Stormwater Pollutant Hot Spots Assessment for the City of Kirkland

Department of Public Works

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Parametrix

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ACRONYMS AND ABBREVIATIONS

µg/L	micrograms per liter
ADT	Average Daily Traffic
BMPs	best management practices
$CaCO_3$	mg/L calcium carbonate
CSO	Combined Sewer Overflow
Ecology	Washington State Department of Ecology
EPA	United States Environmental Protection Agency
GIS	geographic information system
mg/L	milligrams per liter
NAICS	North American Industry Classification System
NPDES	National Pollutant Discharge Elimination System
PAHs	polycyclic aromatic hydrocarbons
ppb	parts per billion
ppm	parts per million
SIC	Standard Industrial Classification
TRV	Toxicity Reference Value
TSD	treatment, storage, and disposal
TSS	total suspended solids
WQC	Water Quality Criterion
WQS	Water Quality Standards
WSDOT	Washington State Department of Transportation

1. INTRODUCTION

A primary goal of the City of Kirkland's 2005 Surface Water Master Plan Update is to improve water quality conditions in the City's receiving waters, including Lake Washington, Forbes and Juanita creeks, and other smaller tributaries. One of the challenges the City faces is deciding which set of projects will help convey the greatest environmental benefit for their effort. This stormwater pollutant hot spots assessment was conducted to provide the City with a planning tool to help prioritize water quality pollution prevention programs, including source control efforts and construction of water quality treatment facilities. This assessment focused on non-point source pollutants that have the potential to be washed from land surfaces into receiving waters. Five pollutants were evaluated in this assessment, based on their prevalence in urban stormwater and potential to cause harm to aquatic species. The pollutants evaluated were:

- Total suspended solids (TSS)
- Dissolved copper
- Dissolved zinc
- Total polycyclic aromatic hydrocarbons (PAHs)
- Diazinon

While three of the City's receiving waters are on the State 303(d) list for impaired water quality for fecal coliforms, temperature, and decreased dissolved oxygen, these water quality concerns were not addressed in this study. This was, in part, because the causes of these impairments are more likely to be point sources and reflect local conditions. This study's focus was at a larger scale of non-point landscape level sources.

The 303(d) water quality impairments found in Kirkland streams typically occur because of localized in-stream or riparian problems, such as reduction of riparian vegetation; fecal material from waterfowl, wildlife and domesticated pets; and the input of human sewage from local septic systems that are failing. The City is currently addressing some of these concerns through: (1) habitat restoration projects, including riparian revegetation on City-owned and privately owned property; (2) educational programs for citizens living near streams; and (3) the emergency sewerage program installing city sewer lines in neighborhoods previously served by individual septic systems. Additional work to trace and target sources of fecal coliform bacteria is on-going.

1.1 POLLUTANT SOURCES AND POTENTIAL ENVIRONMENTAL EFFECTS

Urban stormwater can contain a broad array of pollutants in a number of chemical classes. The five pollutants selected for this study represent the major chemicals of concern identified in regional studies of the Puget Sound area. These pollutants have been identified in recent Puget Sound Partnership issue papers. Copper and zinc are two common constituents generated by both point and non-point sources, and are included here as surrogate representatives for the complete range of metals that could be present in stormwater. These two metals are used extensively in our society for a number of purposes (Table 1), and are very toxic to aquatic organisms. Total PAHs are a broad class of compounds produced by combustion (such as from car engines) and are also found in the materials used for paving roads (Table 1). Diazinon, an organophosphorus pesticide, is included here as a surrogate for the broad spectrum of pesticides used in farm settings and households (both inside and outside the home in gardens) (Table 1). Finally, soil disturbance and erosion can contribute solids to stormwater that drains into local streams and Lake Washington. These particles, or TSS, can block light, limit aquatic plant productivity, and directly harm fish through abrasion (Table 1).

Table 1. Contributing Sources, Transport Mechanisms, and Possible Environmental Effects Of Stormwater Pollutants

Pollutant	Contributing Sources	Transport Mechanism	Environmental Effects
Benzo(a)pyrene (the most toxic of the PAHs)	Residential wood burning, combustion processes, automobile and truck exhausts	Stormwater runoff, Combined Sewer Overflows (CSOs), resuspension of historical sediment contamination	Aquatic: Reduced growth and reproduction, mortality Wildlife: Reproductive effects[1] People: Carcinogen, reproductive effects
Copper	Metal or alloy used in manufacturing of wire, sheet metal and other metal products, preservative, fungicide, automobile brakes and tires	Stormwater runoff, CSOs, wastewater treatment plants, industrial discharges, historical sediment contamination	Aquatic: Reduced growth and reproduction, mortality Wildlife: Reduced growth and reproduction, mortality People: Essential nutrient, very high doses can cause gastric distress, liver and kidney damage, and death
Diazinon	Orchard and farm applications, home insect control, animal dips and flea collars	Stormwater runoff, CSOs, wastewater treatment plants	Aquatic: Mortality Wildlife: Mortality People: Affects the nervous system, and can damage the pancreas. Potent enzyme inhibitor
TSS	Erosion, landslides, construction sites, particulate deposition, streambank erosion	Stormwater runoff, CSOs, flooding	Aquatic: Reproductive effects and mortality Wildlife: No impacts People: No impacts
Zinc	Automobile brakes and tires, rust preventatives, dry cell batteries, and metal alloys. Used in pennies.	Stormwater runoff, CSOs, wastewater treatment plants, industrial discharges, resuspension of historical sediment contamination	Aquatic: Reduced growth and reproduction, mortality Wildlife: Reduced growth and reproduction, mortality People: Essential nutrient. Large doses cause gastric distress, anemia, low levels of HDL cholesterol, copper deficiency

[1] Examples of reproductive effects are reduced egg production and hatchability in birds and fetal resorption, abortion, and reduced pup growth in river otters.

1.2 LITERATURE REVIEW

Past and recent literature surveys of stormwater pollutant loading levels were reviewed for the purposes of assigning loading characteristics to land uses in the City of Kirkland. We preferentially used information reported from three basic sources for all combinations of land uses identified in the City of Kirkland for copper, zinc, TSS, and Total PAHs. In order of priority, we used:

- Data collected on sheet flow chemicals studies conducted in the 1990's and summarized in Pitt et al. (2005b),
- Data collected in the initial landmark studies of stormwater pollutant loadings conducted in the 1970's and 1980's for EPA (reviewed in Pitt et al. 2005a), and
- Recently reported data from stormwater pollutant loading measurements conducted in Southern California (Stein et al. 2007).

As none of these studies reported data for roads with greater than 20,000 Average Daily Traffic (ADT), we used information form the "BA Writers Guidance for Preparing Stormwater Section of Biological Assessments", revised November 13, 2006, to represent pollutants from roads with greater than 20,000 ADT in the City of Kirkland. Lastly, data for diazinon stormwater loads from different land use categories were taken from Schiff and Sutula (2004).

2. METHODOLOGY

This assessment was entirely office-based, utilizing existing geographic information system (GIS) data, literature values for pollutant concentrations, and professional judgment about the appropriate use of the data in the assessment. It is possible that changes to any of the parameters used in the assessment could dramatically change the results.

GIS was the primary tool used to evaluate potential stormwater pollutant hot spots. GIS data layers provided the foundation for the assessment, using data that were available from the City's GIS department. Pollutant concentration data for different land uses (such as residential vs. commercial, streets vs. lawns) were obtained from recent urban stormwater literature. Additionally, businesses that could potentially contribute pollutants beyond the average concentrations reported for commercial or industrial properties were identified through the City's business license records, Washington State Department of Ecology's (Ecology's) toxic cleanup program listings, and a review of the City's telephone directory.

Pollutant concentrations were assigned to the individual land use classifications, and a 1-acre grid was overlaid onto the land use/pollutant concentration layer (Figure 1). Hot spot maps were created for individual pollutants by calculating a single concentration value for each grid cell, based on the weighted average of pollutant concentration by area. The concentrations were contoured in GIS to show potential hot spots for individual stormwater pollutants.

Cumulative stormwater pollutant hot spots were also identified for the sum of the five pollutants evaluated. In order to compare the potential for water quality improvement, individual concentrations were weighted by pollutant toxicity levels, termed toxic units. Toxic units were assigned to each pollutant so that the different pollutants could be summed and accounted for equally based on their relative toxicity in the environment. The individual data components and methodology are described below.

Once potential water quality hot spots were identified, we reviewed the presence of existing water quality best management practices (BMPs) to determine areas that already receive treatment, and existing wetlands or open spaces that could buffer impacts to receiving waters. We then looked at the "hottest" areas in more detail to evaluate opportunities for water quality treatment.

2.1 DATA COMPONENTS USED IN ASSESSMENT

2.1.1 GIS Data Layers

The City provided the most recent GIS layers for use in this assessment, including the following:

- Zoning
- Surface water features
- Water quality BMPs
- Road classifications
- Wetlands
- Impervious surfaces
- Average daily traffic volumes

The road classification layer was merged with the impervious surface layer to create polygons, because the road classification layer consisted of lines that could not be used in the assessment. Additionally, I-405, which is outside the City's jurisdiction, was included in the assessment as a high-traffic freeway to acknowledge potential freeway impacts that occur within the City's boundary and potential opportunities to team with the Washington State Department of Transportation (WSDOT) to mitigate stormwater pollutant impacts.

2.1.2 Land Uses Based on Zoning

Based on our review of land use in the City of Kirkland and zoning GIS coverages that show current and future zoning in the City, we used the following existing categories for this assessment:

- Commercial
- High Density Residential
- Industrial
- Institutions
- Light Manufacturing Park
- Low Density Residential
- Medium Density Residential
- Office/Multi-family
- Office
- Park/Open Space

Pollutant loading values are available in the literature for all land use categories except two (light manufacturing park, and office/multi-family). Table 2 lists the loading values used in the assessment as well as the references for those values. For each zoning category, we used the mean concentration value reported in the literature. The most common values reported for copper and zinc were for total concentrations, while the Washington State water quality criteria for these constituents were developed for dissolved concentrations. Consequently, total copper and zinc concentrations were translated into dissolved concentrations using the appropriate acute and chronic metals translators developed by USEPA (1996). For the two land use categories for which pollutant loading values were not represented in the literature, we made assumptions that are described in Table 2.

In addition to zoning classifications, the City also has an impervious surface GIS coverage that breaks down surfaces into different types of impervious and pervious surfaces. We used the impervious surface data as one of the criteria for prioritizing the hot spots.

2.1.3 Industrial and Commercial Businesses

The direct use of commercial and industrial land use classifications by themselves is not likely to completely capture the potential for certain businesses to contribute greater amounts of the pollutants of interest based on their specific industrial activities. Following the approach used by the United States Environmental Protection Agency (EPA) in regulating specific business classes for the General Industrial Stormwater permit, Standard Industrial Classification (SIC) codes that correspond to EPA's North American Industry Classification System (NAICS) codes for different types of business categories that process, store, or use any of the five pollutants evaluated in this study were used to classify the City of Kirkland businesses (Table 3). We assigned codes to businesses operating in the City by reviewing business license data supplied by the City, reviewing telephone book listings, and reviewing Ecology's toxics cleanup program website listing.

The business locations that fit descriptions shown in Table 3 were geocoded and added to the land use/zoning GIS layer. The business parcels were assigned pollutant concentrations based on the 95 percent confidence interval of the reported mean values in the literature reviewed under the assumption that these businesses were major contributors of certain stormwater pollutants.

2.1.4 Pollutants

The five pollutants evaluated in this assessment (TSS, dissolved copper, dissolved zinc, total PAHs, and diazinon) were chosen due to their ubiquitous presence in urban stormwater and demonstrated toxicity to aquatic organisms. TSS, copper, and zinc are common pollutants associated with roadway runoff, and the concentrations of these pollutants associated with different land uses are heavily documented. PAHs are also common in stormwater runoff, and are strongly associated with coal-tar asphalt sealants used in roadway overlays, as well as private parking lot and driveway resurfacing projects. Diazinon was chosen as a surrogate for all pesticides because of its demonstrated toxicity.

These pollutants exhibit toxicity at different levels (e.g., copper toxicity is recorded in micrograms per liter (µg/L) or parts per billion (ppb) while TSS toxicity to aquatic organisms is found in the milligrams per liter (mg/L) or parts per million (ppm) range, over a 1,000-fold difference between the two). To overcome this disparity and create a common measurement level for comparison, we used "toxic units" in our cumulative hot spot evaluation. These units were originally proposed by the EPA for assessing different pollutants, and are calculated by the following formula:

$$\text{Toxic Units} = \frac{\text{Concentration } (\mu\text{g/L or mg/L})}{\text{Toxicity Reference Value } (\mu\text{g/L or mg/L})}$$

Where: Toxicity Reference Value (TRV) = the concentration at which the pollutant is considered harmful to aquatic organisms.

Toxic units less than one indicate that the pollutant concentration will not significantly harm aquatic organisms. Toxic units greater than one indicate concentrations that have the potential to significantly harm aquatic organisms. Toxic units can be added together for different pollutants to create a comparative cumulative score. Areas with high cumulative pollutant scores indicate "hot spots" where concentrations of one or more chemical are at levels that could be harmful to aquatic life and will require large amounts of water in the receiving water bodies to dilute them to levels that will not be significantly harmful.

We used existing State Water Quality Standards (WQS) for copper and zinc and a draft Water Quality Criterion (WQC) for diazinon as TRVs for these three pollutants. The criteria for copper and zinc are hardness dependent, so we assumed a hardness of 25 mg/L calcium carbonate ($CaCO_3$) as a representative value for the receiving waters in and around the City of Kirkland, including Juanita and Forbes creeks and Lake Washington. Ecology and EPA have not provided a WQC for total PAHs, but EPA has developed a draft WQC for individual PAHs. We used EPA's draft criterion for the most toxic PAH, benzo(a)pyrene, as a conservative measure of total PAH toxicity, adjusted to the 10^{-4} risk level[1].

[1] This adjustment was made based on the differences in expected exposure levels. In the original EPA TRV, the benzo(a)pyrene was based on consuming a fish meal every week from a waterbody over a 70 year period, which could result in an extra cancer in 1,000,000 people. Our determination was that this consumption level is orders of magnitude greater than those experienced by recreational fishers in the Kirkland area, an adjustment in the risk level as made to reflect this difference.

Table 2. Pollutant Loading Concentrations by Land Use

Current Zoning	Cu, Dissolved (µg/L)			Zn, Dissolved (µg/L)			Total PAH (ng/L)			Diazinon (ng/L)		TSS (mg/L)			Assumptions/ Sources
	Mean	SD[1]	CI[2]	Mean	SD[1]	CI[2]	Mean	SD[1]	CI[2]	Mean	CI[2]	Mean	SD[1]	CI[2]	
Commercial	53.6	25.3	75.8	130.8	58	181.6	1200	580	1708	324	57	15	8.1	22.1	
High Density Residential	19.1	5.3	23.7	193.1	99.3	280.1	4400	2600	6679	99.2	12.6	97	74	162	
Industrial	151.6	32.2	179.8	574.5	234.4	780	1500	860	2254	89.6	8.7	130	140	142	
Institutions	53.6	25.3	75.8	130.8	58	181.6	1200	580	1708	324	57	15	8.1	22.1	Equal to Commerical Loading
Low Density Residential	16.4	4.6	20.4	58.3	10.7	67.7	1400	600	1926	67.6	4.4	22	8.6	41	
Medium Density Residential	17.8	4.9	22.1	125.7	55	173.9	2900	1600	4302	83.4	8.5	59.5	41.3	95.7	Average of High and Low Density Residential
Office	17.8	4.9	22.1	125.7	55	173.9	2900	1600	4302	83.4	8.5	59.5	41.3	95.7	Equal to Medium Density Residential
Park/Open Space	7.3	2.3	9.3	22.9	11.2	32.7	-	-	-	20	0	33	ND	-	
Road (<10,000 ADT)	4.9	3.7	-	36.8	36.4	-	ND	ND	-	ND	ND	38.9	55.8	-	
Road (10,000 - 20,000 ADT)	19.3	10.2	-	115.6	84.6	-	ND	ND	-	ND	ND	240.2	150.8	-	
Road (20,000 - 60,000 ADT)	19.4	17.4	-	106.8	100.8	-	ND	ND	-	ND	ND	66.9	56.7	-	
Road (>60,000 ADT)	56.6	--	-	345.1	--	-	ND	ND	-	ND	ND	192	--	-	

[1]Standard Deviation
[2]95% Confidence Interval
ADT = Average Daily Traffic (number of cars)

Table 3. Industries and SIC Codes Specifically Identified in the Industrial NPDES Stormwater General Permit that are Potential Sources of the Pollutants

Industry	SIC Code	NAICS Code[1]	Possible Sources of:				
			Copper	Zinc	Total PAHs	Diazinon	TSS
Food and Related Products	20xx	311XXX	--			X	X
Furniture and Fixtures	25xx	337XXX			X		X
Chemicals and Allied Products	28xx	325XXX	X	X	X	X	X
Facilities Storing, Transferring, Formulating or Packaging Vegetable Oils, such as Biodiesel.	2869	325110			X	X	X
Petroleum Refining and Related Industries	29xx	324XXX			X		X
Primary Metal Industries	33xx	331XXX	X	X			X
Fabricated Metal Products	34xx	332XXX/ 333XXX	X	X			X
Industrial and Commercial Machinery and Computer Equipment	35xx	332XXX/ 333XXX	X	X	X		
Electronic and Other Electrical Equipment and Components	36xx	335XXX	X	X	X		
Transportation Equipment	37xx	336XXX			X		X
Miscellaneous Manufacturing Industries	39xx	339XXX	X	X	X	X	X
Railroad Transportation and Vehicle Maintenance Shops (including vehicle rehabilitation, mechanical repairs, painting, fueling, and lubrication)	40xx	482XXX/ 488XXX	X	X	X		X
Local and Suburban Transit and Interurban Highway Passenger Transportation and Vehicle Maintenance Shops (including vehicle rehabilitation, mechanical repairs, painting, fueling, and lubrication)	41xx	485XXX	X	X	X		X
Motor Freight Transportation	42xx	484XXX/ 493XXX 562XXX	X	X			X
Farm Product Storage	4221	493130			X	X	X

Table 3. Industries and SIC Codes Specifically Identified in the Industrial NPDES Stormwater General Permit that are Potential Sources of the Pollutants (continued)

Industry	SIC Code	NAICS Code[1]	Possible Sources of:				
			Copper	Zinc	Total PAHs	Diazinon	TSS
United States Postal Service and vehicle maintenance shops (including vehicle rehabilitation, mechanical repairs, painting, fueling, and lubrication).	43xx	491110	X	X	X		X
Active Landfills (including, but not limited to, woodwaste and inert landfills, transfer stations, open dumps, compost facilities, and land application sites, except as described in S1.B.6 or B.7)	4953	562212	X	X	X	X	X
Hazardous Waste Treatment, Storage, and Disposal (TSD) Facilities, and Recycling Facilities Regulated under Chapter 173-303 Washington Administrative Code (WAC). Universal waste handlers regulated under WAC 173-303-573, or oil recyclers regulated under WAC 173-303-515.	4953	562221	X	X	X	X	X
Recycling Facilities Involved in the Recycling of Materials (including but not limited to, metal scrapyards, battery reclaimers, salvage yards, auto recyclers, and automobile junkyards)	5015 and 5093	423140 and 425110	X	X	X	X	X
Petroleum Bulk Stations and Terminals	5171	424710			X		X
Farm Supply and Feed Stores	5191	444220				X	X

1 NAICS codes taken from “2002 NAICS to 1987 SIC Code Relationships”, at http://www.epa.gov/ttn/chief/codes/naics02tosic87.pdf. Accessed June 15, 2007.

