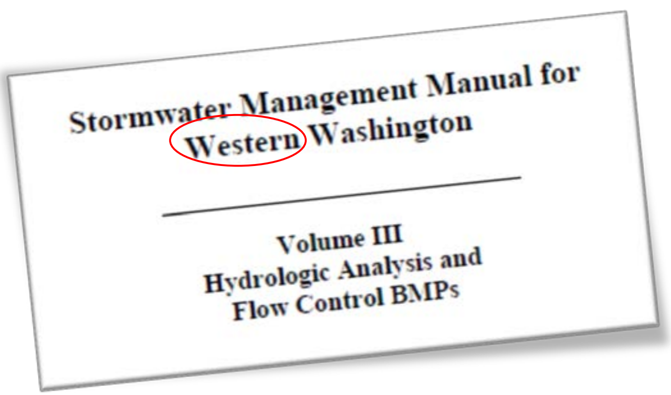
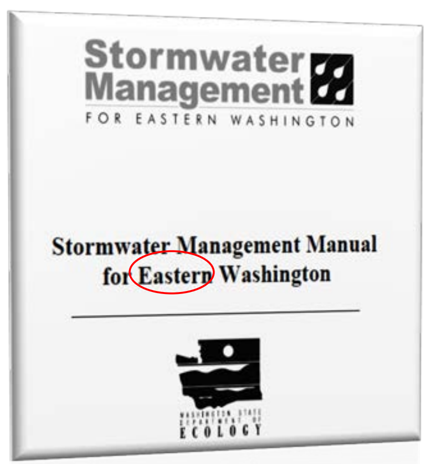
Determining Infiltration Rates:
Approaches, Challenges & Lessons Learned

May 16, 2017


Stormwater Management Manual for Western Washington

Volume III
Hydrologic Analysis and
Flow Control BMPs



Stormwater Management Manual for Eastern Washington

Presented by
Andrew Austreng, LHG

Aspect CONSULTING

Presentation Outline

- **Overview of Site Characterization & Testing**
- **Pilot Infiltration Test (PIT) Specifics**
- **Approaches and Challenges**
- **Lessons Learned &Tools Available**

Infiltration Testing: *Site Characterization*

- **Suitability Criteria**
  - Max Infiltration Rates **with** Treatment
    - Western: 3 in/hr (design)
    - Eastern: 2.4 in/hr
  - Minimum Rate **without** Treatment
    - Western: 48-hr drain
    - Eastern: 72-hr drain
  - 5’ separation between GW and/or low *k* *(3’ possible)*
  - Setback from 15% slope
- **Subsurface Investigation** *(Report)*

Subsurface Investigation: *Approaches*

Western WA

- Assume 0.5 in/hr for investigation area
- 5x pond depth *(at least 10 ft)*
- Characterize GW *(<50 ft)* - **monitor 1 wet season**

Eastern WA

- 3 excavations within pond
- 5 ft below bottom *(at least 10 ft if no info available)*

Key to determining mounding potential…..

Subsurface Investigation: *Existing Info*

Geologic Maps/Studies

- Consider Scale
- Evaluate Source of Info

Eastern WA: *Determining Infiltration Rates*

Four Recommended Tests

1. Borehole *(deep or high k)*
2. Drywell *(confirmatory)*
3. Ring Infiltrometer *(surficial or high k)*
4. **Test Pit**

Single-Ring Inflitrometer

100 ft ^{2} PIT (large-scale)

Western WA: *Infiltration Testing*

Three Recommended Tests

1. Large-scale PIT (100 ft^2)
2. Small-scale PIT (12-36 ft^2)
   - < 1 acre
   - High rates
   - Permeable pavement, etc.
3. Grain Size
   - When not compacted *(recessional outwash)*

PIT: *Eastern & Western Procedures*

	Western	Eastern
Depth of Test	*Pit Bottom*	*2 to 5 ft Below*
Testing Season	*12/1 – 4/1*	*--*
Pit Area	*12 - 100 ft^2*	*8 ft^2*
Saturation Time	*> 5hrs*	*< 2hrs*
Stable Flow	*≥1 hr*	*0.5 hrs*
Falling Head	*Until Dry*	*30 min*

- **Flow Stable at 5% variation**
- **Western more conservative** *(mounding)*

PIT Method: *Qualitative Mounding (Western)*

- **Over-excavate**

- **Boreholes**

Eastern WA: *PIT Calculations*

Reclamation Procedure

Low Water Table:

$$k_{20} = \frac{qV}{2\pi h^2}\left\{ \ln\left[\frac{h}{r} + \sqrt{\left(\frac{h}{r}\right)^2 + 1}\right] - \frac{\sqrt{1 + \left(\frac{h}{r}\right)^2}}{\frac{h}{r}} + \frac{1}{\frac{h}{r}} \right\}$$

High Water Table:

$$k_{20} = \frac{qV}{2\pi h^2}\left[\frac{\ln\left(\frac{h}{r}\right)}{\frac{1}{6} + \frac{1}{3}\left(\frac{h}{T_u}\right)^{-1}}\right]$$

- ***Determines permeability coefficient*** *(not gradient)*

Western WA: *PIT Calculations*

- **Calculations**
  - ***Ki*** = Q/A

$$50\ gpm = 400\ \frac{ft^3}{hr}; \qquad \frac{400\ ft^3 hr^{-1}}{100\ ft^2} = 4\ ft/hr$$

- **Correction Factors**

Issue	Factor
Heterogeneity	*0.33 - 1*
Large PIT	*0.75*
Small PIT	*0.5*
Other (small scale)	*0.4*
Grain Size	*0.4*
Long-term fouling	*0.9*

= 0.12 to 0.68

Western WA: *Calculations (Detailed Design)*

Described in Western for:

- Drainage > 10 acres
- Low *k* within 15 feet *(10 feet)*

6. **Calculate Conservative Gradient (mounding)**
7. **Correct for Aspect ratio** *(pit bottom)*
8. **Size for 48-hr drawdown** *(6 ft max head)*
9. **Run MODRET** *(or other analytical)*

Western WA: *Grain Size Calculations*

Calculations:

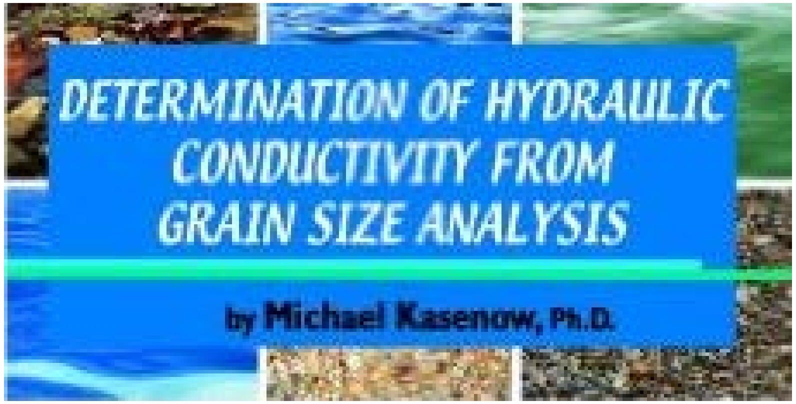
- Massmann (2003)
- Harmonic mean, or
- Lowest *k* if w/in 5 feet

Need to Consider:

- Hydraulic gradient
- Soil structure *(e.g., varves, laminae)*
- Compaction during construction

Confirm with Other Methods….

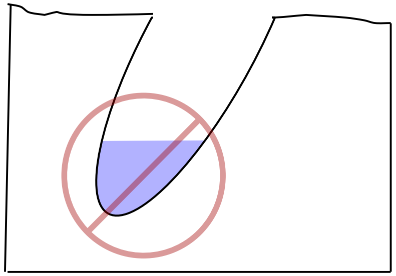
Test Pit	*Hydraulic Conductivity (ft/hr)*			PIT Results
	Massmann	*USBR*	*Pavchich*	
PIT 1	5.1	0.9	1	**0.9 to 1.2**
PIT 2	2.9	0.4	0.4	**0.4 to 0.5**



