
Hydrology & Hydraulics
A Primer for
Floodplain and Stormwater Managers
presented by
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URS

Definition of Hydrology

- **Webster's dictionary: "The science dealing with the properties of water on the surface of the land, in the soil and underlying rocks, and in the atmosphere."**
- **For the purposes of this discussion: The quantity of water flowing in a stream, typically measured in cubic feet per second (cfs)**

Definition of Hydraulics

- **Webster's dictionary: "The branch of science that deals with practical applications of water in motion."**
- **The characteristics of water flow in a stream.**
- **Typically results in a water surface elevation data that can be plotted on a contour map to develop floodplain boundaries.**

Overview of Presentation

Hydrology

Hydraulics

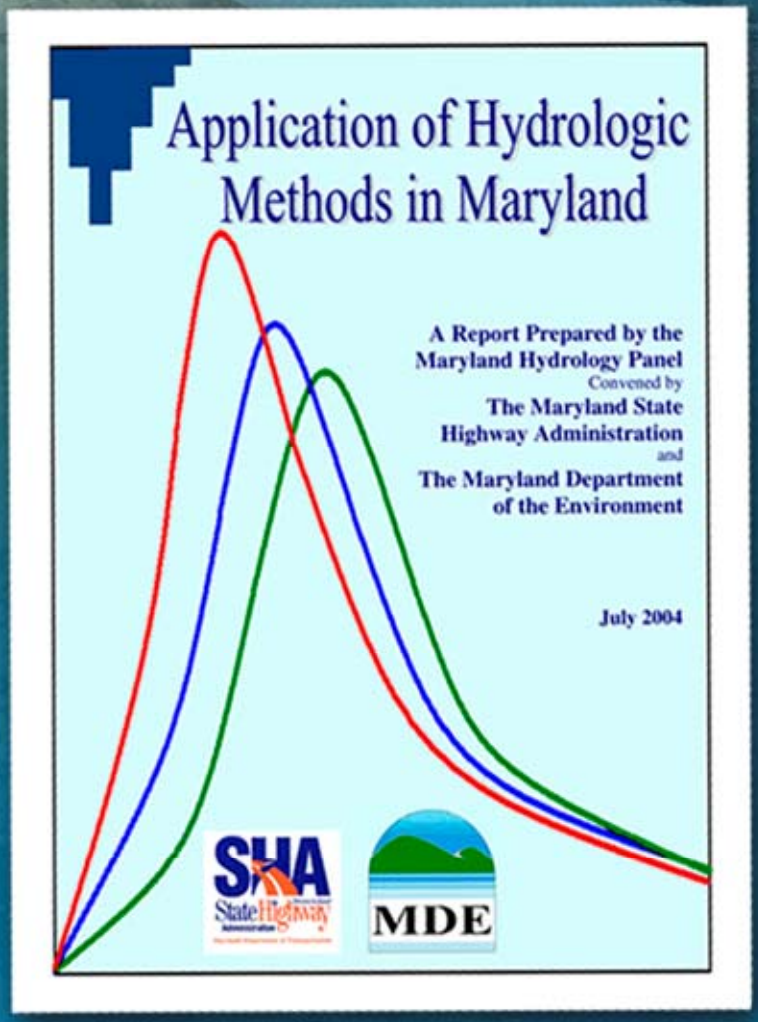
Hydrology

- Hydrologic Cycle
- Recurrence Intervals
- Hydrologic Methods
  - Rainfall-Runoff
  - Flood Flow Frequency Analyses for gaged streams
  - Regression analyses on ungaged streams

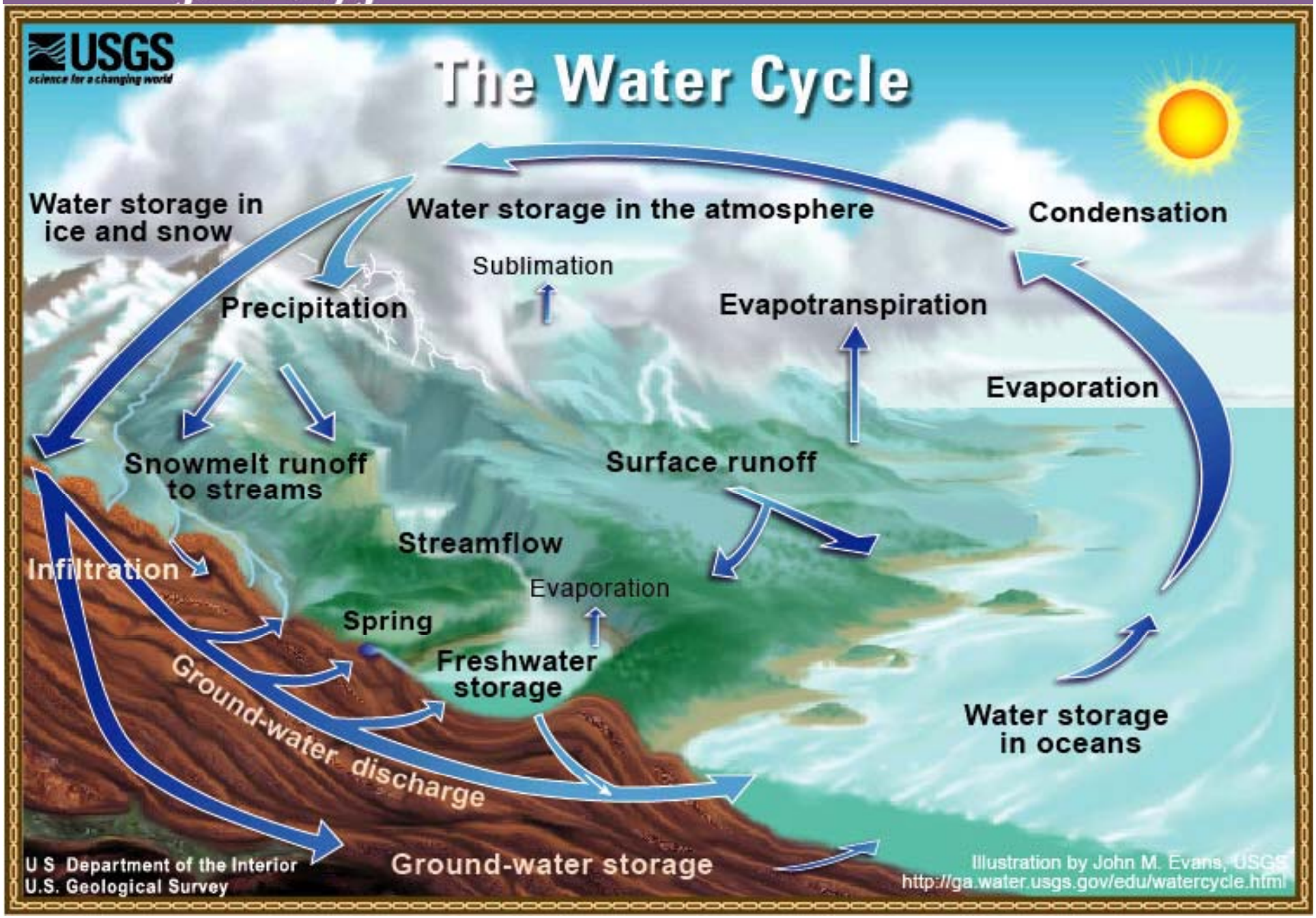
FEMA Guidelines

- **Hydrologic review procedures for Flood Insurance Studies are given in Guidelines and Specifications for Flood Hazard Mapping Partners**
  - **Appendix C: Guidance for Riverine Flooding Analyses and Mapping, pages C-12 to C-15**
- **http://www.fema.gov/fhm/dl_cgs.shtm**

