An Economic Analysis of the North Seattle Reclaimed Water Project

Seattle Public Utilities

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Executive Summary

The City of Seattle will soon have an opportunity to provide reclaimed water to large irrigators and other potential users of non-potable water in the northern half of its retail water service area. King County, the regional provider of wastewater treatment, is currently constructing the Brightwater Reclaimed Water Backbone Project which is designed to bring reclaimed water from the new Brightwater Treatment Plant to a portal about one mile from the northeast corner of Seattle's retail water service area. Essentially all wastewater at the plant will be treated to reclaimed water standards whether it is used as reclaimed water or simply discharged into Puget Sound. The County intends to be the wholesale supplier of reclaimed water with water utilities responsible for constructing distribution infrastructure and providing retail service between the Backbone and potential customers. Therefore, Seattle Public Utilities (SPU) has conducted an economic analysis to determine whether it should take advantage of this opportunity to connect to the Backbone. The overall conclusion of the analysis is that the proposed North Seattle Reclaimed Water Project would not be a sound investment for the region due to high costs, a low level of benefits, and the availability of much lower-cost alternatives for achieving comparable benefits.

The analysis begins by identifying what the benefits of a North Seattle reclaimed water project might be. Overall, six general types of potential benefits to be gained from reclaimed water in this region are identified. These fall into two broad categories: water supply and environmental.

<u>Water Supply</u>: Supply benefits can be further divided into three subcategories:

- Quantity – In areas where existing supplies are insufficient to meet current and/or anticipated demand, reclaimed water may be a cost-effective and sustainable source of additional supply.
- Reliability – If reliability of supply is an issue, reclaimed water can supplement existing water sources thereby improving their current and future reliability.
- Cost – Where existing potable supplies have high operating costs, reclaimed water may be a more cost-effective source of non-potable water.

<u>Environmental:</u> There are also three basic subcategories of potential environmental benefits from reclaimed water:

- "Upstream" effects – Substituting reclaimed water for potable water from other sources can improve environmental conditions in the watersheds from which the potable water is extracted. Depending on the source of supply, this can result in less depletion of aquifers, reduced salt water intrusion, increased stream flows, expanded wetlands, improved habitat conditions, etc.
- "Downstream" effects – By diverting treated effluent to land application, the use of reclaimed water can reduce effluent flows and the discharge of pollutants to receiving waters leading to improved water quality and habitat conditions.
- "Direct" effects – Reclaimed water can also be used directly to recharge aquifers, augment stream flows, or restore wetlands.

One of these potential benefits, direct environmental effects, was dropped after initial consideration. While direct stream augmentation may benefit a stream by increasing base flows, without additional treatment it would also be expected to degrade water quality in fresh-water streams and lakes due to remaining concentrations of phosphorous and other nutrients. Because of this and the lack of known sites in the North Seattle area for groundwater recharge and wetlands restoration, no additional analysis of direct environmental benefits as a potential benefit was undertaken. The remaining five benefit types were evaluated further as potential drivers for the North Seattle Project:

1. Augmenting the available supply for the Seattle regional water system
2. Contributing to supply reliability for the Seattle regional water system
3. Avoiding some variable costs of providing potable water
4. Providing "upstream" environmental benefits to both regional and local source watersheds by diverting/pumping less water from them
5. Providing "downstream" environmental benefits to Puget Sound by reducing the volume of treated effluent, and therefore the amount of pollutants, discharged into it

Market Analysis:

The greater the demand for reclaimed water, the greater the potential benefits. Therefore, the first step in quantifying both the benefits and costs of the North Seattle Project was to assess the demand for reclaimed water in the study area. The area that could be served by the North Seattle Project includes all of the City of Shoreline and north Seattle as far south as the University of Washington. In total, 60 potential reclaimed water customers were identified for further analysis. The different types of customers are summarized in the table below:

Golf Courses	4
Cemeteries	7
Parks	19
Schools	23
Other	7
TOTAL	60

There are two kinds of potential reclaimed water customers in the study area: those who currently obtain their water from SPU or the Shoreline Water District and those with their own source of non-potable water. All the golf courses and most of the cemeteries have their own source of non-potable water. All the parks and schools plus several of the cemeteries use municipal water for their irrigation needs.

Total potential demand of these customers was estimated at 314 million gallons per year with almost all of it, 309 MG, occurring in the 6 month irrigation season. Expressed in millions of gallons per day, potential irrigation season demand was estimated at about 1.7 mgd with 1 mgd of that used by the seven self-supplied irrigators. Six of the municipally-supplied customers also have some demand for non-potable water during the off-peak season amounting to 0.03 mgd.

Project Costs:

Full life-cycle costs of the North Seattle Project were identified and, to the extent possible, quantified. Included were capital and O&M costs for the City of Seattle and King County, as well as customer costs and environmental/social costs and risks. The preliminary estimate of capital costs is $87 million. Annual operating costs include those for Seattle's share of disinfection and pressurizing the Backbone, pressurizing the distribution system, and the estimated cost to society of associated CO_2 emissions. These costs total $750,000 per year. Their present value over a 50 year time horizon discounted at 2.5% is $21 million. The estimated total monetized present value cost of the project is $108.6 million.

Benefits:

Each of the five benefit types was described in detail and quantified to the extent possible. Three of the benefit types are mutually exclusive and so are considered together.

Augmenting Existing Supply/Enhancing Supply Reliability/Improving Environmental Conditions in Regional Source Watersheds

Based on the market analysis, the North Seattle Project could reduce demand from Seattle's regional supply system by as much as 0.69 mgd over an irrigation season. This reduction in demand could be:

- made available to augment existing supplies and help meet future increases in demand, or
- kept in storage to enhance supply reliability, or
- released from storage to increase flows in Seattle's source rivers, thereby improving instream fish habitat and other environmental conditions.

However, it couldn't provide all these benefits at the same time. If the water freed up by substituting reclaimed water is used to enhance supply reliability, it's not available to increase streamflows or to meet additional demand. Similarly, if the water is left in the source rivers, it can't be used to meet additional demand or improve supply reliability.

Relative to SPU's total water supply, 0.69 mgd is a very small, almost imperceptible quantity. Alone, it would not add to supply or improve reliability in a detectable way. However, as part of a portfolio of measures that together produced a significant reduction in demand, the North Seattle Project could be seen as contributing to an increase in supply or reliability. No attempt is made to put a dollar value on this. Rather, it is quantified in physical terms only, i.e., whatever supply or reliability benefit is associated with a 0.69 mgd reduction in irrigation-season demand.

Relative to dry season flows in the Cedar and Tolt rivers which provide Seattle's water, 0.69 mgd is an even smaller quantity. An assessment of the potential effects of the North Seattle Project on these rivers found that an additional 0.69 mgd might produce increases in minimum stream flows in the range of 0.1% to 1.3%. This translates to even smaller increases in minimum stream depths ranging from 0.01 to 0.07 inches or in percentage terms, 0.04% to 0.24%. The analysis suggests that the North Seattle Project would result in exceedingly small changes in annual mean stream flow, monthly average minimum stream flow, and monthly average minimum water elevation. Therefore, the environmental impacts of the project on the Cedar and South Fork Tolt rivers would be difficult to detect.

Avoiding Variable Cost of Providing Potable Water: By reducing the use of potable water, the North Seattle Project would provide a benefit by reducing the variable costs associated with treating and pumping the water. The variable cost of providing potable water from SPU is about $0.09 per hundred cubic feet (ccf). The variable cost for irrigators with their own sources is estimated at $0.12 per ccf. Both of these estimates include the environmental cost of greenhouse gas emissions associated with the power required for pumping. Total avoided costs work out to be $31,000 per year with a present value of about $880,000 (over 50 years with a 2.5% discount rate).

Improving Environmental Conditions in Local Source Watersheds: To the extent that current sources of potable water in the project area impose negative environmental impacts on their source watersheds, reducing the demand for potable water by substituting reclaimed water would provide environmental benefits. Benefits to SPU's regional system watersheds were analyzed separately from the benefits to local source watersheds in the study area.

The seven potential reclaimed water customers in the North Seattle/Shoreline area that irrigate using their own wells or surface water diversions may have an impact on dry season flows in local streams. By providing reclaimed water for irrigation, the project could eliminate the need for surface and groundwater withdrawals by self-supplied irrigators (SSIs) and leave more water available to the local watershed ecosystems.

A consultant was engaged to assess the potential environmental benefits of providing reclaimed water to the seven potential reclaimed water customers in the North Seattle/Shoreline area that irrigate using their own wells or surface water diversions. The consultant identified three major watersheds that might be affected by self-supplied irrigators who together withdraw about 1.0 mgd. The impact of eliminating water withdrawals by the SSIs was analyzed to the extent possible given severe data constraints. The consultant concluded that there could be some baseflow-related environmental benefits associated with supplying reclaimed water to SSIs in two of the three watersheds. The largest SSI with 0.3 mgd of irrigation demand was located in the watershed thought to derive no benefit from a reduction in groundwater withdrawals. Therefore, some environmental benefit was assumed to be associated with providing a substitute source of water to 6 of the 7 SSIs with combined demand of about 0.7 mgd. No attempt was made to assign a dollar value to this benefit.

Improving Environmental Conditions in Puget Sound: An array of contaminants from a variety of sources and transport mechanisms add a mix of pollutants that affects Puget Sound water quality. One of these sources is treated wastewater. The average daily flow from all wastewater treatment facilities discharging to Puget Sound is estimated to be about 475 mgd. Of this, more than 40% comes from King County's two regional treatment plants. The total average daily discharge from these two plants is about 200 mgd.

One of the primary benefits cited for the use of reclaimed water in western Washington is its positive impact on water quality in Puget Sound. By diverting for use on land what would otherwise be advanced secondary-treated effluent discharged to the Sound, the North Seattle Project would reduce the discharge of pollutants to Puget Sound. Potential demand for the North Seattle reclaimed water project is estimated at about 314 million gallons per year or 0.86 mgd.

Using this volume of reclaimed water would keep about 3.1 metric tons of nitrogen, 26 billion Colony Forming Units (CFU) of fecal coliform, and 2.4 metric tons each of Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS) out of the Sound each year. This represents about 0.04% to 0.05% of the total amount of these pollutants currently discharged from King County's existing treatment plants.

The benefits of the North Seattle Project can be summarized as follows:

- An unquantified but minimal benefit to the Seattle regional water supply system associated with reducing irrigation season demand from the system by 0.69 mgd. This benefit could take the form of increased supply, reliability, or streamflows in the source rivers.
- An unquantified but small environmental benefit to several urban watersheds associated with reducing the withdrawals of six of the seven major self-supplied irrigators by a total of 0.7 mgd.
- The avoidance of potable water variable costs with a present value of $880,000
- The withholding of 3.1 metric tons of nitrogen, 26 billion CFU of fecal coliform, and 2.4 metric tons each of BOD and TSS annually from being discharged into Puget Sound

Project Alternatives:

A number of alternatives to the North Seattle Project were considered that provide one or more of the five benefits summarized above. These alternatives include:

- installing natural drainage systems in North Seattle
- switching self-supplied irrigators from their own sources to Seattle municipal water
- intensifying existing water conservation programs
- reducing the minimum drawdown level for the Tolt reservoir to increase water supply and reliability
- improving the level of treatment at existing wastewater treatment plants

Cost-Effectiveness Analysis:

Cost-effectiveness analysis involves specifying a set of benefits or level of service, then comparing the costs of various alternatives that can deliver those benefits. The alternative with the lowest life-cycle costs is the most cost-effective. This can be a helpful shortcut when the benefits of a project are difficult to quantify in dollar terms, as is the case here, but the options under consideration provide the same or at least similar benefits. The option having the lowest present value cost becomes the preferred option as long as it can be convincingly argued that the benefits, though unquantified, clearly outweigh the cost of the least cost option.

None of the alternatives considered individually provide all the benefit types that have been ascribed to the North Seattle Project. Therefore, several of them were combined to produce a bundled option that covers all the benefits and is directly comparable to the North Seattle Project. The bundled alternative consists of three components:

- Providing six of the seven self-supplied irrigators with 0.7 mgd of Seattle municipal water over the irrigation season, eliminating their withdrawals from local watersheds.

- Offsetting the demand of the six new irrigation customers plus all the potential reclaimed water customers that currently use Seattle municipal water by increasing Seattle's investment in water conservation enough to achieve 1.4 mgd in conservation savings over and above what's already planned.
- Installing a 1 mgd Membrane Bioreactor (MBR) facility at the South treatment plant in Renton to reduce pollutant discharge to Puget Sound.

Switching the six self-supplied irrigators to Seattle municipal water would involve new service and meter installations, costing less than $50,000 for all six. This would achieve the identical benefit to local watersheds as the North Seattle Project by providing an alternative source of supply, allowing these irrigators to stop using their own supplies. However, this would increase peak season demand on Seattle's regional supply system by 0.7 mgd. Since the North Seattle Project would *reduce* peak season demand on the Seattle system by 0.69 mgd, the bundled option must reduce demand or increase supply capacity by at least 1.4 mgd in order to provide equivalent reliability and environmental benefits as the North Seattle Project.

Intensifying SPU's existing conservation program could save an additional 1.4 mgd of water demand. Ramping up rebate levels on high efficiency fixtures and appliances enough to achieve 1.4 mgd in conservation savings over and above what's already planned is estimated to cost up to $310,000 per year over a period of 20 years. Assuming average measure lives of 20 years, the program could be run continuously to preserve the savings indefinitely. In present value terms, that would be $8.8 million. This would produce a *net* reduction in municipal demand of 0.7 mgd, providing the identical supply, reliability, or environmental benefit to the SPU supply system as the North Seattle Project. It would also avoid the same $880,000 in variable water costs from current sources.

An alternative means of achieving the Puget Sound benefit of reducing the discharge of pollutants is to improve the level of treatment at existing King County treatment plants. A facility to produce Class A reclaimed water could be installed at the South treatment plant. This would take a portion of the secondary-treated effluent, treat it to reclaimed water standards using Membrane Bioreactor (MBR) technology, and then return it to the effluent stream being discharged to the Sound. This would significantly reduce the concentration of priority pollutants in the treated effluent, on average by a factor of 11.

The analysis made use of a model for estimating the cost of producing reclaimed water developed by a consultant for King County. The smallest facility for producing Class A water from secondary effluent analyzed by the model has a capacity of 1 mgd. Estimated capital costs would be $14 million with O&M costs of about $360,000 per year Discounted at 2.5% over 50 years, the present value cost of the facility would be about $18.3 million.

The impact of this higher level of treatment on 1 mgd of effluent would be to remove 43.4 metric tons of nitrogen, 18.0 metric tons of BOD, 20.7 metric tons of TSS, and 304 billion CFU of fecal coliform from the effluent stream. These reductions are 8 to 14 times larger than what would be removed by the North Seattle Project.

Table 1: Comparative Effectiveness for Removing Priority Pollutants from Puget Sound

	Units	Reduction in Discharge to Puget Sound: North Seattle Project	Reduction in Discharge to Puget Sound: 1 mgd MBR Treatment	Factor by which MBR Reduction Exceeds North Seattle Project
Total Nitrogen	Metric Tons/yr	3.1	43.4	14
BOD	Metric Tons/yr	2.4	18.0	8
TSS	Metric Tons/yr	2.4	20.7	9
Fecal Coliform	BCFU*/yr	26	304	12

* Billions of Colony Forming Units

As shown in Table 2 below, the North Seattle Project has an estimated present value cost of $109 million. The bundled alternative would have a total cost of about $27 million: $46,000 to switch self-supplied irrigators to Seattle municipal water, $8.8 million for intensified conservation, and $18.3 million for the MBR treatment facility. This is one fourth the cost of the North Seattle Project. However, as explained above, the MBR facility would remove about 8 to 14 times more pollutants (11 times on average) than the North Seattle Project. To make an apples-to-apples comparison of benefits, the cost of the MBR plant can be divided by 11 to represent that portion of the plant associated with removing an equivalent amount of pollutants from Puget Sound as the North Seattle Project. Adjusting costs in this way, $1.7 million of the MBR plant costs are allocated to the bundled option. As shown in Table 2 below, this implies a bundled option cost of $10.5 million for providing benefits equivalent to the North Seattle Project.

Table 2: Total and Adjusted Present Value Cost for Components of the Bundled Alternative

Individual Alternatives		Present Value Cost	Benefits Relative to North Seattle Project	Cost for Equivalent Benefits*
1	Switch SSIs to Seattle Water	$45,900	Same	$45,900
2	Intensify Conservation Program	$8,800,000	Same	$8,800,000
3	1 MGD MBR Facility at South Plant	$18,260,000	8-14 times greater*	$1,660,000
Total PV Cost for Bundled Alternative		$27,105,900	-	$10,505,900
PV Cost for North Seattle Project		$108,562,922	-	$108,562,922
% of North Seattle Project Cost		25%	-	10%

* For ease of exposition, an average of 11 times greater is used to calculate the cost for equivalent benefits.

Conclusions:

- At $109 million, the North Seattle Reclaimed Water project is not a cost-effective means of achieving its identified benefits. The bundled alternative would generate the same level of benefits for a fraction of the North Seattle Project's cost.
- A sensitivity analysis was conducted which found the overall conclusions of the analysis to be unaffected by major changes to key estimates and assumptions.

- An analysis of the project's distributional implications determined that, since the project's most significant benefits extend well beyond Seattle's retail service area, potential reclaimed water customers and Seattle/Shoreline water ratepayers could end up paying a larger proportion of project costs than their share of benefits.

It is therefore recommended that SPU not proceed with the North Seattle Reclaimed Water Project. Before recommending the bundled option for implementation, a fuller analysis of the environmental problems facing the Puget Sound basin and the available alternatives for addressing them would have to be undertaken.

Introduction

The concept of reclaimed water makes a lot of sense. Rather than using fresh water just once and then treating it so that it can be disposed of, it can be treated to a higher standard and used again. Reclaimed water[1] is often an important part of the solution where water supply is limited, demand is growing, and new supply is expensive or non-existent. Many areas of the world with high water stress conditions (especially the Middle East, North Africa, some parts of Europe, Asia and Australia) have turned to reclaimed water to augment supplies. The same is true in the regions of the U.S., such as in California, Nevada, Arizona, Texas and Florida, with serious water supply and/or wastewater disposal issues.

