EVALUATING EFFECTIVENESS OF BIORETENTION CELLS IN TREATING HIGHLY POLLUTED BRIDGE RUNOFF

A proposal submitted to Stormwater Action Monitoring (SAM) Program

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Submitted by

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PROJECT PURPOSE

INTRODUCTION

The proposed project will measure the quantity and quality of stormwater runoff from the Aurora Bridge (State Route 99) before and after treatment in bioretention cells prior to discharging into the Lake Washington Ship Canal. Its goals will be to:

- Determine if a bioretention treatment system receiving highly elevated stormwater runoff pollutant concentrations can produce effluent water quality sufficient to achieve Washington's water quality standards;
- Demonstrate the utility of bioretention to treat stormwater runoff from bridges, the most direct source of contamination to receiving waters.

FIT WITH STORMWATER WORK GROUP (SWG) PRIORITIES

The proposed project addresses the following priority topic:[1]

> LID, Structural BMPs, Retrofits, O&M – Topics for Studies—11. Gather data about eligible Structural Stormwater Control (SSC) project types to inform future requirements and/or implementation.

Phase I Municipal Stormwater Permittees are required to implement a program for Structural Stormwater Controls (SSC) as part of their Stormwater Management Program (SWMP). Ecology aims this program toward retrofitting existing developed areas and promotes planning and prioritization of these projects to reduce impacts to watershed hydrology and pollutant discharges from municipal separate storm sewer systems.[2] Project types for consideration named in the Permit's Fact Sheet include: 2—new runoff treatment facilities, and 4—retrofitting of existing stormwater facilities.[3] The proposed project fits into both of these categories, representing assessment of facilities new both to the specific setting (retrofit of the Aurora Bridge storm drain system) and the general setting (major highway bridges).

Successfully achieving the project's goals stated above will inform future Permit requirements and Permittees' implementation of requirements in several ways. The results will provide guidance to Ecology in specifying requirements for the most challenging stormwater management problems, those involving high pollutant concentrations and mass loadings proximate to receiving waters. Washington State Department of Transportation (WSDOT) and municipalities operating street and road systems will have a demonstration of how well a prominent SSC type works for bridge applications, and an estimate of its performance lifespan given the high contaminant loads. Documentation of effective performance will give both regulator and Permittees confidence that bioretention can function over timeframes of interest to protect receiving waters in these situations. On the other hand, if it is shown that performance or lifespan do not rise to the necessary level in these demanding circumstances, Ecology will have the knowledge needed to support investigation of more effective options. Permittees will be saved efforts and expenses on facilities that do not meet their Permit compliance needs.

INVOLVEMENT OF STORMWATER PERMITTEES IN THE PROPOSED PROJECT

A Technical Advisory Committee (TAC) is in the process of formation, which includes several

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[1] Stormwater Action Monitoring (SAM); Effectiveness Study and Source Identification Project; *Round 3* Request for Proposals; January 22, 2020.

[2] Fact Sheet for the Phase I, Western Washington Phase II, and Eastern Washington Phase II Municipal Stormwater Permits at 6.5.50.

[3] *Ibid.* at 6.5.52 S5.C.7.a.

Stormwater Permittees and with vacant seats for additional members. Our Outreach Manager, will lead the TAC to solicit their guidance at the beginning of the project and throughout.

SIGNIFICANCE FOR STORMWATER MANAGEMENT PROGRAMS

WSDOT has approximately 1,583 vehicular bridges and culverts over 20 feet in length that span over water.[1] Each county road agency and most city street departments operate over-water bridges too. Most of these bridges discharge stormwater runoff into receiving waters, at the risk of maintaining beneficial uses in those waters. Furthermore, many are in settings where bioretention would fit and could be constructed adjacent to the bridges to reduce those risks. As covered below under the topic Technical Rationale and Site Setting for the Project, bioretention has been demonstrated to be capable of effective treatment when implemented properly, but has not often been assessed in bridge applications. Also, as discussed later, the setting of the proposed project, Seattle's Aurora Bridge, has been found to produce very elevated stormwater pollutant concentrations. This result is probably related to its age, a factor shared by many other bridges in the state, which are also likely to discharge contaminants at somewhat or highly elevated levels. Previous studies have not tested bioretention performance under these conditions.

Confirmation of performance at a bridge with challenging circumstances would lend confidence to specifying bioretention for other bridges and additional settings with relatively contaminated runoff. With the large number of potential application sites, the knowledge gained from the proposed project will be useful for years to come as renovations to older bridges occur. Notably, in the near-term, the Washington State Legislature through a 2019 proviso awarded $1.5 million towards construction of bridge bioretention cells, which included those at the Aurora Bridge, as well as two additional cells at either end of the Interstate-5 Bridge. The City of Seattle is planning to replace two of its bridges, the Ballard Bridge, which also impacts the Lake Washington Ship Canal, and the Magnolia Bridge, which has runoff feeding into Elliott Bay. The Bullitt Foundation is funding a strategic plan, which is being led by our TAC team Outreach Manager, for additional projects at sites on the Skagit, Nooksack and Duwamish Rivers.

PROJECT DESCRIPTION AND SCOPE OF WORK

TECHNICAL RATIONALE AND SITE SETTING FOR THE PROJECT

Aurora Bridge Storm Runoff Water Quality

In 2017 grab samples were collected during five storm events directly from a vertical downspout draining the Aurora Bridge near the northwest corner of N 34th Street and Troll Avenue N.[2] Sampling was timed to occur as soon after the onset of runoff as possible to represent the "first flush" of pollutant transport. The samples were transported under temperature control to a nearby state-certified laboratory immediately upon completing collection. Laboratory analyses were performed employing the same methods proposed below for use in this project.

Maximum concentrations of all measured parameters were higher than mean and median concentrations (by 1.1 to 3.3 times), and mean and median concentrations were markedly higher (3.4 to 13.8 times) than those from highway runoff studies conducted elsewhere (Table 1). The only exception was for lead when Aurora Bridge results were compared to measurements made

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[1] https://www.wsdot.wa.gov/bridge/our-bridges/preservation (accessed on April 22, 2020).
[2] After Salmon-Safe, Inc. Undated. The Aurora Bridge Mitigation Project. https://static1.squarespace.com/static/5d700128787fd700010d616d/t/5d8ec669d167f61d3eaba2a5/1569638010035/The-Aurora-Bridge-Mitigation-Project-Salmon+Safe+Report+%285MB%29.pdf (last accessed on April 20, 2020).

during the era of leaded gasoline (1977–1982). While only five samples were collected at the Aurora bridge, the results exhibit a consistent pattern of highly elevated concentrations, as demonstrated by the relative congruity of the means and medians and the observation that minimum values usually exceeded the medians or means in other studies. There is definite concern with this finding, since the bridge's runoff flows into the Lake Washington Ship Canal, a key salmon migration corridor, and from there to Puget Sound.

