Scaling and Application of Climate Projections to Stormwater and Wastewater Resilience Planning

Seattle Public Utilities and King County

Ship Canal Water Quality Project – Combined Sewer Overflow Program – Preparing for Extreme Rainfall with Climate Ready Design


Ship Canal
WATER QUALITY PROJECT
Project Overview
Investing in the Health of the Sound and the Future of Our Region
How we're working with the community
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Summary

Seattle Public Utilities' (SPU's) Ship Canal Water Quality Project used both observations of increased precipitation and overflows with modeled future extreme precipitation projections to inform the design of a 2.7-mile-long storage tunnel to manage combined sewage and stormwater overflows into the future.

The Backstory

During heavy rains, Seattle's combined stormwater/wastewater system experiences overflows that can send polluted stormwater and wastewater into the Lake Washington Ship Canal, Salmon Bay and Lake Union. Driven by a consent decree obligation to reduce these overflows, SPU and King County Wastewater Treatment Division (King County) initiated the Ship Canal Water Quality Project in 2013. The project, SPU's largest ever infrastructure investment, includes building an underground storage tunnel that will significantly reduce the amount of polluted stormwater and wastewater that flows into the Ship Canal waterway. The project will be operational in 2025 and is expected to prevent an average of 75 million gallons of combined stormwater and wastewater from entering Seattle's waterways each year.

The Challenge

The Ship Canal Water Quality Project's design began in 2013 with an expected completion date in 2025. Taking climate change into consideration, initial designs included a 6% scaling factor to account for potential future precipitation increases. This scaling factor was selected based on early model projections that suggested a 0 - 15% increase in extreme precipitation by the end of century. However, the combination of heavy rains in 2015 and 2016 and improvements in climate modeling, specifically related to extreme precipitation projections, suggested that the 6% scaling factor would not be adequate to prevent future overflows.

Project Timeline
Project initiated in 2013. Expected completion in 2025.

Project Area/ Geographic Scale
Ship Canal, between Puget Sound and Lake Union, in the City of Seattle and King County, WA

Study Focus
Extreme Participation, Stormwater Flooding, Preventing Sewer Overflows, Combined System Storage

Lead Agency
Seattle Public Utilities and King County Wastewater Treatment Division

Target Audience
PWD staff, various City departments

Type of Data Used
Observed precipitation records, statistically and dynamically downscaled global climate models

Types of Precipitation Inputs Used
Spatially varying timeseries

The Approach

SPU and King County considered several options before deciding on the underground storage tunnel. Alternative options included green infrastructure and local detention facilities. Overall costs were similar, but the tunnel resulted in fewer impacts to nearby communities and greater operational flexibility.

The initial design phase considered a 14-foot (ft) diameter storage tunnel. To support the project, SPU updated its rainfall statistics using historical data and future precipitation projections. The preliminary results revealed that observed precipitation trends showed that current precipitation values had already increased more than the 6% assumed to account for future increases. These results were consistent with similar analyses completed by King County, as well as observations from 2015 and 2016.

The Outcome

The Ship Canal Water Quality Project storage tunnel size was increased in diameter from its original design of 14 ft to 18 ft 10 inches (in), to capture the expected increase in stormwater volume. The upsizing of the tunnel from a unique diameter (14 ft) to an industry standard size (a size often used for transportation tunnels) also minimized additional capital cost. The larger diameter design increased the tunnel storage volume from ~15-million gallons to about 30-million gallons with only $30 million in additional costs.

Practical Applications

The engineers' in-depth knowledge of existing performance issues paired with improved existing and future condition precipitation analyses led to concerns about the initial proposed tunnel size. SPU and King County made the decision to upsize the tunnel. With leadership on board, and community support for the larger project, the project moved forward with the larger storage volume design.

MudHoney, the 18 foot diameter Tunnel Boring Machine, and crew will build the conveyance tunnel for the Ship Canal Project. (Image courtesy of Seatte Public Utilities.)

