Appendix 10-A

Climate Change Impact Analysis Memorandum

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memorandum

date	September 1, 2023
to	Kate Tourtellot, City of Monroe
cc	Alex Dupuy, MIG
from	Nick Hart and Rachel M. Gregg, Environmental Science Associates
subject	Climate Change Impacts Analysis for the City of Monroe: Shorelines and Natural Environment Element

Introduction

ESA and MIG are assisting the City of Monroe with their Comprehensive Plan Update. As part of this process, this Climate Change Impacts Analysis was prepared in support of the ongoing update to the Shorelines and Natural Environment Element of the Monroe Comprehensive Plan. This memo includes a state-of-the-science synthesis on observed and projected changes of concern for the City of Monroe. Changes in air and stream temperatures, precipitation patterns, snowpack, streamflow, sediment dynamics, drought, and wildfire regimes will affect Monroe’s ecological assets and critical areas, including fish and wildlife habitats, wetlands, critical aquifer recharge areas, and soils and geologically hazardous areas.

Climate Change: Trends, Observations, and Projections

Climate change is projected to have wide-ranging implications in the Puget Sound region. Table 1 provides an overarching summary of both the observed and projected changes for climate-related variables. Projected changes are presented from the Climate Mapping for a Resilient Washington tool (Climate Impacts Group [CIG] n.d.) unless otherwise noted. Projected future conditions from this tool are presented across two time periods—mid-century (2040–2069) and late century (2070–2099)—compared to a historical baseline period of conditions observed between 1980 and 2009. Climate change projections used for this analysis are built upon Representative Concentration Pathway (RCP) 8.5 (Stocker et al. 2013), a scenario for global greenhouse gas concentrations representing a “business-as-usual” trajectory in which greenhouse gas emissions remain unabated. This scenario and others like it were developed by the Intergovernmental Panel on Climate Change and detail the effects of human activities on greenhouse gas emissions and the global climate. The use of RCP 8.5 projections is considered to be best practice for planning processes as it represents a likely worst-case scenario for climate change impacts. The exceptions in the table below are the stream temperature projections from NorWeST (Isaak et al. 2017) and the snowpack projections from Roop et al. (2020), which use a slightly lower emissions scenario (A1B, which is comparable to RCP 6.0).

TABLE 1. OBSERVED AND PROJECTED CHANGES IN CLIMATE-RELATED VARIABLES.

Climate Variable	Trend	Observed Changes	Projected Changes
Air Temperature	▲	Lowland areas surrounding Puget Sound (including Monroe) have experienced a 1.3°F increase in air temperatures between 1895 and 2014. During this period, nighttime average high temperatures increased faster than daytime temperatures (Mauger et al. 2015). There has been no observed significant trend in daytime heat or cold events between 1895 and 2011 (Snover et al. 2013).	*Mid-Century (2040-2069):* Average daily summer (June-August) temperatures for Snohomish County are expected to increase by 6.3°F from the historical baseline of 70°F experienced between 1980 and 2009. The number of days with high temperatures (over 100°F) in Monroe is expected to increase by less than 1 day. *Late Century (2070-2099):* Average daily summer temperatures are expected to be 10.3°F warmer. There may be nearly 3 days over 100°F per year in Monroe.
Precipitation	▲▼	There has been no significant trend in annual precipitation for the Puget Sound region (Mauger et al. 2015). Spring (March-May) precipitation increased by 27% between 1895 and 2014 (Mauger et al. 2015). The frequency and intensity of heavy rainfall increased modestly across Western Washington (Mauger et al. 2015).	*Mid-Century (2040-2069):* Monroe may experience an increase in total annual precipitation of approximately 9% compared to the baseline period, above the average of a 6.9% increase across Snohomish County. Changes in precipitation will not be distributed evenly throughout the year, with winters growing wetter and summers drier. This trend is projected to manifest as a 10% decrease in late-summer (July 15–September 15) precipitation. Heavy (2-year storm) and extreme (25-year storm) precipitation may occur 9% and 14% more frequently, respectively. *Late Century (2070-2099):* Total annual precipitation in Monroe may increase nearly 12%. Late-summer precipitation will still be out of balance. Heavy (2-year storm) and extreme (25-year storm) precipitation may occur 14% and 23% more frequently, respectively.
Snowpack	▼	The average spring snowpack in the Cascades declined by about 30% from 1955 to 2016 (Roop et al. 2020). Glaciers in the Skykomish River basin declined in area from 3.8 to 2.1 square kilometers (1.46 to 0.8 square miles) between 1958 and 2009 (Pelto 2011).	Snowpack will continue to decline and accelerate with warming temperatures. *Mid-Century (2040-2069):* Spring snowpack in the Cascades is projected to continue declining by 38-46% under a lower emissions scenario (Roop et al. 2020). *Late Century (2070-2099):* Spring snowpack in the Cascades is projected to decline by 56–70% under a higher emissions scenario (Roop et al. 2020).
Streamflow	▲▼	Spring peak streamflow has shifted up to 20 days earlier in snow-dominant watersheds in Puget Sound (Roop et al. 2020). All watersheds in Washington have shown reduced summer flows since the early 2000s (CIG 2009).	Streamflow projections include potential increases in winter and decreases in summer. *Mid-Century (2040-2069):* Compared to historical levels, streamflow ratios in the Skykomish River and Woods Creek are expected to shift to become higher in the winter (November–February) and lower in the spring (March–June). Summer streamflow (June–September) will decrease by 58% in the Skykomish River and 17% in Woods Creek. Low streamflow days are expected to increase, with the Skykomish River experiencing 29–34 more low-flow days annually. *Late Century (2070-2099)*: The trend in winter-spring streamflow ratios is expected to continue. Summer streamflow in the Skykomish will decline by 74% and Woods Creek by 21%. The Skykomish River will experience an additional 47–51 days of low streamflows.