State of Maryland



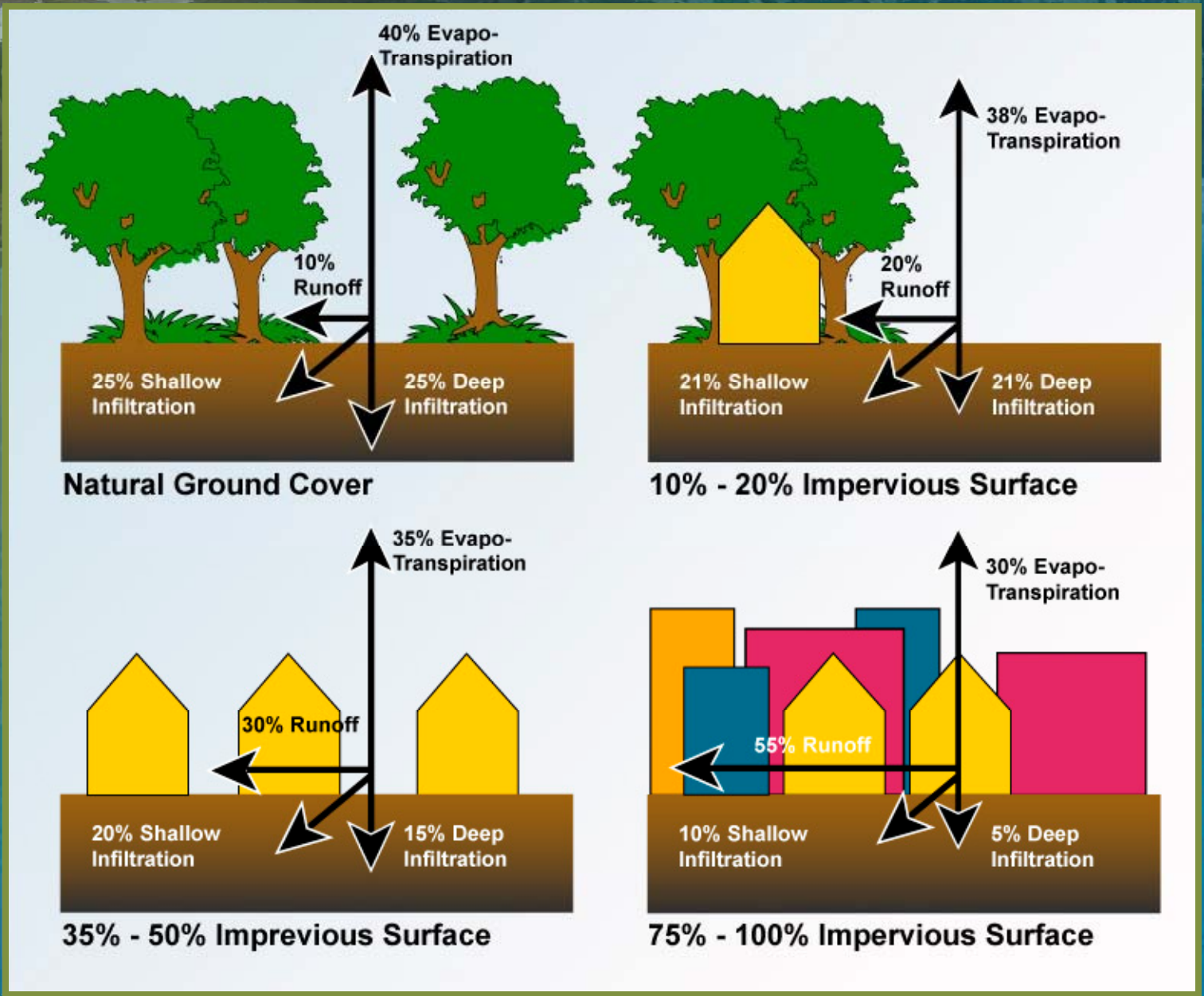
Hydrology


USGS
science for a changing world
The Water Cycle
Water storage in ice and snow
Water storage in the atmosphere
Condensation
Sublimation
Precipitation
Evapotranspiration
Evaporation
Snowmelt runoff to streams
Surface runoff
Streamflow
Infiltration
Evaporation
Spring
Freshwater storage
Ground-water discharge
Water storage in oceans
Ground-water storage
U S Department of the Interior
U.S. Geological Survey
Illustration by John M. Evans, USGS
http://ga.water.usgs.gov/edu/watercycle.html