Equally, no criterion has been developed by either regulatory agency for TSS. However, several states have adopted criteria for TSS levels. We selected the most conservative value, 25 ppm for this evaluation. We used that value here as a TRV to calculate TSS toxic units. Table 4 lists the criteria used to develop toxic units. Table 5 list the toxic units used in this assessment.

Table 4. Criteria Used to Develop Toxic Units

Pollutant	Water Quality or Other Criterion	Source	Comments and Assumptions
Dissolved Copper	4.29 µg/L	State Water Quality Standard	Calculated based on hardness of 25 mg/L $CaCO_3$ assumed for Kirkland receiving waters
Dissolved Zinc	28.7 µg/L	State Water Quality Standard	Calculated based on hardness of 25 mg/L $CaCO_3$ assumed for Kirkland receiving waters
Total PAHs	17.99 ng/L	EPA Draft Water Quality Criterion for Benzo(a)pyrene	Benzo(a)pyrene is one of the most toxic PAHs, and was used as a conservative measure of total PAH toxicity. A conservative value was based on significant human consumption of affected aquatic organisms.
Total Suspended Solids	25 mg/L	Survey of States with Adopted Criteria for TSS	While the lowest value was 20 mg/L, 3 of the 6 states with criteria had adopted 25 mg/L. This value was selected for this analysis.
Diazinon	115.7 ng/L	EPA Recommended Water Quality Criteria	Toxicity to aquatic organisms.

Table 5. Toxic Units Used in Evaluation

Current Zoning	Copper Toxic Unit (chronic)	Zinc Toxic Unit (chronic)	PAHs Toxic Unit (HH)	Diazinon Toxic Unit (acute/chronic)	TSS Toxic Unit (Cnd/U.S.)	Total Toxic Units by Zoning
Commercial	12.5	4.6	6.67	2.8	0.6	27.17
High Density Residential	4.4	6.7	24.44	0.8	3.88	40.23
Industrial	35.3	20.0	8.33	0.8	5.2	69.56
Institutions	12.5	4.6	6.67	2.8	0.6	27.12
Low Density Residential	3.8	2.0	7.78	0.6	0.88	15.09
Medium Density Residential	4.1	4.4	16.11	0.7	2.38	27.66
Office	4.1	4.4	16.11	0.7	2.38	27.68
Park/Open Space	1.7	0.8	0	0.2	1.3	3.98
Road (<10,000 ADT)	1.1	1.3	ND	ND	1.6	4.00
Road (10,000 - 20,000 ADT)	4.5	4.0	ND	ND	9.6	18.10
Road (20,000 - 60,000 ADT)	4.5	3.7	ND	ND	2.7	10.90
Road (>60,000 ADT)	13.2	12	ND	ND	7.7	32.90

ND = Pollutant not reported for this land use.

ADT = Average Daily Traffic (number of cars)

2.2 GIS HOT SPOT ASSESSMENT

Following compilation and organization of the data described above, a grid consisting of 1-acre cells was constructed in GIS. Two separate sets of analyses were performed: one for each of the individual pollutants, and one for the cumulative pollutants based on the total toxic units.

2.2.1 Individual Pollutant Hot Spot Maps

A single concentration was assigned to each 1-acre grid cell by calculating a weighted average of the individual zoning classifications by the pollutant concentration associated with that zoning, as shown in Table 6.

Table 6. Example of Calculating a Weighted concentration for Dissolved Copper

Zoning Classification	Area Represented (acres)	Concentration (µg/L)	Weighted concentration (µg/L-acre)
Commercial	0.5	53.6	26.8
Medium Density Residential	0.2	17.8	3.56
Parks/Open Space	0.2	7.3	1.46
Road (10,000 to 20,000 ADT)	0.1	19.3	1.93
		Total Cell Concentration (µg/L)	33.8

The concentrations calculated for each cell were then contoured in GIS to create pollutant hot spot maps for each constituent. The color scheme and ranges of concentrations emphasized by each color were chosen so that the “hottest” hot spots would be highlighted on the maps.

2.2.2 Cumulative Pollutant Hot Spot Map

Similar to the individual pollutant hot spot maps, a cumulative map was developed by calculating the weighted average of total toxic units for each grid cell.

3. RESULTS

As described in the previous section, the methodology used in this assessment was based on existing GIS layers and published literature values for different pollutants. The hot spots identified on the resulting maps (Figures 1 through 7) represent *potential* areas that could contribute pollutants to receiving waters through stormwater runoff. Water quality monitoring would be necessary to confirm or deny whether the particular areas identified on the following maps are actually contributing pollutants to the City's receiving waters.

Additionally, because this assessment was completed using a 1-acre grid cell (Figure 1), large land areas that have a particular land use tend to skew the concentration for each cell toward the particular concentration represented by the large land area. It is well known that untreated stormwater runoff from roads contributes pollutants to receiving waters. In this assessment, the roads did not show up as hot spots because the linear nature of these features represents small portions of each grid cell. The exception is I-405, which traverses a large area in the middle of the city and has high traffic volumes that potentially contribute greater amounts of pollutants. The grid cells with smaller roads in them were more influenced by surrounding land uses.

The following sections describe the results of both the individual pollutant mapping and the cumulative toxic unit mapping.

3.1 INDIVIDUAL POLLUTANT HOT SPOTS

Individual pollutant hot spot maps are shown in Figures 2 through 6. For all pollutants, two hot spot areas stand out as having the potential for higher concentrations of four out of five of the pollutants evaluated. These include:

- Commercial and industrial areas near Totem Lake in the Juanita Creek sub-basin
- South Rose Hill commercial corridor along NE 85th Street in the Forbes Creek sub-basin

All of these areas are heavily commercial or industrial areas within the City, and the types of businesses located there have the potential to contribute many of the pollutants evaluated in this assessment. Other commercial areas, such as downtown Kirkland and Juanita did not show up consistently on the individual pollutant hot spot maps. This could be because the businesses located in these areas are more likely to be retail and food-oriented businesses that have less potential to contribute pollutants to stormwater.

The copper and zinc hot spot maps (Figures 2 and 3) are nearly identical, as these pollutants have similar sources from their use in automobiles and metal products. The TSS hot spot locations (Figure 4) are also similar to copper and zinc, but include fewer areas within the City.

Total PAHs and diazinon hot spots are shown in Figures 5 and 6. PAHs are fairly ubiquitous as shown on the PAHs hot spot map (Figure 5) and much of the City has the potential for high concentrations of these compounds. The highest concentrations appear in large areas of high density residential development, but commercial and industrial areas also have the potential for high concentrations. Specific locations include:

- North Rose Hill neighborhood, just south of Totem Lake
- Northern City limit near Evergreen Hospital
- South Juanita neighborhood
- Moss Bay and Everest neighborhoods near downtown Kirkland

In this assessment, diazinon is mostly associated with commercial areas and institutions that have large landscaped areas, which are regularly maintained, sometimes with the use of pesticides. In addition to some of the other hot spots mentioned above for other pollutants, additional hot spots are highlighted on the diazinon map (Figure 6). These include:

- Kirkland downtown retail core on the waterfront and Central Way
- Northwest College in the Central Houghton neighborhood
- Carillon Point retail and business area
- South Juanita business area

This assessment could be under-representing the home-owner's use of diazinon, because no data were found in the literature to represent this source.

3.2 CUMULATIVE POLLUTANT HOT SPOTS

The cumulative pollutant hot spot map, based on the sum of toxic units for dissolved copper, dissolved zinc, TSS, diazinon and PAHs is shown in Figure 7. Three primary areas show up on the cumulative pollutant hot spot map as being "hotter" than other areas. These include the area east of Totem Lake, the Norkirk neighborhood north of NE 85th Street, and the Everest neighborhood along 116th Avenue NE. The cumulative hot spots do not exactly line up with any one of the individual pollutant maps. Several areas that are highlighted as "hot" on the individual pollutant maps are not shown as being such a priority when looked at relative to toxicity and in combination with other pollutants.

4. PRIORITIZATION OF POLLUTANT HOT SPOTS

The pollutant concentrations used in this assessment were based on a review of data in recent stormwater literature and are not based on any actual measurements of stormwater generated within the boundaries of the City of Kirkland. In general, the pollutant concentrations reported in the literature for most land uses in Kirkland, with the exception of parks and open space, are greater than the water quality thresholds discussed in Section 2.1.4. The hot spots highlight those areas with the highest concentrations. This underscores the ubiquitous nature of these pollutants in the urban environment and the need to treat stormwater runoff before it reaches local receiving waters. Over 80 percent of the City was built prior to the development of current stormwater management standards, and therefore stormwater runoff from most of the City's urban areas does not receive water quality treatment. A map showing age of development is shown in Figure 8. Because it is not economically feasible to treat *all* stormwater runoff from the built environment, this assessment highlights areas to focus treatment or other programs to minimize the potential impact from stormwater pollutants.

Before any capital improvement program is developed to address potential pollutant hot spots identified in this evaluation, we recommend field verification of potential pollutants through water quality monitoring (including related compounds not assessed here, such as other metals and pesticides). Additionally, existing pollution prevention programs should be reviewed with respect to effectiveness. As the City decides how best to spend the limited resources available for improving water quality within its jurisdiction, policy decisions will need to be made with regard to balancing source control programs with treatment.

4.1 PRIORITIZATION CRITERIA

Several criteria were applied to compare and prioritize the hot spots and provide additional information that can guide the City in deciding where to focus available resources. The criteria we used to prioritize hot spots for water quality treatment include:

- Total number of potential pollutants and relative toxicity
- Proximity to sensitive water bodies and beneficial uses
- Presence of existing stormwater BMPs and age of development
- Potential for human contact through passive recreation
- Proximity to areas slated for redevelopment
- Proximity to City-owned property or facilities
- Area of pollution-generating impervious surfaces

The locations of hot spots that were further evaluated are shown on Figure 9. A qualitative ranking (low, medium, high) was developed for the hot spots based on the criteria listed above (Table 7).

4.1.1 Potential for Multiple Pollutants and Relative Toxicity

Most of the areas identified as hot spots (Figure 9) have the potential for the presence of multiple pollutants, including copper, zinc, TSS, PAHs, and diazinon. This analysis produced only a few hot spots with single pollutants, and generally those were either for PAHs or diazinon. Higher concentrations of PAHs are associated with high-density residential areas, so these areas showed up as hot spots for PAHs.

Diazinon has the potential to be present in heavily managed landscape areas associated with commercial and institutional properties; therefore, these areas showed up as hot spots for diazinon. The single-pollutant hot spots, with the exception of the South Juanita area and downtown Kirkland, were assigned lower priority. The South Juanita and downtown Kirkland hot spots consist of high-density residential neighborhoods with the potential to contribute PAHs, and large commercial areas with the potential for diazinon or pesticide use. Because these areas are very close to swimming beaches on Lake Washington or adjacent to Juanita Creek (South Juanita hot spot), we included them on our priority list.

The cumulative pollutant hot spot map (Figures 7 and 9) show the "hottest" areas relative to toxicity. All five of the pollutants evaluated in this analysis were normalized relative to their median concentration by land use, individual toxicity and water quality thresholds. The three areas identified as the "hottest" on this map were given highest priority based on relative toxicity, even though they might not have been the highest priority based on other criteria.

4.1.2 Proximity to Sensitive Receiving Waters and Beneficial Uses

We reviewed the City's stream and surface water GIS data layer relative to the identified hot spots. Several hot spots are fairly close to sensitive receiving waters, including Totem Lake, Lake Washington, and Forbes and Juanita Creeks. The ultimate receiving water for Kirkland's stormwater runoff is Lake Washington, either by direct discharge to the Lake, or via one of the tributary streams including Juanita and Forbes creeks. Kirkland has many swimming beaches located on Lake Washington, as well as a large boating community that utilizes the waterfront. The lower reaches of Juanita and Forbes creeks are utilized by anadromous and resident fish species including coho salmon and cutthroat trout (The Watershed Company. 1998). Recreation and aquatic habitat are just two of the beneficial uses of Kirkland's receiving waters.

Totem Lake has the greatest cluster of pollutant hot spots surrounding it (Figure 9), and it appears that much of the storm drainage in this area discharges directly to the lake without treatment. Other hot spots are in proximity to Lake Washington, including the South Juanita and downtown Kirkland hot spots discussed above. Hot spots adjacent to sensitive receiving waters were assigned higher ranks.

4.1.3 Existing Stormwater BMPs and Age of Development

We reviewed the City's stormwater infrastructure GIS layer to evaluate whether some of the hot spots identified are already being treated, or whether there are opportunities to retrofit existing facilities to provide additional or enhanced treatment. In general, the existing water quality treatment facilities appear to be treating roadway runoff or newer residential developments. Most of the hot spots shown on Figure 9 are located in older commercial and industrial areas that were likely developed prior to the implementation of current stormwater treatment practices (Figure 8). Hot spots with existing BMPs were assigned lower ranks.

4.1.4 Potential for Human Contact

The potential for human contact from the pollutants evaluated in this study is possible in areas where outdoor recreation occurs, such as the Lake Washington beaches. With the exception of the South Juanita and downtown Kirkland hot spots, the potential for human contact is negligible. Hot spots with the potential for human contact were ranked higher.

4.1.5 Potential for Redevelopment

There is a lot of new development and redevelopment occurring in Kirkland, providing opportunities to replace and upgrade surface water infrastructure and provide water quality treatment where none previously exists. Two hot spots stand out as having the potential for water quality treatment as part of redevelopment projects: the South Rose Hill area, and Totem Lake north (Figure 7). New water quality treatment facilities are planned for the City's capital improvement project on NE 85th Street in the South Rose Hill area. The hot spots identified adjacent to NE 85th Street could potentially be treated in conjunction with the roadway project. The Totem Lake Mall redevelopment project is currently in the design phase, and provides an opportunity to incorporate water quality facilities into the design of this project. Hot spots that could be treated in conjunction with redevelopment or new development were ranked higher.

4.1.6 Proximity to City-owned property

The only hot spot identified in proximity to City-owned facilities is the Norkirk hot spot, which includes the City's maintenance shop. It appears that this area is already being treated by water quality swales, but if this is not the case, the City could decide to incorporate new water quality facilities on the maintenance shop property to treat some of this area.

4.1.7 Area of Pollution-Generating Impervious Surfaces (PGIS)

We organized the City's GIS layer for impervious and pervious surfaces into three categories based on the description of each polygon (i.e., road, parking lot, roof, sidewalk); pollution-generating impervious surfaces (PGIS), non pollution-generating impervious surfaces, and pervious surfaces (Figure 10). Hot spots located in areas with large amounts of PGIS were ranked higher.

4.2 FOCUSED WATER QUALITY HOT SPOT LOCATIONS

Each of the prioritized potential water quality hot spots listed in Table 7 are shown in greater detail in Figures 11 through 21. The priority of the hot spot, as well as rationale for including it are shown on the individual figures. Surface water features, including natural and constructed drainage systems and existing water quality treatment are shown for planning purposes.

4.3 FOCUSED POLLUTANT HOT SPOTS

The pollutant hot spots shown in Figure 11 are enlarged in Figures 12 through XX to show surface water infrastructure, topography and other features that could be useful in planning future water quality treatment projects, areas for retrofitting, or monitoring locations. The focused hot spots are organized by priority, with the highest ranked locations shown first followed by lower ranking locations. In many cases, the hot spots span drainage divides and may require multiple facilities or monitoring points to adequately address the presence of potential pollutants.

