An Economic Analysis of the North Seattle Reclaimed Water Project

Appendices

Seattle Public Utilities

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APPENDICES

Appendix A

Summary of Earlier Studies of Reclaimed Water by Seattle and King County

Several reclaimed water feasibility studies have been performed over the last 10 years in King County. The studies and their conclusions are briefly described below. Note that with the exception of the business case analysis of the Brightwater Backbone, the various analyses of reclaimed water have defined “cost effectiveness” and “economic feasibility” in the narrower financial sense. Attempts were generally not made to identify and quantify benefits of reclaimed water. Rather, the cost per ccf at which a potential project could provide reclaimed water was usually calculated and compared to the price of potable water or the per ccf cost of developing a new potable water source. Unless the per ccf cost of a reclaimed water project was found to be less than, equal to, or at least not too much more than the cost of potable water, it was deemed “impractical” or “not cost effective.”

1995 Recycled Water Demand Study, Duwamish Corridor

In 1995, the City of Seattle Water Department published the *Recycled Water Demand Study, Duwamish Corridor*. The study examined future demand for recycled water for customers along the Duwamish Corridor in the cities of Seattle and Tukwila. The study concluded that due to high cost, technical challenges, and only modest water savings, the development of a large recycled water treatment and distribution infrastructure was impractical at the time.

King County Reclaimed Water Studies

In 1995, King County, the City of Seattle Water Department and the City of Renton published a study titled *Water Reclamation and Reuse: A Feasibility Study for the King County Metropolitan Area*. The study concluded that under most conditions, the present cost of reclaimed water service would be higher than the Seattle marginal cost for developing new potable supplies. A successful project would have to serve a reasonably large demand (at least one MGD) and be located adjacent to a source of secondary treated effluent. The report noted that the King County Renton Effluent Transfer System (RETS) 96-inch pipeline in the Duwamish Corridor already had twelve taps in place for reclamation and reuse. Therefore, site-specific reuse projects along the Duwamish Corridor were suggested as having the most potential to be cost-effective.

In 2000, King County published another study titled *Reclaimed Water Program Demonstration Phase - Identification of Potential Satellite Projects for Direct Non-Potable Uses* (King County DNR, 2000). This study recommended completing a feasibility study for a Sammamish Valley Reclaimed Water Production Facility. More recently, however, King County decided that the area could be served more appropriately by reclaimed water from the Brightwater Plant, and plans for the interim facility were halted.

SPU 2003 Wastewater Reclamation and Rainwater Harvesting Study

In 2002, Seattle Public Utilities (SPU, formerly Seattle Water Department) compiled a list of over 90 potential reclaimed water and rainwater harvesting opportunities in SPU’s service area (about 75% of King County). Eleven of the projects were selected for further evaluation. Project descriptions and preliminary cost estimates were developed for each alternative. The project descriptions included the reclaimed water source, the end user, and the facility size, location and components. The projects were evaluated based on five criteria: annualized cost per ccf, annual purchased water reduction, initial capital cost, political complexity, and partnering potential. The study concluded that only the Birmingham Steel/West Seattle Golf Course alternative had a unit cost of water that was low enough to be considered for implementation ($1.88/ccf). The other projects' unit costs of water were considered too high ($10-$64/ccf) to justify the projects, except on the basis of other merits such as ease of implementation or other unique circumstances.

Brightwater Project Analyses

In 2006, King County released its *Draft White Paper: Reclaimed Water Backbone Project, Version 3.0* which described proposed conveyance facilities to deliver reclaimed water to potential users from the Brightwater Wastewater Treatment Plant. The plan consisted of three phases. The first phase included the construction of two backbone pipeline segments, the South Segment (to Sammamish Valley) and the West Segment (to Ballinger Way Portal). This phase included bringing the South Segment on-line. Phase II involved increasing pumping capacity at the Brightwater Plant and bringing the West Segment into service. Phase III consisted of constructing a distribution system from both backbones. The white paper provided a review of alternatives evaluated, demand estimates and anticipated costs. It was concluded that:

- Distributing Class A water from Brightwater could provide a number of environmental and social benefits.
- A preliminary market assessment indicated a large demand and need for reclaimed water that could support the cost of the backbone conveyance system.
- The backbone project is the least costly means of distributing reclaimed water from the planned Brightwater treatment plant to irrigation customers in the area.
- It will be possible to recover the project's full costs through rates charged to the recipients of reclaimed water that are competitive with, or less than current potable water rates.
- The decision to build the backbone pipeline must be made immediately or the opportunity will be lost.

After the Brightwater Backbone proposal was rolled out to area wastewater utilities in late 2005, SPU took a second look at the backbone project and produced its own analysis. In its *Review and Assessment of King County Reclaimed Water Proposal - SPU Business Case Analysis: Identifying and Evaluating Alternatives, Benefits and Costs*, SPU arrived at different conclusions than the County. The major conclusions of the study were:

- The project would not be cost-effective for the region.
- Project benefits (i.e., the impact of the project on extending potable supplies and improving stream flow conditions for salmon) would be very small.
- A number of alternatives exist for obtaining the same or more benefits at a fraction of the cost.
- The potential demand for reclaimed water in the project service area was significantly overestimated in the White Paper.
- The project would not come close to paying for itself through sales of reclaimed water.

King County Reclaimed Water Feasibility Study

In 2007, King County prepared a reclaimed water feasibility study to meet the provisions of Regional Wastewater Services Plan policy objectives. The study reviewed reclaimed water technologies, revenue sources, markets, and environmental and regional benefits.

Overall findings of the feasibility study are as follows:

- Reclaimed water is an effective wastewater management tool.
- Reclaimed water technologies in use at West Point and South Treatment Plants and planned for the Carnation and Brightwater Treatment Plants are highly effective.
- Benefit-cost analysis and tools like the WaterReuse Foundation's framework should be used to evaluate projects.
- Sources of revenue are varied and may be increasing at state and federal levels.
- Feasible projects would include one or more of the following characteristics:
    - Reclaimed water is a requirement or a secondary benefit of new or upgraded wastewater facilities.
    - Reclaimed water demand is close to supply.
    - Reclaimed water will mitigate or benefit another environmental objective for which others will contribute to costs.
- Public education and research/development are essential to maintain public support for reclaimed water.
- A comprehensive reclaimed water plan is needed that identifies and prioritizes water resource management needs for a full range of beneficial uses.

Green River Reclaimed Water Study

Also in 2007, King County completed a preliminary analysis of reclaimed water options in the Green River Valley to answer questions raised by the Cities of Auburn, Covington, Kent, Renton, and Tukwila. The key questions addressed in the study were:

- What treatment processes and equipment are necessary to produce and deliver Class A reclaimed water to the Green River Valley?
- How much reclaimed water might be made available through each production/delivery scenario?
- What can be estimated about the relative capital and operating costs for each production/delivery scenario?
- What appears to be the most feasible approach to producing and delivering reclaimed water in the Green River Valley based on preliminary estimated costs, capacities, demands, and operational issues?

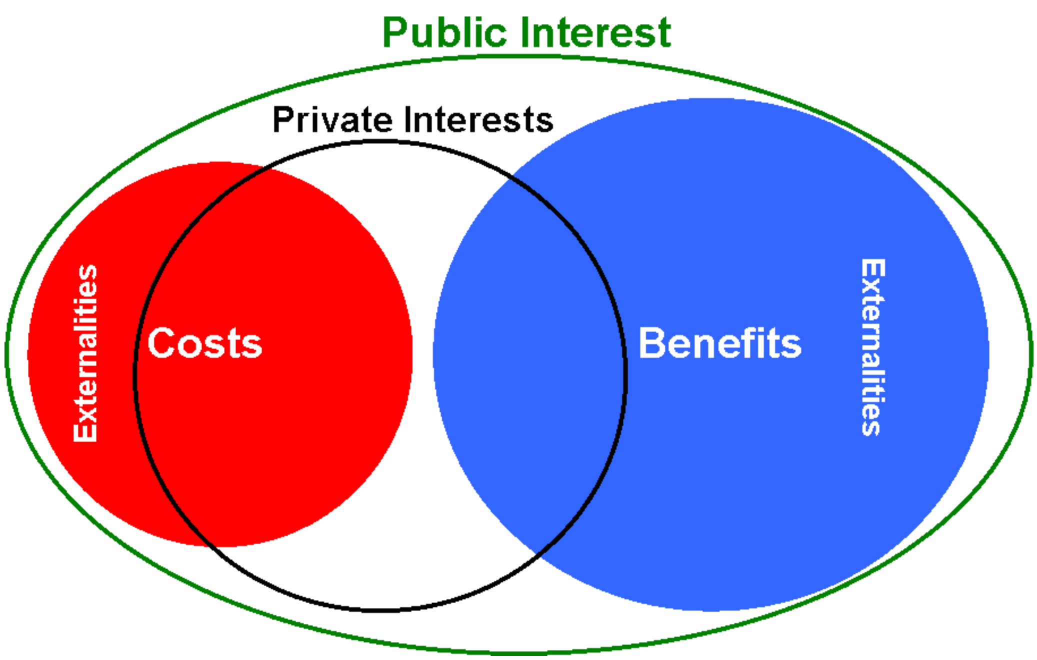
The study considered various delivery options, including a South plant backbone, satellite reclaimed water polishing plants, and satellite reclaimed water treatment plants. Preliminary cost estimates and analysis of ability to meet reclaimed water demands were prepared for each delivery option. Of the three scenarios assessed, the South plant backbone appeared to be the most cost-effective overall, offering the greatest flexibility to support varied reclaimed water demand, distribution, and supply needs.

Appendix B

Principles of Benefit-Cost Analysis

As the name implies, benefit-cost analysis is a systematic evaluation of the advantages (benefits) and disadvantages (costs) of a set of alternative actions. It entails adjusting conventional business profit-and-loss calculations to reflect social instead of just private objectives, criteria, and constraints. The goal is to account for *all* benefits and costs of potential actions, (financial, environmental and social,) even those that do not have readily observable market values.

Private and public entities assess benefits and costs differently. While a private company is only interested in the benefits it can capture and the costs it must pay, a governmental agency should consider all benefits of a project no matter who receives them, and all costs regardless of who bears them. This difference in the perspectives of private and public entities is illustrated in the diagram below.



Costs that a private company doesn't have to pay and benefits that it cannot collect are known as ***externalities***. For example, a private decision to drive to work will probably consider the costs of fuel, maintenance and parking but not the "external" costs that one more driver imposes on the rest of society. These externalities include increased traffic congestion and higher levels of green house gases and other pollutants. An example of a positive externality would be the case of a landowner who, by choosing not to develop her land, preserves a water recharge source for an aquifer shared by the entire community. A benefit-cost analysis tries to draw a circle around all the costs and benefits, "***internalizing***" all the externalities.

Several other concepts are central to understanding the reasoning behind benefit-cost analysis. These are scarcity, choice, opportunity cost, and efficiency. ***Scarcity*** refers to the fact that we live in a finite world with limited resources but seemingly unlimited wants. We must therefore make ***choices*** in how we use our time, labor, capital and natural resources. And every choice has an ***opportunity cost***, i.e., the benefits we could have had if we had made a different choice. While the cost of a good or service often is thought of in monetary terms, the opportunity cost of a decision is what must be given up (the next best alternative) as a result of the decision.

Finally, ***economic efficiency*** is the ratio or proportionality between the value of the human objective achieved ("benefits" or "satisfactions") and the value of the scarce resources expended to achieve it (opportunity costs). When an economist calls a situation or a practice "inefficient," he is claiming that we could achieve the same desired goals with the expenditure of fewer scarce resources, or, put another way, that the amount of resources being employed could potentially produce even more of the beneficial results intended than they do. Efficiency simply means making the most we can of the limited resources we have – getting the most "bang for the buck."

The goal of benefit-cost analysis is more than simply determining whether a project's benefits exceed its costs. It's to identify which project among all the alternatives produces the greatest ***net*** benefits, i.e., the project with benefits that exceed its costs by the largest margin. Such a project achieves the goal of economic efficiency.

Moving away from high concept and more into the nuts and bolts of benefit-cost analysis is the issue of finding a common unit of measure. The problem is the standard economist cliché, "you can't compare apples to oranges." Before all the costs can be totaled and subtracted from the sum of all the benefits, everything must be expressed in the same units and the traditional choice of units is dollars. While dollar values for many components of benefit-cost analysis are easily obtained – for example, the land, labor, capital and resources used in building a project – others require more effort. If a project results in reduced traffic congestion (driver hours), reduced cancer risk (deaths per million), or improved habitat for endangered species (spotted owls per acre), the challenge is to translate these different units into dollars. Ideally, all benefits and costs can be quantified in dollar terms.

Even when that has been accomplished, there remains one more step because not all dollars are equal. A dollar a year from now is not worth as much as a dollar now. A dollar 10 years from now is worth even less. Why? There are three reasons: time preference, the opportunity cost of capital, and risk.[1] If you ask me for $100 now and promise to pay me the $100 back in a year, I'm going to say no. If I give you that $100, I'll lose the option of using it myself to buy something I need or want right now. I'll also lose the option of saving that $100 and earning interest. Finally, there's the risk that you will not pay me back as promised. So to get that $100 from me now, you'll have to promise to pay me back more than $100 a year from now. The extra amount that must be paid, expressed as a percentage, is the discount rate. If I'm just willing to give you $100 in exchange for your promise to repay me $103 in one year, my discount rate is 3%.[2] In other words, $100 a year in the future is worth 3% less to me than it is now.

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[1] There's actually a fourth reason - inflation - that reduces the worth of future dollars, but this is handled differently. Economists adjust for inflation by using "constant" or "real" dollars as their unit of measure. Constant dollars are dollar amounts that have been adjusted by means of price and cost indices to eliminate the effects of price inflation and allow the direct comparison of dollar values across years.

[2] This is a "real" discount rate with no inflation premium because it's associated with "real" dollars.

This concept is used to convert the dollar value of benefits and costs that will occur in various future years to "present values," a common unit of measure that allows "apples to apples" comparison. The present value of a future benefit is equal to its future value in real dollars reduced by the discount rate (say 3%) as many times as the number of years in the future the benefit will occur.[3] Calculating present values is one of the necessary tasks in conducting a benefit-cost analysis.

The other basic steps of benefit-cost analysis are summarized below:

- Identify the problem(s) to be solved. Determine objective(s).
- Define the "baseline," i.e. the current situation and what will happen if no action is taken.
- Identify possible alternatives for solving the problem/achieving the objective.
- Identify all benefits and costs for each alternative.
- Quantify benefits and costs in real dollars.
- Calculate Present Values (PV) of all benefits and costs.
- Calculate the Net Present Value (NPV) for each alternative. The NPV is the PV of all the benefits minus the PV of all the costs.
- Identify the preferred alternative, usually the one with the highest NPV. (In some circumstances, it's more appropriate to use benefit/cost ratios.)

Some of these steps sound easy enough but are often difficult to accomplish in practice. Probably the biggest challenge for benefit-cost analysis is quantifying all benefits and costs, especially environmental externalities, in dollars. Externalities, by their very nature, are often characterized by a paucity, if not the complete absence, of hard data. For example, consider a potential reclaimed water project that could provide water to a several farms, parks and golf courses, allowing them to reduce withdrawals from their own wells which are believed to be in hydraulic continuity with a nearby stream with less than ideal flow and temperature conditions for various types of fish including one endangered species. Scores of questions would have to be answered to quantify the environmental benefits: How would the reduced well withdrawals affect ground water levels? What is the extent of hydraulic continuity between ground water and stream? What is the temperature differential? How would the increased flow of colder groundwater impact water temperature as well as the width and depth of the stream? What effect would these changes have on the different fish populations?

Assuming the science was available to answer these questions, there would still remain the task of assigning approximate dollar values to the estimated increase in fish populations. Market prices would provide little help in determining the value of these fish, except perhaps as a food source. But what about their value in preserving bio-diversity (the endangered species) or improved recreational opportunities (the non-endangered species)? Economists have developed a number of non-market valuation methods to try to estimate dollar values for these kinds of "outside-the-market" services provided by ecosystems. (A good description of many of these can be found on the website "Ecosystem Valuation" at http://www.ecosystemvaluation.org.)

[3] In mathematical terms, the present value (PV) is equal to the future value (FV) divided by (1+r) to the t power, where r equals the discount rate and t equals how many years in the future the benefit occurs:

$$PV = \frac{FV}{(1+r)^t}$$

Stated Preference Methods

- *Contingent Valuation Method*
  Estimates economic values for virtually any ecosystem or environmental service. The most widely used method for estimating non-use, or "passive use" values. Asks people to directly state their willingness to pay for specific environmental services, based on a hypothetical scenario.

- *Contingent Choice Method*
  Estimates economic values for virtually any ecosystem or environmental service. Based on asking people to make tradeoffs among sets of ecosystem or environmental services or characteristics. Does not directly ask for willingness to pay – this is inferred from tradeoffs that include cost as an attribute.

Revealed Preference Methods

- *Hedonic Pricing Method*
  Estimates economic values for ecosystem or environmental services that directly affect market prices of some other good. Most commonly applied to variations in housing prices that reflect the value of local environmental attributes.

- *Travel Cost Method*
  Estimates economic values associated with ecosystems or sites that are used for recreation. Assumes that the value of a site is reflected in how much people are willing to pay to travel to visit the site.

Other Methods

- *Benefit Transfer Method*
  Estimates economic values by transferring existing benefit estimates from studies already completed for another location or issue.

None of these methods are perfect; in fact, most have serious shortcomings. They can be time-consuming and costly to conduct with massive data requirements, susceptible to numerous kinds of bias and a tendency to produce inconsistent results. The drawbacks are really too numerous to be described herein but again, the reader is referred to the Ecosystem Valuation website for a fuller exposition. In short, all these methods should be used with caution.

Fortunately there are sometimes shortcuts that can allow the analyst to avoid having to use one of the non-market valuation methods.

- **The 80/20 Rule:** The familiar 80/20 rule often applies to economic analysis, i.e. you can probably get 80% of what's possible out of the analysis for about 20% of the effort. And 80% is often good enough to make an unambiguous project decision. Once all costs have been estimated, it may become clear that not all the benefits have to be quantified to know which option is superior. At that point, you may stop quantifying those benefits, although you should be able to describe them qualitatively. For example, suppose that Option A has $100 in benefits and $50 in costs. Option B has $110 in *quantified* benefits and $40 in costs plus an additional unquantified benefit from reduced pollution. Because Option B has $10 more in quantified benefits and $10 less in costs, even without the additional benefits from reduced pollution, it is preferred to Option A. It's not necessary to quantify the benefits from reduced pollution to conclude that the Net Present Value for Option B is both positive and greater than the NPV for Option A.

- **Cost Effectiveness Analysis:** The phrases cost effectiveness analysis and benefit-cost analysis are often confused. 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 but all 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.

Another shortcoming 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. These groups may include direct beneficiaries, all a utility's ratepayers, and the entire region or beyond. For example, consider a project to improve the quality of stormwater discharge that benefits the whole region by enhancing fish habitat. A spillover benefit of the project is aesthetic improvements to the neighborhood. The capital costs are funded through the utility's drainage rates but neighborhood volunteers will perform required maintenance to keep the project functioning. This is depicted in the perspectives table, below.

Perspectives Analysis Summary Table – Stormwater Project

	Neighbors	Rest of Ratepayers	Rest of Region	TOTAL
Habitat Benefits (PV)	$50	$199,950	$400,000	$600,000
Aesthetic Benefits (PV)	$100,000			$100,000
TOTAL BENEFITS	**$100,050**	**$199,950**	**$400,000**	**$700,000**
Capital Costs (PV)	$50	$499,950		$500,000
O&M Costs (PV)	$15,000			$15,000
TOTAL COSTS	**$15,050**	**$499,950**	**$0**	**$515,000**
NET PRESENT VALUE	**$85,000**	**-$300,000**	**$400,000**	**$185,000**

Capital costs are shared by the neighbors (who are also ratepayers) and the rest of the ratepayers. Habitat benefits are shared between ratepayers (including the neighbors) and the rest of the region. A skilled economist has managed to assign dollar values to the habitat and aesthetic benefits. A standard benefit-cost analysis has identified this project as the preferred option with a Net Present Value of $185,000. However, the perspectives analysis reveals that the costs and benefits are not spread evenly among the different groups. While the neighbors pay very little of the cost, they get a portion of the habitat benefits and all the aesthetic benefits, enjoying $85,000 in benefits above their costs. The rest of the ratepayers are the big losers in this, paying $300,000 more in costs than they get back in benefits. In the winners column is the rest of the region which gets $400,000 in benefits without paying any of the costs.

If the utility only considers the welfare of its own ratepayers in deciding which projects to undertake, it will reject this project, even though this would clearly be a mistake from society's point of view. By identifying beneficiaries of the project outside the utility's service area, the perspectives analysis could be used to facilitate equitable cost recovery, providing justification for grants and other external financial assistance from county or state agencies, and possibly making the difference between the project going forward or not. This could be especially important considering the current legal climate in which utilities are being restricted from providing services outside their line of business or to anyone other than their ratepayers.

Despite its challenges and shortcomings, benefit-cost analysis can be a very useful tool in helping public agencies to:

- Ask the right questions,
- Make good investment decisions,
- Avoid costly mistakes, and
- Get the most "Bang for the Buck."

Appendix C

A Summary of "An Economic Framework for Evaluating the Benefits and Costs of Water Reuse"

developed by Bob Raucher and the WateReuse Foundation

The WateReuse Foundation framework is, in essence, a tool to help water agencies and other water sector professionals apply the standard tools of economic benefit-cost analysis to potential investments in reclaimed water. The full 188 page report, entitled "An Economic Framework for Evaluating the Benefits and Costs of Water Reuse," and the accompanying CD-ROM can be obtained from the WateReuse Foundation. An order form can be found at:

http://www.watereuse.org/files/images/wrf_03-006-02_Proj_Prof_0.pdf

An overview and summary of the framework is provided, below. Much of the information is excerpted directly from the WRF report.

The report begins by noting that one of the key challenges for reclaimed water projects is that financial assessments of such projects may often appear unfavorable, even if total project benefits outweigh the project's costs. While financial analyses are very important and useful in many ways, they typically provide too limited a context with which to evaluate the true social worth of a reclaimed water project. This is because a financial analysis focuses strictly on revenue and cost streams internal to the water agency, its purpose to determine whether projected revenues and other funding sources will be sufficient to pay for a project's capital and operating costs. Like the decision-making process of a private company, a financial analysis ignores externalities, (i.e. the costs the agency doesn't have to pay and the benefits that don't provide revenue).

In contrast, an economic analysis takes into account, not only financial costs and revenues, but the full range of benefits and costs associated with a project from the perspective of society as a whole. These can include environmental and social benefits and costs not captured in a financial analysis. Economic analysis answers questions such as:

- Is the value of all of the benefits of a project greater than the value of all the costs, (i.e. does the project have a positive net present value)?
- How do the net present values of an array of alternative projects compare?

The term "full social cost accounting" refers to the economics perspective of trying to identify and account for all the benefits and costs of a potential action or policy, regardless of who bears the impact, or whether the impact can be valued using observed market prices. In other words, the benefit-cost analysis framework is intended to help utilities include benefits, costs, and risks borne "internally" by the wastewater (and/or water supply) agency as well as those impacts borne "externally" by other parties (e.g., ratepayers, other agencies, special interest groups, the broader region, and society as a whole).

How does an agency demonstrate that a reclaimed water project is "economically and environmentally appropriate," or that a project has "equitable access to benefits" and provides "the greatest public benefits?" Today, many wastewater and water supply agencies are individually developing their own "templates" for comparing alternatives and selecting water reuse management plans. These individual approaches vary in their quality and extent, and are likely to include widely differing approaches with widely differing effectiveness. And, as the public grows increasingly aware of and interested in water reuse and supply planning for their communities, the necessity for thorough, acceptable analyses of alternatives continues to grow. A uniform and well-founded approach is needed to ensure quality, reduce utility effort, and promote broader acceptance and usefulness.

To address this need, the WRF report provides an analytical framework for conducting a "full social cost accounting of the benefits and costs of reclaimed water projects. The benefit-cost analysis framework enables project evaluators to undertake structured comparative analyses of alternative approaches to help determine which projects should be undertaken and which should not. Benefit-cost analysis is widely used, and in some cases federally mandated, in evaluating complex projects that have substantial environmental and social impacts. However, benefit-cost analysis alone does not provide all the answers. For example, it does not address the equity issues that often arise with public projects.

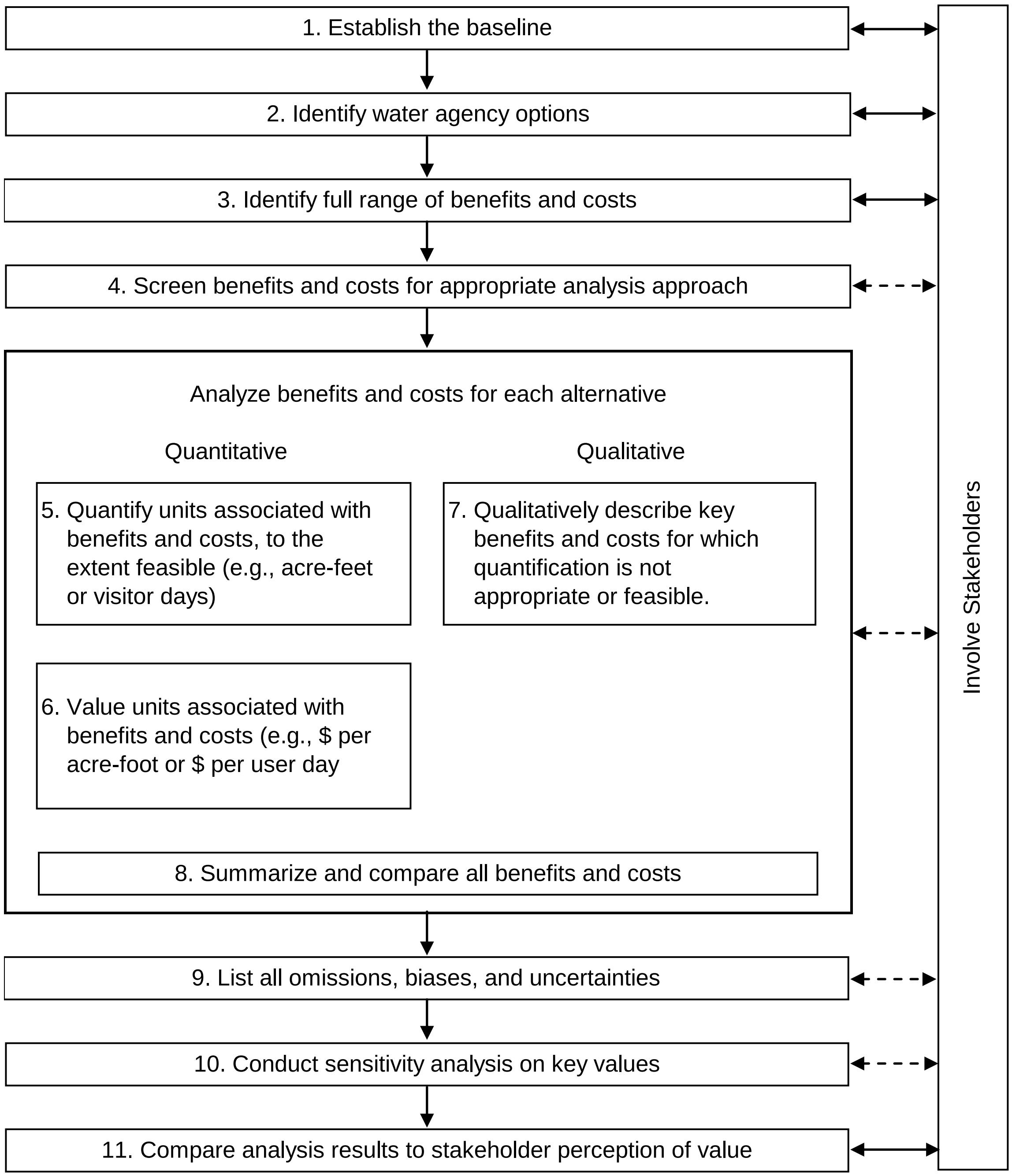
A perspectives analysis is useful in sorting through the distributional implications of a reclaimed water project. It addresses the question of who benefits and who pays.

There are several perspectives to consider when analyzing benefits and costs of a reclaimed water project. These include the direct beneficiary perspective, the water and/or wastewater ratepayer perspective, the regional perspective, and the societal perspective. A benefit from one perspective may be a cost from another perspective. For instance, providing reclaimed water at rates less than the price of potable water is a benefit to the reclaimed water customer, but may be a cost to ratepayers. Understanding and tracking all of these perspectives is key to understanding motivations for supporting reclaimed water projects and possibilities for cost-sharing arrangements. Identifying the beneficiaries of projects as well as those who bear the costs can help facilitate equitable cost recovery, provide justification for grants and other external financial assistance, and enable more extensive stakeholder identification and involvement.

In addition to developing tools to elucidate the financial, environmental, social and distributional implications of reclaimed water projects, another key function of the economic framework is to provide a means through which agencies can communicate their key assumptions, inputs, and findings with impacted communities and stakeholders. The WRF framework can and should be used to facilitate a process wherein input is invited from relevant individuals and organizations, and through which utilities systematically reveal the key assumptions, input values, sensitivities, and other factors embodied in the analysis.

The following steps make up the economic framework for analysis of reclaimed water projects, and are summarized in the figure below.

Steps in the Economic Analysis Framework



Step 1. Establish the baseline

Defining the baseline is a very critical step, not just because it establishes the accounting stance within which reclaimed water projects and other options are evaluated and compared, but also because it establishes the problem solving context within which the water reuse and other alternatives are being considered by the agency and the community as a whole.

The baseline represents the outcomes associated with the “no action” status quo. This base case may entail doing nothing (i.e., not pursuing a water reuse project, or not augmenting the utility’s water supply through an alternative to reuse), or undertaking already planned actions. The baseline is the mark against which changes resulting from the project alternatives are measured. It is important to define the scale and timing of the impacts of the baseline, articulate what problems the proposed project (or range of project alternatives) are intended to resolve, be explicit about assumptions, and engage stakeholders about their perspective of what happens under a no action, status quo baseline.

Presumably, a water agency or community is considering reclaimed water (and perhaps other water supply augmentation options) because it is seen as a possible solution to a current or anticipated problem or set of problems. Thus, in defining the baseline for the economic analysis, it is critical that the baseline be defined in a manner that helps articulate what problem(s) and/or value enhancements the reuse project and its alternatives would address. By specifying “what is the problem to be solved,” the economic analysis is then suitably framed to compare how well reclaimed water and other options serve as vehicles to solve the problem(s) and provide the community with outcomes it values.

Another challenge to defining the baseline is that the “with” and “without” context can become a place where stakeholder and utility hidden agendas or disagreement over core assumptions often arise. For example, setting the baseline may set off a debate between the utility and stakeholders, over future demand projections (e.g., where some members of the community hold alternative views about the size and pace of future population growth, or about the effectiveness of additional conservation opportunities). Therefore, it is important to carefully define the baseline, be transparent about underlying assumptions, and engage relevant stakeholders at this critical stage of the economic analysis. The assumptions underlying these future projections should also be clearly stated, and may become a focal point for discussions with stakeholders (and/or serve as a basis for sensitivity analyses), as discussed later in Step 10.

Step 2. Identify water agency options

One important key to conducting a proper economic evaluation is to place reuse in a comparative context, evaluating these options in terms of both a default scenario of no new water supplies, as well as comparing reuse to other water supply alternatives specific to given regions (e.g., additional surface water extractions, agricultural-urban water transfers, water conservation). It is therefore essential to identify and develop all the relevant utility options that will be compared to the baseline, and to each other.

Obviously, the more options that are considered, the more complex the analysis will become. However, the results will also be most valuable if all the relevant feasible options are evaluated. It is also useful to scale project options to a common size or objective. For options available at different scales, it is helpful to consider staging or combinations of options.

Step 3. Identify the full range of relevant benefits and costs for selected option

Develop a thorough inventory of all likely costs and benefits associated with each of the project alternatives (options). Include costs and benefits beyond those faced by the utility alone or customers alone. In other words, try to identify *all* the benefits and costs – financial, social, and environmental – regardless of to whom they may accrue, or where they might be realized.

Note that that it is important to establish and then carefully maintain the appropriate accounting stance. Benefits and costs must be defined and measured relative to the baseline chosen in Step 1. For example, if a reclaimed water project would eliminate the need to build a new source of potable supply, then how the related benefits and costs are accounted for depends on the baseline. If the baseline scenario assumes the new potable supply would be built, then the avoided cost of building it would be one of the benefits of the reclaimed water project. If however, no new supply is assumed in the baseline and building a new potable supply is one of the alternatives under consideration, then the avoided cost of new supply would NOT be a benefit of the reclaimed water option. Instead, it would show up as a cost of the potable option.

Step 4. Screen benefits and costs for appropriate analysis approach

In the screening step, the analyst determines which costs and benefits can and should be analyzed quantitatively, which should be described only qualitatively, and which are insignificantly small and can be eliminated from further analysis.

Step 5. Quantify units associated with benefits and costs, to the extent feasible

In the first step of valuing a benefit or cost, the amount (quantity) of the outcome (e.g., water or resource use) should be established. These quantity outcomes may be a volume of water delivered (e.g., AF), number of recreational user outings enabled by enhanced instream flows or provided by reuse-fed wetlands (e.g., recreational hiking or angling days per year), or in whatever units the outcomes are most readily and meaningfully measured. It is important to match the quantity units of measurement to whatever metric is available for the corresponding dollar values (e.g., if the valuation in step 6 uses a $/household measure, then the quantification in step 5 should be aimed at estimating the number of households affected). Ranges of quantity estimates (rather than a single point estimate) may be used to better represent variability or uncertainty associated with resource use estimates.

Step 6. Value units associated with benefits and costs in monetary terms

Once the quantity of resource use has been estimated, a per unit dollar value often can be assigned to the benefit or cost, to reach a total value (quantity times per unit value). The per unit values can be expressed as dollars per unit of water (e.g., dollars per acre-foot) or dollars per unit of resource use (e.g., dollars per visitor day). Ranges of values may be used to better represent per unit resource valuations. Annual benefit or cost values should be projected over the project life (and converted to Present Values as per Step 8).

Step 7. Qualitatively describe key benefits and costs for which quantification is not appropriate or feasible

It may not be feasible or desirable to express some types of benefits or costs in quantitative or monetary terms (as per screening in step 3). However, it is always important to describe these nonquantified benefits and costs in a meaningful, qualitative manner. These benefits and costs may be described qualitatively, in part, by using a simple scale indicating the likely impact on net project benefits. Impacts can be qualitatively ranked on a 5-point scale, ranging from -2 to +2, to reflect unquantified relative outcomes that span from very negative to very positive (e.g., a "-1" may signify an outcome with moderate unquantified costs, and a "+2" may represent a high unquantified benefit). Qualitative ratings should be accompanied by descriptions of the impact, and should be explicitly carried through the analysis.

Step 8. Summarize all present value costs and benefits, and compare benefits to costs

Quantitative benefit or cost projections over time (from Step 6) should be discounted to present values at an appropriate discount rate. The present values of monetized benefits and costs should be summarized in one location (i.e., a summary table), along with the listing and ranking of those benefits described only qualitatively (from Step 7). Calculate the Net Present Value (NPV) for each alternative by subtracting the present value costs from the present value benefits. It is important that one summary table include both the monetized benefits and costs, as well as a listing and some qualitative assessment of the non-quantified benefits and costs, so that reviewers do not overlook potentially important outcomes when reviewing the empirical results. Distributional aspects also should be presented (Perspectives Analysis).

Step 9. List and assess all omissions, biases, and uncertainties

All omissions, biases, and uncertainties associated with the estimated benefits and costs, should be explicitly documented. The impact that these may have on the final outcome of the analysis (e.g., in terms of their likelihood of increasing or decreasing net benefits, or an uncertain direction of change in net benefits) should be noted.

Step 10. Conduct sensitivity analyses on key values

Sensitivity analyses should be conducted on key variables or benefit and cost estimates, to explore and communicate the impact of assumptions, uncertainty, or natural variability. Use sensitivity analyses to identify which assumptions or uncertainties have the largest impact on the outcome of the analysis (e.g., identify which assumptions might change the net benefits of an option from positive to negative, or alter the ranking of options in terms of their relative net benefits).

Step 11. Compare analysis results with values from stakeholder perspective

The quantitative and qualitative values that result from the analysis and from the various sensitivity analyses should be compared with stakeholder expectation of values. This comparison of expected values to the values derived in the analysis can be informative both as a check on the reasonableness of the analysis results and as a process for working with stakeholders to realize (or at least better articulate) the values that the reuse project provides to stakeholders. This understanding of values may become the basis for cost-sharing agreements with stakeholders to share costs for a project according to the relative shares of benefits derived from the project.

The vertical box on the right side of the above diagram emphasizes that stakeholder involvement should be sought throughout the project identification and valuation process, with stronger involvement (represented by the solid-line arrows as opposed to the dashed-line arrows) recommended at certain portions of the process (e.g., especially at the outset, and again to review and discuss findings).

The economic analysis tool is best used to evaluate and compare *projects* rather than *programs*. The framework could be used in a general way to evaluate a program but that would be more challenging because some of the data will be "squishier" on a regional or program-wide basis. For example, augmenting stream flow may provide a benefit for some streams in the region but not others. Some projects in a program may turn out to be worthwhile but others not. It is difficult to sort all this out except on a project by project basis.

Appendix D

Inputs and Assumptions for the Firm Yield Estimate

Firm yield of the water supply system is estimated using a simulation model developed by Seattle Public Utilities called the Conjunctive Use Evaluation (CUE) model. Additional details of the model and inputs are documented in the final report titled *Firm Yield of Seattle's Existing and Alternative Water Supply Sources*, April 2006, prepared by Seattle Public Utilities.

Model Inputs and Assumptions

⇨ Firm yield is based on the **98% reliability standard**—one shortfall occurs in the 76 years of historic record.

⇨ **Historic weekly inflows** reconstructed for water year 1929 through 2004 are used.

⇨ **Total system demand** is shaped on a monthly demand pattern based on the average of actual deliveries from calendar year 1994 to 2000.

⇨ **Sources of supply are operated conjunctively as a single system.**

⇨ **Operational assumptions include:**

- Cedar River System:
  Meet Cedar River Habitat Conservation Plan instream flow commitments below Landsburg, assuming flashboards in place on Overflow Dike.
  Fixed rule curve of Chester Morse Lake 1550'/Masonry Pool 1546' for November-February; 1560' both for May-August.
  Minimum levels for Chester Morse Lake: 1532'; Masonry Pool: 1510'

- South Fork Tolt System:
  Meet instream flows from 1988 Tolt Settlement Agreement (with treatment project).
  Fixed rule curve 1754' for October-January; 1765' for March-August.
  Minimum level for South Fork Tolt Reservoir: 1710'
  Treatment/Transmission capacity: 120 MGD

- Seattle Well Fields:
  10 MGD withdrawn for 14 weeks as needed from July-December.
  5 MGD recharged for 14 weeks from January-March.

Results

Based on the above, **the system-wide firm yield is 171 million gallons per day**.