Conditions That Affect the Hydrologic Cycle

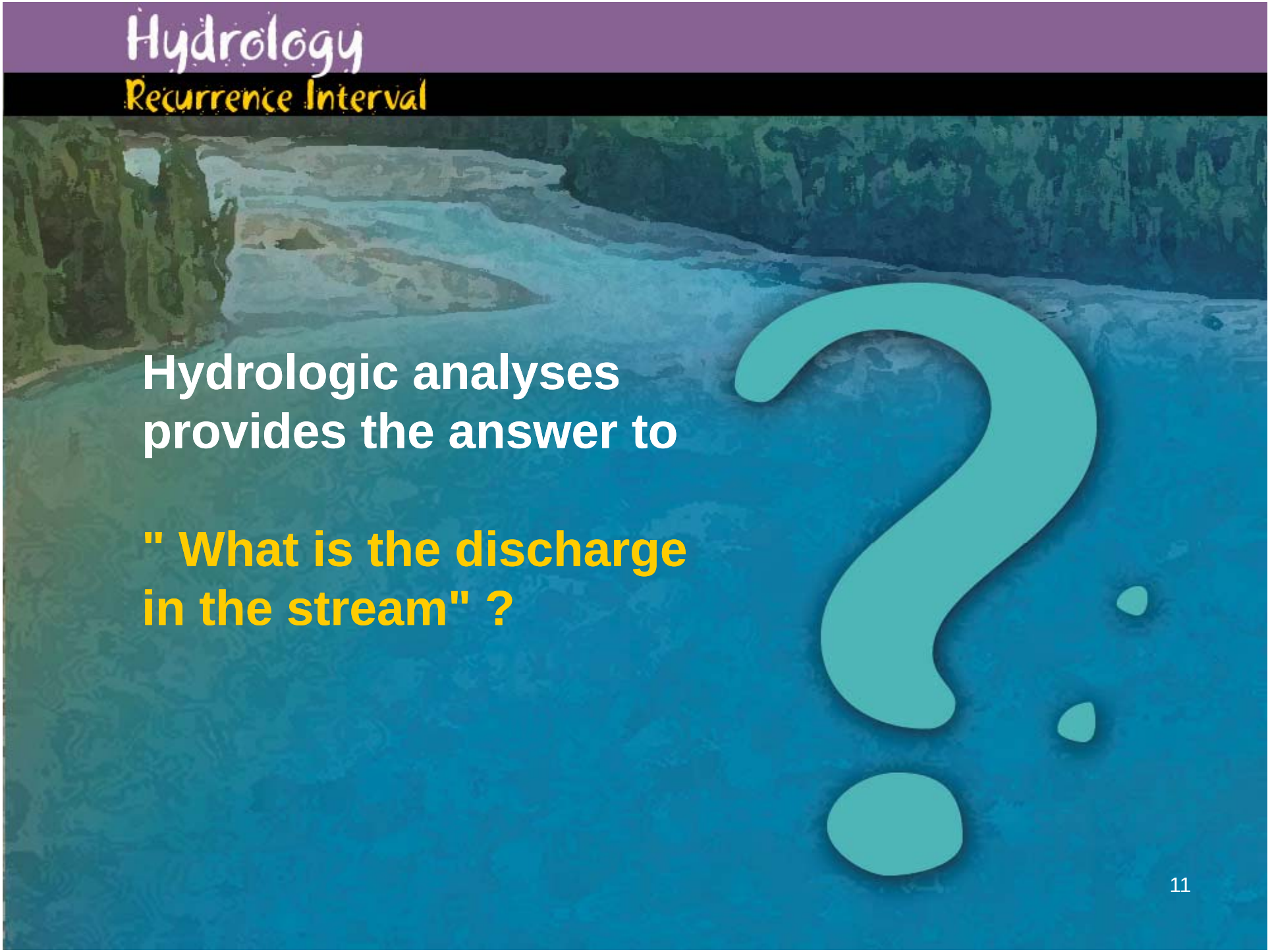
- **Land use**
  - **Land use type**
  - **Percent impervious**
- **Soils**
- **Land slope**
- **Drainage area**
- **Storage facilities (e.g., reservoirs, ponds)**

Hydrology


40% Evapo-Transpiration
10% Runoff
25% Shallow Infiltration
25% Deep Infiltration
Natural Ground Cover
38% Evapo-Transpiration
20% Runoff
21% Shallow Infiltration
21% Deep Infiltration
10% - 20% Impervious Surface
35% Evapo-Transpiration
30% Runoff
20% Shallow Infiltration
15% Deep Infiltration
35% - 50% Imprevious Surface
30% Evapo-Transpiration
55% Runoff
10% Shallow Infiltration
5% Deep Infiltration
75% - 100% Impervious Surface

Hydrology

Recurrence Interval



Hydrologic analyses provides the answer to

" What is the discharge in the stream" ?

Typical Recurrence Intervals

- **National Flood Insurance Program**
  - **10-, 50, -100-, 500-year storm event**
- **Storm Water Management**
  - **1-, 10-, 100-year storm event**

Hydrology

Recurrence Interval

Recurrence interval, in years	Probability of occurrence in any given year	Percent chance of occurrence in any given year
500	1 in 500	.2
100	1 in 100	1
50	1 in 50	2
25	1 in 25	4
10	1 in 10	10
5	1 in 5	20
2	1 in 2	50

Methods for Calculating Discharge

- **Rainfall-Runoff methods**
- **Flood Flow Frequency Analyses for gaged streams**
- **Regression analyses on ungaged streams**

Considerable variability in discharges using different hydrologic methods

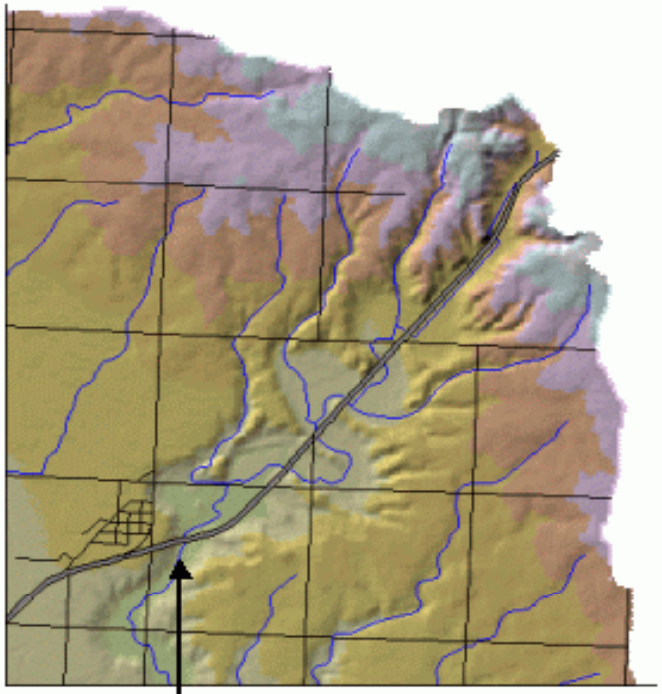
Compilation of Equations to Estimate Flood Discharges Using:

- **Rainfall data**
- **Soils information**
- **Watershed characteristics**
- **Land use data**

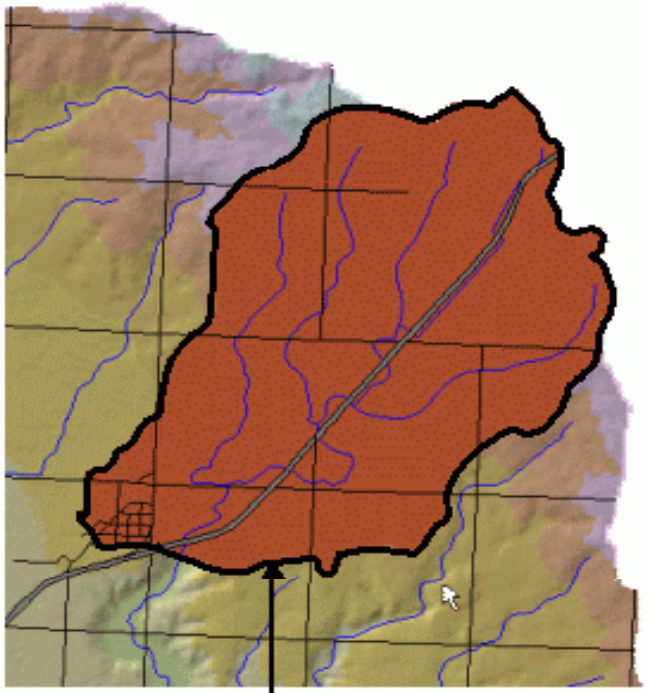
Rainfall-Runoff Models

- **The most widely used models are:**
  - **USACE HEC-1, HEC-HMS**
  - **NRCS (SCS) TR-20**
- **Common automated models**
  - **WISE, Watershed Concepts**
  - **GIS Hydro, University of MD**

