DRAFT
TECHNICAL MEMORANDUM

Date: March 11, 2022

To: Carly Greyell, King County Department of Natural Resources and Parks, Water and Land Resources Division

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Subject: Unit Cost Basis for Water Quality Benefits Evaluation (431-TM1)

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TABLES

ATTACHMENTS

GLOSSARY OF TERMS

AACE	Association for the Advancement of Cost Engineering
BMP	best management practice
BOE	Basis of Estimate
CCI	Construction Cost Index
County	King County
CSO	combined sewer overflow
DNR	(Washington State) Department of Natural Resources
Ecology	Washington State Department of Ecology
ENR	*Engineering News-Record*
FV	future value
GSI	green stormwater infrastructure
Herrera	Herrera Environmental Consultants, Inc.
LCC	life-cycle cost
LCCA	life-cycle cost analysis
LTCP	Long-Term Control Plan
NPV	net present value
O&M	operations and maintenance
PDF	Portable Document Format
PRISM	Project Reporting and Information System Management
PV	present value
RKI	Robin Kirschbaum Inc.
ROW	right-of-way
SDOT	Seattle Department of Transportation
SF	square foot/feet
SPU	Seattle Public Utilities
SUSTAIN	System for Urban Stormwater Treatment and Analysis Integration Model
TM	technical memorandum
UIC	underground injection control
WQBE	Water Quality Benefits Evaluation
WRIA	Water Resource Inventory Area
WSDOT	Washington State Department of Transportation
WTD	(King County) Wastewater Treatment Division

PURPOSE AND BACKGROUND

The King County Wastewater Treatment Division (WTD) is developing the Water Quality Benefits Evaluation (WQBE) toolkit to inform King County (County) decision-making processes regarding selection of cost-effective water quality improvement investments, reducing pollutant load, and improving ecological and human-health outcomes. This toolkit will be applied to a suite of potential projects and programs that could improve water quality and could be implemented in the areas draining to the WTD service area receiving waters. The results of the evaluation of the projects and programs will provide information about the multiple water quality benefits of potential WTD investments within the context of potential regional investments in other areas of the drainage basins. This information will provide technical support for County discussions with stakeholders, regulators, and decision makers related to water quality investments and policies. The toolkit will also be adaptable and designed to respond to the values supported by the region and WTD ratepayers (including those identified by the Regional Engagement effort of the Clean Water Plan) and future strategic planning needs at the division and department levels (including Clean Water Healthy Habitat).

The WQBE toolkit is being developed in two phases over a period extending from 2020 through 2022. During Phase 1 (2020), a preliminary set of models was developed. In Phase 2 (2021–2022), these models are being further calibrated and refined to support County planning efforts (e.g., Clean Water Plan and Combined Sewer Overflow [CSO] Long-Term Control Plan [LTCP] efforts). Implementation of preliminary analyses using the WQBE toolkit will be performed during its development phases; once finalized, the WQBE toolkit will be used to support a wide range of future planning efforts by the County and potentially other municipalities within the County's jurisdictional borders.

To support preliminary model development in Phase 1, the Herrera Environmental Consultants, Inc. (Herrera) team developed a suite of "Actions" comprising structural practices that improve water quality. These Actions provide the unit building blocks ("Unit Actions") that were aggregated and combined to develop water quality "Programs," or groups of Actions that can be implemented to improve water quality over a broad geographic area. Fact Sheets were developed to document the defining characteristics of each Action and Program, including costs, performance, and modeling inputs. Subsequent work in Phase 1 included modeling these Programs to identify the most cost-effective combinations of Actions or "Packages" for reducing pollutant loads or stormwater volumes.

The Herrera team documented the process used to develop Phase 1 Actions and Programs for the WQBE toolkit in a technical memorandum (420-TM1). This document provided guidance for interpreting the Action and Program Fact Sheets, while supporting detailed documentation on the technical basis of the Fact Sheet content is provided as a series of appendices.

This technical memorandum (431-TM1) documents the methodology and approach used to develop cost estimates for the Phase 1 Actions. It specifically provides revised cost assumptions for each Action that were developed for Phase 2 based on lessons learned from Phase 1.

COST ESTIMATING METHODOLOGY AND APPROACH

This section provides an overview of the methodology and approach used to estimate direct construction cost, indirect non-construction cost, project cost, and life-cycle cost (LCC) for each Action.

Overview

The estimating methodology used to generate planning-level cost estimates is based on an order-of-magnitude cost estimate with planning-level, conceptual scope, and limited conceptual design provided by Herrera and Robin Kirschbaum Inc. (RKI) consultants including design assumptions and dimensions. This was augmented by information from the *King County Surface Water Design Manual*, *City of Seattle Stormwater Manual*, Washington State Department of Ecology (Ecology) *Stormwater Management Manual for Western Washington*, and historical agency and proprietary design and detail information from online sources. General and specific assumptions that influence the cost estimates are documented in the cost spreadsheet for each Action.

The Herrera team developed a suite of Actions comprising structural and non-structural practices that improve water quality. These Actions will be modeled in the System for Urban Stormwater Treatment and Analysis Integration Model (SUSTAIN) to identify the most cost-effective combinations of Actions for reducing pollutant loads and/or stormwater volumes.

A "Unit Action" represents a typical vertical profile, areal footprint, and associated design-drainage area for a specific Action being modeled in SUSTAIN. These Unit Actions need to be a representative footprint of an Action defined to be compatible with the SUSTAIN model. Cost optimization is used to determine the collective sizes and/or number of Unit Actions required to achieve a certain pollutant load reduction target. Each Unit Action has an associated total implementation cost.

This cost estimating effort focuses on the capital and operations and maintenance (O&M) costs for the Unit Actions. The programmatic costs associated with executing groups of Unit Actions within a Program will be defined after further development of the SUSTAIN model is completed and is a future scope element.

Planning-level cost estimates were developed for the Unit Actions and variations listed in Table 1.

Table 1. WQBE Actions and Variations.	
Action	**Description**
Green Stormwater Infrastructure (GSI)	
Rain Garden Installation	WQBE_01_Rain Garden Installation on Property
Bioretention Planter	WQBE_02A_Bioretention Planter on Property
	WQBE_02B_Bioretention Planter in ROW
	WQBE_02C_Bioretention Planter with Property Cost
Bioretention Installation	WQBE_03A_Bioretention Underdrain on Property
	WQBE_03Aa_Bioretention Underdrain with Property Cost
	WQBE_03B_Bioretention No Underdrain on Property
	WQBE_03Bb_Bioretention No Underdrain with Property Cost
	WQBE_03C_Bioretention Underdrain in ROW
	WQBE_03D_Bioretention No Underdrain in ROW
Bioswale Installation	WQBE_04A_Bioswale in ROW
	WQBE_04B_Bioswale on Public Property
	WQBE_04C_Bioswale with Property Cost
Media Filter Drains	WQBE_05A_Media Filter Drain Underdrain
	WQBE_05B_Media Filter Drain No Underdrain
Drywell	WQBE_06A_Drywell on Property
	WQBE_06B_Drywell with Bioretention Planter on Property
Deep UIC Wells	WQBE_07A_Deep UIC Well on Property
	WQBE_07B_Deep UIC Well in ROW
	WQBE_07C_Deep UIC Well with Property Cost
	WQBE_07D_Deep UIC Well with Filter in ROW
	WQBE_07E_Deep UIC Well with Bioretention Planter in ROW
Permeable Pavement	WQBE_08A_Pervious Concrete Sidewalk (no sand layer)
	WQBE_08B_Porous Asphalt Driveway (with sand layer)
	WQBE_08C_Permeable Paver Driveway (with sand layer)
	WQBE_08D_Permeable Paver Plaza (no sand layer)
Stormwater Retention/Detention/Infiltration	
Depaving (Removal of Impervious Surfaces)	WQBE_9A_Removal of Impervious Surfaces on Property (wheel strips)
	WQBE_9B_Removal of Impervious Surfaces on Property (no wheel strips)
Stormwater Treatment Wetland	WQBE_20A_ Stormwater Treatment Wetland on Public Property
Detention Vault	WQBE_11A_Detention Vault on Public Property
	WQBE_11B_Detention Vault in ROW
	WQBE_11C_Detention Vault with Property Cost

Table 1 (continued). WQBE Actions and Variations.

