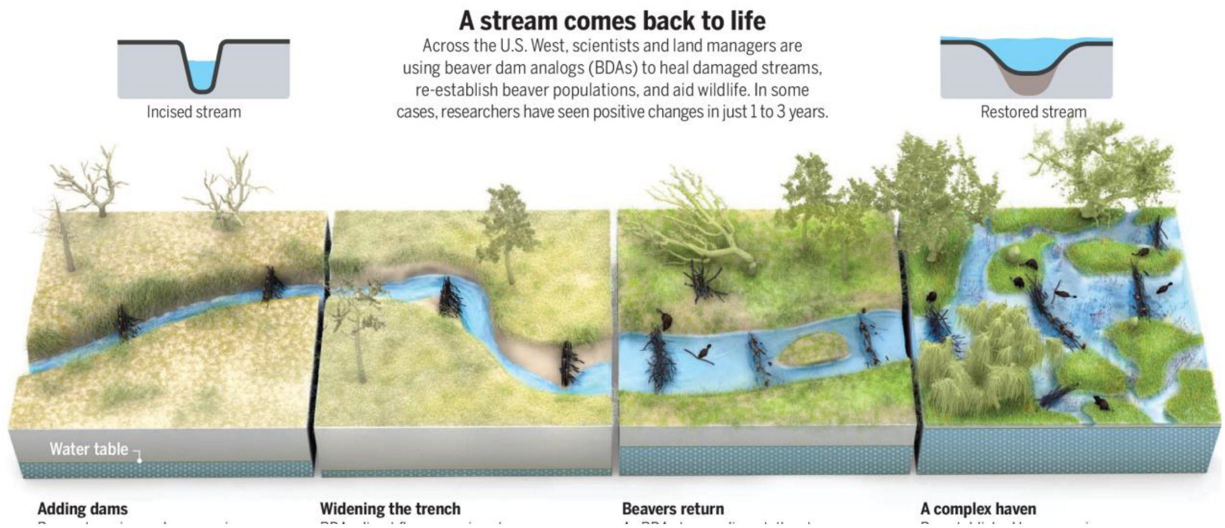

Figure 2. Desired restoration sequence following BDA installation. From Goldfarb (2018).

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(3) Chuckanut Community Forest/Hundred Acre Wood trail map and assessment

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). In the decade since CCF was opened to public access, ecological conditions and aesthetic qualities have been degraded by construction of new trails, widening of existing trails, and associated disturbances to soil, vegetation, woody debris, wildlife, and wetlands. Trail proliferation has degraded CCF ecological conditions and experiences of some human visitors, who become lost amidst an expanding web of trails. Trail proliferation and widening also have displaced sensitive species.

In September 2022, Bellingham City Council voted to rename CCF to "Hundred Acre Wood" (HAW), and approved the HAW Master Plan (COB 2022). The Master Plan calls for removal of unsanctioned trails, but there is no comprehensive inventory or map of trails in the park. Spatial data on trail extent and distribution are needed to plan and implement a restoration and trail removal program. In addition, achieving City Council's goal to "balance" recreational uses vs. nature protection require some measure of the extent of recreational impacts. Your work on this project will help meet these restoration needs.

You should conduct your work on this project in four steps.

1. Collect spatial data on all trails. Distinguish between wide (> 1 meter) and narrow (< 1 meter) trails. You should record trail spatial data using a GPS receiver, and record continuous traces for each trail in UTM coordinates (map datum NAD 83).
2. Display trails on a map. Distinguish wide vs. narrow trails, and trails marked in the HAW Master Plan Implementation Map (Figure 3 below; page 29, Figure 12 in COB 2022) vs. trails omitted from the map. You also should create a trail shape file(s) that could be included in other GIS products.
3. Create two additional maps overlaying trail impact buffers on (1) the trail map from step 2 and (2) the HAW Master Plan Implementation Map. Impact buffers should extend 75 meters on both sides of each trail (Dertien et al. 2018).
4. Determine the total area in CCF/HAW beyond impact buffers, for both maps in step 3.
5. Prepare a brief report describing your work and interpreting your results. The report should include your three maps from steps 2-3. You also should submit trail shape file(s) described in step 2.

