VII. ADAPTING TO THE EFFECTS OF CLIMATE CHANGE IN THE FRESHWATER ENVIRONMENT

This section presents adaptation actions culled from the scientific literature and interviews with experts.

In this report, "adaptation" refers to the IPCC's definition: "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities."[1206]

Many water supply sources (rivers, lakes, groundwater basins, etc.) are already over-allocated, suffer degraded water quality, and are often not in sufficient condition to support endangered species.[1207] Climate change will exacerbate these water challenges, leading to insufficient water for people and the environment and making it increasingly difficult to meet the needs of both.[1208]

Adaptation is one of two major ways in which climate-related risks can be managed (the other is mitigation, which includes strategies to reduce greenhouse gas sources and emissions, and enhance greenhouse gas sinks).[1209] Even if global greenhouse gas emissions were to be stabilized near their current levels, atmospheric concentrations would increase throughout the 21st century, and might well continue to increase slowly for several hundred years after that.[1210] Thus, mitigation can reduce climate-related risks only in the longer term.[1211] Adaptation has emerged as a necessary response to and preparation for the unavoidable impacts of global climate change.[1212]

Adaptation is in its infancy and the field is developing in a rapid and *ad hoc* fashion.[1213] However, general and specific approaches to adaptation action are emerging, as are common tenets of adaptation action.[1214] Along with these, existing conservation activities are being applied to climate change adaptation, and new activities are also being developed.[1215] The states, provinces, and tribal governments of the NPLCC region are developing climate change adaptation strategies. Each of these topics is covered in turn:

- **Framework for Adaptation Action:** A general approach and specific planning and management approaches to adaptation action, derived from published and grey literature.
- **Common Tenets of Adaptation Action:** Adaptation principles derived from the literature.
- **Climate Adaptation Actions:** Adaptation actions are organized into five broad categories, including information gathering and capacity building; monitoring and planning; infrastructure

1206 *IPCC. *Climate Change 2007: Impacts, Adaptation and Vulnerability: Introduction.* (2007, p. 6)
1207 Natural Resources Defense Council (NRDC). *Climate Change and Water Resource Management: Adaptation strategies for protecting people and the environment.* (2010, p. 1)
1208 NRDC. (2010, p. 1)
1209 Asian Development Bank (ADB). *Climate Proofing: A risk-based approach to adaptation.* (2005, p. 7); Information on mitigation available from Parry et al. (2007, p. 878)
1210 *ADB. (2005, p. 7)
1211 ADB. (2005, p. 7)
1212 *Gregg et al. (2011, p. 30)
1213 *Gregg et al. (2011, p. 30)
1214 ADB (2005); Gregg et al. (2011); Heller and Zavaleta (2009); NOAA. *Adapting to Climate Change: A Planning Guide for State Coastal Managers*. (2010a)
1215 See, for example, Baron et al. (2009); Heller and Zavaleta (2009); Mawdsley, O'Malley, and Ojima (2009); NOAA. *Adapting to Climate Change: A Planning Guide for State Coastal Managers*. (2010a); U.S. EPA. *Synthesis of Adaptation Options for Coastal Areas.* (2009)

and development; governance, policy, and law; and, conservation, restoration, protection and natural resource management. The actions described represent the range of ideas suggested by the scientific literature on climate change adaptation. They are not intended as recommendations.

- **Status of Adaptation Strategies and Plans:** Brief descriptions of the development and implementation of state, provincial, and selected tribal adaptation strategies in the NPLCC region.

1. FRAMEWORK FOR ADAPTATION ACTIONS

General Approach to Adaptation Action

Adaptation actions are undertaken either to avoid or take advantage of actual and projected climate change impacts either by decreasing a system's vulnerability or increasing its resilience.[1216] This may entail reprioritizing current efforts as well as identifying new goals and objectives to reduce overall ecosystem vulnerability to climate change.[1217] The former – reprioritizing current efforts – is known as a "bottom-up" or "project-based" approach and involves integrating climate change considerations into existing management and program structures.[1218] The latter – identifying new goals and objectives – is known as a "top-down" or "landscape-based" approach and is particularly useful for broad-scale efforts, such as those conducted at regional, state, or national levels for one or more sectors.[1219]

General approaches to and principles of adaptation action in both human and natural systems have been addressed in past reports.[1220] A review of these reports indicates the approaches and adaptation principles are consolidated typically into four broad steps:

1. **Assess current and future climate change impacts and conduct a vulnerability assessment**.[1221] The vulnerability assessment may focus on a species, place, program, community, or anything else of concern to those doing the assessment, and should include exposure (the nature and degree to which a system is exposed to significant climatic variations), sensitivity (the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli), and adaptive capacity (ability of the system to respond effectively), as well as interactions with other factors, such as existing stressors or possible changes in human resource use patterns.[1222] In all cases, the assessment should begin with the overall goal of those carrying it out (e.g. sustainable fisheries management, coastal habitat protection).[1223] Further information on conducting vulnerability assessments is provided in Section 3 of this Chapter.
2. **Select conservation targets and course of action**.[1224] This step includes identifying, designing, prioritizing, and implementing management, planning, or regulatory actions and policies that reduce the vulnerabilities and/or climate change effects identified in Step 1.[1225] *Note that Steps 1 and 2 are interchanged in some reports (CIG 2007; Heller & Zavaleta 2009), and are considered iterative by others (Glick et al. 2009).*

[1216] *Gregg et al. (2011, p. 29). The authors cite ADB (2005), Levin & Lubchenco (2008), Lawler (2009). Pew Center (2009).
[1217] *Glick et al. (2011a, p. 7)
[1218] Glick et al. (2011a, p. 7); Glick et al. (2011b, Box 1.1, p. 13)
[1219] Glick et al. (2011a, p. 8); Glick et al. (2011b, Box 1.1, p. 13)
[1220] *Gregg et al. (2011, p. 30)
[1221] Gregg et al. (2011); Glick et al. (2009); Heller & Zavaleta (2009); NOAA (2010a); U.S. AID (2009); CIG (2007); ADB (2005); Pew Center. (2009)
[1222] *Gregg et al. (2011, p. 30)
[1223] *Gregg et al. (2011, p. 30)
[1224] Gregg et al. (2011); Glick et al. (2009); Heller & Zavaleta (2009); NOAA (2010a); U.S. AID (2009); CIG (2007); Pew Center. (2009)
[1225] Gregg et al. (2011); Glick et al. (2009); Heller & Zavaleta (2009); NOAA (2010a); U.S. AID (2009); CIG (2007)

3. **Measure, evaluate, and communicate progress** through the design and implementation of monitoring programs that assess changes in the chosen parameters of management and/or policy effectiveness.[1226]
4. **Create an iterative process to reevaluate and revise the plan, policy, or program,** including assumptions.[1227]

In some reports, a wider planning process and team-building activities precede Step 1 above. For example, the process outlined in NOAA's *Adapting to Climate Change: A Planning Guide for State Coastal Managers* (2010) begins with a planning process that includes scoping the level of effort and responsibility; assessing resource needs and availability; assembling a planning team and establishing responsibilities; and, educating, engaging & involving stakeholders.[1228] The Climate Impacts Group *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments* (2007) includes similar steps: scope climate change impacts in major sectors; build and maintain support to prepare for climate change by identifying a "champion" and audience, and developing and spreading a message; and, build a climate change preparedness team.[1229] The Asian Development Bank's (2005) approach begins with capacity building and provision, enhancement, and application of data, tools, and knowledge.[1230]

Specific Planning and Management Approaches to Adaptation Action

Implementing actions now to improve water quality and supplies, protect aquatic ecosystems, and improve flood management will help reduce future impacts related to climate change.[1231] One of many approaches to adaptation planning and management in the freshwater environment is that outlined in the *U.S. National Action Plan: Priorities for Managing Freshwater Resources in a Changing Climate.*

This draft *National Action Plan* includes preliminary recommendations that may change as it is further developed.[1232] The six recommendations and associated supporting actions are:

- ***Establish a planning process and organizational framework*** to adapt water resources management to a changing climate.[1233]
- ***Improve water resources and climate change information for decision-making*** by strengthening data for understanding climate change impacts on water, creating a program to align "hydroclimatic" statistics, implementing a surveillance system for tracking waterborne disease threats, providing information to identify areas likely to be inundated by sea level rise, and expediting implementation of a wetlands mapping standard.[1234]
- ***Strengthen assessment of vulnerability of water resources to climate change*** by publishing a long-term plan for Federal "downscaling" of climate model projections, developing a Federal

[1226] Gregg et al. (2011); Glick et al. (2009); Heller & Zavaleta (2009); NOAA (2010a); U.S. AID (2009); CIG (2007); ADB (2005)
[1227] Gregg et al. (2011); Glick et al. (2009); NOAA (2010a); U.S. AID (2009); CIG (2007); ADB (2005)
[1228] NOAA. (2010a)
[1229] CIG. (2007)
[1230] ADB. (2005, p. 95)
[1231] ADB. (2005, p. 7); information on mitigation is from Parry et al. (Eds). *Climate Change 2007: Impacts, Adaptation, Vulnerability: Appendix 1: Glossary.* (2007, p. 878)
[1232] Interagency Climate Change Adaptation Task Force. *National Action Plan: Priorities for Managing Freshwater Resources in a Changing Climate (Draft).* (June 2, 2011, p. 2)
[1233] Interagency Climate Change Adaptation Task Force. (June 2, 2011, Table 1, p. 4)
[1234] Interagency Climate Change Adaptation Task Force. (June 2, 2011, Table 1, p. 4)

internet portal, developing a pilot climate change/water vulnerability index, developing tools to build capacity for vulnerability assessments, assessing the vulnerability of National Forests and Grasslands, and promoting free and open access to water resources data.[1235]

- ***Improve water use efficiency*** by developing nationally consistent metrics for water use efficiency, making water use efficiency an explicit consideration in the Principles and Standards for water resources projects and in the new National Environmental Policy Act guidance on climate change, and enhancing agency coordination and creating a "toolbox" of key water efficiency practices.[1236]
- ***Support integrated water resources management*** by strengthening the role of river basin commissions in climate change adaptation, revising Federal water project planning standards to address climate change, working with States to review flood risk management and drought management planning and identify "best practices" to prepare for hydrologic extremes in a changing climate, and developing benchmarks for incorporating adaptive management into water project designs, operational procedures, and planning strategies.[1237]
- ***Educate water resource managers and build capacity*** by establishing a core training program on climate change science, focusing existing youth outreach programs on climate change and water issues, engaging land grant colleges in climate change adaptation research, and increasing graduate level fellowships in water management and climate change.[1238]

[1235] Interagency Climate Change Adaptation Task Force. *National Action Plan: Priorities for Managing Freshwater Resources in a Changing Climate (Draft).* (June 2, 2011, Table 1, p. 4)
[1236] Interagency Climate Change Adaptation Task Force. *National Action Plan: Priorities for Managing Freshwater Resources in a Changing Climate (Draft).* (June 2, 2011, Table 1, p. 4)
[1237] Interagency Climate Change Adaptation Task Force. *National Action Plan: Priorities for Managing Freshwater Resources in a Changing Climate (Draft).* (June 2, 2011, Table 1, p. 4)
[1238] Interagency Climate Change Adaptation Task Force. *National Action Plan: Priorities for Managing Freshwater Resources in a Changing Climate (Draft).* (June 2, 2011, Table 1, p. 4)

2. COMMON TENETS OF ADAPTATION ACTION

No single element or component of adaptation is a solution on its own, and there is no universally best set of solutions.[1239] Successfully adapting to climate change relies on a mixture of approaches as well as perpetual review and modification as new information comes to light, new ideas are generated, and additional changes take place.[1240] Scientists are increasingly emphasizing the concepts of maintaining or improving ecosystem resistance and resilience,[1241] as well as enabling or facilitating the ability of a species or ecosystem to change,[1242] e.g. via response or realignment.[1243] A review of the published and grey literature indicates the following are common tenets of adaptation action:

- Remove other threats and reduce non-climate stressors that interact negatively with climate change or its effects.[1244]
- Establish or increase habitat buffer zones and corridors, including adjustments to protected area design and management such as expanding reserve networks.[1245]
- Increase monitoring and facilitate management under uncertainty, including scenario-based planning and adaptive management (Box 20).[1246]

Four additional tenets were also found in the literature, although they were not cited universally:

- Manage for ecological function and protection of biological diversity, including restoration of habitat and system dynamics.[1247]
- Implement proactive management and restoration strategies, which may include translocations.[1248]
- Reduce local and regional climate change, e.g. via restoration, planting vegetation.[1249]
- Reduce greenhouse gas emissions.[1250]

[1239] *Gregg et al. (2011, p. 30)
[1240] *Gregg et al. (2011, p. 30)
[1241] *Glick et al. (2009, p. 12)
[1242] *Glick et al. (2009, p. 13)
[1243] *U.S. Fish and Wildlife Service. *Rising to the urgent challenge: strategic plan for responding to accelerating climate change (pdf).* (2010, Sec1:16). The authors cite Millar et al. (2007) for information on realignment.
[1244] Gregg et al. (2011); Lawler (2009); Glick et al. (2009)
[1245] Gregg et al. (2011); Lawler (2009); Glick et al. (2009)
[1246] Gregg et al. (2011); Lawler (2009); Glick et al. (2009)
[1247] Glick et al. (2009); Lawler (2009)
[1248] Glick et al. (2009); Lawler (2009)
[1249] *Gregg et al. (2011, p. 32)
[1250] *Gregg et al. (2011, p. 33)

Box 20. Managing uncertainty: Scenario-based planning and adaptive management.

Scenario-based planning: Scenario planning is a concept developed by Peterson, Cumming, & Carpenter (2003).[1251] It is a systematic method for thinking creatively about possible complex and uncertain futures.[1252] The central idea of scenario planning is to consider a variety of possible futures that include many of the important uncertainties in the system rather than to focus on the accurate prediction of a single outcome.[1253] In this context, the scenarios are not predictions or forecasts but, rather, a set of *plausible* alternative future conditions.[1254] Scenario planning is appropriate for systems in which there is a lot of uncertainty that is not controllable.[1255] This approach is used by the IPCC (see Box 2 and Appendix 2 for an explanation).

Adaptive management: Adaptive management is a systematic approach for improving resource management by learning from management outcomes.[1256] It puts management actions into an experimental framework, specifying what information is needed to evaluate management success and how and when it will be used to adjust management actions.[1257] In theory, adaptive management allows for the management of highly uncertain systems.[1258] It is useful not only when the future is uncertain, but when there is uncertainty about which management approach is best or how the system being managed functions even under today's conditions.[1259] It may be particularly useful in cases where immediate action is required to address short-term and/or potentially catastrophic long-term consequences or where management actions are likely to have no regrets near-term benefits.[1260] While it is a common complaint that current environmental rules and regulations lack the flexibility needed for true adaptive management, the U.S. Department of the Interior's technical guide to adaptive management provides both suggestions for and examples of effective adaptive management in the federal context.[1261]

[1251] Glick et al. (2009, p. 18)
[1252] Peterson et al. *Scenario planning: a tool for conservation in an uncertain world*. (2003, p. 359)
[1253] Peterson et al. (2003, p. 359)
[1254] Glick et al. (2009, p. 18)
[1255] Peterson et al. (2003, p. 365)
[1256] Williams, Szaro and Shapiro. *Adaptive Management: The U.S. Department of the Interior Technical Guide.* (2009, p. 1). The authors cite Sexton et al. (1999) for this information.
[1257] Gregg et al. (2011, p. 32)
[1258] Lawler. (2009, p. 85)
[1259] Glick et al. *Restoring the Great Lakes' Coastal Future: Technical Guidance for the Design and Implementation of Climate-Smart Restoration Projects.* (2011a, p. 39)
[1260] Glick et al. *Restoring the Great Lakes' Coastal Future: Technical Guidance for the Design and Implementation of Climate-Smart Restoration Projects.* (2011a, p. 39). The authors cite Ojima and Corell (2009) and Climate Change Wildlife Action Plan Working Group (2008) for this information.
[1261] Glick et al. (2011b, Box 1.2, p. 15). The authors cite Williams et al. (2007) for the technical guide.

Box 21. Adaptation and Adaptive Management: Complementary but Distinct Concepts.

Adaptation and adaptive management are distinct concepts that are frequently confused with one another.[1262] As described earlier, adaptation refers to strategies designed to prepare for and cope with the effects of climate change.[1263] In contrast, adaptive management is one particular approach to management in the face of uncertainty, and is not necessarily tied to climate change (see Box 20)[1264]

Adaptation to climate change is characterized by making decisions in the face of uncertainty.[1265] Because of the uncertainties associated with predicting the effects of future climates on species and ecosystems, flexible management will almost certainly be a component of well-designed adaptation strategies.[1266] However, while the adaptive management framework is structured to enable managers to act in the face of uncertainty, other management approaches and philosophies are also designed to address different levels of uncertainty (e.g. scenario-based planning).[1267]

To summarize, adaptive management can be an important component of adaptation efforts, but not all adaptive management is climate change adaptation, nor is all climate change adaptation necessarily adaptive management.[1268]

1262 Glick et al. (2011b, Box 1.2, p. 15).
1263 Glick et al. (2011b, Box 1.2, p. 15).
1264 Glick et al. (2011b, Box 1.2, p. 15).
1265 Glick et al. (2011b, Box 1.2, p. 15).
1266 Glick et al. (2011b, Box 1.2, p. 15).
1267 Glick et al. (2011b, Box 1.2, p. 15).
1268 Glick et al. (2011b, Box 1.2, p. 15).

3. CLIMATE ADAPTATION ACTIONS – INFORMATION GATHERING AND CAPACITY BUILDING

Building capacity in organizations, managers, practitioners, decision-makers, and the public can increase the ability to plan, develop, and implement adaptation strategies.[1269] There are multiple factors that can affect capacity to engage in adaptation, including generic factors such as economic resources and more specific factors such as quality and quantity of information, and training and technological resources.[1270] The sections below describe components of information gathering and capacity building.

Conduct/gather additional research, data, and products

Gathering research, data, and products on actual and projected climate change impacts is critical to supporting adaptation action.[1271] Models and research products have predicted a range of plausible scenarios; as these tools are refined, many indicate that the extent and magnitude of climate impacts may be greater than previously thought.[1272] Incorporating the best available science, traditional ecological knowledge, and citizen science efforts may improve climate adaptation decisions.[1273] For example, the Climate Action Knowledge Exchange (CAKE) is aimed at building a shared knowledge base for managing natural systems in the face of rapid climate change[1274] and the Climate Ready Water Utilities (CRWU) Toolbox provides access to resources containing climate-related information relevant to the water sector.[1275]

Create/enhance technological resources

Technological resources can make adaptation action easier and more accessible.[1276] These resources include the tools that can support information exchange, modeling of vulnerability and risk, and decision-making.[1277] These resources can help planners, managers, scientists, and policy makers to identify priority species and areas for conservation, generate inundation and hazard maps, and ascertain organizations and communities that have successfully implemented adaptation strategies.[1278]

Conduct vulnerability assessments and studies

Vulnerability assessments help practitioners evaluate potential effects of climatic changes on ecosystems, species, human communities, and other areas of concern.[1279] Vulnerability assessments and studies can identify impacts of concern, a range of scenarios that depend on the frequency and magnitude of changes, who and what is at risk from these impacts, and what can be done to reduce vulnerability and increase

[1269] *Gregg et al. (2011, p. 46)
[1270] *Gregg et al. (2011, p. 46)
[1271] *Gregg et al. (2011, p. 53)
[1272] *Gregg et al. (2011, p. 53)
[1273] *Gregg et al. (2011, p. 53)
[1274] * Climate Action Knowledge Exchange (CAKE). *About.* (2011). Available at http://www.cakex.org/about (accessed 8.22.2011).
[1275] * U.S. EPA. *Climate Ready Water Utilities Toolbox.* (August 5, 2011). Available at http://www.epa.gov/safewater/watersecurity/climate/toolbox.html (accessed 8.22.2011).
[1276] *Gregg et al. (2011, p. 70)
[1277] *Gregg et al. (2011, p. 70)
[1278] *Gregg et al. (2011, p. 70)
[1279] *Gregg et al. (2011, p. 54)

resilience.[1280] Specifically, climate change vulnerability assessments provide two essential components to adaptation planning:

- Identifying *which* species or ecosystems are likely to be most strongly affected by projected changes; and
- Understanding *why* these resources are likely to be vulnerable, including the interaction between climate shifts and existing stressors.[1281]

Determining *which* resources are most vulnerable enables managers to better set priorities for conservation action, while understanding *why* they are vulnerable provides a basis for developing appropriate management and conservation responses (emphasis in original). [1282] In other words, they can provide a factual underpinning for differentiating between species and systems likely to decline and likely to thrive, but do not in themselves dictate adaptation strategies and management responses.[1283] This emphasizes the fact that a vulnerability assessment is not an endpoint, but a source of information that can be incorporated into planning and decision-making.[1284]

Vulnerability is a function of exposure and sensitivity to change as well as adaptive capacity, which can all vary greatly depending on geography, genetic or species diversity, resources, and other factors.[1285] Vulnerability assessments are, therefore, structured around assessments of these distinct components.[1286] Furthermore, because vulnerability assessments should elucidate the specific factors that contribute to a species' or habitat's vulnerability, they can help managers identify options for reducing that vulnerability through management and conservation actions.[1287] In some cases there may be practical management options, but in other cases the factors leading to vulnerability may be very difficult or simply not feasible to address.[1288] This is an important consideration in selecting conservation targets and objectives.[1289] The key steps and associated actions for assessing vulnerability to climate change are listed in Table 17.

The EPA's Climate Ready Estuaries program compiled best practices and lessons learned for vulnerability assessment efforts including:

- Recognize that non-climate drivers, such as development, pollution, and population growth, often exacerbate climate change vulnerabilities.[1290]
- When working with limited data, use readily available scientific best professional judgment to help support decision-making.[1291] Surveying both local and regional experts and stakeholders can assist in building knowledge, as they have access to some of the most up-to-date information and research.[1292]

[1280] *Gregg et al. (2011, p. 54)
[1281] *Glick et al. (2011b, p. 1)
[1282] *Glick et al. (2011b, p. 1)
[1283] *Glick et al. (2011b, p. 3)
[1284] *Glick et al. (2011b, p. 77)
[1285] *Gregg et al. (2011, p. 54)
[1286] *Glick et al. (2011b, p. 2)
[1287] *Glick et al. (2011b, p. 77)
[1288] *Glick et al. (2011b, p. 77)
[1289] *Glick et al. (2011b, p. 77)
[1290] *U.S. EPA. *Lessons Learned from the Climate Ready Estuaries Program*. (2011, p. 2)
[1291] *U.S. EPA. (2011, p. 2)
[1292] *U.S. EPA. (2011, p. 2)

- Focus on emergency and disaster management, which is one area National Estuary Programs can work with local and state governments to incorporate climate change issues.[1293] *For further information on emergency and disaster management, please see "Invest in/enhance emergency services planning and training" in this Section and "Develop a disaster preparedness plan" in Section 6 of this Chapter*.
- Collaborate with and use local partners, such as universities, non-profits, Sea Grants, and National Estuarine Research Reserves to fill information gaps.[1294]
- Determine scope – vulnerability assessments do not necessarily have to be broad in scope.[1295] Focusing on the vulnerability of a specific resource may generate momentum for adaptation.[1296] This lesson is echoed by Glick et al.'s "landscaped-based" and "project-based" approach to climate-smart conservation, described previously (see Section 1 in this Chapter).[1297]

Table 17. Key Steps for Assessing Vulnerability to Climate Change.

