King County Reclaimed Water Comprehensive Plan

Benefit-Cost Analysis of Reclaimed Water Strategies

WORKING DRAFT

March 2012

King County

Department of
Natural Resources and Parks
Wastewater Treatment Division

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King County Wastewater Treatment Division
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EXECUTIVE SUMMARY

This report was prepared to support the development of a Reclaimed Water Comprehensive Plan for King County's Wastewater Treatment Division (WTD). The purpose of the Reclaimed Water Comprehensive Plan is to determine if, how, when, where, and by what funding mechanisms the County's existing reclaimed water program should expand over the next 30 years, through 2040 and beyond.

The work documented in this report was conducted as part of Step 4 of the reclaimed water planning process as amended and approved by the King County Council in May 2011.This report addresses the economic issues related to the three reclaimed water strategies that were developed and approved earlier, during Step 3, and incorporates findings from a number of other reports on the potential economic effects of the strategies on specific environments . The engineering analysis and definition of the three strategies, also completed as part of Step 4, appears in a separate report.[1]

The three reclaimed water strategies were developed for planning and evaluation purposes only and are not intended to necessarily represent any future reclaimed water improvement projects or any implied preference or commitment on the part of any interested parties or potential end users.

Each strategy approved and developed represents a concept for producing and distributing reclaimed water to serve potential uses identified during the reclaimed water planning process. The uses include both nonpotable consumptive uses (irrigation, commercial, industrial) and environmental enhancement uses (wetland enhancement and associated indirect groundwater recharge and/or streamflow augmentation). The following are brief descriptions of the strategies:

- **Redmond/Bear Creek Basin Brightwater Centralized Strategy.** Reclaimed water would be produced through the membrane bioreactor (MBR) process at the Brightwater Treatment Plant for distribution to two areas—one in the immediate vicinity of the plant and one farther south above Lake Sammamish—via new pipelines connected to the South Segment of the Brightwater reclaimed water pipeline.
- **Renton/Tukwila South Plant Centralized Strategy**. Reclaimed water would be produced through expansion of the South Treatment Plant's tertiary sand filtration system for distribution to an area just south of Lake Washington via extension of an existing pipeline that delivers reclaimed water to the City of Tukwila.
- **Reclaimed Water Skimming or Polishing Decentralized Strategy.**[2] This strategy represents opportunities for smaller scale reclaimed water implementation. Infrastructure was constrained to a single treatment plant of up to 0.5 mgd capacity and up to 1 mile of

[1] More information on the reclaimed water comprehensive planning process is available at http://www.kingcounty.gov/environment/wastewater/RWCompPlan.aspx. More information on prior reclaimed water strategy development and identification is available at http://your.kingcounty.gov/dnrp/library/wastewater/rw/CompPlan/1012_RWCPStrategyReport.pdf. Additional reports are available at http://www.kingcounty.gov/environment/wastewater/RWCompPlan/Library.aspx#4.

[2] A skimming plant removes some of the raw wastewater from pipelines that carry the wastewater to regional plants for treatment and then treats the wastewater to reclaimed water quality for local distribution. A polishing plant removes some secondary-treated effluent from pipelines exiting regional treatment plants and treats the effluent to reclaimed water quality standards.

reclaimed water pipeline. Three potential areas and configurations were identified to help define the decentralized strategy:

- An MBR skimming plant located in the Interbay area of Seattle would produce reclaimed water from untreated wastewater in adjacent conveyance pipelines for distribution near the plant via a new pipeline.
- A sand filtration polishing plant located in Seattle on the west side of the Duwamish River would produce reclaimed water from flows in the Effluent Transfer System (ETS) pipeline that carries South plant secondary effluent for discharge at Alki Point in West Seattle. The reclaimed water would be distributed to nearby uses via a new pipeline.
- An MBR skimming plant located in the lower Green River Valley in south King County would produce reclaimed water from untreated wastewater in adjacent conveyance pipelines for distribution near the plant via a new pipeline.

This benefit-cost analysis, using a framework developed by the WaterReuse Foundation (Raucher et al. 2006), considers benefits and costs from the perspective of society as a whole, looking at how each strategy would affect the value of water-related goods and services available to the households and businesses of King County rather than how it would affect the revenues of WTD and water utilities. In many instances, insufficient data are available to quantify benefits and costs in monetary, or even physical, terms. The report provides qualitative discussions of these benefits and costs.

The analysis produces a range of estimates for the present value of the quantified benefits and quantified costs for each strategy, and a qualitative assessment (0, 1, or 2) of those that cannot be quantified given current information. When a strategy is likely to have no effect on a potential benefit or cost, a qualitative value of 0 is assigned. Effects that are of low likelihood, magnitude, and/or importance are assigned a 1, and effects of high likelihood, magnitude and/or importance are assigned a 2.

Table 1 summarizes the overall results. The top of the table compares the high and low estimates of the quantifiable benefits with the high and low estimates of the quantified costs. The bottom of the table summarizes the qualitative assessments of each strategy's benefits and costs for which there currently is insufficient information to support quantification.

At the top of the table, the first line shows the net present value for each strategy measuring the benefits at the top of the range of estimates and the costs at the bottom. With this assumption, each strategy, except Interbay and Lower Green River Valley (LGRV), has a positive net present value. The second line, in contrast, reverses the assumption and calculates net present value measuring benefits at the bottom of the range and costs at the top. With this assumption, each strategy has a negative net present value.

In general, the strategies with higher production of reclaimed water have higher quantified costs and benefits, as well as higher qualitatively-described benefits. The Brightwater Strategy, followed by the South Plant strategy, has the highest potential net quantified benefits (high quantified benefits minus low quantified costs), and the greatest potential net quantified costs (low quantified benefits minus high quantified costs). The analogous numbers for the decentralized strategies show the Duwamish has the highest potential net quantified benefits.

Interbay has the highest potential net quantified costs. LGRV has the lowest potential net quantified benefits.

Table 1. Benefit-Cost Analysis Results

	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	Net Present Value of Quantified Benefits and Costs				
Higher Benefits to Lower Costs	$390,000,000	$44,000,000	$(7,000,000)	$9,300,000	$(15,000,000)
Lower Benefits to Higher Costs	$(190,000,000)	$(95,000,000)	$(31,000,000)	$(9,300,000)	$(28,000,000)
	Count of Benefits Described Qualitatively				
Score of 2	9	3	0	0	0
Score of 1	10	13	11	9	11
Insufficient Information	0	0	0	0	0
	Count of Costs Described Qualitatively				
Score of 2	0	0	0	0	0
Score of 1	2	1	1	0	0
Insufficient Information	3	3	3	3	3

The results of the benefit-cost analysis suggest that the strategies have potential to yield benefits that exceed the costs. Uncertainty regarding the details of the strategies and their economic effects, however, precludes a definitive determination. The uncertainty has several dimensions. Past studies provide a range, sometimes a wide range, of estimates for the per-unit value of specific costs and benefits. Each of the strategies has been defined only in general terms, obscuring how many units of each type of benefit it will produce and where its benefits will fall in each range of per-unit value. Mechanisms have yet to be developed for securing funding from different groups of beneficiaries to cover the costs of each strategy.

1.0. INTRODUCTION

This report was prepared to support the development of a Reclaimed Water Comprehensive Plan for King County's Wastewater Treatment Division (WTD). The purpose of the Reclaimed Water Comprehensive Plan is to determine if, how, when, where, and by what funding mechanisms the County's existing reclaimed water program should expand over the next 30 years, through 2040 and beyond.

WTD' existing reclaimed water program consists of facilities at the Brightwater, South, West Point, and Carnation Treatment Plants. The Brightwater reclaimed water system has the capacity to distribute up to 7 million gallons per day (mgd) of reclaimed water from the treatment facility to areas along the distribution pipe from Brightwater south into the City of Bothell and in the Sammamish Valley. South Treatment Plant has the capacity to produce 1.3 mgd of reclaimed water for use at the treatment plant and distribution north for uses in the City of Tukwila. West Point Treatment Plant has the capacity to produce up to 0.5 mgd for use at the treatment plant site. The Carnation Treatment Plant sends all reclaimed water from the treatment facility to the wetlands at the Chinook Bend Natural Area in accordance with the County's commitment to use the wetlands as its primary discharge location rather than the Snoqualmie River.

The work documented in this report was conducted as part of Step 4 of the reclaimed water planning process as amended and approved by the King County Council in May 2011. The report addresses the economic issues related to the three reclaimed water strategies that were developed and approved earlier, during Step 3, and incorporates findings from a number of other reports on the potential economic effects of the strategies on specific environments.[3] The definition the three strategies, also completed as part of Step 4, is documented in the technical memorandum *Engineering Analysis and Definition of Reclaimed Water Strategies* (King County 2012a).

Throughout the development, definition, and analysis of the strategies, WTD applied County Council–approved evaluation criteria to assess how each strategy addresses the three drivers for the Reclaimed Water Comprehensive Plan—regional wastewater system planning, creating resources from wastewater, and protecting Puget Sound water quality.[4]

The strategies were developed for planning and evaluation purposes only and are not intended to necessarily represent any future reclaimed water improvement projects or any implied preference or commitment on the part of any interested parties or potential end users.

This introduction briefly describes the strategies and then outlines the objectives both of the effort to refine the strategies and of the benefit-cost analysis. Succeeding chapters present the approach used in the benefit-cost analysis, the baseline scenario for current and future conditions should WTD pursue none of the reclaimed water strategies, detailed descriptions of the benefits and costs associated with the reclaimed water strategies, and the results of the benefit-cost analysis for the strategies.

[3] More information on the reclaimed water comprehensive planning process is available at http://www.kingcounty.gov/environment/wastewater/RWCompPlan.aspx. More information on prior reclaimed water strategy development and identification is available at http://your.kingcounty.gov/dnrp/library/wastewater/rw/CompPlan/1012_RWCPStrategyReport.pdf. Additional reports are available at http://www.kingcounty.gov/environment/wastewater/RWCompPlan/Library.aspx#4.

[4] Information on the drivers can be found in the plan purpose and need statement at http://your.kingcounty.gov/dnrp/library/wastewater/rw/CompPlan/0907_PurposeNeedStatement_UpdateJune2010.pdf.

1.1 Description and Location of Strategies

Each strategy approved and developed represents a concept for producing and supplying reclaimed water to serve potential uses identified during the reclaimed water planning process. The uses include both nonpotable consumptive uses (irrigation, commercial, industrial) and environmental enhancement uses (wetland enhancement and associated indirect groundwater recharge and/or streamflow augmentation). The following are brief descriptions of the strategies:

- **Redmond/Bear Creek Basin Brightwater Centralized Strategy.** Reclaimed water would be produced through the membrane bioreactor (MBR) process at the Brightwater Treatment Plant for distribution to two areas—one in the immediate vicinity of the plant and one farther south above Lake Sammamish—via new pipelines connected to the South Segment of the Brightwater reclaimed water pipeline.
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- **Reclaimed Water Skimming or Polishing Decentralized Strategy.**[5] This strategy represents opportunities for smaller scale reclaimed water implementation. Infrastructure was constrained to a single treatment plant of up to 0.5 mgd capacity and up to 1 mile of reclaimed water pipeline. Three potential areas and configurations were identified to help define the decentralized strategy:
    - An MBR skimming plant located in the Interbay area of Seattle would produce reclaimed water from untreated wastewater in adjacent conveyance pipelines for distribution near the plant via a new pipeline.
    - A sand filtration polishing plant located in Seattle on the west side of the Duwamish River would produce reclaimed water from flows in the Effluent Transfer System (ETS) pipeline that carries South plant secondary effluent for discharge at Alki Point in West Seattle. The reclaimed water would be distributed to nearby uses via a new pipeline.
    - An MBR skimming plant located in the lower Green River Valley in south King County would produce reclaimed water from untreated wastewater in adjacent conveyance pipelines for distribution near the plant via a new pipeline.

The locations of the strategies are shown in Figure 1.

1.2 Objectives of This Benefit-Cost Analysis

This benefit-cost analysis uses a framework developed by the WaterReuse Foundation (Raucher et al. 2006), adapted to the circumstances of King County. It considers benefits and costs from the perspective of society as a whole, looking at how each strategy would affect the value of

[5] A skimming plant removes some of the raw wastewater from pipelines that carry the wastewater to regional plants for treatment and then treats the wastewater to reclaimed water quality for local distribution. A polishing plant removes some secondary-treated effluent from pipelines exiting regional treatment plants and treats the effluent to reclaimed water quality standards.

water-related goods and services available to the households and businesses of King County rather than how it would affect the revenues of WTD and water utilities. This is not to say that these potential financial impacts are not important from the perspective of each entity, only that these separate perspectives are not the subject of this report.

The information presented serves as a basis for addressing these questions:

- What are the benefits and costs of each reclaimed water strategy relative to a baseline (no-action or without-project) scenario, accounting for both those that are quantifiable and those that can be described in qualitative terms only?
- What is the difference between the value of the benefits (direct and indirect) and the value of the costs (direct and indirect) for each reclaimed water strategy, over the 30-year planning horizon for the project?
- How do the net economic benefits (the benefits minus the costs, which could be positive or negative) of the three reclaimed water strategies compare to each other?
- What key benefits and costs influence the results of the benefit-cost analysis and how does their uncertainty affect the findings of the benefit-cost analysis?

In addressing these questions, this report provides information to satisfy several steps of the economic analysis portion of the reclaimed water planning process, as outlined in the technical memorandum *Identification of Potential Economic Benefits of Production and Use of Reclaimed Water* (King County 2009a):

- Establish a baseline to define the outcomes associated with the “no action” alternative.
- Assign and estimate values for benefits and costs to comprehensive plan reclaimed water strategies.
- Conduct a benefit-cost analysis.

This report does not address two other steps of the economic analysis identified in the 2009 memorandum on benefits:

- Identify alternatives to reclaimed water that may achieve similar benefits.
- Conduct sensitivity analysis.

An evaluation of the technical feasibility, benefits, and costs of alternatives to reclaimed water could occur prior to making project-specific recommendations about expanding any portion of the existing regional reclaimed water system. If determined necessary, a sensitivity analysis could be conducted on key variables of the benefit and cost estimates described in this report to explore the impact of assumptions, uncertainty, and variability.

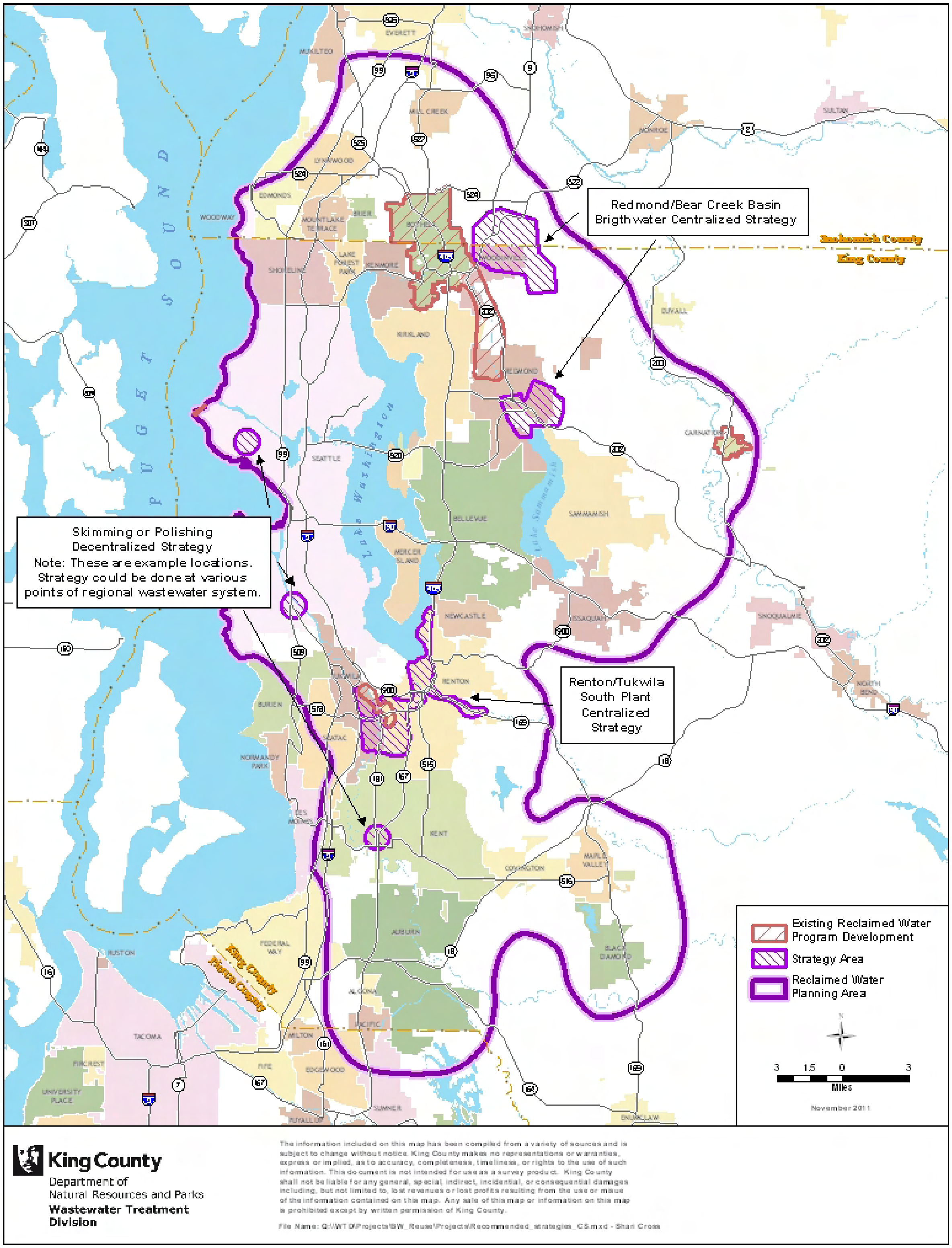

Figure 1. Reclaimed Water Strategies Recommended for Analysis

2.0. APPROACH FOR THE BENEFIT-COST ANALYSIS

The primary objective of this technical memorandum is to describe the benefits and costs of each reclaimed water strategy relative to a baseline scenario in which the County pursues none of the strategies. The analysis uses a framework developed by the WateReuse Foundation (Raucher et al. 2006) to synthesize available information regarding the potential economic benefits and costs that are likely to arise from the three reclaimed water strategies.

Two technical memoranda prepared in 2009 for King County's Reclaimed Water Comprehensive Plan summarized a list of potential economic benefits and costs that could arise from the production and use of reclaimed water, *Identification of Potential Benefits of Production and Use of Reclaimed Water* (King County 2009a) and *Identification of Potential Costs of Production and Use of Reclaimed Water* (King County 2009b). The availability of more specific data describing the design parameters of each of the potential reclaimed water strategies and their potential effects on natural and human-built capital (see King County 2012a-f) now supports description of some of the specific benefits and costs likely to arise from each strategy.