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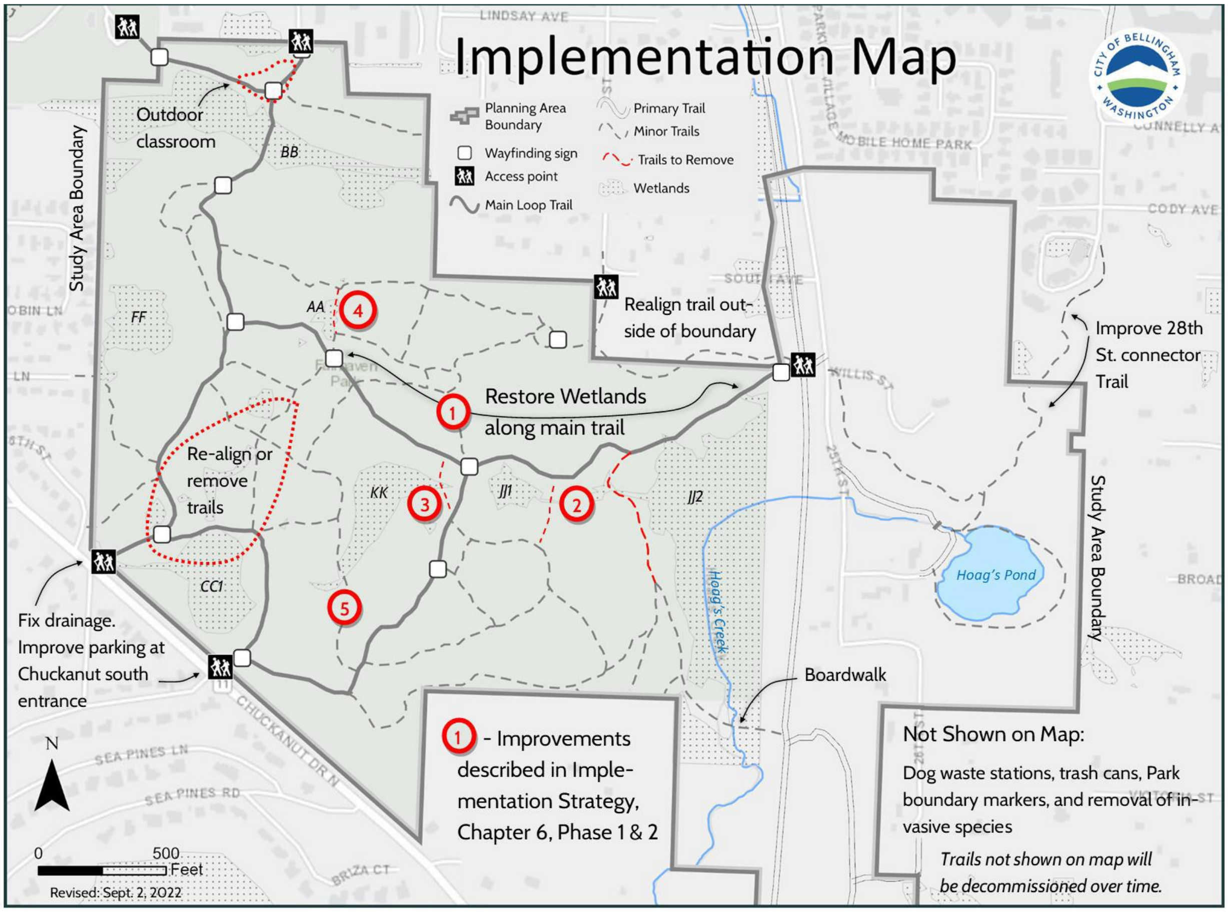


Figure 3. Hundred Acre Wood Master Plan, implementation map. From COB (2022).

(4) 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:

