MGS Flood
Continuous Flow Model for Stormwater Facility Design

Training Workshop

February 6, 2002

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MGS Engineering Consultants Inc.
Olympia, WA

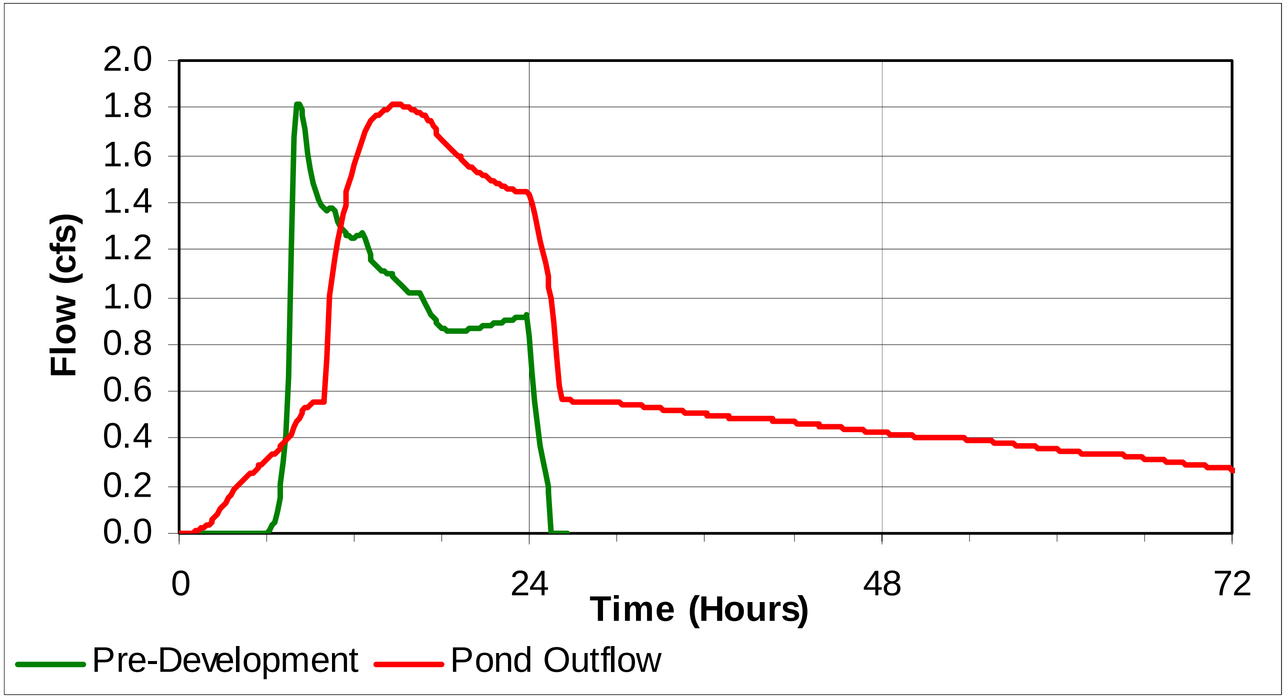
Agenda

8:00-8:30	Registration/Arrive
8:30-9:00	Stormwater Detention Standards and New State Requirements (Bruce)
9:00-9:30	Gaged Precipitation Input – Where we are Now Extended Precipitation Timeseries Input – Where we are Going (Mel)
9:30-10:00	Flood Model Overview (Bruce)
10:00-10:15	Break
10:15 -12:00	Work Session using Stormwater Model I ▪ Roadway Widening Detention Pond (Manual Design) (Bruce and Mel)
12:00-1:00	Lunch (on your own)
1:00 - 4:00	Work Session using Stormwater Model II ▪ Roadway Widening Detention Pond (Automatic Design) ▪ Roadway Widening Infiltration Pond (Automatic Design with Manual modifications ▪ Water Quality Wet Pond Design ▪ Any Class Defined Design Problems as time Allows (Bruce and Mel)

Detention Standards and the New State Requirements

	Current Practice	New Approach
Design Goal	Flood Control	Stream Channel Stability
Design Standard	Peak Flow 2-year & 10-year	Match Flow Duration
Model Type	Single Event (SCS, SBUH)	Continuous (MGSFlood, HSPF)

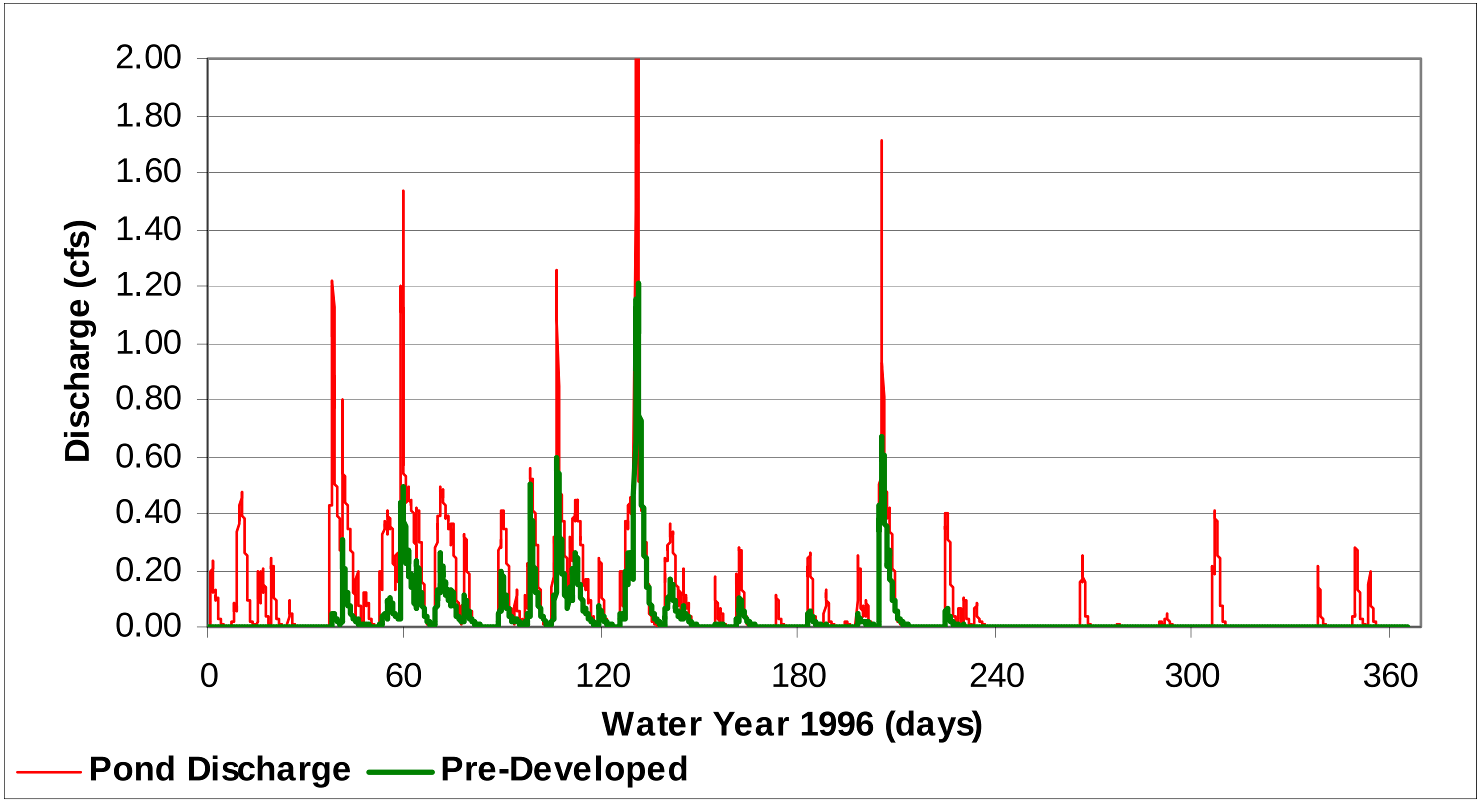
Single Event Pond Design



(Hydrographs Computed Using SBUH)

- **Flood Peak is Reduced to Predeveloped Level, but higher Runoff Volume Extends Length of Flood**
- **Results in More Erosive Work done on Stream Channel than in Predeveloped Condition**

Performance of Single Event Pond Design



Note:

Many More Runoff Events in Postdeveloped Condition…

Also Results in Greater Erosive Work on Receiving Channels

Use of Continuous Flow Model for Pond Design

- **Hydrological Simulation Program FORTRAN (HSPF) is the basis for MGS Flood, KCRTS, and WWHM** (HSPF http://www.epa.gov/ceampubl/ceamhome.htm)

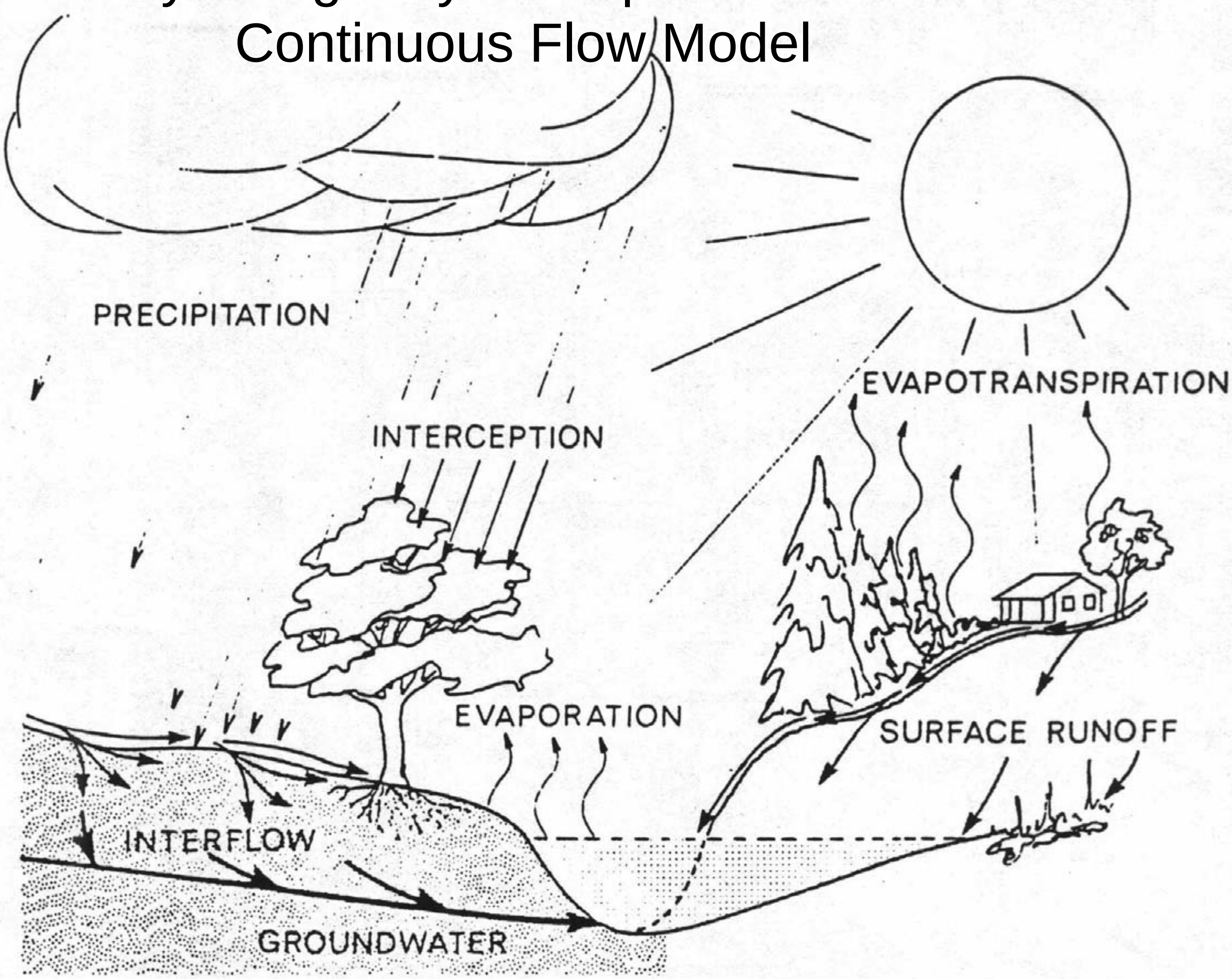
- **Simulates hourly runoff for 50 to 150 years (depending on precipitation/ evaporation record)**

- **Allows for pond performance to be evaluated using a wide range of storms and antecedent conditions,**

- **Allows for Calculation of *Flow Duration Statistics*, which are used to design ponds for Channel Stability,**

- **Rainfall-Runoff algorithms in HSPF are more detailed than SCS, produces much better estimates of runoff.**

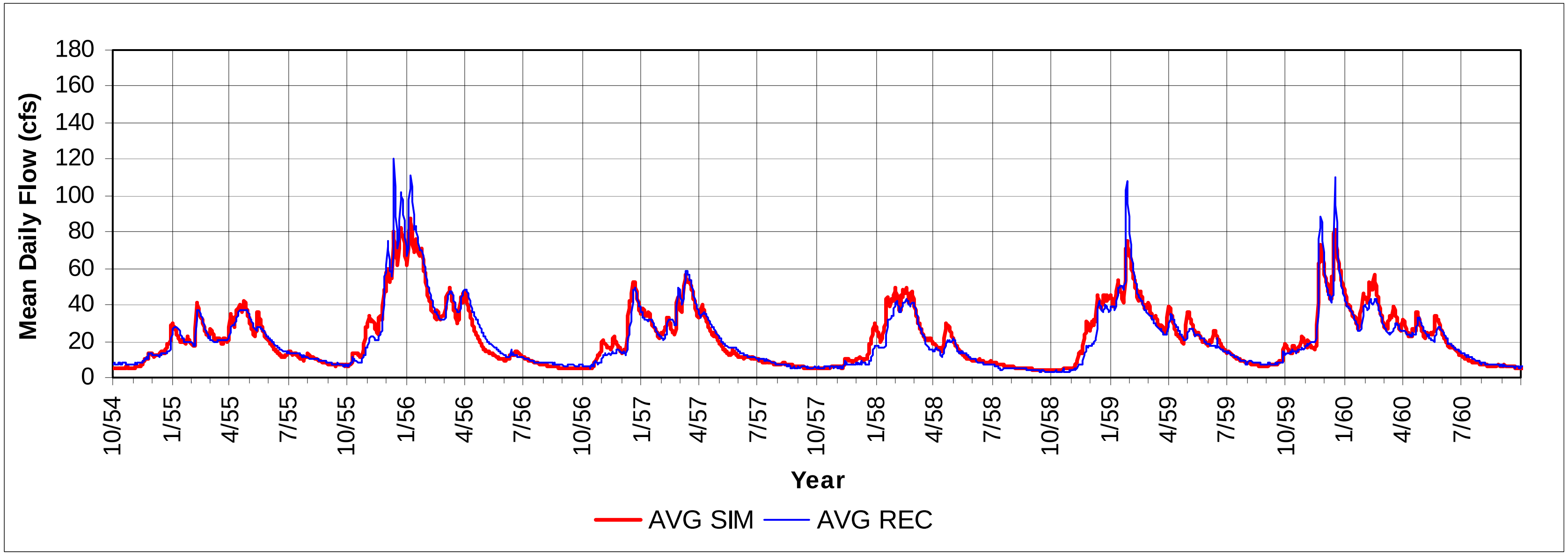
Hydrologic Cycle Represented in Continuous Flow Model



THE HYDROLOGIC CYCLE

How Well Does HSPF do at Runoff Simulation?

Example HSPF Model Calibration, Simulated and Recorded Flows
Rock Creek, Cedar River Watershed, King County



Pond Design for Channel Stability:

Control the Duration of Flow to Predeveloped Levels Above the Bedload Movement Threshold

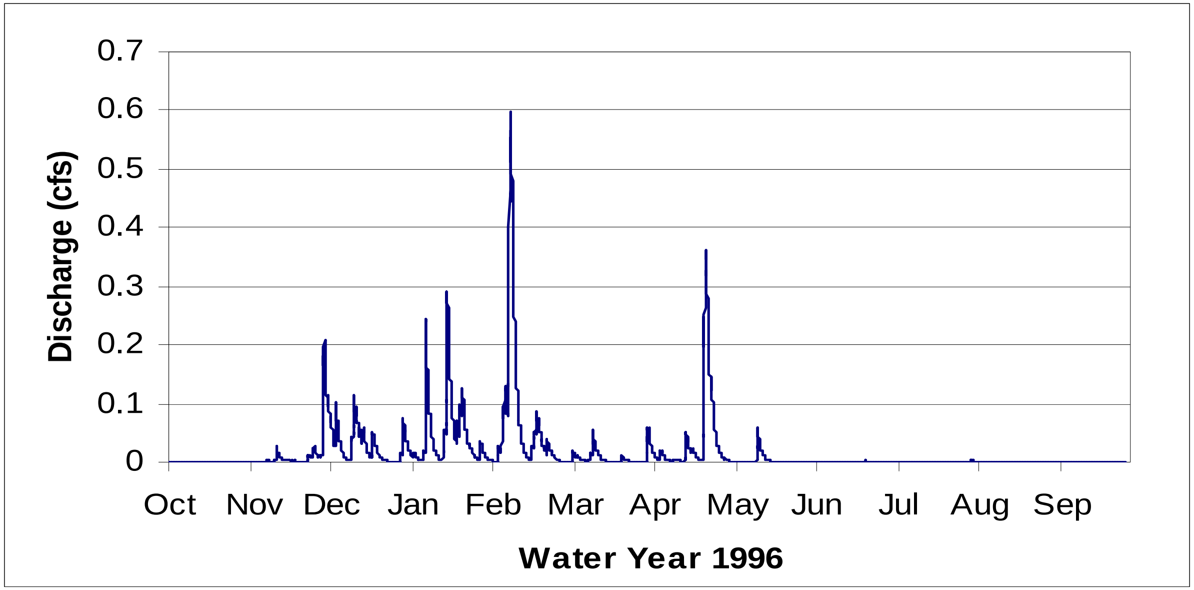
Bedload Movement Threshold:

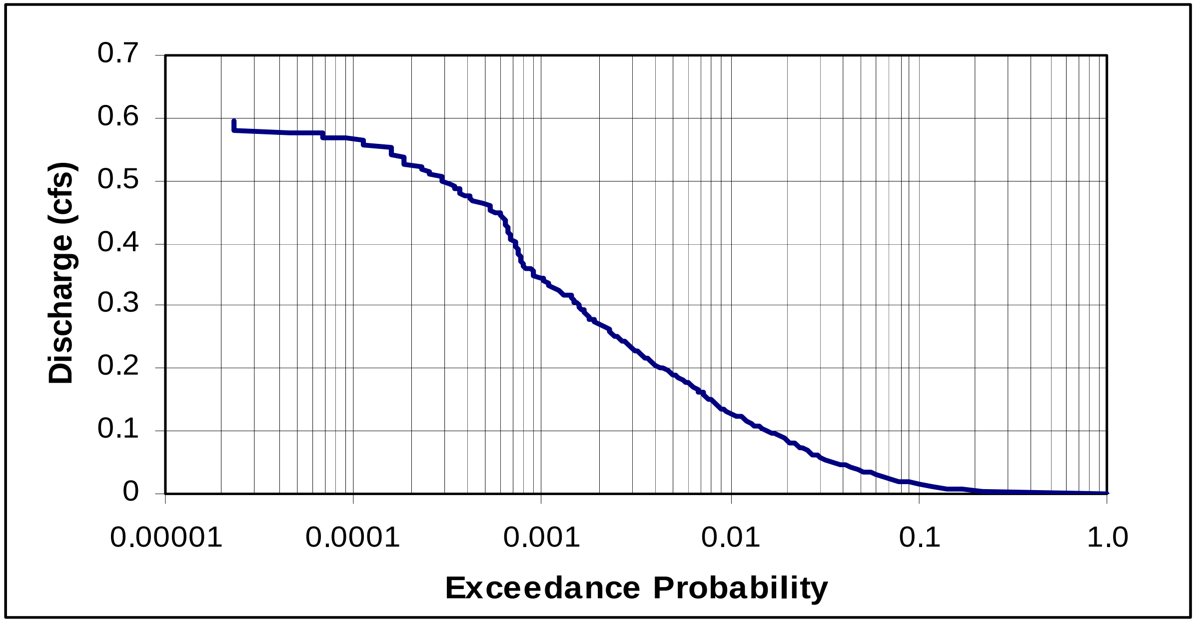
"A rate of about 50-percent of the predevelopment 2-year discharge is a credible generic value for the initiation of sediment transport in gravel-bedded streams …"

(Derek Booth, 2000)

Flow Duration Definition:

Track the Fraction of Time that a Flow is Equaled or Exceeded

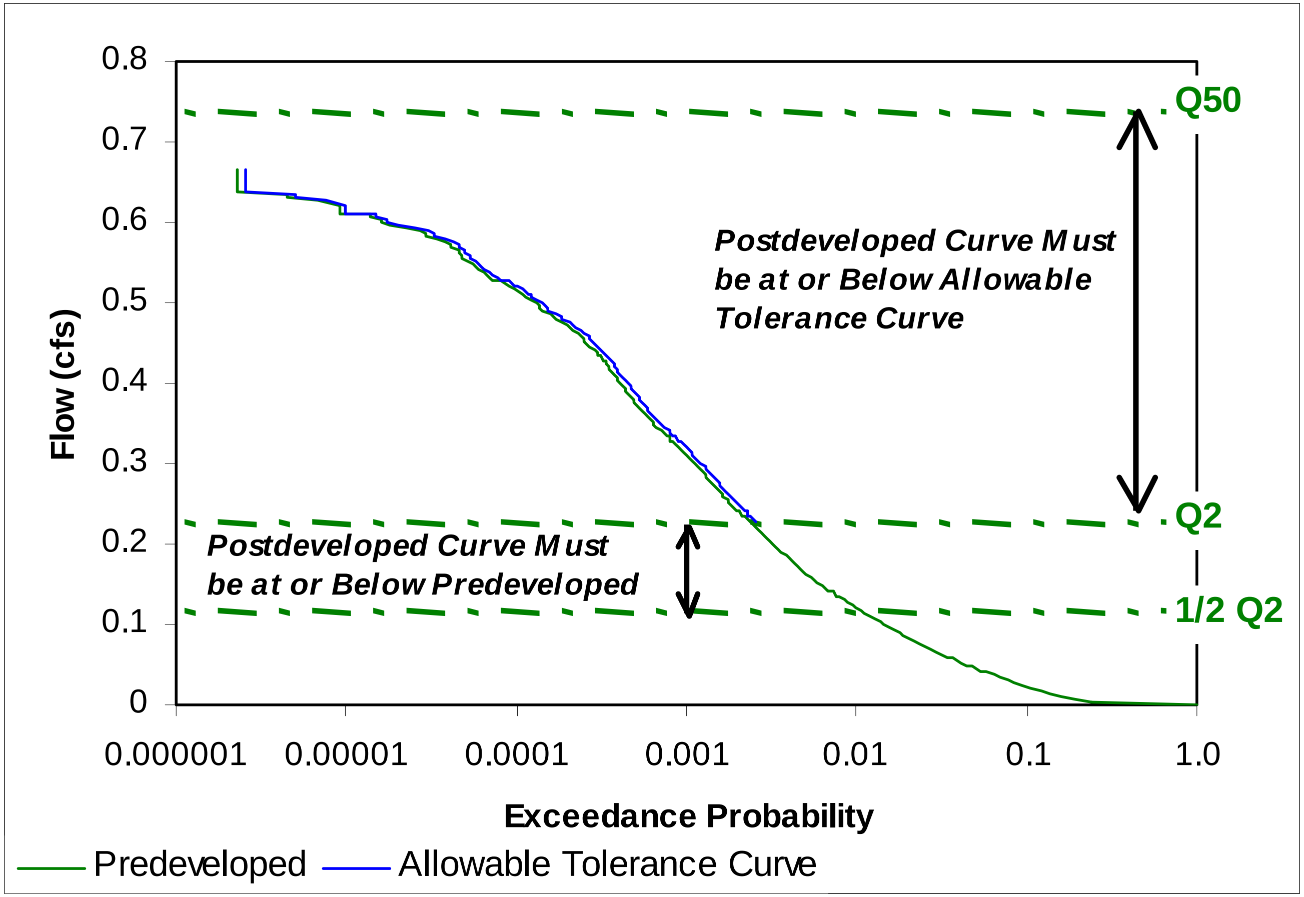




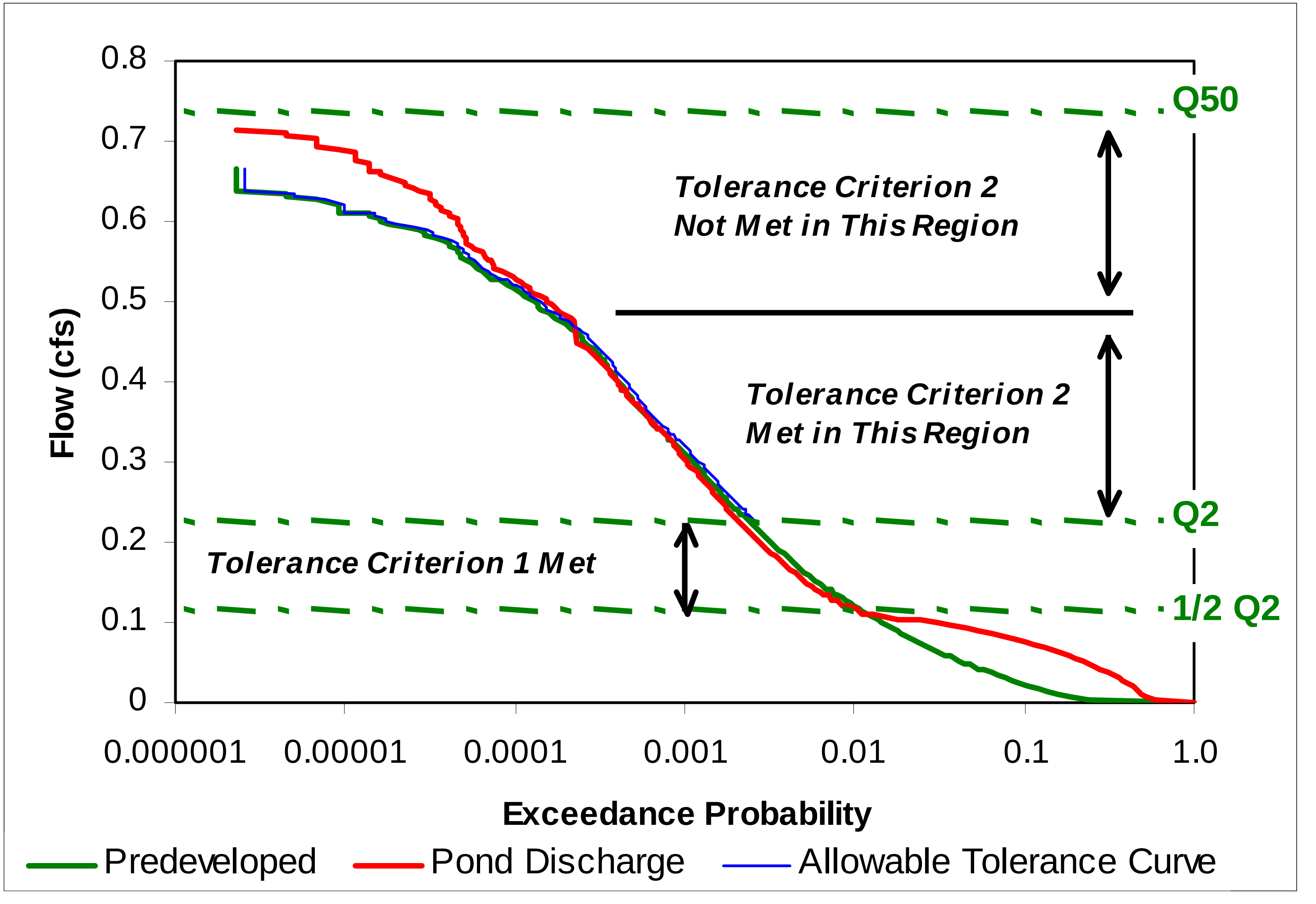
Ecology Duration Standard:

Match developed flow Durations to predeveloped durations from 50-percent of the 2-year to the full 50-year peak flow.

Ecology Duration Standard Tolerance:

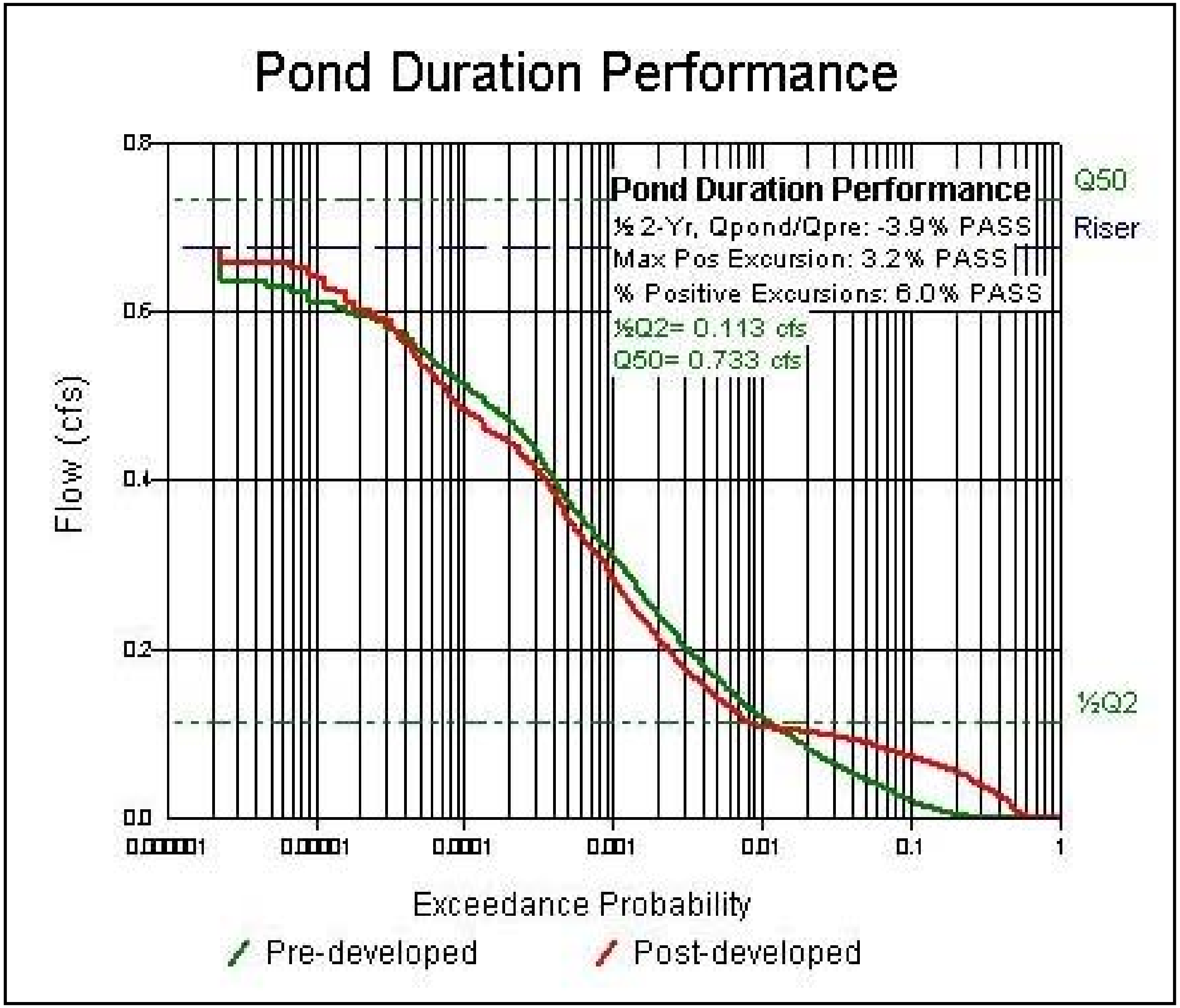


Pond Performance Example



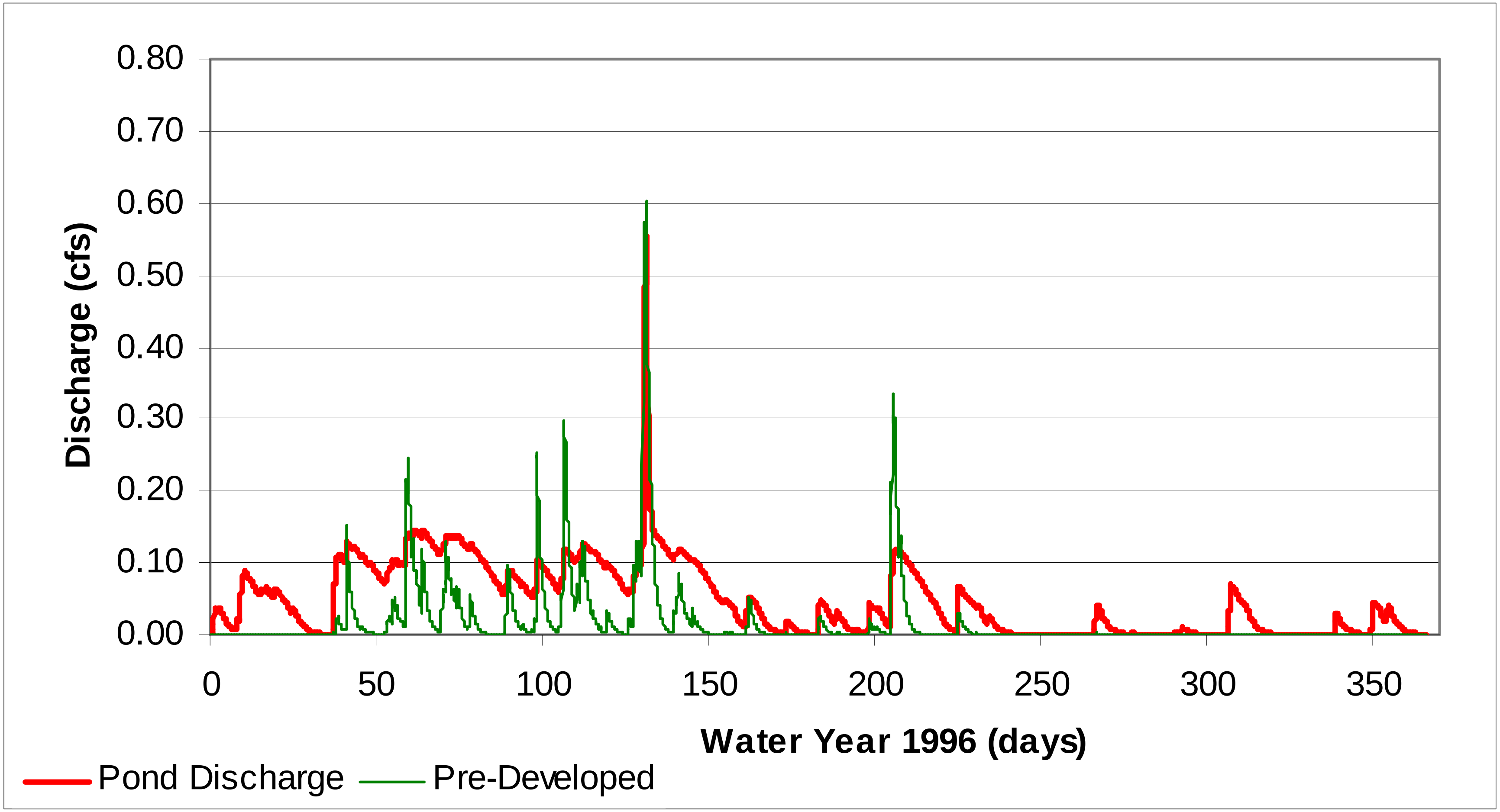
(Pond Fails Criterion 2, and Does not Meet Flow Duration Standard)

MGS Flood Pond Performance Plot



Note: Performance Criteria will be changed to Ecology's New Criteria

Performance of Duration Standard Pond



Computing Flood Recurrence Intervals

Single Event Model

Flood Recurrence Interval Equals Precipitation Recurrence Interval
(Unfortunately, this is rarely true!)

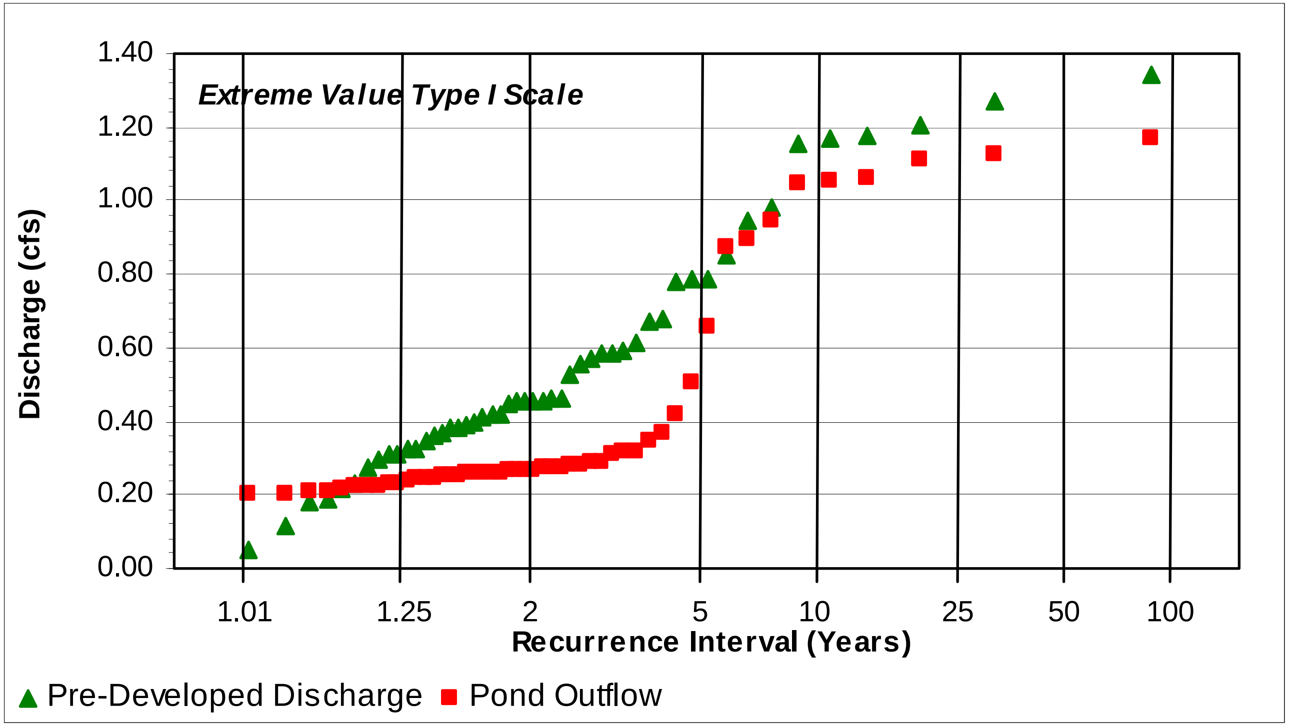
Continuous Model

1. Get Highest Flow Peak from Each Year of Simulation
2. Rank the Flows from Highest to Lowest
3. Assign Recurrence Interval (*Tr*) to Each Flow
   Using the Formula:

$$Tr = \frac{N + 0.12}{i - 0.44}$$

Where: N is the total number of years simulated
i is the rank of the peak flow from highest to lowest.