Watershed Boundary Delineation



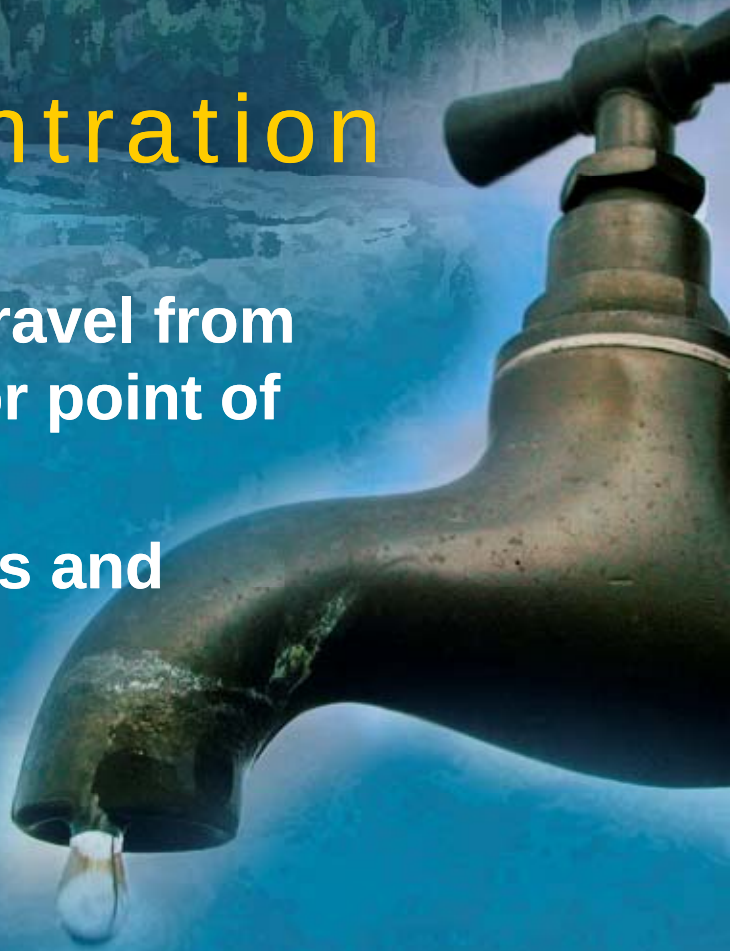
Watershed Outlet



Watershed Boundary

Time of Concentration

- **The time for drop of water to travel from the basin divide to the outlet or point of interest**
- **Computed based on “n” values and channel geometry**



Infiltration Losses

- **Initial loss is a function of antecedent conditions**
- **Infiltration during a storm is typically modeled using the Runoff Curve Number approach**

Determine Runoff Curve Number SCS Method

Land use and treatment or hydrology		Hydrologic soil group			
Practice	Condition	A	B	C	D
Fallow Straight Row	----	77	86	91	94
Row Crops Straight Row	Poor	72	81	88	91
Straight Row	Good	67	78	85	89
Contoured	Poor	70	79	84	88

Source: SCS, Urban Hydrology for Small Watersheds, TR-55

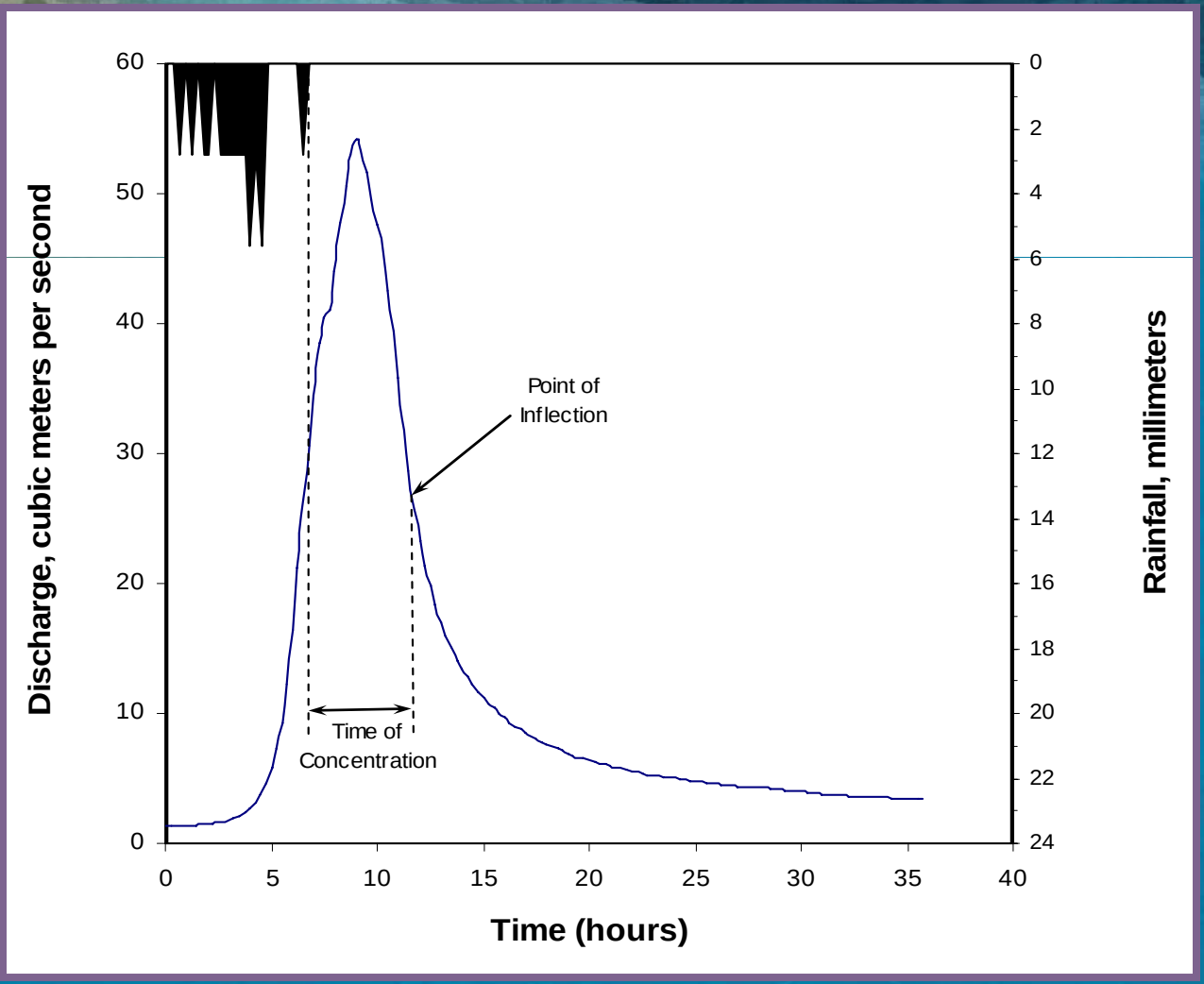
Rainfall or Precipitation Input

- **Total storm depth and frequency**
- **Time distribution**
- **Storm duration - varies from 2 to 24 hours**
- **Uniform rainfall over the watershed**

