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Climate Drivers of Change

Temperatures have increased, and will continue to increase

Air temperatures have increased in the Puget Sound region by about 1.3°F between 1895 and 2014. All but six years from 1980 to 2014 were warmer than the 20th century average. Looking at the future, we are locked into at least some continued warming. For the 2050s, if emissions are reduced globally, it will still be on average 4.2°F warmer. If we don’t reduce emissions, that temperature increase will be closer to 5.5°F. While the climate system is complex, it’s clear that the primary cause of recent warming is CO₂ emissions from human activities such as burning fossil fuels and deforestation.

Why Equity?

Climate change will not impact everyone in the same way – even within the same city.

In Seattle, climate change will present new challenges, such as sea level rise, but will also act as a stressor that will exacerbate existing inequalities between communities, and potentially set back efforts to remedy them.

It is important to recognize who in Seattle will feel not only the direct, but also indirect impacts of climate change, and how they will feel them, to continue advancing equity across the city.

This document explores a set of climate change topics that are expected to impact life in Seattle in the future. Each topic is briefly summarized, key points are highlighted using infographic diagrams, and a map showing the spatial “overlap” between Seattle’s historically marginalized communities and the expected impact areas is presented. Taken together, these elements are intended to provide a jumping-off point for policy development and discussion.
Equity Index Basemap

Map 1: Dark blue shows the highest scoring areas in the Equity Index, and help indicate where to should look for equity impacts of climate change.

Note: While this map shows which neighborhoods equity populations are concentrated in, it is important to point out that individuals from these groups live everywhere in the city.

Unusual Circumstances in the University District

The University District’s high equity index score is driven by low incomes among the student population. However, many (though certainly not all) of these students are financially supported by family members. While there are certainly equity implications in the University District, this area is hashed in the resulting maps to alert the reader to these unusual circumstances.

Dark blue areas score the highest

The top third of equity index scores are shown in dark blue on the map. These are areas that have a combination of one or more demographic conditions: high percentage people of color, high percentage of households at or below 200% of the Federal poverty level, high percentage of population born in another country, and high percentage of households with limited English proficiency.

Dashed Red Line is City Limits

The study area extends beyond Seattle city limits; partially because census tracts don’t exactly track city boundaries, but also to look at areas, like White Center, what are under consideration for annexation.

References:

The Equity Index was created referencing the Environmental Equity Assessment Pilot produced by the City of Seattle’s Office of Sustainability and Environment for the Equity and Environment Initiative. To learn more about their methodology, visit: https://www.arcgis.com/apps/MapSeries/index.html?appid=4c14645fec154ae8978dcd42c94b76ba. The City of Seattle and King County Open GIS Data were referenced in the production of overlays and basemap content.
Reading the Bivariate Maps

The Climate Equity Atlas uses Bivariate Choropleth maps, which are a way of visualizing the combined impact of two variables together. The dark purple areas (outlined in yellow) in the map on the facing page show where the darkest blue and darkest pink areas on the maps below overlap – in other words, the areas that are in the highest category for both the equity index and the climate variable.

Climate Concern Map:
Dark pink areas have the highest climate concern, while grey areas have the lowest. The yellow overlay shows the physical locations of relevant hazards.

Equity Basemap:
Dark blue areas have the highest equity index scores, and the grey areas have the lowest equity index scores.

An example of the bivariate that combines the two maps above is on the facing page.

Visualizing both variables together highlights locations where certain populations may be facing a disproportionate share of the impacts of climate change, and also preserves the ability to investigate other areas and ask questions that are more nuanced.
Dark purple areas have the highest equity index scores and the highest climate concern.

This color shows areas that have medium equity index scores and the highest climate concern.

This color shows areas that have medium equity index scores and medium climate concern.

This color shows areas that have medium equity index scores and low climate concern.

This color shows areas that have low equity index scores and medium climate concern.

This color shows areas that have low equity index scores and low climate concern.

This color shows areas that have low equity index scores and low climate concern.

This color shows areas that have low equity index scores and low climate concern.

This color shows areas that have low equity index scores and low climate concern.