…..WDOT

PIT Method: *Data Collection Tips*

- **Dimensions are Critical!!**
  - $Ki = \frac{Q}{A}$



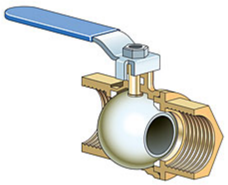
- **Consider Shoring**

PIT Method: *Data Collection Tips*

Flow Metering

- **Adjusting Valves** ***(5% threshold)***

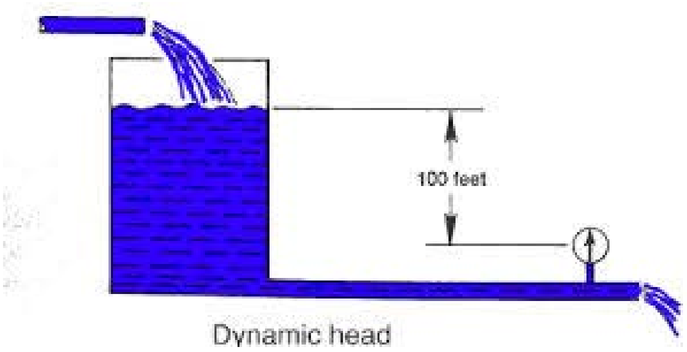
Butterfly



Ball

Gate

- **Rate Will Vary with Head**

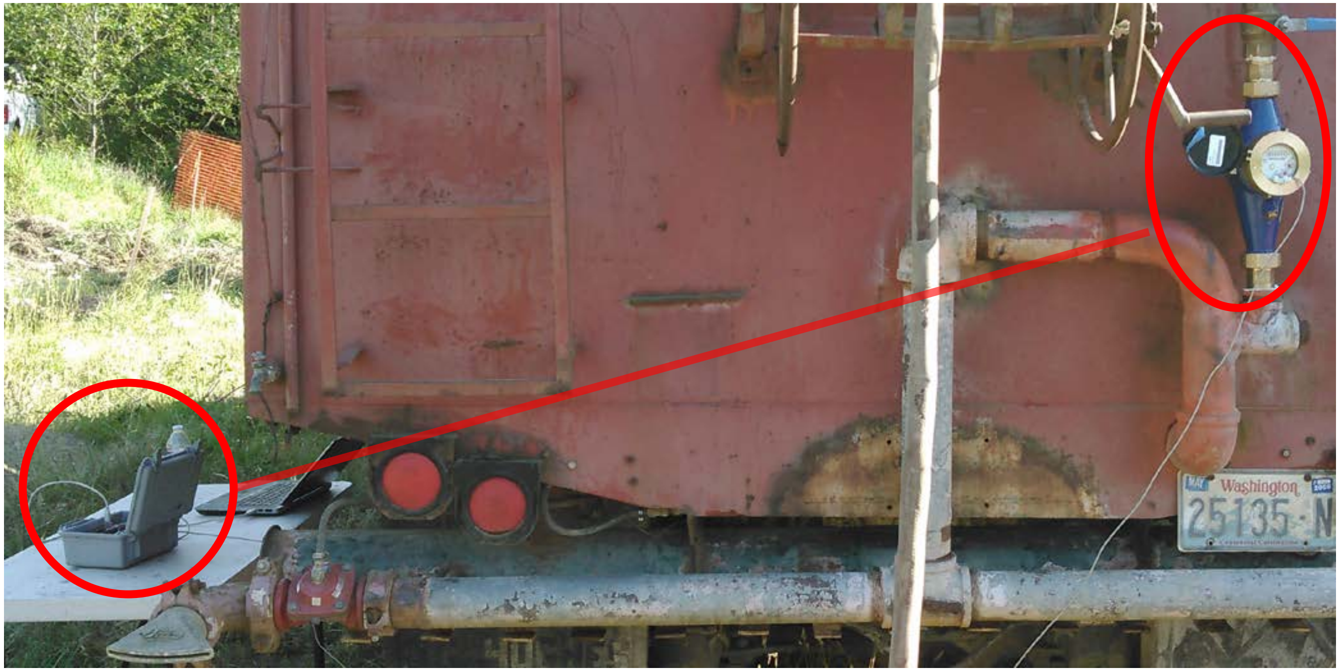


MJ Series

PIT Method: *Data Collection Tips*

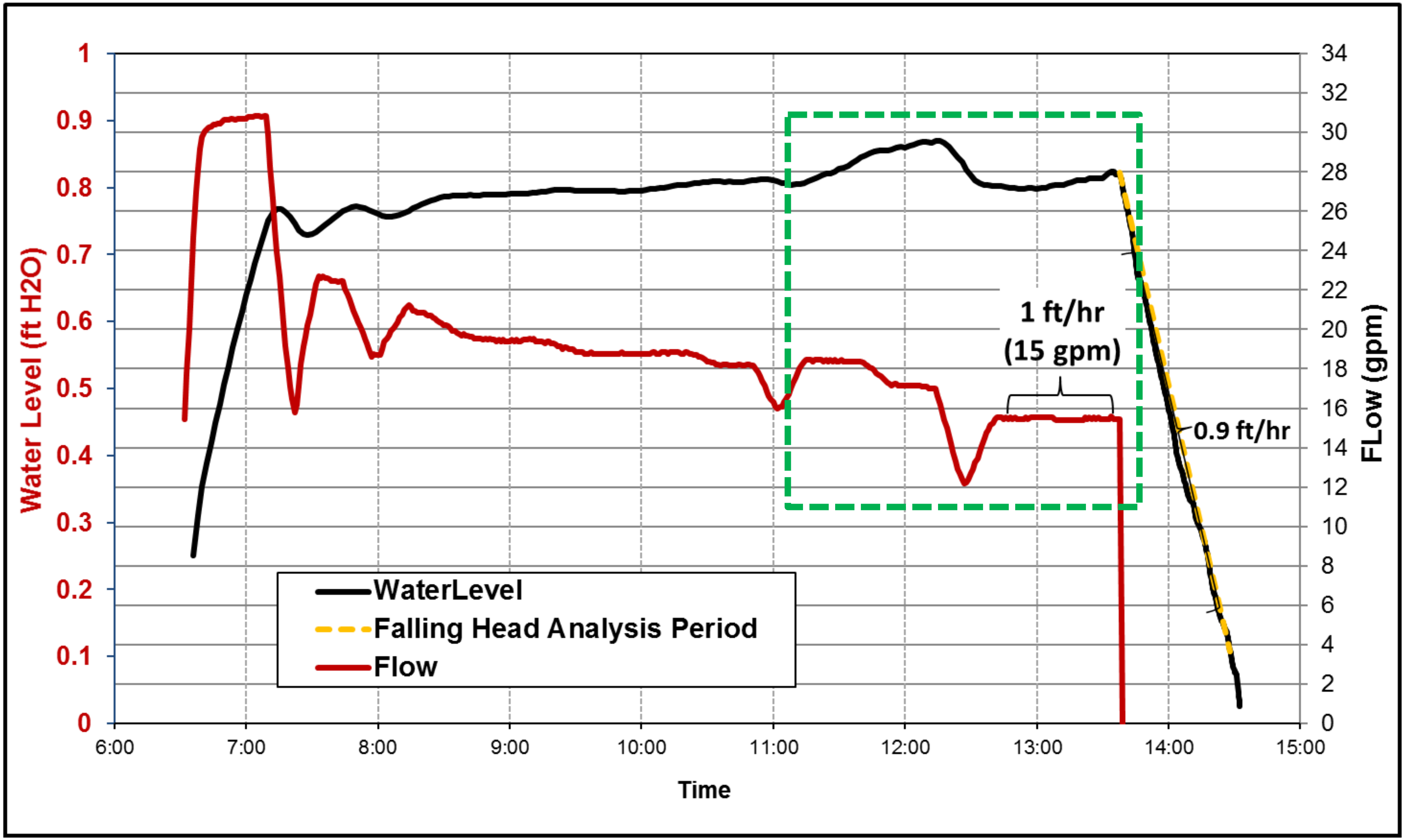
Automation

- Pressure Transducer
- Pulse Meter + datalogger



PIT Method: *Challenges*

"Constant Head"



Tools Available…

	Within each blank cell, enter comment codes as follows: C = Complete R = Revise (i.e., make corrections) N/A = Not Applicable M = Missing (i.e., please include) IC = Incomplete
	DETERMINE METHOD OF ANALYSIS
1	Typically use the Simple Method for the following types of sites (subject to City approval): • For small facilities serving short plats or commercial developments less than 1 acre of contributing area • High infiltration capacity soils (NRCS [SCS] soil types A or B) • Other infiltration facilities performing successfully at nearby locations • No drinking water wells, steep slopes, or other sensitive features within 500 feet • Low risk of flooding and property damage in the event of clogging or other failure of the infiltration system
2	Typically use the Detailed Method for the following types of sites (subject to City approval): • A large contributing drainage area • Low infiltration capacity soils (NRCS [SCS] soil types C or D) • History of unsuccessful infiltration facility performance, or no history of successful infiltration performance at nearby locations • High groundwater levels or depth to low permeability layer less than 10 feet • High risk of flooding in the event of clogging or other failure.
	STEPS FOR THE DESIGN OF INFILTRATION FACILITIES SIMPLIFIED APPROACH (SWMMWW Volume III, Section 3.3.4) Applies to Infiltration Ponds/Basins, Trenches, Vaults, and Tanks (note: does not apply to Downspout Full Infiltration Systems)
	Step 1: Select a Location
3	Location selected based on preliminary surface and sub-surface characterization study (SWMMWW Volume III, Section 3.3.5) and preliminary check of Site Suitability Criteria (SWMMWW Volume III, Section 3.3.7). (See also Step 4.)
	Step 2: Estimate Volume of Stormwater
4	WWHM, MGSFlood, or other approved continuous runoff model is used to generate an influent file to size the infiltration facility. (See also Step 6 for sizing criteria.)
	Step 3: Develop Trial Infiltration Facility Geometry (for initial modeling purposes only, see SWMMWW Volume III, Section 3.3.4, Step 3)
	Step 4: Complete More Detailed Site Characterization Study and Consider Site Suitability Criteria

City of Edmonds

Public Works Department, Engineering Division

121 5th Ave N
Edmonds, WA 98020

Pilot Infiltration Test (PIT) Field Checklist

Call before you dig – Utility Locates 811

Project Address: ______________________ Date: ______________

Permit Number: ______________ Contact Information: ______________________

Other Project Information: ______________________________________

☐ Include site map or drainage control plan, with test locations clearly marked.

The intent of this checklist is to provide a summary of stormwater BMP infiltration testing requirements associated with the Pilot Infiltration Test (PIT). All projects and associated plans are also subject to the minimum requirements outlined in ECDC Chapter 18.30, as well as the specific subsurface investigation and infiltration testing requirements outlined in the City of Edmonds Stormwater Addendum, Appendix B. See also Stormwater Addendum Appendix A for site constraints that may preclude infiltration facility feasibility for some BMPs.