This analysis considers benefits and costs from the perspective of society as a whole. To that end, it determines the benefits and costs looking at how each strategy would affect the value of water-related goods and services available to the households and businesses of King County rather than at how the strategies would affect the revenues of WTD and water utilities. Payments and revenues are certainly relevant from the perspective of individual entities, but they cannot easily be included in a benefit-cost analysis because the cost from the perspective of the payer is negated by the benefit from the perspective of the payee. This is not to say that these potential financial impacts are not important, only that they are not the subject of this report. Future analyses could assess the benefits and costs of the reclaimed water strategies from individual stakeholder perspectives.

This chapter outlines the approach to quantifying benefits and costs and to describing benefits and costs qualitatively when data are insufficient to quantify. It also describes the time period for the analysis and the discount rate used to compare benefits and costs that accrue at different times.

2.1 Approach to Describing Benefits and Costs

To identify the benefits and costs associated with the three reclaimed water strategies, this analysis draws on prior research. This research includes several technical memoranda that describe the expected biophysical effects of the reclaimed water strategies on the region as well as documents that define the potential benefits and costs of reclaimed water programs in general terms. Specifically, this analysis draws on the technical memoranda that describe the biophysical effects of each strategy on the region's built environment: lakes, rivers and streams; wetlands; Puget Sound; and WTD's existing and planned treatment and conveyance systems (King County 2012b-f). The effects identified in these memoranda were screened to determine which represent specific benefits and which represent specific costs, from the perspective of society as a whole. This analysis also draws on the 2009 King County technical memoranda on benefits and costs, which defined the potential benefits and costs of a generic reclaimed water program and identified potential unit values, as well as beneficiaries and cost bearers, given a general set of assumptions for a generic reclaimed water program. Since the release of the 2009 memoranda, several reports have been released focusing on reclaimed water, including a report from the National Resource Council on water reuse (National Research Council 2012). To the extent relevant, their findings also inform this report. Finally, this analysis incorporates the capital and operation/maintenance costs associated with each reclaimed water strategy that are reported in the technical memorandum *Engineering Analysis and Definition of Reclaimed Water Strategies* (King County 2012a)

Using the more up-to-date and strategy-specific information, the values in the 2009 King County memoranda were updated and adjusted to reflect the most accurate estimates available. These estimates are used to assign values to the quantifiable benefits and costs arising from each of the three strategies. As appropriate, values derived for benefits are consistent with the benefit-transfer methodology described in Raucher et al. (2006, p. 34) and the 2009 technical memorandum on benefits.

This analysis presents quantified benefits and costs as ranges. This approach explicitly recognizes the uncertainty regarding both the biophysical or engineering estimate of how much of a particular benefit may materialize (the quantity) and the price people may be willing to pay to secure the benefit. Similar uncertainty surrounds the cost estimates. Where possible, this report identifies the sources of uncertainty and explains how they would affect the actual benefits and costs if a strategy were implemented.

In many instances, insufficient data are available to quantify benefits or costs in monetary or even physical terms. The report provides qualitative discussions of these benefits and costs to offer decision-makers information about their potential likelihood, magnitude, and relative importance. For some economic effects, quantification could become possible were each strategy more thoroughly fleshed out and were additional scientific studies to become available on how Puget Sound’s natural and human systems interact with and respond to changes in the short and long run. Also, as individuals and organizations become more aware of ecosystem services, and as markets to provide these services continue to develop, information about the value of some benefits, and local willingness to pay them, could become available to estimate currently unquantifiable benefits. For other benefits and costs, uncertainty may always be too great to meaningfully quantify them. In any case, the benefits and costs that cannot be quantified with existing information are not necessarily less important than those that are quantified. The absence of sufficient information to determine monetary value does not mean the value is zero. Decision makers should consider the evidence of both unquantifiable and quantified benefits and costs to weigh their relative importance.

The approach to estimating the relative importance of unquantifiable benefits and costs used in this analysis follows Raucher et al. (2006, p. 31), assessing whether there is likely to be no effect for a particular strategy (0 value) or a positive or adverse effect. **For positive and adverse effects, a relative value of 1 or 2 is provided. Effects that are of low likelihood, magnitude, and/or importance are assigned a 1, and effects of high likelihood, magnitude and/or importance are assigned a 2.**

2.2 Approach to Comparing Benefits and Costs

For each reclaimed water strategy, the report presents the benefits and the costs (both those which are quantified and those described qualitatively) relative to the baseline scenario. To compare the benefits to the costs within each strategy and to compare benefits and costs across strategies, a single value, called the net present value, is calculated for the benefits and costs associated with each strategy. This calculation reflects two assumptions: (1) a uniform time period over which all relevant benefits and costs accrue, and (2) a discount rate, to adjust values occurring at different times to a single, common point in time. The underlying assumptions for both are described below. The present value of the quantified benefits and costs are compared by subtracting the present value of the costs from the present value of the benefits.

The net present value reflects the quantified benefits and costs, but does not capture the unquantifiable, yet important, benefits and costs. For this reason, **the net present value of the quantifiable benefits and costs always constitutes only one part, not the complete representation of each strategy's benefits and costs.**

2.2.1 Time Horizon

Project-specific conditions dictate the appropriate time horizon for conducting a benefit-cost analysis. No single time period fits all circumstances. Federal and professional guidance for conducting benefit-cost analyses, including guidance from the Office of Management and Budget (OMB), suggests tailoring the time frame to capture all important benefits and costs likely to arise from a project or regulatory action (OMB 2003). In its *Guidelines for Preparing Economic Analyses*, the U.S. Environmental Protection Agency (EPA) recommends that the time horizon of an analysis coincide with the time span of the physical effects that arise from a project or action (EPA 2010). Moreover, EPA emphasizes that the "time horizon should be long enough that the net benefits for all future years (beyond the time horizon) are expected to be negligible when discounted to the present" (EPA 2010, pp. 6-5). For projects with ecological effects, longer time horizons may be required to satisfy this condition. The U.S. Army Corp of Engineers' (USACE) recommendations coincide with those of the OMB and the EPA but add that "appropriate consideration should be given to environmental factors that may extend beyond the period of analysis" (U.S. Water Resources Council 1983).

The County's planning horizon for its Reclaimed Water Comprehensive Plan is 30 years. Although each strategy's exact timeline remains unknown, the analysis assumes that production of reclaimed water would not begin immediately. The analysis includes an eight-year capital planning period from 2012 to 2019, with expenditures occurring from 2014 to 2019, and assumes the County would begin producing reclaimed water for sale or distribution in 2020. It then accounts for the benefits and costs that would accrue over the next 30 years, from 2020 to 2050. Consistent with EPA and USACE guidance, the analysis identifies when a benefit or cost is expected to continue to accrue beyond the 30-year period, and describes the implications for the results of the analysis.

2.2.2 Discount Rate

Discounting is used in economics to account for time preferences, that is, the preference for benefits or money earlier rather than later. Part of this preference is due to the opportunity cost of committing money and other resources to a strategy to generate benefits in the future and losing the opportunity for interest and other means of growing resources and benefits over time. While not ideal, discounting is often also used as a means to account for risk and uncertainty in future effects. Implementing a discount factor entails reducing values that would materialize in the future by a percentage over time to standardize those occurring at different times to their equivalent, present value. The WateReuse framework (Raucher et al. 2006, p. 40) does not recommend a specific discount rate for benefit-cost analyses, but suggests why it may be appropriate to select among several discount rates, ranging from 3 percent to 7 percent per year (in real terms, not accounting for additional inflation). The lower end of this range represents the social rate of time preference—the rate at which society is generally willing to postpone consumption today for consumption in the future—while the upper end reflects the historical long-run marginal pretax rate of return on an average investment in the private sector, which would include risk. OMB currently mandates that federal agencies apply a real discount rate of 2.3 percent per year to evaluate the benefits and costs of federal programs. This rate is lower than in past years, reflecting current economic conditions.

The analysis presented in this report uses a discount rate of 3 percent per year. This rate reflects both the social rate of time preference and current economic conditions. Different rates could be applied in a future sensitivity analysis of the report’s findings. The analysis uses the discount rate to standardize all costs and benefits to 2011 dollars. Consequently, costs and benefits occurring in the future are weighted less than equivalent costs and benefits occurring soon. While various financing mechanisms could allow manipulation of the timing of certain financial effects, this analysis focuses on the timing that reflects the actual commitment (costs) or realization (benefits) of resources, goods, or services.

3.0. THE BASELINE SCENARIO

The baseline scenario identifies future conditions likely to materialize if none of the strategies were implemented, providing an important reference point for determining the benefits and costs of the three proposed reclaimed water strategies. Differences between conditions expected in the baseline scenario and those expected with implementation of a strategy provide the basis for determining each strategy's benefits and costs.

The baseline scenario incorporates assumptions about King County's regional wastewater treatment system and reclaimed water program; water quality in Puget Sound; the status of water resources in the county's rivers, streams, wetlands, and aquifers; and other factors that influence the potential demand for and costs of providing reclaimed water. It also includes the assumptions applied to specific areas that would receive reclaimed water, to clearly define conditions without reclaimed water and thus the benefits and costs that arise from using reclaimed water.

3.1 King County's Regional Wastewater Treatment System and Existing Reclaimed Water Program

The baseline scenario assumes that the regional wastewater treatment system and existing reclaimed water program will operate within the expectations established in King County's *Regional Wastewater Services Plan* (RWSP) and derivative documents, such as annual reports and budget forecasts,[6] but without the anticipated investments associated with the three reclaimed water strategies. The RWSP outlines the following through 2030:

- Current treatment requirements at treatment plants.
- Current and forecasted future wastewater flows.
- Infrastructure and costs associated with the existing reclaimed water program.
- Infrastructure and costs associated with planned conveyance system improvements.
- Infrastructure and costs associated with combined sewer overflow control improvements.

The County assumes that additional investments, as yet undetermined, likely will need to be made after 2030 to maintain the regional wastewater system.

3.2 Puget Sound Water Quality

The baseline scenario assumes that water quality in Puget Sound will exhibit characteristics expected in current plans. The baseline scenario, therefore, makes the following assumptions:

- No changes are anticipated in requirements of discharge/loadings to Puget Sound. If requirements change in the future, benefits and costs associated with each of the strategies could be higher or lower than those estimated in this report. Changes in requirements are established in Washington state law and are written into NPDES permits.

[6] The *Regional Wastewater Services Plan* and related documents are available at http://www.kingcounty.gov/environment/wtd/Construction/planning/rwsp.aspx.

- Other sources will deliver nutrient loadings to Puget Sound as documented in the Department of Ecology's *South Puget Sound Dissolved Oxygen Study* (Washington State Department of Ecology 2011).[7]

3.3 Water Resources in the Planning Area

The baseline scenario assumes future conditions of King County's rivers, streams, wetlands, and aquifers will reflect a continuation of current conditions.

The technical memorandum *Reclaimed Water Strategy Effects on Lakes, Rivers, and Streams* documents the current conditions of the water bodies that reclaimed water strategies would affect, including the Bear-Evans watershed, the Sammamish River Basin, and the Cedar River (King County 2012c), as described below.

- The Bear-Evans Creek Basin suffers from low summer base flows, elevated summer water temperatures, and low dissolved oxygen. These conditions impair portions of Bear-Evans Creek's ability to support aquatic life, including salmonids and cold-water mussels. Analysis by King County indicates a declining trend in summer low flow at the mouth of Bear Creek (King County 2001). Summer temperatures in Bear Creek are expected to increase in the near future due to climate change.
- Cottage Lake, in the Bear-Evans Creek Basin, is threatened by eutrophication caused by excessive phosphorus input and increased algal growth, which impairs the lake's beneficial uses. A Total Maximum Daily Load (TMDL) for point and non-point sources of phosphorus is established.
- Sammamish River suffers from low dissolved oxygen, higher summer temperatures, and elevated fecal coliform concentrations. These factors impair the river's aquatic life, including threatened salmonids, and its contact recreational use. TMDLs need to be established. Summer temperatures in the Sammamish River are expected to increase further in the near future due to climate change.
- The Cedar River's flows are moderated by release of water stored by Seattle Public Utilities (SPU). Although SPU is required to maintain minimum flow levels in the river during the summer, instream flows during summer months are still limited. The number of days that the Cedar River does not meet minimum instream flow targets is expected to increase in the future. Summer temperatures in the Cedar River are expected to increase in the near future due to climate change.
- The Cedar River discharges to Lake Washington, which has long suffered from diminished water quality resulting from discharges of treated wastewater. Although the lake has experienced improvements since direct wastewater discharges ceased in the late 1960s, improving its water quality has remained a regional priority. The lake is sensitive to phosphorous loading and the maintenance of current water-quality levels assumes that phosphorous loading stays at or below current levels (Tetra Tech ISG, Inc. and Parametric, Inc. 2003).

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[7] The Department of Ecology report presents three major sources of nutrient loadings into Puget Sound: watershed loads from rivers and streams whose watersheds drain into the area; septic system loads from near-shore, on-site septic systems; and wastewater treatment plant loads from these plants and other industrial sources that discharge effluent directly into marine waters.

The technical memorandum *Reclaimed Water Strategy Effects on Wetlands* documents the current conditions of existing wetlands and areas potentially suitable for wetlands within the reclaimed water service area (King County 2012d). The memorandum found:

- Wetlands exist throughout the study area. Wetlands that interact with the Sammamish River, while providing some services, have enhancement potential.
- Wetlands do not currently exist in the vicinity of the Cedar River application site, but enhancement of existing conditions could result in wetland creation.
- Wetlands in the vicinity of Crystal and Cottage Lakes (about 130 acres and 129 acres, respectively) are of high quality and likely would not be enhanced through application of reclaimed water. These wetlands are already prone to flooding in the winter.

Current conditions of other water resources in the planning area are documented in preliminary assessment documents developed as part of the reclaimed water strategy development (King County 2010a-c). The papers document that summer flows are lower in some basins in the planning area. Future characteristics of water resources over the 30-year planning horizon are expected to remain the same as current conditions, which implies that, in many of the region's water bodies, summer base flows are expected to continue to decline. Efforts to restore stream flows in the region, driven by flow restoration programs to promote salmon recovery, may be developed and implemented for some water bodies during the time horizon of this analysis (Shared Strategy Development Committee 2007). Insufficient information exists to explicitly incorporate the results of these efforts into the baseline scenario.

3.4 Other Baseline Factors that Influence the Market for Reclaimed Water

The baseline scenario incorporates current expectations for several background variables that may affect future market conditions for reclaimed water:

- Population and employment growth are expected to follow trends described by the Puget Sound Regional Council and incorporated into its Vision 2040 plan (Puget Sound Regional Council 2009).
- Current potable and non-potable consumptive water demand and supply are expected to follow trends described in the 2001 and 2009 Central Puget Sound Water Supply Outlooks (Central Puget Sound Water Suppliers' Forum 2001 and Water Supply Forum 2009).

Other factors may affect the market for reclaimed water, positively or negatively, but their trends have not been well described or are far less certain:

- Climate change, which may affect future water supply and irrigation demand.
- Changes in capital and operating costs for alternative supplies of water.
- Potential demand for non-potable consumptive and environmental enhancement uses of reclaimed water, including water for mitigation purposes.

Sufficient data do not exist to properly incorporate the full extent of the potential uncertainty that changes in these variables and their trends would generate. Some have suggested, for example, that conservation efforts may reduce demand below trends projected in the Central Puget Sound

Water Supply Outlooks (Central Puget Sound Water Initiative 2002). Modeling efforts produce mixed signals regarding the expected future precipitation patterns under climate change scenarios in western Washington, although some point to minimal changes or increases in precipitation (Mote and Salathe 2010). The uncertainty that surrounds many of the factors that form the baseline scenario and influence the market for reclaimed water in the Puget Sound region contributes to the inability to quantify some of the costs and benefits of the strategies.

3.5 Other Analytical Assumptions

This benefit-cost analysis makes several other clarifying assumptions, which could be refined should more specific information become available.

- For all strategies except the Lower Green River Valley Decentralized Strategy, all irrigation (both agricultural and non-agricultural) and commercial/industrial sources of demand for reclaimed water currently use potable water from a utility to satisfy demand for water.
- Land that would be converted to new wetlands currently resides in floodplains, or is otherwise of no value for development or uses other than natural area.
- Efficient delivery systems allow full use of water made available, without leakage or other non-beneficial loss.
- The real values of quantified costs and benefits will not change significantly over the planning horizon, except as noted in Chapter 4.0.
- Water scarcity and environmental quality will not deviate substantially from existing conditions and trends over the planning horizon. The potential effects should this assumption fail are considered in the discussions of the uncertainty of various benefits in Chapter 4.0.

4.0. DESCRIPTION OF BENEFITS AND COSTS

This chapter describes the benefits and costs that may arise from the three reclaimed water strategies. While each strategy may not yield every benefit or generate every cost, and while the level of both can vary by strategy, considerable commonality exists across strategies. For each benefit or cost, this chapter describes the pathway by which it would occur, identifies the strategy or strategies from which it would arise, lists the groups or entities potentially benefiting or incurring costs, and describes the sources of uncertainty and potential sensitivity or variability that might influence the benefit or cost now and in the future. For quantified benefits, the annual quantity and unit value is provided, with a description of the source of the value. For benefits and costs described qualitatively, available information about their importance is summarized.

The value of each benefit and cost is neither absolute nor immutable but depends on the level of demand for and supply of the goods and services that reclaimed water would provide, as well as on the demand for and supply of complementary and substitute goods and services. For this reason, the descriptions identify potential beneficiaries (sources of demand) as well as potential sensitivities in the conditions that may influence the demand for and supply of reclaimed water and complementary and substitute goods and services.

This chapter concludes with a description of other efforts in the region likely to produce complementary and substitute goods and services, which indicate that the region is willing to pay for many of the benefits reclaimed water would produce.

4.1 Benefits

In keeping with the framework developed by the WateReuse Foundation (Raucher et al. 2006) and the structure of the 2009 King County memorandum *Identification of Potential Benefits of Production and Use of Reclaimed Water*, this report categorizes benefits as either direct or indirect. Direct benefits are those realized by the users of reclaimed water or by ratepayers of utilities who experience cost savings resulting from the reclaimed water program. Indirect benefits are those that have environmental, recreational, human health, and economic and social effects. Indirect benefits arise from effects that occur as reclaimed water is produced and consumed instead of other sources of water, leading to changes in the environment and consumer behavior. Indirect environmental benefits also occur as reclaimed water is applied directly to enhance environmental flows, leading to ecological improvements and changes in the quantity or quality of goods and services available to society. Among the benefits likely to emerge from the three reclaimed water strategies, sufficient information is available to quantify only a few in monetary terms.

For each category, if applicable, this section presents tables listing detailed information about the direct and indirect quantified benefits as well as the direct and indirect benefits that are described qualitatively. Also for each category, if applicable, this section notes any benefits listed in the 2009 memorandum that are not included in this analysis, either because they are not expected to arise from any of the strategies, or because they are accounted for by other benefits that are included in the analysis.