This means that given the conditions in all but one of the last 76 years, Seattle's water supply system would be able to provide for at least 171 mgd of annual average demand while meeting all obligations to provide guaranteed instream flows for fish. Because of the highly variable nature of rainfall, snowpack, and inflows, Seattle's supply system can provide more than 171 mgd in most years. 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, i.e., Morse Lake Dead Storage.

Seattle's current demand for water is 45 mgd *below* its firm yield – a significant change from 20 years ago. In 1990, total system demand was 170 mgd, about equal to firm yield. Since then however, the combined effects of higher water rates, the 1993 plumbing code, conservation programs, and improved system operations have reduced total water demand to around 126 mgd. This is despite an 18% increase in service area population.

Continued code and programmatic conservation savings followed by a declining block of demand from the Cascade Water Alliance 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 171 mgd until after 2060.

Brief History of Water Shortage Conditions and Curtailments

Since the 1980s, there have been three water shortage curtailments and one advisory. These are briefly described, below.

1987
Previous year demand: 168 MGD, Actual supplied: 169 MGD
Firm Yield Estimate: 175 MGD

Reservoirs were at normal levels on June 1, but the summer weather was unusually warm and dry, drawing down the reservoirs at higher than normal rates.

Lawn restrictions were put in place in early August 1987. Fall rains were very late. Both reservoirs were drawn down below normal minimum operating levels, and didn't return to normal until February 1988.

In hindsight and under current operating constraints, 1987 conditions were such that it would not have been possible to meet demand as high as the yield of 171 MGD and provide currently required normal instream flows.

Note: 1987 was the worst year on record in terms of water supply conditions and it redefined firm yield. When the yield model was improved in the mid-1990s and inflow data from 1987 included, the estimate of firm yield was reduced to 160 mgd. The completion of the Tolt Treatment plant in 2001 added 11 mgd to firm yield (by allowing additional drawdown of the Tolt reservoir) bringing the total to the current 171 mgd.

1992
Previous year demand: 163 MGD, Actual supplied: 133 MGD
Firm Yield Estimate: 160 MGD

Because the winter was unusually warm, snowpack and flows into the reservoirs were at record low levels. Nonetheless, the reservoirs were managed to maintain normal flood control storage. In late February, it was evident that there was insufficient snowpack to fill the storage reservoirs and that the likelihood of recovery by June 1 due to rainfall was minimal. When snow survey data from Stampede Pass became available on April 1, it was then the 5th lowest on record since 1945.

Mandatory curtailment actions were put in place in May 1992, and rescinded in September as supply levels returned to normal with the onset of fall rains. In hindsight, there would have been enough water to meet demand as high as the pre-Tolt treatment plant firm yield of 160 MGD while providing current normal minimum instream flows.

2001
Previous year demand: 148 MGD, Actual supplied: 135 MGD
Firm Yield Estimate: 171 MGD (after completion of Tolt treatment plant)

Snowpack appeared to be very similar to that of 1992, and water supply forecasts made through the end of the year looked dire in early March. Snowpack ended up peaking at 75% of normal, and reservoirs were full or nearly full by June. Nonetheless, with a state-wide drought emergency in effect, Seattle asked customers starting in early April, to voluntarily reduce water use by 10%.

In hindsight, there would have been enough water to meet demand as high as the 171 MGD firm yield and to provide current normal minimum instream flows.

2005
Previous year demand: 142 MGD, Actual supplied for year: 126 MGD
Firm Yield Estimate: 171 MGD

The worst snowpack in 60 years of record occurred this year, causing Seattle to enter into the advisory stage. Effective reservoir management and some late spring/early summer rainfall brought reservoirs back to near normal levels. By early July, the advisory was lifted.

In hindsight, there would have been enough water to meet demand as high as the firm yield of 171 MGD and to provide current normal minimum instream flows.

Appendix E

Reclaimed Water Market Analysis Methodology

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[4] 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.[5] 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

4 Reclaimed Water Backbone Project, Draft White Paper Verson 3.0, March 2006
5 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).

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. 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:

The Water Budget Equation: Water consumption for self-supplied irrigators – golf courses and cemeteries – can be estimated in a number of ways which are described in the next two sections. These methods make use of metered consumption data, survey data on application rates and irrigated acreage, and "rules of thumb" from local irrigation experts. Another more general approach is the water budget equation.[6] The estimates produced by all of these various methods are compared to each other to check for consistency and confirm the reasonableness of the estimates. The irrigation season water budget for the Seattle area is calculated below.

$$\text{Irrigation Season Water Budget} = \frac{\mathbf{ET_0 \times C_{wb} \times A}}{\mathbf{C_u}}$$

ET_0 = Reference ET: Rate of evapotranspiration during the irrigation season from an extensive surface of cool-season turf grass actively growing at about 12 cm, well-watered. Average historical ET for the Seattle area is 20.64 inches for the months April through September. Average rainfall during the irrigation season is 10.46, of which we assume 25% can be used

[6] 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

effectively by plants (or 2.62 inches). Assuming that an irrigation system is designed to account for rainfall, Reference ET for this region is about 18 inches a year (total ET minus effective rainfall).

C_{wb} = Water Budget Adjustment Factor: Species Factor (K_s) divided by system efficiency (IE).

K_s = Species factor: accounts for water needs of different types of plants. For example, the species factor for shrubs with an average water requirement is 0.50; the average species factor for turf grass is 0.70.

IE = Estimated System Efficiency: Includes the *hardware* and the *management* (human element) of the system. (Distribution uniformity can be measured by an audit and gauges the efficiency of the hardware, but does not account for how the system is managed, e.g., whether the watering schedule is regularly adjusted to track changes in the weather). An average efficiency is 75%.

A = Total landscaped area in acres

C_u = Conversion Factor to CCF

Irrigation Season Water Budget in Seattle = (18.025 X (0.7/0.75) X 1) / 0.0275
= 612 ccf per acre per season
= 457,600 gallons per acre per season

Golf Courses: In addition to the survey, several other methods of estimating irrigation use for golf courses were employed. First of all, there are three public golf courses in Seattle that use municipal water for irrigation so that metered consumption data is available from the SPU billing system. Another public course, Jackson Park, has its own source of supply but has been metering its withdrawals since 2005. Metered irrigation consumption for these golf courses is shown in the table below.[7]

Annual Irrigation Consumption of Seattle Public Golf Courses in Millions of Gallons

			6 Mo Avg Consumption in MGD			Total Use
	Holes	Period	Low	High	Average	in MG
Interbay	9	2003-2007	0.04	0.07	0.05	9.3
Jackson Park	18+	2005-2008	0.14	0.18	0.15	28.3
Jefferson	18+	2003-2007	0.12	0.17	0.15	26.7
West Seattle	18	1999-2007	0.04	0.18	0.13	23.4

[7] Only one of these Seattle golf courses, Jackson Park, is a potential customer for reclaimed water from the Brightwater plant. The others are all south of the ship canal.

These numbers are broadly consistent with several rules-of-thumb provided by Scott Kuhn, P.E. of Kuhn Associates, a designer of irrigation systems for many golf courses in the Seattle area. These are:

- Golf courses generally apply 10.5 to 14 inches per year of water to their turf.
- Courses with optimized systems will be at the lower end of that range.
- An 18+ hole course irrigating 80-100 acres would be expected to use between 25 and 40 million gallons a season. 30 MG is probably most typical.
- Peak use may be as much as 1 inch per week - maybe as much as 1.3 inches under unusually hot dry conditions.
- Courses are generally irrigated at night for 6 to 8 hours.

These guidelines imply the following water use factors: 10.5 to 14 inches of water per season works out to from **381 ccf** (285,000 gallons) to **508 ccf** (380,000 gallons) per acre per season. One inch of water in the peak week implies a ratio of peak week to peak season flow of **1.86**.[8] Finally, assuming peak week and peak day flows are equal, peak hour flow would be 3 to 4 times higher than peak day flow.

Jackson Park irrigation consumption is right in the middle of this range. From 2005 through 2007, Jackson Park averaged 31 million gallons per season. This fell to just 24.9 MG in 2008 after much of the irrigation system was automated. Jackson Park staff expect their water use to decline a bit more in the next several years as they get the last 10% of the system automated and slightly reduce the irrigated area. In this analysis, it is assumed that water demand at Jackson Park remains at 25.5 MG (i.e., 2008 consumption adjusted for weather) or 0.14 mgd over the 6 month irrigation season. With about 75 acres irrigated, that works out to 455 ccf (340,000 gallons) per acre per season.

None of the other golf courses in the study area meter their irrigation consumption. Seattle Country Club reports that it has a new, very efficient irrigation system, that it irrigates some landscaping as well as turf totaling about 100 acres, and that it tends to keep its turf drier than other courses. Its application rate is therefore assumed to be at the lower end of the guidelines. Specifically, the application rate is assumed to be 11.5 inches per year (418 ccf per acre) which is about half way between Jackson Park's application rate and the low end of the guidelines. This results in estimated irrigation consumption of 31 MG or 0.17 mgd.

Nile Country Club's irrigation system is older, manual and presumably less efficient than Seattle County Club's and Jackson Park's. Its application rate is therefore assumed to be at the top of the range (508 ccf/acre/season). However in the survey, Nile reports that they irrigate only 35 acres, a much smaller area than is typical for 18 hole golf courses. This produces an estimate of irrigation consumption for the Nile Country Club of 13 MG or 0.07 mgd. The least amount of information is available for Sand Point County Club which covers about 90 acres in total. It's assumed that 75 of those acres are irrigated at the same higher application rate assumed for Nile Country Club resulting in an estimate of almost 29 MGD or 0.16 mgd in irrigation consumption. The table below shows the golf courses in the study area and estimates of their irrigation consumption.

[8] 14 inches per 26 week season is equal to 0.5385 inches per week. The ratio of peak week to average week is therefore 1/0.5385 = 1.86.

Estimated Irrigation Consumption for Golf Courses

Customer	Acres Total	Acres Irrigated	6 Month MG	6 Month MGD	Pk Month MGD	ccf/acre/ season	Supply 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.

Using the monthly reference ET to estimate monthly water use for Holyrood given consumption of 6000 ccf in the peak month, Holyrood's monthly consumption would be as follows:

	Reference ET	As % of Pk Month	CCF	MG
April	1.88	41%	2,500	1.9
May	2.69	59%	3,500	2.6
June	2.73	60%	3,600	2.7
July	4.56	100%	6,000	4.5
August	4.12	90%	5,400	4.0
September	2.05	45%	2,700	2.0
TOTAL	18.03		23,700	17.7

This totals to 17.7 million gallons of irrigation consumption over a 6 month season or 0.097 mgd. With 40 acres irrigated (as reported in the survey), that works out to 593 ccf/acre/year, just under the estimated irrigation season water budget of 612 ccf/acre/season for turf.

Irrigation season consumption for Calvary has averaged about 12.6 million gallons (0.07 mgd) over the period 2004 through 2008. This is equivalent to 482 ccf/acre/year. Bikur Cholim, Herzl Memorial and Machzikay Hadath/Seattle Sephardic cemeteries all have exempt wells. It is assumed that they use their wells first and then meet any need beyond the 5000 gpd limit on their wells with purchased water. It is also assumed that average use of the exempt wells over the 6 month irrigation period is 4500 gpd which is supplemented by metered water purchased from SPU. For Herzl and Machzikay Hadith, this works out to almost exactly the same volume per acre as Calvary. However, Bikur Cholum appears to have a lower application rate than the other cemeteries of 323 ccf/acre. Overall, cemeteries appear to use comparable amounts of water per acre than golf courses ranging from 323 to 593 ccf per acre and averaging 470 ccf/acre. No water consumption information is available for Acacia and Evergreen-Washelli. A figure of 537 ccf/acre is applied to the number of irrigated acres at Acacia and Evergreen-Washelli to estimate their irrigation consumption. This is half way between the application rates for Holyrood and Calvary.

Estimated Irrigation Consumption for Cemeteries

Customer	Acres Total	Acres Irrigated	6 Month MG	6 Month MGD	Pk Month MGD	ccf/acre/ season	Supply 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. Determining what portion of total consumption is used for irrigation was the primary challenge. Meters are labeled as irrigation meters, domestic meters, deduct or chargeable meters. Of course all the water measured through irrigation meters can be assumed to be for irrigation. Some irrigation water may be going through domestic meters as well. If there is a deduct or chargeable meter associated with a domestic meter, the amount of the total not being charged for sewer can be determined and it can be assumed that that amount is also used for irrigation. Sometimes though, some water flowing through domestic meters may also be going to irrigation, especially school and park in Shoreline that are not charged for sewer by Seattle. The overall assumption was that if consumption through a domestic meter shows a summer time peak, the amount of consumption in excess of the winter base is also being used for irrigation. For schools, the base during the summer is reduced to reflect that there should be less domestic use in the summer when school is not in session. The reduction amounts applied to the base are May 0%, June 0%, July 50%, August 90%, September 50%, and October 0%. Nine parks had no meters and two more had meters but no consumption on them. These were all assumed to have no irrigation after confirming this with satellite photos.

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 the table at the end of this appendix.

University of Washington: Three different non-potable uses were identified at the University of Washington: irrigation, steam plant replacement water and Drumheller Fountain. An initial estimate of potential reclaimed water demand was made by examining metered consumption data for each end-use at the UW with all three totaling about 0.2 mgd on an average annual basis. Of course irrigation consumption occurs almost entirely between May and September but steam plant/cooling water use also peaks strongly during the summer. Total use of non-potable water at the UW appeared to average 0.42 mgd over the 5 month peak season.

In October, SPU and county staff met with three representatives of UW Facilities Services to confirm the initial assumptions about the university's potential demand for reclaimed water. Much new information was provided by UW staff resulting in significant revisions of the estimate of potential demand. The particulars are summarized below.

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. It was explained that reclaimed water would probably not be suitable for use in the boilers which require very high and consistent water quality. The possibility was not ruled out entirely however. Pretreatment might solve the problem and there are examples of reclaimed water being used in steam plants elsewhere in the country (e.g. University of Massachusetts). Overall, it was thought highly likely that reclaimed water could be used for cooling; much less likely for heating.

This raised the question of how to estimate how much water goes to cooling. Heating water use is pretty constant for 9 months of the year with probably half as much used in the 3 warmest months, June through August. Thus, the amount of water used for cooling can be estimated by subtracting 175% of 6-month winter use from total annual heating/cooling use.[9]

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. This project is now being investigated. The feasibility and probability of the project moving forward is uncertain.

[9] Cooling Use = Total Annual Heating/Cooling Use – Heating Use
Heating Use = 100% of 6 Month Winter Use + Summer Heating Use
Summer Heating Use = (100% + 50%) x (6 Month Winter Use)/2 = 75% of 6 Month Winter Use
Therefore, Heating Use = 175% of 6 Month Winter Use

Irrigation: Irrigation water for the sports fields east of 25th Ave NE runs through two irrigation meters into a dedicated distribution system. This 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 with deduct meters at each spur. Converting this to reclaimed water would require installing a parallel purple pipe system throughout the campus west of 25th Ave NE. This is not considered feasible by UW Facilities staff.

Drumheller Fountain: The pool and fountain used between 10,000 and 16,000 ccf per year during the years 2003 through 2005. However, much of this water was lost through leakage. Recent efforts to seal the pool have been successful and fountain-related consumption dropped to only 1,800 ccf in 2007. It was concluded that this would be the best estimate of future demand for draining and refilling the fountain every year.

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. There was less concern about the brief exposure from the occasional tossing of individuals into the pool.

The estimate of UW demand for reclaimed water was significantly revised taking into account all of the above information:

<u>Estimated Reclaimed Water Demand for Cooling</u>: Of the average 54,200 ccf used for heating and cooling over the year, an estimated 29,000 ccf are used for cooling based on the methodology outlined above. This is equivalent to 118,400 gallons per day during the 6-month cooling season (May-October). If the project to use Lake Washington water for cooling goes forward however, the demand for using reclaimed water for cooling will be zero.

<u>Estimated Reclaimed Water Demand for Irrigation</u>: Of the average 35,600 ccf used per year for irrigation at the university, only 8,100 ccf flows through the separated irrigation system that serves the sports fields east of 25th Avenue NE. As mentioned above, it appears that this is the only section of campus that could easily be converted to reclaimed water. This is equivalent to 33,000 gallons per day during the 6-month irrigation season (May-October).

<u>Estimated Reclaimed Water Demand for Drumheller Fountain</u>: Water used to clean, refill and operate the fountain is now 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. 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.

<u>Estimated Total UW Demand for Reclaimed Water</u>: 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 159,000 gpd (0.16 mgd) or as low as 33,000 gpd (0.03 mgd) over 6 months.

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**

Miscellaneous: 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.

Miscellaneous Potential Reclaimed Water Customers

Customer	Address	Type	Water Supplier	MGD 6 Mo Pk	MGD 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.[10] 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.

[10] 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.

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.

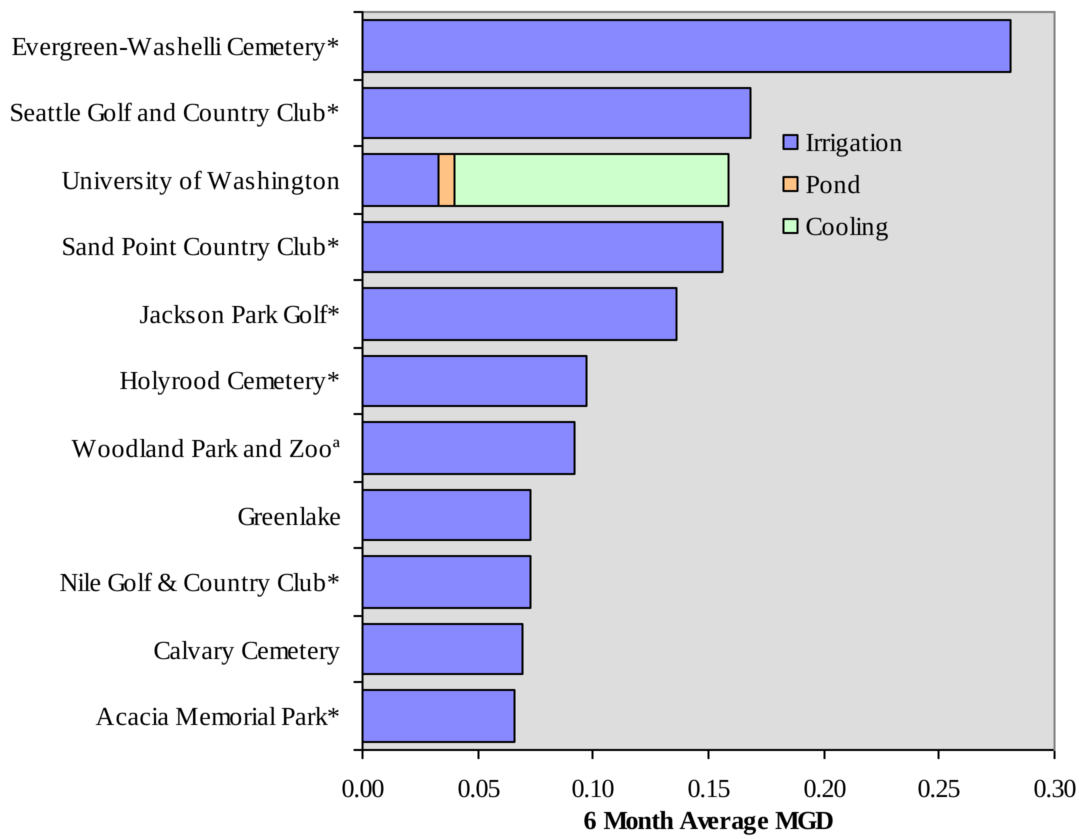
Based on an analysis of daily SPU system consumption over 15 years, it was estimated that the ratio of peak-day to peak-month consumption for irrigators is 1.4. Irrigators were also assumed to water 8 hours per day implying a peak-hour rate of consumption 3 times as much as peak-day. This produces a 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 below, the top eleven non-potable water users (which include all seven self-supplied users) consume 1.37 mgd or 80% of the total.

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**

Consumption in 6 Month MGD for Top 11 Potential Customers



* Self-Supplied
[a] Includes Lower Woodland

The table 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

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

Appendix F

Reclaimed Water System Costs

The cost of the distribution system for reclaimed water from the Ballinger Portal to the identified customers in the North Seattle and Shoreline areas is composed of a network of pipes and the pumping capacity to deliver it throughout the system at sufficient pressure. To reach all the identified potential customers will require about 35 miles of pipeline varying from 4 to 20 inches in diameter. The distribution system has been modeled to bring reclaimed water to the potential customers in an efficient manner. Pipe alignments will be constructed in street right-of-ways, avoiding major arterials if possible, and minimizing crossing Aurora Avenue and I-5. The alignment for the full distribution system is shown at the end of this document.

<u>Distribution Network</u>

A hydraulic model of the proposed system has been constructed using EPANet (a hydraulic modeling program). The system layout, lengths, and elevations have been determined from SPU's GIS system. The pipelines have been sized to carry the peak instantaneous flow with a minimum pressure of 10 psi within the distribution network. A recent analysis of pipe installation project costs for pipes from 8 to 30-inches in diameter has been done by SPU engineering department. The pipe costs include the costs for pipeline design, construction, construction management, and surface restoration costs. The following table shows the estimated breakdown of contractor costs.

Contractor Construction Cost per Lineal Foot – Water Main

Dia "	A $	B $	C $	D Feet	E $	F $	G $	H $	I $	J $	K $	L $	M $
4	$50	$5	$16	2.5	$6	$11	$10	$1	$99	$9	$11	$12	**$130**
6	$75	$6	$16	2.5	$6	$11	$10	$2	$125	$11	$14	$15	**$165**
8	$90	$7	$16	2.5	$6	$11	$10	$2	$141	$13	$15	$17	**$187**
10	$105	$8	$16	2.5	$6	$11	$10	$2	$158	$14	$17	$19	**$208**
12	$115	$9	$16	2.5	$6	$11	$10	$2	$169	$15	$18	$20	**$223**
16	$160	$14	$16	3.5	$9	$15	$10	$13	$236	$21	$26	$28	**$311**
20	$200	$16	$16	4	$10	$17	$10	$16	$285	$26	$31	$34	**$375**
24	$325	$18	$16	4.5	$11	$19	$10	$26	$425	$38	$46	$51	**$560**
30	$425	$24	$16	5.25	$13	$22	$10	$34	$544	$49	$59	$65	**$717**

Key:
- A. Installed RJ Pipe
- B. Bedding
- C. Saw Cut, assume 2
- D. Trench Width
- E. Remove Pavement
- F. Temporary Paving
- G. Traffic Control
- H. Thrust Block, % of A.
- I. Subtotal
- J. Inflation - 2007 to 2009
- K. Mobilization
- L. Sales Tax
- M. Total

The design, construction management, and surface restoration costs have been determined as a percentage of the contractor construction cost of the water main. Design and construction management are 25% each. Asphalt pavement (AS) is the standard restoration and is the same cost for all pipe sizes because the whole panel must be replaced for cuts longer than 100 feet, $10 per lineal foot times the 12 foot lane width. The following table shows the cost per lineal foot of the total project.

Total Construction Cost – Water Main

Pipe Dia	Contractor	Design	Constrctn Mgmnt	$/LF	Replace Asphalt	Replace Concrete	$/LF Asphalt	$/LF Concrete
4*	$130	$33	$33	$195	$120	$360	$315	$555
6*	$165	$41	$41	$248	$120	$360	$368	$608
8	$187	$47	$47	$280	$120	$360	$400	$640
10	$208	$52	$52	$312	$120	$360	$432	$672
12	$223	$56	$56	$334	$120	$360	$454	$694
16	$311	$78	$78	$467	$120	$360	$587	$827
20	$375	$94	$94	$563	$120	$360	$683	$923
24	$560	$140	$140	$841	$120	$360	$961	$1,201
30	$717	$179	$179	$1,076	$120	$360	$1,196	$1,436

* Costs for 4 and 6 inch pipe are estimates that were not included in SPU Engineering analysis. They have been scaled accordingly in regards to the other costs for installing pipe within the City limits. The actual pipe cost is not the largest portion of the total overall costs.

The estimated cost of installing pipeline 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 demand for reclaimed water that could be served 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 reduces total pipeline cost by 13% 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**.

Distribution System Pumping

In order to provide the reclaimed water to the distribution system, a pump station will need to be constructed at the top of the Ballinger Portal. King County has stated it will provide water to the surface with no additional pressure. For this analysis, it was assumed that a big enough pump would be installed to pressurize the entire system and additional booster station would not be necessary.

In the scenario where every potential customer is provided water, the estimated peak hour demand is approximately 8,800 gpm. There is no storage within the system, so the entire amount will have to be pumped into the system. Using the hydraulic model, approximately 600 feet of head is required to provide the entire instantaneous demand to the entire system while maintaining a minimum of 10 psi throughout the system. Consideration will have to be taken into account that the installed distribution system can handle the pressures that may be seen throughout the system. Pressure reducing valves may be necessary at some properties throughout the system in order to lower pressure as it enters some of the potential customers' sites.

Three pumps of the same pumping capacity (3,000 gpm) have been chosen in this analysis. It will provide the ability to ramp up the flow to meet the peak hour demand. Other options that could be used are three pumps of different sizes or variable frequency drives to better match the projected flow. Based on a flow of 3,000 gpm per pump and an anticipated head of 600 ft, a 450 kW motor will be necessary to provide the required lift with total efficiencies of approximately 77%. The maximum total flow that has been projected for the reclaimed water system is 314 MG for the year. At a capacity of 3,000 gpm, the pumps will take approximately 1,700 hrs to pump the entire amount. This results in an energy requirement of approximately 765,000 kWh (450 kW * 1,700 pump run time). The cost of the energy required to pump this entire amount would be about $47,000 per year at a rate of $0.06/kWh.

An initial estimate of the facility to house the pumping station is $1,000,000. This would involve a simple building to house the pumps and motors, provide electrical service, and possibly rechlorination facilities. There may be additional costs depending on whether SPU has to pay for costs to purchase or lease the land.

Pressurizing the West Segment of the Brightwater Backbone

The Brightwater treatment plant and Phase I of the reclaimed water backbone are scheduled for completion in 2012. Because these facilities are already under construction, they are considered to be "sunk costs." Therefore, Seattle's share of these costs is not included in the benefit-cost analysis[11]. 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. 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). More recently, King County estimated the annual O&M costs for the Backbone's West segment to be $395,000 in 2009 dollars.

Only a portion of Phase II costs should be allocated to the Seattle project, however, because other jurisdictions besides Seattle might be expected to make use of the west segment of the Backbone. It is argued here that the share of Phase II costs allocated to the Seattle project should be 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.

[11] 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.

Using design capacity in the denominator could underestimate Seattle's share of costs if, as is possible, demand for reclaimed water from the West segment never reaches capacity. Some of the costs would remain unallocated. Capacity for pipes and pumps is generally based on instantaneous or peak hour flows. Maximum hourly demand of North Seattle project customers for reclaimed water is estimated at12.7 mgd. King County has estimated that the west segment of the backbone has a maximum peak *day* capacity of 12 mgd but this has not been translated into a maximum peak hour flow. It is therefore difficult to say what portion of total west segment capacity would be used by the North Seattle project.

Method for Estimating Share of Brightwater Backbone Phase II Costs to Seattle Project

Calculating Seattle share of West Segment						
Current Demand Estimates for 17 Potential Customers Identified in Backbone White Paper Analysis						
		6 month MGD				
1	Jackson Park	0.1394				
2	Seattle Golf and Country Club	0.1708				
3	Nile Temple	0.0727				
4	Holyrood	0.0969				
5	Paramount Open Space	No Mtr				
6	Northcrest	No Mtr				
7	Hamlin	0.0106				
8	Shorecrest High	0.0111				
9	Acacia Memorial	0.0659				
10	Twin Ponds	0.0002				
11	Ronald Bog	0.0000				
12	Paramount School Park	0.0194				
13	Shoreline Christian High	0				
14	Richmond Highlands	0				
15	Ridgecrest	0.0051				
16	Meridian	No Mtr				
17	Cromwell	0				
a	Total for 17	0.5921				
	Total in CCF	144,065				
					6 mo days	5 mo days
From Backbone White Paper Analysis (BWRW-CustomerDataNew.xls)					182	152
b	Total of 17 from White Paper Analysis	3.20	mgd over 5 months			
c	6 month equivalent for 17	2.68	mgd over 6 months		(b*152)/182	
d	Total West Segment from White Paper Analysis	8.17	mgd over 5 months			
e	6 month equivalent for Total West Segment	6.82	mgd over 6 months		(d*152)/182	
f	Non-Seattle/Shoreline Demand from White Paper	4.15	mgd over 6 months		e-c	
g	Ratio of SPU estimate to KC estimate	22%			a/b	
h	Adjusted Non-Seattle/Shoreline West Segment	0.92	6 mo. mgd		f*g	
i	Total Seattle Project	1.69	6 mo. mgd			
j	Total West Segment	2.61	6 mo. mgd		h+i	
	Seattle Share	**65%**			i/j	

Seattle's share of Backbone Phase II costs was calculated as shown in the spreadsheet extract, below. Seventeen of the 50 potential customers identified in the current analysis were also included in the original White Paper analysis by King County. The current estimate of non-potable water 6-month peak demand for these 17 customers is 0.6 mgd, (row a). The White Paper estimate of demand for these same 17 customers was 3.2 mgd (row b). However, this estimate was for a 5-month peak season and is converted to a 6-month peak equivalent of 2.68 mgd (row c). This is four and a half times greater than the current estimate.[12] Put another way, the current estimate is 22% of the White Paper estimate (row g). Total potential 5-month peak season demand from the west segment was estimated to be 8.17 mgd in the White Paper which is equivalent to 6.82 mgd spread over 6 months (row e). Subtracting 2.68 mgd (row c) implies total west segment demand outside of Seattle and Shoreline of 4.15 mgd (row f). Assuming that the non-Seattle/Shoreline demand in the White Paper was overestimated to the same extent as the demand for the 17 potential customers in Seattle and Shoreline, this is adjusted by multiplying by 22% to obtain 0.92 mgd (row h). Adding in the estimated demand of all 50 potential customers identified in the current analysis of the North Seattle project (1.69 mgd , row i) produces a total of 2.61 mgd (row j) for the potential demand along the west segment. Seattle's share of this total is **65%**.

More recently as part of its reclaimed water comprehensive planning process, King County has compiled new estimates of the potential demand for reclaimed water in areas that could be served from the west segment of the backbone. These areas are designated W1, W2, and W3 in a set of "conceptual reclaimed water strategies" presented by King

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[12] This large discrepancy can be explained by the different methods used to obtain the estimates and the different purposes for which the estimates were made. King County's methodology was laid out in a project memorandum from Carollo Engineers to King County Department of Natural Resources and Parks dated June 20, 2005. The first paragraph under "Methods" on page 1, stated:

"The water consumption calculations for all consumer categories except the industrial category are based on land surface area and assume an agronomic rate of 0.33 MGD of water for every 100 acres with a 75% efficiency factor (25% of the irrigation water applied will be lost to either evaporation of other inefficiencies) during the months of May through September. *It should be noted that this calculation gives an upper bracket on the amount of irrigation water needed. The conversion factor is based on agricultural crops, which are typically irrigated more than land used for landscaping, and most of the parks sampled do not currently irrigate.*" (Emphasis added.)

This combined with the assumption that 100% of a potential customer's land area was irrigated resulted in extremely high estimates of potential reclaimed water demand. However, that may have been the intent as it appears the purpose of the County's demand estimates was not to assess the market for reclaimed water but to establish the maximum possible demand for the purpose of sizing the backbone pipeline. Such over-estimation may be appropriate when the goal is to avoid the risk of under-sizing the system.

As outlined in Appendix E, SPU used a number of methods and data sources to estimate potential demand for reclaimed water. The primary data source was metered consumption data from Seattle and Shoreline billing records for those potential customers currently using publicly-supplied water. Other estimating methods made use of, survey data on application rates and irrigated acreage, "rules of thumb" from local irrigation experts, and an application of a water budget equation 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.

County at an April 29, 2010 workshop. Total estimated demand for reclaimed water in these areas net of customers that would be served by the North Seattle project is 2.13 mgd. However, it appears this may also be an overestimate. The estimates of non-Seattle irrigation demand in King County's analysis are obtained by multiplying an estimate of the number of acres irrigated by 835 ccf per acre per season. Based on the analysis presented in Appendix E, this is more than double the rate irrigation water is actually applied. Taking total consumption of Seattle/Shoreline irrigators in the "W3" area and dividing by King County's estimate of their total irrigable acres produces an average application rate of 365 ccf/year. This is 44% of the application rate assumed by King County. Multiplying King County's estimate of non-Seattle/Shoreline demand for reclaimed water along the west segment by 44% and adding in the 1.69 mgd of potential demand from the North Seattle Project produces a total estimate of west segment demand of 2.69 mgd, of which Seattle's share is **63%**. Using King County's unadjusted estimates implies a Seattle share of 44%.

The 65% factor was applied to total Phase II costs representing Seattle's share. The result is **$9.7 million** in Phase II capital costs and **$256,000** in annual O&M costs allocated to the Seattle project.

On-site Distribution Costs

Additional costs associated with the installation of a reclaimed water system involve the onsite distribution of the water. The infrastructure the various potential customers have for use of the reclaimed water range from an existing irrigation system to nothing on site. In addition, each new customer will need a meter to quantify the amount of water being used.

The average cost of installing a meter and connecting the onsite system to the distribution system ranges from $500 to $5,000 depending on the size of the system. The total for this portion of the on-site systems is $90,000. Additional, some systems will be required to either upgrade or install new on-site distribution networks in order to take advantage of the reclaimed water. Approximately 15 potential customers have been identified that will need an on-site distribution system. These customers account for approximately 320 acres of property. Based on the types of properties and the existing land uses, approximately 10% of these areas have been determined to be irrigable land for a total of 32 acre or 1.4 million sq ft. Costs vary for the installations of irrigation systems depending on the quantity of materials needed. The range of costs has been determined to be in the range from $0.10 to $0.50/sq ft. The total cost of on-site distribution system has been calculated to cost in the range of $230,000 to $790,000.

Summary

- Optimized distribution system: $76 million at build out
- Distribution System Pumping: $1 million capital, $47,000 yearly electrical costs
- Backbone Phase II Pumping: $9.6 million capital, $253,000 yearly O&M
- Onsite distribution - $230,000 - $790,000, average about $500,000.

Appendix G

Seattle Public Utilities

Memorandum

Date:	**October 8, 2009**
To:	**Bruce Flory**
From:	**Rand Little**
Re:	**Assessment of potential instream flow effects with proposed use of reclaimed water to reduce SPU water system demand**

Introduction

A number of interested parties are examining a potential project using reclaimed water to provide municipal water within the current Seattle Public Utilities (SPU) drinking water service area. This memorandum attempts to provide an assessment of the potential effects of this project on instream resources in the Cedar and South Fork Tolt rivers, the primary SPU municipal water supply sources.

To provide context for the assessment, the memorandum summarizes prominent features of basin hydrology, current water management activities, operating objectives and the current framework for managing instream flows downstream of SPU storage facilities. The analysis then assesses the potential effects of the project on stream flows, on river stage and finally on metrics of habitat availability for salmonid fishes.

The analysis assumes that the reclaimed water project would provide an average of 0.72 million gallons per day (MGD) in municipal supply over a 6-month period from April through September. The analysis further assumes that water would be provided according to the following average monthly pattern:

April	0.35 MGD
May	0.55 MGD
June	0.65 MGD
July	1.38 MGD
August	1.00 MGD
September	0.40 MGD.

The analysis also assumes that all of the water provided by the reclaimed water project would result in a direct and equal reduction in water diverted from the Cedar and South Fork Tolt rivers.

Overview of Cedar and South Fork Tolt River Hydrology

The basic hydrologic template for both the Cedar and the South Fork Tolt rivers is similar to other, low elevation, un-glaciated systems draining the west slope of the Cascade Mountains. Abundant rainfall in the fall and early winter often produces the largest flow volumes of the year. These events can be partially augmented by associated snowmelt during occasional heavy, warm precipitation events. As snow pack accumulates during the heart of the winter, stream flows often moderate. Snowmelt, coupled with rainfall, maintains stream flows at moderate to high levels during the spring. Snowmelt is typically complete by about mid-June as rainfall also becomes less abundant. During the summer, dry season flows generally recede to base levels and typically reach their lowest levels of the year in September. As October arrives, fall rains usually begin and the cycle repeats itself.

SPU operates water storage facilities on both systems. The operation of these systems tends to reduce the magnitude of both high and low stream flow events downstream. Water is also extracted from both systems for municipal water supply. Because of these activities, flows below the facilities are often lower and more stable than unregulated flows would be. However, there are times of the year in both systems when regulated flows are significantly higher than unregulated flows. For most of the summer, flows in the South Fork Tolt are augmented by reservoir releases to provide flows that are usually higher than under unregulated conditions. From late September through late October, flows in the Cedar are similarly augmented to provide levels above what would often occur naturally.

Because significant inflows can enter both river systems below SPU’s storage reservoirs, flows in downstream portions of the river still exhibit some amount of natural variability. In addition, the reservoirs have limited storage capacity, which can be filled during very large peak flow events. In these situations, much of the natural reservoir inflow must be passed directly downstream. Recent hydrographs exhibiting annual stream flow characteristics are provided in Figures 1 and 2.

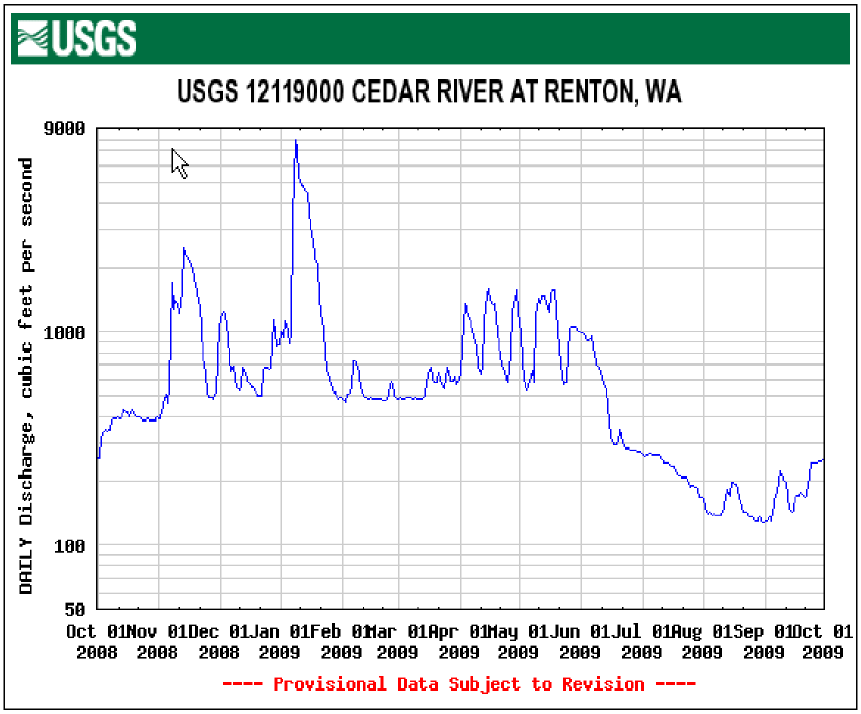

Figure 1: Mean daily stream flow Cedar River at Renton for water year 2008.