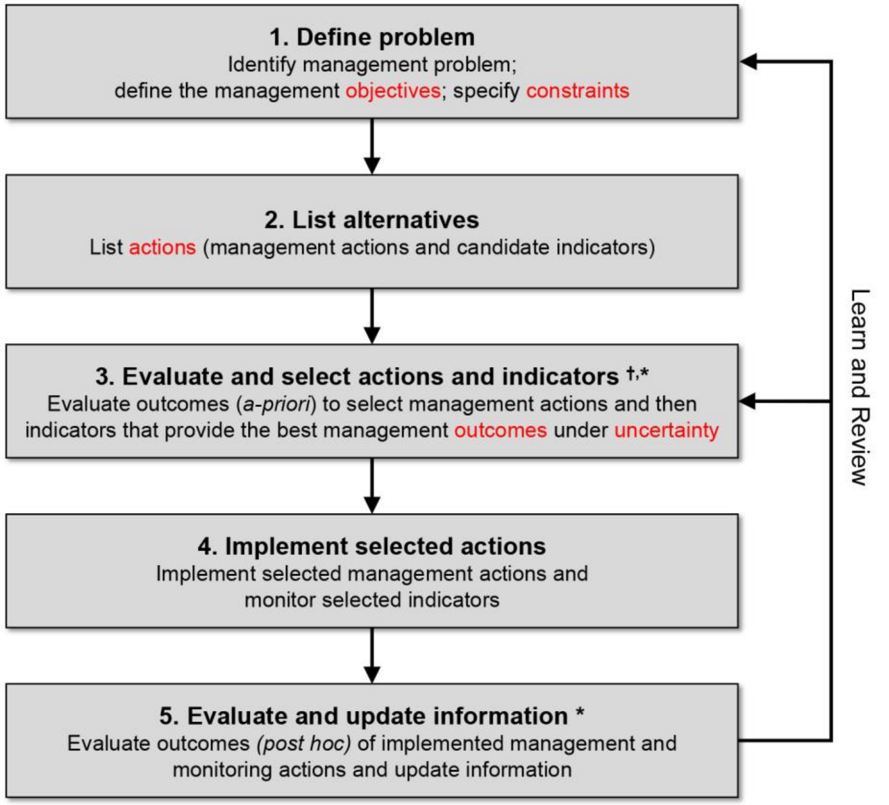
Protect existing forested, riparian, and wetland habitat.
Restore riparian forest cover.
Restore important habitat links.
Install connectivity structures, e.g., road overpasses or underpasses for wildlife.

(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.



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).

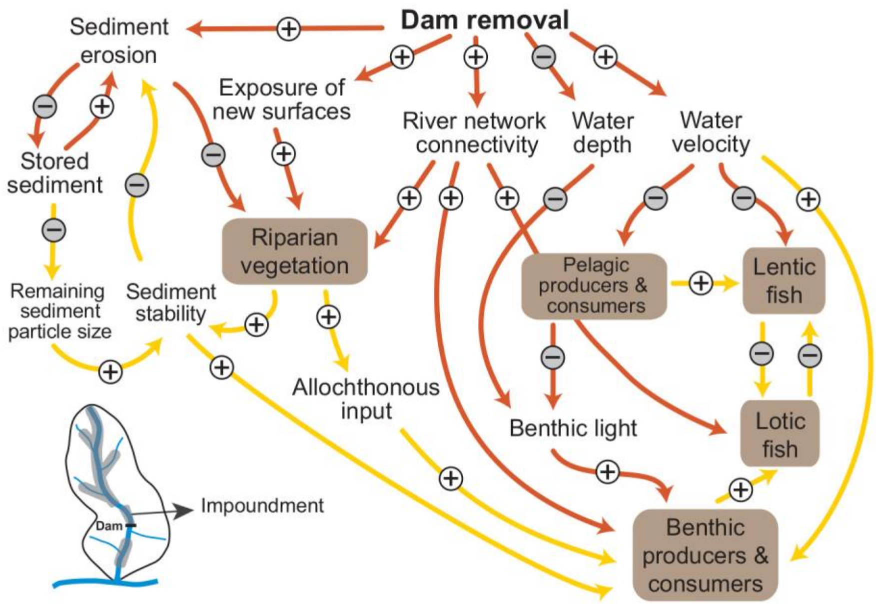


Figure 3. Causal-loop diagram depicting the cause-and-effect links and associated feedback loops influencing dam removal responses within the former reservoir. Sediment erosion and changes in channel hydraulics alter the environment from one that favors pelagic production and lentic fish assemblages 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.

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.