Flow Duration Pond, Peak Flow Performance



Note:

- Peak flow Reduced at or below predeveloped Level (Flow-Duration Ponds do a Good Job at Flood Control),
- ½ of Data Lies Below the 2-Year
- Few Data points beyond the 10-year (because of record length),

Use of Precipitation Time-Series in Continuous Hydrological Modeling

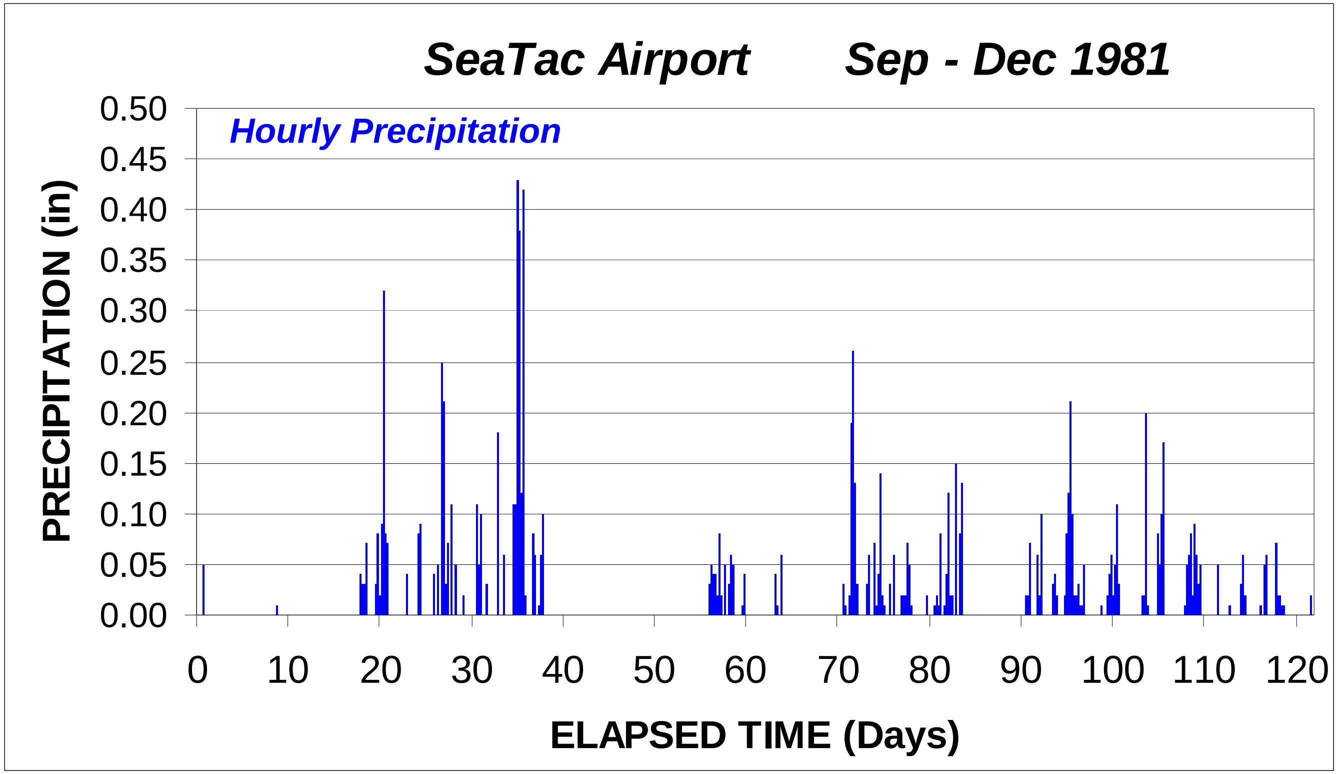
- ***Past/Common Practice***

- use of nearest precipitation gage

- ***New/Future Practice***

- extended precipitation time-series

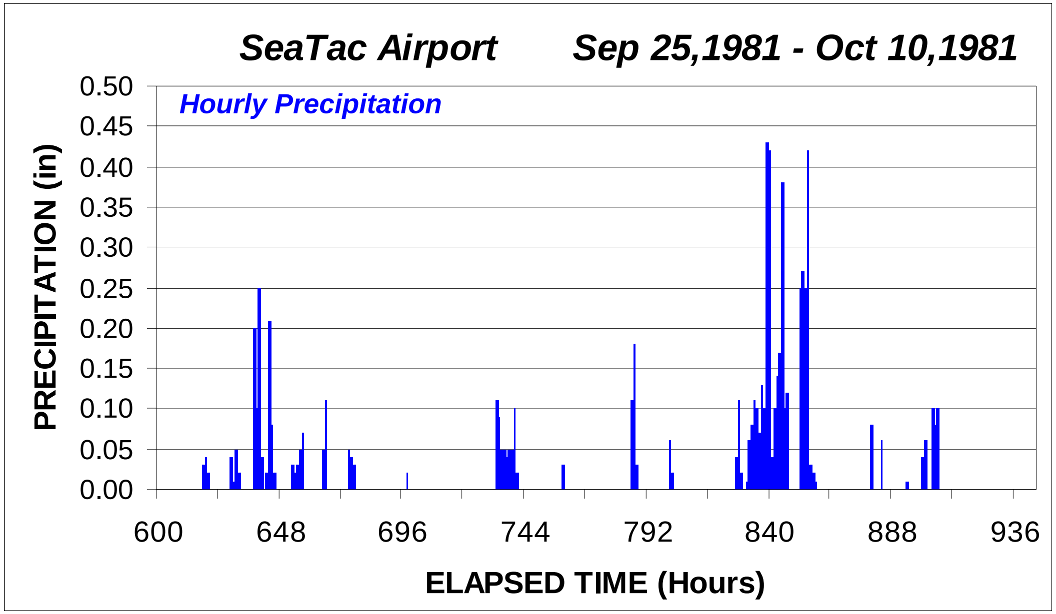
Hourly Precipitation Time-Series

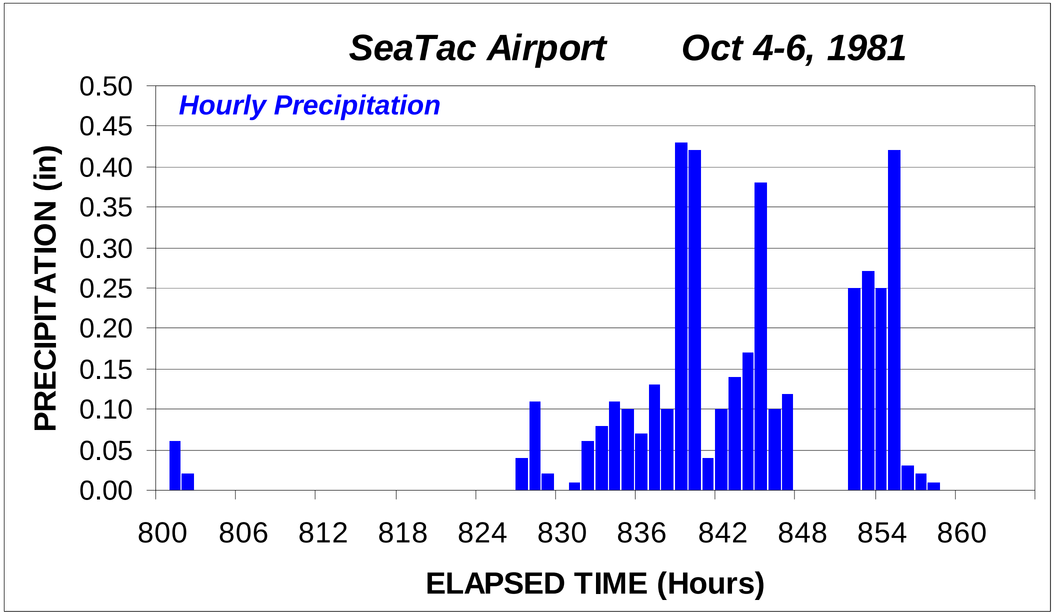


Sequence of Hourly Precipitation

MGS Engineering Consultants, Inc.

Hourly Precipitation Time-Series





Selection of Precipitation Time-Series

Common Practice

25-Year 24-Hour Isopluvial Map NOAA Atlas #2

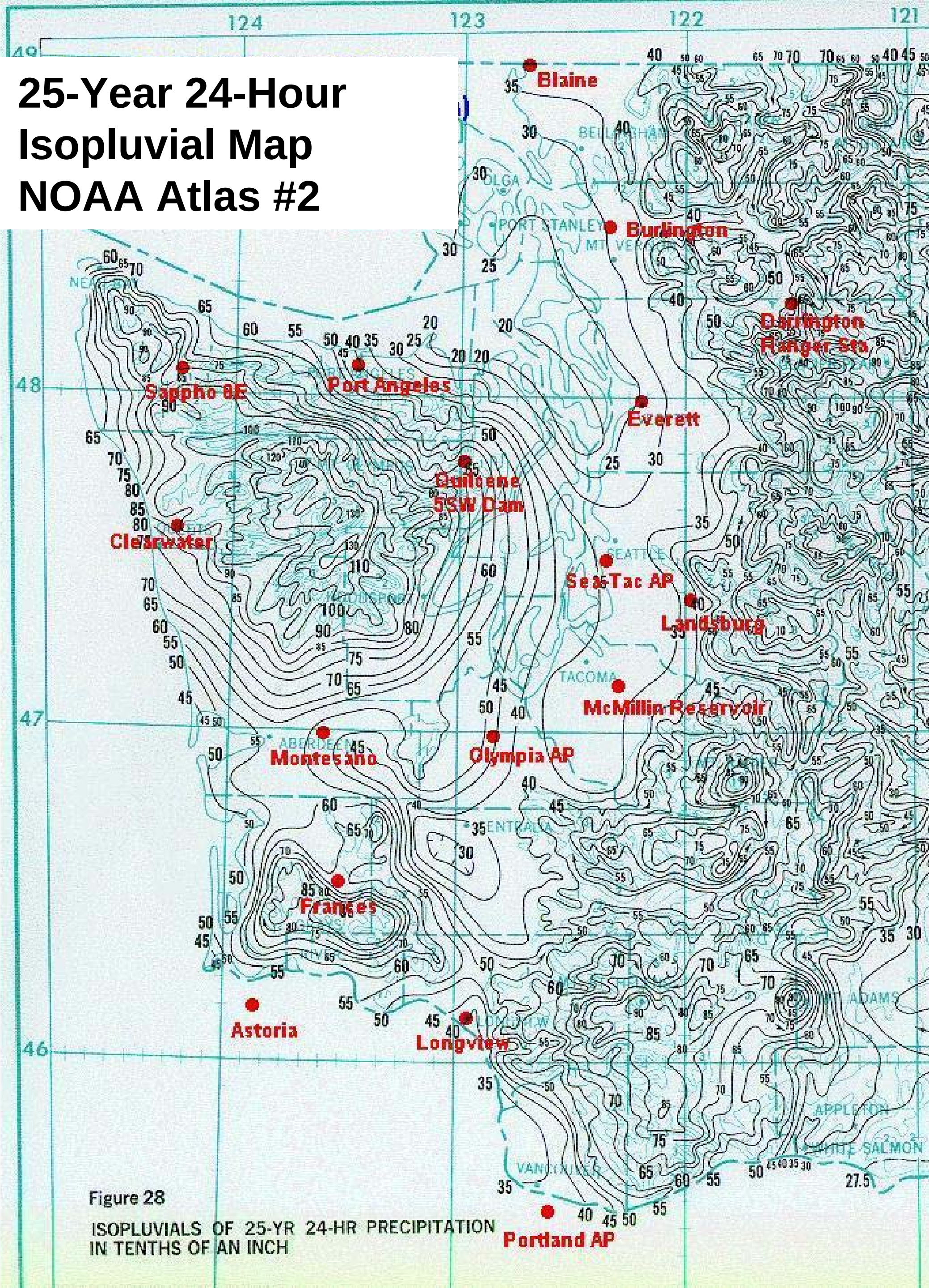


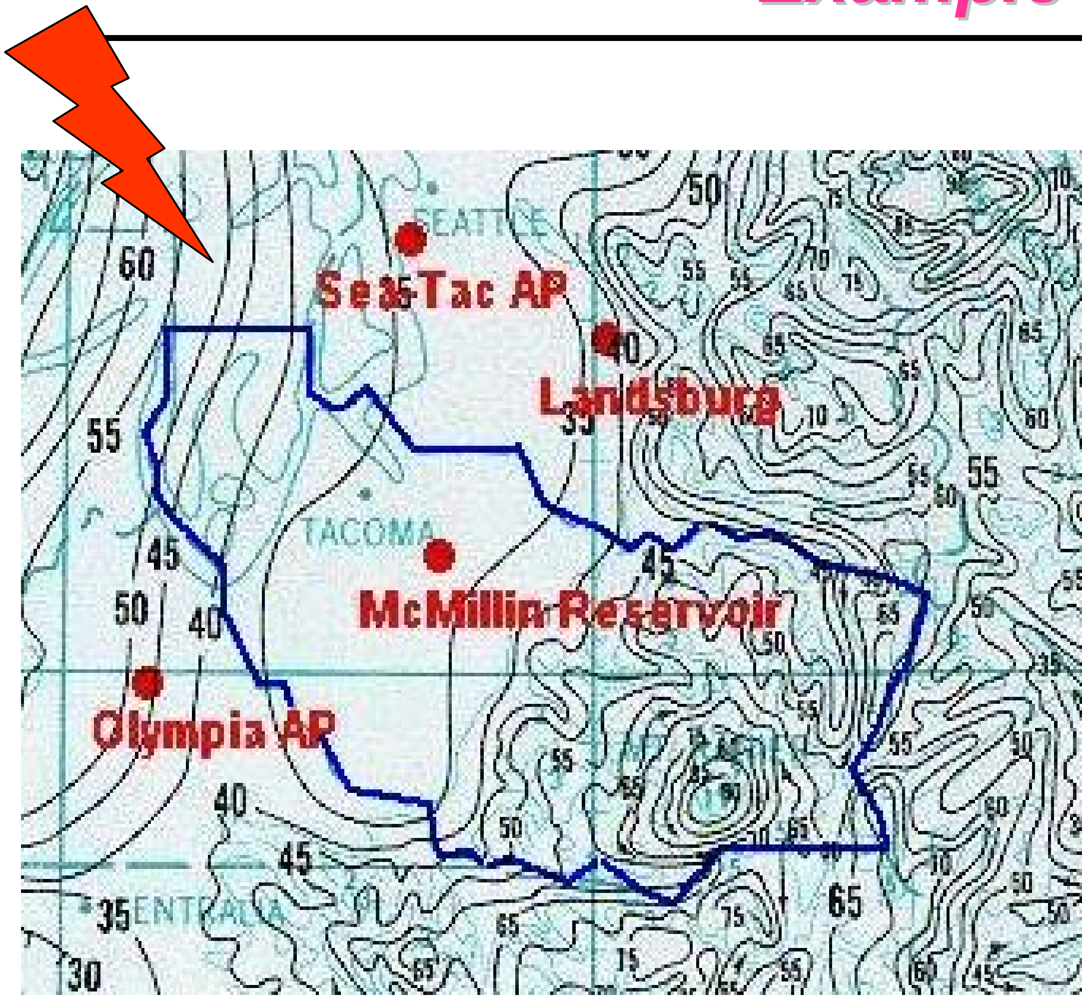
Figure 28
ISOPLUVIALS OF 25-YR 24-HR PRECIPITATION IN TENTHS OF AN INCH

Use Nearest Hourly Gage

Multiply All Hourly Values by <u>Single</u> Scaling Factor

Scaling Factor is Ratio of 25-Year 24-Hour Precipitation at Site of Interest Relative to Gage

Selection of Precipitation Time-Series
Example



25-Year 24-Hour Isopluvial Map - NOAA Atlas #2

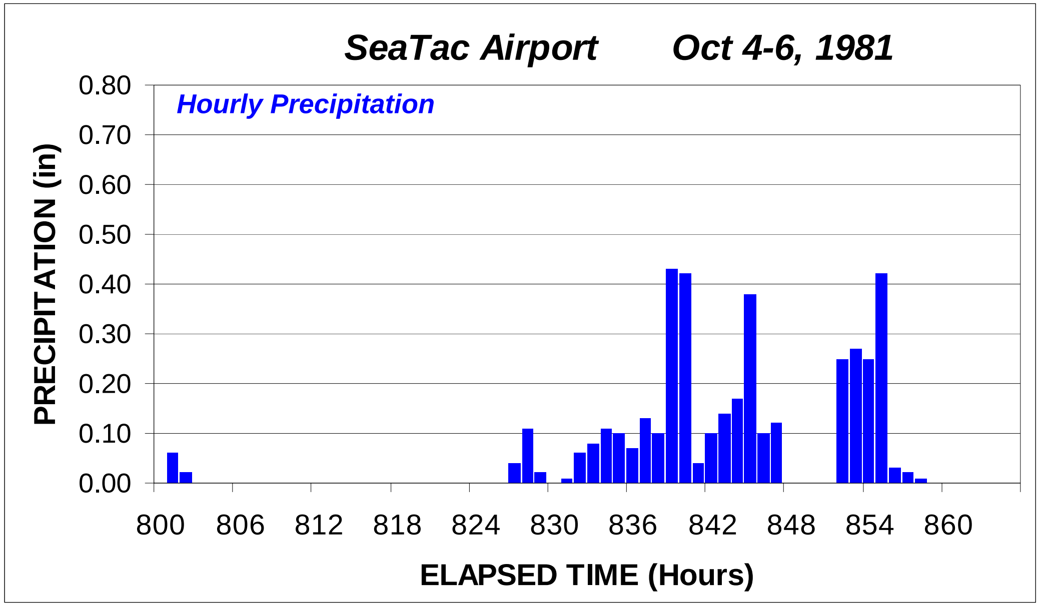
Site of Interest
in Kitsap County

5.1-inches
25-Year 24-Hour

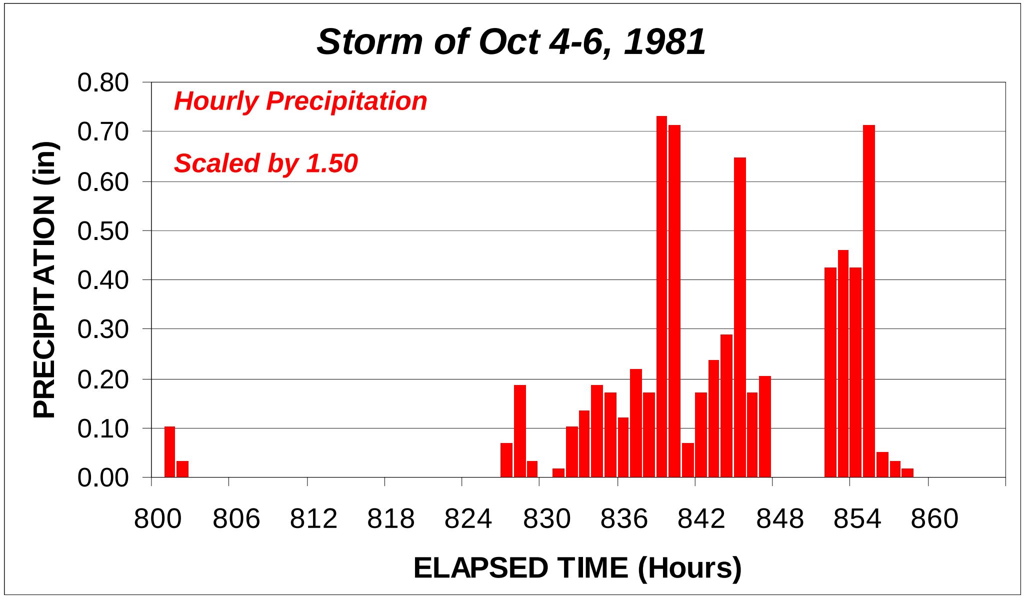
Use Sea-Tac Gage
3.0-inches
25-Year 24-Hour

Scaling Ratio = 1.70
(5.1/3.0)

<u>Simple</u> Scaling of Hourly Precipitation Time-Series



Storm Scaled by 1.7 for Kitsap County Site



Selection of Precipitation Time-Series

Common Practice of Simple Scaling

Shortcomings

1. Nearest Gage *May Not* have "Representative" Record

By chance - via Mother Nature

Record may be an "active record"

with one or more extreme storm events (outliers)

Or

Record may be a "benign record"

with the absence of many noteworthy storms

And/Or

Record may be of poor quality

- missing data and machine malfunctions

Selection of Precipitation Time-Series

Common Practice of Simple Scaling

Shortcomings

2. Storm Characteristics Vary by Duration and Season

Not Possible to Rescale Time-Series
with Single Scaling Factor
and Obtain Correct Storm Characteristics
at all Durations at the Site of Interest:

Different Scaling factors needed for range of durations:
2-hr, 6-hr, 24-hr, 3-day, 10-day, 30-day, 90-day, Annual

Selection of Precipitation Time-Series

Common Practice of Simple Scaling

Shortcomings

3. Many gages have short record lengths (< 40-years)

Record Length Usually Too Short
for Intended Design Purposes

→ Computation of Flow-Duration Curves at 50-Year Level

→ Estimation of 100-Year Flood

Solution to Shortcomings of Simple Scaling

Create
Extended Precipitation Time-Series

Grew out of basic need for:

robust statistical method
for transposing time-series
from one site to another

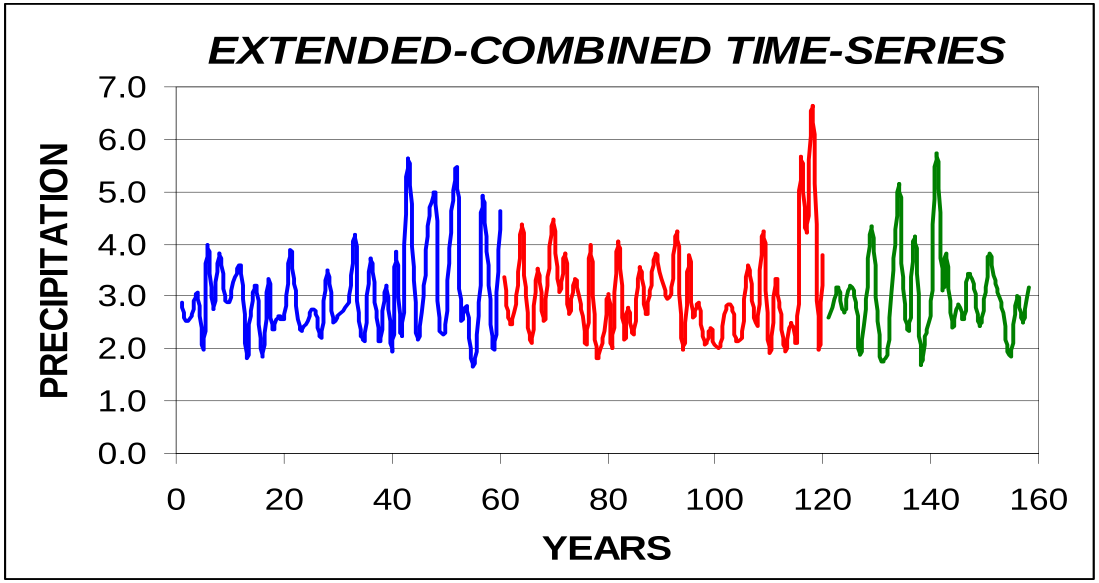
Extended Precipitation Time-Series

- ***WHAT** is extended time-series record*
- ***WHY** use extended time-series record*
- ***HOW** were extended time-series developed*

***What* is an Extended Precipitation Time-Series**

Long Precipitation Record

Obtaining by Combining Records from Distant Stations



Record from Each Station Rescaled

to have Storm Statistics Representative of Site of Interest

***What** is an Extended Precipitation Time-Series*

Long Time-Series Created by Combining Precipitation Records

Vancouver, BC	*38-years*
Seattle, WA	*60-years*
Salem, OR	*60-years*

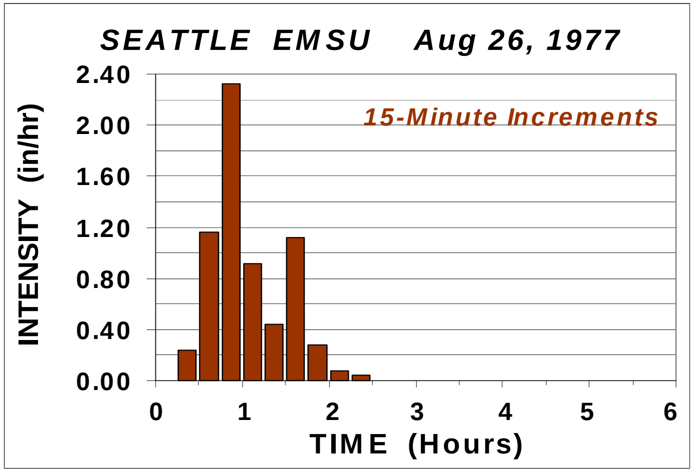
***Why* use Extended Precipitation Time-Series**

