# Is it Financially Viable to Offer For Use Water that is Produced During the Extraction of Coalbed Natural Gas? Using Data and Cost Models from the Powder River Basin in Wyoming to Extend Evaluations to Other Regions in the United States.

Casey Bates, MS Candidate in Forest Resources – College of the Environment, University of Washington

*Exploring the possibility of using Geographic Information Systems to perform detailed cost analyses*

**INTRODUCTION**

Coalbed natural gas (CBNG) production is on the rise throughout the United States. Supply of natural gas from this source accounted for 9.8% of the total natural gas produced in the nation during 2009 according to the U.S. Energy Information Administration (EIA) (EIA, 2011). The Powder River Basin (PRB) in Wyoming has experienced a mineral rush for this resource unparalleled around the nation. The number of drilled CBNG wells in PRB exceeded 18,000 in 2004 (Bank and Kuuskraa , 2006). In 2009, Wyoming produced 28.2% of the nation's share of CBNG and 96.3% of this came from the PRB (EIA, 2011; WOGCC, 2011).

Coalbed natural gas is a relatively pure form of natural gas and does not require refinement after extraction. It is comprised almost entirely of methane and therefore only requires compression into the distribution line for use by consumers. Conventional natural gas on the other hand often requires oil separation processes that may cause significant greenhouse gas emissions during processing (WRAP, 2009).

Although CBNG is relatively pure compared to conventional natural gas production of this mineral resource is controversial because significant amounts of water are "produced" during the extraction process. The Wyoming Oil and Gas Conservation Commission reports that over 567 million barrels of product water were brought to the surface in 2009 alone as a result of CBNG extraction (WOGCC, 2011). Such large quantities of water have proven to be problematic due to the highly-erodible nature of soils in Wyoming. Furthermore, product water is often high in sodicity and salinity (USGS, 2000). For these reasons, disposal of product water from CBNG extraction is highly regulated and can be very expensive.

Disposal options depend on a variety of factors such as permit approval, product water characteristics, well proximity to treatment facilities, groundwater aquifer receiving potential, surface water regulations, soil composition and capital and operating costs (Rice 2000). The preferred method of disposal by CBNG developers is surface discharge, but as mentioned above there exist many barriers to utilize this method. One method of dealing with product water that is becoming increasingly more attractive to CBNG producers is crop irrigation, known within the industry as "land application." Land application is less expensive than many disposal options because little infrastructure is required, but doing so is generally only allowable when product water is not sodic or saline. Treatments do exist to reduce sodicity and salinity in CBNG product water prior to disposal but current options are expensive and CBNG producers tend to avoid such options due to cost (Personal Observation).

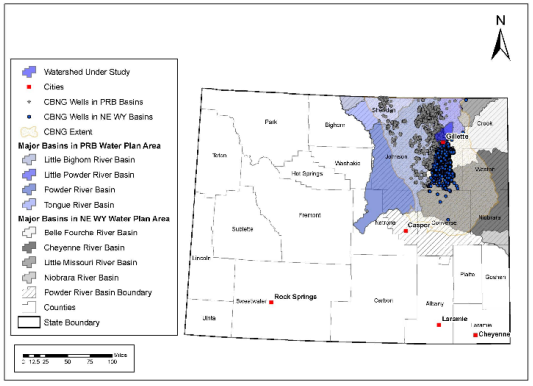
**PURPOSE AND BACKGROUND**

The purpose of this poster is to demonstrate some potential uses for Geographic Information Systems (GIS) to assess the financial viability of offering for use product water from CBNG extraction. Coalbed natural gas production is technically recoverable from numerous reserves around the United States including western states such as Colorado, Wyoming and New Mexico and states east of the Rockies such as Alabama and Virginia, but economic recoverability depends largely on treatment and disposal of product water (Bank and Kuuskraa , 2006; EIA, 2011). While surface discharge is often permitted and is preferable to CBNG producers because of relatively low cost for disposal, numerous environmental problems may arise from this method of disposal. Through the use of GIS, I intend to use data and economic models from the PRB to determine whether or not it is financially viable to treat and offer for use (e.g. land application for agriculture) product water from other CBNG production regions around the United States.

**COALBED NATURAL GAS PRODUCTION SITES IN POWDER RIVER BASIN, WY**

The map below shows CBNG production sites (to date as of 2002) in two Water Plan areas developed by the State of Wyoming and the major basins included in each area. Also shown on the map is the USGS Powder River Basin Province boundary, extent of known CBNG reserves within the PRB and a heavily-drilled watershed north of Gillette Wyoming known as the Little Powder River – Dry Creek watershed that will be explored in greater detail on other maps in this poster.