Action	Description
Detention Pond	WQBE_12A_Detention Pond on Public Property
	WQBE_12B_Detention Pond with Property Cost
Infiltration Pond	WQBE_13A_Infiltration Pond Till Soil on Public Property
	WQBE_13B_Infiltration Pond Outwash Soil on Public Property
	WQBE_13C_Infiltration Pond Till Soil with Property Cost
	WQBE_13D_Infiltration Pond Outwash Soil with Property Cost
	WQBE_13E_Infiltration Pond Outwash Soil with High Rate Underground Filter on Public Property
Infiltration Vault	WQBE_14A_Infiltration Vault Till Soil on Public Property
	WQBE_14B_Infiltration Vault Outwash Soil on Public Property
	WQBE_14C_Infiltration Vault Till Soil in ROW
	WQBE_14D_Infiltration Vault Outwash Soil in ROW
	WQBE_14E_Infiltration Vault Till Soil with Property Cost
	WQBE_14F_Infiltration Vault Outwash Soil with Property Cost
	WQBE_14G_Infiltration Vault Outwash Soil with High Rate Underground Filter on Public Property
Cistern	WQBE_16_Cistern on Property
Gray Stormwater Treatment	
Wet Pond	WQBE_18A_ Wet Pond on Public Property
	WQBE_18B_ Wet Pond with Property Cost
Wet Vault	WQBE_19A_ Wet Vault on Public Property
	WQBE_19B_ Wet Vault in ROW
	WQBE_19C_ Wet Vault with Property Cost
Stormwater Treatment Wetland	WQBE_20A_ Stormwater Treatment Wetland on Public Property
	WQBE_20B_ Stormwater Treatment Wetland with Property Cost
High Rate Underground Filter System installation	WQBE_21A_High Rate Underground Filter in Urban ROW PCCP
	WQBE_21B_High Rate Underground Filter in Highway ROW PCCP
	WQBE_21C_High Rate Underground Filter in Urban ROW HMA
	WQBE_21D_High Rate Underground Filter in Highway ROW HMA
	WQBE_21E_High Rate Underground Filter on Public Property
	WQBE_21F_High Rate Underground Filter with Property Cost
Regional Vegetated Media	WQBE_22A_Regional Vegetated Media Stormwater Facility on Public Property
	WQBE_22B_Regional Vegetated Media Stormwater Facility with Property Cost

Estimating Basis

Action unit costs were developed from a conceptual design basis combined with accepted design practice and engineering judgment. Differing approaches and assumptions may also meet an acceptable standard of care but may have a significant effect upon cost development. Cost modeling assumptions were developed for each Action to guide the cost development process and maintain consistency with accepted design practices and the WQBE goals. Cost modeling assumption definitions include:

- Design standards (e.g., *King County Surface Water Design Manual*, *City of Seattle Stormwater Manual*, Ecology *Stormwater Management Manual of Western Washington*, etc.)
- Facility assumptions (e.g., treatment media type and depth, drains, piping, location and surface restoration, etc.)
- Facility location and area (e.g., urban roadway, residential property, etc.)

Refer to the Basis of Estimate (BOE) documentation in Attachment A for initial preliminary concept and site assumptions that were used in cost model development. The Unit Action cost estimate spreadsheets contain BOE information for the following:

- Design basis (specific to cost assumptions)
- Planning basis
- Cost basis
- Allowances
- Estimating assumptions
- Contingency
- Management reserve
- Benchmarking

The BOE is considered a "living document" and information provided may be updated when the Unit Action definition or approach undergo changes or are further defined.

Cost Estimate Development

Cost estimates were developed in general conformance with the Association for the Advancement of Cost Engineering (AACE) and King County WTD estimating guidelines. AACE classifies estimates into five class types as outlined in AACE Recommended Practice 18R-97. The cost estimate classification varies, depending upon the project definition and primary estimating characteristics. The estimate classification is distinguished by the degree of project definition and the intended purpose or use of the estimate. The AACE guideline matrix for estimate classification system is provided in Table 2 below.

Table 2. AACE Estimate Class and Characteristics

AACE Estimate	Degree of Project Definition	Typical Estimate Purpose	AACE Expected Accuracy Range
Class 5 (Pre-Class 5)	0% to 2%	Conceptual screening	-50% to +100%
Class 4	1% to 15%	Concept study, order of magnitude, feasibility study	-30% to +50%
Class 3	10% to 40%	Budget, authorization, control	-20% to +30%
Class 2	30% to 70%	Control	-15% to +20%
Class 1	70% to 100%	Check estimate, bid/tender, change order	-10% to +15%

Source: AACE International, 2005.

In addition to the estimate classes listed above, AACE recognizes that special considerations apply when developing costs intended for planning-level screening or long-range strategic planning. These estimates were designated as Class 10 estimates in AACE publication RP111r-20 and were designated as Pre-Class 5 by the CSO Long-Term Control Planning team. Class 5 and Pre-Class 5 (AACE Class 10) estimates are assigned the same accuracy range, contingency, and uncertainty allowances as the AACE Class 5 estimate. The distinguishing feature between an AACE Class 5 estimate and a Pre-Class 5 estimate is that traditionally, a Class 5 estimate is prepared for a near-term project. Pre-Class 5 estimates are prepared to provide planning-level comparisons or conceptual screening for projects that may be constructed 10 years or more in the future.

The WQBE Unit Action cost estimates were designated and prepared as Pre-Class 5 estimates to provide for comparison and screening between different Unit Actions or a suite of Actions. Table 2 lists the allowances and expected accuracy range for the AACE estimate classes. For the purpose of this TM, Pre-Class 5 and Class 5 estimates are assigned the same estimating characteristics and may be used interchangeably.

Cost estimates for the WQBE toolkit were developed in two phases. In Phase 1, Action total project cost estimates were initially developed to support Phase 1 modeling. Phase 2 of the cost estimating was focused on refining the total project and life-cycle costs to reflect a programmatic approach to the Actions. These Unit Action costs provide reasonable estimates of

project costs, while also accounting for contingency and uncertainty. Including contingency and other allowances in the project costs includes risk and uncertainty in cost-effectiveness determinations. In both Phases 1 and 2, costs were determined using the WTD cost estimating tool, hereafter called the WTD cost estimate sheet, a Microsoft Excel workbook used to capture, organize, and develop the estimate from project components and assumptions. The WTD cost estimate sheet was selected for use in the WQBE toolkit to provide consistency in how the cost estimates were developed to allow for cost comparisons across the alternatives developed for the CSO LTCP and CSO Water Quality and Optimization programs.