- *Allows use of high-quality stations with long records*
  - *Avoids pot-luck of using nearby stations*

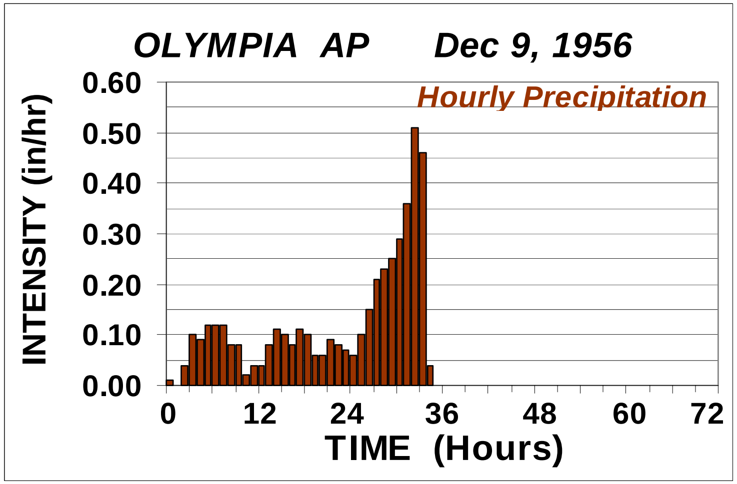
Many hourly stations have short records of poor-quality (missing data)

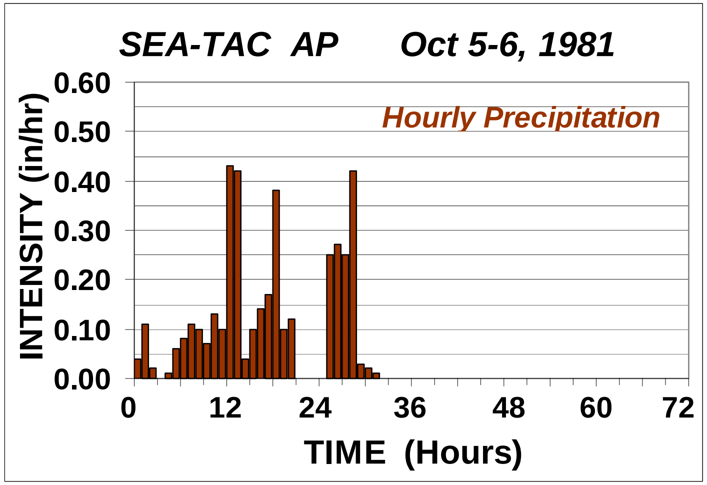
- *Provides greater diversity and variability of storm temporal patterns*
- *Provides for increased number of extreme events*
- *Allows Interpolation of 50-year and 100-year floods rather than extrapolation*

Greater Sampling of Storm Magnitudes and Temporal Patterns

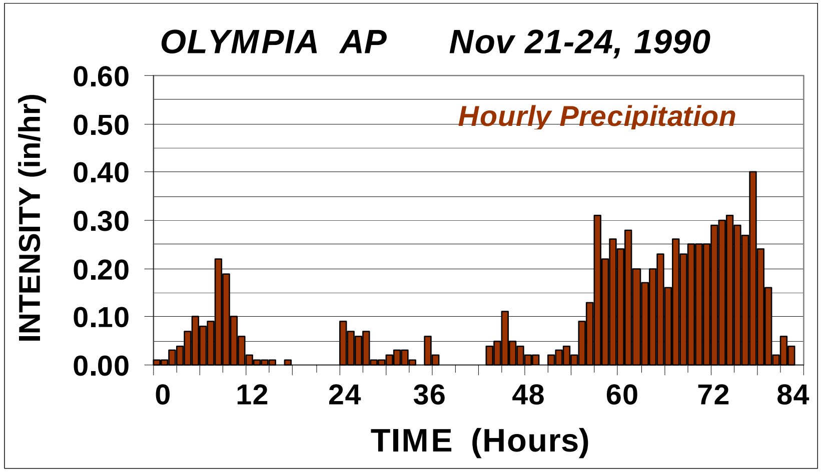


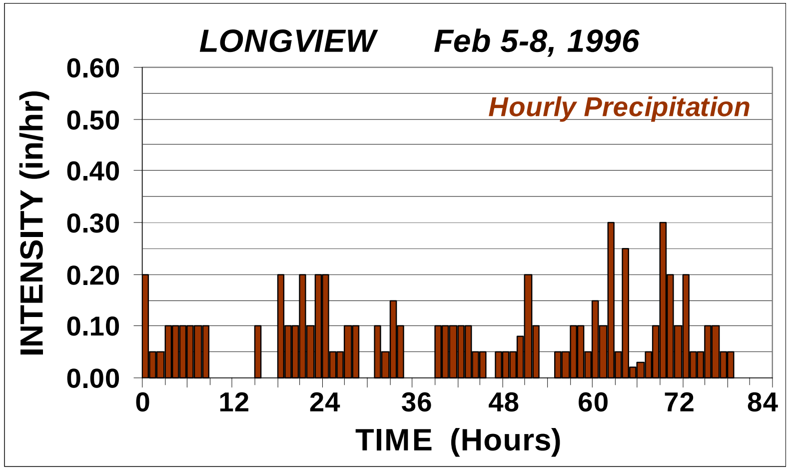
Larger Sample of Storm Temporal Patterns allows more rigorous testing of detention pond performance

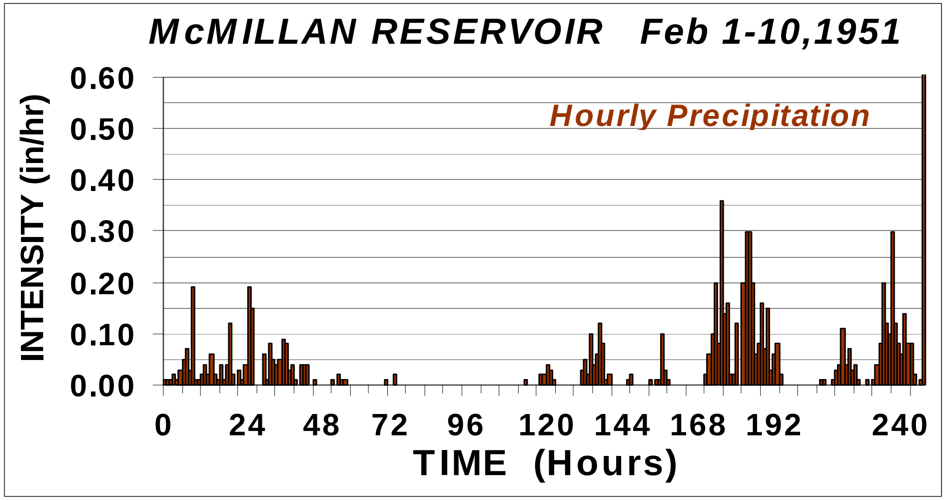




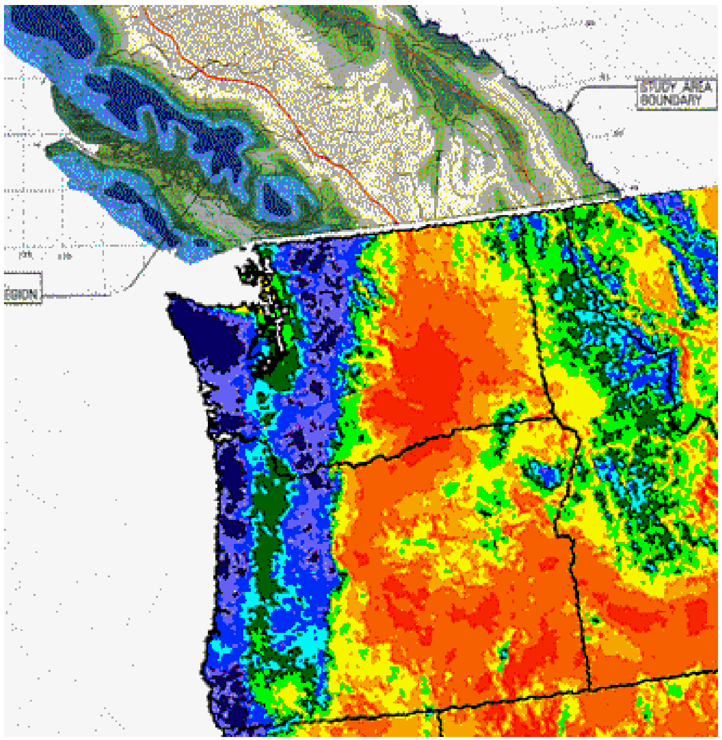
Greater Sampling of Storm Magnitudes and Temporal Patterns







HOW - *Create Long Time-Series by Pooling Data from Climatologically Similar Areas*



Non-Orographic Lowlands East of Coastal Mountains

- *Lowlands British Columbia*
- *Puget Sound Lowlands*
- *Willamette Valley*

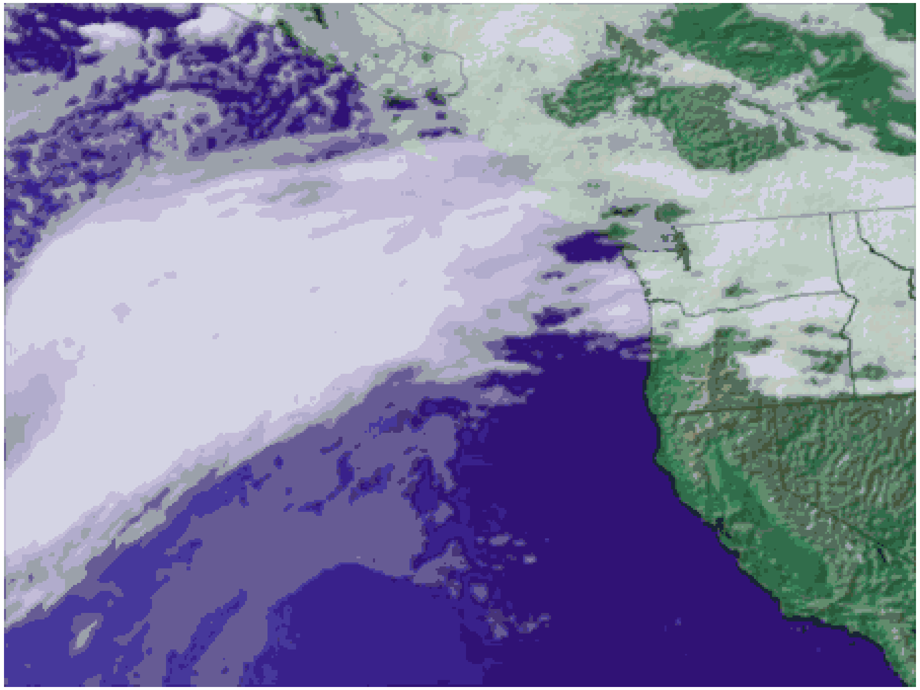
Similarity

- *Seasonality of storms*
- *Storm temporal patterns*
- *Magnitude-frequency curves*

HOW - Create Long Time-Series by Pooling Data from Climatologically Similar Areas

Independence of Data Allows Combining of Precipitation Records

Widely Separated Stations have Independent Records at Durations of Interest (affected by different storms)



Heaviest Precipitation Storm Tracks / Storm Centers Typically Cover Only Portion of Climatological Region

Create Long Time-Series by Combining Precipitation Records

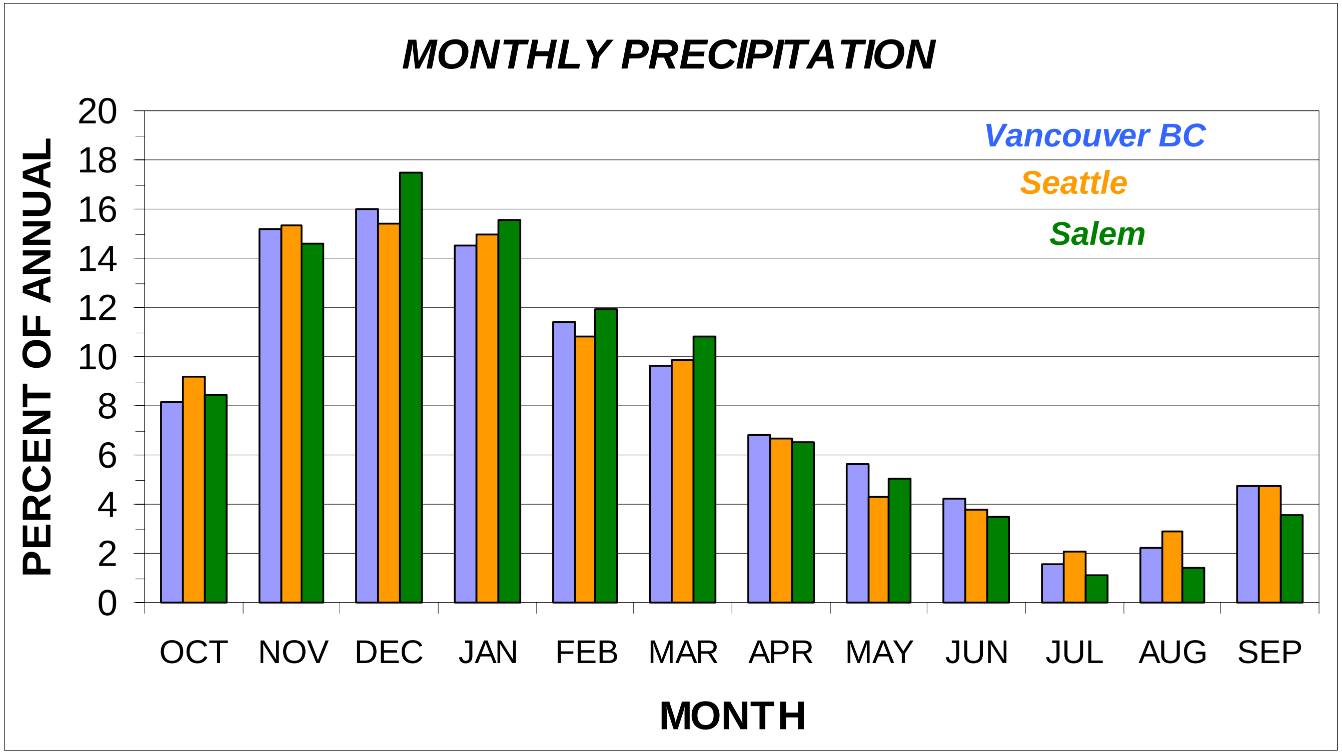
Stations with Hourly Records

Vancouver, BC	*38-years*
Seattle, WA	*60-years*
Salem, OR	*60-years*

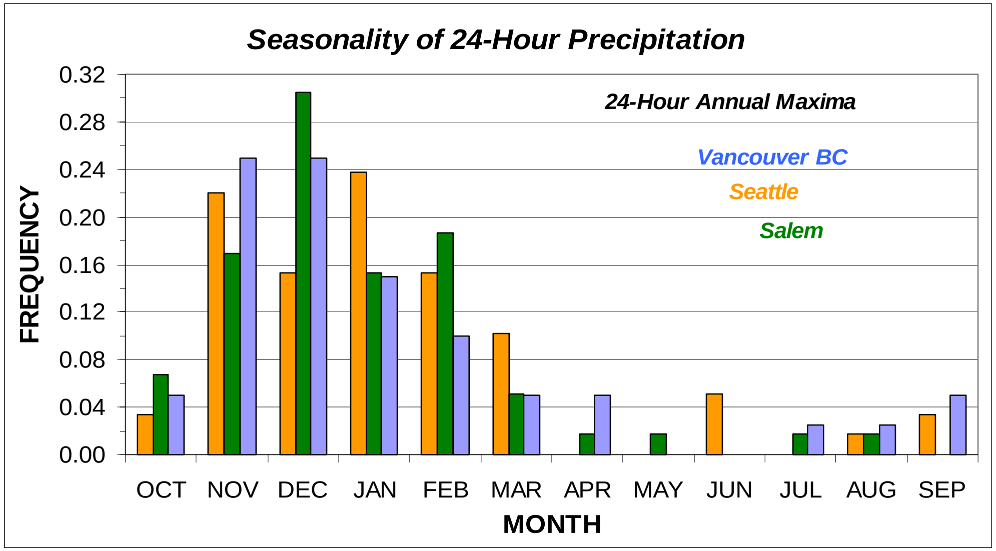
Independence of Storms at Widely Separated Stations 24-Hour Precipitation

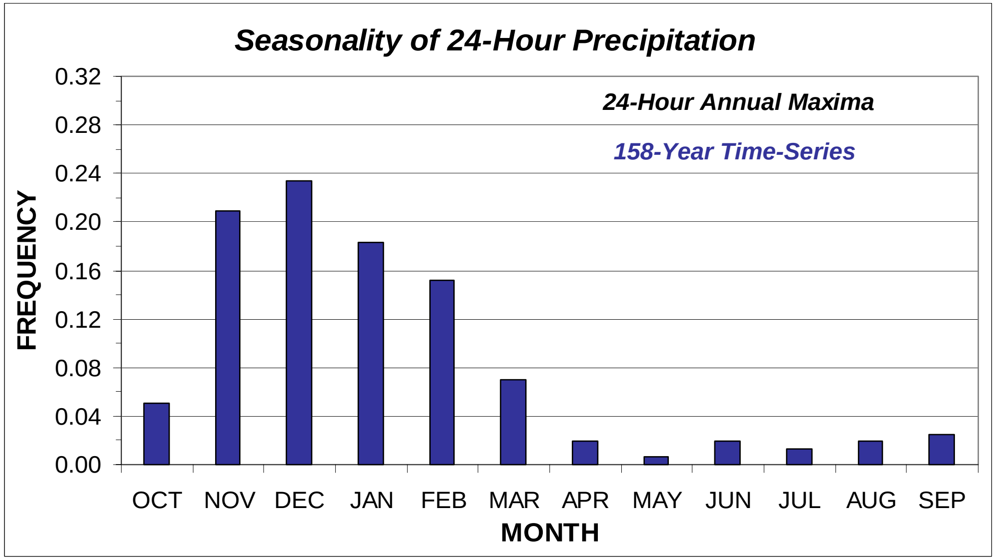
DATES OF GREATEST 24-HOUR PRECIPITATION			
RANK OF STORM	**VANCOUVER, BC**	**SEATTLE, WA**	**SALEM, OR**
Greatest Precip	12 / 25 /1972	10 / 05 / 1981	11 / 18 / 1996
2	12 / 16 / 1979	11 / 23 / 1990	10 / 26 / 1994
3	10 / 16 / 1975	11 / 23 / 1986	02 / 16 / 1949
4	01 / 18 / 1968	02 / 08 / 1996	03 / 30 / 1943
5	11 / 02 / 1989	01 / 17 / 1986	12 / 02 / 1987
6	10 / 30 / 1981	11 / 25 / 1998	01 / 20 / 1972
7	07 / 11 / 1972	01 / 08 / 1990	02 / 05 / 1996
8	01 / 17 / 1986	03 / 04 / 1972	02 / 09 / 1961
9	11 / 20 / 1980	02 / 06 / 1945	01 / 03 / 1956
10th Largest	08 / 29 / 1991	11 / 19 / 1959	01 / 14 / 1974