Locally, Seattle and King County have been looking at reclaimed water for over a decade as a means to help protect Puget Sound, improve stream and habitat conditions, and augment the region's water supplies. Numerous analyses of reclaimed water in King County have been completed with several currently in process. The studies and their conclusions are briefly described in Appendix A.

Since 1997, King County's existing treatment plants, South Plant in Renton and West Point in Seattle's Discovery Park have produced and used reclaimed water. It is used as process water for operations at both plants in lieu of potable water. The South Plant also uses Class A reclaimed water for on-site irrigation, as well as piping it to irrigate nearby sports fields. The Regional Wastewater Services Plan called for the County to expand production and use of reclaimed water over the next 30 years.

Reclaimed water was a key criterion in the siting process for the Brightwater Treatment plant now under construction. The specific criterion stated that "King County shall seek North Treatment Facility sites that provide opportunity for water reclamation and reuse."[2] Membrane bioreactor (MBR) treatment technology was selected for the Brightwater Treatment system and Carnation Treatment Plant in order to better protect receiving waters by creating cleaner effluent than conventional treatment processes. MBR can also treat water to meet Washington State's strict reclaimed water standards, making it safe for many uses in industry and irrigation. Essentially all wastewater at the Brightwater plant will be treated to reclaimed water standards whether it is actually used as reclaimed water or simply discharged into Puget Sound.

The Brightwater Reclaimed Water Backbone Project: In November 2005, King County approved Phase 1 of the Brightwater Reclaimed Water Backbone Project. This project, now under construction, was designed to distribute up to 21 million gallons per day (mgd) of reclaimed water to large irrigators in the Sammamish Valley and along the effluent pipeline running west from the new Brightwater treatment plant also under construction. The project is divided into three phases with the first phase consisting of two segments. The West segment involves placing a dedicated pipeline parallel to the effluent pipe inside the Brightwater tunnel

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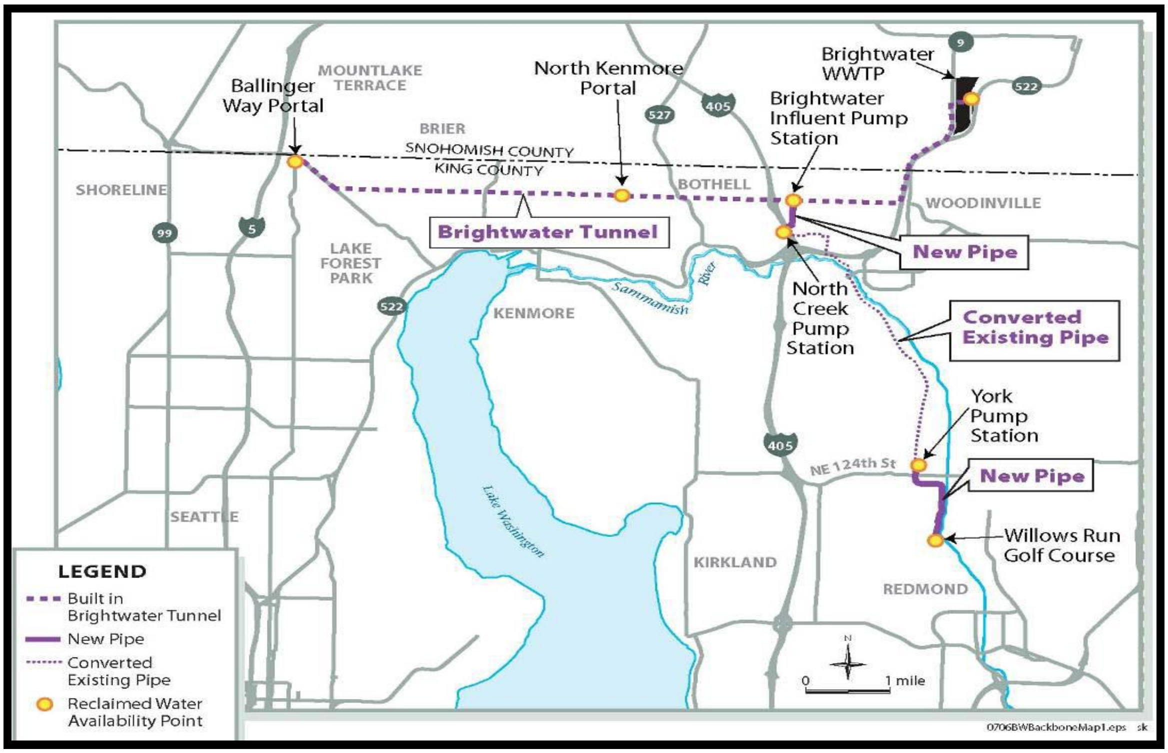
1 The term "reclaimed water" refers specifically to the treatment and reuse of wastewater. The water is treated to a standard generally higher than that required for discharge to a receiving water body and reused for non-potable (irrigation, industrial processes, toilet flushing, etc.) or indirect potable (ground water recharge) purposes.

2 Reclaimed Water Backbone Project, Draft White Paper Verson 3.0, March 2006, page 10.

from the plant to the Ballinger Way Portal in Lake Forest Park. The South segment connects the West segment to an existing pipe that runs down the Sammamish Valley. The estimated capital cost of Phase I was $26 million, of which $15 million was for the West segment.

When the West segment is completed, additional pumping will be required to bring water to the surface at the Ballinger Way Portal. Phase II of the project installs pumps at the Brightwater plant to bring the West segment into service. Capital costs were estimated at $13 million. The third and final phase of the project is to construct a purple-pipe distribution system to deliver reclaimed water from the Backbone portals to final end-users. While the cost to King County of Phase III was originally estimated at $88 million, the county has since expressed its preference[3] to only be a wholesaler of reclaimed water from the Backbone with water utilities assuming responsibility for constructing distribution infrastructure and providing retail service between the Backbone portals and potential customers. It is therefore up to the water utilities in whose service areas potential backbone customers are located to conduct their own economic analyses and determine whether it makes sense to hook up to the Backbone and build a reclaimed water distribution system.

Figure 1: Map of the Brightwater Reclaimed Water Backbone Project



[3] "*King County's preference is to act as a wholesale supplier of reclaimed water to the water utility, for use by the utility as just one of potentially several sources of supply, and for the water utility to retail the water to the end users within their defined service areas*." Reclaimed Water Backbone Project, Draft White Paper Verson 3.0, March 2006, page 35. Also, "*Our preference is that we wholesale reclaimed water from the Backbone to existing water utilities who retail to potential customers."* Presentation to Regional Reclaimed Water Technical Committee by Don Theiler, September 15, 2006.

The purpose of this analysis is to determine whether SPU should build a reclaimed water distribution system from the Ballinger Way Portal to potential customers in its service area. Included in the analysis are potential customers in the Shoreline Water District that, owing to their location along the distribution lines that would connect Seattle to the Backbone, could share in the costs. The economic analysis utilizes the asset management approach to decision-making that SPU has been refining over recent years. This approach is consistent with the framework developed by Dr. Bob Raucher and the WateReuse Foundation for applying standard benefit-cost analysis tools to the evaluation of reclaimed water projects.[4]

The Asset Management Approach:

Seattle Public Utilities has been applying an asset management approach to decision-making since 2002. The overall goal of asset management can be summarized as making investment decisions that meet agreed-upon customer and environmental service levels while minimizing lifecycle costs. The asset management process features a Business Case which describes a problem or opportunity, identifies a number of alternatives for addressing the problem or opportunity, and then analyzes which alternative if any provides the most value in excess of its cost. Standard benefit-cost or cost-effectiveness analysis is used as appropriate. The intent is to account for all benefits and costs of a potential action, regardless of who receives the benefits or bears the costs. This includes financial, environmental and social benefits and costs which together are referred to as *Triple Bottom Line*. SPU's asset management approach is consistent with the framework developed by Dr. Robert Raucher and the WateReuse Foundation for applying standard benefit-cost analysis tools to the evaluation of reclaimed water projects. For a summary of basic principles of benefit-cost analysis, see Appendix B. The WateReuse Foundation's economic framework for evaluating reclaimed water projects is summarized in Appendix C.

Applying the concepts of Asset Management and the WateReuse Foundation's framework for evaluating reclaimed water, the analysis of the Seattle's share of the Backbone Project (henceforth referred to as the North Seattle Project) is organized as follows:

<u>Step 1</u>: Describe the problem(s) to be solved by the North Seattle Project and define the state of the world if neither the project nor any of its alternatives are pursued. This establishes the base case to which reclaimed water projects and other options are compared. This step also involves an initial high-level assessment of potential benefits from the project.

<u>Step 2</u>: Conduct market analysis. The magnitude of project benefits and costs is a function of the demand for reclaimed water in the study area. For this reason, a market analysis is conducted to identify potential customers and estimate likely demand for reclaimed water.

<u>Step 3</u>: Identify and quantify full life-cycle costs of project. This includes capital and O&M costs as well as customer costs, and possible environmental and social costs and risks. For cost estimating purposes, pipeline and pump size are determined by the demand for reclaimed water as determined in the previous step.

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[4] "An Economic Framework for Evaluating the Benefits and Costs of Water Reuse," 2008, WateReuse Foundation. See Appendix C for a brief summary.

Step 4: Identify and quantify project benefits. This includes all benefits – financial, social, and environmental – regardless of to whom they may accrue, or where they might be realized. Benefits are then described and quantified, if not in dollars, at least in terms of physical units of measure such as tons of nitrogen kept from being discharged in Puget Sound.

Step 5: Identify and analyze alternatives for achieving project goals. Alternative projects are specified so as to provide benefits the same as or greater than the project. Full life-cycle costs of all options are identified and quantified.

Step 6: Evaluate project and alternatives using cost effectiveness rather than benefit-cost analysis. This involves specifying a set of benefits or level of service, then comparing the costs of various alternatives that can deliver those benefits. The alternative with the lowest life-cycle costs is the most cost effective. This approach is appropriate when, as in this case, the benefits of a project are difficult to monetize but all options under consideration provide the same or similar benefits.

Step 7: Conduct sensitivity analyses on key assumptions and value estimates in order to explore the robustness of the results with respect to uncertainty.

Step 8: Perform perspectives analysis to assess the distributional implications of the project and its alternatives (i.e., who gains and who pays).

Step 1 – Problem Statement and Base Case

A business case usually starts with a problem or problems to be solved and then identifies what projects might help solve them. In this analysis, that process is reversed. It begins with the North Seattle Project and then asks what problems the North Seattle Project could help solve. In general, the use of reclaimed water in this region could provide solutions to many types of problems which can be broken down into two broad categories: water supply and environmental.

Water Supply: Supply benefits can be further divided into three subcategories:

- *Quantity* – In areas where existing supplies are insufficient to meet current and/or anticipated demand, reclaimed water may represent a cost-effective and sustainable source of additional supply.
- *Reliability* – If reliability of supply is an issue, reclaimed water can supplement existing water sources thereby improving their current and future reliability.
- *Cost* – Where existing potable supplies have high operating costs, reclaimed water may be a more cost-effective source of non-potable water.

Environmental: There are also three basic subcategories of potential environmental benefits from reclaimed water:

- *"Upstream" effects* – Substituting reclaimed water for potable water from other sources can improve environmental conditions in the watersheds from which the potable water is extracted. Depending on the source of supply, this can result in less depleted aquifers, reduced salt water intrusion, increased stream flows, expanded wetlands, improved habitat conditions, etc.
- *"Downstream" effects* – By diverting treated effluent to land application, the use of reclaimed water can reduce effluent flows and the discharge of pollutants to receiving waters leading to improved water quality and habitat conditions.
- *"Direct" effects* – Reclaimed water can also be used directly to recharge aquifers, augment stream flows, or restore wetlands.

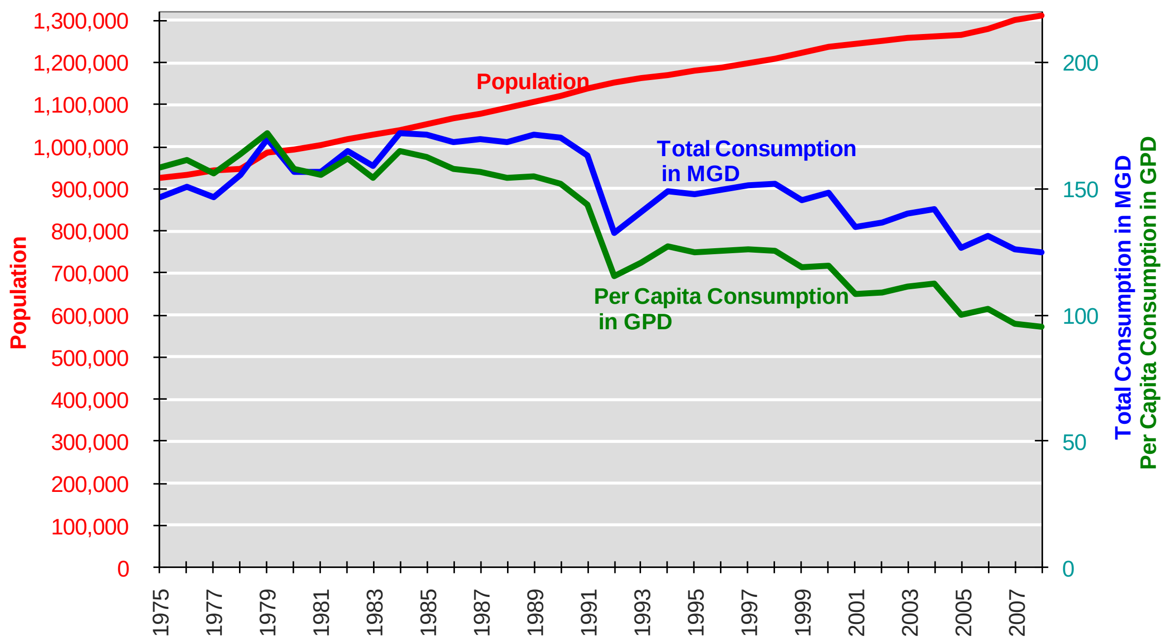
The Reclaimed Water Backbone was approved and the North Seattle Project is now under consideration because together they are seen as providing a possible solution to a current or anticipated problem or set of problems. Therefore, it is expected that they would provide one or more of the general benefits described above. Each of these benefit types is examined below to determine whether it is a possible outcome of the North Seattle Project.

Water Supply:

Quantity: Reclaimed water represents a potential source of new supply when the potable water supply is limited, demand is growing, and new supply is costly in dollar and/or environmental terms. This describes the situation Seattle faced twenty years ago when water demand was fast approaching its supply capacity. In its 1993 Water Supply Plan, Seattle examined a number of new supply options including a diversion of the North Fork Tolt River, a higher dam on the Cedar River, and a new dam on the North Fork Snoqualmie River. Seattle also looked at reclaimed water and water conservation as new sources of supply and ultimately committed to a demand management strategy as the least costly, most environmentally benign option.

Seattle launched an aggressive conservation program, cut non-revenue water in half through improved system operations, and implemented a seasonal rate structure with marginal rates that were increased rapidly over the next decade. At the same time, a new state plumbing code went into effect that established efficiency standards for all new toilets, shower heads and faucet aerators. As a result, water consumption plummeted even as service area population continued to grow. Since 1990, Seattle system water demand declined from 170 million gallons per day (mgd) to under 130 mgd while population has increased almost 20%. On a per capita basis, water consumption has fallen by 37%.

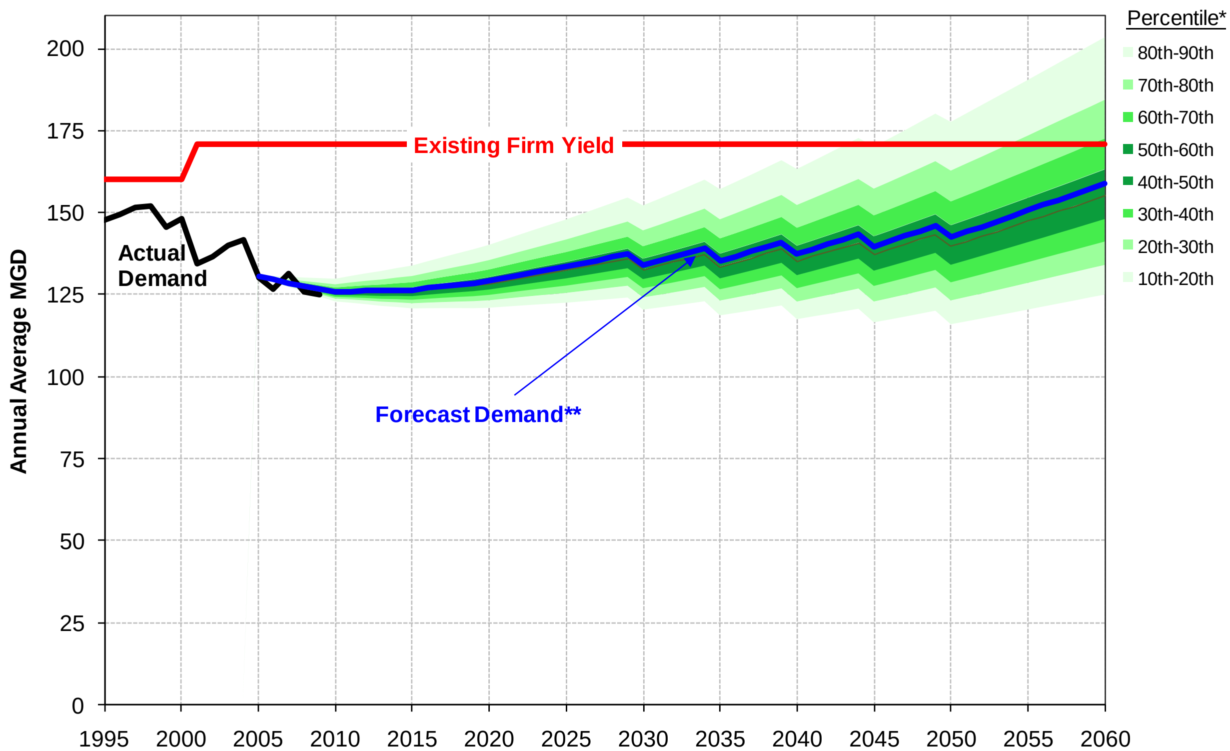
Figure 3: **Growth in Population and Water Consumption**
Seattle Regional Water System: 1975-2008



On the supply side, a filtration plant was brought online in 2001 that, as a side benefit, increased Seattle's firm yield[5] by 11 mgd. Thus over the past 20 years, Seattle has gone from a situation of short supply to surplus. Seattle's retail and wholesale demand for water is now 45 mgd *below* its firm yield. Continued code and programmatic conservation savings followed by a declining block of demand from the Cascade Water Alliance[6] is forecast to offset the impact of population growth on water demand for many decades. As a result, total demand isn't projected to reach existing firm yield of 171 mgd until sometime after 2060.