## Coalbed Natural Gas (CBNG) Production Sites in Powder River Basin, WY

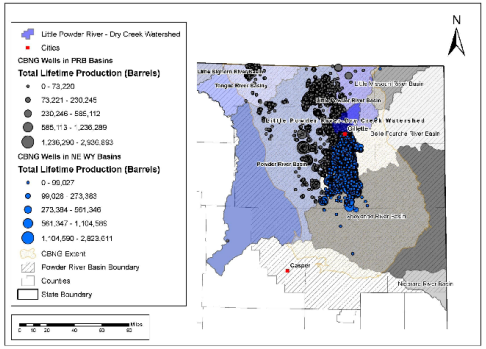



**LIFETIME CBNG PRODCTION PER WELL IN POWDER RIVER BASIN, WY**

The map below shows the total CBNG production (in barrels – 42 gallons) from 1987 to 2002 for each well in PRB as reported by individual well owners to the Wyoming Oil and Gas Conservation Commission.

| WATER PLAN AREA | POWDER RIVER BASIN | NORTHEAST WYOMING |
|---|---|---|
| TOTAL WELLS (TO DATE 2002)* | 6184 | 5161 |
| TOTAL PRODUCTION (IN BARRELS) FOR ALL WELLS: | 391,779,363 | 773,539,775 |
| MEAN LIFETIME PRODUCTION / WELL (BARRELS): | 63,353 | 149,881 |
| MAX PRODUCTION FOR A SINGLE WELL: | 2,936,893 | 2,823,611 |

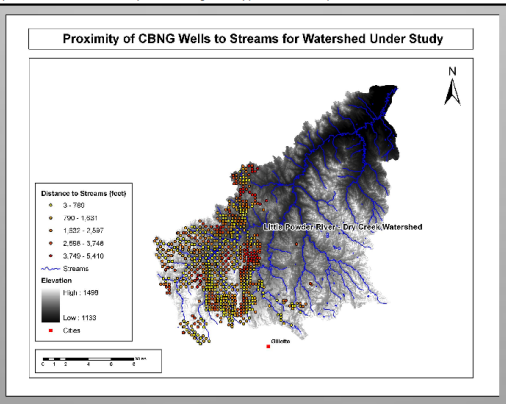
## Lifetime CBNG Production per Well in Powder River Basin, WY




**PROXIMITY OF COALBED NATURAL GAS WELLS TO STREAMS FOR LITTLE POWDER RIVER – DRY CREEK WATERSHED**

The following map shows an area that is of interest because of the high density of wells that have been drilled in the western portion of the watershed. Using GIS provides a number of different options for spatial analysis of data. This example shows the distance from each production well to the nearest perennial or intermittent stream. This analysis may be of potential interest to a CBNG producer in cases where surface discharge of product water is permitted. For example, a producer may need to know how much infrastructure (e.g. pipeline) is required to move the product water from the outfall to the permitted discharge waterway (Personal Observation).

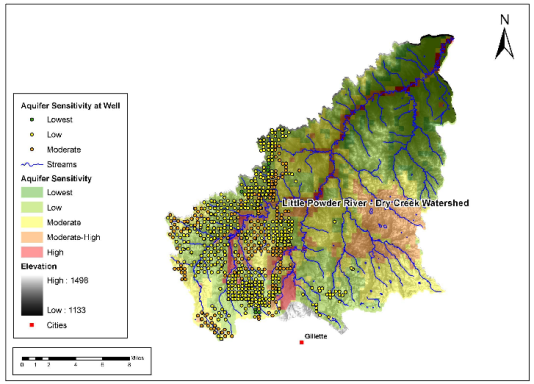
## Proximity of CBNG Wells to Streams for Watershed Under Study




**COALBED NATURAL GASS WELLS IN LOW-TO-MODERATE AQUIFER SENSITIVITY AREAS**

The following map shows the CBNG wells in the Little Powder River – Dry Creek Watershed that directly overlay aquifers with low-to-moderate sensitivity. All CBNG wells that fall in moderate-high or high areas were removed from the map (reducing the number of wells in this aquifer from 1,059 to 916). This provides an example of how one might determine environmental risk for each well based on aquifer sensitivity. But also see that this example raises an interesting point; most areas flow into regions of high aquifer sensitivity. NOTE: Due to multiple wells at each site, the number of wells shown on the map is far lower than the actual total.

## Coalbed Natural Gas Wells in Low-to-Moderate Aquifer Sensitivity Areas




**REFERENCES**

Bank, G.C., and Kuuskraa, V. (2006). The Economics of Powder River Basin Coalbed Methane Development. Prepared for: U.S. Department of Energy. Advanced Resources International, Inc.

EIA. (2011). Natural gas gross withdrawals and production for 2009. Available at: http://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FGW_mmcf_a.htm and http://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FGC_mmcf_a.htm. Accessed 06 June 2010.

