THE IMPORTANCE OF NATURAL WATERSHED HYDROLOGY

AND HOW TO ADVANCE IT IN URBAN AREAS

Pacific Northwest Forest Hydrology

- **Surface runoff** rare, slow sheet flow when it occurs

Trees

- Intercept rainfall, **evaporate** much
- Create “duff”, which absorbs and stores water
- Take water from soil and store and **transpire** it

Soils

- Store considerable water
- **Infiltrate** and convey to groundwater and water bodies through subsurface paths

Urban Hydrology

- Trees removed, hydrologic services lost
- Soils removed and compacted in construction, much storage lost

- Most land cover impervious and impervious-like surfaces
- Hydrologic output surface runoff instead of evapotranspiration, and infiltration
- Runoff occurs rapidly in pipes and ditches
- Human activities generate hundreds of water pollutants

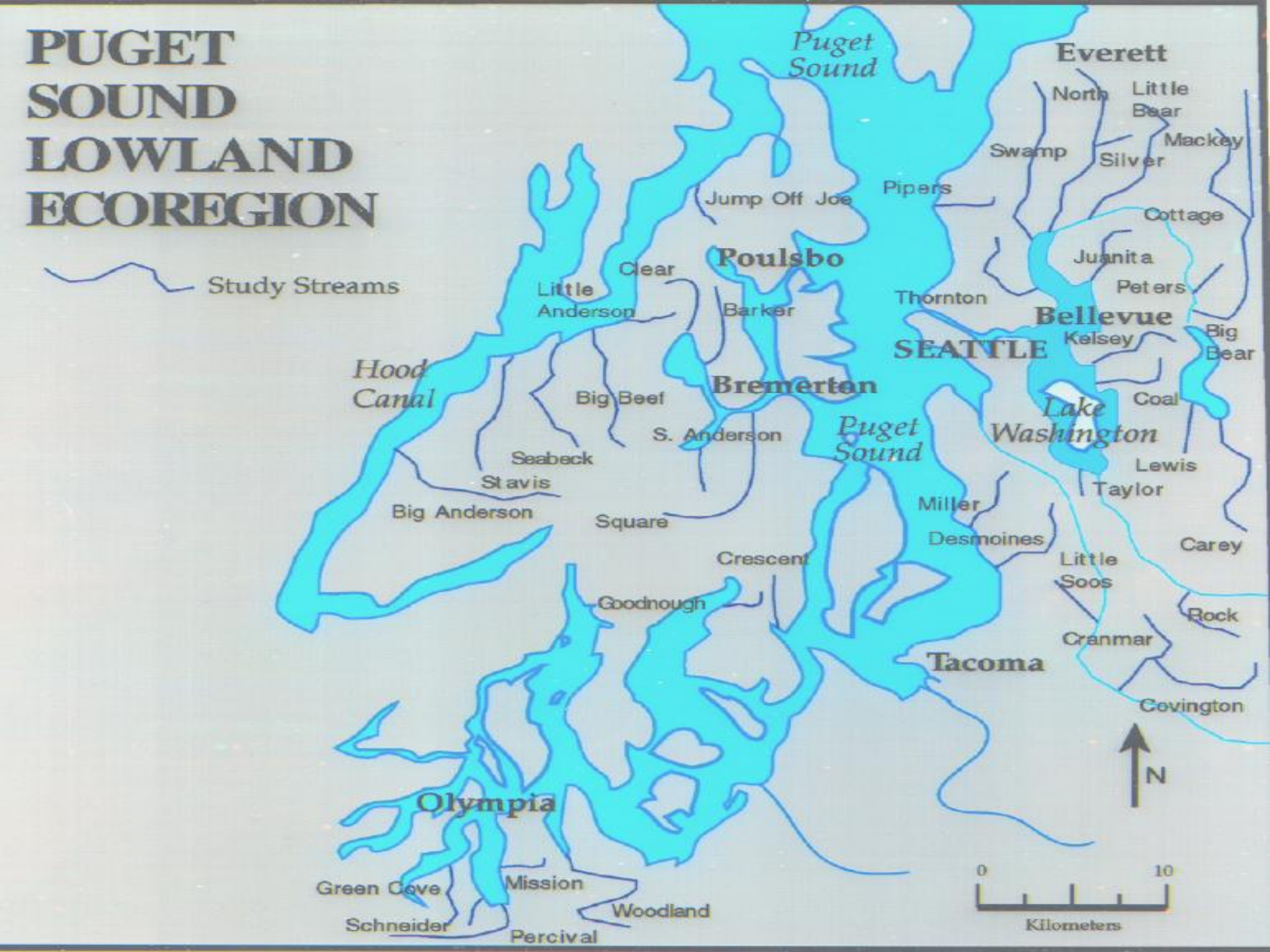
Forested and Urban Hydrology Compared

Impervious	~0%	~20%	~60%	~95%
<u>Surface runoff</u> Total output	< 5%	~20%	~55%	~85%
2-year peak Stream flow	1X	~2X	~4X	-

Impacts of Urban Hydrology on Streams and Aquatic Life

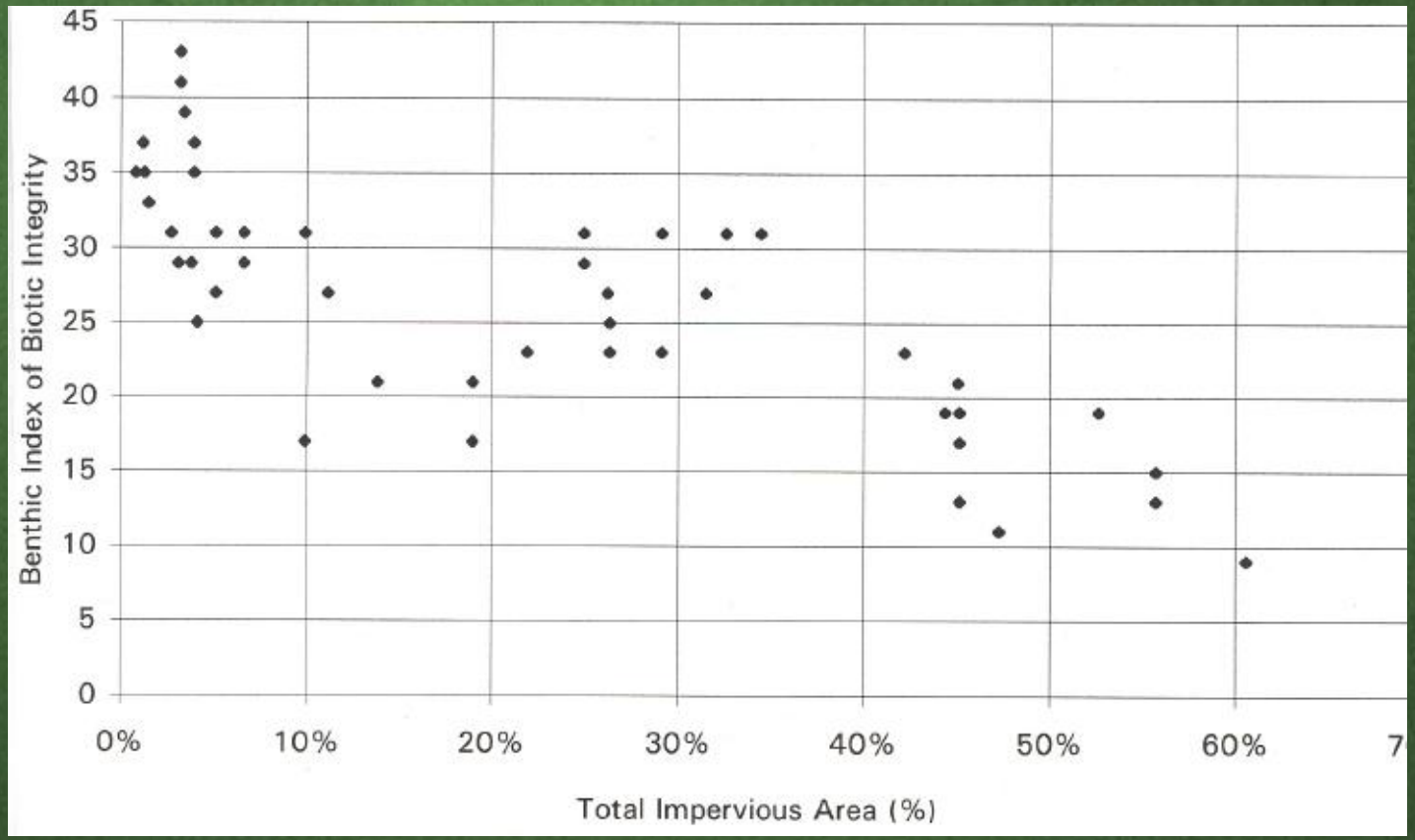
- High velocities sweep away small life, stress fish, cause bed and bank erosion and loss of riparian vegetation
- Increased sediments reduce light, irritate fish tissues, carry other pollutants, clog fish spawning gravels and fill pools
- From land runoff, higher pollutant concentrations and mass loadings