[5] "Firm yield" is defined below in the discussion of supply reliability.
[6] The Cascade Water Alliance, a group of eight cities and water districts that currently purchase about 27 mgd from Seattle, is planning on leaving SPU's water supply system and developing Lake Tapps, the next large new source of supply that is expected to increase the region's supplies by 65 mgd.

Figure 4: Forecast of Water Demand, Ranges of Uncertainty, and Existing Firm Yield



* Percentiles represent the probability that demand is less than the value shown. Ranges reflect uncertainty in projected household employment, price and income growth, price elasticity, income elasticity, and conservation.

** Forecast shows impact of declining block contract with Cascade Water Alliance after 2029. Prior to 2029, the forecast reflects actual demand projected for Cascade which is expected to be less than Cascade's block.

Given the amount of excess capacity now enjoyed by the regional Seattle system as well as the number of decades it is expected to persist, the additional increment to Seattle's water supply that would be provided by bringing reclaimed water to North Seattle appears to be of little immediate benefit. However, reclaimed water could provide a future benefit if and when demand again approaches existing supply. Therefore, quantity of water supply is considered a possible driver for the North Seattle Project.

Reliability: A different but related issue is water supply reliability. The amount of water available from Seattle's two primary sources – the Cedar and South Fork Tolt Rivers – varies significantly over the course of a year and from one year to the next. Flows in these rivers are managed through the use of dams that store winter and spring rain and snowmelt runoff. This stored water helps prevent winter flooding and provides municipal water supply, hydropower, and guaranteed stream flows for fish and river health throughout the year. Because of the tremendous variability in stream flows from year to year, SPU uses the concept of "firm yield" to characterize the amount of water it can supply with a high level of reliability. Seattle's firm yield is defined as the amount of water that could be delivered in all but the worst year on record over the past 76 years while maintaining agreed-upon minimum instream flows and without lowering reservoirs below minimum levels.[7]

With demand so far below firm yield, Seattle's water system is considered to be reliable with low risk of shortages requiring water use curtailments.[8] Still, there's always a chance that a year will occur with less favorable weather and hydrological conditions than have been experienced in the past. The prospect of climate change and its impact on both water supply and demand also increase the uncertainty around future reliability.

Using an analysis by the University of Washington Climate Impacts Group (UW-CIG)[9] which lays out different climate change scenarios for the Puget Sound region, SPU has recently evaluated how such changes would affect the performance of the existing supply system. While each of the climate scenarios would be expected to reduce future yields, a number of modifications to operational practices and modest changes to existing system infrastructure have been identified that could mitigate the expected impacts of climate change on yield.

Given the uncertainty about weather variability and climate change, improving the robustness and reliability of Seattle's supply system may be a benefit to which reclaimed water could contribute. Therefore, water supply reliability is considered a possible driver for the North Seattle Project in this analysis.

<u>Cost:</u> The cost of providing municipal water supply is both very high and very low. Total annual cost for SPU's water division is almost $200 million. With 55 to 60 million hundred cubic feet (ccf) in annual billed consumption, that works out to about $3.50 per ccf. For Seattle's retail service area, total costs divided by total billed consumption is approximately $5.00 per ccf. However these are average costs which are made up almost entirely of fixed costs. Only the variable or *marginal* costs of providing water are relevant because only they would be reduced by substituting reclaimed water for municipal water. These costs, which increase or decrease with changes in the volume of treated water delivered, are relatively low. They include chemical costs for treatment and energy costs for treatment and pumping (though because the Seattle system operates mostly on gravity, pumping requirements are low). The variable cost of providing water is estimated at about $0.06 per ccf. To this is added the environmental cost of the energy used in pumping not reflected in its dollar cost, i.e., the cost of greenhouse gas emissions. The methodology for doing so is explained more fully in the cost chapter and in Appendix F. The estimate of this cost for the Seattle system is $0.03 per ccf, resulting in total variable costs of about $0.09 per ccf. Variable costs for several large irrigators with their own local supplies of water are of a similar magnitude.

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7 This means that in most years, Seattle's supply system would be able to provide more, and sometimes much more, than 171 mgd. However in the worst year on record, the system would not be able to both supply 171 mgd and meet instream flow requirements without accessing emergency supplies.

8 Note that while mandatory water use restrictions were imposed in response to the 1992 drought, such action would probably not be taken today if similar drought conditions occurred. This is because demand is much lower, firm yield is higher (due to the Tolt filtration plant) and operation of the water system is more sophisticated than in 1992. For more detail, see Appendix D.

9 Polebitski, A., L. Traynham, and R.N. Palmer. 2007. "Technical Memorandum #5: Approach for Developing Climate Impacted Streamflow Data and its Quality Assurance/Quality Control" A report prepared by the Climate Change Technical Subcommittee of the Regional Water Supply Planning Process, Seattle, WA.

By reducing the use of water from current supplies and avoiding the associated variable costs, the North Seattle Project could provide a benefit. Thus, avoiding the variable costs associated with current water sources is considered a possible driver for the North Seattle Project.

Environmental:

Upstream: If current sources of potable water in the project area have negative environmental impacts and if reducing demand on these sources would reduce those impacts, then substituting reclaimed water for potable water could improve environmental conditions in the source watersheds. There are two kinds of potential reclaimed water customers that would be served by the North Seattle Project: those who currently obtain their water for non-potable uses from the Seattle municipal system and those with their own sources of non-potable water. It is therefore possible that by providing an alternative source of water, the project could improve environmental conditions in both Seattle's source watersheds and local watersheds.

Most streams in the Central Puget Sound region experience low flow problems during years of low rainfall, in the sense that their flows are lower than normal which can degrade habitat conditions and possibly lead to higher rates of mortality for fish. Natural problems with low flows tend to occur in the summer and early fall, after extended periods with little to no precipitation, when groundwater inflows are at their lowest and snowpacks have already melted. These natural low flow problems can be aggravated, sometimes dramatically, by human impacts the most obvious of which is the withdrawal of water for out-of-stream use. However, the extraction of water for consumptive use is only one of many contributors to low flows. Human land uses also create stream flow problems. Forest cover, native soils and wetlands naturally act to balance the hydrologic cycle, moderating peak flows and helping recharge groundwater. When they are removed or degraded, especially when they are replaced by impervious surfaces such as roads or buildings, there can be increased peak flows, sedimentation, changes in channel structure, and less groundwater to support baseflows during summer and early fall.

SPU's primary water management goals for both its Cedar and South Fork Tolt systems focus on the protection of salmonid fishes and the promotion of overall river health while providing an adequate supply of municipal water. SPU's operation of water storage facilities on both systems moderates the severity of both high and low stream flow events. For most of the summer, flows in the South Fork Tolt are increased by reservoir releases to provide flows that are usually higher than under natural conditions. From late September through late October, flows in the Cedar are similarly augmented to provide levels above what would often occur naturally, particularly if fall rains return later than normal. In addition, SPU typically provides operating margins of 3 to 20 cubic feet per second (cfs) over and above guaranteed minimum flow levels, while in most years, "supplemental flows" well above minimum flows are also provided. Nevertheless, reducing customer demand for water in the summer and early fall could provide SPU with additional flexibility in optimizing instream habitat conditions. Therefore, the potential for improving environmental conditions in Seattle's source watersheds is considered to be a possible driver for the North Seattle Project.

Potential reclaimed water customers in the North Seattle/Shoreline area that irrigate using their own wells or surface water diversions might be reducing dry season flows in local streams. Most of the streams in this area flow through urbanized drainage basins with hardened landscapes and dense storm drain networks that combine to increase peak flows from storm events and reduce base flows during the summer irrigation period. One stream, Thornton Creek, has already been identified as having low-flow problems (Lombard and Somers, 2004) but other streams could also probably benefit from increased summer baseflows. By providing reclaimed water for irrigation, the project could eliminate the need for surface and groundwater withdrawals by self-supplied irrigators and leave more water available to the local watershed ecosystems. Therefore, the potential for improving environmental conditions in local watersheds is included as a possible driver for the North Seattle Project.

Downstream: An array of contaminants from a variety of sources and transport mechanisms add a mix of pollutants that affects Puget Sound water quality, and one of these sources is treated wastewater. The average daily flow from all wastewater treatment facilities discharging to Puget Sound is estimated to be about 475 mgd. Of this, more than 40% comes from King County's two regional treatment plants. The total average daily discharge from these two plants is about 200 mgd.

One of the primary benefits cited for the use of reclaimed water in western Washington is its positive impact on water quality in Puget Sound. By diverting for use on land what would otherwise be advanced secondary-treated effluent discharged to the Sound, the North Seattle Project reclaimed water would reduce the discharge of pollutants to Puget Sound. Therefore, reducing pollutant loadings to the Sound is considered a driver for the North Seattle Project.

Direct: Reclaimed water can also be used directly to augment stream flows, recharge aquifers, or restore wetlands.

While direct stream augmentation with reclaimed water may benefit a stream by increasing base flows, it may also present water quality issues without additional treatment. Given that keeping reclaimed water out of Puget Sound is thought to improve its water quality, discharging reclaimed water directly into small urban streams could degrade their water quality. As will be discussed later in this analysis, treating wastewater to reclaimed water standards greatly reduces the concentrations of nitrogen, phosphorous, and other nutrients compared to secondary treated wastewater. Nevertheless, the remaining concentrations of these nutrients if not removed through additional treatment, especially phosphorous, are enough to degrade water quality should reclaimed water be introduced directly into fresh-water lakes or streams.

Even if there is no compelling groundwater benefit, percolating reclaimed water into the groundwater would provide a disposal function, reducing the volume of reclaimed water discharged into the Sound and improving its water quality. But if the main purpose of percolation ponds is to avoid discharging reclaimed water to Puget Sound, there's no particular reason to do this in the North Seattle/Shoreline area. Much expense could be avoided by locating the ponds as close as possible to where reclaimed water is produced.

SPU has no information as to where in the North Seattle/Shoreline area there may be some benefit to restoring wetlands or adding directly to groundwater. Without known sites for wetland restoration or groundwater recharge, and given the water quality concerns related to direct uses of reclaimed water, groundwater recharge, wetlands restoration and direct stream flow augmentation are not considered to be drivers for the North Seattle Project.

Step 2 - Reclaimed Water Market Analysis

To estimate both benefits and costs of providing reclaimed water to North Seattle and Shoreline from the Reclaimed Water Backbone's Ballinger Portal, it is necessary to assess the demand for reclaimed water in the study area. The first step in this process is to identify potential customers with non-trivial non-potable water uses (such as irrigation, cooling/heating, industrial process, etc.) for which reclaimed water could provide a substitute. Next is to measure or estimate the amount of non-potable water used by each potential customer. Finally, potential customers' interest in switching over to reclaimed water must be ascertained, as well as barriers to adoption that may exist for some customers and the extent to which these barriers may be overcome.

Identifying Potential Reclaimed Water Customers:

King County's Draft White Paper on the Backbone Project[10] identified 8 potential reclaimed water customers in Seattle Public Utilities' retail service area plus 10 additional potential customers in the Shoreline Water District and the City of Mountlake Terrace that, owing to their location along the distribution lines that would connect Seattle to the Ballinger Portal, could share in the costs. The original list of 18 potential reclaimed water customers has been expanded in this analysis to include potential customers in the City of Shoreline west of the reclaimed water distribution system originally envisioned by King County plus a number of potential customers south of 145th Street and north of the ship canal. Many of these customers were identified using a map provided by the county (Potential Reclaimed Water End Users – County Line to Mountlake Vicinity: June 2008). The map shows the locations of golf courses, cemeteries, parks, schools and several industrial process users that could have significant non-potable water demand. Billing data from SPU and the Shoreline Water District were analyzed to identify other large water users with the potential to utilize reclaimed water.

In total, 60 potential reclaimed water customers in the study area were identified for further analysis.[11] Most of these were irrigators though several had non-irrigation uses for non-potable water. The different types of customers and their frequency are summarized in the table below:

Golf Courses	4
Cemeteries	7
Parks	19
Schools	23
Other	7
TOTAL	60

Determining Potential Demand for Reclaimed Water:

The estimates of potential demand for reclaimed water will be used in several ways, some of which will require different units of measure. In assessing the benefits of reclaimed water on water quality in Puget Sound, annual volume is the relevant concept which can be expressed in millions of gallons or average annual million gallons per day. For benefits to municipal supplies

[10] Reclaimed Water Backbone Project, Draft White Paper Version 3.0, March 2006

[11] Initially, 76 potential customers were identified but 11 parks and 5 schools were found to have no irrigation whatsoever leaving 60 potential customers for further analysis.

that are constrained by peak season storage, peak season flow is most important and can be expressed in millions of gallons per day averaged over the peak season. Both peak season and peak month flows will be most useful in assessing the environmental benefits of reclaimed water to local streams. Finally for cost estimating purposes, pipes and pumps will be sized based on the maximum hourly demand for reclaimed water. Therefore in what follows, potential demand for reclaimed water will be expressed as:

- an annual volume in millions of gallons (MG)
- in millions of gallons per day (mgd) averaged over the peak season
- in mgd for the peak month
- the maximum hourly flow in gallons per minute (gpm)

For the purposes of this analysis, the peak season is defined as 6 months. Billing records of irrigators show consumption spanning as many as 7 months and as few as 2 months with an average of about 5 months. However, almost all irrigation takes place somewhere in the 6-month period between mid-April and mid-October. Also, the Irrigation Water Management Society defines the watering season in Seattle as the 6 months April through September and provides evapotranspiration and rainfall data for those months (http://www.iwms.org/seattle_area.asp).

As noted earlier, there are two kinds of potential reclaimed water customers: those who currently obtain their water from SPU or the Shoreline Water District and those with their own source of non-potable water. All the golf courses and most of the cemeteries have their own source of non-potable water. All the parks and schools plus several of the cemeteries use municipal water for their irrigation needs. Metered water consumption data from SPU and the Shoreline Water District, survey data, and water budget calculations were used to estimate irrigation and other non-potable water consumption for the 60 potential customers. SPU staff conducted a survey of potential reclaimed water customers though the results were less than hoped for (see Appendix J). Some customers could not be reached and others could not provide the desired information. Another difficulty was the absence of metered consumption data for most of the irrigators with their own sources.

Self-Supplied Non-Potable Water Users:

Water consumption for self-supplied irrigators – golf courses and cemeteries – can be estimated in a number of ways. These methods make use of metered consumption data, survey data on application rates and irrigated acreage, "rules of thumb" from local irrigation experts, and an application of a water budget equation[12] to Seattle conditions. The estimates produced by all of these various methods were compared to each other to check for consistency and to confirm the reasonableness of the estimates.

Golf Courses: Data from multiple sources were used to estimate irrigation consumption for golf courses. Information from the survey on acres irrigated was combined with application guidelines provided by Kuhn Associates[13] to estimate irrigation use for unmetered golf courses. These estimates were found to be consistent with irrigation consumption at three public golf courses in Seattle but outside the study area. Since these golf courses use municipal water for

[12] Wilson, Tim. *Site Water Management Planning, A Handbook for Landscape, Water Conservation, Golf & Irrigation Professionals*. Bilhah Publications, 2004. pp50-51. See also: http://www.iwms.org/seattle_area.asp

[13] Scott Kuhn, P.E. of Kuhn Associates, a designer of irrigation systems for many golf courses in the Seattle area.

irrigation, metered consumption data could be obtained through SPU's billing system. Finally, actual consumption data was available for one of the golf courses in the study area, Jackson Park, which has been metering its withdrawals since 2005. The table below shows the golf courses in the study area and estimates of their irrigation consumption. See Appendix E for details on the derivation of these consumption estimates.

Table 3: Estimated Irrigation Consumption for Golf Courses

	Acres		6 Month		Pk Month	ccf/acre/	Supply
Customer	Total	Irrigated	MG	MGD	MGD	season	Source
Nile Country Club	90	35	13.3	0.07	0.14	508	Self
Jackson Park	161	75	25.5	0.14	0.29	455	Self
Seattle Country Club	140	100	31.3	0.17	0.39	418	Self
Sand Point	90	75	28.5	0.16	0.29	508	Self
Total Golf Courses			98.6	0.54	1.11		

Cemeteries: Several sources of data provide reasonably consistent information on the amount of water used for irrigation at cemeteries. One cemetery, Calvary Cemetery purchases all its water from SPU so billing records of metered consumption are available. Three more cemeteries, Bikur Cholim Cemetery, Herzl Memorial Park and Machzikay Hadath/Seattle Sephardic, have exempt wells which are supplemented by purchases from SPU. In an earlier survey, Holyrood Cemetery reported using 6000 ccf per month in the peak months. All of this data produced similar estimates for per acre consumption. The table below shows the cemeteries in the study area and estimates of their irrigation consumption. Again, see Appendix E for details on the derivation of these consumption estimates.

