



U.S. Department  
of Transportation  
**Federal Highway  
Administration**

FHWA Climate Resilience Pilot Program:

# Oregon Department of Transportation

The Federal Highway Administration's (FHWA)'s Climate Resilience Pilot Program seeks to assist state Departments of Transportation (DOTs), Metropolitan Planning Organizations (MPOs), and Federal Land Management Agencies (FLMAs) in enhancing resilience of transportation systems to extreme weather events and climate change. In 2013-2015, nineteen pilot teams from across the country partnered with FHWA to assess transportation vulnerability to extreme weather events and climate change and evaluated options for improving resilience. For more information about the pilot programs, visit: [http://www.fhwa.dot.gov/environment/climate\\_change/adaptation/](http://www.fhwa.dot.gov/environment/climate_change/adaptation/).

Oregon's north coast is served by highway routes that run along coastal bluffs, rivers, estuaries, and a mountain range. In the past, precipitation events have resulted in flooding, high water, landslides, rock falls, and coastal erosion. The Oregon DOT pilot project engaged maintenance and technical staff and utilized asset data to assess the vulnerability of highway infrastructure to extreme weather events and higher sea levels. For select priority hazard areas, the pilot conducted further analysis of specific adaptation sites, options, benefits, and costs.



## Scope

The study area covered two counties on Oregon's north coast: Clatsop and Tillamook Counties. The vulnerability assessment focused on ten state-owned highway corridors, totaling nearly 300 miles of roadways. Primary climate drivers include extreme precipitation events, coastal flooding, and storm surge.

Using the results of the vulnerability assessment, the team selected a 25-mile Study Corridor to narrow the focus of the adaptation analysis. Five landslide and storm hazard sites were evaluated within the Study Corridor.

## Objectives

- Assess the vulnerability of highways in the study area to known and projected climate impacts.
- Develop and evaluate a set of site-specific adaptation strategies for vulnerable infrastructure and conduct a benefit-cost analysis.
- Collaborate with stakeholders, including state and local agencies and coastal communities, planning for resilience to climate hazards on the north coast.



A failed section of U.S. 101 after extreme storms in March 2012. Photo credit: Oregon Department of Transportation



Debris from a landslide covered Oregon Highway 6 in March 2014. Photo credit: Oregon Department of Transportation



Road collapse along U.S. 101 after extreme storms. Photo credit: Oregon Department of Transportation

## Approach

**Collect and process asset and climate data.** The ODOT project team collected a range of asset data, including maintenance dispatch records, repair frequencies and costs, as-built plans, geology and engineering design reports, and historic photos and maps. The team compiled the asset data into a Geographic Information System (GIS).

The climate information compiled included data from regional climate studies and assessments, storm event thresholds tied to ODOT’s maintenance dispatch records, sea level rise projections, and coastal erosion rates. ODOT processed the downscaled global climate models (GCM) climate data for the historical (1976-2005), near-term (2006-2035), and long-term (2036-2065) time frames. The team coordinated with the Oregon Coastal Management Program to develop GIS inundation maps of the mid-century sea level rise projection.

**Conduct workshop to assess vulnerability.** The project team held a workshop with the district maintenance crew and technical staff to identify hazard hotspots in the study area and anticipated levels of disruption. The project team presented the participants with historical and future climate data and a web-based GIS map with layers on existing conditions, locations of known hazards, weather-related incident response, and future sea levels. Using the information provided and their local knowledge, participants identified “climate hazard sites” and rated the anticipated levels of disruption to the transportation system from climate impacts at each site. The results from the workshop and additional analysis informed asset categorization into vulnerability ratings of Low, Medium, High, or Extreme.

**Define critical assets.** In order to consider asset criticality, the team utilized an existing ODOT study, the *Oregon Highways Seismic Options Report*. The study identified critical connections that would result in significant economic and other losses if they were disrupted. The team compared these “Lifeline Routes” with the pilot’s final highway vulnerability ratings to consider potential consequences on highways most important to population centers, emergency response, and economic and regional connectivity.