This checklist does not preclude the use of professional judgment to evaluate and manage risk associated with design, construction, and operation of infiltration BMPs. Justification for testing procedures that deviate from the minimum investigation requirements specified in Appendix B shall be documented in a stamped and signed letter from a professional soil scientist certified by the Soil Science Society of America (or an equivalent national program), a professional engineer licensed in the State of Washington in civil engineering, a geologist, a hydrogeologist, or a licensed engineering geologist registered in the State of Washington, any of whom must also have experience in infiltration and groundwater testing and infiltration facility design.

Before you start call Utility Locates 811 to request locates of utilities at your site.

SMALL-SCALE PILOT INFILTRATION TEST (SMALL PIT) AND LARGE-SCALE PILOT INFILTRATION TEST (LARGE PIT):
(Note: The test methods outlined below may be modified due to site conditions if recommended by the licensed professional and the reasoning is documented in the testing report.)

1. Indicate type of test:
   ☐ Small PIT
   ☐ Large PIT
2. Date and time of tests: ______________________
3. Will the infiltration test be within the footprint of the proposed infiltration facility? (Yes / No)
4. If "no," explain why: ______________________
5. ☐ Dig an infiltration test pit
6. Test pit excavated to bottom elevation of the proposed facility (Yes / No)
   (See City of Edmonds Stormwater Addendum, Appendix B for additional details.)

DRAFT

Pierce County BMP Sizing Calculator for Flow Control

Project Information:

Precipitation Zone →
Site Mean Annual Precipitation → in
Soil Type →
New and Replaced Impervious Area → sf
Flow Control Standard Achieved? →

LID Runoff Reduction Methods	Facility Size		Credit	Area Mitigated
Partial Dispersion				
Downspout, Sheet Flow, or Concentrated	Dispersed Impervious Area	sf	x (___ x ___ + ___) *enter precipitation zone*	= ___ sf
Green Roof				
>4" Growth Medium	Green Roof Area	sf	x (___ x ___ + ___) *enter precipitation zone*	= ___ sf
Permeable Pavement Surface				
Subgrade Slope ≤ 2% Design Infiltration Rate in/hr	Permeable Pavement Area	sf	x ___ *enter precipitation zone* *Aggregate Storage Depth for Flow Control* = ft	= ___ sf
Subgrade Slope 2-5% Design Infiltration Rate in/hr	Permeable Pavement Area	sf	x (___ x ___ + ___) *enter precipitation zone* *Aggregate Storage Depth for Flow Control* = ft	= ___ sf

Infiltration Feasibility Assessment for Seattle-Tacoma International Airport

2017 Washington Municipal Stormwater Conference

Aspect CONSULTING

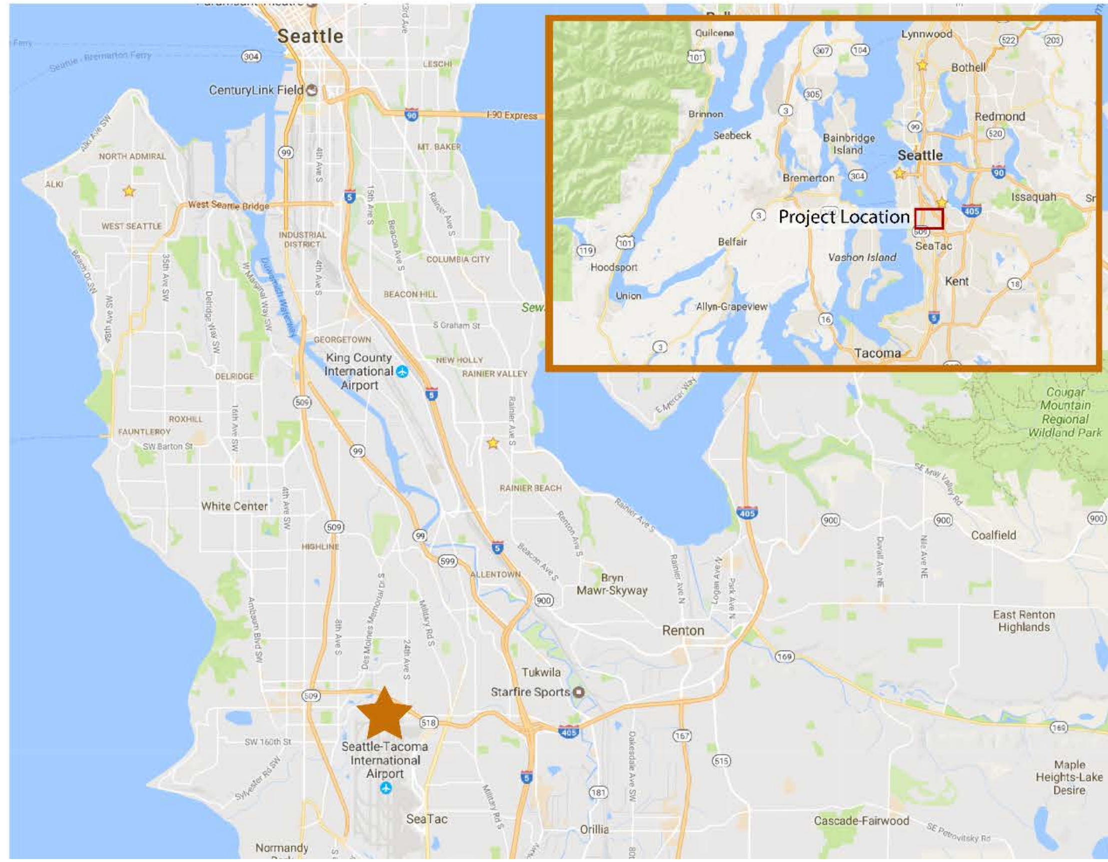
Tom Atkins, PE, LG

Port of Seattle®

Presentation Outline

- STIA Overview
  - Airport layout and operations
  - Stormwater management
  - Geology/hydrogeology
  - Need for infiltration assessment
- Approach
- Results

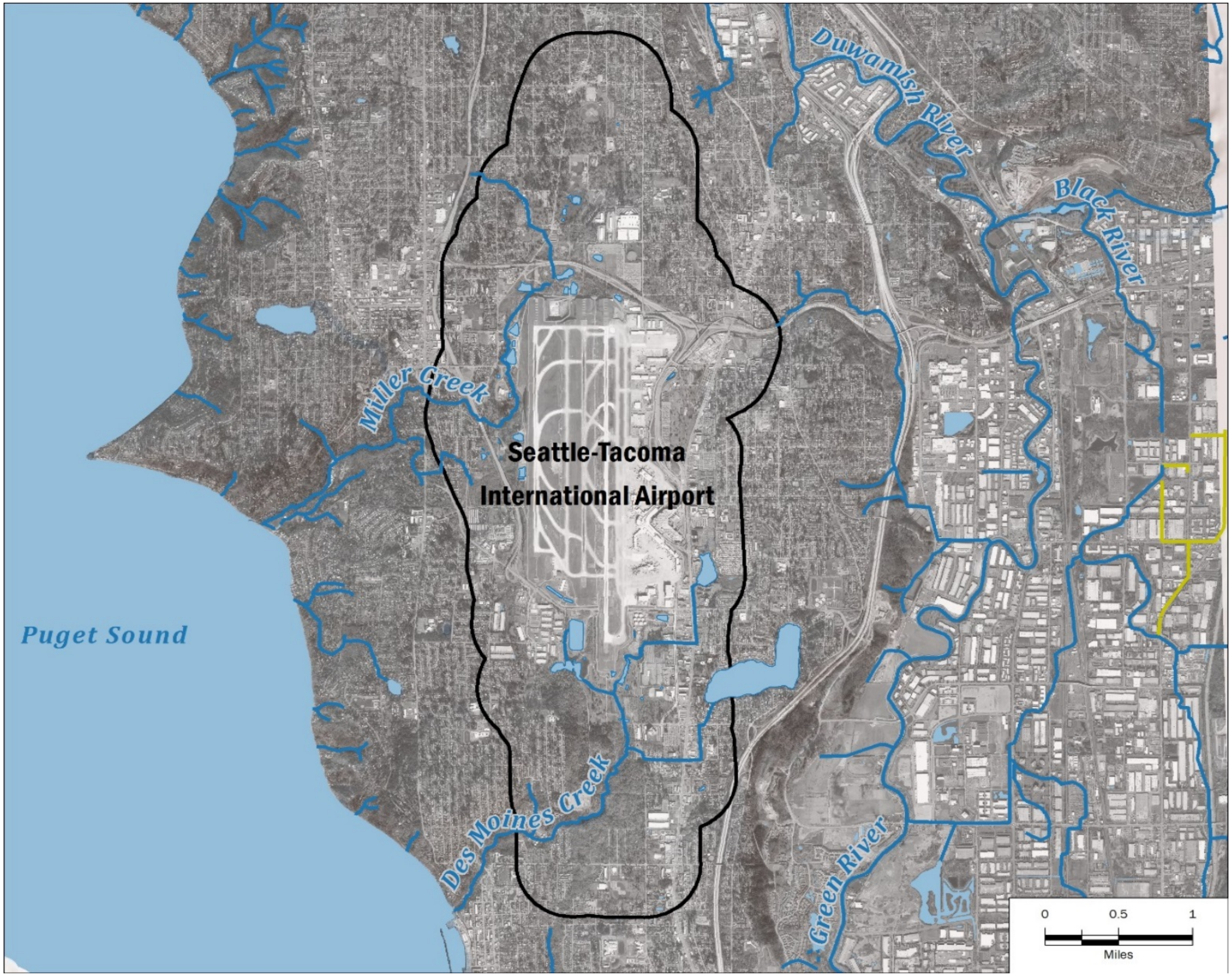
Seattle-Tacoma International Airport
Project Location