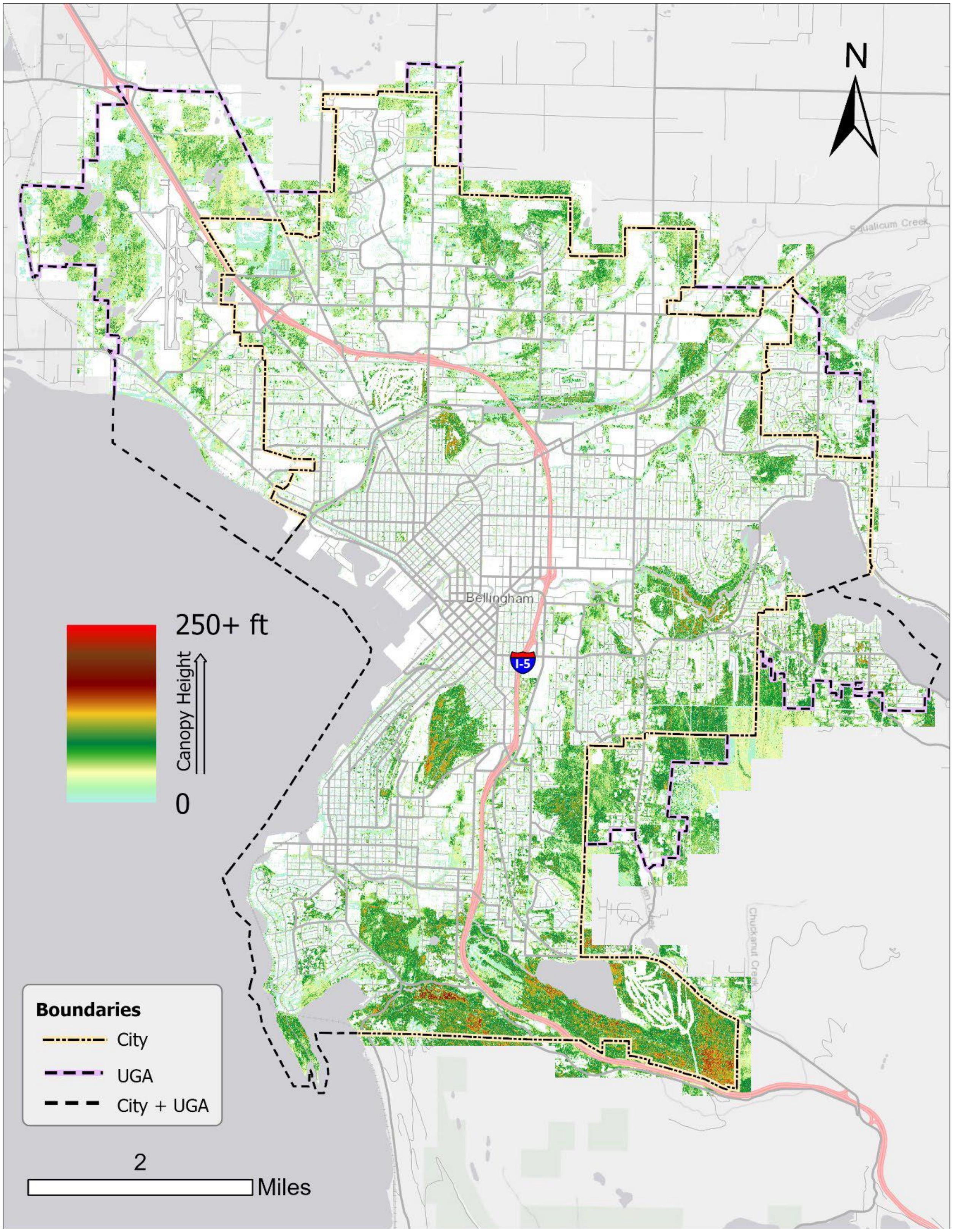


Figure 5. Canopy Height Model (CHM), derived from 2013 LiDAR data. From Diamond Head Consulting (2021b), Figure 20.

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(5) Pollinator Pathway design

Insect pollinators are vital to biodiversity conservation. At a global scale, insects pollinate 75% of crops used by humanity and 94% of wild flowering plants (Vanbergen 2013). Bees and other pollinators have declined markedly across the Pacific Northwest and other regions of the world (Hallmann et al. 2017, Kolbert 2020, Soroye et al. 2020, Forister et al. 2021). Pollinator declines have been attributed to multiple causal factors, including habitat loss and fragmentation, changing land use and agricultural practices, climate change, expanding application of pesticides and herbicides, invasive plants, and invasive parasites (Vanbergen 2013, Wintle et al. 2019, Brindle and van Rensburg 2020, Forister et al. 2021).

Developing pollinator pathways has been proposed as a solution to pollinator declines (Stiles 2019). Pollinator Pathways are pesticide-free corridors of native plants that provide nutrition and habitat for pollinators (www.pollinator-pathway.org). The Pollinator Pathway concept was first developed in Seattle, WA, and has been implemented most widely in the northeastern United States (www.pollinator-pathway.org). Five Washington cities, including Bellingham, are enrolled in the Bee City USA program. Three Washington universities are enrolled as affiliates in the Bee Campus USA program. Western Washington University is the latest member, enrolling in August 2022 (Fairhaven College 2022). Although commitments required to enroll as a Bee Campus support pollinator conservation, they are vague and primarily aspirational (Xerces Society 2021). This project option provides a substantive design to achieve the second commitment: "Create and enhance pollinator habitat on campus by increasing the abundance of native plants and providing nest sites."