Table 1. Aurora Bridge Stormwater Runoff in Comparison to Highways Elsewhere

	Aurora Bridge (not all data shown for brevity)				Margin of Aurora Bridge Central Tendency Compared to:		
Variable (unit)[a]	Min	Max	Mean	Median	NSQD Freeway Median[b]	1977-1982 Study Median[c]	California Study Mean[d]
TSS (mg/L)	319	1890	755	567	5.7X	4.3X	6.6X
Cu (μg/L)	200	471	315	311	8.9X	7.8X	3.4X
Pb (μg/L)	301	690	420	345	13.8X	0.5X	4.8X
Zn (μg/L)	1410	2520	1770	1570	7.9X	4.1X	5.0X
TPH-Dx (μg/L)	No Data	503	317	339	No Data	No Data	No Data
TPH-heavy oil (μg/L)	3310	13300	8240	7290	No Data	No Data	No Data

[a] TSS—total suspended solids; Cu—total recoverable copper; Pb—total recoverable lead; Zn—total recoverable zinc; TPH—total petroleum hydrocarbons; Dx—Diesel.
[b] National Stormwater Quality Database.
[c] Based on data from Western Washington monitoring stations on I-5 and SR-520 lanes carrying 42,000-53,000 average vehicles per day. The Seattle Department of Transportation 2014 Traffic Report gives the volume as 37,950 vehicles per day on Aurora Avenue N south of N 145th Street.
[d] California Department of Transportation. 2004. BMP Retrofit Pilot Program Final Report. Note: Results of sampling highway runoff (prior to receiving treatment) at a number of sites in Los Angeles and San Diego Counties on urban freeways carrying higher traffic loads than Aurora Avenue.

Bioretention Stormwater Treatment Installed at the Aurora Bridge

Following collection of baseline Aurora Bridge water quality data, three bioretention projects were planned to mitigate negative effects on the Ship Canal and Puget Sound ecosystems. The first two projects (Phases 1 and 2) were initiatives of a private developer, Stephen C. Grey & Associates (SGA), in the process of constructing two buildings immediately to the west and east of the bridge. In addition to treating its own stormwater, SGA voluntarily tied bridge downdrains that had discharged directly to the Ship Canal into its bioretention units, sized adequately to treat the additional inflow. The western unit went into service in 2017 and treats an average annual discharge of approximately 200,000 gallons from 9000 ft^2 of bridge road-surface flowing through one downdrain. The equivalent figures for the eastern unit, expected to be in service in 2020, are approximately 400,000 gallons from 20,000 ft^2 of road surface through two downdrains.

The third project (Phase 3) is a cooperative state and private initiative to build a bioretention unit under the bridge near the Ship Canal bank. It is currently under construction with completion expected in late spring 2020. This bioretention unit will treat an average annual flow of approximately 1,235,000 gallons from 119,000 ft^2 of north- and southbound lanes from three downdrains, representing an estimated 98 percent of all runoff generated. Previously, two of the drains went directly to the Ship Canal, and the third went to the capacity-limited combined sanitary-storm sewer. Because of hydrogeologic limitations in the area, all three cells are lined and fitted with underdrains to collect treated water for discharge to the Ship Canal. Despite the impediment to deep infiltration, it has been observed at the Phase 1 unit that water does not often flow on the surface to the downstream end, indicating substantial storage in the soil and some water loss through evapotranspiration. (An aerial view of the project location and graphic depictions of the three bioretention phases are attached at the end of the proposal.)

Previous Research on Bioretention Performance

Bioretention is a well-established stormwater management practice, developed in the early stages of the low impact development (LID) movement, now more commonly termed green stormwater infrastructure (GSI). Its performance has been demonstrated in a number of studies, but few at bridges and none with the influent pollutant concentrations as elevated as at the Aurora Bridge.

Liu et al. (2014) summarized discharge volume and pollutant mass loading reductions measured in many bioretention studies, primarily conducted North Carolina and Maryland, and found variability, but generally effective discharge volume and pollutant mass loading reduction.[1] In Washington state, Chapman and Horner (2010) studied an unlined bioretention unit receiving Seattle street runoff and found a 74% reduction in cumulative volume discharge over time and 79–96% reduction in a variety of pollutant mass loadings (except dissolved phosphorus with 28% reduction).[2] SAM has sponsored several bioretention performance studies: (1) reduction of polychlorobiphenyls (PCBs) in vegetated mesocosms, (2) two bioretention cells receiving runoff from a Federal Way street, (3) four bioretention planter boxes draining SR-99 in the Echo Lake basin in Shoreline, and (4) a study of bioretention media blends to improve treatment.

The only research on bioretention serving highway bridges measuring a broad spectrum of pollutants has been in North Carolina[3] and California,[4] covering a total of 15 sites. The influent pollutant concentrations in these cases were much lower than measured at the Aurora Bridge. These studies established pollutant concentration, but not mass loading, changes from influent to effluent.

MONITORING PROGRAM DESIGN

Monitoring Tasks and Sequence

The monitoring program will involve the following tasks, performed in the order shown: 1) Prepare quality assurance project plan (QAPP); 2) Install monitoring equipment; 3) Train field personnel in operating monitoring equipment; 4) Flow monitoring and sample collection; 5) Sample analysis; 6) Database development and data analysis; 7) Data interpretation and 8) Communication.

Preparing Quality Assurance Project Plan (QAPP)

A QAPP is intended to ensure projects that collect and analyze environmental data develop plans for field, laboratory, and analytical activities that meet quality standards appropriate to the goals and scope of the project. The QAPP will be prepared according to Ecology guidelines.[5] It will be

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[1] Liu, J., D.J. Sample, C. Bell, and Y. Guan. 2014. Review and Research Needs of Bioretention Used for the Treatment of Urban Stormwater. *Water* 2014 (6):1069-1099.

[2] Chapman, C. and R.R. Horner. 2010. Performance Assessment of a Street-Drainage Bioretention System. *Water Environment Research* 82(2):109-119.

[3] Winston, R.J., M.S. Lauffer, K. Narayanaswamy, A.H. McDaniel, B.S. Lipscomb, A.J. Nice, and W.F. Hunt. 2015. Comparing Bridge Deck Runoff and Stormwater Control Measure Quality in North Carolina. Journal of Environmental Engineering, 141(1):04014045.