4.1.1 Direct Benefits

Below, Table 2 presents quantified direct benefits and Table 3 presents direct benefits that are described qualitatively. The numbers associated with each benefit, such as 3.D.3, come from the 2009 King County technical memorandum on benefits.

The following direct benefits were identified in 2009 but not included in this analysis:

3.D.1 Savings from using reclaimed water to avoid costs of wastewater treatment and conveyance. No benefit in this category is expected to result from any of the strategies.

3D.2 Reclaimed Water Sales Revenues. It is not appropriate to include revenues from water sales as quantified benefits in a benefit-cost analysis that is conducted from the perspective of society as a whole, because doing so would double-count benefits and costs already included in the analysis.

3.D.4 Energy savings from avoided pumping costs for importing water. No benefit in this category is expected to result from any of the strategies.

Table 2. Quantified Direct Benefits

3.D.3 Avoided increases in groundwater pumping costs					
Description	Reclaimed water may be used to recharge aquifers, raising the water table and reducing pumping costs. Pumping costs also can be avoided by substituting reclaimed water for nonpotable water supplies obtained from groundwater. For this benefit, the analysis assumes that 50 percent of all non-wetland-related reclaimed water would replace water that otherwise could be pumped from groundwater sources under the Brightwater Centralized Strategy, the South Plant Centralized Strategy, and the Lower Green River Valley Decentralized Strategy.				
Key Beneficiaries	Water utility using groundwater Self-supplied users of groundwater				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X			X
Annual Quantity (MG)	152.09	117.14			70.27
Unit Value ($/kWh)	$0.06 to $0.10 This value is based on the current (effective April 1, 2011) average electricity rate for large and small demand general service in the reclaimed water planning area. Rates range from $0.06 to $0.10 based on the timing and quantity of use (Puget Sound Energy 2011).				
Uncertainty & Sensitivity	It is unclear precisely which groundwater supplies would not be used because of each strategy. Therefore, the source and pumping depths and distances must be generalized. Sensitivity analyses can address these energy demands as well as energy costs.				

3.D.5 Increased supply reliability					
Description	By replacing potable water consumption that otherwise would occur, reclaimed water would free up a portion of the region's potable water supply for other uses. This additional potable water could be used as insurance against water-use reductions arising from droughts and other supply interruptions, increasing water-supply reliability for potable-water customers. Based on recent experience in the region, the likelihood of water shortages occurring in any given year, using the definition of "drought conditions" set by the State of Washington (WAC 173-166-300), is 20 percent. The magnitude of the use reductions associated with these drought conditions is assumed to be 30 percent under baseline conditions. The degree to which reclaimed water strategies might improve the reliability of potable water supplies would depend on how the displaced potable water supplies resulting from each strategy would be distributed to households subjected to water-use restrictions in King County. Spread evenly across all households currently receiving potable water from Seattle Public Utilities, the amount of displaced water would reduce water-use reductions by less than 1 percent; concentrated among a subset of households in King County, it could eliminate water-use reductions.				
Key Beneficiaries	Customers of water utility Customers of reclaimed water wholesaler				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Annual Quantity (# of Households)	15,096–552,462	11,627–552,462	1,367–552,462	2,157–552,462	N/A
Unit Value ($ per household per year)	$2.05–$275	$1.58–$275	$0.19–$275	$0.29–$275	Unquantifiable given available information
	These values represent the amount water customers are willing to pay to reduce or eliminate future shortages, based on studies of customers' willingness to pay to avoid different magnitudes and frequencies of water shortages. The lower value for each strategy represents a household's marginal willingness to pay for a slight easing (less than 1 percent) in a 30-percent reduction in water use expected to occur with a 10-percent annual occurrence rate (Barakat & Chamberlin, Inc. 1994). This small value is applied across all households receiving water from Seattle Public Utilities in King County. The higher value represents a household's willingness to pay to avoid entirely a 30-percent reduction in water use with a 10-percent annual occurrence rate (Barakat & Chamberlin, Inc. 1994). This larger value is applied to a smaller number of households, derived from the amount of potable water available, because of the reclaimed water program, to fully satisfy 30 percent of a households' expected consumption in an average year. It is likely, given current policies and system operations protocols, that responsibility for a water supply shortage would be allocated among all customers supplied by a utility and, thus, the reliability benefit would be shared				

	among all customers. This scenario would result in a lower benefit for a larger number of households. It is also possible, however, that policies or system operations could result in an allocation scenario more closely resembling the alternative scenario: that fewer households experience no use reduction in the face of drought and, thus, a larger per-household willingness to pay. The analysis includes both scenarios to illustrate the full range of potential outcomes. The quantified values do not include the value of increased supply reliability from commercial and industrial customers. Insufficient information is available to estimate the commercial and industrial benefit, which would derive from reducing short-run, shortage-related curtailments in output (Chang 2003). Including it would increase the overall value of water-supply reliability, perhaps substantially. All of the supply reliability benefit in the Lower Green River Valley Decentralized Strategy would accrue to agricultural water users. Insufficient information is currently available to quantify this benefit.
Uncertainty & Sensitivity	Unit value represents residential studies conducted among Northern Californians, which may not represent willingness to pay in the Puget Sound region. The willingness to pay may vary depending on the actual effect it has on customer's experience avoiding drought-related water-use reductions. Sensitivity analysis may vary the magnitude of water-use reductions and/or the number of households affected. It may also change the assumption that water utilities would use displaced water for this purpose, in favor of other purposes, such as avoiding costs to increase potable water supplies to meet new sources of demand.

Table 3. Direct Benefits Described Qualitatively

3.D.7	**Savings from using reclaimed water to avoid costs of developing/purchasing water supply to recharge an aquifer**				
Description	The delivery of reclaimed water to customers and uses that do not require potable water would allow a utility to avoid costs of developing/purchasing more costly potable water and reducing rates for customers/ratepayers. At this time, the Cities of Redmond and Renton do not expect to achieve any capital or operations cost savings from having access to reclaimed water. No benefits are expected in the short term, but with population growth and associated increasing total demand for water, these avoided costs for developing additional water supplies would materialize over a longer time period.				
Key Beneficiaries	Water utility Customers/ratepayers				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Relative Importance	2	2	1	1	1

Uncertainty & Sensitivity	With conservation and/or changes in population growth rates and development patterns, these benefits might accrue sooner or later or not all within the 30-year planning timeframe. They also might be smaller or larger, if future water shortages are smaller or larger than expected.				

3.D.8 Savings from using reclaimed water to avoid costs of water supply treatment and transmission					
Description	Water utility would deliver reclaimed water to customers and uses that do not require potable water. Diminished demand for potable water could allow the utility to avoid capital costs to expand its water supply treatment and/or transmission capabilities and defer rate increases for customers/ratepayers. Current variable costs reported by Seattle Public Utilities are about $0.09 per CCF (Seattle Public Utilities 2010).				
Key Beneficiaries	Water utility Customers/ratepayers				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Relative Importance	2	2	1	1	1
Uncertainty & Sensitivity	With conservation and/or changes in population growth rates and development patterns, these benefits might accrue sooner or later or not all within the 30-year planning timeframe. They also might be smaller or larger, if future water shortages are smaller or larger than expected. While the benefit may be small given the expected amount of reclaimed water produced by each of the strategies, if the scale of the reclaimed water program grows, benefits to utilities and ratepayers from reduced treatment and transmission costs may become significant.				

4.D.1 Increased flexibility regarding disposition of treated effluent					
Description	Ongoing environmental deterioration, population growth, climate change, and other factors likely will put additional stress on water quality and quantity issues in Puget Sound, relative to current conditions. Production and use of reclaimed water would provide King County with another option for disposing of treated effluent. By developing the capacity to treat water to reclaimed status anywhere within King County, the County would gain a buffer against acute or chronic effects of treated effluent in hotspots. The magnitude of this benefit varies by strategy relative to the amount of water treated to reclaimed status.				
Key Beneficiaries	King County WTD Customers/ratepayers				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X

Relative Importance	2	1	1	1	1
Uncertainty & Sensitivity	The magnitude of this benefit is sensitive to the propensity of effluent discharge sites to respond negatively to discharge of effluent not treated to reclaimed status. The greater the sensitivity, now or in the future, the greater would be the benefit.				

4.1.2 Indirect Environmental Benefits

Below, Table 4 presents quantified indirect environmental benefits and Table 5 presents indirect environmental benefits that are described qualitatively. The numbers associated with each benefit, such as 3.E.2, come from the 2009 King County technical memorandum on benefits.

The following indirect environmental benefits were identified in 2009 but not included in this analysis:

3.E.1 Enhancement of downstream habitats. This benefit is likely already incorporated into the value associated with benefit 3.E.5, Increased Instream Flows. To the extent that people are willing to pay separately for this benefit, the value of 3.E.5 may underestimate the total value of benefits that derive from increasing instream flows.

3.E.3 Reduced risks to threatened or endangered species (other than Pacific salmon). This benefit is likely already incorporated into the value associated with benefit 3.E.5, Increased Instream Flows. To the extent that people are willing to pay separately for this benefit, the value of 3.E.5 may underestimate the total value of benefits that derive from increasing instream flows.

3.E.4 Reduced risks to threatened or endangered species (Pacific salmon). This benefit is likely already incorporated into the value associated with benefit 3.E.5, Increased Instream Flows. To the extent that people are willing to pay separately for this benefit, the value of 3.E.5 may underestimate the total value of benefits that derive from increasing instream flows.

4.E.1 Reduced risk of subsidence resulting from declining groundwater levels. No benefit in this category is expected to result from any of the strategies. .

4.E.2 Enhanced coastal ecosystems. This benefit is likely already incorporated into the value associated with benefit 3.E.5, Increased Instream Flows. To the extent that people are willing to pay separately for this benefit, the value of 3.E.5 may underestimate the total value of benefits that derive from increasing instream flows.

4.E.3 Enhanced protection for utilities' source water areas. No benefit in this category is expected to result from any of the strategies.

4.E.4 Improvements in water quality (e.g., temperature, toxic substances, sediment). This benefit is likely already incorporated into the value associated with benefit 3.E.5, Increased Instream Flows. To the extent that people are willing to pay separately for this benefit, the value of 3.E.5 may underestimate the total value of benefits that derive from increasing instream flows.

Table 4. Indirect Quantified Environmental Benefits

3.E.2 Enhanced environmental restoration, wetland restoration					
Description	Use of reclaimed water to create new wetlands would increase the ecosystem's ability to produce related goods and services, such as water purification, that are economically important to society. Using reclaimed water to augment existing wetlands may, depending on timing and location of the application, increase the supply of wetland-related goods and services. WTD expects new wetland acres would provide habitat, improve water quality, and contribute to base flows in downstream water bodies. Depending on the final design, new and enhanced wetlands may provide additional wet weather storage capacity, which could reduce downstream flooding.				
Key Beneficiaries	General public				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X			
Annual Quantity (Acres New Wetland)	26	16			
(Acres Enhanced Wetland)	23	0			
Unit Value ($/acre)	$23,000 to $348,000 (One-time value in 2020) This range of value applies only to acres of new wetland. It reflects recent costs incurred to construct an acre of new wetland in Washington (Patora 2009), and represents society's willingness to pay for new wetland acreage. It is consistent with other estimates of wetland creation costs, including the Army Corps of Engineers' finding that the per-acre cost of wetlands created for mitigation banks ranges from $42,000 to $126,000 (Patora 2009). Wetlands created in urban areas tend to cost more per acre: the average cost to create a wetland mitigation credit for one acre of wetland in Snohomish County ranges from $175,000 to $250,000 (Woodward, personal communication). These avoided cost estimates likely underestimate the total value of goods and services derived from wetlands. Washington Department of Ecology has used a range of $23,600 to $1.7 million to represent the total net-present value (NPV) of an acre of wetland (Patora 2009). A meta-analysis of studies estimating the total value derived from single-service wetlands suggests wetlands provide $2 to $9,753 worth of benefits per acre per year (Woodward and Wui 2001). Assuming these benefits begin to accrue in eight years (2020), their NPV would be $28 to $155,000 per acre through 2050. The actual value would depend on the additional quality and functions wetlands provide with the application of reclaimed water, with higher-quality wetlands that produce a wide range of services closer to urban areas and sources of demand trending toward the higher end of these ranges.				

Uncertainty & Sensitivity	This range of value may overestimate or underestimate the actual value of additional wetland acres created by the reclaimed water strategies. The value could be lower than the range suggests for two reasons. One, the range of value assumes wetlands created by the strategies would be functionally equivalent to wetlands created for the purpose of meeting wetland mitigation requirements or to sell as wetland bank credits. This assumption may not be correct because the reclaimed water strategies supply water for wetlands but do not cover the full effort required for wetland restoration. Two, the range of value does not clearly account for the ecosystem services that would be lost by converting land to a wetland. The actual value could be higher than the range suggests for several reasons. Studies show that values for natural ecosystems, including wetlands near urban areas, increase with population growth and growth in per-capita gross domestic product (Brander et al. 2006), so it is expected that the per-unit value would increase over time. It is likely that enhanced wetland acres would provide additional economic benefits than those represented in the studies underling the range of value, but insufficient information exists to quantify the marginal effects or to understand the marginal value they provide.

3.E.5 Increased instream flows

Description	Use of reclaimed water to augment streamflows or to displace the withdrawal of water from streams has the potential to enhance the ability of aquatic and streamside ecosystems to provide economically important goods and services. Augmented streamflows in the Bear Creek Basin (Brightwater Centralized Strategy) have the potential to improve aquatic habitat for salmonids and a population of freshwater mussels by reducing temperatures and increasing dissolved oxygen, especially during the low-flow summer season. The annual quantity shown below reflects reclaimed water applied for environmental purposes and water left instream that would have been withdrawn from surface sources but for the availability of reclaimed water. The actual amount could be higher if water that would have been pumped from groundwater sources, but for the availability of reclaimed water, also contributes to instream flows by raising the water table or otherwise interacting with surface water resources. Data were not available to quantify this effect.				
Key Beneficiaries	General public				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Annual Quantity (Acre-Feet)	9,082	939	85	133	0
Unit Value ($/Acre-Foot)	$4 to $3,000 The value associated with increased instream flows is highly dependent on the timing of application and total quantity relative to baseline instream flows. Water applied during low-flow summer months in streams with minimal base flows supporting highly sensitive ecological resources would have the highest value. Water applied during high-flow winter months or flows that represent “a drop in				

	the bucket" compared to existing base flows would have lower values, or potentially no value. The lower end of this range comes from the value of water for environmental purposes identified in a meta-analysis of water transactions in Washington between 1990 and 2003 (Brown 2004). That analysis identified a range of market prices for water purchased for environmental purposes in Washington of $4 to $400 per acre-foot per year in 2010 dollars, with a median value of $50 (Brown 2004). Transactions since 2003 suggest a higher value may be appropriate for additional flows in some streams during the summer season when streamflows are most limited. The Washington Water Trust recently acquired a water right on Orcas Island for conservation purposes for around $800 per acre-foot (Cronin, personal communication). Transactions in the Yakima Basin that secured water for environmental purchases ranged from $700 to $2,000 per acre-foot (Washington Department of Ecology 2010c). The Cities of Olympia, Lacey, and Yelm recently acquired water for instream flows to mitigate lower streamflows on the Deschutes River resulting from water withdrawn for municipal purposes for $1,500 and $3,000 per acre-foot (City of Olympia and the Nisqually Indian Tribe 2010).
Uncertainty & Sensitivity	The range of value represents recent transactions in Washington State, but not necessarily in King County. The analysis in Brown (2004) represents a small number of transactions, and the study's author indicates a high level of uncertainty in drawing conclusions from his data. More recent transactions from the Puget Sound region suggest higher values may be warranted in flow-limited basins during low-flow periods where additional flows would support high-demand goods and services, such as increased survival of threatened or endangered salmon, recreational use, or increased reliability of municipal water supplies. Values reflect the price of water under past and current conditions. As water demand increases and supply becomes scarcer, the value of instream flow likely will increase. Increasing instream flows may have many different biophysical effects, including improving downstream habitat, increasing salmon populations, reducing stream temperatures, and improving water quality parameters in Puget Sound. To the extent that people are willing to pay to increase instream flows in order to achieve these effects, the value of increased instream flows incorporates the value associated with these other benefits. To the extent that people are willing to pay separately for these and other benefits, the value used here may underestimate the total value of increased instream flows. Sensitivity analysis may examine the effect of applying different unit values to different amounts of instream flow, based on the timing and location of flows. It may also change the assumption that water utilities would leave instream for environmental purposes the water displaced by reclaimed water.

Table 5. Indirect Environmental Benefits Described Qualitatively

3.E.6	**Increased carbon sequestration and reduced greenhouse gas emissions**
Description	Use of reclaimed water to improve the health and functions of wetland and riparian ecosystems would expand the ability of plants and trees to sequester carbon and dampen the anticipated adverse effects of climate change.
Key Beneficiaries	General public

Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X			
Relative Importance	2	1			
Uncertainty & Sensitivity	Methods to calculate carbon sequestration capacity in wetland vegetation are available. Applying them would entail knowing the species, growth rates, and other characteristics of the wetlands. The value of the sequestered carbon would be estimated using the method described in cost 4.E.1, below. While the range for the unit cost attempts to capture some of the uncertainty regarding the potential costs associated with climate change, there remains considerable debate about whether these values adequately reflect the full range of risks, especially if little action is taken to curb carbon emissions. Higher estimates have appeared in the economic literature, which attempt to account for the potential costs associated with the risk that emissions of greenhouse gases could lead to catastrophic outcomes (Stern 2006, Gerst et al. 2010).				

4.1.3 Indirect Recreation Benefits

While at least two of the three strategies—the Brightwater and South plant strategies—may affect the quantity and quality of recreational opportunities related to wetland creation and enhancement, data are currently unavailable to quantify the economic value associated with these benefits. Table 6 presents the indirect recreation benefits that can be described qualitatively. The numbers associated with each benefit, such as 3.R.1, come from the 2009 King County technical memorandum on benefits.

Table 6. Indirect Recreation Benefits Described Qualitatively

3.R.1	**Increased instream, near-stream, and wetland recreation**
Description	Use of reclaimed water to increase streamflows and streamside ecosystems would directly or indirectly enhance instream recreational opportunities, especially during the summer when flows are low. Boaters and other recreationists would derive benefits from the increased recreational opportunities, businesses selling recreation-related goods or services would experience increased sales, and nearby property values would increase. The strategies that provide the most streamflow augmentation, particularly for low-flow waterways, have the greatest potential to provide this benefit.
Key Beneficiaries	Consumers of instream, near-stream, and wetland recreation opportunities Businesses that support recreation Owners of property near enhanced recreational opportunities Beneficiaries of the increase in the property-tax base

Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X				
Relative Importance	1				
Uncertainty & Sensitivity	It is unclear the extent to which receiving waterbodies would be flow-limited for recreation under the baseline scenario. To the extent that there are seasonal or drought conditions whereby flow and dependent processes are constrained, and recreation is responsive to the application of reclaimed water, the benefit would present itself. This benefit is sensitive to the scarcity of water in these and nearby waterbodies and to the preferences of recreationalists for conditions that require water augmentation.				