Climate Variable	Trend	Observed Changes	Projected Changes
Sediment Dynamics	▲▼	Sediment dynamics are influenced by warming temperatures, intense precipitation events, and flooding. The Lower Skykomish River has been shaped by sediment transport, erosion, and channel migration over time.	Increased streamflows and flooding can cause increased rates of sediment transport, which may increase the risk of erosion and avulsion in the Lower Skykomish River (Snohomish County Surface Water Management [SWM] 2023). *Mid-Century (2040-2069):* Woods Creek is projected to experience 12% higher peak flows, while the Skykomish River peak flow is expected to increase by 39%. *Late Century (2070-2099)*: Woods Creek is projected to experience 13% higher peak flows, while the Skykomish River peak flow is expected to increase by 60%.
Drought	▲	Drought conditions have increased since the early 2000s (CIG 2009).	*Mid-Century (2040-2069):* Projections indicate a 22% chance of total summer precipitation (June–August) of at or below 75% of normal precipitation. *Late Century (2070-2099)*: Drought projections indicate a 36% chance of total summer precipitation (June–August) of at or below 75% of normal precipitation.
Stream Temperatures	▲	Stream temperatures increased between 1980–2009 (Isaak et al. 2012).	*Mid-Century (2040-2069):* Average August stream temperatures in the Skykomish River and Woods Creek are projected to increase by 2.6°F from a baseline of 62.85°F in the Skykomish River and 61.14°F in Woods Creek (U.S. Forest Service [USFS] n.d.-a). *Late Century (2070-2099):* Average August stream temperatures are projected to increase by 4.47°F in the Skykomish River and 4.34°F in Woods Creek compared to historic baselines (USFS n.d.-a).
Wildfire	▲	The frequency and extent of wildfires have increased since the 1970s (CIG 2009). Fire seasons between 2003 and 2012 averaged 84 days longer than in 1973–1982 (Westerling 2016).	In general, areas west of the Cascades are less at risk from wildfires (Snover et al. 2013). Projections indicate that the likelihood of wildfire in Monroe is low across both time periods. *Mid-Century (2040-2069):* There is a 3% change that Monroe will have climate and fuel conditions favorable to wildfire. *Late Century (2070-2099)*: There is a 10% change that Monroe will have climate and fuel conditions favorable to wildfire.

NOTES:
Projections are derived from the Climate Mapping for a Resilient Washington tool (CIG n.d.) unless otherwise noted in parenthetical references.

Potential Impacts of Climate Change

Monroe’s critical areas will face a broad range of challenges due to changing climatic conditions. These areas provide critical ecosystem services, such as fish and wildlife habitat, flood and erosion control, groundwater recharge, water and air purification, and recreation. These natural habitats may help to buffer the impacts of climate change in the city, including warmer air and stream temperatures, more extreme flood events, sediment loading of waterways, and lower summer streamflows.