The goal of a Pollinator Pathway is to create a corridor of contiguous native pollinator gardens throughout a community. Effective Pollinator Pathways also are continuous in time: they provide nectar resources to pollinators throughout the growing season, from spring through fall. Pollinator Pathways provide markedly better pollinator foraging conditions than exist in many human-dominated landscapes (Denekas 2019). Recently published results on honeybee foraging found worker bees fly on average 492 meters bees between their hives and nectar sources in urban areas (Samuelson et al. 2021). Foraging was more difficult for bees in rural agricultural areas, where the average foraging distance was 743 meters. The authors attributed greater distances in agricultural areas due to lower plant diversity and flowering periods that were shorter and synchronous (Samuelson et al. 2021). Conditions likely are more challenging for solitary bees, which require closer nectar sources because they lack support from large colonies.

For this project, you will design a pollinator pathway for the WWU main campus in Bellingham. Your design should include a map of displaying locations of pollinator gardens across campus. It should describe planting and management practices that would support diverse pollinators (Denekas 2019). Table 1, below, might provide a helpful template. Information in Table 2 on native flowering plants and their flowering phenology might also assist your design work.

Table 1. Pollinator Pathways: recommended practices and design elements (adapted from Jordan et al. 2019).

1 Provide food and habitat: plant or maintain flowering trees, shrubs, and forbs native to this region.

2 Continuous flowering phenology: include species with diverse flowering times, from spring to fall.

3 Avoid pesticides (insecticides, herbicides, fungicides) and synthetic fertilizers. Use organic materials and methods. Use non-chemical landscaping methods.

4 Provide water for bee nest construction. Bees do not require large or deep sources; wet sand can provide water without supporting mosquito breeding.

[5-10: Let go of desire for manicured spaces, which deprive bees of food and habitat.]

5 Provide or reserve bare soil for ground-nesting bees, esp. in south-facing aspects.

6 Remove or shrink lawns. For retained lawns, reduce mowing frequency and allow clover plants.

7 Leave dead wood on site or add woody debris.

8 Leave leaf litter on site. If leaf litter must be removed from some areas, move it to shrub/forest edges.

9 Mulch lightly, and avoid heavy wood chips, chemically treated wood chips, and plastic weed barriers.

10 Leave senescent wildflower stems over winter. Prune pithy shrub stems to create bee nest sites.

11 Install signage to explain pollinator habitat and conservation to neighbors and passers-by.

Table 2. Native Flowering Plants for Western Washington Bee Gardens (prepared by Jim Davis, Anu Singh-Cundy, Fred Rhoades, Abe Lloyd, and Audrey Mechtenberg)

Species		Flowering	Height (ft.)	Habitat
Oval-Leaved Huckleberry	(*Vaccinium ovalifolium*)	March / April	6	PS, Sh
Evergreen Huckleberry	(*Vaccinium ovatum*)	March /April	6	Su, PS, Sh
Red-Flowering Currant	(*Ribes sanguineum*)	March / April	10	Su, PS
Tall Oregon-Grape	(*Mahonia aquifolium*)	March / April	6	PS, Sh
Indian Plum	(*Oemleria cerasiformis*)	March / April	8	PS, Sh
Black Twinberry	(*Lonicera involucrata*)	April / May	8	Su, PS
Pacific Rhododendron	(*Rhododendron macrophyllum*)	April / May	16	PS, Sh
Dull Oregon-Grape	(*Mahonia nervosa*)	April / May	2	Su, PS, Sh
Salmonberry	(*Rubus spectabilis*)	April / May	9	Su, PS, Sh
Bleeding Heart	(*Dicentra formosa*)	April / May	2	Su, PS, Sh
Pacific Waterleaf	(*Hydrophyllum tenuipes*)	May / June	2	Su, PS
Trailing Blackberry	(*Rubus ursinus*)	May / June	3	Su, PS, Sh
Salal	(*Gaultheria shallon*)	May / June	4	Su, PS, Sh
Western Serviceberry	(*Amelanchier alnifolia*)	May / June	16	Su, PS, Sh
Thimbleberry	(*Rubus nutkanus*)	May / June	5	Su, PS, Sh
Snowberry	(*Symphoricarpos albus*)	June / July	6	PS, Sh
Pacific Ninebark	(*Physocarpus capitatus*)	June / July	8	Su, PS
Hardhack	(*Spiraea douglasii*)	June / July	6	Su, PS
Fireweed	(*Chamaenerion angustifolium*)	July / August	9	Su

Sun - Su
Part Shade -
PSShade – Sh

<u>Other non-native plants to consider</u>

Rhododendron (non-native varieties)
Azaleas (not-native varieties)
Pink Heather
Cotoneaster (shrub form)
California Lilac

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(6) Dam Retention-Removal Decision Framework

Rivers are exceptionally important to humanity and biodiversity. 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

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