Table 7. List of Hot Spots and Prioritization Criteria

		General Hot-spot Location											
Prioritization Questions	**Response that leads to higher priority**	**Totem Lake East**	**Totem Lake Southeast**	**Totem Lake North**	**Totem Lake Southwest**	**South Rose Hill**	**Moss Bay**	**Norkirk**	**Downtown Kirkland**	**North Rose Hill**	**Evergreen Hospital**	**South Juanita Neighborhood**	**Everest**
Are there multiple pollutants?	*More pollutants equals higher priority*	Cu, Zn	Cu, Zn, TSS, diazinon	Cu, Zn, TSS, Diazinon	Cu, Zn, TSS, PAHs	Cu, Zn, TSS, PAHs	PAHs	Cu, Zn	PAHs, diazinon	PAHs	PAHs	PAHs, diazinon	Cu, Zn, PAHs
Are the cumulative toxic units greater than 50?	*Greater toxic units equals higher priority*	Yes	No	No	No	No	No	Yes	No	No	No	No	Yes
Is the Hot-Spot close to sensitive receiving waters?	*Close proximity equals higher priority*	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	No
Is there potential for human contact from passive recreation opportunities?	*Potential for human contact equals higher priority*	No	No	No	No	No	No	No	Yes	No	No	Yes	No
Are there existing water quality treatment facilities?	*Existing facilities equals lower priority*	No	No	No	Yes	No	Yes	Yes	No	No	No	No	No
Is the Hot-Spot located on or adjacent to City-owned property?	*City-owned equals higher priority*	No	No	No	No	No	Yes	Yes	No	No	No	No	No
Was more than 50% of the Hot-Spot developed prior to 1990?	*Property developed prior to 1990 equals higher priority*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes

Table 7. List of Hot Spots and Prioritization Criteria (continued)

		General Hot-spot Location											
Prioritization Questions	**Response that leads to higher priority**	**Totem Lake East**	**Totem Lake Southeast**	**Totem Lake North**	**Totem Lake Southwest**	**South Rose Hill**	**Moss Bay**	**Norkirk**	**Downtown Kirkland**	**North Rose Hill**	**Evergreen Hospital**	**South Juanita Neighborhood**	**Everest**
Are there large contiguous areas of pollution-generating impervious surfaces in the Hot-Spot?	*Large areas of PGIS equals higher priority*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes
Is the Hot-Spot on or adjacent to properties slated for redevelopment or capital improvement?	*Slated for redevelopment equals higher priority*	No	No	Yes	No	Yes	No	No	No	No	No	No	No
	Relative Priority	**Very High**	**High**	**High**	**Med**	**High**	**Med**	**Very High**	**High**	**Low**	**Low**	**High**	**Very High**

4.4 OTHER PRIORITIZATION CONSIDERATIONS

Most of the hot spots identified in this assessment are located on privately owned property. This adds a level of complexity, because the City currently has limited resources and regulatory authority to require treatment on properties that were developed prior to current stormwater treatment standards and regulations. The City is in the process of retrofitting their own facilities as infrastructure is replaced and upgraded. Additionally, the City has developed programs to identify illicit discharges (improper wastewater hookups to the storm drainage system) and educate business owners about pollution prevention programs. The City now needs to decide when and how to treat potential water quality problems that are the cumulative result of business enterprises and residential land uses within the City boundaries. These are challenging questions that many other jurisdictions are also dealing with in an attempt to balance the environmental and economic health of their communities.

4.5 REGULATORY FRAMEWORK

As the City works toward compliance with the National Pollutant Discharge Elimination System (NPDES) Phase II permit requirements, this assessment can be used to help guide City efforts including public education and outreach, and development of an illicit discharge detection and elimination program. The City has an excellent public education and outreach program that regularly provides citizens with information on how they prevent stormwater pollution and improve water quality in the City's watersheds. The hot spot maps (Figures 1 through 6) can be used to guide education efforts for specific neighborhoods or business centers in the City. Additionally, the Phase II permit requires procedures for locating priority areas likely to have illicit discharges, including an evaluation of land uses and associated business/industrial activities present. This hot spots analysis could be used to fulfill that requirement as part of the illicit discharge detection and elimination program.

5. DISCUSSION AND RECOMMENDATIONS

The potential stormwater pollutant hot spots identified in our analysis are in areas with high densities of commercial and industrial development that generally have higher concentrations of pollutants in stormwater runoff. One of the interesting findings of this analysis was that the road network, with the exception of Interstate 405, does not show up as stormwater pollutant hot spots. This observation could be in part due to the 1-acre grid cell size used in the analysis, with adjacent non-polluting land uses diluting the effects of roadway runoff. The roads by themselves aren't significant contributors per unit area, but when added together as a whole, they can be a significant source of contaminants to the overall watershed (particularly those roads with curbside parking or frequent stop/start traffic). To date, City of Kirkland funding for stormwater quality improvements has focused on city road rights-of-way. The City will continue to retrofit roadways as infrastructure is upgraded, however, the overall strategy for improving water quality must look beyond public roadways and infrastructure. Because the roads aren't showing up as hot spots, it's possible that stormwater management approaches that look beyond public roadways may afford greater advances towards the discharge of clean stormwater runoff in the City of Kirkland. It may be more cost effective from a technical standpoint and more beneficial to the City's water resources to retrofit larger, blockier pieces of property, rather than linear roadways where stormwater BMPs must compete with other utilities for space.

The general types of stormwater pollutant hot spots identified in this analysis are listed in Table 8, along with the data behind the development of the hot spot, and the uncertainties associated with hot spot identification. Table 8 also lists potential projects that could be completed to minimize the uncertainties, and those that could have a positive effect even with the inherent uncertainties.

As discussed previously, this assessment was purely a literature-based analysis that applied pollutant concentrations from those reported in the literature to the City's zoning map. The degree to which certain land uses or roadways are contributing the pollutants evaluated to Kirkland's receiving waters will not be known without field audits and water quality monitoring. Even without monitoring, we believe that there is enough regional data to support moving forward with water quality treatment facilities to improve the quality of the City's receiving waters. Below are several possible next steps for the City of Kirkland to continue in its role as a municipal leader in the field of stormwater management and make meaningful advances in the approach to water quality treatment.

5.1 WATER QUALITY MONITORING

To reduce the uncertainty of whether the stormwater pollutant hot spots are even contributing pollutants to the City's receiving waters, we recommend establishing a water quality monitoring program downstream of the identified hot spots to confirm or refute the presence of potential pollutants as well as to provide a basis for trend analysis as improvements occur. Additionally, because most of the hot spots are associated with privately owned properties, it is important to continue business outreach efforts to provide an understanding of the City's efforts and good will, obtain permission for access to monitoring sites, provide education regarding pollution prevention, and provide technical assistance for containing or treating runoff that cannot be eliminated.

Table 8. Data and Uncertainties Associated with Different Pollutant Hot Spots Identified in Analysis

General Type of Pollutant Hot Spot	Pollutants Present	Supporting Data	Assumptions and Uncertainties in hot spot analysis	What can be done to reduce uncertainties?	Relative Cost	What can be done without additional data?	Relative Cost
Areas with high densities of commercial and industrial land uses	Copper, Zinc, PAHs, Diazinon (commercial, see below) and TSS (industrial)	Pollutant loading literature reports high concentrations of copper and zinc for these land uses relative to other types of land uses	Literature values were assumed to apply to Kirkland businesses that fit these categories. This may not be true.	Collect water quality data from representative hot spots in industrial and commercial areas to confirm or deny assumptions used in analysis. Field check GIS data and confirm or deny the presence of water quality facilities.	Moderate-High	Retrofit commercial and industrial areas with water quality treatment facilities to bring facilities up to current guidelines for new development.	Moderate (depending on level of private sector participation)
		Most City of Kirkland properties that are zoned commercial and industrial were developed prior to 1990 (see Figure 8)	It was assumed that water quality facilities don't exist on properties developed prior to 1990, because stormwater regulations didn't require these types of BMPs.				
		Commercial and industrial zoned properties in Kirkland have high percentages of pollution-generating impervious surfaces (see Figure 10).	Source control BMPs could be in place to minimize the chance of pollutants reaching receiving waters, thus making them ineffective PGIS.				

Table 8. Data and Uncertainties Associated with Different Pollutant Hot Spots Identified in Analysis (continued)

General Type of Pollutant Hot Spot	Pollutants Present	Supporting Data	Assumptions and Uncertainties in hot spot analysis	What can be done to reduce uncertainties?	Relative Cost	What can be done without additional data?	Relative Cost
High Density Residential Areas	PAHs, Diazinon (see below)	Pollutant loading literature reports high concentrations of PAHs and moderate levels for copper, zinc, diazinon, and TSS relative to other land uses.	PAHs are typically associated with parking lot sealants, and these may or may not be used extensively in high density residential areas in Kirkland.	Collect water quality data from representative hot spots in industrial and commercial areas to confirm or deny assumptions used in analysis	Moderate-High	Ban the use of parking lot sealants that contain PAHs.	??
Roads greater than 60,000 ADT (I-405)	Copper, Zinc and TSS (no data on other pollutants evaluated)					Work with WSDOT to provide full water quality treatment as it constructs new I-405 projects through Kirkland. Contribute to water quality treatment fund to ensure adequate facilities get implemented.	Moderate- High
Areas with high densities of commercial, high density residential and institutions	Diazinon	Pollutant loading literature reports relatively high concentrations of diazinon	Diazinon was used as a surrogate for all pesticides, as it is the most toxic and data is available. It may or may not be used extensively in Kirkland	Review sales receipts from City retailers that carry products containing diazinon to get an idea of the amount used in Kirkland. Collect water quality data from representative hot spots to confirm or deny the presence of diazinon in receiving waters.	Moderate-High	Ban the sale of diazinon within the City limits	??

5.1.1 Field Confirmation of Pollutant Hot Spots

Water quality samples should be collected to confirm the presence and levels of pollutants in receiving waters or the constructed drainage system. We identified some candidate monitoring locations with respect to the mapped pollutant hot spots (Figure 23) that could be incorporated into the City's existing or future water quality monitoring program. Specific monitoring details are not presented here, but would need to be developed as part of a Quality Assurance Project Plan (QAPP).

5.1.2 Redevelopment

The City has a unique opportunity to monitor the potential for sites redeveloped with explicit water quality improvement goals to reduce pollutant loading to the City's receiving waters. In particular, one of the hot spots, the Totem Lake Mall area, currently has no water quality treatment facilities treating stormwater runoff. The redeveloped mall will be required to install water quality BMPs to comply with current stormwater codes. It would be useful for City stormwater managers to collect baseline water quality data prior to redevelopment and again after development has been completed to evaluate the effect of retrofitting this large commercially-zoned area with water quality BMPs as well as to make a future case for either increasing or reducing future redevelopment water quality facility requirements.

5.2 WATER QUALITY RETROFITTING

As mentioned above and shown on the hot spot maps created from this analysis, many of the hot spots are located on private property. This presents a challenge to City stormwater managers trying to comply with NPDES Phase II requirements and maintain productive relationships with the business community. Much of the private development in the City was constructed prior to knowledge of the impact of non-point source pollution from stormwater runoff and the implementation of current stormwater codes. In order to make any meaningful reduction in pollutants transported to receiving waters through stormwater runoff, privately owned properties will need to be retrofitted with water quality treatment facilities. Source control programs that take steps to eliminate or minimize pollutants before they have a chance to come in contact with stormwater can be effective for point source type pollutants, but are infeasible for minimizing pollutants emanating from uncovered parking lots in dense commercial and residential areas.

A comparative example of the potential benefit of retrofitting private parking lots with water quality facilities relative to roadways is shown in Table 9. Commercial properties have the potential for higher concentrations of copper and other pollutants, than roadways. Therefore, it should be possible to remove greater quantities of pollutants from the equivalent surface area of a commercial parking lot versus a roadway. The example for copper in Table 9 shows that three times the area of road surface would need to be treated to remove the same mass of pollutants from a 1-acre commercial parking lot. Kirkland has approximately 1400 acres of roadway, excluding I-405, and approximately 600 acres of parking lots. Using the example in Table 9, only 75 percent of the parking lots would need to be retrofitted with water quality BMPs to achieve the equivalent reduction in copper from treating *all* of Kirkland's roadways.

Retrofitting privately-owned property will require careful planning and thoughtful partnerships between the City and the business community. On the spectrum of possibilities between regulation and water quality credit trading, there are several different approaches that would produce the same end result, but would cost the public or the business community more depending on the approach chosen.

Table 9. Example of Potential Reduction in Copper Loading for Different Land Surfaces

Land Surface	Area (acres)	Equivalent Area	Pre-treatment Cu loading (lbs/acre/year)	Post-treatment Cu loading (pounds/acre/year)[1]
Commercial	1	200 stall parking lot	4.8	2.4
Industrial	1	200 stall parking lot	13.6	6.8
Road (<60K ADT)	1	870 linear feet of a 50-wide road	1.72	0.86

[1] Post-treatment loading assumes water quality BMP removes 50% of the copper in stormwater routed through the facility.

The spectrum of potential new approaches are described in more detail below. Additionally, Table 10 shows the list of approaches relative to public and private impacts and considerations. A table such as this could be used to evaluate potential public and private impacts, as well as mitigation measures before deciding on a preferred retrofit strategy.

Some potential options for managing stormwater from private properties are discussed in the following sections.

5.2.1 Require Water Quality Retrofitting

Requiring private businesses to comply with current regulations and retrofit their facilities with water quality treatment is on one end of the spectrum between public and private participation in the goal of improving water quality in Kirkland. In its goal to comply with NPDES Phase II permit conditions as well as the Clean Water Act, the City could implement code changes requiring private property owners to install water quality treatment facilities. This could be done in the very near future, or over an extended time period, such as 10 years, during which times various incentives could be implemented to help defray the expense of facility construction or to allow businesses to plan for the expense. A longer time frame would also allow the City to increase its base of knowledge regarding hot spots, retrofits and the most effective locations and techniques for stormwater pollutant reduction in the City.

5.2.2 Provide Business Incentives for Retrofitting

Another alternative to promote water quality retrofitting of private facilities is to provide business incentives such as reduced surface water fees in exchange for retrofitting. The City could also encourage the installation of pervious pavement in areas that have good infiltration potential, again with reduced surface water fees as an incentive. It is likely that incentives would be most effective if linked to a certain date when businesses would be required to have stormwater treatment technologies in place.

5.2.3 Establish City Fund for Private Retrofit Projects

The City has a strong interest in making positive water quality changes to its receiving waters for its own interests as well as for the benefit of the Puget Sound region. By establishing grants for private businesses to retrofit their property, the City could potentially make a bigger difference than retrofitting their own facilities. The grants from the City would show private business that the City is serious about water quality, and would provide businesses the opportunity to jump-start their own environmental stewardship programs and make a positive difference.

Table 10. Approaches and Considerations for Water Quality Retrofitting in Kirkland

		RETROFIT APPROACH				
		Potential New Approaches				Current Approach
IMPACTS		Require Retrofit of Privately-owned Properties	Provide Incentives for Businesses to Retrofit their Properties	Establish Grants for Businesses	Establish Water Quality Trading System	Retrofit Roadways as Infrastructure is Upgraded
Impact to Private vs. Public Entities	Public (Rate payer)					
	Private (Business Community)					
Type of Impact and Considerations	Loss of Business					
	Traffic Delays					
	Property Acquisition					
	Degree of Water Quality Improvement					
	Operation and Maintenance					
	Long-term Performance of Water Quality BMPs					
	Loss of Parking Spaces					
	Competition with other Utilities for Space					
	Property Values					
	Legal Liabilities					
	Construction Cost					
	Public Health Risk					

Non-profits, schools and institutions should also be considered for potential water quality retrofit funding. School and institutions in particular, likely have large pollution-generating impervious surfaces that would be logical places to demonstrate how retrofitting can be accomplished.

5.2.4 Trade Water Quality Credits between Public and Private Entities

The City could look into creating a system which would allow private businesses, government agencies, and other City stakeholders to make water quality improvements that have a common value that can be bought and sold by others that are unable to provide water quality treatment because of site constraints or other mitigating factors. This ecosystem marketplace approach is gaining momentum in other parts of the country, but has not yet been used extensively for water quality issues. However, the Lake Tahoe region has established a system to deal with nutrient loading in the Lake, and it appears to be quite successful in reducing the eutrophication issues. Similarly, entities in the Willamette Valley in Oregon are taking dramatic steps forward in the water quality trading arena.

5.3 INVESTIGATE OTHER METHODS FOR ACHIEVING POSITIVE IMPROVEMENTS IN WATER QUALITY

Other methods to make improvements in water quality in the City of Kirkland include limiting the sale and use of pollutants that contribute to water quality degradation, such as diazinon, and parking lot sealants that contain PAHs. Additionally, the City could support and participate in organizations geared toward finding acceptable replacement materials for copper and zinc in brake linings and other automobile parts. Reducing the sale and use of materials that contribute to water quality degradation could have a huge impact on the quality of surface water resources, well beyond what can be achieved through treatment.

5.4 POTENTIAL USE OF BIOTIC LIGAND MODEL

As science furthers understanding of natural systems, water quality standards may need to be modified or flexible enough to reflect the inherent variability in ecosystem conditions. The Biotic Ligand Model is a tool that could be applied to Kirkland's streams to evaluate the carrying capacity for streams to accommodate certain pollutants such as copper and zinc. In some instances, concentrations of copper or zinc above the water quality standards, may still be protective of aquatic organisms if the right environmental conditions are present.