Conversion of Rainfall Excess to Runoff

- **Choice of using NRCS (SCS), Snyder, or Clark unit hydrograph**
- **Can vary peaking factor in NRCS or Snyder unit hydrograph methods**

Hydrograph Components



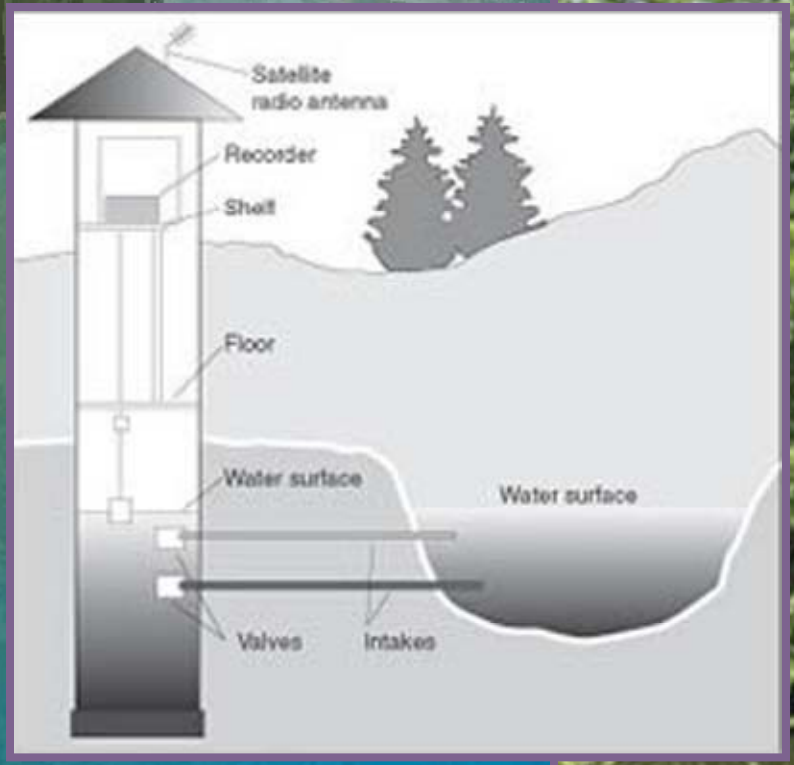
USGS Gaging Stations Collect:

- **Discharge**
- **Flow depth**
- **Rainfall**
- **Water temperature and chemistry data**

Web site for USGS gage data, including over 200 locations in MD: http://water.usgs.gov/nwis/sw

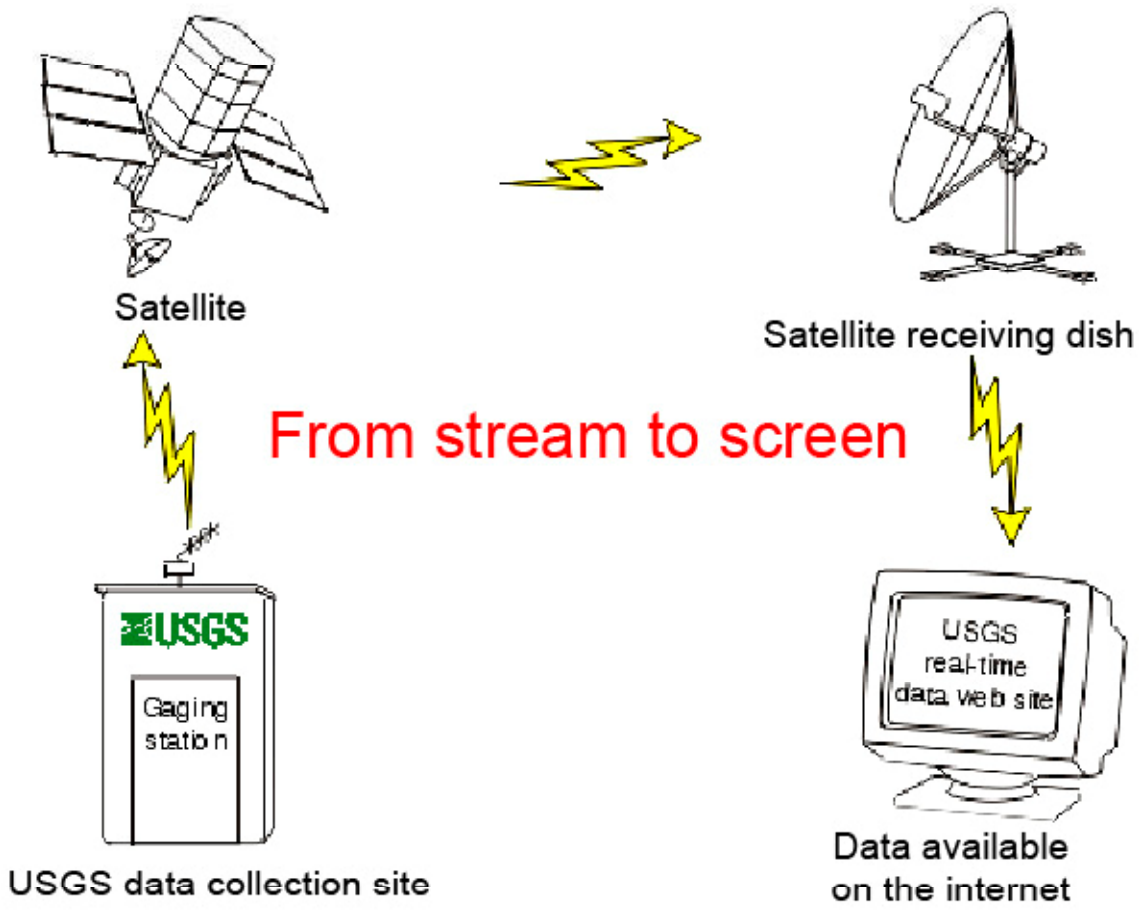
Hydrology

Gaged Streams



Hydrology

Gaged Streams



Considerations for Use of Gaging Data

- **Record length**
  - **Rule of thumb: rarest flood that can be predicted is double the period of record**
  - **Data are considered reliable when there is at least 30 years recorded**
- **Homogeneous watershed characteristics (e.g., land use changes due to development)**
- **Most accurate type of analysis if you have good data over a long period of time**