PUGET SOUND LOWLAND ECOREGION



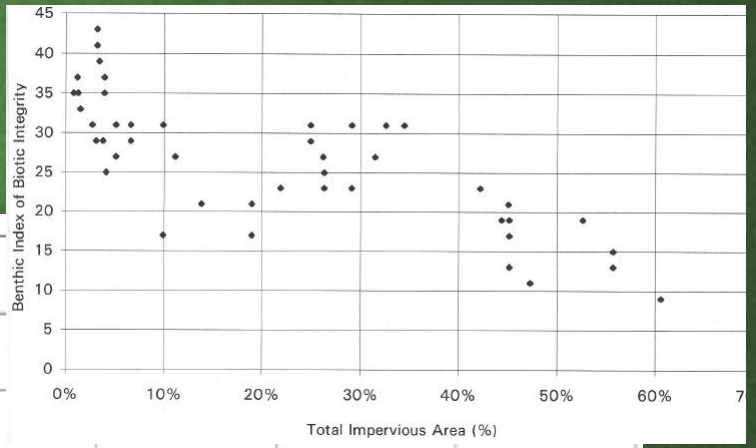
Benthic Index of Biotic Integrity, a Measure of Bottom-Dwelling Invertebrate Community Health

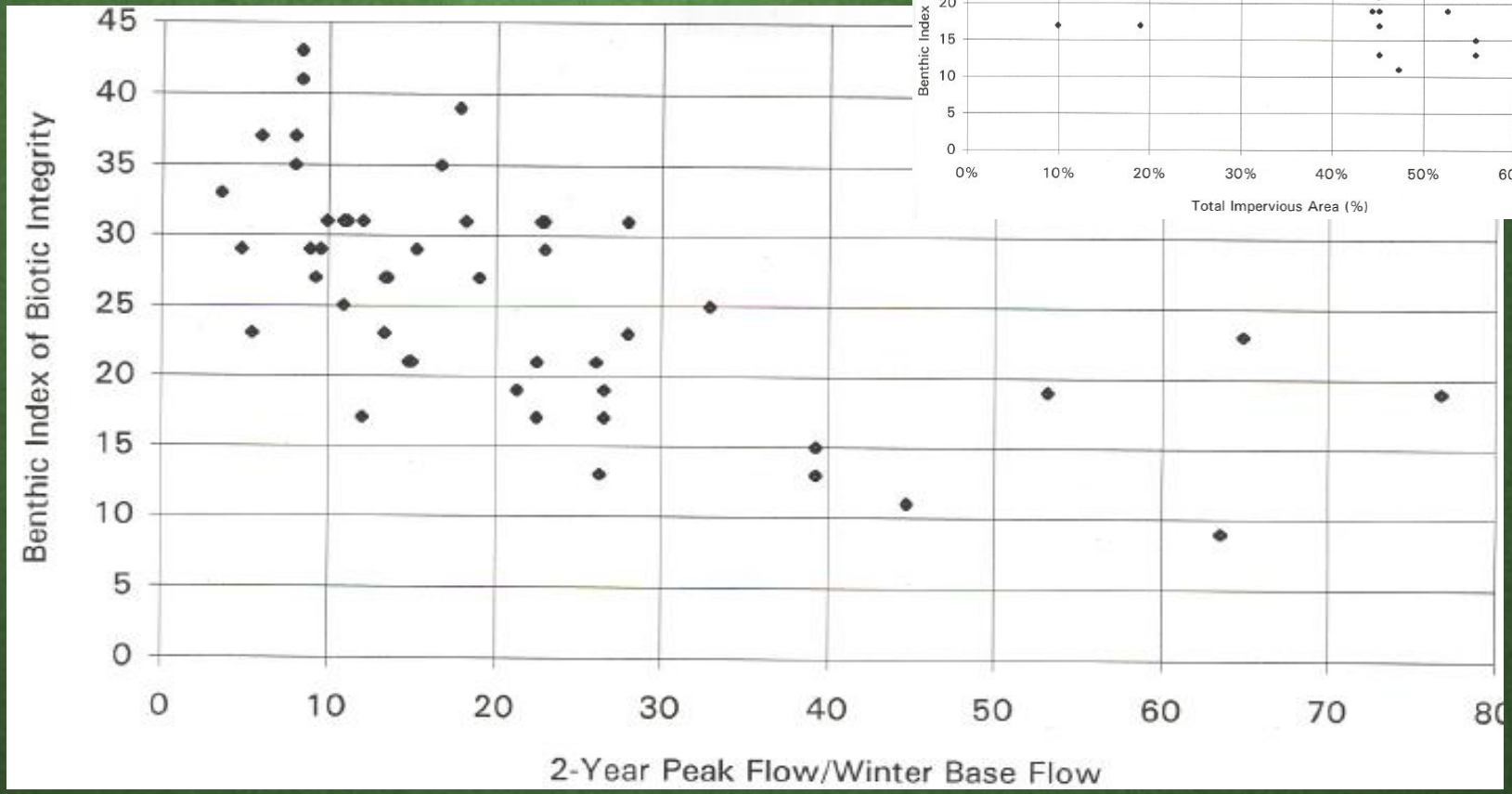
Highest B-IBI only possible with < 5% impervious; lowest inevitable with > 45%



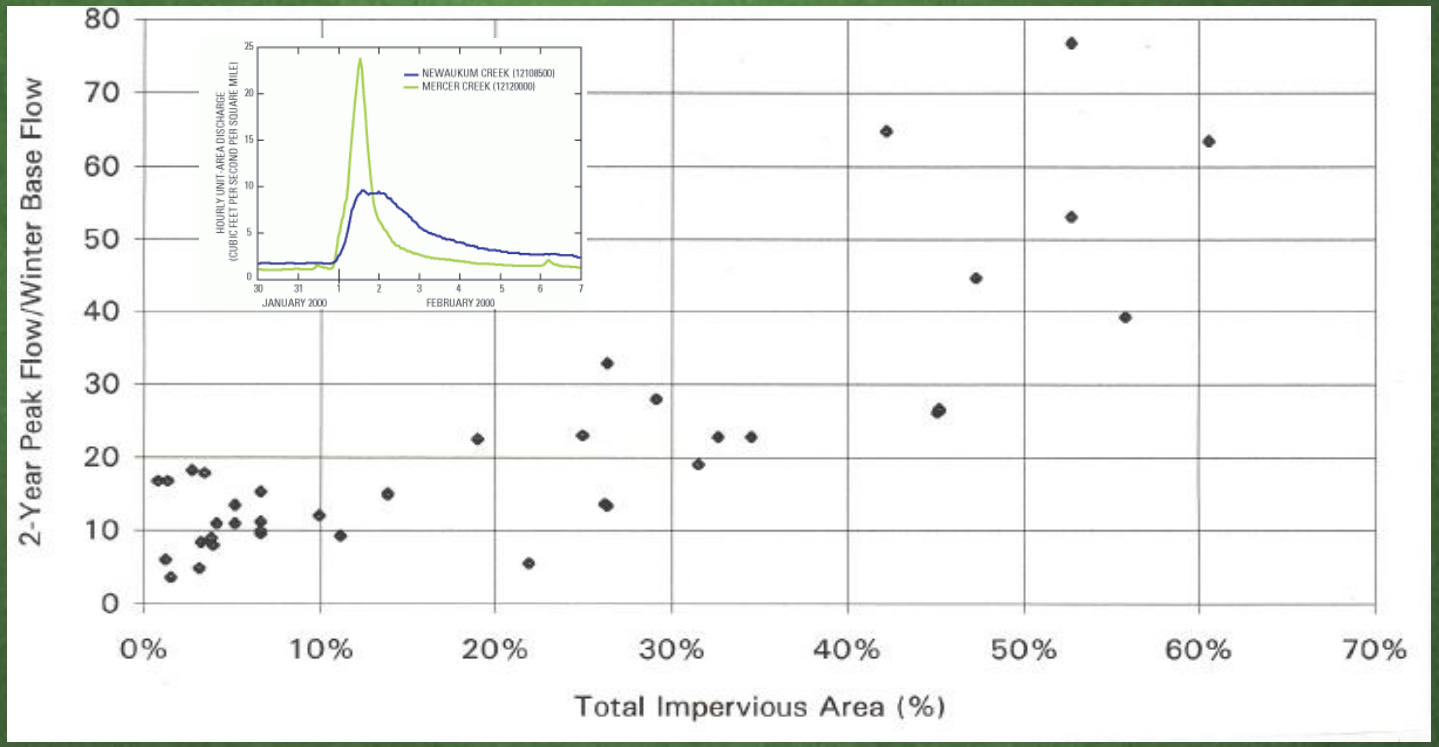
B-IBI declines in a similar pattern with impervious area and peak flow rate rise