The Biotic Ligand Model shows that the amount of total organic carbon (TOC) in the aquatic environment affects the bioavailability of metals and nutrients to sensitive aquatic organisms. For instance, if there was more carbon input into the system (trees, leafy debris), the TOC content would likely increase, which would allow for greater loads of copper to be discharged to the system without further detrimental effects to the organisms. Using the Biotic Ligand Model, the City could also evaluate whether increasing carbon inputs through revegetation, etc., may be more effective at alleviating the affects of copper of other constituents in stormwater than treating the water prior to discharge.

The University of Washington's School of Forestry has been collecting data necessary to run this model. It would be useful to partner with the University to research urban streams (an example could be the comparison of the Juanita Woodlands with the Forbes creek area) and evaluate the feasibility and usefulness of using the model to develop loading parameters.

5.5 ESTABLISH MEASURABLE GOALS FOR WATER QUALITY IMPROVEMENT

It is important for the City to establish measurable goals for improving water quality. While this is no easy task, the first step is to determine what the baseline is from which to measure progress. This hot spots analysis identifies several locations (almost all on private property) for which to prioritize water quality treatment in the City of Kirkland. Figure 8 shows the date of property development in Kirkland, highlighting the extent of properties without stormwater controls (assuming properties did not install water quality BMPs prior to the regulatory requirement to do so). Once policy decisions are made on the best strategy for implementing water quality retrofit projects, the City should consider making a list of measureable goals with costs and associated timelines, such as those shown below. In most of the goals listed, the pollutant hot spots identified in this report provide a basis for initial prioritization.

- Consider reducing certain pollutants by X pounds per year. Simple pollutant loading evaluations can be done with the GIS analysis completed in this study. Using assumed BMP treatment efficiencies, based on NPDES data from WSDOT or others, it's possible to calculate the reductions that would be accomplished by treating certain land surfaces.
- Consider treating X number of commercial parking spaces, or Y length of roadway, or Z acres of high density development parking spaces on an annual basis.
- Consider spending X dollars per year on retrofitting the hot spots in this analysis, working through the list as money is available.
- Campaign for a reduction of X% in the use of parking lot sealants that contribute PAHs to stormwater runoff. Find alternatives for sealing parking lots.
- Campaign for the elimination of the sale and use of diazinon within the City limits within X years.
- Participate in industry, municipal or scientific organizations aimed at finding acceptable alternatives for the use of copper and zinc in brake linings and automobile parts.

6. REFERENCES

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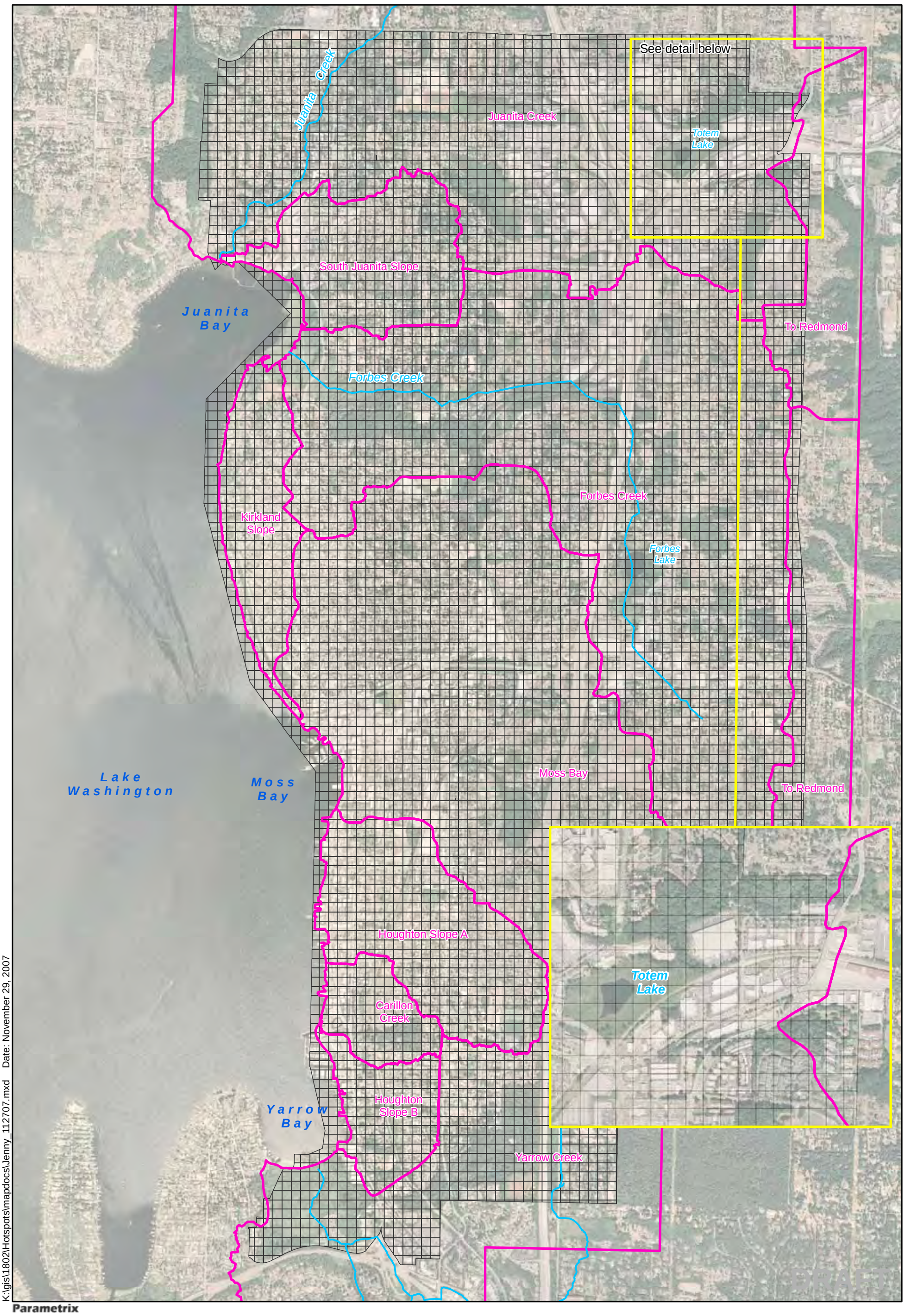
FIGURES



K:\gis\1802\Hotspots\mapdocs\Jenny_112707.mxd Date: November 29, 2007

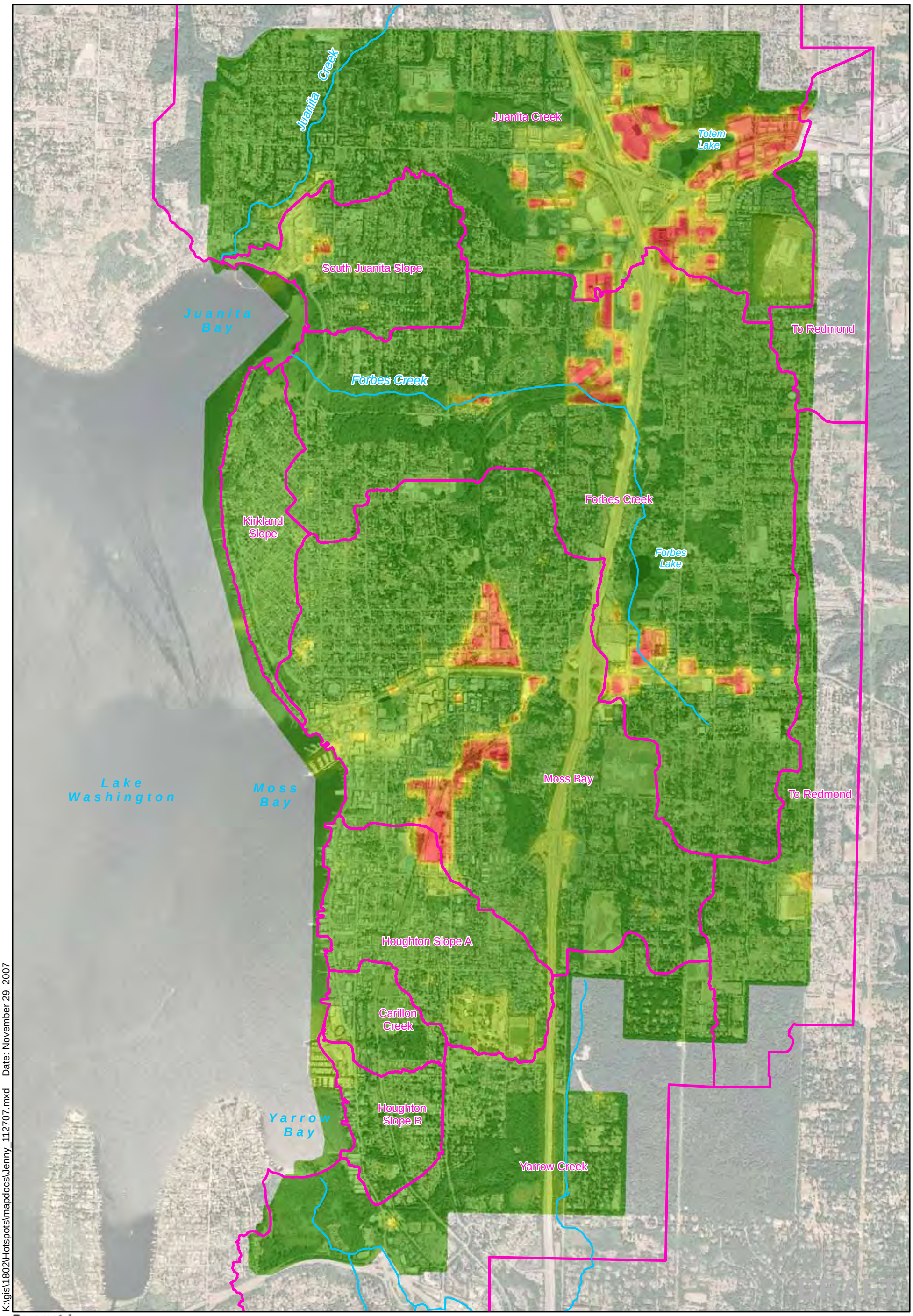
Parametrix

0 2,000
Scale in Feet

Legend

- 1- acre grid
- Surface Water Basin
- Stream

Figure 1
Vicinity Map
with1-acre Grid Cells



K:\gis\1802\Hotspots\mapdocs\Jenny_112707.mxd Date: November 29, 2007

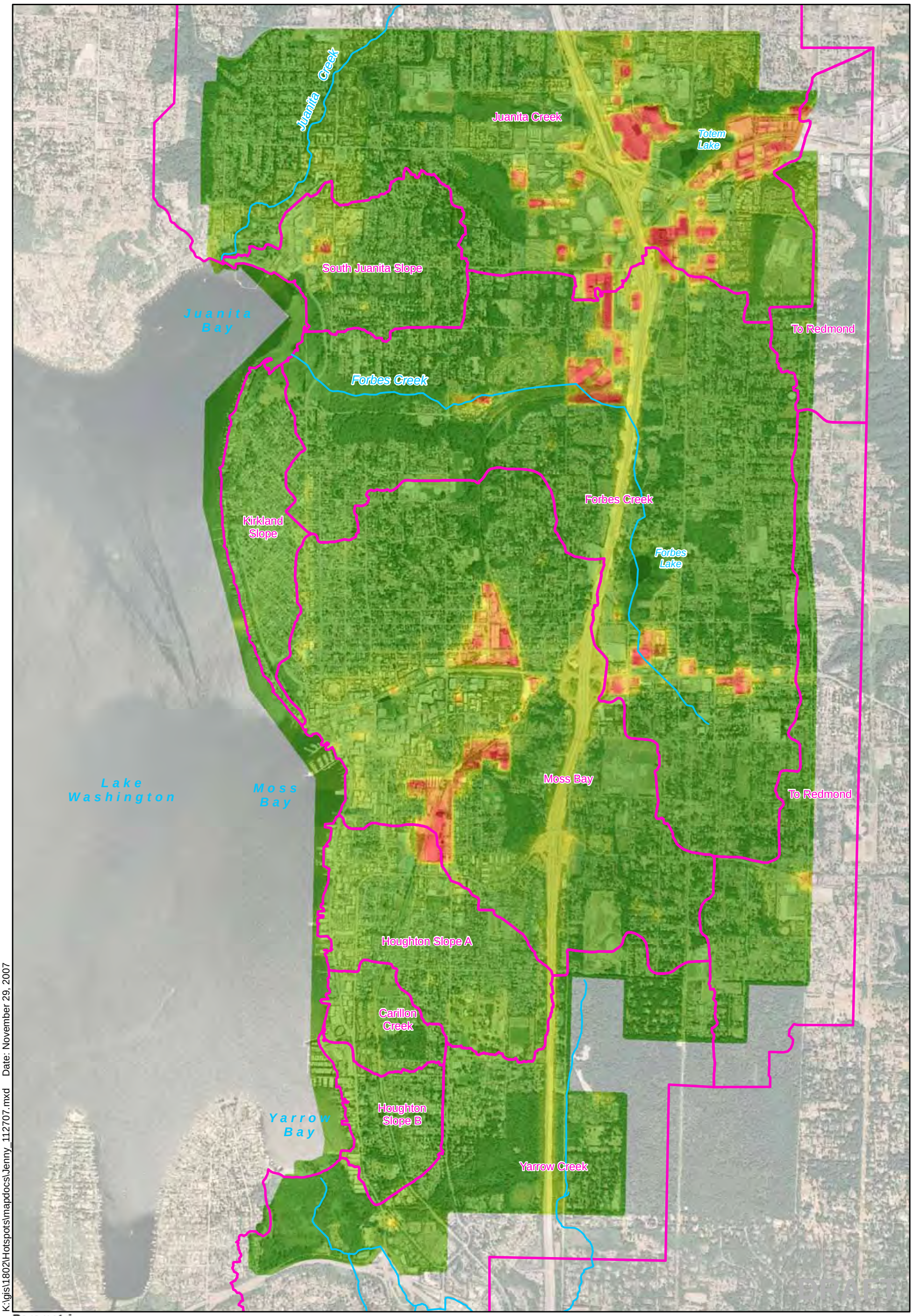
Parametrix

0 2,000
Scale in Feet

Legend

Copper (ug/L)
- 7 - 23
- 24 - 41
- 42 - 59
- 60 - 77
- 78 - 98
- 99 - 119
- 120 - 139
- 140 - 161
- 162 - 179
- Surface Water Basin
- Stream

Figure 2
Copper Hot Spots



K:\gis\1802\Hotspots\mapdocs\Jenny_112707.mxd Date: November 29, 2007

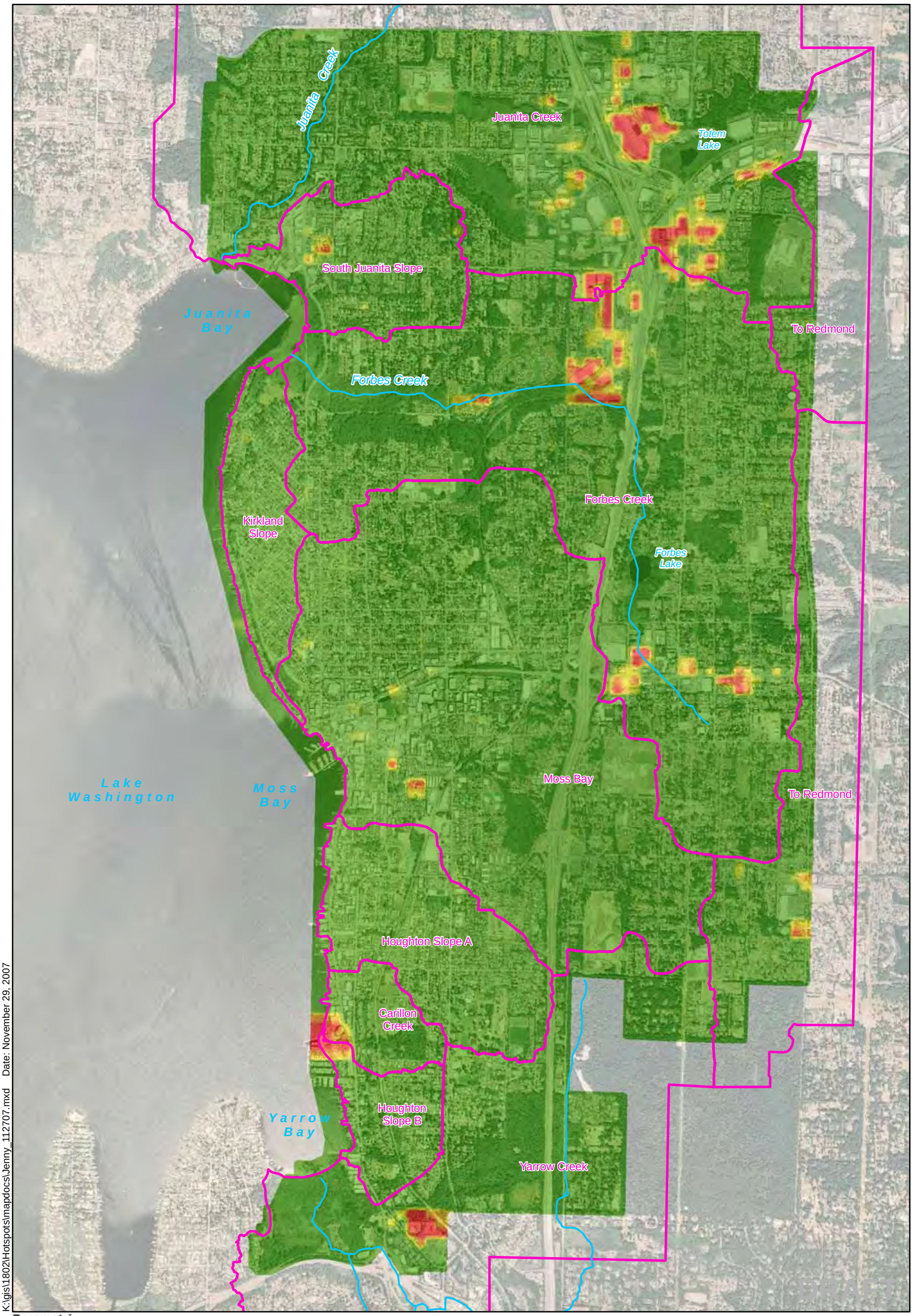
Parametrix

0 2,000
Scale in Feet

Legend

Zinc (ug/L)
- 23 - 88
- 89 - 154
- 155 - 249
- 250 - 352
- 353 - 439
- 440 - 525
- 526 - 608
- 609 - 700
- 701 - 780
- Surface Water Basin
- Stream