STIA Overview

- Located in City of SeaTac 12 miles south of downtown Seattle
- Largest airport in the Pacific Northwest
- 1600 acres with 3 streams discharging to Puget Sound
- 45 million passengers in 2016
- Largest generator of vehicle trips in the state and a 13,000-car parking garage*
- Substantial future development plans

Study Area



Duwamish River
Black River
Miller Creek
Seattle-Tacoma
International Airport
Puget Sound
Des Moines Creek
Green River
0
0.5
1
Miles

Stormwater Management

- 2 Collection and Conveyance Systems
  - Industrial Wastewater System (IWS)
    - Aircraft/vehicle maintenance
  - Storm Drainage System (SDS)
    - Runways/expressways, terminal, service roads
- Individual NPDES Permit
  - IWS
  - Non-construction stormwater
  - Construction stormwater

Low Impact Development

- Port's *LID Guidelines* being developed
- *Stormwater Management Manual for Aviation Division Property* being updated
- Broad-scale infiltration assessment needed to provide guidance for identifying future stormwater infiltration opportunities
- Assessment primarily focused on hydrogeologic considerations

Infiltration Assessment Approach

- Determine important factors
- Identify and obtain existing available information
- Create GIS layers of each factor
- Determine infiltration feasibility of each unique combination of factors
- Create summary shallow and deep infiltration feasibility maps

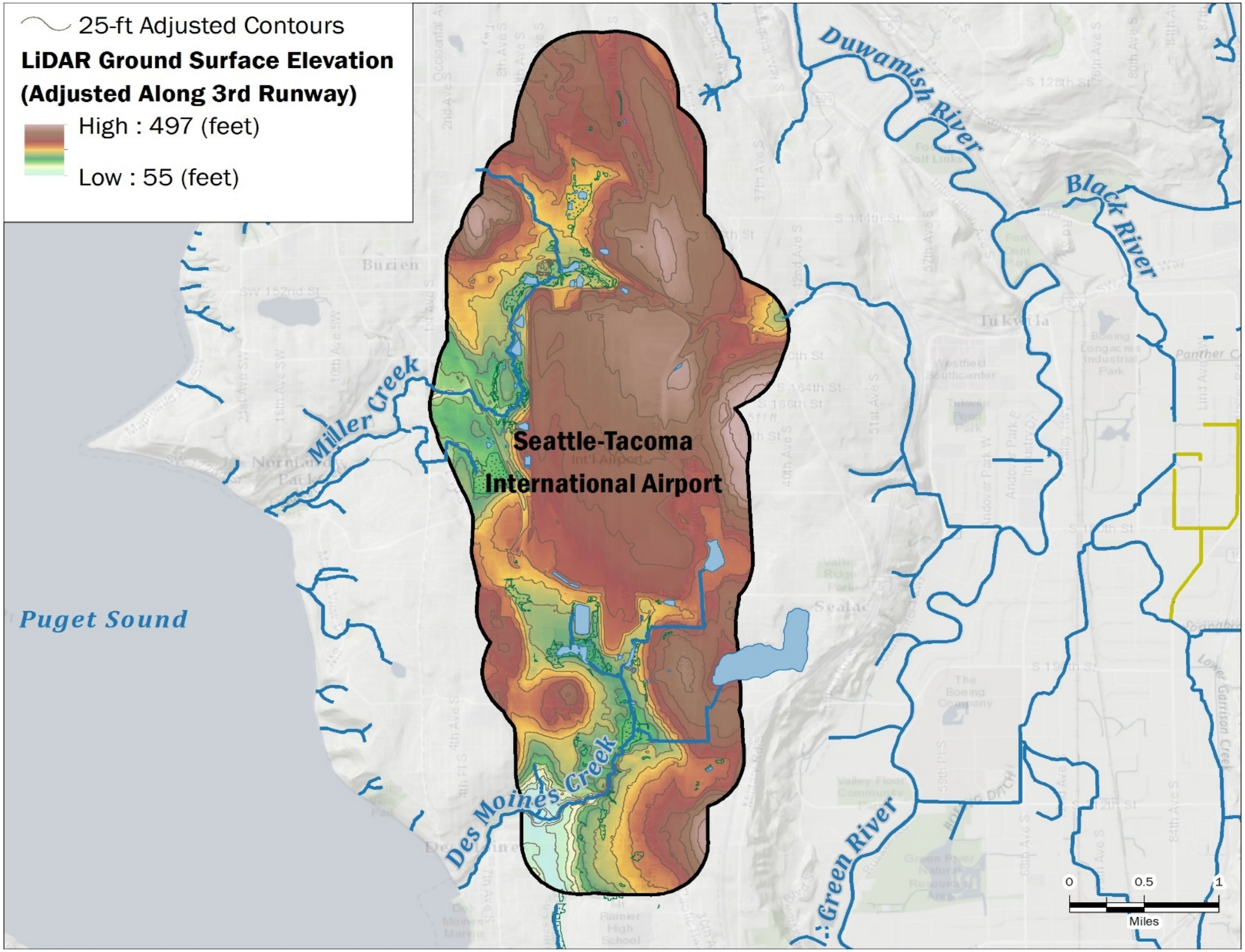
Information Sources

- Substantial amount of existing information
  - LiDAR elevation and Port topographic survey data
  - Surficial geologic maps
  - Subsurface geologic and hydrogeologic information from the 2008 Groundwater Study
  - Sensitive and critical areas
  - Other notable information

Topographic Layer

- Created using LiDAR that was adjusted to post-Third Runway conditions using Port survey data
- Ground elevations range from 60 ft (southwest area) to over 500 ft above mean sea level (central area)

Ground Surface Elevation



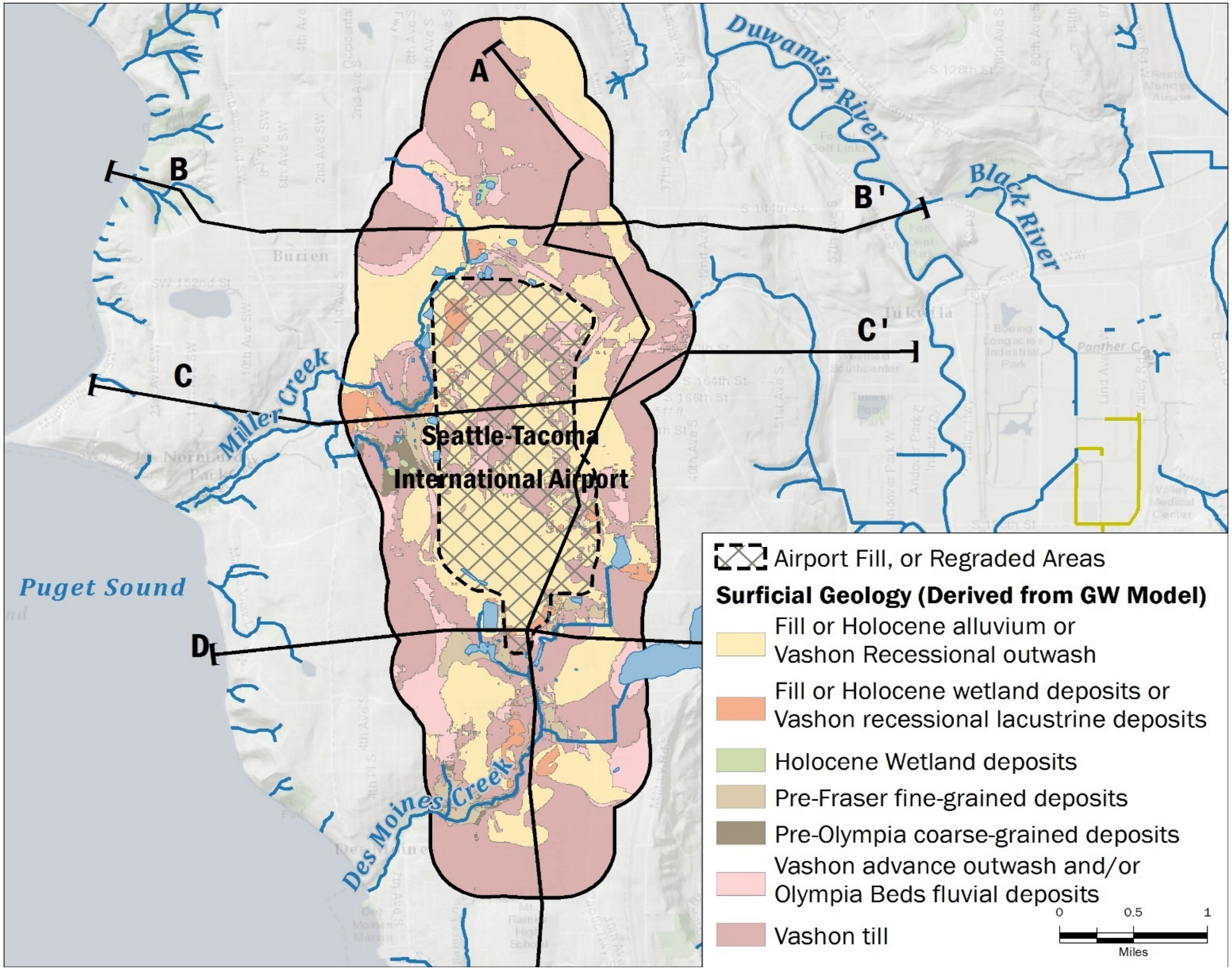
Surficial Geologic Units

- Based on regionally significant surficial geologic units modeled in 2008 Groundwater Study
- Also identified Airport fill and regraded areas