[4] California Department of Transportation (Caltrans). 2014. Caltrans, District 4, San Francisco Oakland Bay Bridge (SFOBB) Bioretention Pilot Project, Final report, CTSW-RT-14-288.05.3. Caltrans, Sacramento, California.

[5] https://ecology.wa.gov/About-us/How-we-operate/Scientific-services/Quality-assurance/Quality-assurance-for-NEP-grantees (accessed April 22, 2020).

completed and submitted for approval within the first month after notice to proceed.
The QAPP, and the entire monitoring program, will be predicated on achieving the goals stated earlier and the following specific objectives pursued toward that outcome:

- Obtain sufficient representative flow records, water levels, storm-composite samples and soil samples to characterize Phase 3 bioretention unit influent and effluent volumes, flow rate patterns, water quality and treatment capacity with defined levels of certainty;
- Conduct systematic observations and grab sampling at Phases 1 and 2 bioretention units' influent and effluent points to form a semi-quantitative portrait of their performance;
- Perform sample analyses that meet defined quality assurance/quality control (QA/QC) targets;
- Apply a database structure and data analysis procedures capable of fully defining the Phase 3 bioretention characteristics and capacity with statistically based levels of certainty; and
- Use results to develop and present recommendations for the use of bioretention in circumstances of highly elevated stormwater runoff pollutant concentrations and at bridges.

Installing Monitoring Equipment

The Green Futures Research and Design Laboratory already owns key monitoring equipment needed for the project, the ISCO Model 6712C sampler and ISCO Model 730 bubbler flow modules (three of each). Sets of each will installed at the inlet and outlet of the largest (Phase 3) bioretention unit. The third set will serve as backup should malfunction occur. The equipment will be powered by marine deep cycle batteries and installed in secure, locked housings, purchased for the project. Pressure transducers with built-in dataloggers will be hung in PVC wells installed in the center of each of the two Phase 3 bioretention cells to continuously monitor water levels that will, with flow data, provide knowledge about water retention times and flow through the system. Educational signage will be created and installed to explain the purpose of the monitoring equipment, project and process.

Training Field Personnel in Operating Monitoring Equipment

To meet the proposed project's goals and objectives it will be necessary to operate the flow monitoring and sampling equipment with a high level of competency and according to the criteria stated below in Flow Monitoring and Sample Collection. Because such operation requires skill that cannot be gained from manuals, the responsible personnel will be trained by a person experienced in the work retained on a short-term basis for this task.

Flow Monitoring and Water Sample Collection

Phase 3 Bioretention Unit. The ISCO flow modules will be connected to the ISCO samplers, and they will both trigger the samplers at specified flow rates and continuously collect and record flow data at programmed intervals. The automatic samplers are programmable with respect to sampling intervals, volume, sample composition, and triggering criteria. Samples will be collected via PTFE tubing suctioned with a peristaltic pump into 2.5-gallon containers.

Precipitation forecasts by National Oceanographic and Atmospheric Administration or equivalent will be used for estimation of precipitation quantities and patterns. When storm events are forecasted, samplers will be programmed to collect flow-weighted composite samples, meaning a sample aliquot will be drawn at a specified flow interval after a minimum flow quantity is detected. This strategy yields overall storm-event mean pollutant concentrations (EMCs, mass per unit volume) and mass loadings (mass per unit time).

The criteria for a valid storm event will be forecasts of: (1) total precipitation—minimum 0.15 inch, (2) antecedent dry period—6 hours with less than 0.04 inches of rain, and (3) minimum storm duration—1 hour. Events meeting those criteria will be selected for actual sampling to: (1) represent a range of storm sizes and intensities, and (2) be spaced sufficiently (ideally, at least one week apart) to allow time for pollutants to accumulate between wash-off periods. However, the latter criterion could be relaxed to take advantage of opportunities to acquire target sample numbers and increase representativeness.

The criterion for a valid composite sample will be one consisting of a minimum of 10 sample aliquots representing at least 75 percent of the runoff hydrograph. The goal will be to capture at least 12 storm events in each of two years, beginning as soon as possible after notice to proceed. The majority of the events will be selected during the wet season (October-March), but a smaller number will be sampled in the remaining months for full, representative characterization. A key target will be the first major runoff event after the dry season.

Phases 1 and 2 Bioretention Units. The two smaller units will not be fitted with monitoring equipment because their positions offer little space and poor security for the equipment. However, a systematic protocol will be developed within the QAPP for field personnel to observe water flow to, within, and from them, and to make detailed notes on those observations. The protocol will also specify taking some influent and effluent grab samples for analysis, with a target of five samples from each unit in each of two years.

Field Records. Field personnel will record complete information in a waterproof field notebook. Notes will include date and time, meteorological and flow conditions, field measurements, visual observations, and any unusual conditions or circumstances. A chain-of-custody record will accompany the samples. Upon return to the office, the quality assurance officer will review copies of the field notes and signed chain-of-custody record.

Water Sample Analysis

Water samples will be transported immediately after collection to a state-certified laboratory for the analyses listed in Table 2. QA/QC procedures will be specified fully in the QAPP but will include random field duplicate samples, field blanks, method blanks, laboratory control samples, matrix spikes, laboratory replicates, and laboratory internal standards.

Table 2. Water Quality Variables, Analytical Methods, and Sample Handling Specifications

Water Quality Variable	Method[a]	Preservation	Max Hold Time
Total suspended solids	SM 2540-D	4°C	7 days
pH	SM 4500-HB	4°C	None
Total phosphorus	SM 4500-PF	H_2SO_4 to pH <2; 4°C	28 days
Ortho-phosphate phosphorus	SM 4500-PF	H_2SO_4 to pH <2; 4°C	48 hours
Total nitrogen	SM 4500-N	H_2SO_4 to pH <2; 4°C	28 days
Ammonia-nitrogen	SM 4500-NH_3	H_2SO_4 to pH <2; 4°C	28 days
Nitrate+nitrite-nitrogen	SM 4500-NO_2, NO_3	H_2SO_4 to pH <2; 4°C	28 days
Fecal coliform bacteria	SM 9222-D	4°C	6 hours
Total petroleum hydrocarbons-Diesel	Ecology (NWTPH-Diesel)	HCl to pH <2; 4°C	28 days
Total petroleum hydrocarbons-heavy oil	Ecology (NWTPH-heavy oil)	HCl to pH <2, 4°C	28 days
Total and dissolved Cu, Pb and Zn	EPA 200.8 (ICP-MS)	HNO_3 to pH <2, 4°C	6 months

[a] SM—Standard Methods for the Examination of Water and Wastewater (American Public Health Association, American Water Works Association, Water Environment Federation, 2017)