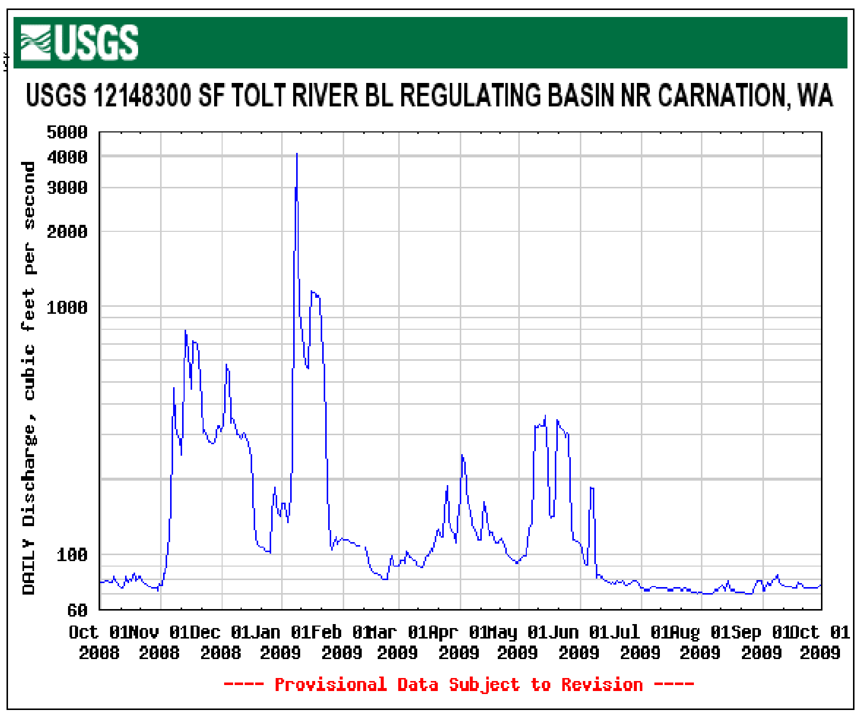

Figure 2: South Fork Tolt River mean daily stream flow for water year 2008.

Overview of River and Reservoir Management Framework

The primary water management objectives for both the Cedar and South Fork Tolt systems are to provide an adequate supply of high quality municipal water and to protect instream resources. Secondarily, the systems are operated to provide downstream flood protection and hydroelectric power. The systems form the primary municipal and industrial water source for approximately 1.4 million people in the Seattle metropolitan region. Approximately 70% of the region's annual water supply is provided by the Cedar system, with the remainder provided from the South Fork Tolt system and occasional small, infrequent use of Seattle's well fields. The rivers below SPU's facilities are home to important species of fish and wildlife, including several species listed under the federal Endangered Species Act.

The management of instream flows on both systems is governed by formal agreements with regulators, federal, state and tribal agencies charged with the management of fisheries resources. The development of appropriate instream flow management regimes was supported by many years of interagency investigations, discussion and negotiation. Representatives from these same organizations oversee implementation of the agreements and associated instream flow management regimes. Regimes for both systems focus on the protection of salmonid fishes and the promotion of river health while continuing to provide an adequate supply of municipal water. Ongoing monitoring and analysis programs, also overseen by the designated interagency forums, support implementation of the regimes.

In the Cedar, instream flow management practices are integrated with reservoir and land management practices through the Cedar River Watershed Habitat Conservation Plan and Muckleshoot Tribe/City of Seattle Settlement Agreement to protect bull trout, nesting loons, other species and the habitats upon which they depend.   River and reservoir management on the Tolt is governed by a Federal Energy Regulatory Commission Hydropower License and associated South Fork Tolt Settlement Agreement. Seattle's land management practices are guided by the South Fork Tolt Watershed Management Plan, which is in the final stages of development.

Analysis of Potential Effects of Proposed Reclaimed Water Project on Instream Resources

Initial project assumptions as stated above provide the general framework for the analysis. The analysis also assumes that reclaimed water replaces water currently used from SPU's system and that this water would be applied directly to augment guaranteed minimum stream flows in the Cedar and South Fork Tolt Rivers. This assumption may lead to an overstatement of the relative magnitude of project effects for several reasons. First, SPU typically provides an operating margin of 3 to 20 cfs over and above guaranteed minimum flow levels. In addition, the applied savings may occur during periods of heavy rainfall and/or water abundance when stream flows are well above required guaranteed minimum levels. And finally, the comparison points selected for this analysis are located in upstream locations near SPU's diversion points. Flows in the river increase downstream of these points due to the input of natural inflows. Natural inflows can result in significantly increased stream flow levels in the lower areas of both the Cedar and South Fork Tolt Rivers. For these reasons, the analysis may overstate the relative magnitude of the project effects on instream resources.

Table 1 provides an analysis of the potential effects on annual stream flow in each system as measured at United States Geological Survey (USGS) stream flow monitoring stations just downstream of SPU's diversion facilities. Mean annual stream flow could potentially increase by as much as 0.05% in the Cedar River and 0.11% in the South Fork Tolt River as a result of the project. Table 2 provides a more detailed monthly view of stream flow increases and projects that mean minimum monthly stream flows could increase by as much as 0.13% to 1.26% in the Cedar River and 0.26% to 1.07% in the South Fork Tolt River.

Table 3 provides a summary of potential increases in mean monthly water elevation (or depth) in each river. Mean minimum monthly water elevation may increase by as much as 0.02 inches to 0.07 inches in the Cedar and 0.06 to 0.12 inches in the South Fork Tolt.

Assessments of the effects of stream flow on specific instream biota are very challenging and often controversial (MacDonnell et al. 1989, Gillilan and Brown 1997). Locke et al. (2008) discuss the complexities of instream flow assessment and the benefits of comprehensive assessment approaches. These approaches are expensive and often very time consuming. Fortunately, a substantial amount of work has been conducted in the past on the Cedar and South Fork Tolt rivers in an attempt to assess the effects of stream flow on salmonid fishes. On both systems, this work has provided a metric called Weighted Usable Area (WUA) as a means for expressing habitat availability for specific species and life stages at varying levels of stream flow (Cascades Environmental Services 1991, Stober et al. 1983, Steward and Stober 1984 and R.W Beck, Inc. 1984). This metric is developed through extensive fieldwork and use of the Physical Habitat Simulation Model (PHABSIM), a component of the Instream Flow Incremental Methodology as described in Bovee et al. (1998). In both systems, this work was conducted with oversight by interagency committees composed of state, tribal and federal fisheries resource agencies. In Table 4, we use changes in WUA under the current and post project conditions as a measurement of the potential effects of the project on key species and life stages in each system. Table 4 indicates small reductions in WUA with the project that range from –0.06% to -0.30% in the Cedar. In the Tolt, the project could result in changes ranging from -0.03% to +0.43%.[1]

In summary, the analysis suggests that the project would result in relatively small changes in annual mean stream flow, monthly average minimum stream flow, monthly average minimum water elevation and WUA. These changes are small enough to suggest that the effects of the project on the Cedar and South Fork Tolt rivers would be difficult to detect. For the reasons stated previously, the values provided in Tables 1 through 4 may somewhat overstate the magnitude of the actual differences between current and post- project conditions.

cc: Tom Fox

[1] As described in Bovee et al. 1998, WUA area values often exhibit maximum levels within specific flow ranges. When flows decrease or increase beyond these ranges, WUA values often decline as water velocity becomes too slow or too fast, water depth becomes too shallow or too deep, river substrate becomes too large or too small and proximity to cover becomes too great.

Table 1: Assessment of Effect on Annual Average Stream Flow

Assume: -Average 6-month savings in combined water demand from Cedar and South Fork systems is 0.72 MGD

-All savings are allocated to river flows: 70% to Cedar River stream flow and 30% to South Fork Tolt stream flow:

Difference in Annual Average Stream Flow:

Cedar River

Present average annual flow in Cedar River as measured below Landsburg Dam = 522 MGD

Average 6-month demand reduction = 0.72 MGD x 0.7 = 0.504 MGD

Average 12-month demand reduction = 0.504/2 = 0.252 MGD

Change in average annual flow = 0.252/522 = 0.048%

Tolt River

Present average annual flow in Tolt as measured below the Regulating Basin = 100 MGD

Average 6-month demand reduction = 0.72 MGD x 0.3 = 0.216 MGD

Average 12-month demand reduction = 0.216/2 = 0.108 MGD

Change in average annual flow = 0.108/100 = 0.108%

Table 2: Assessment of Effect on Average Monthly Minimum Stream Flow

Assume: Average monthly savings in combined water demand from Cedar and South Fork systems according to the following schedule

April	0.35 MGD
May	0.55 MGD
June	0.65 MGD
July	1.38 MGD
August	1.00 MGD
September	0.40 MGD

All savings are allocated to river flows: 70% to Cedar River stream flow and 30% to South Fork Tolt stream flow:

Cedar River (*USGS gage 12117600; Cedar River near Landsburg below Diversion)*

Month	Current average monthly minimum stream flow (cfs)	W/project average monthly minimum stream flow (cfs)	% change in average Cedar River minimum stream flow
April	320.5	320.9	0.13%
May	262.2	262.8	0.23%
June	245.6	246.3	0.29%
July	196.0	197.5	0.80%
August	87.6	88.7	1.26%
September	130.0	130.5	0.39%

South Fork Tolt River (*USGS gage 12148300; SF Tolt River below Regulating Basin)*

Month	Current average monthly minimum stream flow (cfs)	W/project average monthly minimum stream flow (cfs)	% change in average SF Tolt River minimum stream flow
April	67.0	67.2	0.26%
May	69.0	69.3	0.37%
June	60.0	60.3	0.50%
July	60.0	60.6	1.07%
August	61.0	61.5	0.76%
September	56.0	56.2	0.33%

Table 3: Assessment of Effect on Average Monthly River Stage

Assume: -Average monthly savings in combined water demand from Cedar and South Fork systems according to the following schedule

April	0.35 MGD
May	0.55 MGD
June	0.65 MGD
July	1.38 MGD
August	1.00 MGD
September	0.40 MGD

-All savings are allocated to river flows: 70% to Cedar River stream flow and 30% to South Fork Tolt stream flow:

***Cedar River** (USGS gage 12117600; Cedar River near Landsburg below Diversion)*

Month	**Current average monthly minimum river stage** (inches)	**W/project average monthly minimum river stage** (inches)	**Increase in average water elevation** (inches)
April	40.38	40.40	0.02
May	38.53	38.55	0.02
June	38.06	38.09	0.03
July	36.00	36.06	0.06
August	30.81	30.88	0.07
September	33.06	33.09	0.03

***South Fork Tolt River** (USGS gage 12148300; SF Tolt River below Regulating Basin)*

Month	**Current average monthly minimum river stage** (inches)	**W/project average monthly minimum river stage** (inches)	**Increase in average water elevation** (inches)
April	25.80	25.82	0.02
May	26.04	26.08	0.04
June	25.08	25.12	0.04
July	25.08	25.12	0.04
August	25.20	25.26	0.06
September	24.72	24.73	0.01

Table 4: Assessment of Effect on Average Monthly Weighted Usable Area (WUA) for Salmon and Steelhead

Assume: -Average monthly savings in combined water demand from Cedar and South Fork systems according to the following schedule

April	0.35 MGD
May	0.55 MGD
June	0.65 MGD
July	1.38 MGD
August	1.00 MGD
September	0.40 MGD

-All savings are allocated to river flows: 70% to Cedar River stream flow and 30% to South Fork Tolt stream flow:

-Flow/WUA relationships as per previous PHABSIM analyses by Cascades Environmental Services 1991, Stober et al. 1983, Steward and Stober 1984 and R.W Beck, Inc. 1984.

Cedar River juvenile salmon River *(River Mile 21.8 to mouth)*

Month	**Current WUA at average monthly minimum flow** (ft^2./1000 linear ft.)	**W/project WUA at average monthly minimum flow** (ft^2./1000 linear ft.)	**% Change in WUA**
April	4,473.2	4,470.6	-0.06%
May	4,865.7	4,860.3	-0.11%
June	5,346.2	5,338.6	-0.14%
July	6,122.3	6,103.8	-0.30%
August	7,394.1	7,389.6	-0.06%
September	6,992.6	6,986.1	-0.09%

South Fork Tolt River adult steelhead *(River Mile 2.5 to 7.9)*

Month	**Current WUA at average monthly minimum flow** (total ft^2.)	**W/project WUA at average monthly minimum flow** (total ft^2.)	**% Change in WUA**
April	120,169	120,300	0.11%
May	121,925	122,213	0.24%
June	91,956	91,929	-0.03%
July	90,813	91,011	0.22%
August	88,668	89,045	0.43%
September	87,755	88,058	0.35%

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Appendix H

TECHNICAL MEMORANDUM
TASK 3.0 – BASE CASE CONDITIONS

Providing Retail Reclaimed Water Service from the Brightwater Backbone to SPU Customers: An Economic Analysis

Prepared for

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Prepared by

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October 16, 2009 – Final

Contents

Tables

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Introduction

In late 2005, the King County Council approved funding for the Brightwater Reclaimed Water "Backbone" project. In Phase 1 of the Backbone project, King County (County) is adding reclaimed water pipes in tunnels already being built for the Brightwater wastewater treatment plant conveyance system. Phase 2 of the Backbone project would add the pump stations necessary to bring reclaimed water through the new reclaimed water pipe system to portals located in north King County. Phase 3 of the Backbone project is construction of the distribution network necessary to allow customers to purchase the reclaimed water.

Since Phase 1 of the Backbone Project began, the county has expressed its preference to be only a wholesaler of reclaimed water from the Backbone, with water utilities assuming responsibility for constructing distribution infrastructure (Phase 3) and providing retail service between the Backbone portals and potential customers. It is therefore up to water utilities, in whose service areas potential backbone customers are located, to conduct their own benefit-cost analyses and determine whether their share of Phase 3 of the Backbone project is cost-effective.

Purpose and Scope

The *Draft White Paper: Reclaimed Water Backbone Project, Version 3.0* (King County DNR 2006) identified at least eight potential reclaimed water customers in the Seattle Public Utilities (SPU) retail service area. In addition, one potential customer was identified in the City of Edmonds water service area and nine customers were identified in the Shoreline Water District, because of their location along distribution lines that would connect Seattle to the Backbone. This original list has been expanded 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.

Herrera Environmental Consultants (Herrera) is assisting SPU in determining the potential environmental benefits of using reclaimed water in the SPU retail service area. Herrera's objectives are to both describe and quantify the environmental benefits of using reclaimed water in place of surface and groundwater withdrawals, and to assist SPU in identifying alternatives that achieve the same environmental benefits as reclaimed water use. This work is intended to inform SPU's broader economic analysis of providing retail reclaimed water service from the Brightwater Backbone project to SPU customers. For the purposes of this analysis, the provision of reclaimed water from the Brightwater Backbone to customers in SPU's retail service area is referred to as the North Seattle Reclaimed Water Project (the North Seattle project or project).

This technical memorandum provides an essential piece of that economic analysis – the existing (base case) environmental conditions of Puget Sound and watershed areas in the SPU retail service area. Potential benefits of using reclaimed water will be compared to base case environmental conditions. This memorandum includes analysis of:

- Existing environmental conditions of Puget Sound
- Existing environmental conditions of SPU service area watersheds, including analysis of existing base flows, water quality, and habitat area

This memorandum also presents overall conclusions about existing environmental conditions of potentially affected ecosystems.

Affected Environment

King County is currently designing and constructing the Brightwater Wastewater Treatment Plant. This facility will treat wastewater with membrane bioreactor technology, resulting in a high quality effluent. The County plans to make this reclaimed water available to local water districts. The use of reclaimed water from the North Seattle project could affect the receiving waters for treated effluent (Puget Sound) and the urban watersheds in SPU's retail service area where potential customers are located.

Puget Sound

Discharge of treated water to Puget Sound, a navigable water of the United States, is regulated by the Washington State Department of Ecology (Ecology) under authority granted by the U.S. Environmental Protection Agency (EPA) and as delineated in a National Pollutant Discharge Elimination System (NPDES) permit to be issued for the facility. Though the permit for the Brightwater plant has not yet been issued, it can be assumed that discharges from the plant will not contribute to any violations of the numerical standards identified in the WAC (WAC 173-201A), and will likely improve aggregate pollutant loadings from all King County treatments plants.

One of the primary benefits cited for using reclaimed water in western Washington is a positive impact on water quality in Puget Sound. By diverting to terrestrial use what would otherwise be tertiary-treated effluent discharged to the Sound, reclaimed water can alter pollutant loadings entering Puget Sound. Because the Brightwater plant will discharge to Puget Sound, it is included in the analysis of the base case environmental conditions, and will undergo further analysis in Task 4 to quantify benefits.

Service Area Watersheds

Service area watersheds are those located within the SPU's retail service area, and contain water users (primarily in Seattle, Shoreline, and Edmonds) that could be supplied with reclaimed water from the project through the Ballinger Portal. These watersheds include Thornton Creek, Boeing Creek, McAleer Creek (including Lake Ballinger), Lyon Creek, Densmore Drainage basin (Licton Springs), and Piper's Creek.

Self-supplied irrigators (SSIs) (i.e., irrigators that draw local surface or groundwater for irrigation) are present in several of these watersheds. By providing a source of reclaimed water for irrigation, the project would eliminate the need for surface and groundwater withdrawals by SSIs, leaving water available to the watershed ecosystem.

A set of screening level criteria was developed during the environmental analysis 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 for base case (Task 3) and post-project (Task 4) conditions. Those that failed to meet these criteria were considered unlikely to realize a meaningful change in environmental conditions, and were not evaluated further.

Screening Criteria

The screening criteria were structured around the affected service area watersheds (rather than the water users) in order to focus on potential changes in streamflows and surface water and habitat conditions from cessation of ground and surface water withdrawals. The criteria, their justification, and any uncertainty potentially affecting the utility of these criteria are described below.

Criterion 1: Is a SSI present in the service area watershed?

Justification: Service area watersheds without self-supplied water users will not benefit from reclaimed water distribution. Because there is a possibility that the groundwater recharge area and the direction of groundwater flow may not align with the boundaries of a surface watershed, groundwater withdrawals may potentially affect base flow conditions in adjacent drainages. Although accurate assessment of conflicting ground and surface water flow patterns cannot be predicted given the scope of this analysis, exclusion of these possibilities from the analysis could lead to an underestimation of potential benefits. However, based on best professional judgment, any resulting effect or benefit would likely not be significant enough to satisfy remaining screening criterion.

Uncertainty: The effect of groundwater withdrawals on surface water conditions in adjacent drainages.

Criterion 2: Are one or more SSIs located "upstream" of a designated critical area (CA)

Justification: CAs represent environmental attributes that are recognized for the ecological importance and societal value. CAs of interest include wetlands, streams, lakes, and other waterbodies. If upstream SSIs are present, the project could release the existing withdrawal to support stream flows or wetland conditions.

Uncertainty: None identified.

Criterion 3: Is the CA a flow control exempt waterbody?

Justification: Flow control exempt waterbodies include Lake Washington, Lake Union and the Ship Canal, and Puget Sound. These systems are considered flow control exempt by Ecology for the purpose of stormwater management impacts on peak and base flow conditions (Ecology 2005). These systems are sufficiently large to be insensitive to any incremental change in freshwater input that would result from the project.

Uncertainty: This criterion does not account for the possibility that localized groundwater inputs could provide thermal refuge or other beneficial habitat conditions in the nearshore environment. This potential will be acknowledged but not addressed further in the environmental analysis.

<u>Criterion 4</u>: Does the current withdrawal account for more than 20 percent of the annual minimum 7 day average base flow conditions in the affected service area watershed?

<u>Justification</u>: Increased summer base flow in excess of the natural variability in base flow conditions is likely to produce a measurable beneficial change in aquatic habitat and water quality conditions. The selected percentage is based on a preliminary statistical analysis of variability in base flow conditions in a service area watershed (McAleer Creek), as compared to ecologically meaningful indicators of hydrologic alteration defined by Richter et al. (1996).

Specifically, this preliminary statistical analysis included data for King County Gage 35c (at the mouth of McAleer Creek). The analysis involved calculating annual minimum 7-day mean flows for water years 1998 to 2007, and then calculating the mean and standard deviation of the annual minimum 7-day means. We found the coefficient of variation was ~20 percent, i.e., the standard deviation in annual minimum 7-day mean flows (0.98 cubic feet per second [cfs]) was approximately 20 percent of the mean annual minimum 7-day mean flow (4.68 cfs). It is reasonable to assume that other streams potentially affected by the reclaimed water project have similar variability (coefficients of variation) in base flow.

Groundwater withdrawals influence surface water conditions differently than direct surface water withdrawals. For this reason, a correction factor will be applied to groundwater withdrawals to account for the effect that infiltration may have on groundwater reaching surface waters. This "surface-groundwater factor" will be based on the expected effect of local geology on groundwater movement (see Figure 1 for application in the decision tree).

Available data is likely sufficient to evaluate base flow conditions with adequate statistical rigor. In all cases, best professional judgment will be used to help estimate if the withdrawal potentially represents a significant component of base flow. All streams that run dry during the base flow period will be assumed to benefit from increased base flow. To remain conservative in our analysis, the individual SSI withdrawals in each stream, rather than aggregate SSI withdrawals in each stream, will be compared to base flow conditions.

<u>Uncertainty</u>: For several service area watersheds it is uncertain whether there are sufficient flow data available for statistical evaluation of base flow conditions. Preliminary review found sufficient data were available for Thornton and McAleer, and Boeing Creeks. It is unknown what data are available for Licton Springs and how complete the data is for Pipers Creek. Some data is available for Licton Springs via the Densmore Drainage Basin Plan. Herrera also has some recent (2008) flow data for all monitoring stations on Piper's Creek over the last ten years, and other water quality data through 2005-2006. It is unknown what data are available for other waterbodies potentially affected by self-supplied irrigators not yet identified.

<u>Criterion 5</u>: Is the affected waterbody 303(d) listed for dissolved oxygen (DO) or water temperature?

<u>Justification</u>: Several surface water bodies in the study area are listed on the 303 (d) list for elevated temperature and/or depressed DO. Marginal increases in streamflow (i.e., base flows) may improve DO and temperature conditions, thereby facilitating future attainment of water quality standards. This criterion was added since an increase of base flow of less than 20 percent could improve temperature and DO.

Uncertainty: None identified.

A decision tree used for screening drainage systems for further analysis is presented in Figure 1. This decision tree employs the analysis criteria described in the previous section.

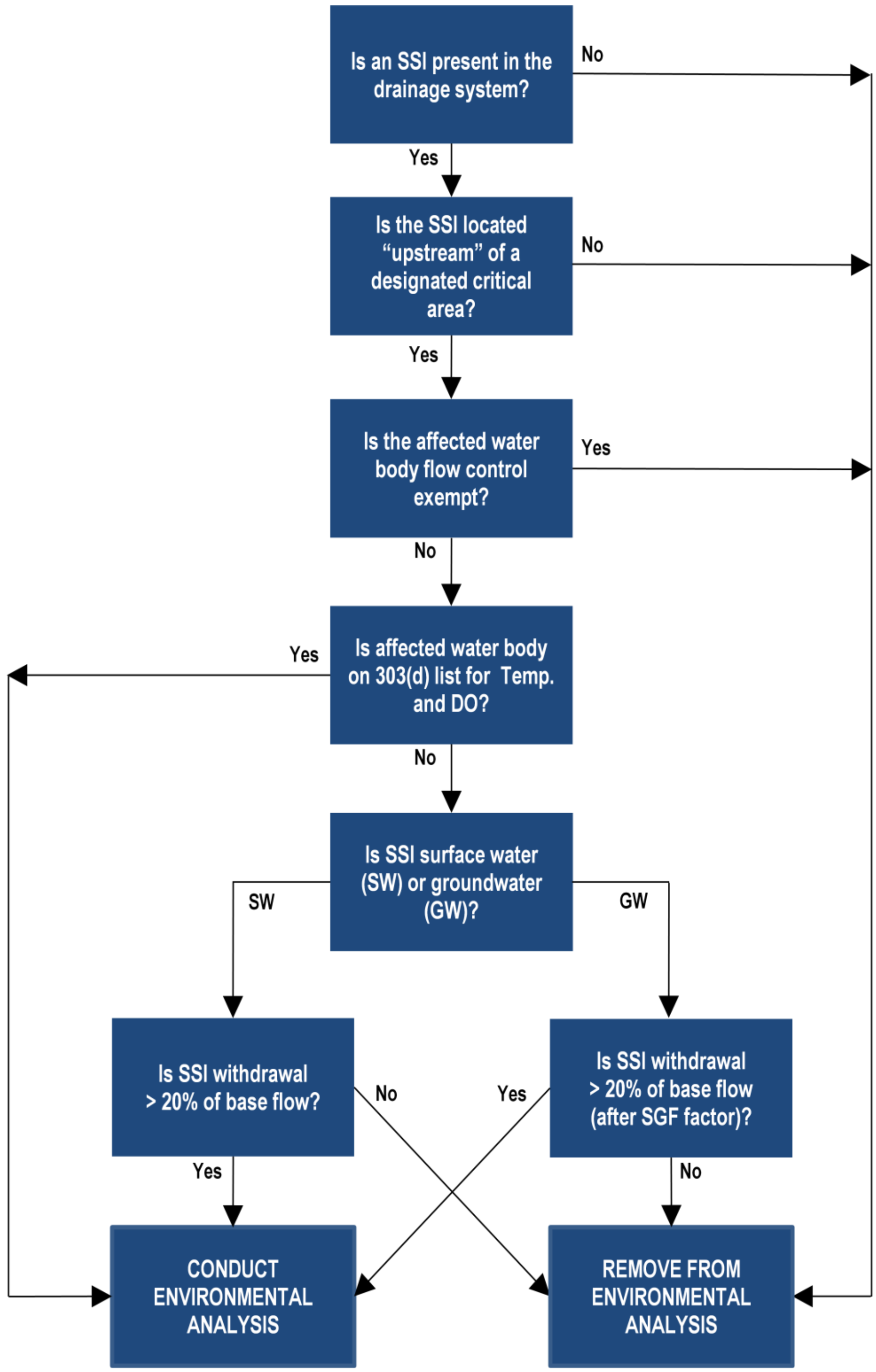

Figure 1. Decision tree for screening drainage systems for Base Case analysis.

Application of Threshold Criteria to Potentially Affected Watersheds

Application of the threshold criteria began with the compilation of readily available data, including:

- King County and SPU drainage basin GIS data
- King County and SPU critical areas (streams and wetlands) GIS data
- 303(d) listing information

These data were used to identify which watersheds/streams would be affected if nine cemeteries and golf courses that are currently self-supplied irrigators (SSI) switched to reclaimed water from the project, as well as to answer the questions posed in the decision flow chart (Figure 1). Table 1 summarizes the results of application of the threshold criteria for each SSI.

Despite the indication from the screening analysis that many of the criteria were met for the Seattle Country Club, only a small portion of the irrigation flow is likely to drain to Boeing Creek, with most irrigation flow likely draining to ungauged tributaries to Puget Sound. Insufficient data for Boeing Creek prevented it from being analyzed for potential benefits from the North Seattle project. However, generally speaking, Boeing Creek and these other creeks draining to Puget Sound are small and have relatively smaller watersheds than Thornton and McAleer Creeks, and could benefit to a greater degree from reduced surface and groundwater withdrawals within their boundaries, depending on local geology and hydrogeology.

Table 1. Results from application of the threshold criteria for each SSI.

Watershed (s)	Customer	Address	Total Area (acres)	Irrigated Area (acres)	Average Irrigation Flow (cfs) [1]	Groundwater (GW) or Surface Water (SW) Withdrawal?	Average 7-day Minimum Flow at Stream's Mouth (cfs)	Standard Deviation of 7-day Minimum Flow at Stream's Mouth (cfs)	Flow Data Notes	Other Flow Notes	Notes on Irrigation as a Percentage of Baseflow	Phase II Analysis Decision Criteria					Analyze in Phase II study?	Rationale for analysis in Phase II
												Criteria 1: Is SSI present in a service watershed	Criteria 2: Downgradient Sensitive Areas	Criteria 3: Is Affected Waterbody Flow Control Exempt?	Criteria 4: Average Irrigation Water Usage as Percentage of Baseflow	Criteria 5: Is Affected Waterbody on 303(d) List for Temperature or Dissolved Oxygen?		
McAleer Creek	Nile Country Club This site is in the McAleer Creek watershed and adjacent to Lake Ballinger.	6601 244th St SW	90	35	0.23 (0.14)	SW	4.6	0.79	McAleer Creek at Mouth (King County gage 35c), Water years 1992 - 2007			Yes	Lake Ballinger, McAleer Creek	No	5.0% (3.0%)	Yes, McAleer Creek is listed for dissolved oxygen but not temperature	Yes	303(d) listing Uncertainty around applicability of existing Temp. data to new temp. criteria.
	Holyrood This site is in the McAleer Creek watershed. An unnamed tributary flows from the east side of Holyrood site to McAleer Creek.	205 NE 205th St	80	40	0.18 (0.18)	GW	4.6	0.79	McAleer Creek at Mouth (King County gage 35c), Water years 1992 - 2007		No infiltration factor was applied.	Yes	McAleer Creek, No mapped wetlands downstream of site.	No	3.9% (3.9%)	Yes, McAleer Creek listed for dissolved oxygen but not temperature		
Thornton Creek (North Fork)	Jackson Park The site is in the North Fork Thornton Creek watershed, upstream of its confluence with Littles Creek	1000 NE 135th St	161	60	0.32 (0.26)	SW	2.5	0.99	Thornton Creek near Mouth (USGS 12128000), Water years 1997 - 2007 (including earlier records [water years 1946, 1962-1968, 1997-2007] results in an average 7-day minimum of 3.4 cfs)			Yes	Streams, Palustrine scrub-shrub and forested wetlands adjacent to Thornton Creek	No	12.8% (10.4%)	Yes, Thornton Creek (lower reach of mainstem) is listed for temperature and dissolved oxygen	Yes	303(d) listing, In addition, the >20% of baseflow criteria may be met on North Fork even though it is not met at mouth
Thornton Creek (tributary)and Inverness Creek	Sand Point Approximately 1/3 of this site drains to an unnamed tributary of Thornton Creek. This unnamed tributary is mapped with headwaters near the Sand Point site's northwest corner and mouth in Thornton Creek near its outlet into Lake Washington. From the information available it is difficult to say how much of the remaining area in the site drains to Lake Washington directly via groundwater/interflow or via Inverness Creek, a small stream with headwaters mapped near the site's ssoutheast corner.	8333 55th Ave NE	90	45	0.31 (0.29)	GW	2.5	0.99	Thornton Creek near Mouth (USGS 12128000), Water years 1997 - 2007 (including earlier records [water years 1946, 1962-1968] results in an average 7-day minimum of 3.4 cfs)	No flow or basin area available for Inverness Creek, one of the affected watersheds.	This percentage was calculated for Thornton Creek with the assumption that 1/3 of the site drains there. A percentage should be calculated for Inverness Creek, but no flow data are available. Similarly a percentage should be calculated for the Thornton Creek tributary, not Thornton Creek itself, but flow data are not available. No infiltration factor was applied.	Yes	Streams, Palustrine scrub-shrub wetland near the NW corner of the site, adjacent to unnamed tributary, Palustrine forested wetland near the mouth of Thornton Creek into Lake Washington	No	4.1% 3.8%	Yes, Thornton Creek (lower reach of mainstem) is listed for temperature and dissolved oxygen		303(d) listing, In addition the 20% baseflow criteria may be met for Inverness Creek or Thornton Creek tributary
Thornton Creek (Littlebrook Creek) and West Lake Washington - Lake Forest Park	Acacia The eastern ~2/3 of this site is mapped in the King County basin map as West Lake Washington - Lake Forest Park basin. An unnamed stream originates near the NE corner of the Acacia site and drains some portion of the eastern ~2/3 of the site. The western ~1/3 of the site is in the watershed of Littlebrook Creek, a tributary to Thornton Creek. Littlebrook Creek's mapped headwaters are approximately 1,500 feet south of the Acacia site.	14951 Bothell Way NE	60	30	0.14 (0.12)	GW	2.5	0.99	Thornton Creek near Mouth (USGS 12128000), Water years 1997 - 2007 (including earlier records [water years 1946, 1962-1968] results in an average 7-day minimum of 3.4 cfs)	No flow or basin area available for the unnamed stream that is one of the affected watersheds.	This percentage was calculated for Thornton Creek with the assumption that 1/3 of the site drains there. A percentage should be calculated for the unnamed stream, but no flow data are available. Similarly a percentage should be calculated for the Littlebrook Creek, not Thornton Creek itself, but flow data are not available. No infiltration factor was applied.	Yes	Streams, Wetlands mapped along Littlebrook Creek and Thornton Creek.	No	1.8% (.16%)	Yes, Thornton Creek (lower reach of mainstem) is listed for temperature and dissolved oxygen		303(d) listing, In addition the 20% baseflow criteria may be met for unnamed stream or Thornton Creek tributary

Notes:

1. Average Irrigation Flow (cfs). First figure represents original estimate of irrigation flow, used in the application of the threshold criteria for each SSI. Subsequent to the application of screening criteria, estimated irrigation flows were revised to reflect the most recent market assessment (figures in parenthesis). The revised estimates are used in the impact analysis, and the lower numbers do not change the screening results.

Table 1 (continued). Results from application of the threshold criteria for each SSI.

Watershed (s)	Customer	Address	Total Area (acres)	Irrigated Area (acres)	Average Irrigation Flow (cfs) [1]	Groundwater (GW) or Surface Water (SW) Withdrawal?	Average 7-day Minimum Flow at Stream's Mouth (cfs)	Standard Deviation of 7-day Minimum Flow at Stream's Mouth (cfs)	Flow Data Notes	Other Flow Notes	Notes on Irrigation as a Percentage of Baseflow	Phase II Analysis Decision Criteria					Analyze in Phase II study?	Rationale for analysis in Phase II
												Criteria 1: Is SSI present in a service watershed	Criteria 2: Downgradient Sensitive Areas	Criteria 3: Is Affected Waterbody Flow Control Exempt?	Criteria 4: Average Irrigation Water Usage as Percentage of Baseflow	Criteria 5: Is Affected Waterbody on 303(d) List for Temperature or Dissolved Oxygen?		
Densmore Drainage Basin	Evergreen Washelli This site is in the West Lake Washington - Seattle North basin (King County map), which is labeled as the Densmore drainage basin in the City of Seattle basin map. The site is approximately 4,000 feet south (downslope) from Bitter Lake and approximately 5,000 feet north (upgradient) from the mapped headwaters of Licton Springs.	11111 Aurora Ave N	160	128	0.59 (0.53)	GW	No flow data available. Flow assumed to be smaller than that of the other streams in this matrix, i.e. baseflow <1.5 cfs				No infiltration factor was applied.	Yes	Licton Springs (~5,000 feet downgradient) is the nearest mapped sensitive area.	No	Presumably >20%	No, Green Lake listed for other parameters	Yes	Irrigation water use assumed to be greater than 20% of baseflow. Uncertainty around applicability of existing Temp. data to new temp. criteria.
Boeing Creek	Herzl Memorial This site is in the Boeing Creek watershed, approximately 300 feet from the mapped headwaters.	16747 Dayton Ave N	4	3.85	0.006 (0.02)	GW	1.5	No standard deviation possible. Only one summer's data available	Boeing Creek near Beach Drive (King County Gage 04j), Water Year 1992 (Looking at McAleer Creek's data, water year 1992's 7-day minimum flow was equal to its 1992 - 2007 average 7-day minimum flow)		No infiltration factor was applied.	Yes	Boeing Creek, Wetlands along Boeing Creek	No	0.4% (1.3%)	No	No	Irrigation water usage much less than 20% of baseflow, no 303(d) listing
	Machzikay Hadath This site is in the Boeing Creek watershed, approximately 3,100 feet east from the stream's mapped headwaters.	1230 N 167th St	3	1.86	0.006 (0.011)	GW	1.5	No standard deviation possible. Only one summer's data available	Boeing Creek near Beach Drive (King County Gage 04j), Water Year 1992 (Looking at McAleer Creek's data, water year 1992's 7-day minimum flow was equal to its 1992 - 2007 average 7-day minimum flow)		No infiltration factor was applied.	Yes	Boeing Creek, Wetlands along Boeing Creek	No	0.4% (0.7%)	No		
	Seattle Country Club The vast majority of this site drains to ungauged tributaries of Puget Sound, and Boeing Creek, although a small portion of the Seattle Country Club does drain into the Densmore drainage basin that serves Licton Springs. The mapped headwaters of Licton Springs are over two miles south of the Seattle Country Club.	210 NW 145th	112	56	0.37 (0.32)	GW	No flow data available. Flow assumed to be smaller than that of the other streams in this matrix, i.e. baseflow <1.5 cfs					Yes	One mapped wetland in Seattle Country Club, other wetlands in the vicinity are adjacent to Bitter and Haller lakes, Licton Springs stream	No	Presumably >20%	No, Green Lake listed for other parameters	Yes	Irrigation water use assumed to be greater than 20% of baseflow

Notes:

1. Average Irrigation Flow (cfs). First figure represents original estimate of irrigation flow, used in the application of the threshold criteria for each SSI. Subsequent to the application of screening criteria, estimated irrigation flows were revised to reflect the most recent market assessment (figures in parenthesis). The revised estimates are used in the impact analysis, and the lower numbers do not change the screening results.

Existing Environmental Conditions – Puget Sound

This section presents a brief assessment of priority pollutants in the Puget Sound, and identifies the pollutants used in subsequent analysis. It includes an assessment of current wastewater effluent quality from treatment plants in the region, providing the baseline data for estimating expected effluent quality from Brightwater.

Since Brightwater will be the first advanced secondary treatment plant in the region, existing data on secondary treatment plants in the region will (for certain parameters) overestimate effluent concentrations from Brightwater. To account for this overestimation, literature comparing secondary and advanced secondary treatment effluent quality is used to "scale" expected Brightwater effluent concentrations. Lastly, anticipated effluent volumes are used to calculate pollutant loading to Puget Sound under base case conditions.

<u>Methods of Analysis</u>

Use of Pollutant Concentrations in Estimating Base Case Conditions

Priority Pollutants in Puget Sound

Puget Sound receives flow from 10,000 streams and rivers that carry runoff from a terrain with myriad land uses (PSAT 2007). A combination of agricultural and urban/suburban development has lead to an increased loading of a wide variety of pollutants to the Sound.

Historically, pollution in Puget Sound deep water habitat has not been an issue (King County 2004), but in the near shore elevated levels of bacteria and nutrients have led to degraded water quality. Nearshore pollution tends to be most concentrated in areas with poor tidal circulation (e.g., Hood Canal, Budd Inlet, Penn Cove), and near outfalls in urban areas (e.g., Duwamish Estuary) (PSAT 2007). Nitrogen loading is of particular concern because marine environments, including the Puget Sound, are nitrogen limited systems (Bernhard 1997). This means that additional nitrogen loading will contribute to system productivity and increase the potential for harmful algal blooms (Paerl 2008). Harmful algal blooms have long been an issue of concern in Puget Sound because they can lead to toxicity that can affect human health through direct contact and contribute to paralytic shellfish poisoning (Horner 1998).

It has been shown that nitrogen and phosphorus loading combined can lead to higher productivity than nitrogen loading alone (Bernhard 1997); consequently, it is important to recognize that although marine systems are nitrogen limited, phosphorus loading may contribute to increased productivity within the complex community of primary producers present in Puget Sound ecosystems.