Rice, C.A., Ellis, M.S., and Bullock Jr, J.H. (2000). Water co-produced with coalbed methane in the Powder River Basin, Wyoming: Preliminary compositional data: U.S. Geological survey open-file report 00-372. 20 p.

WOGCC. (2010). Wyoming Oil and Gas Conservation Commission. Coal bed methane production tables and graphs available online at: http://wogcc.state.wy.us/. Accessed 06 June 2010.

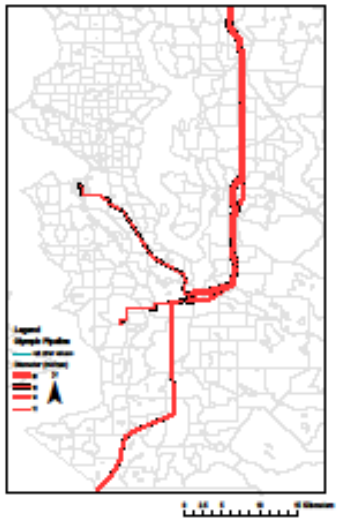
Western Regional Air Partnership (WRAP). (2009). Development of scoping paper for the oil and gas industry – draft 1a.

U.S. Geological Survey (USGS). (2000). Water produced from coalbed methane. USGS fact sheet FS-156-00. November 2000.

# King County Coastal Environmental Resources: Olympic Pipeline Oil Spill Scenario

*Research Question: What coastal environmental resources are threatened by the event of a land based Olympic Pipeline spill?*

The Olympic Pipeline in King County



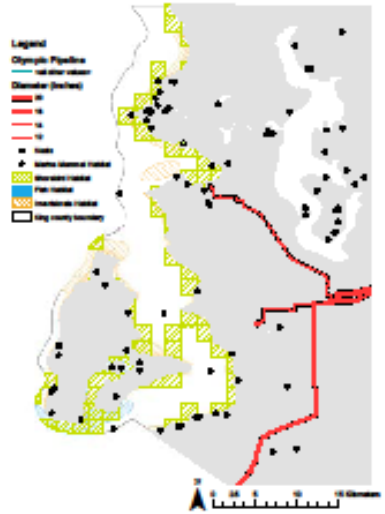
## What is the Olympic Pipeline?

The Olympic Pipeline, owned and operated by BP, is a critical piece of Western Washington infrastructure. It transports petroleum products from refineries in Whatcom and Skagit Counties down to the Ports of Seattle and Portland, as well as to critical airplane fueling sites. The oil travels in high-pressure bursts, heading down the line between 250 and 1440 psi. Within King County itself, the main stem of the Olympic pipeline traverses approximately 66 kilometers with two spurs to the Port of Seattle and Boeing Field adding another 20 and 7.5 kilometers, respectively. Breaches of the pipeline are possible due to human error, valve failure during a pressure surge, poor maintenance or replacement of existing lines or acts of terrorism to name a few. In 1999, the Olympic Pipeline suffered an explosion in Bellingham , killing three youths, and spilling over 250,000 gallons of gasoline.

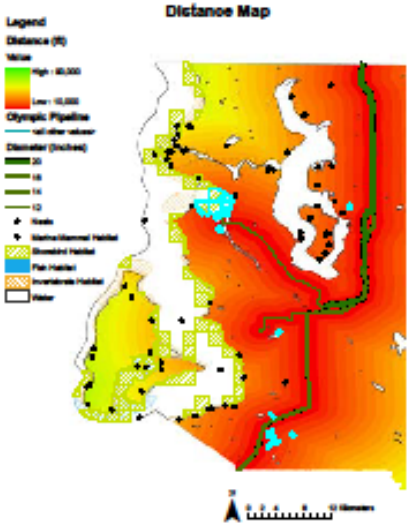
## What Environmental Resources?

King County is home to several types of shorebirds, alcids, and gulls which use the coastal area between the Pipeline and the Puget Sound (and Lake Washington) as nesting ground. There are also aquatic mammals with habitat in the same range that might be affected. If the oil were able to reach the water either through stream transport or overland flow, there are near shore invertebrate and fish habitats that could also be at risk. The map below is adapted from NOAA's Environmental Sensitivity Index and depicts nesting areas and habitat for King County's coastal birds, mammals, invertebrates and fish. Further environmental impacts such as toxicity to vegetation, soil contamination and water pollution are not captured in this map, but would definitely be a major environmental concern in the even of a major pipeline spill.

