Technical Memorandum

Jacobs

Emergency Well Siting Study

Date:	June 19, 2024
Project name:	Emergency Well Siting Study Scoping and Planning
Project no:	W3X94619
Attention:	Astri Niederkorn
Client:	City of Bellevue
Prepared by:	Suzanne Ball, Aaron Cantrell, Esther Chang, Thomas Jones, Matt Maring, Enoch Nicholson
Reviewed by:	Matt Maring, Enoch Nicholson
Revision no:	0.2

1100 112th Avenue NE
Suite 500
Bellevue, WA 98004-5118
United States

T +1.425.453.5000

www.jacobs.com

Introduction

The Emergency Well Siting Study Scoping and Planning Project (the Project) was initiated to support the potential development of emergency water supply well resources within the City of Bellevue (City or Bellevue).

- The Bellevue water system is currently configured to receive drinking water from the Seattle Public Utilities (SPU) regional water supply system. This means that in the case of a SPU water supply interruption, the City of Bellevue water system will not have a direct supply of water until SPU water service is restored.
- Bellevue system water storage reservoirs and system interties with adjacent water utilities do provide some capacity to support water delivery independent of the SPU supply, however, given practical storage volume limitations and the fact that adjacent water utilities also generally rely on the SPU system for at least a portion of their water supply, Bellevue system storage and interties are not sufficient to maintain water supply for Bellevue during extended SPU service outages.
- Evaluations have suggested that prolonged interruptions to SPU regional water supply spanning multiple weeks could be possible as a result of a major seismic event and/or other major regional emergency scenarios.

To mitigate the risk and reduce the potential economic impacts of extended water supply interruptions in Bellevue as part of a major emergency event, the City is exploring the potential to develop its own emergency water supply wells. The City owns and operates four small water supply wells that are not currently configured to support drinking water supply into the Bellevue water system, but could be upgraded to support emergency water supply operations. The City is also exploring the potential to develop other additional emergency water supply wells that could further augment emergency water supply capacity, and retained Jacobs Engineering Group Inc. (Jacobs and/or Consultant) to perform scoping and planning work relating to existing and potential additional future water supply wells.

- The City Utilities Department is working to evaluate and optimize use of its existing water supply wells (Samena Well No. 3 and Crossroads Wells No. 5, 6, and 7) in support of irrigation, other non-potable water demands, and as local emergency water supply as a means to enhance community resilience. As part of a future efforts, the City plans to continue to evaluate how the existing wells can best be used, and whether they should continue to be maintained in their current state, be reconditioned, or whether replacement wells should be constructed at the existing well sites.

- The City is also interested in exploring development of additional water supply wells and groundwater supply capacity to meet community resilience and emergency water supply needs. The recently completed Bellevue Water Distribution System Seismic Vulnerability Assessment (SVA) project concluded that availability of water supply following a major seismic event could be critical to community resilience and recovery, and that local emergency well supplies could be effectively utilized as a limited stopgap supply should regular water supply delivery from SPU be interrupted or curtailed. It is assumed that potential new water supply wells would be permitted under the Washington State Department of Ecology Emergency Water Source Authorization (consistent with RCW Chapters 90.03, 90.44, and RCW 43.70.310 and 90.54.020(3)(a)).

Emergency water supply well development would be aligned with the City's Emergency Water Supply Master Plan, and findings of the recently completed Bellevue SVA, both of which recommend development and enhancement of local emergency water supply wells, and other water system resilience enhancements, as a means to mitigate the impacts of and expedite recovery following a major seismic event.

The following sections detail evaluations completed relative to existing and potential future emergency well supplies within the City of Bellevue:

- Existing Wells Assessment and Improvement Approach Recommendations
- Well Siting and Infrastructure Analysis
- Well Operations and Usage Cost/Benefit Analysis
- Well Scoping and Planning Recommendations Summary

Existing Wells Assessments and Improvement Approach Recommendations

The following sections summarize assessments and recommendations completed relative to the existing City Crossroads and Samena wells. Each of the wells were evaluated relative to condition, configuration, and expected resilience based on review of previously compiled information provided by the City. Given concerns noted with the wells and the potential for expanded future use as emergency water supply sources, well reconditioning and well redrilling and replacement, are summarized and overviewed as potential well supply improvement alternatives. Additional details are documented in City of Bellevue Samena and Crossroads Water Supply Wells Assessment Technical Memorandum (TM), which is included as **Appendix A**.

Existing Well Condition Assessment

A review and evaluation of the existing City Crossroads and Samena wells, including assessments of their condition, configuration, and resilience, was conducted relative to potential future use as emergency water supply sources. The existing City wells each date to the 1950s or early 1960s, were constructed using mild steel well casings, and exhibit varying degrees of scaling, fouling, and sand and sediment intrusion.

Should the City wish to use and maintain the four existing wells as emergency water supply sources, or for other continued uses including irrigation supply, degradation and issues noted indicate that the wells are at a minimum are likely in need of significant reconditioning, or should potentially instead be redrilled and replaced. Well assessment observations, summaries and analysis of potential well reconditioning and replacement approaches, and order of magnitude cost estimates are summarized in the following sections, with additional detail included in **Appendix A**.