In addition to nutrients and toxics loading from stormwater runoff and treatment plant effluent has become an issue as animal tissues and marine sediments have shown an increasing accumulation of these pollutants (PSAT 2007). However, it should be noted that the vast majority of toxics are delivered to the Sound via surface runoff (Hart Crowser 2007) and advanced secondary treatment does not provide additional toxics removal over secondary (see below). Consequently, the toxics analyzed in this study are included for reference, while the nutrients and fecal coliform will serve as the benchmark against which costs and benefits should be weighed.

Nutrients, bacteria, metals, and organic chemicals in the Puget Sound have been identified as constituents of concern (King County 2004; PSAT 2007), thus the analysis presented below will include the following constituents (in order of importance):

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

Other pollutants such as hormone disruptors and pesticides have also been identified as contaminants of concern; however there is limited data on potential effluent concentrations from Brightwater for these less studied pollutants; consequently, they are not included in this analysis.

Effluent Concentrations

Multiple data sources were used to estimate Brightwater effluent concentrations for the nine constituents listed in the previous section (note: some constituents listed above are inclusive of others, for example Ammonia-N and Nitrate-N are both included in Total Nitrogen). A previous King County study (King County 2005) used data from the membrane bioreactor (MBR) pilot studies conducted at West Point to estimate effluent concentrations from the MBR treatment system to be installed at Brightwater. These data are presented in Table 2 along with estimates of secondary effluent concentrations from the South King County Treatment Plant. If MBR technology was not applied at Brightwater, then effluent concentration would be expected to be similar to the secondary treatment concentrations listed in Table 2.

Table 2. Estimated nutrient effluent concentrations from traditional secondary treatment and MBR treatment.

Parameter	Estimated Secondary Quality [a]	Estimated MBR Quality	Units
Ammonia-N	31.3	0.6	mg/L
Nitrate-N	2.78	2.0	mg/L
Total Nitrogen	34.0	2.6	mg/L
Ortho-phosphate	3.15	1.5	mg/L
Total Phosphorus	3.33	1.5	mg/L

Adapted from King County (2005)

[a] Estimated secondary effluent quality from Department of Ecology EIM database entry for South King County Treatment Plant

Effluent data for the parameters of interest not listed in Table 2 (i.e., fecal coliform bacteria, copper, zinc, and bis(2-ethylhexyl)phthalate) were estimated from other sources. Estimates of copper, zinc, and bis(2-ethylhexyl)phthalate were derived from a data set of Puget Sound wastewater treatment plant effluent concentrations compiled by Ecology for a Puget Sound toxic chemicals loading report (Herrera 2008).

The original sources of these data included Ecology's Water Quality Permit Life Cycle System (WPLCS) database, discharge monitoring reports provided by permittees, and Water Quality Program permit managers. Only data from the past 5 years was used in the estimates. Because there were no advanced secondary treatment plants in the Ecology datasets, the effluent values may not be indicative of the concentrations that will be exported from Brightwater. To determine if the data from the secondary plants could be used as an estimate of effluent concentrations from Brightwater, a literature review was conducted.

Although most conventional WWTP were initially designed to remove organic matter and nutrient loading, metals tend to be retained in conventional activated sludge plants (Buzier et al. 2006). In at least one instance, the addition of MBR technology to a secondary treatment plant has been shown to further increase dissolved copper removal (Fatone et al. 2008), but most studies indicate that increased metals treatment through MBR treatment is never realized (Buzier et al. 2006; Ekster and Jenkins 1996). MBR technology has been shown to significantly increase the biological processing and sequestration of nutrients and organic matter over secondary treatment (Mack et al. 2004), but unless advanced secondary treatment technologies such as biogenic hydrogen sulphide treatment are used, further metal reduction past that achievable with secondary treatment is unlikely (Chuichulcherm et al. 2001; Mack et al. 2004). Consequently, the metals values from Ecology's regional treatment plant effluent datasets can be used to estimate expected concentrations from Brightwater without the use of a scaling factor.

Similarly, bis(2-Ethylhexyl)phthalate readily sorbs to sediments and thus secondary treatment procedures that effectively remove sediment will also effectively remove bis(2-Ethylhexyl)phthalate. Unlike for the parameters listed in Table 2, additional treatment from MBR treatment is not anticipated for copper, zinc, and bis(2-ethylhexyl)phthalate).

Secondary treatment plants are also designed for wastewater disinfection and are effective at reducing fecal coliform bacteria (Metcalf & Eddy Inc. and Tchobanoglous 1979). However, it has been shown that MBR improves bacteria treatment by a factor of 2.3 (Zhang and Farahbakhsh 2007). In addition, the disinfection system designed for Brightwater is expected to reduce coliform concentration to below 2.2 CFU/100 mL (King County 2003). Consequently, the Ecology regional treatment plant bacteria effluent data was adjusted to estimate fecal coliform bacteria effluent concentrations from Brightwater (Table 3).

To verify if these effluent estimates were accurate the resultant values were compared with estimates in King County's final environmental impact statement for Brightwater (King County 2003). For the data that were available, the EIS estimates and the regional medians were comparable except for Bis(2-Ethylhexyl)phthalate which was estimated to be nearly twice as high in the Brightwater EIS (8.2 micrograms/L versus 4.5 micrograms/L) (Table 3). Bis(2-Ethylhexyl)phthalate concentrations in wastewater are frequently below blank-corrected reporting limits, thus estimates of central tendency are complicated and dependent upon the statistical method applied. Consequently, for the purposes of this analysis we applied the more conservative values of 4.5 micrograms/L (Table 3). In this analysis, this concentration is used to estimate the Bis(2-Ethylhexyl)phthalate load reduction to the Sound through reuse. If the larger value was used there is the potential that the benefit of reuse may be overestimated, thus the lower value of 4.5 micrograms/L is a more conservative estimate.

Table 3. Estimated Brightwater effluent concentrations for selected priority pollutants.

Parameter	Regional Median [a]	Number of Samples	Scaling Factor [b]	Estimated Quality [c]	EIS Estimate [d]	Units
Dissolved Copper	11	41	1	11	9.5	µg/L
Dissolved Zinc	47	45	1	47	35	µg/L
Bis(2-Ethylhexyl)phthalate	4.5	25	1	4.5	8.2	µg/L
Fecal Coliform Bacteria	24.1	2799	11	2.2	2.2	CFU/ 100mL

[a] Data source: Ecology's Water Quality Permit Life Cycle System (WPLCS) database, discharge monitoring reports provided by permittees, and Water Quality Program permit managers.

[b] Scaling factors were applied to adjust secondary treatment estimates to MBR treatment estimates.

[c] Estimated effluent quality for Brightwater was calculated by dividing the regional median data by the scaling factor.

[d] Brightwater effluent values were estimated as part of the EIS process (King County 2003), these values were included for comparison to the values estimated as part of this report.

NA = not available

µg/L = micrograms/Liter

Table 3 provides data from the Ecology regional treatment plant data sets and from the Brightwater EIS. For the regional data median values for each parameter and number of samples are reported. Median values were chosen to estimate the central point of the data to reduce the influence of outliers on the dataset.

Effluent Volume

Total effluent discharge from Brightwater will be routed to Puget Sound. A portion of the discharge will also be recycled for in-plant uses, but this amount is considered negligible for the calculations in this memorandum. Due to infiltration inflow to the plant, wet weather discharges from Brightwater are expected to be greater than dry weather discharges.

For analytical purposes, the wet season encompasses October through March, while the dry (irrigation) season extends from April to September. After the treatment plant is online and at capacity, average annual effluent flow from Brightwater is estimated to be 31.3 mgd (Simmonds 2009). Data for wet weather flows during the same period are projected to be 36 mgd (Simmonds 2009). To estimate average flows for the irrigation season the wet weather flow rate was applied to the average number of wet days (daily precipitation greater than 0.10 inches) that is expected in a typical year. Historical (1972 through 1998) meteorological data from a National Climatic Data Center cooperative station (#457458) (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wa7458) in Seattle, Washington were used to estimate the anticipated number of wet days. The number of wet days was multiplied by the anticipated wet weather flows and then weighed against the average annual flows to back calculate dry weather flows. These values were then used along with estimates of the number of wet days in each season (irrigation season and non-irrigation season) to calculate Brightwater effluent flow rates for each season (Table 4).

Table 4. Estimated Brightwater Effluent Discharge.

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. (mgd = million gallons per day)

[b] annual flow estimate is average of seasonal estimates

Data Availability

Brightwater is the first large scale advanced secondary treatment plant in the region; consequently, the available data that could be used to estimate effluent quality from the plant were limited. A 2005 King County White Paper (King County 2005) was used to estimate nutrient concentrations treatment plant effluent. The King County White Paper referenced pilot test studies of MBR systems, including a system that was installed and tested at the West point Treatment Plant from June 2002 through June 2003. Composite water samples were collected 3 times weekly during the year of monitoring and the average results were reported. The values for nutrients from this report are the closest analog to what can be expected to be exported from Brightwater. In addition, Table 2 reports estimates of nutrient levels for secondary treatment. These values were derived from South King County Treatment Plant data collected from the Department of Ecology's EIM database. The average n value for each parameter was 14 and the data were collected beginning in August of 2006.

The dissolved copper, dissolved zinc, bis(2-ethylhexyl)phthalate, and fecal coliform bacteria data were not as readily available as the nutrient data. Two methods were used to estimate the concentrations of these parameters in Brightwater effluent. First, data from secondary treatment plants were taken from a comprehensive Department of Ecology report on toxic loading from Puget Sound treatment plants (Herrera 2008) and then a literature review was conducted to identify if MBR treatment provided additional removal for these parameter. Second, estimates from the Brightwater EIS (King County 2003) were reported. Both methods produced similar results for each parameters except bis(2-ethylhexyl)phthalate (further explanation provided in the *Effluent Concentrations* section above).

Lastly, estimates of flows derived from conversations and email correspondence with Jim Simmonds of King County. Mr. Simmonds provided estimates of flow that were more up-to-date than the estimates originally reported in the Brightwater EIS (King County 2003).

Important Assumptions

As with any study that involves estimating future conditions, numerous assumptions need to be accepted in order for the analysis to be useful. For this study the important assumptions were:

- Water quality data from the MBR pilot study at West Point and from other data sources used in King County (2005) are a reasonably accurate estimate of Brightwater effluent concentrations.

- Flows from Brightwater will not differ significantly from projected flows.
- Literature results regarding MBR treatment for metals, organic chemicals, and fecal coliform are applicable to Brightwater.
- Regional results for secondary treatment plants regarding metals, organic chemicals, and fecal coliform export can be applied to Brightwater.

It should be understood that there is inherent error in the above assumptions, but that such assumption are a requirement when there are no data sources that can provide more accurate estimates of conditions.

Base Case Results

The previous sections presented the methodology and results for effluent concentration estimations and seasonal hydraulic loading rate estimations for the Brightwater Treatment Plant. The calculation of mass loading to the Sound is then simply an arithmetic exercise. For each season the following formula was used to calculate base case loading to the Sound:

$$M_{(Kg)} = Q_{(L)} \times X_{(Kg/L)}$$

Where:

M_{Kg} = Mass of pollutant in kilograms
Q_L = Seasonal effluent volume in liters
$X_{Kg/L}$ = Pollutant concentration in kilograms per liter

The results of these calculations are presented in Table 5.

Table 5. Estimated annual and seasonal mass loading (in kilograms) to Puget Sound from Brightwater with no reclaimed water export through the West Backbone – 2012.

Constituent	Brightwater Effluent Concentration	Concentration Units	Load to Sound Wet Season	Load to Sound Dry Season	Load to Sound Annual	Loading Units
Ammonia-N	0.6	mg/L	13,300	12,760	26,061	Kg
Nitrate-N	2.0	mg/L	44,335	42,534	86,868	Kg
Total Nitrogen	2.6	mg/L	57,635	55,294	112,929	Kg
Fecal Coliform	2.2	CFU/100mL	488	468	956	Billions of CFU
Ortho-phosphate	1.5	mg/L	33,251	31,900	65,151	Kg
Total Phosphorus	1.5	mg/L	33,251	31,900	65,151	Kg
Copper	11	µg/L	244	234	478	Kg
Zinc	47	µg/L	1,042	1,000	2,041	Kg
Bis(2-Ethylhexyl)phthalate	4.5	µg/L	100	96	195	Kg

CFU = colony forming unit
mg/L = milligram per liter
mg/L = microgram per liter
Kg = kilogram

Implications

Extent of the Current Problem

There are 39 sites across Puget Sound that are routinely monitored for nutrients, fecal coliform bacteria, temperature, and dissolved oxygen. All 39 sites show some "level of concern" and 8 are classified as "highest concern" (PSAT 2007). The eight "highest concern" sites are Budd Inlet, South Hood Canal, Saratoga Passage, Possession Sound, Penn Cove, Commencement Bay, Elliott Bay, and Sinclair Inlet. Locations of "high" concern include Bellingham Bay, Oakland Bay, Case Inlet, Discovery Bay, Strait of Georgia, Carr Inlet, Port Orchard, West Point, Skagit Bay and Port Susan. Thus, the West Point treatment plant discharges to a site of high concern, while the Renton and Brightwater treatment plants do not discharge to sites of highest or high concern. In addition, 96 marine sites, 24 lakes, and 24 streams and rivers are 303d listed for toxic chemical violations (PSAT 2007) and numerous category 5 impaired water designations exist for zinc, copper, and bis(2-ethylhexyl)phthalate contaminated surface waters across the Puget Sound lowlands (Washington 303d list).

These findings indicate that the Puget Sound is an impacted system that would benefit from reduced pollutant loadings. It is difficult to predict how transferring wastewater load from Renton and West Point to the Brightwater discharge point would impact the Sound. As indicated above, the West Point Treatment Plant discharges to an area of high concern with regard to water quality. Once Brightwater is online, total loading to this area from King County Wastewater would be reduced from what it would otherwise be, however, a small portion of the load would be transferred north to the waters off of Edmonds, Washington. Because these waters are of a higher quality than the waters off of West Point, there is a greater potential for pollutant dilution and thus reduced environmental impact. However, some water quality issues could potentially be transferred rather than eliminated.

The Brightwater EIS (King County 2003) indicates that "Small amounts of microbiological and chemical contaminants would be discharged into the marine environment. Estimated concentrations at the edge of the acute and chronic mixing zones would meet all applicable standards or criteria. Outside the regulatory mixing zone, concentrations of these pollutants are anticipated to meet water quality criteria." This indicates that pollutant concentrations within the water column should not be of concern, but the Puget Sound is a depositional environment and consequently pollutant loading does not simply dilute and disappear. There are numerous backwaters, especially in urban embayments (e.g., Possession Sound, north of the Brightwater outfall), where pollutants can accumulate in the sediment and in the tissues of living organisms.

The best available science indicates that water and sediment quality in the Puget Sound is in decline (PSAT 2007). Consequently, any pollutant loading to the Sound must be considered a detriment to the health of the system. Lastly, it should be noted that early autumn (September) is the most sensitive time of the year for the Sound (Ecology 2002). Consequently, pollutant loading at the end of the dry season has the potential to be more deleterious to near shore aquatic organisms than loading during the wet season.

Current Base Case

King County provides wholesale wastewater treatment services to about 1.4 million people in numerous cities and local sewer utilities in King County and portions of Snohomish and Pierce counties. The cities and sewer utilities own and operate independent collection systems which carry wastewater flows in their service area to King County's regional system for treatment. There are two major treatment plants in King County's service area, West Point Treatment Plant in Seattle and South Plant in Renton. These provide conventional activated sludge secondary treatment with a combined capacity to treat 248 mgd of average wet weather flow.

King County currently discharges about 200 mgd (average wet season flow) of secondary-treated effluent into Puget Sound from its major two treatment plants. Average dry weather flows are about 150 mgd. Applying these flows to the effluent concentrations from Tables 6 and 7, the existing King County treatment plants discharge about 8,200 metric tonnes of nitrogen, 805 metric tonnes of phosphorus, and 58 trillion colony forming units of fecal coliform into Puget Sound each year.

Table 6. Pollutant Loads to Puget Sound from Existing King County Treatment Plants.

		Pollutant Load to Puget Sound					
		Mass in Kg*			Mass in Metric Tonnes *		
Constituent	Secondary Effluent Concentration	Summer	Winter	Annual	Summer	Winter	Annual
Ammonia-N	31.3 mg/L	3,252,359	4,312,782	7,565,141	3,252	4,313	7,565
Nitrate-N	2.78 mg/L	288,868	383,052	671,920	289	383	672
Total Nitrogen	34 mg/L	3,532,914	4,684,811	8,217,725	3,533	4,685	8,218
Fecal Coliform	24.2 CFU/100mL	25,146	33,345	58,491	25,146	33,345	58,491
Copper	11 µg/L	1,143	1,516	2,659	1.1	1.5	2.7
Zinc	47 µg/L	4.884	6.476	11.360	4.9	6.5	11.4
Bis(2-Ethylhexyl) phthalate	4.5 µg/L	468	620	1,088	0.5	0.6	1.1
Ortho-phosphate	1.5 µg/L	327,314	434,034	761,348	327	434	761
Total Phosphorus	1.5 µg/L	346,018	458,836	804,854	346	459	805

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

Table 7. Pollutant Loads to Puget Sound from All King County Treatment Plants.

	Metric Tonnes of Pollutants*								
	Existing Treatment Plants			Net Impact of Brightwater			Totals with Brightwater		
Constituent	Summer	Winter	Annual	Summer	Winter	Annual	Summer	Winter	Annual
Ammonia-N	3,252	4,313	7,565	-568	-761	-1329	2,685	3,551	6,236
Nitrate-N	289	383	672	-14	-19	-34	274	364	638
Total Nitrogen	3,533	4,685	8,218	-581	-779	-1360	2,952	3,906	6,858
Fecal Coliform*	25,146	33,345	58,491	-4069	-5456	-9526	21,077	27,888	48,965
Copper	1.1	1.5	2.7	0	0	0	1.1	1.5	2.7
Zinc	4.9	6.5	11.4	0	0	0	4.9	6.5	11.4
Bis(2-Ethylhexyl)phthalate	0.5	0.6	1.1	0	0	0	0.5	0.6	1.1
Ortho-phosphate	327	434	761	-31	-41	-71	297	393	690
Total Phosphorus	346	459	805	-34	-45	-79	312	413	726

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

Base Case Conditions in the Future

When the new Brightwater treatment plant comes online in 2012, it will have the capacity to treat 36 mgd of Average Wet Weather Flow to the higher standard described above. 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. According to Simmonds (2009), this will be 31.3 mgd in the wet season and 19.4 mgd in the dry season. This should reduce pollutant loadings as follows.

The addition of Brightwater should reduce nitrogen and fecal coliform loads by about 14% and phosphorus by about 9%. Metals and phthalate loadings are not expected to change.

Existing Environmental Conditions – Service Area Watersheds

This section describes the existing local conditions for the service area watersheds identified during application of the threshold criteria. Service area watersheds are those located within the SPU's retail service area, and contain water users (primarily in Seattle, Shoreline, and Edmonds) that could be supplied with reclaimed water through the North Seattle project. Watersheds included in the analysis are Thornton Creek, McAleer Creek (including Lake Ballinger), and the Densmore Drainage basin (Licton Springs). Existing conditions are characterized using three categories of quantitative and qualitative metrics, including:

1. **Hydrologic, hydrogeologic, and hydraulic conditions:** present base flows based on historical flows

2. **Water quality:** Temperature, dissolved oxygen, and ortho-phosphate phosphorus and copper loadings.

3. **Wetted habitat area:** The area of instream habitat and riparian wetlands in the service area watersheds under the base case range of base flow conditions.

<u>Hydrologic and Hydrogeologic Conditions</u>

This section discusses the base case hydrologic and hydrogeologic conditions in the selected service area watersheds, as they relate to base flow. The *Habitat Area* section below also discusses the hydrologic and hydraulic conditions as they relate to habitat area.

Methods of Analysis

Average base flow rates were evaluated for the May to September irrigation season. The following sections present the methods, assumptions, and results of this analysis. Subsequent sections describe the extent to which base case base flows impact water quality and wetted habitat area; however, this section combines the quantitative base flow analysis results with professional judgment to discuss the degree to which insufficient base flows represent a problem for the study watersheds. Assessment of potential project impacts on base flow conditions will be described in a subsequent (Task 4) memorandum.

The summary of base case stream flow and base flow patterns in each of the three study watersheds was based on available historical flow monitoring data. Following is a description of the Points of Analysis (POAs) selected for the base flow analysis, and a summary of how the irrigation season base flows were extracted for each of these POAs.

Data Availability

Within each of the three study watersheds, the hydrologic analysis began by compiling all of the available historical stream flow data. Preference for selecting the points of analysis was based on: 1) proximity and representativeness of the types of habitat to later be evaluated for potential benefits, 2) proximity to watershed locations with existing available data, and 3) proximity to the

SSIs. In addition to these factors, data availability and quality were also primary factors in selecting POAs for further base flow analysis.

Ideally, several POAs would be located downstream of and close to all SSIs being analyzed. However, POAs could only be selected where the available data record is sufficient for determining base flows: at flow gauges with consistent, continuous data, with at least 2 years of record. The only locations with datasets meeting these criteria included three locations on Thornton Creek, two locations on McAleer Creek, and one flow gauge station in the pipe network draining to Licton Springs in the Densmore drainage basin. The locations of these POAs are illustrated in Figure 2.

While establishing multiple POAs within the downstream channel network in close proximity to each SSI being assessed would be ideal, this was only possible for a few of the SSIs. For Jackson Park Golf Course, Holyrood Cemetery, and Nile Country Club, there were sufficient flow data for base flow analysis both within a mile downstream of the SSI and further downstream. In general, although sites closer to the creek mouth were further downstream of the SSI, those sites also had the most complete and continuous datasets and were therefore also included in the analysis. For Evergreen Washelli Cemetery, only one flow data set (i.e., the combined records of SPU stations 108 and 118) covering multiple irrigation seasons worth of data was available.

For the remaining SSIs, Acacia Cemetery, Sand Point Golf Course, and Seattle Country Club, no quantitative analysis of base flow was possible due to a lack of flow monitoring stations on unnamed tributaries. Approximately two thirds of the Acacia site drains to a small unnamed tributary to Lake Washington; the other third drains to a tributary of Thornton Creek. No flow data are available for either tributary. Similarly, one third of the Sand Point site drains to an unnamed Thornton Creek tributary, while two thirds drains to Inverness Creek, another small tributary of Thornton Creek. Neither stream has available flow data.

The vast majority of the Seattle Country Club property also drains to ungauged tributaries to Puget Sound and Boeing Creek. Although a small portion of the Seattle Country Club does drain into the Densmore drainage basin that serves Licton Springs, it was determined that this potential base flow contribution would be so slight and only minimally expressed given that Licton Springs is located over 2.5 miles downstream of Seattle Country Club. For these reasons, Seattle Country Club was not quantitatively assessed in the base flow analysis.

While no quantitative analysis could be performed at these three SSIs, the analysis of one large SSIs' effects on base flow in a small stream/wetland complex (i.e., Evergreen Washelli impacts on Licton Springs/Densmore drainage basin) may yield results that could be qualitatively extended to Acacia, Sand Point, and Seattle Country Club. It is an unfortunate coincidence that the drainages that could potentially experience the greatest benefits from base flow augmentation are often those streams that are either ephemeral or too small to have flow gauge resources allocated to them.

Many of these small drainages, such as Inverness Creek and the small unnamed tributaries leading directly to Lake Washington or Puget Sound, also have highly developed upper watersheds with dense storm drain infrastructure which conveys peak flows directly to the creeks rather than allowing the runoff to infiltrate and recharge base flows. Licton Springs, within the Densmore drainage basin, is one such developed watershed with the majority of its upper basin connected to the storm drain network, and very small summer base flows. Therefore, the extent to which Licton Springs actually benefits from base flow augmentation could be qualitatively extrapolated to these other small drainages, in general terms. However, without any data to compare, it will not be possible to quantitatively extrapolate, the characterization of benefits from reclaimed water use at those sites, nor to their basins as a whole.

Table 8 summarizes the POAs selected for base flow analysis of the SSIs as well as the available periods of record for those locations. Even some of the most complete datasets had some gaps in the data. For SPU flow monitoring station STA033 (Thornton POA2), there were a total of 241 days of data gaps over the 10-year (March 1999 to April 2009) period of analysis, including 95 days with data gaps over the irrigation season of May through September. For SPU station STA066 (Thornton POA1), there were 74 days with data gaps between January 2004 and April 2009, but no data gaps during the irrigation season. For King County gage 35c at McAleer POA2, there were a total of 100 days with data gaps between October 1991 and January 2009, including one 16-day gap during the irrigation period. For King County gage 35a (McAleer POA1), there were 267 days with data gaps over the period of record (January 1989 to February 1993), including one 153-day data gap during the early irrigation season of 1992.

Use of Historical Streamflow Data in Estimating Base Case Conditions

The historical streamflow monitoring data were used to estimate base case conditions during the five-month irrigation season, which begins in May and extends through September. The flow data for each POA were loaded into a common Matlab database and a hydrograph separation algorithm was implemented to separate base flow from storm flow. The hydrograph separation algorithm used was the sliding interval minimum method. This method was selected because it is a straightforward moving minimum technique that is easy to explain and because it is part of the widely used HYSEP hydrograph separation program. This method selects the minimum flows recorded during a selected time interval to represent the base flow for that time interval. The only adjustable parameter in the sliding interval method is the interval of time (in days) over which the moving minimum is taken. If the interval is too long, the resulting base flow time series is excessively smoothed, and it may underestimate true base flow if it is associating one minimum value over a longer period of time. On the other hand, if the selected interval is too short, the computed base flow time series ends up including too much direct runoff (e.g., the minimum flow recorded during a 2-day-long storm event will not represent a base flow). As an example of the sensitivity of the base flow separation results to the interval used, Figures 3, 4, and 5 show a comparison of results for McAleer Creek using 3-, 15-, and 30-day intervals, respectively. The total base flows for the year shown in these plots were 7,318, 5,580, and 5,038 acre-feet when extracted by 3-day, 15-day, and 30-day sliding interval minimum method. The plots show the extraction methods yield different results in the wet season (e.g., November), but they give similar results during the irrigation season when there is less day-to-day variability in streamflow.

Figure 2. Summary of Points of Analysis for Assessed Self Supplied Irrigators

Table 8. Summary of points of analysis and relative periods of record used for the base flow analysis.

	Station ID	Applicable Self Supplied Irrigator	Station Location	Data Source	Available Period of Record	Period of Analysis	Data Gaps During Period of Analysis [a]
Thornton Creek							
TC-POA1	STA066/ STA064	Jackson Park Golf Course	Downstream end of Jackson Park Golf Course	SPU	1999-Present	1999-Present	0% during irrigation season; 3.8% total
TC-POA2	STA033	Jackson Park Golf Course	NE 110th / 35th Ave NE	SPU	1992-Present	1999-Present	6.2% during irrigation season; 6.6% total
McAleer Creek							
MC-POA1	35a	Nile Country Club, Holyrood Cemetery	Below 15th Ave NE	King County	1989-1994	1991-1993	25 % during irrigation season; 17.9% total
MC-POA2	35c	Nile Country Club, Holyrood Cemetery	Near Mouth	King County	1991-Present	1991-1993	0.6% during irrigation season; 1.5% total
Licton Springs/ Densmore Drainage Basin							
LS-POA1	STA108	Evergreen Washelli Cemetery	10030 Interlake Ave N Pipe	SPU	2003-2004	2003-2004	37 % during irrigation season; 50% total
	STA118	Evergreen Washelli Cemetery	10030 Interlake Ave N Pipe	SPU	2006-2008	2006-2008	37% during irrigation season; 50% total

Notes:

[a] Data gaps expressed as the ratio of the number of days of data gaps over the total number of days within the period of analysis (or irrigation season)

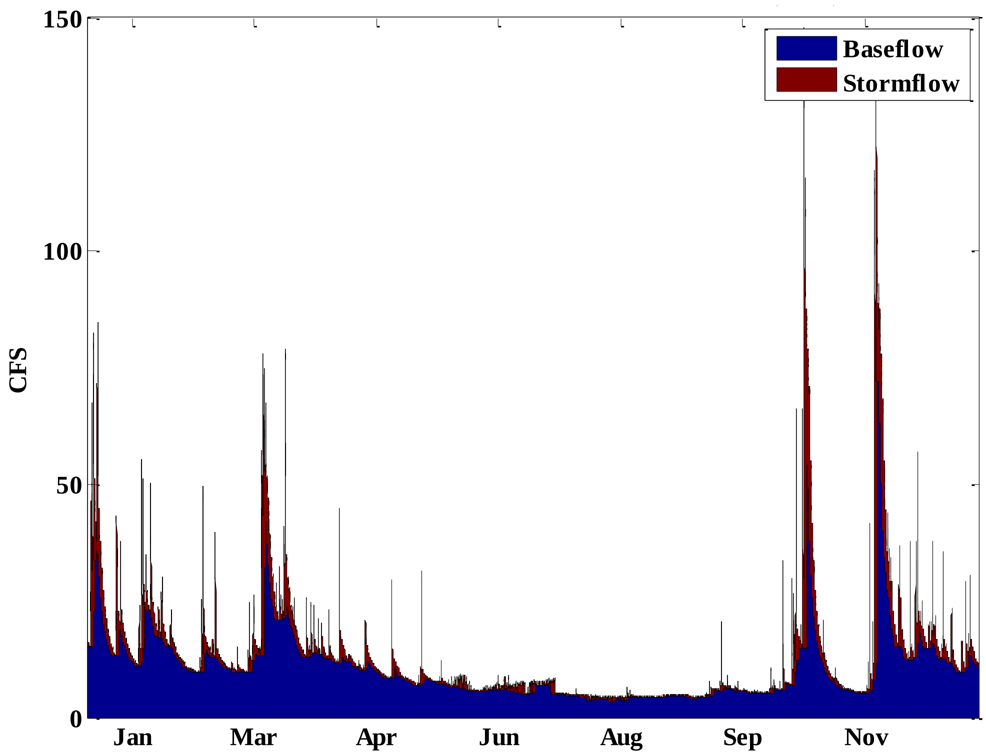

Figure 3. Base flow extraction for McAleer Creek (2003) by sliding interval method with 3-day interval.

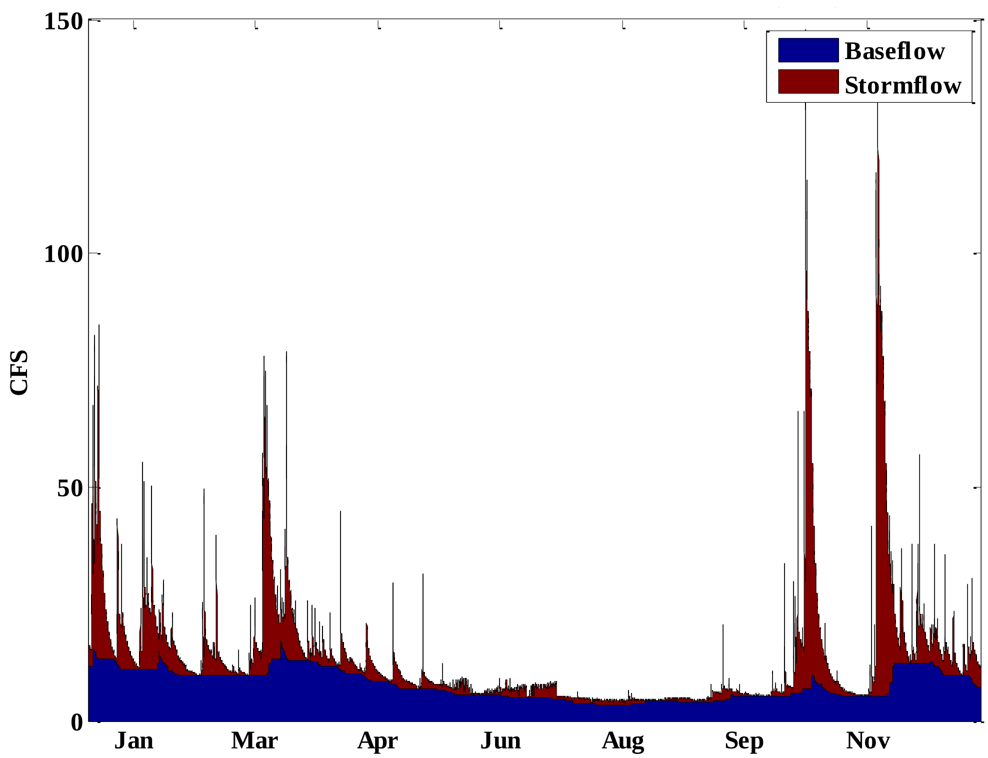

Figure 4. Base flow extraction for McAleer Creek (2003) by sliding interval method with 15-day interval.

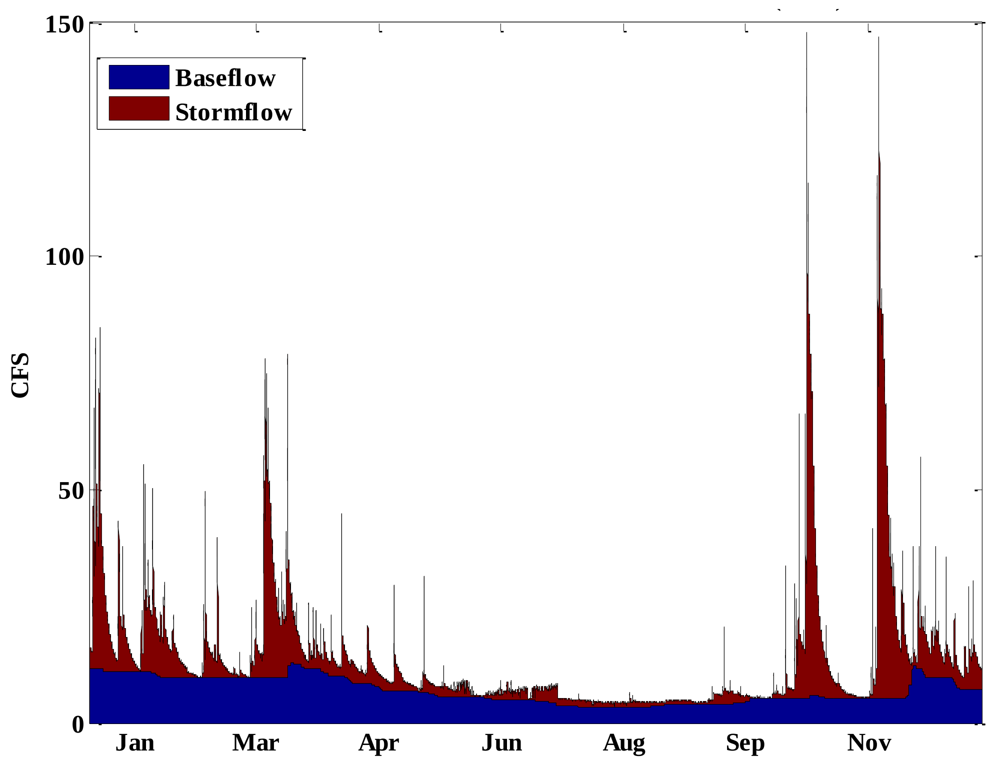

Figure 5. Base flow extraction for McAleer Creek (2003) by sliding interval method with 30-day interval.

The low sensitivity in estimated irrigation-season base flow to the interval used is likely due to the fact that the Puget Sound region does not typically experience long storms during those months. For the remainder of this study, the middle interval, or the 15-day interval, was used for base flow separation.

Important Assumptions

Several assumptions were made in order to complete this base flow analysis. One important assumption was that the base case conditions described here will be applicable in the future, if and when the project is actually implemented. Given the already developed nature of the service area watersheds described here, there are no anticipated land use changes that are expected to have a significant impact on hydrology. Assessment of potential future climate change impacts to hydrologic characteristics was beyond the scope of this project.

Another important assumption is that although the base flow results are only directly applicable to the specific locations for which data was available and the quantitative analysis completed, the general findings of the analysis can be generally extended to other locations within the same watershed and to other un-gauged streams of similar size, geology, and land use characteristics that could be potentially affected by the project.

Methods for developing the Surface Water/Groundwater Factor (SGF)

For the areas adjacent to each SSI using groundwater, the geology was evaluated to determine a surface water-groundwater factor (SGF). The SGF represents the percentage of the pumped water that is derived from nearby creeks or streams. For the base case conditions, the SGFs are used to estimate the fraction of the groundwater well withdrawal that affects stream flow. SGFs will be used to evaluate possible changes in base flow as a result of self-supplied irrigators ceasing their groundwater withdrawals and switching to the use of reclaimed water.

The SGF for each groundwater withdrawal area was based on an evaluation of well log inventories for self supplied irrigators and numerical modeling estimates provided in Improving the Quality and Quantity of In-Stream Habitat by Resting Groundwater Extraction Wells (Massmann 2008). No new data were generated or computer modeling performed to determine the SGFs provided in this study.

Irrigation wells were inventoried for the two groundwater self supplied irrigators being evaluated for the base case, including Holyrood and Evergreen-Washelli cemeteries (see Figure 2). The following resources were reviewed:

- The Pacific Northwest Center for Geologic Mapping Studies <http://geomapnw.ess.washington.edu>
- The Washington State Department of Ecology Well Log Viewer <http://apps.ecy.wa.gov/welllog>
- Groundwater Management in King County <http://www.kingcounty.gov/environment/waterandland/groundwater.aspx>
- Water Supply Bulletin No. 20, Geology and Ground-Water Resources of northwestern King County, Washington by Liesch, Price, and Walters

The references provided well and geologic information for each of the irrigators. Table 9 summarizes the wells, including screened zones, and distance from surface water bodies. The water usage estimates summarized in Table 8 were provided by SPU.

The SGF that represents the percentage of the pumped water derived from nearby creeks and streams was determined for each of the five irrigators listed above. Well "resting" describes the situation where a groundwater well that has been historically pumped is not used, with the deliberate intent of allowing aquifer recharge or reversal of groundwater flow away from the well and towards other natural features such as streams or springs. Percentages refer to the percentage of flow that would normally be extracted by the well that is then available to flow towards another discharge point when the well is rested.

The modeling results from the Massman study suggest that relatively shallow wells (depending on the geologic formation in which the well is completed) within approximately 3,000 feet of streams provide the best likelihood for seasonal benefits from well resting. Well depth is a major factor influencing determination of SGF. Typically shallow wells refer to wells completed in unconfined water table aquifers, and which are generally less than 50 feet deep; deep wells are completed in confined or semi-confined aquifers. Wells that are further than 3,000 feet from streams and deeper may result in benefits to streamflow, but these benefits will be spread out over the year.

Table 9. Irrigator wells for groundwater self-supplied irrigators evaluated for base case conditions.