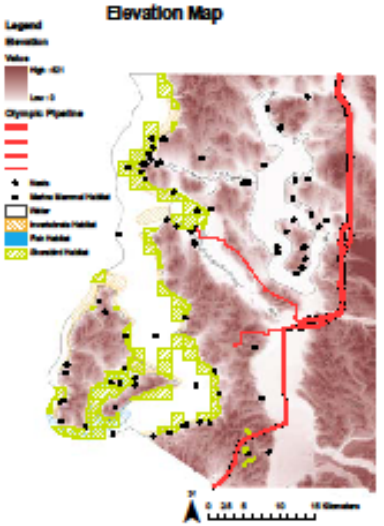
Selected Coastal Species Habitat in King County



Distance Map



Elevation Map



## Threat to Resources

The threat to these resources from coming into contact with oil from the pipeline is a function of their distance from the pipeline and if they are positioned downhill from the pipeline among other things such as the land cover and possible barriers between them. This poster will only explore distance and elevation as a starting point to understanding the potential threat.

The distance map above illustrates the proximity of the habitats to pipelines. 11 of the 86 mapped nests lie within 3 kilometers of the pipeline, as does several coastal and inline shorebird habitats. These areas are highlighted in cyan. While shorebirds 3 kilometers away might not come into direct contact with the oil, it is important to remember that habitat disturbance is more likely to arise from increased traffic due to recovery efforts nearby.

The elevation map above shows that the pipeline tends to be located on higher ground, while the habitats are on lower ground making it possible for spilled oil to reach the basins where coastal wildlife reside. Depending on the location of the breach, it appears that the nests around Lake Washington are more likely to come into contact based on their proximity and relative elevation. Other sites might be the inland marine mammal habitat in South King County. The habitats on t he southern coast are partially shielded by a small ridge.

The exploratory data shown here suggests that shorebirds and their habitat are the coastal resources most threatened by potential spills from the Olympic Pipeline. Disaster planning and preparedness should take this into account to mitigate any harm done to the birds either from direct contact with oil, or from habitat destruction associated with recovery efforts.

Vivian Sevath
Net ID: vsevath@uw.edu
CFR520/GIS350
Spring 2011
June 6, 2011
Final Poster Project

# Proof of Concept: Native species conservation in existing business parks, Redmond, WA

K. Dyson

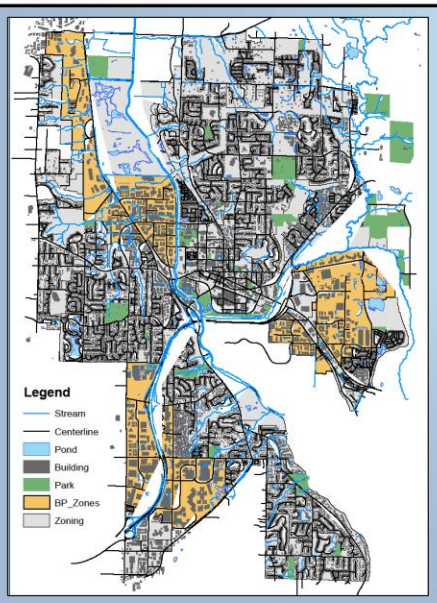
*Urban Ecology and Research Lab, University of Washington*

## BACKGROUND

The expanding sphere of human influence is forcing conservation biologists and urban planners to consider how conservation can happen in the spaces that people inhabit. One space that has not been given much attention is where people work – including business and industrial parks. These spaces often occupy large sections of land near the urban/rural interface and may therefore be of conservation value.

## PURPOSE AND HYPOTHESIS

Very few studies have examined the conservation value or potential of business and industrial parks. This first pass evaluation aims to quantify the potential area for both traditional and rooftop conservation in business park, industrial areas, and manufacturing parks within the bounds of Redmond, WA.

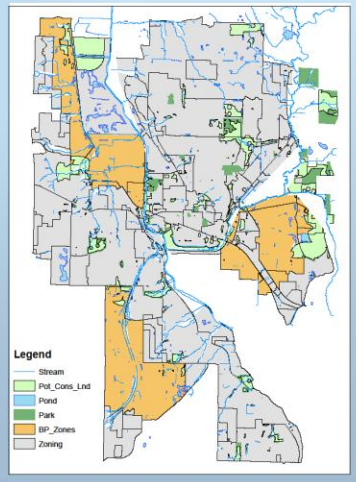


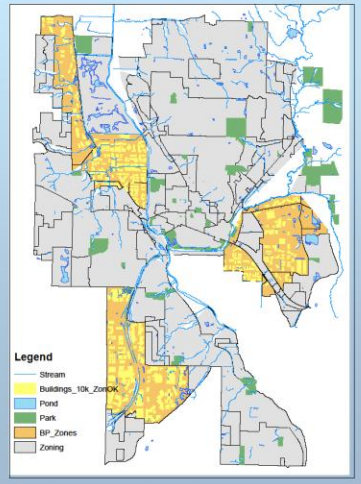

## MATERIALS AND METHODS

Two analyses were performed. First, map geometry was used to delineate and quantify areas on land zoned for business, industrial, or manufacturing (collectively called business parks). Second, the area for rooftop conservation in these zones was quantified. All analysis was performed in ArcGIS 9.3.1. Datasets were acquired from the Redmond city website: http://www.redmond.gov/cms/One.aspx?portalId =169&pageId=7404.