This color shows areas that have medium equity index scores and medium climate concern.

This color shows areas that have medium equity index scores and the highest climate concern.

This color shows areas that have low equity index scores and the highest climate concern.

This color shows areas that have the highest equity index scores and low climate concern.

This color shows areas that have the highest equity index scores and low climate concern.
Seattle is not usually associated with heat waves and extreme heat — and that makes us even more vulnerable when it does happen, as Seattleites are not acclimated to heat events.\(^\text{13}\)

Nationwide, heat is the number-one weather related killer, claiming 1500 lives in an average year.\(^\text{14}\) Under a warming climate, the frequency, severity, and duration of heat waves is expected to increase\(^\text{1}\) — having an especially acute impact on Seattle’s equity communities.

**EXTREME HOT DAYS**

will happen more often in the future, and Seattle will heat up more due to the urban heat island effect.

Only 22.7% of people of color in Seattle have A/C (compared to 33.1% for whites)\(^\text{14}\)

The number of projected excess deaths in Seattleites age 45+ by 2080\(^\text{16}\)

**URBAN HEAT ISLANDS**

Cities can be as much as 27°F warmer than their surrounding undeveloped areas due to the Urban Heat Island Effect.\(^\text{17}\)

**Extreme Heat Can Cause:**
1. Dizziness and fainting
2. Cardiovascular problems
3. Respiratory problems, particularly for patients with COPD or asthma
4. Heat cramps and vomiting

With high humidity, Seattle can start seeing public health impacts at 78.9°F\(^\text{13}\)

Dark roofs
Dark materials on roofs absorb heat and warm the city.

Sparse vegetation
Developed urban spaces often have low canopy cover and lack large swaths of vegetation that help cool a city.

Urban canyons
Tall street signs, narrow streets, create a heat-trapping canyon.

Impervious surfaces
Dark paving materials like asphalt and concrete absorb heat.

---

89 deaths
Map 2: Dark purple shows where equity populations in Seattle were more likely to be exposed to more extreme temperatures from heat islands on hot days.

Equity Index

Prevalence of Impervious Surface

Combined Highest Risk/Priority

Equity Index

The dark purple tracts that are outlined in yellow are the tracts that are most affected by both climate and equity variables.

References:
The Impervious Surface distribution was created using the 2007 City of Seattle Land Use Land Cover dataset. Surface Temperature was calculated & created in-house referencing landsat data taken on August 01, 2015.

King County and City of Seattle Datasets were also used in the production of overlays and base map content.
Poor air quality has a clear connection to health. Air pollutants are known to cause asthma, heart disease, stroke, diabetes, low birth weights, and other negative health complications, even at low concentration levels. People who live or work in areas with high concentrations of roadways, industry, landfills, brownfields, and airports are more exposed to these types of pollutants. Across the nation, low-income populations and people of color are consistently overrepresented in communities that have the poorest air quality, and Seattle is no exception. Rising temperatures and increased wildfires under climate change will exacerbate current air quality challenges and health outcomes.

Pollen can be a problem for people with respiratory conditions and allergies. With climate change, the pollen season will start earlier, last longer and be stronger. Emissions from transit and industry are a severe burden on human health. The impacts of climate change, particularly increasing temperatures, will cause these impacts to be felt more acutely.

Wildland fire is a major source of particulate matter, and is especially harmful for populations with asthma and respiratory diseases. More area is expected to burn each year under climate change.

By the 2050s, there will be a 1 in 3 chance every year that more than 2 million acres burns in Washington state. And by 2070 we will expect the current area burned west of the Cascades to double.

The average cost of an outpatient ER visit for asthma is $1502.

The average cost of a hospital stay for an adult with asthma is $6600.

In 2010, children in the Duwamish Valley, where 32% of the population was foreign-born, were 1.7x more likely to be hospitalized for asthma than the rest of King County.

Asthma is the leading cause of missed school days nationwide, a key determinant of academic performance.

Black adults are admitted to the hospital for asthma-related conditions over 3x as often as non-Hispanic whites.

They are 3x more likely to die from asthma-related conditions than non-Hispanic whites (2013).