3.R.2 Enhancement of green spaces for recreational use (e.g., golf courses, soccer fields, parks)

Description	Use of reclaimed water for irrigation would facilitate the establishment of new green spaces and allow existing green spaces to be kept greener longer during the dry months. The additional amenities would benefit users, passers-by, and nearby residents. The (public or private) entities responsible for producing the green spaces would enjoy savings from lower irrigation costs. Businesses selling related goods and services (golf equipment, picnic baskets, etc.) would realize increased revenues from higher demand for their products. The strategies that generate the most irrigation water have the greatest potential to provide this benefit, particularly during drought conditions.				
Key Beneficiaries	Producers and consumers of goods and services of parks, golf courses, soccer fields, etc. Businesses selling goods and services associated with green spaces Owners of nearby properties				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X		
Relative Importance	2	1	1		
Uncertainty & Sensitivity	This benefit is sensitive to the level of water scarcity and cost-savings. Data and interviews suggest that water scarcity or high water costs do not restrict the supply of most irrigated recreational areas. Under certain drought conditions, though, this relationship could change. Also, if reclaimed water lowers the cost of irrigation for green spaces, future benefits might materialize. The Brightwater Centralized Strategy likely would produce higher benefits in this category than the other strategies because it generates more reclaimed water and because it would send water to Marymoor Park. Irrigation at Marymoor Park is currently limited by its piping system. Irrigated areas do not receive sufficient irrigation and several areas of the park do not receive any irrigation. With reclaimed water, over 20 acres of currently un-irrigated land could be irrigated, increasing the quality and quantity of recreation opportunities in the park (personal communication with Karl Kostal, Park District Maintenance				

Coordinator, King County).

4.1.4 Indirect Human Health Benefits

No benefits related to human health could either be quantified or described qualitatively.

The following indirect human health benefit was identified in 2009 but not included in this analysis. The number 3.H.1 associated with the benefit comes from the 2009 King County technical memorandum on benefits.

3.H.1 Reduced public health risk as urban trees irrigated by reclaimed water remove pollutants from the air. No benefit in this category is expected to result from any of the strategies.

4.1.5 Indirect Economic and Social Benefits

Below, Table 7 presents quantified indirect economic and social benefits and Table 8 presents indirect economic and social benefits that are described qualitatively. The numbers associated with each benefit, such as 3.ES.4, come from the 2009 King County technical memorandum on benefits.

The following indirect environmental benefits were identified in 2009 but not included in this analysis:

3.ES.1 Increased property values (adjacent to suburban riparian greenways). The changes in suburban greenways resulting from the application of reclaimed water through any of the three strategies are not expected to produce effects large enough to influence adjacent property values.

3.ES.7 Flood protection. No benefit in this category is expected to result from any of the strategies.

3.ES.9 Avoided energy costs to businesses and local industry (natural gas). No benefit in this category is expected to result from any of the strategies.

Table 7. Indirect Quantified Economic and Social Benefits

3.ES.4 Savings in fertilizer usage					
Description	Residual nutrients in reclaimed water may fertilize land where used for irrigation, decreasing the amount and cost of additional fertilizer applications.				
Key Beneficiaries	Agricultural producers Consumers of agricultural products General public				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
		X	X	X	X

Annual Quantity (Acre-feet applied for irrigation)		725	30	154	269
Unit Value ($ per acre-foot of water applied for irrigation)	$44 This value represents the average price of fertilizer that otherwise would be applied for agricultural and landscaping purposes (King County 2008).				
Uncertainty & Sensitivity	This value may underestimate or overestimate the actual benefit irrigators derive from nutrients in reclaimed water. The actual level of benefit would depend on baseline fertilization practices, which likely vary considerably across irrigators, type of landscape or crop irrigated, and the degree to which irrigators actually change their fertilization practices in response to reclaimed water. Furthermore, there could be additional costs and benefits associated with this change in fertilizer usage insofar as a decrease in demand for fertilizer decreases fertilizer production, reducing greenhouse gas emissions from producing and transporting fertilizer and influencing other externalities associated with mining fertilizer inputs. Sensitivity analysis may vary the value of savings in fertilizer usage across users to model potential behavioral responses.				

3.ES.8 Avoided energy costs to businesses and local industry (electricity)

Description	Use of reclaimed water to heat and/or cool buildings would lower electricity costs.				
Key Beneficiaries	Building owners Customers				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
			X		
Annual Quantity (kWh per year)			73,000		
Unit Value ($ per kWh)	$0.06 to $0.10 This value is based on the current (effective April 1, 2011) average electricity rate for large and small demand general service in the reclaimed water planning area. Rates range from $0.06 to $0.10 based on the timing and quantity of use (Puget Sound Energy 2011).				
Uncertainty & Sensitivity	This value may underestimate or overestimate the actual benefit businesses enjoy, depending especially on the type of heating/cooling technology actually affected by reclaimed water.				

Table 8. Indirect Economic and Social Benefits Described Qualitatively

3.ES.2 Increased property values (adjacent to urban parks)					
Description	Use of reclaimed water to provide green space, improve instream water quality, or provide other environmental improvements would increase the value of nearby properties. Use of reclaimed water to increase the supply and/or reliability of water for municipal-industrial uses would stimulate economic growth and increase growth-related values of property in areas where tight supplies and/or restricted reliability would curtail growth. Evidence does not suggest any of the strategies would generate these effects on the scale typically associated with increases in property values. The strategies with the greatest impacts on treated volume and water availability would have the greatest chance of generating this benefit. To the extent that the high level of water quality treatment becomes general knowledge, it may improve King County's reputation as an attractive place to live, driving up property values overall.				
Key Beneficiaries	Property owners adjacent to urban parks Consumers of public services dependent on growth-related tax revenue				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X			
Relative Importance	1	1			
Uncertainty & Sensitivity	Under drought conditions of high water scarcity, if reclaimed water allows some areas to maintain irrigation while surrounding areas do not, the importance of this benefit might be noticeable, at least on a short-term basis. The magnitude of the benefit would be sensitive to the magnitude and frequency of such extreme scarcity scenarios.				

3.ES.3 Increased property values (adjacent to golf courses)	
Description	Use of reclaimed water to provide green space, improve instream water quality, or provide other environmental improvements would increase the value of nearby properties. Use of reclaimed water to increase the supply and/or reliability of water for municipal-industrial uses would stimulate economic growth and increase growth-related values of property in areas where tight supplies and/or restricted reliability would curtail growth. Evidence does not suggest any of the strategies would generate these effects on the scale typically associated with increases in property values. The strategies with the greatest impacts on treated volume and water availability would have the greatest chance for generating this benefit. To the extent that the high level of water quality treatment becomes general knowledge, it may improve King County's reputation as an attractive place to live, driving up property values overall.
Key Beneficiaries	Property owners adjacent to golf courses Consumers of public services dependent on growth-related tax revenue

Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X		
Relative Importance	1	1	1		
Uncertainty & Sensitivity	Under drought conditions of high water scarcity, if reclaimed water allows some areas to maintain irrigation while surrounding areas do not, the importance of this benefit might be noticeable, at least on a short-term basis. The magnitude of the benefit would be sensitive to the magnitude and frequency of such extreme scarcity scenarios.				

3.ES.5 Commercial salmon harvest

Description	Production and use of reclaimed water would result in improved aquatic and marine habitat for salmon. Larger salmon populations would increase the catch available to the commercial salmon industry. The increased supply of wild salmon would lower prices for consumers, and increased salmon consumption would have health benefits for consumers. To some extent, all strategies would reduce pollutant discharge to Puget Sound and would contribute to this benefit. The scale of the different strategies, however, suggests that only the Brightwater Centralized Strategy has sufficient capacity to influence the commercial salmon harvest in the region.				
Key Beneficiaries	Commercial salmon industry Consumers of wild salmon				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X				
Relative Importance	1				
Uncertainty & Sensitivity	This benefit would be highly sensitive to the responsiveness of salmon populations to the changes in habitat generated by the strategies, especially if the future sees drought conditions and high temperatures that degrade salmon habitat in the Puget Sound Basin. The actual value of commercial salmon harvest may vary, sometimes considerably, from year to year.				

3.ES.6 Recreational salmon harvest

Description	Production and use of reclaimed water would result in improved aquatic and marine habitat for salmon. Larger salmon populations would increase the catch available to the salmon anglers and generate additional demand for related businesses. The increased catch and consumption of salmon would have health benefits for consumers. Some strategies potentially would directly augment streamflow in salmon-supporting streams. To the extent that all strategies reduce pollutant discharge to Puget Sound, they all contribute to this highly valuable benefit. The scale of the different strategies, however, suggests that only the Brightwater Centralized Strategy has sufficient capacity to

	influence the recreational salmon harvest in the region.				
Key Beneficiaries	Salmon anglers Businesses in the recreational fishing industry Consumers of wild salmon				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X				
Relative Importance	1				
Uncertainty & Sensitivity	This benefit would be highly sensitive to the responsiveness of salmon populations to the changes in habitat generated by the strategies, especially if the future sees drought conditions and high temperatures that degrade salmon habitat in the Puget Sound Basin. The actual value of commercial salmon harvest may vary, sometimes considerably, from year to year. The demand for and value of recreational fishing activity likely will increase over time.				

4.ES.1 Increased economic growth

Description	Production and use of reclaimed water would stimulate economic activity in related businesses. Availability of reclaimed water would support general economic growth insofar as it would relax constraints associated with the quantity, reliability, and environmental impacts of municipal-industrial water systems. General economic growth would yield financial benefits for growth-related businesses, property owners, and public services. Increased economic growth related to a particular application of reclaimed water would be case-specific. Effects from increased economic growth may include changes in expenditures, the supply of goods and services, amenities and quality of life, and the cost of doing business. Changes in jobs and incomes resulting from production of reclaimed water are not the same as changes in the supply of goods and services resulting from the reclaimed water comprehensive plan. First-order effects would be offset, more or less, by second-order effects that would materialize if, for example, new jobs drew resources away from jobs elsewhere in the county. If net expenditures or employment increase, however, a strategy would provide a net stimulus. There is little direct evidence regarding the relationship between reclaimed water programs and economic growth that is applicable to these strategies. They offer potential increases in water availability to support new demand, and by creating an aura of environmental quality and community stewardship, they may attract businesses and skilled labor sensitive to these characteristics. The strategies generating the largest volumes of reclaimed water (Brightwater and South Plant Centralized Strategies) likely would have larger impacts than strategies generating less reclaimed water, which would provide little, if any, increase in economic growth.
Key Beneficiaries	Reclaimed water-related businesses Growth-related businesses Owners of property that experiences growth-related increases in value Consumers of public services dependent on growth-related tax revenues

Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X			
Relative Importance	1	1			
Uncertainty & Sensitivity	This benefit is sensitive to the level of constraint that water supply otherwise would place on economic growth and to the strategies' direct and indirect effects on the area's attractiveness to households and businesses.				

4.ES.2 Increased ability for water projects to leverage other community projects

Description	Use of reclaimed water would enable the development of community projects that otherwise would not be possible due to lack of an affordable, reliable supply of water in an appropriate location. The level of benefit resulting from leveraging other community projects with a particular application of reclaimed water would be case-specific.				
Key Beneficiaries	Reclaimed water-related businesses Growth-related businesses Owners of property that experiences growth-related increases in value Consumers of public services dependent on growth-related tax revenues				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Relative Importance	1	1	1	1	1
Uncertainty & Sensitivity	This benefit is sensitive to the degree of constraint that future water availability would impose on community projects and to the benefits that these projects would provide.				

4.ES.3 Improved management of water resources

Description	Use of reclaimed water to displace the use of potable water for customers and uses that don't require it would increase the supply of potable water for other customers and uses, diminish the demand for raw water, and decrease the local water utility's exposure to the decisions of environmental regulators, non-local water suppliers, and other external entities. A strategy provides a valuable benefit if it decreases the likelihood that other water users with senior rights outside of King County's jurisdiction will capture flows that otherwise would be put to beneficial use by King County. Water utilities elsewhere that do not have primacy for their entire water supply have made major and costly capital investments in pipelines, reservoirs, desalination plants, and water reuse purely to meet this benefit. These costs represent, at a minimum, the benefit of local control. If a given project will allow King County to avoid such a situation, the project will provide an equivalent benefit. This benefit is related to the overall contribution of each particular strategy to

	alleviating water scarcity among sources of water demand.				
Key Beneficiaries	Water utilities Reclaimed water utilities General public				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Relative Importance	2	1	1	1	1
Uncertainty & Sensitivity	This benefit is highly sensitive to the frequency and severity of general and localized water scarcity.				

4.ES.4 Reinforced cultural/spiritual values					
Description	Production and use of reclaimed water would enhance attributes of the environment having cultural/spiritual value. The level of benefit related to reinforced cultural/spiritual values resulting from a particular application of reclaimed water would be case-specific. The strategies that positively affect conditions that have cultural/spiritual value, such as salmon populations and health of natural areas, will have the greatest potential to generate this benefit.				
Key Beneficiaries	Individuals who derive cultural/spiritual value from environmental resources enhanced by the use of reclaimed water				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X			
Relative Importance	2	1			
Uncertainty & Sensitivity	This benefit is sensitive to the ability of a strategy to affect water-availability constraints on natural systems providing cultural/spiritual values. The value would increase if the culturally/spiritually significant natural resource, such as salmon populations, becomes scarcer. Cultural/spiritual values may not be quantifiable in monetary terms through benefit-cost analysis.				

4.ES.5 Reinforced cultural values associated with a conservation ethic	
Description	Production and use of reclaimed water would respond to preferences of some individuals, businesses, and groups for diminishing impacts on the environment. The level of benefit related to reinforced cultural values associated with a conservation ethic resulting from a particular application of reclaimed water would be case-specific.
Key Beneficiaries	Individuals who derive value from actions that promote natural-resource conservation

Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Relative Importance	2	1	1	1	1
Uncertainty & Sensitivity	The generation and use of reclaimed water on its own has the potential to generate this benefit, but the benefits of an individual strategy likely would depend on the level of awareness and the nature of the environmental effects achieved. Cultural values may not be quantifiable in monetary terms through benefit-cost analysis.				

4.ES.6 Enhanced aesthetic values

Description	Use of reclaimed water would lead to improvements in green space, instream water quality, elements of Puget Sound affected by discharged water effluent, and other natural-resource amenities from which people derive aesthetic value. The increase in value would affect the value of nearby properties; the level of activity in real estate, tourism/recreation, and other industries; and the revenue public entities derived from the increases to support the provision of public services. The level of benefit related to reinforced cultural values associated with a conservation ethic resulting from a particular application of reclaimed water would be case-specific. Strategies providing more potential irrigation water would provide greater benefit than those providing less water for irrigation.				
Key Beneficiaries	Consumers of natural-resource amenities enhanced by reclaimed water Owners of properties near the enhanced amenities Businesses associated with the enhanced amenities Consumers of public services dependent on values and activities derived from the enhanced amenities				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X			
Relative Importance	1	1			
Uncertainty & Sensitivity	This benefit is sensitive to the responsiveness of aesthetic elements of the local environment to increased production and use of reclaimed water.				

4.ES.7 Increased agricultural production

Description	Use of reclaimed water for irrigation at prices lower than alternative supplies (if available) would increase the supply of locally produced agricultural supplies available to consumers, increase farmers' net revenues, and reinforce efforts to prevent farmland from being converted to other uses. The level of benefit arising from increased agricultural production related to a particular application of reclaimed water would be case-specific. Strategies providing more potential irrigation water would provide greater benefit than those providing less water for

	irrigation.				
Key Beneficiaries	Agricultural producers Consumers of agricultural products General public				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
					X
Relative Importance					1
Uncertainty & Sensitivity	This benefit is sensitive to the scarcity of water to meet agricultural demand, and the cost-savings offered via reclaimed water.				

4.ES.8 Increased reliability of water supplies for agricultural irrigation

Description	Access to reclaimed water for irrigation would induce farmers to undertake production of higher-value crops requiring a reliable source of irrigation water. The level of benefit arising from increased reliability of water supplies for agricultural production would be case-specific. Strategies providing more potential irrigation water would provide greater benefit than those providing less water for irrigation.				
Key Beneficiaries	Agricultural producers Consumers of agricultural products General public				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
					X
Relative Importance					1
Uncertainty & Sensitivity	This benefit is sensitive to the scarcity of water to meet agricultural demand, and the increase in net farm earnings resulting from irrigators' access to reclaimed water.				

4.ES.10 Reductions in risk associated with climate change

Description	Production and use of reclaimed water would provide an additional source of water to meet demand in the face of potential water shortages associated with anticipated increases in the incidence and severity of low streamflows during summer months and increased inter-annual variation in streamflows. The level of decreased risk associated with reductions in impacts of climate change directly, such as changes in ecosystem functions, increased insect and disease outbreaks, and increased fire, drought, and other events, as well as changes in society's response to climate change, including implementation of regulation to control greenhouse gas emissions and other adaptation and mitigation measures, would be case-specific. Strategies providing more potential water generally would provide greater benefit than those providing less water.

Key Beneficiaries	General public				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Relative Importance	2	2	1	1	1
Uncertainty & Sensitivity	This benefit is sensitive to the actual impacts of climate change on streamflows and improvement in public understanding of each strategy's potential effects.				

4.ES.11 Increased public education					
Description	Production and use of reclaimed water would generate opportunities to provide the public with information on the benefits of water reuse and conservation. In general it seems likely that there is little variation in public education planned across strategies, but the most publicly visible strategies and strategy-effects will have the most potential benefit.				
Key Beneficiaries	General public				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Relative Importance	1	1	1	1	1
Uncertainty & Sensitivity	This benefit is sensitive to the level of public awareness generated by each strategy.				

4.ES.12 Reduced risk of enforcement/litigation costs associated with water rights	
Description	Use of reclaimed water, by displacing the use of water from a stream or aquifer, would allow a water utility or industrial water user to avoid bumping against the limits of its existing water rights and incurring costs to develop additional water rights. The state and other interested parties would avoid costs associated with clarifying the boundaries of existing water rights or evaluating an application for new water rights. Enforcement/litigation costs avoided by the use of reclaimed water would be case-specific. Strategies providing more potential water generally would provide greater benefit than those providing less water.
Key Beneficiaries	General public Water utility Customers/ratepayers Taxpayers

Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Relative Importance	1	1	1	1	1
Uncertainty & Sensitivity	This benefit is sensitive to the frequency of future conditions that limit the supply of water to satisfy all water rights in the region.				