Key Steps	*Associated Actions*
Determine objectives and scope	• Identify audience, user requirements, and needed products • Engage key internal and external stakeholders • Establish and agree on goals and objectives • Identify suitable assessment targets • Determine appropriate spatial and temporal scales • Select assessment approach based on targets, user needs, and available resources
Gather relevant data and expertise	• Review existing literature on assessment targets and climate impacts • Reach out to subject experts on target species or systems • Obtain or develop climatic projections, focusing on ecologically relevant variables and suitable spatial and temporal scales • Obtain or develop ecological response projections
Assess components of vulnerability	• Evaluate climate sensitivity of assessment targets • Determine likely exposure of targets to climatic/ecological change • Consider adaptive capacity of targets that can moderate potential impact • Estimate overall vulnerability of targets • Document level of confidence or uncertainty in assessments
Apply assessment in adaptation planning	• Explore why specific targets are vulnerable to inform possible adaptation responses • Consider how targets might fare under various management and climatic scenarios • Share assessment results with stakeholders and decision-makers • Use results to advance development of adaptation strategies and plans

Source: Modified from Glick et al. Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment. (2011b, Box 2.1, p. 19).

1293 *U.S. EPA. (2011, p. 2)
1294 *U.S. EPA. (2011, p. 2)
1295 *U.S. EPA. (2011, p. 2)
1296 *U.S. EPA. (2011, p. 2)
1297 Glick et al. (2011a, p. 7)

Conduct scenario planning exercises

Scenario planning involves the creation of a series of scenarios specifically for the planning process in question, as well as narratives to accompany those scenarios.[1298] It also involves the use of those scenarios for evaluating policy/management options.[1299] Scenario planning allows participants to identify actions that work well across multiple scenarios, to discover options for dealing with uncertainty, and can improve adaptive management (and adaptation).[1300]

Increase organizational capacity

Sufficient organizational capacity is needed to support adaptation activities at all levels of government.[1301] This strategy includes improving the resources, tools, knowledge, and institutional support required to increase organizational capacity.[1302]

Create/host adaptation training and planning workshops

While many researchers, conservation practitioners, and resource managers understand the reality of climate change, they are often still challenged by what actions to take.[1303] As a result, the conservation and resource management community needs assistance developing its thinking on dealing with climate change, finding the information or data it needs to make informed decisions, and finding people to interact with on this topic as individuals develop their own approaches.[1304] Training and planning workshops can provide context, guidance, and practical examples of how adaptation is being addressed on-the-ground.[1305]

Provide new job training for people whose livelihoods are threatened by climate change

This strategy directly addresses the potential economic consequences of global climate change.[1306] Increased water temperatures and ocean acidification will severely impact fisheries, aquaculture, and ecotourism and recreation based on natural resources.[1307]

Create new institutions (training staff, establishing committees)

Creating committees and advisory bodies and having properly trained staff can institutionalize climate change considerations within an organization.[1308] Technical experts, scientists, and other staff can contribute important knowledge and recommendations to support governmental decision-making on climate adaptation.[1309]

[1298] *Gregg et al. (2011, p. 59)
[1299] *Gregg et al. (2011, p. 59)
[1300] *Gregg et al. (2011, p. 59). The authors cite Peterson (2003) for this information.
[1301] *Gregg et al. (2011, p. 48)
[1302] *Gregg et al. (2011, p. 48)
[1303] *Gregg et al. (2011, p. 56)
[1304] *Gregg et al. (2011, p. 56)
[1305] *Gregg et al. (2011, p. 56)
[1306] *Gregg et al. (2011, p. 55)
[1307] *Gregg et al. (2011, p. 55)
[1308] *Gregg et al. (2011, p. 46)
[1309] *Gregg et al. (2011, p. 46)

Coordinate planning and management across institutional boundaries

Many climate change impacts will affect multiple jurisdictions at once whether the effects are felt at local, regional, national, or international scales.[1310] Because climatic variability is not confined by political or social boundaries, cross-jurisdictional coordination of planning and management can improve adaptation efforts.[1311] Increased cooperation may include information sharing, improved communication, and establishing formal partnerships to share resources, funds, and knowledge.[1312]

Invest in/enhance emergency services planning and training

Climate change is expected to increase risks to public health and safety throughout North America.[1313] Warmer temperatures and changes in precipitation patterns will likely increase incidences of wildfires and drought, pests and diseases, and intense heat waves.[1314] Integrating climate change concerns into emergency services planning and training, including police, fire and rescue, and emergency medical services, will be important to limit public health and safety risks.[1315]

Create stakeholder engagement processes

As mentioned previously, gaining public buy-in for adaptation can be critical to ensuring the effectiveness of any strategy.[1316] Engaging stakeholders can occur in a variety of ways; for example, participating in meetings and workshops, one-on-one interactions, and websites, among others.[1317] Activities like interactive, participatory discussions, problem solving sessions, and role-playing exercises have been used to engage stakeholders in climate adaptation.[1318] The EPA's Climate Ready Estuaries program compiled best practices and lessons learned for stakeholder engagement efforts including:

- Leverage existing efforts.[1319]
- Focus on local issues.[1320] Presenting local evidence of climate change (e.g., changes in seasonal events or animal behavior, local projections of wetland loss) to local officials and the general public is often a useful approach to build support for adaptation.[1321]
- Link climate change adaptation messages to clean water supply and stormwater drainage.[1322] This can be an effective way to engage local decision-makers, as constituents are increasingly concerned about these issues.[1323]
- Target entities most responsible for construction and maintenance of public infrastructure (e.g., municipalities, counties or regional authorities) first to encourage greater willingness to engage

[1310] *Gregg et al. (2011, p. 49)
[1311] *Gregg et al. (2011, p. 49)
[1312] *Gregg et al. (2011, p. 49)
[1313] *Gregg et al. (2011, p. 50)
[1314] *Gregg et al. (2011, p. 50)
[1315] *Gregg et al. (2011, p. 50)
[1316] *Gregg et al. (2011, p. 57)
[1317] *Gregg et al. (2011, p. 57)
[1318] *Gregg et al. (2011, p. 57)
[1319] *U.S. EPA. (2011, p. 3)
[1320] *U.S. EPA. (2011, p. 3)
[1321] *U.S. EPA. (2011, p. 3)
[1322] *U.S. EPA. (2011, p. 3)
[1323] *U.S. EPA. (2011, p. 3)

on the impacts of sea-level rise due to the significant fiscal implication of infrastructure loss or damage.[1324]
- Conduct meetings or phone calls with key stakeholders to help identify what stakeholders are already working on and their key needs for undertaking climate change adaptation.[1325]

Increase/improve public awareness, education, and outreach efforts

This strategy relates to improving the links between science, management, decision-making, and public awareness.[1326] These efforts may be in the form of presentations and workshops, print and internet media, steering and advisory committees, and traditional educational venues.[1327] More interactive approaches tend to be better at ensuring a two-way flow of information, recognizing that scientists must learn from managers, policy makers, and the public as well as vice-versa.[1328] Enabling managers and decision-makers to incorporate climate adaptation into practice requires that the appropriate science be available in useable forms when needed.[1329] The broader public also needs to be engaged in climate adaptation and be made aware of the potential ways that climate change may affect the economy, natural resources, livelihoods, health, and well-being.[1330] Gaining public buy-in may increase political and social capital to support climate adaptation action at local, regional, national, and international levels.[1331]

[1324] *U.S. EPA. (2011, p. 3)
[1325] *U.S. EPA. (2011, p. 3)
[1326] *Gregg et al. (2011, p. 51)
[1327] *Gregg et al. (2011, p. 51)
[1328] *Gregg et al. (2011, p. 51)
[1329] *Gregg et al. (2011, p. 51)
[1330] *Gregg et al. (2011, p. 51-52)
[1331] *Gregg et al. (2011, p. 52)

4. CLIMATE ADAPTATION ACTIONS – MONITORING AND PLANNING

The sections below describe components of monitoring and planning.

Evaluate existing monitoring programs for wildlife and key ecosystem components

Monitoring systems provide information that managers can use to adjust or modify their activities through the process of adaptive management.[1332] This approach would evaluate the current state of the systems that collect, analyze, and interpret environmental information.[1333] It would determine how programs will need to be modified to provide management-relevant information on the effects of climate change and what new monitoring systems will need to be established in order to address gaps in knowledge of climate effects.[1334] The costs to adapt existing monitoring systems and develop new monitoring systems are likely to be high.[1335] In many cases this will probably require new legislation and regulations, and possibly new tools and approaches to monitoring.[1336] It will also require better integration and coordination across existing monitoring programs.[1337]

Improve coordinated management and monitoring of wetlands

Three options for improving coordinated management and monitoring of wetlands are:

- Promote climate-smart integrated resource management at the watershed level by offering financial and other incentives[1338]
- Use legislative reauthorizations to explore new ways to protect biodiversity and ecosystems in light of climate change and to integrate preservation and restoration[1339]
- Support research on the impacts of climate change (and the effectiveness of various management options) on wetlands[1340]

Incorporate predicted climate change impacts into species and land management

Information about actual and potential climate change impacts can be of benefit to land and natural resource managers in making decisions and taking actions.[1341] Climate change is not addressed in many existing natural resource plan documents.[1342] This strategy would use existing natural resource planning mechanisms to inform decision-making on a broad spectrum of natural resource management topics.[1343] Many existing natural resource plans already contain provisions for updates and revisions, which could

[1332] *Heinz Center (2008, p. 29). The authors cite Walters (1986), Margoluis and Salafsky (1998), and Williams, Szaro, and Shapiro (2007) for this information.
[1333] *Heinz Center (2008, p. 29). The authors cite Walters (1986), Margoluis and Salafsky (1998), and Williams, Szaro, and Shapiro (2007) for this information.
[1334] *Heinz Center (2008, p. 29)
[1335] *Heinz Center (2008, p. 30)
[1336] *Heinz Center (2008, p. 30)
[1337] *Heinz Center (2008, p. 30). The authors cite The Heinz Center (2006) for this information.
[1338] *OTA. (1993, p. 197)
[1339] *OTA. (1993, p. 197)
[1340] *OTA. (1993, p. 197)
[1341] *Heinz Center (2008, p. 30)
[1342] *Heinz Center (2008, p. 30). The authors cite Hannah, Midgley and Millar (2002) for information on existing natural resource plan documents, and Mawsdsley (unpublished data) for information on endangered species recovery plans and State Wildlife Action Plans.
[1343] *Heinz Center (2008, p. 30)

provide a mechanism for incorporating information about climate change effects and adaptation strategies.[1344]

The problems with this approach are mainly practical at present: there is a definite cost associated with revisiting and revising management plans; in practice, many resource management plans are updated infrequently.[1345] While detailed predictions of potential climate change effects have only been available for a small subset of species and areas,[1346] considerable progress is being made in down-scaling of climate information for use at more local levels.[1347] Below, three examples are provided for incorporating predicted climate change impacts into species and land management:

- **Incorporate climate change into wetland restoration planning:** To incorporate climate change into wetland restoration planning, one option is to establish wetland reference sites to document the impacts of climate change and to determine the effectiveness of management and adjustment strategies.[1348] Another option is to develop protection and adjustment tools through the use of "pilots."[1349] In all cases, monitoring success and failures[1350] and actively making the results of studies broadly available to the public and other practitioners[1351] is suggested.
- **Incorporate climate change considerations into aquatic invasive species management plans:** The process could be initiated by conducting facilitated meetings and/or workshops to identify specific management strategies and research needs to inform management strategies.[1352] State (or other jurisdictions) councils also could work with one another to share information on climate-related data across regions.[1353] Coordination and information sharing among states (or other jurisdictions) will also facilitate the implementation of activities that are adapted to climate change effects.[1354] State and federal agencies (as well as other jurisdictions) also could collaborate in areas such as aquatic invasive species data collection, specifically where the spatial scale of the biological and environmental data needed by the federal government may be more efficiently collected by a state.[1355] In turn, the data provided to the federal government by states (or other jurisdictions) may be used in modeling scenarios that also would benefit state aquatic invasive species management efforts.[1356]

  Please see the description of "Prevent establishment of aquatic invasive species" found in the section "Manage aquatic and riparian invasive and non-native species in a changing climate" for information on additional methods for incorporating climate change in aquatic invasive species management efforts.

[1344] *Heinz Center (2008, p. 30)
[1345] *Heinz Center (2008, p. 30-31)
[1346] Heinz Center (2008, p. 31). The authors cite The Heinz Center (2007) for this information.
[1347] *Bridging the Gap: Downscaling Climate Models to Inform Management Actions.* Workshop held November 3, 2010. Documents available at www.dfg.ca.gov/climatechange/downscaling-workshop/ (accessed 7.10.2011).
[1348] *Association of State Wetland Managers (ASWM). *Recommendations for a National Wetlands and Climate Change Initiative.* (2009, p. 12)
[1349] *ASWM. (2009, p. 12)
[1350] *ASWM. (2009, p. 12)
[1351] *ASWM. (2009, p. 12)
[1352] *U.S. EPA. (2008b, p. 4-2)
[1353] *U.S. EPA. (2008b, p. 4-2)
[1354] *U.S. EPA. (2008b, p. 4-2)
[1355] *U.S. EPA. (2008b, p. 4-2)
[1356] *U.S. EPA. (2008b, p. 4-2)

- **Incorporate climate change considerations into Ecosystem-Based Management (EBM):** EBM is an integrated approach to management that considers the entire ecosystem, including humans.[1357] The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need.[1358] Ecosystem-based management differs from current approaches that usually focus on a single species, sector, activity or concern; it considers the cumulative impacts of different sectors.[1359] Specifically, ecosystem-based management:
  - Emphasizes the protection of ecosystem structure, functioning, and key processes;
  - Is place-based in focusing on a specific ecosystem and the range of activities affecting it;
  - Explicitly accounts for the interconnectedness within systems, recognizing the importance of interactions between many target species or key services and other non-target species;
  - Acknowledges interconnectedness among systems, such as between air, land and sea; and
  - Integrates ecological, social, economic, and institutional perspectives, recognizing their strong interdependences.[1360]

Develop dynamic landscape conservation plans

Dynamic landscape conservation plans include information on fixed and dynamic spatial elements, along with management guidelines for target species, genetic resources, and ecosystems within the planning areas.[1361] Fixed spatial elements include protected areas where the land use is fully natural.[1362] Dynamic spatial elements include all other areas within the landscape matrix, where land use may change over time.[1363] The plan includes a desired future condition for each element, based on predicted shifts in distribution of species and other ecosystem components, as well as any intermediate steps that may be necessary to transition between current and future condition.[1364] The management guidelines suggest mechanisms and tools for management (such as land acquisition, riparian plantings, or other wildlife-friendly farming practices) and specific government agencies responsible for implementation.[1365] The actual planning activities required to develop these plans are likely to be compatible with other local or regional-scale planning projects such as State Wildlife Action Plans or watershed management plans.[1366] However, planning efforts can be resource-intensive.[1367] Recommendations such as suggesting that certain spatial elements (i.e., areas of land or water) will need to be converted from human uses to "natural" management are likely to prove controversial.[1368]

1357 *West Coast EBM Network. *Community-based management of coastal ecosystems: Highlights and lessons of success from the West Coast Ecosystem-Based Management Network (pdf).* (2010, p. 2)
1358 *West Coast EBM Network. (2010, p. 2)
1359 *West Coast EBM Network. (2010, p. 2)
1360 *West Coast EBM Network. (2010, p. 2) The authors cite McLeod et al. (2005) for this information.
1361 *Heinz Center (2008, p. 31). The authors cite Hannah and Hansen (2005) for this information.
1362 *Heinz Center (2008, p. 31)
1363 *Heinz Center (2008, p. 31)
1364 *Heinz Center (2008, p. 31)
1365 *Heinz Center (2008, p. 31)
1366 *Heinz Center (2008, p. 31)
1367 *Heinz Center (2008, p. 31)
1368 *Heinz Center (2008, p. 31)

Develop/implement adaptive management policies and plans

Because of the uncertainty about climate change, its effects, and appropriate management responses, adaptive management policies and plans can play an important role in climate change adaptation (although adaptive management is not inherently linked to climate adaptation, see Box 21).[1369] Adaptive management involves testing hypotheses about system function and management efficacy and adjusting behavior and actions based on experience and actual changes.[1370] These decisions can be either active or passive; active adaptive management involves experimenting with multiple options in order to determine the best strategy, while passive adaptive management requires selecting and implementing one option and monitoring to determine if changes are needed.[1371]

For example, the Climate Resilience Evaluation and Awareness Tool (CREAT) allows users to evaluate potential impacts of climate change on their water utility and to evaluate adaptation options to address these impacts using both traditional risk assessment and scenario-based decision-making.[1372] CREAT provides libraries of drinking water and wastewater utility assets (e.g., water resources, treatment plants, pump stations) that could be impacted by climate change, possible climate change-related threats (e.g., flooding, drought, water quality), and adaptive measures that can be implemented to reduce the impacts of climate change.[1373] The tool guides users through identifying threats based on regional differences in climate change projections and designing adaptation plans based on the types of threats being considered.[1374] Following assessment, CREAT provides a series of risk reduction and cost reports that will allow the user to evaluate various adaptation options as part of long-term planning.[1375]

Changes to land use planning and zoning

This may include restricting or prohibiting development in erosion zones, redefining riverine flood hazard zones, or increasing shoreline setbacks.[1376] It may be difficult to attain agreement among all parties.[1377] Redefining riverine flood hazard zones to match projected expansion of flooding frequency and extent protects riverine systems and zones, but may impact flood insurance or require changing zoning ordinances, which can be difficult.[1378]

Integrate floodplain management and reservoir operations using Ecosystem-Based Adaptation

Ecosystem-based adaptation, or EBA, refers to the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change.[1379] At a recent conference held by the American Water Resources Association, Opperman et al. (2011) outlined a

[1369] *Gregg et al. (2011, p. 71)
[1370] *Gregg et al. (2011, p. 71)
[1371] *Gregg et al. (2011, p. 71)
[1372] *U.S. EPA. *Climate Resilience Evaluation and Awareness Tool (CREAT) (website).* (2011)
[1373] *U.S. EPA. *Climate Resilience Evaluation and Awareness Tool (CREAT) (website).* (2011)
[1374] *U.S. EPA. *Climate Resilience Evaluation and Awareness Tool (CREAT) (website).* (2011)
[1375] *U.S. EPA. *Climate Resilience Evaluation and Awareness Tool (CREAT) (website).* (2011)
[1376] *U.S. EPA. *Synthesis of Adaptation Options for Coastal Areas*. (2009, p. 14)
[1377] *U.S. EPA. (2009, p. 14)
[1378] *U.S. EPA. (2009, p. 14)
[1379] *Opperman et al. *Integrated floodplain-reservoir management as an ecosystem-based adaptation strategy to climate change (conference proceedings).* (April 18-20, 2011, p. 2) The authors cite IUCN (2009) for the definition of ecosystem-based adaptation.

rationale for integrated floodplain-reservoir management as an ecosystem-based adaptation (EBA) strategy to climate change.

Large-scale floodplain reconnection below dams can enable a reduction of reservoir flood-storage space, essentially transferring flood-storage functions from the reservoir to the downstream floodplain.[1380] By liberating some or all of a reservoir's flood-control storage, the reservoir can provide greater benefits in the form of increased hydropower, enhanced water-supply reliability, and environmental flows.[1381] Through this integration, floodplain reconnection serves as an EBA strategy for both flood risk and drought risk.[1382] This approach attaches economic value to floodplains, in the form of the increased reservoir benefits they facilitate by managing floodwater, and thus can provide revenue for funding floodplain restoration.[1383]

Though the integration of floodplain management and reservoir operations is not a panacea, Opperman et al. recommend the investigation of the full range of benefits from floodplain reconnection as an EBA strategy in already developed systems, as well as greater appreciation for the multiple benefits—including to the resiliency of water-management systems—provided by functioning, flooding floodplains in regions undergoing development of infrastructure.[1384]

Community planning

Local-level planning and involvement are key to achieving on-the-ground implementation of adaptation strategies.[1385] Although international and national action are needed to address broad policies and reform, community planning and management have greater effects on local resources through land use planning and zoning.[1386] Building local capacity is especially important for dealing with disaster risk management and gaining stakeholder support for action.[1387]

Ensure that wildlife and biodiversity needs are considered as part of the broader societal adaptation process

Modern wildlife professionals and natural resource managers are aware that management activities take place within a broader societal context, and that the broader society must be supportive in order for management to succeed.[1388] Managers can take proactive steps to engage local and regional government entities in adaptation planning, thereby ensuring that the needs of wildlife and natural resources are included at the start of these discussions.[1389]

[1380] *Opperman et al. (April 18-20, 2011, p. 7)
[1381] *Opperman et al. (April 18-20, 2011, p. 3)
[1382] *Opperman et al. (April 18-20, 2011, p. 3)
[1383] *Opperman et al. (April 18-20, 2011, p. 3)
[1384] *Opperman et al. (April 18-20, 2011, p. 3)
[1385] *Gregg et al. (2011, p. 62)
[1386] *Gregg et al. (2011, p. 62)
[1387] *Gregg et al. (2011, p. 62)
[1388] *Heinz Center (2008, p. 32)
[1389] *Heinz Center (2008, p. 32)

5. CLIMATE ADAPTATION ACTIONS – INFRASTRUCTURE AND DEVELOPMENT

The sections below address threats to the built environment and other infrastructure from climate change impacts in the freshwater environment.