Highest B-IBI only possible with 2-year frequency rise < 10X





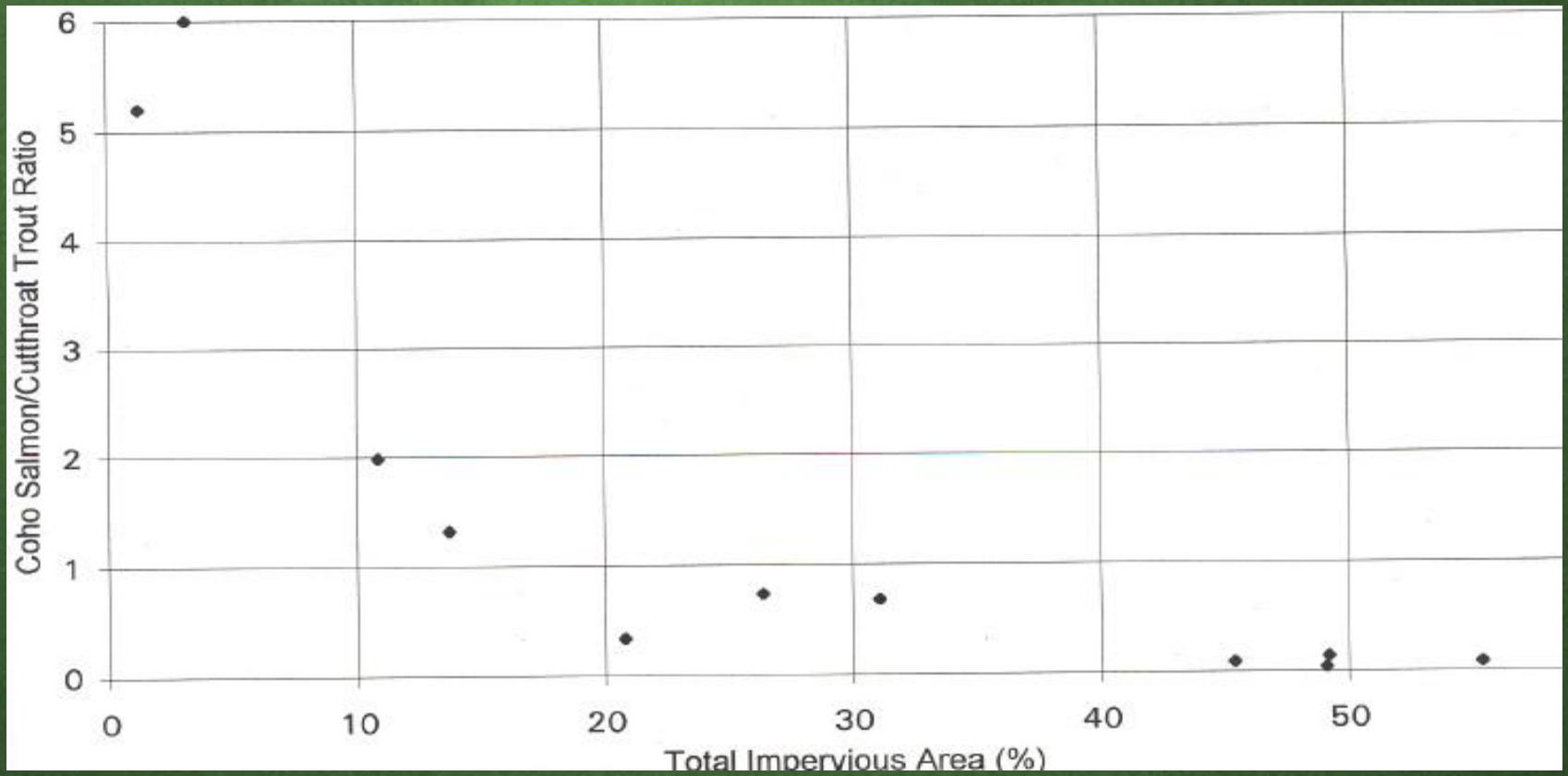
Hydrology Relative to Urbanization



2-year frequency rise ≤ 10X generally only possible with impervious < 7%

Fish Community Relative to Urbanization

Coho salmon lose in competition with cutthroat trout, a species more tolerant of urban hydrology