Well Reconditioning Options

Well reconditioning can include both mechanical and chemical techniques. Successful reconditioning efforts can improve well yields and water quality, support continued and improved well functionality, and may provide a cost-effective means to address declining well capacity, degrading water quality, well water cloudiness, sand intrusion and infilling, as well as well screen clogging, biofouling, and encrustation issues. However, given that subsurface conditions cannot be fully known and are difficult to assess, well reconditioning can also tend to deliver inconsistent outcomes and varying degrees of success, especially where significant biofouling, screen encrustation, sand intrusion, and well infilling are evident.

Based on review of available data, each of the existing City wells exhibit varying degrees of sand and sediment intrusion, infilling, screen encrustations, and biofouling. The steel well casings will have corroded internally and externally to varying degrees over time, are likely approaching the end of their useful lives, and cannot be considered to be as seismically resilient as modern thermoplastic well casing materials. While the existing well screens are similar to currently produced products, the sand and sediment infilling that is evident with the existing wells suggests that the screen slot and/or surrounding filter pack materials are not appropriately sized or placed relative to the surrounding aquifer strata, creating unintended pathways where excessive amounts of fine-grained materials can enter into the well interior and adversely impact well performance and functionality.

Well reconditioning can be an attractive option when the benefits can be anticipated to be significant, lasting, and long-term, and where the costs to perform and repeat well reconditioning activities as can frequently become necessary over time are significantly less than costs to redrill and replace the well. As further detailed and described in **Appendix A**, given the challenges and degraded condition noted for the existing City wells, reconditioning cannot be recommended as a viable approach to improve the functionality of the existing City wells in support of emergency water supply and resilience goals.

Well Redrilling and Replacement Options

Given that well reconditioning is not likely to be a viable means to address and resolve issued noted with the existing City wells, redrilling and replacement of the wells may become a desirable pathway to establish independent and resilient sources of emergency water supply. There appears to be sufficient available space on each of the existing well properties to redrill and construct replacement wells such that significant water rights adjustments and approvals would not be required.

A planning level estimate of the costs that could likely be involved in replacing each of the City's four existing wells via a standalone capital improvement project are summarized in the table below. Estimated well redrilling and replacement project costs are based on an Opinion of Probable Construction Cost (OPCC) developed consistent with Association for the Advancement of Cost Engineering (AACE International) Class 5 estimating guidelines and subject to an expected accuracy range of minus 30 percent to plus 50-percent. Should multiple wells, for example the three wells located at the Crossroads site, be replaced via a single combined capital improvement project, it is likely that some economies of scale could be realized that may tend to somewhat reduce the overall redrilling and replacement costs.

Table 1. Well Redrilling and Replacement Cost Estimate

Project Element	Estimated Cost
Planning and Design (34.1% of Construction Cost)	$820,000
Real Property	$0
Construction (AACE International Class 5 Estimate Range = $1,675,000 to $3,590,000)	$2,390,000
Other Construction Phase Costs (10.7% of Construction Cost)	$260,000
Subtotal (excluding Contingency Allowances)	**$3,470,000**
Contingency Allowance (40% of Other Costs)	$1,390,000
Total (inclusive of Contingency Allowance)	**$4,850,000**

The cost estimate does not include any specific allowances for real property costs given that the wells would be located on existing City owned properties, but otherwise includes allowances for typical planning, design, permitting, and construction phase support consistent with standard City capital project planning allowances. Additional details and recommended well redrilling and replacement approaches are further described in **Appendix A**.

Well Siting and Infrastructure Analysis

The City may benefit from developing additional supply resources beyond its four existing Crossroads and Samena groundwater well assets. To assess characteristics and areas within the Bellevue water system where siting potential emergency water supply wells could be most effective and beneficial, a well siting and infrastructure analysis was conducted. The analysis considers a variety of relevant factors including proximity and accessibility relative to:

- water utility infrastructure
- critical water supply customers
- water system customer distributions and density
- streets and accessibility
- known sources of potential contamination
- social equity factors
- potential seismic event impacts and risks

Other common well siting considerations that are not known to exhibit significant variability across the City geographically, such hydrogeologic conditions and natural resource groundwater quality, are not directly considered as part of this analysis.

The well siting and infrastructure analysis is conducted on a quarter-quarter section (QQ) basis, with each QQ representing a square measuring approximately 0.25 miles, or around four standard city blocks, along each edge. Each of the 653 QQs spanning the City are comparatively scored and ranked according to common analysis criteria as described in the following sections.