To find potential land in business parks that could be managed for conservation, we wanted to find areas near existing habitat (using parks as a proxy), water resources, and more than 100 feet from buildings and roads. To accomplish this, four buffers were performed -- the ponds at 1000 ft, streams at 500 ft, and parks at 1000 feet, and buildings and roads at 100 feet -- using the Buffer (Analysis) tool. Then, the streams and ponds buffers were unioned, and intersected with the parks buffer to form a layer with desirable characteristics. To remove complex geometry the layer was buffered at 0.05 feet (about half an inch). This added slightly to the total area, but the overall effect is likely negligible. The roads and buildings layer were also unioned to form a layer with undesireable characteristics. Finally, the road/building layer was used as an eraser on the stream/pond/park layer (left figure).

To find buildings with the potential for rooftop garden conservation, all buildings over 10,000 feet in area were selected. (right figure)

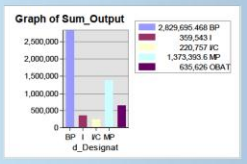


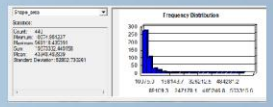




## RESULTS

This analysis found that about 65 acres of land in business parks could be managed for species conservation, and about 32 acres in manufacturing parks. Smaller amounts are available for conservation in industrial land. This may be highly sensitive to the buffer distances.

Approximately 438 acres are available as rooftop habitat between 400 buildings.



## CONCLUSIONS

There is potential for conservation on lands zoned for business, industry, or manufacturing in Redmond. More traditional conservation, including managing land for wildlife species opportunities are enhanced by the proximity to non-park green space including open land and golf courses, as seen below. Further, traditional conservation may be supported by numerous opportunities for rooftop conservation.

## BIBLIOGRAPHY

Thank you City of Redmond, for making your data open and accessible.

# Are fresh water streams potential reservoirs for opportunistic *S. aureus* and methicillin-resistant *S. aureus* [MRSA] at marine recreational beaches?

Marilyn C. Roberts[1], Emily Levin-Edens[1], Amy Stiffarm[2], David No[1], Olusegun O. Soge[1], and John Scott Meschke[1]
Department of Environmental & Occupational Health Sciences, University of Washington, Seattle, WA Salish Kootenai College, Pablo, MT[2]

## Abstract

**Background**: Contact with seawater has been associated with a four-fold increased risk of *Staphylococcus aureus* skin infections in children. Methicillin-susceptible *S. aureus* [MSSA] and methicillin-resistant *S. aureus* [MRSA] have been isolated from a variety of recreational marine beaches suggesting a potential risk to beach visitors. The aim of the study was to determine the spatial distribution of MSSA/ MRSA at two urban recreational marine beaches.

**Methods:** Eight-five sand, 56 marine and 124 fresh water stream samples were collected multiple times over a two month time period in the summer of 2010. Samples were enriched in Bacto® m Staphylococcus Broth with of 75 µg/ml polymyxin and 0.01% potassium tellurite. Presumptive *S. aureus* were biochemically verified.

**Results:** Thirty-eight (14.3%) samples were *S. aureus* positive including 27 (10.2%) MRSA and 11 (4%) MSSA with 4 (4.7%), 3 (5.4%) and 20 (16.1%) MRSA positive samples from sand, marine water and stream water respectively. Of the 27 fresh water stream sites sampled multiple times, 37% of the sites were positive for MRSA and/or MRSA and *S. aureus* ≥ 2 times.

**Conclusion:** The fresh water streams were the most commonly MRSA contaminated samples and the source of the MRSA contamination is unknown. This study extends our knowledge of the types of MRSA distributed throughout recreational beach environments. Further studies are needed to determine the source of MRSA contamination especially in the fresh water streams since these were more often MRSA positive.

## Methods

*Staphylococcus aureus* is a common cause of serious and life-threatening infections. The prevalence of MRSA has increased rapidly over the last decade due in large part to the emergence of community acquired MRSA.

