Potential Benefits of Water Supply Regionalization: A Case Study the Seattle and Everett Water Systems

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Abstract

Central Puget Sound includes three of the four largest and fastest growing counties in Washington state: Snohomish, King, and Pierce. Three city public utilities (Everett, Seattle, and Tacoma) supply water from four water reservoirs to most of the population in these counties. These agencies face common challenges, which include meeting increasing instream flow requirements, providing water to growing wholesaler populations and developing new water supply sources. One alternative to costly new water supply development is regionalization: connecting the supply systems, promoting the transfer of water rights and making more efficient use of existing sources. A regional water supply model is presented that evaluates the benefits from interconnecting the three utilities and managing the supply system from a regional perspective. The results indicate that sufficient storage exists in the Everett system to supply the region through 2040 demand projections. An Everett– Seattle intertie (ESI) improves long-term supply availability, provides needed supply redundancy for the Everett system, and can enhance instream flows in the Cedar and South Fork Tolt Rivers. When the intertie is operated only during low flow years, the same water supply benefits are derived, but the enhancement of instream flows is decreased.

Introduction

This paper investigates the use of water supply regionalization to meet increasing water demands. The Puget Sound Region in the Pacific Northwest is experiencing challenges of stricter water quality standards, decaying infrastructure, increasing water demands, and pressure from the implementation of the Endangered Species Act. The region has grown dramatically in the last twenty years. Two droughts (in 1987 and 1992) and their associated water curtailments demonstrated the relative vulnerability of the region to water demands exceeding water supplies. Over 1×10^9 of water supply infrastructure investments have been outlined for the region to meet water quality and water supply goals. Water reuse and conservation have emerged as continued sources of water supply, but new source development is also contemplated. Water supply regionalization represents an emerging alternative to meet many of the water supply goals that the region faces, and this paper addresses this option.

Regionalization

For many metropolitan areas today, water managers are finding it extremely difficult to bring on-line new sources of water supply and are looking instead at improved operations, conservation, and increased efficiency to meet water demands. Interbasin water transfers and regionalization are also being examined as practical means of increasing water supply and providing supply redundancy for water utilities. Regionalization of water supplies can be defined simply as "the integration or cooperation on a regional basis" (Grigg, 1989). Regionalization often requires careful agreements between utilities, such as water transfers between water rights holders. The primary reasons for regionalization include the promise of lower water supply costs, higher water supply reliability, and greater certainty of source acquisition. The Seattle regional area water system has been examined previously as an example of de facto regionalization: a large water utility serving many smaller purveyors (Lund, 1988).

While there are legal and political barriers to regionalization, many states and utility districts have established new laws encouraging the practice. North Carolina, Florida, Virginia, Colorado, California, New Jersey, Pennsylvania, Maryland and Massachusetts passed legislation to promote regionalization to some degree (Grigg, 1989; Okun, 1981)

One example of extremely successful regionalization is from the Washington, D.C. area during the early 1980's. Past hydrologic conditions, predicted increases in demands, environmental concerns, the costs of alternative solutions, and political necessity combined to make water supply regionalization a logical choice (Palmer, et. al., 1982; Sheer, 1989). As in the case of regionalizing the Washington, D.C. water supply, the institutions involved must be ready for a new and unique perspective in solving their problems, and not be bound by perceived constraints on how water has been managed in the past.

Obstacles to regionalization include uncertainty in net water supply gain, legal issues associated with water transfer, the development of appropriate operating policies, environmental ramifications, political obstacles and costs (Nunn, 1988; Ingram, 1992; Howe, 1978). In addition, perhaps the most significant obstacle is the need to craft agreements among the water supply entities, establishing tangible benefits that outweigh the political and institutional costs associated with regionalization.

Problem Setting

The majority of water supply in Central Puget Sound Region is supplied by large, municipal owned public utilities that supply water to the counties in which they are located (Figure 1). These cities are each experiencing urban sprawl, and their populations are growing together. Seattle, Tacoma and the South King County region are investing heavily in one regional water transfer, the Tacoma-Seattle Intertie (TSI). The TSI, a portion of Tacoma's Second Supply Project (SSP), is permitted and scheduled to be completed in 2004 (Tacoma, 1999). This transfer sets the stage for further regionalization of Central Puget Sound in the form of an intertie between Everett and Seattle (ESI). The TSI is the result of over 15 years of planning and negotiation. The plan for the second supply project was developed in 1970, and the first phase completed in 1975. Final agreements with Seattle and the South King County region are still being developed (Seattle, 1997). The complexity of this process is indicative of obstacles water resource managers face today.