Irrigators	Total Well Depth (feet below ground surface)	Screened Zone (feet below ground surface)	Distance from Surface Water Body (feet)
Holyrood Cemetery			
1953 well	565	480-590 and 500 to 515	<1,500
1958 well	369	NA	<1,500
Estimated water usage (per SPU) 17.7 million gallons per 6 months Peak use 0.21 million gallons per day			
Evergreen-Washelli Cemetery			
1927 well	260	NA	>3,000
1947 well	300	155-188	>3,000
1950 well	238	NA	>3,000
1952 well	785	N A	>3,000
1955 well	185	165-185	>3,000
1959 well	169	134-154	>3,000
1987 well	126	109-126	>3,000
1989 well	143	92-123	>3,000
Estimated water usage (per SPU) 51.4 million gallons per 6 months Peak use 0.61 million gallons per day			

The well withdrawals for the five irrigators in this study (all of which are considered deep wells) fell into two modeling scenarios presented in the Massman paper; one scenario provided a SGF for deep wells located within 3,000 feet of a stream and the other scenario provided a SGF for deep wells located further than 3,000 feet from streams. The SGF for each scenario is divided into four sources that would receive a percentage of flow during well resting. The four sources include lower (downgradient) springs and streams and upper (upgradient) springs and streams.

From the Massman paper, the SGF estimated for deep wells near a stream was 43 percent. This SGF included 13 percent of the flow returned to lower springs, 7 percent returned to lower streams, 4 percent returned to upper springs, and 19 percent returned to upper streams. The SGF estimated for deep wells greater than 3,000 feet from a stream was 44 percent, including 12 percent returned to lower springs, 7 percent returned to lower streams, 4 percent returned to upper springs, and 21 percent returned to upper streams.

Base Case Results

Table 10 presents for each POA a summary of the base case average base flows for the irrigation season. The average total flows and the percentage of the base flow to the total flow are also summarized for each POA.

Table 10. Average base case base flows for each POA.

Point of Analysis (POA)	Base Case Average May - September Base Flow (cfs)	Base Case Average May - September Total Flow (cfs)	Base Flow Percentage of Total Flow May – September (%)
Licton Springs (LS-POA1)	0.05	0.56	8
McAleer Creek (MC-POA1)	2.02	3.45	58
McAleer Creek (MC-POA2)	6.46	7.74	84
Thornton Creek (TC-POA1)	0.84	1.30	65
Thornton Creek (TC-POA2)	1.30	2.78	47

The results indicate that for the period of analysis, the base flow comprises a fairly large percentage (between 47 and 84 percent) of the total flow for all of the POAs,except for Licton Springs. In other words, the POAs are not completely dictated by storm flows during the irrigation season, and thus an increase or decrease in the base flow would be more likely to have an impact on the total flow. For Licton Springs, a fairly small watershed that is dominated by storm drain infrastructure, the base flows during the irrigation period are very small and estimated to be approximately 8 percent of the total flow. It should be noted, however, that the flow gauge for the Licton Springs POA (LS-POA1) is located in a stormwater conveyance pipe that discharges to the open channel/wetland area of Licton Springs. In actuality, Licton Springs is also influenced by the surface expression of shallow, subsurface groundwater. The quantity of that surface expression could not be assessed due to a lack of data, but is expected to be small in comparison to average base flow quantities.

Hydrogeologic Surface Water/Groundwater Factor (SGF) Results

Based on the irrigator well depth and locations relative to surface water bodies shown on Figure 2, a brief discussion of how these SGFs would apply to each of the five irrigators is provided below.

- The Holyrood wells are very deep and within 1,500 feet of Lake Ballinger and McAleer Creek. Because of the depth of these wells, a SGF of 43 percent would apply to these wells. However, based on the proximity to Lake Ballinger, the return flow percentages would be different. Twenty percent of the flow to the lower springs and streams would likely discharge into Lake Ballinger and 23 percent of the flow to upper streams and springs would discharge to McAleer Creek.
- The Evergreen-Washelli wells are very deep and greater than 3,000 feet from a surface water body. An SGF of 44 percent would apply to these wells, including 4 percent returned to upper springs, and 21 percent returned to upper streams and 19 percent to Licton Springs.

Implications

The base case base flow rates presented in Table 10 will later be compared to the expected with-project base flow amounts. The base flow augmentation resulting from resting surface water withdrawals and using reclaimed water is expected to be equal to the average amount of surface water currently used for irrigation. The base flow augmentation resulting from resting groundwater withdrawals is expected to be equal to the average amount of groundwater currently used for irrigation multiplied by the surface water/groundwater factor (SGF). The associated benefits of such base flow augmentation will be further described in the Task 4 memorandum.

Extent of the Problem

The service area watersheds included in the base flow analysis all represent urbanized drainage basins which are currently impacted by the hydrologic alterations due to hardened landscapes, dense storm drain networks, and surface water and/or groundwater withdrawals. All of these alterations have combined to alter the routing and timing of channel flows, and have effectively resulted in reduced base flows during the summer irrigation period. Runoff and infiltration from imported irrigation water may offset the impacts related to urbanization that lead to impaired or reduced (i.e., low) base flows. Despite the potential for imported irrigation water to offset some of the reduction relative to historic conditions, this factor does not likely outweigh numerous other influences associated with urbanization. The relationships between these lessened base flows and the water quality and available aquatic habitat will be further developed in the subsequent sections of this memorandum.

Base Case Conditions in the Future

The assumption is made that the base case described in this section will be an adequate description of the base case for the planning horizon for the proposed project (ca. 20 years). This assumption is made because most of the service area watersheds are effectively “built out” now, and there is little opportunity for significant land use changes that would impact the hydrologic characteristics described here. The potential impacts of climate change on base case average base flows over the next 20 years were not evaluated.

Water Quality

This section discusses current water quality conditions in streams near specific self-supplied irrigators (SSIs) in the SPU retail service area who could use reclaimed water instead of using their own wells.

Analyzed water quality parameters include stream temperature, concentrations of dissolved oxygen, phosphorus (orthophosphate and total), and copper (dissolved and total). These parameters were evaluated because:

- They often impact urban stream biota.
- Their levels can be affected by discharge of reclaimed water to streams.
- Data are commonly available for these parameters.
- They represent a range of potential fate, transport, and impact mechanisms among all water quality variables.

Temperature and dissolved oxygen are typically the primary limiting factors for salmonids in urban streams, and urban streams are commonly on the 303(d) list of impaired waters for these two parameters (Ecology 2009).

While some particulate phosphorus becomes bioavailable in streams, orthophosphate phosphorus is the dissolved fraction of total phosphorus that entirely biologically available, and is the limiting nutrient for primary productivity (algae growth) in urban streams. Phosphorus pollution causes eutrophication of urban streams and lakes, resulting in low dissolved oxygen concentrations from the decay of algae. This eutrophication is why freshwaters are commonly on the 303(d) list of impaired waters for total phosphorus.

Dissolved copper is toxic to stream biota at very low concentrations in Puget Sound streams that have a low water hardness. Copper toxicity decreases with increasing water hardness.

Reclaimed water contains relatively high concentrations of phosphorus and copper. It may also contain elevated concentrations of pesticides and other organic compounds that are toxic to stream biota. However, organic compounds are rarely measured or detected in urban streams. Although urban streams are commonly on the 303(d) list for fecal coliform bacteria, inidicating the presence of human pathogens and a public health concern, fecal coliform bacteria are not present in reclaimed water due to its effective disinfection before use.

Methods of Analysis

The methods used to describe the base case conditions for stream temperature, dissolved oxygen, phosphorus, and copper are summarized and explained below. All available data were compiled for the irrigation season (May through September) and included only those data considered to be of acceptable quality by data source.

Temperature

Increased summer base flow increases stream depth and typically decreases the surface area to volume ratio of an urban stream in a confined channel. This, in turn, may increase the thermal mass of the stream, making the water less susceptible to heating from the air and stream bed. For SSIs whose primary water source is groundwater, reduced groundwater pumping may increase groundwater export to nearby streams. In summer, groundwater is generally cooler than surface water (Stonestrom and Constantz 2003) so this increase in groundwater contribution may decrease stream temperatures during the irrigation season. The resultant lower water temperatures from both of these scenarios are favored by native fish and other aquatic organisms.

Before predicting change in stream temperature due to the proposed project, it is essential to know the base case stream temperatures and water quality standards. These base case data exist only for a few points along the lowland creeks that would be affected by flow augmentation from the North Seattle project. It is assumed that these points, called points of analysis (POAs), will be representative of the thermal conditions in all the affected fluvial habitats. To determine what the base case for temperature is at the POAs for which data were available, the mean irrigation season daily maximum temperature was calculated for each POA using data reported by King County (2009) for one site (POA2) on McAleer Creek (15-minute data from1997 to 2008) and Seattle Public Utilities (2009) for two sites (POA1 and POA2) on Thornton Creek (15-minute data from 2003 to 2008). These data are summarized in the results section that follows. In addition to examining available temperature data, the 303(d) list (Ecology 2009) was reviewed to see whether Thornton and McAleer Creeks are listed for temperature.

Dissolved Oxygen

The dissolved oxygen concentration in a stream is an important factor for determining embryo survival and habitat utilization by fish and other aquatic life (Greig et al. 2007). Dissolved oxygen concentrations usually decline to their annual minimum in early autumn. While dissolved oxygen dynamics are complex and highly variable even on a short (day) time scales, the pattern of lower dissolved oxygen in early autumn generally occurs because: 1) stream oxygen capacity, known as the saturation concentration, decreases with increasing temperature, and 2) oxygen consumption increases with increased stream biological activity in early autumn (due to microbial decay of organic material). Dissolved oxygen is being examined in this study because the proposed project may increase base flow and decrease stream temperature – factors that could lead to an increase in dissolved oxygen, and may discharge organic matter to the stream that could lead to a decrease in dissolved oxygen.

For the description of the base case dissolved oxygen conditions, all available concentration data of high quality (described below) were compiled for the irrigation season (May through September). As was the case with stream temperature, dissolved oxygen data were not available for all streams of interest or POAs. Data were only available for Thornton POA3 (including USGS data from station 12128000, Washington Department of Ecology data for station TC-3, and King County station 0434) and McAleer POA2 (King County site A432)). Mean concentrations for each of these POAs were calculated to provide a measure of the central tendency of the data. In addition the 303(d) list (Ecology 2009) was reviewed to determine whether the streams have been listed for dissolved oxygen impairment.

Phosphorus and Copper

With land application of reclaimed water at a low hydraulic loading rate, i.e., a small amount of reclaimed water per unit area, most pollutants of concern in the reclaimed water will likely be adsorbed to soils, taken up biologically, or otherwise sequestered before entering streams (Asano et al. 2007, Barbarick et al. 1998). Also, it is assumed that irrigation rates will be similar to low intensity precipitation, and irrigation will generate a relatively small amount of surface runoff that directly conveys pollutants to streams. Rather than model the fate of all pollutants conveyed in irrigation water, phosphorus and copper were selected as representative pollutants for an analysis of how base flow augmentation from reclaimed water irrigation could affect pollutant concentrations in Thornton and McAleer Creeks.

In describing the base case phosphorus and copper conditions, the first step is to calculate the average concentrations of phosphorus and copper in the streams of interest. If the observed concentrations are all above their method detection limits, this step is straightforward. In other cases, where many observations are at or below detection limits, it is necessary to find the average concentration using regression on order statistics (ROS) (Helsel 2005).

Data were only available for Thornton POA3 (King County site 0434) and McAleer POA2 (King County site A432). Data collected for identified storm events were not included in the analysis. Average concentrations are presented in the results section below. For context, they are compared to relevant water quality standards and guidelines. In addition the 303(d) list (Ecology 2009) was reviewed to determine whether the streams have been listed for phosphorus and copper impairment.

Data Availability

For the three POAs in Thornton Creek and one POA in McAleer Creek, there are enough temperature, dissolved oxygen, phosphorus, and copper data for the analysis of base case water quality conditions. For the other four POAs, there are no water quality data available at all. In all analyses, input data did not include any datasets rated by SPU to be low quality.

It makes sense that Thornton Creek and McAleer Creek would have similar water quality patterns given their similar watershed size and land use. If there were no data for McAleer Creek, it would not be implausible to, for example, extrapolate results of the temperature analysis from Thornton Creek onto McAleer Creek. Unfortunately, the other affected watersheds lacking temperature data are generally much smaller than McAleer and Thornton Creek watersheds, making quantitative extrapolation of results unlikely to yield useful results. In addition, one of the other affected watersheds (the Densmore Basin) contains Bitter Lake, a waterbody where temperature effects would likely be much different than those for streams. For these smaller affected watersheds, the water quality analysis will have to be qualitative, relying on general “lessons learned” from the analyses in Thornton and McAleer Creeks.

Assumptions

The description of base case water quality conditions is relatively straightforward. Few assumptions are required. An important assumption is that the POAs selected for description of base case water quality conditions are representative of their respective waterbodies’ typical conditions. For Thornton Creek this assumption is met by having several POAs available on the stream. For McAleer Creek, this assumption is likely met because the POA used for water quality analysis is located at the mouth. Another important assumption is that the findings of the water quality analysis for Thornton and McAleer Creeks may be applied qualitatively to other potentially affected streams that lack monitoring data.

Base Case Results

Table 11 presents the mean value, standard deviation, and coefficient of variation for temperature, dissolved oxygen, total phosphorus, orthophosphate phosphorus, total copper, and dissolved copper. Water quality standards and guidelines are presented for context in this table, though it is important to note that the water quality standards are not evaluated by comparison to mean conditions. For example, the dissolved oxygen standard is based on the minimum 1-day average concentration. These results are summarized for each parameter below.

Temperature

Thornton Creek is currently identified as a category 5 impaired waterbody for temperature on the 303(d) list (Ecology 2009). Consequently, measures that would improve thermal conditions in that watershed would benefit resident fish. McAleer Creek runs slightly cooler than Thornton and is not on the 303(d) list for temperature. However, the mean daily maximum temperature of McAleer Creek (15.1°Celsius [C]) is only slightly lower than that for the two POAs on Thornton

Creek (15.3 and 15.9°C). Numerous studies have shown that lower temperatures (around 8-9°C) may increase salmonid productivity (Beacham and Murray 1990; Poole et al. 2001).

Numerous (greater than 900) daily maximum temperature records are available for two upstream sites on Thornton Creek (POA1 and POA2) and the mouth of McAleer Creek (POA2). These results exhibit a relatively low standard deviation and coefficient of variation (approximately 10 percent) during the irrigation season.

Dissolved Oxygen

Though the mean dissolved oxygen concentrations for the base case irrigation season meet (i.e., are greater than) the water quality criterion presented in Table 11, both McAleer and Thornton Creek are on the 303(d) list for dissolved oxygen because the dissolved oxygen criterion is based on the lowest 1-day minimum value and not a seasonal mean value. Thus, any improvement in dissolved oxygen concentrations would be expected to increase habitat value for fish and other aquatic species.

Numerous (greater than 80) dissolved oxygen records are available for mouths of Thornton Creek (POA3) and McAleer Creek (POA2). These results exhibit a relatively low standard deviation and coefficient of variation (approximately 10 percent) during the irrigation season.

Phosphorus

Although neither stream is currently identified as an impaired water body for total phosphorus on the 303(d) list, both streams drain to Lake Washington, which is identified as a category 5 impaired waterbody for total phosphorus (Ecology 2009). Table 11 indicates that average total phosphorus concentrations in Thornton and McAleer Creeks exceed the EPA-recommended guideline for Puget Sound lowland streams. High levels of this nutrient can lead to excessive primary productivity and subsequently depressed levels of dissolved oxygen in receiving waters (Lake Washington). Any measure that would reduce phosphorus concentrations could potentially benefit resident organisms.

Numerous (greater than 100) total phosphorus records are available for mouths of Thornton Creek (POA3) and McAleer Creek (POA2). These results exhibit a relatively high standard deviation and coefficient of variation (approximately 20 to 40 percent) during the irrigation season.

Table 11. Base case water quality (May–September) in Thornton and McAleer Creeks.

	Thornton POA1	Thornton POA2	Thornton POA3	McAleer POA2
Temperature (Daily Maximum)				
Water Quality Standard (°C) [a]	13.0	13.0	13.0	13.0
Mean (°C)	15.3	15.9	--	15.1
Maximum (°C)	21.2	19.3		18.9
Standard Deviation (°C)	1.5	2.0	--	1.4
Coefficient of Variation (%)	9.8	12.6	--	9.3
Number of Records	918	918	0	1,621
Period of Record	2003 - 2008	2003 - 2008	--	1998 - 2008
Dissolved Oxygen				
Water Quality Standard (mg/L) [a]	8.0	8.0	8.0	8.0
Mean (mg/L)	--	--	9.6	10
Minimum (mg/L)			7.3	8.0
Standard Deviation (mg/L)	--	--	1.0	0.7
Coefficient of Variation (%)	--	--	10.4	7.0
Number of Records	0	0	184	86
Period of Record	--	--	1972 - 2008	1996 - 2008
Total Phosphorus				
Water Quality Standard (ug/L) [b]	19.5	19.5	19.5	19.5
Mean (ug/L)	--	--	82	67
Standard Deviation (ug/L)	--	--	33	15
Coefficient of Variation (%)	--	--	40	22
Number of Records	0	0	114	130
Period of Record	--	--	1985 - 2008	1985 - 2008
Orthophosphate Phosphorus				
Water Quality Standard (ug/L)	---	---	---	---
Mean (ug/L)	--	--	44	39
Standard Deviation (ug/L)	--	--	14	12
Coefficient of Variation (%)	--	--	32	31
Number of Records (Nondetects)	0	0	114	129
Period of Record	--	--	1985 - 2008	1985 - 2008
Total Copper				
Water Quality Standard	---	---		---
Mean (ug/L)	--	--	8.1	3.2
Standard Deviation (ug/L)	--	--	4.9	5.3
Coefficient of Variation (%)	--	--	60	166
Number of Records (Nondetects)	0	0	89 (2)	14 (3)
Period of Record	--	--	1993 - 2007	1993 - 2007
Dissolved Copper				
Water Quality Standard (Chronic) [a]	2.5	2.5	2.5	3.2
Mean (ug/L)	--	--	2.6	0.58
Standard Deviation (ug/L)	--	--	1.1	0.54
Coefficient of Variation (%)	--	--	42	93
Number of Records (Nondetects)	0	0	43 (0)	11 (8)
Period of Record	--	--	1998 - 2007	1993 - 2007

[a] WAC 173-201A (2006) criterion for freshwaters designated for salmonid spawning, rearing, and migration. Criteria conditions vary by parameter; temperature is based on the 7-day average of the daily maximum value, dissolved oxygen is based on the lowest 1-day minimum value, and dissolved copper is based on and a 4-day average concentration and the associated water hardness (mean values of 22.3 and 16.8 mg/L as $CaCO_3$ were used for McAleer POA2 and Thornton POA3, respectively). In addition, temperature and dissolved oxygen criteria include limitations on changes in ambient values due to human actions.

[b] U.S. EPA (2000) recommended criterion for total phosphorus in freshwater streams that is based on the 25th percentile of all seasonal median values for reference streams in the Puget Sound lowlands subecoregion.

Copper

The chronic criterion for dissolved copper is 2.5 µg/L for Thorton Creek (POA3), based on a mean hardness of 16.8 mg/L as $CaCO_3$ for Thornton POA3, and 3.2 µg/L for McAleer POA2,based on a mean hardness of 22.3 mg/L as $CaCO_3$. (Table 11). As is apparent from Table 11, the average concentration at Thornton POA3 slightly exceeds the standard while the average concentration at McAleer is less than the water quality standard. However, the criterion is based on a 4-day average concentration not to be exceeded more than once every 3 years, and dissolved copper concentrations should be compared to the specific hardness-dependent criterion associated with the hardness measured in the same sample used for copper analysis. Therefore, comparison of an average dissolved copper concentration to a criterion based on the average hardness concentration does not accurately reflect the frequency of copper criteria exceedance and the potential effects of copper on stream biota. In addition, sublethal effects have been identified in fish at concentrations as low as 2.3 µg/L (Baldwin et al. 2003) and have been shown to depend on the concentration of dissolved organic carbon. While it is difficult to determine to what degree decreases in dissolved copper concentration will improve fish habitat and survival, any decrease in copper concentrations in these watersheds would likely benefit resident fish.

A moderate number (42) of dissolved copper records are available for mouth of Thornton Creek (POA3). Relatively few (11) dissolved copper records are available for the mouth of McAleer Creek (POA2), and most (8) of these records include non-detected values. These results exhibit a relatively high standard deviation and coefficient of variation (approximately 40 to 90 percent) during the irrigation season. A detailed analysis of how varied detection limits and water hardness relate to dissolved copper criteria and potential risks to stream biota has not been conducted for the base case analysis.

Implications

Extent of the Problem

The affected watersheds are urban, with ample room for improvement in stream water quality. Based on the 303(d) list, water quality impairment has been identified for temperature dissolved oxygen, and dissolved copper in Thornton Creek and temperature and dissolved oxygen in McAleer Creek among the evaluated water quality parameters. For the parameters not appearing on the 303(d) list, including phosphorus and copper (for McAleer Creek) there is still room for improvement and increased habitat value would be expected from water quality improvements in each of these parameters.

Base Case Conditions in the Future

The assumption is made that the base case characterized in this memorandum is an adequate description of the base case for the planning horizon of the proposed project (ca. 20 years). This assumption is made because most of the watersheds of interest are effectively “built-out” now, and there is little opportunity for significant land use change and concomitant change in pollutant generation processes.

Habitat Area

This section presents the methods and results for establishing the base case (existing) aquatic habitat area and conditions at specific POAs in the three basins that contain SSIs: McAleer Creek, Thornton Creek, and Densmore Drainage basins.

The SSIs covered in this aquatic habitat analysis include:

- Nile Country Club and Holyrood Cemetery (McAleer Creek basin)
- Evergreen Washelli Cemetery (Densmore basin, which includes Licton Springs)
- Jackson Park (Thornton Creek basin)

The POAs, generally downstream of the SSIs, are shown in Figure 2: McAleer Creek (MC-POA1 and MC-POA2), Thornton Creek (TC-POA1 and TC-POA2), and Licton Springs (LS-POA1).

This base case analysis will be used to estimate the resulting change in aquatic habitat area for each POA if SSIs reduce their surface water or groundwater withdrawals and use reclaimed water from the proposed Brightwater system.

Methods of Analysis

The habitat analysis describes the fluvial geomorphology of the channel, including wetted width and depth based on estimates and actual field measurements (cross sections). This analysis also qualitatively describes the existing habitat conditions at the POAs downstream of the SSIs in an effort to characterize habitat availability and potential use based on the species already present. POAs were selected based on the criteria for analysis of hydrology and water quality parameters which are described in the *Methods* portions of the *Hydrologic and Hydrogeologic Conditions*, and *Water Quality* sections of this document.

Use of Wetted Area in Estimating Base Case Conditions

For this analysis, two indicators of wetted habitat area (wetted cross-sectional area and wetted surface area) were used to characterize conditions at each POA. Cross-sectional surveys and an application of the Manning's equation were used for determining the wetted cross-sectional (vertical) area including the channels wetted width and depth. Wetted surface (horizontal) area was determined based on the wetted width and length of the stream segment considered for each POA.

Wetted Cross-sectional Area

The habitat analysis uses four primary inputs for estimating cross-sectional habitat area at each POA, which are listed below and then described in more detail.

- Estimates of existing baseflow referenced from the results of the baseflow analysis (see *Hydrologic and Hydrogeologic Conditions* section)

- Description of existing channel geometries (bankfull width, bank height, wetted width, and water depth) derived from channel cross-section surveys at representative locations for each POA
- Current visual observations of channel morphology, slope, and roughness for each POA
- Existing wetted cross-sectional area and wetted width at each POA output, obtained from an application of the Manning's equation

Estimates for baseflow under the base case (existing) condition are referenced from the results of the baseflow analysis completed under Task 3.1A (*Hydrologic and Hydrogeologic Conditions* section). Average reach slopes for each POA were estimated using the stream alignment and digital elevation information (contours) provided by SPU. These reach slope estimates were compared to the channel profile data provided for TC-POA1 and TC-POA2.

Cross-sectional data used in the habitat analysis were provided by SPU for the downstream POA on Thornton Creek, TC-POA2. Additionally, cross-sectional surveys were performed for the upstream POA on Thornton Creek, TC-POA1, two sites on McAleer Creek, MC-POA1 and MC-POA2, as well as one site at Licton Springs within the Densmore Basin, LS-POA1. Cross-sections were surveyed at locations that were considered generally characteristic (i.e., representative) of the stream reach associated with each POA based on qualitative visual observations in the field. A visual characterization of Manning's n was also performed at the time the cross-sectional surveys were completed. Manning's n was estimated using the methodology outlined in Chow (1959).

The Manning's equation was then used to estimate the wetted cross-sectional area (or channel cross sectional area inundated by the base flow water surface elevation) and wetted width corresponding to the base case baseflow. The Manning's equation is listed below.

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$

Where,

Q	=	base flow discharge (cfs)
n	=	Manning's n roughness coefficient
A	=	cross sectional area (sf)
R	=	hydraulic radius (ft)
S	=	reach average slope (ft/ft)

Wetted Surface Area

The output from the Manning's equation application, along with the visual observations of channel conditions, was then used to derive the wetted surface area for each POA. The wetted surface area was estimated based on the segment (or length) of channel which was considered for each POA. For the purpose of this analysis, the channel length applied to each POA for estimating the wetted surface area was 50 feet. Based on qualitative field observations, this length (25 feet upstream and 25 feet downstream from each cross-section) was generally characteristic of channel geomorphology and flow conditions at each associated cross-section.

Derivation of the wetted surface area provides another basis for comparing the base case conditions against future (post-project) conditions to estimate the change in aquatic habitat area at each POA (analysis to be formed under Task 4).

In order to further describe the geographic extent to which current habitat conditions might apply, stream reaches that are considered representative of, and associated with, the POA were selected. Although stream reaches were not considered in estimating wetted surface area for POAs, the reach lengths provide a means for later extrapolation of wetted surface area to a geographic extent for which POA is likely representative.

The stream reach length associated with each POA was selected based on an evaluation of geospatial GIS (Geographic Information System) information provided by SPU, and qualitative field observations of the channel geomorphology and flow characteristics. GIS data, including aerial photography, digital elevation information, stream and stormwater conveyance network alignments, were reviewed to determine reach boundaries and were supported by field observations. Thus, the stream reaches associated with each POA generally exclude portions of the stream which are beyond major changes in hydrologic inputs (tributaries or stormwater outfalls), land use characteristics, or other significant features (e.g., culverts) that would influence channel geometry and flow characteristics.

The stream reach that is considered representative of, and associated with, each POA is listed in Table 12.

Table 12. Stream reach lengths associated with each POA.

Associated Point of Analysis (POA)	Stream Reach Length (feet)	Approx. Distance from Self Supplied Irrigator (SSI) (feet)	Upstream Extent	Downstream Extent
Licton Springs (LS- POA1)	715	5,200	Culvert inlets at N 97th Street	Culvert outlet at intersection of N 95th Street and Woodlawn Avenue N
McAleer Creek (MC-POA1)	600	4,000	Confluence with upstream tributary	estimated upstream limit of backwater influence from the culvert at 15th Avenue NE
McAleer Creek (MC-POA2)	2,350	17,200	Confluence with upstream tributary	estimated upstream limit of backwater influence from the culvert at NE 170th Street
Thornton Creek (TC-POA1)	780	300	Golf course bridge	estimated upstream limit of backwater influence from the culvert at 10th Avenue NE
Thornton Creek (TC- POA2)	1,064	12,000	Stormwater inputs at NE 113th Street	confluence of north and south branches of Thornton Creek

Habitat Conditions

In additional to qualitative observations of flow conditions and channel morphology, slope, and roughness, POA sites were visually assessed for factors that might influence the potential for habitat benefits to occur from increased flow or wetted surface area. For example, stream characteristics such as gravel size and embeddedness (i.e., the degree to which materials, generally cobble and gravel, are covered or buried in stream bottom sediments) were noted. In addition, general features that can affect hydraulic conditions such as gradient, depth, presence of pools and large woody debris in close proximity to the channel or floodplain, culverts and obstructions, were also noted where present. This field assessment was limited to a general qualitative review in the vicinity of the POAs.

Data Availability and Data Quality

As stated before, cross-sectional data were provided by SPU for the downstream POA on Thornton Creek, TC-POA2. Where data were limited or inadequate, surveys were conducted to collect additional cross-sectional data. Data was collected for the upstream POA on Thornton Creek, TC-POA1, two sites on McAleer Creek, MC-POA1 and MC-POA2, as well as one site at Licton Springs within the Densmore basin, LS-POA1.

It is reasonable to expect that habitat use at each POA extends across a broad spectrum of individual species. A comprehensive list of species occurrence for the basins and POAs was not available for inclusion in the analysis. Potential species presence assumed for the analysis was based on qualitative field observations by Herrera staff in June 2009, general knowledge of Puget Sound lowland stream habitat and ecology, and review of the Thornton Creek Watershed Characterization Report (SPU 2000). Salmonid species presence was determined based on review of SalmonScape (WDFW 2009) and StreamNet (PSMFC 2009) data sets, and King County Department of Natural Resources maps depicting known freshwater distribution of salmon and trout (King County 2001).

Important Assumptions

By applying a channel segment length (50 feet), the resultant value for wetted surface area provides a basis for evaluating current habitat area associated with each POA, and to the stream reach (Table 12). However, the segment length applied to each POA, as well as the reach lengths (Table 12) for which each POA is considered representative, are based on limited qualitative (sometimes subjective) observations, and data that may not reflect small scale site-specific variations. The length of stream determined applicable to each POA does not necessarily account for minor variations in channel hydraulics and habitat conditions, nor is it likely to represent the system overall.

Base Case Results

Species presence for each POA is summarized in Table 13 where "X" indicates likely presence. In order to present concisely the broad range of species, and because a comprehensive list of individual species could not be reasonably attained or included in the scope of the analysis, species are grouped in the table and described in more detail where appropriate below.

A log of photos showing existing habitat conditions is contained in Appendix A. Licton Springs (LS-POA1) (Photo 1, Appendix A) is characterized by a network of small ground-fed flows, and a braided low gradient channel. Previous restoration efforts including vegetation and channel modification have attempted to reduce invasive plant species, increase native plant species, and increase water retention to support amphibian use of wetland habitat. The habitat likely supports aquatic invertebrates and amphibians as well as wood ducks and other bird species.

Table 13. Species occurrence for POAs included in the habitat area analysis.

Point of Analysis (POA)	Amphibians	Aquatic Invertebrates	Birds	Salmonids	Other Fish
Licton Springs (LS- POA1)	X	X	X		
McAleer Creek (MC-POA1)	X	X	X	X	X
McAleer Creek (MC-POA2)	X	X	X	X	X
Thornton Creek (TC-POA1)	X	X	X	X	X
Thornton Creek (TC- POA2)	X	X	X		X

Visual observations at McAleer Creek (MC-POA1 and MC-POA2) indicate that the stream reach containing the POAs provides relatively moderately good habitat suitable for supporting aquatic species (Photo 2, Appendix A). Floodplain connectivity, although limited in some portions of the reach, suggests that increased base flows could potentially improve habitat structure beyond existing conditions. This would occur in instances where the increased wetted area extends into areas containing large woody debris (Photo 3, Appendix A) and areas of various channel depths and structure. Species likely to use this habitat, and to directly or indirectly benefit from the habitat, include fall-run Chinook, coho, and sockeye salmon (sockeye do not occur as far upstream as MC-POA1); as well as native trout, sculpin, and lamprey species; aquatic invertebrates; amphibians; and bird species.

Thornton Creek (TC-POA1) is a partially restored site (a restoration project that included channel reconstruction and additions of large woody debris was implemented in 2003) with relatively high habitat value for aquatic species as a result of improved structure and hydraulic conditions (e.g., presence of large woody debris) as well as good riparian cover (Photo 4, Appendix A). The site is characteristic of a relatively stable channel due to its restored structure and good floodplain connectivity, which may augment the potential for long-term benefits from a future increase in base flows and a more natural hydrology.

Species likely to use this habitat include cutthroat and rainbow trout, and threespine sticklebacks, and non-native species: bass and sunfish (Lantz et al 2008, Wild Fish Conservancy 2000); amphibians such as Northwestern salamander, and Pacific tree frog, Western garter snake, and various aquatic invertebrates and bird species. The relatively high quality riparian area likely provides a significant source of organic input that is important to aquatic invertebrates.

Aquatic invertebrates such as mayflies, stoneflies, and caddisflies, in turn, may be an important food source for other species including amphibians, birds, and fish that occur locally or downstream of the POA. Fall-run Chinook, coho, and sockeye salmon; as well as native trout, sculpin, and lamprey species occur in the watershed downstream of the POA. Therefore, these species may indirectly benefit from available habitat at this POA to the extent that in increased production (food base), or reduced water temperatures (due to increased water depths), may extend downstream. This potential benefit will be more closely examined in the analysis of benefits (Task 4).

Thornton Creek (TC-POA2) is primarily characterized by armored and hardened banks, generally confining the channel and restricting channel migration (Photo 5, Appendix A). This likely exacerbates the altered hydrology (e.g., "flashy" stream flows and reduced base flow) and associated reduced habitat area that results, in part, from other influences of urbanization (e.g., vegetation clearing and increased impervious surface). The hardened bank and poor channel structure also equate to a general reduction in floodplain connectivity from historical condition, which limits the potential for increased wetted area as a result of increased base flow.

The POA is likely representative of the majority of the developed channel segments, based on review of aerial images and visual observations on the ground. Species potentially using habitat in this area include fall-run Chinook, coho, and sockeye salmon; as well as native trout, sculpin, and lamprey species; amphibians such as Northwestern salamander and Pacific tree frog, Western garter snake, various bird species, and aquatic invertebrates.

It is anticipated that any increase in baseflow is unlikely to provide significant additional habitat area at TC-POA2 because the steep banks and the hardened channel reduce the potential for increase in wetted surface area. However, assuming increased water depth would reduce water temperatures; this could represent a habitat improvement for species that favor these conditions (e.g., salmon and trout), as Thornton Creek is currently considered impaired with regard to water temperature according to Washington Department of Ecology's 303(d) list (*Water Quality* section).

Average base flows, wetted widths, depths, wetted cross-sectional areas, and wetted surface areas calculated by Herrera for each POA are shown in Table 14. Additional information regarding the cross-sections at each POA is included in the attached spreadsheets (Appendix B).

Table 14. Average base case base flows and habitat areas for each POA.

Point of Analysis (POA)	Average Base Flow (cfs)	Wetted Width (ft)	Average Depth (ft)	Wetted Cross-Sectional Area (sf)	POA Segment Length (ft)	Wetted Surface Area (sf) [a]	Reach Length (ft)
Licton Springs (LS-POA1)	0.05	3.80	0.11	0.10	50	190	715
McAleer Creek (MC-POA1)	2.02	6.93	0.23	1.59	50	819	600
McAleer Creek (MC-POA2)	6.46	16.38	0.27	4.36	50	347	2,350
Thornton Creek (TC-POA1)	0.84	10.74	0.12	1.30	50	537	780
Thornton Creek (TC-POA2)	1.30	7.55	0.18	1.36	50	377	1,064

[a] Wetted surface area was calculated by multiplying POA length (50 feet) by wetted width.

Implications

The two indicators of wetted habitat area used in the analysis of base case conditions; estimated wetted cross-sectional area and wetted surface area, will be compared relative to estimates for the post-project conditions in subsequent analysis (i.e., Providing Retail Reclaimed Water Service from the Brightwater Backbone to SPU Customers: An Economic Analysis – Task 4, Effects of the Retail Reclaimed Water Project on Watershed Conditions).

This section describes the potential effects on habitat that could generally apply across all watersheds, with regard to potential changes in habitat area as measured by an increase in wetted area. This section is also intended as a general discussion to put into context the usefulness of wetted habitat area as an indicator of the base case conditions and of the potential benefits of the post-project conditions.

In non-constrained channel segments, increased baseflows that result in increased wetted habitat area can improve access to, or increase the amount of, off-channel slack water habitat. This productive habitat type often supports aquatic vegetation and benthic algae, and provides diversity in systems that are otherwise dominated by high-velocity, less-productive habitat (Johnston and Naiman 1990). Several species including cutthroat trout, bull trout, sculpins, sockeye and coho salmon, and dace species have been shown to commonly use vegetated habitat in off-channel areas (Pollock et al. 2003), and would likely benefit from connectivity and access to these areas.

Mayflies, stoneflies, and caddisflies, use various aquatic habitats and depend on the detritus of decaying leaves, wood, and other stream life for survival. Increased water surface area and backwater habitat can benefit these and other aquatic invertebrates which, in turn, provide a food source for other species including salmon and birds.

The anticipated increase in wetted area potentially resulting from the post-project increase in flow, may be used as one indicator of potential benefit related to habitat, as the increase could provide additional habitat for fish, birds, and other wildlife. However, it should be recognized that while an increase in baseflows could potentially result in an increase in wetted area, not all wetted area is functional from the species habitat utilization perspective. This is particularly true for salmonid species, where habitat use varies with specific life-history stages. For example, in a stream channel segment experiencing increased wetted area, the shallow wetted edges may not be suitable for adult salmonid spawning, but may be used by juvenile salmonids for protection, resting, and downstream migration.

In that context, potential benefits may be limited to indirect improvements such as increased food production (as described above) or improved water quality, and may not necessarily provide additional habitat area for use by certain species or life-history stages (e.g., for fish to migrate or spawn). This would especially be the case with incremental increases in wetted area. Therefore, wetted area is only one indicator of habitat improvement.

Although the focus of this section is habitat area, and other sections of this analysis address aspects of hydrology (*Hydrologic and Hydrogeologic Conditions* section) and water quality (*Water Quality* section), some parameters of habitat (e.g., stream and channel structure, hydraulic conditions and sediment transport, gravel composition, and riparian structure), are not fully considered within the scope of this analysis.

In addition to the direct increase in habitat area (i.e., wetted cross-sectional area and surface area), increased flows may also affect habitat quality. Habitat conditions which indirectly may be affected by changes in the flow regime, and which may ultimately influence the benefit or effects of flow augmentation (i.e., reduced withdrawals or augmentation by groundwater), include elements such as sediment transport, gravel size and embeddedness, hydraulic conditions such as depth and velocity, and temperature.

Increased baseflows may, for example, contribute to reduce water temperature and increase dissolved oxygen (see *Water Quality* section), which are important factors to the survival and development of several native fish species. Increased flows may also affect habitat complexity or the amount of a specific type of habitat available to various species. This occurs, for example, if the additional flow increases water depth or velocity to levels more suitable for migration or spawning, or if it results in improved connections to backwater habitat.

Flow conditions may limit use of the habitat by certain species. For example, water depth, velocity, and substrate composition (influenced by sediment transport), can limit where salmon are able to construct redds. The range of conditions preferred by several fish species occurring in Thornton Creek and McAleer Creek (WDFW 2009 and PSMFC 2009) are summarized in Table 15. Although it is outside the scope of the habitat area analysis, base case, and post-project baseflows may be compared to data in Table 15 to evaluate potential effects of increased flow relative to the preferences of species that are potentially present. Further hydrologic analysis of each POA and associated stream reach may be necessary to determine the potential for altered sediment transport and subsequent substrate conditions.

Table 15. Water depth, velocity, substrate size, and area required for spawning criteria for some salmonids (Reiser and Bjornn 1991, as cited in Saldi-Caromile 2004).