A workshop was conducted following the initial cost development to review the assumptions and methodologies used in developing Phase 1 estimates. Details regarding the workshop as they relate to water quality development are provided in Section 1.2 of Appendix B. A summary of the estimating cost refinements that were identified and implemented with WQBE Phase 2 cost development is listed below. WQBE Phase 2 cost refinements include:

- Revising the estimate class to Pre-Class 5 (AACE Class 10) to capture the long-term planning window associated with WQBE Action development and to be consistent with the CSO LTCP estimate development.

- Revisiting the cost contingency and indeterminates allowance multipliers. The multipliers were evaluated based on specific complexity and assumed project complexity associated with the Actions. Complexity assignments based on Action categories are described within subsequent sections in this TM. Specific contingency factors, uncertainty factors, and complexity factor assignments are detailed within each Action estimate within the Basis of Estimate tab.

- Property costs were initially referenced from appraised land values within the Seattle area. Land costs were revisited to provide land values outside of the Seattle area and that were more reflective of costs within King County.

- The Actions were scaled within the WTD workbook to provide indirect costs that were more reflective of the anticipated cost for a suite of Actions or anticipated Program size.

To remain consistent with the CSO LTCP cost estimate development, the total project cost for each Action was used to update the LCC model workbooks. The LCCs (described in further detail in subsequent sections) were estimated for each Action.

The design basis, developed by Herrera and RKI, was used to develop a cost concept for each Action. The design basis included concept scope and description, preliminary design assumptions, dimensions, and design standards. Refer to Appendix B for details on the design assumptions used for developing the Action cost models. The design basis was used to develop the quantities and estimated construction costs for each Action. Cost allowances were assigned where there was insufficient information to develop quantities within the estimate.

The design basis was augmented using referenced requirements from the following sources:

- *King County Surface Water Design Manual*
- *City of Seattle Stormwater Manual*
- Ecology *Stormwater Management Manual for Western Washington*
- Historical agency and vendor design and detail information

A BOE summary sheet (within the spreadsheet cost estimating tool) was prepared to document key estimating assumptions, design details, estimating factors, and exclusions for each Action. A copy of the BOE summary sheet is provided with the cost spreadsheets in Attachment A.

Total Project Cost Estimates

The WTD cost estimating spreadsheet was used to develop a total project cost for each Action. The total project cost consists of:

- Direct construction cost, which represents the probable cost of construction
- Indirect or non-construction costs, which represent design, permitting, real estate, and other costs associated with the development and administration of a project

Direct Construction Cost

This section describes the methodologies and assumptions used to estimate direct construction costs for the Unit Actions. Direct construction costs represent the costs associated with physical construction of a project and include:

- Subtotal construction costs, which is also called the probable cost of construction bid. The subtotal construction costs include:
    - Contractor overhead and profit and general conditions (included in line-item unit prices)
    - Contractor bonds and insurance (included in line-item unit prices)
    - Contractor mobilization and demobilization (10 percent) based on County experience
- Allowance for indeterminates or design allowance for undefined scope work. The amount is based on a percentage of the subtotal construction costs assigned based on Action type and anticipated complexity as follows:

  - 15 percent for Green Stormwater Infrastructure (GSI) Actions
  - 20 percent for Stormwater Retention/Detention/Infiltration and Gray Stormwater Treatment Actions
  - 25 percent for the Regional Vegetated Media Stormwater Facility (regional facility) Action

- Street use permits: Seattle Department of Transportation (SDOT) street use permit fees for work within Seattle right-of-way (ROW) (varies by Unit Action).
- Project contingency multipliers were assigned based on anticipated project complexity and the level of uncertainty as follows:
  - 15 percent for GSI Actions
  - 25 percent for Stormwater Retention/Detention/Infiltration and Gray Stormwater Treatment Actions
  - 30 percent for the Regional Vegetated Media Stormwater Facility (regional facility) Action

Additional Construction Costs

Additional direct construction costs are included within the WTD cost estimate model and reflect the cost of markups and contingencies in addition to the calculated subtotal of construction costs. These costs include:

- Construction change order allowance (10 percent) based on County experience
- Retail sales tax (10.1 percent) in Seattle
- Outside agency construction (e.g., utility relocations; user-defined, varies by Unit Action)

Year of Construction Cost

Engineering News-Record (ENR) monitors construction costs across the country. The ENR Construction Cost Index (CCI) averages the cost of a set amount of labor and materials over a 20-city average of labor rates and material costs. In addition, ENR has specific CCI average values for the Seattle area.

To maintain estimating consistency between Unit Actions, all costs were escalated to August 2019 dollars using Seattle ENR CCI values. Should a Unit Action be selected for future development, it is recommended that construction costs be adjusted to the projected mid-year of construction.

Indirect Non-Construction Costs

Indirect costs represent "soft costs," which are costs outside of those that are directly part of the construction (or installation), but are required to complete the construction. Examples of indirect costs include design, permitting, real estate procurement, etc. WTD tracked indirect project costs for completed capital improvement projects using its Project Reporting and Information System Management (PRISM) Database. In 2011 WTD updated its WTD cost estimate sheet to incorporate indirect project cost information from the PRISM database. The WTD PRISM cost database information, built into the WTD cost estimating sheet, was used to estimate indirect costs for each Action using the conveyance project type.

WTD gathered indirect project cost data from the PRISM database for 53 projects that were over $1 million in construction cost and from 27 baselined projects that were under $1 million in construction costs. The costs from these referenced key projects were used to develop indirect project costs based on project construction costs. Table 3 depicts how the WTD cost estimate sheet assigns indirect project costs as a percentage of the Action's subtotal of construction cost.

Table 3. WQBE Indirect Costs Assigned Based on Subtotal Construction Cost.

Subtotal Construction Cost Range	Indirect Costs Assigned (%)
$1,000,000–$5,000,000	82.12%
$5,000,000–$10,000,000	68.36%
More than $10,000,000	61.17%

The WTD cost estimate spreadsheet assigns indirect costs based on a percentage of a project's subtotal construction costs. The indirect cost model within the estimate spreadsheet was developed and intended for use on large, capital improvement projects. The projects used to develop the indirect cost model generally had construction cost ranges shown in Table 3 above. Singularly, the subtotal construction cost for each WQBE Action is less than the WTD cost estimate spreadsheet's indirect cost tool was intended to model. However, while the WQBE Action unit costs are discrete, it is anticipated that each Action will be part of a larger project, suite of combined Actions, or installed as part of a Program. Indirect costs for the WQBE Actions were assigned using a scaled subtotal construction cost assuming the total project or Program cost ranges listed below:

- Indirect costs for GSI Actions were based on $20 million to $25 million construction cost. The subtotal cost range was selected as typical for a GSI Program.
- Indirect costs for Stormwater Retention/Detention/Infiltration and Gray Stormwater Treatment Actions were based on $10 million to $15 million subtotal construction cost. The construction cost range was selected as a typical project size for this type of Action.

In addition to project type and estimated construction cost, the following series of project calibrations were selected in the cost model to develop an indirect cost profile:

- Initiatives (art, sustainability): determined that the Actions would not be considered eligible for the initiatives
- Operations support
- Facility inspection used
- In-house legal used
- Modeling used
- Water and Land Resources Division support used

The WTD cost estimate sheet assigned indirect costs as a percentage of the estimated subtotal construction cost based on a developed cost profile from the following nine key PRISM categories:

- Design Engineering
- Construction Management
- Permitting and Licenses
- Operations Support
- Community Relations
- Environmental Planning and Management
- Real Estate: Permitting, Right-of-Way, and Monitoring
- Project Management
- Project Controls

The WTD cost estimate sheet cost model profile assigns indirect costs based on project complexity within the key PRISM categories. There are four complexity levels within the PRISM categories:

- Low complexity indicates a simplified or straightforward cost profile. For example, the Rain Garden Action, which uses a simple, preapproved design with little permitting required, was assigned a low complexity profile.