4.2 Costs

In keeping with the framework developed by the WateReuse Foundation (Raucher et al. 2006) and the structure of the 2009 King County memorandum *Identification of Potential Costs of Production and Use of Reclaimed Water,* this report categorizes costs as either direct or indirect. Direct costs include out-of-pocket costs borne by WTD to produce and deliver reclaimed water, as well as ancillary additional costs borne by water users and utilities for each strategy. Indirect costs are those that have adverse environmental, recreation, human health, and economic and social effects. This description of costs does not explicitly consider financing costs, but the overall benefit-cost analysis in Chapter 5.0 accounts for them through the discounting process.

For each category, if applicable, this section presents tables listing detailed information about the direct and indirect quantified costs as well as the direct and indirect costs that are described qualitatively. Also for each category, if applicable, this section notes any costs listed in the 2009 technical memorandum that are not included in this analysis, either because they are not expected to arise from any of the strategies, or because they are accounted for by other costs that are included in the analysis.

4.2.1 Direct Costs

Below, Table 9 presents quantified direct costs and Table 10 presents direct costs that are described qualitatively. The numbers associated with each cost, such as 3.D.1a, come from the 2009 King County technical memorandum on costs.

The following direct costs were identified in 2009 but not included in this analysis:

3.D.6. O&M Costs for Customer. The analysis assumes an irrigator, industrial water user, or utility would incur no net change in operation and maintenance costs, relative to the baseline scenario, when using reclaimed water and does not include this cost in the analysis.

3.D.7 Loss of Potable Water Sales. It is not appropriate to include anticipated revenues from water sales as quantified benefits in a benefit-cost analysis. Similarly, it is not appropriate to include the costs associated with potential decreases in potable water sales.

3.D.8 Reclaimed Water Program Administrative Costs. No cost in this category is expected to result from any of the strategies.

3.D.9 Reductions in Anticipated Reclaimed Water Sales Revenue. It is not appropriate to include anticipated revenues from water sales as quantified benefits in a benefit-cost analysis.

Similarly, it is not appropriate to include potential reductions in anticipated reclaimed water sales revenue.

3.D.10 Increases in Groundwater Pumping Costs. No cost in this category is expected to result from any of the strategies.

Table 9. Quantified Direct Costs

3.D.1a Capital costs for reclaimed water production					
Description	Costs to purchase equipment and construct facilities to be used in the production of reclaimed water.				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Unit Cost (Incurred 2014–2019)	$28,210,000–$60,450,000	$6,160,000–$13,200,000	$11,130,000–$23,850,000	$1,750,000–$3,750,000	$11,130,000–$23,850,000
	These values include capital costs to produce reclaimed water (as estimated in King County 2012a) and the acquisition or opportunity cost of land. To calculate NPV, this analysis assumes these costs begin accruing in 2014. The County will accrue 1 percent of the costs in 2014, 10 percent in 2015, 15 percent in 2016, 30 percent in 2017, 30 percent in 2018, and 14 percent in 2019.				
Uncertainty & Sensitivity	These values are preliminary estimates based on current designs and assumptions and are accurate within a range of -30 to +50 percent (King County 2012a).				
3.D.1b Land acquisition costs for reclaimed water production					
Description	Costs to purchase land to be used in the production of reclaimed water.				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Unit Cost (Incurred in 2014)	$0–$700,000	$0–$450,000	$450,000–$1,000,000	$130,000	$95,000–$99,000
	The range reflects different assumptions used to estimate the per-acre value of land for each strategy. Average land values were derived for commercial/industrial land in each zip code in which a strategy would be located, based on 2011 market values reported by the King County Assessor. For strategies located on land already owned by King County, the analysis considers the opportunity cost of the land, rather than acquisition costs. A range of $0 to the average market value of similar land in the area is used to account for the opportunity cost.				
Uncertainty	Land values are based on averages for the general area of the County where the				

& Sensitivity	strategy would be located. Actual land values may be higher or lower than those used here.

3.D.2 O & M costs for reclaimed water production

Description	This category sometimes is called operation, maintenance, and on-going replacement (OM&R). It includes costs for the administration, supervision, operation, maintenance, preservation, and protection of the reclaimed water production facilities. Typical expenses cover routine repairs and alterations of buildings, equipment, and care of grounds; maintenance and operation of buildings and other plant facilities; security; earthquake and disaster preparedness; environmental safety; property, liability, and all other insurance relating to property; and facility planning and management.				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Unit Cost (Annual cost incurred 2020–2050)	$1,016,000	$260,000	$128,000	$38,000	$138,000
	These values include annual non-labor O&M treatment costs to produce reclaimed water as well as the labor costs associated with O&M (estimated in King County 2012a).				
Uncertainty & Sensitivity	These values are preliminary estimates based on current designs and assumptions and are accurate within a range of -30 to +50 percent (King County 2012a).				

3.D.3a Capital costs for reclaimed water storage and distribution

Description	Costs to purchase equipment and to construct facilities to be used in the distribution of reclaimed water.				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Unit Cost (Incurred 2014–2019)	$60,480,000–$129,600,000	$43,120,000–$92,400,000	$2,590,000–$5,550,000	$2,590,000–$5,550,000	$1,680,000–$3,600,000
	These values include capital costs to distribute reclaimed water (as estimated in King County 2012a) and the acquisition cost of land for easements. If the County already owns equipment, the value shown equals opportunity cost or the benefit forgone from using it to produce reclaimed water, rather than for the best alternative opportunity. To calculate NPV, this analysis assumes these costs begin accruing in 2014. The County will accrue 1 percent of the costs in 2014, 10 percent in 2015, 15 percent in 2016, 30 percent in 2017, 30 percent in 2018, and 14 percent in 2019.				
Uncertainty & Sensitivity	These values are preliminary estimates based on current designs and assumptions and are accurate within a range of -30 to +50 percent (King County 2012a). Land values are based on averages for the general area of the County where each				

	strategy would be located. Actual land values may be higher or lower than those used here. To the extent that this cost does not include right-of-way (ROW) fees that would be charged on distribution pipes located in the ROW, it underestimates the full capital costs for distribution of reclaimed water.				
3.D.3.b Land acquisition costs for reclaimed water storage and distribution					
Description	Costs to purchase land to be used for the storage and distribution of reclaimed water.				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Unit Cost (Incurred 2014–2019)	$140,000–$3,700,000	$510,000–$1,300,000	$1,300,000–$2,900,000	$400,000–$680,000	$280,000–$380,000
	The range reflects different assumptions used to estimate the per-acre value of land for each strategy. Average land values were derived for commercial/industrial land in each zip code in which a strategy would be located, based on 2010 market values reported in King County Assessor data. To calculate NPV, this analysis assumes these costs begin accruing in 2014. The County will accrue 1 percent of the costs in 2014, 10 percent in 2015, 15 percent in 2016, 30 percent in 2017, 30 percent in 2018, and 14 percent in 2019. Financing costs are not considered in this analysis. Values do not include any applicable ROW fees. If distribution is located on County land, assuming King County assesses a ROW fee, the cost would represent the opportunity cost of occupying space that could be used for other purposes in the future. If distribution is located on land owned by other jurisdictions, the cost should include any applicable ROW charges levied by those jurisdictions. ROW fees typically are levied annually and may be based on a percent of the revenue collected from delivering the service, by linear foot, or by diameter of pipe.				
Uncertainty & Sensitivity	Land values are based on averages for the general area of the County where the strategy would be located. Actual land values may be higher or lower than those used here.				
3.D.3.c Wetland construction costs					
Description	Costs to construct wetlands.				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X			
Unit Cost (Incurred 2014–2019)	$60,000–$900,000	$37,000–$560,000			
	Recent costs incurred to construct new wetlands in Washington ranged from $23,00–$348,000 per acre (Patora 2009). Since all new wetlands associated with the strategies will extend from existing wetlands, and likely will cost less to				

	construct than a new isolated wetland, this analysis assumes wetland costs will equal 10 percent of the potential range, $2,300–$34,800 per acre. To calculate NPV, this analysis assumes these costs begin accruing in 2014. The County will accrue 1 percent of the costs in 2014, 10 percent in 2015, 15 percent in 2016, 30 percent in 2017, 30 percent in 2018, and 14 percent in 2019. Financing costs are not considered in this analysis.
Uncertainty & Sensitivity	The actual costs attributed to wetland construction are not included in the technical memorandum *Engineering Analysis and Definition of Reclaimed Water Strategies* (King County 2012a) and may be higher or lower than the estimates provided here depending on the complexity of the area surrounding new wetlands.

3.D.4 O & M costs for reclaimed water storage and distribution

Description	This category sometimes is called OM&R, for operations, maintenance, and replacement. It includes costs for the administration, supervision, operation, maintenance, preservation, and protection of the reclaimed water distribution facilities. Typical expenses cover repairs and routine alterations of facilities, equipment, security; earthquake and disaster preparedness; environmental safety; and liability and all other insurance relating to property.				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Unit Cost (Annual cost incurred 2020–2050)	$1,133,000	$507,000	$110,000	$110,000	$103,000
	These values include annual non-labor O&M treatment costs to distribute reclaimed water as well as the labor costs associated with O&M (as estimated in King County 2012a).				
Uncertainty & Sensitivity	These values are preliminary estimates based on current designs and assumptions and are accurate within a range of -30 to +50 percent (King County 2012a).				

3.D.5 Capital Costs for Customer Retrofits and Training

Description	Costs to reclaimed water customer to establish a reclaimed water service at the use site and train individuals in the rules governing reclaimed water use.				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Unit Cost (One-time cost in 2020)	$760,000-$5,000,000	$780,000-$6,375,000	$120,000-$750,000	$110,000-$625,000	$10,000-$125,000
	These values represent one-time costs incurred by reclaimed water users assuming that irrigation retrofits cost $10,000–$125,000 per user and industrial retrofits cost $50,000–$250,000 per user.				

Uncertainty & Sensitivity	These values are estimates of potential costs incurred by irrigation and industrial reclaimed water users. The actual costs could be greater or less than these estimates depending on retrofit and training requirements unique to each reclaimed water user.

Table 10. Direct Costs Described Qualitatively

3.D.11 Reduced Customer Water Supply Flexibility					
Description	The potential for a reclaimed water customer to have less flexibility as compared to other water supply options (self-supply and/or a water utility).				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Relative Importance	Insufficient information is available at this time to determine the relative importance of this cost.				
Uncertainty & Sensitivity	Factors that may affect the importance of this cost to customers include the design and potential redundancy built into irrigation and other water supply systems, legal and regulatory issues that govern the delivery and application of reclaimed water, and the preferences of the customer.				

4.2.2 Indirect Environmental Costs

Below, Table 11 presents quantified indirect environmental costs and Table 12 presents indirect environmental costs that are described qualitatively. The numbers associated with each cost, such as 4.E.1, come from the 2009 King County technical memorandum on costs.

The following indirect environmental costs were identified in 2009 but not included in this analysis:

4.E.2. Salinity Impacts from Landscape Irrigation on Grass and Plants. No cost in this category is expected to result from any of the strategies.

4.E.3 Increase in Groundwater Salinity. No cost in this category is expected to result from any of the strategies.

Table 11. Quantified Indirect Environmental Costs

4.E.1 Environmental Impacts of Increased Energy Consumption					
Description	Additional carbon dioxide emissions accompanying increase in energy consumption required to treat water to reclaimed water standards and distribute to end use.				
Applicable Strategies	Brightwater Centralized	South Plant Centralized	Interbay Skimming Decentralized	Duwamish Polishing Decentralize	Lower Green River Valley Decentralized

	Strategy	Strategy	Strategy	d Strategy	Strategy
	X	X	X	X	X
Annual Quantity (Tons of Carbon Dioxide Equivalent)	2,259	776	17	25	25
Unit Cost ($ per ton of Carbon Dioxide Equivalent)	$28.23 to $102.33 (in 2020, when reclaimed water production commences, increasing annually to $47.93–$313.93 by 2050)				
	While the range for the unit cost captures some of the uncertainty regarding the potential costs associated with climate change, some research indicates the cost my exceed the upper end of the range, especially if little action is taken to curb carbon emissions (Stern 2006, Gerst et al. 2010).				
Uncertainty & Sensitivity	While the range for the unit cost described above attempts to capture some of the uncertainty regarding the potential costs associated with climate change, there remains considerable debate about whether these values adequately reflect the full range of risks, especially if little action is taken to curb carbon emissions. Higher estimates have appeared in the economic literature, which attempt to account for the potential costs associated with the risk that emissions of greenhouse gases could lead to catastrophic outcomes (Stern 2006, Gerst et al. 2010).				

Table 12. Indirect Environmental Costs Described Qualitatively

4.E.4 Reduced Water Quality[8]					
Description	Adverse effects on water quality from the application of reclaimed water. This is a possible consequence of applying reclaimed water in phosphorous-limited environments where there is a risk of increased eutrophication. These conditions are present in Cottage and Crystal Lakes and could arise from the application of environmental enhancement flows under the Brightwater Centralized Strategy.				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X				
Relative Importance	1				
Uncertainty & Sensitivity	Factors that may affect the importance of this cost include the ecosystem's response to the application of reclaimed water as well as society's assessment of and response to changes in water-quality parameters.				

[8] This cost was not included in the original 2009 King County technical memorandum on costs.

4.2.3 Indirect Recreation Costs

Table 13 below presents indirect recreation costs that are described qualitatively. The numbers associated with each cost, such as 4.R.1, come from the 2009 King County technical memorandum on costs.

Table 13. Indirect Recreation Costs Described Qualitatively

4.R.1 Reduced Value of Recreational Opportunities Arising from Potential Stigma					
Description	Some people may see a shift to using reclaimed water rather than untreated (groundwater or surface water) or potable water to irrigate as posing a greater risk of exposure to harmful or noxious materials. Survey research of the general public found responses to using reclaimed water for different uses varied, with the most frequent negative responses for uses such as pools and spas (85 percent negative response), ponds and fountains (44 percent negative response), and residential landscape irrigation (26 percent negative response). When asked about irrigation of athletic fields, just 16 percent of respondents had a negative response; golf course irrigation elicited an 11 percent negative response. The survey did not explicitly address park irrigation or schoolyard irrigation (Hall and Rubin 2002, cited in EPA 2004).				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X		
Relative Importance	1 (Golf, Park, Schoolyard)	1 (Athletic Field, Golf, Park, Schoolyard)	1 (Golf, Park)		
Uncertainty & Sensitivity	The response from King County residents to irrigating public spaces used for recreation may be similar to or different from the survey results reported by Hall and Rubin (2002). Stronger negative reactions would increase the importance of this cost in the overall assessment of a strategy. It is also possible that the application of reclaimed water to areas where recreational uses take place would elicit no negative response, or potentially a positive response (see benefit 4.ES.5, for example).				

4.2.4 Indirect Human Health Costs

No indirect costs related to human health could either be quantified or described qualitatively.

The following indirect human health cost was identified in 2009 but not included in this analysis. The number 4.H.1 associated with the cost comes from the 2009 King County technical memorandum on costs.

4.H.1 Increased Public Health Risk Due to Increased Contact with Reclaimed Water. No cost in this category is expected to result from any of the strategies.

4.2.5 Indirect Economic and Social Costs

Table 14 below presents indirect economic and social costs that are described qualitatively. The numbers associated with each cost, such as 4.ES.2, come from the 2009 King County technical memorandum on costs.

The following indirect economic and social cost was identified in 2009 but not included in this analysis.

4.ES.1 Increased Urban Growth Externalities (Congestion, Pollution, Other Adverse Effects). No cost in this category is expected to result from any of the strategies.

Table 14. Indirect Economic and Social Costs Described Qualitatively

4.ES.2 Reclaimed Water Production Facility Externalities					
Description	Construction of reclaimed water facilities requires the purchase and development of land that may result in negative effects on others. For example, the operation of reclaimed water facilities requires operating equipment that produces air emissions and generates vehicle traffic associated with operating the facility.				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Relative Importance	Insufficient information is available at this time regarding construction and operation plans to determine the relative importance of this cost.				
Uncertainty & Sensitivity	Factors that may affect the importance of this cost include construction duration, number of vehicles leaving and entering each day, number and proximity to adjacent property owners, and steps taken during project planning and construction to mitigate disruptions for neighbors.				
4.ES.3 Inequitable Regional Access to Reclaimed Water					
Description	Some in the community may perceive that the strategies do not fairly provide access to reclaimed water by people of all races, cultures, incomes, or educational levels, or by people with other characteristics.				
Applicable Strategies	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
	X	X	X	X	X
Relative Importance	Insufficient information is available at this time to determine the relative importance of this cost.				
Uncertainty & Sensitivity	Factors that may affect the importance of this cost include perceptions of the fairness of the process that determines which customers receive reclaimed water, accessibility and availability of technical and financial assistance to help potential customers understand the potential costs and benefits of using reclaimed water, and general education efforts associated with the reclaimed water program.				

4.3 Complementary and Substitute Goods and Services

Public and private efforts at the local, county, regional, and state levels provide benefits similar to those that the reclaimed water strategies would provide, such as enhancing streamflows and improving habitats. This section provides an overview of these other efforts. The three reclaimed water strategies would to some extent contribute to the identified ecological goals of the other efforts.

Funding for and interest in the other efforts demonstrate that demand exists for the benefits that they provide. The priorities that they have established provide insight into the areas of greatest social demand for the benefits. The expenditures associated with the efforts provide insight into the willingness to pay for the benefits, which is a means to estimating their value. In some instances, the complementary and substitute goods and services inform benefit and cost estimates for this report and help in assigning the relative importance of benefits and costs described qualitatively.

4.3.1 Puget Sound Partnership

Puget Sound is currently experiencing declines in ecological function, water quality, habitat availability, and wildlife populations (Puget Sound Partnership 2009). In 2007, the Washington State Legislature created the Puget Sound Partnership with the mission of restoring Puget Sound by 2020. Toward this goal, the Partnership has assessed the current status of Puget Sound and identified drivers for ecological decline. The Partnership coordinates actions across local, state, and federal agencies to restore ecosystem structures and functions. It developed an Action Agenda that prioritizes and implements the most cost- effective projects to achieve restoration (Puget Sound Partnership 2008). The top three priorities for the Puget Sound Partnership are:

- Protect intact ecosystem processes, structures, and functions that sustain Puget Sound.
- Restore ecosystem processes, structures, and functions that sustain Puget Sound.
- Prevent water pollution at its source.

These priorities guide landscape-scale and local project selection and funding, and they focus on protecting the large remaining riparian, estuarine, and nearshore areas, reducing water pollution sources such as stormwater, and reducing shoreline armoring and impervious surfaces.

4.3.2 Puget Sound Salmon Recovery Plan

In 2007, the National Marine Fisheries Service adopted the Puget Sound Salmon Recovery Plan (Shared Strategy Development Committee 2007). The plan outlines several general goals that the organization hopes to achieve by 2055:

- Improve fresh and marine water quality for all species.
- Improve Chinook population numbers.
- Reduce reliance on hatcheries.