Make infrastructure resistant or resilient to climate change

This strategy involves the consideration of climate change in both the planning of new or retrofitting of existing infrastructure, including stormwater systems, transportation, water supply, or buildings.[1390] Three examples are provided here:

- **Incorporate wetland protection into infrastructure planning:** The incorporation of wetland protection in transportation planning, sewer utilities, and other infrastructure planning helps protect infrastructure.[1391] It may also help maintain water quality and preserve habitat for vulnerable species.[1392]
- **Manage realignment and deliberately realign engineering structures:** Realignment of engineering structures affecting rivers, estuaries, and coastlines could reduce engineering costs, protect ecosystems and estuaries, and allow for natural migration of rivers.[1393] However, it can be costly.[1394]
- **Develop adaptive stormwater management practices:** *Please see the following adaptation action "Develop more effective stormwater infrastructure" for information on adaptive stormwater management practices.*

Develop more effective stormwater infrastructure

In general, the purpose of stormwater management is to control the amount of pollutants, sediments, and nutrients entering water bodies through precipitation-generated runoff.[1395] However, it also plays an important role in preventing damage to the built environment and the natural systems that protect it.[1396] Existing drainage systems may be ill-equipped to handle the amount of stormwater runoff that will accompany the more intense rainfall events expected in the future.[1397]

Adaptive stormwater management practices such as removing impervious surface and replacing undersized culverts minimize pollutant and nutrient overloading of existing wetlands.[1398] Further, promoting natural buffers and adequately sizing culverts preserves natural sediment flow and protects water quality of downstream reaches.[1399] Effective stormwater infrastructure could reduce future

[1390] *Gregg et al. (2011, p. 61)
[1391] *U.S. EPA. (2009, p. 13)
[1392] *U.S. EPA. (2009, p. 13)
[1393] *U.S. EPA. (2009, p. 11)
[1394] *U.S. EPA. (2009, p. 11)
[1395] *NOAA. (2010a, p. 93)
[1396] *NOAA. (2010a, p. 93)
[1397] *NOAA. (2010a, p. 93)
[1398] *U. S. EPA. (2009, p. 20)
[1399] *U. S. EPA. (2009, p. 15)

occurrences of severe erosion[1400] and maintain or improve water quality. However, they may require costly improvements.[1401] Additional modifications include:

- Updating stormwater regulations,
- Incorporating green infrastructure (*please see "Green infrastructure and low-impact development" in this section for further information*),
- Limiting/removing impervious surfaces,
- Acquiring easements for new and wider drainage ditches,
- Implementing and enforcing stream dumping regulations,
- Improving carrying and storage capacity of streams, channels, and basins through ongoing maintenance,
- Installing larger pipes and culverts (*Please see the section "Maintain, restore, or create stream and watershed connectivity" for information on improved culvert design.*),
- Adding pumps,
- Creating retention and detention basins, and
- Converting culverts to bridges.[1402]
- Phase out all combined sewer systems in the region.[1403]

Green infrastructure and low-impact development

As it relates to water resource management and protection, "green infrastructure" is a comprehensive approach that promotes the use of natural and built systems to improve infiltration, evapotranspiration, capture, and reuse of stormwater at regional, community, and site scales.[1404] It uses soil and vegetation in lieu of or in addition to the "hard" or "gray" infrastructure typically used to divert, store, and treat stormwater.[1405] Some aspects of green infrastructure will need to be managed through regulations (e.g., land use, building codes) and land acquisition programs; others will be most effective when promoted through outreach, education, and training.[1406]

In general, regional green infrastructure is an interconnected network of natural lands and waters that provide essential environmental functions (e.g., wetlands, floodplains, and forests) and the buffers that protect them.[1407] Examples of community and site-level green infrastructure practices that may help coastal communities adapt to climate change include:

- Vegetated swales and median strips,
- Urban forestry,
- Porous pavement,
- Rain gardens,
- Green roofs,

[1400] *Palmer et al. (2008, p. 33)
[1401] *U. S. EPA. (2009, p. 20)
[1402] *NOAA. (2010a, p. 93-94). The authors note that since some modifications and enhancements could encourage growth in the short-term, growth controls may also be needed.
[1403] Comment from reviewer (June 2011).
[1404] *NOAA. (2010a, p. 94)
[1405] *NOAA. (2010a, p. 94)
[1406] *NOAA. (2010a, p. 94)
[1407] *NOAA. (2010a, p. 95)

- Rain barrels and cisterns, and
- Downspout disconnection.[1408]

By helping to maintain and restore natural hydrology and removing nutrients, pathogens, and pollutants from stormwater, these approaches:

- Improve water quality and groundwater recharge,
- Reduce stormwater flooding,
- Protect ecosystems,
- Provide habitat,
- Provide recreational opportunities, and
- Improve aesthetics.[1409]

Build storage capacity

Damming rivers for conservation purposes is a controversial concept.[1410] They may provide managers with the ability to store water and manage river flows (timing, volume, temperature) to best suit the needs of salmon.[1411] In watersheds without sufficient water storage (natural or not), damming rivers may be an idea worth discussing.[1412] There are many arguments against building more dams including: the barrier to fish passage (both adults and out-migrating smolts), the impact on species besides salmon, and the impacts on the geomorphology of the river.[1413] Dam construction is also expensive.

[1408] *NOAA. (2010a, p. 95)
[1409] *NOAA. (2010a, p. 95)
[1410] *Nelitz et al. *Helping Pacific Salmon Survive the Impact of Climate Change on Freshwater Habitats.* (2007, p. 101)
[1411] *Nelitz et al. (2007, p. 101)
[1412] *Nelitz et al. (2007, p. 101)
[1413] *Nelitz et al. (2007, p. 101)

6. CLIMATE ADAPTATION ACTIONS – GOVERNANCE, POLICY, AND LAW

Local, regional, and national governments play important roles in many climate change policies and provide support to resource managers, conservation practitioners, and communities.[1414] Many projected climate impacts will have transboundary effects and require multilateral adaptation efforts.[1415] The sections below describe components of governance, policy, and law.

Note: Governance is not distinguished clearly from policy and law, as evidenced by the incorporation of policy and/or law into wide-ranging definitions of governance.[1416]

Develop a disaster preparedness plan

Coastal hazards, such as erosion, landslides, and extreme weather events, can harm people and property; climate change is projected to exacerbate these effects in both frequency and magnitude.[1417] Disaster preparedness plans can help coastal communities identify risks and vulnerabilities and develop options for response and recovery.[1418]

Maintain adequate financial resources for adaptation

Economic barriers are frequently cited by groups as reasons for not taking adaptation action.[1419] If adaptation activities focus on building climate change into existing efforts or frameworks (e.g., incorporating climate projections into bridge designs or harvest limits), ensuring adequate financing for adaptation means simply ensuring that project budgets reflect any needed additional funding (e.g. more materials needed for a higher bridge, or downscaled climate model scenarios for use in planning).[1420] Climate adaptation actions undertaken as a new and distinct set of activities (e.g., scenario planning exercises) will require new and distinct funding.[1421]

Some adaptation actions require up-front financial investment but more than pay for themselves in reduced long-term expenditures, meaning that grants or loans may be appropriate sources of financing.[1422] Grants can also provide short-term funds for strategy development and testing, but over the longer term it is important to diversify, for instance by building support for governmental adaptation funding, forging new partnerships, or reworking organizational budgets.[1423] Establishing endowments (e.g., the $90 million provincial endowment that established the Pacific Institute for Climate Solutions in British Columbia) can provide more stable funding than year-by-year funding.[1424] Increased and sustainable funding sources can

[1414] *Gregg et al. (2011, p. 67)
[1415] *Gregg et al. (2011, p. 67)
[1416] United Nations Economic and Social Council. Committee of Experts on Public Administration (Fifth Session). *Definition of basic concepts and terminologies in governance and public administration (pdf, website).* (2006).
[1417] *Gregg et al. (2011, p. 68)
[1418] *Gregg et al. (2011, p. 68)
[1419] *Gregg et al. (2011, p. 69)
[1420] *Gregg et al. (2011, p. 69)
[1421] *Gregg et al. (2011, p. 69)
[1422] *Gregg et al. (2011, p. 69)
[1423] *Gregg et al. (2011, p. 69)
[1424] *Gregg et al. (2011, p. 69)

help organizations and governments overcome financial constraints and adapt to changing environmental conditions.[1425]

Review existing laws, regulations, and policies

This strategy would initiate a review of all applicable laws, regulations, and other public policies related to wildlife management, natural resource management, and biodiversity conservation.[1426] Many of these laws and regulations are decades old, and most were developed before climate change became a significant concern.[1427] Actually addressing the deficiencies that are identified through these reviews may be difficult without significant political will to overcome institutional inertia.[1428] There will likely be significant concern expressed from all sides about any sweeping revisions to existing laws and regulations.[1429]

Create new or enhance existing policy

Legislation, regulations, agreements, and enforcement policies at local, regional, national, and international levels can be created or enhanced to support climate adaptation action.[1430] New legislative tools or regulations may be necessary to address specific climate change impacts.[1431] For example, given that existing wildlife and biodiversity legislation is often decades old, new legislative or regulatory approaches may very well be needed to address specific effects or challenges associated with climate change.[1432] Another example concerns in-stream flow rights: where in-stream flow rights do not currently exist, laws that define in-stream water flow as a legitimate and legal use of water could be passed. The obvious benefit of maintaining in-stream flows is to aquatic ecosystems. There are also opportunities to use existing regulatory frameworks to support conservation and management efforts to decrease the vulnerability of natural and human systems,[1433] provided that the program managers are given the flexibility needed to directly address climate threats.[1434]

[1425] *Gregg et al. (2011, p. 69)
[1426] *Heinz Center. (2008, p. 33)
[1427] *Heinz Center. (2008, p. 33)
[1428] *Heinz Center. (2008, p. 33)
[1429] *Heinz Center. (2008, p. 33)
[1430] *Gregg et al. (2011, p. 72)
[1431] *Heinz Center. (2008, p. 34)
[1432] *Heinz Center. (2008, p. 34)
[1433] *Gregg et al. (2011, p. 72)
[1434] *Heinz Center. (2008, p. 34)

Additional actions

The following adaptation actions for governance, policy, and law were found in the literature, but were not discussed in detail or are described elsewhere in this report:

- Create permitting rules that constrain locations for landfills, hazardous waste dumps, mine tailings, and toxic chemical facilities[1435]
- Floodplain zoning: *Please see the section "Reduce effects of increased flooding and extreme flow" for an explanation of floodplain zoning.*
- Flood hazard mapping: *Please see the section "Reduce effects of increased flooding and extreme flow" for an explanation of flood hazard mapping.*

[1435] *U.S. EPA. (2009, p. 10)

7. CLIMATE ADAPTATION ACTIONS – SPECIES AND HABITAT CONSERVATION, RESTORATION, PROTECTION AND NATURAL RESOURCE MANAGEMENT

Addressing adaptation in management and conservation is necessary to deal with the actual and potential effects of climate change on ecosystems and the functions and services they provide.[1436] Climate change may have negative *and* positive effects on wildlife and habitat.[1437] Managers and conservation practitioners can decrease ecosystem vulnerability by directly addressing expected climate change effects in policies and plans or by reducing the stressors that can exacerbate climate impacts.[1438] The sections below describe components of species and habitat conservation, restoration, protection, and natural resource management to consider to address potential climate change impacts.

Maintain, restore, or increase in-stream flow to address changes in snowpack, runoff, and streamflow regimes

The available evidence suggests that climate change may have profound impacts on water resource availability.[1439] Climate change will affect not only initial surface runoff into a stream system, but also rates of evaporative loss, seepage to groundwater aquifers, recharge from those aquifers and rates of consumptive use from irrigation withdrawals along the entire stream system.[1440] Hydrologic analyses of plausible climate change scenarios indicate possible substantial reductions in streamflows in some areas, increased flood frequencies in other areas, and changes in the seasonal pattern of flows, with reduced summer flows likely in many mountainous and northern river basins.[1441]

<u>Assess barriers to determine the potential for improving flow</u>

Assessment of barriers such as dams and diversion structures to determine the potential for improving flow[1442] may include the following activities:

- Develop reservoir release options with dam managers and/or design structures for temporary storage of flood waters before they reach the reservoir.[1443]
- Remove dams in areas with high evaporation, and consider methods to divert water to groundwater storage to provide for later use.[1444]
- Adjust outlet height on dam to release high quality water to downstream rivers (e.g., deeper waters are typically cooler than surface waters).[1445] With large changes in reservoir water levels,

[1436] *Gregg et al. (2011, p. 35)
[1437] *Gregg et al. (2011, p. 35)
[1438] *Gregg et al. (2011, p. 35)
[1439] *Miller et al. *Water allocation in a changing climate: institutions and adaptation*. (1997, p. 157)
[1440] *Miller et al. (1997, p. 167)
[1441] *Miller et al. (1997, p. 157). The authors cite Schaake (1990), Waggoner (1990), and Duell (1992) for this information.
[1442] *Nelson et al. (2007, p. 41)
[1443] *Palmer et al. (2008, p. 34)
[1444] *Palmer et al. (2008, p. 34)
[1445] *Palmer et al. (2008, p. 34)

the outlet height on dams may need adjusting to ensure high quality water to downstream rivers.[1446]

- Maintain the natural flow regime through managing dam flow releases upstream (e.g. through option agreements with willing partners) to protect flora and fauna in drier downstream reaches, or to prevent losses from extreme flooding.[1447] Water releases from dams and transporting fish may be necessary short-term solutions in times of drought or extreme low flows.[1448]
- Manage water storage and withdrawals to smooth the supply of available water throughout the year.[1449]
- Improve culvert design. *Please see the section "Maintain, restore, or create stream and watershed connectivity" for information on improved culvert design.*

Adapt water rights

The prospect of climate changes makes it more important to give explicit attention to the tradeoff between the initial costs of clarifying the rights of multiple water users and the future costs of conflicts that may arise if water availability changes.[1450] The desires of competing water users for certainty, flexibility and protection of environmental values must now be accommodated within the context of increasing hydrologic uncertainty.[1451] This suggests a number of factors that policymakers could consider in the upcoming decades as water statutes are modified, as adjudications are carried out, and as decisions are made regarding water transfers, issuance of new permits and protection of environmental values:[1452]

- **Improve the predictability of the limits of individual rights under a variety of possible climatic conditions:** It may be valuable to define limits on allowable consumptive use as a basis for reducing the adverse impacts of climate change on junior users and instream flows.[1453] For example, state regulations could specify consumptive use thresholds at which owners of existing water rights could reasonably be required to modify their diversions and application practices as climatic conditions change.[1454] State water authorities should explicitly incorporate such conditions in the specification of any new water rights.[1455]
- **Further document and clarify consumptive use rights:** The prospect of climate change suggests that it may be valuable to better document water withdrawals and consumptive uses, as well as natural variations in streamflows and groundwater levels.[1456] Such efforts should be targeted at reducing the basis for future disputes and providing adequate information for water transfers should water scarcity become more prevalent.[1457]
- **Better integrate groundwater and surface water rights:** In planning for the integration of groundwater and surface water rights, water authorities should give attention to how the

[1446] *Palmer et al. (2008, p. 36)
[1447] *Palmer et al. (2008, p. 33)
[1448] *Lawler (2009, p. 87). The authors cite Palmer et al. (2008) for this information.
[1449] *Palmer et al. (2008, p. 33)
[1450] *Miller et al. (1997, p. 170)
[1451] *Miller et al. (1997, p. 170)
[1452] *Miller et al. (1997, p. 170)
[1453] *Miller et al. (1997, p. 170)
[1454] *Miller et al. (1997, p. 170)
[1455] *Miller et al. (1997, p. 170)
[1456] *Miller et al. (1997, p. 171)
[1457] *Miller et al. (1997, p. 171)

hydrologic interactions between groundwater and surface water sources may be affected by a range of possible future changes in the local and regional climate.[1458]

- **Create flexibility to move water to more valuable uses:** Flexibility in water allocation can be achieved either through markets or through administrative action.[1459] The key is to ensure that the method chosen provides a fair and efficient means of moving some aspect of the water resource to a more valuable use.[1460]
- **Purchase or lease water rights:** The purchase or lease of water rights to enhance flow management options can be a valuable tool.[1461] For example, the establishment of dry-year option agreements with willing private partners can ensure that flows during droughts remain sufficient to protect critical habitats and maintain water quality.[1462] A strengthening of environmental flow programs and water use permit conditions to maintain natural flow conditions will also be critical.[1463]
- **Enhance the ability to condition rights in a fair and efficient manner to provide appropriate protection for environmental values:** Authorities could specifically condition new water rights to alert users to possible future modification of the rights and to explicitly spell out the climatic and environmental conditions under which such modifications can be expected.[1464] In addition, it would be valuable to develop clear policy statements regarding modifications of established rights in the event of future climate change or long-run drought, together with explicitly stated standards of evidence that will be used to determine when hydrologic conditions have changed sufficiently to warrant implementation of the regulations.[1465] Open discussion of the criteria by which policy options should be evaluated will also be valuable.[1466]

Create and preserve a water supply "safety margin"

The possibility of conflicts between competing water users might be reduced if instream flows are explicitly treated as a buffer to be used to absorb the impact of changing climatic conditions.[1467] Rather than setting a single minimum flow standard to be used as a target for avoiding serious adverse impacts on fisheries and other aquatic resources, a range of environmentally desirable flow levels could be defined.[1468] The lower level might serve as a trigger for water authorities to enhance instream flows by purchasing water or implementing restrictions on existing rights, while the upper level would be used as the target for conditioning new rights.[1469] For example, administrators could grant new permits subject to the condition that they not deplete streamflows beyond the upper flow- level target.[1470] If flows increase, water users could fully exercise the new rights.[1471] If flows decline, the impact would fall first on the

[1458] *Miller et al. (1997, p. 171)
[1459] *Miller et al. (1997, p. 172)
[1460] *Miller et al. (1997, p. 172)
[1461] *Palmer et al. (2008, p. 36-37)
[1462] *Palmer et al. (2008, p. 37)
[1463] *Palmer et al. (2008, p. 37)
[1464] *Miller et al. (1997, p. 174)
[1465] *Miller et al. (1997, p. 174)
[1466] *Miller et al. (1997, p. 174)
[1467] *Miller et al. (1997, p. 174)
[1468] *Miller et al. (1997, p. 174)
[1469] *Miller et al. (1997, p. 174)
[1470] *Miller et al. (1997, p. 174)
[1471] *Miller et al. (1997, p. 174)

conditioned permits, then on the buffer and finally on current water uses.[1472] Where water is already fully appropriated, authorities could create such a buffer by purchasing water rights from willing sellers to reduce existing consumptive uses (see the previous adaptation action *"Adapt water rights"* for further information on purchasing water rights).[1473] Where unappropriated water is available, they could more easily create such a buffer by incorporating appropriate conditions in the definition of new rights and by closing some streams to new appropriations unless and until there is considerable evidence that wetter conditions are likely to prevail.[1474]

Implement low impact irrigation practices

Low impact irrigation practices include optimizing irrigation timing and implementing drip irrigation. Optimized irrigation timing involves managing the daily timing of irrigation to minimize evaporation during warm periods and waste during rain.[1475] For example, in a pilot project on the Nicola River (at Kilchena, British Columbia), a number of mini irrigation monitoring stations were installed to track soil moisture and weather conditions.[1476] The monitoring station is linked to the farmer's phone so they know when the fields need to be irrigated.[1477]

Drip irrigation technology has the potential to at least double the crop yield per unit of water.[1478] However, drip irrigation does not necessarily save water when considered from a basin scale.[1479] In an integrated basin-scale analysis of the Upper Rio Grande Basin of North America, Ward & Pulido-Velazquez (2008) conclude adoption of more efficient irrigation technologies reduces valuable return flows and limits aquifer recharge.[1480]

Divert water from other locations

Like dams, diversions are very controversial and may provide managers with the ability to store water and manage river flows (timing, volume, temperature) to best suit the needs of salmon.[1481] However there are major impacts to both the area where the water is removed and the area where the water is diverted to.[1482]

Additional actions

The following adaptation actions for maintaining, restoring, or increasing in-stream flow were found in the literature, but were not discussed in detail, or they are described elsewhere in this report:

- Maintain free-flowing rivers[1483]
- Reduce water extraction[1484]

[1472] *Miller et al. (1997, p. 174)
[1473] *Miller et al. (1997, p. 174)
[1474] *Miller et al. (1997, p. 174)
[1475] *Nelitz et al. (2007, p. 100)
[1476] *Nelitz et al. (2007, p. 100)
[1477] *Nelitz et al. (2007, p. 100)
[1478] *Nelitz et al. (2007, p. 100). The authors cite Postel (2000) for this information.
[1479] *Ward and Pulido-Velazquez. *Water conservation in irrigation can increase water use*. (2008, p. 18219). The authors cite Molden (2007) for this information.
[1480] *Ward and Pulido-Velazquez. (2008, p. 18215)
[1481] *Nelitz et al. (2007, p. 102)
[1482] *Nelitz et al. (2007, p. 102)
[1483] *Nelson et al. (2007, p. 41)
[1484] *Lawler. (2009, p. 87). The authors cite Hansen et al. (2003) for this information.

- Place snow fences to increase snowpack[1485] and/or alter snowpack patterns
- Disconnect road drainage from stream networks to restore natural patterns of flow.[1486]
- Minimize ground disturbance and land-use changes that reduce groundwater recharge, and implement Best Management Practices that encourage groundwater recharge from impervious and disturbed areas.[1487]
- Support and restore healthy beaver populations: *Please see the section "Maintain and restore wetlands and riparian areas" for an explanation of supporting and restoring beaver populations.*
- Restore riparian habitat: *Please see the section "Maintain and restore wetlands and riparian areas" for an explanation of restoring riparian habitat*

Case Study 1. Willamette Water 2100: Anticipating water scarcity and informing integrative water system response in the Pacific Northwest.

Climate impacts addressed: Changes in snowpack, runoff, groundwater and streamflow regimes

Description: In October 2010, faculty from Oregon State University, the University of Oregon, and Portland State University began a five-year project to evaluate how climate change, population growth, and economic growth will alter the availability and the use of water in the Willamette River Basin on a decadal to centennial timescale. The National Science Foundation sponsored project provides a means to ask "what if" questions about climate impacts on the hydrologic system and freshwater ecosystems. It has four objectives: identify and quantify the linkages and feedbacks among hydrologic, ecological, and socioeconomic dimensions of the water system; determine where and when human activities and climate change will create water scarcities; evaluate a broad range of strategies that could enable this region to prevent, mitigate, or adapt to water scarcities; and, lastly to create a transferable method of predicting where climate change will create water scarcities and where those scarcities will exert the strongest impacts on human society. The project team is using Envision, a modeling framework developed at OSU, to visualize and assess alternative future scenarios. Envision integrates a geographic information system with hydrological, ecological, and socio-economic process models, and user-defined policies that guide land and water management decisions parcel-by-parcel. As Envision steps through time, it generates maps and datasets depicting the interaction of policies with the changing conditions forecasted by the hydrologic, ecological and socio-economic models. The project includes a "stakeholders learning and action network" (SLAN) of agricultural and municipal water users, local public officials and natural resources professionals from federal, state, and local agencies. Currently, the SLAN is meeting with the team scientists to inform and critique the modeling framework and develop realistic policy scenarios. In future years, the SLAN will help analyze model results and convey results to their constituents.

Sources: Personal interview (June 2011); Willamette Water 2100. http://water.oregonstate.edu/ww2100 (accessed 6.29.2011).; Envision. http://envision.bioe.orst.edu<http://envision.bioe.orst.edu/> (accessed 6.29.2011).

1485 *Lawler. (2009, p. 89). The authors cite Hansen et al. (2003) for this information.
1486 *Furniss et al. (2010, p. 51)
1487 *Furniss et al. (2010, p. 51)

Reduce effects of increased flooding and extreme flow

Restore the natural capacity of rivers to buffer climate change impacts

Establishing or restoring ecological buffer zones (buffers) along streams and other water bodies may be done through a variety of methods including land acquisition around rivers[1488] (*Please see the section "Maintain, restore, or create stream and watershed connectivity" for information on land acquisition*), levee setbacks to free the floodplain of infrastructure,[1489] and supporting healthy beaver populations *(Please see the section "Maintain and restore wetlands and riparian areas" for an explanation of supporting and restoring beaver populations)*.