Soil Sample Collection and Analysis

Soil samples will be collected at the start and end of the wet season in each of the two project years in order to assess the removal capacity and operational lifetime of the bioretention cells under the high contaminant loads of Aurora bridge. Six vertical soil cores will be collected in acid-washed plastic liners along a transect of the Phase 3 unit. Cores will be sequentially collected in 2-ft increments to the bottom of the soil profile. Core ends will be covered with plastic caps and kept on ice in the field. Immediately after collection, cores will be transported to Dr. Neumann's lab at the University of Washington, where they will be loaded into an anaerobic glove box and sectioned into 1-inch increments. The inner portion of each increment will be retained and placed into acid-washed and ashed glass bottles. For budgetary purposes, eight increments from each core will be analyzed at a state-certified laboratory by EPA Method 1312: Synthetic Precipitation Leaching Procedure. The method simulates natural leaching processes that result from water infiltration through contaminated soils. Chemical analytes listed in Table 2 will be analyzed in the soil leachate. The soil depths chosen for analysis will emphasize those near to the ground surface, but will span the entire soil profile. Samples not analyzed will be frozen and kept in Dr. Neumann's lab until the project ends in case additional data are required.

Database Development and Data Analysis

At the project outset, a spreadsheet database will be developed to archive results and perform analyses. The database features and the analyses performed using it will include: (1) any qualifications reported by the laboratory; (2) comparisons of results to water quality criteria; (3) calculations of influent and effluent pollutant mass loadings and their relative differentials; (4) statistical significance of differences in influent and effluent pollutant concentrations; (5) mass of pollutants retained within the cells, based on influent and effluent concentrations, and on soil analyses; (6) capacity of system to retain pollutants and estimated performance lifespan; and (7) pollutant concentration statistical descriptors in both soil and water, such as frequency distribution, mean, median, geometric mean, reliable maximum (for water, the highest discharge concentration normally expected, computed as the 90^{th} percentile of all measured concentrations), and irreducible minimum (for water, the lowest discharge concentration normally expected, computed as the 10^{th} percentile of all measured concentrations).

Data Interpretation

The performance of the Phase 3 bioretention unit will be assessed with respect to its ability to meet the minimum requirement of the 2019 Stormwater Management Manual for Western Washington, which is to treat at least 91% of the predicted post-development runoff. In addition, while stormwater discharge to the Ship Canal is not subject to a flow control standard, past experience with bioretention indicates that it does offer some runoff quantity control even with a liner. For extending project results to locations where a flow control standard does apply, performance of the Phase 3 bioretention unit will be assessed with respect to its ability to meet the Flow Control Performance requirement of the Manual.

Beyond these requirements, pollutant concentration and mass loading changes from the inlet to outlet will be evaluated to illustrate effects on water quality indices that can be expected with use of bioretention. Effluent concentrations will also be compared to regulatory numeric limits, such as receiving water quality criteria and effluent limits and benchmarks applied to general point source discharges.

Comparison of the concentration, depth and spatial distribution of contaminants retained on soil from before and after each wet season, as well as from year 1 and year 2, will be used, along with knowledge of total soil mass within the bioretention system and the corresponding chemical mass loading, to estimate the operational capacity and performance lifespan of the system. The effort will elucidate contaminant transport through, retention in and loss from a bioretention system receiving highly contaminated bridge runoff, enabling easy identification of design strengths and potential improvements.

Communication of Project Findings

At the conclusion of the above tasks the project team will give a presentation to the SWG. The final report will then be written, taking into account comments received at the SWG presentation. Next will come a two-page summary of the project results and conclusions following the SAM Fact Sheet template. Beyond the end of the project budget coverage, at least one paper will be written for technical journal publication; and at least one conference presentation will be given.

PROJECT TEAM DESCRIPTION

Responsibilities of the individuals involved in this project are summarized in Table 3.

Table 3. Summary of Team Roles and Responsibilities

Role	Personnel	Time Dedicated to Project	Responsibility
Principal Investigator, Project Manager	Nancy Rottle, RLA, FASLA UW Professor Director, UW GFL	2 months over project timeframe	Project integration and management, Liaison with SAM and SWG
Technical Advisor, Co-Principal Investigator	Dr. Rebecca B. Neumann UW Associate Professor	2 months over project timeframe	Supervise research scientist
Technical Advisor, Co-Principal Investigator	Dr. Richard Horner, UW Research Professor Emeritus	4 months over project timeframe	Guide monitoring program design and data analysis; quality assurance officer
Outreach Manager	Ellen Southard, LFA	24 hrs/year	Lead Technical Advisory Committee
Research Scientist (or alternate)	Dr. Rachel Strickman	25% for 24 months	Install and operate monitoring equipment, handle samples, record and ianalyze data
Assisting Graduate Student	To be determined, as fits project needs	700 hours over 2 years	Assist with field tasks; design and produce signage and final communication products
State-Certified Laboratory	TBD, e.g. Fremont Labs		Perform analyses and QA/QC
Technical Advisory Committee (confirmed so far)	Alex Nguyen, WSDOT Tracy Tackett, Seattle Pub. Util. Lori Blair, Boeing and WA State NPDES Advisory Committee Jessica Engel, P.E., King County Stormwater Jose Carresquero, KC DOT Aaron Clark, Stewardship Partners Lucas Hall, Long Live the Kings Dylan Ahearn, Herrera Environ. Rachael Meyer, Weber Thompson Chris Hilton, Nature Conservancy Dan Kent, Salmon-Safe	Five Meetings and on-call Advice	Technical experts providing the project team advice and evaluation

Project Team Leaders

Dr. Richard Horner, UW Research Professor Emeritus in Environmental Engineering, is a recognized leader in stormwater research, serving as principal or co-principal investigator on more than 40 research projects. As a member of the National Academy of Sciences-National Research Council committee on Reducing Stormwater Discharge Contributions to Water Pollution, he advised on the links between stormwater discharges and impacts on water resources, the state of the science of stormwater management, and on policy recommendations to the U.S. EPA relative to municipal, industrial, and construction stormwater permitting.

Professor Nancy Rottle directs the UW Green Futures Research and Design Lab (GFL). A licensed landscape architect with over 20 years of professional experience, Nancy led the GFL's SeaGrant-funded performance monitoring of Kitsap County's Manchester Stormwater Park.

Dr. Rebecca Neumann has led the hydro-biogeochemistry group at University of Washington since 2011. She is an expert on transport and reaction of contaminants within interconnected environmental compartments, including surface waters, groundwaters, soils, and plants.