- Improve the quality of recreation opportunities along waterways.
- Improve business opportunities by clearly defining regulations.
- Protect working landscapes (farms and timberlands).

The plan acknowledges that historical and likely future increases in population, especially in western King County, pose hurdles to water quality improvement and salmon recovery. Even so, the plan suggests there are enough fish and habitat to build on for successful recovery, especially if restoration efforts are aligned with compatible goals at the local watershed level. The plan breaks down the region into watershed groups, with the Green/Duwamish and the Lake Washington/Cedar/Sammamish groups being the two that are most relevant to complementing the benefits that reclaimed water strategies could provide.

The Green/Duwamish and central Puget Sound watershed runs along the Green River from the Cascades to the Duwamish as it empties into Puget Sound. From north to south, the watershed stretches from Seattle to Auburn. The plan identifies several factors limiting Chinook populations: reduced water quality, hydromodification, loss of rearing and migratory habitat, reduced sediment quality, alteration of habitat forming processes, degraded riparian conditions, and non-native species. The plan divides the watershed into five parts, the most relevant here being the Lower Green River, the Duwamish Estuary, and the marine nearshore area. The plan outlines the need for actions improving habitat in the waterways such as levee setbacks, revegetation, land acquisition, habitat restoration, and stream flow restoration.

The Lake Washington/Cedar/Sammamish watershed runs from the Cascades to Puget Sound and contains the Cedar River, the Sammamish River, Lake Washington, and Lake Sammamish. From north to south, the watershed stretches from Everett to Seattle. The plan identifies several factors limiting habitat quality in the watershed: altered hydrology (low base flows, high peak flows), loss of floodplain connectivity, lack of riparian vegetation, disrupted sediment processes, loss of channel and shoreline complexity, fish passage barriers, and degraded water and sediment quality. The plan outlines the need for actions over the next ten years that include floodplain, shoreline, and riverine restoration; revegetation; wetland enhancement; habitat improvements; and water quality improvements.

4.3.3 King County Flood Control District

The 2006 *King County Flood Hazard Management Plan* recommends regional policies, programs, and projects to reduce the risk to people and property from river flooding and channel migration in King County (King County 2007). The purpose of this plan is to create a long-term vision for flood hazard management for King County’s floodplains, with an emphasis on major river systems, and to recommend specific near-term actions consistent with that vision. Several of the plan’s goals and objectives identify flow restoration as well as protection of ecological structures and processes potentially included in areas impacted by the reclaimed water strategies, including the following:

- Reduce the risks from flood and channel migration hazards.
- Avoid or minimize the environmental impacts of flood hazard management.

- Remove or retrofit existing river facilities or modify maintenance practices to protect, restore, or enhance riparian habitat and to support recovery of species listed under the Endangered Species Act.
- Prioritize flood hazard management project and program recommendations based on level of risk, cost-effectiveness over the long term, and consistency with regional natural resource management protocols.
- Manage activities in rivers and floodplains in a manner compatible with multiple and sometimes competing uses, including existing and proposed urban development within cities; flood and channel migration risk reduction; agriculture; fish and wildlife habitat improvements; open space, recreation, water supply, and hydropower.
- Promote the economic and ecological sustainability of river corridors.

4.3.4 Lower Duwamish Waterway Superfund Site

The last 5.5 miles of the Green-Duwamish River system before it reaches Puget Sound is a heavily used industrial area that has generated a variety of toxic chemicals over the years, culminating in its 2001 inclusion in the EPA's National Priorities List and designation as the Lower Duwamish Waterway Superfund Site (EPA 2010b). Sediments (mud and sand on the river bottom) in and along the waterway contain a wide range of contaminants from years of industrial activity and from stormwater. Currently, the EPA and Washington Department of Ecology are collaborating to remediate the area and design large-scale restoration projects.

4.3.5 Water Quality Grants and Loans

Washington Department of Ecology administers three programs that fund water quality improvement projects. By assisting in project funding, these programs invest in the state's infrastructure and support local, county, tribe, and non-profit efforts geared toward improving water quality. The programs operate through an application process in which projects are selected to maximize benefits from the state's tax revenues.

- **Centennial Grant Program –** Provides state funding for projects that improve and protect water quality. Eligible projects typically include wastewater treatment construction, stream restoration, on-site septic projects, and education and outreach.
- **Clean Water Act Section 319 Grant Program –** Provides a combination of state and federal funding for pollution control projects related to nonpoint sources.
- **Clean Water State Revolving Fund Loan Program –** Provides low-interest loans with a combination of state and federal funding for wastewater treatment construction projects, nonpoint source pollution control projects, and other eligible projects that improve water quality (Washington Department of Ecology 2011b).

Of the three programs, the Clean Water State Revolving Fund Loan Program is most relevant here as it provides support for projects similar to each of the reclaimed water strategies. Since 2010, the program has provided funding for five projects related to reclaimed water. Table 15 summarizes the projects.

Table 15. Funding for Reclaimed Water-related Projects in Washington Through the State's Revolving Loan Program

Funding Year	Project Name, County	Total Cost	Expected Benefit
2010	Arlington City Wastewater Treatment Plant Upgrade and Expansion, Snohomish County	$31.2 million	• Reduce wastewater discharge into Stillaguimish River and Puget Sound • Improve water quality and support shellfish habitat
2010	Deschutes Parkway to Tumwater Reclaimed Water Pipeline, Thurston County	$2.1 million	• Reduce wastewater discharge into Puget Sound • Improve water quality in Budd Inlet
2011	Septic Tank Elimination Project, Spokane County	N/A	• Transfer water treatment from septic system to water reclamation facility, reducing groundwater contamination
2011	Belfair Wastewater and Reclamation Facilities – Design and Construction, Mason County	N/A	• The project would remove septic tanks within the UGA while addressing water quality issues in Hood Canal.
2011	Freeland Sewer System Phase I, Island County	N/A	• The project would design a sewage collection system and reclaimed water plant for water reuse by aquifer recharge.

Sources: Washington State Department of Ecology 2010a, 2010b.

5.0. BENEFIT-COST ANALYSIS

Drawing from the benefits and costs described in the previous chapter, this chapter presents the present value of the benefits and costs for each strategy from the perspective of society at large. The present values of the benefits and costs are calculated through 2050 and discounted at an annual rate of 3 percent.

5.1 Redmond/Bear Creek Basin Brightwater Centralized Strategy

The Redmond/Bear Creek Basin Brightwater Centralized Strategy focuses on expanding reclaimed water service in the vicinity of the Brightwater Treatment Plant, including areas in and around the Cities of Woodinville and Redmond. WTD has identified 31 potential sources of demand for reclaimed water produced from this strategy across four general categories, summarized in Table 16. For the purpose of this analysis, it is assumed reclaimed water displaces potable water for all types of use except environmental enhancement.[9] As reclaimed water displaces demand for potable water, it is assumed potable water utilities reduce their withdrawals of water for potable use, allowing water to remain in streams and aquifers except when it is used to improve reliability for existing customers during drought conditions.[10]

[9] If the analysis assumes, instead, that reclaimed water satisfied otherwise unfulfilled demands (as is done for its use in environmental enhancement), the analysis would account directly for the benefits arising from the additional goods and services available to society with the strategy. This analysis, however, assumes reclaimed water itself does not produce any new goods and services compared to those produced with potable water under the baseline (except those produced through environmental enhancement). Instead, it allows for cost savings in the production of potable water, or for the displaced potable water to provide goods and services that otherwise would not be available to households and businesses.

[10] Alternative assumptions could be made for what the utility does with potable water supplies freed up by the availability of reclaimed water. A utility could, for example, sell the water to new users. This water would no longer be available to provide supply reliability and environmental benefits, but it would produce other benefits for society.

Table 16. Reclaimed Water Uses for the Brightwater Strategy

Type of Use	Annual Volume (MG)	Duration (Days) 7/12 mo.
Environmental Enhancement	2,810.50	365
Irrigation–Agricultural	80.85	153
Irrigation–Non-Agricultural (Total)	201.18	153
Cemetery	7.85	153
Commercial	1.44	153
Golf Course	60.08	153
School	26.64	153
Park	105.16	153
Commercial/Industrial (Total)	98.20	365
Industrial Cooling	22.24	365
Industrial Process	17.95	365
Industrial Wash Water	20.74	365
Industrial General	37.28	365
Total	**3,190.73**	

Source: King County 2012a

The environmental enhancement use involves applying water to new and existing wetlands, where it would flow downstream and augment instream flows. Three wetland enhancement application areas include locations near Crystal Lake, Cottage Lake, and Lake Sammamish. Application in these areas would create 26 acres of new wetlands and augment water levels in 23 acres of existing wetlands. Water applied in the wetlands would flow downstream through Cottage Lake Creek and Bear Creek into the Sammamish River, augmenting flows by about 12 cubic feet per second.

Reclaimed water produced by Brightwater's membrane bio-reactor treatment processes satisfies Class A reclaimed water requirements, and can be directly applied for non-potable consumptive uses. Because this strategy includes potential wetlands enhancement uses, additional tertiary nutrient removal treatment processes for phosphorus and possibly nitrogen may be required for reclaimed water flows delivered to areas where environmental wetland enhancements are proposed.

5.1.1 Benefits of the Brightwater Strategy

The Brightwater strategy would generate both direct and indirect benefits. Quantifiable direct benefits would materialize if the production and use of reclaimed water displaces the use of potable water that then increases the reliability of water supplies during future water shortages. Quantifiable indirect benefits would materialize if the application of reclaimed water to wetlands increases their productivity, or if water utilities reduce withdrawals of water from streams, resulting in increased instream flows. Table 17 shows these quantified benefits. Additional benefits likely would materialize under this strategy, but insufficient information currently exists to quantify them. Table 18 identifies these benefits and shows their relative importance, based on a qualitative assessment.

Table 17. Quantified Benefits of the Brightwater Strategy

Benefit[1]	Annual Value (Lower Estimate)	Annual Value (Higher Estimate)	Net Present Value[2] (Lower estimate)	Net Present Value[2] (Higher Estimate)
3.D.3 Avoided increases in groundwater pumping costs	$14,000	$23,000	$220,000	$360,000
3.D.5 Increased supply reliability (residential customer perspective)	$1,100,000	$4,200,000	$18,000,000	$66,000,000
3.E.2 Enhanced environmental restoration, wetland restoration	$600,000	$9,000,000	$470,000	$7,100,000
3.E.5 Increased instream flow	$43,000	$27,000,000	$680,000	$430,000,000
Total	$14,000	$23,000	$220,000	$360,000

Notes: [1] D=Direct Benefits, E=Environmental Benefits–Indirect, R=Recreational Benefits–Indirect, ES=Economic and Social Benefits–Indirect. The benefit identifier corresponds to benefits labels identified in the 2009 memorandum on benefits.

[2] Net present value represents the total present value of the benefits accrued over the planning horizon, discounted at an annual rate of 3 percent.

Table 18. Benefits Assessed Qualitatively for the Brightwater Strategy

Benefit[1]	Relative Importance[2]
3.D.7 Savings from using reclaimed water to avoid costs of developing/purchasing water supply to recharge an aquifer	2
4.D.1 Increased flexibility regarding disposition of treated effluent	2
3.E.6 Increased carbon sequestration and reduced greenhouse gas emissions	2
3.R.1 Increased instream, near-stream, and wetland recreation	1
3.R.2 Enhancement of green spaces for recreational use (e.g., golf courses, soccer fields, parks)	2
3.ES.2 Increased property values (adjacent to urban parks)	1
3.ES.3 Increased property values (adjacent to golf courses)	1
3.ES.5 Commercial salmon harvest	1
3.ES.6 Recreational salmon harvest	1
4.ES.1 Increased economic growth	1
4.ES.2 Increased ability for water projects to leverage other community projects	1
4.ES.3 Improved management of water resources	2
4.ES.4 Reinforced cultural/spiritual values	2
4.ES.5 Reinforced cultural values associated with a conservation ethic	2
4.ES.6 Enhanced aesthetic values	1
4.ES.10 Reductions in risk associated with climate change	2
4.ES.11 Increased public education	1
4.ES.12 Reduced risk of enforcement/litigation costs associated with water rights	1

Notes: [1] D=Direct Benefits, E=Environmental Benefits–Indirect, R=Recreational Benefits–Indirect, ES=Economic and Social Benefits–Indirect. The benefit identifier corresponds to benefits labels identified in the 2009 memorandum on benefits.

[2] Relative importance reflects qualitative assessment of the expected likelihood each benefit will materialize and its importance.

5.1.2 Costs of the Brightwater Strategy

The costs of the Brightwater strategy include quantified estimates of capital costs (including land acquisition and opportunity costs) and operation and maintenance (O&M) costs for production and distribution of reclaimed water. The quantified costs, shown in Table 19 also reflect the value of increased carbon dioxide emissions associated with the additional consumption of electricity to produce reclaimed water. Table 20 shows expected costs for which insufficient data exist to support monetary quantification. These costs assessed qualitatively primarily represent the capital and O&M costs customers would incur to receive reclaimed water and maintain infrastructure and institutional controls to manage the risks of using reclaimed water, as well as potential reductions in the value of recreational opportunities that might involve contact with reclaimed water.

Table 19. Quantified Costs of the Brightwater Strategy

Cost[1]	Annual Value (Lower Estimate)	Annual Value (Higher Estimate)	Net Present Value[2] (Lower estimate)	Net Present Value[2] (Higher Estimate)
3.D.1.a Capital costs for RW production	$28,000,000	$60,000,000	$24,000,000	$52,000,000
3.D.1.b Land acquisition costs for RW production	$700,000	$700,000	$0	$660,000
3.D.2 O&M costs for RW production	$1,000,000	$1,000,000	$16,000,000	$16,000,000
3.D.3.a Capital costs for RW distribution	$60,000,000	$130,000,000	$52,000,000	$110,000,000
3.D.3.b Land acquisition costs for RW distribution[3]	$140,000	$3,700,000	$130,000	$3,500,000
3.D.3.c Costs for wetland creation	$60,000	$900,000	$51,000	$780,000
3.D.4 O&M costs for RW distribution	$1,100,000	$1,100,000	$18,000,000	$18,000,000
3.D.5 Capital costs for customer retrofits and training	$760,000	$5,000,000	$600,000	$3,900,000
4.E.1 Environmental impacts of increased energy consumption	$80,000	$13,000,000	$1,300,000	$5,900,000
Total	$92,000,000	$220,000,000	$110,000,000	$210,000,000

Notes: [1] D=Direct Costs, E=Environmental Costs–Indirect, ES=Economic and Social Costs–Indirect. The cost identifier corresponds to cost labels identified in the 2009 memorandum on costs.

[2] Net present value represents the total present value of the benefits accrued over the planning horizon, discounted at an annual rate of 3 percent.

Table 20. Costs Assessed Qualitatively for the Brightwater Strategy

Cost[1]	Relative Importance[2]
3.D.11 Reduced customer water supply flexibility	Insufficient Information
4.E.4 Reduced water quality	1
4.R.1 Reduced value of recreational opportunities arising from potential stigma	1
3.H.1 Increased public health risk due to increased contact reclaimed water	Insufficient Information
4.ES.2 Reclaimed water production facilities externalities	Insufficient Information
4.ES.3 Inequitable regional access to reclaimed water	Insufficient Information

Notes: [1] D=Direct Costs, E=Environmental Costs–Indirect, ES=Economic and Social Costs–Indirect. The cost identifier corresponds to cost labels identified in the 2009 memorandum on costs.

[2] Relative importance reflects qualitative assessment of the expected likelihood each cost will materialize and its importance.

5.1.3 Comparison of Benefits and Costs of the Brightwater Strategy

Table 21 illustrates several ways to compare the quantified benefits to the quantified costs. The net present value reflects the quantified benefits and costs but does not capture the unquantifiable, yet important, benefits and costs. The counts of benefits and costs described qualitatively are listed by relative importance.

Table 21. Net Present Value of the Brightwater Strategy

Comparison Description	Estimate
Net Present Value: Higher Benefits to Lower Costs	$390,000,000
Net Present Value: Higher Benefits to Higher Costs	$290,000,000
Net Present Value: Lower Benefits to Lower Costs	$(91,000,000)
Net Present Value: Lower Benefits to Higher Costs	$(190,000,000)
Count of Benefits Described Qualitatively with Score of 2	9
Count of Benefits Described Qualitatively with Score of 1	10
Count of Costs Described Qualitatively with Score of 1	2
Count of Costs Described Qualitatively with Score of 2	0
Count of Costs for which Insufficient Information is Available to Assess	3

5.1.4 Omissions, Biases, and Uncertainties Associated with Benefits and Costs of the Brightwater Strategy

The description of the benefits and costs, both quantified and unquantified, in Chapter 4.0 highlights potential omissions, biases, and factors that contribute to uncertainty in whether and to what extent each benefit or cost may materialize.

5.2 Renton/Tukwila South Plant Centralized Strategy

The Renton/Tukwila South Plant Centralized Strategy focuses on expanding reclaimed water service in the vicinity of the South Treatment Plant, including areas in and around the Cities of Renton and Tukwila. WTD has identified 43 potential sources of demand, across three general categories, for reclaimed water produced from this strategy. These are summarized in Table 22. For the purpose of this analysis, it is assumed reclaimed water displaces potable water for all types of use except environmental enhancement.[11] As reclaimed water displaces demand for potable water, it is assumed potable water utilities reduce their withdrawals of water for potable use, allowing water to remain in streams and aquifers except when it is used to improve reliability for existing customers during drought conditions.[12]

Table 22. Reclaimed Water Uses for the South Plant Strategy

Type of Use	Annual Volume (MG)	Duration (Days/Year)
Environmental Enhancement	182.50	365
Irrigation–Non-Agricultural (Total)	236.41	153
Athletic Field	6.24	153
Commercial	16.56	153
Golf Course	109.94	153
Industrial	9.67	153
Other	0.64	153
Park	88.13	153
School	5.24	153
Commercial/Industrial (Total)	56.43	365
Cooling	0.62	365
Industrial Cooling	36.21	365
Industrial Wash Water	19.60	365
Total	**475.34**	

Source: King County 2012a

The environmental enhancement use involves applying water to new and existing wetlands on the south side of the Cedar River near Renton, where it would flow downstream and augment instream flows. Application in this area would create 16 acres of new wetlands. Water applied in the wetlands would flow downstream through the Cedar River, augmenting flows by about one cubic foot per second.

[11] If it is assumed, instead, that reclaimed water satisfied otherwise unfulfilled demands (as is done for its use in environmental enhancement), the analysis would account directly for the benefits arising from the additional goods and services available to society with the strategy. This analysis, however, assumes reclaimed water itself does not produce any new goods and services compared to those produced with potable water under the baseline (except those produced through environmental enhancement).