The average cost of a hospital stay for an adult with asthma is $6600.
Air Quality Hazards

Map 3: Dark purple shows where equity populations in Seattle were more likely than the rest of the population to be exposed to impaired air quality and pollutants.

References:

The Air Quality Index was created from a dataset provided by the Puget Sound Clean Air Agency. It references the Community Air Tool (CAT) which combines air pollution, health sensitivity factors, and age demographics.

King County and City of Seattle Datasets were also used in the production of overlays and basemap content.
Flooding in urban settings can not only cause immediate threats to safety and property, but can also have lingering impacts after the event, such as displacement, disruption of vital systems and infrastructure, economic stress, and harmful indoor air quality due to mold. Periodic urban and coastal flooding events are not new for many areas of Seattle and can sometimes be deadly. Seattle is expected to experience more flooding under climate change, both along shorelines due to Sea Level Rise, and in urban flood areas, due to increased extreme rain events and urban impervious cover.

**WHERE IT FLOODS**

In Seattle, most of the neighborhoods that experience flooding are home to historically disadvantaged communities. Flooding may occur more frequently as the climate changes.

**By 2100**

In the Puget Sound region, extreme precipitation events will intensify and occur more frequently. By the end of the century, the number of days with rain over 1 inch is projected to increase by 13%, and the number of days with rain over 3 inches is projected increase by 22%.

**Urban Flooding Areas**

39,000 people in Seattle live in an area vulnerable to flooding, and flooding more frequently under climate change (dark blue). Flooding can lead to mold inside homes. Indoor mold has impacts on health, particularly on people with respiratory conditions.

Potential impacts from flooding

- Damage to Property
- Disruption of work and business
- Impacts to physical health and fatalities
- Mental health impacts
- Reduced recreation opportunities
- Pollution
- Water-borne illnesses from swimming and shellfish harvesting
- Threats to critical infrastructure

By 2100
Affordable Housing in the Flood Zone

Map 4: Dark purple shows where equity populations in Seattle live in relation to more affordable housing (low median home values), and hashed grey denotes flood-prone areas. As housing gets less affordable across the city, low-income populations may concentrate in more affordable areas – which also may be in flood zones.

References:
Median Home Price data is from the US Census American Community Survey 5-year estimates, 2011-2015.1

The Urban Flood Zone data is from the City of Seattle’s SHIVA analysis.2

City of Seattle & King County open datasets were referenced in the production of overlays and basemap content.

1. City of Seattle & King County open datasets were referenced in the production of overlays and basemap content.
2. The Urban Flood Zone data is from the City of Seattle’s SHIVA analysis.
Stormwater sweeps along streets and other impervious surfaces, picking up contaminants along the way and depositing them into our local water bodies. This is the most significant single source of toxic chemicals in the Puget Sound, and threatens not only fish and wildlife habitat, but people who eat local fish and shellfish. Of particular concern are outfalls known as Combined Sewer Overflows (CSOs), outfalls in which untreated sewage wastewater and stormwater overflow during major rain storms.

CSOs are of interest because they occur in targeted areas and carry a suite of toxic chemicals. CSOs are particularly a problem in the Duwamish River, which is an EPA Superfund site. Increased extreme precipitation events under climate change will exacerbate the challenge of protecting habitat and human health from pollution associated with both stormwater and CSOs.

Communities of color have the highest rates of fish consumption, and for many there are no real alternatives for resident seafood.

Some families rely on local fish for a significant source of protein in their diet.

**What’s in stormwater?**

- Spilled oil
- Detergent
- Pesticides
- Fertilizer
- Bacteria
- Chemicals

When rain falls on impervious surfaces like pavement, it pick up and concentrates contaminants as it flows.

Stormwater is the single largest source of pollution to the Puget Sound.
Exposure to CSOs in 2015

Map 5: Dark purple shows where equity populations in Seattle lived next to waterbodies that experienced the most CSOs by volume in 2015.

The dark purple tracts that are outlined in yellow are the tracts that have the highest Equity Index scores and were most exposed to CSOs by volume in 2015, a record rainy winter.