Species	Minimum Depth (m)	Velocity (m*sec)	Substrate Mix Size Range (mm)	Mean Redd Area (m)	Req'd Area per Spawning Pair (m)
Fall Chinook salmon	0.24	0.30 – 0.91	13 – 102	5.1	20.1
Coho salmon	0.18	0.30 – 0.91	13 – 102	2.8	11.7
Sockeye salmon	0.15	0.21 – 1.07	13 – 102	1.8	6.7
Rainbow trout	0.18	0.48 – 0.91	6- 52	0.2	
Cutthroat trout	0.06	0.11 – 0.72	6 – 102	0.09 – 0.9	

Although more commonly associated with peak flows, altered flows in general and resultant changes in water velocity and channel structure, could potentially contribute to the stabilization or de-stabilization of natural processes such as sediment transport. This can, in turn affect the suitability of the habitat for various species. Land use also frequently influences these processes. In urban settings, restoration is frequently restricted by site-specific constraints, and by a highly altered hydrologic, sediment transport, and vegetative character of the stream or watershed overall. Site constraints include property boundaries, utilities, road crossings, and frequent grade controls in the form of culverts, bridges, weirs, and utility crossings (Miller et al. 2001).

Due to these constraints, restoration efforts aimed at stabilizing urban stream systems are frequently limited to managed restoration activities that tend to be short term in duration (requiring continued management or maintenance), whereas base flow restoration, especially in relatively stable channels, may be longer lasting. Therefore in the case of some POAs discussed herein, there is potential for long term improvement. The extent of benefits resulting from altered flow velocity will likely depend on site specific conditions at each POA, and may be limited by anthropogenic constraints.

As a precaution, it should be recognized that increased flows in highly modified systems may adversely affect some species if the presence of anthropogenic modifications (such as culverts and bank armoring), or a lack of woody debris, results in increased bed and bank erosion. Even if flow increases are incremental, and generally occur in summer low flow periods, additional restoration efforts concurrent with increased flows may be necessary in some stream reaches to avoid the potential for adverse impacts. Efforts might include improvements to existing culverts and channel banks or the introduction of large wood in simplified channels to roughen the channel. As mentioned previously, further assessment outside the scope of the analysis may be required to determine the full extent of or potential for benefit, and to determine the need for additional restoration actions on a site specific or watershed scale.

Extent of the Problem

Based on existing (i.e., base case) wetted cross-sectional and surface areas, as well as qualitative field observations, each POA exhibits conditions suitable to support various native fish and other aquatic species. However, observations also indicate that current conditions commonly associated with urban streams, including altered hydrology, represent impairment on habitat quantity and quality. As stated previously, the extent to which this impairment currently exists is uncertain, primarily due to the dynamic of numerous factors that affect stream structure, habitat quantity, and the habitat's suitability for a range of species.

Base Case Conditions in the Future

Habitat area is closely linked with flow regime and habitat structure. Changes in these features may affect habitat area (i.e., quantity) as well as habitat quality, or the area's suitability for various species.

There is a wide range of factors influencing wetted habitat area in fluvial systems. These include conditions that are expected to be relatively stable and constant over a 20-year or greater time span; watershed geology, topography, soil permeability, and climate. Precipitation may be less predictable, but still relatively constant over the long term. Wetted habitat area may also be affected by stressors that are frequently associated with urbanization, urban environments, or management actions. Typical stressors that may directly or indirectly affect stream habitat area include channel and riparian modifications (e.g., bank armoring, large woody debris placement, vegetation clearing or re-vegetation), changes in water withdrawal, introduction of non-native species, changes in land use, and stormwater runoff.

Barring significant channel modification or restoration action, as well as any significant changes in land use, the extent of impervious surface, or water appropriation and usage; future conditions are expected to be similar to current conditions. Conversely, significant changes in the amount or type of stressors (assumed not to occur for the purposes of the analysis) would likely affect habitat area.

Overall Watershed Environmental Conditions

This section describes overall environmental conditions for each watershed (Densmore drainage basin, McAleer Creek, and Thornton Creek). Conditions are described based on the three categories of analysis: hydrologic, hydrogeologic, and hydraulic conditions; water quality; and wetted habitat area.

Extent of the Problem

Relationships between reduced base flows, water quality, and available aquatic habitat within analyzed watersheds are numerous and dynamic. Thus, the degree to which existing conditions impair or benefit aquatic species is determined in part by factors beyond the scope of this analysis. However, this analysis provides the basis for a general overview of watershed environmental conditions, to the extent that POA results are representative of the respective watersheds. The relationships between analyzed parameters (including consideration of factors outside the scope of the analysis), are described in general terms below and in the *Habitat Area* and *Water Quality* sections above.

The analyzed service area watersheds are currently impacted by conditions commonly associated with urbanization (e.g., hardened landscapes, dense storm drain networks, and surface water and groundwater withdrawals). All of these alterations impair the quantity and quality of habitat for various species by altering the routing and timing of channel flows.

Runoff and infiltration from imported irrigation water may offset the impacts related to urbanization that lead to impaired or reduced (i.e., low) base flows. The complete range of factors contributing to current base flow, and how much each factor contributes relative to historic conditions, were not quantitatively considered in the analysis. Despite the potential for imported irrigation water to offset some of the reduction relative to historic conditions, this factor does not likely outweigh numerous other influences associated with urbanization.

Although each watershed provides marginally suitable habitat conditions to support native fish and other aquatic species, the stressors associated with urbanization have considerably altered existing (base case) conditions from historical conditions and resulted in reduced base flows during the summer irrigation period, reduced water quality, and limited aquatic habitat. Current low base flows, even though they are partly comprised of run-off and infiltration from imported irrigation water, nonetheless represent an impacted condition.

Densmore Drainage Basin (Licton Springs)

Licton Springs is in the urbanized Densmore drainage basin, with the majority of its upper basin connected to the storm drain network. The current urbanized environment likely contributes to low summer flows (estimated at 0.05 cfs and representing only 8 percent of the total flow for the same POA), as well as the "flashy" flow patterns typical of urban streams. Suitable aquatic habitat is limited within the basin, in part because much of the basin's flow is contained within storm drainage pipes upstream and downstream of the approximately 715 feet long Licton Springs stream reach (Table 12) that is surface flow. Although the reach may contain habitat suitable for amphibians, aquatic invertebrates, and birds, it does not support salmonid and other fish species. Water quality data was not available for Licton Springs, and only limited qualitative analysis was performed to evaluate baseflow in relation to general habitat conditions. However, based on qualitative field observations and evaluation of general conditions, the watershed is highly impacted by stressors that affect flow regime and subsequently the availability and suitability of wetted habitat area. Altered stream flow patterns including reduced baseflow can also affect the diversity and structure of macroinvertabrate assemblages (Konrad and Booth 2005) which can, in turn, affect other species that are dependent on those assemblages. Therefore, current low baseflows likely represent reduced habitat availability and an associated reduction in benefits to the species present. The extent to which low base flows are inadequate or represent impairment in the context of habitat and species is limited. Due to barriers and other environmental constraints that prevent fish presence, low base flow likely affects macroinvertabrate population size and diversity, and to a lesser extent amphibians and bird species, but does not likely affect fish.

McAleer Creek

McAleer Creek is generally influenced by stressors or characteristics that are commonly associated with urbanization including water withdrawal, increased impervious surface, and resultant reduced baseflows and "flashy" flow pattern. Current baseflows (6.46 cfs and 2.02 cfs at MC-POA2 and MC-POA1, respectively) likely represent reduced baseflows relative to historical conditions as a result of urbanization, and also likely contribute to current elevated temperatures, as well as reduced availability or suitability of habitat for various species.

Although McAleer Creek is not indicated as impaired for temperature according to the 303(d) list, the mean irrigation season maximum temperature (15.1°C) exceeds the water quality standard (13°C) used for this analysis (Table 11). It should be noted that 303(d) listings depend on a number of factors, including data availability and review, and the absence of a 303(d) listing does not mean the stream is unimpaired:. Elevated temperatures can stress fish, particularly when occurring in conjunction with reduced dissolved oxygen levels. Temperatures that exceed threshold levels impair development, spawning, migration, and distribution and can reduce resistance to disease and toxic substances in various species (Black et al. 1991; Heath and Hughes 1973). Salmonids may also become more susceptible to infectious diseases at elevated temperatures between 14 to 20^{o}C (Harrahy et al. 2001; Tops et al. 2006).

Additionally, the analysis indicates that average total phosphorus concentration in this watershed exceeds the EPA-recommended guideline for Puget Sound lowland streams. High levels of this nutrient can lead to excessive primary productivity and subsequently depressed levels of dissolved oxygen. According to the 303(d) list, McAleer Creek has reduced dissolved oxygen. Although the seasonal mean value (10 mg/L at MC-POA2) meets the water quality standard used for the analysis of this parameter, dissolved oxygen levels may be poor from an aquatic species utilization perspective for periods during the low flow season.

Qualitative visual observations of hydrology, hydraulics, and general features potentially affecting habitat utilization by various species indicate that the watershed provides moderately good habitat for aquatic species including salmonid. However, the watershed is considered to provide only moderately suitable habitat for aquatic species based on reduced water quality. Elevated temperatures and reduced dissolved oxygen in this watershed represent a likely impairment on aquatic species growth and development, and may also limit spawning and migration, as well as increase the susceptibility of various species to disease and toxins.

Thornton Creek

Current baseflows in Thornton Creek are estimated at 0.84 cfs and 1.30 cfs at TC-POA1 and TC-POA2 respectively. These likely represent low baseflows resulting from urbanization. Stressors related to urbanization are also associated with poor stream health or biological condition, and Thornton Creek exhibits “very poor” conditions as measured by the benthic index of biological integrity (Booth et al. 2004).

Reduced water quality was identified for temperature, dissolved oxygen, and dissolved copper in Thornton Creek, based on 303(d) listings. The mean irrigation season daily maximum water temperatures in Thornton Creek (15.3°C at TC-POA1, and 15.9°C at TA-POA2) exceed the water quality standard (13°C) for this watershed. Reduced baseflow resulting from stressors that are related to urbanization (e.g., water withdrawal, channel modification, and stormwater runoff) and the associated reduced water quality can have considerable impact on the suitability of the habitat for aquatic species as described above for McAleer Creek.

The mean irrigation season dissolved oxygen level (9.6 mg/L) in the Thornton Creek watershed meets the water quality standard used in the analysis. However the streams category on the 303(d) list indicates that the watershed is impaired, and may have reduced dissolved oxygen levels that exceed (are less than) the water quality standard based on lowest one day minimum. Additionally, the analysis indicates that average total phosphorus concentration in Thornton Creek exceeds the water quality recommendation, which may lead to excessive primary productivity and subsequently depressed levels of dissolved oxygen.

Based on observations in the field and the review of pertinent literature and data for this analysis, the Thornton Creek watershed exhibits notable variation in physical environmental conditions. The physical variations (e.g., hydraulics, and channel and bank characteristics) are considerable between the POAs (see Habitat Area Analysis, Results), and the variability likely extends to other parameters (i.e., habitat and water quality) and throughout the watershed. The variation may limit the accuracy with which results for the POAs are applied to other specific areas within the watershed, or to the watershed as a whole. However, evaluation of the POAs included in the analysis suggest that the watershed is highly influenced by stressors that are related to urbanization, and exhibits poor to moderate environmental conditions with regard to habitat utilization.

Base Case Conditions in the Future

Environmental conditions are closely linked between flow regime, water quality (e.g., temperature, dissolved oxygen, and pollutant levels), and habitat structure. Changes in these features may affect habitat area (i.e., quantity) as well as habitat quality, or the area’s suitability for various species. However, in the absence of significant restoration action or changes in land use, the primary stressors assumed to have the most influence on the current environmental conditions (i.e., stressors that are associated with urban environments) are expected to remain relatively constant. Given the nature and level of development within the watersheds considered in this analysis, significant changes in the amount or type of stressors are unlikely to occur within the next 20-year timeframe that is considered for the base case conditions.

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Appendix I

TECHNICAL MEMORANDUM
TASK 4.0 – POST-PROJECT BENEFITS

Providing Retail Reclaimed Water Service from the Brightwater Backbone to SPU Customers: An Economic Analysis

Prepared for

Seattle Public Utilities

October 2009-Final

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Introduction

In late 2005, the King County Council approved funding for the Brightwater Reclaimed Water "Backbone" project. In Phase 1 of the Backbone project, King County is adding reclaimed water pipes in tunnels already being built for the Brightwater wastewater treatment plant conveyance system. Phase 2 of the Backbone project would add the pump stations necessary to bring reclaimed water through the new reclaimed water pipe system to portals located in North King County, south Snohomish County, and the Sammamish valley.

Since King County approved Phase 1 of the Backbone Project and began construction, the county has expressed its preference to be only a wholesaler of reclaimed water from the Backbone, with water utilities assuming responsibility for constructing distribution infrastructure (Phase 3) 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 benefit-cost analyses and determine whether their share of Phase 3 of the Backbone Project is cost-effective.

Purpose and Scope

The *Draft White Paper: Reclaimed Water Backbone Project, Version 3.0* (King County DNR 2006) identified at least eight potential reclaimed water customers in the Seattle Public Utilities (SPU) retail service area. In addition, one potential customer was identified in the City of Edmonds water service area and nine customers in the Shoreline Water District, because of their location along distribution lines that would connect Seattle to the Backbone. This original list has been expanded 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.

Herrera Environmental Consultants (Herrera) is assisting SPU to determine the potential environmental benefits of using reclaimed water in SPU's retail service area. This work is intended to inform SPU's economic analysis of providing retail reclaimed water service from the Brightwater Backbone project to SPU customers. For the purposes of this analysis, the provision of reclaimed water from the Brightwater Backbone to customers in SPU's retail service area is referred to as the North Seattle Reclaimed Water Project (the North Seattle project or project). The objectives of Herrera's work are (1) to describe and quantify, where possible, environmental benefits of using reclaimed water in place of surface and/or groundwater withdrawals, and (2) to assist SPU in identifying alternatives to the use of reclaimed water to achieve the same environmental benefits described in (1).

This technical memorandum provides an assessment of the post-project environmental conditions of Puget Sound and the watershed areas in SPU's retail service area. The post-project environmental conditions are those that display any potential benefits of using reclaimed water, when compared with the base case conditions. This memorandum includes analysis of the following:

- Post-project environmental conditions of Puget Sound
- Post-project environmental conditions of Service Area watersheds, including:
  - Analysis of post-project base flows and project benefits
  - Analysis of post-project water quality and project benefits
  - Analysis of post-project habitat area and project benefits
- Overall conclusions regarding environmental benefits of the systems affected by the project.

Affected Environment

The use of reclaimed water from the North Seattle project has the potential to affect the receiving waters for treated effluent (Puget Sound), as well as the urban watersheds in SPU's retail service area where potential customers are located. The Task 3 Technical Memorandum: Base Case Conditions, identifies the existing conditions in Puget Sound, and in the service area watersheds potentially affected by the project. The Task 3 Memo also describes the Self-Supplied Irrigators (SSIs) located in the service area watersheds, and the screening criteria and justification used to identify those most likely to benefit from the project and for which base-case and post project analysis was warranted. These watersheds include Thornton Creek, McAleer Creek, and Densmore Drainage basin.

Effects of the North Seattle Reclaimed Water Project on Puget Sound Conditions

This section presents a summary assessment of priority pollutants in the Puget Sound, and identifies the pollutants that are used to assess the effects of the retail reclaimed water project on Puget Sound conditions. The analysis uses current wastewater effluent quality from treatment plants in the region as the baseline data for estimating expected effluent quality from Brightwater, with advanced secondary treatment effluent quality "scaled" to account for the expected Brightwater effluent concentrations. Lastly, estimated reclaimed water irrigation volumes are used to calculate the pollutant loading reduction to Puget Sound.

Methods of Analysis

The Task 3 Technical Memorandum: Base Case Conditions, identifies the methods of analysis used to characterize existing water quality conditions in Puget Sound and expected pollutant loading from Brightwater directly to the Sound (without the North Seattle reclaimed water project). In order to assess the pollutant load reduction to the Sound that would be realized by the project, the Brightwater effluent concentrations estimated in Task 3 were applied to estimated reclaimed water demand volumes. The resultant pollutant load, which is primarily applied to the landscape through irrigation, will be dispersed in numerous North King County and Snohomish County watersheds. For the purposes of this analysis it was assumed that this pollutant load would be highly attenuated through these watersheds and that the resultant pollutant loading to the Sound via runoff from the watersheds would be negligible. An analysis of reclaimed water use on surfaces waters within these watersheds is provided in the next section.

Use of Pollutant Concentrations in Estimating Post-Project Conditions

Priority Pollutants in Puget Sound

Nutrients, bacteria, metals, and organic chemicals in the Puget Sound have been identified as constituents of concern (King County 2004; PSAT 2007). Consequently, this analysis and the Task 3: Base Case Conditions analysis, include the following constituents (in order of importance):

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

Other pollutants, such as hormone disruptors and pesticides have also been identified as contaminants of concern, however there is limited data on potential effluent concentrations from Brightwater for these less studied pollutants; consequently, they have not been included in this analysis.

Effluent Concentrations

The Task 3 Technical Memorandum: Base Case Conditions, identifies the effluent concentrations used to characterize existing water quality conditions in Puget Sound. As with the Task 3 analysis, this assessment uses multiple data sources to estimate Brightwater effluent concentrations for the nine constituents listed in the previous section (note: some constituents listed above are inclusive of others, for example Ammonia-N and Nitrate-N are both included in Total Nitrogen). Estimates of nutrient export were derived from a King County report (King County 2005) which used data from the membrane bioreactor (MBR) pilot studies conducted at West Point to estimate effluent concentrations from the MBR treatment system to be installed at Brightwater. These data are presented in Table 1 along with estimates of secondary effluent concentrations from the South King County Treatment Plant (for comparison purposes).

Table 1. Estimated nutrient effluent concentrations from traditional secondary treatment and MBR treatment.

Parameter	Estimated Secondary Quality [a]	Estimated MBR Quality	Units
Ammonia-N	31.3	0.6	mg/L
Nitrate-N	2.78	2.0	mg/L
Total Nitrogen	34.0	2.6	mg/L
Ortho-phosphate	3.15	1.5	mg/L
Total Phosphorus	3.33	1.5	mg/L

Adapted from King County (2005)

[a] Estimated secondary effluent quality from Department of Ecology EIM database entry for South King County Treatment Plant

Table 2 shows effluent data for the parameters of interest not listed in Table 1 (i.e., fecal coliform bacteria, copper, zinc, and bis(2-ethylhexyl)phthalate), which were estimated from other sources, as noted. The Task 3 Technical Memorandum: Base Case Conditions, identifies the sources of the data for effluent concentrations used to characterize post-project water quality conditions in Puget Sound.

Table 2. Estimated Brightwater effluent concentrations for selected priority pollutants.

Parameter	Number of Samples	Regional Median [a]	Scaling Factor [b]	Estimated Quality [c]	EIS Estimate [d]	Units
Dissolved Copper	41	11	1	11	9.5	µg/L
Dissolved Zinc	45	47	1	47	35	µg/L
Bis(2-Ethylhexyl)phthalate	25	4.5	1	4.5	8.2	µg/L
Fecal Coliform Bacteria	2799	24.1	11	2.2	2.2	CFU/ 100mL

[a] Data source: Ecology's Water Quality Permit Life Cycle System (WPLCS) database, discharge monitoring reports provided by permittees, and Water Quality Program permit managers.

[b] Scaling factors were applied to adjust secondary treatment estimates to MBR treatment estimates.

[c] Estimated effluent quality for Brightwater was calculated by dividing the regional median data by the scaling factor.

[d] Brightwater effluent values were estimated as part of the EIS process (King County 2003), these values were included for comparison to the values estimated as part of this report.

NA = not available
µg/L = micrograms/Liter

Effluent Volume

Under post-project conditions, total effluent discharge from Brightwater will be routed to three primary areas: the South Backbone, the West Backbone (which includes the North Seattle project), and to Puget Sound. A portion of the discharge will also be recycled for in-plant uses, but this amount is considered negligible for the calculations in this memorandum. Due to infiltration inflow to the plant, wet weather discharges from Brightwater are expected to be greater than dry weather discharges.

Phase I of the backbone project is under construction and will connect the Brightwater Treatment Plant to the Ballinger Way Portal; this phase of the project is anticipated to be completed in 2011. If sufficient demand materializes, Phase II will add pumps to pressurize the west backbone and bring reclaimed water to the surface at the Ballinger Way portal. Potential demand for reclaimed water at the Ballinger Way portal from Seattle and Shoreline customers served by the North Seattle project is estimated to be 1.7 million gallons per day (mgd) over the 6 month irrigation season (Flory 2009). During the remainder of the year, the Seattle/Shoreline demand is anticipated to be considerably less, only about 0.03 mgd, or 1.8% of dry season demand (Flory 2009) (Table 3). It should be noted that the Flory (2009) estimates do not represent total potential demand for reclaimed water along the West Backbone, but rather only for customers served by the North Seattle project. After completion of the West Backbone other users outside the study area (e.g., Bothell, Northshore, and south Snohomish County) could potentially increase demand for reclaimed water.

For analytical purposes, the wet season encompasses October through March, while the dry (irrigation) season extends from April to September. After the treatment plant is online and at capacity, average annual effluent flow from Brightwater is estimated to be 31.3 mgd (Simmonds 2009). Data for wet weather flows during the same period are projected to be 36 mgd (Simmonds 2009). To estimate average flows for the irrigation season the wet weather flow rate was applied to the average number of wet days (daily precipitation greater than 0.10 inches) that is expected in a typical year. Historical (1972 through 1998) meteorological data from a National Climatic Data Center cooperative station station (#457458) (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wa7458) in Seattle, Washington were used to estimate the anticipated number of wet days. The number of wet days was multiplied by the anticipated wet weather flows and then weighed against the average annual flows to back calculate dry weather flows. These values were then used along with estimates of the number of wet days in each season (irrigation season and non-irrigation season) to calculate Brightwater effluent flow rates for each season (Table 3).

Table 3. Estimated water balance for the West Backbone project.

Season	Brightwater Total Effluent Discharge (mgd)	North Seattle Project Demand (mgd)
Wet (October-March)	36.0	0.03
Dry (April-September)	26.7	1.7
Annual	31.3	0.87

mgd = million gallons per day

Data Availability

The Task 3 Technical Memorandum: Base Case Conditions, identifies the availability of data used to estimate Brightwater effluent concentrations and loading rates. Data regarding demand for reclaimed water is limited to one market analysis report produced by Seattle Public Utilities (Flory 2009). This report identified 60 potential reclaimed water customers and included results from surveys to determine water demand from these customers. No other data sources regarding future reclaimed water demand were available.

Important Assumptions

The Task 3 Technical Memorandum: Base Case Conditions, identifies the important assumptions used to estimate Brightwater effluent concentrations and loading rates. Additional assumptions related to estimates of demand that were presented in Flory (2009) include:

- The number of potential customers that would use reclaimed water is accurate. These estimates of demand may change as customers connect to the reclaimed water system.
- The estimated potential water demand for each customer is accurate.

<u>Post-Project Results</u>

The previous sections presented the methodology and results for effluent concentration estimations and seasonal hydraulic loading rate estimations for the Brightwater Treatment Plant and for estimated demand from SSIs in the Seattle retail service area. The calculation of mass load

$$M_{(Kg)} = V_{(L)} \times C_{(Kg/L)}$$

reductions to the Sound is then simply an arithmetic exercise. For each season and phase, the following formula was used to calculate post-project load reduction to the Sound:

Where:

$M_{(Kg)}$	=	Mass of pollutant in kilograms
$V_{(L)}$	=	Seasonal effluent volume in liters
$C_{(Kg/L)}$	=	Pollutant concentration in kilograms per liter

The results of these calculations are presented in Table 4. As can be seen from Table 4, loading reduction to Puget Sound as a result of the North Seattle project is minimal during the wet season and more substantial during the dry season. This is, of course, because the demand for reclaimed water is much less during the wet season when irrigation is not necessary. The estimates of load reduction in Table 4 should be considered in assessments of the costs and benefits of the North Seattle Reclaimed Water project.

Table 4. Estimated annual and seasonal mass load reduction (in kilograms) to Puget Sound due to the North Seattle Reclaimed Water Project.

			Load Reduction to Sound			
Constituent	Effluent Concentration	Concentration Units	Dry Season	Wet Season	Annual	Loading Units
Ammonia-N	0.6	mg/L	707	12	719	Kg
Nitrate-N	2.0	mg/L	2355	42	2397	Kg
Total Nitrogen	2.6	mg/L	3062	54	3116	Kg
Fecal Coliform	2.2	CFU/100mL	26	0.5	26.5	Billions of CFU
Copper	11	µg/L	13	0.2	13.2	Kg
Zinc	47	µg/L	55	1	56	Kg
Bis(2-Ethylhexyl)phthalate	4.5	µg/L	5	0.1	5.1	Kg
Ortho-phosphate	1.5	mg/L	1766	31	1798	Kg
Total Phosphorus	1.5	mg/L	1766	31	1798	Kg

CFU/100mL = colony forming units per 100 milliliters

mg/L = milligrams per liter

µg/L = micrograms per liter

Kg = kilograms

Implications

Extent of the Benefits

As stated in Task 3 Technical Memorandum: Base Case Conditions, the Puget Sound is a sensitive estuarine environment that is in decline. While much of the Sound is healthy, rapid urbanization of coastal environments is leading to degraded conditions in the nearshore and isolated embayments (PSAT 2007). The best available science indicates that water and sediment quality in the Puget Sound is progressively degrading (PSAT 2007). Consequently, any additional loading to the Sound must be considered a detriment to the health of the system. Given this, the pollutant load reductions that will be realized by reclaiming water for irrigation purposes (Table 4), must be considered a net benefit to the ecologic health of the Sound. To estimate the extent of this benefit is difficult because the fate and transport of these pollutants relative to biologically sensitive areas within the Sound is complex. Instead of determining the extent of the benefit, it is recommended that the pollutant load reduction realized by water reclamation be used as a metric against which other pollutant load reduction strategies can be gauged. Is it recommended that in future alternatives analyses the pollutant load reduction values presented in Table 4 be used to weigh the benefits of water reclamation against other pollutant load reduction strategies.

Post-Project Conditions in the Future

When projecting the results of this analysis into the future, there are two primary assumptions that are made. The first is that effluent quality from the reclaimed water system will not change. In reality, effluent quality could decrease, as the treatment plant ages, or increase as filtration technology improves. The second assumption is that demand for reclaimed water will not differ significantly from the values presented in Table 3 and Flory (2009). As with any market analysis there is error involved and actual demand for reclaimed water could be higher or lower than estimated.

Effects of the North Seattle Reclaimed Water Project on Watershed Conditions

This section presents the future post-project conditions for the service area watersheds identified during application of the threshold criteria, described in the Task 3 Technical Memorandum: Base Case Conditions. The service area watersheds (watersheds) are those located within the Seattle Public Utilities' retail service area, and contain water users that could be supplied with reclaimed water through the North Seattle project, primarily in the Cities of Seattle, Shoreline, and Edmonds. Service area watersheds included in the analysis are Thornton Creek, McAleer Creek (including Lake Ballinger), and the Densmore Drainage basin (Lichton Springs). As with the Base Case conditions, post-project conditions are characterized using three categories of quantitative and/or qualitative metrics, including:

1. Hydrologic, hydrogeologic, and hydraulic conditions: present base flows based on historical flows with the addition of irrigation volumes.

2. Water quality: Temperature, dissolved oxygen, and ortho-phosphate phosphorus and copper loadings

3. Wetted habitat area: The area of instream habitat and riparian wetlands in the service area watersheds under the post-project range of baseflow conditions.

Hydrologic and Hydrogeologic Conditions

This section discusses the post-project hydrologic and hydrogeologic conditions in the selected service area watersheds, primarily related to base flow. A subsequent section, *Habitat Area*, also includes a discussion of post-project hydrologic and hydraulic conditions as they relate to habitat area.

Methods of Analysis

The Task 3 Technical Memorandum: Base Case Conditions, identified the methods of analysis used to characterize existing hydrologic and hydrogeologic conditions at points of analysis (POAs) in the service area watersheds. This memorandum compares the Task 3 base flow conditions to the base flow conditions that are likely to result from the North Seattle reclaimed water project .

Figures 1 and 2 describe the hydrologic inputs and outputs for each POA impacted by surface water and groundwater irrigators, respectively. As Figure 1 illustrates, the base flow augmentation resulting from resting surface water withdrawals and using reclaimed water was calculated as the equivalent of the average amount of surface water currently used for irrigation. As shown in figure 2, base flow augmentation resulting from resting groundwater withdrawals was calculated as the average amount of groundwater currently used for irrigation multiplied by the surface water/groundwater factor (SGF). The development of the surface water/groundwater factor (SGF) is described within the methods of the Task 3 Technical Memorandum: Base Case

Conditions section, and is applied in this memorandum to determine the fraction of the groundwater withdrawal that actually affects stream base flow.

The actual calculation of the post-project base flows for each POA is dependent on both the type and amount of withdrawal as well as the number of upstream SSIs. For the Licton Springs point of analysis (LS-POA1), Evergreen Washelli Cemetery, a groundwater irrigator, is the only upstream irrigator assessed. Both of the two points of analysis on McAleer Creek, MC-POA1 and MC-POA2, are located downstream of one surface water irrigator, Nile Country Club, and one groundwater irrigator, Holyrood Cemetery. Jackson Park Golf Course, a surface water irrigator, is the SSI upstream of the two points of analysis on Thornton Creek (TC-POA1 and TC-POA2). Figure 3 shows the location of the POAs with respect to the SSIs.

Use of Historical Streamflow Data in Estimating Post-Project Conditions

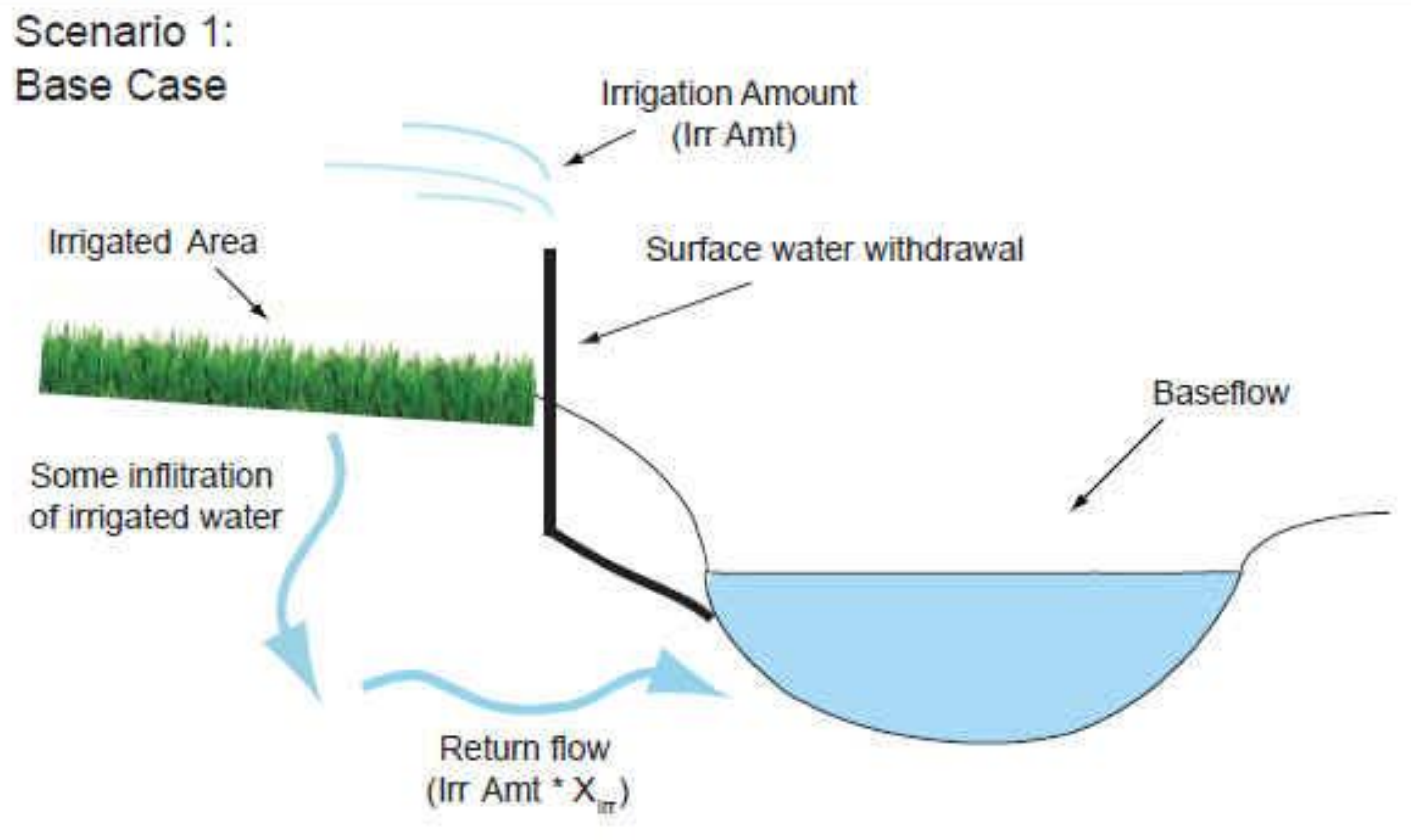
The Task 3 Technical Memorandum: Base Case Conditions, describes the data sources and the analysis of available data used to determine the base case base flow conditions referenced here.

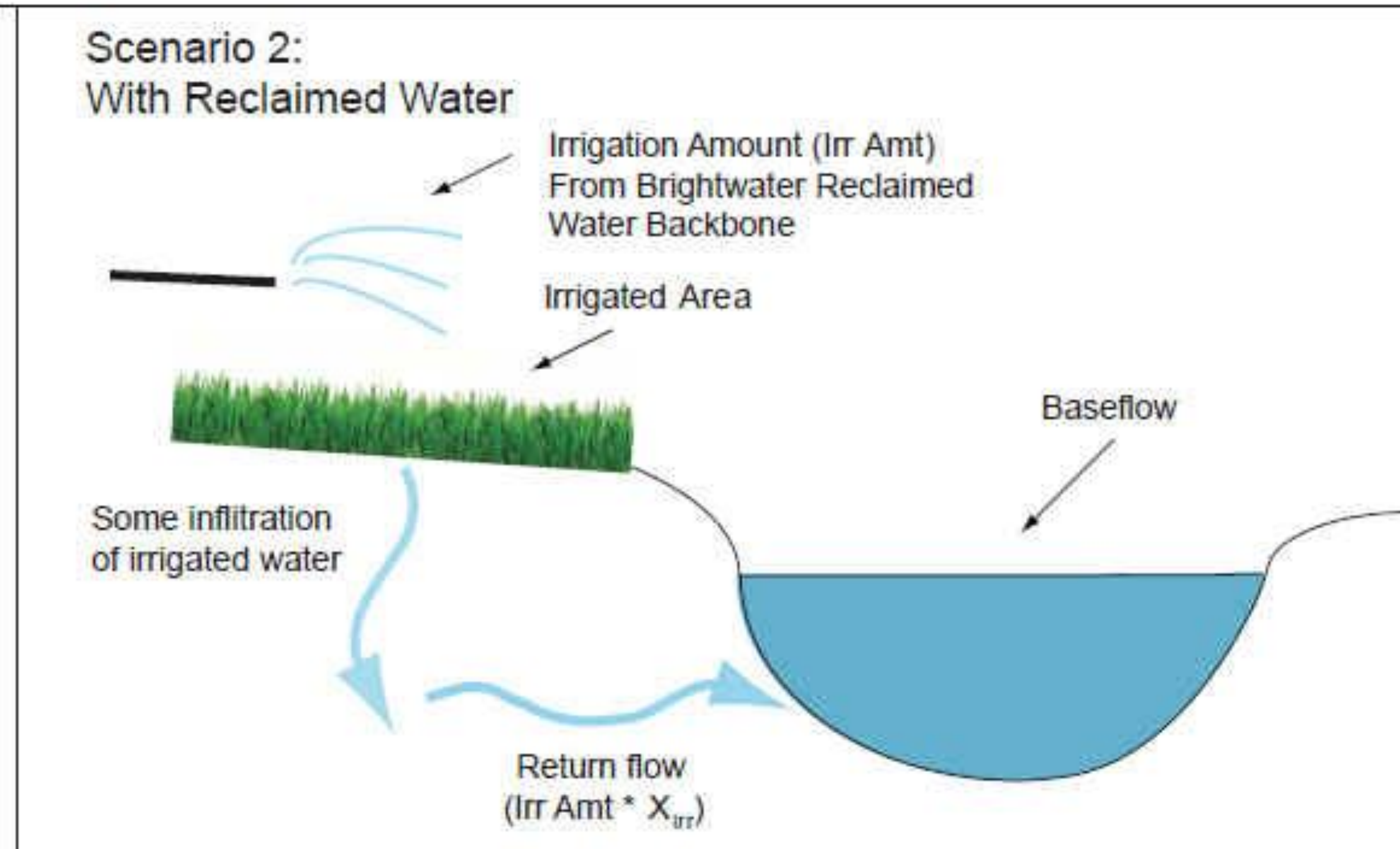
Data Availability

The Task 3 Technical Memorandum: Base Case Conditions, identifies the availability of flow data used to select the POAs as well as to estimate post-project hydrologic conditions in the service area watersheds. Table 5 reiterates the POAs used for post-project base flow analysis of the SSIs as well as the available periods of record for those locations. The locations of these POAs are illustrated in Figure 3.

Table 5 presents a summary of data gaps for each flow monitoring station for the entire period of analysis, as well as for the irrigation seasons within the period of analysis. Generally, the Thornton Creek stations have a long period of record and relatively few data gaps, while the McAleer and Licton Springs stations have shorter periods of record and significantly more data gaps.

For SPU flow monitoring station STA033 (Thornton POA2), there were a total of 241 days of data gaps over the 10-year (March 1999 to April 2009) period of record, including 95 days of data gaps over the irrigation season of May through September. For SPU station STA066 (Thornton POA1), there were 74 days of data gaps between January 2004 and April 2009, but no data gaps during the irrigation season. For King County gage 35c at McAleer POA2, there were a total of 100 days of data gaps between October 1991 and January 2009, including one 16-day gap in the irrigation period. For King County gage 35a (McAleer POA1), there were 267 days of data gaps over the period of record (January 1989 to February 1993), including one 153-day data gap in the early irrigation season in 1992. For the combined records of SPU station 108 and 118 near Licton Springs, the data record lasted from late September 2003 to late October 2007. In this record there was a gap from October 2004 to October 2006, which includes 745 days overall and 306 days during the irrigation season.