Table 4: Estimated Irrigation Consumption for Cemeteries

	Acres		6 Month		Pk Month	ccf/acre/	Supply
Customer	Total	Irrigated	MG	MGD	MGD	season	Source
Holyrood	80	40	17.7	0.097	0.150	593	Self
Acacia	60	30	12.1	0.066	0.102	537	Self
Evergreen Washelli	160	128	51.4	0.281	0.434	537	Self
Bikur Cholum	6.2	3.7	0.9	0.005	0.006	323	Self/SPU
Herzl Memorial	5.4	5.4	1.9	0.011	0.017	484	Self/SPU
Machzikay Hadath	4.6	3.0	1.0	0.006	0.007	462	Self/SPU
Calvary*	40	35	12.6	0.069	0.146	482	SPU
Total Cemeteries			97.7	0.534	0.861		

For both golf courses and cemeteries, the preponderance of the evidence suggests irrigation application rates between 400 and 600 ccf per acre per season. This is a bit below, but overall broadly consistent with, the rate of 612 ccf per acre implied by the water budget equation.

Municipally-Supplied Non-Potable Water Users:

Schools and Parks: The two categories having the largest number of potential reclaimed water customers are schools and parks. Fortunately for measuring purposes, these types of users are almost always connected to the municipal water system and their consumption is metered monthly or bimonthly. Billing data for these customers was extracted from SPU and Shoreline Water District billing system for the period 2004 or 2005 through 2008. In some cases, irrigation water is metered separately leaving no question about how much water was used for irrigation. In others, the portion of total consumption going to irrigation had to be estimated.

Twenty-two schools (excluding the University of Washington) were identified with a total of 0.16 mgd of possible irrigation over the 6 irrigating months. That works out to an average of about 7,000 gallons per day per school. Out of all the Seattle Public Schools in the study area, only three were found to have any irrigation, even though some of the schools with no irrigation had irrigation meters. According to the resource conservation specialist at Seattle Public Schools, irrigation is mostly done to establish new turf or landscaping. Once that has been accomplished after three years or so, irrigation is generally discontinued. Therefore, Seattle Public Schools are unlikely to be dependable reclaimed water customers.

There were 19 parks with irrigation totaling 0.29 mgd. However, more water is used at one location than at all the other parks combined: Green Lake Park, Woodland Zoo and Lower Woodland Park, which are all contiguous, together use 165,000 gpd over the irrigation season. All the other parks average about 7,600 gpd per park.

Irrigation consumption data for individual schools and parks are provided in Table 9 at the end of the chapter. More details on the calculation of irrigation demand for schools and parks can be found in Appendix E.

<u>University of Washington</u>: Three different non-potable uses were identified at the University of Washington: irrigation, steam plant replacement water and Drumheller Fountain.

Irrigation: Irrigation water for the UW sports fields runs through two irrigation meters into a dedicated distribution system which could easily be converted to reclaimed water as it is isolated from the rest of the university's potable water system. Unfortunately, all other irrigation is widely dispersed throughout the campus and comes directly off the potable water system. Converting this to reclaimed water is not considered feasible by UW Facilities staff.
About 33,000 gallons per day during the 6-month irrigation season are used to irrigate the UW sports fields.

Steam Plant/Cooling: Water is used in the boilers of the steam plant all year long and also in cooling towers during the warmer months May through October. However, reclaimed water is not considered suitable for use in the boilers which require very high and consistent water quality. Reclaimed water could be used for cooling which has an estimated demand of 118,400 gallons per day during the 6-month cooling season (May-October). Complicating matters somewhat is a possible project that would take water from Lake Washington, run it through heat exchangers for cooling, and then return it to Union Bay. This would eliminate the need to purchase water for cooling, save power, and provide an additional environment benefit of lowering water temperature in Union Bay. It would also eliminate cooling demand for reclaimed water. The feasibility and probability of the project moving forward is uncertain..

Drumheller Fountain: Water used to clean, refill and operate the fountain is about 1,800 ccf per year with most of the use occurring within the span of a single month, usually in the summer. Averaged over 6 months, this is equivalent to 7,300 gpd. There is some question about whether it would be acceptable to use reclaimed water in Drumheller Fountain due to concern about windborne mist from the fountain considering the high pedestrian traffic around the fountain and the proximity of medical facilities. Reclaimed water could be used for this purpose assuming health concerns are resolved, approvals from the Departments of Health and Ecology are obtained, and getting reclaimed water to this central campus location is not cost prohibitive given the volume of water in question.

Estimated Total UW Demand for Reclaimed Water: Potential UW demand for reclaimed water is highly uncertain and depends on whether the Lake Washington cooling water proposal goes forward and, to a lesser extent, whether using reclaimed water in the fountain would be allowed. The various possibilities are shown in the table below. Overall, demand could be as high as 0.16 mgd or as low as 0.03 mgd over the 6 month summer season.

Table 5: Potential University of Washington 6-Month Summer Season Demand for Reclaimed Water in Gallons Per Day

	All	No Fountain	No Cooling	No Fountain or Cooling
Cooling	118,400	118,400	0	0
Irrigation	33,000	33,000	33,000	33,000
Fountain	7,300	0	7,300	0
Total GPD	**158,700**	**151,400**	**40,300**	**33,000**
6 Mo MGD	**0.16**	**0.15**	**0.04**	**0.03**

<u>Miscellaneous:</u> A final check was done for other potential reclaimed water customers by extracting consumption data on all customers served by SPU north of the ship canal that use more than 1,000 ccf per year (2,000 gallons per day). A visual inspection of this list for possible non-potable use in Shoreline and within striking distance of a pipeline from Jackson Park to the University of Washington produced seven additional potential customers (all in Shoreline). Total 6-month peak season non-potable water use for this group is 44,000 gallons per day. This is also the only group to have some possible demand for reclaimed water in the off-peak season. Total potential demand in the 6-month winter season is about 32,000 gpd.

Table 6: Miscellaneous Potential Reclaimed Water Customers

			Water	MGD	
Customer	Address	Type	Supplier	6 Mo Pk	Off-Peak
Brown Bear Car Wash	16030 Aurora Ave N	Car Wash	SPU	0.005	0.005
Highland Sports Center	18005 Aurora Ave N	Ice Skating	SPU	0.004	0.004
King County Transfer Station	2300 N 165th St	Solid Waste	SPU	0.001	0.001
King County Transit	2141 N 165th St	Transit	SPU	0.008	0.002
King County Wastewater	2205 N 205th St	WW Treatment	SPU	0.002	0.002
King County Wastewater	20001 Richmond Beach Dr NW	Pump Station	SPU	0.015	0.015
Sky Nursery	18528 Aurora Ave N	Nursery	SPU	0.009	0.003
TOTAL				**0.044**	**0.032**

Note: Except for Sky Nursery and King County Transit, these customers have constant consumption throughout the year.

Summary of Potential Demand in Study Area

Of the 76 potential customers originally identified, 60 were found to have some irrigation or other non-potable demand for water. Total potential demand of these customers is estimated at 320 million gallons per year with almost all of it, 314 MG, occurring in the 6 month irrigation season.[14] Expressed in millions of gallons per day, potential irrigation season demand is estimated to be about 1.7 mgd with 1 mgd of that going to the 7 self-supplied irrigators. Seven of the 53 municipally-supplied customers have some demand for non-potable water during the off-peak season though it only amounts to 0.03 mgd.

Table 7: Potential Demand for Reclaimed Water in Study Area by Customer Category

	Number of Potential Customers	Water Consumption					
			MGD				
		MG	6 Mo Off-Pk	6 Mo Pk	Pk Mo	Pk Hr	
Total Non-Potable	**60**	**320**	**0.03**	**1.72**	**3.19**	**12.94**	
Self Supplied	**7**	**182**	**0.00**	**1.00**	**1.81**	**7.59**	
Golf Courses	4	99	0.00	0.54	1.11	4.64	
Cemeteries	3	84	0.00	0.46	0.70	2.94	
Municipally Supplied	**53**	**138**	**0.03**	**0.72**	**1.38**	**5.36**	
Schools	23	58	0.00	0.31	0.57	2.05	
Parks	19	52	0.00	0.29	0.59	2.48	
Cemeteries	4	14	0.00	0.08	0.16	0.67	
Miscellaneous	7	14	0.03	0.04	0.05	0.15	

Peak month consumption for municipally-supplied customers was obtained from metered consumption data extracted from SPU and Shoreline billing systems. The maximum one inch per week guideline was used to estimate peak month consumption for golf courses and the peak factor implied by the monthly reference ET from the water budget equation was used to calculate peak month consumption for self-supplied cemeteries. Overall, peak-month to peak-season factors for municipally supplied customers varied between 1.4 and 3.4 averaging 2.0. Golf course peak factors also averaged 2.0 but cemeteries were a little lower averaging about 1.6.

Based on an analysis of daily SPU system consumption over 15 years, it was estimated that the ratio of peak-day to peak-month consumption for irrigators is 1.4. Irrigators were also assumed to water 8 hours per day implying a peak-hour rate of consumption 3 times as much as peak-day. This produces a ratio of peak-hour to peak-month of 4.2. Several non-irrigation customers were assumed to have peak-hour to peak-day factors of 2 rather than 3 and a couple more were assumed to use water evenly over the 24 hour period with peak-day consumption equal to peak-month.

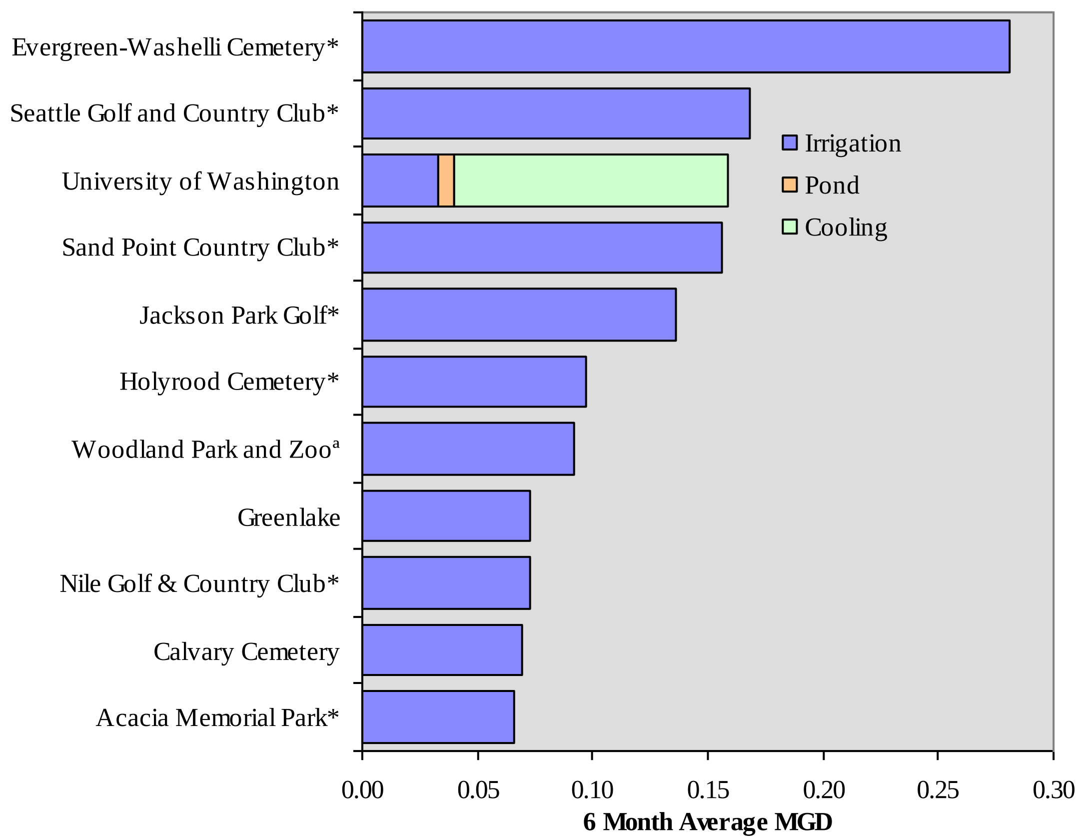
Potential reclaimed water customers vary widely in their water demand. The largest is Evergreen-Washelli Cemetery with 0.28 mgd of peak season demand and the smallest, Twin Pond Park with 0.0002 mgd.. As shown in the Table 8 below, the top eleven non-potable water users (which include all seven self-supplied users) consume 1.37 mgd or 80% of the total.

[14] This assumes that the University of Washington would use reclaimed water for irrigation, cooling, and the fountain. If the other cooling option involving Lake Washington water is approved, demand for reclaimed water would be reduced by about 22 MG a year or 0.12 mgd.

Table 8: Top Eleven Non-Potable Water Consumers in Study Area

	Top 11 Customers	Address	City	Water Supplier	Type	6 Mo Pk MGD	Annual MG
1	Evergreen-Washelli Cemetery	11111 Aurora Ave N	Seattle	Self	Cemetery	0.28	51.4
2	Seattle Golf and Country Club	210 NW 145th	Shoreline	Self	Golf	0.17	31.3
3	University of Washington	1700 NE 45th St.	Seattle	SPU	School	0.16	29.0
4	Sand Point Country Club	8333 55th Ave NE	Seattle	Self	Golf	0.16	28.5
5	Jackson Park Golf	1000 NE 135th St	Seattle	Self	Golf	0.14	25.5
6	Holyrood Cemetery	205 Northeast 205th St	Shoreline	Self	Cemetery	0.10	17.7
7	Woodland Park and Zoo	822 N 59th St	Seattle	SPU	Park	0.09	16.8
8	Greenlake	7201E Green Lake Dr NE	Seattle	SPU	Park	0.07	13.3
9	Nile Golf & Country Club	6601 244Th St SW	MT	Self	Golf	0.07	13.3
10	Calvary Cemetery	5041 35th Ave. NE	Seattle	SPU	Cemetery	0.07	12.6
11	Acacia Memorial Park	14951 Bothell Way NE	Shoreline	Self	Cemetery	0.07	12.1
TOP 11 SUBTOTAL						**1.37**	**251.6**
	Remaining 49 Potential Customers: Range from 0.0002 to 0.03 MGD					**0.34**	**68.6**
GRAND TOTAL						**1.72**	**320.3**

Figure 5: Consumption in 6 Month MGD for Top 11 Potential Customers



* Self-Supplied
[a] Includes Lower Woodland

Table 9 below displays all the potential customers by type and their non-potable water demand expressed in MG, 6-month mgd, 1-month mgd, peak hour mgd and gpm.