Ellen Southard has served as the Project Manager for the Aurora Bridge project since 2016, facilitating efforts to advance permitting pathways for public private partnerships and convening the design, construction and fund-raising team for the Aurora Bridge bioretention project. She has 17 years' experience working on low impact development and green infrastructure projects.

Dr. Rachel Strickman is a biogeochemist with expertise in field and laboratory skills, managing and analyzing scientific data, and communicating results to scientists and land managers.

PROJECT MANAGEMENT

Project Management will include:

1. Work with SAM to develop and finalize Scope of Work, Contract, Schedule.
2. Finalize Technical Advisory Committee membership; Meet; Obtain and apply advisement; Maintain ongoing communication
3. Hire staff; Jointly develop work plan; Finalize and obtain approval for QA/QC plan; Order materials; Liaise with Analytical Lab; Obtain trainings
4. Coordinate equipment installation and signage with project owners and designers
5. Meet regularly for Progress Reporting; Keep meeting minutes with Action Items.
6. Ongoing: Maintain communication with SAM and Team; progress and schedule tracking
7. Quarterly Reporting of activity progress and project updates; TAC advisement; data quality assurance; findings to date.

PROJECT BUDGET AND SCHEDULE

Table 4 Proposed Schedule

	2021				**2022**				**2023**
Task Description	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	
1. Project Management	x	x	x	x	x	x	x	x	
2. Technical Advisory Committee	x		x		x		x		x
3. QAPP	x								
4. Equipment Set-up, Training, Supplies, Signage	x								
5. Data Collection and Analyses		x	x	x	x	x	x	x	
6. Database Analyses and Interpretation				x				x	
7. Presentation and Response								x	
8. Final Communication Materials + Presentation(s)									x

Proposed Budget

The proposed budget has been calculated based upon the PIs' prior experiences with similar projects, for the time, equipment, lab fees and materials needed to conduct the monitoring of water and soils over a 2-year period. Oversight and performance of tasks include project management; development of the QAPP; collection of samples; sample analyses; maintenance of analyses database; interpretation of findings; convening and responding to the Technical Advisory Committee; and communication of findings, as described above and outlined in Table 4, Proposed Schedule. While the overall budget was based on specific anticipated costs of labor, services, materials and other expenses, the anticipated costs of deliverables below have been based on a combination of percent of labor effort, combined with known expenses. Indirect costs apply to salaries only.

Table 5 Proposed Overall Budget – See Table 3 for descriptions of Roles and Time Dedicated; Table 4 for Schedule; and Table 6 for Budget per Deliverable.

Budget Item	**Amount**	**Required For:**
Salaries with Benefits	$183,881	PIs /PM, Research Scientist, Assistant, TAC Lead
Equipment	0	Already owned: Samplers, Flow Meters, Jars– Saving approx. $15,000
Supplies, Training, Signage	$11,150	Lab Supplies, Batteries, Transducers, Tubing, Signage, Equipment Housing, Training, Refreshments, Printing
Laboratory Fees	$102,400	Water and Soil Sample Analyses – Fremont Lab
Travel	$500	Transport to Site and Lab
Conference Expenses	$2,000	Regional Conferences – Fees and Travel
Indirect	$53,868	
TOTAL	**$353,799**	

Table 6 Budget per Deliverable

Deliverable	**Primary cost**	**% of Budget**	**Estimated Cost**
1. Project Management	Personnel	10% of Labor	$ 17,956
2. Technical Advisory Committee	Personnel + Expenses	Ellen Southard + $500 supplies	$ 4,820
3. QAPP	Personnel	5% of Labor	$ 8,978
4. Supplies, Equipment Set-up, Training, Signage	Personnel + Supplies	5% of Labor, + Service + Signage +$7800 Supplies	$ 17,928
4. Monitoring Process, Data Collection and Lab Analyses	Personnel + Lab Fees + Travel	60% of Labor + Lab Fees + Travel	$212,137
5. Database Analyses and Interpretation	Personnel	12% of Labor	$ 21,547
6. Presentation and Response	Personnel	3% of Labor	$ 5,387
7. Final Communication Materials + Presentation(s)	Personnel + Supplies + Conference Expenses	5% of Labor + $200 supplies + Expenses	$ 11,178
Indirect costs	Personnel		$ 53,868
Total Estimated Cost			**$353,799**

ATTACHMENT: FIGURES

Figure 1. Aerial View of Project Area with Bridge Runoff Basins

Figure 2. Stormwater Runoff-Producing Drainage Basins and Storm Drain System (left), and Location and Concept Design of Aurora Bridge Phase III Bioretention Unit (right)