Analysis Criteria

Eleven well siting and infrastructure criteria, as described in the following sections, are assessed for each of the 653 QQs across the City. Each QQ is comparatively scored and then ranked according to the relevant characteristics and considerations listed. Then a multi-objective decision analysis (MODA) process is applied, consistent with City of Bellevue Utilities Department Business Case Analysis Guidelines, to identify

QQs and areas most suitable for emergency well supply siting based on the individual criteria rankings. Additional background information and details relative to the QQ analysis are summarized in the appendices as follows:

- **Appendix B:** Well Siting Criteria Scoring
- **Appendix C:** Well Siting Criteria Rankings
- **Appendix D:** Interactive Well Siting Criteria Mapping Tool

Criterion 1: Seismic Backbone Pipe Routes

The Bellevue Water Distribution System Seismic Vulnerability Assessment (SVA) recommends near term development of seismically resilient water system backbone piping along identified corridors. These alignments would be upgraded and equipped with water mains and components specifically designed to be capable of surviving and remaining in active service through major seismic events. Should supply from the SPU regional water system become interrupted as a result of a major seismic event or other emergency, this backbone piping could function in concert with local water supply sources to support emergency water supply delivery as well as speed post-event water system repairs and water service restoration.

The SVA identifies five seismic backbone pipe routes (A, B, G, L, and M) as recommended for near term seismic resilience improvements. For the purposes of evaluating potential emergency water supply well locations and supporting efficient connections from potential supply sources into the backbone pipe network, QQs are ranked according to their proximity to one of the planned seismic backbone pipe routes, as summarized in the following table.

Table 2. Seismic Backbone Pipe Route Rankings

Ranking	Distance (mi) from QQ to nearest Backbone Pipe Route	Ranked QQs
5	≤ 0.25	150
4	> 0.25 – 0.5	75
3	> 0.5 – 1.0	169
2	> 1.0 – 2.0	217
1	> 2.0	42

Criterion 2: Water Pressure Zones

The Bellevue water system is composed of approximately 70 distinct water system pressure zones (WPZs) configured to support supply delivery to Bellevue water utility customers across varied service area topography. Among these, the SVA identified Lake Hills 520, Factoria 290, Bellevue 400, Enatai 300, and Somerset 850 (LH520, FA290, BV400, EN300, SS850) as a priority for emergency water supply delivery and post-event water service restoration. These WPZs are prioritized over others based on their proximity to, and supply interconnections with, SPU regional water supply inlets and pipelines; their relatively large customer bases, service areas, and water storage facility capacities; and their water supply feed connections into smaller adjacent and downstream pressure zones.

Locating emergency water supply resources within these priority WPZs maximizes associated benefits relative to emergency water supply distribution, facilitation and prioritization of post-event system repairs, and optimized progression towards systemwide water service recovery. For the purposes of evaluating

potential emergency water supply well locations, QQs are ranked according to their locations within or intersecting one of the identified priority WPZs as summarized in the following table.

Table 3. Water Pressure Zone Rankings

Ranking	Water Pressure Zone Proximity	Ranked QQs
5	QQ falls entirely within priority WPZs	200
3	QQ includes portions of priority WPZs	204
1	QQ does not intersect with any priority WPZs	249

Criterion 3: Critical Customers

The Bellevue water system provides water service for critical customers grouped in three categories based on relative water service criticality and priority. Bellevue critical water supply customers typically span community emergency response and healthcare functions as detailed below:

- Category 1 Critical Customers
  - Overlake Hospital Campus
  - Kaiser Permanente Bellevue Medical Center
  - Seattle Children's Bellevue Clinic and Surgery Center
  - Bellevue School District high schools (4)
  - Bellevue community centers (3)
  - Washington State Department of Transportation (WSDOT) Emergency Operations Center and Road Maintenance Facility
  - WSDOT Bridge Maintenance Facility
  - Bellevue City Hall
- Category 2 Critical Customers
  - Community emergency water supply distribution locations
  - Emergency shelter locations
  - Bellevue Fire Stations 1 through 10
  - Washington State Patrol District 2 Bellevue Office
  - Bellevue School District elementary and middle schools
  - Bellevue College campus
  - Bellevue Service Center
  - Bellevue Utilities Eastgate Yard
  - Local medical and urgent care clinics
- Category 3 Critical Customers
  - Elective or non-urgent care centers

- Malls and shopping centers
- Pharmacies and doctor office centers
- Assisted living centers
- 520 Reservoir and Pump Station – Utilities Maintenance District Assembly Point
- Clyde Hill Reservoir – Utilities Maintenance District Assembly Point

In emergency situations where water supply may be interrupted, restoring and maintaining water supply service to critical customers takes top priority. Locating potential emergency water supply sources in close proximity to critical customer clusters and locations provides direct benefits relative to the ability to restore and maintain water service at these locations, and effectively support community emergency response and recovery activities.

For the purposes of evaluating potential emergency water supply well locations relative to critical customers proximity, QQs are scored and ranked according to the types and numbers of identified critical customer located inside and within 0.25 miles of each QQ, as summarized in the following tables.

Table 4. Critical Customer Scoring

Critical Customer Category	Critical Customer Scoring
1	10
2	4
3	1

Table 5. Critical Customer Ranking

Ranking	Total Critical Customers Score within 0.25 miles of QQ	Ranked QQs
5	≥ 40	7
4	30 – 39	9
3	20 – 29	23
2	10 – 19	142
1	0 – 9	472

Criterion 4: Streets and Accessibility (Arterials)

A major seismic event has the potential to interrupt water service to Bellevue residences and businesses for potentially extended periods before system repairs and service restoration can be effected. The distribution and accessibility of emergency water supply source locations is a priority relative to vehicle, public transportation, and pedestrian routes and access. Individuals would need to travel to collect water from emergency water supply sources, and community water distribution and emergency response centers located around the City.