Scenario 1: Base Case

<u>Inputs</u>:

- $Baseflow_{no\ irrigation}$ = Stream baseflow if irrigators did not divert surfacewater
- Irr Amt = Irrigation amount, average flow of surface water diversion for irrigation (cfs, from SPU)
- X_{irr} = Fraction of the irrigation water that returns to the stream and contributes to baseflow (%, determined from WWHM)
- Return flow = Portion of irrigation amount that returns to the stream to recharge baseflow(cfs, Irr Amt * X_{irr})

<u>Water Balance</u>:

$$Baseflow_{base\ case} = Baseflow_{no\ irrigation} - \text{Irr Amt} + (\text{Irr Amt} * X_{irr})$$

Scenario 2: With Reclaimed Water

<u>Inputs</u>:

- $Baseflow_{no\ irrigation}$ = Stream baseflow if irrigators did not divert surfacewater
- Irr Amt = Irrigation amount, average flow of surface water diversion for irrigation (cfs, from SPU)
- X_{irr} = Fraction of the irrigation water that returns to the stream and contributes to baseflow (%, determined from WWHM)
- Return flow = Portion of irrigation amount that returns to the stream to recharge baseflow (cfs, Irr Amt * X_{irr})

<u>Water Balance</u>:

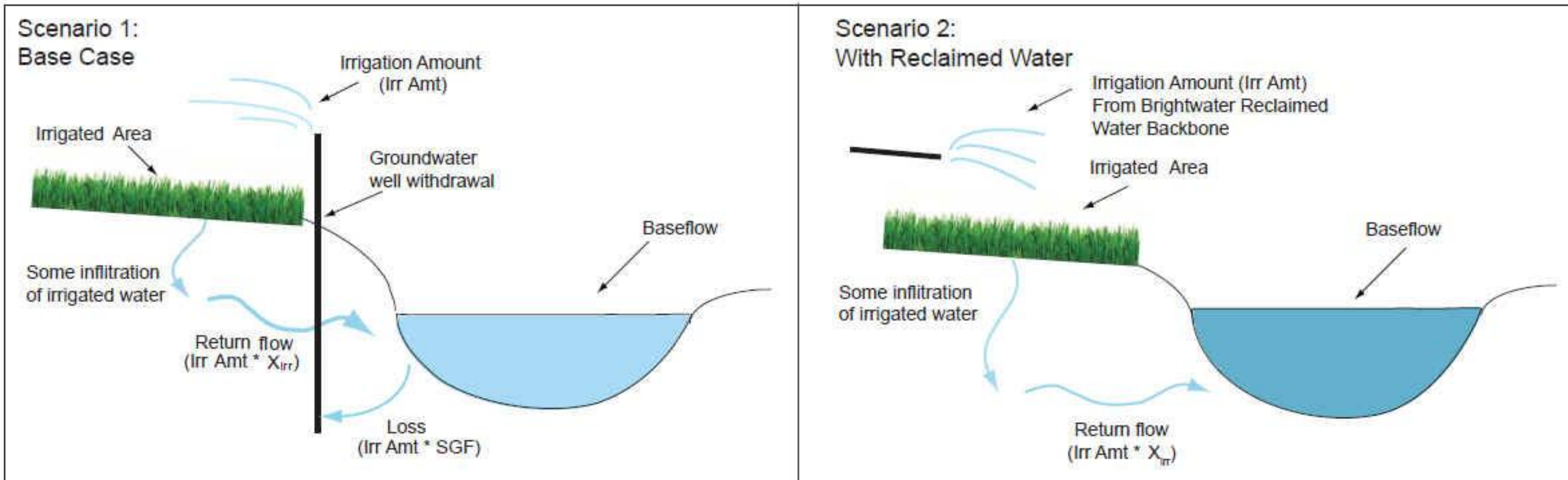
$$Baseflow_{with\ reclaimed\ water} = Baseflow_{no\ irrigation} + (\text{Irr Amt} * X_{irr})$$

<u>Net change in baseflow</u>:

$$Baseflow_{with\ reclaimed\ water} - Baseflow_{base\ case} = \text{Irr Amt}$$

Note: Graphics are not to scale.

Figure 1. Hydrologic impacts of baseflow augmentation from surface water irrigators.



Scenario 1: Base Case

Inputs:

$Baseflow_{no\ irrigation}$	= Stream baseflow if irrigators did not withdraw groundwater
IrrAmt	= Irrigation amount, average flow of surface water diversion for irrigation (cfs, from SPU)
X_{irr}	= Fraction of the irrigation water that returns to the stream and contributes to baseflow (%, determined from WWHM)
Return flow	= Portion of irrigation amount that returns to the stream to recharge baseflow (cfs, IrrAmt * X_{irr})
SGF	= Surface water/groundwater factor, represents the fraction of the groundwater well withdrawal that affects stream flow (from hydrogeologist)
Loss	= Baseflow drawdown due to groundwater well irrigation withdrawal (cfs, IrrAmt * SGF)

Water Balance:

$Baseflow_{base\ case} = Baseflow_{no\ irrigation} - Irr\ Amt * SGF + Irr\ Amt * X_{irr}$

Scenario 2: With Reclaimed Water

Inputs:

$Baseflow_{no\ irrigation}$	= Stream baseflow if irrigators did not withdraw groundwater
Irr Amt	= Irrigation amount, average flow of surface water diversion for irrigation (cfs, from SPU)
X_{irr}	= Fraction of the irrigation water that returns to the stream and contributes to baseflow (%, determined from WWHM)
Return flow	= Portion of irrigation amount that returns to the stream to recharge baseflow (cfs, Irr Amt * X_{irr})
SGF	= Surface water/groundwater factor, represents the fraction of the groundwater well withdrawal that affects stream flow (from hydrogeologist)

Water Balance:

$Baseflow_{with\ reclaimed\ water} = Baseflow_{no\ irrigation} + (Irr\ Amt * X_{irr})$

Net change in baseflow:

$$Baseflow_{with\ reclaimed\ water} - Baseflow_{base\ case} = Irr\ Amt * SGF$$

Note: Graphics are not to scale

Figure 2. Hydrologic impacts of baseflow augmentation from groundwater irrigators.

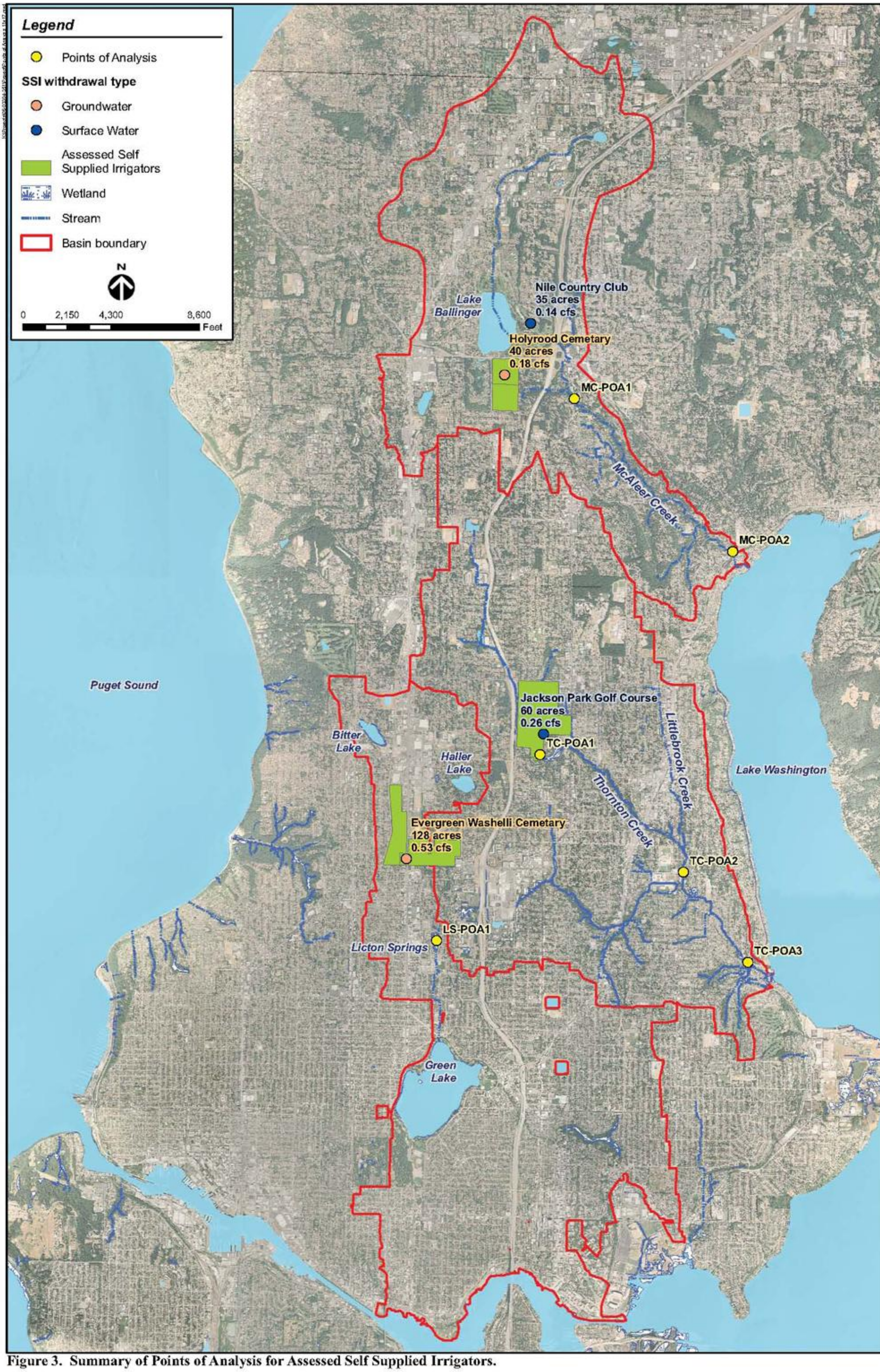


Figure 3. Summary of Points of Analysis for Assessed Self Supplied Irrigators.

Table 5. Summary of points of analysis and relative periods of record used for the post-project base flow analysis.

	Station ID	Applicable Self Supplied Irrigator	Station Location	Data Source	Available Period of Record	Period of Analysis	Data Gaps During Period of Analysis [a]
Thornton Creek							
TC-POA1	STA066/ STA064	Jackson Park Golf Course	Downstream end of Jackson Park Golf Course	SPU	1999-Present	1999-Present	0% during irrigation season; 3.8% total
TC-POA2	STA033	Jackson Park Golf Course	NE 110th / 35th Ave NE	SPU	1992-Present	1999-Present	6.2% during irrigation season; 6.6% total
McAleer Creek							
MC-POA1	35a	Nile Country Club, Holyrood Cemetery	Below 15th Ave NE	King County	1989-1994	1991-1993	25 % during irrigation season; 17.9% total
MC-POA2	35c	Nile Country Club, Holyrood Cemetery	Near Mouth	King County	1991-Present	1991-1993	0.6% during irrigation season; 1.5% total
Licton Springs/ Densmore Drainage Basin							
LS-POA1	STA108	Evergreen Washelli Cemetery	10030 Interlake Ave N Pipe	SPU	2003-2004	2003-2004	37 % during irrigation season; 50% total
	STA118	Evergreen Washelli Cemetery	10030 Interlake Ave N Pipe	SPU	2006-2008	2006-2008	37% during irrigation season; 50% total

Notes:

[a] Data gaps expressed as the ratio of the number of days of data gaps over the total number of days within the period of analysis (or irrigation season)

Important Assumptions

The Task 3 Technical Memorandum: Base Case Conditions, identifies several important assumptions used to derive the base flow conditions referenced in this memorandum. In addition, the following assumptions were also necessary to estimate post-project hydrologic conditions in the service area watersheds.

One assumption key to this analysis of project benefits is that there would be no losses of base flow augmentation between two points of analysis located on the same stream. In other words, if there are two points of analysis located downstream of the same self supplied irrigator, the quantity (i.e. cfs) of flow augmentation experienced at the upstream point of analysis is assumed to be the same for the downstream point of analysis. In actuality there are many hydrologic gains and losses experienced along a stream channel's length that can be caused by variable characteristics such as substrate variability, locations of increased or decreased hyporheic interactions, as well as the presence of springs and wetlands. However, the small amounts of base flow augmentation potentially resulting from this project are not expected to change the locations nor the amounts of hydrologic gains or losses from what is currently being experienced. Furthermore, assessing the percentage of the augmented base flow that might be lost between two points of analysis located in separate reaches of the same watershed was beyond the scope for this study. Therefore, it is assumed that there are no losses of the augmented flow quantity between the two points of analysis. For example, the two points of analysis on Thornton Creek, TC-POA1 and TC-POA2, both experience an increased base flow of 0.26 cfs, equivalent to the average irrigation amount at Jackson Park Golf Course upstream.

The irrigation amounts listed in this section are referenced values from the SPU market analysis and are assumed to be the average irrigation flow experienced during the irrigation period, from May through September.

Methods for Developing the Surface Water/Groundwater Factor (SGF)

The Task 3 Technical Memorandum: Base Case Conditions, identifies the methods for determining the surface water/groundwater factor (SGF) for use in estimating the fraction of each SSI's groundwater well withdrawal that affects stream flow. The method used was based on a 2008 study performed by Joel Massman at the University of Washington prepared for King County regarding the effects of resting groundwater extraction wells on creek water quality and quantity (Massman 2008). For the post-project conditions analysis, SGFs are used to evaluate possible changes in base flow as a result of self-supplied irrigators ceasing their groundwater withdrawals and switching to the use of reclaimed water.

Table 6 summarizes the wells, including screened zones, and distance from surface water bodies. The water usage estimates summarized in Table 6 were provided by SPU.

Post-Project Results

Table 7 summarizes the irrigation amounts, the surface water/groundwater factors, and the total net new base flow resulting from the project for each POA.

Table 6. Irrigator wells for groundwater self-supplied irrigators evaluated for post-project conditions.

Irrigators	Total Well Depth (feet below ground surface)	Screened Zone (feet below ground surface)	Distance from Surface Water Body (feet)
		Holyrood Cemetery	
1953 well	565	480-590 and 500 to 515	<1,500
1958 well	369	NA	<1,500
Estimated water usage (per SPU) 17.7 million gallons per 6 months; Peak use 0.21 million gallons per day			
		Evergreen-Washelli Cemetery	
1927 well	260	NA	>3,000
1947 well	300	155-188	>3,000
1950 well	238	NA	>3,000
1952 well	785	N A	>3,000
1955 well	185	165-185	>3,000
1959 well	169	134-154	>3,000
1987 well	126	109-126	>3,000
1989 well	143	92-123	>3,000
Estimated water usage (per SPU) 51.4 million gallons per 6 months; Peak use 0.61 million gallons per day			

Table 7. Summary of the net new base flows at each POA resulting from the project.

POA	1st SSI UPstrm.	Avg. Irr. Amt. for 1st SSI UPstrm (cfs)	1st SSI UPstrmSGF	1st SSI UPstrm Irr. Amt. X SGF	2nd SSI UPstrm	Avg. Irr. Amt. for 2nd SSI UPstrm (cfs)	2nd SSI UPstrmSGF	2nd SSI UPstrm Irr. Amt. X SGF	Net New Base flow from project (cfs)
Licton Springs (LS- POA1)	Evergreen Washelli Cemetery	0.53	0.44	0.23	N/A	N/A	N/A	N/A	0.23
McAleer Creek (MC-POA1)	Holyrood Cemetery	0.18	0.43	0.08	Nile Country Club	0.14	1	0.14	0.22
McAleer Creek (MC-POA2)	Holyrood Cemetery	0.18	0.43	0.08	Nile Country Club	0.14	1	0.14	0.22
Thornton Creek (TC-POA1)	Jackson Park Golf Course	0.26	1.00	0.26	N/A	N/A	N/A	N/A	0.26
Thornton Creek (TC- POA2)	Jackson Park Golf Course	0.26	1.00	0.26	N/A	N/A	N/A	N/A	0.26

UPstrm. = Upstream

Irr. = Irrigation

N/A = Not Applicable

Table 8 provides a comparison of the base case base flows, the with-project base flows, and the irrigation amount for each Point of Analysis. Table 8 provides the same data in terms of the percent increase in base flows resulting from the project, as compared to the base case.

Table 8. Comparison of the base case base flows, the with-project base flows, and the irrigation amount for each Point of Analysis.

POA	Base Flow (cfs)		Total Flow (cfs)		Base Flow as percentage of Total Flow (cfs)		Irrigation Amount (cfs)
	Base Case	With Project	Base Case	With Project	Base Case	With Project	
Licton Springs (LS- POA1)	0.05	0.28	0.56	0.79	8	35	0.53 [a]
McAleer Creek (MC-POA1)	2.02	2.23	3.45	3.67	58	61	0.32 [b]
McAleer Creek (MC-POA2)	6.46	6.68	7.74	7.95	84	84	0.32 [b]
Thornton Creek (TC-POA1)	0.84	1.10	1.30	1.56	65	70	0.26 [c]
Thornton Creek (TC- POA2)	1.30	1.56	2.78	3.04	47	51	0.26 [c]

[a] includes Evergreen Washelli Cemetery as upstream irrigator
[b] includes Nile Country Club and Holyrood Cemetery as upstream irrigators
[c] includes Jackson Park Golf Course as upstream irrigator

Implications

Extent of the Benefits

The results of this study indicate that:

- The project is expected to increase the amount of creek flow that is derived from base flow for all POAs other than the downstream POA for McAleer Creek (MC-POA2).
- Increased baseflow during the irrigation season is expected to contribute to a more stable flow rate and volume that is present in the channel throughout the irrigation season.
- Benefits may be most profound for the POAs located further upstream in their respective basins, where urbanization has led to storm drain infrastructure that effectively conveys stormwater runoff and where there is not much contributing drainage area that can otherwise sustain a consistent base flow rate and volume (e.g. TC-POA1 and MC-POA1).

The following text provides a discussion of the amount of baseflow augmentation expected for each of the three study watersheds.

Thornton Creek

Because the Thornton Creek POAs are directly impacted by the surface water withdrawals from the Jackson Park Golf Course, the project benefits of halting that withdrawal directly relate to leaving that irrigation amount in the stream channel. Therefore, both TC-POA1 and TC-POA2 experience significant increases in base flows resulting from the project, from 0.84 to 1.10 cfs and from 1.30 to 1.56 cfs respectively.

McAleer Creek

The McAleer Creek POAs are also expected to experience increased base flows resulting from the project. For MC-POA1, the upstream POA for McAleer Creek, the project results in an increase of base flow from 2.02 to 2.23cfs. For MC-POA2, the downstream POA for McAleer Creek, the project results in an increase of base flow from 6.46 cfs to 6.68 cfs. It should be noted that both of the McAleer POAs are downstream of Lake Ballinger, which helps to provide a consistent base flow to those locations throughout the year.

Licton Springs

For Licton Springs, the project is expected to increase the base flow from 0.05 to 0.28 cfs. In addition, this increase in base flow also causes the percentage of total flow derived from base flow to increase from 8 to 35 percent, thus providing a more consistent base flow quantity and volume during the irrigation period. Although these increases are significant in terms of percentage value increases relative to the base case, the post-project base flow is still relatively small and may not be enough to cause any significant benefits to water quality or wetted habitat.

The water quality and habitat impacts of these base flow increases are further described in subsequent sections of this memorandum.

Post-Project Conditions in the Future

The assumption is made that the post-project conditions described in this section will be an adequate depiction of base flow conditions for the planning horizon for the proposed project (ca. 20 years). This assumption is made because most of the service area watersheds are effectively "built out" now, and there is little opportunity for significant land use changes that would further impact the hydrologic characteristics described here. Evaluation of the potential impacts of climate change on the post-project base flows over the next 20 years was beyond the scope of work for this project.

Water Quality

This section discusses the post-project water quality conditions of streams near specific self-supplied irrigators (SSIs) in the SPU retail service area that would receive reclaimed water instead of using their own surface water or groundwater sources. As with the Task 3 Base Case analysis, the post-project assessment analyzed stream temperature and concentrations of dissolved oxygen, phosphorus (orthophosphate and total) and copper (dissolved and total). These parameters were evaluated because:

- They often impact urban stream biota.
- Their levels can be affected by discharge of reclaimed water to streams.
- Data are commonly available for these parameters.
- They represent a range of potential fate, transport, and impact mechanisms among all water quality variables.

The Task 3 Technical Memorandum: Base Case Conditions discusses the selection of these water quality parameters and their applicability to the assessment of the service area watershed conditions in further detail.

Methods of Analysis

The Task 3 Technical Memorandum: Base Case Conditions, identifies the methods of analysis used to characterize existing water quality conditions in service area watersheds. This section details the methods used to quantify project water quality benefits and impacts. Each water quality parameter analyzed is discussed separately.

Stream Temperature

Changes in stream flow may affect temperature. In general, lower flows result in higher stream temperatures (Neumann et al 2003). The effect of flow on stream temperature has been evaluated using physically based deterministic models and less computationally intensive empirical regression models. Empirical regression models are attractive because they are much more easily developed. Neumann et al. (2003) reviewed a number of different multiple regression models for modeling stream temperature of the Truckee River in Reno, Nevada. They found the best predictors for summer's daily maximum stream temperatures were daily maximum air temperature and daily mean stream flow. More specifically, they found the following equation for stream temperature:

, where and

are in degrees C, and is in cubic feet per second (cfs).

The effect of flow on Truckee River temperature can be analyzed in their equation by inserting two values for $Q_{dailymean}$, 250 cfs and 500 cfs, for example, multiplying them by 0.013, and then comparing the two resulting values. Doing so suggests increasing baseflow from 250 cfs to 500 cfs would result in a 3.25 °C decrease in stream temperature.

The information about the Truckee River temperature model in the above paragraph is provided simply as context for how predictor variables were selected in the current analysis: the Truckee River equation itself was not used for analyzing project impacts. The Regression equation used to evaluate the subject watersheds (POAs) was developed by Herrera for this analysis using local data, based on the concept used in the Truckee River study (specifically the use of daily max air temp and daily mean stream flow as predictors of daily max stream temp). While there is no groundwater term in the equation, groundwater effects on stream temperature are included in the equation's flow term. This is because the regression is based on flows and temperatures from the irrigation season when variations in flow are mostly attributable to variations in groundwater baseflow.

Similar regression equations were developed for Thornton Creek (POA1 and POA2) and McAleer Creek (POA2). Since daily maximum air temperature and daily mean stream flow were identified as good predictors by Neumann et al. (2003), these predictor variables were used for Thornton and McAleer Creek. The stream flow, air temperature, and stream temperature data used in the regressions for McAleer Creek came from King County (2009) (15-minute data from 1997 to 2008). For Thornton Creek POA1 and POA2, the stream flow and temperature data came from SPU (2009) (15-minute data from 2003 to 2008). Air temperature data from McAleer Creek (King County 2009) were used for Thornton Creek because air temperature data were not available for either of the Thornton Creek sites. Only irrigation season observations were used in running the regression analysis. After computing the regression equations, as illustrated above for the Truckee River, the average summer base flow values before and after the project were inserted into the regression equations to find the project's temperature impact at each of the three locations analyzed.

Dissolved Oxygen

Dissolved oxygen levels in streams in the watersheds of interest could be affected by the proposed reclaimed water irrigation project in several ways. First, concomitant increases in base flow could influence stream temperature and indirectly affect dissolved oxygen by affecting oxygen's saturation concentration. If this were the case and stream temperature decreased as a result of base flow augmentation, increases in dissolved oxygen levels would be expected. In addition, if there is runoff (return flow) of reclaimed water used for irrigation, stream dissolved oxygen levels could decrease by the biochemical oxygen demand (BOD) and nutrients in reclaimed water that stimulate growth of oxygen consuming microbes in the stream. Finally, dissolved oxygen concentrations are typically much lower in groundwater than stream water, such that changes in the amount of groundwater inflow to the stream could affect the concentration of dissolved oxygen in the stream.

To analyze the indirect effect of base flow augmentation on dissolved oxygen concentration via stream temperature, the effect of base flow augmentation on stream temperature is first calculated (as described in the preceding section). Then the dissolved oxygen saturation concentrations are calculated for the predicted daily maximum stream temperatures before and after the project. The difference between these values is part of the dissolved oxygen impact of the project.

The ideal way to analyze the potential impact of return flow's BOD loading on dissolved oxygen would be to use a standard Streeter-Phelps equation for BOD decay and oxygen reaeration (Metcalf and Eddy 1991). Unfortunately, one of the key pieces of information needed for this equation, the background BOD concentration of the affected streams, is lacking. Since return flow would be a small component of total flow in streams (shown in the results section below), the results of a Streeter-Phelps equation would be highly sensitive to any assumed background BOD concentration. Typical BOD concentrations range from 1 mg/L in pristine streams to 17 mg/L in urban runoff (Welch and Jacoby 2004), and have been estimated to be less than 2 mg/L in reclaimed water (citation). Given the lack of stream BOD concentration data and the relatively low BOD concentration in reclaimed water, the effects of return flow on dissolved oxygen are discussed semi-qualitatively.

Stream dissolved oxygen concentrations could also be indirectly affected by the presence of nutrients in return flow. Nutrient enrichment of stream waters would stimulate the growth of attached algae, which produce oxygen during the day through photosynthesis. Oxygen would be consumed by heterotrophic bacteria and other microbes that grow on the organic matter produced by decaying algae. Effects of nutrient enrichment on dissolved oxygen are too complex to estimate with reasonable certainty and, thus, are only address qualitatively.

Phosphorus and Copper

The proposed reclaimed water irrigation project could affect stream phosphorus and copper concentrations if there is return flow of reclaimed water. If return flow is not considered, no project impact on phosphorus or copper concentrations would be expected because these pollutants would be retained in soils and vegetation where reclaimed water is applied.

A dilution analysis was undertaken to test the effect of potential return flow on stream concentrations of phosphorus and copper. More specifically, a "worst case" scenario for return flow was calculated by assuming that 5 percent of the reclaimed water irrigation would discharge to streams without phosphorus or copper removal. Return flow could occur by runoff of pollutants in irrigation waters from pervious and impervious surfaces during dry or wet weather. An important factor in the dilution analyses is the ratio between the irrigation return flow rate and the stream flow rate after the project. These values were calculated in the hydrologic analysis described above; they are presented again in the phosphorus and copper results section below. They form multiplication factors in the dilution analysis.

The other important parts of the equation are the streamwater and reclaimed water phosphorus and copper concentrations. The streamwater concentrations came from King County data for Thornton POA3 (King County site 0434) and McAleer POA2 (King County site A432). The analysis only used data from May to September of 1985 to 2008. Only non-storm observations were included. The reclaimed water phosphorus and copper concentrations came from the Puget Sound conditions section of this memorandum.

The dilution analysis was also completed for hardness as a test of whether the project would affect hardness and therefore metals toxicity. The necessary input data included mean hardness values from streams and from pilot testing studies of future effluent.

Data Availability and Quality

The Task 3 Technical Memorandum: Base Case Conditions, identifies the availability of data used to estimate base case and post-project water quality conditions in the service area watersheds. All water quality datasets used had been classified by SPU as datasets believed or known to be of high quality.

Important Assumptions

The Task 3 Technical Memorandum: Base Case Conditions, identifies the important assumptions used to estimate base case water quality conditions in the service area watersheds. Key assumptions made in this analysis of project impacts and benefits are listed below:

- For the analysis of temperature data, it is assumed that the effect of future baseflow increases on stream temperature can be addressed by regressing stream flows and air temperatures versus stream temperatures using existing data for the irrigation season from the past 5 to 11 years. It is also assumed that potential groundwater return flow temperature effects are included in the day to day variations in base flow used to build the regression model because base flow is comprised entirely of groundwater return flow.

- For the analysis of return flow effects on stream concentrations, it is assumed that return flow will average 5 percent of irrigation flow as a worst case scenario. Return flow could occur by runoff of pollutants in irrigation waters from pervious and impervious surfaces during dry or wet weather. The duration of this impact is limited to the daily irrigation period and would not occur throughout the irrigation season.
- Complete capture of contaminants in reclaimed water is assumed and that any breakthrough of contaminants from soils would be accounted for in the 5 percent assumption for return flow. No modeling has been developed to assess potential for "breakthrough" of reclaimed irrigation water contaminants from soils after numerous years of loading.

Post-Project Results

The results section below discusses project benefits and impacts separately for stream temperature, dissolved oxygen, phosphorus, and copper.

Stream Temperature

McAleer POA2

No project temperature impact was found at this point of analysis. The regression of daily maximum stream temperature on daily maximum air temperature and daily mean streamflow was completed using all available irrigation season data for 1997 to 2008. This included a sample size of 1,569 daily observations. The resulting multiple regression equation had an R^2 value of 0.55 and a p value less than 0.001. The equation is presented below, with confidence intervals for each coefficient:

Where and are temperatures in degrees C, and is flow in cubic feet per second (cfs).

The regression approach incorporates the effects of groundwater temperature on the observed stream temperature, in addition to the effects of changes in the surface area to depth ratio on the amount of heat retention. It should be noted that a total of 76 data points had residual confidence intervals not containing zero, suggesting they were outliers (Helsel and Hirsch 1992). Log transformation of flow values did not reduce the number of regression outliers.

It is notable that the sign of the flow term in the regression is positive, i.e. suggesting temperature increases with increasing base flow. Inserting the pre- and post-project average irrigation season flow values, 7.74 and 7.95 cfs, respectively, shows the effect on temperature is very small: +0.009 °C (i.e. 7.95×0.046 minus 7.74×0.046). From this it is concluded that McAleer Creek temperature is not highly sensitive to flow, and there would be no project impact on stream temperature at this location.

Thornton POA1

No biologically significant temperature increase is expected at this point of analysis. For Thornton POA2, multiple regression was completed based on all available SPU (2009) stream temperature and flow data and King County (2009) McAleer Creek data for air temperature for May to September of 2003 to 2008. This included 703 daily data points for regression. The resulting equation presented below had a low R^2 value of 0.34 and p value less than 0.001:

Where and are temperatures in degrees C, and is flow in cubic feet per second (cfs).

In addition to poorly fitting the data, as evidenced by the low R^2 value, this equation had 39 outlying residuals. Log transformation of flow values did not reduce the number of outliers.

Inserting the pre- and post-project average streamflow values, 1.30 and 1.56, respectively, into this equation shows the effect of the project on temperature is +0.17 °C. However, a high degree of uncertainty is associated with this predicted effect because a low amount of the variance (34 percent) in stream temperature is explained by stream flow and air temperature.

Thornton POA2

The project impact on temperature at this location was found to be insignificant. For Thornton POA2, multiple regression was completed based on all available SPU (2009) stream temperature data and flow data and King County (2009) McAleer Creek data for air temperature for May to September of 2003 to 2008. This resulted in 796 daily data points and a regression equation with an R^2 of 0.66 and a p value less than 0.001.

Where and are temperatures in degrees C, and is flow

in cubic feet per second (cfs).

This regression had the same problem as the regression for McAleer POA2 and Thornton POA1: there were 52 outlier observations. Again, log transformation did not reduce the number of outliers.

The resulting equation was similar to that of McAleer POA2 in that $Q_{dailymean}$ had a small positive coefficient. Inserting the before and after project average irrigation season flow values, 2.78 and 3.04 cfs, respectively, shows the project impact on stream temperature is +0.016 °C. From this it can be concluded that the project would not impact stream temperature.

Dissolved Oxygen

As introduced in the methods section, there are two classes of possible project effects on dissolved oxygen. These include 1) possible effects on the dissolved oxygen saturation concentration via project effects on stream temperature, and 2) effects associated with return flow of reclaimed water to streams.

To analyze the effect of the project on dissolved oxygen saturation concentration, the results of the temperature analysis were used. The largest (though highly uncertain and likely to be biologically insignificant) temperature effect was observed on Thornton POA1 (+0.17 °C). The average daily maximum stream temperature for Thornton POA1 is 15.3 °C. The difference between the saturation concentrations associated with 15.3 and 15.47 °C is 0.036 mg/L. Based on this, it is concluded that the project would not increase or decrease dissolved oxygen concentrations at any POA a significant amount by affecting stream temperature.

King County's pilot testing of a membrane bioreactor system showed reduction of BOD concentrations from 180 mg/L to less than 2 mg/L (King County 2004). This is remarkable BOD removal performance, even among the BOD effluent concentrations observed in other advanced treatment systems reviewed by Metcalf and Eddy (1991). Since a BOD concentration in effluent of less than 2 mg/L is not that much greater than probable stream BOD concentrations and the worst case scenario for return flow amounts to less than 3.5 percent of total flow (shown in the following section), it is concluded that the BOD in return flow would not have a significant effect on instream dissolved oxygen. It is acknowledged, however, that return flow could have an indirect effect on stream BOD and dissolved oxygen by affecting stream phosphorus concentrations and the resulting algae growth (discussed below).

Phosphorus and Copper

Table 9 below compares the pre- and post-project stream flows at each POA. These comparisons are made for average base flow during dry weather only and average total flow during the entire irrigation season. It also lists the project's reclaimed water irrigation amounts upstream of each POA. As described above, a "worst case" scenario for return flow was developed by assuming that 5 percent of irrigation flow discharges to streams without removal of pollutants. The table shows that if return flow averages 5 percent of irrigation, it will be relatively small percentage of total stream flow. Specifically, return flow to Thornton and McAleer Creeks would be less than 1 percent of the stream flow, and return flow to Licton Springs would be 3.3 percent of the stream flow.

Table 9. Estimated worst case scenario for irrigation return flow.

POA	Base Flow (cfs)		Total Flow (cfs)		Irrigation Flow (cfs)	Worst Case Scenario for Return Flow[a] (cfs)	Worst Case Scenario for Return Flow (Percent of Total Flow After Project)
	Before Project	After Project	Before Project	After Project			
Licton Springs (LS- POA1)	0.05	0.28	0.56	0.79	0.53b	0.027	3.34%
McAleer Creek (MC-POA1)	2.02	2.23	3.45	3.67	0.32c	0.016	0.44%
McAleer Creek (MC-POA2)	6.46	6.68	7.74	7.95	0.32c	0.016	0.20%
Thornton Creek (TC-POA1)	0.84	1.10	1.30	1.56	0.26d	0.013	0.82%
Thornton Creek (TC- POA2)	1.30	1.56	2.78	3.04	0.26d	0.013	0.42%

[a] Irrigation amount times 5 percent

[b] includes Evergreen Washelli as upstream irrigator

[c] includes Nile Country Club and Holyrood as upstream irrigators

[d] includes Jackson Park Golf Course as upstream irrigator

Table 10 shows the impact of potential return flow on stream phosphorus and copper concentrations. The table shows little to no impact on stream copper and hardness concentrations. This is because the reclaimed water copper and hardness concentrations are within an order of magnitude of the background stream water copper and hardness concentrations. For total phosphorus, 5 percent return flow would increase concentrations in the stream by 4 to 7 percent (3 to 6 ug/L). For orthophosphate phosphorus, return flow would increase concentrations in the stream by 8 to 14 percent (3 to 6 ug/L). An increase in orthophosphate phosphorus concentrations of this magnitude would likely result in increased attached algae growth and may reduce the dissolved oxygen concentrations from algae decay. It is important to note that concentration increases would not necessarily persist all irrigation season: they would occur as long return flow enters streams, an event that is shorter-lived than the entire irrigation season.

Table 10. Return flow impacts on streamwater phosphorus and copper concentrations

	Total Phosphorus (ug/L)	Orthophosphate (ug/L)	Total Copper (ug/L)	Dissolved Copper (ug/L)	Hardness (mg/L as $CaCO_3$)
Base Case Stream Concentrations					
McAleer Creek (MC-POA2)	67	39	3.2	0.58	22.3
Thornton Creek (TC- POA3)	82	44	8.1	2.6	16.8
Reclaimed Water Concentrations					
	1,500[b]	1,500[b]	11[d]	11[c]	31.2[e]
Estimated Stream Concentration With 5 Percent Return Flow					
McAleer Creek (MC-POA2)	70	42	3.2	0.60	22.3
Thornton Creek (TC- POA3)[a]	88	50	8.1	2.6	16.9

[a] Since no analysis of project impacts on flow was completed for TC-POA3, these calculations are based on flow augmentation calculated for Thornton Creek POA2

[b] Source: King County (2005)

[c] Source: Data source: Ecology's Water Quality Permit Life Cycle System (WPLCS) database, discharge monitoring reports provided by permittees, and Water Quality Program permit managers.

[d] Since effluent is from a membrane bioreactor, the total copper concentration in effluent assumed to be same as dissolved copper concentration.

[e] Source: King County (2004)

It is notable that even though the project is unlikely to affect copper concentrations, it will likely increase copper loading to Lake Washington. This is because the copper concentration will remain unchanged while the flow rate will increase 3 and 20 percent for McAleer Creek (POA2) and Thornton Creek (POA2), respectively. Similarly, the loading rate for phosphorus to Lake Washington will likely increase because of increased concentrations and increased flow rates. The increased loading of copper to Lake Washington from the project is considered relatively insignificant because the summer (dry season) flows and loads from McAleer and Thornton Creeks are a relatively small portion of the winter (wet season) flows and loads to Lake Washington. While this may also be said for phosphorus, the high potential for impacts to Lake Washington from increased dissolved phosphorus loading during the summer algae growing season may warrant further analysis using a lake modeling approach.

Implications

Extent of the Benefits/Impacts

In summary, no project water quality benefits or impacts were identified for temperature. Dissolved oxygen is unlikely to be affected by base flow augmentation or by direct BOD loading. Copper concentrations in stream are unaffected by the project's worst case scenario for return flow, but orthophosphate phosphorus concentrations may increase by 8 to 14 percent under the same scenario. It is likely that this increase in phosphorus concentration would increase primary productivity (algae growth) of the stream, which could result in dissolved oxygen decreases in stream, but modeling this collection of processes is considered beyond the scope of this analysis. Slight increases in loading rates of phosphorus and copper to Lake Washington are expected, but these are likely a small portion of the total annual loads of these constituents to this large water body.

Post-Project Conditions in the Future

It is assumed that this characterization of project water quality benefits and impacts will be valid for the planning horizon of the project. Over time, after many years of reclaimed water application, there is increased potential for contaminant breakthrough from loaded soils and increased stream water contaminant concentrations. It is assumed, however, that this breakthrough will be small enough to be included within the increased contaminant load predicted for 5 percent return flow.

<u>Habitat Area</u>

This section presents the methods and results for establishing the post-project aquatic habitat area and conditions at specific POAs in the three basins that contain SSIs: McAleer Creek, Thornton Creek, and Densmore Drainage basins. Habitat area was analyzed to evaluate the potential benefits that result at each POA if SSIs reduce their surface water or groundwater withdrawals and use reclaimed water from the proposed Brightwater system. This analysis was conducted to estimate post-project aquatic habitat area, and relative change from base case conditions, that would be expected as a result of the project.

As with the Task 3 analysis, the SSIs covered in this aquatic habitat analysis include:

- Nile Country Club and Holyrood Cemetery (McAleer Creek basin)
- Evergreen Washelli Cemetery (Densmore basin, which includes Licton Springs)
- Jackson Park (Thornton Creek basin)

The POAs, generally downstream of the SSIs, are shown in Figure 3: McAleer Creek (MC-POA1 and MC-POA2), Thornton Creek (TC-POA1 and TC-POA2), and Licton Springs (LS-POA1).

Methods of Analysis

The Task 3 Technical Memorandum: Base Case Conditions, identifies the methods of analysis used to characterize existing habitat area conditions in service area watersheds, including use of wetted area. The same methods are used to characterize watershed habitat area conditions due to the effects of the retail reclaimed water project, with minor variations. These include:

- The calculation inputs (e.g., predicted post-project baseflow values) are referenced from the results of the benefit analysis (*Hydrologic and Hydrogeologic Conditions* section) as opposed to the base case analysis.
- Estimated changes in habitat are applied to the stream segments indentified in the base case analysis (Task 3 Technical Memorandum: Base Case Conditions, Habitat Area), which are considered generally representative of, and associated with, the POAs in the analysis.

To evaluate post-project conditions and potential changes in aquatic habitat area, two parameters provided the basis of this analysis:

- Wetted cross-sectional area
- Wetted surface area

As with the Task 3 analysis, Aquatic habitat area is described quantitatively based on analysis of relevant baseflow (*Hydrologic and Hydrogeologic Conditions* section) and the fluvial geomorphology of the channel, including wetted width and depth based on estimates and actual field measurements (cross sections) associated with each POA (Task 3 Technical Memorandum: Base Case Conditions, *Habitat Area*).