Seasonal Similarity of Precipitation

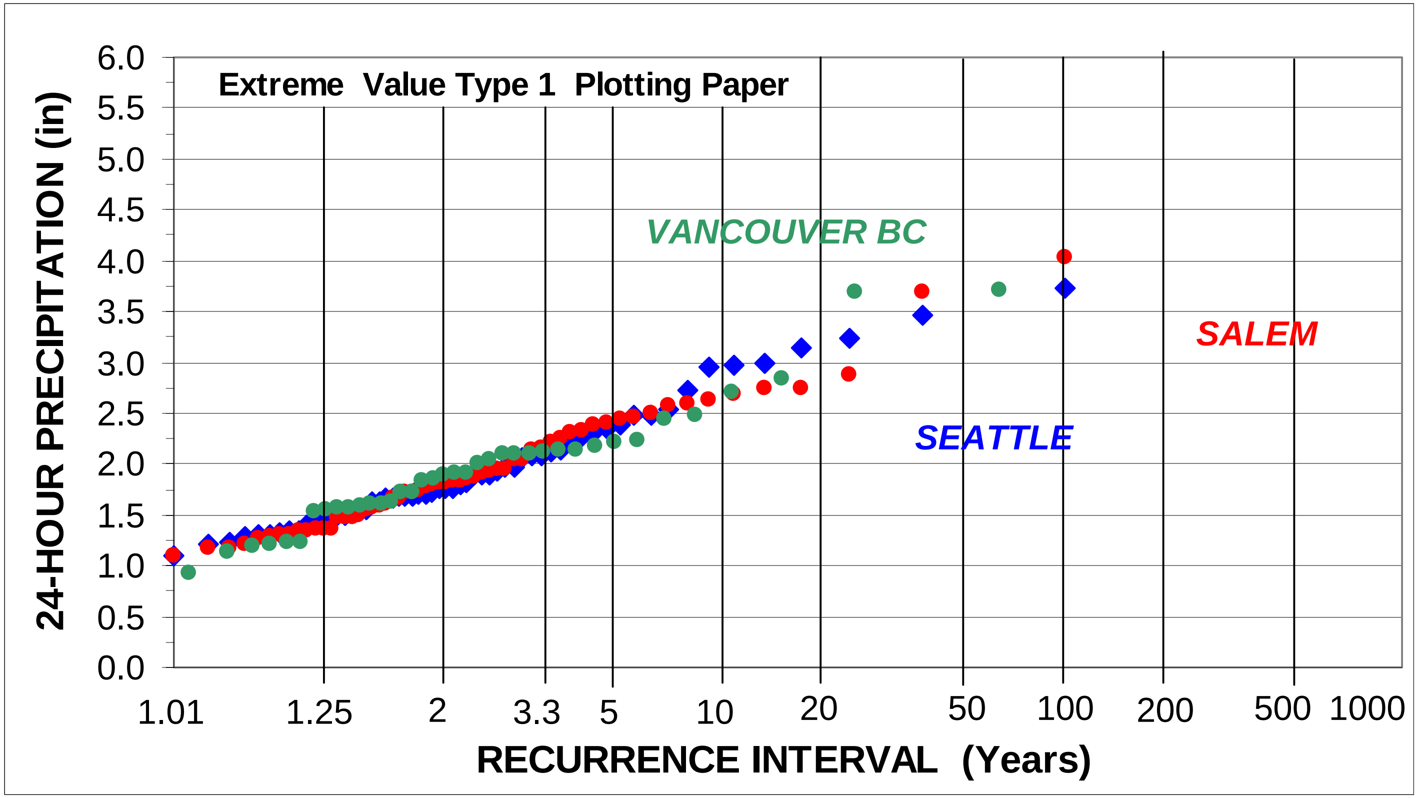


Seasonal Similarity of Precipitation





Similarity of Magnitude-Frequency Curves



How - Extended Precipitation Time-Series

Rescale Precipitation Increments

consistent with

Regional Statistical Storm Characteristics

for

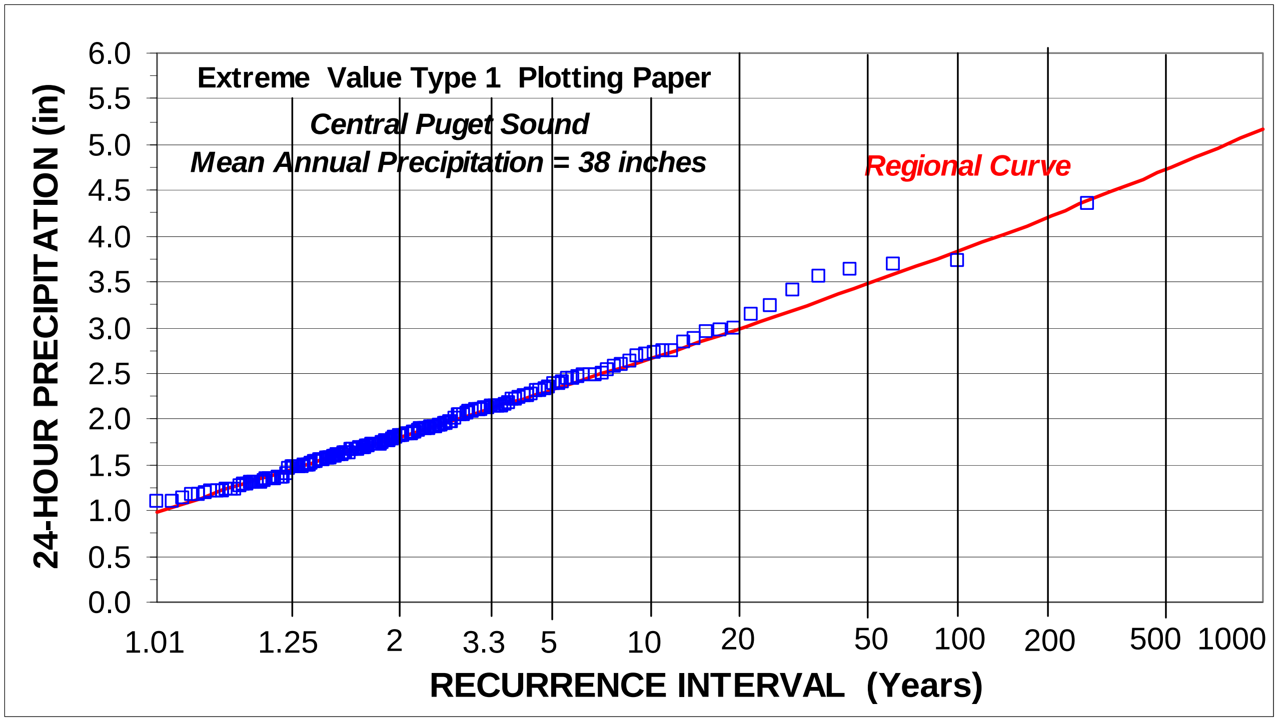
Magnitude-Frequency

for:

2-hr, 6-hr, 24-hr, 72-hr,
10-day, 30-day, 90-day, Annual Durations

How - Extended Precipitation Time-Series

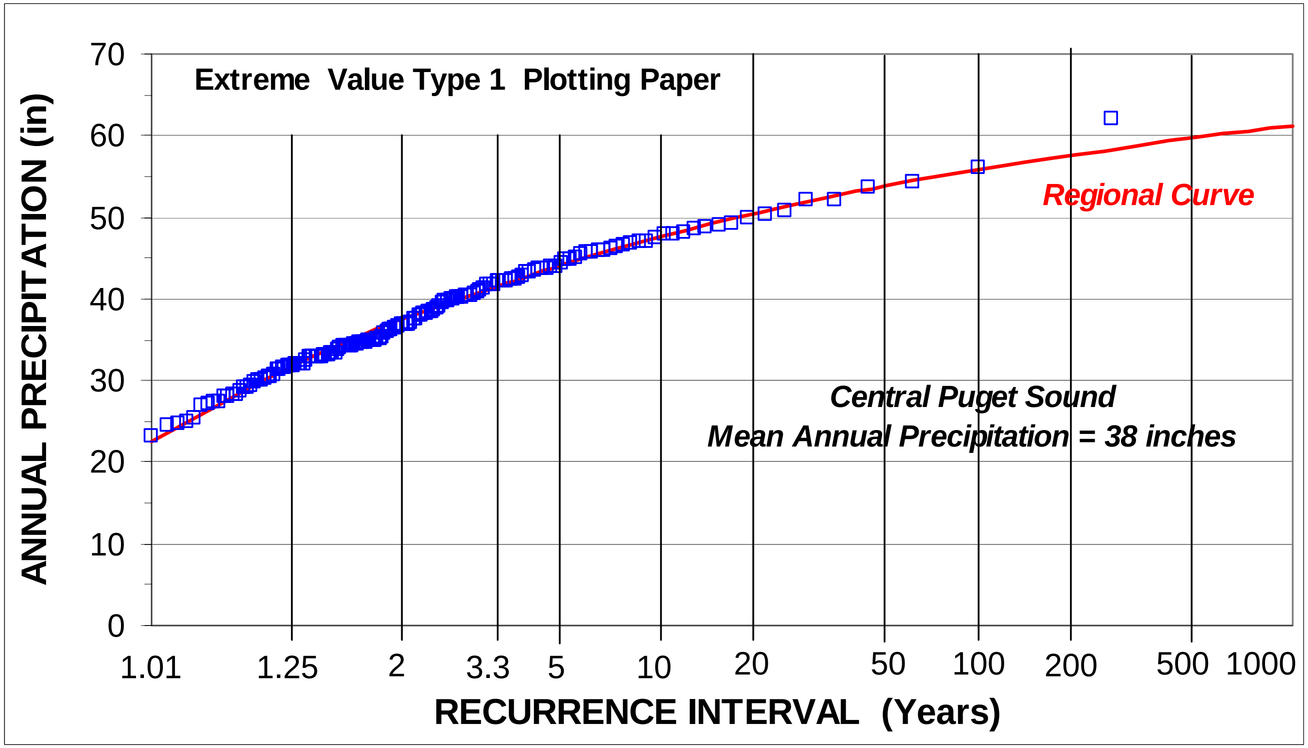
Rescale Precipitation Data
based on Regional Storm Statistics



To Preserve Storm Characteristics
Hourly - Daily – Weekly - Monthly - Annual

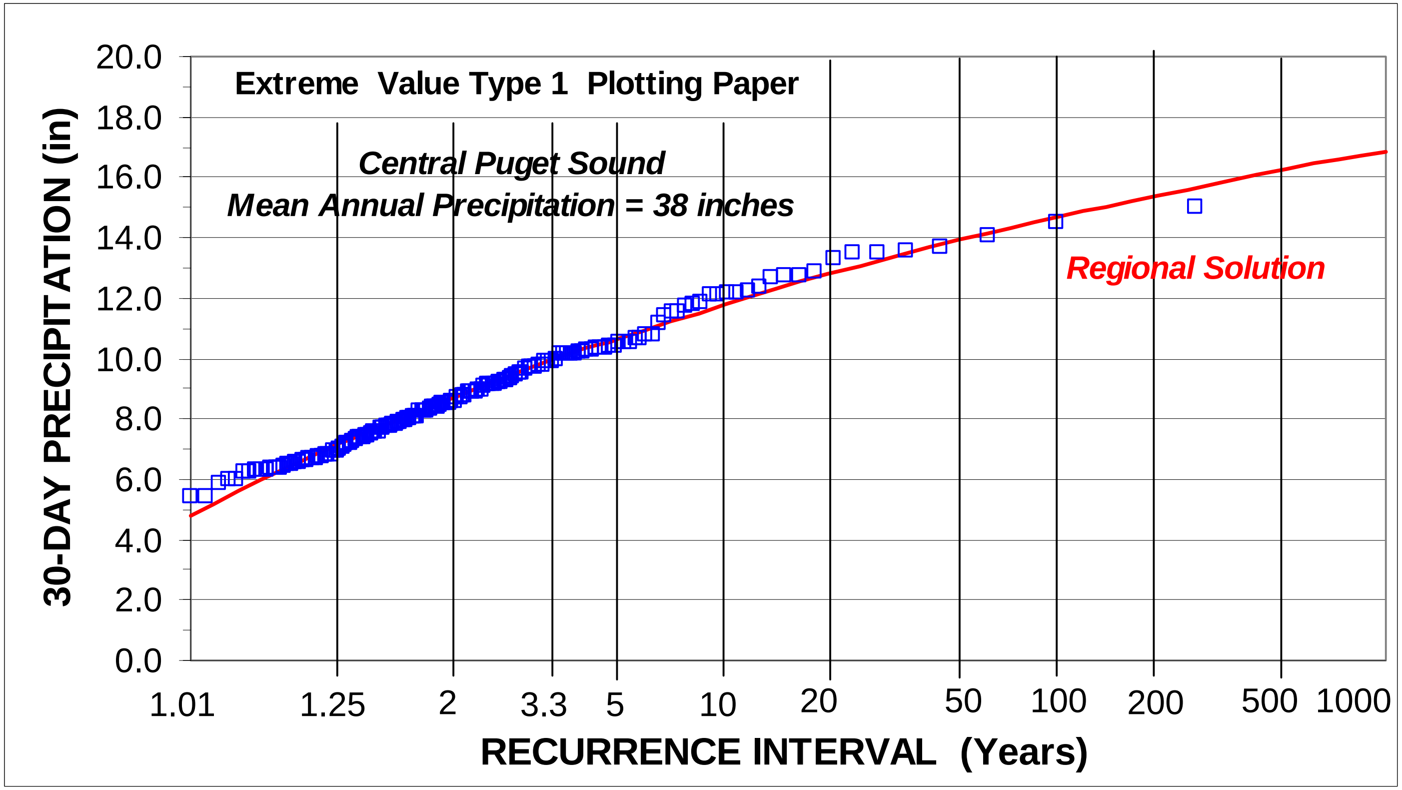
Comparison of Precipitation Magnitude-Frequency with Regional Magnitude-Frequency Relationships

Annual Precipitation 158-Year Record



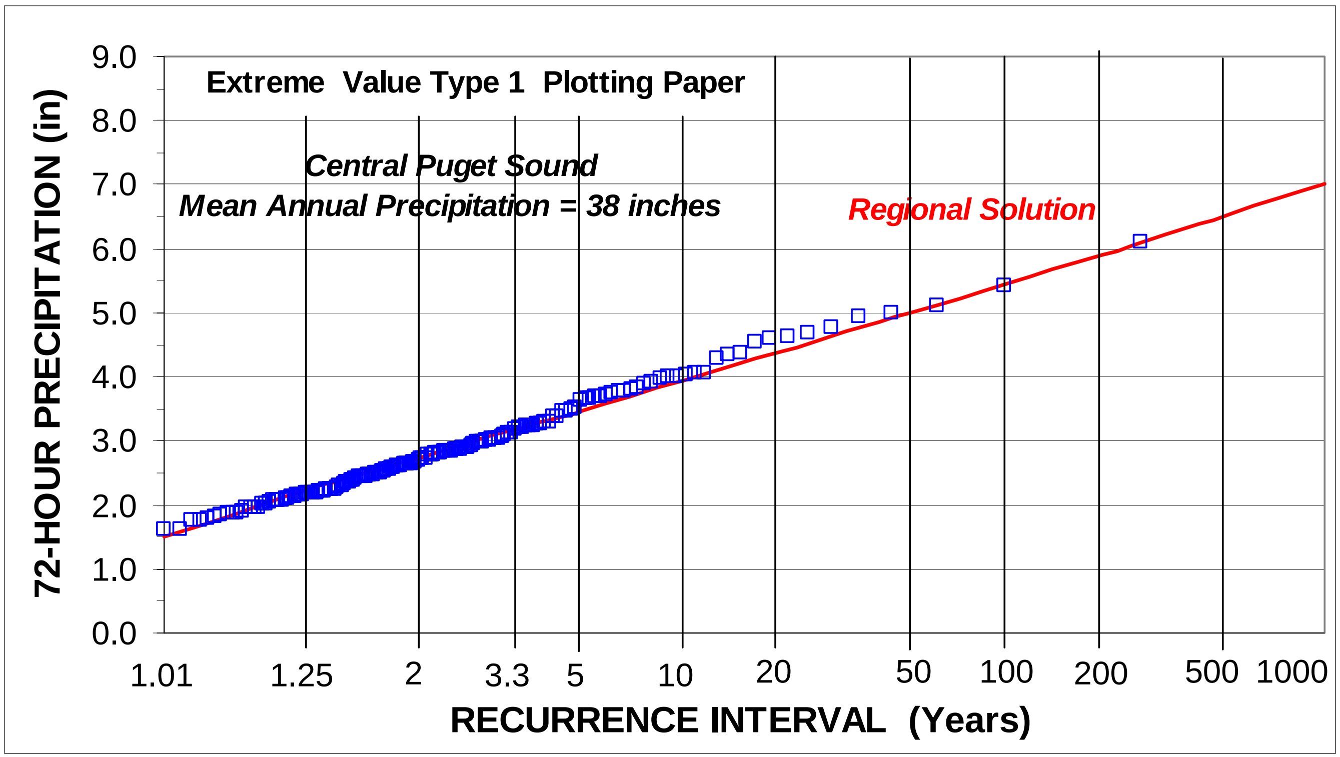
Comparison of Precipitation Magnitude-Frequency with Regional Magnitude-Frequency Relationships

30-Day Precipitation 158-Year Record



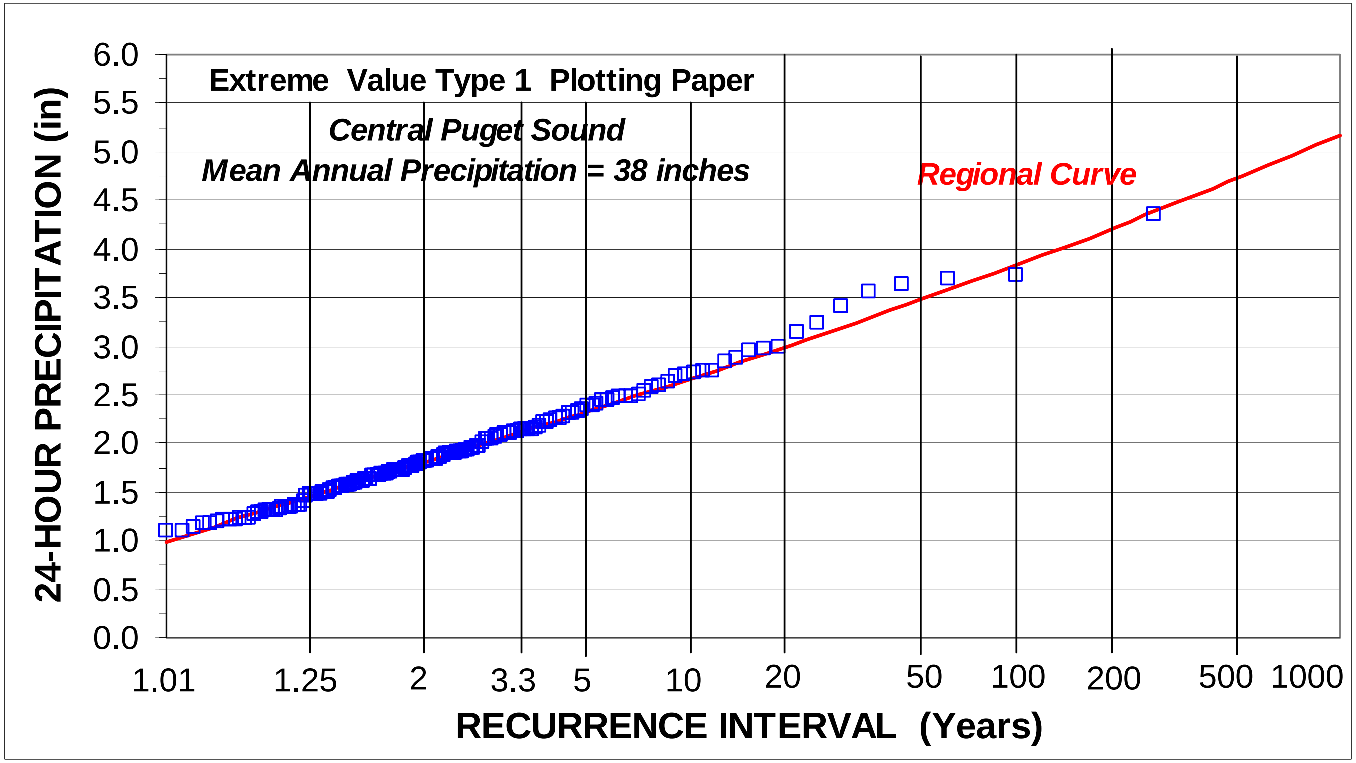
Comparison of Precipitation Magnitude-Frequency with Regional Magnitude-Frequency Relationships

72-Hour Precipitation 158-Year Record



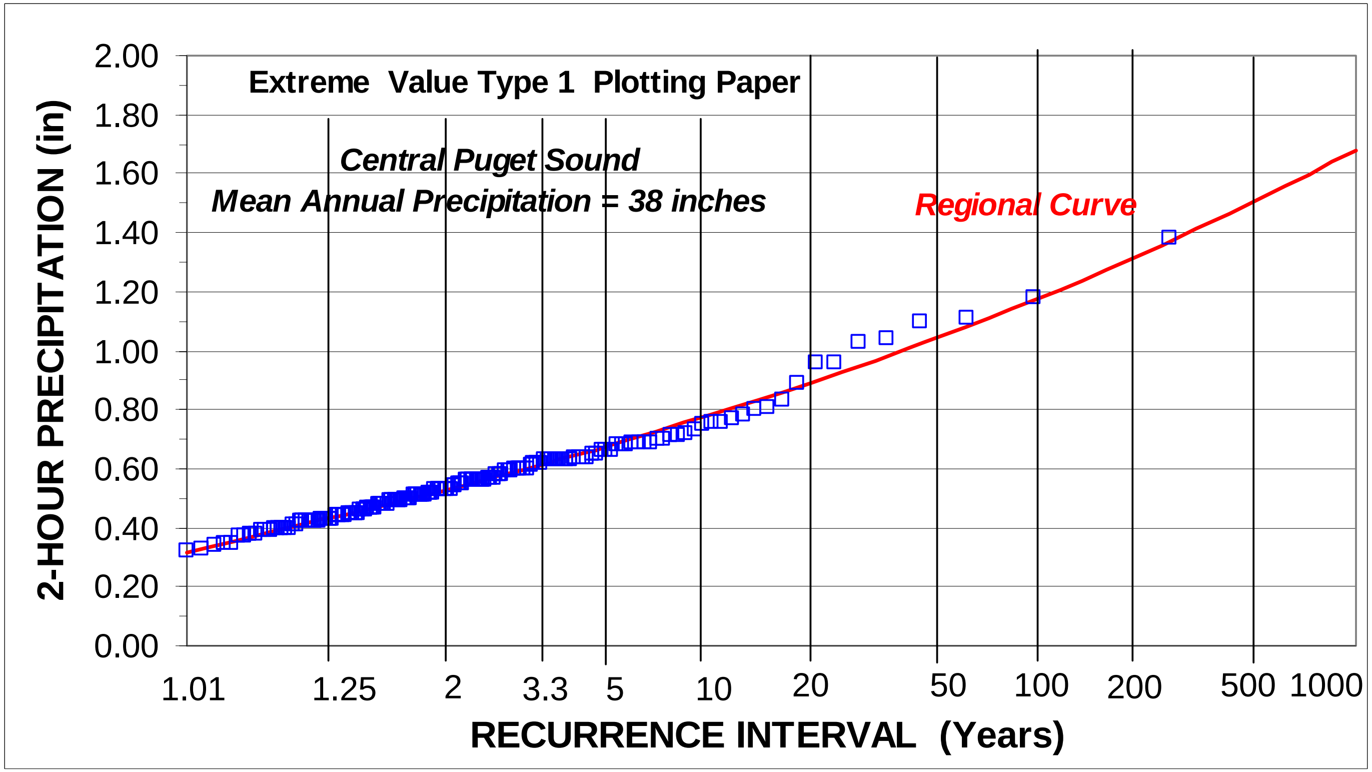
Comparison of Precipitation Magnitude-Frequency with Regional Magnitude-Frequency Relationships