In Bellevue, primary transportation corridors are generally associated with the streets network and associated arterials (as defined in the City of Bellevue Comprehensive Plan). For the purposes of evaluating potential emergency water supply well locations relative to streets and accessibility, QQs are scored and ranked according to the length and types of arterial streets located inside and within 0.1 miles of each QQ, as summarized in the following tables.

Table 6. Scoring Applied to Length (mi) of Arterials by Category

Arterial Category	Arterial Scoring
Major	2
Minor	1.5
Collector	1
Other	1

Table 7. Street and Accessibility (Arterials) Ranking

Ranking	Total Arterial Score within 0.1 miles of QQ	Ranked QQs
5	> 2.0	78
4	> 1.0 – 2.0	173
3	> 0.5 – 1.0	196
2	> 0 – 0.5	124
1	0	82

Criterion 5: Customer Density

Water usage rates vary seasonally in Bellevue, with winter water demands most closely approximating residential and commercial baseline water needs exclusive of seasonal irrigation use. Prioritizing potential emergency water supply locations in alignment with typical winter water use distributions is a priority relative to optimizing the potential reach and benefits of emergency water supplies relative to the actual locations where water is needed and will be used.

For the purposes of aligning water customer density with potential emergency water supply well locations, QQs are scored and ranked according to the magnitude of typical winter water demand (WWD, based on 2019 water usage records in millions of gallons per day, MGD) located inside and within 0.25 miles of each QQ, with a priority on residential over commercial water needs, as summarized in the following tables.

Table 8. Scoring Applied to Winter Water Demand (WWD) Usage Values (MGD)

Water Usage Category	Usage Scoring
Single Family	1
Multi-Family	1
Commercial	0.25

Table 9. Customer Density Ranking

Ranking	Total Winter Water Demand Score within 0.25 miles of QQ	Ranked QQs
5	≥ 0.25	25
4	0.2 – < 0.25	21
3	0.15 – < 0.2	39
2	0.1 – < 0.15	151
1	< 0.1	417

Criteria 6 and 7: Groundwater and Surface Contamination

Locating potential emergency water supply wells away from potential sources of contamination is a priority relative to optimizing source water quality and minimizing potential adverse risks and effects to the public. Data on sites within Bellevue having known groundwater, soil, and/or surface water contamination are sourced from Washington State Department of Ecology (Ecology) 2018 and 2022 databases, extended to include historical fire training sites known or suspected to include PFAS contamination resulting from use of firefighting foams.

To avoid contaminated sites and adverse impacts on natural resource water quality, in evaluating potential emergency water supply well locations, QQs are scored and ranked according to reported levels of contamination noted at individual sites located inside and within 0.5 miles of each QQ, as summarized in the following tables. The worst-case contamination conditions are considered in the evaluations in instances where individual sites are associated with multiple different contamination reports.

Table 10. Scoring Applied to Contaminated Sites

Contamination Sites Category	Contamination Scoring
Groundwater (GW) or Soil and Surface Water (SSW) contamination reported to be above cleanup levels or at unknown levels	2
GW or SSW contamination reported to be below cleanup levels	1

Table 11. Groundwater Contaminated Sites Ranking

Ranking	Total Groundwater Contamination Score within 0.5 miles of QQ	Ranked QQs
5	0	134
4	1 – 2	93
3	3 – 5	140
2	6 – 10	114
1	> 10	172

Table 12. Soil and Surface Water Contaminated Sites Ranking

Ranking	Total Soil and Surface Water Contamination Score within 0.5 miles of QQ	Ranked QQs
5	0	88
4	1 – 2	116
3	3 – 5	182
2	6 – 10	138
1	> 10	129

It should be noted that Ecology groundwater, soils, and surface water contamination information is summarized at relatively low resolution and does not include extensive detail on the specific contaminants or levels noted to be present. More detailed site-specific contamination documentation that may be available in Ecology records should be further reviewed and assessed on a site-specific basis as part of future well siting evaluations.

Criteria 8 and 9: Equity – Average Income and Car Ownership

Two social equity considerations, household income and car ownership, are directly evaluated as part of this well siting and infrastructure analysis. Each of these equity factors represent important considerations relative to individual ability to effectively prepare for and manage challenges that may be encountered during local and community emergencies.

Differences in household incomes and available financial resources can impact both the ability to appropriately prepare for and react to emergency situations. Higher income households may tend to exhibit higher levels of emergency preparedness (e.g., may maintain better emergency food and water stores and/or personal water treatment resources). In order to provide more equitable support and service relative to household income variability and patterns, consideration should be given to locating community emergency water supply sources in closer proximity to lower income areas.