Figure 3
Zinc Hot Spots



K:\gis\1802\Hotspots\mapdocs\Jenny_112707.mxd Date: November 29, 2007

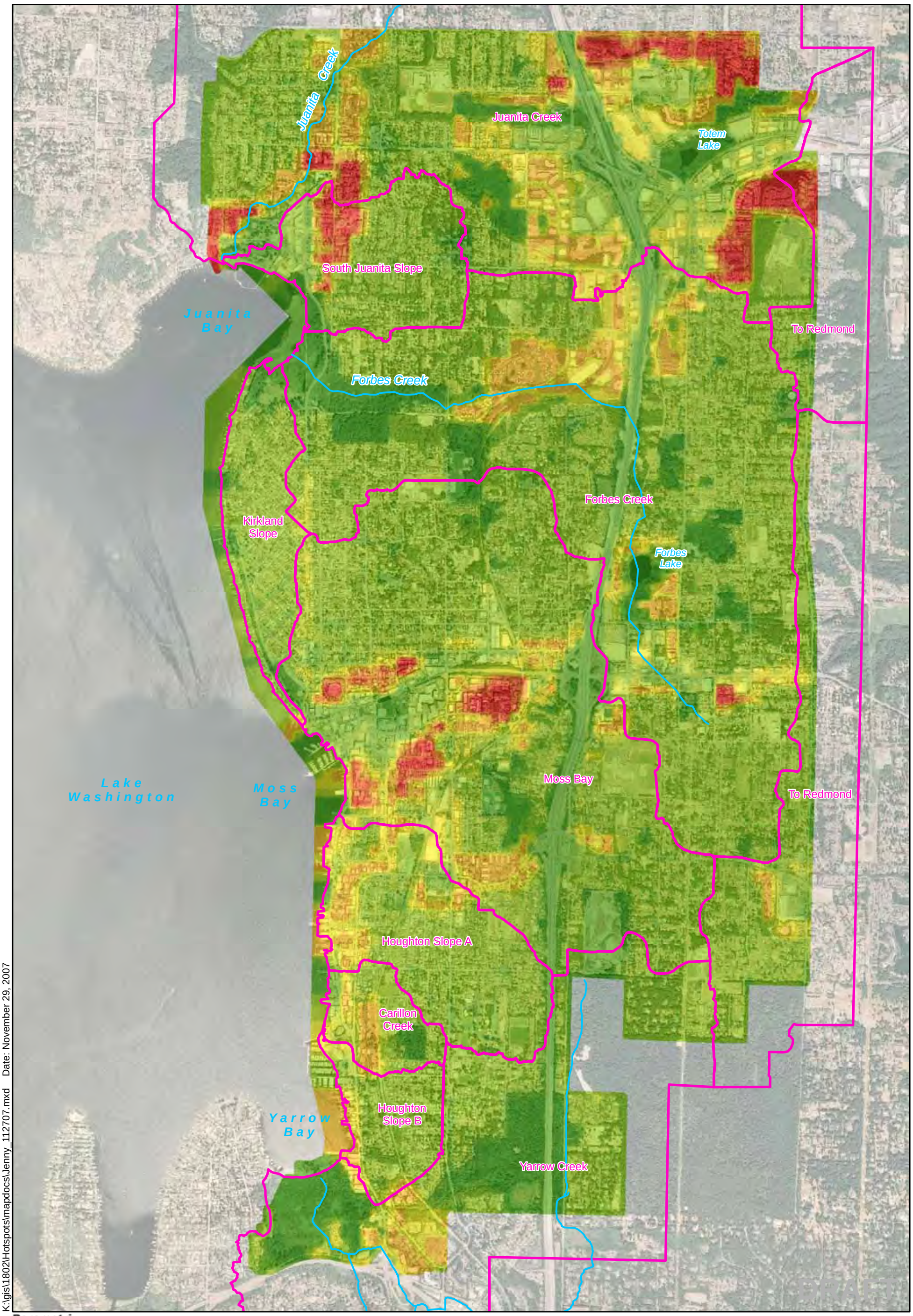
Parametrix

0 2,000
Scale in Feet

Legend

TSS (mg/L)
- 15 - 171
- 172 - 328
- 329 - 484
- 485 - 641
- 642 - 797
- 798 - 953
- 954 - 1,110
- 1,111 - 1,266
- 1,267 - 1,423
- Surface Water Basin
- Stream

Figure 4
TSS Hot Spots



K:\gis\1802\Hotspots\mapdocs\Jenny_112707.mxd Date: November 29, 2007

Parametrix

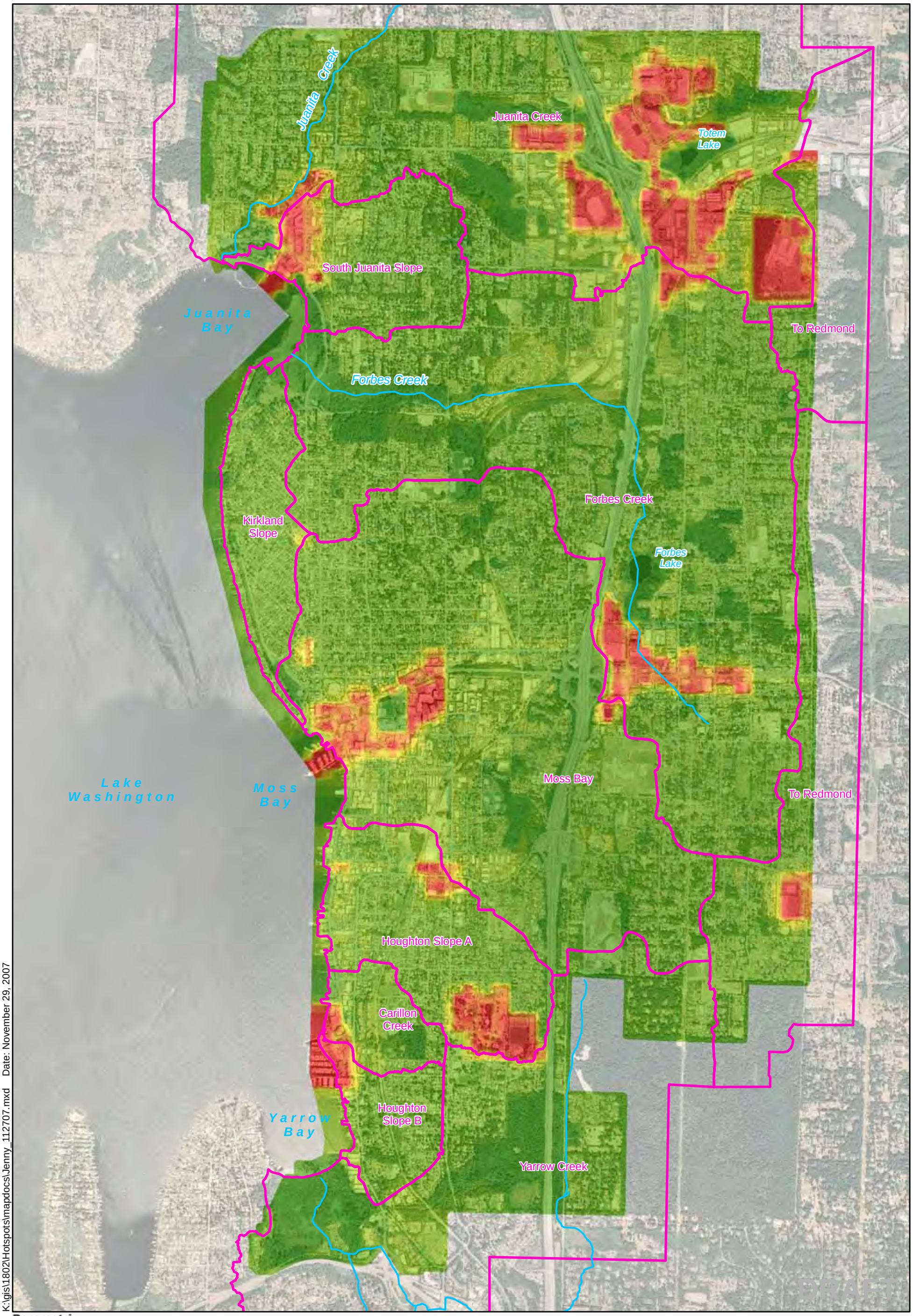
0 2,000
Scale in Feet

Legend

PAHs (ng/L)

- 0 - 466
- 467 - 1,053
- 1,054 - 1,501
- 1,502 - 1,984
- 1,985 - 2,502
- 2,503 - 3,002
- 3,003 - 3,503
- 3,504 - 4,020
- 4,021 - 4,400
- Surface Water Basin
- Stream

Figure 5
Total PAHs Hot Spots



K:\gis\1802\Hotspots\mapdocs\Jenny_112707.mxd Date: November 29, 2007

Parametrix

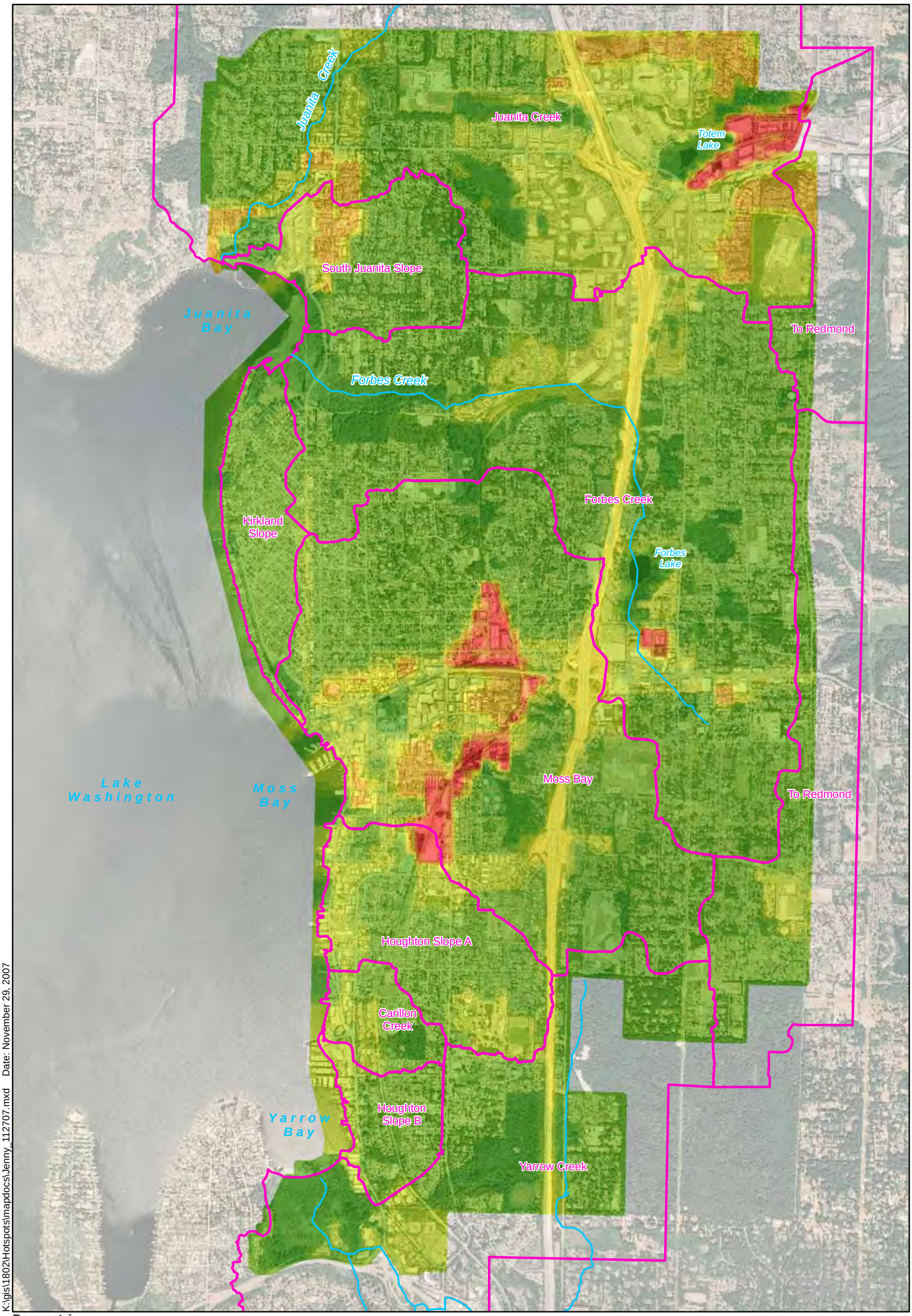
0 2,000
Scale in Feet

Legend

Diazinon (ng/L)

- 0 - 37
- 38 - 71
- 72 - 100
- 101 - 137
- 138 - 178
- 179 - 219
- 220 - 259
- 260 - 299
- 300 - 324
- Surface Water Basin
- Stream

Figure 6
Diazinon Hot Spots



K:\gis\1802\Hotspots\mapdocs\Jenny_112707.mxd Date: November 29, 2007

Parametrix

0 2,000
Scale in Feet

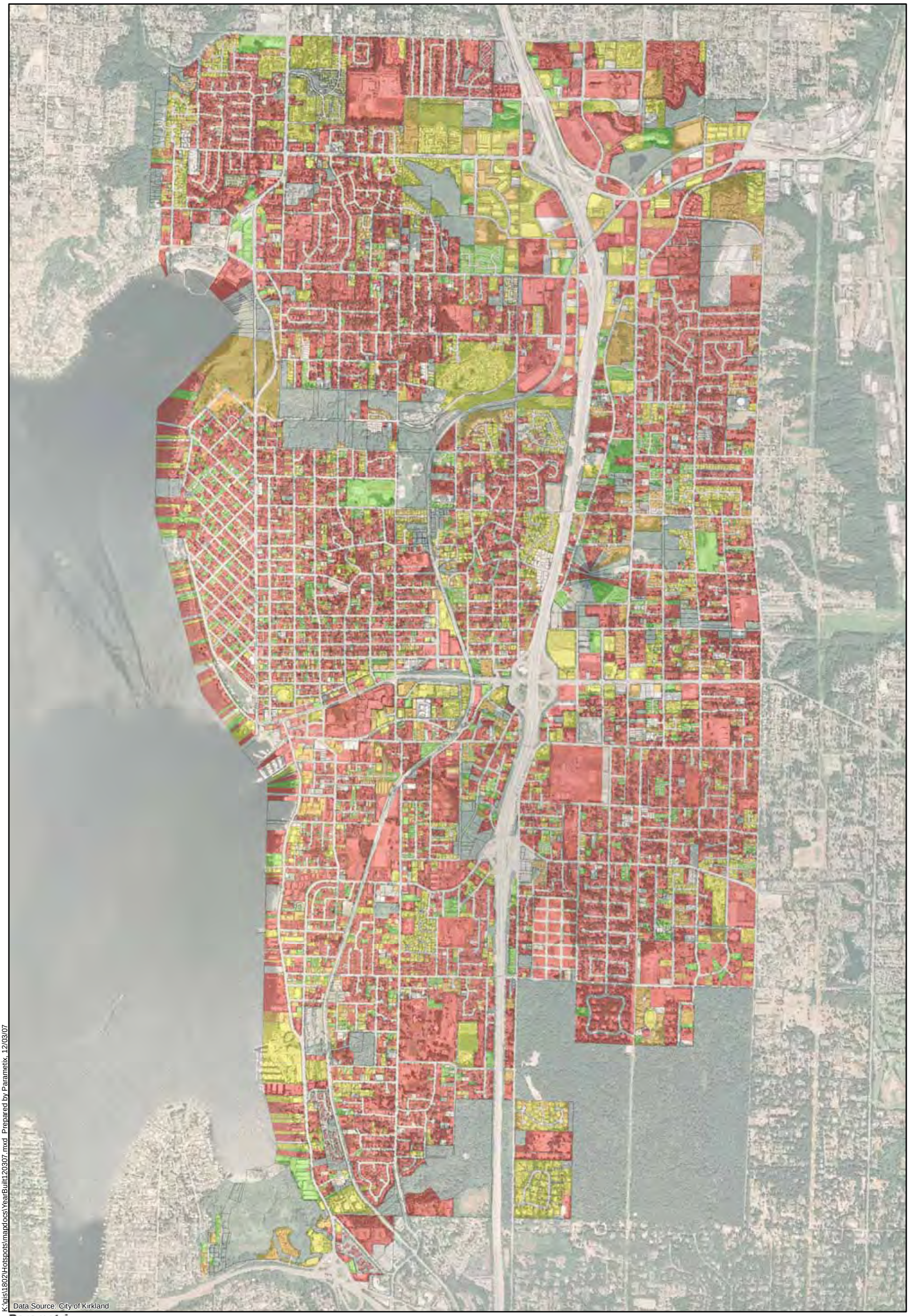
Legend

Cumulative Toxic Units*

- 4 - 10
- 11 - 18
- 19 - 24
- 25 - 29
- 30 - 35
- 36 - 44
- 45 - 54
- 55 - 63
- 64 - 70
- Surface Water Basin
- Stream