24-Hour Precipitation 158-Year Record



Comparison of Precipitation Magnitude-Frequency with Regional Magnitude-Frequency Relationships

2-Hour Precipitation 158-Year Record



Model Deliverables
Western Washington
Extended Precipitation Time-Series

Datasets of Incremental Precipitation

Puget Sound → hourly time-series, 158-yr record

Pierce County → hourly time-series, 158-yr record

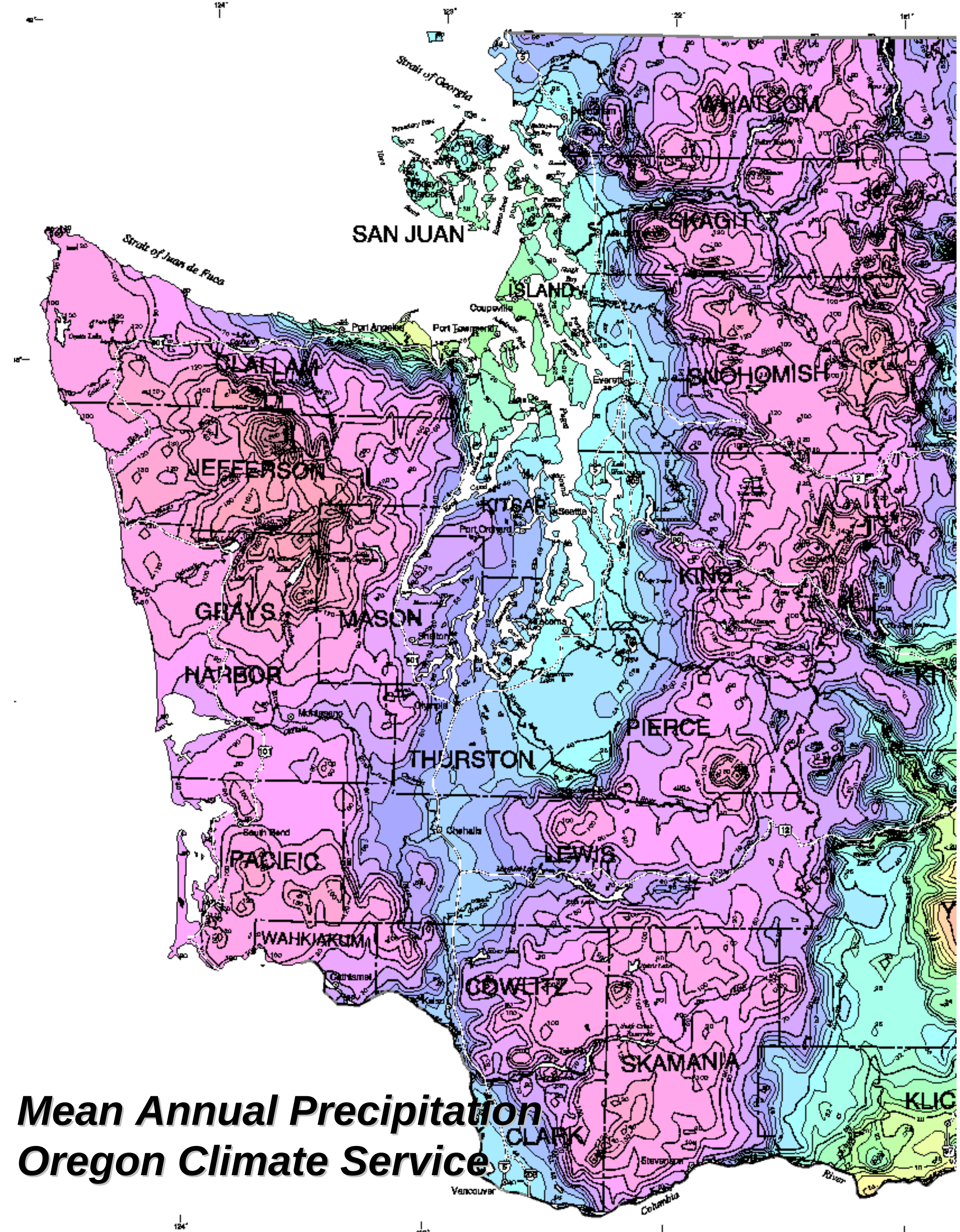
Vancouver WA Area → hourly time-series, 121-yr record

Western Washington Lowlands and Foothills

subdivided into zones of mean annual precipitation on 4-inch increments from 32 to 60-inches

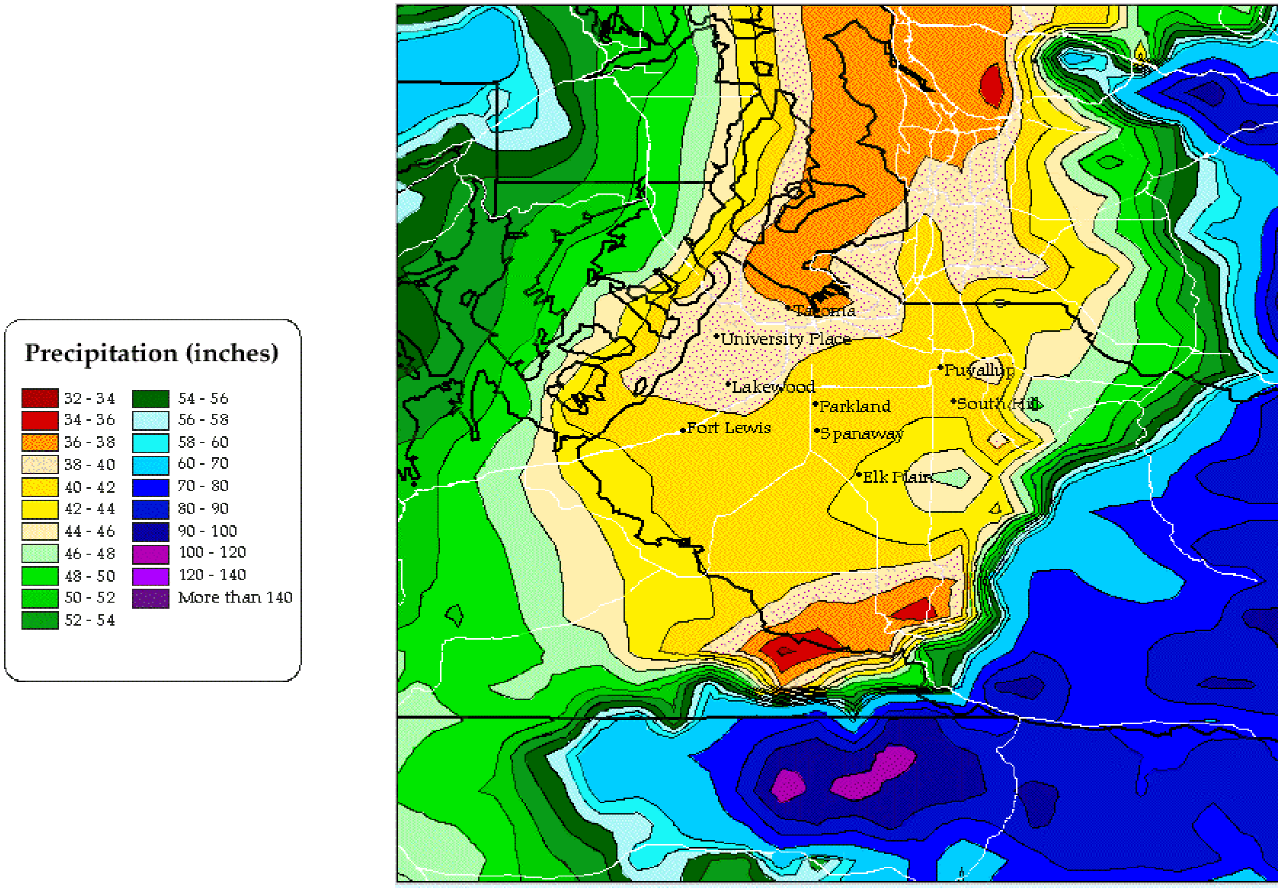
Vancouver Area
8 time-series

Puget Sound
16 time-series
separate zones West and East of Central Puget Sound



Mean Annual Precipitation
Oregon Climate Service

PIERCE COUNTY - 15 Separate Time-Series
One per 2-inch Zone of Mean Annual Precipitation



38 – 52 inches

Leeward / Windward

Central

Puget Sound

Mean annual precipitation is based on 1961-1990 averages, obtained using the PRISM model by Chris Daly of the Spatial Climate Analysis Service at Oregon State University. Data used in PRISM were collected at NOAA Cooperative stations and USDA-NRCS SNOTEL stations.

Use of Precipitation Time-Series in Continuous Hydrological Modeling

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TRAINING TODAY

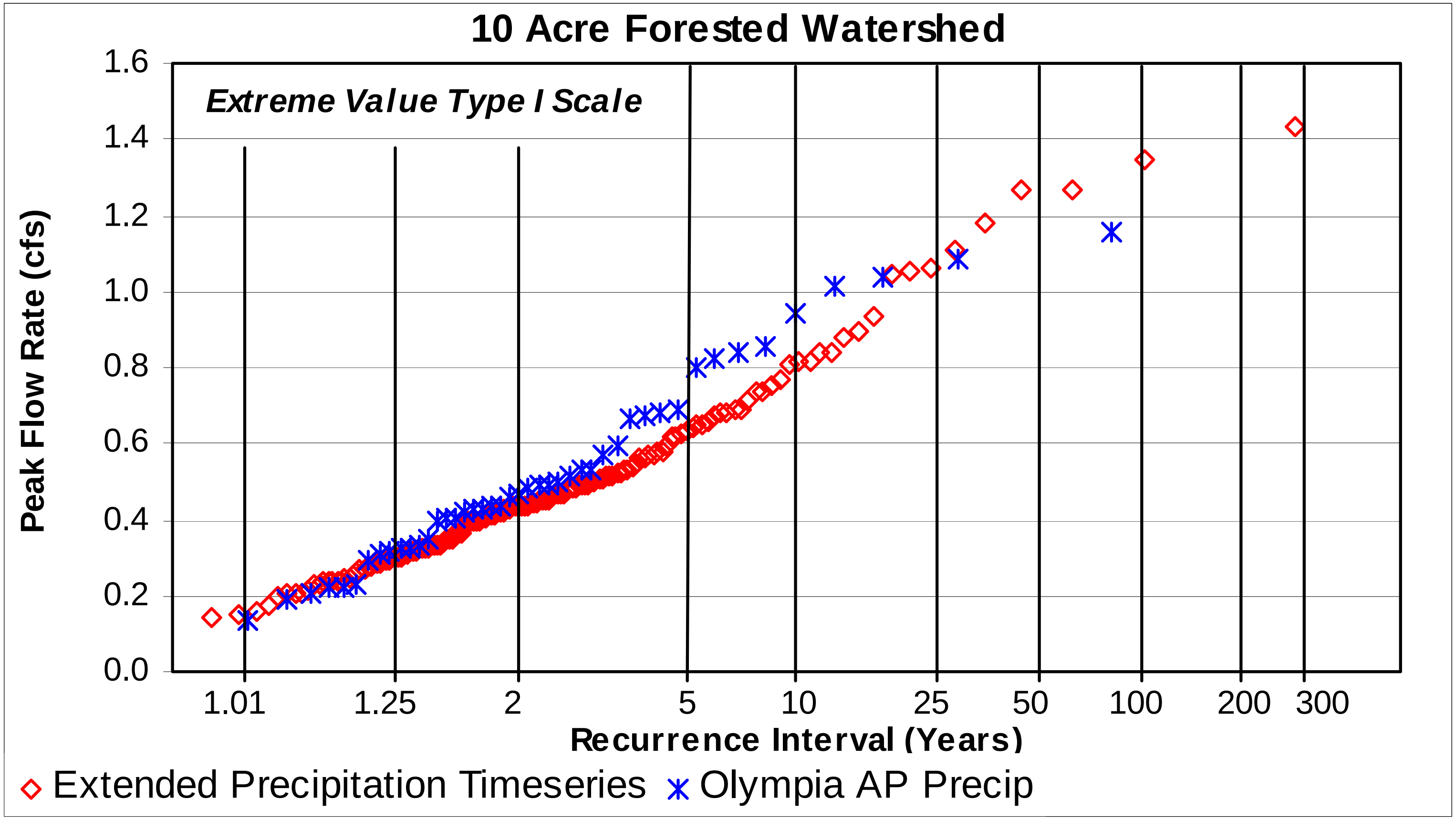
examples based on simple scaling using 24-hour 25-year precipitation

COMING IN APRIL, 2002

model delivered with extended precipitation time-series

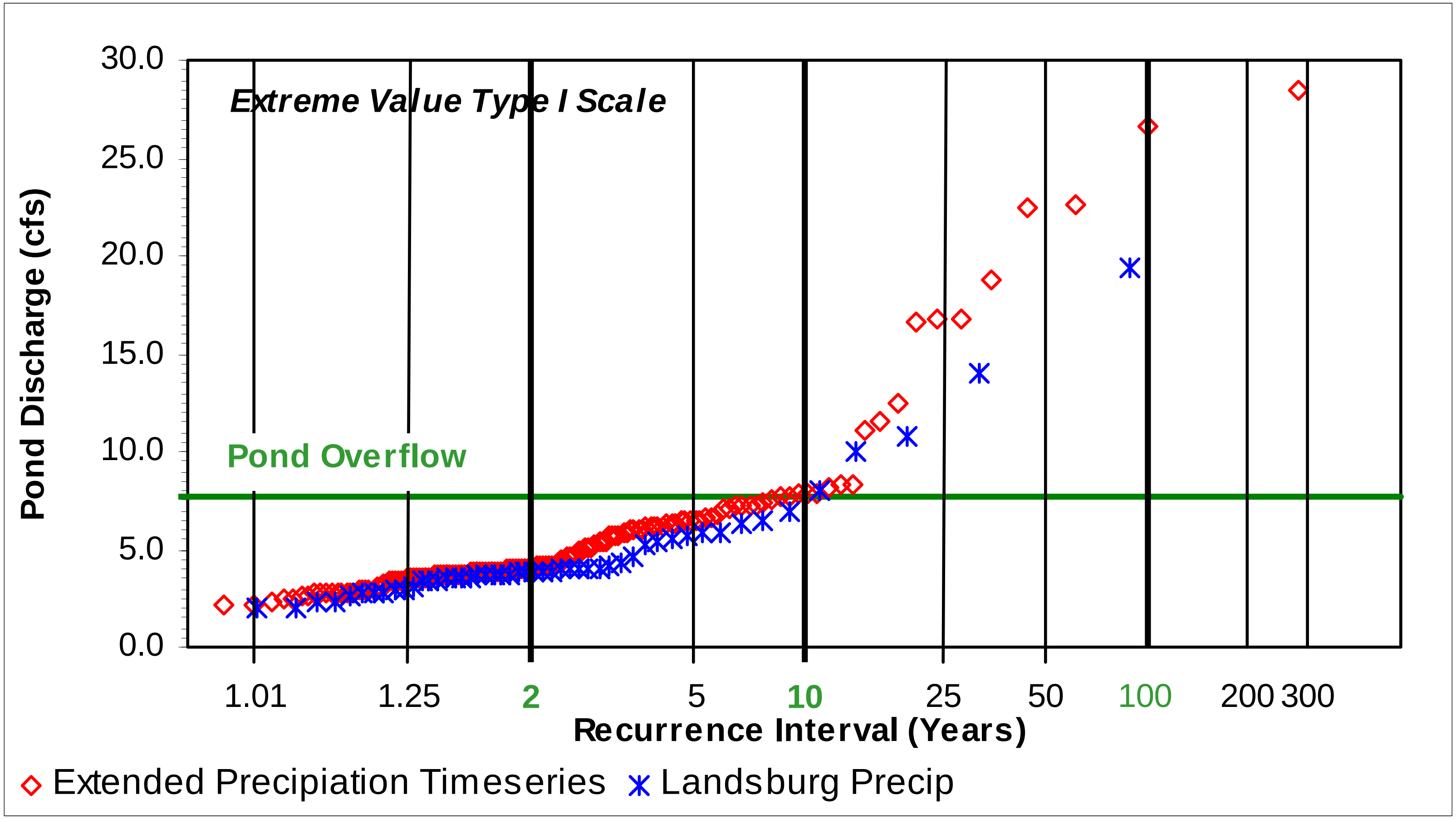
Peak Flow Comparison Forested Site

158-Year Record and 45-Year Gage Record



Peak Flow Comparison Stormwater Pond

158-Year Record and 45-Year Gage Record



MGS Flood Public Domain Version

Features:

- Meets Ecology’s Stormwater Guidelines
- Uses HSPF Computational Algorithm
- Optionally Include Groundwater Discharge
- Multiple Subbasin Capability
- Can Design Facilities for “Re-development” Conditions
- Contains Statistics and Graphics Routines
- Can be Calibrated if Desired
- Final Release June 2002

MGS Flood Proprietary Version

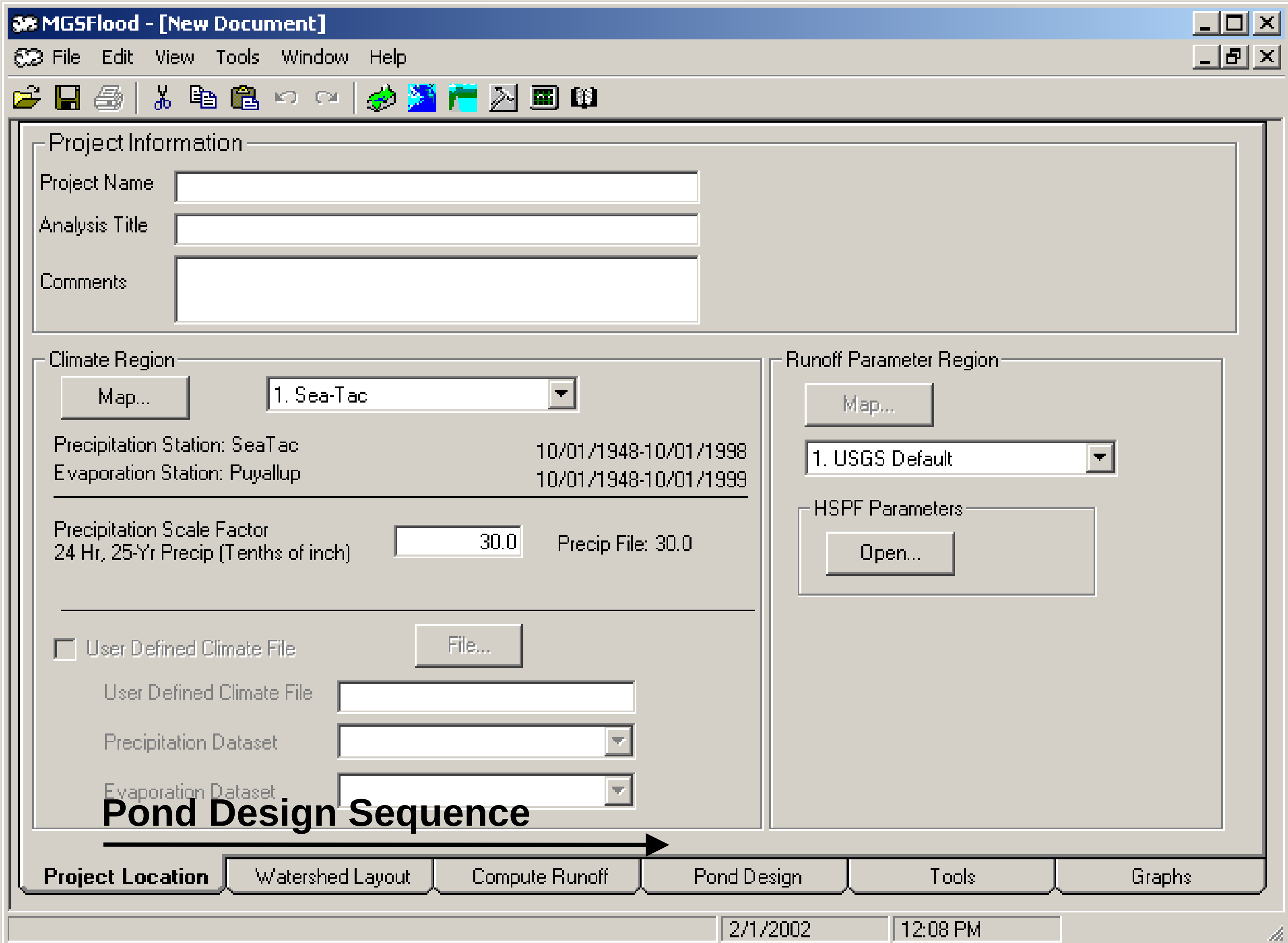
Includes
Pond Hydraulics and Optimization Routines