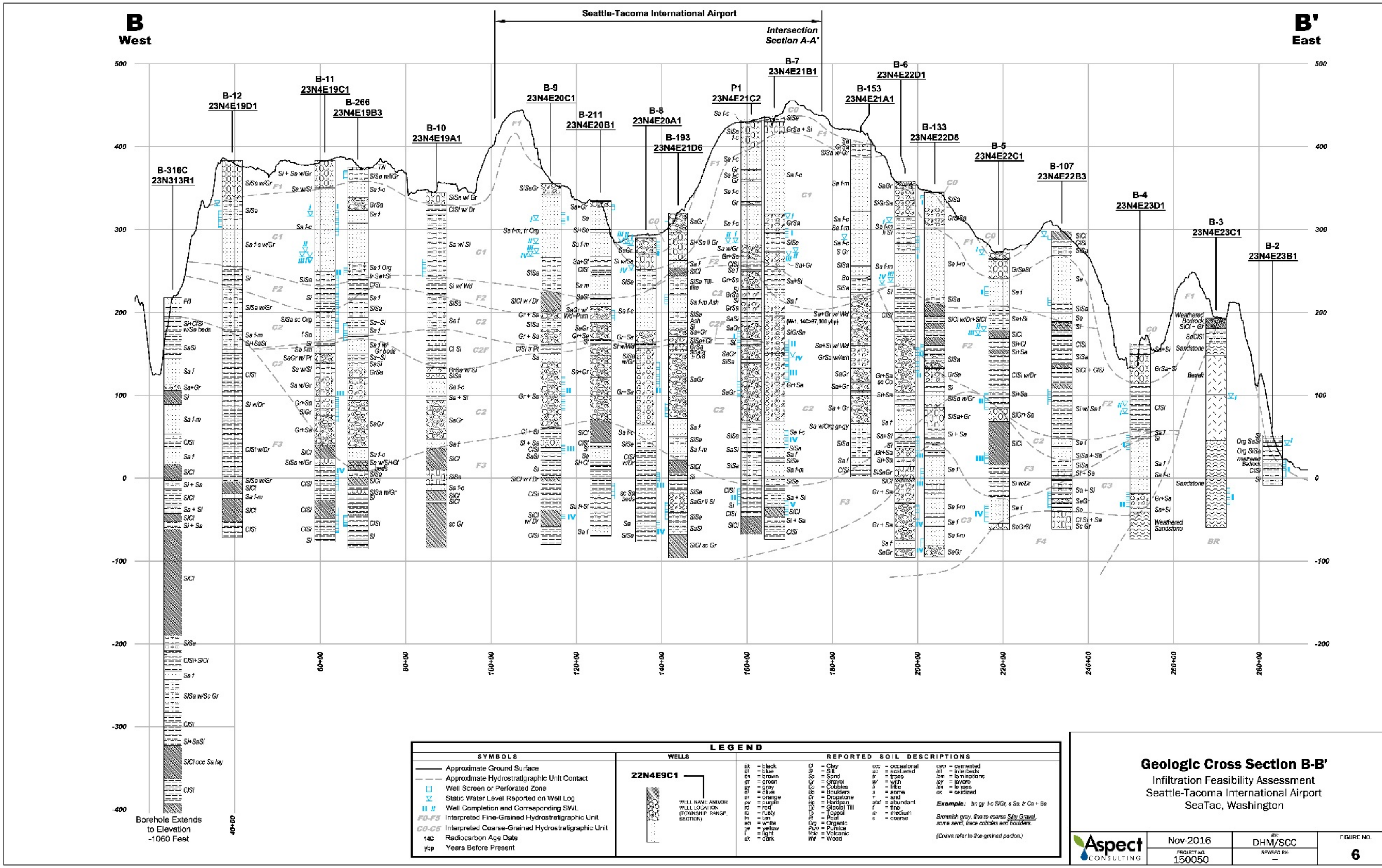
Geology/Hydrogeology

- Puget Sound lowland glaciation resulted in glacially sculpted uplands
- Post-glacial erosion has locally incised the uplands and created steep-sided ravines
- 2008 groundwater study identified 12 regional hydrostratigraphic units
- Vashon glacial till (Qvt) covers much of STIA’s high plateau area
- Advance outwash (Qva) stratigraphically below the glacial till

Surface Geology



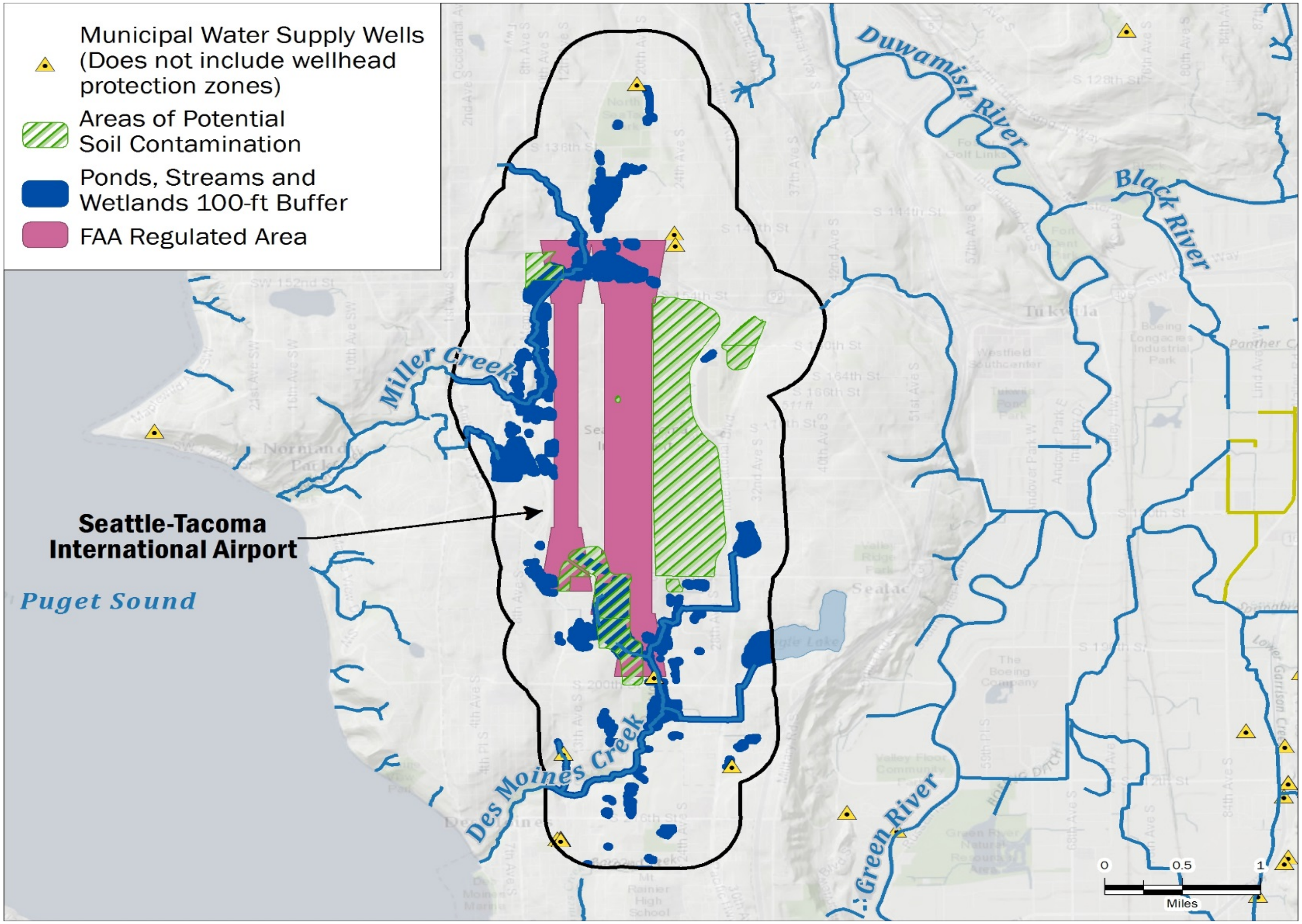
Cross-Section B-B’



Sensitive, Critical and Other Notable Areas Layer

- Streams, ponds, lakes and wetlands with 100-ft buffers included
- FAA regulated areas
  - Runway Safety Areas
  - Object-free Areas
  - Protection Zones
- Areas of potential soil contamination
- Municipal water supply wells