Household car ownership can be a second factor affecting individual ability to respond appropriately and independently to emergency situations. In the case of extended water service interruptions affecting residences and places of business, household vehicle access can facilitate access to emergency water supply resources available at community emergency response and distribution centers. To support more equitable access, consideration should be given to locating community emergency water supply resources in areas where car ownership is less common.

For the purposes of evaluating household income and car ownership considerations relative to potential emergency water supply well locations, QQs are ranked according to estimated average household income and car ownership metrics within each QQ as summarized in the following tables. Household incomes and car ownership metrics are evaluated on a QQ basis according to 2020 census tract data. Where QQs may extend into multiple census tracts, QQs average incomes and car ownership metrics are estimated according to the proportion of each QQ associated with each census tract.

Table 13. Equity – Average Income Ranking

Ranking	Average QQ Household Income ($K)	Ranked QQs
5	80 – 120	65
4	120 – 140	104
3	140 – 160	189
2	160 – 200	239
1	> 200	56

Table 14. Equity – Car Ownership Ranking

Ranking	QQ Households Owning At Least One Car (%)	Ranked QQs
5	< 80	7
4	80 – 85	39
3	85 – 90	74
2	90 – 95	105
1	95 – 100	428

Criterion 10: Drafting Sites

Water drafting sites include identified locations where the Bellevue Fire Department has determined it should be able to use fire pumper trucks to draft / withdraw surface water for firefighting purposes from lakes, ponds, or other impoundments. Such sites may be leveraged for firefighting as backup supplies in instances where needed fire flows are unavailable directly from the Bellevue water system. In emergency situations involving prolonged water service interruptions, these locations may also represent potential sources of emergency community water supply. This means that potential emergency water supply sources may tend to be more beneficial on balance if they are located in areas that are further removed from predetermined Fire Department water drafting sites.

For the purposes of evaluating potential emergency water supply well locations, QQs are ranked according to their proximity to predetermined Bellevue Fire Department water drafting sizes, as summarized in the following table.

Table 15. Drafting Site Ranking

Ranking	Distance (mi) from QQ to nearest Drafting Site	Ranked QQs
5	≥ 1.0	219
4	0.4 – < 1.0	225
3	0.2 – < 0.4	102
2	0.1 – < 0.2	43
1	< 0.1	64

Criterion 11: Seismic Fault Zones

As further detailed in the SVA, the most significant known seismic risks for Bellevue and the surrounding vicinity are understood to revolve around potential Cascadia Subduction Zone (CSZ) or Seattle Fault Zone (SFZ) events. While potential impacts of a CSZ event are likely to be relatively uniform across the King County and Puget Sound lowlands (subject to local geology and liquefaction risks), impacts from a SFZ event could tend to be more localized and concentrated along associated fault zones extending through Seattle, across north Mercer Island, and into Bellevue.

Branches of the SFZ matrix are understood to extend across Lake Washington and into Bellevue, generally paralleling along the Interstate 90 corridor. In the event of a major SFZ seismic event, shaking peak ground accelerations, and ground deformations are generally likely to be most intense along and near fault lines and in areas with soils susceptible to liquefaction, and less intense though potentially still significant at increasing distance from the SFZ fault lines. Given this it may be preferable to seek to locate emergency water supply sources further away from fault lines where utility and supply infrastructure is more insulated from and less susceptible to seismic damage.

For the purposes of evaluating potential emergency water supply well locations, QQs are ranked according to their proximity to known and suspected branches of the SFZ as summarized in the following table.

Table 16. Seismic Fault Zone Ranking

Ranking	Distance (mi) from QQ to nearest Seattle Fault line	Ranked QQs
5	≥ 2	259
4	1.5 – < 2.0	91
3	1 – < 1.5	82
2	0.5 – < 1.0	81
1	< 0.5	140

Well Siting Recommendations Analysis

A MODA process is used consistent with City of Bellevue Utilities Department Business Case Analysis Guidelines to collectively weigh and assess the various well siting and infrastructure analysis criteria ranks on a QQ basis in order to identify and assess suitable areas in which to potentially locate emergency water supply wells.

To implement the MODA process, representative Bellevue water utility staff, as well as Jacobs water system and seismic analysis subject matter experts, were asked to assign relative importance and weighting scores to each of the eleven evaluation criteria categories described previously. MODA weighting importance opinions from each contributor are then averaged to determine an overall priority weight to be applied to individual QQ evaluation criteria rankings in order to characterize the suitability of each QQ for potential emergency water supply siting.

A summary of the evaluation criteria and applied MODA weighting is included in the following table, with overall Well Siting and Infrastructure Analysis results presented in **Figure 1** thereafter.