**Select sites for adaptation analysis.** The project team selected a highway Study Corridor for detailed adaptation analysis based on the vulnerability ratings and designation as a Lifeline Route. ODOT then evaluated potential sites within the corridor that face diverse climate drivers, can present adaptation options that are scalable, and are representative of other sites along Oregon’s coastal Highway 101. The pilot ultimately arrived at five high risk hazard sites within the 25-mile Study Corridor. ODOT used the FHWA Coupled Model Intercomparison Project (CMIP) Climate Data Processing Tool to analyze downscaled projected precipitation conditions at the selected sites.

**Identify adaptation strategies.** To inform the selection of adaptation options, the team reviewed maintenance records, conducted site visits, evaluated the climate and Light Detection and Ranging (LIDAR) data, and relied on institutional experience regarding the performance of similar design and construction projects under existing conditions. The analysis also evaluated cross-sections of existing terrain and roadway geometry at the sites to assess adaptation options to landslide impacts. ODOT developed multiple adaptation options at each of the five sites, ranging from a “do nothing” scenario, to options for increased operations and maintenance, to options with significant construction and engineering requirements (see Table 1).

Table 1. Adaptation options identified for each site.

| Site             | Hazard type                            | Climate driver   | Adaptation option   |
|------------------|--|--|---|
| Arch Cape        | Landslide, coastal erosion             | Extreme precipitation, sea level rise, and storm surge | Construct a soldier pile wall with further support by tieback strands to support the roadway.   |
| Falcon Cove      | Landslide (fill slope failure)         | Extreme precipitation                                  | Reconstruct the fill slope with an all-weather material and replace the culvert with a larger pipe.   |
| Gallagher Slough | Coastal erosion, roadbed scour         | Extreme precipitation, sea level rise, and storm surge | Raise the roadway and bridge elevations to the point where they are above projected flood levels and armor the existing slopes with riprap.             |
| Jetty Creek      | Landslide, coastal erosion             | Extreme precipitation, sea level rise, and storm surge | Construct a soldier pile wall designed to increase resisting forces in order to retain landslides.  |
| Rockaway Beach   | Coastal erosion, roadbed scour, debris | Sea level rise, tidal extremes, storm surge            | Construct ocean debris barriers, widen and reinforce existing channels, and replace the existing box culverts with slightly elevated bridge structures. |

**Conduct benefit-cost analysis.** The team conducted a benefit-cost analysis (BCA) to compare the cost of a baseline scenario with the construction and long-range maintenance costs of the adaptation options. Due to similarities among the adaptation sites and options, the project team narrowed down the scope of the BCA to two sites and a single “permanent fix” adaptation option at each site.

The benefit component of the analysis evaluated primarily time savings, reductions in vehicle operating cost, and safety improvement. The cost component reflected the cost of the adaptation investment compared to the cost of repeated repairs in the baseline scenarios. The team conducted the analysis for 30 years into the future. Key

assumptions included the frequency of site failures under future climate conditions; the engineering, construction, and maintenance costs for each option; and the value of time savings. ODOT also evaluated the regional economic impact from a long-term road closure scenario of a section of US 101 within the Study Corridor.

**Regulatory review.** The pilot team recognized that existing land use policies along the coast may limit the feasibility of coastal adaptation projects. The pilot reviewed federal, state, and local land use regulations in order to understand the restrictions, especially since ODOT has limited experience implementing larger coastal hazard mitigation projects.

## Key Results & Findings

**Vulnerabilities.** The most vulnerable highways in the study area are located: in the Coast Range (a mountainous area subject to rock fall and landslides); along larger road cuts or fill slopes; in low-elevation areas adjacent to rivers and estuaries; and in coastal areas (see Figure 1). Nearly all the designated Lifeline Routes, which are essential for emergency response and economic connectivity, were found to be vulnerable to projected climate impacts.

**BCA of adaptation options.** The BCA found that the benefits of the adaptation options at the two sites are not sufficient to justify the implementation costs. Key factors that contributed to this result were the availability of detour routes and low traffic volumes, especially during the off-peak winter months.

**Regulatory constraints.** Coastal infrastructure adaptation options such as armoring or realigning transportation facilities can be subject to multiple standards and permit applications from different regulatory authorities, which increase the costs and time for implementation. The regulatory constraints may put ODOT in a position to select the regulatory path of least resistance, which in some cases may result in a less strategic, shorter term fix.

“ODOT’s pilot study was a valuable test of assessment methods for common coastal hazards that will likely worsen with the effects of climate change.”