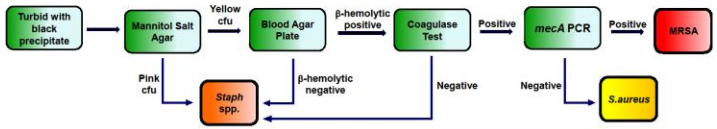
A total of 265 grab samples were processed between July and August 2010

| Location | Events | Dry Sand | Wet Sand | Marine Water | Stream Water |
|---|---|---|---|---|---|
| Beach A | 4 | 15 | 19 | 18 | 37 |
| Beach B | 6 | 27 | 24 | 38 | 87 |
| Total | 10 | 42 | 43 | 56 | 124 |

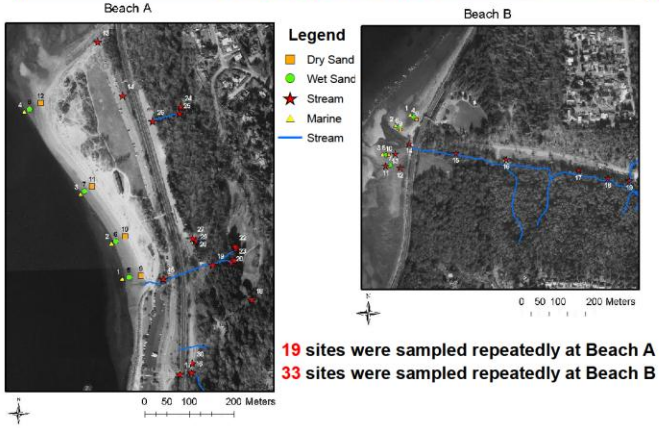
**Marine and Stream Samples:**
- 1 L of marine and stream water collected 2-4 inches below surface and processed within 24 hours
- 25 mL water cultured 1:1 with enrichment broth

**Sand Samples:**
- 50 g of wet (intertidal) or dry (high tide) sand processed within 24 h
- 10 g sand vigorously shaken for 10 min in enrichment broth and incubated

Samples incubated at 36.5°C, 5% $CO_2$:

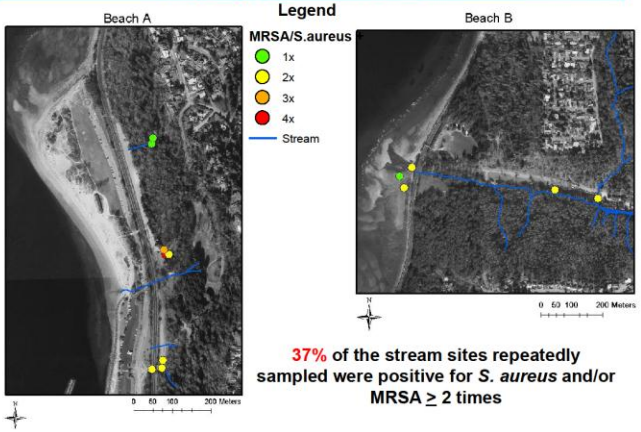



## Sampling Distribution




**19 sites were sampled repeatedly at Beach A**
**33 sites were sampled repeatedly at Beach B**

## Sampling Distribution Results




**37% of the stream sites repeatedly sampled were positive for *S. aureus* and/or MRSA ≥ 2 times**

## Results

| | No. of Samples | No. MRSA | % MRSA | 95% CI |
|---|---|---|---|---|
| Beach A | 176 | 20 | 11.4 | 6.7 – 16.1 |
| Beach B | 89 | 5 | 5.6 | 0.8 – 10.4 |
| Total | 265 | 25 | 9.4 | 7.0 – 14.0 |

## Conclusions

- **This study found a wide variety of MRSA strains distributed throughout both marine and fresh water recreational environments, especially in the fresh water drainage and creeks that traverse and drain into the marine beaches.**
- **Fresh water samples were significantly associated with MRSA and constituted 71% of the MRSA isolates found from both marine and fresh water recreational beaches.**

# Nisqually State Park Forest Health Thin

Susan Nawbary

**Stand Background**

Two stands, totaling 120 acres. (Figure 1). Stands have same species composition; 90% Douglas-fir; remaining 10%: Big Leaf Maple, Red Alder, Bitter Cherry, Western Hemlock, Red Cedar, and Cottonwood. Barneston and Kapowsin soils compose all four stands. These stands have low wind-throw hazard ratings of 1 and 2, for Kapowsin and Barneston, respectively.

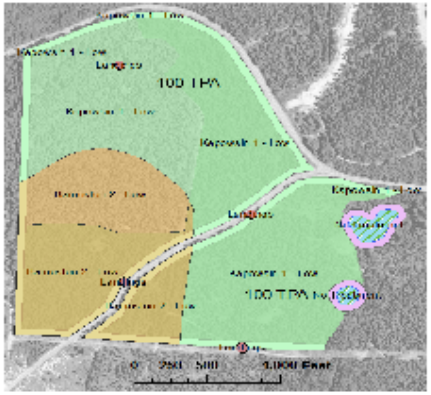



**Figure 1. Soil types and wind-throw hazard level. Hazards of 0-2 are considered low.**

**Prescription**

Thin from below, with residual trees per acre (TPA) of 100 and average spacing 20 ft. Overall spacing will range from 18 – 25 ft. Due to the nature of the thin, residual trees will be left with variable spacing because of the random distribution of larger trees. Trees removed will be Douglas-fir only. Less vigorous will be removed..