Fish and Wildlife Habitats

Aquatic Habitats

The Lower Skykomish River provides habitat resources for many aquatic species, primarily freshwater and anadromous fishes. Among these species are steelhead, bull trout, and Pacific salmon species that utilize the river as they migrate upstream to spawning locations (SWM and Sustainable Lands Strategy [SLS] 2018). Heightened winter flows will likely increase scouring, erosion, and sedimentation of rivers and streams that provide critical habitat for aquatic species, which may smother or entomb redds (salmon egg “nests”). Increased flooding may also flush smolts downstream. Decreased summer flows will contribute to increased stream temperatures and decreased connectivity of side channels in floodplains that are important for young fish (Raymond et al. 2014). Changes in streamflows may also favor the establishment of invasive and non-native species. Rising air and stream temperatures, extreme heat, and drought will also impact aquatic habitats. For example, warming air temperatures affect species that require cool waterways such as salmonids, resulting in inhibited migration and breeding patterns and mortality (Mantua et al. 2010). Heat stress, increased predation, and migration blockage due to warming stream temperatures may increase stress on salmon populations (Mantua et al. 2009; LeDoux et al. 2017). Increases in stream temperatures may also present rearing challenges for some salmonids, which slow the growth rate of juveniles (LeDoux et al. 2017). As drought and extreme heat increasingly co-occur, terrestrial plant species that provide important shade to aquatic ecosystems (USFS n.d.-b) will face greater stress and may experience shifts to younger age classes or species types (Washington Department of Fish and Wildlife [WDFW] 2015).

Upstream changes will also have impacts on aquatic ecosystems within Monroe. Increased wildfire occurrence upstream of Monroe may contribute to higher levels of sedimentation and pollutants entering waterways due to post-fire instability (Raoelison et al. 2023). As extreme precipitation events increase in frequency and intensity, polluted runoff from impervious developed areas will enter waterways more frequently, particularly if municipal stormwater systems are unable to handle increased flow rates. This impact may be experienced most acutely in aquatic ecosystems in the three basins (Woods Creek, Skykomish River, French Creek) into which Monroe has stormwater outfalls (City of Monroe 2015; LeDoux et al. 2017; U.S. Environmental Protection Agency [EPA] n.d.; Washington State Department of Ecology [Ecology] 2023a). Shifts in the composition and abundance of non-native and invasive species may occur under climate change, potentially increasing competition stress with native species (Gervais et al. 2020).

Terrestrial Habitats

Most of the Monroe planning area as defined by the City of Monroe in their 2015 Comprehensive Plan has been urbanized, although some pockets of terrestrial habitats exist (City of Monroe 2015). Riparian habitats along the Skykomish River and Woods Creek in Monroe are adapted to current climate conditions, which include periodic high flows and flooding. Increased flood levels and higher flow rates may affect these habitats’ ability to continue to provide ecosystem functions and services in a changing climate (SWM 2023). Increased incidence of drought and shifts in streamflow patterns will likely reduce the availability of water in these habitats, affecting seedling germination rates and adult survival (WDFW 2015). Warmer and drier conditions may also contribute to a shift in vegetation types with more drought-adapted species, including both native and non-native, invasive species (WDFW 2015; Albright et al. 2021). Lower soil moisture has been shown to decrease vegetation moisture (Sonisa et al. 2021), which in turn decreases the cooling effects of vegetation on the surrounding environment (Kurn et al. 1994).

Shifting seasonal patterns such as an earlier incidence of spring conditions and a longer, warmer, and drier summer period may impact species adapted to current climate conditions. Changes in the start of spring will change the availability of food sources, creating timing mismatches for migratory species and disconnects from established reproductive cycles, which may lead to decreased species success (Snover et al. 2013). Mortality rates for some plant species may increase due to pests and pathogens taking advantage of shifting climate conditions and increased host stress due to drought or heat (Raymond et al. 2014). Further, productivity in water-limited ecosystems is expected to decrease, affecting plant growth rates for species, including Douglas fir (Littell et al. 2010). A projected increase in days with high wildfire danger by mid-century combined with recreational uses in or near some riparian areas can create elevated risk of human-caused fire events (National Park Service n.d.) despite low projected risk of wildfire occurrence (CIG n.d.).

Given the urbanized nature of much of the Monroe planning area, few large mammals exist within the planning area, though many smaller mammals such as opossum, raccoon, red fox, and skunk have been observed within city limits (City of Monroe 2015). Of these species, the Cascade red fox is listed as being highly vulnerable to increasing temperatures (WDFW 2015). Reptiles and amphibians including frogs, toads, salamanders, turtles, lizards, and snakes occur within Monroe, and in general, these species are expected to experience moderate to high vulnerability due to increasing air and stream temperatures, shifting precipitation patterns, drought, and wildfire (WDFW 2015). For example, the Puget Oregonian snail, which is sensitive to canopy loss, increased temperatures, and reduced soil moisture (WDFW 2015). Many bird species are also vulnerable to climate change, with Monroe playing host to a variety of migratory waterfowl and overwintering birds of prey (City of Monroe 2015). The National Audubon Society identified 217 bird species in Snohomish County that are vulnerable to increasing air temperatures, shifting springtime conditions, and loss of habitat by late century, inclusive of migratory species (Audubon 2019).