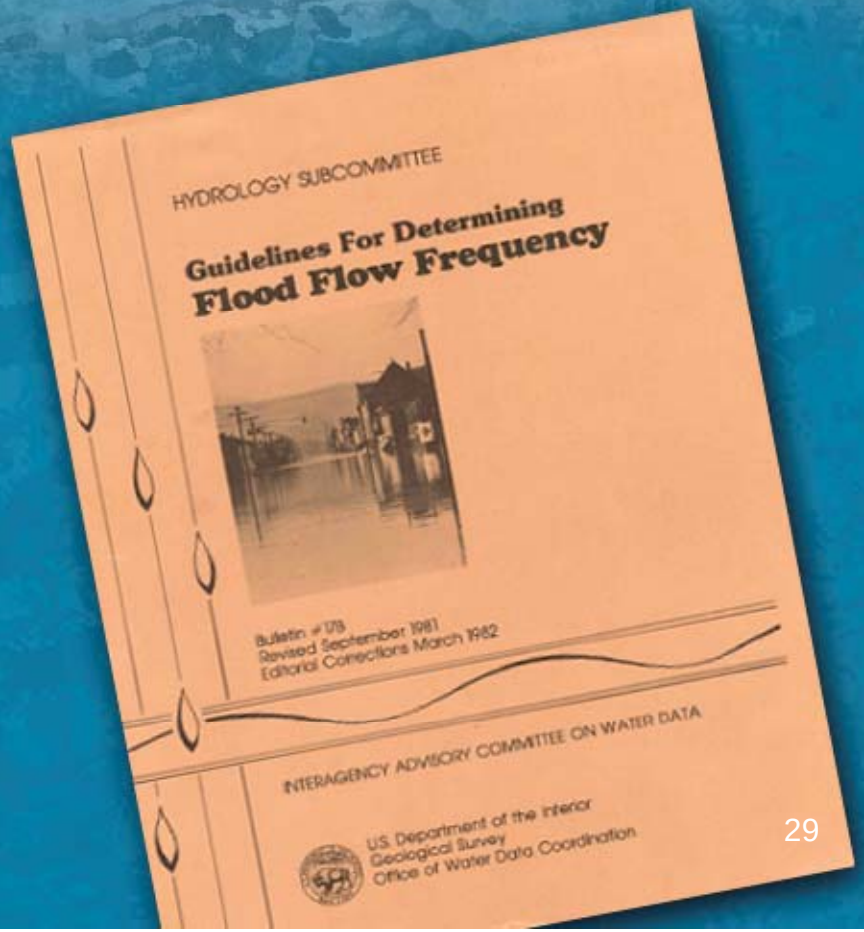
For Ungaged Locations on Gaged Streams

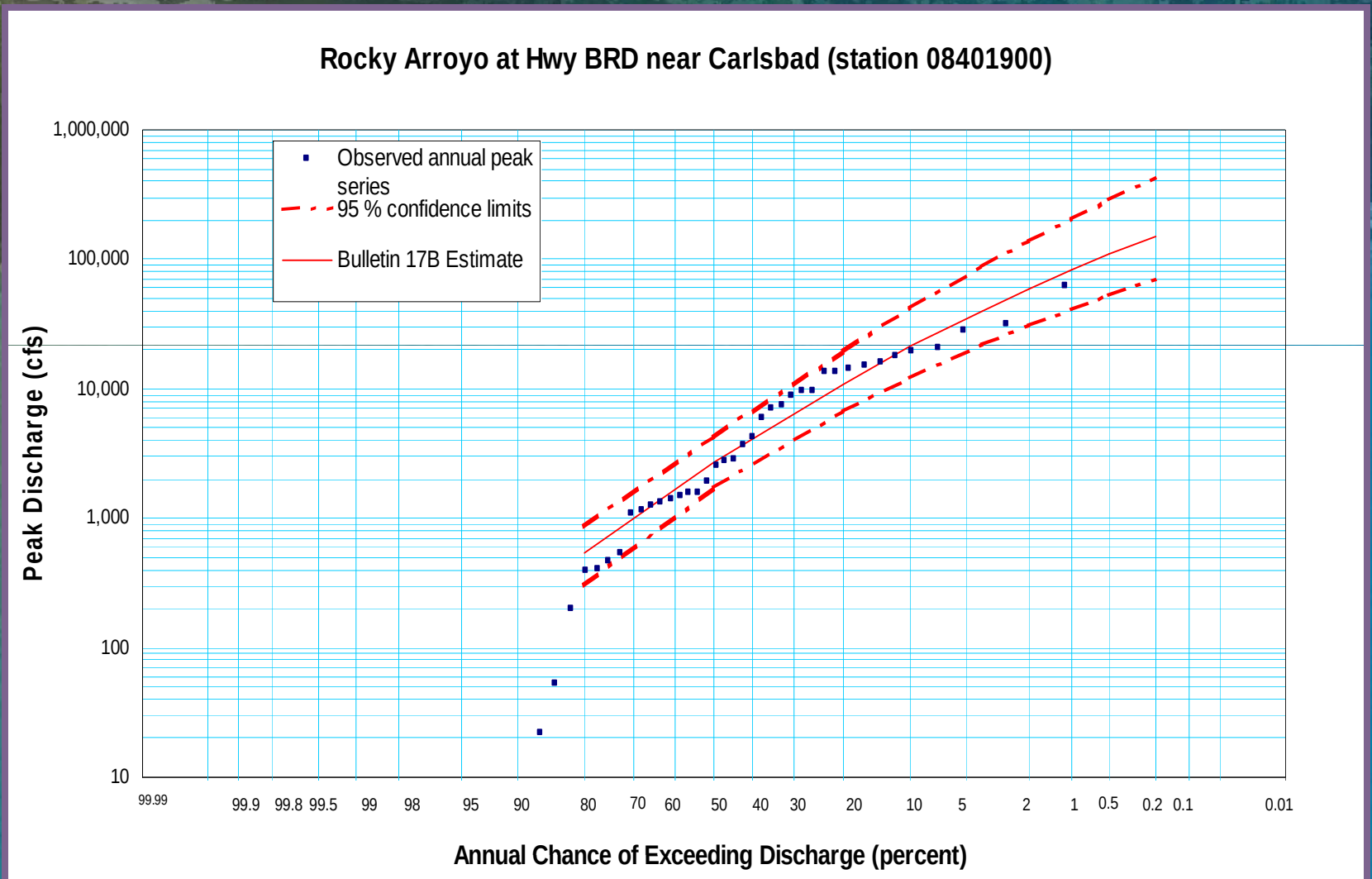
- Use data from gaged streams
- Conduct Flood Flow Frequency Analyses
- Procedures outlined in Bulletin 17B
  - Typically a ratio of drainage area
  - Applicable for areas within 50 and 200 percent of the drainage area at the gaging station
- Compare to results of regression analyses

Flood Flow Frequency Analysis

- **Methodology outlined in USGS Bulletin 17B**

Bulletin 17B Guidelines can be downloaded from FEMA's web site at:
http://www.floodmaps.fema.gov/pdfarchive/dl_flow.pdf




Rocky Arroyo at Hwy BRD near Carlsbad (station 08401900)
Observed annual peak series
95 % confidence limits
Bulletin 17B Estimate
Peak Discharge (cfs)
1,000,000
100,000
10,000
1,000
100
10
99.99
99.9
99.8
99.5
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.01
Annual Chance of Exceeding Discharge (percent)

Programs Typically Used

- **HEC-FAA Frequency Analyses – COE, 1992**
- **PEAKFQ Annual Flood Frequency Analyses Using Bulletin 17B Guidelines (USGS)**