Buffers are similar to setbacks (and may be included within setbacks), but are typically designed to protect the natural, rather than the built, environment.[1490] By protecting natural resources, buffers protect the natural and beneficial functions those resources provide.[1491]

Specifically, buffers are land use regulations designed to reduce the impacts of land uses (e.g., development) on natural resources by providing a transition zone between a resource and human activities.[1492] Typically, buffers are maintained in their natural vegetative state and activities such as vegetation removal, soil disturbance, and construction are restricted or prohibited.[1493]

The effectiveness of any buffer will depend on several factors, including size, elevation, vegetation, slope, soil, permitted activities, adjacent land uses, stormwater flow, and erosion rate.[1494] In addition, effectiveness will also be dependent on property owner compliance and the monitoring and enforcement of buffer regulations.[1495] If drafting new or revised buffer regulations, consider these characteristics as well as how buffers, and the natural resources they protect, might be affected by climate change in the next century.[1496]

> ***Zoning*** can be used to regulate parcel use, density of development, building dimensions, setbacks, impervious surfaces, type of construction, landscaping, etc. It can also be used to regulate where development can and cannot take place. ***Subdivision regulations*** go beyond zoning regulations. They may limit the subdivision of land in inappropriate areas; specify characteristics such as size, shape, orientation, and layout; set standards for infrastructure, open space, buffers, landscaping, and access/egress; and require hazard assessments and the consideration of impacts on neighboring lands.
>
> *Source: NOAA. Adapting to climate change: A planning guide for state coastal managers. (2010a, p. 65-66).*

Protective services (i.e. benefits) include providing habitat and connectivity; minimizing erosion and flooding by stabilizing soil, providing flood storage, and reducing flood velocities; and improving water quality through filtration of harmful sediment, pollutants,

[1488] Palmer et al. (2008, p. 33)
[1489] Palmer et al. (2008, p. 33)
[1490] *NOAA. (2010a, p. 85)
[1491] *NOAA. (2010a, p. 85)
[1492] *NOAA. (2010a, p. 85)
[1493] *NOAA. (2010a, p. 85-86)
[1494] *NOAA. (2010a, p. 86)
[1495] *NOAA. (2010a, p. 86)
[1496] *NOAA. (2010a, p. 86)

and nutrients.[1497] As climate changes, buffers will also be able to support inland wetland migration as well as carbon sequestration.[1498]

Floodplain zoning

Intended to create a healthy, safe, and orderly community while balancing a diversity of interests, ideally as envisioned by a comprehensive plan, zoning is one of the most commonly used methods of regulating land use.[1499]

Floodplain zoning is an example of a zoning application that, if thoughtfully drafted, can provide multiple benefits.[1500] In addition to protecting life and property (and reducing economic risk to communities, states, and the federal government), benefits of floodplain zoning can include resource conservation, open space preservation, public access, and water-quality protection.[1501] Floodplain regulations that just meet the minimum requirements of the National Flood Insurance Program are more focused on how to build safely in the floodplain and may not provide the additional benefits.[1502]

Current regulations may need to be revised to accommodate for new conditions.[1503] A state may want to encourage local governments to review the adequacy of their zoning, make changes and additions as appropriate, and to consider climate change in future zoning decisions.[1504] As the need for new districts arises, model language can help ease the process and advance state interests.[1505]

Flood hazard mapping

Flood hazard maps are prepared for areas adjacent to water bodies to provide land owners, insurers and regulators with information on their risks of flooding from a variety of environmental conditions.[1506] Flood hazard maps are used to plan for and reduce impacts from the riverine and coastal flooding that would likely result from cyclones, heavy rains, storm surges, extreme tides, and tsunamis.[1507] Once the maps are generated, the information can be incorporated into risk reduction procedures (including evacuation and community-based disaster risk reduction plans) or adaptation measures (e.g., construction of flood control structures; establishment of warning systems; formulation of development policies and standards such as setbacks, zoning, building codes, etc.).[1508] Flood hazard maps can also be used to guide development away from sensitive habitats in floodplains, maintain critical ecosystem services (such as flood storage in wetlands), maintain the natural and beneficial function of floodplains, protect public lands, guide development to low hazard areas, and reduce impacts to development.[1509]

[1497] *NOAA. (2010a, p. 85)
[1498] *NOAA. (2010a, p. 86)
[1499] *NOAA. (2010a, p. 65)
[1500] *NOAA. (2010a, p. 65)
[1501] *NOAA. (2010a, p. 65)
[1502] *NOAA. (2010a, p. 65)
[1503] *NOAA. (2010a, p. 66)
[1504] *NOAA. (2010a, p. 66)
[1505] *NOAA. (2010a, p. 66)
[1506] *USAID. *Adapting to coastal climate change: A guidebook for development planners.* (2009, p. 127)
[1507] *USAID. (2009, p. 127)
[1508] *USAID. (2009, p. 127)
[1509] *USAID. (2009, p. 127, 129)

The mapping of flood hazards typically begins by taking observed data or historic information on previous events and combining it with hypothetical information about future events to predict the potential magnitude of flood waters.[1510] This can be done with the use of engineering computer models or through participatory mapping.[1511] Before mapping flood hazards, deciding how the information will be used by communities and governments will determine the technical requirements of the mapping activity and help make a match between budget and the scope of the mapping effort.[1512]

Additional actions

The following adaptation actions for reducing the effects of increased flooding and extreme flow were found in the literature, but are not described in detail or are described elsewhere in this report:

- Remove sediment from reservoirs to increase water storage capacity in short-term[1513]
- Create wetlands and off-channel basins for water storage during times of extreme flows:[1514] This may prevent excess water from reaching reservoirs and reduce downstream flows[1515] and reduce erosion during high flow periods.[1516]
- Close road segments[1517]
- Design culverts to improve connectivity and mobility, e.g. oversize new and replacement culverts:[1518] *Please see the section "Maintain, restore, or create stream and watershed connectivity" for information on improved culvert design.*
- Integrate floodplain management and reservoir operations using Ecosystem-Based Adaptation. *Please see the section "Monitoring, planning, infrastructure, and development" for information on integrating floodplain management and reservoir operations with Ecosystem-Based Adaptation.*

Moderate or reduce water temperature

Release cold water from lakes or reservoirs

Using cold water pools to maintain cooler river temperature is a strategy that is used extensively in California and has been tried with varying degrees of success in BC. [1519] For example, temperature control curtains are a tool to enable the withdrawal of cooler water from a reservoir with thermal stratification and are being used in the Trinity River Reservoir, CA.[1520] They may be a cost effective way of selectively withdrawing cooler water from a reservoir with thermal stratification.[1521] In Cameron Lake (Vancouver Island, BC), a computer system monitors river temperatures and releases water from the weir on the lake

[1510] *USAID. (2009, p. 128)
[1511] *USAID. (2009, p. 128)
[1512] *USAID. (2009, p. 128)
[1513] *Lawler. (2009, p. 87). The authors cite Palmer et al. (2008) for this information.
[1514] *Lawler. (2009, p. 87). The authors cite Palmer et al. (2008) for this information.
[1515] *Lawler. (2009, p. 87). The authors cite Palmer et al. (2008) for this information.
[1516] *Palmer et al. (2008, p. 33)
[1517] *Hayward et al. *Managing fish and wildlife habitat in the face of climate change: USDA Forest Service perspective.* (2009, p. 104)
[1518] *Hayward et al. (2009, p. 104)
[1519] *Nelitz et al. (2007, p. 104)
[1520] *Nelitz et al. (2007, p. 104)
[1521] *Nelitz et al. (2007, p. 104). The authors cite Vermeyen (1997) for this information.

as needed during critical spawning times.[1522] This has resulted in summer water temperatures that are more tolerable to salmon.[1523] Considerations for the use of cold water releases from lakes or reservoirs to reduce water temperatures include:

- There may only be a local effect on temperature[1524]
- Effect on the ecosystem, colder is not always better for all species or communities[1525]
- Engineering challenges & costs of maintaining and accessing cold water source[1526]
- Climate change is expected to result in ecosystems shifting from glacierized or snow dominated to snow or rain dominated.[1527] These changes (i.e. less snow melt and more rain) will affect the cold water source and the methods used to maintain a cold water supply.[1528] For example, a reduction of snowmelt in the Trinity River watershed would mean that greater carryover storage (minimum water level in the reservoir) would be necessary as lowering the level too far warms the reservoir.[1529]

Low-impact forestry practices

A reduction in stream shade is the dominant mechanism by which forestry activities can increase stream temperature.[1530] Maintaining stream shade at natural levels can prevent harvesting-related stream heating.[1531] Riparian buffer strips of approximately 98 feet (~30 m) were found to provide sufficient shading and prevent increases in stream temperature.[1532] However, a recent study of Flat Branch, a perennial second-order tributary of the Tallulah River Watershed in Georgia, found no significant difference in summertime mean or minimum temperature between cut and uncut areas, although a small but statistically significant increase in monthly summer maximum stream water temperature occurred within the cut area following harvest.[1533] Water temperatures were not different from reference levels at the below-cut site.[1534]

Transplant stocks or species to take advantage of differences in physiological characteristics[1535]

A possible strategy given increasing stream temperatures is to transplant temperature tolerant stocks or species to warmer streams.[1536] This strategy could be controversial as it risks the ability to maintain unique stocks (and could result in a decrease in biodiversity or an increase in "non-native" species).[1537]

1522 *Nelitz et al. (2007, p. 104). The authors cite Vermeyen (1997) for this information.
1523 *Nelitz et al. (2007, p. 104). The authors cite Vermeyen (1997) for this information.
1524 *Nelitz et al. (2007, p. 104)
1525 *Nelitz et al. (2007, p. 104)
1526 *Nelitz et al. (2007, p. 104)
1527 *Nelitz et al. (2007, p. 104). The authors cite Stahl (2007) for this information.
1528 *Nelitz et al. (2007, p. 104)
1529 *Nelitz et al. (2007, p. 104). The authors cite Deas (1997) for this information.
1530 *Teti. *Shade and Stream Temperature (website).* (2003/04, p. 4)
1531 *Teti. (2003/04, p. 1)
1532 *Shrimpton et al. *Removal of the riparian zone during forest harvesting increases stream temperature: are the effects cumulative downstream?* (2000, p. 534)
1533 *Clinton et al. *Flat Branch Monitoring Project: Stream water temperature and sediment responses to forest cutting in the riparian zone.* (2010, p. 3)
1534 *Clinton et al. (2010, p. 3)
1535 *Nelitz et al. (2007, p. 40)
1536 *Nelitz et al. (2007, p. 99)
1537 *Nelitz et al. (2007, p. 99)

Experience with transplanting stocks for enhancement has had limited success, so this strategy may be difficult to implement.[1538] Information on species and stock specific environmental thresholds, ranges and ecology is critical to informing management actions.[1539]

Build a groundwater-fed side channel

Groundwater injection to surface waters moderates water temperature and provides flows in rearing channels.[1540] Groundwater-fed side channels are less prone to winter scouring of eggs and juveniles.[1541] They also provide a water supply through the summer.[1542] Considerations to include in building a groundwater-fed side channel include:

- Groundwater source, sufficient space and the right slope, substrate (gravel; clay, sand, and silt do not work)[1543]
- If set up properly, groundwater channels are self-fed and therefore self- sustaining.[1544]

Additional actions

The following adaptation actions for moderating or reducing water temperature were found in the literature, but are not described in detail or are described elsewhere in this report:

- Identify and protect existing thermal refugia[1545]
- Manipulate run-timing to avoid peak temperatures[1546]
- Support and protect ground water resources in the watershed through monitoring and regulation of groundwater extraction and pumping[1547]
- Riparian restoration: Maintaining riparian vegetation is particularly important to help maintain cool stream temperatures.[1548] *Please see the section "Maintain and restore wetlands and riparian areas" for information on riparian restoration.*
- Floodplain restoration: *Please see the previous section "Reduce effects of increased flooding and extreme flow" for information on restoring the natural capacity of rivers to buffer climate change impacts.*
- Protect headwaters: *Please see the section "Preserve habitat for vulnerable species" for information on protecting headwaters.*

Maintain or improve water quality

As described in Chapter 3 Section 5, the most important factors that influence the effects of climate change on water quality are increases in atmospheric and water temperatures and changes in the timing

[1538] *Nelitz et al. (2007, p. 99)
[1539] *Nelitz et al. (2007, p. 99)
[1540] *Nelitz et al. (2007, p. 105)
[1541] *Nelitz et al. (2007, p. 105)
[1542] *Nelitz et al. (2007, p. 105)
[1543] *Nelitz et al. (2007, p. 105)
[1544] *Nelitz et al. (2007, p. 105)
[1545] *Lawler. (2009, p. 87). The authors cite Hansen et al. (2003) this information.
[1546] *Nelitz et al. (2007, p. 99)
[1547] Comment from reviewer (June 2011)
[1548] *Nelitz et al. (2007, p. 106)

and amount of streamflow.[1549] For example, higher surface water temperatures will promote algal blooms and increase the bacteria and fungi content.[1550] In regions where intense rainfall is expected to increase, pollutants (pesticides, organic matter, heavy metals, etc.) will be increasingly washed from soils to water bodies.[1551]

Implement low-impact forestry practices

For example, maintain riparian buffers, avoid steep slopes, and minimize the use of chemicals.[1552] Management of logging roads is another option.[1553] For example:

- Design to minimize sediment input[1554]
- Use crushed rock to reduce surface erosion[1555]
- Install adequate drainage structures and stream crossings[1556]
- Deactivate old logging roads and restore land to its original condition[1557]

Additional actions

The following adaptation actions for maintaining or improving water quality were found in the literature, but were not described in detail or are described elsewhere in this report:

- Develop more effective stormwater infrastructure *e see the section "Climate adaptation actions – infrastructure and development" for information. Pleas on effective stormwater infrastructure.*
- Green infrastructure and low-impact development (LID). *Please see the section "Climate adaptation actions – infrastructure and development" for information on green infrastructure and LID.*
- Support/restore healthy beaver populations. *Please see the section "Maintain and restore riparian areas" for information on healthy beaver populations. It follows the next action/*

Address climate change impacts on glaciers

As one reviewer noted, actions to address climate change impacts on glacier size and abundance are provocative and highly unlikely to be implemented in this region (e.g. spread foam or cloth covering on glaciers in the summer).[1558]

1549 *Pike et al. (2010, p. 728)
1550 *Kundzewicz et al. (2007, p. 188). The authors cite Hall et al. (2002) and Kumagai et al. (2003) for information on algal blooms and Environment Canada (2001) for information on bacteria and fungi content.
1551 *Kundzewicz et al. (2007, p. 188). The authors cite Fisher (2000), Boorman (2003b), and Environment Canada (2004) for this information.
1552 *Nelitz et al. (2007, p. 106)
1553 *Nelitz et al. (2007, p. 106)
1554 *Nelitz et al. (2007, p. 106)
1555 *Nelitz et al. (2007, p. 106). The authors cite Roni et al. (2001) for this information.
1556 *Nelitz et al. (2007, p. 106)
1557 *Nelitz et al. (2007, p. 106)
1558 Personal communication with reviewer, April 2011; Orlove. *Glacier retreat: reviewing the limits of human adaptation to climate change*. (2009, p. 28)

Maintain and restore riparian areas

The riparian ecosystem is particularly important given climate change, since riparian vegetation provides shade which helps to cool tributaries.[1559] In addition, riparian vegetation provides a source of large woody debris which improves the quality of rearing habitat and provides habitat for a number of other wildlife species.[1560]

Restore riparian habitat

River restoration projects can be used to achieve a variety of goals, such as stabilizing eroding banks, repairing in-stream habitat, or promoting fish passages from areas with high temperatures and less precipitation.[1561] However, riparian restoration without ecosystem function restored may require periodic intervention as well as expensive actions such as floodplain grading.[1562] Thus, it is important to conserve the watershed function.[1563] Conserving habitat may be less expensive and more effective than restoring habitat.[1564]

A study by Battin et al. (2007) indicates the success of riparian/watershed restoration may vary based on the elevation of the area to be restored and the climate change impacts projected for the region.[1565] Battin et al. note that projects that rely on the preservation of relatively undisturbed high-elevation streams that derive a significant proportion of their flow from snowmelt may be especially vulnerable to climate change (e.g., the Snohomish Basin in WA), and the intuitively appealing idea that high-elevation watersheds should be the top priority for restoration and preservation in the face of climate change may prove to be incorrect in the region.[1566] However, watersheds at elevations and latitudes higher than those considered in the study may continue to receive most of their winter precipitation as snow and thus respond differently to climate change.[1567] For further information on this study, please see Case Study 4.

Riparian restoration activities may include:

- **Channel reconfiguration, dam removal or retrofit, floodplain restoration, dam-based flow management, and/or bank stabilization:**[1568] Restoring slope stability, for example, prevents slides, erosion, and fine sediment deposition.[1569] It can be done before starting habitat improvements in the main channel.[1570]
- **Restore connectivity with floodplain and channel meander capacity:** One benefit is to create diverse riparian habitat for wildlife, vegetation, and bird species and to provide winter refugia for anadromous fish.[1571]

[1559] *Nelitz et al. (2007, p. 109)
[1560] *Nelitz et al. (2007, p. 109)
[1561] *Palmer et al. (2008, p. 33)
[1562] *Nelitz et al. (2007). The authors cite Orr et al. (2006) for this information.
[1563] *Nelitz et al. (2007, p. 100)
[1564] *Nelitz et al. (2007, p. 100)
[1565] *Battin et al. (2007)
[1566] *Battin et al. (2007, p. 6724)
[1567] *Battin et al. (2007, p. 6724)
[1568] *Lawler. (2009, p. 87)
[1569] *Nelitz et al. (2007, p. 107). The authors cite Hartman et al. (1996) for this information.
[1570] *Nelitz et al. (2007, p. 107). The authors cite Hartman et al. (1996) for this information.
[1571] Comment from reviewer (June 2011).

- **Plant riparian vegetation to restore large woody debris and boulders in stream channels to create deeper pools:**[1572] Planting riparian vegetation provides a long-term source for woody debris and ensures adequate flows to ensure the natural hydrological processes occur to maintain sediment budgets and channel complexity.[1573] It takes fifteen to twenty years to see habitat effects of riparian planting.[1574] A detailed understanding of the timing of seed dispersal and recruitment requirements is needed in order to best determine which plants are most suitable and how to manage the flows most effectively.[1575] There may be tradeoffs between species in terms of the shade they provide and the water they require.[1576] Re-establishing successional processes for pioneer species would require channel meandering with formation of new alluvial surfaces and flow regimes that mimic the natural frequency and timing.[1577] In terms of where to focus riparian planting, interviews conducted by Nelitz et al. (2007) suggest the focus for riparian planting should be in the tributaries.[1578] The impact of shading on large rivers is minimal.[1579] Tributaries will remain cooler with sufficient shading and this will flow into the mainstem providing cold water refuges in the mainstem.[1580] These are used by adult migrating fish as holding areas and they can move between these in order to find an appropriate spawning area.[1581] In terms of specific species to plant, Roni et al. (2002; as cited in Nelitz et al., 2007) suggest planting conifers in riparian zones after disturbances because they provide a better long-term source of woody debris.[1582]
- **Instream habitat enhancement:** There is evidence that instream habitat enhancement may be effective for increasing freshwater productivity for some species.[1583] However they tend to have limited persistence and they should be employed only where short term enhancement is needed.[1584] A more holistic approach is needed in the long term, restoring ecological function so that the instream enhancements are unnecessary (e.g. restore large woody debris).[1585]
- **Additional riparian restoration activities**
    - Use drought-tolerant plant varieties to help protect riparian buffers.[1586]
    - Minimize temperature increases by maintaining well-shaded riparian areas and limiting groundwater withdrawals.[1587]

1572 *TU. *Healing Troubled Waters: Preparing trout and salmon for a changing climate.* (2007, p. 11)
1573 *Nelitz et al. (2007, p. 107). The authors cite USFWS and HVT (1999) for this information.
1574 *Nelitz et al. (2007, p. 109)
1575 *Nelitz et al. (2007, p. 109)
1576 *Nelitz et al. (2007, p. 109)
1577 *Nelitz et al. (2007, p. 109). The authors cite Orr et al. (2006) for this information.
1578 *Nelitz et al. (2007, p. 109). The authors cite Nina Hemphill, Trinity River Restoration Program, pers. comm. for this information.
1579 *Nelitz et al. (2007, p. 109). The authors cite Al von Finster, Fisheries and Oceans Canada, pers. comm. for this information.
1580 *Nelitz et al. (2007, p. 109)
1581 *Nelitz et al. (2007, p. 109). The authors cite Nina Hemphill, Trinity River Restoration Program, pers. comm. for this information.
1582 *Nelitz et al. (2007, p. 109)
1583 *Nelitz et al. (2007, p. 107). The authors cite Roni et al. (2002), Lacey et al. (2004), and Ward et al. (2006) for this information.
1584 *Nelitz et al. (2007, p. 107). The authors cite Roni et al. (2002) for this information.
1585 *Nelitz et al. (2007, p. 107)
1586 *Palmer et al. (2008, p. 33)
1587 *Furniss et al. (2010, p. 51)

- Avoid over-grazing (elk, moose, deer) either via hunting or by restoring populations of predators (e.g. wolves).[1588]
- Prevent excessive livestock grazing and damage to riparian vegetation through exclusion and/or proper grazing management such as rest-rotation.[1589]
- Restore beaver populations[1590]

Protect the assets of Wild and Scenic Rivers

The Wild and Scenic River System was created to protect and preserve the biological, ecological, historic, scenic and other "remarkable" values of U.S. rivers.[1591] In light of climate change impacts and their anticipated effects on habitat, biodiversity, and other ecological assets, it may be useful to emphasize such natural values when designating new Wild and Scenic Rivers.[1592] In addition, where two outstandingly remarkable values are in conflict within the same designated river—as sometimes happens, for example, between habitat and recreational values—an open and fair process in which climate change impacts are considered needs to be used to evaluate the priorities.[1593] Given limited financial and human resources, Palmer et al. (2008) identify actions for the protection of Wild and Scenic River assets under conditions of climatic change:

- Increase monitoring capabilities in order to acquire adequate baseline information on water flows and water quality, thus enabling river managers to prioritize actions and evaluate effectiveness.[1594]
- Increase forecasting capabilities and develop comprehensive scenarios so that the spectrum of possible impacts, and their magnitude, can reasonably be anticipated.[1595]
- Strengthen collaborative relationships among federal, state, and local resource agencies and stakeholders to facilitate the implementation of adaptive river management strategies.[1596] For example, because the agencies administering Wild and Scenic Rivers have little or no authority over dam operations, a proactive collaboration among the agencies involved – at federal, state, and local levels – is critical.[1597]
- Forge partnerships and develop mechanisms to ensure environmental flows for Wild and Scenic Rivers in basins that experience water stress.[1598]
- Work with land use planners to minimize additional development on parcels of land adjacent to Wild and Scenic Rivers, and optimally to acquire floodplains and nearby lands that are not currently federally owned or ensure they are placed in protected status.[1599]
- Build flexibility and adaptive capacity into the Comprehensive River Management Plans for Wild and Scenic Rivers, and update these plans regularly to reflect new information and scientific understanding.[1600]

[1588] Comments from reviewers. (June & July 2011)
[1589] Comment from reviewer. (July 2011)
[1590] Comment from reviewer. (June 2011)
[1591] *Palmer et al. (2008, p. 37)
[1592] *Palmer et al. (2008, p. 37)
[1593] *Palmer et al. (2008, p. 37)
[1594] *Palmer et al. (2008, p. 38)
[1595] *Palmer et al. (2008, p. 38)
[1596] *Palmer et al. (2008, p. 38)
[1597] *Palmer et al. (2008, p. 36)
[1598] *Palmer et al. (2008, p. 38)
[1599] *Palmer et al. (2008, p. 38)

Support/restore healthy beaver populations

Beavers are ecosystem engineers because their building activities can change, maintain, or create habitats by modulating the availability of resources of both biotic and abiotic materials for themselves and for other species.[1601] Similarly, their foraging activity also alters organic material availability, thus creating habitat for other species, because tree felling by beavers for feeding purposes rarely entails the consumption of the whole plant material.[1602] The strength (i.e., magnitude and nature) of beaver impact varies from site to site, depending on the geographical location, relief, and the impounded habitat type.[1603] Consequently, they may not be significant controlling agents of the ecosystem in all parts of their distribution.[1604] According to the Washington Department of Fish and Wildlife (2004), beaver can be reintroduced to any watershed where they have been extirpated within the following parameters:

- The channel is less than 3% slope to minimize dam blow-outs;
- The water supply is perennial or beaver are released on ephemeral streams during a period with sufficient water to create a dam and lodge;
- The stream geomorphology is such that beaver activities will be supported. For example beaver do not seem to colonize as well in volcanic stream systems due to the instability of the channel;
- Beaver will not cause unacceptable damage to public or private property or facilities;
- There is an adequate food source (at least 18 acres of willow or 6 acres of *Populus* species within 100 feet (~30 meters) of the stream) and dam building materials;
- Their activities will not conflict with other management prescriptions, such as endangered species management or instream flow issues;
- The valley is at least 60 feet (~18 meters) wide (150 feet, or ~46 meters, or more is best); and,
- The site is below 6,000 feet (~1828 meters) elevation. The short growing season and heavy snowfall above this elevation may be limiting factors for beaver.[1605]

Implement low-impact livestock grazing practices

Low-impact livestock grazing techniques can include:

- Riparian fencing;
- Rotational grazing;
- Offstream water development (prevents cattle from needing to directly access the river);
- Brush and woody vegetation control/removal;
- Rangeland Water Quality Management Plan;
- Riparian restoration *(Please see the section "Maintain and restore wetlands and riparian areas" for information on riparian restoration.);*

[1600] *Palmer et al. (2008, p. 38)
[1601] *Rosell et al. *Ecological impact of beavers Castor fiber and Castor canadensis and their ability to modify ecosystems.* (2005, p. 248). The authors cite Jones, Lawton & Shachak (1994) and Gurney and Lawton (1996) for this information.
[1602] *Rosell et al. (2005, p. 248)
[1603] *Rosell et al. (2005, p. 248)
[1604] *Rosell et al. (2005, p. 248)
[1605] *WA-DFW. *2004 Stream Habitat Restoration Guidelines: Final Draft: Beaver Re-introduction.* (2004, p. 3). The authors cite McKinstry and Anderson (1999) for problem areas to avoid as well as benefits that landowners feel they receive from beaver. The authors cite Vore et al. (1993) for information on food source, valley width, and maximum elevation.