[12] Alternative assumptions could be made for what the utility does with potable water supplies freed up by the availability of reclaimed water. A utility could, for example, sell the water to new users. This water would no longer be available to provide supply reliability and environmental benefits, but it would produce other benefits for society.

Reclaimed water produced by South plant's activated sludge wastewater treatment and tertiary reclaimed water sand filter processes satisfies Class A reclaimed water requirements, and can be applied for non-potable consumptive uses directly. However, the sand filter has limited capacity to produce reclaimed water, and the system would require expansion or replacement to meet demands identified in the strategy area. Although one small wetlands enhancement use has been identified within the strategy area, no additional nutrient removal tertiary treatment beyond Class A standards is currently assumed for the South Plant reclaimed water strategy. Nutrient removal is not assumed for the South Plant strategy because the discharge is to a constructed beneficial use wetland. It is assumed that, due to the net increase in environmental function derived as a result of the discharge of reclaimed water, nutrient removal will not be required under current Washington state regulations.

5.2.1 Benefits of the South Plant Strategy

The South plant strategy would produce quantifiable direct benefits if the production and use of reclaimed water displaces the use of potable water that then increases the reliability of water supplies during future water shortages. Quantifiable indirect benefits would materialize if the application of reclaimed water to wetlands increases their productivity, if the use of reclaimed water reduces withdrawals of water from streams, resulting in increased instream flows, or if irrigation with reclaimed water reduces irrigators' fertilizer costs. Table 23 shows these quantified benefits. Additional benefits likely would materialize under this strategy, but insufficient information currently exists to quantify them. Table 24 identifies these benefits and shows the qualitative assessment of their relative importance.

Table 23. Quantified Benefits of the South Plant Strategy

Benefit[1]	Annual Value (Lower Estimate)	Annual Value (Higher Estimate)	Net Present Value[2] (Lower estimate)	Net Present Value[2] (Higher Estimate)
3.D.3 Avoided increases in groundwater pumping costs	$11,000	$18,000	$170,000	$280,000
3.D.5 Increased supply reliability (residential customer perspective)	$870,000	$3,200,000	$14,000,000	$51,000,000
3.E.2 Enhanced environmental restoration, wetland restoration	$370,000	$5,600,000	$290,000	$4,400,000
3.E.5 Increased instream flow	$4,400	$2,800,000	$70,000	$45,000,000
3.ES.4 Savings in fertilizer usage	$32,000	$32,000	$510,000	$510,000
Total	$1,300,000	$12,000,000	$15,000,000	$100,000,000

Notes: [1] D=Direct Benefits, E=Environmental Benefits–Indirect, R=Recreational Benefits–Indirect, ES=Economic and Social Benefits–Indirect. The benefit identifier corresponds to benefits labels identified in the 2009 memorandum on benefits.

[2] Net present value represents the total present value of the benefits accrued over the planning horizon, discounted at an annual rate of 3 percent.

Table 24. Benefits Assessed Qualitatively for the South Plant Strategy

Benefit[1]	Relative Importance[2]
3.D.7 Savings from using reclaimed water to avoid costs of developing/purchasing water supply to recharge an aquifer	2
4.D.1 Increased flexibility regarding disposition of treated effluent	2
3.E.6 Increased carbon sequestration and reduced greenhouse gas emissions	2
3.R.1 Increased instream, near-stream, and wetland recreation	1
3.R.2 Enhancement of green spaces for recreational use (e.g., golf courses, soccer fields, parks)	2
3.ES.2 Increased property values (adjacent to urban parks)	1
3.ES.3 Increased property values (adjacent to golf courses)	1
3.ES.5 Commercial salmon harvest	1
3.ES.6 Recreational salmon harvest	1
4.ES.1 Increased economic growth	1
4.ES.2 Increased ability for water projects to leverage other community projects	1
4.ES.3 Improved management of water resources	2
4.ES.4 Reinforced cultural/spiritual values	2
4.ES.5 Reinforced cultural values associated with a conservation ethic	2
4.ES.6 Enhanced aesthetic values	1
4.ES.10 Reductions in risk associated with climate change	2
4.ES.11 Increased public education	1
4.ES.12 Reduced risk of enforcement/litigation costs associated with water rights	1

Notes: [1] D=Direct Benefits, E=Environmental Benefits–Indirect, R=Recreational Benefits–Indirect, ES=Economic and Social Benefits–Indirect. The benefit identifier corresponds to benefits labels identified in the 2009 memorandum on benefits.

[2] Relative importance reflects qualitative assessment of the expected likelihood each benefit will materialize and its importance.

5.2.2 Costs of the South Plant Strategy

The costs of the South plant strategy include quantified estimates of capital costs (including land acquisition and opportunity costs) and operation and maintenance (O&M) costs for production and distribution of reclaimed water. The quantified costs, shown in Table 25 also reflect the value of increased carbon dioxide emissions associated with the additional consumption of electricity to produce reclaimed water. Table 26 shows expected costs for which insufficient data exist to support monetary quantification. These costs assessed qualitatively primarily represent the capital and O&M costs customers would incur to receive reclaimed water and maintain infrastructure and institutional controls to manage the risks of using reclaimed water, as well as potential reductions in the value of recreational opportunities that might involve contact with reclaimed water.

Table 25. Quantified Costs of the South Plant Strategy

Cost[1]	Annual Value (Lower Estimate)	Annual Value (Higher Estimate)	Net Present Value[2] (Lower estimate)	Net Present Value[2] (Higher Estimate)
3.D.1.a Capital costs for RW production	$6,200,000	$13,000,000	$5,300,000	$11,000,000
3.D.1.b Land acquisition costs for RW production	$450,000	$450,000	$0	$420,000
3.D.2 O&M costs for RW production	$260,000	$260,000	$4,100,000	$4,100,000
3.D.3.a Capital costs for RW distribution	$43,000,000	$92,000,000	$37,000,000	$79,000,000
3.D.3.b Land acquisition costs for RW distribution	$510,000	$1,300,000	$480,000	$1,200,000
3.D.3.c Costs for wetland creation	$37,000	$560,000	$32,000	$480,000
3.D.4 O&M costs for RW distribution	$510,000	$510,000	$8,100,000	$8,100,000
3.D.5 Capital costs for customer retrofits and training	$780,000	$6,400,000	$620,000	$5,000,000
4.E.1 Environmental impacts of increased energy consumption	$28,000	$4,500,000	$450,000	$2,000,000
Total	$52,000,000	$120,000,000	$56,000,000	$110,000,000

Notes: [1] D=Direct Costs, E=Environmental Costs–Indirect, ES=Economic and Social Costs–Indirect. The cost identifier corresponds to cost labels identified in the 2009 memorandum on costs.

[2] Net present value represents the total present value of the benefits accrued over the planning horizon, discounted at an annual rate of 3 percent.

Table 26. Costs Assessed Qualitatively for the South Plant Strategy

Cost[1]	Relative Importance[2]
3.D.11 Reduced customer water supply flexibility	Insufficient Information
4.R.1 Reduced value of recreational opportunities arising from potential stigma	1
3.H.1 Increased public health risk due to increased contact reclaimed water	Insufficient Information
4.ES.2 Reclaimed water production facilities externalities	Insufficient Information
4.ES.3 Inequitable regional access to reclaimed water	Insufficient Information

Notes: [1] D=Direct Costs, E=Environmental Costs–Indirect, ES=Economic and Social Costs–Indirect. The cost identifier corresponds to cost labels identified in the 2009 memorandum on costs.

[2] Relative importance reflects qualitative assessment of the expected likelihood each cost will materialize and its importance.

5.2.3 Comparison of Benefits and Costs of the South Plant Strategy

Table 27 illustrates several ways to compare the quantified benefits to the quantified costs. The net present value reflects the quantified benefits and costs but does not capture the unquantifiable, yet important, benefits and costs. The counts of benefits and costs described qualitatively are listed by relative importance.

Table 27. Net Present Value of the South Plant Strategy

Comparison Description	Estimate
Net Present Value: Higher Benefits to Lower Costs	$44,000,000
Net Present Value: Higher Benefits to Higher Costs	$(10,000,000)
Net Present Value: Lower Benefits to Lower Costs	$(41,000,000)
Net Present Value: Lower Benefits to Higher Costs	$(95,000,000)
Count of Benefits Described Qualitatively with Score of 2	3
Count of Benefits Described Qualitatively with Score of 1	13
Count of Costs Described Qualitatively with Score of 1	1
Count of Costs Described Qualitatively with Score of 2	0
County of Costs for which Insufficient Information is Available to Assess	3

5.2.4 Omissions, Biases, and Uncertainties Associated with Benefits and Costs of the South Plant Strategy

The description of the benefits and costs, both quantified and unquantified, in Chapter 4.0 highlights potential omissions, biases, and factors that contribute to uncertainty in whether and to what extent each beneit or cost may materialize.

5.3 Interbay Skimming Decentralized Strategy

The Interbay Skimming Decentralized Strategy would produce and distribute reclaimed water in the Interbay area of Seattle, between the Queen Anne and Magnolia neighborhoods. The service area for this strategy is a 1 mile radius surrounding a conceptual treatment plant site with a single distribution main. The Interbay strategy and other decentralized strategy areas are intended to represent opportunities for implementing smaller scale reclaimed water efforts subject to certain infrastructure limitations.

WTD has identified three potential sources of demand, across two general categories, for reclaimed water produced in this strategy, summarized in Table 28. For the purpose of this analysis, it is assumed reclaimed water displaces potable water for all types of use. As reclaimed water displaces demand for potable water, it is assumed potable water utilities reduce their withdrawals of water for potable use, allowing water to remain in streams and aquifers except when it is used to improve reliability for existing customers during drought conditions.[13] Reclaimed water produced by the Interbay skimming treatment plant would satisfy Class A reclaimed water requirements, and could be applied for non-potable consumptive uses directly.

[13] Alternative assumptions could be made for what the utility does with potable water supplies freed up by the availability of reclaimed water. A utility could, for example, sell the water to new users. This water would no longer be available to provide supply reliability and environmental benefits, but it would produce other benefits for society.

Table 28. Reclaimed Water Uses for the Interbay Strategy

Type of Use	Annual Volume (MG)	Duration (Days/Year)
Irrigation–Non-Agricultural (Total)	9.62	153
Golf Course	9.30	153
Park	0.32	153
Commercial/Industrial (Total)	24.81	365
Industrial Cooling	24.81	365
Total	**34.43**	

Source: King County 2012a

5.3.1 Benefits of the Interbay Strategy

The Interbay strategy would produce quantifiable direct benefits if the production and use of reclaimed water displaces the use of potable water that then increases the reliability of water supplies during future water shortages. Quantifiable indirect benefits would materialize if the use of reclaimed water reduces withdrawals of water from streams, resulting in increased instream flows, if the irrigation with reclaimed water reduces irrigators' fertilizer costs, or if the use of reclaimed water reduces electricity costs for businesses and local industry. Table 29 shows these quantified benefits. Additional benefits likely would materialize under this strategy, but insufficient information currently exists to quantify them. Table 30 identifies these benefits and shows the qualitative assessment of their relative importance.

Table 29. Quantified Benefits of the Interbay Strategy

Benefit[1]	Annual Value (Lower Estimate)	Annual Value (Higher Estimate)	Net Present Value[2] (Lower estimate)	Net Present Value[2] (Higher Estimate)
3.D.5 Increased supply reliability (residential customer perspective)	$100,000	$380,000	$1,600,000	$6,000,000
3.E.5 Increased instream flow	$400	$250,000	$6,300	$4,000,000
3.ES.4 Savings in fertilizer usage	$1,300	$1,300	$21,000	$21,000
3.ES.8 Avoided energy costs to businesses and local industry (electricity)	$4,400	$7,300	$70,000	$120,000
Total	$110,000	$640,000	$1,700,000	$10,000,000

Notes: [1] D=Direct Benefits, E=Environmental Benefits–Indirect, R=Recreational Benefits–Indirect, ES=Economic and Social Benefits–Indirect. The benefit identifier corresponds to benefits labels identified in the 2009 memorandum on benefits.

[2] Net present value represents the total present value of the benefits accrued over the planning horizon, discounted at an annual rate of 3 percent.

Table 30. Benefits Assessed Qualitatively for the Interbay Strategy

Benefit[1]	Relative Importance[2]
3.D.7 Savings from using reclaimed water to avoid costs of developing/purchasing water supply to recharge an aquifer	1
4.D.1 Increased flexibility regarding disposition of treated effluent	1
3.R.2 Enhancement of green spaces for recreational use (e.g., golf courses, soccer fields, parks)	1
3.ES.3 Increased property values (adjacent to golf courses)	1
4.ES.2 Increased ability for water projects to leverage other community projects	1
4.ES.3 Improved management of water resources	1
4.ES.5 Reinforced cultural values associated with a conservation ethic	1
4.ES.10 Reductions in risk associated with climate change	1
4.ES.11 Increased public education	1
4.ES.12 Reduced risk of enforcement/litigation costs associated with water rights	1

Notes: [1] D=Direct Benefits, E=Environmental Benefits–Indirect, R=Recreational Benefits–Indirect, ES=Economic and Social Benefits–Indirect. The benefit identifier corresponds to benefits labels identified in the 2009 memorandum on benefits.

[2] Relative importance reflects qualitative assessment of the expected likelihood each benefit will materialize and its importance.

5.3.2 Costs of the Interbay Strategy

The costs of the Interbay strategy include quantified estimates of capital costs (including land acquisition and opportunity costs) and operation and maintenance (O&M) costs for production and distribution of reclaimed water. The quantified costs, shown in Table 31 also reflect the value of increased carbon dioxide emissions associated with producing reclaimed water. Table 32 shows expected costs for which insufficient data exist to support monetary quantification. These costs assessed qualitatively primarily represent the capital and O&M costs customers would incur to receive reclaimed water and maintain infrastructure and the institutional controls to manage the risks of using reclaimed water.

Table 31. Quantified Costs of the Interbay Strategy

Cost[1]	Annual Value (Lower Estimate)	Annual Value (Higher Estimate)	Net Present Value[2] (Lower estimate)	Net Present Value[2] (Higher Estimate)
3.D.1.a Capital costs for RW production	$11,000,000	$24,000,000	$9,600,000	$20,000,000
3.D.1.b Land acquisition costs for RW production	$1,040,000	$1,000,000	$430,000	$980,000
3.D.2 O&M costs for RW production	$130,000	$130,000	$2,000,000	$2,000,000
3.D.3.a Capital costs for RW distribution	$2,600,000	$5,600,000	$2,200,000	$4,800,000
3.D.3.b Land acquisition costs for RW distribution	$1,300,000	$2,900,000	$1,200,000	$2,700,000
3.D.4 O&M costs for RW distribution	$110,000	$110,000	$1,800,000	$1,800,000
3.D.5 Capital costs for customer retrofits and training	$120,000	$750,000	$95,000	$590,000
4.E.1 Environmental impacts of increased energy consumption	$610	$100,000	$10,000	$45,000
Total	$16,000,000	$35,000,000	$17,000,000	$33,000,000

Notes: [1] D=Direct Costs, E=Environmental Costs–Indirect, ES=Economic and Social Costs–Indirect. The cost identifier corresponds to cost labels identified in the 2009 memorandum on costs.

[2] Net present value represents the total present value of the benefits accrued over the planning horizon, discounted at an annual rate of 3 percent.

Table 32. Costs Assessed Qualitatively for the Interbay Strategy

Cost[1]	Relative Importance[2]
3.D.11 Reduced customer water supply flexibility	Insufficient Information
4.R.1 Reduced value of recreational opportunities arising from potential stigma	1
3.H.1 Increased public health risk due to increased contact reclaimed water	Insufficient Information
4.ES.2 Reclaimed water production facilities externalities	Insufficient Information
4.ES.3 Inequitable regional access to reclaimed water	Insufficient Information

Notes: [1] D=Direct Costs, E=Environmental Costs–Indirect, ES=Economic and Social Costs–Indirect. The cost identifier corresponds to cost labels identified in the 2009 memorandum on costs.

[2] Relative importance reflects qualitative assessment of the expected likelihood each cost will materialize and its importance.

5.3.3 Comparison of Benefits and Costs of the Interbay Strategy

Table 33 illustrates several ways to compare the quantified benefits to the quantified costs. The net present value reflects the quantified benefits and costs but does not capture the unquantifiable, yet important, benefits and costs. The counts of the benefits and costs described qualitatively are listed by relative importance.

Table 33. Net Present Value of the Interbay Strategy

Comparison Description	Estimate
Net Present Value: Higher Benefits to Lower Costs	$(7,000,000)
Net Present Value: Higher Benefits to Higher Costs	$(23,000,000)
Net Present Value: Lower Benefits to Lower Costs	$(15,000,000)
Net Present Value: Lower Benefits to Higher Costs	$(31,000,000)
Count of Benefits Described Qualitatively with Score of 2	0
Count of Benefits Described Qualitatively with Score of 1	11
Count of Costs Described Qualitatively with Score of 1	1
Count of Costs Described Qualitatively with Score of 2	0
County of Costs for which Insufficient Information is Available to Assess	3

5.3.4 Omissions, Biases, and Uncertainties Associated with Benefits and Costs of the Interbay Strategy

The description of the benefits and costs, both quantified and unquantified, in Chapter 4.0 highlights potential omissions, biases, and factors that contribute to uncertainty in whether and to what extent each benefit or cost may materialize.

5.4 Duwamish Polishing Decentralized Strategy

The Duwamish Polishing Decentralized Strategy would produce and distribute reclaimed water on the west side of the Duwamish River in Seattle. The service area for this strategy is a 1 mile radius surrounding a conceptual treatment plant site with a single distribution main. The Duwamish strategy and other decentralized strategy areas are intended to represent opportunities for implementing smaller scale reclaimed water efforts subject to certain infrastructure limitations.

WTD has identified two potential sources of demand for reclaimed water produced in this strategy, across two general categories, summarized in Table 34. For the purpose of this analysis, it is assumed reclaimed water displaces potable water for all types of use. As reclaimed water displaces demand for potable water, it is assumed potable water utilities reduce their withdrawals of water for potable use, allowing water to remain in streams and aquifers except when it is used to improve reliability for existing customers during drought conditions.[14] Reclaimed water produced by the Duwamish polishing treatment plant would satisfy Class A reclaimed water requirements, and could be directly applied for non-potable consumptive uses.

[14] Alternative assumptions could be made for what the utility does with potable water supplies freed up by the availability of reclaimed water. A utility could, for example, sell the water to new users. This water would no longer be available to provide supply reliability and environmental benefits, but it would produce other benefits for society.