References:
The Combined Sewer Overflow exposure map was created using City of Seattle and King County Data on locations of sewer outfalls, and City of Seattle and King County 2015 Concurrence reports. The exposure index reflects a score based on the summed volumes for all outfalls abutting a census tract in 2015, weighted by shoreline area for each tract.6 City of Seattle & King County open datasets were referenced in the production of overlays and basemap content.
Transit is a vital part of life in Seattle, and is a central solution to getting to net zero emissions in the region as a whole. As the region invests its transit system and prepares for the future, it should also recognize that resilient, accessible transit is particularly vital to equity communities.

Public transit done right can contribute to resilience – or done wrong, can hinder the ability of transit-reliant populations to cope with the adverse impacts of climate change.

Climate change impacts, such as landslides, flooding, and blackouts can cause significant disruptions to the transit system. In addition to funding and planning a robust public transit system – which will help reduce greenhouse gases and will simultaneously provide resilience for community members – Seattle should provide protections for a transit system which will be increasingly vulnerable to disruptions.

**DISRUPTIONS TO TRANSIT**

Climate change impacts, such as landslides, flooding, and blackouts, can cause significant disruptions to the transit system.

A Sound Transit Climate Vulnerability study identified sea level rise, flooding, landslides, and rail buckling under extreme heat as particular impacts of concern.

- Landslides can affect roads, and Sounder commuter rail
- Flooding can make roads impassable or severely delay normal transit routes.
- Increasing extreme heat events can cause rail buckling along rail and freigh lines.
- Sea level rise may routinely flood roads near shorelines.

Vulnerable populations are more likely to have fewer transportation options.

- **Wet pavement is implicated in 13% of all crash fatalities.**
- **The combined impact of the 2007 I-5 and I-90 closures due to flooding was almost $75 million.**

**TRANSIT DISRUPTIONS DON’T AFFECT EVERYONE EQUALLY**

Vulnerable populations are more likely to have fewer transportation options.

<table>
<thead>
<tr>
<th>Type</th>
<th>Annual Salary</th>
<th>Can Work From Home</th>
<th>Sick/Safe Leave</th>
<th>Likely to Lose Job if Misses Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salaried Office Job</td>
<td>$64,000</td>
<td>Often</td>
<td>Receives</td>
<td>Will likely not lose job if misses shift</td>
</tr>
<tr>
<td>Construction</td>
<td>$41,000</td>
<td>Cannot work from home</td>
<td>Sick/safe leave</td>
<td>Will likely not lose job if misses shift</td>
</tr>
<tr>
<td>Hourly Retail</td>
<td>$31,200</td>
<td>Cannot work from home</td>
<td>Does not receive sick/safe leave</td>
<td>Might lose job if misses shift</td>
</tr>
</tbody>
</table>
Map 7: Dark purple shows where transit stops that serve equity populations in Seattle may be subject to more frequent disruption due to physical hazards under climate change.

The dark purple tracts that are outlined in yellow are the tracts that are most affected by both climate and equity variables. The Transit Risk Index is a quarterly weighted index of Current Access (the percent of each census tract within 400m of a transit stop, transit stops combined stops from King County Transportation Geodatabase, clipped to our study area), Transit Disruption Hazards (Percent of Current Access area that is overlaid by a landslide hazard, from City of Seattle Known Landslide, Potential Slide, and Steep Slope Critical Areas, or a flood hazard, from the FEMA 500-year flood plane, and City of Seattle 12’ Sea Level Rise Projections and Urban Flooding Areas), and Ridership (Percent ridership per census tract from 2015 American Community Survey at the US Census Bureau).

City of Seattle & King County open datasets were referenced in the production of overlays and basemap content.
Trees in cities – in parks and open spaces, on private and public property, and along roadways – serve important functions, and are key assets for climate change adaptation and mitigation.

Not only do trees mitigate some of the environmental challenges associated with climate change, including increased temperatures, flooding, and stormwater runoff, and impacts to air quality, but they also help to increase human resilience by supporting physical and mental health and enhancing social connections among neighbors. Across the U.S., trees are not evenly distributed, with higher-income neighborhoods more likely to have higher rates of tree cover than lower-income neighborhoods, and the same pattern holds true in Seattle.