HABITAT TYPES RELATIVE TO URBANIZATION

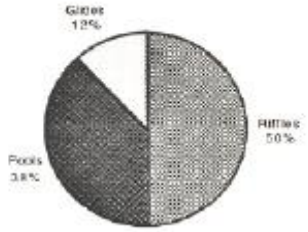


Figure 47a: Sub-basin %TIA < 5%

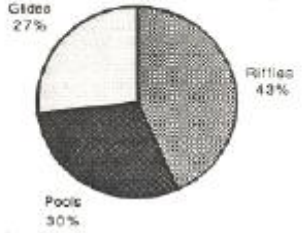


Figure 47b: Sub-basin %TIA 5-10%

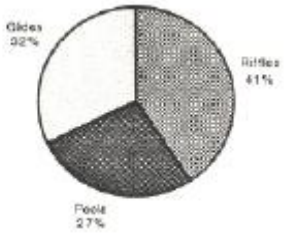


Figure 47c: Sub-basin %TIA 10-20%

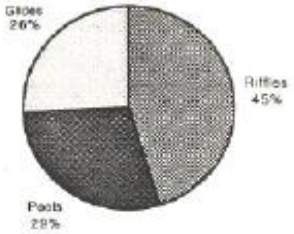


Figure 47d: Sub-basin %TIA 20-30%

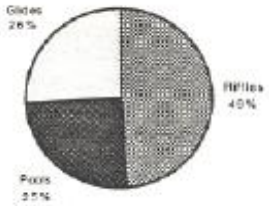


Figure 47e: Sub-basin %TIA 30-45%

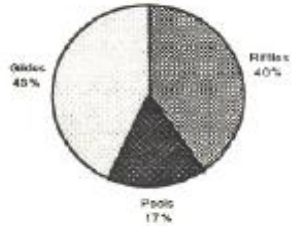
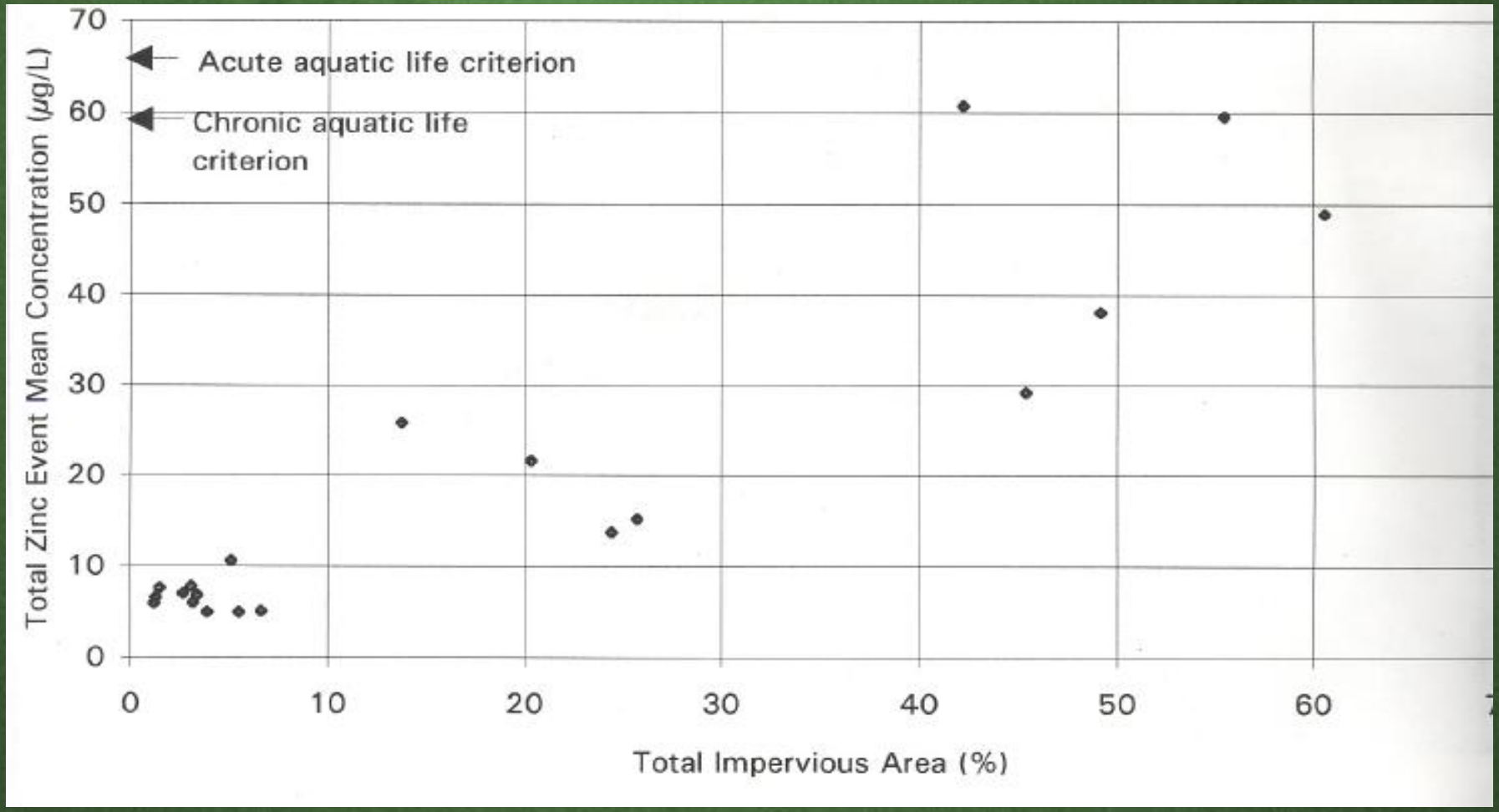
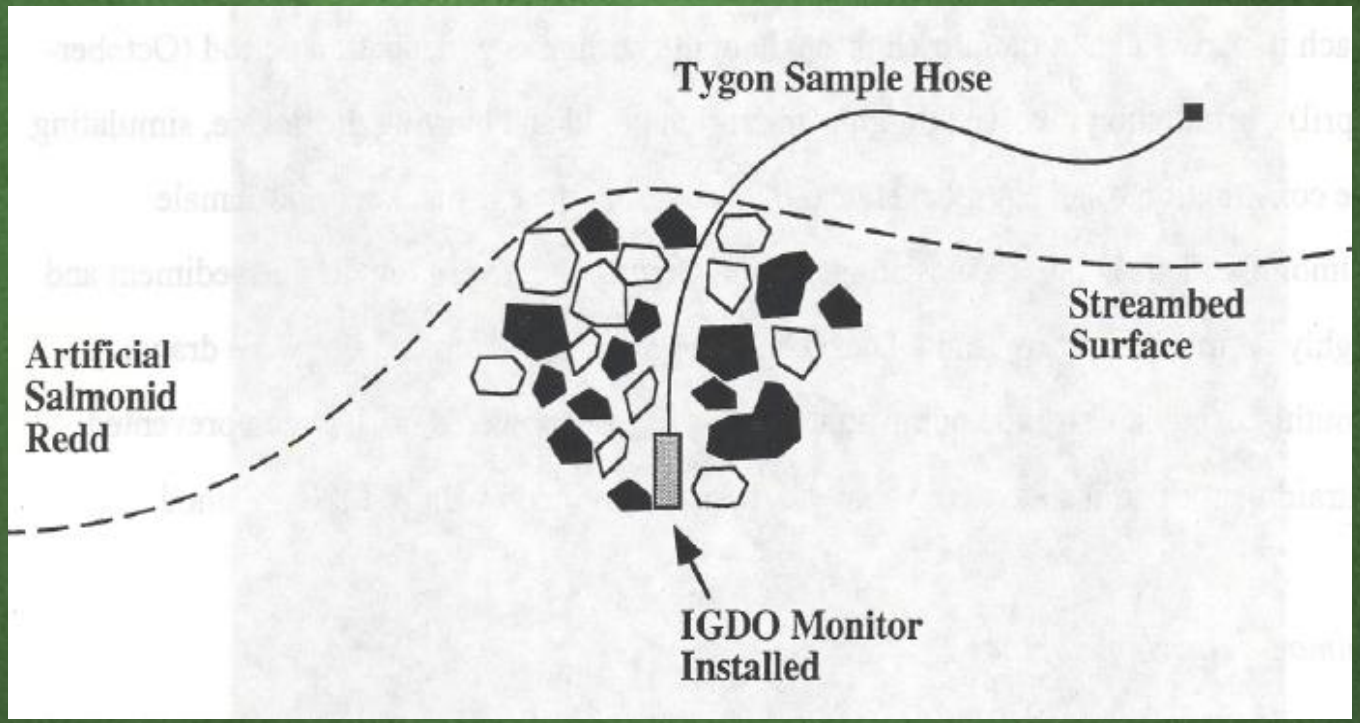