Table 9: Non-Potable Water Demand of Potential Reclaimed Water Customers

Customer	Address	City	Type	Water Supplier	MG Annual	MGD 6 Mo Pk	MGD Pk Mo	MGD Off-Pk	MGD Pk Hr	GPM Pk Hr
Total Non-Potable Water Use					**320.3**	**1.72**	**3.19**	**0.03**	**12.94**	**8,989**
Municipally Supplied Non-Potable Water Use					**140.5**	**0.74**	**1.4**	**0.0**	**5.4**	**3,766**
PARKS					**52.4**	**0.29**	**0.59**	**0**	**2.48**	**1,725**
Seattle Parks					**44.0**	**0.24**	**0.51**	**0**	**2.14**	**1,483**
Bitter Lake	13035 Linden Ave. N.	Seattle	Park	SPU	1.14	0.006	0.014	-	0.061	42
Cowen Park	1450 Ravenna Blvd NE	Seattle	Park	SPU	1.41	0.008	0.014	-	0.060	42
Dahl Playfield	7700 25th Ave. NE	Seattle	Park	SPU	1.91	0.010	0.026	-	0.109	76
Greenlake	7201-7601 E Green Lake Dr NE	Seattle	Park	SPU	13.31	0.073	0.171	-	0.719	499
Laurelhurst Playfield	4544 NE 41st. St.	Seattle	Park	SPU	0.92	0.005	0.009	-	0.036	25
Lower Woodland	5300 Stone Way NE	Seattle	Park	SPU	3.96	0.022	0.051	-	0.214	149
Maple Leaf	8200 Roosevelt Ave NE	Seattle	Park	SPU	0.52	0.003	0.005	-	0.021	14
Meadowbrook Playfield	10515 35th Ave NE	Seattle	Park	SPU	2.31	0.013	0.025	-	0.104	72
Northacres Park	12718 1st Ave. N.	Seattle	Park	SPU	1.33	0.007	0.020	-	0.083	58
Ravenna Park	5412 Ravenna Ave NE	Seattle	Park	SPU	3.37	0.018	0.046	-	0.195	135
View Ridge Playfield	7043 45th Ave NE	Seattle	Park	SPU	0.94	0.005	0.011	-	0.046	32
Woodland Park and Zoo	822 N 59th St	Seattle	Park	SPU	12.88	0.070	0.116	-	0.488	339
Shoreline Parks					**8.39**	**0.05**	**0.08**	**0**	**0.35**	**243**
Hillwood Park	3rd Ave. NW & NW 190th St.	Shoreline	Park	SPU	1.10	0.006	0.014	-	0.061	42
Ronald Bog Park	2121 N 175th St	Shoreline	Park	SPU	0.43	0.002	0.004	-	0.018	12
Shoreview Park	700 NW Innis Arden Way	Shoreline	Park	SPU	0.39	0.002	0.005	-	0.019	13
Twin Ponds Park	2341 N 155th St	Shoreline	Park	SPU	0.04	0.0002	NA	-		
Hamlin Park	1st Ave NE & N 190th St	Shoreline	Park	Shoreline	1.95	0.011	0.020	-	0.084	58
Paramount School Park	835 NE 155th St	Shoreline	Park	Shoreline	3.55	0.019	0.032	-	0.134	93
Ridgecrest Park	1st Ave. NE & N 161st St.	Shoreline	Park	Shoreline	0.92	0.005	0.008	-	0.034	24
SCHOOLS					**57.6**	**0.31**	**0.57**	**0**	**2.05**	**1,421**
Seattle Public Schools					**3.2**	**0.02**	**0.04**	**0**	**0.18**	**125**
Eckstein Middle School	3003 NE 75th St.	Seattle	School	SPU	0.45	0.002	0.007	-	0.029	20
John Rogers Elementary School	4030 NE 109th St	Seattle	School	SPU	1.14	0.006	0.021	-	0.089	62
Summit K-12	11051 34th Ave NE	Seattle	School	SPU	1.56	0.009	0.015	-	0.061	43
Shoreline Public Schools					**15.3**	**0.08**	**0.16**	**0**	**0.67**	**469**
Albert Einstein Middle School	19343 3rd Ave. NW	Shoreline	School	SPU	1.65	0.009	0.013	-	0.054	37
Echo Lake Elementary	19345 Wallingford Ave. N	Shoreline	School	SPU	0.50	0.003	0.006	-	0.025	17
Highland Terrace Elementary	100 N 160th St.	Shoreline	School	SPU	1.03	0.006	0.008	-	0.035	25
Meridian Park Elem/Shoreline Children's	17077 Meridian Ave. N	Shoreline	School	SPU	0.56	0.003	0.010	-	0.042	29
Parkwood Elementary	1815 N 155th St.	Shoreline	School	SPU	0.35	0.002	0.006	-	0.025	17
Shorewood High School	17300 Fremont Ave. N	Shoreline	School	SPU	2.99	0.016	0.035	-	0.149	104
Sunset Elementary	17800 10th Ave. NW	Shoreline	School	SPU	0.73	0.004	0.006	-	0.026	18
Syre Elementary	19545 12th NW	Shoreline	School	SPU	1.01	0.006	0.008	-	0.035	24
Educational Service Center	18560 1st Ave. NE	Shoreline	School	SPU	0.30	0.002	0.004	-	0.016	11
Briercrest Elementary	2715 NE 158th St.	Shoreline	School	Shoreline	0.56	0.003	0.007	-	0.028	19
Kellogg Middle School	16045 25th Ave. NE	Shoreline	School	Shoreline	2.06	0.011	0.020	-	0.085	59
North City Elementary	816 NE 190th St.	Shoreline	School	Shoreline	0.87	0.005	0.008	-	0.032	22
Ridgecrest Elementary	16516 10th Ave. NE	Shoreline	School	Shoreline	0.67	0.004	0.008	-	0.035	24
Shorecrest High School	15343 25th Avenue NE	Shoreline	School	Shoreline	2.03	0.011	0.021	-	0.089	62
Private Schools					**8.1**	**0.04**	**0.09**	**0**	**0.38**	**261**
Lakeside High School	14050 1st Ave. NE	Seattle	School	SPU	2.01	0.011	0.018	-	0.078	54
Lakeside Middle School	13510 1st Ave. NE	Seattle	School	SPU	0.85	0.005	0.010	-	0.042	29
Villa Academy	5001 50th Ave. NE	Seattle	School	SPU	0.25	0.001	0.003	-	0.011	7
Kings Schools Ministry of Crista	19303 Fremont Ave. N.	Shoreline	School	SPU	4.98	0.027	0.058	-	0.245	170
Colleges					**31.1**	**0.17**	**0.28**	**0**	**0.82**	**568**
Shoreline Community College	16101 Greenwood Ave N	Shoreline	School	SPU	2.06	0.011	0.024	-	0.099	69
University of Washington	1700 NE 45th St.	Seattle	School	SPU	29.03	0.159	0.256	-	0.718	499
CEMETERIES					**16.5**	**0.09**	**0.18**	**0**	**0.74**	**512**
Calvary Cemetery	5041 35th Ave. NE	Seattle	Cemetery	SPU	12.62	0.069	0.146	-	0.611	424
Bikur Cholim Cemetary	1340 N. 115th St.	Seattle	Cemetery	Self & SP	0.89	0.005	0.006	-	0.025	17
Herzl Memorial Park/Herzl Ner-Tamid	16747 Dayton Ave N	Shoreline	Cemetery	Self & SP	1.94	0.011	0.017	-	0.070	48
Machzikay Hadath/Seattle Sephardic	1214-1230 N 167th St	Shoreline	Cemetery	Self & SP	1.03	0.006	0.007	-	0.031	22
OTHER MUNICIPALLY SUPPLIED NON-POTABLE USE					**13.9**	**0.04**	**0.05**	**0.03**	**0.15**	**107**
Brown Bear Car Wash	16030 Aurora Ave N	Shoreline	Car Wash	SPU	1.69	0.005	0.005	0.005	0.009	6
Highland Sports Center	18005 Aurora Ave N	Shoreline	Ice Skating	SPU	1.56	0.004	0.004	0.004	0.009	6
King County Transfer Station	2300 N 165th St	Shoreline	Solid Waste	SPU	0.35	0.001	0.001	0.001	0.002	1
King County Transit	2141 N 165th St	Shoreline	Transit	SPU	1.91	0.008	0.017	0.002	0.070	48
King County Wastewater	2205 N 205th St	Shoreline	WW Treatment	SPU	0.60	0.002	0.002	0.002	0.002	1
King County Wastewater	20001 Richmond Beach Dr NW	Shoreline	Pump Station	SPU	5.59	0.015	0.015	0.015	0.015	11
Sky Nursery	18528 Aurora Ave N	Shoreline	Nursery	SPU	2.23	0.009	0.011	0.003	0.048	33
Self-Supplied Non-Potable Water Use					**179.8**	**0.98**	**1.79**	**0**	**7.52**	**5,224**
CEMETERIES					**81.2**	**0.44**	**0.69**	**0**	**2.88**	**1,999**
Acacia Memorial Park	14951 Bothell Way NE	LFP	Cemetery	Self	12.06	0.066	0.102	-	0.427	297
Holyrood Cemetery	205 Northeast 205th St	Shoreline	Cemetery	Self	17.73	0.097	0.150	-	0.628	436
Evergreen-Washelli Cemetery	11111 Aurora Ave N	Seattle	Cemetery	Self	51.44	0.281	0.434	-	1.823	1266
GOLF COURSES					**98.6**	**0.54**	**1.11**	**0**	**4.64**	**3,224**
Nile Golf & Country Club	6601 244Th St SW	MT	Golf 18	Self	13.30	0.073	0.14	-	0.570	396
Jackson Park Golf	1000 NE 135th St	Seattle	Golf 18+	Self	25.51	0.139	0.29	-	1.222	849
Seattle Golf and Country Club	210 NW 145th	Shoreline	Golf 18	Self	31.26	0.171	0.39	-	1.629	1131
Sand Point Country Club	8333 55th Ave NE	Seattle	Golf 18	Self	28.51	0.156	0.29	-	1.222	849

Step 3 - Reclaimed Water System Costs

In this section, full life-cycle costs of the proposed Seattle reclaimed water project are identified and, to the extent possible, quantified. Included are capital and O&M costs for the City of Seattle and King County, as well as customer costs and environmental/social costs and risks. Costs are expressed in present value dollar terms for the benefit-cost analysis, and as a levelized cost per ccf of reclaimed water provided when assessing how much customers would have to pay to recover the public investment in the project.

Distribution Network

The largest single cost of the North Seattle Project is for installation of a reclaimed water distribution system from the Ballinger Portal to the 60 potential customers scattered throughout North Seattle and Shoreline. It would require about 35 miles of pipeline varying from 4 to 20 inches in diameter to reach all the identified potential customers. The pipeline route has been designed to bring reclaimed water to potential customers with the greatest efficiency. Pipelines would be located in street right-of-ways and would avoid major arterials as much as possible. Crossings of Aurora Avenue and I-5 would be minimized with I-5 crossings occurring only at underpasses. The proposed alignment for the full distribution system and the location of all identified potential customers are shown in Figure 6.

Hydraulic modeling, GIS data, and a recent analysis of pipe installation costs by SPU engineers were used to determine system layout, pipe sizes and costs. Costs for pipeline design, construction, construction management, and street surface (asphalt) restoration are included in the estimate of installation costs and summarized in the table below on a per lineal foot basis by pipe diameter. (More detail on these costs can be found in Appendix F.)

Table 10: Total Cost of Pipe Installation by Pipe Diameter

Pipe Diameter	Total Cost per lineal foot
4"*	$285
6"*	$320
8"	$371
10"	$414
12"	$443
16"	$679
20"	$821

*Costs for 4 and 6 inch pipe are scaled down from the SPU Engineering Analysis estimates.

The estimated cost of installing pipe to distribute reclaimed water to all 60 identified potential customers is **$89.6 million**. However, this cost can be trimmed significantly with very little reduction in benefit by eliminating some stretches of the pipeline system that go too far to serve too few customers with too little demand. There are a number of spurs off the main pipeline that serve just one or a few small customers at costs many times higher per unit of demand than the rest of the system. Removing these sections eliminates 8 miles of pipe, reduces total pipeline cost by 15% and cuts the number of potential customers down to 50 while forgoing only 2% of the potential demand for reclaimed water. The pipe installation cost for this “optimized” system is **$75.8 million**. Potential demand that could be served by this “optimized” system is shown in Table 11 below.

Figure 6

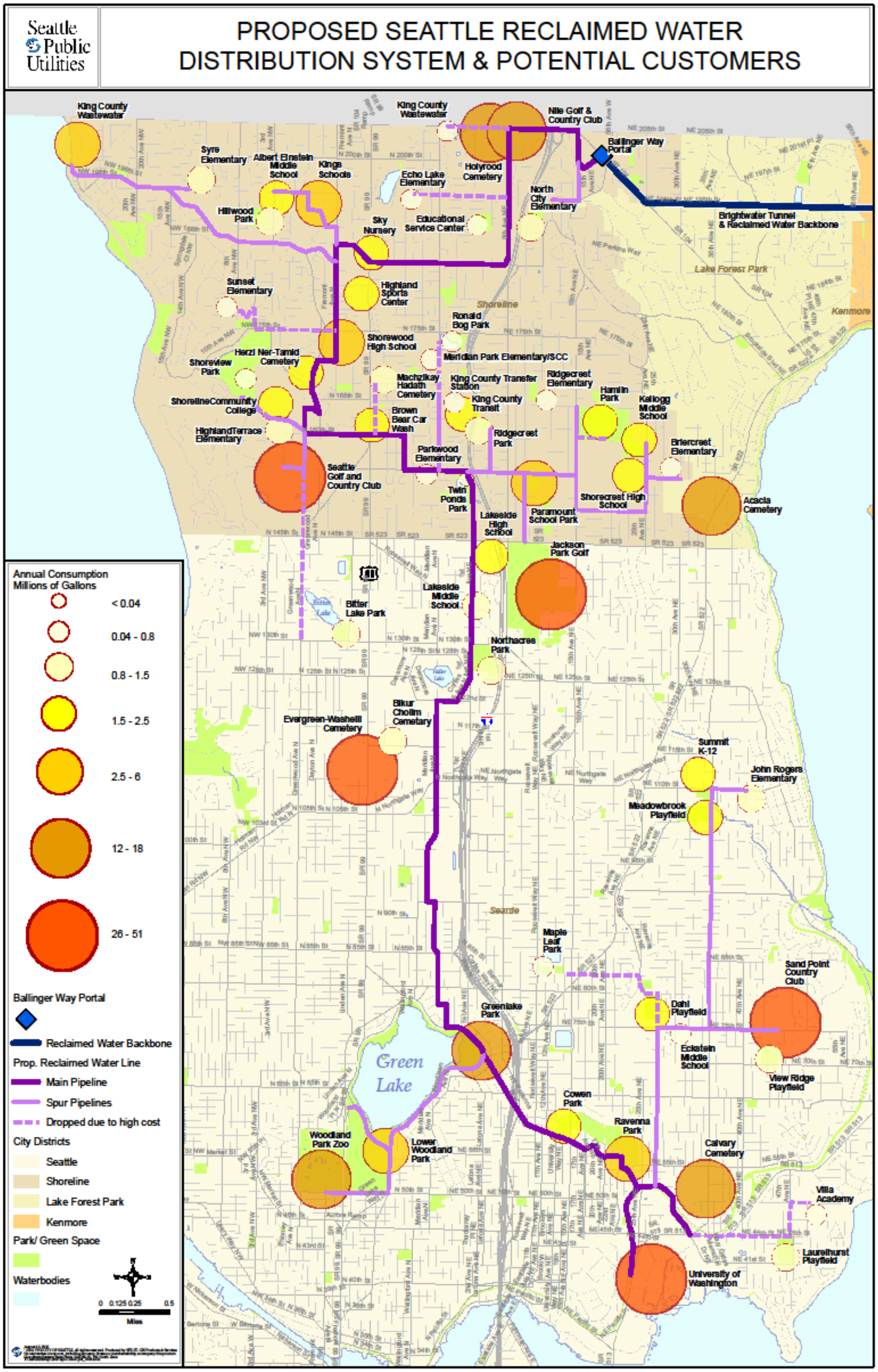

Seattle Public Utilities
PROPOSED SEATTLE RECLAIMED WATER DISTRIBUTION SYSTEM & POTENTIAL CUSTOMERS
King County Wastewater
Syre Elementary
Albert Einstein Middle School
Kings Schools
Echo Lake Elementary
Holyrood Cemetery
Nile Golf & Country Club
Ballinger Way Portal
North City Elementary
Hillwood Park
Sky Nursery
Educational Service Center
Brightwater Tunnel & Reclaimed Water Backbone
Lake Forest Park
Sunset Elementary
Highland Sports Center
Shoreline
Kenmore
Ronald Bog Park
Shorewood High School
Herzl Ner-Tamid Cemetery
Shoreview Park
Meridian Park Elementary/SCC
Machzikay Hadath Cemetery
King County Transfer Station
Ridgecrest Elementary
Hamlin Park
ShorelineCommunity College
King County Transit
Kellogg Middle School
Brown Bear Car Wash
HighlandTerrace Elementary
Ridgecrest Park
Briercrest Elementary
Parkwood Elementary
Seattle Golf and Country Club
Twin Ponds Park
Shorecrest High School
Acacia Cemetery
Lakeside High School
Paramount School Park
Jackson Park Golf
Bitter Lake Park
Lakeside Middle School
Northacres Park
Bikur Cholim Cemetery
Evergreen-Washelli Cemetery
Summit K-12
John Rogers Elementary
Meadowbrook Playfield
Seattle
Maple Leaf Park
Sand Point Country Club
Dahl Playfield
Greenlake Park
Eckstein Middle School
View Ridge Playfield
Green Lake
Cowen Park
Ravenna Park
Woodland Park Zoo
Lower Woodland Park
Calvary Cemetery
Villa Academy
Laurelhurst Playfield
University of Washington
Annual Consumption Millions of Gallons
< 0.04
0.04 - 0.8
0.8 - 1.5
1.5 - 2.5
2.5 - 6
12 - 18
26 - 51
Ballinger Way Portal
Reclaimed Water Backbone
Prop. Reclaimed Water Line
Main Pipeline
Spur Pipelines
Dropped due to high cost
City Districts
Seattle
Shoreline
Lake Forest Park
Kenmore
Park/ Green Space
Waterbodies
0 0.125 0.25 0.5
Miles

Table 11: Potential Demand for Reclaimed Water Served by "Optimized" Distribution System by Customer Category

	Number of Potential Customers	Water Consumption					
			MGD				
		MG	6 Mo Off-Pk	6 Mo Pk	Pk Mo	Pk Hr
Total Non-Potable	**50**	**314**	**0.03**	**1.69**	**3.12**	**12.68**
Self Supplied	**7**	**182**	**0.00**	**1.00**	**1.81**	**7.59**
Golf Courses	4	99	0.00	0.54	1.11	4.64
Cemeteries	3	84	0.00	0.46	0.70	2.94
Municipally Supplied	**43**	**132**	**0.03**	**0.69**	**1.32**	**5.10**
Schools	19	56	0.00	0.30	0.55	1.94
Parks	14	49	0.00	0.27	0.55	2.33
Cemeteries	4	14	0.00	0.08	0.16	0.67
Miscellaneous	6	13	0.03	0.04	0.05	0.15

Pumping

The Brightwater treatment plant and Phase I of the reclaimed water backbone are scheduled for completion in 2012. However, in order to bring reclaimed water to the surface at the Ballinger Portal, Phase II of the backbone project will also have to be built. Phase II consists of pump stations at the Brightwater facility and Ballinger Portal, as well as disinfection facilities, with total construction costs estimated at $15 million.[15] Not all of this is allocated to the Seattle project, however. The figure has to be reduced by the Seattle project's share of total potential reclaimed water demand from the West segment of the Backbone which is estimated at 64%[16]. King County estimates the annual O&M costs for the Backbone's West segment to be $395,000 in 2009 dollars. Therefore, **$9.7 million** in Phase II capital costs and **$256,000** in annual O&M costs are allocated to the Seattle project.

In addition to the Phase II pumps which will bring reclaimed water to the surface, a pump station will be needed at the Ballinger Portal to pressurize the distribution system. The cost of the pump station is estimated at about **$1 million** with annual electricity cost for distribution system pumping estimated at about **$47,000**.[17]

[15] The King County Draft White Paper on the Reclaimed Water Backbone, Version 3, page 26, Table 4, provides an estimate of Phase II costs of $13 million in 2005 dollars which is equivalent to $15 million in 2009 dollars. (The Seattle Consumer Price Index-W has increased 15.3% from 2005 to 2009.)

[16] Note that the share of Phase II costs allocated to the Seattle project is based the on Seattle's share of *total potential reclaimed water demand* from the West segment rather than the design capacity of the West segment. Using design capacity in the denominator would underestimate Seattle's share of costs if, as is likely, demand for reclaimed water from the West segment never reaches capacity. More detail on calculating Seattle's share of Phase II costs are found in Appendix F.
Also note also that since Phase I of the Backbone project is already under construction, it is considered a "sunk" cost and Seattle's share of those costs is not included in the benefit-cost analysis.

[17] This assumes that three 3,000 gpm pumps, each with 450 KW motors will be needed to deliver the 314 million gallons of annual demand for reclaimed water. This will take about of 1,744 hours of pumping time and require 785,000 KWh of electricity (450 KW * 1,744 hrs pump run time). At $0.06 per KWh, this would cost about $47,000 per year. Again, see Appendix F for details.

On-site Distribution Costs

There are also some up-front customer costs involved in converting to reclaimed water. For customers with separate irrigation systems, there is just the added the cost of installing a meter. Other customers will have the additional cost of isolating their irrigation system from their potable supply. The preliminary estimate of these costs for all customers is about $500,000.