Sensitive, Critical and Other Areas



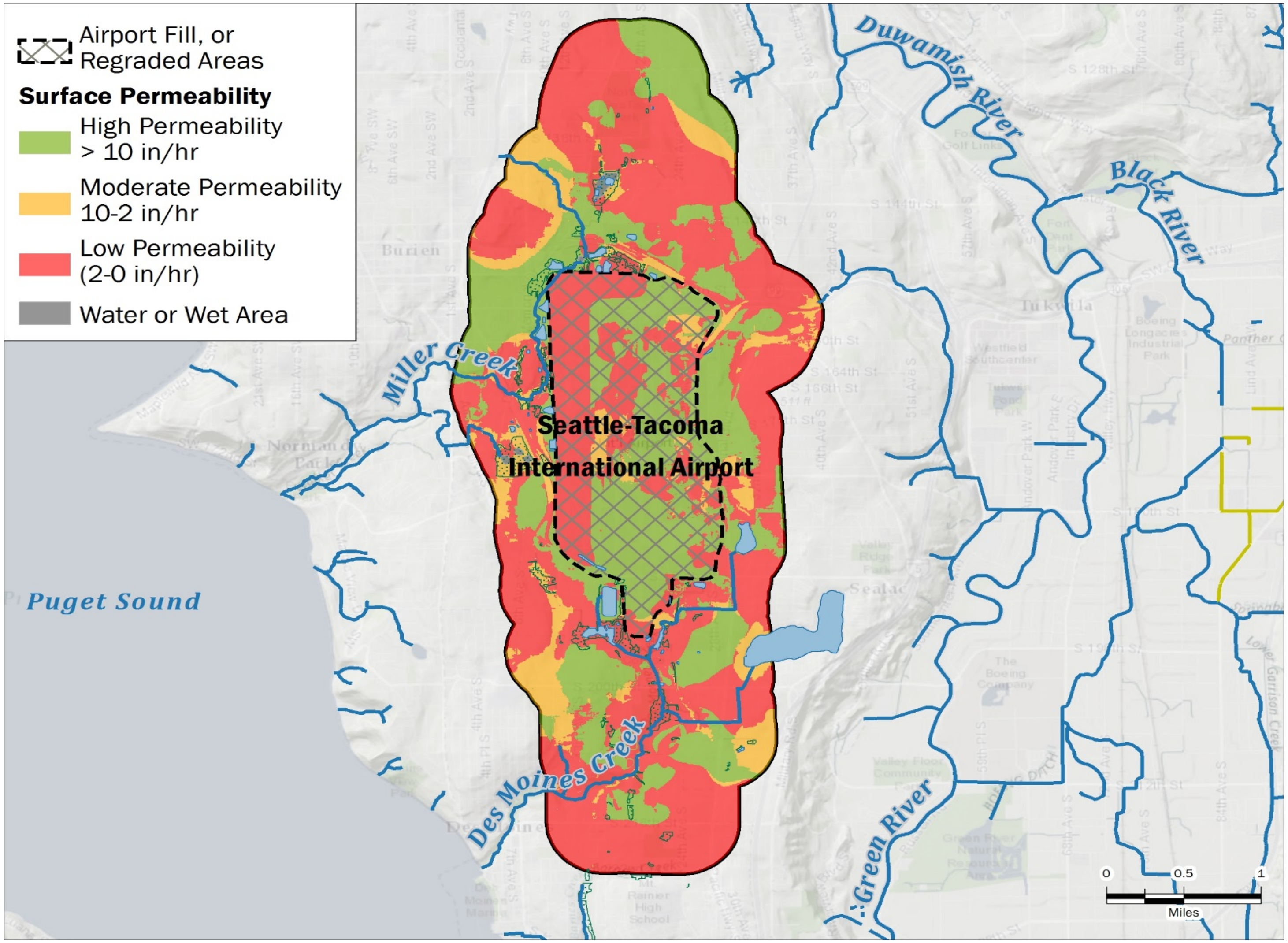
Infiltration Feasibility Factors

- Surface geology/gross unit hydraulic conductivity
- Surface slope gradient
- Proximity to steep slopes and landslide hazard areas
- Thickness of permeable unsaturated zone
- Depth to permeable receptor unit

Surface Geology/Permeability

- Geologic units categorized into broad permeability categories
- High permeability
  - Vashon Recessional Outwash Qvr
- Moderate Permeability
  - Alluvium Qal
  - Vashon Advance Outwash Qva
  - Older coarse-grained deposits Qpf
- Low Permeability
  - Vashon Glacial Till Qvt and other fine-grained deposits

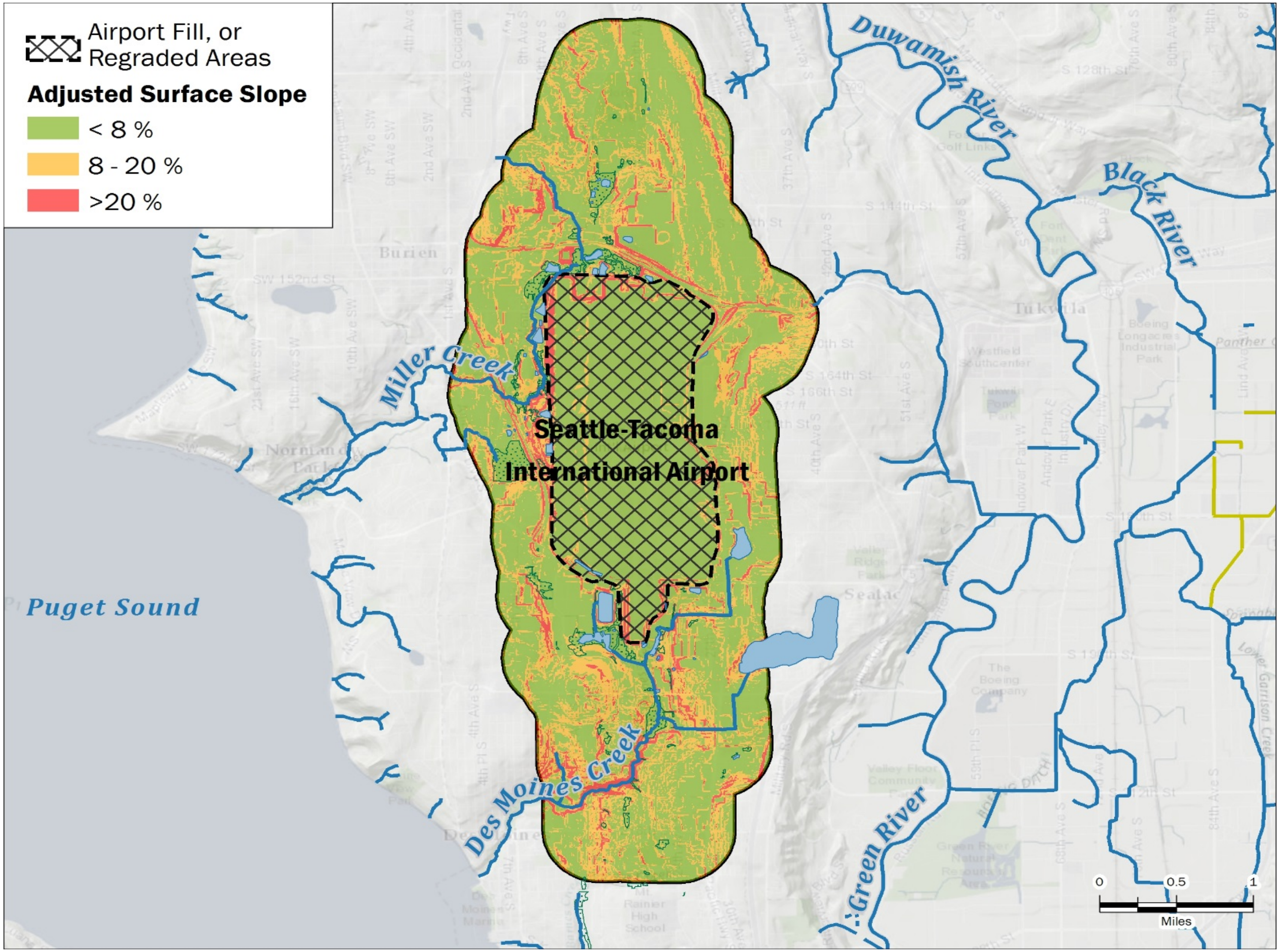
Surface Permeability



Surface Slope Gradient

- Surface slope was divided into three categories
  - Low Gradient (<8%)
  - Moderate Gradient (8 – 20%)
  - High Gradient (>20%)