Figure 47f: Sub-basin %TIA > 45%

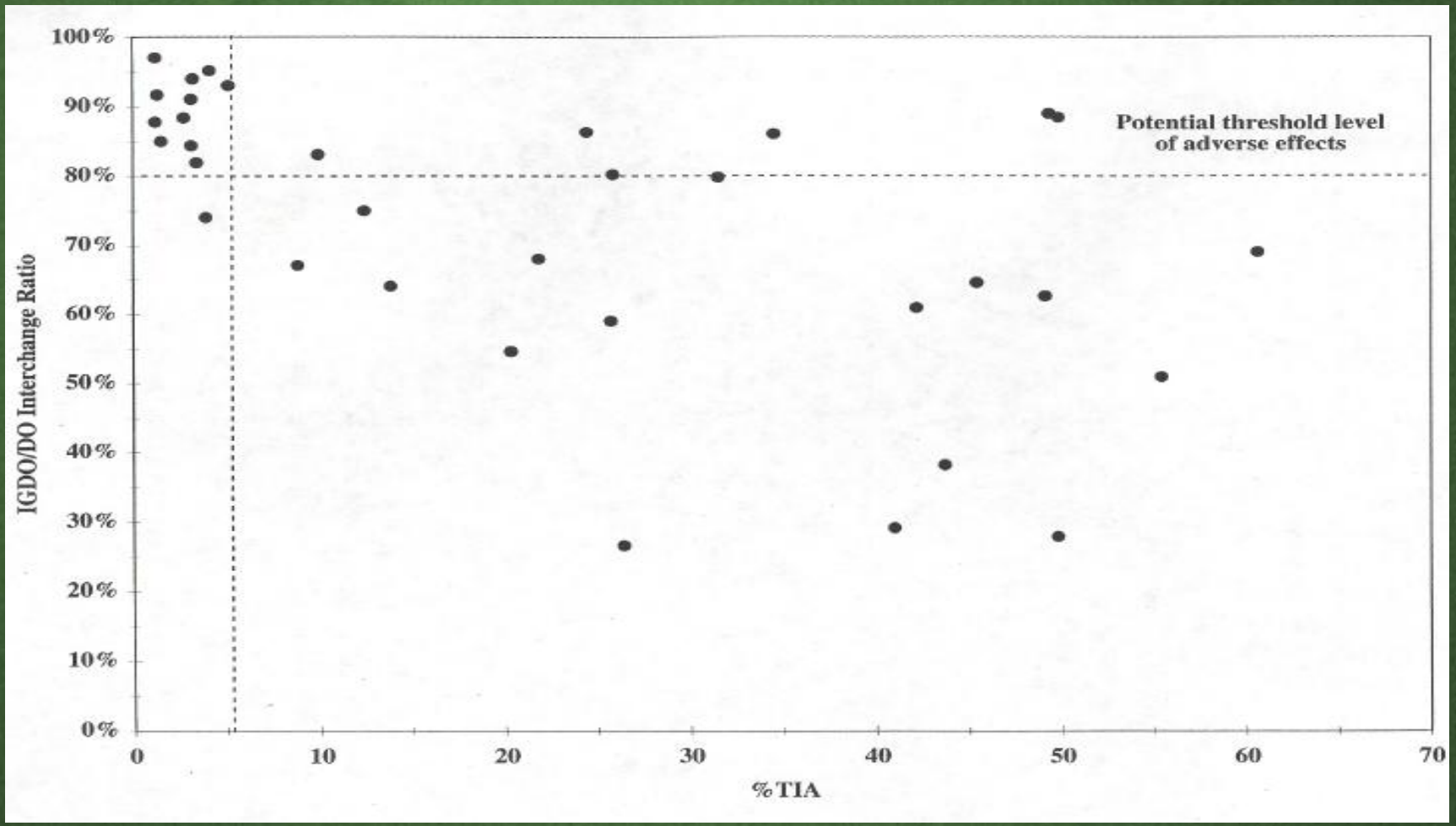
Water Quality Relative to Urbanization



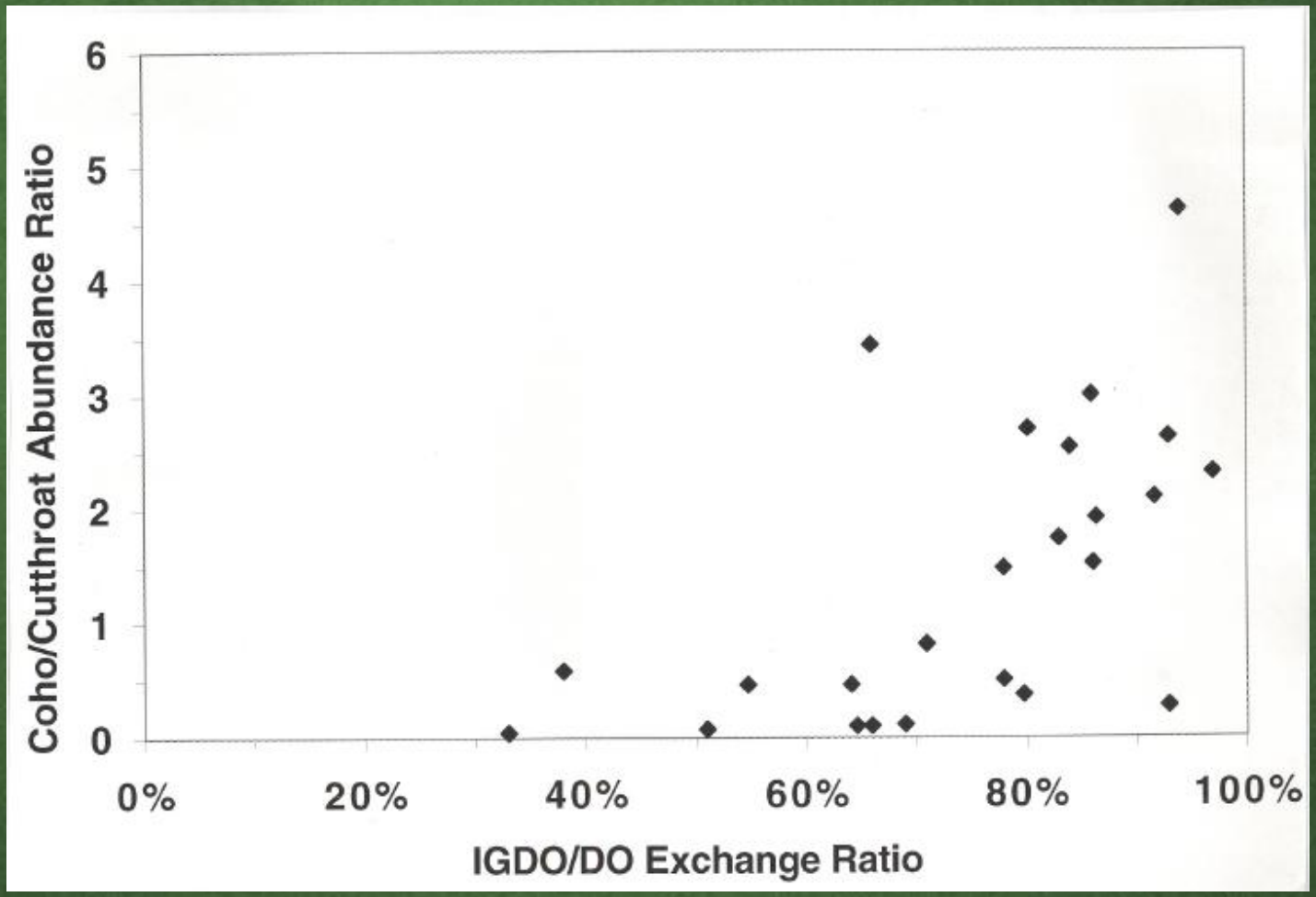
INTRAGRAVEL DISSOLVED OXYGEN (IGDO) MONITOR



IGDO RELATIVE TO URBANIZATION



IGDO and Salmon Success



What Can Be Done to Alleviate Urban Impacts?

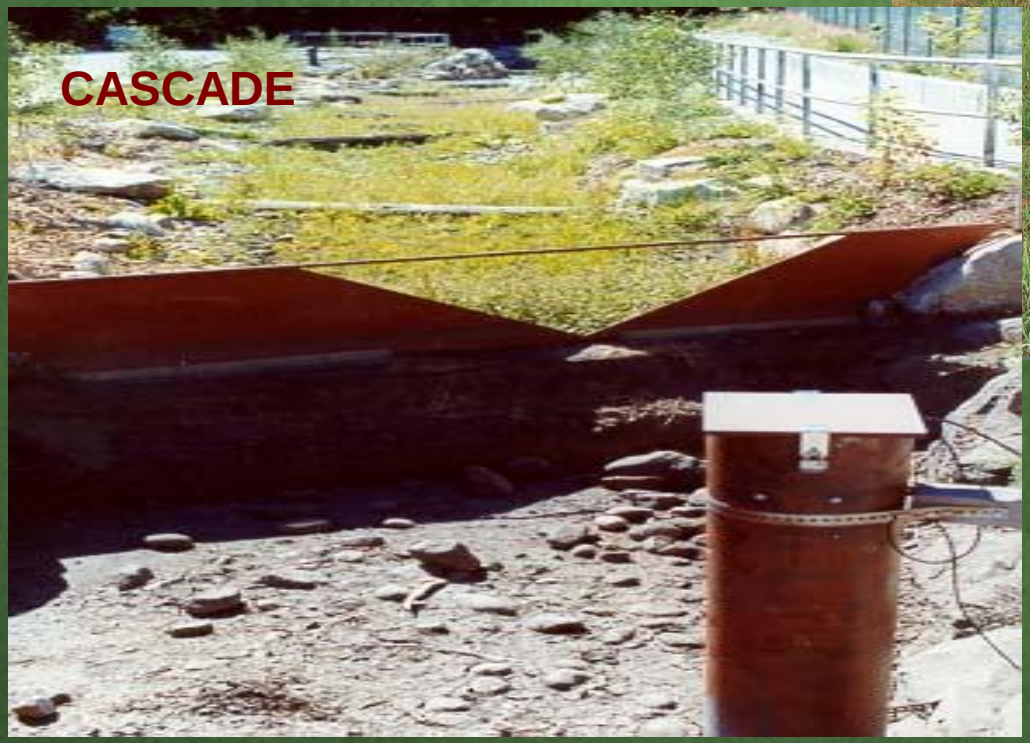
Naturalizing urban drainage systems by utilizing or mimicking hydrologic functioning of natural vegetation and soil to reduce the quantity of stormwater runoff produced and improve the quality of remaining runoff