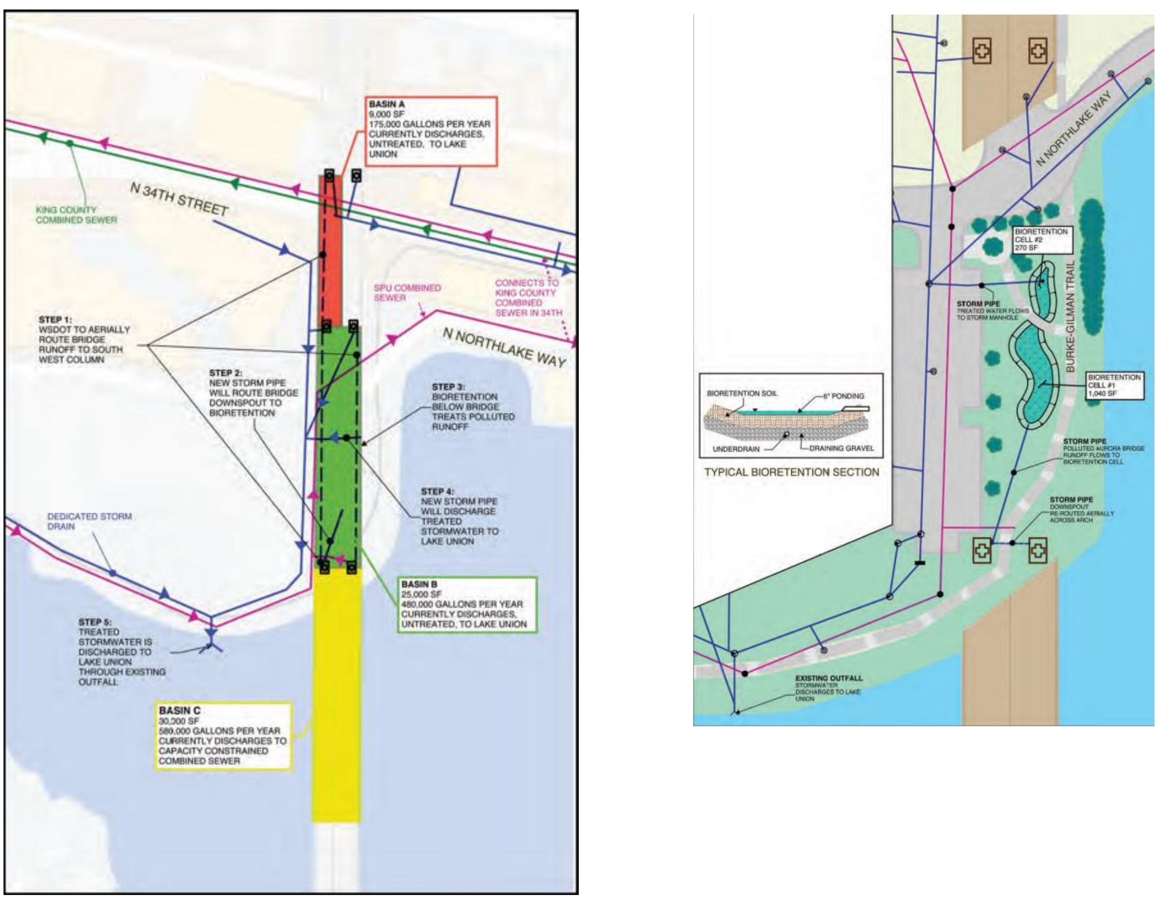


Figure 3. Aurora Bridge Bioretention Phases I and II, Completed (top) and Under Construction (bottom). Proposed grab sample monitoring.

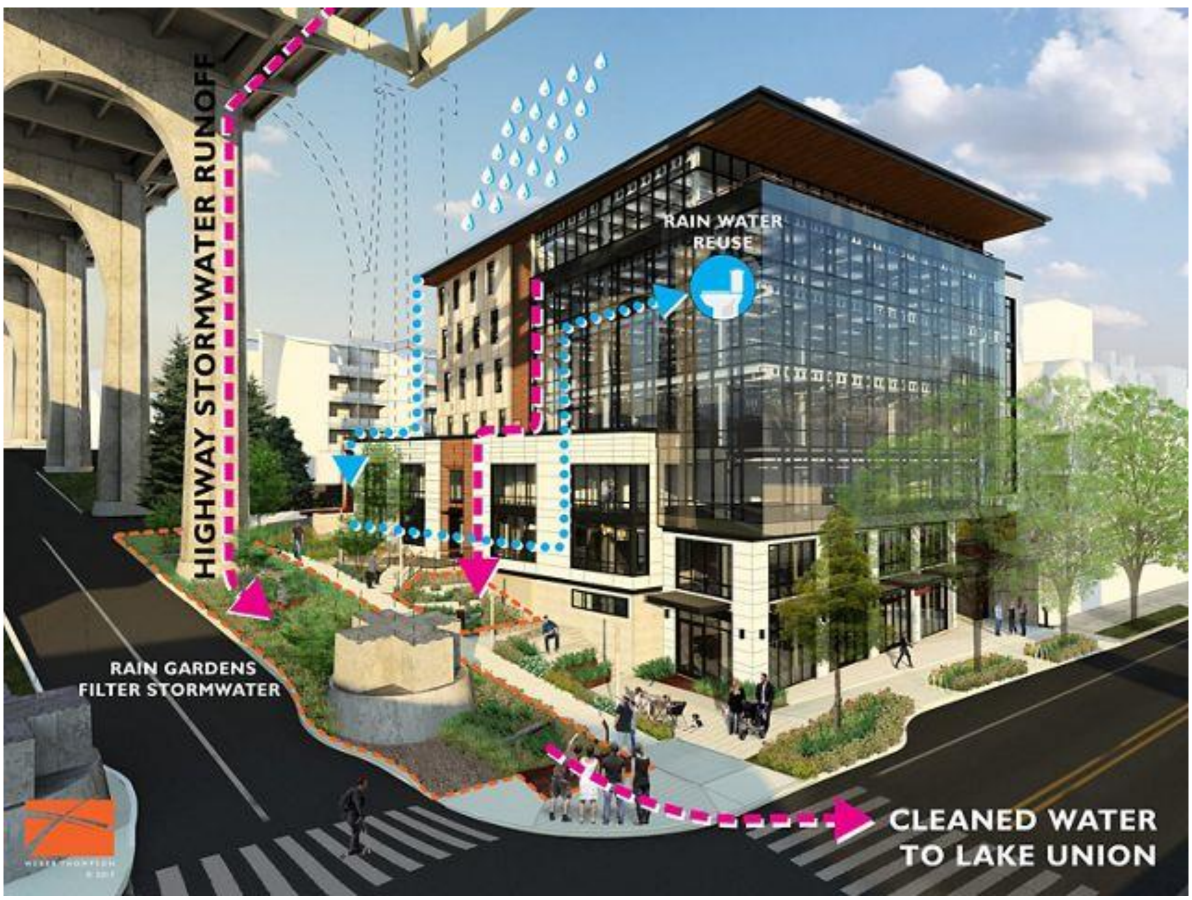
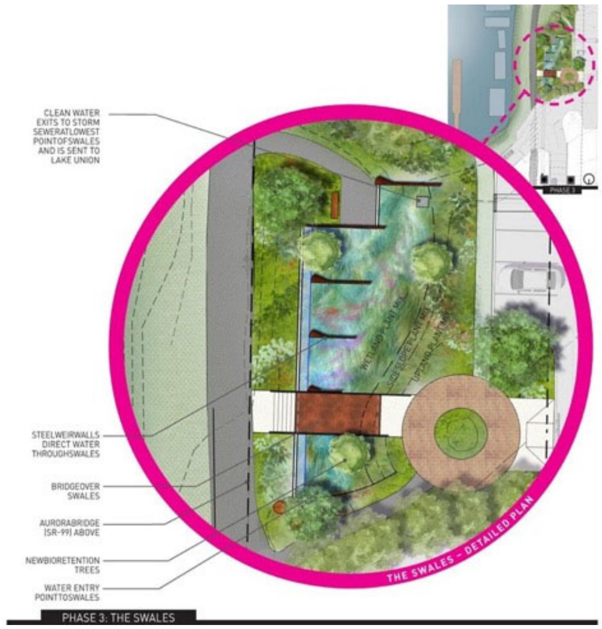
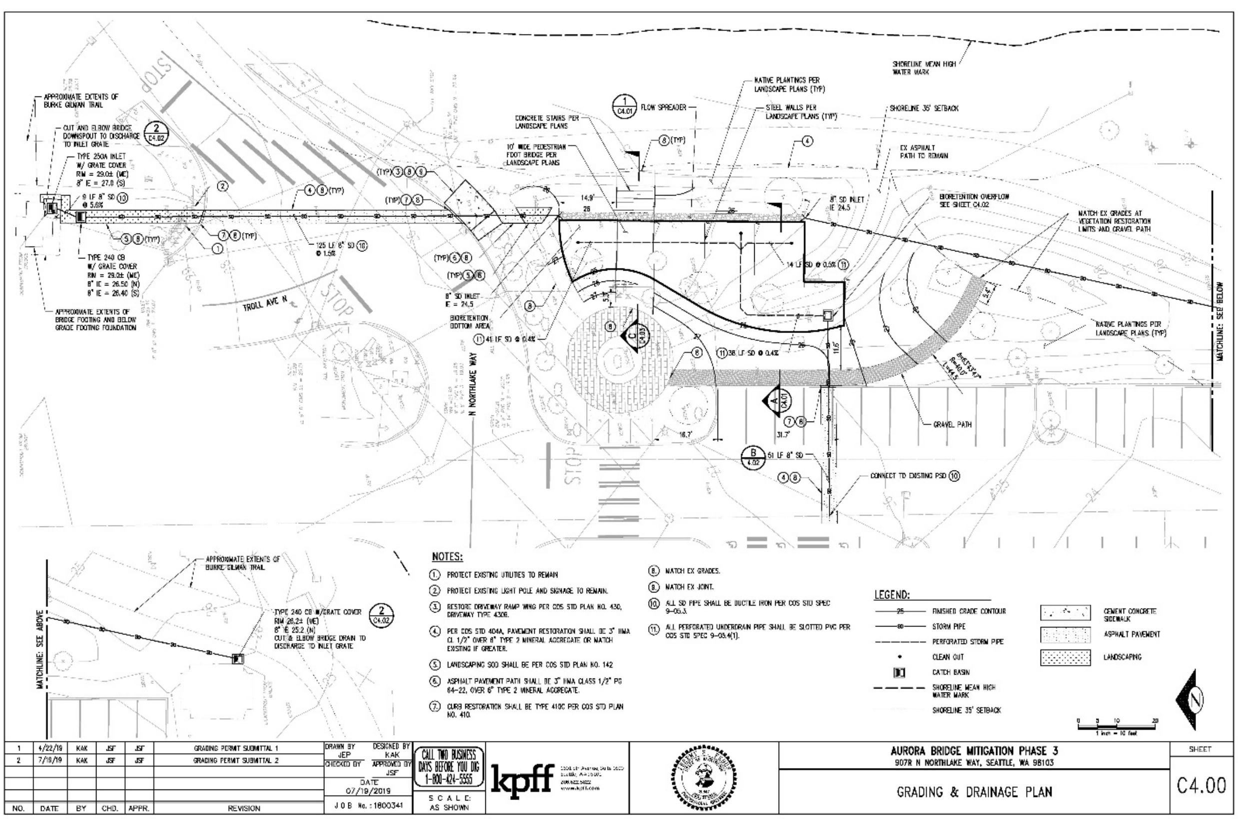