- Controlled burning; and,
- Native perennial grass restoration.[1606]

Maintain and restore wetlands

Promote or sustain wetland accretion and nourishment

Four options for promoting or sustaining wetland accretion and nourishment are:

- Divert sediments to nourish wetlands.[1607]
- Adopt buffers to reduce potential for erosion and pollution, to keep water temperatures low, and to allow migration of plants and animals.[1608]
- Flood storage to reduce erosion and wash out events: *Please see "Reduced effects of increased flooding and extreme flow) for further information on flood storage.*
- Water recharges to keep water temperatures low and prevent wetland drying: *Please see "Maintain, restore, or increase in-stream flow to address changes in snowpack, runoff, and streamflow regimes" and "Moderate or reduce water temperature" for further information.*

Facilitate wetland migration

Wetland migration is facilitated by identifying wetlands most able to migrate, the sites to which they could migrate, and acquiring lands important for migration (including buffer zones).[1609] Requiring building setbacks from coastal and riparian wetlands is another option,[1610] as is reducing Federal subsidies such as U.S. Coastal Zone Management Act funds and flood insurance in areas that have not established setback or "planned retreat" policies.[1611]

Protect existing wetlands

Existing wetlands may be protected by augmenting and coordinating monitoring of wetlands to test and refine hypotheses about climate change, its effects, and the effectiveness of various management options.[1612] A number of existing and potential Federal policy and regulatory actions are available, including:

- Implement and oversee the no-net-loss policy;
- Expand coverage and strengthen enforcement of U.S. Clean Water Act Section 404 to protect all wetlands and to account for plausible effects of climate change;
- Design Federal projects to incorporate climate change predictions and safeguard water and sediment flow to wetlands; and,
- Eliminate Federal incentives for wetland destruction.[1613]

[1606] *Nelitz et al. (2007, p. 106)
[1607] *ASWM. (2009, p. 12)
[1608] *ASWM. (2009, p. 11)
[1609] *OTA. (1993, p. 197)
[1610] *OTA. (1993, p. 197)
[1611] *OTA. (1993, p. 197)
[1612] *OTA. (1993, p. 197)
[1613] *OTA. (1993, p. 197)

Requiring direct payments or traded obligations and acquiring key wetlands that may be lost soon are additional options.[1614] For example, developing a list of high-priority wetlands within an integrated resource management framework would help direct funds to areas and wetland types that are either insufficiently protected now or that could be especially vulnerable to climate change.[1615]For further information on prioritizing wetlands with large carbon stores, please see the adaptation action that follows this one *"Prioritize retention/protection of wetlands with large carbon stores."*

Prioritize retention/protection of wetlands with large carbon stores

Unless already known, wetland prioritization could begin by identifying wetlands with strong restoration potential under climate change conditions.[1616] For example, wetlands with deep carbon deposits could be identified and targeted for acquisition or more stringent regulations.[1617] Another route is to use existing watershed plans and other land use planning to determine the processes and actions needed to increase the resistance and resilience of wetlands and watersheds in the face of climate change.[1618] The Association of State Wetland Managers (2009) suggests regulatory agencies at all levels of government should amend regulations to better protect wetland carbon stores.[1619] Further, permittees should be required to estimate carbon impacts in seeking permits, and mitigation and compensation measures should be required.[1620]

Additional actions

The following adaptation actions for maintaining and restoring wetlands were found in the literature, but are described elsewhere in this report:

- Restore degraded or converted wetlands: Restoration of degraded or converted wetlands may include removal of hard engineering structures that degrade wetlands and restoration of more naturally regulated water and sediment flow.[1621] Fully funding existing restoration programs helps facilitate wetland restoration.[1622]
- Improve coordinated management and monitoring: *Please see the section "Climate adaptation actions – monitoring and planning" for information on improving coordinated management and monitoring.*
- Incorporate climate change into wetland restoration planning: *Please see the section "Climate adaptation actions – monitoring and planning" for information on incorporating climate change into wetland restoration planning.*
- Promote wetland connectivity and persistence: *Please see the section "Maintain, restore, or create stream and watershed connectivity" for information on promoting wetland connectivity and persistence.*

[1614] *OTA. (1993, p. 199)
[1615] *OTA. (1993, p. 199)
[1616] *ASWM. (2009, p. 11)
[1617] *ASWM. (2009, p. 11)
[1618] *ASWM. (2009, p. 12)
[1619] *ASWM. (2009, p. 12)
[1620] *ASWM. (2009, p. 12)
[1621] *OTA. (1993, p. 197)
[1622] *OTA. (1993, p. 197)

Maintain and restore lake shorelines

Note to the reader: These actions are culled from a City of Seattle guidebook, and can be applied to homes all around Lake Washington (WA).[1623] Additionally, most of the information is relevant to Lake Samammish (WA),[1624] and may be relevant for similar lakes in other areas of the NPLCC.

The actions listed here are examples of alternatives to armored shorelines (e.g. concrete, riprap, sheetpile, or another type of bulkhead) known as Green Shorelines.[1625] A cost-comparison of armored and Green shorelines is found in Table 19, and a decision-tree for selecting one or more of the actions described below can be found in Figure 30 (see p. 199 and 200, respectively).

Install or restore full beaches

On the right site (see Figure 30), beach restoration can be straightforward:[1626]

1. **Remove the bulkhead:** The costs of removing a bulkhead depend on the site's accessibility and the type of bulkhead, as shown in Table 18.

Table 18. Bulkhead removal costs per linear foot.
Reproduced from Seattle Department of Planning and Development (DPD). (n.d., p. 25) by authors of this report.

Site Access	*Bulkhead material (removal)*		
	Wood	Riprap	Concrete
Accessible from land and water	$30-40	$45-60	$95-110
Accessible from water only	$40-55	$55-80	$100-125

2. **Lay back the slope to a stable angle:** Beach slope is a critical component of a successful restoration project.[1627] A well-designed slope provides resistance to erosion, reducing the need for maintenance.[1628] Slopes of 7:1 or flatter are ideal (seven horizontal feet for each vertical foot), but slopes up to 4:1 can be stable in some circumstances.[1629]
3. **Add appropriate gravel and plants:** New beaches should be made of an appropriate gravel material.[1630] Although people tend to think of sand when they think of shorelines, sand erodes quickly in most parts of Lake Washington.[1631] Instead, use clean, well-rounded gravel 1/8" to 2" size – specifics will depend on wave energy and your proximity to known sockeye spawning grounds.[1632] Contact the Washington State Department of Fish and Wildlife to learn about

[1623] *Seattle-DPD. *Green Shorelines: Bulkhead Alternatives for a Healthier Lake Washington.* (n.d., p. 2)
[1624] *Seattle-DPD. (n.d., p. 2)
[1625] *Seattle-DPD. (n.d.)
[1626] *Seattle-DPD. (n.d., p. 6)
[1627] *Seattle-DPD. (n.d., p. 7)
[1628] *Seattle-DPD. (n.d., p. 7)
[1629] *Seattle-DPD. (n.d., p. 7)
[1630] *Seattle-DPD. (n.d., p. 7)
[1631] *Seattle-DPD. (n.d., p. 7)
[1632] *Seattle-DPD. (n.d., p. 7)

requirements.[1633] If sand is desired it should either be placed well above the water line or physically separated from the gravel beach using stone or wood.[1634]

Additionally, a successful design for a restored beach must address how the beach will meet neighboring properties.[1635] This is not a concern if neighbors already have or are restoring their own beaches, but it is necessary to plan how the edges of a beach will meet any neighboring bulkheads.[1636] There are two strategies for meeting adjacent bulkheads:

- Install rocks, wood, plantings, or concrete walls at the edges of your beach to reinforce the transition area from beach to bulkhead – these areas will be subject to greater erosive forces.[1637]
- Add extra fill below the water line at the edges of the property – this protects the beach from the erosive forces of neighboring bulkheads and protects the bulkheads from undercutting.[1638] For shoreline restoration purposes, twenty-five cubic yards of fill are allowed outright in the water so long as they do not create dry land.[1639] More may be approved depending on site conditions.[1640]

Some erosion to beaches is normal over time.[1641] This can be offset by beach nourishment, the periodic addition of gravel.[1642] When a project is designed and installed properly, some nourishment is likely to be necessary every five to ten years.[1643] To make beach nourishment easier, it is ideal to include periodic fill as part of the maintenance plan in the initial construction permit.[1644] This can help avoid needing to obtain a local permit to add gravel to the beach in the future.[1645] If nourishment is not covered in the initial permit, a shoreline exemption for each instance of beach nourishment will need to be obtained.[1646] Time and costs for this process depends on the local jurisdiction.[1647]

<u>Install or restore beach coves</u>

A beach cove is a beach along a portion of a property's waterfront, flanked on both sides with hard structural elements.[1648] This is a useful strategy to improve habitat quality and water access while keeping armoring if it is necessary.[1649] Like full beaches, beach coves should use appropriately sized gravel, and typically not sand.[1650] Beach nourishment will be needed with about the same frequency as with a full beach restoration (every five to ten years), but less fill is needed since the beach area is smaller.[1651]

[1633] *Seattle-DPD. (n.d., p. 7)
[1634] *Seattle-DPD. (n.d., p. 7)
[1635] *Seattle-DPD. (n.d., p. 7)
[1636] *Seattle-DPD. (n.d., p. 7)
[1637] *Seattle-DPD. (n.d., p. 7)
[1638] *Seattle-DPD. (n.d., p. 7)
[1639] *Seattle-DPD. (n.d., p. 7)
[1640] *Seattle-DPD. (n.d., p. 7)
[1641] *Seattle-DPD. (n.d., p. 7)
[1642] *Seattle-DPD. (n.d., p. 7)
[1643] *Seattle-DPD. (n.d., p. 7)
[1644] *Seattle-DPD. (n.d., p. 7)
[1645] *Seattle-DPD. (n.d., p. 7)
[1646] *Seattle-DPD. (n.d., p. 7)
[1647] *Seattle-DPD. (n.d., p. 7)
[1648] *Seattle-DPD. (n.d., p. 8)
[1649] *Seattle-DPD. (n.d., p. 8)
[1650] *Seattle-DPD. (n.d., p. 8)
[1651] *Seattle-DPD. (n.d., p. 8)

Localized erosion can occur where the bulkhead meets the beach on either side of the cove.[1652] Two techniques that help prevent this from happening include:

- Angling the ends of the bulkhead away from the water to dissipate wave energy and decrease erosion, and
- Adding extra gravel fill below the water line to help prevent undercutting of the bulkhead.[1653]

As with full beaches, beach cove slopes should typically be no steeper than 4:1, i.e. four horizontal feet to one vertical foot (7:1 is a good goal, but steeper slopes can be stable when appropriate materials are used).[1654] Beach coves provide less shoreline for wading and other beach activities, and they do less to improve habitat.[1655] While fish biologists have observed juvenile salmon using pocket beaches around Lake Washington, research suggests that the fish gravitate to larger beaches and plantings when they are available.[1656]

Set back bulkheads

If there is not an adequate setback between the water line and the house, a bulkhead may be necessary to protect houses or other structures.[1657] In many cases, however, the bulkhead can be moved back from the high water mark, providing benefits to the homeowner and the lake ecosystem.[1658] Part of the bulkhead can be set back to create a reinforced beach cove, or the whole thing can be set back to create a new beach all across the shoreline.[1659]

Whether setting a bulkhead back or replacing it in the same location, angling back the batter (the slope of the bulkhead) is generally a good idea.[1660] With every wave that hits it, a vertical bulkhead reflects most of the wave energy back into the lake.[1661] This leads to turbulence and erosion, which results in deeper water at the bulkhead's base.[1662] A sloped bulkhead does a better job of absorbing and dissipating energy, creating less erosion and lengthening the service life of the investment.[1663] For Lake Washington, engineers generally recommend a bulkhead slope of 3:1 where site constraints will allow it.[1664]

Install logs

Logs can provide strategically placed "hard engineering" structural reinforcement while complementing the aesthetic of a more natural beach project, and, in some cases, enhancing ecological function.[1665] Logs

1652 *Seattle-DPD. (n.d., p. 8)
1653 *Seattle-DPD. (n.d., p. 8)
1654 *Seattle-DPD. (n.d., p. 8)
1655 *Seattle-DPD. (n.d., p. 8)
1656 *Seattle-DPD. (n.d., p. 8)
1657 *Seattle-DPD. (n.d., p. 10)
1658 *Seattle-DPD. (n.d., p. 10)
1659 *Seattle-DPD. (n.d., p. 10)
1660 *Seattle-DPD. (n.d., p. 11)
1661 *Seattle-DPD. (n.d., p. 11)
1662 *Seattle-DPD. (n.d., p. 11)
1663 *Seattle-DPD. (n.d., p. 11)
1664 *Seattle-DPD. (n.d., p. 11)
1665 *Seattle-DPD. (n.d., p. 12)

must be anchored securely in place.[1666] There are several ways to secure a log, but it is most commonly done using duckbill anchors and cables or by partially burying the log.[1667]

Logs used for habitat enhancement should be as complex as possible, with root wads and some branches still attached.[1668] Some restoration efforts have installed logs perpendicular to the shoreline to enhance fish habitat.[1669] Logs in the water can improve nearshore habitat by creating salmon refuge areas.[1670] However, they should not extend beyond a depth of two feet (~0.6 meters) below ordinary high water.[1671] Anything beyond this is thought to create habitat for predator fish species that prey on salmon.[1672] In some cases, logs are not allowed to extend horizontally beyond the water line, since they can interfere with natural movement of sediments.[1673]

Install or restore vegetated buffers

Diverse shoreline plantings contribute to aquatic habitat in several important ways:

1. Vegetation provides diffuse shade to the water's edge, creating conditions that help juvenile fish blend in with their surroundings;
2. They restore natural food web processes to the shoreline – plants are home to insects and other small organisms, which become fish food when they fall into the water;
3. They provide twigs, branches and leaves, which create important refuges from birds and bigger fish; and,
4. Planted strips protect water quality by filtering excess nutrients and other contaminants from stormwater.[1674]

Considerations for planting vegetated buffers include:

- **Buffer width:** This depends on what your lot can accommodate.[1675] While bigger is better, even a few feet can provide benefits.[1676] For most new residences along Lake Washington, Seattle requires at least a 25' building setback.[1677] This means a 5-10' vegetated buffer can easily fit on most sites, and 15-20' is often feasible.[1678]
- **Type and location of plants:** Native plants are ideal, not only because they often have lower water and maintenance needs, but also because they help draw birds and beneficial insects to the yard.[1679] Ideally, shrubs and perennials should be directly adjacent to the water's edge, overhanging the lake wherever possible.[1680] When a property has a bulkhead, however, trees and

[1666] *Seattle-DPD. (n.d., p. 13)
[1667] *Seattle-DPD. (n.d., p. 13)
[1668] *Seattle-DPD. (n.d., p. 13)
[1669] *Seattle-DPD. (n.d., p. 13)
[1670] *Seattle-DPD. (n.d., p. 13)
[1671] *Seattle-DPD. (n.d., p. 13)
[1672] *Seattle-DPD. (n.d., p. 13)
[1673] *Seattle-DPD. (n.d., p. 13)
[1674] *Seattle-DPD. (n.d., p. 14)
[1675] *Seattle-DPD. (n.d., p. 14)
[1676] *Seattle-DPD. (n.d., p. 14)
[1677] *Seattle-DPD. (n.d., p. 14)
[1678] *Seattle-DPD. (n.d., p. 15)
[1679] *Seattle-DPD. (n.d., p. 14)
[1680] *Seattle-DPD. (n.d., p. 14)

large shrubs need to be sited carefully to prevent damage to shoreline armoring.[1681] Black cottonwood, for example, is an ideal tree to plant next to beach areas, but its vigorous root system could cause problems for a riprap bulkhead.[1682]

- **Use of emergent plants:** Emergent plants provide excellent habitat and erosion control, but they often struggle on Lake Washington due to the lake's unusual hydrological conditions – the lake's water level is managed at the Ballard Locks such that high water occurs in the summer and low water occurs in the winter.[1683] Emergent plants may work well in protected parts of Lake Washington, or areas with shallow nearshore slopes.[1684]
- **Permitting:** As long as all plants are placed above the high water mark, no permits are necessary to plant shoreline vegetation.[1685]

Conduct slope bioengineering

Slope bioengineering is a term used for an array of different techniques that use plant material as a self-renewing, ecologically sustainable way to hold soil and gravel in place.[1686] These "soft engineering" techniques are commonly used in parks and natural areas for ecological restoration projects, but they may also be used on residential properties.[1687] Cuttings should be collected from an approved site – in Washington, the city parks department or Department of Natural Resources can be contacted for information.[1688] Permits are required for any slope bioengineering installations at or below ordinary high water.[1689] Examples of these techniques include:

- **Live stakes:** Live stakes are a key element of almost all bioengineering projects.[1690] These are cuttings from plants that will grow roots when inserted into moist ground.[1691] Willows, dogwoods, and other shoreline species adapted to reproduce through cuttings are all viable candidates.[1692] Live stakes can be a simple and cost-effective way to bind soil in place and provide plant cover.[1693]
- **Fascines:** Fascines are long bundles of thin branches, tightly bound with twine.[1694] They are partially buried in trenches parallel to incoming waves and "nailed" into place with live stakes.[1695] These thick masses of branches provide immediate structural support, catch sediment coming from upslope, and can establish their own roots and new growth.[1696] Since they are usually

[1681] *Seattle-DPD. (n.d., p. 14)
[1682] *Seattle-DPD. (n.d., p. 14)
[1683] *Seattle-DPD. (n.d., p. 14)
[1684] *Seattle-DPD. (n.d., p. 14)
[1685] *Seattle-DPD. (n.d., p. 14)
[1686] *Seattle-DPD. (n.d., p. 16)
[1687] *Seattle-DPD. (n.d., p. 16)
[1688] *Seattle-DPD. (n.d., p. 17)
[1689] *Seattle-DPD. (n.d., p. 17)
[1690] *Seattle-DPD. (n.d., p. 17)
[1691] *Seattle-DPD. (n.d., p. 17)
[1692] *Seattle-DPD. (n.d., p. 17)
[1693] *Seattle-DPD. (n.d., p. 17)
[1694] *Seattle-DPD. (n.d., p. 17)
[1695] *Seattle-DPD. (n.d., p. 17)
[1696] *Seattle-DPD. (n.d., p. 17)

composed of several different species, the resultant growth comes in as a thicket of mixed plants.[1697] For this reason, fascines should be placed carefully to avoid blocking views.[1698]

- **Live revetment:** Live revetment is used to stabilize steep banks.[1699] Geotextile fabric holds earth-filled terraces in place.[1700] Further structural support is provided by live stakes driven through the fabric.[1701]

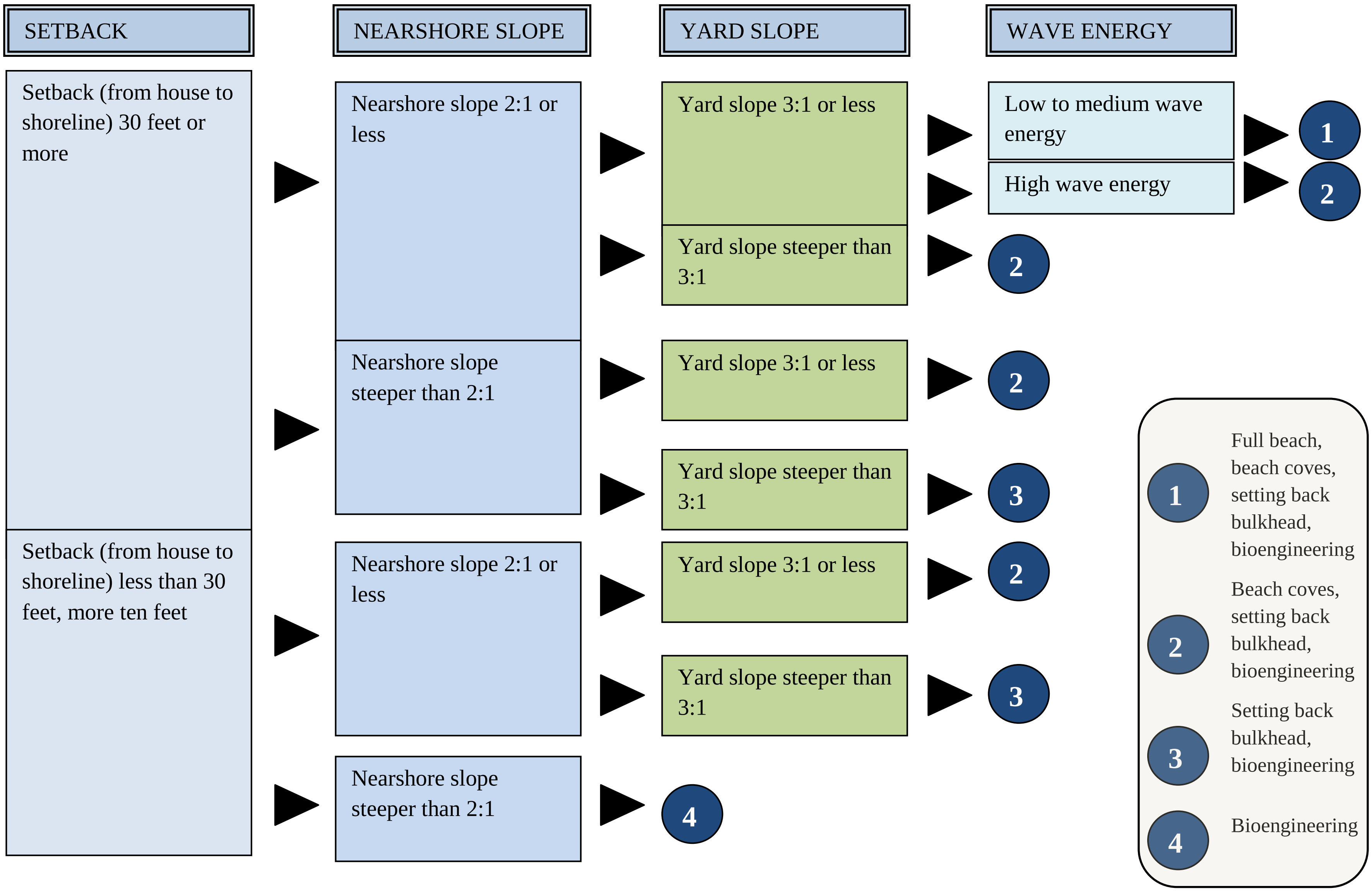
Table 19. Shoreline construction costs (as of 2008).
Reproduced from Seattle DPD (n.d., p. 25) by authors of this report.