Environmental Costs

There are a number of environmental and social costs/risks of constructing and operating the reclaimed water system, most of which will be described but not quantified in the analysis. One example is traffic congestion, noise, and disruption caused by tearing up 27 miles of urban streets to install the purple pipe distribution system. Other possible costs are the risk of reclaimed water getting into streams and the perceived health risk of human contact with reclaimed water. However, one environmental cost that is not insignificant and which can be quantified is the greenhouse gas emissions from the energy used to pressurize the Backbone and the Seattle distribution system. This is over and above the dollar cost of purchasing the electricity to operate the pumps. The emissions cost will be partially offset on the benefits side by any reductions in greenhouse gas emissions from the self-supplied irrigators not using their wells and less potable water being drawn from the Seattle system.

Energy requirements for distribution system pumping are estimated to require about 785,000 KWh per year. For pressurizing the Backbone and bringing reclaimed water to the surface at Ballinger Way, King County reports the energy needed will be 6,180,000 KWh per year, of which, as explained above, 65% is allocated to the Seattle project. Therefore, the total energy requirement for delivering reclaimed water to customers of the Seattle project would be:

$$6{,}180{,}000 \text{ KWh} \times 0.65 + 785{,}000 \text{ KWh} = 4{,}787{,}000 \text{ KWh}$$

Most, but not all of the power provided by City Light and Puget Sound Energy is hydroelectric. New demands for energy are met by increased generation from more expensive thermal plants - either coal or gas turbine. Coal plants produce about 2.1 pounds of CO_2 for each KWh of electricity while natural gas plants produce about 1.3 pounds. Assuming the marginal power source for City Light and PSE is coal,[18] the Seattle project will create 4,559 tons of additional CO_2 emissions per year. While economists have long argued over the correct value to use for the social cost of carbon, a figure of $100 per ton of CO_2 is thought reasonable for this analysis.[19] This results in an annual cost of **$456,000**.

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[18] 36% of Puget Sound Energy electricity generation is coal and 20% is natural gas. For Seattle City Light, the proportions are 1.4% coal and 0.6% natural gas.

[19] A number of economists have attempted to roughly estimate the optimal "carbon price," based on computer models that incorporate data on economic growth, rising greenhouse emissions, abatement costs and expected climatic damages. A recent iteration of a model developed by William Nordhaus pegs the optimal carbon tax at $12 per ton of CO_2 increasing at a rate of 3 percent annually to reflect increasing damages from global warming. Many other economists consider this way too low. The Stern Review calculated the social cost of CO_2 equivalent at $110 per ton (in 2009 $s). More recently still, Harvard economist Marty Weitzman concluded that the Stern estimate is the more reasonable given that most other economists haven't taken plausible worse-case scenarios into account when estimating expected climatic damages.

Bottom Line

For the purpose of the benefit-cost analysis, the total monetized cost of the Seattle reclaimed water project is summarized in the table below. Included are the initial capital costs of the Seattle distribution system, Seattle's share of Phase II, O&M costs, the social cost of greenhouse gas emissions, and the cost to customers to connect to the system. Since Phase I of the Backbone is currently under construction, it is considered a sunk cost[20] and is not included in this calculation. The preliminary estimate of capital costs is **$87.0 million**. Annual operating costs include those for Seattle's share of disinfection and pressurizing the Backbone, pressurizing the distribution system, and the estimated cost to society of associated CO_2 emissions. These costs total **$758,800** per year. Their present value over a 50 year time horizon discounted at 2.5%[21] is $21.5 million. The estimated total present value cost of the project is **$108.6 million**.

Present Value Cost of the North Seattle Reclaimed Water Project

Capital Costs	$87,041,600
Seattle Distribution System (Pipe)	$75,828,800
Distribution System Pump Station	$1,000,000
Seattle's Share of Phase II (65%)	$9,712,800
Customer On-Site Costs	$500,000
Annual Costs	$758,800
Distribution System Pumping	$47,100
Seattle's Share of Phase II (65%)	$255,800
Environmental Cost of CO_2 Emissions	$455,900
Present Value of Annual Costs	$21,521,322
(Over 50 years discounted at 2.5%)	
Total Present Value Cost of Seattle Project	**$108,562,922**

[20] Sunk costs are costs that have already been incurred, cannot be recovered, and therefore should not be considered relevant to subsequent decisions. They should not be included in a benefit-cost analysis nor used to justify continuing a project.

[21] The impact of different assumptions about time horizons and discount rates are explored in the Sensitivity Analysis section of this paper.

Step 4 - Reclaimed Water Project Benefits

As summarized in the base case section, there are several broad categories of potential benefits from the North Seattle reclaimed water project. These are:

- Increased available supply for the Seattle regional water system
- Improved reliability of the Seattle regional water system
- Reduced variable costs of providing potable water
- Improved environmental conditions in *regional* source watersheds
- Improved environmental conditions in *local* source watersheds
- Improved environmental conditions in Puget Sound

In this section, each of these benefits is described in detail and quantified to the extent possible. Three of the benefit types are mutually exclusive and so are considered together.

Increased Supply/Enhanced Reliability/Improved Environmental Conditions in Regional Source Watersheds

Based on the market analysis, the North Seattle Project could reduce demand from Seattle's regional supply system by as much as 0.69 mgd over an irrigation season. This reduction in demand could be:

- made available to augment existing supplies and help meet future increases in demand, or
- kept in storage to enhance supply reliability,[22] or
- released from storage to increase flows in Seattle's source rivers, thereby improving instream fish habitat and other environmental conditions.

However, it couldn't provide all these benefits at the same time. If the water freed up by substituting reclaimed water was used to enhance supply reliability, it would not be available to increase streamflows or meet additional demand. Similarly, if the water was left in the source rivers, it couldn't be used to meet additional demand or improve supply reliability.

Relative to SPU's total water supply (171 mgd firm yield), 0.69 mgd is a very small, almost imperceptible quantity. Alone, it would not add to supply or improve reliability in a detectable way. However, as part of a portfolio of measures that together produced a significant reduction in demand, the North Seattle Project could be seen as contributing to an increase in supply or reliability.[23]

[22] Note that the terms "reliability" and "supply reliability" that appear throughout this document are used in the general rather than technical sense. SPU applies a "98% reliability" standard in its supply analysis and firm yield estimations. None of the actions described herein would change the reliability standard.

[23] In addition to system reliability, it could be argued that individual users of non-potable water who switch from municipally-supplied water to reclaimed water would enjoy a higher level of reliability. There's always a small but non-zero probability that a water shortage, brought on by unusual weather and hydrological conditions, could induce SPU to ask its customers to temporarily curtail their water consumption. Non-potable water users who have switched to reclaimed water would not be subject to such a request. However since curtailments are infrequent, generally voluntary, and of short duration, the benefit of avoiding the possibility of curtailment for those potential reclaimed water customers now using Seattle water is thought to be quite small. This potential benefit was not considered further in the analysis.

Relative to dry season flows in the Cedar and Tolt rivers which provide Seattle's water, 0.69 mgd is an even smaller quantity. An assessment of the potential effects of the North Seattle Project on these rivers found that an additional 0.69 mgd might produce increases in minimum stream flows in the range of 0.1% to 1.3%. This translates to even smaller increases in minimum stream depths ranging from 0.01 to 0.07 inches or in percentage terms, 0.04% to 0.24%. The analysis suggests that the North Seattle Project would result in exceedingly small changes in annual mean stream flow, monthly average minimum stream flow, and monthly average minimum water elevation. Therefore, in the judgment of SPU fisheries staff, the environmental impacts of the project on the Cedar and South Fork Tolt rivers would be difficult to detect. More details are provided in Appendix G.

This analysis does not attempt to put a dollar value on the regional supply/reliability/environmental benefit that may be provided by the North Seattle Project. Instead, it remains quantified in physical terms: a 0.69 mgd reduction in irrigation-season demand. Alternative actions that could produce similar or greater reliability benefits will be identified and compared to the North Seattle Project for cost-effectiveness.

Avoiding Variable Cost of Providing Potable Water

By reducing the use of potable water and avoiding the associated variable costs, the North Seattle Project would provide a benefit. As described above in the Problem Statement section, the variable cost of providing potable water from the SPU regional supply system is about $0.09 per ccf. The variable cost for irrigators with their own sources is estimated at $0.12 per ccf. Both of these estimates include the environmental cost of greenhouse gas emissions associated with the power required for pumping. As shown in the table below, total avoided costs work out to be about $31,000 per year with a present value of about $880,000 (over 50 years with a 2.5% discount rate).

Table 12: Avoided Potable Water Costs

	Annual Consumption		Variable Operating Costs		Power Use in kWh		CO_2 Emissions Cost		Total Variable Costs	
	MG	CCF	per CCF	Total	per CCF	Total	per CCF	Total	per CCF	Total
Self Supplied	100	133,126	$0.08	$10,650	0.40	53,250	$0.04	$5,000	$0.12	$15,650
Municipally Supplied	132	176,398	$0.06	$10,584	0.28	50,097	$0.03	$4,800	$0.09	$15,384
Annual Total	232	309,524	-	$21,234	-	103,347	-	$9,800	-	$31,034
Present Value over 50 years discounted at 2.5%				$602,243				$277,951		$880,194

Improving environmental conditions in local source watersheds

Potential reclaimed water customers in the North Seattle/Shoreline area that irrigate using their own wells or surface water diversions may have an impact on dry season flows in local streams. Most of the streams in this area flow through urbanized drainage basins with hardened landscapes and dense storm drain networks that combine to increase peak flows from storm events and reduce base flows during the summer irrigation period. One stream, Thornton Creek, has already been identified as having low-flow problems (Lombard and Somers, 2004) but other streams could also probably benefit from increased summer baseflows. By providing reclaimed water for irrigation, the project would eliminate the need for surface and groundwater withdrawals by self-supplied irrigators and leave more water available to the local watershed ecosystems.

SPU contracted with Herrera Environmental Consultants to describe and quantify the environmental benefits to local watersheds of using reclaimed water in place of surface and groundwater withdrawals. A number of watersheds were examined including Thornton Creek, Boeing Creek, McAleer Creek, Lyon Creek, Densmore Drainage basin, and Piper's Creek. A set of screening level criteria was developed to provide a consistent way to identify watersheds in Seattle's retail water service area with the potential to realize a meaningful environmental benefit from the project. Watersheds that satisfied these criteria were considered likely to realize a measurable benefit and would undergo further analysis. Those that failed to meet these criteria were considered unlikely to realize a significant change in environmental conditions, and were not evaluated further. The smaller, partially-self-supplied irrigators (Bikur Cholim, Herzl Memorial, and Machzikay Hadath cemeteries) were screened out through this process. See Appendix H for more details.

The consultant identified three major watersheds that might be affected by self-supplied irrigators (SSIs) and for which sufficient stream flow data was available: Thornton Creek, McAleer Creek (including Lake Ballinger), and the Densmore Drainage basin (Licton Springs). No stream flow data was available for a number of small streams and unnamed tributaries that could be influenced by water withdrawals by Acacia Cemetery, Sand Point Golf Course, and Seattle Country Club. The impact of eliminating water withdrawals by the SSIs was analyzed to the extent possible given these severe data constraints.

The consultant concluded that McAleer Creek would probably experience a minor increase in baseflow resulting in habitat conditions with minor benefits to fish. Similarly, Thornton Creek would also be expected to experience minor habitat improvements, but no significant improvement to water quality, as a result of increased flows. However in both watersheds, the small improvements in habitat conditions would not be expected to result in significant increases in biological productivity. Finally Densmore-Licton Springs was expected to experience the largest percentage increase in base flows but derive no actual benefit from it in terms of habitat. This is because it is highly influenced by the urban storm drainage system and is, in fact, mostly piped.

It was therefore concluded that there could be some environmental benefit to supplying reclaimed water to SSIs in the McAleer and Thorton Creek watersheds to replace withdrawals from their own sources. However, there appear to be no local environmental benefits associated with switching SSIs in the Densmore Drainage Basin to reclaimed water. Although no analysis was possible for Boeing Creek and the various small tributaries, it was nevertheless assumed that some small environmental benefit might also be expected from substituting reclaimed water for water from SSIs own sources in these watersheds. As shown in the table below, demand for the seven large self-supplied irrigators totals almost 1 mgd. However, Evergreen Washelli is excluded because of its location in the Densmore Basin. Environmental benefits to the other local watersheds are associated providing 0.7 mgd of reclaimed water to the remaining SSIs. More detail on the analysis of environmental benefits for urban watersheds can be found in Appendix I.

Table 13: Self-Supplied Irrigators by Watershed

Self Supplied Irrigator	Watershed(s)	Benefit?	6 Mo Pk MGD	Annual MG
Nile Golf & Country Club	McAleer Crd / Lake Ballinger	Minor	0.07	13
Holyrood Cemetery	McAleer Cr	Minor	0.10	18
Jackson Park Golf	Thornton Cr (North Fork)	Minor	0.14	26
Sand Point Country Club	Thornton Cr (tributaries) / Inverness Cr	Unknown	0.16	29
Acacia Memorial Park	Thornton Cr (tributaries) / Other small	Unknown	0.07	12
Seattle Golf and Country Club	Boeing Cr / Densmore Drainage Basin	Unknown	0.17	31
Evergreen-Washelli Cemetery	Densmore / Licton Springs	No	0.28	51
Total SSI	All	-	0.98	180
Total Net of Evergreen-Washelli	**All Except Densmore**	**-**	**0.70**	**128**

Improving environmental conditions in Puget Sound

An array of contaminants from a variety of sources and transport mechanisms add a mix of pollutants that contribute to water quality problems in Puget Sound. One of these sources is treated wastewater and a major pollutant of concern in treated wastewater is nitrogen. Discharges from wastewater treatment plants, septic systems, and other sources can overload Puget Sound with nitrogen which accelerates algae growth. As the algae die and decay, they use up the dissolved oxygen in the water, creating low oxygen conditions that can kill fish and other marine life.

The average daily flow from all wastewater treatment facilities discharging to Puget Sound is estimated to be about 475 mgd. Of this, more than 40% comes from King County's two regional treatment plants, the West Point Treatment Plant in Seattle and South Plant in Renton. The total average daily discharge from these two plants is about 200 mgd. These provide conventional activated sludge secondary treatment with a combined capacity to treat 248 mgd of average wet weather flow.

Herrera Environmental Consultants analyzed a number of pollutants that have been identified as constituents of concern by King County and the Puget Sound Partnership.[24] These are:

- Total Nitrogen
  - Ammonia-N
  - Nitrate-N
- Fecal Coliform
- Total Phosphorus
  - Ortho-phosphate
- Total Phosphorus
- Copper
- Zinc
- Bis(2-Ethylhexyl)phthalate

[24] *State of the Sound*, Puget Sound Action Team, 2007.

Some of the pollutants identified by Herrera in Appendix H are not considered in the benefits analysis. Secondary treated wastewater contains about one tenth as much phosphorus as nitrogen by weight but, though phosphorus is a nutrient of concern when discharged into fresh water, it is not considered a problem in marine waters. Metals and chemicals such as copper, zinc, and phthalates are pollutants of concern but secondary and advanced secondary treatment do a good job of removing them from treated wastewater. These substances enter the Sound primarily from surface run-off and atmospheric deposition with only a few percent of the total attributable to wastewater treatment plants.

The estimated amounts of these pollutants discharged into the Sound from King County treatment plants was calculated based on effluent concentrations and average annual discharges of 200 mgd as shown in the table below. Measures of Biological Oxygen Demand (BOD) and Total Suspended Solids (TSS) were also calculated.

Table 14: Pollutant Loads to Puget Sound from Existing King County Treatment Plants

Constituent	Secondary Effluent Concentrations	Pollutant Load to Puget Sound Kg*	Metric Tonnes*
Total Nitrogen	34 mg/L	9,395,363	9,395
Ammonia-N	31.3 mg/L	8,649,260	8,649
Nitrate-N	2.8 mg/L	768,209	768
Fecal Coliform*	24.2 CFU/100mL	66,873	66,873
BOD	15 mg/L	4,145,013	4,145
TSS	17 mg/L	4,697,681	4,698

*Mass of Fecal Coliform measured in Billions of Colony Forming Units (CFU)

The two existing King County treatment plants discharge about 9,400 metric tons of nitrogen, and 66,900 billion Colony Forming Units (CFU) of fecal coliform into Puget Sound each year. BOD and TSS discharges are about 4,100 and 4,700 metric tons per year, respectively.

The new Brightwater treatment plant will use membrane bioreactor (MBR) treatment technology to produce a higher quality effluent that meets Washington State's strict standards for reclaimed water. This will reduce pollutant loadings to Puget Sound compared to conventional treatment processes while also providing a supply of reclaimed water. Typical pollutant concentrations for secondary treated wastewater and advanced secondary (MBR) treated wastewater were obtained from several sources[25] and are reported in the table below. Moving to MBR treatment reduces the concentration of total nitrogen in the effluent by a factor of 13. Fecal coliform is reduced by a factor of 11 and BOD and TSS by factors of about 8. This is consistent with King County's assessment that overall, the effluent from Brightwater "will be seven to 10 times cleaner than typical secondary treated wastewater."[26] For more detail, see Appendix H.

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25 Reclaimed Water Backbone Project, Draft White Paper Version 3.0, March 2006, page 12; Final Environmental Impact Statement – Brightwater Regional Wastewater Treatment System, Appendix3-A, November 2003, Page 10; King County presentation on Brightwater Treatment Technology, 8/20/08; Washington State Department of Ecology EIM database entry for South King County Treatment Plant.