Definition

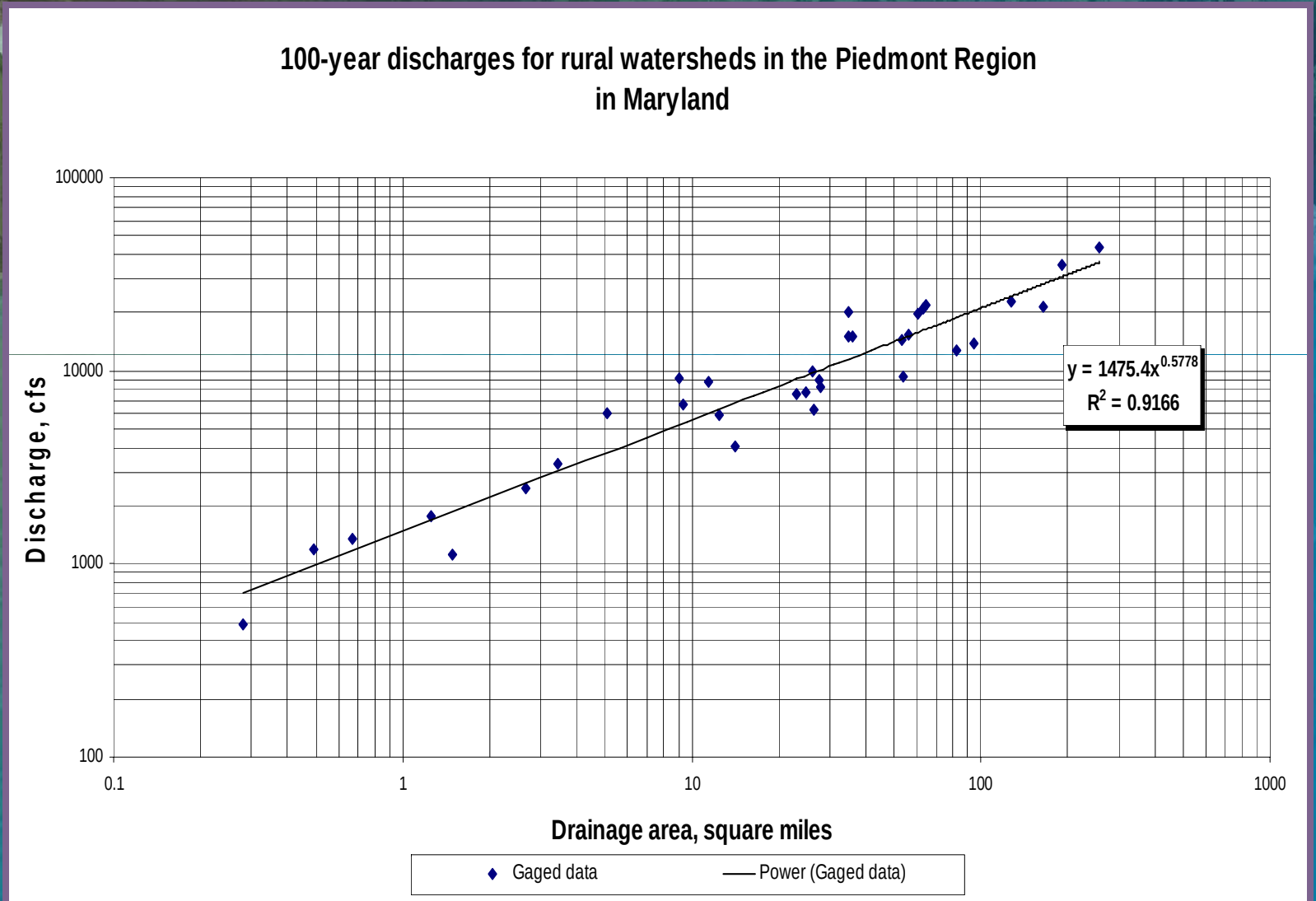
- **Regression analysis is a statistical tool for evaluating the relationship of one or more independent variables (continuous or discrete) to a single continuous dependent variable.**

Use of Regression in Hydrology

- **Regression analysis is used to relate flood discharges at gaging stations to watershed and climatic characteristics such as**
  - **Drainage area**
  - **Channel slope**
  - **Mean annual precipitation**