Table 17. Criteria and Weighting for Multi-Objective Decision Analysis

Evaluation Criteria	Assessment Scale/ Units	Highest Ranking	Lowest Ranking	Weighting
1. Seismic Backbone Pipe Routes	Distance (mi) from QQ to nearest Backbone Pipe Route	≤ 0.25	> 2.0	12%
2. Water Pressure Zones	QQ Water Pressure Zone Proximity	QQ falls entirely within preferred pressure zones	QQ does not intersect with preferred pressure zones	8%
3. Critical Customers	Total Scaled Critical Customers Score within 0.25 miles of QQ	≥ 40	0 – 9	16%
4. Streets and Accessibility (Arterials)	Total Scaled Arterial Mileage Score within 0.1 miles of QQ	> 2.0	0	9%
5. Customer Density	Total Scaled Winter Water Demand Score within 0.25 miles of QQ	≥ 0.25	< 0.1	14%
6. Groundwater Contamination	Total Scaled Groundwater Contamination Score within 0.5 miles of QQ	0	> 10	9%
7. Surface Contamination	Total Scaled Surface Contamination Score within 0.5 miles of QQ	0	> 10	8%
8. Average Income (Equity)	Average QQ Household Income ($K)	80 – 120	> 200	4%
9. Car Ownership (Equity)	QQ Households Owning At Least One Car (%)	< 80	95 – 100	4%
10. Drafting Sites	Distance (mi) from QQ to nearest Drafting Site	≥ 1.0	< 0.1	3%
11. Seismic Fault Zones	Distance (mi) from QQ to nearest Seattle Faultline	≥ 2	< 0.5	13%

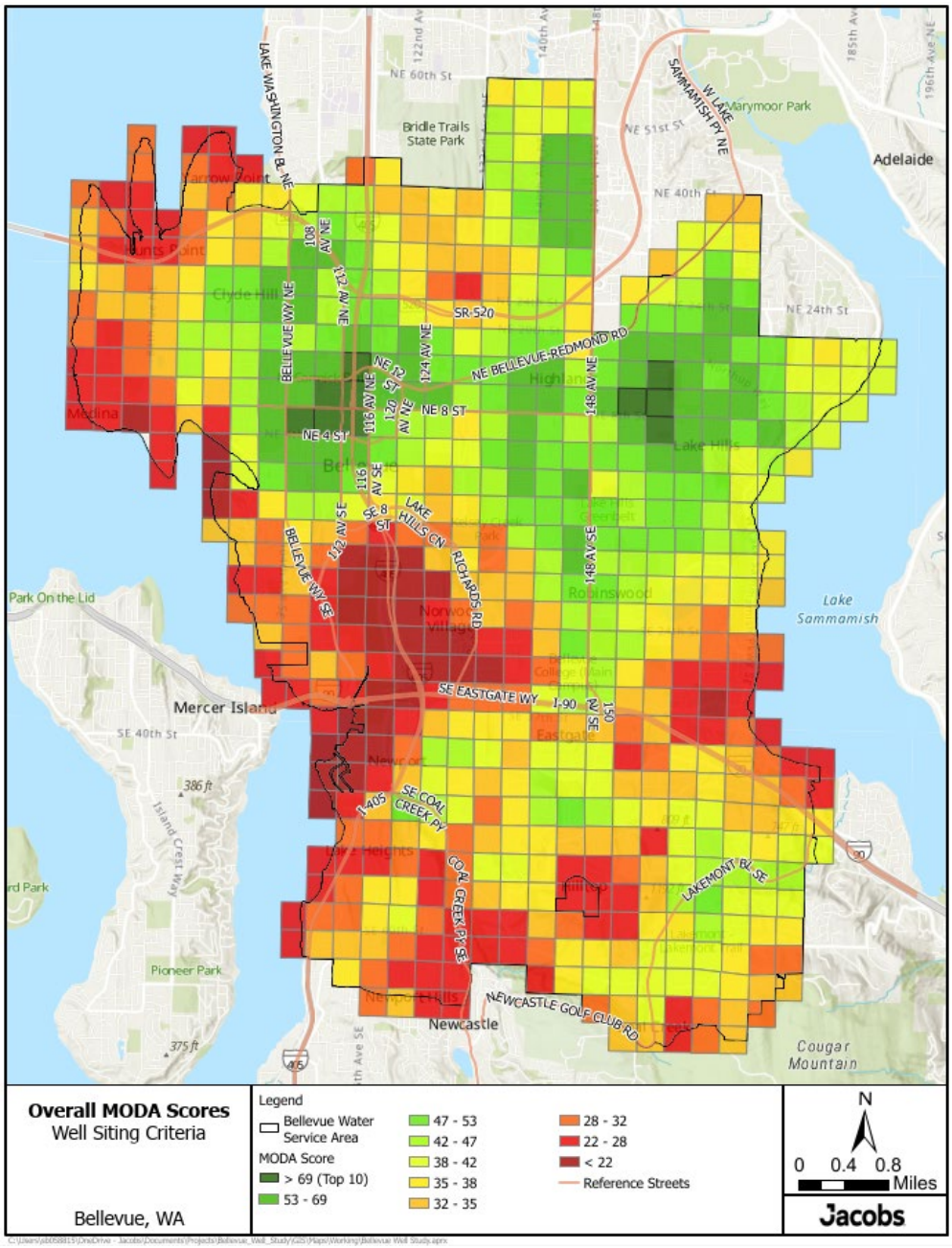

Figure 1. MODA scores for all QQs

Based on the evaluation criteria rankings considered through the MODA process, optimal locations for emergency water supply well siting appear to center in and around downtown Bellevue, extend eastward south of the Bel-Red corridor, and focus in and around the Crossroads area extending to portions of the Lake Hills, Northeast Bellevue, and Bridle Trails neighborhoods. Although these areas were highly ranked for emergency water supply well siting on balance, they also appear to coincide closely with more highly developed and historically commercial and industrial areas of the City, where groundwater and surface contamination concerns appear to be more highly concentrated as reflected in Ecology databases. Specific contamination concerns in these areas, potential adverse impacts, and available mitigations relative to emergency water supply well siting should be reviewed on a site-specific basis in the future as well development efforts are advanced.