*The cumulative toxic unit represents a compilation of five pollutants, including TSS, Total PAHs, Copper, Zinc, and Diazinon

Figure 7
Cumulative Toxic Unit Hot Spots



K:\gis\1802\Hotspots\mapdocs\YearBuilt120307.mxd Prepared by Parametrix, 12/03/07

Parametrix

0 2,000
Scale in Feet

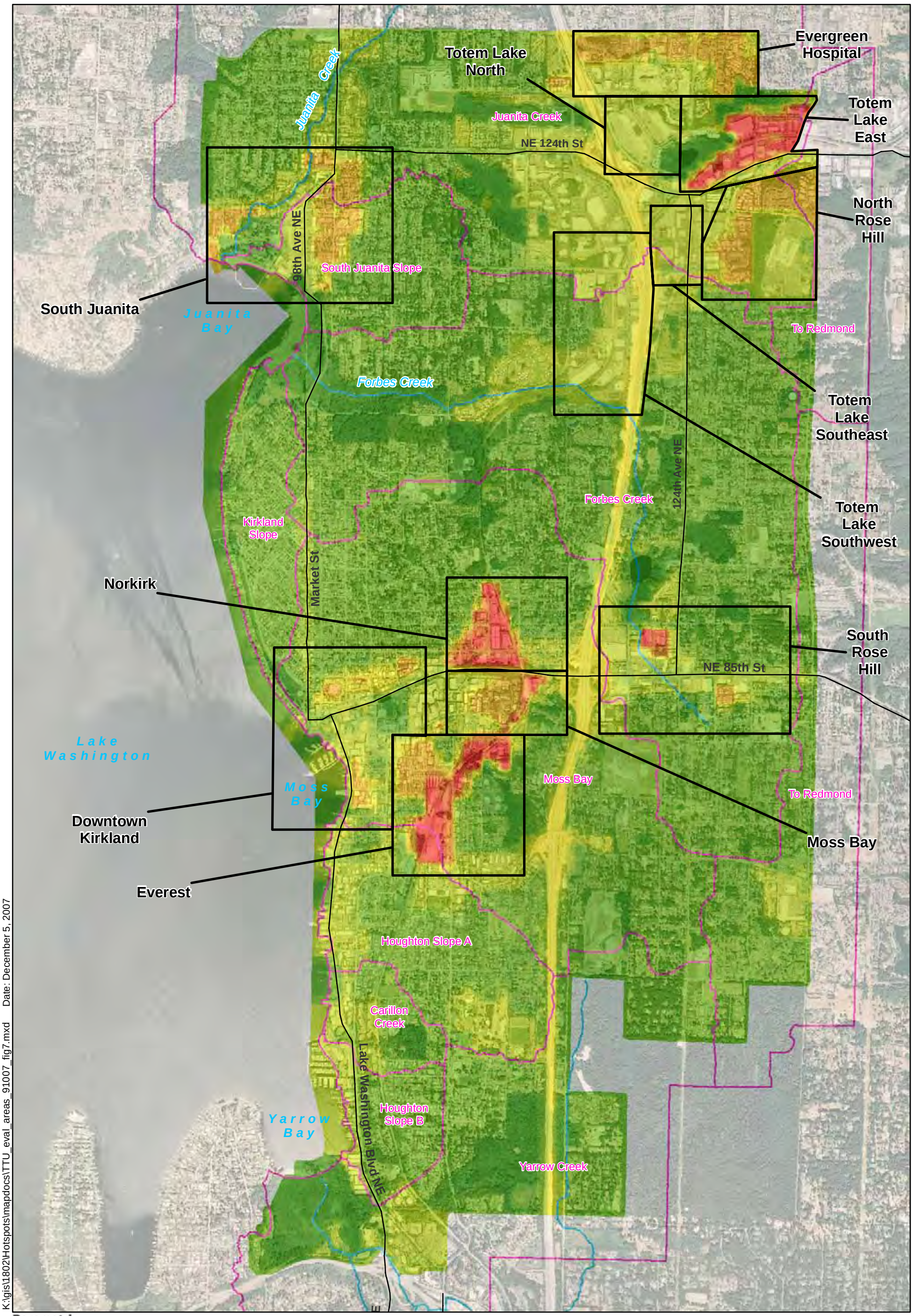
Legend

Year Developed

- Park, Wetland, no data (1079 acres)
- through 1982 (2897 acres)
- 1983 - 1990* (769 acres)
- 1991 - 1998 (448 acres)
- 1999 - 2005 (337 acres)

*Property developed prior to 1990 is unlikely to have stormwater controls

Figure 8
Date of Property Development in Kirkland



K:\gis\1802\Hotspots\mapdocs\TTU_eval_areas_91007_fig7.mxd Date: December 5, 2007

Parametrix

0 2,000
1 inch equals 2,000 feet

Legend

Cumulative Toxic Units*

- 4 - 10
- 11 - 18
- 19 - 24
- 25 - 29
- 30 - 35
- 36 - 44
- 45 - 54
- 55 - 63
- 64 - 70
- Stream
- Surface Water Basin

*The cumulative toxic unit represents a compilation of five pollutants, including TSS, Total PAHs, Copper, Zinc, and Diazinon

Figure 9
Focused Hot Spot Locations

K:\gis\1802\Hotspots\mapdocs\Fig9_PGiS.mxd Date: December 3, 2007

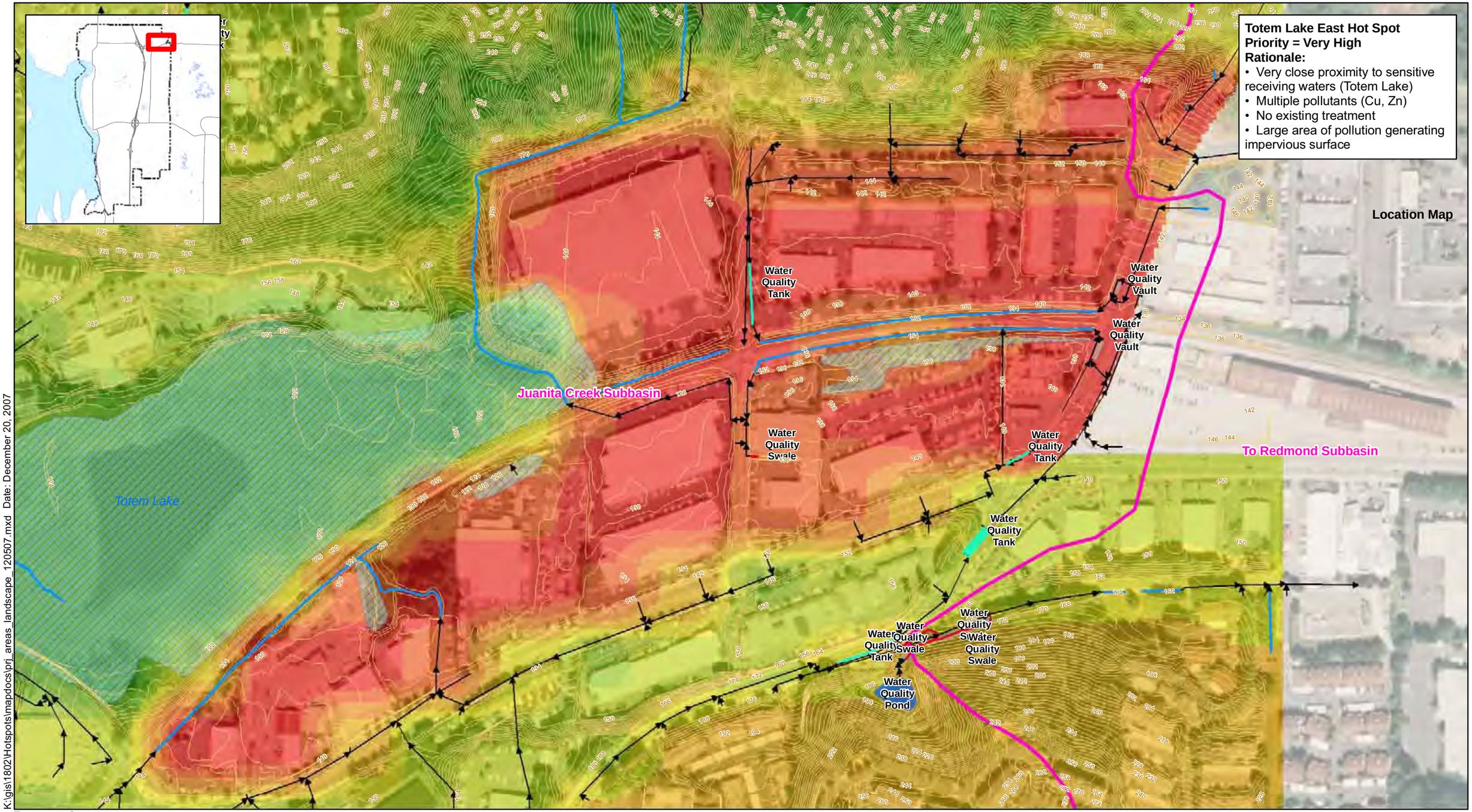
Parametrix

0 2,000
Scale in Feet

Legend

- Non Pollution Generating Surfaces (Rooftops, Sidewalks, Patios, etc.)
- Pollution Generating Surfaces (Roads, Parking Lots, etc.)
- Pervious Surface
- Surface Water Basin
- Stream

Figure 10
Location of Impervious Surfaces in Kirkland



K:\gis\1802\Hotspots\mapdocs\pri_areas_landscape_120507.mxd Date: December 20, 2007

Parametrix

0 320
Feet

Legend

Cumulative Toxic Units*
- 4 - 10
- 11 - 18
- 19 - 24
- 25 - 29
- 30 - 35
- 36 - 44
- 45 - 54
- 55 - 63
- 64 - 70
- Wetlands
- Stream or Ditch

Pipes
- Pipes
- Culvert
- Pond
- Swale
- Tank
- Vault

BMP's
- Pond
- Swale
- Vault
- Surface Water Basins

*The cumulative toxic unit represents a compilation of fine pollutants including TSS, Total PAHs, Copper, Zinc, and Diazinon

Figure 11
Totem Lake East Potential Hot Spot

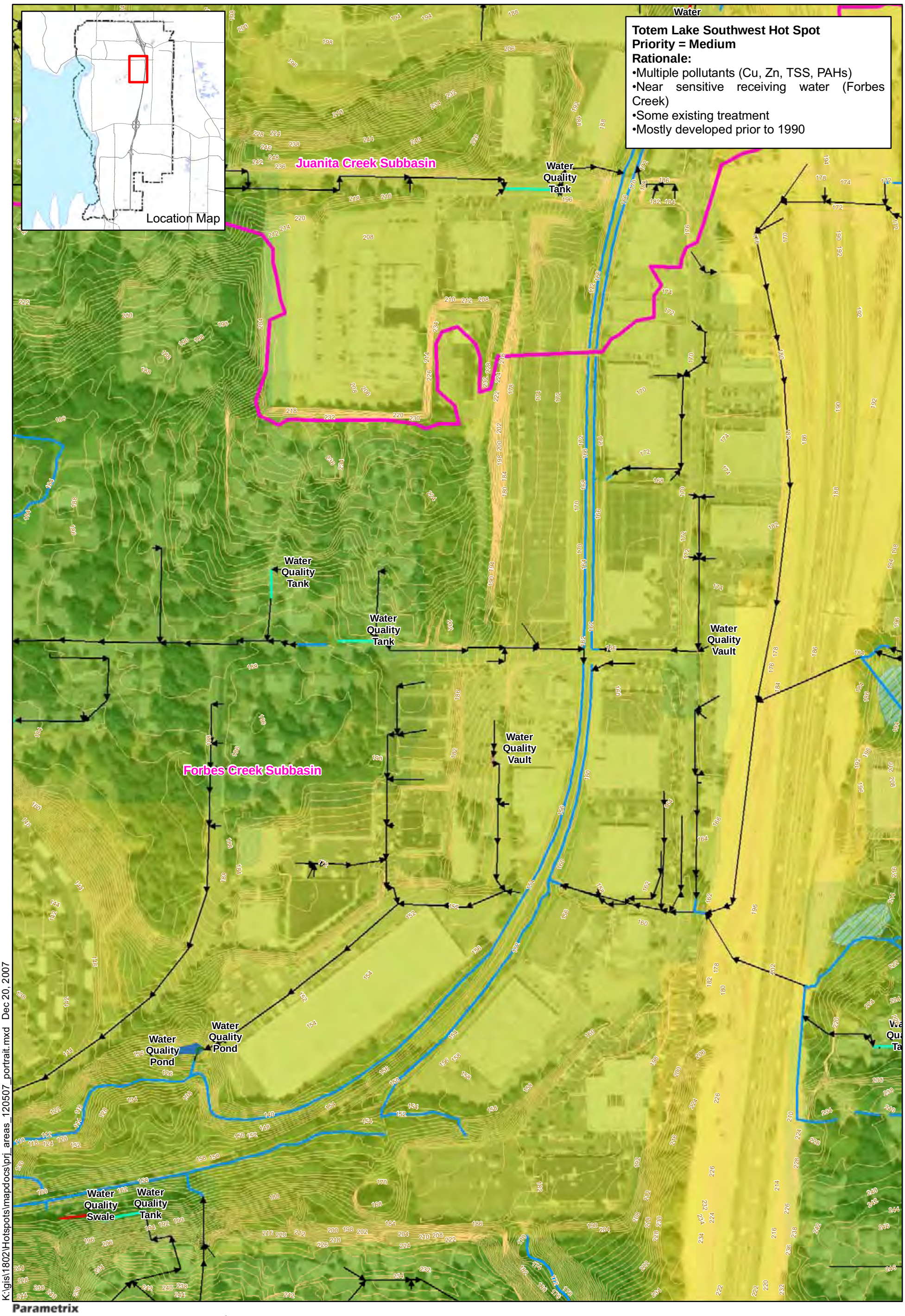


Figure 12
Totem Lake Southwest Potential Hot Spot

K:\gis\1802\Hotspots\mapdocs\prj_areas_120507_portrait.mxd Dec 20, 2007

Parametrix

Legend

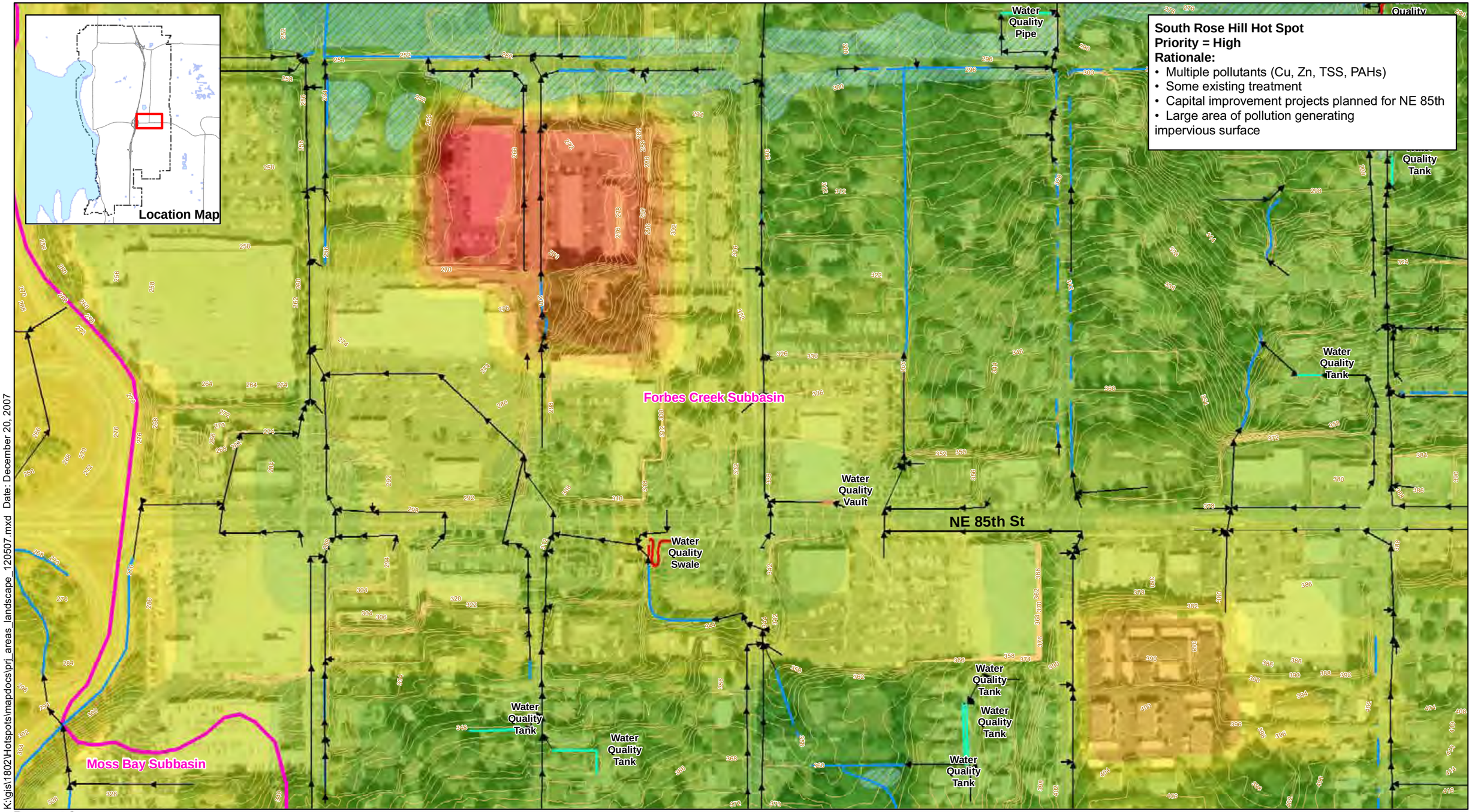
Cumulative Toxic Units*
- 4 - 10
- 11 - 18
- 19 - 24
- 25 - 29
- 30 - 35
- 36 - 44
- 45 - 54
- 55 - 63
- 64 - 70
- Wetland
- Stream or Ditch