**Trees can help mitigate the impacts of climate change, but might be harder to plant and see thrive in the future.**

Trees have many benefits:

- Trees help reduce midday temperatures.
- Trees can help shade streams, providing refuges for salmon and other aquatic organisms.
- Trees help remove air pollutants.
- Trees help reduce home energy use by blocking wind gusts.

Trees have many public health benefits. They can also help cool cities. They can reduce midday temperatures 0.36°F per percent canopy cover increase – increasing canopy cover 10% could cool the city by 3.6°F.

**Impacts to Trees**

Both very young and very old trees are more susceptible to climate impacts such as shifts in pest distribution and drought.
Map 8: Dark purple shows where equity populations lived in areas that had the lowest tree canopy cover in the City.

The dark purple tracts that are outlined in yellow are the tracts that are most affected by both climate and equity variables.

References:

The Canopy Index was created from a dataset provided by the City of Seattle. City of Seattle & King County open datasets were referenced in the production of overlays and basemap content.
Climate change will stress the health of many Seattleites, particularly in equity communities. Extreme heat can have direct and indirect health impacts. Extreme weather events can expose populations to physical hazards, disrupt administration of vital health services or medications, and even reduce indoor air quality through promoting mold growth.

Climate change can also impact mental health, through repeated health and economic stresses. This may lead to more people seeking healthcare, particularly in Seattle’s historically underserved neighborhoods.

Health care centers themselves may be vulnerable to the impacts of climate change due to disruptions in the global supply chain, floods and other physical hazards, and the effects of extreme heat.

One study found a 78% increase in diabetes mortality on an extreme heat day in King County for 45-65 year olds.

People with diabetes are less able to cool their body, and get dehydrated more easily.

The rate of deaths in black populations from diabetes as a primary cause is nearly 3x the rate of whites.

In one study, the mean cost of a hospitalization for someone with diabetes was $10,937.

Health Care Facilities at Risk

While Seattle does not experience hurricanes, the impacts and failures after Hurricane Katrina made landfall in the Gulf Coast can highlight some vulnerabilities in health care centers in the Seattle Region. As the flood waters rolled in and many hospitals in New Orleans lost power, they relied on emergency generators. These systems, however, were not linked to cooling or demudification systems, so temperatures inside the hospitals quickly rose to dangerous levels. To control pathogens, many hospitals also have sealed windows that cannot be opened, hampering the facility’s ability to mitigate heat.

In Seattle, some hospitals may be ill-equipped to weather an extreme heat emergency. Some hospitals and health facilities in Seattle still use swamp coolers to provide cooling, which can fail in instances of high humidity. An extreme heat event that caused even a short blackout could have large consequences for our local health care system, and may lead to the need to evacuate patients. Fortunately, hospitals can undertake infrastructure improvements and planning processes to greatly reduce these risks, such as installing key-operable windows in patient’s rooms, placing critical infrastructure above the first floor, and retrofits to create a facility that will prevent overheating if cooling or ventilation fails during the summer.
The ability of community members to withstand the shocks and stresses imposed by climate change is complex, and many aspects of it, like neighborhood assets and social capital, are difficult to measure. Relationships between residents and community institutions are a large element of a community’s ability to withstand the stresses of climate change.

Displacement can negatively impact social capital -- and in turn, a community’s resilience. Placemaking, social networks, and even the presence of public art in a community can be forces that increase overall resilience to climate change. While these aspects are often intangible, they are also critical in adaptation planning.

### Community assets and social connections increase resilience to climate change

**Natural assets** contribute to community resilience both through physically mitigating hazards, such as extreme heat and stormwater, and by providing gathering spaces for a community. Recent research points to access to green space as improving mental health outcomes.

**Community assets** such as public art, institutions, and frequently used gathering spaces contribute to resilience by providing an opportunity for connection to other social groups and other resources, and by providing an opportunity for knowledge-sharing.

**Social connections** and social capital within community members increase resilience by facilitating the sharing of resources and knowledge, and by providing personal connections to outside resources.