Top rankings for emergency water supply well siting appear to be primarily driven by distance from known and suspected SFZ branches, proximity to critical customer concentrations and identified seismic backbone pipe routes, alignment with customer density, baseline water demand distributions, and priority water pressure zones, and also arterial density and access. **Appendix D** includes an interactive map that includes summaries of all QQ evaluation input scoring data, output ranks, and collective MODA scores, allowing users to explore the interplay between various emergency water supply well siting assessment factors. This map can be viewed and manipulated via clickable PDF viewer software such as those available from Adobe, Bluebeam, and PDF-XChange.

Well Operations and Usage Benefit/Cost Analysis

The following sections detail considerations relative to emergency supply well operations and usage, measures to optimize and maintain well emergency operations readiness, other complimentary well usage strategies including potential use for irrigation of City parks, potential water quality and treatment provisions, and assessments of benefit-cost relationships relative to potential State and Federal improvement project funding opportunities.

Well Operations Considerations and Strategies

Operational and asset management strategies for emergency water supply resources generally seek to prioritize operational readiness and resilience to help ensure that associated infrastructure will perform as expected and reliably when needed. Water supply resources and associated process and mechanical equipment can generally be expected to operate best when they are not subject to extended periods of idling or disuse. To maintain equipment and best ensure operational readiness, water supply wells should generally be operated and exercised at least briefly on a monthly or bi-monthly basis, and will benefit from more extended, routine, and continuous operational cycles on at least a seasonal basis.

In addition to reserve use for emergency water supply, seeking to operate City wells regularly to support other water needs, including irrigation of adjacent City parks and open spaces for example, offers multiple complimentary benefits in terms of maximizing the value derived from supply well capital investments, offsetting potable water use and associated costs for irrigation, and maintaining and demonstrating operational readiness of supply well resources and equipment. Each of the existing City well sites are located in reasonable proximity to City parks and irrigable spaces, including Crossroads Park immediately across the street from the Crossroads well site, and the Federal Field baseball diamond and Larsen Lake Park and Blueberry Farm located a few blocks north of the Samena Well site. In addition to emergency water supply use, consideration should be given to extending dedicated irrigation water supply lines from the City wells to existing irrigation supply feed points within these parks areas as a means to support and promote community benefit and regular seasonal usage and exercising of the wells.

Water quality delivered from the Crossroads and Samena wells can generally be expected to be good based on historical data. Given this and expected well use for emergency and potentially irrigation supply, well water treatment beyond potentially basic disinfection chlorination is not likely to be needed or warranted. Ability to support chlorination via bulk sodium hypochlorite solution (5-percent bleach) is likely preferrable to other options. Onsite hypochlorite generation systems could also be considered, but involve greater complexity, higher implementation and maintenance costs, and a larger overall spatial footprint. Disinfection using chlorine gas cylinders and vacuum injection systems tends to be undesirable given the additional accidental gaseous chemical release risks associated with gas cylinder transportation and storage.

Well Replacement Benefit/Cost Analysis

Community improvement efforts that are focused on increasing emergency preparedness and resilience, and mitigating and reducing associated economic risks, can be eligible for funding support through a variety of State and Federal grant and loan programs. Funding awards are typically prioritized in part based on Benefit-Cost Analysis (BCA) results that compare the expected risk reduction economic benefits

of a hazard mitigation effort against the associated implementation costs on a net-present value basis. BCA results are typically expressed in terms of a Benefit-Cost Ratio (BCR). Improvement programs are considered to be cost-effective when the expected economic risk-reduction benefits exceed the program costs, resulting in a BCR greater than 1.0, with higher BCR values indicating more advantageous outcomes.

The improvement costs considered in a BCA evaluation should span full project lifecycle costs, including associated planning, design, and construction capital costs, plus expected operation and maintenance (O&M) expenses. For redrilling and replacement ofthe four existing City wells, total capital costs exclusive of contingency allowances are estimated at approximately $3.47M each, as summarized previously in **Table 1**, or around $13.9M in total for all four well replacements.