Pipes
- Pipes
- Culvert
- Pond
- Swale
- Tank
- Vault
- Surface Water Basins

*The cumulative toxic unit represents a compilation of five pollutants,including TSS, Total PAHs, Copper, Zinc, and Diazinon

0 200 Feet

Figure 13
Totem Lake North Potential Hot Spot



K:\gis\1802\Hotspots\mapdocs\prj_areas_landscape_120507.mxd Date: December 20, 2007

Parametrix

0 320
Feet

Legend

Cumulative Toxic Units*
- 4 - 10
- 11 - 18
- 19 - 24
- 25 - 29
- 30 - 35
- 36 - 44
- 45 - 54
- 55 - 63
- 64 - 70
- Wetlands
- Stream or Ditch

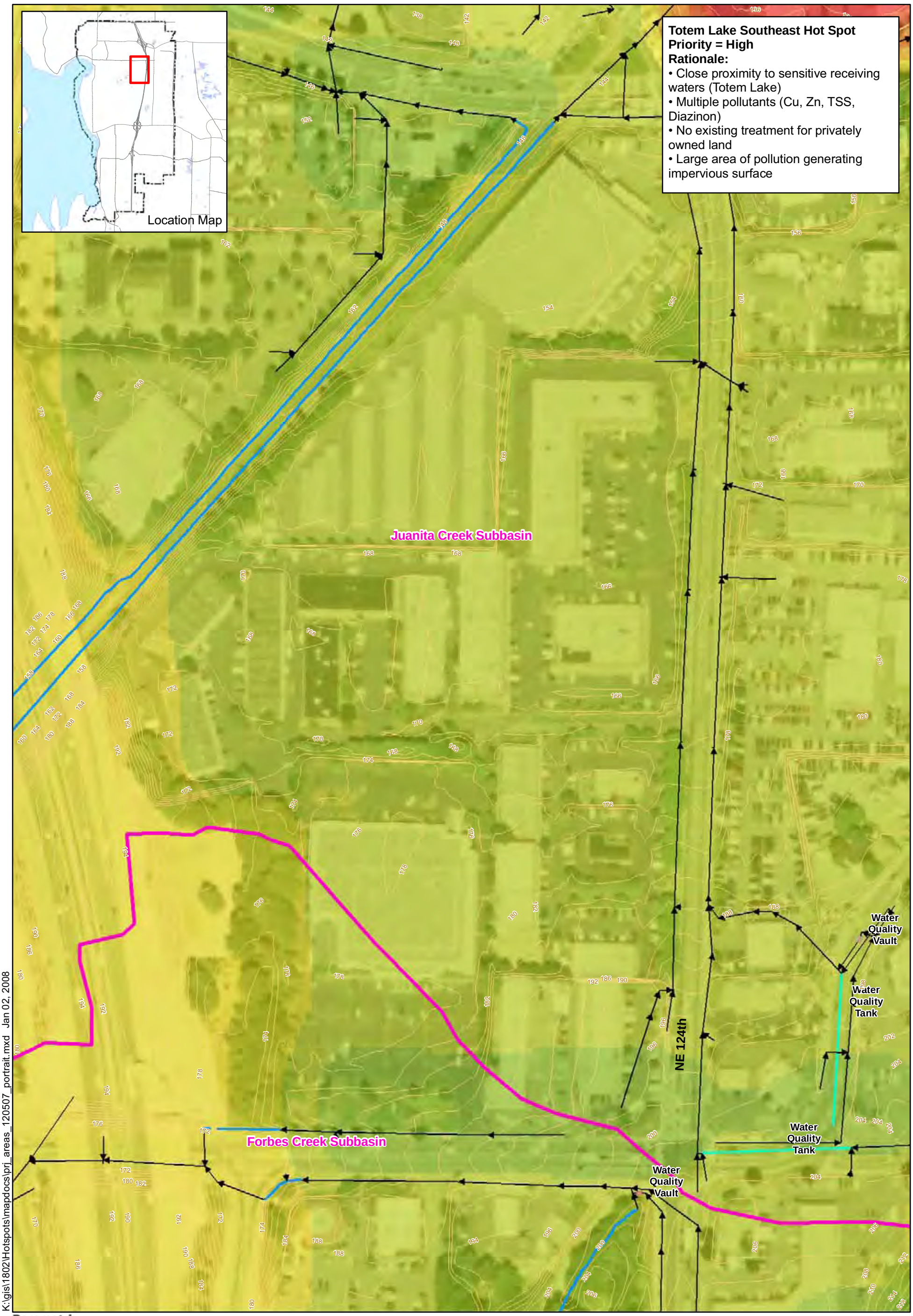
Pipes
- Pipes
- Culvert
- Pond
- Swale
- Tank
- Vault

BMP's
- Pond
- Swale
- Vault

- Surface Water Basins

*The cumulative toxic unit represents a compilation of fine pollutants including TSS, Total PAHs, Copper, Zinc, and Diazinon

Figure 14
South Rose Hill
Potential Hot Spot



K:\gis\1802\Hotspots\mapdocs\prj_areas_120507_portrait.mxd Jan 02, 2008

Parametrix

Legend

Cumulative Toxic Units*
- 4 - 10
- 11 - 18
- 19 - 24
- 25 - 29
- 30 - 35
- 36 - 44
- 45 - 54
- 55 - 63
- 64 - 70
- Wetland
- Stream or Ditch

Pipes
- Pipes
- Culvert
- Pond
- Swale
- Tank
- Vault
- Surface Water Basins

*The cumulative toxic unit represents a compilation of five pollutants,including TSS, Total PAHs, Copper, Zinc, and Diazinon

0 180 Feet

Figure 15
Totem Lake Southeast Potential Hot Spot

K:\gis\1802\Hotspots\mapdocs\prj_areas_landscape_120507.mxd Date: December 20, 2007

Parametrix

0 200
Feet

Legend

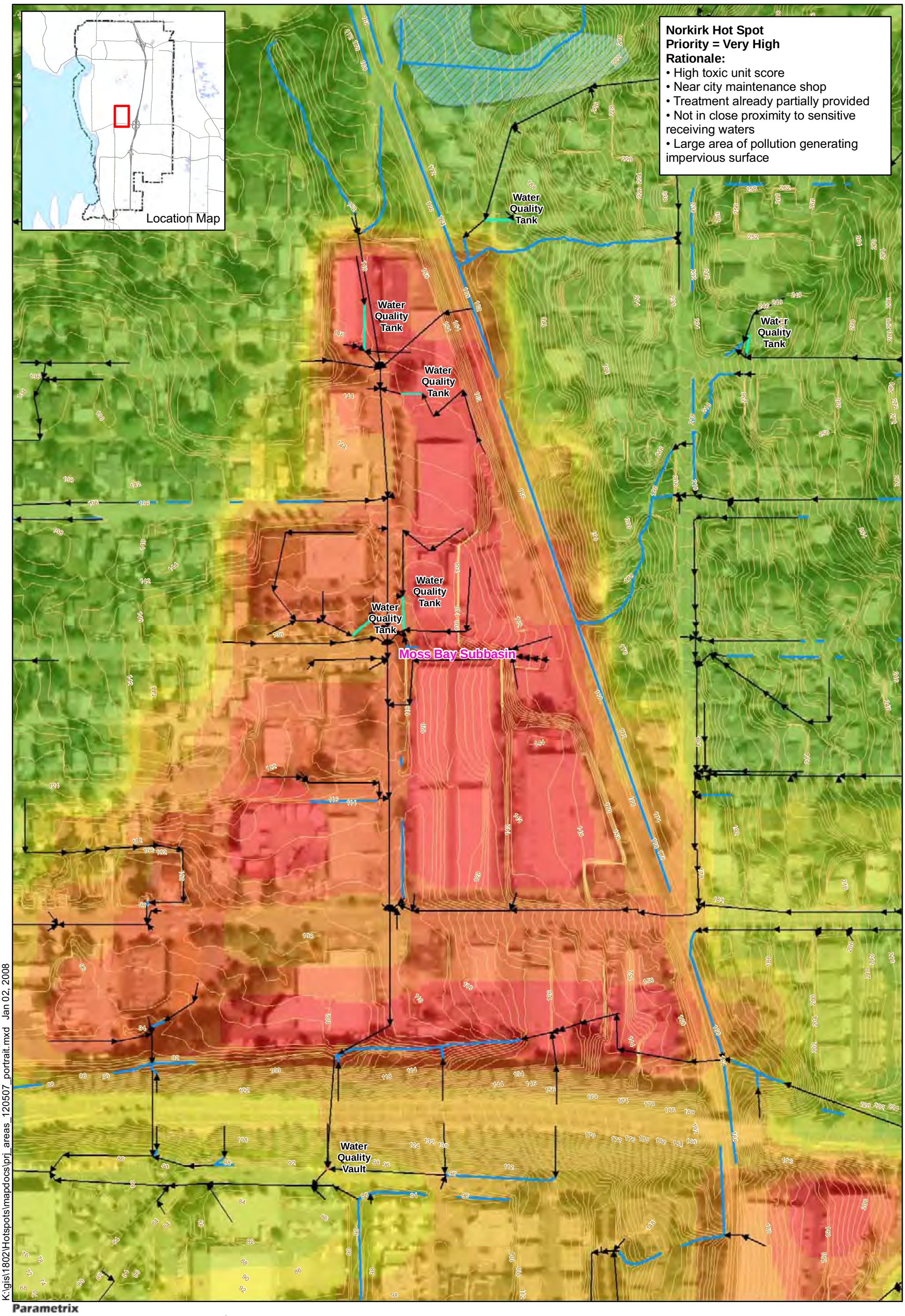
Cumulative Toxic Units*
- 4 - 10
- 11 - 18
- 19 - 24
- 25 - 29
- 30 - 35
- 36 - 44
- 45 - 54
- 55 - 63
- 64 - 70
- Wetlands
- Stream or Ditch

Pipes
- Pipes
- Culvert
- Pond
- Swale
- Tank
- Vault

BMP's
- Pond
- Swale
- Vault
- Surface Water Basins

*The cumulative toxic unit represents a compilation of fine pollutants including TSS, Total PAHs, Copper, Zinc, and Diazinon

Figure 16
Moss Bay
Potential Hot Spot



K:\gis\1802\Hotspots\mapdocs\pri_areas_120507_portrait.mxd Jan 02, 2008

Parametrix

Legend

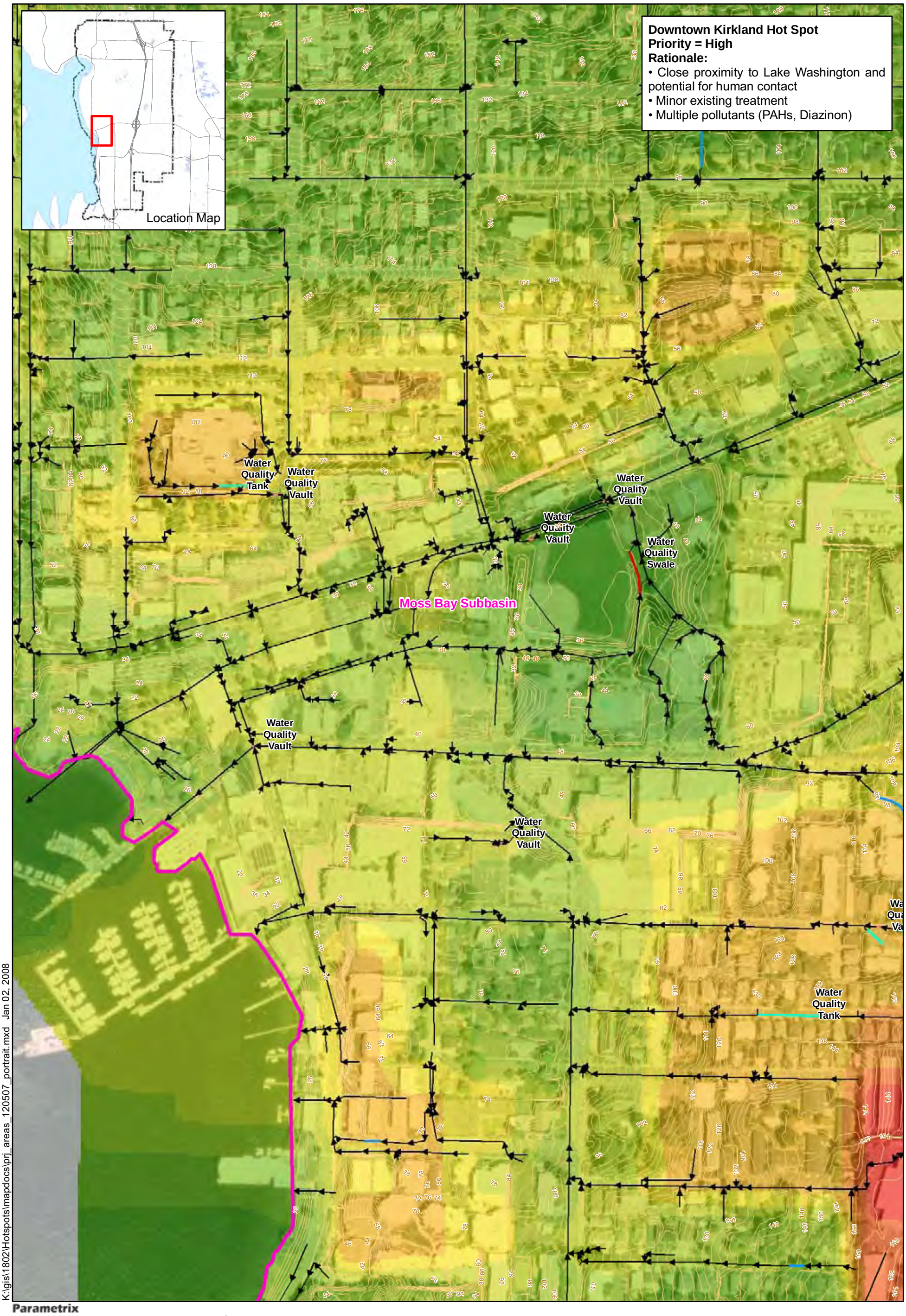
Cumulative Toxic Units*
- 4 - 10
- 11 - 18
- 19 - 24
- 25 - 29
- 30 - 35
- 36 - 44
- 45 - 54
- 55 - 63
- 64 - 70
- Wetland
- Stream or Ditch

Pipes
- Pipes
- Culvert
- Pond
- Swale
- Tank
- Vault
- Surface Water Basins

*The cumulative toxic unit represents a compilation of five pollutants,including TSS, Total PAHs, Copper, Zinc, and Diazinon