**Case Study: Social capital as a source of Resilience after Hurricane Katrina**

An dramatic example of how social capital can increase a community’s resilience can be found in the aftermath of Hurricane Katrina in New Orleans, LA. For most of New Orleans, the return rate of evacuees after flooding was slow. In contrast, one small neighborhood that is the most densely settled Vietnamese community in the nation, known locally as Versailles, had higher return rates than the rest of the city, and some of the earliest returners.

The community’s robust social networks, and the social capital of the Mary Queen of Vietnam church located in the community, are likely the reason for this relatively rapid recovery. The church itself provided sanctuary for around 50 individuals who did not evacuate, and was able to mobilize its communication networks through a segment on Radio Saigon to connect family members who had evacuated with their kin who were sheltering in the church. After the flood waters retreated, the church again used its networks to reach out to evacuees in other states and facilitate their return home, as well as providing a hub for the rebuilding process.
Climate change will reduce access to traditional foods, such as fish, shellfish, and native plants

Salmon, a culturally important species for Coast Salish peoples, face a number of threats due to climate change.39

1) Warmer ocean temperatures may shift the range of some salmon species.

2) Warmer stream temperatures cause young salmon to be more susceptible to predation, parasites, and disease.

3) Shrinking snowpack will lead to reduced stream flow in salmon streams.

4) Sea Level Rise may inundate estuaries, which are a key habitat for young salmon.

5) Increasing severe storms and floods can sweep eggs away before they have a chance to hatch, and stormwater can increase the toxin load in local water bodies.

6) Increasing forest fires can affect the water quality of salmon streams.

7) Ocean acidification may cause a decline in populations of small mollusks, an important food source for young salmon.

Every recreational shellfish bed along Seattle’s shorelines is closed due to pollution and bio-contamination.38

Stormwater challenges, driven by increasing extreme precipitation (as seen on the previous spread) will hamper long-term and existing efforts to restore these beds.
Nutrition is a staple of human wellness and can affect near-term and long-term health, academic performance, and job performance. For Seattle’s ethnically diverse communities, culturally appropriate foods can be a vital way to connect with shared histories, values, and communities. Climate change can affect the access to these foods both through impacts on the productivity of certain foods themselves, as well as by impacting the affordability of these foods. Access to fresh local produce is currently limited in some neighborhoods in Seattle and future access and affordability may be further impacted by the global impacts of climate change.

**LOCAL AGRICULTURE**

For Washington agriculture, climate change might help before it hurts.

CO₂ enrichment and longer growing seasons may boost agricultural productivity in the short term.

However, long-term increasing droughts may have a negative impact in the long-term.

Fortunately, local agriculture is expected to be highly adaptable:

- Farmers may switch to different varieties that are more heat, drought, or pest resistant.
- They can also shift planting dates to accommodate changing climate regimes.
- Controlling the spread of pests and diseases can improve the overall resilience of crops and livestock.

While it is unclear how the global influence might change food prices in the Seattle area under climate change, any increase may put stress on low-income families in Seattle.

- Nationally, 15% of U.S. households are food-insecure, meaning they lack access to affordable food.
- Globally, the price of cereal grains is expected to rise under climate change.
- In 2013, poor families in the US spent on average 21% of their income on food.
Text References:


2. ibid. Temperature rise projected for the 2050s, relative to the 1970-1999 average for the low emissions and high emissions scenarios.

3. The “rainiest days” are the top 1% of days identified as days with the top 1% in daily water vapor transport, which is the driver of heavy rain events in our region. From Warner, M.D., Mass, C.F., and Salathe, E.P, 2014. “Changes in Winter Atmospheric Rivers along the North American West Coast in CMIPS Climate Models.” Journal of Hydrometeorology. Vol 16: pp 118-128.

4. At the Seattle tide gauge, sea level has risen by +8.6 inches from 1900-2009. Section 4 in Climate Impact Group’s State of Knowledge.


29. Map layer for urban flooding areas acquired through personal conversation with the Seattle Office of Emergency Management, and was produced for the 2014 SHIVA analysis cited above.