SEATTLE'S NATURAL DRAINAGE SYSTEM PROJECTS

Relatively Flat Street Situation

- Impervious reduction
- Compost-amended soils
- Several vegetation canopy layers

Sloping Street Situation



SEA Street Performance

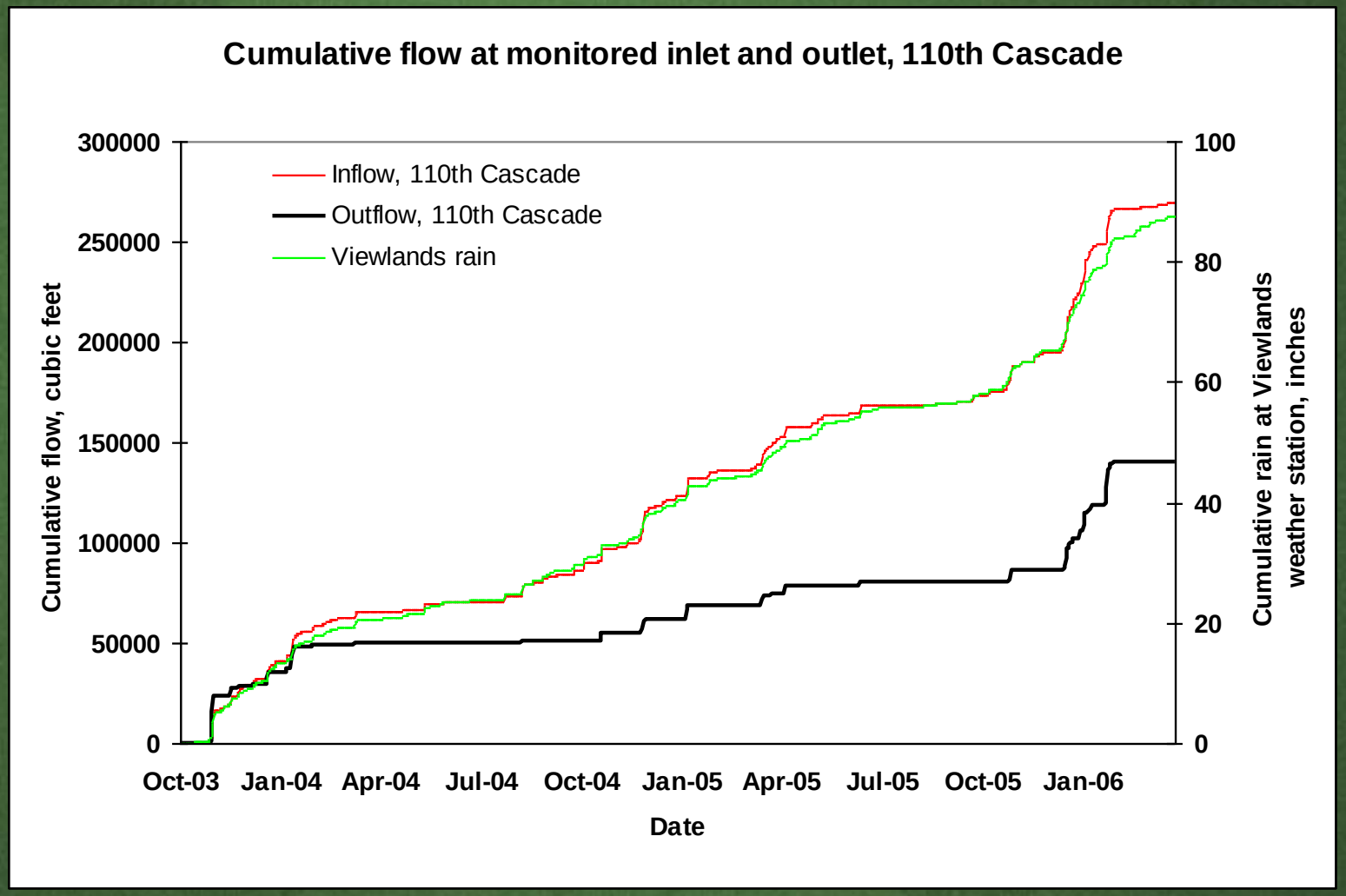
- Baseline—Old street discharged in all 35 events monitored
- First 2 years—Discharged in only 6.8% of events and 1.9% of volume/unit rainfall as old street
- Since Dec. 14, 2002:
  - No discharge despite 10/03 largest storm and 11/06 wettest month in history
  - Thought that maturing vegetation—
    - Intercepts rain for evaporation
    - Stores water in tissue for transpiration
    - Pipes water along roots for infiltration

NW 110th Cascade

3” of river rock
12” of swale mix (70% mineral aggregate, 30% decomposed organic soil matter)