Table 34. Reclaimed Water Uses for the Duwamish Strategy

Type of Use	Annual Volume (MG)	Duration (Days/Year)
Irrigation–Non-Agricultural (Total)	50.23	153
Industrial	50.23	153
Commercial/Industrial (Total)	4.10	365
Industrial Cooling	4.10	365
Total	**54.33**	

Source: King County 2012a

5.4.1 Benefits of the Duwamish Strategy

The Duwamish strategy would produce quantifiable direct benefits if the production and use of reclaimed water displaces the use of potable water that then increases the reliability of water supplies during future water shortages. Quantifiable indirect benefits would materialize if the use of reclaimed water reduces withdrawals of water from streams, resulting in increased instream flows, or if the irrigation with reclaimed water reduces irrigators' fertilizer costs. Table 35 shows these quantified benefits. Additional benefits likely would materialize under this strategy, but insufficient information currently exists to quantify them. Table 36 identifies these benefits and shows the qualitative assessment of their relative importance.

Table 35. Quantified Benefits of the Duwamish Strategy

Benefit[1]	Annual Value (Lower Estimate)	Annual Value (Higher Estimate)	Net Present Value[2] (Lower estimate)	Net Present Value[2] (Higher Estimate)
3.D.3 Avoided increases in groundwater pumping costs	$0	$23,000	$0	$0
3.D.5 Increased supply reliability (residential customer perspective)	$160,000	$4,200,000	$2,600,000	$9,500,000
3.E.2 Enhanced environmental restoration, wetland restoration	$0	$9,000,000	$0	$0
3.E.5 Increased instream flow	$630	$27,000,000	$10,000	$6,400,000
3.ES.4 Savings in fertilizer usage	$6,800	$0	$110,000	$110,000
Total	$170,000	$40,000,000	$2,700,000	$16,000,000

Notes: [1] D=Direct Benefits, E=Environmental Benefits–Indirect, R=Recreational Benefits–Indirect, ES=Economic and Social Benefits–Indirect. The benefit identifier corresponds to benefits labels identified in the 2009 memorandum on benefits.

[2] Net present value represents the total present value of the benefits accrued over the planning horizon, discounted at an annual rate of 3 percent.

Table 36. Benefits Assessed Qualitatively for the Duwamish Strategy

Benefit[1]	Relative Importance[2]
3.D.7 Savings from using reclaimed water to avoid costs of developing/purchasing water supply to recharge an aquifer	1
4.D.1 Increased flexibility regarding disposition of treated effluent	1
4.ES.2 Increased ability for water projects to leverage other community projects	1
4.ES.3 Improved management of water resources	1
4.ES.5 Reinforced cultural values associated with a conservation ethic	1
4.ES.10 Reductions in risk associated with climate change	1
4.ES.11 Increased public education	1
4.ES.12 Reduced risk of enforcement/litigation costs associated with water rights	1

Notes: [1] D=Direct Benefits, E=Environmental Benefits–Indirect, R=Recreational Benefits–Indirect, ES=Economic and Social Benefits–Indirect. The benefit identifier corresponds to benefits labels identified in the 2009 memorandum on benefits.

[2] Relative importance reflects qualitative assessment of the expected likelihood each benefit will materialize and its importance.

5.4.2 Costs of the Duwamish Strategy

The costs of the Duwamish strategy include quantified estimates of capital costs (including land acquisition and opportunity costs) and operation and maintenance (O&M) costs for production and distribution of reclaimed water. The quantified costs, shown in Table 37, also reflect the value of increased carbon dioxide emissions associated with producing reclaimed water. Table 38 shows expected costs for which insufficient data exist to support monetary quantification. These costs assessed qualitatively primarily represent the capital and O&M costs customers would incur to receive reclaimed water, maintain infrastructure, and implement institutional controls to manage the risks of using reclaimed water.

Table 37. Quantified Costs of the Duwamish Strategy

Cost[1]	Annual Value (Lower Estimate)	Annual Value (Higher Estimate)	Net Present Value[2] (Lower estimate)	Net Present Value[2] (Higher Estimate)
3.D.1.a Capital costs for RW production	$1,800,000	$3,800,000	$1,500,000	$3,200,000
3.D.1.b Land acquisition costs for RW production	$130,000	$130,000	$130,000	$130,000
3.D.2 O&M costs for RW production	$38,000	$38,000	$610,000	$610,000
3.D.3.a Capital costs for RW distribution	$2,600,000	$5,600,000	$2,200,000	$4,800,000
3.D.3.b Land acquisition costs for RW distribution	$400,000	$680,000	$380,000	$650,000
3.D.4 O&M costs for RW distribution	$110,000	$110,000	$1,800,000	$1,800,000
3.D.5 Capital costs for customer retrofits and training	$110,000	$630,000	$87,000	$490,000
4.E.1 Environmental impacts of increased energy consumption	$890	$150,000	$15,000	$66,000
Total	$5,200,000	$11,000,000	$6,700,000	$12,000,000

Notes: [1] D=Direct Costs, E=Environmental Costs–Indirect, ES=Economic and Social Costs–Indirect. The cost identifier corresponds to cost labels identified in the 2009 memorandum on costs.

[2] Net present value represents the total present value of the benefits accrued over the planning horizon, discounted at an annual rate of 3 percent.

Table 38. Costs Assessed Qualitatively for the Duwamish Strategy

Cost[1]	Relative Importance[2]
3.D.11 Reduced customer water supply flexibility	Insufficient Information
3.H.1 Increased public health risk due to increased contact reclaimed water	Insufficient Information
4.ES.2 Reclaimed water production facilities externalities	Insufficient Information
4.ES.3 Inequitable regional access to reclaimed water	Insufficient Information

Notes: [1] D=Direct Costs, E=Environmental Costs–Indirect, ES=Economic and Social Costs–Indirect. The cost identifier corresponds to cost labels identified in the 2009 memorandum on costs.

[2] Relative importance reflects qualitative assessment of the expected likelihood each cost will materialize and its importance.

5.4.3 Comparison of Benefits to Costs of the Duwamish Strategy

Table 39 illustrates several ways to compare the quantified benefits to the quantified costs. The net present value reflects the quantified benefits and costs but does not capture the unquantifiable, yet important, benefits and costs. The counts of benefits and costs described qualitatively are listed by relative importance.

Table 39. Net Present Value of the Duwamish Polishing Decentralized Strategy

Comparison Description	Estimate
Net Present Value: Higher Benefits to Lower Costs	$9,300,000
Net Present Value: Higher Benefits to Higher Costs	$4,000,000
Net Present Value: Lower Benefits to Lower Costs	$(4,000,000)
Net Present Value: Lower Benefits to Higher Costs	$(9,300,000)
Count of Benefits Described Qualitatively with Score of 2	0
Count of Benefits Described Qualitatively with Score of 1	9
Count of Costs Described Qualitatively with Score of 1	0
Count of Costs Described Qualitatively with Score of 2	0
County of Costs for which Insufficient Information is Available to Assess	3

5.4.4 Omissions, Biases, and Uncertainties Associated with Benefits and Costs of the Duwamish Strategy

The description of the benefits and costs, both quantified and unquantified, in Chapter 4.0 highlights potential omissions, biases, and factors that contribute to uncertainty in whether and to what extent each benefit or cost may materialize.

5.5 Lower Green River Valley Skimming Decentralized Strategy

The Lower Green River Valley (LGRV) Skimming Decentralized Strategy would produce and distribute reclaimed water along the floor of the LGRV, including areas in and around the Cities of Kent and Auburn. The service area for this strategy is a 1 mile radius surrounding a conceptual treatment plant site with a single distribution main.

WTD has identified one potential source of demand for reclaimed water produced in this strategy, described in Table 40. For the purpose of this analysis, it is assumed reclaimed water displaces potable water for all types of use. As reclaimed water displaces demand for potable water, it is assumed potable water utilities reduce their withdrawals of water for potable use, allowing water to remain in streams and aquifers except when it is used to improve reliability for existing customers during drought conditions.[15] Reclaimed water produced by the LGRV skimming treatment plant would satisfy Class A reclaimed water requirements, and could be applied for non-potable consumptive uses directly.

[15] Alternative assumptions could be made for what the utility does with potable water supplies freed up by the availability of reclaimed water. A utility could, for example, sell the water to new users. This water would no longer be available to provide supply reliability and environmental benefits, but it would produce other benefits for society.

Table 40. Reclaimed Water Uses for the LGRV Strategy

Type of Use	Annual Volume (MG)	Duration (Days/Year)
Irrigation–Agricultural	87.83	153
Total	**87.83**	

Source: King County 2012a

5.5.1 Benefits of the LGRV Strategy

The LGRV strategy would produce quantifiable direct benefits if the production and use of reclaimed water results in reduced groundwater pumping costs or displaces the use of potable water that then increases the reliability of water supplies during future water shortages. Quantifiable indirect benefits would materialize if the use of reclaimed water reduces withdrawals of water from streams, resulting in increased instream flows, or if the irrigation with reclaimed water reduces irrigators' fertilizer costs. Table 41 shows these quantified benefits. Additional benefits likely would materialize under this strategy, but insufficient information currently exists to quantify them. Table 42 identifies these benefits and shows the qualitative assessment of their relative importance.

Table 41. Quantified Benefits of the LGRV Strategy

Benefit[1]	Annual Value (Lower Estimate)	Annual Value (Higher Estimate)	Net Present Value[2] (Lower estimate)	Net Present Value[2] (Higher Estimate)
3.D.3 Avoided increases in groundwater pumping costs	$6,000	$11,000	$100,000	$170,000
3.ES.4 Savings in fertilizer usage	$12,000	$12,000	$190,000	$190,000
Total	$18,000	$23,000	$290,000	$360,000

Notes: [1] D=Direct Benefits, E=Environmental Benefits–Indirect, R=Recreational Benefits–Indirect, ES=Economic and Social Benefits–Indirect. The benefit identifier corresponds to benefits labels identified in the 2009 memorandum on benefits.

[2] Net present value represents the total present value of the benefits accrued over the planning horizon, discounted at an annual rate of 3 percent.

Table 42. Benefits Assessed Qualitatively for the LGRV Strategy

Benefit[1]	Relative Importance[2]
3.D.7 Savings from using reclaimed water to avoid costs of developing/purchasing water supply to recharge an aquifer	1
4.D.1 Increased flexibility regarding disposition of treated effluent	1
4.ES.2 Increased ability for water projects to leverage other community projects	1
4.ES.3 Improved management of water resources	1
4.ES.5 Reinforced cultural values associated with a conservation ethic	1
4.ES.7 Increased agricultural production	1
4.ES.8 Increased reliability of water supplies for agricultural irrigation	1
4.ES.10 Reductions in risk associated with climate change	1
4.ES.11 Increased public education	1
4.ES.12 Reduced risk of enforcement/litigation costs associated with water rights	1

Notes: [1] D=Direct Benefits, E=Environmental Benefits–Indirect, R=Recreational Benefits–Indirect, ES=Economic and Social Benefits–Indirect. The benefit identifier corresponds to benefits labels identified in the 2009 memorandum on benefits.

[2] Relative importance reflects qualitative assessment of the expected likelihood each benefit will materialize and its importance.

5.5.2 Costs of the LGRV Strategy

The costs of the LGRV strategy include quantified estimates of capital costs (including land acquisition and opportunity costs) and operation and maintenance (O&M) costs for production and distribution of reclaimed water. The quantified costs, shown in Table 43, also reflect the value of increased carbon dioxide emissions associated with producing reclaimed water. Table 44 shows expected costs for which insufficient data exist to support monetary quantification. These costs assessed qualitatively primarily represent the capital and O&M costs customers would incur to receive reclaimed water, maintain infrastructure, and implement institutional controls to manage the risks of using reclaimed water.

Table 43. Quantified Costs of the LGRV Strategy

Cost[1]	Annual Value (Lower Estimate)	Annual Value (Higher Estimate)	Net Present Value[2] (Lower estimate)	Net Present Value[2] (Higher Estimate)
3.D.1.a Capital costs for RW production	$11,000,000	$24,000,000	$9,600,000	$20,000,000
3.D.1.b Land acquisition costs for RW production	$99,000	$99,000	$90,000	$94,000
3.D.2 O&M costs for RW production	$140,000	$140,000	$2,200,000	$2,200,000
3.D.3.a Capital costs for RW distribution	$1,700,000	$3,600,000	$1,400,000	$3,100,000
3.D.3.b Land acquisition costs for RW distribution	$280,000	$380,000	$260,000	$360,000
3.D.4 O&M costs for RW distribution	$100,000	$100,000	$1,600,000	$1,600,000
3.D.5 Capital costs for customer retrofits and training	$10,000	$130,000	$7,900	$99,000
3.E.1 Environmental impacts of increased energy consumption	$890	$150,000	$15,000	$66,000
Total	$13,000,000	$29,000,000	$15,000,000	$28,000,000

Notes: [1] D=Direct Costs, E=Environmental Costs–Indirect, ES=Economic and Social Costs–Indirect. The cost identifier corresponds to cost labels identified in the 2009 memorandum on costs.

[2] Net present value represents the total present value of the benefits accrued over the planning horizon, discounted at an annual rate of 3 percent.

Table 44. Costs Assessed Qualitatively for the LGRV Strategy

Cost[1]	Relative Importance[2]
3.D.11 Reduced customer water supply flexibility	Insufficient Information
3.H.1 Increased public health risk due to increased contact reclaimed water	Insufficient Information
4.ES.2 Reclaimed water production facilities externalities	Insufficient Information
4.ES.3 Inequitable regional access to reclaimed water	Insufficient Information

Notes: [1] D=Direct Costs, E=Environmental Costs–Indirect, ES=Economic and Social Costs–Indirect. The cost identifier corresponds to cost labels identified in the 2009 memorandum on costs.

[2] Relative importance reflects qualitative assessment of the expected likelihood each cost will materialize and its importance.

5.5.3 Comparison of Benefits and Costs of the LGRV Strategy

Table 45 illustrates several ways to compare the quantified benefits to the quantified costs. The net present value reflects the quantified benefits and costs but does not capture the unquantifiable, yet important, benefits and costs. The counts of benefits and costs described qualitatively are listed by relative importance.

Table 45. Net Present Value of the LGRV Strategy

Comparison Description	Estimate
Net Present Value: Higher Benefits to Lower Costs	$(15,000,000)
Net Present Value: Higher Benefits to Higher Costs	$(28,000,000)
Net Present Value: Lower Benefits to Lower Costs	$(15,000,000)
Net Present Value: Lower Benefits to Higher Costs	$(28,000,000)
Count of Benefits Described Qualitatively with Score of 2	0
Count of Benefits Described Qualitatively with Score of 1	11
Count of Costs Described Qualitatively with Score of 1	0
Count of Costs Described Qualitatively with Score of 2	0
County of Costs for which Insufficient Information is Available to Assess	3

5.5.4 Omissions, Biases, and Uncertainties Associated with Benefits and Costs of the LGRV Strategy

The description of the benefits and costs, both quantified and unquantified, in Chapter 4.0 highlights potential omissions, biases, and factors that contribute to uncertainty in whether and to what extent each benefit or cost may materialize.

5.6 Summary and Discussion of Results

The review of benefits and costs for each strategy in this report reveals a wide range of potential benefits and costs across the three reclaimed water strategies, some of which can be quantified but many of which cannot, given currently available information. Table 46 summarizes the net present value of the quantified benefits and costs and the benefits and costs described qualitatively.

Table 46. Summary of Benefit-Cost Analysis Results

	Brightwater Centralized Strategy	South Plant Centralized Strategy	Interbay Skimming Decentralized Strategy	Duwamish Polishing Decentralized Strategy	Lower Green River Valley Decentralized Strategy
Net Present Value of Quantified Benefits and Costs					
Higher Benefits to Lower Costs	$390,000,000	$44,000,000	$(7,000,000)	$9,300,000	$(15,000,000)
Higher Benefits to Higher Costs	$290,000,000	$(10,000,000)	$(23,000,000)	$4,000,000	$(28,000,000)
Lower Benefits to Lower Costs	$(91,000,000)	$(41,000,000)	$(15,000,000)	$(4,000,000)	$(15,000,000)
Lower Benefits to Higher Costs	$(190,000,000)	$(95,000,000)	$(31,000,000)	$(9,300,000)	$(28,000,000)
Count of Benefits Described Qualitatively					
Score of 2	9	3	0	0	0
Score of 1	10	13	11	9	11
Insufficient Information	0	0	0	0	0
Count of Costs Described Qualitatively					
Score of 2	0	0	0	0	0
Score of 1	2	1	1	0	0
Insufficient Information	3	3	3	3	3

In general, the strategies with higher production of reclaimed water have higher quantified costs and benefits. This relationship extends into the qualitatively-described benefits as well.

The top of the table compares the high and low estimates of the quantifiable benefits with the high and low estimates of the quantified costs. The Brightwater strategy, followed by the South plant strategy, has the highest potential net benefits (high quantified benefits minus low quantified costs) and the greatest potential net costs (low quantified benefits minus high quantified costs). The analogous numbers for the decentralized strategies show the Duwamish strategy has the highest potential net quantified benefits, the Interbay strategy has the highest potential net quantified costs, and the LGRV strategy has the lowest potential net quantified benefits.

The results of the benefit-cost analysis suggest that uncertainty in the costs and benefits plays a very important role in identifying the economically best strategy from the perspective of society as a whole. A review of the uncertainty drivers across the quantified and unquantified effects reveals that, in general, increasing population growth, environmental degradation, water scarcity, and exogenous forces, such as climate change, will tend to increase the potential net benefits of each strategy. While considerable science suggests such trends are likely, it is difficult to directly quantify the probabilities in ways that allow their incorporation into the quantitative measures of net benefits. Consequently, to the extent that these trends come to pass, the most active strategies would have the greatest net benefits.

The wide range of benefits, and their potential overlap, also makes full specification of potential benefits difficult. For example, the Brightwater strategy shows a wide range of potential quantified and unquantified benefits, but currently available information does not allow careful measurement that yields complete estimation of their value without double counting. The full set of identifiable benefits and the best means to quantify them do not easily provide mutually exclusive estimations, since no readily identifiable set of mutually exclusive benefits exists that would collectively cover (exhaust) the full set of benefits. Consequently, avoiding double counting requires excluding some benefits from the quantified analysis. The result is that the strategies that potentially provide the widest range of benefits also likely experience the greatest underestimation of quantifiable benefits in order to avoid double counting.

Additional uncertainty arises from the incomplete consideration, given current information about the strategies, of the potential distribution of benefits and costs. For example, the benefits of consumptive uses of reclaimed water can include lower rates for end consumers, lower production costs for commercial users, lower production costs for water suppliers, and greater water availability for all. Available data on market prices and production costs, though, do not allow isolation of the marginal gains to different groups in cost savings, which economists call consumer surplus, and production savings, called producer surplus. This situation results partly from uncertainty regarding appropriate pricing for reclaimed water. Therefore, the estimates of benefits and cost savings by producers and consumers of reclaimed water and potable water are not likely to completely cover all savings (surplus) value in order to avoid double counting. Again, these circumstances support the conclusion that the analysis likely underestimates the total benefits for the strategies that would provide the greatest potential water supply effects: Brightwater, followed by South plant.

6.0. REFERENCES

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