- Routine complexity indicates typical design or duties without unique issues or concerns. For example, the Detention Vault Action was assumed to require typical design and construction monitoring. While the Action requires permitting, no unique permitting issues were anticipated with this installation. The Detention Vault Action was assigned a routine complexity profile.

- Moderate complexity indicates that there will be elevated costs or concerns associated that are higher than normally found with that type of project. For example, the Stormwater Treatment Wetland Action was assumed to require elevated support for permitting, and environmental planning and management. The Stormwater Treatment Wetland Action was assigned a moderate complexity profile.

- High complexity indicates that the project may have risks associated with it that can require intense support or concerns that may cause significant delivery and schedule delays. For example, a tunnel project that crosses a bay or requires disturbance along the shoreline area may require extensive permitting, have elevated risk associated with the construction, or may require extensive community-relations outreach. The tunnel project may be assigned a high complexity profile. None of the WQBE Phase 2 Actions were considered to have a high complexity profile.

The cost model was established to calculate the indirect cost for each of the key PRISM categories' project complexity with baseline costs set at the "Routine" complexity setting. Indirect costs within each key category were refined (increased or decreased) for each Action by selecting a lower or higher complexity input value. Complexity factors for the WQBE Action units were assigned based on the following:

- Low complexity for GSI Actions

- Routine complexity for Stormwater Retention/Detention/Infiltration and Gray Stormwater Treatment Actions

- Moderate complexity for Regional Vegetated Media (regional) Action

The complexity factors used in developing the cost model for each Action were documented in the BOE assumptions.

Real Estate Costs

The WQBE Actions represent high-level concepts and it is unknown where construction will occur. In determining real estate costs, the following sources were considered:

- WTD appraised land values from the CSO LTCP cost estimates were used to determine property costs from the Seattle area.

- Assessed land costs from areas within King County that were outside of the Seattle area were obtained from the King County Department of Assessments appraised land values.

An average land cost of $54 per square foot (SF) was assigned for acquisition based on an average of Seattle area land costs and assessed land costs in King County outside of the Seattle area. The overall project contingencies are applied to the property costs. Real estate cost assumptions, where used, are documented in the estimate spreadsheet for each Unit Action.

Total Project Costs

Total project costs were estimated for each Unit Action by summing the direct construction costs and indirect non-construction costs using the WTD cost estimating tool. The summary sheet provides a summary of costs for each Unit Action that includes the following information:

- Total direct construction costs, which includes:
    - Estimated probable cost of construction bid (directly estimated using engineered quantities and unit pricing analysis)
    - Additional direct cost
    - Additional construction costs (from PRISM and user-defined allowances)
    - Other capital charges (from PRISM)
- Total indirect non-construction costs (from PRISM and user-defined allowances):
    - Design and construction consulting services
    - Permitting and agency support
    - ROW
    - WTD staff labor
    - Miscellaneous services and materials
    - Non-WTD support
- Total project cost, which includes both direct and indirect construction costs

As detailed under the Cost Estimate Development section, the WQBE estimates were prepared as Pre-Class 5 estimates intended for planning-level screening or alternative comparison for long-range strategic planning. Attachment A contains Portable Document Format (PDF) files of the WTD estimating spreadsheet tool for each of the Unit Actions' cost estimates.

Life-Cycle Cost

A life-cycle cost analysis (LCCA) was prepared using the WTD LCC Model to provide an evaluation of the developed concepts over an established analysis period. The LCCA considers initial capital costs and future costs, such as capital replacement and O&M costs. A 30-year analysis period was selected for the LCCA.

For the WQBE Actions, the LCC was the total project capital cost plus the net present value (NPV) of ongoing capital replacement and O&M over the analysis period of the project. Project LCCs combine capital replacement and O&M costs to allow reasonable comparisons between concepts with high project costs and those with high O&M costs. Project LCCs were estimated by considering:

- Total project cost comprising both direct construction cost and indirect project costs
- Capital replacement cost, which was the cost to replace components during the life-cycle period
- Annual O&M costs, which included labor, chemicals, supplies, and energy costs

The LCCA estimates are to be considered preliminary level (Pre-Class 5) because of the limited information available and the planning-level engineering that has occurred.

Life-Cycle Cost Analysis Assumptions

The following general assumptions were used in the WTD LCC Model:

- Initial capital cost:
    - Initial capital cost is input into the WTD LCC Model as total project cost and not construction cost. Indirect non-construction cost is estimated using the WTD PRISM database program and cost model and not estimated using standard WTD LCC Model assumptions.
    - Initial capital cost was assumed to occur in a single year.
    - If capital costs are incurred over multiple years (large projects), total project cost was entered into the WTD LCC Model as a fraction of the total project cost depending on the number of years for implementation. For example, if a Program is implemented over 10 years, 1/10 of the total project cost will be entered into the WTD LCC Model for each year for 10 years. The first year will be listed as initial capital cost, and subsequent years will be entered as one-time capital replacements.

- Capital replacement cost:
    - Capital replacement is input into the WTD LCC Model as total project cost and not construction cost. Indirect non-construction cost is estimated using the WTD PRISM database program and cost model and not estimated using standard WTD LCC Model assumptions. Indirect non-construction cost (ancillary cost) for capital replacement was manually adjusted to $0 in the WTD LCC Model.
    - If capital replacement (or Program implementation cost) occurs more frequently than every 5 years, annual cost was manually entered into the WTD LCC Model because the WTD LCC Model is not set up for less than 5-year increments.

The following is a general representation of how NPV is calculated within the WTD LCC Model:

$$Project\ Net\ Present\ Value\ (NPV) =$$

$$PV\ (Initial\ Capital\ Costs) + PV(Capital\ Replacment\ Costs) + PV(O\&M\ Costs)$$

In general, future values (FVs) are converted to present values (PVs) by the following equation:

$$PV = FV\frac{FV}{(1+i)^n}$$

Where: i = annual interest rate (provided by County), n = year of expenditure.

- Life-cycle assumptions:
    - Period: 30 years
    - Initial year of operations: 2021
    - Year of analysis: 2019
    - Construction start: 2020
- Cost assumptions:
    - Cost estimate dollar basis year: 2019
    - General conditions markup: 0 percent (general conditions markup was included in the project costs prior to entry into the WTD LCC Model)
    - Construction cost escalation: 3.5 percent
- O&M and general cost escalation:
    - Projects: 3.0 percent

- Programs: 3.5 percent (because it is associated with Program implementation and not necessarily O&M)
- O&M labor rate growth: 3.2 percent
- Direct labor rate as of year of analysis: $47.97
- Washington (retail) sales tax: 10.1 percent
- Project cost contingency allowance: 0 percent (because project costs are entered into the WTD LCC Model and not construction costs)
- WTD labor overhead: 150 percent (this is a County-controlled rate applied to raw labor costs calculated for O&M activities)
- The O&M labor cost formula is listed below:

$$O\&M\ Labor\ Costs\ =$$

$$Labor\ Hours\ per\ Year\ \times Direct\ Labor\ Rate\ \times WTD\ Overhead\ Rate$$