The ESI option has not been studied extensively. Legal and political impediments have hindered a full evaluation of the project. Despite these impediments, the ESI represents perhaps the most promising alternative source of water for the growing metropolitan region. Seattle would benefit significantly from increased supply sources, Everett would benefit from added supply redundancy and transmission augmentation, and smaller, regional rivers would be less burdened as they experience increased protection from further withdrawal. As regional planning and environmental pressures increase, a regionally managed intertie between Everett and Seattle may contribute many solutions to these difficult problems.

Seattle owns two reservoirs in King County, one on the South Fork Tolt River and the other on the Cedar River. The two reservoirs have a total active available storage of approximately 80,000 acre-ft and are operated for flood control, instream flow enhancement, and as sources of municipal water supply.

Everett serves Snohomish County with its supply source on the Sultan River (via Spada Reservoir and Lake Chaplain). Everett co-owns this system with Snohomish County Public Utility District No. 1 (SnoPUD). SnoPUD operates Spada Reservoir to maximize power production at their hydroelectric power plant. All water used for water supply generates electricity. Currently about 25% of power producing flow supports the water supply demands (through low-head (Francis) turbines instead of high-head (Pelton) turbines). Because of changes in available heads, water that is used for both purposes produces less energy than water used solely for hydropower.

Problem Approach

To evaluate the feasibility of the ESI, a simulation model was created with the ability to evaluate a series of intertie alternatives and a suite of analysis metrics were defined that included political, environmental, and performance metrics. The Cascade Yield SimulaTion and AnaLysis Model (CRYSTAL) was developed to enhance regional water supply planning in the Central Puget Sound area. The input data for CRYSTAL are current regional demand projections, historical streamflows, as well as existing transmission capacities, water right, and instream flow requirement constraints. Existing operating rules, as well as proposed operating rules, are evaluated with CRYSTAL, as well as numerous measures of performance related to interbasin water transfers.

The CRYSTAL Model is based on a number of past studies (Karpack, 1992; Seattle, 1998; SnoPUD, 1999; CH2MHILL, 1998), but was recently reprogrammed in the Powersim programming environment and significantly enhanced. Many regional agencies contributed to the revisions in the CRYSTAL model, including Seattle Public Utilities, Tacoma Public Utilities, Everett Public Works, Snohomish County PUD, U.S. Army Corps of Engineers, Washington State Department of Ecology (Ecology), and the Muckleshoot Indian Tribe. This model has been used to evaluate the regional utility responses to the Endangered Species Act (Nelligan-Doran, 1999).



Figure 1: Tri-County Water Service Areas

In the analysis that follows, three basic alternatives are evaluated: the status quo, a permanent ESI transfer, and a contingent ESI transfer. The status quo scenario consisted of all of the projects in the region that have begun a permitting or construction process and are anticipated to be completed within the next five years. The alternative scenarios are summarized in Table 1.

	Alternative:				
1. Status quo	2. Permanent Water Transfers ¹ Plus Status Quo			3. Contingent Water Transfers ² Plus Status Quo	
Tacoma-Seattle Intertie, SF Tolt Treatment Facility, Tolt II Pipeline	25 mgd (2a)	50 mgd (2b)	75 mgd (2c)	1 in 3 (3a)	1 in 10 (3b)

Table 1: Alternative Test Scenarios

Notes: 1: Every year from July through October

2: Years are chosen by the most severe 16 and 6 hydrologic sequences for Seattle, respectively

A comprehensive analysis requires estimation of potential impacts on all stakeholders. The metrics used in this preliminary analysis are provided in Table 2. Yearly average slackwater, a new metric, was derived for this analysis. Slackwater determines the volume of water remaining in the reservoir after each year of operation that could have been released to augment fish flows. While releasing this full amount operationally improbable, it provides a good indicator of the amount of environmental stewardship (i.e. higher fish releases) that could have taken place.

Table 2: Summary of CRYSTAL Model measures of performance

	Performance	Environmental
Evaluated with model	Safe yield, weekly and annual reliability, quantity of shortfalls, average days of supply remaining at the end of drawdown	Percentage of time above minimums, yearly averaged slackwater
Evaluated w/o model	Legal and political feasibility	Legal and Political feasibility

Results

Evaluation of the Status Quo

When evaluating the status quo alternative, the Everett system proved 100% reliable through 2040 demand projections. During the same period, Seattle experienced failures in meeting all uncurtailed demands beginning in the year 2020 and failed to achieve the desired 98% reliability in year 2030. This implies that the Seattle system currently is stressed more heavily than the Everett system.