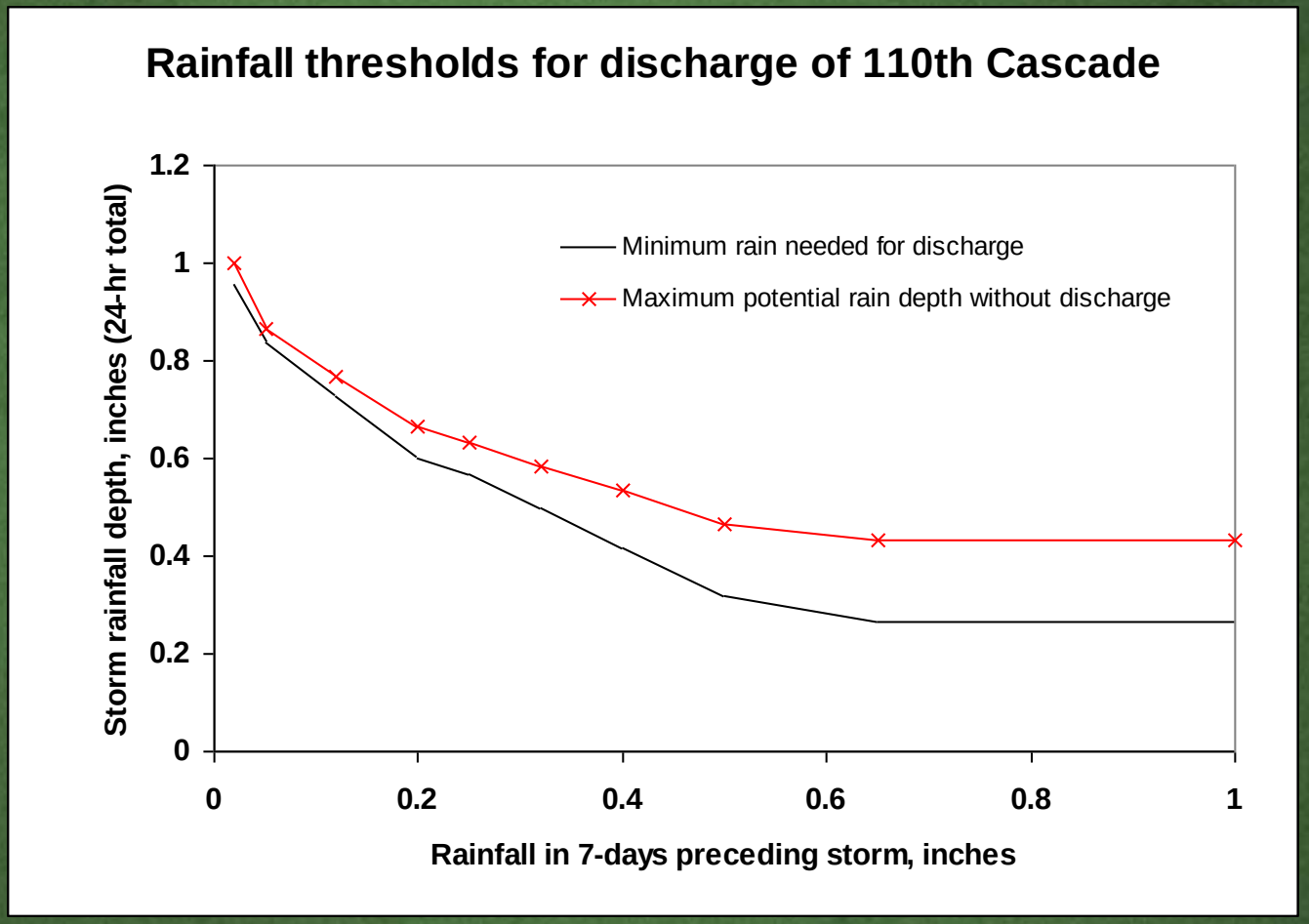
12 cells

Runoff Volume Retention



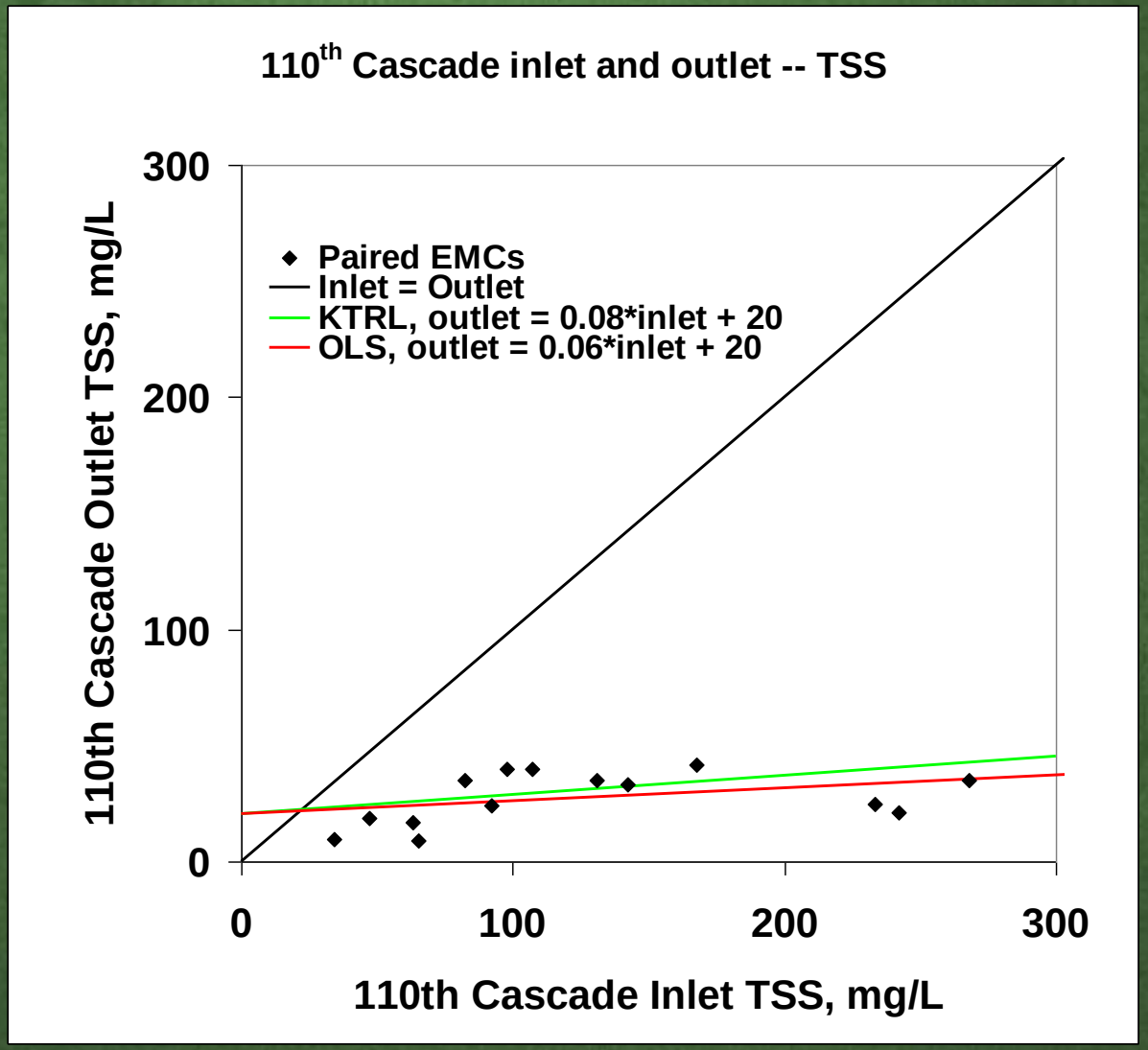
System retained at least 48% of all inflows, and probably closer to 75% considering non-monitored intermediate flows

Outlet Hydrology

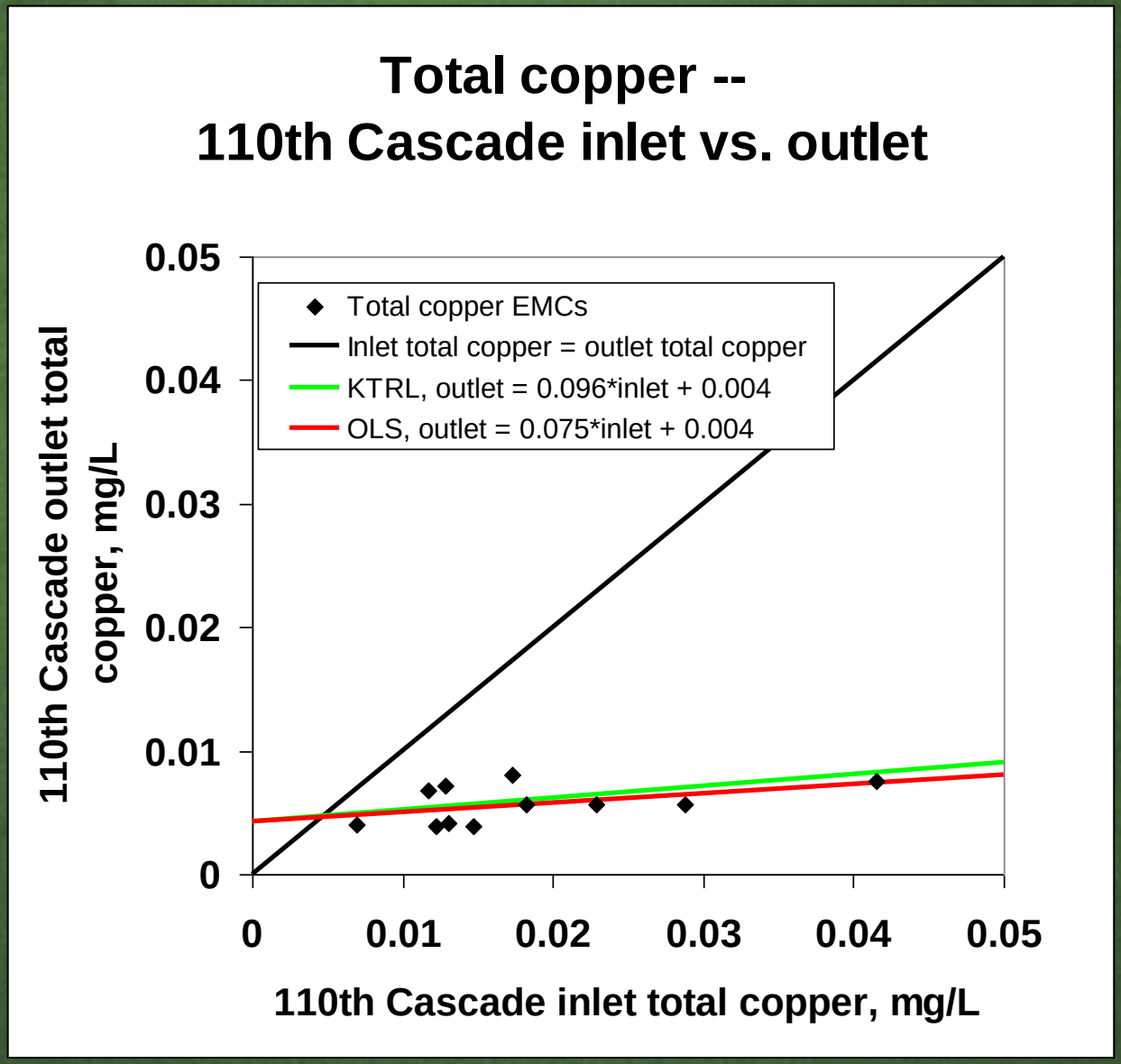


- Discharged in only 49 of 235 storms
- Fully retained storms up to 1” in dry conditions
- Fully retained storms up to 0.3” in any condition