Data inputs and outputs	Observed precipitation. SPU uses statistically downscaled GCMs and King County uses dynamically downscaled GCMs.
Data source	SPU has used two approaches for estimating future precipitation. The original approach used at the project's inception (2010-2014), was based on the correlation that one degree (Celsius) increase of North Pacific temperature would result in approximately 6% more precipitation (the Clausius-Clapeyron relationship). This was the approach SPU had previously used for SPU's combined sewer overflows (CSO) long-term control planning. The revised approach used the best available IPCC AR5 global climate model output along with historical analysis that considered recent changes to observed precipitation trends.
Time Horizons / Climate Scenarios Used	Preliminary analysis relied on historical rainfall measurements. The analysis indicated that engineers should use a scaling factor of 3 – 4% over baseline for precipitation by 2035 and a 12 – 14% increase over baseline by 2100. An average scaling factor of 6% was initially used to inform the tunnel design. Following the heavier than average rainfall in 2015 and increased overflows in 2016, both SPU and King County developed new climate models and updated future projections.
Updates to model runs with the latest IPCC GCM data?	Building off their latest model initially developed in 2017, SPU is committed to incorporating new precipitation information as updated observations and future projections become available.
Use of Precipitation Projections	Hourly or sub-hourly precipitation timeseries are required for most modeling applications; design storms and IDF curves are required for planning and design.
Objective for Using Future Precipitation Projections	Reduce combined stormwater overflows by accounting for future extreme precipitation increases. Account for extreme precipitation in the design of the underground storage tunnel to prevent future combined stormwater and wastewater overflows.
Application	SPU and King County used new information to update the design of the underground storage tunnel, with the goal of reducing combined sewer overflows in the future, under increased precipitation extremes.
Barriers and Challenges	Lack of climate science expertise within the agency provides one barrier. Updating infrastructure to prepare for changing climate conditions requires significant funding, usually above base funding allocations. Ensuring equitable climate preparations across all communities is another challenge. King County is prioritizing the additional funding needed for climate resilience within vulnerable communities that have environmental justice burdens. As this project was for a more affluent community, the County did not fund the climate resilience upgrade.
Events Driving Action	Hurricane Ida impacted the PWD service area during the final stages of rolling out the Guidance, serving as an "eye-opener" as to what can happen as extreme events become more extreme under a warming climate. This attested to the immediate need for this Guidance and helped support acceptance.

Lessons Learned

1. Communicate uncertainty as part of the performance standard to support decision-making.
Rather than rely on a single, set number that may prove incorrect in subsequent years, SPU and King County engineers recognized the value of explaining the range of uncertainty to decision-makers relative to meeting performance standards. If a solution provides a 70% certainty of meeting a performance standard in the future, and decision-makers request an increase to 80 to 90% certainty, overall agency support and buy-in increases. Communicating uncertainties clearly and in a relevant metric can be a powerful tool and can help manage expectations about future changes (e.g., updated science) that could occur later in the design process.

2. Intentionally look at the long-term resiliency of a project.
With hindsight, project team members indicated more robust analysis of observed and future precipitation should have occurred at the beginning of the project. They indicated that the initial approach of applying the average scaling factor of 6% across the lifetime of the project was too simplified and didn't fully account for changes in future condition extreme events. In retrospect, project leads indicated that had they looked at more extreme future scenarios, they may have recognized the increased resilience a larger more-standard diameter tunnel could provide, without a proportionate increase in cost.

3. Climate change is one of many factors influencing project design.
For SPU, the primary driver was regulatory compliance and understanding the potential risks that could occur in the future based on sizing facilities for historical rainfall instead of future projections. As updated science became available, the risk of potential future non-compliance increased, resulting in a design change.

4. Lack of clear climate policies can still lead to resilient decision-making.
Although policies existed for sea level rise, there were no clear policies on how to consider precipitation-related climate impacts during the design phase for this project. However, the robust analysis of future precipitation developed for this project is informing other projects. SPU is one of the most proactive City departments in integrating climate science into capital projects and operations. SPU's approaches are likely to become a model for other departments as adaptation planning and investment becomes more standard.