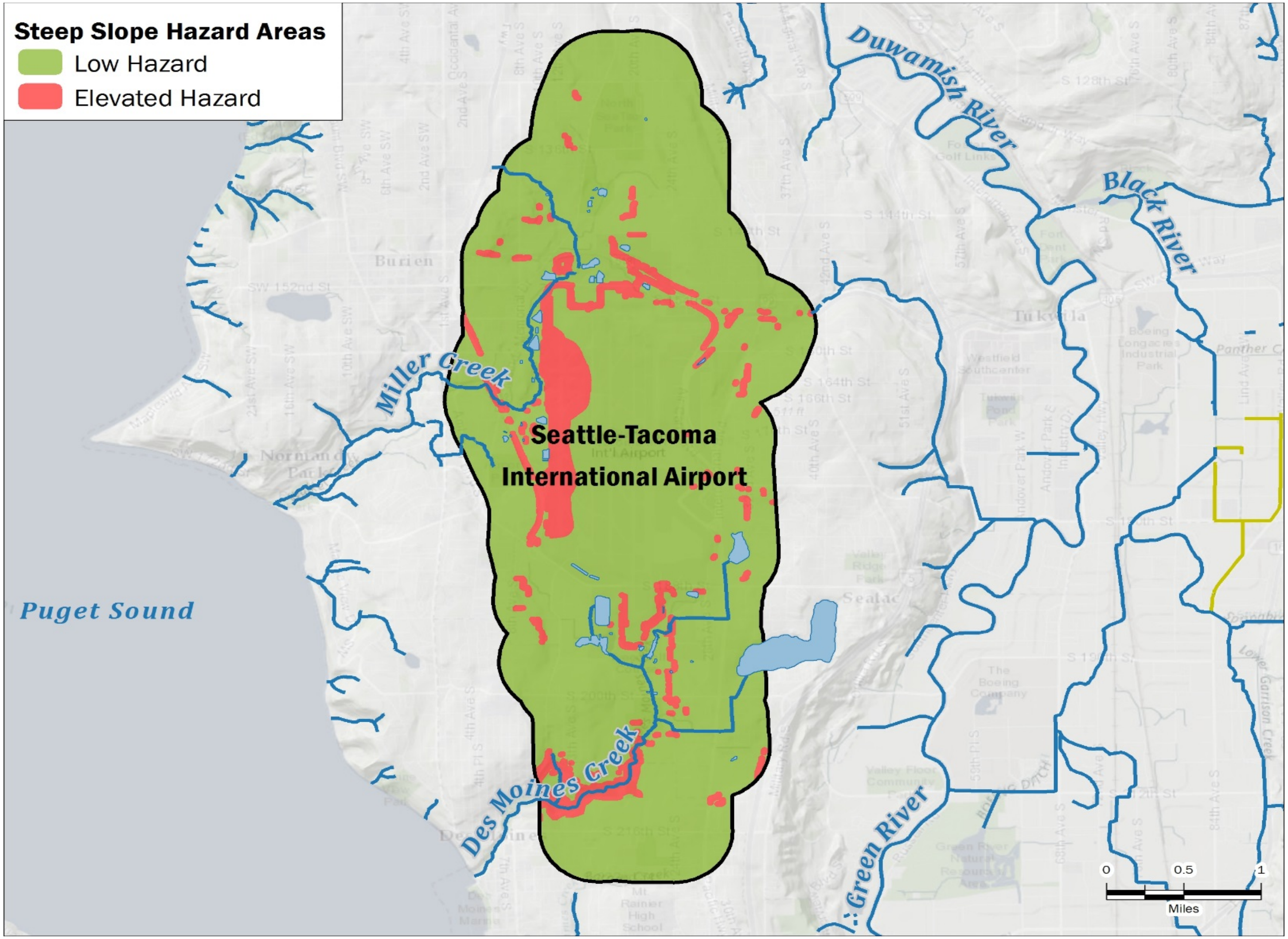
Surface Slope



Steep Slope Hazard Areas

- Two landslide hazard categories
  - High to Moderate Landslide Hazard
    - Slopes >40% plus 100-ft buffer or within 500 ft of a mapped landslide/steep hazard
  - Low Landslide Hazard
    - All other areas except embankment fill
- Infiltration to Third Runway embankment fill is prohibited
  - Fill area estimated by comparing pre- and post-construction topography with a 500 ft buffer east of upper fill

Steep Slope Hazard Areas

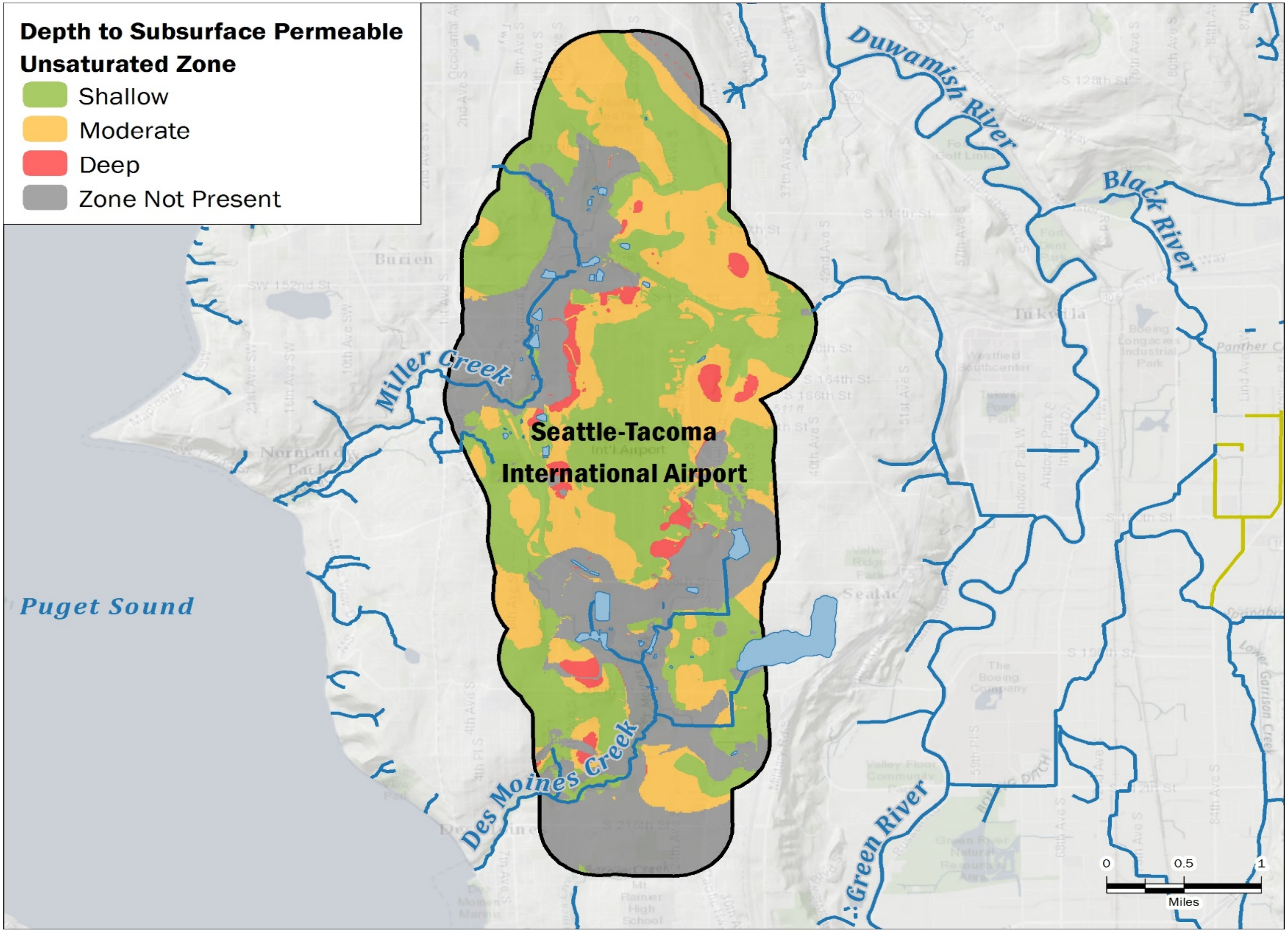


earth+water

Depth to Permeable Unsaturated Zone

- Three depth categories
  - Shallow depth to infiltration receptor (<20 ft)
  - Moderate depth to infiltration receptor (20-50 ft)
  - Deep infiltration receptor (>50 ft)

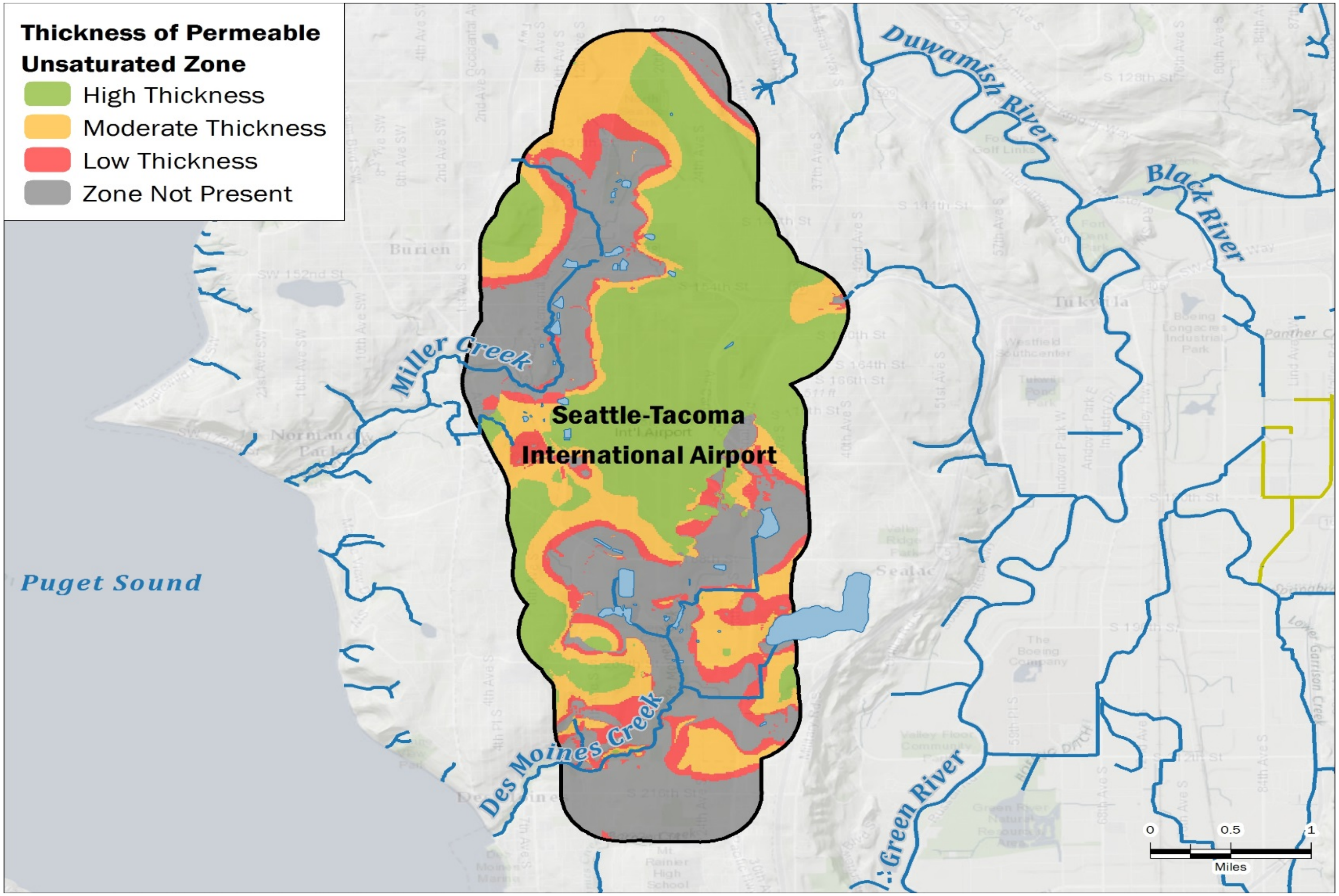
Depth to Subsurface Permeable Unsaturated Zone