Map References:

A. The Equity Index Basemap was created using data from the 2011-2015 5-year spread of the American Community Survey at the tract level, and our methodology was informed by Seattle’s Equity and Environment Initiative Assessment Maps Pilot (https://www.arcgis.com/apps/MapSeries/index.html?appid=4c14645ec154ae8978d642c94fb766a). Tracts were classified into tertiles for visualization.

B. The Urban Heat Island Effect map is heavily skewed towards impervious surfaces due to the data available, and also is showing differences in surface temperature, rather than direct measurements of ambient air temperature. King County is planning a study to directly measure air temperatures in different areas and on different types of surfaces that will produce a more accurate urban heat island map, but the date of this study has still not yet been set.

C. LandSat 7 Data Band 10 for August 1, 2015, which had a high of 92°F and followed two consecutive days of high temperatures reaching 94°F. LandSat data can be downloaded at https://earthexplorer.usgs.gov/.

D. Data provided through personal correspondence with the Puget Sound Clean Air Agency. To learn more about the Agency and their work please visit http://www.pscleanair.org/.


F. Map layer for urban flooding areas acquired through personal conversation with the Seattle Office of Emergency Management, and was produced for the 2014 SHIVA analysis cited above.

G. Spatial outfall location data was scraped from http://www.kingcounty.gov/services/environment/wastewater/cso-status.aspx in August 2016. Total volumes of overflows for 2015 were compiled from King County (http://your.kingcounty.gov/dnrp/library/wastewater/cso/docs/AnnualReport/2015_CSO-CD_Annual.pdf) and City of Seattle (http://www.seattle.gov/util/cs/groups/public/@spu/@drainsew/documents/webcontent/1_050699.pdf) Concurrence reports and added as an attribute to the outfall location layer by matching the outfall identification number.

H. The Homeless Service Provider Distribution was created in-house referencing data found at the following sources:
   - the 2-1-1 website, found at http://crisisclinic.org/education/2-1-1-community-resources/
   - the City of Seattle Human Interest Blog post which can be found at http://humaninterests.seattle.gov/2015/06/29/
   - a map uploaded by the Office of the Mayor which can be found at http://murray.seattle.gov/wp-content/uploads/2015/06/Transitionalencampmentsites.pdf
   - locations published in a article on January 19th, 2016 from the Stranger which can be found at http://www.thestranger.com/blogs/slog/2016/01/19/23447253/heres-where-the-city-will-offer-safe-lots-for-homeless-people-living-in-rvs-and-cars

I. The map & article, which references a Human Services Department (2012 - 2015) dataset, can be found at http://www.seattletimes.com/seattle-news/politics/seattle-officials-say-more-sweeps-of-homeless-camps-in-the-works/

J. The Transit Risk Index is a evenly weighted index of Current Access (the percent of each census tract within 400m of a transit stop, transit stops combined stops from King County Transportation Geodatabase, clipped to our study area), Transit Disruption Hazards (Percent of Current Access area that is overlaid by a landslide hazard, from Seattle Known Landslide, Potential Slide, and Steep Slope Critical Areas, or a flood hazard, from the FEMA 500-year flood plane, and City of Seattle 12’ Sea Level Rise Projections and Urban Flooding Areas), and Ridership (Percent ridership per census tract from 2015 American Community Survey at the US Census Bureau).

K. The Canopy Index was created from a dataset provided by the City of Seattle. It references the Landcover_Citywide_2007 feature class derived from 2ft resolution Quickbird Satellite imagery.

Design:

Layout for document was created by Nick Francis (https://www.behance.net/nickfrancis) and Michelle Francis (http://michellefranciscreative.com/). Template for maps was created by Whitman Arthur Bouton (whitmanarthurbouton@gmail.com). Background infographics on page 8 and 10 were created by Nick Francis. Icons were are from the Noun Project (https://thenounproject.com/)
Policy Solutions

Support and expand “Seattle Neighborhoods Actively Prepare,” particularly in priority communities.