Features:

- **Ability to specify Pond Geometry**
- **Includes a Variety of Hydraulic Structures; Orifice, Orifice w/ Backwater, Weirs, Risers, Sand Filters, Rectangular and V Notch Weirs**
- **Optimization Routine for Automatically Designing Ponds to Ecology Standard**

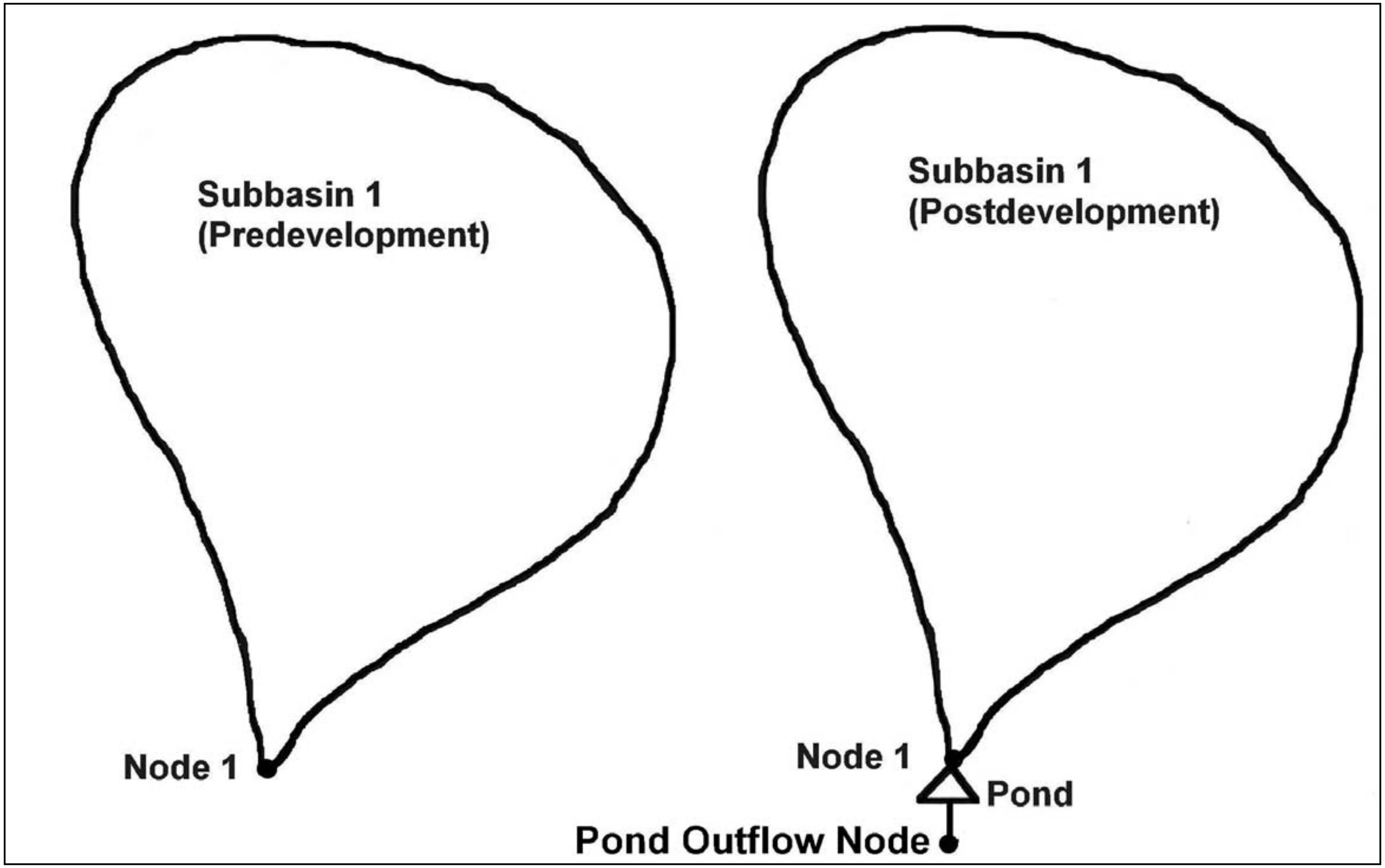
Pond Design Procedure Using MGS Flood

1. Determine Climatic Region and 25-Yr 24-Hour Precip for Site
2. Enter Pre- and Post-development Land use for Each Subbasin
3. Assign Subbasins to “Nodes”, Connect Upstream Nodes to Downstream Nodes
4. Compute Runoff (Saves Pre- and Post-Development Flows 50+ Years at 1-hour timestep)
5. Define Pond Hydraulics (either with Routing Table or Pond Hydraulics Routines)
6. Route Flows, Compute and Plot Duration Curves. Adjust Pond Configuration until Pre- and Postdevelopment Duration Curves Match

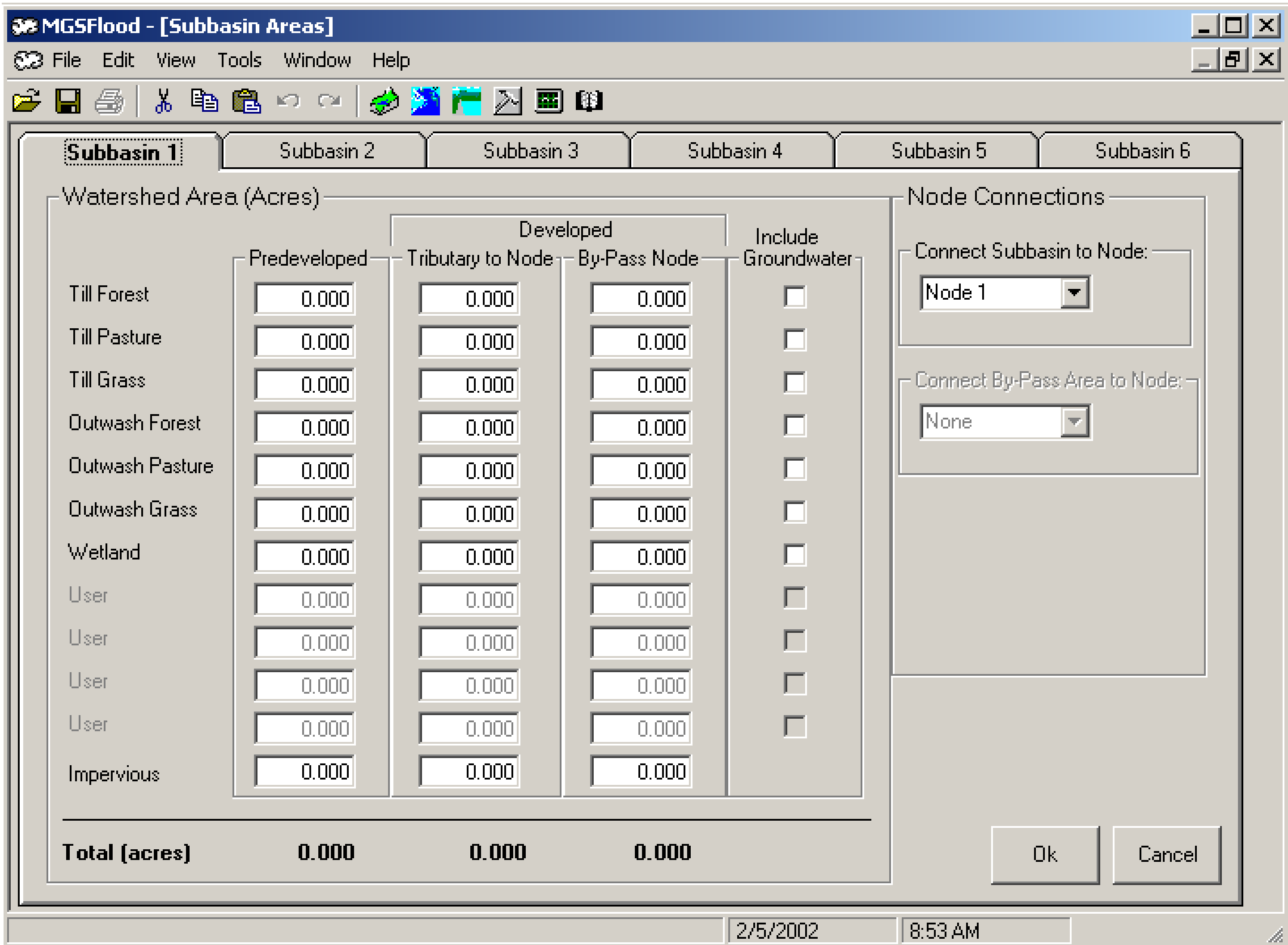

MGSFlood - [New Document]
File
Edit
View
Tools
Window
Help
Project Information
Project Name
Analysis Title
Comments
Climate Region
Map...
1. Sea-Tac
Precipitation Station: SeaTac
10/01/1948-10/01/1998
Evaporation Station: Puyallup
10/01/1948-10/01/1999
Precipitation Scale Factor
24 Hr, 25-Yr Precip (Tenths of inch)
30.0
Precip File: 30.0
User Defined Climate File
File...
User Defined Climate File
Precipitation Dataset
Evaporation Dataset
Runoff Parameter Region
Map...
1. USGS Default
HSPF Parameters
Open...
Pond Design Sequence
Project Location
Watershed Layout
Compute Runoff
Pond Design
Tools
Graphs
2/1/2002
12:08 PM

MGS Flood

Subbasin/Runoff Node Relationship (Simple Example)



Land Use Input Screen



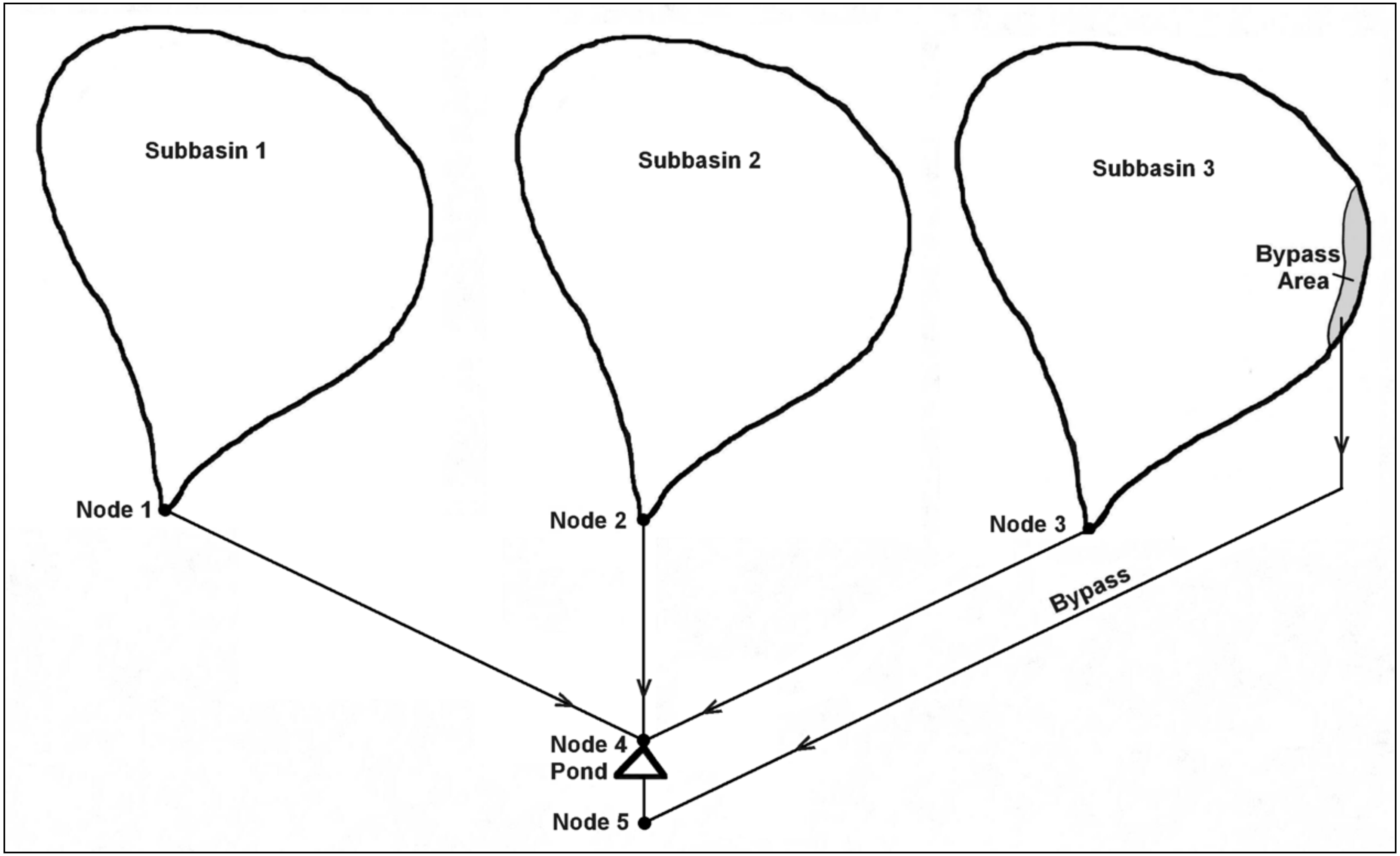
Relationship Between SCS Hydrologic Group and Continuous Model Soil/Geologic Group

SCS Hydrologic Soil Group	MGSFlood HSPF Soil/Geologic Group
A/B	Outwash
C	Till
D	Wetland

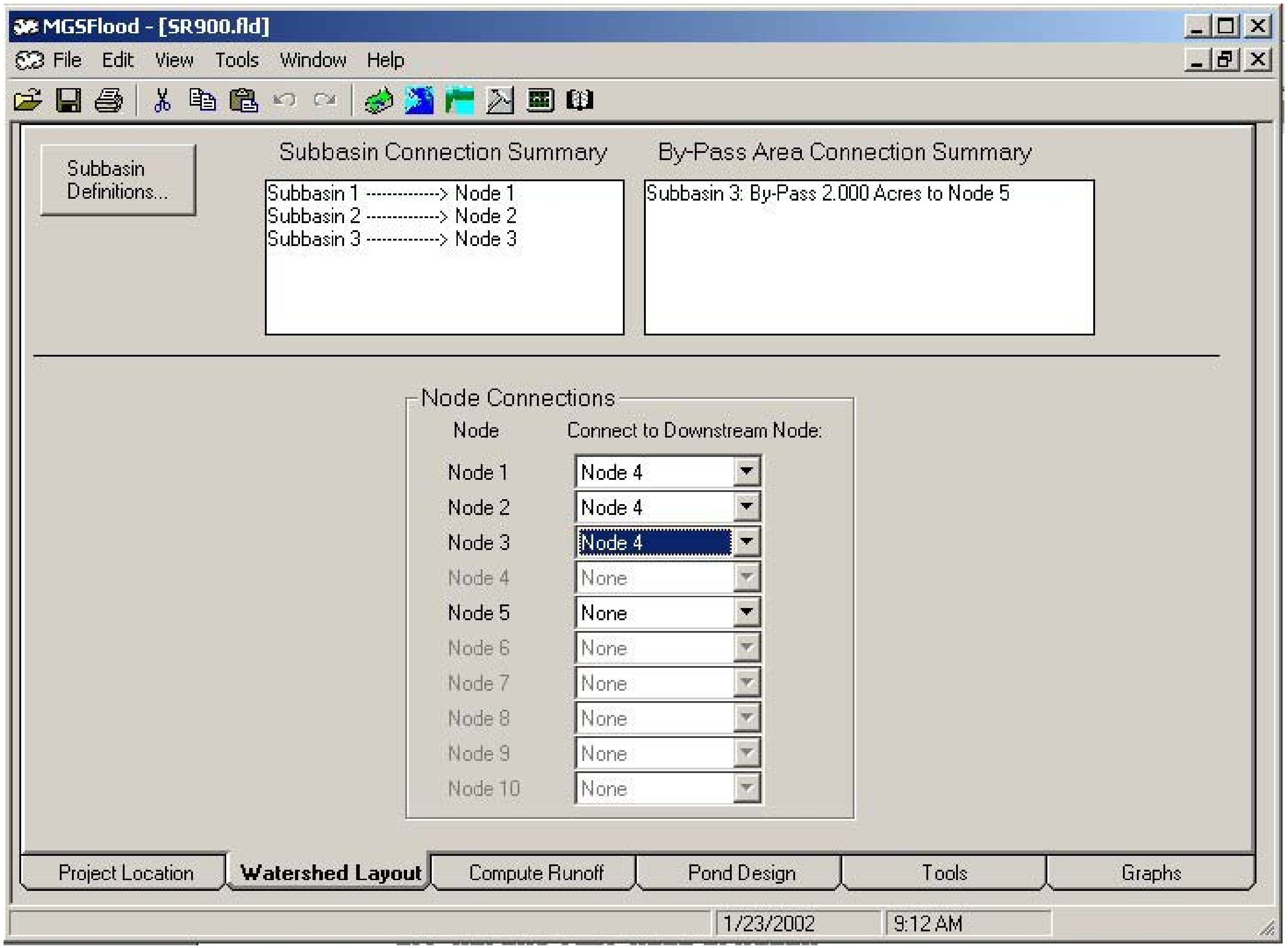
Continuous Model Runoff Parameters were Developed by the USGS (Report No. 89-4052) based on Geology of Puget Sound Lowlands