Figure 4: Schematic Illustration (top) and Construction Document excerpt (bottom) of Bioretention Design for Phase III, under construction Spring 2020. Proposed full monitoring of stormwater and soils.





Washington State
Department of Transportation

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May 5, 2020

Nancy Rottle, RLA, FASLA
Professor, Department of Landscape Architecture
College of Built Environments
Box 355734
University of Washington
Seattle, WA 98195-5734

Dear Miss Rottle,

The Washington Department of Transportation (WSDOT) endorses your University of Washington research proposal to monitor stormwater bridge runoff from the SR 99 Aurora Bridge. The runoff will be treated by a newly constructed bioretention area stormwater BMP. The research will be able to show how effective the bioretention area will be at removing pollutants from bridge runoff in an urban setting. WSDOT is committed to finding innovative methods to reduce stormwater pollution loadings. Bioretention areas are already in WSDOT's toolbox but WSDOT does not have a lot of BMP effectiveness data from bioretention area BMPs. This study would help fill that gap.

To support the research, a WSDOT representative is available to serve on the Technical Advisory Committee (TAC) and provide review and comments on the research proposal, study design, and interim and final reports.

We look forward to working with you on this research proposal.

Regards,

Julie Heilman

Julie Heilman , P.E.,
WSDOT State Hydraulics Engineer

JH:an

SALMON SAFE

1001 SE Water Ave., Ste. 450
Portland, OR 97214
503.232.3750

May 7, 2020

To whom it may concern:

I'm writing this letter in enthusiastic support of University of Washington's Green Futures Research and Design Lab's application to Washington State Department of Ecology's Stormwater Action Monitoring (SAM) grant program to measure the quantity and quality of stormwater runoff from the Aurora Bridge before and after treatment in bioretention cells prior to discharging into the Lake Washington Ship Canal.

As a leading environmental certification nonprofit based in Oregon, Salmon-Safe has worked in the Puget Sound region to inspire development and site management practices that protect water quality and habitat since 2004. Joining with a network of partners, Salmon-Safe was inspired to help start the Seattle Green Bridges project with the goal of managing the contaminated stormwater from Seattle's Aurora Bridge that has been discharged untreated to Seattle's Lake Washington Ship Canal, impacting migrating salmon and resident orcas that depend on those salmon.

This monitoring project is an essential next step to understanding if a bioretention treatment system receiving highly elevated stormwater runoff pollutant concentrations can produce effluent water quality sufficient to achieve Washington's water quality standards as well as demonstrate the utility of bioretention to treat stormwater runoff from bridges. The key technical consultant, Dr. Rich Horner, also has served as Salmon-Safe's primary consulting stormwater scientist for nearly two decades, and we look forward to disseminating the results of Dr. Horner's research with the Green Futures Lab.

Salmon Safe is excited to be part of this ongoing collaboration of organizations and businesses working to complete the Aurora Bridge project and, informed by the outcomes of this important monitoring project, expand this innovative template to other Seattle bridges.

Please let me know if you have any questions about Salmon-Safe or our role in this initiative.

Best regards,

Dan Kent
Co-Founder & Executive Director

Stewardship Partners

April 30, 2020

To Whom It May Concern:

Stewardship Partners is proud to support the Stormwater Action Monitoring project proposed by the U.W. Green Futures Lab and Sites plus Water to monitor stormwater treatment swales treating polluted runoff from the Aurora Bridge in Seattle. Aaron Clark, Ph.D., Director of Strategic Partnerships, is happy to support the project specifically through the Technical Advisory Committee, if approved by the SAM review process and the Pooled Resources Oversight Committee (PRO-C) and would provide monitoring experience and scientific expertise in that capacity.