	Conventional Treatments		**Green Shorelines**		
Cost Category	***Solid bulkheads***	***Riprap***	***Beach Establishment***	***Slope bioengineering***	***Docks***
Capital Costs (per linear foot, except where indicated otherwise)	Average rock or concrete bulkhead is \$350 to \$400, sheetpile is \$800+	Average riprapped bank is \$125 to \$200 feet	Average beach establishment is \$200 to \$500	Average bioengineering project is \$200 to \$500	Average new dock costs \$100 to \$130 per square foot
Design and Permitting	10-15% of capital costs for larger projects (greater than \$100K), 20-25% for smaller projects		7-12% of capital costs for larger projects (greater than \$100K), 15-20% for smaller projects		Similar to bulkheads
Maintenance	No maintenance is usually required for 25-50 year life span of projects		Sand replenishment at a 1-5 year frequency, gravel at a 5-10 years, both \$3 to \$6 per square foot of beach – with proper maintenance, project can last indefinitely		Similar to bulkheads

1697 *Seattle-DPD. (n.d., p. 17)
1698 *Seattle-DPD. (n.d., p. 17)
1699 *Seattle-DPD. (n.d., p. 17)
1700 *Seattle-DPD. (n.d., p. 17)
1701 *Seattle-DPD. (n.d., p. 17)

Figure 30. Green Shorelines Decision Tree *Reproduced from Seattle DPD (n.d., p. 21) by authors of this report.*

Notes: The use of plant buffers or logs is a viable option for any site, including those that employ hard engineering such as bulkheads. Sites with less than a ten foot setback are not included on this decision tree, because in most cases they will depend on concrete, sheetpile, or riprap.



Maintain, restore, or create stream and watershed connectivity

These strategies address the fragmentation, drying, and/or loss of wetlands and wetland habitat due to increased air temperatures, reduced soil moisture, and other stressors.

Promote connectivity and persistence in streams, wetlands, floodplains, and watersheds

Connectivity and persistence can be promoted in a number of ways. For example, re-establishing and maintaining corridors permits migration of plant and animal species.[1702] Since drainage is only partially regulated at federal, state and local levels, controlling wetland drainage would better protect wetland functions and values, as well as protecting carbon stores and carbon sequestering ability.[1703] Similarly, installing water control structures at the outlets of freshwater wetlands may help maintain water levels during dry periods; however, it may be quite expensive, will require maintenance, and will interrupt natural successional cycles.[1704]

In other areas of the watershed, e.g. in streams and floodplains, the following strategies are also available:

- Protect and restore longitudinal connectivity of stream systems to provide species with access to habitats that may be disconnected by changes in flow regime.[1705]
- Improve lateral channel-floodplain connectivity where human disturbance has isolated channels.[1706]

Move dikes back from rivers

Constraints such as dikes prevent natural alluvial processes including meandering, scouring, flooding and sediment transport and create channelized simple rivers.[1707] Setting dikes back allows rivers to meander naturally, restoring connectivity of the river channel to the floodplain.[1708] Complex river channels have significantly more habitat for a range of species and are necessary to maintain ecosystem function.[1709] This strategy is easier in less developed regions, where the floodplain land is not owned by private owners and there are fewer concerns with flooding.[1710] In the Trinity River (CA), dikes are being removed and floodplains are being bought in order to allow the natural alluvial processes to occur.[1711] *For further information on adaptation actions for barriers such as dikes, see "Maintain, restore, or increase in-stream flow to address changes in snowpack, runoff, and streamflow regimes" in this Chapter. For further information on floodplain and wetland restoration, please see "Reduce effects of increased flooding and extreme flow" and "Maintain and restore wetlands," respectively, in this Chapter.*

[1702] *ASWM. (2009, p. 11-12)
[1703] *ASWM. (2009, p. 12)
[1704] *ASWM. (2009, p. 12)
[1705] *Furniss et al. (2010, p. 51)
[1706] *Furniss et al. (2010, p. 51)
[1707] *Nelitz et al. (2007, p. 109). The authors cite USFWS and HVT (1999), and Howie Wright, Okanagan Nation Alliance, pers. comm. for this information.
[1708] *Nelitz et al. (2007, p. 109)
[1709] *Nelitz et al. (2007, p. 109)
[1710] *Nelitz et al. (2007, p. 109)
[1711] *Nelitz et al. (2007, p. 109). The authors cite USFWS and HVT (1999), and Howie Wright, Okanagan Nation Alliance, pers. comm. for this information.

Remove perched culverts or other artificial obstructions

One way to increase amount of freshwater habitats is by removing barriers (e.g., culverts) to allow access to previously utilized areas as well as to areas that may not have had salmon (and other species) previously.[1712] This strategy is used throughout the Pacific Northwest and in California where individual projects are tracked by a FishXing project team (see www.stream.fs.fed.us/fishxing/case.html, accessed 7.10.2011).[1713]

Considerations for culvert removal or redesign include:

- Culverts designed for adult passage often create water velocities that exceed juvenile salmon swimming abilities and prevent juvenile fish from reaching important rearing areas.[1714]
- Smooth culverts lacking roughness or baffles normally impair juvenile fish passage except at very low slopes.[1715]
- Culverts may affect coho in particular because they tend to use smaller streams where there is not as much flow.[1716]
- Culverts affect the movement of nutrients up and downstream.[1717]

Networks of protected areas

Extensive networks of protected areas provide the most efficient way of conserving biodiversity in the face of climate change.[1718] An integrated approach for both freshwater and terrestrial ecosystems is likely to be the most fruitful avenue for conserving wholesale biodiversity in reserve networks.[1719] Given that currently protected areas are typically delineated based on the representation of terrestrial ecosystems and a low number of taxonomic groups (e.g. vascular plants and terrestrial vertebrates), it is unclear if freshwater biodiversity is adequately protected in current protected areas network, and if future shifts in freshwater species' ranges could be accommodated by these areas.[1720] To be efficient for freshwater organisms, protected areas should be based on the characteristics of freshwater ecosystems and the requirements of freshwater organisms.[1721] For example, taking a catchment perspective instead of strict conservation of terrestrial areas that can be easily bounded and protected would be more desirable for conserving freshwater biodiversity.[1722]

[1712] *Nelitz et al. (2007, p. 108)
[1713] *Nelitz et al. (2007, p. 108). The authors cite Nina Hemphill, Trinity River Restoration Program, pers. comm. for this information.
[1714] *Nelitz et al. (2007, p. 108). The authors cite Furniss et al. (1991) for this information.
[1715] *Nelitz et al. (2007, p. 108). The authors cite Robison (1999) as cited in Roni et al. (2002) for this information.
[1716] *Nelitz et al. (2007, p. 108). The authors cite Roni et al. (2002) for this information.
[1717] *Nelitz et al. (2007, p. 108). The authors cite Roni et al. (2002) for this information.
[1718] *Heino, Virkkala and Toivonen. *Climate change and freshwater biodiversity: detected patterns, future trends and adaptations in northern regions.* (2009, p. 49)
[1719] *Heino, Virkkala and Toivonen. (2009, p. 49). The authors cite Abell (2002) for this information.
[1720] *Heino, Virkkala and Toivonen. (2009, p. 49)
[1721] *Heino, Virkkala and Toivonen. (2009, p. 49). The authors cite Saunders, Meeuwig, and Vincent (2002), Toivonen, Leikola and Kallio (2004), and Abell et al. (2007) for this information.
[1722] *Heino, Virkkala and Toivonen. (2009, p. 49). The authors cite Dudgeon et al. (2006) for this information.

Dispersal corridors

Dispersal corridors are vital for species to track changes in climatic conditions.[1723] This is especially relevant for freshwater organisms that rely on rivers and streams for successful dispersal among water bodies.[1724] Even for more highly dispersive species (e.g. insects with a winged terrestrial adult stage and small organisms that survive passive overland dispersal), the distances between suitable water bodies are likely to be important with regard to their chances of tracking climate change.[1725] In the natural settings of formerly glaciated northern regions, for example, lakes are typically numerous and generally highly interconnected by streams, facilitating the movements of species in response to climate change after these northern regions have been reached by freshwater species.[1726]

Management of the matrix between protected areas

Because a great majority of freshwater ecosystems are located outside protected areas and affect those in protected areas, the matrix and its adaptive management is likely to be as important as the protection of new areas for biodiversity conservation.[1727] This would entail planning land use so that harmful influences from built-up areas, agriculture, and forestry do not degrade the state of freshwater ecosystems.[1728]

> ***A conservation easement*** is a legal agreement between a landowner and a land trust or government agency that can be used to restrict development in sensitive and hazard-prone areas. A conservation easement program is likely to be most effective when it has strong planning and outreach components that identify lands that would benefit from easements and inform property owners about easements and their benefits.
> *Source: NOAA. (2010a, p. 67-68)*

Land exchange and acquisition

Land acquisition may enhance floodplain extent and buffer river segments from impacts in the surrounding watershed, and could provide replication in space of at-risk habitats and refugia for species.[1729] For example, where Wild and Scenic Rivers contain naturally occurring refugia, additional river reaches could be acquired.[1730]

A land exchange program, such as a conservation easement, typically transfers some development and management options – such as the right to subdivide or to cut trees – from the landowner to a nonprofit or governmental organization that holds those rights.[1731] The landowner reserves certain rights, such as the right to build additional homes or add roads and also continues to own the property and manage it within the bounds set by the easement.[1732] The easement holder is responsible for monitoring and enforcing easement specifications.[1733] A conservation easement program is likely to be most effective when it has strong

[1723] *Heino, Virkkala and Toivonen. (2009, p. 49)
[1724] *Heino, Virkkala and Toivonen. (2009, p. 49)
[1725] *Heino, Virkkala and Toivonen. (2009, p. 49)
[1726] *Heino, Virkkala and Toivonen. (2009, p. 49). The authors cite Poff et al. (2002) for this information.
[1727] *Heino, Virkkala and Toivonen. (2009, p. 50)
[1728] *Heino, Virkkala and Toivonen. (2009, p. 50)
[1729] *Palmer et al. (2008, p. 34)
[1730] *Palmer et al. (2008, p. 33)
[1731] *Merenlender et al. *Land trusts and conservation easements: Who is conserving what for whom?* (2004, p. 67)
[1732] *Merenlender et al. (2004, p. 67)

planning and outreach components that identify lands that would benefit from easements and inform property owners about easements and their benefits.[1734]

Landowners who donate their easement may be eligible for federal or state tax breaks.[1735] Easements typically apply in perpetuity and are passed on from owner to owner.[1736] Most are placed on individual properties, but they may also be placed on subdivisions or coordinated at a regional scale (e.g., to more effectively manage a strip of land or accommodate wetland migration).[1737]

Case Study 2. Limits to floodplain development: the National Flood Insurance Program and National Marine Fisheries Service Biological Opinion, Puget Sound, WA.

Climate impacts addressed: Increased flooding. Changes in snowpack, runoff, and streamflow regimes. Increased water pollution and corresponding changes in water quality. Increased water temperature.

Description: The National Flood Insurance Program was created by Congress to provide flood insurance for properties that private insurers were unwilling to cover. One of the primary goals of the program is to reduce long-term vulnerability to floods. However, the government-subsidized insurance, combined with sometimes inaccurate floodplain maps and inadequate risk reduction requirements, has instead resulted in continued floodplain development and redevelopment in flood risk areas and degraded habitat for fish and wildlife, including federally protected species under the Endangered Species Act. For example, the National Marine Fisheries Service released a Biological Opinion in 2008 stating that floodplain development supported by the National Flood Insurance Program in Puget Sound (WA) is jeopardizing the continued existence of Puget Sound Chinook salmon, Puget Sound steelhead, Hood Canal summer-run chum salmon, and Southern Resident killer whales, and is likely to adversely modify Puget Sound Chinook salmon, Hood Canal summer-run chum salmon, and Southern Resident killer whale critical habitat. To be ESA-compliant, the National Flood Insurance Program must prevent further harm to salmon habitat by including enhanced development restrictions in the floodway, channel migration zone and riparian buffer area. These development restrictions create an opportunity to restore valuable floodplain functions and reconnect floodplains to upland stream and riparian habitats, thereby improving water quality, preserving habitat for vulnerable species, and reducing flood risk from increasingly severe storms.

Sources: *National Marine Fisheries Service. (September 22, 2008). Puget Sound Biological Opinion; Hewes & Fahlund. (2011). Weathering Change: Policy reforms that save money and make communities safer.*

[1733] *Merenlender et al. (2004, p. 67)
[1734] *NOAA. (2010a, p. 68)
[1735] *NOAA. (2010a, p. 68)
[1736] *NOAA. (2010a, p. 68)
[1737] *NOAA. (2010a, p. 68)

Preserve habitat for vulnerable species

Protect large and environmentally heterogeneous areas

Because large and heterogeneous areas are more likely to incorporate a wider array of different types of lentic (e.g. lakes and ponds) and lotic (e.g. streams and rivers) ecosystems than smaller and more homogenous areas, this approach should lead to preservation of much of regional freshwater biodiversity.[1738] Large protected areas should also accommodate larger parts of whole catchments that are of vital importance for the functioning of freshwater ecosystems and harboring diverse ecological communities.[1739] More heterogeneous protected areas, for example, in terms of mountainous and lowland areas would also provide possibilities for freshwater organisms to track suitable temperature conditions following climate change.[1740] *Please see the section "Maintain, restore, or create stream and watershed connectivity" for additional methods that may allow freshwater organisms to track suitable temperature conditions.*

Support open-space preservation and conservation

Open space preservation and conservation can be accomplished through the management of lands dedicated as open space through a number of the measures, e.g. zoning, redevelopment restrictions, acquisition, easements, setbacks, and buffers (*Please see the sections "Reduce the effects of increased flooding and extreme flow" for information on floodplain zoning, easements, and buffers and "Maintain, restore, or create stream and watershed connectivity" for information on land acquisition*).[1741] While there are costs associated with the management of open space, the public expenditures may be lower than if the land was developed and the provision of full services was required.[1742] Management costs could be defrayed by transferring the title to a nonprofit conservation organization.[1743]

Open space management plans can be developed to guide the acquisition and use of open space in a manner that fulfills multiple community objectives (e.g., trails, athletic fields, campgrounds, community gardens, wildlife refuges, environmental education centers, etc.).[1744] Any such plan should consider the impacts and consequences of climate change, sea level rise and flooding in particular, to ensure that investments are wisely made (land purchase as well as use and amenity placement).[1745] Open space management should also consider the key role of open space in green infrastructure and wetland migration programs (*Please see the section "Maintain or improve water quality" for information on green infrastructure and "Maintain and restore wetlands" for information on wetland migration.*).[1746]

[1738] *Heino, Virkkala and Toivonen. (2009, p. 49)
[1739] *Heino, Virkkala and Toivonen. (2009, p. 49). The authors cite Pringle (2001) and Dudgeon et al. (2006) for this information.
[1740] *Heino, Virkkala and Toivonen. (2009, p. 49)
[1741] *NOAA. (2010a, p. 86)
[1742] *NOAA. (2010a, p. 86)
[1743] *NOAA. (2010a, p. 86)
[1744] *NOAA. (2010a, p. 86-87)
[1745] *NOAA. (2010a, p. 87)
[1746] *NOAA. (2010a, p. 87)

Case Study 3. Climate Change and the Salmon Stronghold Approach.

Climate stressors addressed: Changes in snowpack, runoff, and streamflow regimes. Increased water pollution and corresponding changes in water quality. Increased water temperature.

Description Since 2008, a consortium of federal, state, private, and tribal partners has been collaborating to identify "wild salmon strongholds" throughout California, Oregon, Washington, and Idaho. Salmon strongholds refer to a watershed or watersheds that meet(s) biological criteria for abundance, productivity, genetic and life history diversity, habitat quality, and other biological attributes necessary to sustain viable wild salmon populations across their range. In addition to containing key areas of refugia and populations that can anchor regional salmon recovery efforts, strongholds promote a range of vital ecosystem services – including clean water, carbon sequestration, flood control, and recreation to name just a few. Because they contain extensive intact habitats, which promote a wide range of life history and genetic diversity, strongholds also represent some of the most resilient salmon ecosystems in the face of changing watershed conditions. Among the many changes confronting the rivers of California and the Pacific Northwest, altered streamflow regimes, increasing water temperatures, and shifting food webs pose some of the greatest threats to wild salmon populations.

The identification of salmon strongholds is part of a broader effort being led by the North American Salmon Stronghold Partnership to protect a network of the healthiest remaining wild Pacific salmon ecosystems in North America to ensure the long term survival of salmon, steelhead, and the many species that depend on them. The effort seeks to complement ongoing recovery efforts by promoting greater investment in preventative, proactive conservation strategies in and across strongholds. Emerging climate change science and downscaling models that can "localize" regional climate impacts are vital to informing these strategies. While the designation of strongholds represents a snapshot in time (i.e., it reflects population and habitat conditions today), stronghold partners are taking the necessary steps to ensure strongholds resilient to climate change are protected and strong populations sustained. They plan to use downscaled, local climate change models and the predicted responses of stronghold watersheds to most effectively invest scarce resources across the expansive salmon landscape.

Source: *Personal interview (June 2011); North American Salmon Stronghold Partnership Charter, http://www.wildsalmoncenter.org/programs/north_america/strongholds.php (accessed 6.29.2011).*

Restore riparian habitat

Please see the section "Maintain and restore wetlands and riparian areas" for an explanation of restoring riparian habitat. Listed here are some benefits of riparian habitat restoration for species:

- Increasing physical habitat heterogeneity in channels supports diverse biotic assemblages.[1747] Aquatic fauna may benefit from an increase in physical habitat heterogeneity in the channel,[1748] and replanting or widening any degraded riparian buffers may protect river fauna by providing more shade and maintaining sources of allochthonous (i.e. originating from outside the aquatic system) input.[1749]

[1747] *Palmer et al. (2008, p. 33)
[1748] *Palmer et al. (2008, p. 35). The authors cite Brown (2003) for this information.
[1749] *Palmer et al. (2008, p. 35). The authors cite Palmer et al. (2005) for this information.

- Planting riparian vegetation provides fish and other organisms with refugia.[1750]
- Creating side channels and adjacent wetlands provides refugia for species during droughts and floods.[1751]
- A focus on increasing genetic diversity and population size through plantings or via stocking fish may increase the adaptive capacity of species.[1752]
- Increasing quality of freshwater habitat and hence increasing survival to offset increased mortality due to climate change may help salmon survive climate change.[1753]

<u>Engineer streams and off-channel areas to create artificial habitats that replace lost or degraded rearing habitats</u>

Engineered streams are constructed as natural type channels that meander over a location to maximize functional stream surface area, with variable stream widths that contain the natural components of salmon rearing habitat (pools, riffles, runs, deep ponds).[1754] For example, deep pools provide thermal refuge for adult holding or juvenile rearing.[1755] A pilot engineered stream on the Dungeness River (WA) has had production efficiencies as high as ten fingerlings per square meter, representing more than seventy percent survival of eggs.[1756] Engineered streams cost from $10,000 to $50,000 per kilometer and require ongoing maintenance.[1757]

Spawning channels for sockeye, chum, and pinks have been successful in providing spawning habitat and increasing productivity (e.g., Weaver Creek Channel in the Harrison Lake Basin, BC).[1758] Considerations for creating side channel spawning and rearing habitat include:

- Sufficient woody debris and other sources of instream cover;
- Ensure entrance does not run dry;
- Optimal pond size and depth; and
- High elevation habitats may be particularly important given climate change.[1759] The Yurok Tribe is working to provide tributary habitat, particularly high elevation as a strategy to help endangered coho in the Trinity River (CA).[1760]

<u>Clean gravels</u>

Ideally spawning gravel is free of silt and sand so water can percolate through the redds bringing oxygen to the eggs.[1761] Spawning gravel can be cleaned, but is expensive and fresh sediment may be deposited

[1750] *Palmer et al. (2008, p. 33)
[1751] *Palmer et al. (2008, p. 33)
[1752] *Palmer et al. (2008, p. 35)
[1753] *Nelitz et al. (2007, p. 107). The authors cite Ward et al. (2006) and Nina Hemphill, Trinity River Restoration Program, pers. comm.. for this information.
[1754] *Nelitz et al. (2007, p. 106)
[1755] *Nelitz et al. (2007, p. 108)
[1756] *Nelitz et al. (2007, p. 106). The authors cite Brannon (2006) for this information.
[1757] *Nelitz et al. (2007, p. 106)
[1758] *Nelitz et al. (2007, p. 106)
[1759] *Nelitz et al. (2007, p. 108)
[1760] *Nelitz et al. (2007, p. 108)
[1761] *Nelitz et al. (2007, p. 108)

with later high flows.[1762] This strategy has been tried with limited success in BC in the Horsefly and Nadina Rivers.[1763]

Case Study 4. Projected impacts of climate change on salmon habitat restoration, Snohomish Basin, WA.