MGS Flood

Subbasin and Node Delineation,
Multiple Subbasin Example with Bypass

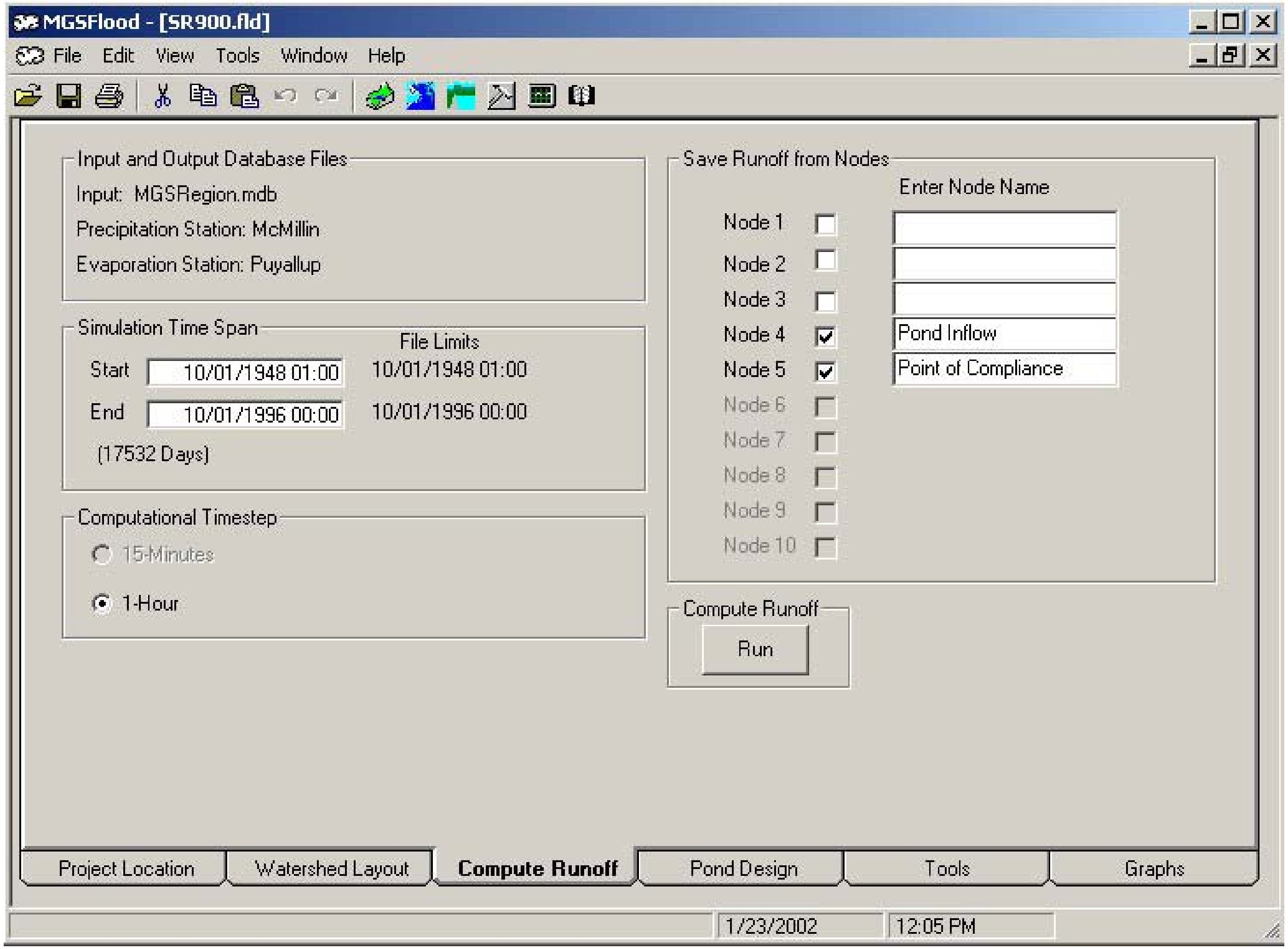


Watershed Layout Showing Node Connections



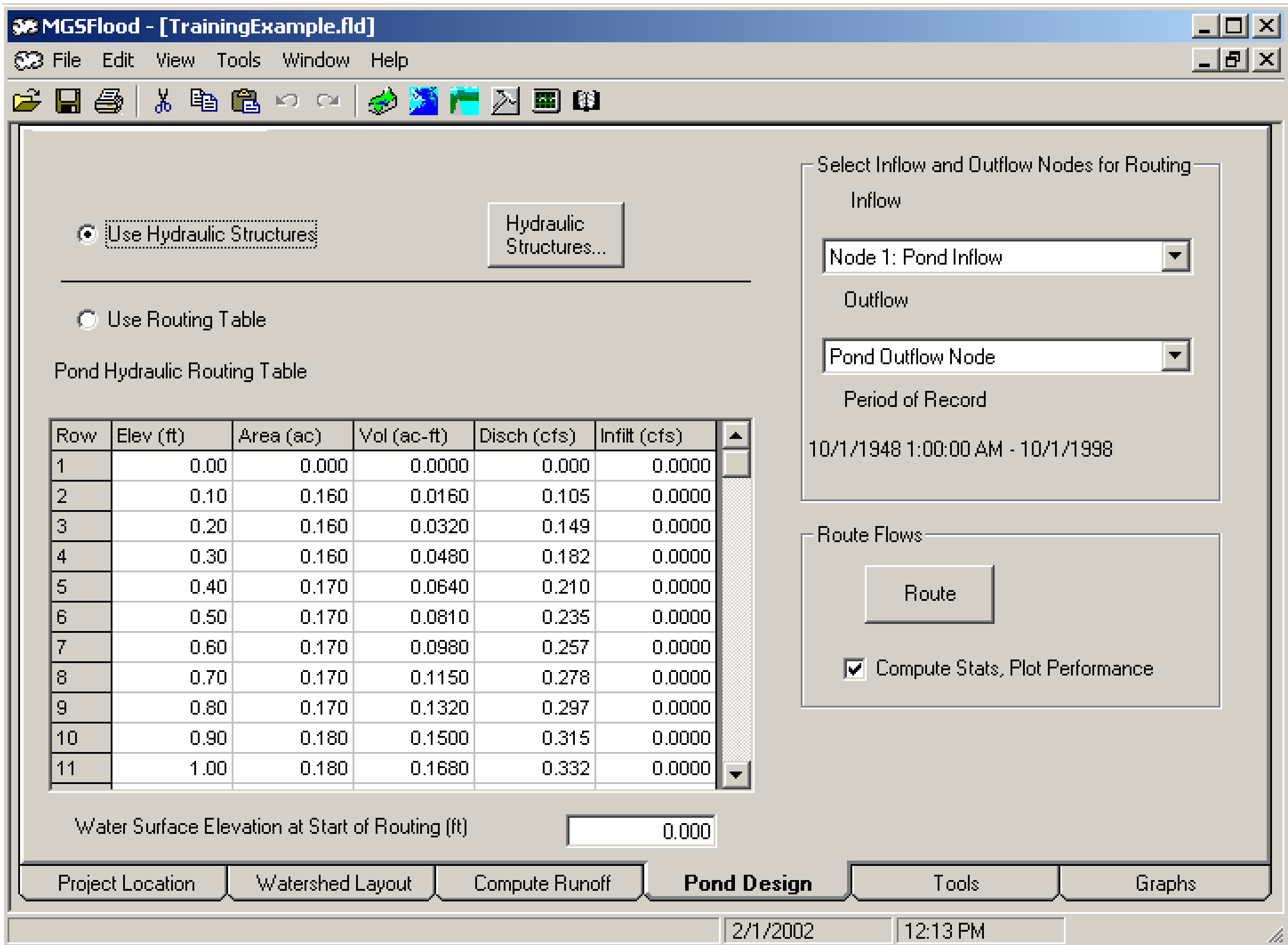
Runoff Computation Tab

Runoff from Nodes 4 and 5 Will be Saved

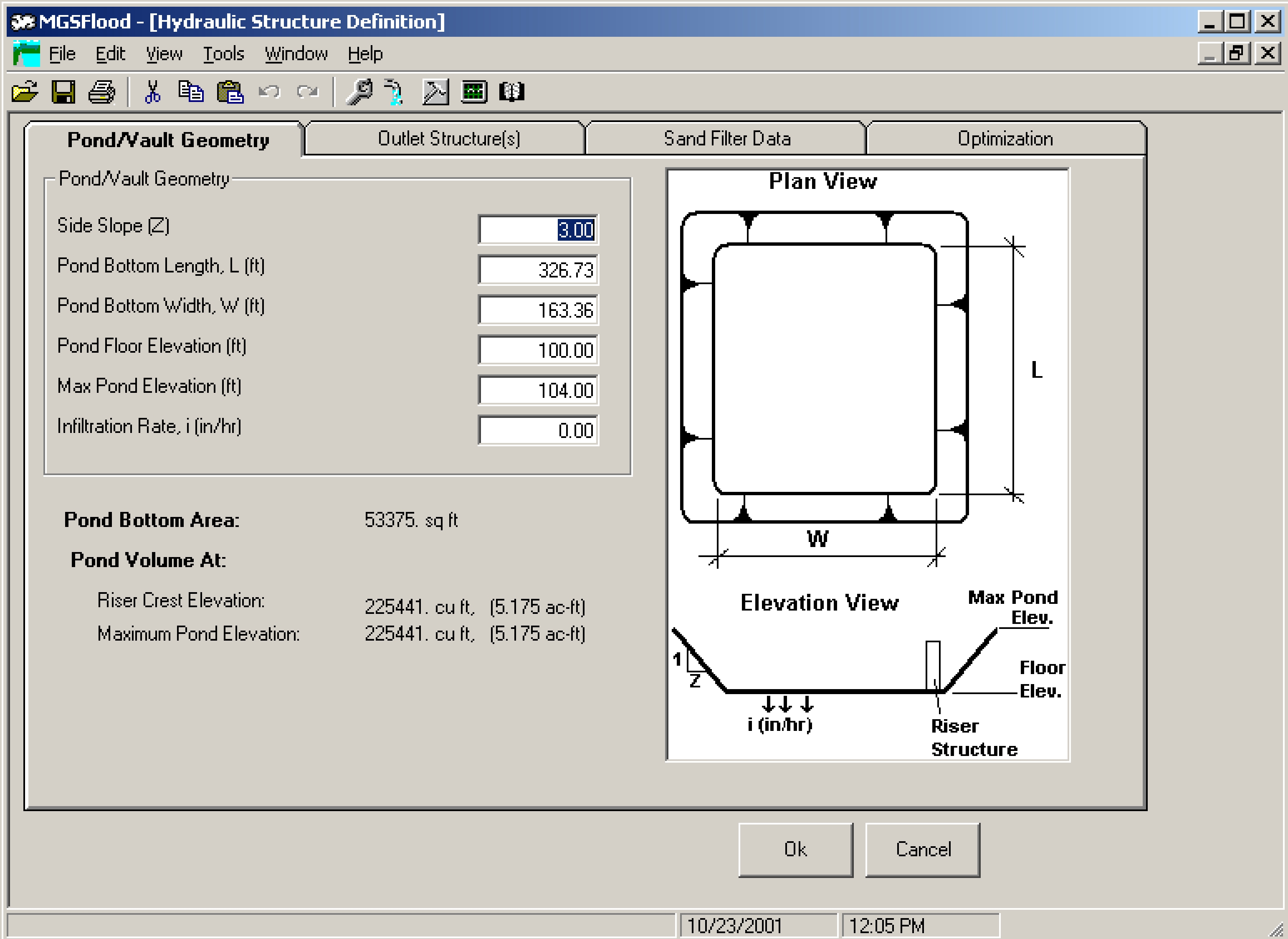


Pond Design Tab, 2-Options:

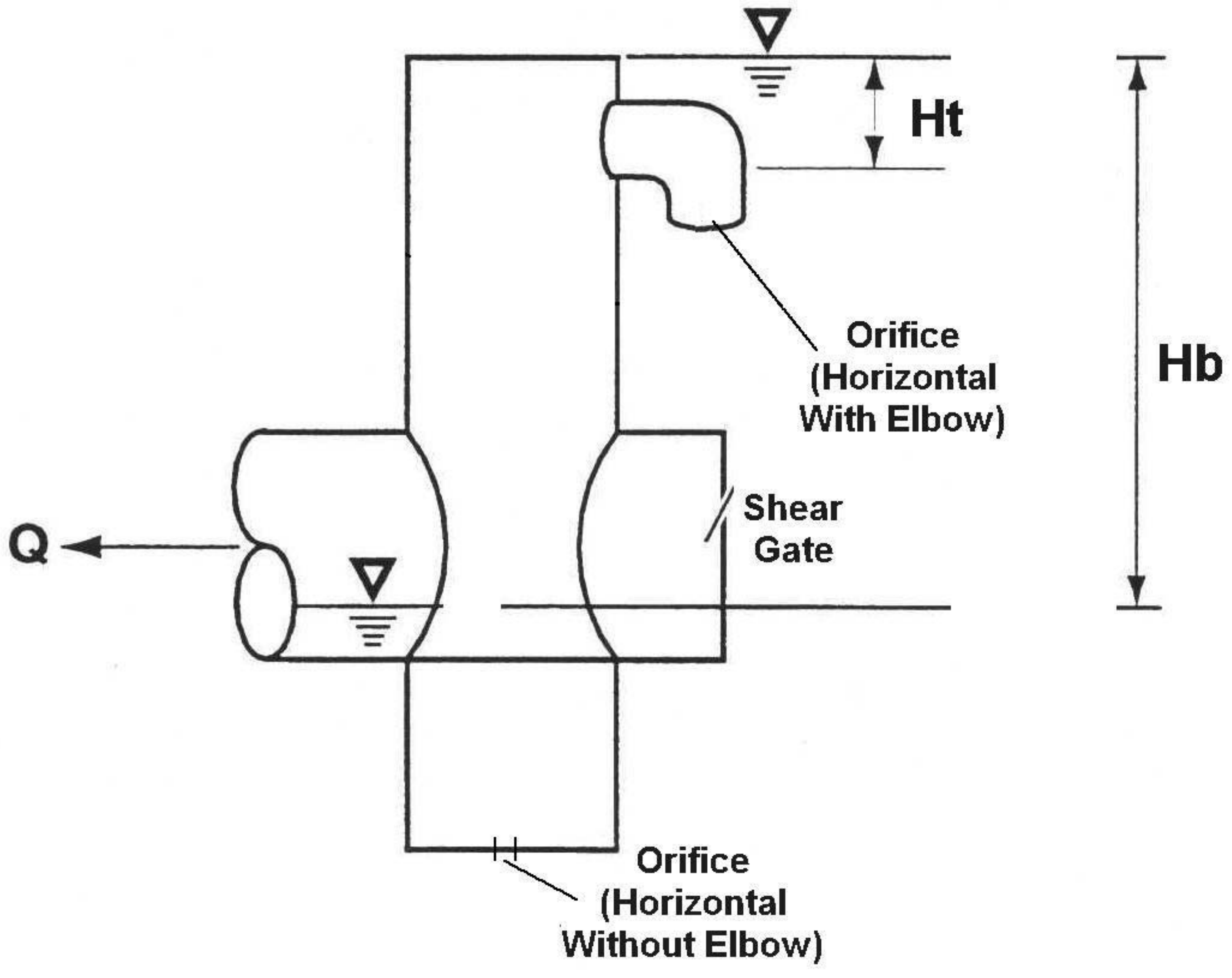
- Routing Table
- Hydraulic Structures/Optimization Routine (Proprietary)



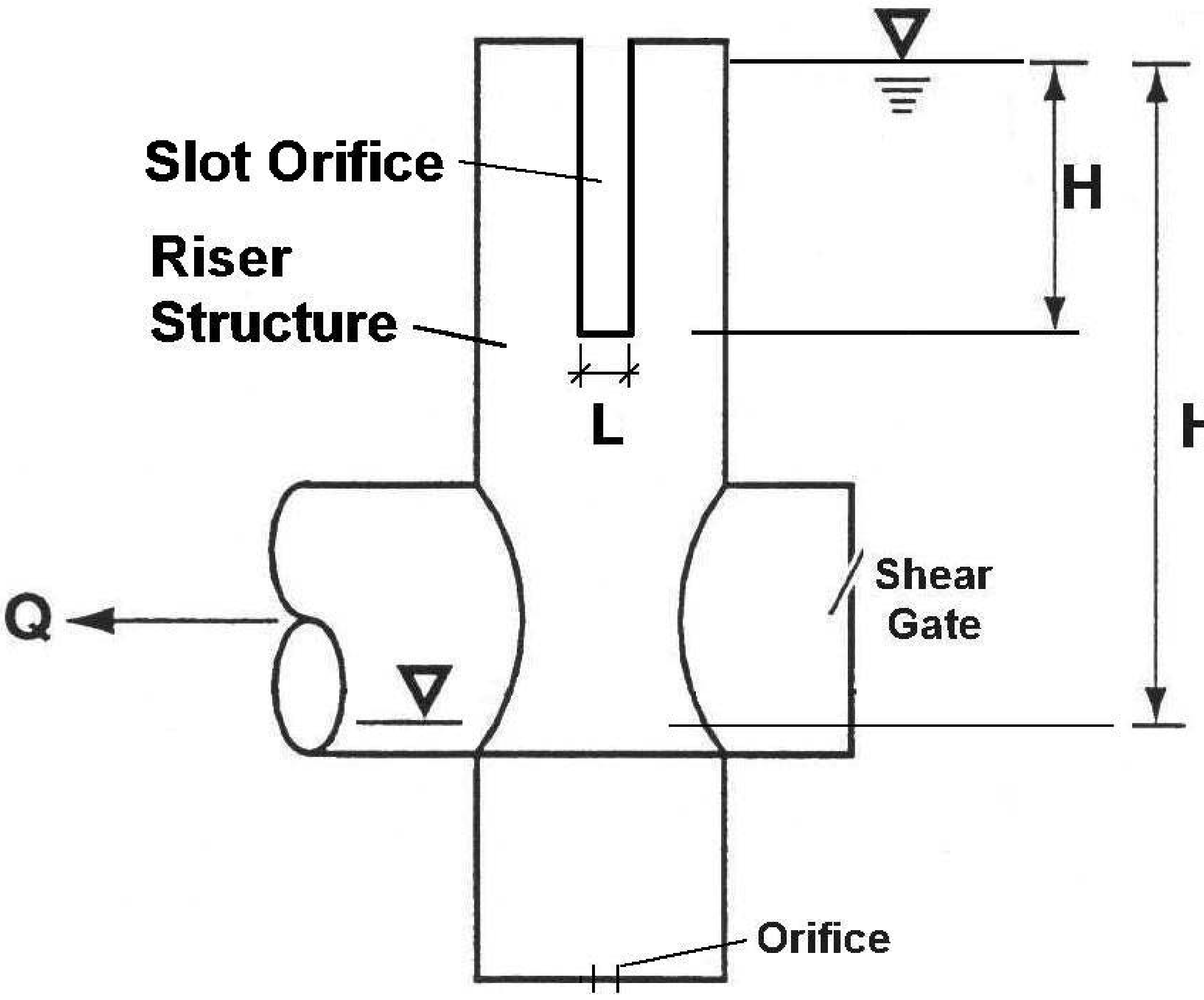
Hydraulic Structures Input Screen



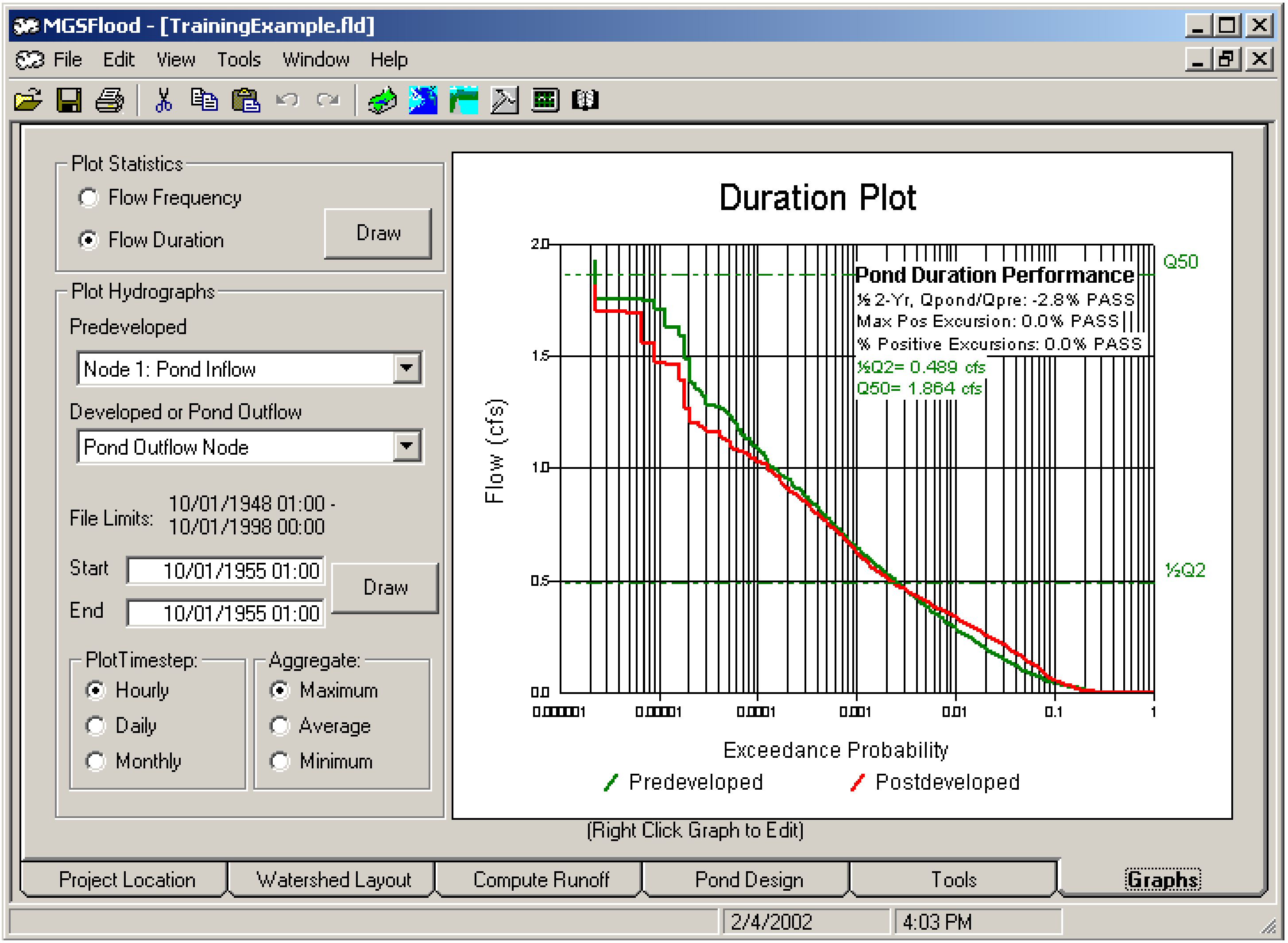
Typical Control Structure Geometry



Control Structure Geometry
Configuration used by Optimization Routine



Graphs Screen (Pond Performance Plot)

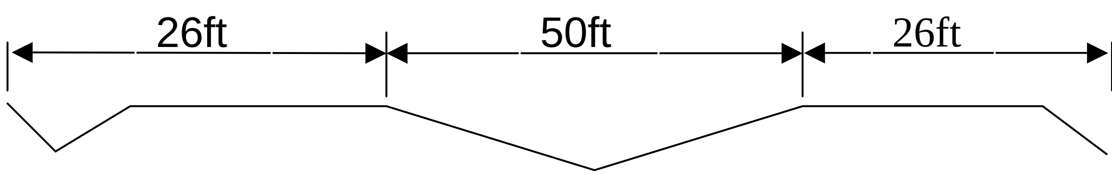


Roadway Widening Problem

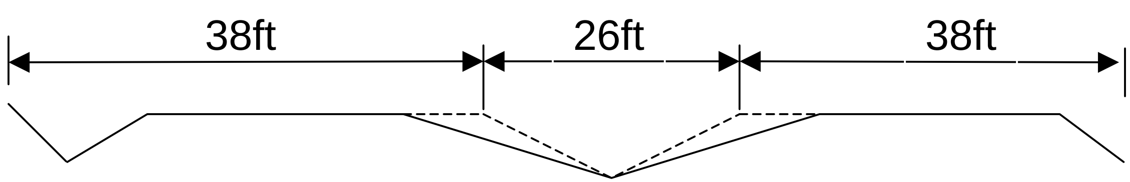
(More info in Notes)

- **Location: City of Des Moines, King County**
- **Add one lane in each direction to existing 2- lane road**
- **New lanes will be constructed on existing grass median**
- **1 acre of off-site forest land is captured by stormdrain system**

Size Stormwater Detention Pond According to Ecology's Flow Duration Standard



Existing



Proposed

Some Points Regarding Detention Requirements for Roads Projects

❖ New impervious surfaces are subject to flow control requirements if they exceed 5,000 sq. ft.

❖ The manual requires the assumption of forest as the pre-developed condition, unless the project proponent can verify that the pre-European settlement condition was prairie.

❖ Replaced impervious surfaces are subject to flow control if there are also new impervious surfaces on the project that will total 5,000 sq. ft. or more and total 50% or more of the existing impervious surfaces within the project limits.

❖ See pages 2-3 and 2-31 of Volume I of the Ecology Stormwater Manual