Wetlands

Wetlands are highly vulnerable to climate change owing to their location at the intersection of land and water. Wetlands provide critical habitat for nearly 65% of mammals and 72% of bird species in Washington and Oregon (Kauffman et al. 2001). Wetland ecosystems in Monroe are concentrated primarily near the Skykomish River, alongside Cutthroat Creek, and in the northwest corner of the Urban Growth Area near Creation and Arena creeks along US-2 (Sartorious 2013). Areas of critical wetland habitat as defined in the 2019 Shoreline Master Program are located in Al Borlin Park and along the shoreline near the Cadman Inc. gravel operation (City of Monroe 2019). Risks to wetlands include changes in precipitation and increases in air temperatures (WDFW 2015). These risks may disrupt the ability of wetlands to provide ecosystem services, which include slowing and storing floodwaters, recharging groundwater, filtering pollutants, and supporting habitat (Ecology 2023b).

The most likely negative impact of climate change on wetland ecosystems is drying. Wetlands that historically have rarely dried out are expected to shift to more frequent drying as summer seasons become warmer and drier (Ecology 2023b; CIG n.d.). This will cause shifts in species types, habitat conversion, and/or habitat loss and degradation (WDFW 2015). Further, wetlands are terrestrial carbon sinks and changes to their viability may result in carbon being released back into the atmosphere (Salimi et al. 2021). Increased winter precipitation may have positive effects on wetlands by creating additional side channel habitats, or negative effects such as reduced opportunity for water storage and increased erosion (WDFW 2015). In Monroe, neither outcome is inherently more or less likely, and management practices will play an important role.

Critical Aquifer Recharge Areas

Groundwater resources in and around the City of Monroe consist of discontinuous aquifers surrounded by less permeable sediments. Most of the lowland and valley portions of the city are built on soils that support moderate infiltration rates, although these areas are generally highly developed and the soils highly disturbed. Areas on the north and west edges of the City of Monroe planning area are primarily composed of soils with low infiltration rates, which may increase the risk of surface water runoff in these areas (City of Monroe 2015). Owing to the city's lack of reliance on groundwater for municipal and private use, no Critical Aquifer Recharge Areas have been identified within the Monroe city limits. Some wells have been identified in the Milwaukie Hill area (City of Monroe 2015).

Increased storm intensity in the fall and winter may create precipitation events that exceed the infiltration capacity of soils, generating increased runoff and decreased absorption of rainfall into groundwater aquifers. While Monroe does not currently rely on groundwater sources, demand for water is likely to grow as temperatures rise and population growth pressures increase. Drought events may diminish the supply of water available from surface water sources, increasing the amount of demand placed on existing water supplies (City of Monroe n.d.) and potentially increasing the need for groundwater resources to meet demand.

Soils and Geologically Hazardous Areas

Geologically hazardous areas are those that are susceptible to erosion, landslides, mass wasting, debris flows, rock falls, and differential settlement. The geological hazard of an area is often a product of soil composition in combination with slope angle, stream proximity, and groundwater seepage. The areas of greatest geological hazard in Monroe are identified as being generally north of Woods Creek Road from Oaks Street to the city limits (City of Monroe 2015). The Snohomish County Hazards Map shows landslide-prone areas that may impact ecosystems at several locations near the Skykomish River, primarily in the areas near the Heidelberg Materials site (Snohomish County n.d.).

Risks associated with geological hazards can be expected to increase with climate change as shifting precipitation patterns will likely increase the occurrence of landslides and accelerate erosion (Mauger and Vogel 2020). The projected increase in precipitation, particularly high-intensity and heavy rainfall over multiple days, will likely increase the number of landslides that occur in hazardous areas. Increased streamflow may cause more aggressive channelization of waterways in areas with constrained floodplains and increase bank instability (Mauger et al. 2015). Soil moisture is expected to decrease during summer months due to a combination of changing precipitation patterns, declining snowpack, and warmer air temperatures (Elsner et al. 2010). Dry soils can increase landslide risk by widening gaps in rocks and soils (Mauger et al. 2015). Decline in plant health near streambanks may contribute to higher erosion risk as the stabilizing effects of vegetation are degraded (USFS n.d.-b).

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