Climate impacts addressed: Changes in snowpack, runoff, and streamflow regimes; Increased flooding and extreme flow; Increased water temperatures; Changes in water quality

Description: To investigate possible interactions between the impacts of climate change and habitat restoration, Battin et al. (2007) modeled Chinook salmon (*Oncorhynchus tshawytscha*) population dynamics in the Snohomish River basin under a variety of future climate and habitat conditions. Using the A2 scenario and two models chosen for their ability to reproduce 20th century hydrologic conditions in the Puget Sound (GFDL R30, HadCM3), they projected changes in spawning Chinook salmon abundance between 2000 and 2050 under three future land-use scenarios (Table A, below). In all model and land-use scenario combinations, projected declines in salmon abundance are lessened as a fuller suite of restoration targets are met; in one case, salmon abundance increases by 19%. The projected changes in salmon abundance vary spatially. In general, the largest declines in abundance are projected at high elevations and more moderate declines and increases in abundance are projected at low- and mid-elevations across all models and land-use scenarios. In contrast, hydrologic impacts are affected little by the choice of land-use scenario and climate models project basin-wide increases in incubation peak flows and pre-spawning temperatures and decreases in spawning flows. The largest hydrologic changes tended to be projected to occur at higher elevations, which consist primarily of federally protected lands and relatively pristine streams where there is little potential for habitat restoration or degradation. Battin et al. state that "model results suggest that, because climate impacts on hydrology are greatest in the highest-elevation basins, and restoration impacts are concentrated at lower elevations, the combined effect of climate change and restoration will be to shift salmon distributions to lower elevations" (p. 6722). Battin et al. conclude that in basins similar to the Snohomish River basin "salmon recovery plans that enhance lower-elevation habitats are likely to be more successful over the next 50 years than those that target the higher-elevation basins likely to experience the greatest snow-rain transition" (p. 6720).

Source: Battin et al. *Projected impacts of climate change on salmon habitat restoration.* (2007). See Figures 3 and 5 in the cited report (p. 6723) for a visual depiction of the results summarized here.

Table A. Basin-wide total percent change in spawning Chinook salmon abundance between 2000 and 2050

Model	***Current land-use*** *(no change from 2001 conditions)*	***Moderate restoration*** *(completion of current restoration projects but no further restoration)*	***Full restoration*** *(all restoration targets in the restoration plan are met)*
GFDL R30	-40	-27	-5
HadCM3	-20	-5	+19

[1762] *Nelitz et al. (2007, p. 108)
[1763] *Nelitz et al. (2007, p. 108)

Establish environmental flow regimes

Operating water storage facilities in a 'fish friendly' manner, by changing the storage and release patterns to account for fish needs is a successful strategy that is being widely used for Pacific salmon.[1764] Considerations include:

- Need sufficient flow and appropriate (e.g., low enough) temperatures for spawners of various species and life history stages, which return at different times of the year;
- Dam releases can be used to make out-migration conditions more favorable; and,
- Timing of increased flows is also important for both establishing and scouring riparian vegetation as well as driving geomorphological processes.[1765]

Improve fish passage

Fish passage devices can improve survival of adults migrating upstream to spawning areas, and juveniles outmigrating to the ocean.[1766] Downstream fish passage technology includes various types of turbines.[1767] Examples of upstream fish passage technology include:

- Fish ladders;
- Improved culvert design *(Please see the section "Maintain, restore, or create stream and watershed connectivity" for an explanation of improved culvert design.);*
- Vertical slot;
- Roughened channels;
- Hybrid fishways; and,
- Mechanical fishways.[1768]

There is a large body of evidence describing how fish passage over hydropower devices can be improved.[1769] For example, the Electrical Power Research Institute has written a Manual of Upstream and Downstream Fish Passage and Protection Technologies for Hydroelectric Application.[1770]

Build better docks

On lakes, overwater structures change underwater light conditions, affecting the behavior of juvenile salmon and their predators.[1771] The following actions can be taken to decrease the impact on sensitive shoreline habitat and species:

- Use grated decking with openings that allow light to pass through;
- Make ramps and walkways narrower, ideally four feet or less for walkways and three feet or less for ramps;

1764 *Nelitz et al. (2007, p. 103)
1765 *Nelitz et al. (2007, p. 103)
1766 *Nelitz et al. (2007, p. 105)
1767 *Nelitz et al. (2007, p. 105)
1768 *Nelitz et al. (2007, p. 105)
1769 *Nelitz et al. (2007, p. 105)
1770 *Nelitz et al. (2007, p. 105). A PDF (~4 MB) of the manual can be downloaded at http://my.epri.com/portal/server.pt?space=CommunityPage&cached=true&parentname=ObjMgr&parentid=2&control=SetCommunity&CommunityID=404&RaiseDocID=000000000001005392&RaiseDocType=Abstract_id (accessed 5.19.2011).
1771 *Seattle-DPD. (n.d., p. 22)

- Avoid using "skirts," i.e. boards on the sides of the dock that extend down to the water (multiple agencies prohibit skirts because of their effects on light in the nearshore area);
- Design the dock such that the bottom of the entire structure is at least eighteen inches above ordinary high water;
- Use structural beams such as glu-lams, which allow longer spans between piles; and,
- Avoid overwater lights that will be on all night.[1772]

In addition, there are measures that can be taken during construction, including careful selection of wood preservatives for any lumber that will have contact with the water (or, use untreated wood), using decking materials that will not require toxic finishes and cleaning agents, scheduling construction during approved work windows, and working with a contractor who is conscientious about preventing spills and minimizing disturbance of sediments (i.e., following Best Management Practices).[1773]

Enrich streams or lakes with nutrients

Add inorganic nitrogen and phosphorus to freshwater environments by using artificial fertilizers or hatchery salmon carcasses.[1774] In BC, surveys indicated decreases of nutrients in watersheds where populations have not been enhanced by hatchery supplementation, fertilization, construction of spawning channels, or other mitigating action.[1775] Considerations for enriching streams or lakes with nutrients include:

- Nutrient concentrations at point of application and downstream,
- Influence of urban areas where nutrient loadings may already be artificially high,
- Application of hatchery carcasses to a site several times through the spawning season rather than all at once, and
- Consider reductions in harvest prior to artificial enhancement of nutrients.[1776]

Conserve freshwater biodiversity[1777]

Freshwater biodiversity may be conserved by reintroducing native species,[1778] reevaluating conservation and recovery programs,[1779] or by increasing genetic diversity through planting or by stocking fish.[1780] Reintroducing native species is highly desirable for species that are prevented from tracking climate change due to human-made dispersal barriers, such as dams, or limited dispersal ability.[1781] It may be desirable to introduce native species that play key roles in ecosystems.[1782] Amongst such species are predatory fish species that are also favored for sport fishing, and species that may be considered as

[1772] *Seattle-DPD. (n.d., p. 23)
[1773] *Seattle-DPD. (n.d., p. 23)
[1774] *Nelitz et al. (2007, p. 107)
[1775] *Nelitz et al. (2007, p. 107). The authors cite Larkin and Slaney (1999) as cited in Roni et al. (2002) for this information.
[1776] *Nelitz et al. (2007, p. 107)
[1777] *Spittlehouse and Stewart. *Adaptation to climate change in forest management.* (2003, Table 1, p. 3)
[1778] *Heino et al. *Climate change and freshwater biodiversity: detected patterns, future trends and adaptations in northern regions.* (2009, p. 50)
[1779] *Spittlehouse and Stewart. (2003, p. 8)
[1780] *Palmer et al. (2008, p. 33)
[1781] *Heino, Virkkala and Toivonen. (2009, p. 50)
[1782] *Heino, Virkkala and Toivonen. (2009, p. 50). The authors cite Hunter (2007) for this information.

ecosystem engineers that participate in processes important to a suite of other species.[1783] However, it is likely to be unsuitable for most freshwater species due to economic constraints and practical difficulties in breeding and moving living organisms.[1784] The reevaluation of conservation and recovery programs is suggested in light of the possibility that the long-term preservation of some rare species may only be possible in artificial reserves or arboreta.[1785]

Case Study 5. Citizen scientists monitor for climate change effects: the Salmon Watcher Program, WA.

Climate impacts addressed: Changes in snowpack, runoff, and streamflow regimes. Increased water temperature.

Description: The Salmon Watcher Program, founded in 1996, trains citizen scientists to monitor the status of salmon populations in streams and rivers throughout King and Snohomish counties in Washington state, focusing mainly on the Lake Washington watershed. Volunteers learn to identify different salmonid species, including Chinook, coho, sockeye, kokanee, and chum. Volunteers then record the species and number of salmon at assigned streams twice a week between September and December (spawning season). Information is also collected on any barriers to salmon passage in the water. The information collected is then passed on to scientists so that they can determine fluctuations in populations; scientists can then use these data sets to identify variability. This project is one of the case studies in the U.S. Global Change Research Program's Climate Change, Wildlife, and Wildlands Toolkit for Formal and Informal Educators, developed to aid educators in communicating how climate change will affect the environment and how people can become "climate stewards."

Source: *Climate Adaptation Knowledge Exchange, http://www.cakex.org/case-studies/852 (accessed May 20, 2011); King County. Salmon Watcher Program. http://www.kingcounty.gov/environment/animalsandplants/salmon-and-trout/salmon-watchers.aspx (accessed May 22, 2011).*

Monitor to determine when and what changes are occurring[1786]

Since many organisms respond to climatic variability and trends, some of these responses may be useful as indicators of climate change.[1787] Golladay et al. (2004) suggest that wetland invertebrates could be divided into four response guilds to indicate hydrologic status that may be adaptable to river/stream systems.[1788] Changes in density-weighted ratios of the following response guilds could be used as indicators of climate driven changes in hydrologic conditions over time:[1789]

- Overwintering residents that disperse passively, including snails, mollusks, amphipods, and crayfish;
- Overwintering spring recruits that require water availability for reproduction, including midges and some beetles;

[1783] *Heino, Virkkala and Toivonen. (2009, p. 50). The authors cite Jones, Lawton and Shachak (1994) for this information.
[1784] *Heino, Virkkala and Toivonen. (2009, p. 50)
[1785] *Spittlehouse and Stewart. (2003, p. 8)
[1786] *Spittlehouse and Stewart. (2003, Table 1, p. 3)
[1787] *U. S. EPA. (2008a, p. 1-9)
[1788] *U. S. EPA. (2008a, p. 1-9)
[1789] *U. S. EPA. (2008a, p. 1-9)

- Overwintering summer recruits that only need saturated sediment for reproduction, including dragonflies, mosquitoes, and phantom midges; and
- Non-wintering spring migrants that generally require surface water for overwintering, including most water bugs and some water beetles.[1790]

Cold-water fish species, and salmon species in particular, may be good indicators of climate-change effects in streams and rivers.[1791] To use a salmon species or any fish species as an indicator, one must be sure not to count or include fish that may have been stocked rather than occur naturally in a particular stream or river.[1792] Species with widespread ranges and high thermal tolerance such as largemouth bass, carp, channel catfish, and bluegills would generally not be good indicators of climate impacts since they are relatively insensitive and their ranges extend south into Mexico.[1793] Another possible effect of increased water temperatures is to reduce dissolved oxygen levels in stream waters.[1794] Darter species are sensitive to benthic oxygen depletion because they feed and reproduce in benthic habitats, making them another potential indicator of climate change.[1795] Monitoring changes in community composition, including shifts from cold- and cool-water dominated systems to warm-water communities, may be another good indicator for the following reasons:[1796]

- It is expected that cool-water and warm-water fishes will be able to invade freshwater habitats at higher latitudes, while cold-water fish will disappear from low latitude limits of their distribution where summer temperatures already reach fish maximum thermal tolerances.[1797]
- In east-west drainages fish may not be able to find thermal refuge and may experience local extinctions.[1798]
- Cold-water fish that do persist at higher altitudes and latitudes may not experience as many winter stresses, and their ranges may expand with increased duration of optimal temperatures.[1799]

Beyond categorization of existing biological indicators as sensitive/insensitive to climate change effects, there are biological metrics that could be considered for incorporation into bioassessment programs that are not currently measured on a routine basis in most existing programs.[1800] Such "novel" indicators are considered specifically because of their sensitivity to climate change effects – most have been predicted or observed in the literature as biological responses to directional climate change, especially increases in water temperature.[1801] Table 20 summarizes examples of such "novel" biological indicators.[1802]

1790 *U. S. EPA. (2008a, p. 1-9)
1791 *U. S. EPA. (2008a, p. 1-11)
1792 *U. S. EPA. (2008a, p. 1-11)
1793 *U. S. EPA. (2008a, p. 1-11)
1794 *U. S. EPA. (2008a, p. 1-11)
1795 *U. S. EPA. (2008a, p. 1-11). The authors cite U.S. EPA (1999) for information on the sensitivity of darter species to benthic oxygen depletion due to their feeding and reproductive habits.
1796 *U. S. EPA. (2008a, p. 1-9)
1797 *U. S. EPA. (2008a, p. 1-9). The authors cite Carpenter et al. (1992) and Tyedmers and Ward (2001) for this information.
1798 *U. S. EPA. (2008a, p. 1-9). The authors cite Carpenter et al. (1992) for this information.
1799 *U. S. EPA. (2008a, p. 1-9). The authors cite Carpenter et al. (1992) and Tyedmers and Melack et al. (1997) for this information.
1800 *U. S. EPA. (2008a, p. 3-5)
1801 *U. S. EPA. (2008a, p. 3-5)
1802 *U. S. EPA. (2008a, p. 3-5)

Considerations for ongoing evaluation of potential novel indicators and their role in adaptation of bioassessment programs include:

- Many of the metrics are more difficult or time- and resource-consuming to measure, especially on a routine basis.[1803]
- Some metrics require sampling techniques and timing or frequency of sampling that are quite different from the commonly applied bioassessment approaches.[1804]
- The potential sensitivity to other (conventional) stressors, in addition to their responsiveness to climate change, will affect how they might be incorporated into a monitoring design and analysis approach.[1805]

Additional actions

The following adaptation actions for preserving habitat for vulnerable species were found in the literature, but are not described in detail or are described elsewhere in this report:

- Study and better understand species that are expected to migrate north and upslope in order to determine which ones are most likely to support wetland functions and values given climate change.[1806]
- Establish programs to move isolated populations of species of interest that become stranded when water levels drop.[1807]
- Install irrigation screens to prevent fish from being pulled into the irrigation system.[1808]
- Maintain representative forest types across environmental gradients; protect primary forests (established forests are often able to survive extensive periods of unfavorable climates and this inertia could extend the time period over which adaptation could take place[1809]
- Establish special protection for multiple headwater reaches that support keystone processes or sensitive species.[1810] Since headwaters often support rare and sensitive species, protecting multiple small headwaters will provide "insurance" against regional species loss if losses occur in one or a few tributaries.[1811]
- Maintain connectivity in a varied, dynamic landscape:[1812] *Please see the section "Maintain, restore, or create stream and watershed connectivity" for actions that minimize fragmentation of habitat and maintain connectivity.*

[1803] *U. S. EPA. (2008a, p. 3-8)
[1804] *U. S. EPA. (2008a, p. 3-8)
[1805] *U. S. EPA. (2008a, p. 3-8)
[1806] *ASWM. (2009, p. 12)
[1807] *Palmer et al. (2008, p. 33)
[1808] *Nelitz et al. (2007, p. 100)
[1809] *Spittlehouse and Stewart. (2003, p. 10)
[1810] *Palmer et al. (2008, p. 33)
[1811] *Palmer et al. (2008, p. 34-35)
[1812] *Spittlehouse and Stewart. (2003, Table 1, p. 3)

Table 20. Novel indicators that may be sensitive to climate change.
Modified from U.S. EPA (2008a, Table 3-2, p. 3-6 to 3-7) by authors of this report. Table continues on following page.

Category	***Metric***	***Comments***	***References***
Phenology	Timing of emergence of mayfly species (also stonefly and caddis species)	Indirect effects on timing of salmonid feeding regime	Harper and Peckarsky, 2006; Briers et al., 2004; Gregory et al., 2000; McKee and Atkinson, 2000
	Timing of trout spawning in warmer water		Cooney et al., 2005
	Rate of development and timing of breeding of the amphipod *Hyallela azteca*		Hogg et al., 1995
Longer growing season	Algal productivity	In northern areas a response to decreased ice cover and increased light penetration	Flanagan et al., 2003
	Number of reproductive periods of amphipod species		Hogg et al., 1995
Life-stage specific	Sex ratios for certain insects (e.g. trichopteran *Lepidostoma*)		Hogg and Williams, 1996
	Smaller size at maturity and reduced fecundity of plecopteran *Nenoura trispinosa* and amphipod *Hyallela azteca*	From increased temperature	Turner and Williams, 2005; Hogg et al., 1995
	Decreased salmon egg to fry survival	Increased turbidity from eroded sediment due to increased precipitation	Melack et al., 1997
Temperature sensitivity	Reduced size of sockeye salmon	Reduced growth and increased mortality in higher temperatures as well as to lower plankton productivity	Melack et al., 1997
	Increased growth rate of juvenile salmon in Alaska		Schindler et al., 2005

	Decreased growth rate of trout		Jensen et al., 2000
Hydrologic sensitivity	Decreased survival of eggs of autumn-spawning salmon (e.g. dolly varden, brook trout, coho salmon)	Results in decreased abundance of autumn-spawning species, and/or change in relative composition between spring and autumn spawners	Gibson et al., 2005
	Decreased fry survival of pink and chum salmon due to earlier (late winter to early spring) peak flows	Earlier emergence and migration of pink and chum salmon fry to estuaries at a time when their food sources have not developed adequately	Melack et al., 1997
	Differential mortality of drought-intolerant mussel species (e.g. *Lampsilis straminea claibornensis*, *Villosa villosa*, *Lampsilis subangulata)*	Results in changes in relative abundance, extirpation of vulnerable species	Golladay et al., 2004

Manage and prevent the establishment of aquatic and riparian invasive and non-native species in a changing climate

Despite the uncertainties in climate change, aquatic invasive species management plays a critical role in overall ecosystem management and should be planned and implemented in a manner that is flexible and considers and monitors for potential changes.[1813]

Prevention measures are implemented to avoid the introduction and establishment of invasive species and are widely recognized as the most effective and cost-efficient tools for combating invasive species.[1814] Addressing invasive species through prevention mechanisms such as early detection and eradication will be less costly over the long-term than post-entry maintenance and control activities that depend on continued commitment and resources as well as on development of successful, targeted control mechanisms.[1815] Thus, prevention activities are key tools for successfully addressing invasive species, and states (or provinces, Tribes, and First Nations) with limited resources may maximize the use of scarce invasive species funds by investing in prevention efforts.[1816] Numerous strategies and measures may be used to manage and prevent the establishment of potentially harmful aquatic /riparian invasive and non-native species, including those described below.

[1813] *NOAA. (2010a, p. 92)
[1814] *U. S. EPA. (2008b, p. 2-12). The authors cite Keller et al. (2007), Leung et al. (2002), NISC (2001) and Wittenberg and Cock (2001) for this information.
[1815] *U. S. EPA. (2008b, p. 2-12 to 2-13). The authors cite Simberloff (2003) and Mack et al. (2000) for this information.
[1816] *U. S. EPA. (2008b, p. 2-13)

Monitoring, mapping and/or survey efforts to identify and mitigate invasive species threats

To address the potential effects of climate change, continued and new monitoring will be necessary to update information systems with data that allow evaluation of those effects.[1817] Monitoring efforts may need to be modified to focus on weakened or changing ecosystems that are more vulnerable to invasion.[1818] Further, monitoring and survey efforts may be used to identify species that are encroaching as a result of expanding ranges.[1819] Adapting monitoring may mean sampling at different temporal or spatial frequencies, or using different sampling techniques.[1820] For example, monitoring to detect range changes may require sampling the distributional and altitudinal edges of species ranges.[1821] This may benefit from acquiring the ability to distinguish between range shifts and species invasions (e.g. decide if plant or animal species migration into an area due to increased temperatures, sea level rise or other climate change factors is to be considered "invasive").[1822]

Adapt information management activities

An information management system will have to support rapid and accurate discovery of data, correlate and synthesize data from many sources, and present the results of data synthesis that meets the needs of users.[1823] In addition to data on species movement and establishment, information on ecosystem conditions—e.g., water temperatures, chemical composition, and salinity levels, where applicable—should also be monitored and evaluated to fully assess invasive-species threats in the context of a changing climate.[1824] Any existing or planned information systems for aquatic invasive species should incorporate information on climate change and its effects on invasive species and have the ability to be updated with monitoring information in order to assess the occurrence of effects.[1825] As more information on effects of climate change on aquatic invasive species becomes available, information systems will require the capacity to be updated.[1826] Then more targeted research may be done that can provide more specific recommendations for aquatic invasive species management in a changing climate.[1827]

Adapt Early Detection and Rapid Response (EDRR) protocols and emergency powers

EDRR refers to efforts that identify and control or eradicate new infestations before they reach severe levels.[1828] Because even the most effective barriers to entry will at some point be breached, EDRR is an important element in preventing and controlling invasive species problems.[1829] In addition to surveying and/or mapping to detect infestations, EDRR efforts may include emergency powers for state agencies to implement control measures quickly and restoration to decrease vulnerability to re-establishment of the

[1817] *U. S. EPA. (2008b, p. 2-15). The authors cite Lee et al. (2008) for this information.
[1818] *U. S. EPA. (2008b, p. 2-14)
[1819] *U. S. EPA. (2008b, p. 2-14)
[1820] *U. S. EPA. (2008b, p. 2-15). The authors cite Hellmann et al. (2008) for this information.
[1821] *U. S. EPA. (2008b, p. 2-15).
[1822] *ASWM. (2009, p. 11)
[1823] *U. S. EPA. (2008b, p. 2-16)
[1824] *U. S. EPA. (2008b, p. 2-16 to 2-17)
[1825] *U. S. EPA. (2008b, p. 2-17). The authors cite Lee et al. (2008) for this information.
[1826] *U. S. EPA. (2008b, p. 2-17)
[1827] *U. S. EPA. (2008b, p. 2-17)
[1828] *U. S. EPA. (2008b, p. 2-15)
[1829] *U. S. EPA. (2008b, p. 2-15)

invading species.[1830] Comprehensive EDRR plans identify participating and lead agencies, potential regulatory requirements for control, and other EDRR protocols.[1831] The effectiveness of EDRR efforts may be improved by monitoring both for the establishment of new infestations as well as for changing conditions in order to better predict which systems may become vulnerable to invasion.[1832]

The Hazard Analysis and Critical Control Points (HACCP) planning framework

Another important prevention tool for invasive species managers is the HACCP planning framework.[1833] As a part of the HACCP planning process, natural resource managers identify potential invasive species and possible points of entry that could result from management activities.[1834] Managers also focus on specific pathways and develop best management practices to prevent these species from being introduced.[1835] This planning framework helps managers assess risk and make more strategic decisions.[1836]

Evaluate vectors for the ability to transmit species under changing conditions

Vectors also may be influenced by changes in climate and should be evaluated for the ability to transmit species under changing conditions.[1837] For example, seaways may remain open for longer periods during the year due to warming temperatures; thus, shipping and boating traffic, a major vector for species such as the zebra mussel, also may increase.[1838] To begin to address these concerns, pathway analysis and species prediction models should be modified to include climate change parameters.[1839]