- Financial assumptions:
  - Percent financed of each capital activity:
    - Projects: 60.0 percent
    - Financing interest rate: 5.25 percent
    - Financing maturity: 30 years
    - Financing costs, capitalized: 2.0 percent
- Economic assumptions:
  - Discount rate, WTD (cost of capital): 5.25 percent. The discount rate accounts for both inflation and the time value of money.
  - WTD real discounted rate: 2.18 percent (if O&M escalation is 3.0 percent) or 1.69 percent (if O&M escalation is 3.5 percent).[1]

[1] Real discount rate of 2.18 percent is the default value in the WTD LCC Model; this is estimated based on a WTD financing interest rate of 5.25 percent and 3 percent annual inflation for O&M and general cost escalation. A real discount rate of 1.69 percent is used when O&M and general cost escalation is assumed to be 3.5 percent annual inflation (instead of 3 percent). It was generally assumed 3.5 percent annual O&M and general cost escalation for Programs to be consistent with 3.5 percent annual construction cost

- Annual growth in electricity consumption: 1.0 percent

Attachment A contains a PDF file of the WTD LCC Model and a Microsoft Excel workbook for each of the Unit Actions' LCC estimate.

Operations and Maintenance Cost

Annual O&M cost was estimated for each Unit Action and generally included the following:

- O&M activities were based on the type of activity provided in the most current version of the Cost and Modeling Assumptions worksheet. Activity sources included:
  - *King County Surface Water Design Manual*, 2016
  - *City of Seattle Stormwater Manual*, 2016
  - Ecology *Stormwater Management Manual for Western Washington*, 2019
  - Kitsap County *Manchester Stormwater Retrofit Drainage Report*, 2014
- Annual labor hours required by maintenance crews for cleanup after major storm events or for periodic inspections and remediation of materials (grass, plantings, permeable pavement, concrete cracks and joints, etc.) and regular maintenance activities for the specific Unit Action, where applicable.
- Annual material replacement, such as plant replacement, grass seed mix, mulch, etc. for the specific Unit Action, where applicable.
- Annual equipment rentals needed to perform maintenance activities for the specific Action, where applicable. Equipment rates were obtained from EquipmentWatch™ (Rental Rate Blue Book®) adjusted for Seattle pricing.

Capital Replacement Cost

Capital replacement cost (items requiring replacement prior to the 30-year life of the Unit Action) was estimated for each Unit Action and generally assumed the following:

- Complete replacement of vegetation along with soils that had been compacted every 10 years, where applicable
- Complete replacement of access gates every 10 years, where applicable

escalation because Programs generally do not have an O&M component, and it was generally assumed 3 percent annual O&M and general cost escalation (default value in WTD LCC Model) for projects because they include an O&M component.

- Complete replacement of mechanical equipment (e.g., flow restrictor, access hatch, outlet structure, baffle, etc.) every 20 years, where applicable

Capital replacement costs were estimated for each Unit Action by summing the construction costs of the specific line items assumed for replacement for the specified interval (e.g., 10 years), including mobilization/demobilization, and then converting the construction cost into project cost by multiplying the subtotal by the ratio of total project cost (excluding land acquisition) to total construction cost for the Unit Action (see equation below). Capital replacement is input into the WTD LCC Model as total project cost and not construction cost. The formula for capital replacement cost is shown below:

$$Total\ Capital\ Replacement\ Project\ Cost =$$

$$Total\ Capital\ Replacement\ Construction\ Cost \times \frac{Total\ Project\ Cost\ (excluding\ land\ acquisition)}{Total\ Construction\ Cost}$$

Total Life-Cycle Cost

Total LCC for each Unit Action was estimated using the WTD LCC Model. Costs were entered into the WTD LCC Model for initial capital (project), capital replacement, and O&M. Total LCC is presented as NPV over 30-year life using the WTD discount rate.

COST SOURCES

This section explains the process used to collect cost information for costs in support of the WQBE toolkit (construction, Program, and O&M costs). The costs for each Unit Action were characterized for each unit (see definition at end of document) of an Action, or the footprint of the Unit Action designed specifically for compatibility with the SUSTAIN model. Costs for the Unit Action items are to be considered preliminary, planning-level costs based on limited or generalized engineering design assumptions.

The following sources were used to develop unit prices using cost data representative of the Seattle/King County region and reviewed to gather data to support development of costs for the Unit Actions. All costs reflect owner's anticipated construction costs (construction contractor pricing) in 2019 dollars:

- **Tabula costing tool (Version 3.1.2):** The County developed Tabula to provide planning-level construction cost estimates for conveyance, tunnel, and storage facilities. The County last updated this program in 2010 with costs based on 2008 dollars (King County, 2010).

- **Seattle Public Utilities (SPU) cost estimating guide:** The SPU estimating guide provides unit cost information for typical elements within public works infrastructure

projects and for building construction. Costs within this sheet were based on 2017 dollars (SPU, 2017).

- **Washington State Department of Transportation (WSDOT) unit bid analysis:** The WSDOT unit bid analysis database contains a bid history for standard unit bid prices from WSDOT projects. This tool contains cost information for excavation, conveyance, best management practices (BMPs), or other typical roadway construction items. The WSDOT database search can be limited to projects within western Washington or other nearby localities, such as the Olympic Peninsula (WSDOT, 2019).

- **Puget Sound BMP cost database:** The Puget Sound BMP cost database report contains cost information from the Puget Sound region for stormwater treatment and BMP elements (e.g., wet ponds, porous pavement, cisterns, constructed wetlands, etc.). Costs from this database report are based on 2012 dollars.

- **King County TMs and reports:** King County TMs (e.g., Legacy Load Removal and the University GSI projects) and existing reports (e.g., Puget Sound BMP Cost Database, Water Resource Inventory Area [WRIA] 9 reports, and University Green Stormwater Infrastructure with GSI cost benchmarking by CH2M Hill) contain both estimated construction costs and historical maintenance cost data. Construction and other cost data within the reports are based on various dates and any applied escalation or inflationary values should be considered on a case-by-case basis.

- **Internet sources:** Internet websites and online data sources were used to estimate specialty costs associated with the GSI Program costs, such as the RainWise Cistern cost from approved vendors listed on the RainWise website at https://www.kingcounty.gov/services/environment/stewardship/nw-yard-and-garden/rain-barrels.aspx.

  Online sources were also used to estimate O&M costs and specialty item costs such as blue roofs and cisterns. Website and online data sources used are as detailed in the Cost Source column of the Cost Data Summary (Table 4).

- **Contractor and vendor quotes:** Vendor quotes were used to calculate bid costs or to verify reported unit cost data for specialty items, such as proprietary stormwater treatment (i.e., Filterra), odor control, and large-value maintenance equipment purchases. Vendor quotes reflect current market conditions at the time the quote was obtained. Quotes should be adjusted to account for installation costs and labor, shipping and handling, and contractor markup and profit.

- **Estimator and agency historical databases:** VMS, Herrera, King County (WTD), SPU, Washington State Department of Natural Resources (DNR), Kitsap County, and other agencies within the Puget Sound area maintain and may post contractor bid prices for publicly bid projects. Bid costs from these sources were used to fill in data gaps from the

other sources or for specialty work (e.g., Maury Island Natural Area Derelict Piling Removal from DNR for creosote pile removal, Manchester Stormwater Retrofit Phase 2 from Kitsap County, RainWise participation and historical participation rates from SPU and WTD, etc.) obtained from other sources. Data obtained from these sources were reviewed to ensure that the quantities and other project parameters were relevant. Costs obtained from these sources were based on various dates and any applied escalation or inflationary values were considered on a case-by-case basis.