**Figure 2. Map of the stands with 100 TPA thin and a 50ft no-cut buffer along roads, private property and wetlands.**

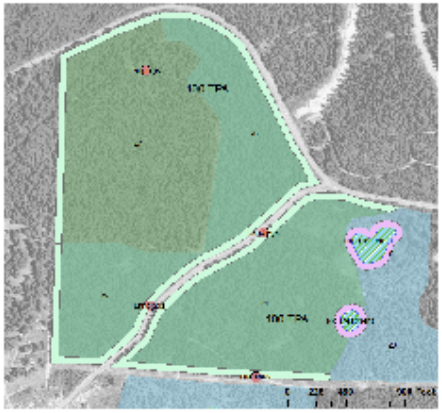



**Figure 3. Landing zones determined by assuming a maximum 900' radius of yarding distance and proximity to roads.**

**Harvest Layout**

Fifty foot wide "no cut" buffers are prescribed along road edges to prevent unauthorized motorized vehicle activity and dumping. Two wetlands near and on the stand will be also protected by a 50' wide "no cut" buffer, as per the Forest Practice Rules WAC222-30-20. Landings have been placed where yarding distances will be less than 900'. Wetland acreages calculated to be 1.4 acres for the northern wetland and .4 acres to the southern wetland. Buffer acreage calculated to be 12 acres, leaving 106 acres of harvestable area.

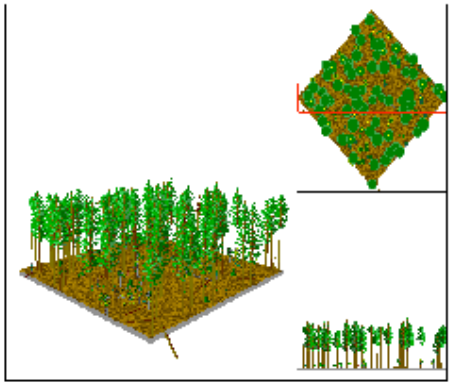


**Figure 4. Forest Vegetation Simulator 30-year projection of TP100 A thin**

**Table 1. Stand Attributes. BA- Basal area. QMD= quadratic mean diameter, Trees per Acre, Stand Density Index.**

| | Stand27 | TriStand |
|---|---|---|
| TPA | 400 | 272 |
| Avg Ht (ft) | 68 | 61 |
| QMD (in) | 8.6 | 8.9 |
| BA ($ft^2$) | 161 | 117 |
| SDI | 313 | 225 |
| Age | 25 | 25 |
| Acres | 43 | 77 |

# Wheels to Water Program

## Connecting Students to Environmental Education in King County

### What is the Wheels to Water Program?

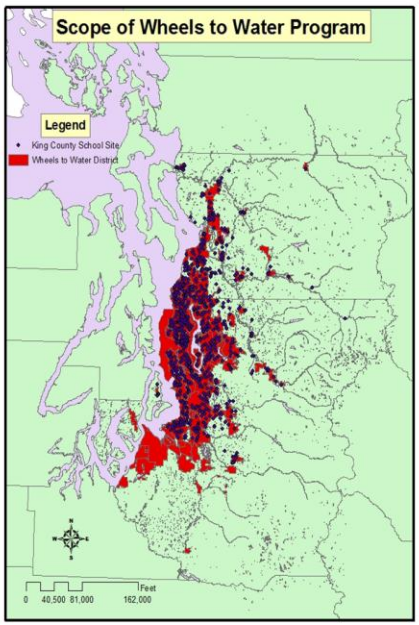
The Wheels to Water Program is a Metro bus transportation assistance program for communities participating in environmental education programs . In the King County Metro area there are many free opportunities for young groups to learn about the environment. One of the most popular opportunities is the King County Treatment Plant tours. Many science and geography classes will travel via the Wheels to Water Program to the nearest treatment plant. The tour includes a presentation and tour around the facility. Other popular programs include tours of the landfill and Nature walks. Currently all classes are given the opportunity to utilize the resources of the Wheels to Water Program. However, due to recent event s it is possible that the Metro Wheels to Water resources will be stretched. These preliminary studies suggest potential solutions which can help cope with the strains put on the limited Wheels to Water resources.