26 Reclaimed Water Backbone Project, Draft White Paper Version 3.0, March 2006, page 11. Also: http://www.kingcounty.gov/environment/wtd/Construction/North/Brightwater/Description/mbr.aspx

Table 15: Estimated Effluent Concentrations from Traditional Secondary & MBR Treatment

Constituent	Effluent Concentrations Secondary	Advanced (MBR)	Ratio
Total Nitrogen	34 mg/L	2.6 mg/L	13.1
Ammonia-N	31.3 mg/L	0.6 mg/L	52.2
Nitrate-N	2.8 mg/L	2.0 mg/L	1.4
Fecal Coliform	24.2 CFU/100mL	2.2 CFU/100mL	11.0
BOD	15 mg/L	2 mg/L	7.5
TSS	17 mg/L	2 mg/L	8.5

It is assumed that the county will divert as much untreated wastewater as possible to Brightwater and reduce the flows to existing plants in order to improve the overall level of treatment. The new Brightwater plant is anticipated to come on line in 2012 at which time it is expected to treat an annual average of about 21 mgd of wastewater. Annual flow through Brighwater is projected

Table 16: Estimated Brightwater Effluent Flows

Season	Brightwater Total Effluent Discharges in mgd[a]		
	2012 (online)	2020	2030
Wet (November–April)	24.6	31.9	36.0
Dry (May–October)	18.2	23.6	26.7
Annual [b]	21.4	27.8	31.3

[a]average dry and wet weather flow effluent discharge estimates from Brightwater Regional Wastewater Treatment System Facilities Plan May 2005, p. ES-2.

to ramp up to about 28 mgd in 2020, reaching capacity at about 31 mgd by 2030. This will have a significant impact on the pollutant load discharged into Puget Sound by King County. Brightwater is estimated to reduce total loadings of nitrogen, fecal coliform, BOD and TSS from all King County treatment plants by about 10% in 2012, ramping up to a 13% reduction by 2030.

Table 17: Impact of Brightwater on Total Pollutant Loadings from King County Treatment Plants

	Metric Tonnes of Pollutants*						Perecent Reduction in Total Loadings		
	Existing Treatment Plants			Net Impact of Brightwater					
Constituent	2012	2020	2030	2012	2020	2030	2012	2020	2030
Total Nitrogen	9,395	9,630	10,194	-928	-1,203	-1,360	-10%	-12%	-13%
Ammonia-N	8,649	8,865	9,384	-907	-1,177	-1,329	-10%	-13%	-14%
Nitrate-N	768	787	834	-23	-30	-34	-3%	-4%	-4%
Fecal Coliform*	66,873	68,545	72,557	-6,502	-8,432	-9,526	-10%	-12%	-13%
Total Phosphorus	920	943	998	-54	-70	-79	-6%	-7%	-8%
BOD	4,145	4,249	4,497	-384	-498	-563	-9%	-12%	-13%
TSS	4,698	4,815	5,097	-443	-575	-649	-9%	-12%	-13%

*Mass of Fecal Coliform measured in Billions of Colony Forming Units (CFU)

The North Seattle Project would provide an additional benefit to Puget Sound by diverting to terrestrial use what would otherwise be some of the advanced secondary-treated effluent discharged to the Sound from the Brightwater plant. Potential demand for the North Seattle Project is estimated at about 314 million gallons per year or 0.86 mgd on an average annual basis. Using this volume of reclaimed water would keep about 3.1 metric tons of nitrogen[27], 26 billion CFU of fecal coliform, and 2.4 metric tons each of BOD and TSS out of the Sound annually. This represents about 0.04% to 0.05% of the total amount of these pollutants currently discharged from King County's existing treatment plants.

Table 18: North Seattle Reclaimed Water Project:
Mass of Selected Pollutants Diverted Annually from Puget Sound

	Metric Tonnes per Year
Total Nitrogen	3.1
Biochemical Oxygen Demand (BOD)	2.4
Total Suspended Solids (TSS)	2.4
Fecal Coliform	26*

*Billions of Colony Forming Units per Year

Summary of Benefits

Overall, the benefits of the North Seattle Project can be summarized as follows:

- An unquantified but minimal benefit to the Seattle regional water supply system associated with reducing irrigation season demand from the Seattle regional water system by 0.69 mgd. This benefit could take the form of increased supply, reliability, or streamflows in the source rivers.
- An unquantified but small environmental benefit to several urban watersheds associated with reducing the withdrawals of six of the seven major self-supplied irrigators by a total of 0.7 mgd.
- The avoidance of potable water variable costs with a present value of $880,000.
- The withholding of 3.1 metric tons of nitrogen, 26 billion CFU of fecal coliform, and 2.4 metric tons each of BOD and TSS annually from being discharged into Puget Sound.

[27] Another possible benefit of diverting nitrogen-containing reclaimed water from Puget Sound to land application is that irrigators could marginally reduce their purchases of fertilizer. However, this benefit is very small relative to the scale of the project and is not included in the analysis. The current price for fertilizer with 30% nitrogen is about $350 per metric ton. This works out to $1170 per ton of nitrogen. The annual value of 3.1 metric tons of nitrogen as fertilizer is therefore about $3600 with a present value of $100,000 discounted at 2.5% over 50 years

Step 5 - Project Alternatives

A number of alternatives were considered that provide one or more of the benefit types that have been ascribed to the North Seattle Project. These include:

- installing natural drainage systems in North Seattle
- switching self-supplied irrigators from their own sources to Seattle municipal water
- intensifying existing water conservation programs
- reducing the minimum drawdown level for the Tolt reservoir to increase water supply
- improving the level of treatment at existing wastewater treatment plants

Installing natural drainage systems (NDS) along street right of ways in North Seattle would reduce storm runoff, allowing it to infiltrate into the groundwater where it would be available to boost summer base flows in Thornton, McAleer and other local creeks. However, to provide the same increase in base flows as estimated for the North Seattle Project, NDS would have to be applied to as many as 200 to 350 blocks at a cost ranging from $65 to $115 million. While this would provide many other significant benefits in addition to higher summer base flows, it would not achieve some of the other specific benefits of the North Seattle Project yet it would cost almost as much.

A much less expensive alternative than the above would be to switch the six self-supplied irrigators from their own sources to Seattle municipal water. Taking Nile Country Club, Holyrood, Seattle County Club, Jackson Park, Acacia, and Sand Point County Club off of their own supplies would provide the identical benefit to local watersheds as the North Seattle Project but it would also increase irrigation season demand on Seattle's water system by 0.7 mgd. The conversion costs would be less than $50,000.

Two alternatives are described here that would offset the increase in Seattle system demand caused by taking on the self-supplied irrigators and then further reduce Seattle system demand by at least 0.7 mgd. SPU's existing conservation program could be intensified to save an additional 1.4 mgd of peak season demand. This would produce a net reduction in municipal demand of 0.7 mgd, providing the identical reliability and environmental benefits to the SPU supply system as the North Seattle Project. It would also avoid the same $880,000 in variable potable water costs. Ramping up rebate levels on high efficiency fixtures and appliances enough to achieve 1.4 mgd in conservation savings over and above what's already planned is estimated to cost up to $310,000 per year over a period of 20 years. Assuming average measure lives of 20 years, the program could be run continuously to preserve the savings indefinitely. In present value terms, that would be $8.8 million.

Alternatively, additional water supply for both municipal and possible environmental uses could be provided by drawing water from the South Fork Tolt Reservoir below the existing normal minimum operating level of 1,710 feet. Setting the minimum drawdown level to 1,695 feet would provide an additional 4 mgd of firm yield at very low capital, operating and environmental cost.[28] This was the lowest cost supply alternative analyzed in SPU's 2007 Water System Plan. Capital costs would be less than $360,000 with annual O&M expenses of around $170,000. The present value cost over 50 years at a 2.5% discount rate is $5.1 million. The Tolt Additional

[28] This elevation is thought to be the lowest drawdown level that would not trigger the need for enhancements of the Tolt water treatment facilities.

Drawdown project would provide several times more reliability and potential environmental benefits to the SPU supply system than the North Seattle Project but would not capture the $880,000 in avoided variable potable water costs.

An alternative for achieving the Puget Sound benefit of reducing the discharge of pollutants is to improve the level of treatment at existing King County treatment plants. A facility to produce Class A reclaimed water could be installed at the South treatment plant. This would take a portion of the secondary-treated effluent, treat it to reclaimed water standards using Membrane Bioreactor (MBR) technology, and then return it to the effluent stream being discharged to the Sound. This would significantly reduce the concentration of priority pollutants in the treated effluent as shown in the table below.

Table 19: Comparison of Effluent Concentrations for Priority Pollutants

	Effluent Concentrations		
Constituent	Secondary	Advanced (MBR)	Ratio*
Total Nitrogen	34 mg/L	2.6 mg/L	13.1
Fecal Coliform	24.2 CFU/100mL	2.2 CFU/100mL	11.0
BOD	15 mg/L	2 mg/L	7.5
TSS	17 mg/L	2 mg/L	8.5

* Number of times by which advanced treatment is "cleaner" than secondary treatment, e.g., there is 13 times more nitrogen in secondary treated effluent than in advanced-secondary treated effluent.

The analysis makes use of a model for estimating the cost of producing reclaimed water developed by a consultant for King County. The smallest facility for producing Class A water from secondary effluent analyzed by the model has a capacity of 1 mgd. Estimated capital costs would be $14 million with O&M costs of about $360,000 per year[29]. Discounted at 2.5% over 50 years, the present value cost of the facility would be about $18.3 million.

The impact of this higher level of treatment on 1 mgd of effluent would be to remove about 43 metric tons of nitrogen, 18 metric tons of BOD, 21 metric tons of TSS, and 304 billion CFU of fecal coliform from the effluent stream. These reductions are 8 to 14 times larger than what would be removed by the North Seattle Project.

Table 20: Comparative Effectiveness for Removing Priority Pollutants from Puget Sound

		Reduction in Discharge to Puget Sound		Factor by which MBR Reduction Exceeds North Seattle Project
	Units	North Seattle Project	1 mgd MBR Treatment	
Total Nitrogen	Metric Tons/yr	3.1	43.4	14
BOD	Metric Tons/yr	2.4	18.0	8
TSS	Metric Tons/yr	2.4	20.7	9
Fecal Coliform	BCFU*/yr	26	304	12

* Billions of Colony Forming Units

[29] Several upward adjustments have been made to the model's cost estimates. The costs have been inflated to 2009 dollars and reflect operation year-round rather than just during the irrigation season. The estimated cost of green house gas emissions associated with the energy used for pumping have also been added.

Step 6 - Cost-Effectiveness Analysis

Cost-effectiveness analysis involves specifying a set of benefits or level of service, then comparing the costs of various alternatives that can deliver those benefits. The alternative with the lowest life-cycle costs is the most cost-effective. This can be a helpful shortcut when the benefits of a project are difficult to quantify in dollar terms, as is the case here, but the options under consideration provide the same or at least similar benefits. The option having the lowest present value cost becomes the preferred option as long as it can be convincingly argued that the benefits, though unquantified, clearly exceed the cost of the least cost option.

None of the alternatives considered individually provide all the benefit types that have been ascribed to the North Seattle Project. Therefore, several of them were combined to produce a bundled option that covers all the benefits and is directly comparable to the North Seattle Project. The bundled option consists of three components:

- Providing six self-supplied irrigators with 0.7 mgd of Seattle municipal water over the irrigation season, eliminating their withdrawals from local watersheds.
- Offsetting the demand of the six new irrigation customers plus all the potential reclaimed water customers that currently use Seattle municipal water by increasing Seattle's investment in water conservation enough to achieve 1.4 mgd in conservation savings over and above what's already planned.
- Installing a 1 mgd MBR facility at the South treatment plant in Renton.

As calculated in the cost section and shown in the table below, the North Seattle Project has an estimated present value cost of $108.6 million. The bundled option would have a total cost of about $27.1 million: $46,000 to switch self-supplied irrigators to Seattle municipal water, $8.8 million for intensified conservation, and $18.3 million for the MBR treatment facility. This is just one fourth the cost of the North Seattle Project. However as explained above, the MBR facility would remove about 8 to 14 times more pollutants (11 times on average) than the North Seattle Project. To make an "apples-to-apples" comparison of benefits, the cost of the MBR plant can be divided by 11 to represent that portion of the plant associated with removing an equivalent amount of pollutants from Puget Sound as the North Seattle Project. Adjusting costs in this way, $1.7 million of the MBR plant costs are allocated to the bundled option. This implies a bundled option cost of $10.5 million for providing benefits equivalent to the North Seattle Project. as shown in the last column of Table 21.

Table 21: Total & Adjusted Present Value Cost for Components of the Bundled Option

Individual Alternatives		Present Value Cost	Benefits Relative to North Seattle Project	Cost for Equivalent Benefits*
1	Switch SSIs to Seattle Water	$45,900	Same	$45,900
2	Intensify Conservation Program	$8,800,000	Same	$8,800,000
3	1 MGD MBR Facility at South Plant	$18,260,000	8-14 times greater*	$1,660,000
Total PV Cost for Bundled Alternative		$27,105,900	-	$10,505,900
PV Cost for North Seattle Project		$108,562,922	-	$108,562,922
% of North Seattle Project Cost		25%	-	10%

* For ease of exposition, an average of 11 times greater is used to calculate the cost for equivalent benefits.

It can therefore be concluded that at $108.6 million, the North Seattle Reclaimed Water Project is not a cost-effective means of achieving the identified benefits. The bundled option would cost only a quarter as much and be able to generate *equivalent* benefits for 10% of the North Seattle Project's cost.

These results illustrate a general principal for addressing the question of what to do with high quality effluent such as that produced by an MBR facility – discharge it directly into receiving waters or divert it for use on land as reclaimed water. If the primary goal is to reduce pollution to receiving waters, a reclaimed water project is cost-effective only if the cost of *distributing* the reclaimed water is smaller than the cost of *producing* more of it. Otherwise, it's more cost-effective to add another MBR facility and discharge the higher quality effluent into receiving waters. While this does not reduce the *volume* of effluent, it decreases pollutant discharges by lowering the *concentration* of pollutants in the effluent. For example, if MBR treatment removes 90% of the pollutants in secondary-treated wastewater, then adding another 1 mgd MBR plant would keep 10 times more pollutants out of the receiving waters than diverting 1 mgd from the original MBR plant for use as reclaimed water. Therefore, in this example, developing a reclaimed water distribution system would have to cost at least 10 times *less* than a new MBR facility in order to be cost effective. Otherwise, the goal of reducing water pollution is more cost-effectively achieved by adding another MBR facility and discharging the higher quality effluent into the receiving waters. In the case of the North Seattle Project, the cost of the distribution system far exceeds this threshold for cost-effectiveness.[30]

Size is another issue. Installing a larger MBR plant than the minimum to reduce pollutant loadings to Puget Sound would likely be even more cost-effective than implied by the above. Due to economies of scale, cost-effectiveness in removing pollutants increases as facility size increases.

As shown in Table 22 below, 1 mgd MBR facility removes 84 times more nitrogen from Puget Sound than the North Seattle Project per dollar spent. At $108 million, a 15 mgd treatment facility would cost almost as much as the North Seattle Project but would keep 210 times more nitrogen out of the Sound. Although an 80 mgd facility, the largest analyzed in King County's model, would cost almost four times as much as the North Seattle Project, it would remove 1,122 times more nitrogen. That works out to 293 times more nitrogen removed per dollar spent.

[30] There are examples of possible reclaimed water projects that could meet this cost-effectiveness rule. The Tacoma Wastewater Treatment Plant discharges into the South Sound through an effluent pipe running within a few hundred feet of a paper mill that purchases approximately 10 mgd of potable water from Tacoma. There have been proposals to improve the level of treatment at the Tacoma plant to reduce the nutrient load to the Sound. If these improvements resulted in the wastewater being treated to reclaimed water standards, additional benefit could be gained at relatively little additional cost by diverting the effluent to the nearby paper mill. This would further reduce pollutant loading to the Sound while freeing up 10 mgd of potable water for other uses.

Table 22: Comparative Effectiveness for Removing Priority Pollutants from Puget Sound

		Reduction in Mass of Priority Pollutants Discharged to Puget Sound			
		N. Seattle	Advanced (MBR) Treatment at South Plant		
	Units	RW Project	1 mgd	15 mgd	80 mgd
Total Nitrogen	metric tons/yr	3.1	43	651	3,471
Fecal Coliform	BCFU*/yr	26	304	4,560	24,317
BOD	metric tons/yr	2.4	18	269	1,437
TSS	metric tons/yr	2.4	21	311	1,658
		Size of Reduction Relative to North Seattle Project			
Total Nitrogen	-	1	14	210	1,122
Fecal Coliform	-	1	12	174	929
BOD	-	1	8	113	604
TSS	-	1	9	131	697
		Project Cost			
Present Value	2009 $s	$108,560,000	$18,260,000	$107,590,000	$415,770,000
		Cost to Achieve Equivalent Pollutant Removal as North Seattle Project			
Total Nitrogen	2009 $s	$108,560,000	$1,300,000	$510,000	$370,000
Fecal Coliform	2009 $s	$108,560,000	$1,570,000	$620,000	$450,000
BOD	2009 $s	$108,560,000	$2,420,000	$950,000	$690,000
TSS	2009 $s	$108,560,000	$2,100,000	$820,000	$600,000
Multiples by which Alternatives Exceed Pollutant Removal of North Seattle Project per Dollar Spent					
Total Nitrogen	-	1	84	213	293
Fecal Coliform	-	1	69	175	241
BOD	-	1	45	114	157
TSS	-	1	52	132	181

* Billions of Colony Forming Units

While the analysis concludes that the bundled option is cost-effective relative to the North Seattle Project, this doesn't mean that the bundled option is the most cost-effective alternative available or that it should be recommended for implementation. Before that decision could be made, a wider range of alternatives would have to be examined and the problem statement would need to be revisited. As discussed at the outset of the report, a business case usually starts with a problem or problems of concern to be solved and then identifies what projects might help solve them. In this analysis, that process was reversed. It began with the North Seattle Project and then asked what problems the North Seattle Project could help solve. These may not be the highest priority problems or the ones that should be tackled first.

A process is now underway through the Puget Sound Partnership to develop a comprehensive problem statement regarding the environmental health of the Puget Sound basin. It may find that reducing nitrogen and other pollutant loadings at the Brightwater outfall site is not the greatest concern. For example, low dissolved oxygen levels are much more of a problem in the South

Sound than farther north so the nitrogen content of wastewater discharges is also of greater concern there.[31] Although the expected benefit to Puget Sound of reducing the pollutants discharged from South Plant may be greater than equivalent reductions at the more northern Brighwater outfall, it might make even more sense and provide greater benefits to Puget Sound to invest in improved wastewater treatment at points farther south before doing so in King County.