The project benefits considered in a BCA evaluation can be based on standardized risk mitigation values, or more detailed community specific economic analyses of the risk-reduction benefits likely to be realized through implementation of a mitigation effor t. Relative to interruptions of drinking water service as may occur as a result of a significant seismic or other major emergency event, the standard value is estimated at $138 per capita per day. The peak water supply capacity for the Crossroads and Samena wells under their associated water rights is 2,660 gallons per minute (gpm), which is equivalent to approximately 3.8 MGD or around one third of total baseline City water system winter average daily water demands. Thus the emergency water supply that could be available from the wells can be assumed to be sufficient to benefit around one third of the City water supply system service population.

As part of a baseline BCA assessment exercise relative to redrilling and replacement of the Crossroads and Samena wells to provision them as emergency water supplies, potential water service interruption impact days that might be expected following a major seismic event, with and without the well emergency water supply available were estimated based on water service restoration timelines projected and evaluated as part of the previous City SVA analysis. A simplified version of the BCA Toolkit and BCA calculator version 6.0 was used to estimate an initial BCR for the Crossroads and Samena redrilling and replacement improvements based on typical local seismic event recurrence intervals and the associated water service interruption intervals that may be likely. Based on the $138 per capita per day standard assumed water service disruption economic impact value, an initial baseline evaluation estimates a well redrilling and replacement improvements BCR at just below 0.9. However, the standard economic impact value used in the analysis is significantly below the City water service economic values estimated via the SVA project effort.

The SVA effort recommended short-term, mid-term, and long-term groupings of water system improvements as means to improve system seismic resiliency. The recommended short-term improvements included emergency supply well development coupled with seismic backbone water piping installations and other water system facility improvements. Based on more detailed City specific economic impact evaluations of potential major seismic event water service disruption scenarios, the SVA estimated potential BCR values ranging well above 1.0 for various groupings of short-term improvements. Consistent with the SVA evaluations and findings it is thus recommended that the City consider packaging emergency water supply well improvements with other recommended water system seismic resilience improvements should it elect to pursue associated State and Federal grant or loan funding. Additionally, to most accurately reflect associated improvement program benefit-cost relationships, it is further recommended that associated BCA evaluations be based on the City-specific economic impact evaluations developed previously through the SVA project effort, rather than relying on available standardized benefit value estimates.

Grant Funding Opportunities

The City could be eligible for outside funding to support emergency water supply well improvements through a variety of applicable State and Federal programs. Funding opportunities that the City may wish to evaluate further in support of future emergency well supply projects could include the following Federal programs:

- Building Resilient Infrastructure and Communities (BRIC) – FEMA

- Midsize and Large Drinking Water System Infrastructure and Sustainability Grant Program – EPA
- Water Infrastructure Finance and Innovation Act (WIFIA) Loan Program - EPA

Well Scoping and Planning Recommendations Summary

The following listing briefly summarizes the key high-level findings and recommendations of the emergency water supply well evaluations documented herein. Additional detail, supporting analyses, and justifications are summarized in the preceding sections, and in the associated Appendices.

- Based on a review of available well information collected and documented by others, the condition of the existing City Crossroad and Samena water supply well infrastructure is significantly degraded. The age, materials, and condition of the wells likely does not provide adequate seismic resilience to reliably function as emergency water supply sources following a major seismic event
- Given the extent of the condition degradation evident with the wells, typical reconditioning approaches are not likely to be sufficient to restore and maintain optimal long-term functionality. Should the City wish to use the Crossroad and Samena wells as emergency water supply sources, it is recommended that the wells be redrilled and replaced on the existing City owned properties under existing water rights. The new well infrastructure should employ thermoplastic well casing materials to support optimal longevity and seismic resilience.
- The water supply capacities that could be available from replacement Crossroad and Samena wells under existing water rights are not likely to be sufficient to support City emergency water supply needs should supplies from the SPU regional water system be interrupted or curtailed for an extended period following a major seismic event or as a result of another large-scale emergency. To increase emergency preparedness, the City may wish to pursue development of additional emergency water supply wells beyond the Crossroads and Samena well sources. Based on evaluations of multiple relevant criteria, optimal locations for emergency water supply well siting appear to center in and around downtown Bellevue, extend eastward south of the Bel-Red corridor, and focus in and around the Crossroads area extending to portions of the Lake Hills, Northeast Bellevue, and Bridle Trails neighborhoods, as further detailed in **Figure 1**.
- To demonstrate and maintain operational readiness, emergency water supply wells should be exercised at least monthly or bimonthly. Seasonal use of emergency supply wells to support other water needs, such as irrigation of adjacent City park properties, can provide complimentary benefits in terms of maximizing the value derived from such infrastructure investments, and maintaining operational readiness.
- There are a variety of State and Federal funding programs that the City may be able to leverage to offset or cover the costs associated with developing emergency water supply wells, or other water system resilience and risk reduction improvements. Funding awards under these programs are typically prioritized at least in part based on benefit-cost analysis and associated BCR estimates that seek to compare improvement economic benefits to associated implementation costs. The City should consider pursuing funding where evaluations of proposed improvements, or groupings of improvements, support higher BCR estimates, near or above 1.5. To most accurately reflect benefits and improvement project justification relative to actual local economic conditions, City specific economic analyses results should be used rather than standardized benefit values whenever possible in determining BCR values.