- **EquipmentWatch™:** HDR Engineering, Inc. maintains a subscription to EquipmentWatch™, which provides access to Rental Rate Blue Book® pricing. The pricing is kept current by extensive ongoing research. This pricing tool is an industry standard for determining equipment values for both use and rental. The rates can be applied across the country or can be adjusted for a specific region, such as the Seattle area. Additional information on EquipmentWatch™ can be found on its website at <equipmentwatch.com>.

- **RSMeans:** RSMeans, an industry resource used in estimating construction costs, was another source of productivity information that was cross referenced for validation (Gordian, 2018). RSMeans researches data to provide construction costs for materials, labor, transportation costs, and equipment rental rates. The rates can be applied across the country or can be adjusted for a specific region, such as the Seattle area. Additional information on RSMeans can be found on its website at <www.RSMeans.com>.

- **Labor rates:** Craft rates and related benefits were estimated using current prevailing wage rates for King County. These labor rates include base wage rate, all applicable fringe benefits, unemployment insurance, and payroll taxes. Workers' compensation insurance is included separately in each work activity based on risk histories.

Cost Source Data Summary

The cost sources used in development of the Unit Action costs are summarized in Table 4 below. Where appropriate, costs were benchmarked using the County's CSO LTCP unit price estimates to maintain estimating cost consistency between the Programs. The cost estimates and estimating approaches used for the WQBE Phase 1 Actions were evaluated against peer projects and programs. The results are documented within the Program Cost Benchmarking Technical Memorandum (hereafter called the Benchmarking TM), prepared by Lotus Water. A copy of the Benchmarking TM is provided as Attachment B and supplemental analysis to the Benchmarking TM is in Attachment C. WQBE Phase 1 Action direct and indirect cost assumptions were evaluated for appropriateness and for cost sensitivity and the results documented in the Evaluation of Water Quality Benefit (WQBE) Project Cost Sensitivity for SUSTAIN Modeling Technical Memo (hereafter called the WQBE Cost Sensitivity TM). A copy of the WQBE Cost Sensitivity TM is provided as Attachment D.

Table 4. Cost Data Summary.

Action	Cost Source
Rain Garden Installation	• King County University GSI, Puget Sound BMP cost database, WSDOT unit bid analysis, SPU cost estimating guide, Tabula, estimator and historical databases • Equipment rates from RSMeans and personnel costs from Washington State prevailing wage rates • O&M guidelines per *Stormwater Management Manual for Western Washington*, 2019
Bioretention Planter	• King County University GSI, Puget Sound BMP cost database, WSDOT unit bid analysis, SPU cost estimating guide, Tabula, estimator and historical databases • Equipment rates from RSMeans and personnel costs from Washington State prevailing wage rates • O&M guidelines per *Stormwater Management Manual for Western Washington*, 2019
Bioretention	• King County University GSI, Puget Sound BMP cost database, WSDOT unit bid analysis, SPU cost estimating guide, Tabula, estimator and historical databases • Equipment rates from RSMeans and personnel costs from Washington State prevailing wage rates • O&M guidelines per *Stormwater Management Manual for Western Washington*, 2019
Bioswale (treatment)	• Construction costs based on WRIA 9 Reports, WSDOT Unit Bid Analysis, SPU/County and estimator and historical databases • Equipment rates from RSMeans and personnel costs from Washington State prevailing wage rates • O&M guidelines per *Stormwater Management Manual for Western Washington*, 2019
Media Filter Drains	• King County University GSI, Puget Sound BMP cost database, WSDOT unit bid analysis, SPU cost estimating guide, Tabula, estimator and historical databases • O&M guidelines per *Stormwater Management Manual for Western Washington*, 2019
Drywell	• King County University GSI, Puget Sound BMP cost database, WSDOT unit bid analysis, SPU cost estimating guide, Tabula, estimator and historical databases • O&M guidelines per *King County Surface Water Design Manual*, 2016

Table 4 (continued). Cost Data Summary

Action	Cost Source
Deep UIC Wells	• Construction costs based on University GSI report, Puget Sound BMP cost database, and estimator and historical cost database • O&M guidelines per *King County Surface Water Design Manual*, 2016
Permeable Pavement	• Construction costs based on University GSI report and estimator and historical cost database • O&M guidelines per *Stormwater Management Manual for Western Washington*, 2019
	• Construction costs based on University GSI report, Puget Sound BMP cost database, WSDOT unit cost database, and estimator and historical cost database • O&M guidelines per *Stormwater Management Manual for Western Washington*, 2019
Depaving (Removal of Impervious Surface)	• Construction costs based on SPU/County and estimator and historical database • O&M minimal and based on professional judgment
Detention Vault	• Construction costs based on WSDOT Unit Bid Analysis, tabula, SPU cost estimating guide, vendor quotes, SPU/County and estimator and historical databases • Equipment rates from RSMeans and personnel costs from Washington State prevailing wage rates • O&M guidelines per *Stormwater Management Manual for Western Washington*, 2019
Detention Pond	• Construction costs based on WSDOT Unit Bid Analysis, tabula, SPU cost estimating guide, vendor quotes, SPU/County and estimator and historical databases • Equipment rates from RSMeans and personnel costs from Washington State prevailing wage rates • O&M guidelines per *Stormwater Management Manual for Western Washington*, 2019
Infiltration Pond	• King County University GSI, Puget Sound BMP cost database, WSDOT unit bid analysis, SPU cost estimating guide, Tabula, estimator and historical databases • O&M guidelines per *Stormwater Management Manual for Western Washington*, 2019
Infiltration Vault	• Construction costs based on WSDOT Unit Bid Analysis, tabula, SPU cost estimating guide, vendor quotes, SPU/County and estimator and historical databases • O&M guidelines per *Stormwater Management Manual for Western Washington*, 2019
Cistern	• RainWise cost based on average rebate amount per cistern for 60 gal, 250 gal, and 600 gal vendor info from <https://www.700milliongallons.org/rainwise/>. • O&M guidelines per *Stormwater Management Manual for Western Washington*, 2019 and *King County Surface Water Design Manual*, 2016

Table 4 (continued). Cost Data Summary

Action	Cost Source
Wet Pond	• King County University GSI, Puget Sound BMP cost database, WSDOT unit bid analysis, SPU cost estimating guide, Tabula, estimator and historical databases • Equipment rates from RSMeans and personnel costs from Washington State prevailing wage rates • O&M guidelines per *Stormwater Management Manual for Western Washington*, 2019
Wet Vault	• Construction costs based on WSDOT Unit Bid Analysis, tabula, SPU cost estimating guide, vendor quotes, SPU/County and estimator and historical databases • O&M guidelines per *Stormwater Management Manual for Western Washington*, 2019
Stormwater Treatment Wetland	• Construction costs based on Manchester Stormwater Retrofit (Kitsap County), King County University GSI, Puget Sound BMP cost database, WSDOT unit bid analysis, SPU cost estimating guide, Puget Sound BMP Cost Database, SPU/County and estimator and historical databases • Equipment rates from RSMeans and personnel costs from Washington State prevailing wage rates • O&M guidelines per *King County Surface Water Design Manual*, 2016
High Rate Underground Filter System	• Construction cost based on vendor quotes and estimator and historical databases • Equipment rates from EquipmentWatch™ (Blue Book®) and personnel costs from LCC model • O&M guidelines per Kitsap County *Operations and Maintenance Manual: Manchester Stormwater Park*, 2015

SUMMARY OF COSTS BY UNIT ACTION

A summary of the costs for each Unit Action is provided in Table 5. The Unit Action drainage area assumptions are summarized in Table 4 of Appendix B. These cost estimates were designated as Pre-Class 5 estimates and are assigned the AACE expected accuracy range of -50% to +100% (see Table 2). This range can be applied to the total project costs.