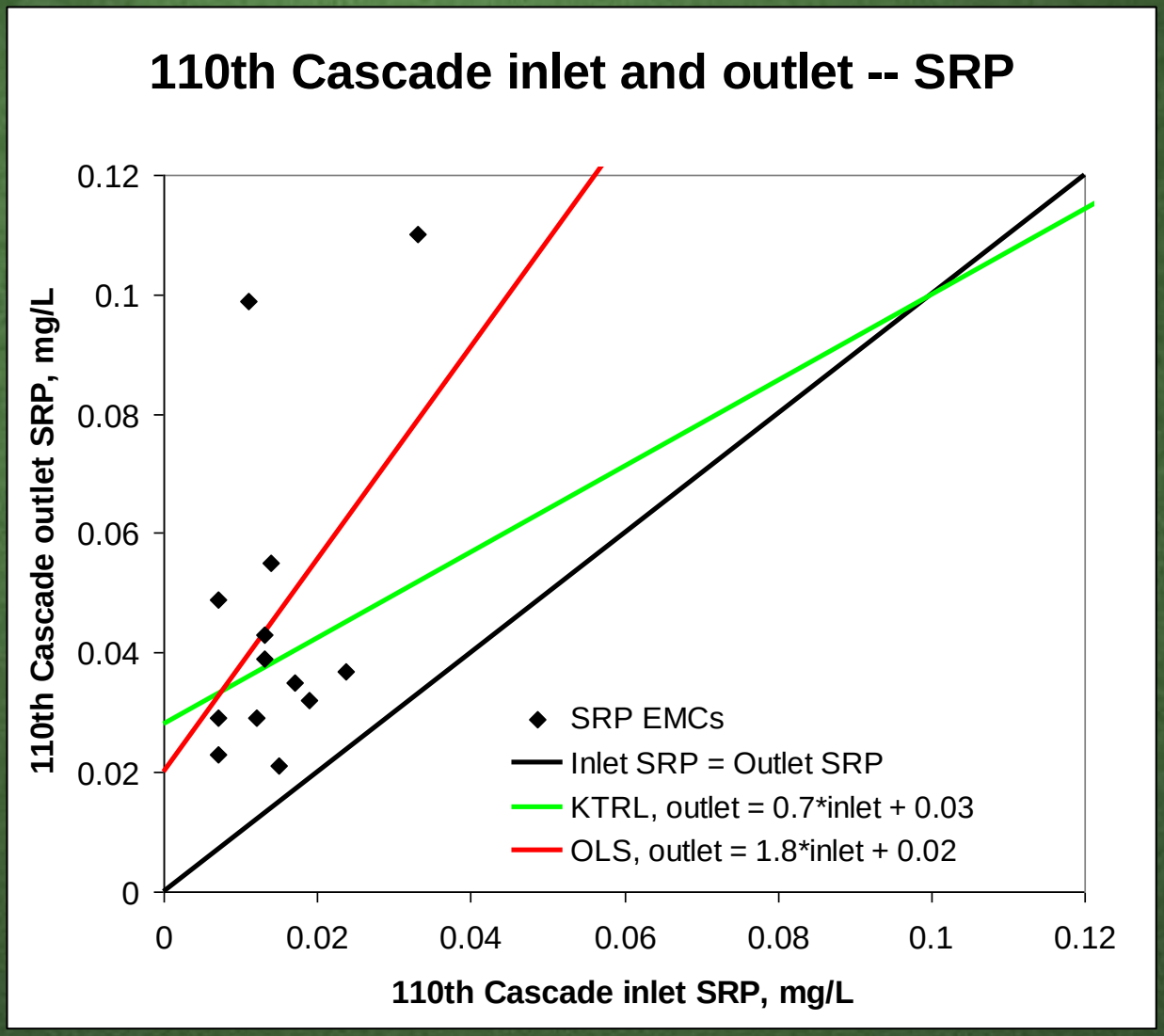
Total Suspended Solids Concentrations



Total Copper Concentrations



Soluble Reactive Phosphorus Concentrations



Summary of Effluent Quality

- Established reliable maximum and irreducible minimum concentrations for pollutants (e.g., 40 and 9 mg TSS/L, respectively)
- Estimated pollutant mass loading reductions

Pollutant	Min. % (90% CI)	% Accounting for Estimated Side Flows	Typ. % with Conventional Practices*
TSS	84 (72-92)	93	50-80
TN	63 (53-74)	82	10-45
TP	63 (49-74)	83	10-60
SRP	-44	28	Negative-20
Total Cu	83 (77-88)	90	30-60
Dissolved Cu	67 (50-78)	79	Negative-60
Total Zn	76 (46-85)	90	30-60
Dissolved Zn	55 (21-70)	86	Negative-60
Total Pb	90 (84-94)	93	75-90
Motor oil	92 (86-97)	96	50-75

*Highly variable depending on volume reduction

Summing Up

- Surface runoff rare in a natural Northwest landscape; infiltration supplies water bodies in dry periods
- Runoff dominates urban hydrology and flows quickly into water bodies
- Increased flow and the pollutants it carries create many negative effects in streams and other waters
- Naturalizing drainage systems by exploiting soils and vegetation goes a long way toward alleviating these impacts
- Range of techniques available to apply in new development, redevelopment, and retrofitting

More Advanced Watershed Analysis

- Watershed Condition Index (WCI) development began with the selection of nine possible metrics chosen because of their relatively high correlation with B-IBI
- 7-variable WCI optimum in fitting B-IBI as a functions of WCI (linear, $R^2 = 0.53$) and CS:CT (exponential, $R^2 = 0.75$)
- Variables:
  - TIA and forest cover—watershed-wide and in 50- and 300-m riparian bands
  - Paved + urban grass-shrub cover in 300-m band

Predicting Biological Integrity

Two methods of predicting category membership:

- Discriminant function analysis (DFA)—combines independent variables into a single variable that best discriminates (according to Wilk's lambda statistic) scoring in selected dependent variable categories
- Logistic regression (LR)—forecasts probability of falling in selected dependent variable categories based on WCI

  $P = e^{L}/(1 + e^{L})$, where the logit $L = b_0 + b_1(WCI)$

Effectiveness of Discriminant Function and Logistic Regression Analyses

	Correctly Predicted in Group By DFA(%)			
Biological Integrity Group	Using WCI Only	Using WCI Variables	Correctly Predicted Not in Group By LR (%)	Correctly Predicted in Group By LR (%)
B-IBI ≥ 85% of best	69	85	100	0
B-IBI ≤ 25% of best	65	61	96	29
CS:CT ≥ 2.0	-	-	91	63
CS:CT ≤ 1.0	-	-	93	86

Cost Comparison

Street/Drainage System Types	Cost Per Block (330 linear ft)
Local/SEA Street	$325,000
Local/Traditional	$425,000
Collector/Cascade	$285,000
Collector/Traditional	$520,400
Broadview Green Grid (15 block area)	Average per block: $280,000

http://www.seattle.gov/util/stellent/groups/public/@spu/@esb/documents/webcontent/spu01_002614.pdf