This analysis also qualitatively describes the post-project habitat conditions at the POAs downstream of the SSIs to put these indicators into the context of general habitat conditions (see *Overall Watershed Environmental Conditions*), and to further describe the quantitative results presented here, in the context of their potential benefits to species or habitat. Post-project habitat conditions are thus described based on the predicted post-project conditions, or expected change from base case conditions, resulting from increased aquatic wetted cross-sectional area and surface area, as well as qualitative field observations regarding current conditions (Task 3 Technical Memorandum: Base Case Conditions).

General habitat conditions are evaluated and discussed further (with regard to the relationships between post-project baseflows, water quality conditions, and habitat area) in the section, *Overall Watershed Environmental Conditions*.

Use of Wetted Area in Estimating Post-Project Conditions

The Task 3 Technical Memorandum: Base Case Conditions discusses the use of wetted area in estimating post-project conditions, including the use of wetted cross-sectional, wetted surface area, and qualitative observations of habitat conditions.

The stream reach that is considered representative of, and associated with, each POA is listed in Table 11.

Table 11. Stream reach lengths associated with each POA.

Associated Point of Analysis (POA)	Stream Reach Length (feet)	Approx. Distance from Self Supplied Irrigator (SSI) (feet)	Upstream Extent	Downstream Extent
Licton Springs (LS- POA1)	715	5,200	Culvert inlets at N 97th St	Culvert outlet at intersection of N 95th St and Woodlawn Ave N
McAleer Creek (MC-POA1)	600	4,000	Confluence with upstream tributary	Estimated upstream limit of backwater influence from the culvert at 15th Ave NE
McAleer Creek (MC-POA2)	2,350	17,200	Confluence with upstream tributary	Estimated upstream limit of backwater influence from the culvert at NE 170th St
Thornton Creek (TC-POA1)	780	300	Golf course bridge	Estimated upstream limit of backwater influence from the culvert at 10th Ave NE
Thornton Creek (TC- POA2)	1,064	12,000	Stormwater inputs at NE 113th St	Confluence of north and south branches of Thornton Creek

Data Availability and Data Quality

The Task 3 Technical Memorandum: Base Case Conditions, identifies the availability and quality of data used to estimate base case and post-project habitat area conditions in the service area watersheds.

Important Assumptions

The Task 3 Technical Memorandum: Base Case Conditions, identifies the important assumptions used to estimate base case and post-project habitat area conditions in the service area watersheds.

Post-Project Results

Species presence for each POA is summarized in Table 12 where "X" indicates likely presence. In order to present concisely the broad range of species, and because a comprehensive list of individual species could not be reasonably attained or included in the scope of the analysis, species are grouped in the table and described in more detail where appropriate below.

Table 12. Species occurrence for POAs included in the habitat area analysis.

Point of Analysis (POA)	Amphibians	Aquatic Invertebrates	Birds	Salmonids	Other Fish
Licton Springs (LS- POA1)	X	X	X		
McAleer Creek (MC-POA1)	X	X	X	X	X
McAleer Creek (MC-POA2)	X	X	X	X	X
Thornton Creek (TC-POA1)	X	X	X	X	X
Thornton Creek (TC- POA2)	X	X	X		X

A comparison of wetted widths and depths for base case and post-project conditions calculated by Herrera for each POA are shown in Table 13. Additional information regarding the post-project cross-sections at each POA is included in the attached spreadsheets (Appendix A).

Table 13. Average post-project base flows and habitat areas for each POA.

Point of Analysis (POA)	Base Case Wetted Width (ft)	Post-project Wetted Width (ft)	Change in Wetted Width (ft)	Percent Change in Wetted Width (%)	Base Case Averag e Depth (ft)	Post-project Averag e Depth (ft)	Change in Averag e Depth (ft)	Percent Change Averag e Depth (%)
Licton Springs (LS-POA1)	3.80	3.80	0.00	0.00	0.03	0.10	0.07	233.33
McAleer Creek (MC-POA1)	6.93	7.03	0.10	1.44	0.23	0.24	0.01	4.35
McAleer Creek (MC-POA2)	16.38	16.43	0.05	0.31	0.27	0.27	0.00	0.00
Thornton Creek (TC-POA1)	10.74	11.17	0.43	4.00	0.12	0.14	0.02	16.67
Thornton Creek (TC-POA2)	7.55	8.14	0.59	7.81	0.18	0.19	0.01	5.56

Across all POAs, the estimated increase in wetted width is relatively small (>0.6 feet) but the percent increase in wetted width ranges from approximately 0% to 7.8%. The percent increase in average depth for Licton Springs (LS-POA1) suggests a relatively substantial (233%) change from base case conditions compared to the other POAs (ranging from approximately 0.0 to 16.7 percent). This is likely due to a combination of several factors including channel geometry, relatively low base case flow of 0.28 cfs (see *Hydrologic, Hydrogeologic, and Hydraulic Conditions*), an average base case depth of 0.03 feet, and the relative increase in the flow expected as a result of the project (0.28 cfs compared to 0.05 cfs, see *Hydrologic, Hydrogeologic, and Hydraulic Conditions*).

The comparison of wetted cross-sectional area and surface area associated with each POA, and the anticipated change between base case and post-project conditions are shown in Table 14.

Table 14. Comparison of base case and post project wetted cross-sectional area and wetted surface area at each POA.

Point of Analysis (POA)	Base Case Wetted Cross-Sectional Area (sf)	Post-project Wetted Cross-Sectional Area (sf)	Change in Wetted Cross-sectional Area (sf)	Percent change in Wetted Cross-sectional Area (%)	Base Case Wetted Surface Area (sf) a	Post-project Wetted Surface Area (sf) a	Change in Wetted Surface Area (sf)	Percent Change in Wetted Surface Area (%)
Licton Springs (LS-POA1)	0.10	0.38	0.28	280.00	190.00	190.00	0.00	0.00
McAleer Creek (MC-POA1)	1.59	1.69	0.10	6.29	346.75	351.50	4.75	1.37
McAleer Creek (MC-POA2)	4.36	4.45	0.09	2.06	819.19	821.50	2.31	0.28
Thornton Creek (TC-POA1)	1.30	1.53	0.23	17.69	536.86	558.50	21.64	4.03
Thornton Creek (TC-POA2)	1.36	1.53	0.17	12.50	377.47	407.00	29.53	7.82

[a] Channel segment length (50 feet) was assumed for each POA to derive wetted surface area. Wetted surface area was calculated by multiplying POA channel segment length by wetted width of the corresponding POA in Table 13.

The expected increase in wetted cross-sectional area ranges between 0.09 and 0.28 square feet across all POAs. The percent increase ranges between 2.06 percent and 17.69 percent with the exception of Licton springs (280%) which is reflective of the change in depth and those associated factors described above for the Licton Springs POA. The estimated increase in wetted surface area across all POAs is between zero (LS-POA1) and approximately 30 feet, or roughly 7.8 percent (TC-POA2).

The Task 3 Technical Memorandum: Base Case Conditions presented a log of photos showing existing habitat conditions, and describes the existing habitat at POAs on McAleer Creek and Thornton Creek obtained through visual observations. These descriptions provide a basis for the following analysis of likely habitat improvements due to increased post-project base flow.

Implications

Extent of the Benefits

The results of this analysis suggest small increases in aquatic habitat area will occur at each POA as a result of the proposed project. The small increases are unlikely to significantly alter general habitat conditions. The potential benefit of this increase is discussed in more detail later in this memorandum (*Overall Post-Project Watershed Conditions*). Increases in aquatic area (i.e., wetted width and depth) must also be considered relative to current conditions and, more importantly, to how those conditions will change in regard to habitat function and species utilization. This is because an increase in habitat area, in relation to habitat function or biological benefit, is not linear. Therefore it is also not easily extrapolated to larger areas (i.e., reaches or basins) based on cumulative addition of small increases expected for a single cross-section. A particular increase in area, regardless of its relevant size to base case conditions, must be compared to its overall affect on habitat, productivity, and biological processes. For example, to what extent the area improves spawning, refuge, foraging, or other conditions necessary for survival.

That being said, and to the extent that the POA channel length and cross-sectional area used in this analysis are representative of the stream reaches associated with each POA (as identified in the evaluation of base case conditions), applying the estimated percent change in wetted surface area for each POA to the stream reaches results in a rough estimate of the potential increase in habitat area that might be expected for that reach under post-project conditions. The estimated increases are shown in Table 14.

Table 15. Estimated increase in wetted surface area for stream reaches considered associated with each POA.

Point of Analysis (POA)	Reach Length (ft)	Percent Change in Wetted Surface Area (%) [a]	Estimated Increase in Wetted Surface Area (sf)
Licton Springs (LS-POA1)	715	0.00	0
McAleer Creek (MC-POA1)	600	1.37	822
McAleer Creek (MC-POA2)	2,350	0.28	663
Thornton Creek (TC-POA1)	780	4.03	3144
Thornton Creek (TC-POA2)	1,064	7.82	8324

[a] Value from Table 14, Percent Change in Wetted Surface Area.

As stated before, the expected increase in wetted width is small (less than 0.6 feet in all cases), while increases in average depth is also expected to be small; less than 0.1 feet (at Licton Springs), and at most 0.02 feet in all other cases. The relatively small increases in depth and width equate to equally small increases in aquatic habitat area, and are unlikely to significantly alter conditions in the context of general habitat function or biological productivity.

Although the analysis indicates an overall increase in habitat area for each reach associated with the McAleer and Thornton Creek PAOs (Table 15), it does not indicate whether the additional habitat area would be more or less suitable for specific species or life history stages, particularly in the case of salmonid species. This represents a potential limitation, or data gap, to be considered in the comparison of alternatives to be completed under Task 7.0 – Evaluate Reclaimed Water Project and Alternatives.

Additionally, it does not directly indicate changes in habitat quality (as opposed to quantity) that might occur as a result of the increased baseflows and associated increased habitat area. The following section, *Overall Watershed Environmental Conditions*, describes in the context of habitat quality the relationships between baseflow, water quality, and habitat area, and the potential implications, or benefits, of altering these habitat features as a result of the proposed project.

Post-Project Conditions in the Future

As described for base case conditions in Task 3, habitat area is closely linked with flow regime and habitat structure. Changes in these features may affect habitat area (i.e., quantity) as well as habitat quality, or the area's suitability for various species. Factors influencing wetted habitat area include those that are expected to be relatively stable and constant over a 20-year or greater time span; watershed geology, topography, soil permeability, and climate. Wetted habitat area may also be affected by stressors associated with urbanization or management actions such as channel and riparian modifications, changes in water withdrawal, introduction of non-native species, changes in land use, and stormwater runoff.

Barring significant channel modification or restoration action, as well as any significant changes in land use, the extent of impervious surface, or water appropriation and usage; post-project conditions in the future (i.e., over the long term) are expected to be similar to the short term conditions expected as a result of the project.

Overall Post-Project Watershed Environmental Conditions

This section describes overall anticipated post-project environmental conditions for each watershed (Densmore drainage basin, McAleer Creek, and Thornton Creek). As with the Task 3 analysis, conditions in this analysis are described based on three categories: hydrologic, hydrogeologic, and hydraulic conditions; water quality; and wetted habitat area. The interrelated roles of the three categories of analysis are first summarized in the context of general habitat and potential benefits based on best available science, project experience, and professional opinion (*Environmental Interactions and Background*), and then described more specifically in regard to the anticipated post-project benefits within the discussion for each basin (*Extent of the Benefits*).

Environmental Interactions and Background

As previously described in the analysis of base case conditions, the service area watersheds are currently impacted by elements commonly associated with urbanization. These include surface water withdrawal, groundwater withdrawal, and dense storm drain systems that convey peak flows directly to streams rather than allowing the runoff to infiltrate and recharge base flows.

Use of reclaimed water by the SSIs in order to reduce their surface water or groundwater withdrawals could result in potential improved habitat benefits for various species. Improved conditions are expected to result from increased baseflows during dry periods, improved water quality, and increased aquatic habitat area. Restoring the routing and timing of channel flows and increasing groundwater inflow contribute to the uniform distribution of streamflow and can produce more stable seasonal temperatures, higher dissolved oxygen during summer, and stable habitat volume (Konrad and Booth 2005).

Increased flow can directly benefit species by increasing the amount of available habitat. Depending on specific conditions on the watershed, reach, or micro-habitat scale, the additional area may provide additional spawning potential, refuge, or foraging opportunity (i.e., increased food production).

For example, increases in wetted depth and width may result in hydraulic connections to off-channel features, or increase the amount of backwater habitat, or improve access to sheltered slack water habitat that is suitable for rearing (e.g., resting and foraging). Improved access to these areas, which often contain habitat for aquatic vegetation and benthic algae, can provide additional refuge and foraging areas for species including cutthroat trout, sculpins, sockeye and coho salmon, and dace. These species have been shown to commonly use vegetated habitat in off-channel areas (Pollock et al. 2003), and would likely benefit to the extent that the species are present (see discussion of base case conditions, Task 3 Technical Memorandum: Base Case Conditions, *Habitat Area*) and to the extent that increased flows provide connectivity and access to backwater habitat or additional food base.

The increase in wetted area may also increase the size of the hyporheic zone, an important element of stream hydrology and ecology. The zones of stream water within streambed sediments contribute to temperature regulation, filtering, and nutrient cycling. The hyporheic zone affects stream chemistry and biological production, and can be important for fish species because, for example, downwelling can provide cooler water, provides oxygen to eggs, and filters fine sediments.

Increased summer baseflow contributes to reduce stream temperatures. This is because shallow waterbodies (i.e., urban streams with reduced baseflow) are susceptible to rapid heating from exposure to sun, and to heated ambient air and soil. As described previously, increasing the baseflow is expected to reduce the surface area to volume ratio, particularly in urban streams where the channel is frequently confined. This, in turn, may increase the thermal mass of the stream, and reduce the potential for heating. Increased (i.e., restored) groundwater contributions, which are typically cooler than surface water, may also reduce stream temperatures. Reduced temperatures can, in turn, result in an associated increase in dissolved oxygen (see Task 3 Technical Memorandum: Base Case Conditions, *Water Quality, Methods of Analysis, Dissolved Oxygen*). The effects of temperature, in combination with dissolved oxygen and pollutant levels, are all important for fish productivity, health, and survival (Beacham and Murray 1990; Black et al. 1991; Greig et al. 2007; Harrahy et al. 2001; Poole et al. 2001).

Extent of the Benefits

This section describes the extent of the specific anticipated benefits due to the North Seattle reclaimed water project, with discussion for each basin analyzed. The benefit that can be obtained from increased flow or wetted area is related to not only increased volume, but also the extent to which the additional water provides suitable habitat, or alters conditions to be more functional from a biological perspective. Given the current conditions, and minor and likely insignificant increases in base flow, water quality parameters, and habitat area that are expected from the project at each POA, the beneficial change in general conditions is likely to be insignificant. Additional details to support this assessment are provided in the following subsections.

The results of the analysis performed indicate that increases in baseflow will result in increased wetted area across all POAs, which can directly benefit fish, birds, and other wildlife by increasing the amount of available aquatic habitat. However, the increases in habitat area (see *Habitat Area* section, *Results*) indicate that at the POAs examined, the project would result in minimal benefit to species, limited to the extent that the species are present (have access to the area), and to the extent that the additional area is suitable for utilization by those species. The extent to which increased wetted area improves habitat, and subsequently results in the benefits described above, is likely to be insignificant at the POAs included in this analysis but could potentially be more significant on a cumulative scale. The scope and methods of the analysis prevent a comprehensive quantitative assessment of cumulative benefits.

Although potential improvements in water quality (e.g., reduced temperature and increased dissolved oxygen) are frequently associated with increases in wetted area as described above, this analysis indicates that benefits related to water quality improvements are not anticipated for the McAleer Creek and Thornton Creek POAs (see *Water Quality, Implications, Extent of the Benefits/Impacts*), and are uncertain (primarily due to the lack of base case water quality data) for Licton Springs in the Desnmore Basin.

Licton Springs

The Licton Springs POA is expected to experience an increase (0.23 cfs) in base flow to 0.28 cfs under post-project conditions compared to 0.05 cfs under base case conditions. The increase is reflective of the fact that Licton Springs is within a fairly small watershed that is highly influenced by the urban storm drainage system and associated runoff, as well as groundwater inflows. Surface water associated with the POA (which contains habitat that would potentially benefit from increased flow) consists of approximately 700 feet of stream located within the Licton Springs Park between culvert inlets at North 97th Street and a culvert outlet at the intersection of North 95th Street and Woodlawn Avenue North. The increase in flow results in primarily increased depth (estimated average depth of 0.10 feet compared to 0.03 feet under base case conditions) and little or no increase in wetted surface area. The increase in base flow and depth may indirectly help to improve water quality through groundwater interactions.

Water Quality data were not available for Licton Springs and thus quantitative evaluation of potential impacts related to water quality were not included in the analysis. However, given the relative increase in baseflow and the fact that it would be entering as groundwater (which is typically cooler than surface water during the irrigation season), it is reasonable to expect a potential increase in functional habitat area for certain species, and perhaps an associated change in water temperature. The extent to which increased depth, or altered temperature or other parameters of water quality would benefit species is unclear, but would likely be minor and limited to macroinvertebrates, amphibians, reptiles, and birds due to a lack of habitat connectivity and barriers to fish passage.

McAleer Creek

The McAleer Creek POAs are expected to experience increased base flows as a result of the project; an estimated 0.21 cfs increase at the upstream POA (MC-POA1) and 0.20 cfs increase at the downstream POA (MC-POA2). The associated increases in habitat area are approximately 1.7 square feet and 4.5 square feet in cross-sectional area at each POA respectively, and 4.8 square feet (MC-POA1) and 2.3 square feet (MC-POA2) increases in wetted surface area. This represents a minor and likely insignificant increase in habitat area to the extent that it is suitable for the species occurring in this watershed.

Currently, reduced baseflows could cause a decrease of suitable spawning velocities for salmon and trout (see Task 3 Technical Memorandum: Base Case Conditions, *Habitat Area*, Table 15). In general, the estimated average velocities for MC-POA1 and MC-POA2, 1.3 and 1.5 f/s respectively, are relatively close to the minimum velocities preferred by these species. These are average velocities for the cross-sections surveyed and are not assumed to represent a limitation on spawning. Clearly, the range of velocities and geographic extent of areas containing suitable spawning velocities would need to be considered in order to quantify the condition or current limitations within the basin in this regard. It may however, be used as an indicator of the base case condition, in general, for the POAs. Minor increases in average velocity (0.05 and 0.02 f/s at each POA in McAleer Creek) that are expected as a result of increased base flows, in combination with additional wetted habitat area and depth, could improve conditions for spawning. However, the extent to which this represents a benefit is also likely to be incremental minor and remains largely unknown within the scope of this analysis.

Analysis of flow and temperature data (see *Water Quality, Post Project Results, Stream Temperature*) indicate that the project will result in an increase (albeit, small increase) in water temperature at MC-POA2 as a result of the project (+0.009 °C). The fact that an increase is predicted may indicate a limitation for applying the regression model (based on daily maximum air temperature and daily mean stream flow) to the streams considered in this analysis. However, as previously stated, the analysis also suggests that temperature is not highly sensitive to flow. In other words, the results indicate that current shallow conditions, and relatively similar shallow conditions expected under post-project flows, do not differ enough to affect temperature to any considerable degree. Therefore, no impact on stream temperature is expected as a result of the project.

Thornton Creek

Base flows in Thornton Creek are expected to increase an estimated 0.26 cfs (TC-POA1 and TC-POA2) from base case conditions. The analysis indicates that Thornton Creek (TC-POA1) would experience an increase in average depth of approximately 13 percent, and an increase of

4.6 percent at TC-POA2. This equates to increases of approximately 0.2 square feet in wetted cross-sectional area, and increases of 22 and 30 square feet in surface area (based on an increase of 0.4 feet in wetted width at TC-POA1 and 0.6 feet in wetted width at TC-POA2). However, the analysis of water quality parameters (*Water Quality, Post-Project Results*) suggest the increase in flow will not result in reduced water temperature or increased dissolved oxygen. As with the McAleer Creek Basin, small increases in wetted surface area, and small increases in depth and velocity (estimated increase of 0.07 f/s and 0.06 f/s in average velocity at each site), could represent minor benefits to aquatic species to the extent that the additional areas improve conditions and the species are present. Increases in area and associated altered habitat conditions are expected to be minor at each POA, but may be greater across multiple locations throughout the stream (i.e., on a cumulative scale).

Summary of Post-Project Benefits

Licton Springs is expected to experience little post-project benefit with regard to overall habitat condition. Improvements to water quality (e.g., temperature) potentially resulting from groundwater contribution remains unknown. However, current conditions including heavy impacts from urbanization and the fragmented (i.e., isolated) habitat reduce the potential for significant improvements in habitat to result from increased base flow.

McAleer Creek will experience a minor increase in baseflow. The increase in baseflow will likely result in minor benefit to fish species with regard to rearing, refuge, and spawning habitat conditions. However, the increase and habitat improvements are not expected to significantly alter water quality, or biological productivity because the minor improvements are unlikely to significantly alter overall habitat conditions from their current state.

Similarly, Thornton Creek will also experience minor habitat improvements, but no significant improvement to water quality, as a result of increased flows. The significance of habitat improvements is limited to small increases in wetted area and associated minor improvements to rearing and spawning habitat conditions. The altered habitat conditions, however, are not expected to result in significant increases in biological productivity because overall habitat conditions are not expected to significantly change from current conditions.

Habitat improvements expected from the project, although minor at each POA and likely insignificant in regard to biological productivity and species survival and success, may be considered as a baseline for alternatives with potentially similar minor benefit. Although the post-project benefits are limited, it is likely that the benefits would be more substantial in the context of cumulative efforts to restore base flows or associated habitat conditions. This may be an important consideration in evaluating the overall benefit of the project relative to alternatives.

Additionally, although the parameters examined here suggest limited benefit in their own context, hydrologic restoration (i.e., restoration of base flows) may have different value relative to alternatives that aim to achieve the same environmental benefits or habitat improvements but through other means. This is, in part, because hydrological impairments may limit the success of restoration efforts in some urban streams (Konrad and Booth 2005). For example, reduced flows may limit the beneficial functions of large woody debris (the addition of which is a common restoration action). Reduced flows may inhibit the potential habitat and water quality benefits of the in-stream large woody debris. Benefits which may be limited include; the creation of a complex depositional environment (which can regulate the transport of sediment, gravel, organic matter, and nutrients), increased floodplain connectivity, increased periphyton growth and secondary production, increased nutrient uptake, and reduced eutrophication of downstream waters, among other benefits. Conversely, increasing base flow may represent an improvement in the natural processes that lead to benefits in water quality and habitat which are associated with large woody debris presence. A similar relationship between flow and other restoration projects, such as wetland vegetation enhancements, may also represent potential cumulative benefits from increased base flow.

In evaluating alternatives, policy makers should therefore consider the potential cumulative effects of the project not fully addressed in this analysis, including the benefits potentially achieved in combination with existing restoration projects, as well as the geographic scale of the project relative to alternatives.

Post-Project Conditions in the Future

Environmental conditions are closely linked between flow regime, water quality (e.g., temperature, dissolved oxygen, and pollutant levels), and habitat structure. Changes in these features may affect habitat quantity and quality, as well as the area's suitability for various species. However, in the absence of significant restoration action or changes in land use, the primary stressors assumed to have the most influence on the current environmental conditions (i.e., stressors that are associated with urban environments) are expected to remain relatively constant. Variation of irrigation flows, precipitation, evapotranspiration, air temperature, length of duration of wet and dry seasons, or other weather changes due to climate are not considered in this analysis, though generally speaking, conditions are not likely to improve as the result of climate change.

Given the nature and level of development within the watersheds, significant changes in the amount or type of stressors are unlikely, and are not expected to alter post-project conditions associated with the project. However, the cumulative effects of future restoration efforts that improve flow regimes (including baseflow), if implemented, could indirectly affect the overall success of the project, other restoration efforts, and the resulting conditions.

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Appendix J

Survey of Potential Reclaimed Water Customers

Name of Potential Reclaimed Water Customer:_________________________________

Contact Person/Title:__________________________________Phone:______________

Prior Information:

Irrigation Water Source: ____SPU ____Shoreline ____Well ____Surface Water

Total acreage:__________ Acreage or % irrigated:__________

Average Peak Season Water Used for Irrigation:________________CCF __________MGD

Introduction:

Hello, my name is __________ with Seattle Public Utilities and I'm calling because we are exploring the market for reclaimed water in north Seattle and Shoreline. [Could I speak to the person most familiar with your irrigation system and the source of water used for irrigation?] By reclaimed water, I mean "wastewater that has been treated to such a high level, that it is considered safe by the Washington State Department of Health for beneficial uses such as irrigation, heating and cooling, and industrial processing.

Based on an analysis of land use in this area, you have been identified as a potential user of reclaimed water that may become available from the Brightwater wastewater treatment plant in the future. We are conducting a survey of major irrigators in order to assess the potential demand for reclaimed water in the area, gain an understanding of current sources of irrigation water, and gauge the interest of potential customers in using reclaimed water. The information you and others provide will ***only*** be used to help us figure out the benefits and costs of bringing reclaimed water to this area. In no way will responding to our questions obligate you to participate in the reclaimed water project under consideration.

Do you have a few minutes to answer our questions?

1) Do you currently irrigate any of your property? ______Yes ______No

2) Do you know the size of your property? (How many acres?)________________________

3) How many acres (or what percent) of your property do you irrigate?__________________

4) What do you irrigate? ____ Crops ____Grass ____Landscaping ____Other

5) Where do you get your water?

for irrigation	for other purposes	
____	____	Local water utility (name?______________________)
____	____	Own source: ground water
____	____	Own source: surface water (name of lake or stream)
		____

6) *If own source, ask:* Is the point of withdrawal on your own property? _____Yes _____No

If not, where is it? ____

7) Is the water you use for irrigation metered? _____Yes _____No

If not, how do you measure or estimate how much water you use for irrigation?______________

____

____

____

8) Are you irrigating as much as you would like? _____Yes _____No

If not, why not?____

____

____

9) Do you have any plans that would either increase or decrease how much you irrigate (such as future expansion, addition of soccer fields or conversion of grass sports fields to turf, etc.)?

______Yes ______No

If yes, please describe:____

____

____

Next, I'd like to ask some questions about how much water you use for irrigation in an average year. (Note that the summer of 2007 had close to average weather, 2003, 2004 and 2006 were hotter and drier than normal, and 2005 was cooler and wetter than normal.)

10) What is your maximum instantaneous rate of application?______________________________

____

11) How much water do you use (or how many hours do you irrigate) in your peak day_______

____

____

12) Do you know the total amount of water you use over the entire irrigation season? _________

____

____

13) Over what period of time (which months?) do you normally irrigate?____________________

____

____

14) On average, how much water do you use (or how many hours a day do you irrigate) in each month during the irrigation season?

	April	May	June	July	Aug	Sept	Oct
Volume							
Hours							

15) What limits how much water you can use from this source?

____ No limits – our water needs are less than any constraint.

____ Water Right

___ Instantaneous flow constraint (Q_i)

___ Annual volume constraint (Q_a)

____ Pumping capacity

____ Source yield or reliability

____ Cost

____ Other____

16) Can you tell us your estimated annual cost of irrigation water?

Cost of purchased water______________________

Cost of operations (pumping costs, etc.)________________________

17) Do you have any interest in using reclaimed water to supplement or replace your current source of irrigation water? ______Yes ______No

18) What changes would have to be made to your current irrigation system in order to be able to use reclaimed water instead of your existing source?

____

____

____

____

19) Can you estimate what that might cost?____

____

____

20) Would this pose a barrier to converting to reclaimed water? ____Yes ____No

21) What kind of assistance might help overcome this barrier? ____Design Engineering

____Cost Sharing ____Grants ____Loans

____Other____

22) Do you see any advantages to you or others in converting to reclaimed water?

____Yes ____No

If yes, what benefits to you see?

____

____

____

____

23) Do you have any concerns about reclaimed water? (What do you see as its disadvantages?)

____

____

____

____

Lastly, we'd like to get some idea, in a general sense, of how much you might be willing to pay to irrigate with reclaimed water if it were available?

For self-supplied respondents, ask:

24) Would you be willing to pay:
_____Nothing
_____Something, but less than the amount you currently spend producing your own water
_____As much as you now spend producing your own water
_____More than what you spend producing your own water

For those purchasing irrigation water from local utility, ask:

25) Would you be willing to pay:
_____Nothing
_____Something, but less than the amount you currently spend to purchase water for irrigation
_____As much as you now spend to purchase irrigation water
_____More than what you spend to purchase water

Thank you!

Additional Notes:

Survey responses are tabulated below:

	Potential Customer	Bikur Cholim Memorial Park	Herzl Memorial Park	Machzikay Hadath/Seattle Sephardic
	Contact	[redacted]	[redacted]	[redacted]
	Address	1340 N. 115th St.	16747 Dayton Ave N	1214-1230 N 167th St
	Customer Category	Cemetary	Cemetary	Cemetary
1	Do you currently irrigate any of your property?	Yes	Yes	Yes
2	Do you know the size of your property? (How many acres?)	4	5	4
3	How many acres (or what percent) of your property do you irrigate?	100%	5	4
4	What do you irrigate?	Grass	Grass	Grass
5	Where do you get your water?	Well & public water	Well & public water	Well & public water
6	If you own your source, is the point of withdrawal on your own property?	Yes	Yes	Yes
7	Is the water you use for irrigation metered?	No	Yes	No
8	Are you irrigating as much as you would like?	No - limit on well. Public water expensive	No - limit on well. Public water expensive	Limitations on the well
9	Do you have any plans that would either increase or decrease how much you irrigate (such as future expansion, addition of soccer fields or conversion of grass sports fields to turf, etc.)?	Yes, maybe	No	Yes - may increase property
10	What is your maximum instantaneous rate of application?	Unknown	Unknown	Unknown
11	How much water do you use (or how many hours do you irrigate) in your peak day?	5 hours	5 hours	5 hours
12	Do you know the total amount of water you use over the entire irrigation season?	No	No	No
13	Over what period of time (which months) do you normally irrigate?	May-October	May-Oct	May - Oct
14	On average, how much water do you use (or how many hours a day do you irrigate) in each month during the irrigation season?			
15	What limits how much water you can use from this source?	Pumping Capacity/yield/reliability	Exempt well	Exempt well
16	Can you tell us your estimated annual cost of irrigation water?			
17	Do you have any interest in using reclaimed water to supplement or replace your current source of irrigation water?	Yes	Yes	Yes
18	What changes would have to be made to your current irrigation system in order to be able to use reclaimed water instead of your existing source?		Replumb	Replumb
19	Can you estimate what that might cost?		?	?
20	Would this pose a barrier to converting to reclaimed water?	No	No	No
21	What kind of assistance might help overcome this barrier?			
22	Do you see any advantages to you or others in converting to reclaimed water?	Supplement existing onsite source, cheaper than city	Supplement existing onsite source, cheaper than city	Supplement existing onsite source, cheaper than city
23	Do you have any concerns about reclaimed water? (What do you see as its disadvantages?)			
24	If you are a self-supplied respondents: Would you be willing to pay:	Less		Something but less then city water
25	If you purchase irrigation water from local utility: Would you be willing to pay:			

	Potential Customer	Acacia	Evergreen Washelli	Holyrood
	Contact	[redacted]	[redacted]	[redacted]
	Address	14951 Bothell Way NE	11111 Aurora Ave N	205 Northeast 205th St
	Customer Category	Cemetary	Cemetary	Cemetary
1	Do you currently irrigate any of your property?	Yes	Yes	Yes
2	Do you know the size of your property? (How many acres?)	60	160	80
3	How many acres (or what percent) of your property do you irrigate?	50%	75%	50%
4	What do you irrigate?	Grass, landscaping	Grass, landscaping	Grass, landscaping
5	Where do you get your water?	Wells	Wells- irrigation	Well
6	If you own your source, is the point of withdrawal on your own property?	Yes	Yes	No, on adjacent property they used to own, have easement
7	Is the water you use for irrigation metered?	No	Yes	No
8	Are you irrigating as much as you would like?	Yes	Yes	No, limited by storage capacity
9	Do you have any plans that would either increase or decrease how much you irrigate (such as future expansion, addition of soccer fields or conversion of grass sports fields to turf, etc.)?	No	Yes	No
10	What is your maximum instantaneous rate of application?	Unknown		Unknown
11	How much water do you use (or how many hours do you irrigate) in your peak day?	12 hrs/day		6 hours
12	Do you know the total amount of water you use over the entire irrigation season?	No		No
13	Over what period of time (which months) do you normally irrigate?	May - Sept	May-Oct	May - Sept
14	On average, how much water do you use (or how many hours a day do you irrigate) in each month during the irrigation season?	Unknown		not sure
15	What limits how much water you can use from this source?	None	No limit	Storage, well fills tank, tank pumps to irrigation system,
16	Can you tell us your estimated annual cost of irrigation water?	Unknown		Not sure
17	Do you have any interest in using reclaimed water to supplement or replace your current source of irrigation water?	Yes		Yes
18	What changes would have to be made to your current irrigation system in order to be able to use reclaimed water instead of your existing source?	Replumb connection, verify strength of irrigation system	Replumb. Ensure strength of system	Replumb connection, check out irrigation system
19	Can you estimate what that might cost?	No	Unknown	No
20	Would this pose a barrier to converting to reclaimed water?	Depsnds on status of irrigation system	Unsure	Depends on state of irrigation system
21	What kind of assistance might help overcome this barrier?	Grant, cost sharing	Grant, cost sharing	Grant, cost sharing
22	Do you see any advantages to you or others in converting to reclaimed water?	May be more reliable	Long term water source, however currently have enough water to irrigate everything	steady stream of irrigation water.
23	Do you have any concerns about reclaimed water? (What do you see as its disadvantages?)	High foot traffic, people use the grounds to sit/picnic	Cost possibly?	Possilby cost
24	If you are a self-supplied respondents: Would you be willing to pay:	As much or less	As much or less	As much or less
25	If you purchase irrigation water from local utility: Would you be willing to pay:			

	Potential Customer	Nile Golf & Country Club	Shoreline Parks	Lakeside School
	Contact	[redacted]		
	Address	6601 244Th St SW	City of Shoreline	14050 1st Ave. NE
	Customer Category	Golf Course	Park	School
1	Do you currently irrigate any of your property?	Yes	Yes	Yes
2	Do you know the size of your property? (How many acres?)	90	Various	
3	How many acres (or what percent) of your property do you irrigate?	35	Various	3.5
4	What do you irrigate?	Grass, landscaping	Grass, landscaping	Grass, landscaping
5	Where do you get your water?	Surface water- irrigation	Public water	Public water
6	If you own your source, is the point of withdrawal on your own property?	No - adjacent lake ballinger		
7	Is the water you use for irrigation metered?	No - pump what they need	Yes	Yes
8	Are you irrigating as much as you would like?	Yes	Yes	No, cost
9	Do you have any plans that would either increase or decrease how much you irrigate (such as future expansion, addition of soccer fields or conversion of grass sports fields to turf, etc.)?	No	Converting a few sports fields to turf, also a few new grass fields as a result of a recent park levy	Switching football field to artificial turf.
10	What is your maximum instantaneous rate of application?	Unknown	Variable	Unknown
11	How much water do you use (or how many hours do you irrigate) in your peak day?	Unknown		4-6 hours
12	Do you know the total amount of water you use over the entire irrigation season?	Unknown		Yes, irrigation meter
13	Over what period of time (which months) do you normally irrigate?	July-Sept	Varies - Apr - Oct	Apr - Oct
14	On average, how much water do you use (or how many hours a day do you irrigate) in each month during the irrigation season?			
15	What limits how much water you can use from this source?	No limits	No limits	
16	Can you tell us your estimated annual cost of irrigation water?			$11k
17	Do you have any interest in using reclaimed water to supplement or replace your current source of irrigation water?	No	Some	Some
18	What changes would have to be made to your current irrigation system in order to be able to use reclaimed water instead of your existing source?	Replumb connection. Possible replacement of portions of existing irrigation system due to age	Replumb connection, verify sufficient pressure	Replumb incoming connection, currently upgrading some of irrigation system
19	Can you estimate what that might cost?	Unknown	No	
20	Would this pose a barrier to converting to reclaimed water?	Unsure	Pressure may	No
21	What kind of assistance might help overcome this barrier?	Grant, cost sharing	Grant, cost sharing	
22	Do you see any advantages to you or others in converting to reclaimed water?	Backup supply?	May irrigate more if cheaper	May reduce reliance on drinking water for irrigation, may witness cost savings. Environmental benefit.
23	Do you have any concerns about reclaimed water? (What do you see as its disadvantages?)	Cost?	Public perception, lanscaping easier than sports fileds	Cost. Public perception.
24	If you are a self-supplied respondents: Would you be willing to pay:	As much or less		
25	If you purchase irrigation water from local utility: Would you be willing to pay:		Less	As much or less

Potential Customer		Shoreline Christian	Shoreline Community College
Contact		[redacted]	
Address		2400 NE 147th St	16101 Greenwood Ave N
Customer Category		School	School
1	Do you currently irrigate any of your property?	No	Yes
2	Do you know the size of your property? (How many acres?)	7	83
3	How many acres (or what percent) of your property do you irrigate?	0	10-20%
4	What do you irrigate?	N/A	Grass, landscaping
5	Where do you get your water?	N/A	Public water
6	If you own your source, is the point of withdrawal on your own property?	N/A	
7	Is the water you use for irrigation metered?	N/A	Yes
8	Are you irrigating as much as you would like?	Yes	Mostly
9	Do you have any plans that would either increase or decrease how much you irrigate (such as future expansion, addition of soccer fields or conversion of grass sports fields to turf, etc.)?	No	No
10	What is your maximum instantaneous rate of application?	N/A	Unknown
11	How much water do you use (or how many hours do you irrigate) in your peak day?	N/A	6 hrs
12	Do you know the total amount of water you use over the entire irrigation season?	N/A	could look it up
13	Over what period of time (which months) do you normally irrigate?	N/A	may - oct
14	On average, how much water do you use (or how many hours a day do you irrigate) in each month during the irrigation season?		2-4 on average
15	What limits how much water you can use from this source?		No
16	Can you tell us your estimated annual cost of irrigation water?		Unknown
17	Do you have any interest in using reclaimed water to supplement or replace your current source of irrigation water?		Yes
18	What changes would have to be made to your current irrigation system in order to be able to use reclaimed water instead of your existing source?	Install an irrigation system	Replumb connection, adequate pressure
19	Can you estimate what that might cost?	Unknown	No
20	Would this pose a barrier to converting to reclaimed water?	Yes	Pressure
21	What kind of assistance might help overcome this barrier?	Grant, cost sharing	Grant, cost sharing
22	Do you see any advantages to you or others in converting to reclaimed water?	Not really, do not plan on irrigating	May be less expensive
23	Do you have any concerns about reclaimed water? (What do you see as its disadvantages?)		People perception, if any - may work better for landscaping than grass
24	If you are a self-supplied respondents: Would you be willing to pay:		
25	If you purchase irrigation water from local utility: Would you be willing to pay:		Less