Average slackwater for Spada Reservoir remains approximately 80,000 AF through the year 2040. The six driest hydrologic years are more affected by increasing water demand, and range from 10% to 20% lower than average. With an average drawdown period of 30 weeks, 80,000 AF of slackwater is the equivalent of 190 cfs. The summer average flow in the Sultan River is 600 cfs, thus the slackwater could increase summer flows by 30% during this period if all this flow was devoted to instream flow augmentation.

Unlike Spada Reservoir, the frequency at which flows on the South Fork Tolt and Cedar Rivers are above the minimum required flows is heavily affected by demand year for the status quo. The percent of time that stream flows are above requirements on the Cedar River start at 70% and decrease to 48% from the year 2000 through 2040. The percent of time that streamflows are above the instream flow requirements on the South Fork Tolt River for this same period begin at 32% and drop to 18%. Cedar average slackwater varies from 18,000 AF to 13,000 AF under 2040 demand projections. With an average drawdown on the Cedar of 20 weeks, the 13,000 AF of slackwater is equivalent to 45 cfs, approximately 18% of the average summer flows for the Cedar River. The South Fork Tolt River has an average slackwater volume of 25,000 AF in 2000 demand projections and drops to 13,700 AF in demand year 2040. At an average drawdown of 23 weeks, 13,700 AF is equivalent to 42 cfs, or about equal to average South Fork Tolt River summer flow of 42 cfs.

Permanent Water Transfer

In this scenario permanent transfers of 25, 50 and 75 mgd are explored (these are denoted as alternatives 2a, 2b and 2c). For all three capacities there is ample Spada storage to provide for all water transfers, as reliabilities remain at 100% and the system experiences no supply shortfalls. Scenario 2a was modeled with existing transmission and water right restrictions, except the capacity of the Francis pipeline. This scenario decreases the average October weeks of supply remaining by 25%. Although this change is significant, in October during projected year 2040 there is still an average 30 weeks of storage remaining, enough to provide system water until May of the following year.

Scenario 2c halves the average October weeks of supply remaining in demand year 2040, but 20 weeks of storage remain, sufficient storage to supply the system until March. The absolute minimum weeks of supply remaining value for this scenario in October of 2040 was 5 weeks, calculated using the Everett demand and the 75 mgd demand of the ESI. This occurred during 1941 which was a region wide drought year. The supply system of Spada is rarely stressed by transferring 75 mgd to Seattle. Dry hydrologic years of 1941-1942, 1987-1988 and 1992 draw the system close to the minimum hydropower elevation of 1337 ft.

Seattle performance is enhanced with the ESI water. Scenario 2a delays the first Seattle system failure from a demand level of 166 mgd to a demand level of 189 mgd, prolonging the onset of failure by 10 years given current demand projections. In scenario 2b, the Seattle system will not fail until 200 mgd, or projected year 2035. Scenario 2c will sustain the Seattle system without failure through 2040 planning projections, or beyond an average demand of 212 mgd.

These positive effects are demonstrated in the combined Seattle reservoir storage and weeks of supply remaining. Scenario 2c increases the weeks supply remaining in the combined system by four weeks in October, from seven to eleven weeks on average. This provides security in late season droughts, and obviously delayed onset of system failures.

Little change is seen in the percent of time above instream flow requirements between options, but available slackwater increases from status quo. Similar to weeks of supply remaining, this decrease in average slackwater is not very worrisome because it was originally very high. The difference in approximate slackwater flow yield for the 75-mgd scenario is equal to approximately 31 cfs, making the river slightly more utilized with the intertie. During dry years the slackwater for the 75-mgd scenario in demand year 2040 is 48,000 AF, or half of the status quo average. This is equivalent to 114 cfs, which is still substantial.

A permanent intertie substantially enhances the percentage flow above instream flow requirements for both the Cedar and South Fork Tolt Rivers. During 2040 flows are above required targets 2% more with a 25 mgd ESI and 12% more for a 75 mgd ESI. Slack water is improved, also. There is almost twice as much average slackwater in the South Fork Tolt River in demand year 2040 with the 75 mgd ESI and an additional 3,000 AF available with the 25 mgd ESI.

Contingent Water Transfers

Contingent water transfers have no effect on Spada reliabilities (they remain at 100% reliability). This scenario increases Spada average weeks of supply remaining markedly in the 1 in 3 scenario up to 40 weeks from 25 weeks. As an average value, this represents an increase in non-defining hydrologic years, or years where there is no danger of shortfall. The average weeks of supply remaining for the transfer years, the driest hydrologic years, will remain the same.