It could also turn out that there are higher priority actions than upgrading municipal wastewater treatment plants that would more cost-effectively improve the health of Puget Sound. Perhaps the region should first direct its limited resources to addressing the problems of failing septic systems along marine shorelines or storm runoff that washes toxic materials from impervious surfaces into rivers, lakes and the Sound. These questions, however, are beyond the scope of this analysis. While insufficient information has been gathered to conclude that the region should proceed with the bundled option, this analysis does conclude that the bundled option would be a much more cost-effective solution than the North Seattle Project to the problems the North Seattle Project would solve.

[31] Washington State Department of Ecology, November 2008, *South Puget Sound Dissolved Oxygen Study: Key Findings on Nitrogen Sources from the Data Report*, Publication no. 08-10-099

Step 7 - Perspectives Analysis

A limitation of benefit-cost analysis is that it doesn't consider the distributional implications of a project. It determines whether total benefits exceed total costs but ignores who wins and who loses. This can be overcome by including a perspectives analysis as part of the project evaluation process. A perspectives analysis links benefits and costs to various groups, identifying who incurs costs and who receives benefits from a particular project

In the perspectives table below, the world is divided into the following groups:

- reclaimed water customers,
- all other Seattle/Shoreline retail water ratepayers *except for* reclaimed water customers,
- all other sewer ratepayers served by King County *except for* Seattle/Shoreline water ratepayers,
- all other residents of the Puget Sound region *except for* those served by King County Wastewater Division, and
- the rest of the world excluding the Puget Sound region.

Table 23: Perspectives Analysis with Percentage of Benefits Received and Costs Paid

	Reclaimed Water Customers	Rest of Seattle Retail Water Ratepayers	Rest of KC Wastewater Ratepayers	Rest of Puget Sound Region	Rest of World	TOTAL
Present Value of Costs	**$507,940**	**$86,034,546**	**$9,092,110**	**$5,790**	**$12,921,886**	**$108,562,272**
Capital Costs	$507,510	$81,329,698	$5,203,702	$0	$0	$87,040,910
O&M Costs	$430	$4,703,594	$3,886,961	$0	$0	$8,590,984
Increased CO_2 Emissions	$0.12	$1,254	$1,447	$5,790	$12,921,886	$12,930,378
Unquantified Costs						
Construction Related	SOME	SOME	NONE	NONE	NONE	-
Real or Perceived Risk	SOME	NONE	NONE	NONE	NONE	-
Present Value of Benefits	**$0**	**$602,270**	**$31**	**$124**	**$277,768**	**$880,194**
Avoided Costs	$0	$602,243	$0	$0	$0	$602,243
Avoided CO_2 Emissions	$0	$27	$31	$124	$277,768	$277,951
Unquantified Benefits						
Puget Sound Benefits	0.001%	15%	17%	68%	0%	-
SPU Supply Reliability	0.004%	46%	54%	0%	0%	-
SPU Watershed	0.004%	46%	54%	0%	0%	-
Local Watershed	0.03%	99.96%	0%	0%	0%	-
Net Present Value*	**-$507,940**	**-$85,432,276**	**-$9,092,079**	**-$5,665**	**-$12,644,118**	**-$107,682,078**
Percent of Costs Paid	0.5%	79.3%	8.4%	0.005%	11.7%	100%

* Does not include unquantified costs and benefits

Project costs are allocated to the different groups as follows. Reclaimed water customers would pay the full $500,000 in on-site costs plus another $8,600 through rates as water and sewer ratepayers. Seattle and Shoreline water ratepayers would pay for all of the distribution system costs of the North Seattle Project ($85 million) plus 46% of King County costs since they represent 46% of King County wastewater ratepayers. It is assumed that King County wastewater ratepayers would pay the full capital and O&M costs of Phase II of the Brightwater Backbone project of which 65% is allocated to the North Seattle Project. This $16.8 million is split between the King County wastewater ratepayers that are also Seattle/Shoreline water ratepayers and the other 54% that are not. The costs of increased CO_2 emissions is a global cost and is allocated based on share of global population, 99.9% of which is outside the Puget Sound region. The percent of total quantified costs paid by each group is shown in the last line of the perspectives analysis table.

Although the benefits are unquantified in dollar terms, the approximate percentage share of each benefit that would be enjoyed by each group can be calculated and is shown in the table. It is assumed that the Puget Sound water quality benefits of the project are distributed proportionally to the whole Puget Sound region in which King County wastewater ratepayers, Seattle/Shoreline retail water ratepayers and reclaimed water customers are a part. The unquantified benefits affecting Seattle's supply system apply to a smaller area, mostly within King County. These benefits are assumed to be spread proportionally to King County wastewater ratepayers since most of them obtain their water – either retail or wholesale – from SPU. Benefits to local watersheds in North Seattle are assumed to be contained within Seattle and Shoreline's retail water service areas.

Given the allocation of costs described above, it appears that the percentage distribution of benefits would be very different than the distribution of costs. Two thirds of the Puget Sound benefit would accrue to people in the region *outside* of King County yet they would be assessed none of the project's cost. Seattle/Shoreline retail water ratepayers would be responsible for over 80% of the cost while receiving about 15% of the Puget Sound benefit and less than 50% of the benefits related to Seattle's water supply. King County sewer ratepayers outside of Seattle and Shoreline would enjoy similar benefits as Seattle and Shoreline but pay only 8% of the cost. Finally, the net cost of increased CO_2 emissions, estimated at $12.5 million, represents a negative externality imposed by the project on the rest of the world.

Calculating levelized costs for the North Seattle Project reveals what reclaimed water rates would have to be in order to recover costs from the users of reclaimed water. All public costs, including those already incurred (sunk costs), must be considered, but private costs are excluded. Therefore in this calculation, Seattle's share of Phase I Backbone costs ($10.6 million) is included but customers' onsite costs ($500,000) are not. As shown in the table below, annualized capital costs over 50 years with a 2.5% real discount rate are $3.4 million. Adding the $759,000 in annual operating costs and dividing by estimated annual demand for reclaimed water produces a levelized cost for revenue recovery of $9.95 per CCF.[32]

Many potential reclaimed water customers report that they would seriously consider switching to reclaimed water if it were available, according to the survey conducted by SPU for this analysis (Appendix J). However, none of the respondents said they would be willing to pay more than their current cost of water for reclaimed water and some said reclaimed water would have to cost less than what they currently pay. For self-supplied irrigators, that cost is very low, around 10¢ per ccf for pumping costs. Summer water rates for municipally-supplied users of non-potable

[32] Note this assumes 100% participation by all potential customers. To the extent that not all potential customers choose to participate, the cost per CCF would be higher. Of course the opposite is also true. If there turn out to be more customers along the pipeline route than initially identified, the cost per ccf could go down.

water are higher at around $4.00 per ccf but still 2.5 times less than the project's levelized cost. Therefore, it appears that revenue from reclaimed water sales would only be sufficient to recover a small portion of the public cost of the North Seattle Project with water and sewer ratepayers picking up the rest.

Levelized Cost Per CCF of the North Seattle Reclaimed Water Project For Establishing Rates to Recover Costs

Capital Costs	$97,096,600
Seattle Distribution System (Pipe)	$75,828,800
Distribution System Pump Station	$1,000,000
Seattle's Share of Phase I (65%)	$10,555,000
Seattle's Share of Phase II (65%)	$9,712,800
Annual Operating Costs	$758,800
Distribution System Pumping	$47,100
Seattle's Share of Phase II (65%)	$255,800
Environmental Cost of CO_2 Emissions	$455,900
Annualized Cost (50 years @ 2.5% discount)	$4,181,800
Annualized Captital Costs	$3,423,000
Annual Operating Costs	$758,800
Annual Demand for Reclaimed Water in CCF	420,089
Levelized Cost per CCF	**$9.95**

However, the perspectives analysis indicates that this is not a problem from an equity standpoint. Reclaimed water for irrigation and other non-potable uses should not be considered a benefit to potential reclaimed water customers because they already have a source of water and would just be switching from one source to another.[33] They would be receiving no more benefit from the North Seattle Project than their non-reclaimed-water-using neighbors so there's no reason for them to be assessed a greater share of project costs than what they would already be paying as water and sewer ratepayers in Seattle and King County.

[33] This does ignore what has been assumed to be a negligible benefit for SPU customers who switch to reclaimed water: the elimination of the possibility of being asked to curtail water use in the event of a municipal water supply emergency. One would expect potential reclaimed water customers to be willing to pay a premium above the price of municipal water if this was perceived by them as a significant benefit.

Step 8 - Sensitivity Analysis

The results of this economic analysis are based on assumptions and estimates around which there is much uncertainty. Costs may be more or less than estimated. There may be more or fewer reclaimed water customers than assumed using more or less non-potable water than estimated. The benefits of using reclaimed water may be higher or lower than estimated and different assumptions about the appropriate discount rates can significantly change the present value calculations. A sensitivity analyses is conducted on key assumptions and value estimates in order to explore the robustness of the results with respect to uncertainty.

Estimated project costs: A reasonable overall error range around the cost estimates is ±25% with even more uncertainty around estimating the social cost of greenhouse gas emissions. King County's reclaimed water comprehensive plan, for example, uses $40 per ton of CO_2 equivalent rather than the $100 used in this analysis. Assuming 25% lower capital and O&M costs, a 60% lower value for greenhouse gas emissions, and a lower share (44% rather than 65%) of Backbone Phase II costs allocated to the project, reduces the estimated project cost from $109 million to $73 million. On the high side, 25% higher overall costs and a 10% higher value for greenhouse gas emissions increases estimated project cost to almost $134 million.

Demand for reclaimed water: There are a number of parameters in estimating potential demand for reclaimed water. These include how many potential customers are there, how much non-potable water do they use, and what proportion of them would actually participate in the program?

All large areas of land that could be irrigated in North Seattle and Shoreline – including all golf courses, cemeteries, parks, and schools – were examined in this analysis,. Water billing records were consulted to identify any other large water users that could have some demand for non-potable water. The analysis originally identified 76 potential reclaimed water customers of which 26 were eliminated because they were found to have no demand for non-potable water or their demand was too small to justify extending a reclaimed water pipeline out to serve them. Because of the comprehensive nature of the search, it is thought unlikely that any potential customers with non-trivial demands for non-potable water were missed.

A number of methods were used to estimate non-potable water use including metered consumption data, survey data on application rates and irrigated acreage, "rules of thumb" from local irrigation experts, and an application of the water budget equation to Seattle conditions. Multiple methods were often used for the same customer to check for consistency and as a result, a high level of confidence in the reasonableness of the estimates is thought to be justified. Hotter, drier summers that could be brought on by climate change would be expected to cause some increase in irrigation demand. On the other hand, recent trends in the demand for irrigation water have been downwards, and those trends are expected to persist as irrigation efficiency improves and grass sports fields continue to be converted to field turf. For the purpose of this sensitivity analysis, an error range for the water consumption estimates of ±30% is used.

Finally, the current estimate of reclaimed water demand assumes 100% of the identified potential customers would participate. It's possible that less than 100% would actually be attained. One possible scenario would be that public schools do not participate along with a few of the private schools and smaller cemeteries and golf courses. In addition, the University of Washington uses reclaimed water for irrigation but not for cooling. This would reduce estimated demand by about 40%.

Benefits - Puget Sound loadings: Although there's much uncertainty around the supply and "upstream" environmental benefits of the project, they are not quantified in the analysis except to relate them to the level of demand by self-supplied or municipally-supplied customers. Therefore, the uncertainty around the demand estimates applies to these benefits.

The Puget Sound benefits relate to reduced pollutant loadings to Puget Sound which are themselves a function of the effectiveness of the MBR wastewater treatment process. Information used in this analysis on pollutant loadings in secondary treated effluent and the reduction in these loadings achieved by MBR treatment was obtained from a number of King County documents. However, the effectiveness of an MBR wastewater treatment system at removing some pollutants can vary based on factors such as the amount of organic material in the wastewater. Because of this, the Brightwater treatment plant may only bring the concentration of nitrogen down to 10 mg/liter instead of 2.6 mg/liter.[34] This reduces the benefit of treating wastewater with MBR but increases the benefit of keeping MBR-treated wastewater out of the Sound. Under these alternative assumptions, moving from secondary to MBR treatment would only reduce the concentration of nitrogen in treated effluent by a factor of 3.4 rather than 13. This means that treated effluent from Brightwater would contain 4 times more nitrogen than if it performed as anticipated in the County's published documents. This also means that diverting the effluent from Brightwater for use as reclaimed water would keep 4 times more nitrogen out of Puget Sound producing a fourfold increase in that particular benefit for the North Seattle Project.

Project Alternatives: The components of the bundled option are assumed to be subject to the same ±25% range in costs as the North Seattle Project. In addition, if actual MBR performance in removing nitrogen and BOD is as low as suggested above, then the benefit of installing a 1 mgd MBR facility at South Plant would be reduced by about one quarter.

Discount Rate: King County Wastewater Treatment Division has generally used a 3% real discount rate in its present value analysis with 7% being used for sensitivity analysis. Similarly, SPU has recently settled on a real discount rate of 2.5% as its baseline for benefit-cost analysis so a higher rate of 5% is used in this sensitivity analysis. The higher discount rate reduces the present value costs of the North Seattle Project and its alternatives by only a small amount because most of the costs are capital costs that occur in the first few years. However, raising the real discount rate to 5% increases the levelized cost of the project (i.e., the rate that would have to be charged reclaimed water customers to recover the public cost of the project over 50 years) from $9.95 to $14.47 per ccf.

Table 24 below summarizes the components of the sensitivity analysis. Three scenarios are presented. The "baseline" scenario reflects all the baseline assumptions and estimates of the

[34] As reported by phone conversation with Betsy Cooper, Wastewater Planner and Program Manager, King County Wastewater Treatment Division.

economic analysis. The "optimistic" scenario combines all the changes in assumptions described above that would be favorable to the North Seattle Project. These include:

- 30% higher demand for reclaimed water
- actual MBR performance lower than expected which increases the nitrogen-removal benefit of the North Seattle Project by a factor of 4 while reducing the Puget Sound benefit of the bundled option by one fourth
- a discount rate of 5% rather than 2.5%
- 25% lower capital and O&M costs for the North Seattle Project
- 25% higher costs for the projects in the bundled option
- 44% of Backbone Phase II costs allocated to the North Seattle Project rather than 65%
- 60% reduction in the estimated social cost of CO_2 emissions

The "pessimistic" scenario is just the opposite, choosing the assumptions that are less favorable for the North Seattle Project.

Table 24: Impact of Sensitivity Analysis on Cost Effectiveness

	Sensitivity Analysis Scenarios		
	"Optimistic"	"Baseline"	"Pessimistic"
Demand for Reclaimed Water (peak season mgd)	2.2	1.7	0.8
Self-Supplied Irrigators	1.3	1.0	0.5
Municipally-Supplied	0.9	0.7	0.3
Puget Sound Benefits (Nitrogen Removal)			
Project (metric tons per year)	11.9	3.1	3.1
Bundled Option (metric tons per year)	33.2	43.4	43.4
Discount Rate	5.0%	2.5%	2.5%
Present Value Costs (millions of $s)			
Project	$72.8	$108.6	$133.8
Bundled Option*	$29.1	$27.1	$20.4
% of North Seattle Project Cost	40%	25%	15%
Bundled Cost for Equivalent Benefits	$15.0	$10.5	$7.9
% of North Seattle Project Cost	21%	10%	6%

* Note that the present value cost of the bundled option in the "Optimistic" scenario is only 7% higher than in the "Baseline" scenario because much of the 25% increase in overall costs is offset by the higher 5% discount rate.

The sensitivity analysis reveals that with all the optimistic assumptions, the North Seattle Project is more attractive than under the baseline assumptions but it is still not cost-effective. Project costs are reduced from $108.6 million to $72.8 million while the present value costs of the bundled option increase to $29 million. The adjusted cost of the bundled option reflecting equivalent benefits increases by 43% over the baseline scenario to $15.0 million. This is still only 21% of the cost of the North Seattle Project and implies that even under the optimistic scenario, the bundled option is about 5 times more cost-effective.

Conclusions

It was estimated that the full life-cycle cost of building and operating a distribution system to deliver reclaimed water from the Ballinger Way portal of the Brightwater reclaimed water backbone to potential customers in North Seattle and Shoreline would be about $108.6 million.

The potential benefits of the North Seattle Project were found to be minimal. The project would be expected to reduce peak season demand from Seattle's regional water supply system by up to 0.7 mgd. By itself, this amount is too small to have a detectable positive impact on regional water supply reliability or environmental conditions in the Cedar and Tolt rivers. The project would also be expected to reduce by up to 1 mgd the peak season withdrawals of self-supplied irrigators from their own local supplies. This might provide small improvements in habitat conditions for several streams in the area though it would not be expected to result in significant increases in biological productivity. Finally, the project would be expected to reduce the discharge of pollutants from King County treatment plants into Puget Sound by about 0.04% to 0.05%.

Some alternative means of achieving these benefits were identified although none of them individually could provide all the benefit types ascribed to the North Seattle Project. Therefore, three of them were combined to produce a bundled option that would provide benefits equal to or greater than those expected from the North Seattle Project. The estimated life-cycle cost of the bundled option is $27.1 million or 25% of North Seattle Project. When adjusted to reflect equivalent benefits, the bundled option cost is $10.5 million which amounts to 10% of the North Seattle Project cost.

The analysis concludes that the North Seattle Project would not be a cost-effective means of attaining these modest benefits. It is therefore recommended that the City of Seattle not proceed with the North Seattle Reclaimed Water Project. This basic conclusion is not affected by major changes to the key estimates and assumptions.

Before recommending the bundled option for implementation, a fuller analysis of the environmental problems facing the Puget Sound basin and the available alternatives for addressing them would have to be undertaken.

Finally, it is hoped that this analysis will serve as a useful example of how the WateReuse Foundation's Framework and asset management principles can be applied to the evaluation of other potential reclaimed water projects in the region.