Table 5. Costs by Unit Action.

Action	Description	Action Unit	Total Direct Construction Cost (a)	Property Acquisition Cost (b)	Total Indirect Non-Construction Cost (c)	Total Project Cost (d)	O&M Costs (Annual) (e)	Net Present Value 30-year Life-Cycle Cost (2019)
Equations						(a)+(b)+(c)		PV(d)+PV(e)
Green Stormwater Infrastructure (GSI)								
Rain Garden Installation	WQBE 01_Rain Garden Installation on Property	25 SF	$17,000	$0	$7,000	$24,000	$2,800	$82,000
Bioretention Planter Installation	WQBE 02A_Bioretention Planter on Property	25 SF	$29,000	$0	$13,000	$42,000	$2,800	$100,000
	WQBE_02B_Bioretention Planter in ROW	25 SF	$39,000	$0	$17,000	$56,000	$2,800	$114,000
	WQBE_02C_Bioretention Planter with Property Cost	25 SF	$29,000	$1,400	$15,000	$44,000	$2,800	$102,000
Bioretention Installation	WQBE_03A_Bioretention Underdrain on Property	85 SF	$59,000	$0	$26,000	$85,000	$2,800	$175,000
	WQBE_03Aa_Bioretention Underdrain with Property Cost	85 SF	$59,000	$14,000	$42,000	$100,000	$2,800	$190,000
	WQBE_03B_Bioretention No Underdrain on Property	85 SF	$57,000	$0	$25,000	$83,000	$2,800	$173,000
	WQBE_03Bb_Bioretention No Underdrain with Property Cost	85 SF	$57,000	$14,000	$41,000	$98,000	$2,800	$188,000

	WQBE_03C_Bioretention Underdrain in ROW	85 SF	$97,000	$0	$42,000	$139,000	$2,800	$230,000
	WQBE_03D_Bioretention No Underdrain in ROW	85 SF	$94,000	$0	$41,000	$135,000	$2,800	$226,000

Table 5 (continued). Costs by Unit Action.

Action	Description	Action Unit	Total Direct Construction Cost	Property Acquisition	Total Indirect Non-Construction Costs	Total Project Cost	O&M Costs (Annual)	Net Present Value 30-year Life-Cycle Cost (2019)
Bioswale Installation	WQBE_04A_Bioswale in ROW	200 SF	$29,000	$0	$12,000	$41,000	$2,600	$111,000
	WQBE_04B_Bioswale on Public Property	200 SF	$14,000	$0	$6,000	$20,000	$2,600	$89,000
	WQBE_04C_Bioswale with Property Cost	200 SF	$14,000	$40,000	$52,000	$66,000	$2,600	$135,000
Media Filter Drains	WQBE_05A_Media Filter Drain Underdrain	200 SF	$24,000	$0	$10,000	$34,000	$2,300	$116,000
	WQBE_05B_Media Filter Drain No Underdrain	200 SF	$21,000	$0	$9,000	$30,000	$2,300	$113,000
Drywell	WQBE_06_Drywell on Property	1 Each	$11,000	$0	$5,000	$16,000	$1,800	$53,000
	WQBE_06B_Drywell with Bioretention Planter on Property	1 Each	$50,000	$0	$22,000	$72,000	$1,900	$112,000
Deep UIC Well	WQBE_07A_Deep UIC Well on Property	1 Each	$32,000	$0	$14,000	$46,000	$2,000	$86,000
	WQBE_07B_Deep UIC Well in ROW	1 Each	$46,000	$0	$20,000	$66,000	$2,000	$106,000
	WQBE_07C_Deep UIC Well with Property Cost	1 Each	$32,000	$1,400	$16,000	$48,000	$2,000	$88,000
	WQBE_07D_Deep UIC Well with Filter in ROW	1 Each	$142,000	$0	$62,000	$204,000	$4,900	$303,000
	WQBE_07E_Deep UIC Well with Bioretention Planter in ROW	1 Each	$762,000	$0	$333,000	$1,095,000	$6,800	$1,239,000

Table 5 (continued). Costs by Unit Action.

Action	Description	Action Unit	Total Direct Construction Cost	Property Acquisition	Total Indirect Non-Construction Costs	Total Project Cost	O&M Costs (Annual)	Net Present Value 30-year Life-Cycle Cost (2019)
	WQBE_07F_Deep UIC Well with Bioretention Planter on Property	1 Each	$650,000	$0	$287,000	$938,000	$6,800	$1,083,000
Permeable Pavement	WQBE_08A_Pervious Concrete Sidewalk (no sand layer)	200 SF	$8,000	$0	$4,000	$12,000	$2,100	$78,000
	WQBE_08B_Porous Asphalt Driveway (with sand layer)	200 SF	$4,000	$0	$2,000	$6,000	$2,200	$60,000
	WQBE_08C_Permeable Paver Driveway (with sand layer)	200 SF	$3,000	$0	$1,000	$4,000	$2,100	$55,000
	WQBE_08D_Permeable Paver Plaza (no sand layer)	200 SF	$3,000	$0	$1,000	$4,000	$2,100	$54,000
Depaving (Removal of Impervious Surfaces)	WQBE_9A_Removal of Impervious Surfaces on Property (wheel strips)	100 SF	$1,000	$0	$1,000	$2,000	$600	$15,000
	WQBE_9B_Removal of Impervious Surfaces on Property (no wheel strips)	100 SF	$1,000	$0	$1,000	$2,000	$600	$15,000
Stormwater Retention/Detention/Infiltration								
Detention Vault	WQBE_11A_Detention Vault on Public Property	1 each	$3,519,000	$0	$2,710,000	$6,229,000	$4,900	$6,352,000
	WQBE_11B_Detention Vault in ROW	1 each	$4,473,000	$0	$3,130,500	$7,603,000	$4,900	$7,727,000
	WQBE_11C_Detention Vault with Property Cost	1 each	$3,519,000	$589,000	$3,446,000	$6,965,000	$4,900	$7,085,000
Detention Pond	WQBE_12A_Detention Pond on Public Property	1 each	$617,000	$0	$484,000	$1,102,000	$9,400	$1,473,000
	WQBE_12B_Detention Pond with Property Cost	1 each	$617,000	$1,073,000	$1,826,000	$2,443,000	$9,400	$2,807,000

Table 5 (continued). Costs by Unit Action.