The enhanced performance that is provided by the original 50 mgd ESI is minimally affected by only transferring water on a frequency of 1 in 3 years. Annual and weekly reliabilities are the same between the two options, and shortfall volume is only slightly higher for the 1 in 3 event. This is due to over year failure events that begin to occur at high demand levels. Decreasing transfer frequency to one in ten years lowers the benefits of the ESI substantially, decreasing annual reliability in the year 2040 from 97% to 93.8%. The expected shortfall volume in 2040 is over twice as much as with the 1 in 3 and permanent options.

There is little impact on the Everett environmental benefits when the intertie is changed from a permanent transfer to a contingent transfer. The percentage time above required flows remains virtually unchanged while the slackwater volume increases 8,000 AF. As the slackwater is already high in Spada, however, this increase is not significant.

Most of the environmental benefits received by the Cedar and South Fork Tolt Rivers from the ESI are nullified when the transfer becomes contingent on dry hydrologic years. This indicates that during permanent transfers much of the water conveyed through the ESI, over two-thirds of hydrologic years, is not used for water supply yield enhancement, but for environmental benefit. The percentage of time flow is above the instream flow requirements for the Cedar River, returns to the status quo value of 48% during demand year 2040 for both the 1 in 3 and 1 in 10 frequencies. The same is true for slackwater, although the frequency of 1 in 3 still results in some slackwater benefits.

Conclusions

Growing water demands in metropolitan areas can present significant challenges to water supply agencies. These challenges include providing safe and reliable water while meeting increasing water demand, more stringent water quality standards, and new environmental constraints. Although offering many advantages, regionalization of water supplies can be difficult due to perceived political constraints. Many regions would prefer to develop new sources of supply rather than sharing existing ones, as it allows them to remain more autonomous and to maintain greater control over solely owned resources.

The current status quo scenario for this region could result in portions of the region struggling to meet water demands while other portions remaining relatively water rich. Regionalization alternatives would allow all water customers to have safe and reliable water for many decades into the future. Regionalization of the Everett system with the Seattle and Tacoma system provides sufficient storage volume through the year 2030, given existing water rights. Regionalization will also provide the entire region with a high degree of water supply reliability through the year 2040 if Everett secures an additional water right for the region. The intertie that would provide this increased reliability can be contingent in nature, allowing independence of the systems in most years. Such a contingent transfer on a one-in-three year basis would provide virtually all of the water supply benefits of a permanent transfer.

An intertie is also a promising alternative in terms of environmental concerns. Currently, the flows in the Sultan River during summer periods are governed by hydropower production, not by limited water quantity. The growing municipal water demands of Everett are not large enough to have a significant impact on the flows in the Sultan River. Under the status quo flows in the Cedar and South Fork Tolt Rivers are affected by increasing municipal water demands during the next forty years. The South Fork Tolt River in particular has been, and will be increasingly, impacted by diversions for water supply. The instream flow requirements for this stream will increasingly become the flow in the river during the summer of dry years. An ESI will greatly enhance slackwater in the Seattle system, allowing for higher potential of environmental metrics is nullified when contingent transfers are employed. That is, a permanent transfer of water is necessary to dramatically improve instream flows for the Seattle system.

This study suggests that the ESI is a viable future supply alternative for the region. These results should spawn many different studies to direct planning efforts, i.e., the effect that conservation and curtailments could be evaluated through a sensitivity analysis on the existing demand projections. Since the future values of instream flow requirements are uncertain, a sensitivity analysis to instream flow requirements would also be beneficial. The trade-off between hydropower revenue and enhanced streamflow from water transfers should be further studied to determine an appropriate balance. The use of

climate prediction to enhance triggers on contingent water transfers could be a valuable tool in improving current reservoir operations.

Meeting future regional water supply challenges requires increased cooperation between regional suppliers and diverse collections of water supply and conservation options. The citizens of Puget Sound have the opportunity to take a truly regional view of water management, one that can minimize the costs of water supply and improve fish habitat. Seattle, Tacoma and the South King County region have invested heavily in one regional water transfer, the TSI. This transfer could encourage the further regionalization of Central Puget Sound. Seattle would benefit from increased supply sources and Everett would benefit from supply redundancy and transmission augmentation. SnoPUD needs to meet increased growth demands for power and balance costs of BPA peaking rates. Regional rivers are becoming more stressed and under heavier protection from local, state and federal agencies. As regional planning and environmental pressures increase, a regionally managed intertie between Everett and Seattle may provide many solutions to these difficult problems.

This case study of the Pacific Northwest is particularly pertinent as the region is facing concerns similar to those faced elsewhere in the US. What this study reveals is equally apropos to the country at large; that is, regionalization can be cost effective, environmentally sound, and can provide improvements in regional system reliability that satisfies growing demands many years into the future.

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