### Who Qualifies for Wheels to Water?

Currently for a school to qualify for the Wheels to Water Program the must fulfill the following Criteria:

- Schools must be located either in King County OR King County Wastewater Service District
- Grades 4-12
- Busses are limited and available on a first-come, first served basis

In an effort to simplify the process of identifying schools which are in King County or the Service District I Have produced a map below. This way Wheels to Water coordinators can quickly identify whether a school lies inside or outside the required district.



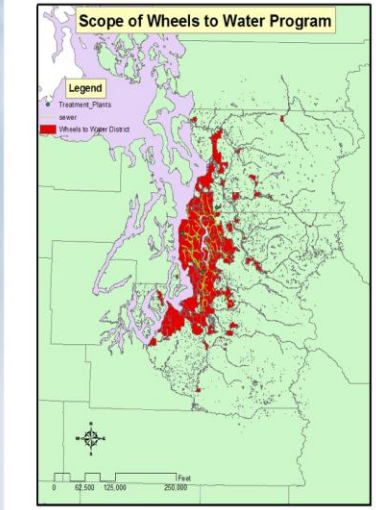

### Beneficiaries of Wheels to Water

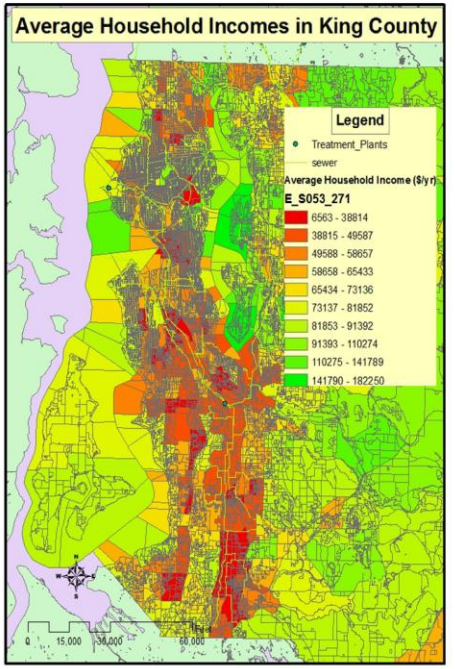
- **Growing Demand for an Environmentally Educated Public.** Recent surveys have shown an increasing demand in workers with environmental skills and understanding. The new generation is often referred to as the "Green Collar" generation of workers. In addition to the demands in the work force, social changes are requiring that the general public have a basic understanding of their environment. Recent movements related to global climate change, waste-management, and resource conservation are becoming the social norm in cities. The Wheels to Water Program is helping in providing our new generation with environmental understanding.
- **Urban Community Needs Opportunities to Interact with Nature.** Despite many 'green movements' starting in urban centers, urban communities are often most deprived of interactions with nature. A large portion of King County youth live in an environment surrounded by buildings and concrete. Wheels to Water allows urban youth to get out and experience nature.

### Upcoming Challenges for Wheels to Water

➢**New treatment Brightwater Treatment Plant Education Center Has Increased the Demand for Wheels to Water:** King County will open a brand new Brightwater Education Facility located at Brightwater this fall. The new site is located North East of Lake Washington. If we compare the Brightwater location and the average household income levels they are located on opposite sides of King County. As a result the Wheels to Water program should not only expect more demand because of new Brightwater Tours, but also a greater average travel distance for each group (for example, Renton classes will be driving to Woodinville for the Education Center).

➢**Budget Cuts are Hitting State Funded Programs, including schools and metro bus transportation:** Recent economic stress has resulted in state budget cuts to public sectors; Seattle schools and public transport funds are being cut. The Wheels to Water program will be affected by both of these sectors. Public education funding cuts will increase the demand for free services such as Wheels to Water. At the same time the cuts to the Metro bus system are reducing the supply of available busses and drivers.




### Optimizing Wheels to Water

➢**Pinpoint which Schools in King County Have the Greatest Demand for Wheels to Water:** Based on the map above we can approximate which regions have the lowest average household income in the King County region. Based on such patterns and each schools location we can approximate which schools have the greatest demand for the Wheels to Water Program.

➢**Approximate Travel Times and Mileage For Each School:** For future research we could develop a spatial map showing the distance of each school to a specific treatment plant or environmental education facility. This distance would represent the cost to Metro for transporting a specific group .

➢**Narrow Scope of Eligible Schools Based on Cost to Metro System and Demand by Community:** By combining the above data a basic algorithm can show which groups of schools demand the Wheels to Water and are cost effective for the metro bus system. Using this system a narrowed scope of eligible schools could be developed. This could provide a more sustainable system for Wheels to Water to continue with.

### Sources:

Kingcounty.gov

Produced by Andrew Vining
CFR 520
#0623967
Final Poster