Thickness of Permeable Unsaturated Zones

- Three thickness categories
  - High thickness (>30 ft)
  - Moderate thickness (10 – 30 ft)
  - Low thickness (<10 ft)

Thickness of Subsurface Permeable Unsaturated Zone



Hydrogeomorphic Units

- Each unique combination of infiltration feasibility factors defines a hydrogeomorphic unit
- Shallow and deep infiltration hydrogeomorphic units determined

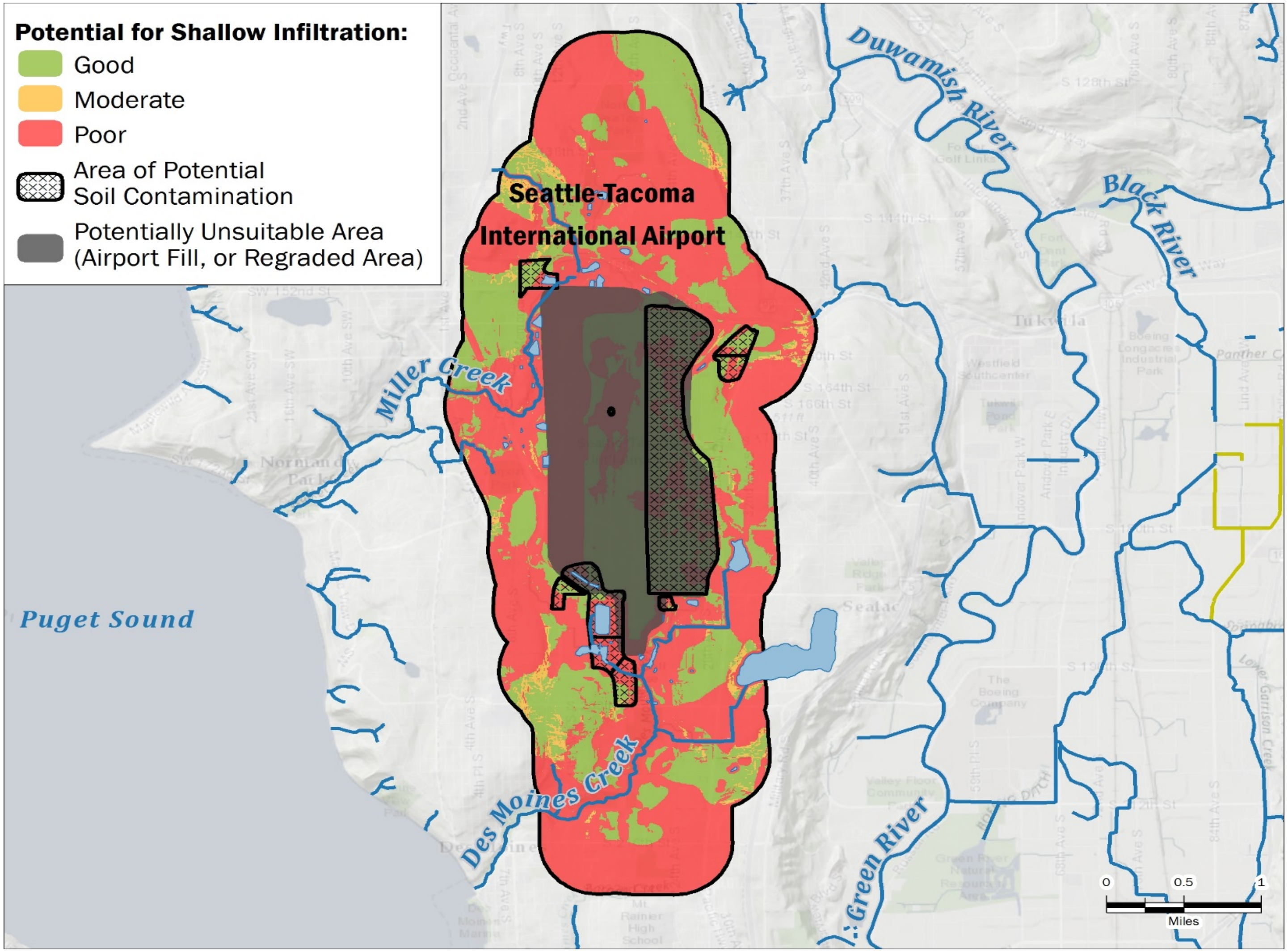
Criteria for Shallow Infiltration Hydrogeomorphic Unit Categories

Feasibility	Permeability	Surface Slope	Unsaturated Zone Thickness	Slope Hazard
Good	Generally the most favorable rating with up to one moderate rating			Low
Moderate	Generally the most favorable rating with up to two moderate ratings			Low
Poor	Generally one or more least favorable rating.			Low
	Any rating			High to moderate

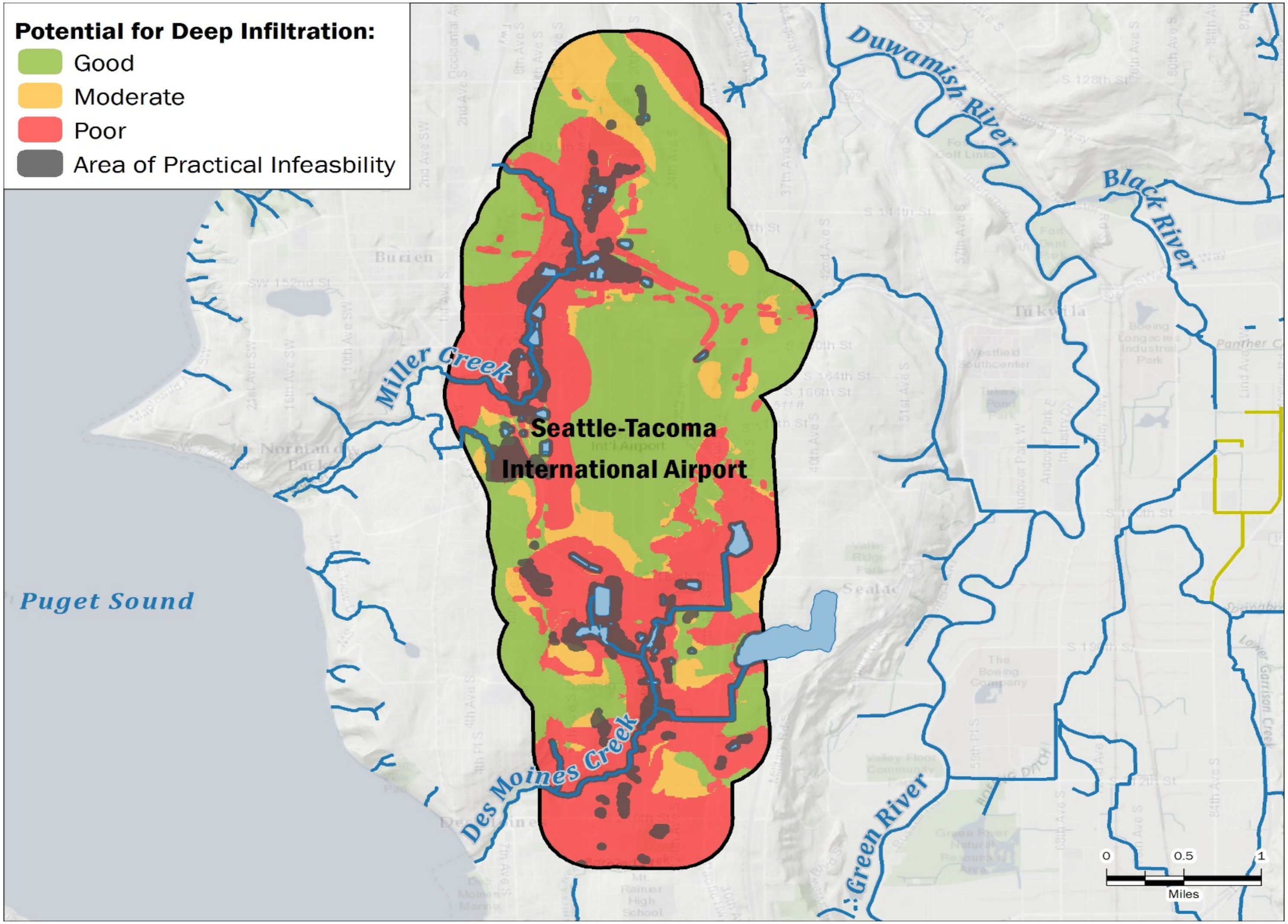
Criteria for Deep Infiltration Hydrogeomorphic Unit Categories

Feasibility	Unsaturated Zone Thickness	Depth to Permeable Unsaturated Zone	Slope Hazard
Good	>10 feet	< 50 feet	Low
Moderate	>10 feet	Any depth	Low
Poor	<10 feet	Any depth	Low
	Any rating		High to moderate

Shallow Infiltration Feasibility



Deep Infiltration Feasibility



Summary of Results

- Over half of the study area is not expected to be suitable for shallow infiltration due to the presence of low permeability glacial till soils or other factors
- Deep infiltration appears feasible in significant portions of the study area, including many areas that were identified as being unsuitable for shallow infiltration
- Areas with relatively thin till cap underlain by outwash soils supports the feasibility of dug or drilled drains

Recent Infiltration Testing Results

- Infiltration testing – conducted in-conjunction with a planned environmental remediation effort at Lake Reba – demonstrated good infiltration
- Result consistent with shallow infiltration feasibility mapping

Questions?

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Stormwater ~ Hydrogeology ~ Water Resources ~ Data Services
Geotechnical Engineering ~ Environmental Remediation

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