0 240 Feet

Figure 17
Norkirk
Potential Hot Spot



K:\gis\1802\Hotspots\mapdocs\prj_areas_120507_portrait.mxd Jan 02, 2008

Parametrix

Legend

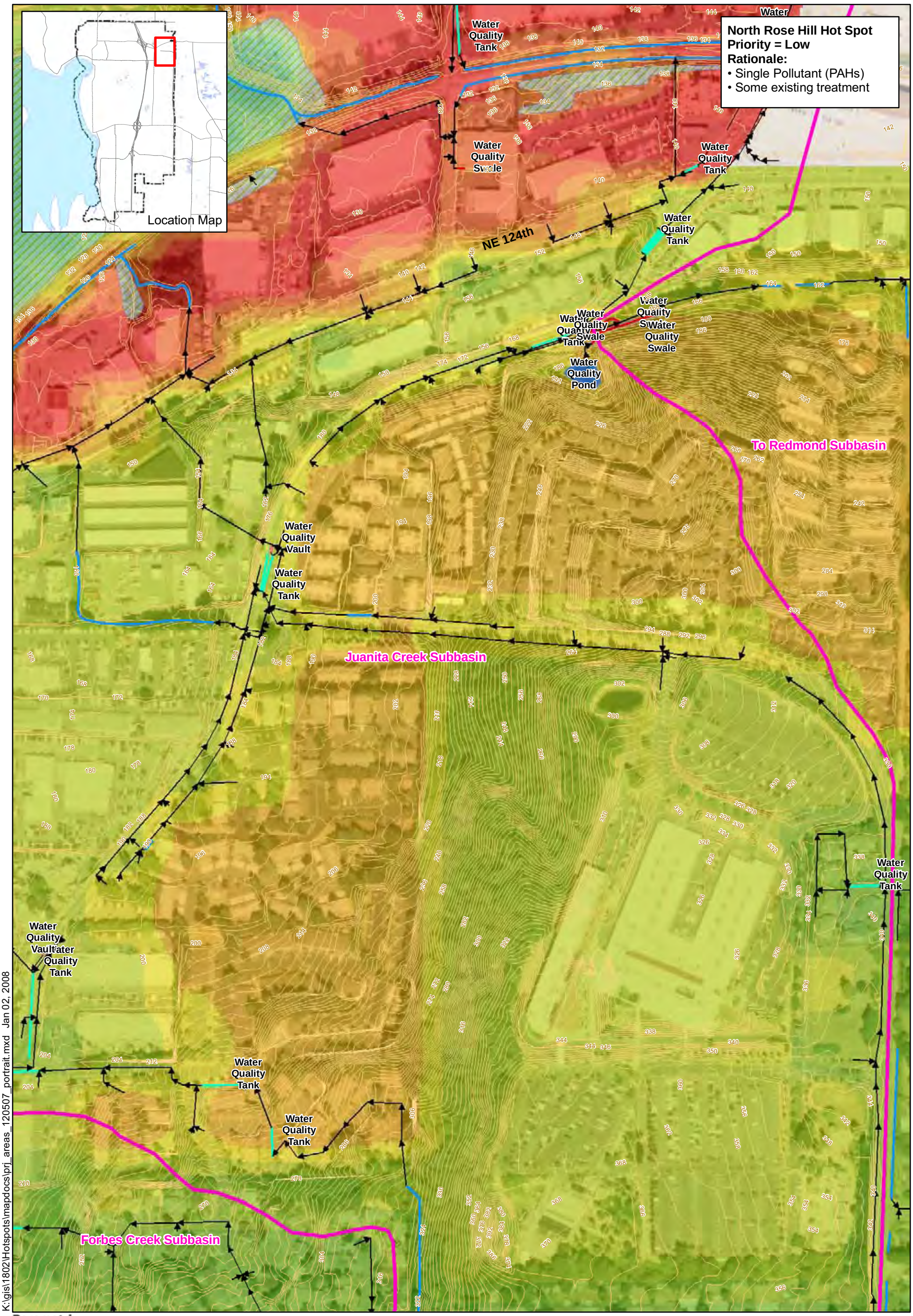
Cumulative Toxic Units*
- 4 - 10
- 11 - 18
- 19 - 24
- 25 - 29
- 30 - 35
- 36 - 44
- 45 - 54
- 55 - 63
- 64 - 70
- Wetland
- Stream or Ditch

Pipes
- Pipes
- Culvert
- Pond
- Swale
- Tank
- Vault
- Surface Water Basins

*The cumulative toxic unit represents a compilation of five pollutants,including TSS, Total PAHs, Copper, Zinc, and Diazinon

0 340 Feet

Figure 18
Downtown Kirkland Potential Hot Spot



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Parametrix

0 320 Feet

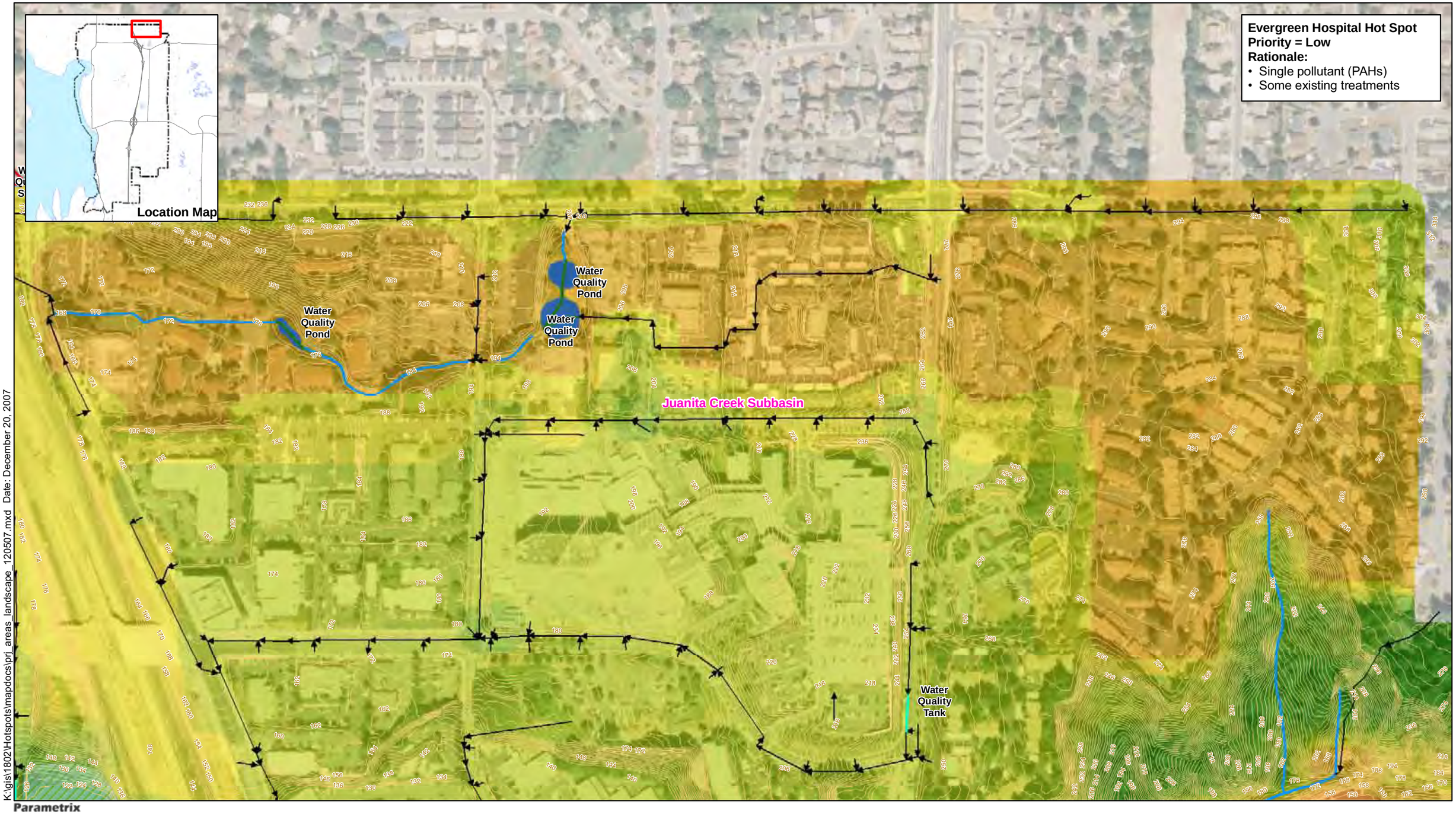
Legend

Cumulative Toxic Units*
- 4 - 10
- 11 - 18
- 19 - 24
- 25 - 29
- 30 - 35
- 36 - 44
- 45 - 54
- 55 - 63
- 64 - 70
- Wetland
- Stream or Ditch

Pipes
- Pipes
- Culvert
- Pond
- Swale
- Tank
- Vault
- Surface Water Basins

*The cumulative toxic unit represents a compilation of five pollutants,including TSS, Total PAHs, Copper, Zinc, and Diazinon

Figure 19
North Rose Hill Potential Hot Spot



0 360
Feet

Legend

Cumulative Toxic Units*
- 4 - 10
- 11 - 18
- 19 - 24
- 25 - 29
- 30 - 35
- 36 - 44
- 45 - 54
- 55 - 63
- 64 - 70
- Wetlands
- Stream or Ditch

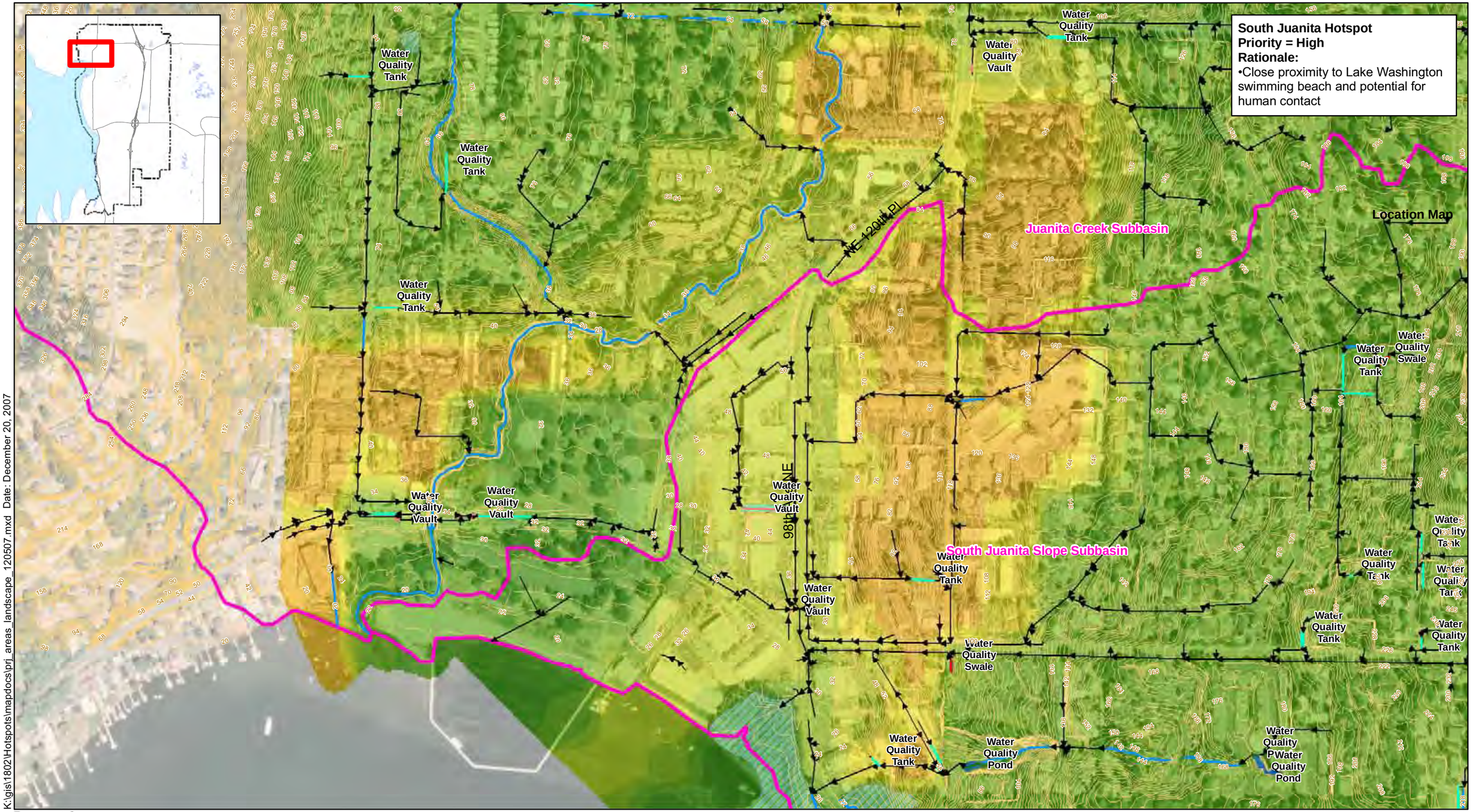
Pipes
- Pipes
- Culvert
- Pond
- Swale
- Tank
- Vault

BMP's
- Pond
- Swale
- Vault

- Surface Water Basins

*The cumulative toxic unit represents a compilation of fine pollutants including TSS, Total PAHs, Copper, Zinc, and Diazinon

Figure 20
Evergreen Hospital Potential Hot Spot



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Parametrix

0 520
Feet

Legend

Cumulative Toxic Units*

- 4 - 10
- 11 - 18
- 19 - 24
- 25 - 29
- 30 - 35
- 36 - 44
- 45 - 54
- 55 - 63
- 64 - 70
- Wetlands
- Stream or Ditch

Pipes

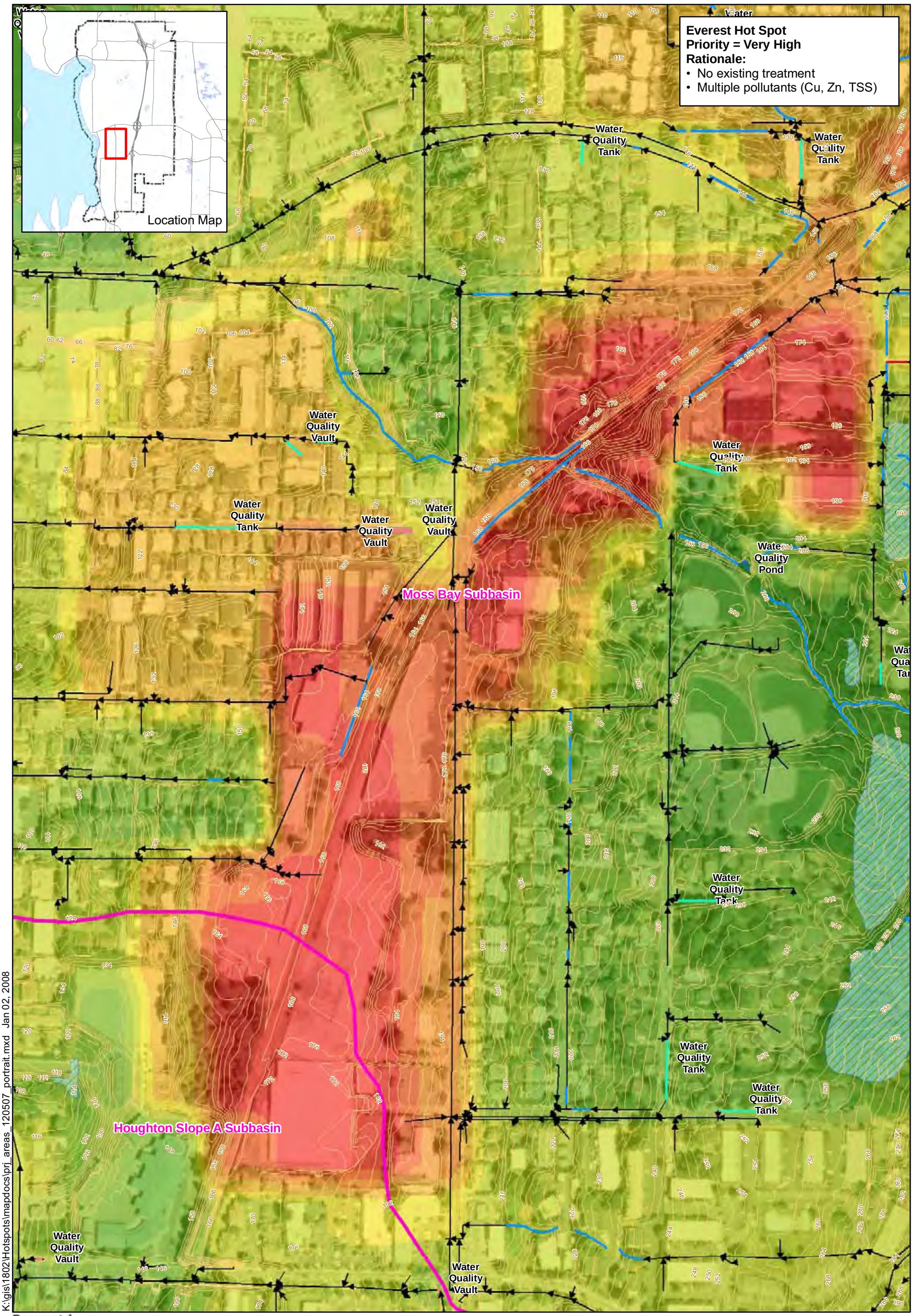
- Pipes
- Culvert
- Pond
- Swale
- Tank
- Vault

BMP's

- Pond
- Swale
- Vault
- Surface Water Basins

*The cumulative toxic unit represents a compilation of fine pollutants including TSS, Total PAHs, Copper, Zinc, and Diazinon

Figure 21
South Juanita Potential Hot Spot



Legend

Cumulative Toxic Units*
- 4 - 10
- 11 - 18
- 19 - 24
- 25 - 29
- 30 - 35
- 36 - 44
- 45 - 54
- 55 - 63
- 64 - 70
- Wetland
- Stream or Ditch

Pipes
- Pipes
- Culvert
- Pond
- Swale
- Tank
- Vault
- Surface Water Basins

*The cumulative toxic unit represents a compilation of five pollutants,including TSS, Total PAHs, Copper, Zinc, and Diazinon

0 340 Feet

Figure 22
Everest
Potential Hot Spot

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Parametrix

Legend

- Stream
- Surface Water Basin

Cumulative Toxic Units*

4 - 10	25 - 29	45 - 54
11 - 18	30 - 35	55 - 63
19 - 24	36 - 44	64 - 70

0 2,000
Scale in Feet

*The cumulative toxic unit represents a compilation of five pollutants, including TSS, Total PAHs, Copper, Zinc, and Diazinon

Figure 23
Candidate Monitoring Locations