The value of the monitoring data from this project will be valuable in determining how best to manage polluted runoff from highways across the state and beyond. As that source of runoff is highly toxic, known to cause mortality in adult and juvenile Coho Salmon, and is not generally treated or managed, especially in urban areas, addressing that pollutant source is critical for Puget Sound recovery. Optimizing and adapting treatment strategies for highway runoff in urban areas with limited space will be a valuable outcome of this project.

In Partnership,

Aaron D. Clark
Director of Strategic Partnerships

(206) 292-9875 | 80 Yesler Way, Suite 315, Seattle, WA 98104 | www.stewardshippartners.org

LONG LIVE THE KINGS
Restoring Wild Salmon

May 4, 2020

To Whom It May Concern:

Long Live the Kings (LLTK) has worked to recover salmon and steelhead in the Pacific Northwest for over 30 years. Our largest project, the Salish Sea Marine Survival Project, draws on the international expertise of 60 partners to understand why salmon and steelhead are dying in the Salish Sea. A component of this project is looking at how exposure to toxics in freshwater may lead to a higher likelihood of mortality related to predation. Furthermore, research from Washington State University and the University of Washington are drawing connections between toxics from roads and adult salmon pre-spawn morality.

As a backdrop to these specific findings, Puget Sound salmon have seen drastic declines over the past three decades, with some listed as Threatened under the Endangered Species Act. Lake Washington Sockeye, one of the few potentially harvestable stocks in the area, recently experienced their lowest return in recorded history. Protecting water quality along their migration route is a factor in their survival. These fisheries are not just important for generational anglers trying to preserve an outdoor tradition in an urban environment, but they are absolutely essential for tribal people who have harvested salmon since time immemorial.

LLTK supports the efforts to use green infrastructure to help protect the waters that these iconic fish rely on for survival, and monitoring is a critical component to the success of current and future projects. By participating in the Technical Advisory committee, LLTK will support the Stormwater Action Monitoring project proposed by the U.W. Green Futures Lab and Sites plus Water to monitor stormwater treatment swales treating polluted runoff from the Aurora Bridge in Seattle.

Sincerely,

Michael Schmidt
LLTK Deputy Director

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www.lltk.org • email: info@lltk.org ♻ *Printed on recycled paper*

HERRERA

May 6, 2020

Ellen Southard, Hon AIA
Salmon Safe
1932 First Ave, Suite 200
Seattle, WA 98101

Re: "Aurora Bridge Bioretention Monitoring" Stormwater Action Monitoring Effectiveness Study Application Support

Dear Ellen:

This letter serves as our confirmation and support of your Stormwater Action Monitoring Effectiveness Study initiative entitled "Aurora Bridge Bioretention Monitoring." Herrera and Salon Safe have been working together on stormwater science since 2007 and are excited to continue our partnership on this project.

As retrofit requirements begin to force the region to be more creative with our BMPs, we see great opportunity for locating treatment at critical junctures between roadways and waterways. The bioretention systems at the Aurora Bridge on Tableau property offer a great case study for how public-private partnerships can be leveraged for shared environmental benefit. As a partner, Herrera will sit on the technical advisory committee for the project and provide technical input on the experimental design.

Please let me know if you have any questions regarding the collaboration. Thank you for your time and consideration of this proposal. We look forward to working with you.

Very truly yours,

Dylan Ahearn
Herrera Environmental Consultants, Inc

2200 Sixth Avenue | Suite 1100 | Seattle, Washington | 98121 | p 206 441 9080 | f 206 441 9108
SEATTLE, WA | PORTLAND, OR | MISSOULA, MT | OLYMPIA, WA | BELLINGHAM, WA

SEATTLE 2030 DISTRICT

May 5st, 2020

To Whom It May Concern,

The Seattle 2030 District is pleased to write this letter of partner commitment to the Aurora Bridge Technical Advisory Committee (TAC) and its proposal to Stormwater Action Monitoring. Our organization has closely worked with the project leads in the past and are looking forward to collaborating on further demonstrate the effectiveness and scale of the Aurora Bridge Project.

For this partnership, the Seattle 2030 District is bringing its proven track record of providing education on and catalyzing investment in green stormwater infrastructure through our membership that consists of developers, building owners, and professional & community stakeholders.

The District will leverage prior projects that focused on community engagement as well as monitoring and mapping stormwater opportunities to contribute to the analysis on the Aurora Bridge as well as identify critical areas that need further infrastructure in order to protect the Puget Sound.

The Seattle 2030 District also has strong working relationships with Seattle Public Utilities, King County Wastewater Treatment Division, and the Seattle Office of Sustainability and Environment. These relationships allow the District to be the primary channel for dialogue between the private and public sectors and helped in the creation of the 2030 Challenge Existing Performance Pilot Program that focuses on incentivizing retrofits in Seattle.

These organizational strengths combine agreeably with the rest of the TAC and their experiences monitoring and supporting stormwater management practices in the Puget Sound region. Together, we can have a significant impact on mitigating the negative effects the built environment has on the Puget Sound.

Respectfully,

Matthew Combe
Executive Director

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WEBER THOMPSON

May 4th, 2020

Nancy Rottle
University of Washington - College of Built Environments
Box 355734
Seattle, WA 98195-5734

Dear Nancy,

I am writing to express my support for the involvement of the Green Futures Lab to monitor water quality of runoff from the Aurora Bridge. I offer my support in any way to the team and would appreciate bring involved on the Technical Advisory Board.

As the Landscape Architect for the project, we have a unique opportunity to quantify the value of green infrastructure in cleaning our waterways, as well as substantiate the efforts that have been working to clean the waters of Lake Union. As of today, the first phase of swales installed at Data 1 (Phase 1) has been functional for more than a year and a half. The second phase at Watershed (Phase 2) has been completed in the last few weeks, and the third phase adjacent to the lake edge (Phase 3) is anticipated to be completed within the coming months.

The timing of this testing is especially valuable given the momentum to understand the reduction in the pollutant load that is entering the lake from the adjacent roadways. Furthermore, this testing provides the opportunity for continuous testing of stormwater runoff, expanding our understanding of the impacts of seasonal changes, weather patterns and traffic loads on the impacts to water quality.

This bioretention monitoring program will elevate the efforts to clean the Aurora Bridge stormwater and will leverage the ongoing efforts to clean the water from the additional 5 bridges that cross Lake Union.

Thank you,

Rachael Meyer

Rachael Meyer, PLA, GRP, LEED AP
Landscape Architecture Principal
Weber Thompson