Precautionary measures and quarantines

Climate changes resulting in increased storm surge and flooding increase the risk of species escape from aquaculture facilities.[1840] In light of these changes, aquaculture facilities may need to take additional precautionary measures against escapes or establishment (e.g., use only triploids, stock only one sex, or use sterile hybrids) or to use only native species.[1841]

Regulation of certain species (e.g. introduction, import, or release requirements)

States may need to alert inspection and border control agencies to new invasive threats, and related inspection priorities may need to be re-assessed in light of these impending threats and pathways.[1842] Import/introduction/release requirements should be based on risk assessments that account for how changing conditions will affect the potential for an area to be invaded.[1843]

[1830] *U. S. EPA. (2008b, p. 2-15)
[1831] *U. S. EPA. (2008b, p. 2-15)
[1832] *U. S. EPA. (2008b, p. 2-15)
[1833] *U. S. EPA. (2008b, p. 2-13)
[1834] *U. S. EPA. (2008b, p. 2-13)
[1835] *U. S. EPA. (2008b, p. 2-13)
[1836] *U. S. EPA. (2008b, p. 2-13)
[1837] *U. S. EPA. (2008b, p. 2-14)
[1838] *U. S. EPA. (2008b, p. 2-14)
[1839] *U. S. EPA. (2008b, p. 2-14)
[1840] *U. S. EPA. (2008b, p. 2-14)
[1841] *U. S. EPA. (2008b, p. 2-14)
[1842] *U. S. EPA. (2008b, p. 2-14)
[1843] *U. S. EPA. (2008b, p. 2-14)

Re-evaluate ongoing land and water management activities

Ongoing land and water management activities should be re-evaluated for their potential to provide new invasion pathways.[1844] For example, waterway engineers could examine passage between water bodies that were historically separated, create barriers to passages, and consider aquatic invasive species spread before re-filling or reconnecting waterways.[1845] In addition, a re-evaluation of appropriate control measures may be necessary in order to make efficient use of state (or provincial, Tribal, First Nations) investments in aquatic invasive species management.[1846] Changing conditions, such as warmer waters, extreme weather events, salt water intrusion, and/or changes in water chemistry, may affect the success of "tried and true" biological, chemical, or mechanical control measures.[1847]

Adapt restoration activities

Restoration of natural systems is critical to preventing re-introduction of an invasive species once it has been eradicated or controlled.[1848] Because healthy ecosystems may be less vulnerable to invasion, restored ecosystems also may be less vulnerable future invasions, thus providing some insurance to investments in invasive species prevention, Early Detection and Rapid Response, and other control measures.[1849] Given that climate change is expected to alter native species and habitats and other ecosystem attributes, restoration designs should emphasize restoration of ecosystem processes (e.g. sediment and nutrient transport, export of woody debris, river-floodplain connections) that were originally disrupted and may have facilitated the establishment of aquatic invasive species.[1850] Restoration projects should include analyses of which native species may thrive in, or at least tolerate, future climate-change conditions and avoid those species that may not be as well suited to future conditions.[1851] In addition, restoration projects may actively remove invasive species that threaten key native species[1852] and undesirable plant species may be controlled through vegetation management treatments.[1853] *Please see the section "Maintain and restore wetlands and riparian areas" for further information on riparian restoration activities.*

Adapt education efforts to increase public awareness regarding particular species and/or pathways[1854]

Many states (or provinces, Tribes, First Nations) conduct public awareness campaigns to inform the public, decision-makers, and other stakeholders about ways to prevent the introduction and spread of invasive species.[1855] Aquatic invasive species outreach campaigns can use their existing efforts to educate the public about new invasive species threats due to climate change.[1856]

[1844] *U. S. EPA. (2008b, p. 2-14)
[1845] *U. S. EPA. (2008b, p. 2-14). The authors cite Rahel and Olden (2008) for this information.
[1846] *U. S. EPA. (2008b, p. 2-16)
[1847] *U. S. EPA. (2008b, p. 2-15)
[1848] *U. S. EPA. (2008b, p. 2-16)
[1849] *U. S. EPA. (2008b, p. 2-16). The authors cite Vitousek et al. (1996) for this information.
[1850] *U. S. EPA. (2008b, p. 2-16)
[1851] *U. S. EPA. (2008b, p. 2-16)
[1852] *Palmer et al. (2008, p. 33)
[1853] *Spittlehouse and Stewart. (2003, p. 10)
[1854] *U. S. EPA. (2008b, p. 2-13)
[1855] *U. S. EPA. (2008b, p. 2-17)
[1856] *U. S. EPA. (2008b, p. 2-17)

Additional actions

An additional action is to incorporate climate change considerations into aquatic invasive species management plans. *Please see the section "Climate adaptation actions – monitoring and planning" for information on incorporating climate change into aquatic invasive species management plans.*

8. STATUS OF ADAPTATION STRATEGIES AND PLANS IN THE STATES, PROVINCES, AND SELECTED TRIBAL NATIONS OF THE NPLCC

Alaska

To address the impacts of climate change on Alaska, Governor Sarah Palin signed Administrative Order 238 on September 14, 2007, which established and charged the Alaska Climate Change Sub-Cabinet to advise the Office of the Governor on the preparation and implementation of a comprehensive Alaska Climate Change Strategy (AO 238).[1857] The Adaptation Advisory Group (AAG) was charged with evaluating and developing options to adapt to climate change.[1858] The Final Report Submitted by the Adaptation Advisory Group to the Alaska Climate Change Sub-Cabinet was released in January 2010. The types of recommendations made by the AAG vary.[1859] The options cover four broad sectors (public infrastructure, health and culture, natural systems, and economic activities) and range from new systems approaches and institutional structures to adoption of new or revised policies, initiatives, and other actions.[1860] The Sub-Cabinet will consider these, as well as recommendations from the Immediate Action Work Group, the Mitigation Advisory Group, and the Research Needs Work Group in the context of other complementary efforts.[1861] A comprehensive Climate Change Strategy for Alaska will then be drafted for consideration by the Governor.[1862]

Yukon Territory

Within the Yukon Territory (186,272 mi^2, 482,443 km^2),[1863] the only land within the NPLCC region is that covered by the Kluane National Park and Preserve (8,487 $miles^2$, 21, 980 km^2; ~4.6% of total area in Yukon Territory),[1864] located in the southwest corner of the Territory. Parks Canada lists impacts in its Pacific Coast parks largely consistent with those described in this report for the region: higher temperatures, a moderate increase in winter precipitation and drier summers, increased ocean surface temperatures, greater storm intensity, and altered ocean currents (please see relevant sections of this report for further information).[1865] Information on climate change adaptation planning for the Kluane National Park and Preserve was limited; however, information on adaptation planning by the Government of Yukon is described below.

The Government of Yukon Climate Change Strategy, released in 2006, sets out the government's role and key goals for its response to climate change.[1866] After its release, Environment Yukon began researching and collecting information needed to develop the Yukon Government Climate Change Action Plan, which was released February 2009.[1867] The Climate Change Strategy includes broad goals targeted at enhancing the awareness and understanding of climate change impacts, taking measures to reduce the levels of

[1857] *AK Department of Environmental Conservation. (2010, Ch 1, p. v-vi)
[1858] *AK Department of Environmental Conservation. (2010, Ch 1, p. vi)
[1859] *AK Department of Environmental Conservation. (2010, Ch 1, p. vi)
[1860] *AK Department of Environmental Conservation. (2010, Ch 1, p. vi)
[1861] *AK Department of Environmental Conservation. (2010, Ch 1, p. vi)
[1862] *AK Department of Environmental Conservation. (2010, Ch 1, p. vi)
[1863] Government of Yukon. *Executive Council Office: General Facts: Land (website).* (2011)
[1864] Parks Canada. *Kluane National Park and Preserve of Canada Management Plan*. (2010, p. 3)
[1865] *Parks Canada. *The Climate is Changing Our National Parks: Impacts on Pacific Parks (website).* (2009)
[1866] *Yukon Government. *Government of Yukon Climate Change Strategy.* (July 2006, p. 1)
[1867] *Yukon Government. *Yukon Government Climate Change Action Plan.* (February 2009, p. 9)

greenhouse gas emissions in Yukon, building environmental, social and economic systems that are able to adapt to climate change impacts and positioning Yukon as a northern leader for applied climate change research and innovation.[1868] The Action Plan, providing clear direction and action, advances the goals of the Climate Change Strategy.[1869] The four goals outlined in the Action Plan are: (1) enhance knowledge and understanding of climate change; (2) adapt to climate change; (3) reduce greenhouse gas emissions; and, (4) lead Yukon action in response to climate change.[1870]

Preparation of the Action Plan included discussions with a wide variety of government and non-government representatives, an interdepartmental workshop, working-group meetings and several external workshops.[1871] A draft of the Action Plan was circulated for public comment from May 12 to July 31, 2008 before its release in February 2009.[1872]

The Yukon government will pursue the implementation of its Climate Change Strategy in partnership and collaboration with First Nation governments, municipalities, industry, the public, the other northern territories and the provinces, the federal government and other governments around the world.[1873] Implementation of the Action Plan will involve all departments and agencies of the Yukon government.[1874] The Yukon government will also work with partners to meet the challenges and opportunities of climate change in Yukon – other governments, non-governmental organizations, industry, and the academic community.[1875]

British Columbia

Building on a framework established in 2007, British Columbia released a Climate Action Plan in 2008.[1876] The section on adaptation outlines a range of coordinated actions to help B.C. adapt to climate change, including options for investing in new ideas and solutions, protecting forests, protecting water, and building carbon smart communities.[1877] The Climate Change Adaptation Strategy addresses three main themes that provide a solid framework to address climate change impacts and adaptation: (1) build a strong foundation of knowledge and tools to help public and private decision-makers across B.C. prepare for a changing climate, (2) make adaptation a part of B.C. Government's business, ensuring that climate change impacts are considered in planning and decision-making across government, and (3) assessing risks and implementing priority adaptation actions in key climate sensitive sectors.[1878]

Washington

In the spring of 2009, Governor Gregoire signed legislation (E2SSB 5560) that included provisions for the formation of an "integrated climate change response strategy" that would "better enable state and local agencies, public and private businesses, nongovernmental organizations, and individuals to prepare

[1868] *Yukon Government. (July 2006, p. 1)
[1869] *Yukon Government. (February 2009, p. 5)
[1870] *Yukon Government. (February 2009, p. 7)
[1871] *Yukon Government. (February 2009, p. 9)
[1872] *Yukon Government. (February 2009, p. 9)
[1873] *Yukon Government. (July 2006, p. 1)
[1874] *Yukon Government. (February 2009, p. 5)
[1875] *Yukon Government. (February 2009, p. 5)
[1876] *Government of British Columbia. *Climate Action Plan*. (2008, p. 1)
[1877] Government of British Columbia. *Climate Action Plan*. (2008, p. 66-69)
[1878] *B.C. Ministry of Environment. *Climate Change Adaptation Strategy (website).* (2011)

for, address, and adapt to the impacts of climate change."[1879] The legislation directs Ecology, in partnership with the departments of Agriculture, Commerce, Fish and Wildlife, Natural Resources, and Transportation to develop an initial state strategy by December of 2011.[1880]

Four Topic Advisory Groups (TAGs) were formed to assist in developing a state strategy for how Washington can prepare for and adapt to the impacts of climate change.[1881] The TAGs are structured around four areas (built environment, infrastructure, and communities; human health and security; ecosystems, species, and habitats; natural resources) and will address a wide range of key issues that citizens, governments, and businesses will face in a changing climate.[1882] The Departments of Agriculture, Ecology, Fish and Wildlife, Health, Natural Resources, Transportation, and the University of Washington lead TAGs that examine climate change impacts and identify preparation and adaptation strategies as well as additional research needs.[1883] TAG members met regularly since their inception in early 2010 through January 2011, including three cross-cutting TAG meetings.[1884] The draft strategy will be completed in Spring 2011, followed by a period of public comment and outreach through Summer 2011.[1885] The final strategy will be submitted to the Legislature in December 2011.[1886]

Jamestown S'Klallam Tribe

In late 2009, Tribal Council approved a proposal by the Tribe's Natural Resources Department to write a formal Jamestown S'Klallam Plan for Climate Change.[1887] The purpose of the plan is to prepare for a warming climate, and to help reduce the Tribe's carbon footprint, to slow down the warming planet.[1888]

Swinomish Indian Tribal Community

In the fall of 2008 the Swinomish Indian Tribal Community started work on a landmark two-year Climate Change Initiative to study the impacts of climate change on the resources, assets, and community of the Swinomish Indian Reservation and to develop recommendations on actions to adapt to projected impacts.[1889] This followed issuance of a Proclamation by the Tribal Senate in 2007 directing action to study and assess climate change impacts on the Reservation.[1890] Under the guidance and coordination of the Swinomish Office of Planning & Community Development, the first year of the project was devoted to assessment of projected impacts, as presented in an Impact Assessment Technical Report issued in the fall of 2009.[1891] The second year of the project was focused on evaluation of strategies and options for recommended actions to counter identified impacts, which resulted in preparation and release of the

[1879] *WA Department of Ecology. *Preparing for impacts: adapting to climate change (website).* (2011)
[1880] *WA Department of Ecology. *Preparing for impacts: adapting to climate change (website).* (2011)
[1881] *WA Department of Ecology. *Topic Advisory Groups (website)*. (2011)
[1882] *WA Department of Ecology. *Topic Advisory Groups (website)*. (2011)
[1883] *WA Department of Ecology. *Topic Advisory Groups (website)*. (2011)
[1884] *WA Department of Ecology. *Topic Advisory Groups (website)*. (2011)
[1885] WA Department of Ecology Topic Advisory Groups. *Integrated Climate Change Response Plan: Draft Topic Advisory Group Work Plan (unpublished internal document).* (2009)
[1886] WA Department of Ecology Topic Advisory Groups. (2009)
[1887] *Jamestown S'Klallam Tribe. *Newsletter (Vol 32, Issue 2) (pdf; website).* (2011, p. 9)
[1888] *Jamestown S'Klallam Tribe. (2011, p. 9)
[1889] *Swinomish Indian Tribal Community. *Swinomish Climate Change Initiative: Climate Adaptation Action Plan.* (2010, p. 1)
[1890] *Swinomish Indian Tribal Community. (2010, p. 1)
[1891] *Swinomish Indian Tribal Community. (2010, p. 1)

Climate Adaptation Action Plan.[1892] The ultimate goal of the project was to help ensure an enduring and climate-resilient community that can meet the challenges of anticipated impacts in the years to come.[1893]

The Action Plan discusses climate change within the context of Swinomish cultural traditions, community health, and cultural resilience, and reviews the relationship between tribal traditions and effective adaptation planning. This information, along with the climate change impacts assessed in the Technical Report and strategic evaluation of many adaptation options, was used to derive the adaptation goals, action recommendations and priorities described in the Action Plan. These are organized into four focal areas (coastal resources, upland resources, physical health, and community infrastructure and services). Strategic evaluation included assessment of six key objectives (comprehensive, sustainable, dynamic response, fiscally feasibile, non-regulatory, and meets community goals).[1894] Strategies were then screened against a number of key considerations (evaluation objectives met, existing authority and capacity versus required authority and capacity, potential internal and external partners, and timeframe anticipated for potential implementation), as well as the vulnerability and estimated risk to the system in question.[1895] At time of writing, the Swinomish are moving forward on a number of their priority actions. For example, they are seeking grants for their work, evaluating existing management plans and regulations, and assessing needed changes to building and zoning codes. A description of the Swinomish Tribe's Climate Adaptation Action Plan can be found at http://www.swinomish-nsn.gov/climate_change/Docs/SITC_CC_AdaptationActionPlan_complete.pdf (accessed 4.7. 2011).

Tulalip Tribe

The Tulalip Adaptation and Mitigation Policy Frameworks for Climate Change lists six criteria for incorporating policies and law in planning and management that allow the Tulalip Tribes to sustainably maintain healthy, resilient human communities in the face of change.[1896] These policies and law need, among other things, to be *integrated* (involve multiple independent sectors in the creation of holistic solutions that address a full range of natural and social factors), *cross-scale* (address problems at multiple scales, and devise scale-appropriate actions, working to ensure policies and actions do not defeat measures taken at any one scale), *adaptive* (monitor and respond to the effectiveness of efforts and advances in scientific and local knowledge, adapt objectives when necessary), *restorative* (use historical baselines for mitigation goals for processes that maintain healthy watersheds and communities), *participatory* (recognize stakeholder equity by including federal, state, tribal and local governments, businesses and citizens in the transparent development of baselines, objectives, and mitigation and adaptation measures), and *sustainable* (design objectives and actions on a basis of ecological and cultural sustainability, and include mechanisms to ensure the sustained financial and administrative support for their implementation).[1897]

1892 *Swinomish Indian Tribal Community. (2010, p. 1)
1893 *Swinomish Indian Tribal Community. (2010, p. 1)
1894 Swinomish Indian Tribal Community. (2010, p. 38)
1895 Swinomish Indian Tribal Community. (2010, p. 40)
1896 *Tulalip Tribes. *Climate Change Impacts on Tribal Resources (pdf; website).* (2006, p. 2)
1897 *Tulalip Tribes. (2006, p. 2)

Oregon

In October 2009, Governor Kulongoski of Oregon asked the directors of several state agencies, universities, research institutions and extension services to develop a climate change adaptation plan.[1898] Among other things, the plan provides a framework for state agencies to identify authorities, actions, research, and resources needed to increase Oregon's capacity to address the likely effects of a changing climate.[1899] *The Oregon Climate Change Adaptation Framework* was released in December 2010. The Framework lays out eleven expected climate-related risks, the basic adaptive capacity to deal with those risks, short-term priority actions for each risk, and several steps that will evolve into a long-term process to improve Oregon's capacity to adapt to variable and changing climate conditions.[1900]

Coquille Tribe

Building on the traditions and values of the Tribal community, the Coquille Indian Tribe is focused on developing a plan to adapt to the challenges presented by climate change and related threats to the tribe's well-being.[1901] Currently, the tribe is focused on building capacity within the Tribal government to understand the impacts of climate change, engaging the tribal community in climate change discourse, and strengthening collaboration and partnerships with non-tribal organizations within the region.[1902] The Tribe has committees in place to identify and investigate the issues, including the Climate Change Committee and the Emergency Preparedness and Disaster Mitigation Committee.[1903] The Climate Change Committee, for example, was established in 2008 and has been tasked by Tribal Council to: become familiar with the causes of climate change and consequences of climate change to the Tribe, tribal members, tribal enterprises and the outlying community; evaluate practices, policies operations and enterprises and make recommendations regarding opportunities, adaptations and mitigations regarding the climate change process as it affects the Tribe and its members; and, provide information to the Tribal membership regarding the causes, effects and prudent responses to climate change.[1904]

In addition to continuing current efforts, the Tribe is preparing a *Climate Action Plan*, a more detailed and informed plan that incorporates insight and knowledge from Tribal members, the Tribe's natural resources and planning staff, information and data from climate scientists, research and other organizations dedicated to climate issues, and the assistance and resources available from local, state and federal government.[1905] The plan will help to further identify local risks to Coquille Tribal land and natural resources, infrastructure and transportation systems, and in turn, the Tribe's culture, economy, health, and safety.[1906] Additionally, impacts to other regions of the northwest and the world that may also bring adverse local impacts will be investigated.[1907] Further information on the Coquille Tribe's efforts around climate change can be found at http://tribalclimate.uoregon.edu/files/2010/11/tribes_Coquille_web2.pdf (accessed 4.7. 2011).

[1898] *State of Oregon. *The Oregon Climate Change Adaptation Framework*. (2010, p. i)
[1899] *State of Oregon. (2010, p. i)
[1900] State of Oregon. (2010, p. i)
[1901] *Institute for Tribal Environmental Professionals. *Climate Change and the Coquille Indian Tribe: Planning for the effects of climate change and reducing greenhouse gas emissions (pdf).* (2011, p. 1)
[1902] *Institute for Tribal Environmental Professionals. (2011, p. 2)
[1903] *Institute for Tribal Environmental Professionals. (2011, p. 2)
[1904] *Institute for Tribal Environmental Professionals. (2011, p. 3)
[1905] *Institute for Tribal Environmental Professionals. (2011, p. 1)
[1906] *Institute for Tribal Environmental Professionals. (2011, p. 1)
[1907] *Institute for Tribal Environmental Professionals. (2011, p. 1)

California

California strengthened its commitment to managing the impacts from sea-level rise, increased temperatures, shifting precipitation and extreme weather events when Governor Arnold Schwarzenegger signed Executive Order (EO) S-13-08 on November 14, 2008.[1908] The order called on state agencies to develop California's first strategy to identify and prepare for these expected climate impacts.[1909] The California Natural Resources Agency (CNRA) has taken the lead in developing this adaptation strategy, working through the Climate Action Team (CAT).[1910] Seven sector-specific working groups led by twelve state agencies, boards and commissions, and numerous stakeholders were convened for this effort.[1911] The strategy proposes a comprehensive set of recommendations designed to inform and guide California decision-makers as they begin to develop policies that will protect the state, its residents and its resources from a range of climate change impacts.[1912] Four comprehensive state adaptation planning strategies were identified by all climate adaptation sectors.[1913] These strategies were intended to be in place or completed by the end of 2010.[1914]

Following a 45-day public comment period since its release as a Discussion Draft in August 2009, the CNRA and sector working groups have revised the strategy incorporating public stakeholder input.[1915] This document will be updated approximately every two years to incorporate progress in strategies and changing climate science.[1916] The current draft reviews projections for temperature, precipitation, sea-level rise, and extreme events, then evaluates climate impacts by sector.[1917]

Yurok Tribe

In 2010, the Yurok Tribe received a grant from the U.S. Environmental Protection Agency for a Climate Change Impacts Assessment and Prioritization Project.[1918] The final goal of the project is the preparation and completion of the Yurok Tribe Climate Change Prioritization Plan and an initial assessment of potential climate change impacts that will serve as a guide for future tribal climate change research and planning efforts.[1919] The project also aims to build tribal government and community capacity via technical training of the program staff and participation in national meetings.[1920] The project will engage the reservation community in potential localized changes through the production of educational materials, including a brochure outlining various opportunities to participate in local and regional climate change planning efforts.[1921]

[1908] *CA Natural Resources Agency. (2009, p. 4)
[1909] *CA Natural Resources Agency. (2009, p. 4)
[1910] *CA Natural Resources Agency. (2009, p. 4)
[1911] *CA Natural Resources Agency. (2009, p. 4)
[1912] *CA Natural Resources Agency. (2009, p. 4)
[1913] CA Natural Resources Agency. (2009, p. 23)
[1914] CA Natural Resources Agency. (2009, p. 23)
[1915] *CA Natural Resources Agency. (2009, p. 4)
[1916] *CA Natural Resources Agency. (2009, p. 4)
[1917] CA Natural Resources Agency. (2009, p. 4)
[1918] U.S. EPA. *Environmental Justice Grant Recipients in the Pacific Southwest: Yurok Tribe Project (website).* (2011)
[1919] *U.S. EPA. (2011)
[1920] *U.S. EPA. (2011)
[1921] *U.S. EPA. (2011)