The Seattle Neighborhoods Actively Prepare, or SNAP project, administered by the Office of Emergency Management, can improve community-level resilience by connecting residents to both information and resources, and increasing social cohesion. Partnering with community organizations to recruit diverse block leaders and funding these block-level positions in priority communities can expand the reach of the program.

Assess access to resilience infrastructure and resources, such as cooling centers.

Providing alternate transportation to cooling stations can help improve resilience during extreme heat events, as transit-reliant populations, such as low-income populations, elderly populations, and populations with existing illnesses such as asthma are also more likely to be impacted from outdoor heat-exposure.

Mobilize existing community programs and organizations, such as Meals on Wheels, to check on seniors and the socially isolated during extreme events.

Elderly populations and socially isolated populations tend to be less mobile than other populations, and may be unable to seek refuge from heat without outside assistance. Mobilizing meals on wheels to do welfare checks and provide assistance, such as ample cool water during extreme heat events, could increase resilience of these populations to the adverse impacts of climate change.

Provide targeted outreach to houseless populations.

Houseless populations are uniquely vulnerable to adverse impacts.

Develop long-term urban planning programs to minimize exposure to adverse impacts from climate change.

Planning programs can help minimize urban heat island formation, particularly through incentivizing green and reflective roofs.

Extend the hours of homeless shelters that have air conditioning on Extreme Heat Event days.

There is already precedent for shelters to extend hours in extreme cold events to provide refuge from the cold, but with more extreme heat days, shelters can play a role and be equipped to provide this service in the summer as well.

Use street trees and shading techniques to create shaded corridors along major walking routes, and add considerations of heat to current pedestrian zoning.

Update design standards to maximize passive cooling techniques in new buildings.

Seattle should continue to pursue aggressive emissions reductions, particularly from vehicle, marine and rail traffic.

The transportation sector is currently the largest source of carbon emissions in Washington State. This action will not only contribute to halting the pace of global warming, but will improve air quality locally.

Invest in local and regional transit that would reduce vehicle miles traveled.

While walking and cycling should also be encouraged, in periods of poor air quality, it could actually expose populations to the impacts of poor air quality. A robust transit system will give vulnerable populations an alternative to personal vehicles.

Lobby at the state and federal level for stricter air quality standards.

Partner with other agencies and organizations for more robust air quality monitoring, and place stations in places with populations that are particularly vulnerable.

Convene a conversation to increase plug-in capability of at-berth ships at the Port of Seattle through the Northwest Seaport Alliance and Seattle Public Utilities to increase the number of ships that are connected to the grid in port.

Raise awareness about schools and child-care facilities in the air quality buffer zone.

Children are more susceptible to the health impacts of poor air quality, and may be more exposed when attending schools and child-care facilities that are near to highways and other heavily trafficked streets. A program to raise awareness of air-quality retrofits could help mitigate this exposure in existing facilities.

Evaluate current planning and permitting processes to explicitly incorporate the impacts of climate change in assessments of feasibility and risk.

Much of our planning frameworks use historical knowledge to determine risk and feasibility, but these historical trends will not be an adequate frame of reference for new conditions under climate change.

Accelerate funding for upgrades and risk reduction efforts in neighborhoods that face cumulative risks.

Work with SPU to catalog yearly instances of urban flooding and create a GIS tool for reporting each response.

SPU does not currently maintain this data or make it available to other departments and organizations.

Identify uses for parcels in the future Sea Level Rise flood zone that would be compatible with and/or alleviate the impacts of episodic flooding and saltwater inundation.

In planning and budgeting processes, be prepared to spend more in a given year to treat stormwater under climate change.

Increase the pace of investment in Green Stormwater Infrastructure, particularly along the Duwamish waterways and near significant CSO inputs.

Actively involve priority communities in designing and implementing Green Stormwater Infrastructure.

Continue to engage in public outreach and communication programs with communities who fish on the Duwamish

Work with fisher communities to find feasible alternate sources of fish protein, and safe ways to engage in culturally important fishing traditions. For example, providing buses to safe fishing areas near the city.

Continue aggressive progress to control all CSOs, and work to exceed the Ecology order.

Continue to engage in public outreach and communication programs with communities who fish on the Duwamish

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