Action	Description	Action Unit	Total Direct Construction Cost	Property Acquisition	Total Indirect Non-Construction Costs	Total Project Cost	O&M Costs (Annual)	Net Present Value 30-year Life-Cycle Cost (2019)
Infiltration Pond	WQBE_13A_Infiltration Pond Till Soil on Public Property	1 each	$395,000	$0	$310,000	$705,000	$5,500	$971,000
	WQBE_13B_Infiltration Pond Outwash Soil on Public Property	1 each	$352,000	$0	$276,000	$629,000	$3,500	$836,000
	WQBE_13C_Infiltration Pond Till Soil with Property Cost	1 each	$395,000	$903,000	$1,439,000	$1,834,000	$5,500	$2,094,000
	WQBE_13D_Infiltration Pond Outwash Soil with Property Cost	1 each	$352,000	$903,000	$1,405,000	$1,758,000	$3,500	$1,959,000
	WQBE_13E_Infiltration Pond Outwash Soil with High Rate Underground Filter System on Public Property	1 each	$424,000	$0	$332,000	$756,000	$6,400	$1,033,000
Infiltration Vault	WQBE_14A_Infiltration Vault Till Soil on Public Property	1 each	$2,577,000	$0	$2,012,000	$4,589,000	$4,900	$4,721,000
	WQBE_14B_Infiltration Vault Outwash Soil on Public Property	1 each	$2,009,000	$0	$1,562,000	$3,572,000	$4,900	$3,709,000
	WQBE_14C_Infiltration Vault Till Soil in ROW	1 each	$3,008,000	$0	$2,245,000	$5,253,000	$4,900	$5,384,000
	WQBE_14D_Infiltration Vault Outwash Soil in ROW	1 each	$2,351,000	$0	$1,769,000	$4,120,000	$4,900	$4,257,000
	WQBE_14E_Infiltration Vault Till Soil with Property Cost	1 each	$2,577,000	$533,000	$2,679,000	$5,256,000	$4,900	$5,385,000
	WQBE_14F_Infiltration Vault Outwash Soil with Property Cost	1 each	$2,009,000	$533,000	$2,229,000	$4,238,000	$4,900	$4,372,000
	WQBE_14G_Infiltration Vault Outwash Soil with High Rate Underground Filter System in ROW	1 Each	$2,368,000	$0	$1,795,000	$4,163,000	$7,800	$4,376,000

Table 5 (continued). Costs by Unit Action.

Action	Description	Action Unit	Total Direct Construction Cost	Property Acquisition	Total Indirect Non-Construction Costs	Total Project Cost	O&M Costs (Annual)	Net Present Value 30-year Life-Cycle Cost (2019)
Cistern	WQBE_16_Cistern on Property	1 each	$18,000	$0	$8,000	$26,000	$2,100	$70,000
Gray Stormwater Treatment								
Wet Pond	WQBE_18A_ Wet Pond on Public Property	553 SF	$383,000	$0	$300,000	$683,000	$2,000	$852,000
	WQBE_18B_ Wet Pond with Property Cost	553 SF	$383,000	$718,000	$1,198,000	$1,581,000	$2,000	$1,745,000
Wet Vault	WQBE_19A_ Wet Vault on Public Property	1 each	$2,852,000	$0	$2,203,000	$5,055,000	$2,900	$5,125,000
	WQBE_19B_ Wet Vault in ROW	1 each	$3,314,000	$0	$2,493,000	$5,806,000	$2,900	$5,874,000
	WQBE_19C_ Wet Vault with Property Cost	1 each	$2,852,000	$538,000	$2,876,000	$5,728,000	$2,900	$5,795,000
Stormwater Treatment Wetland	WQBE_20A_ Stormwater Treatment Wetland on Public Property	503 SF	$360,000	$0	$282,000	$642,000	$2,300	$817,000
	WQBE_20B_ Stormwater Treatment Wetland with Property Cost	503 SF	$360,000	$678,000	$1,130,000	$1,489,000	$2,300	$1,659,000
High Rate Underground Filter System	WQBE_21A_High Rate Underground Filter in Urban ROW PCCP	1 each	$120,000	$0	$75,000	$195,000	$2,900	$254,000
	WQBE_21B_High Rate Underground Filter in Highway ROW PCCP	1 each	$89,000	$0	$56,000	$145,000	$2,900	$204,000
	WQBE_21C_High Rate Underground Filter in Urban ROW HMA	1 each	$86,000	$0	$54,000	$140,000	$2,900	$199,000

Table 5 (continued). Costs by Unit Action.

Action	Description	Action Unit	Total Direct Construction Cost	Property Acquisition	Total Indirect Non-Construction Costs	Total Project Cost	O&M Costs (Annual)	Net Present Value 30-year Life-Cycle Cost (2019)
	WQBE_21D_High Rate Underground Filter in Highway ROW HMA	1 each	$79,000	$0	$50,000	$129,000	$2,900	$188,000
	WQBE 21E_High Rate Underground Filter on Public Property	1 each	$64,000	$0	$42,000	$106,000	$2,900	$165,000
	WQBE 21F_High Rate Underground Filter with Property Cost	1 each	$64,000	$900	$43,000	$107,000	$2,900	$166,000
Regional Vegetated Media	WQBE_22A_Regional Vegetated Media SW Facility on Public Property	5,940 SF	$2,965,000	$0	$3,073,000	$6,038,000	$12,000	$6,562,000
	WQBE_22B_Regional Vegetated Media SW Facility with Property Cost	5,940 SF	$2,965,000	$910,760	$4,259,000	$7,224,000	$12,000	$7,741,000

WQBE Program Terminology

Action: Individual structural and non-structural best management practices (BMPs) or activities to improve water quality (e.g., rain gardens, wet ponds, street sweeping).

Assessment point: Location where a management objective is evaluated during optimization.

Basin: Grouping of catchments and subbasins that represent the primary discharge points and spatial scale for the Tier 2 SUSTAIN optimization.

Basis of Estimate (BOE): Document that details the premise, or basis, from which critical aspects of a project cost estimate were developed including cost and labor estimates, material availability, any assumptions or deviations, any studies or analysis used as a reference, and any other details which impacted the cost estimates.

Catchment: Delineation of drainage areas for the Loading Simulation Program in C++ (LSPC) baseline pollutant loading model and serving as the scale of individual Tier 1 SUSTAIN cost-optimization.

Package: Point on a SUSTAIN cost-effectiveness curve that identifies a specific level of implementation of a Program (e.g., 200 unit rain gardens and 50 unit permeable pavement installations in specified subbasins that represent a cost-effective implementation of a green stormwater infrastructure [GSI] incentive program in the Lake Washington basin).

Programs will be evaluated with the SUSTAIN models by generating a Package of representative Actions optimized for stormwater volume or pollutant load reductions at an assessment point. Previously defined projects could also be incorporated into the SUSTAIN models and included in optimization evaluations as desired.

Program: Group of Unit Actions that could be implemented to improve water quality over a broad geographic area, such as a GSI incentive program in unincorporated areas within the Lake Washington basin or a roadway stormwater treatment program on County-owned roads within the Green/Duwamish basin.

Project: Individual Action or related group of Actions at a specific geographic location for which detailed, spatially explicit characteristics are defined (e.g., a rain garden installation on a specified property or within a small defined area).

Subbasin: Grouping of catchments for which SUSTAIN model output will be reported to inform causal model inputs.

Unit Action: Representative vertical profile, areal footprint, and associated design-drainage area for an Action being modeled in SUSTAIN. Cost-benefit optimization is used to determine the collective sizes and/or number of Unit Actions required to achieve a certain pollutant load reduction target. Each Unit Action has an associated cost that is scalable during optimization to estimate total implementation costs.

Unit: Representative footprint of an Action defined so as to be compatible with the SUSTAIN model.

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ATTACHMENT A

Cost Estimates and Life-Cycle Cost Analysis

ATTACHMENT B

Program Cost Benchmarking TM

ATTACHMENT C

Supplemental Analysis for the Program Cost Benchmarking TM

March 2022

ATTACHMENT D

Evaluation of WQBE Project Cost Sensitivity for SUSTAIN Modeling TM

March 2022