–ODOT Pilot Team

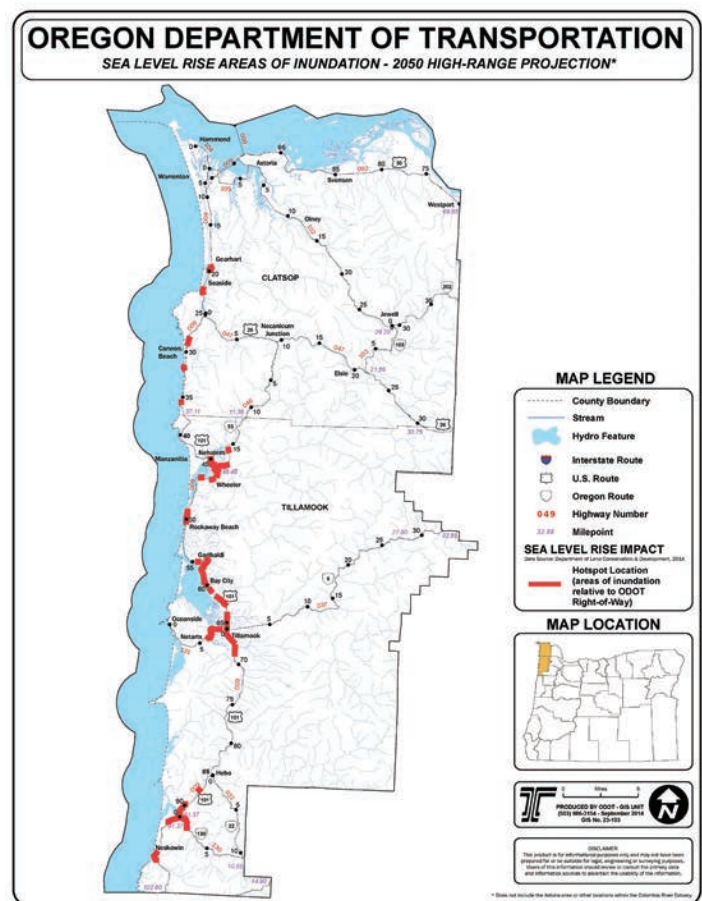


Figure 1. Map of sea level rise hotspot locations under the 2050 high range projection. Red denotes areas of inundation within ODOT right-of-way.

## Lessons Learned

**There are multiple tools and resources to process climate data efficiently.** The team quickly realized that processing the statewide climate data using ArcGIS would take up significant time and resources. The team decided that using the R programming language for statistical computing would be easier and quicker. A local institution, the Oregon Climate Change Research Institute, also provided useful guidance and direction for how to use and interpret the climate data. Additionally, use of the CMIP Climate Data Processing Tool allowed the team to quickly focus and process the climate data to the Study Corridor level for the adaptation analysis.

**Engaging the expertise of maintenance field staff was helpful in identifying vulnerabilities and priorities.** Furthermore, geospatial mapping of the maintenance dispatch records was an effective way to visualize the weather hotspots and engage maintenance and asset managers regarding priorities.

**The geographic scope of the BCA may affect the results.** An analysis of benefits and costs at the corridor-level may yield different results than a site-level analysis. The existence of viable detour routes for a single site was a key factor in determining outcomes, but a corridor-scale BCA would need to take into account larger failed sections of roadway if more than one site is likely to be impacted in a given event. The cost efficiencies of developing an adaptation project at a larger scale may also influence the BCA outcomes towards more cost-effective results.

## Next Steps

The analysis and findings from the pilot will be used to inform ODOT's future planning and assessments. ODOT's Adaptation Work Group recommends the following implementation priorities:

- Implement a program for data monitoring and research at high-risk sites.
- Develop project review guidance that utilizes the sea level rise mapping.
- Integrate adaptation with other hazards resilience planning efforts, including investigating opportunities to prioritize adaptation planning in Lifeline Routes most vulnerable to climate impacts.
- Formalize detour routes for priority corridors, since viable detour routes are essential to system resilience.

### For More Information

Final report available at:  
[www.fhwa.dot.gov/environment/climate/adaptation/2015pilots/](http://www.fhwa.dot.gov/environment/climate/adaptation/2015pilots/)

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