Hydrology

Regression Analysis

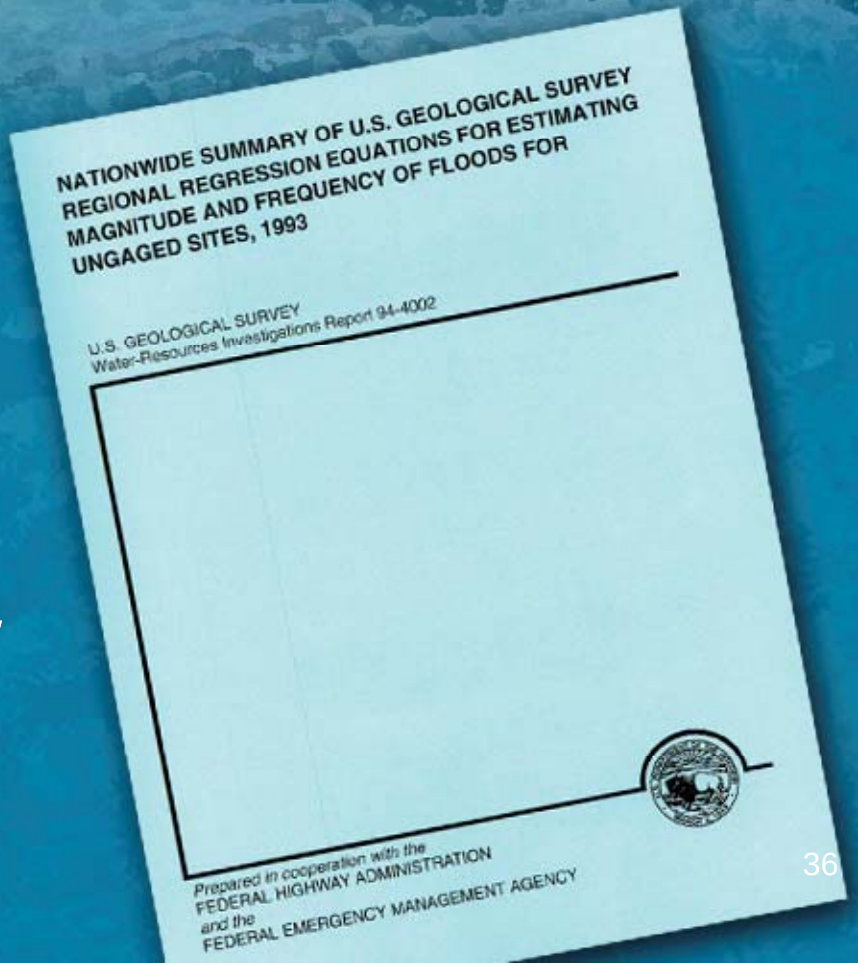


Regional Regression Equations

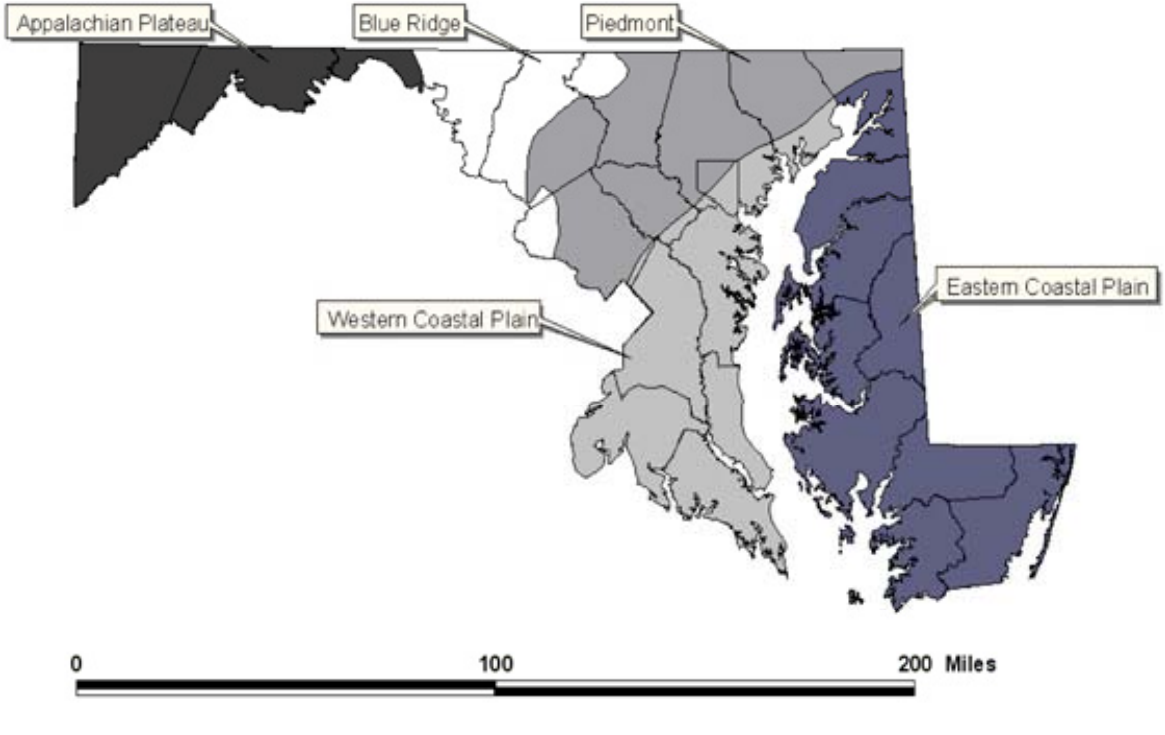
- **This method is recommended by:**
  - **State DOT's for design of bridges and culverts**
  - **FEMA**

USGS National Flood Frequency Program

- **In 1993, the USGS, compiled regression equations**
- **Version 3.2 of the NFF program, available since 2002**
  - **http://water.usgs.gov/software/nff.html**



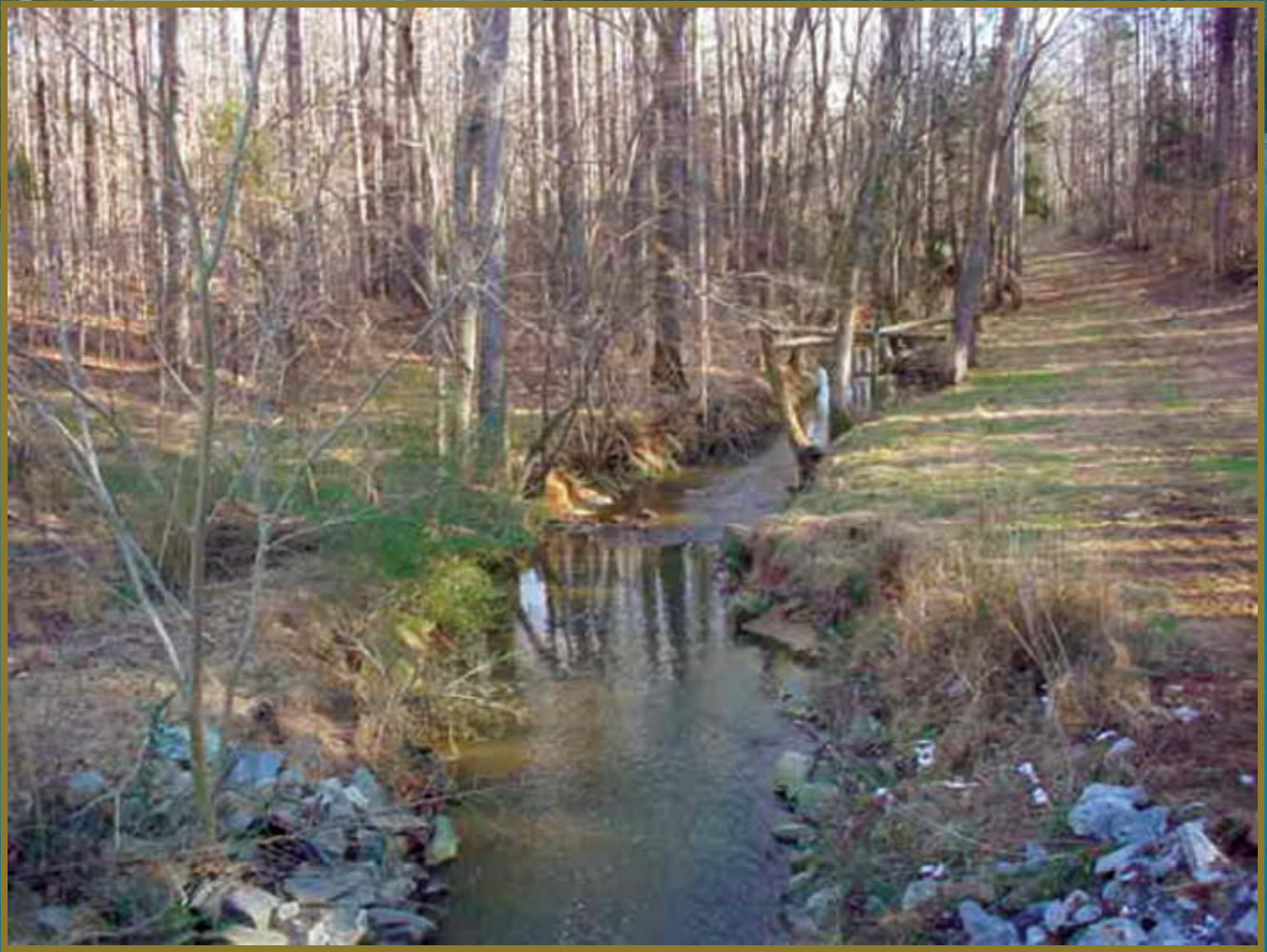
Maryland Regression Equations Developed for 5 Rgions



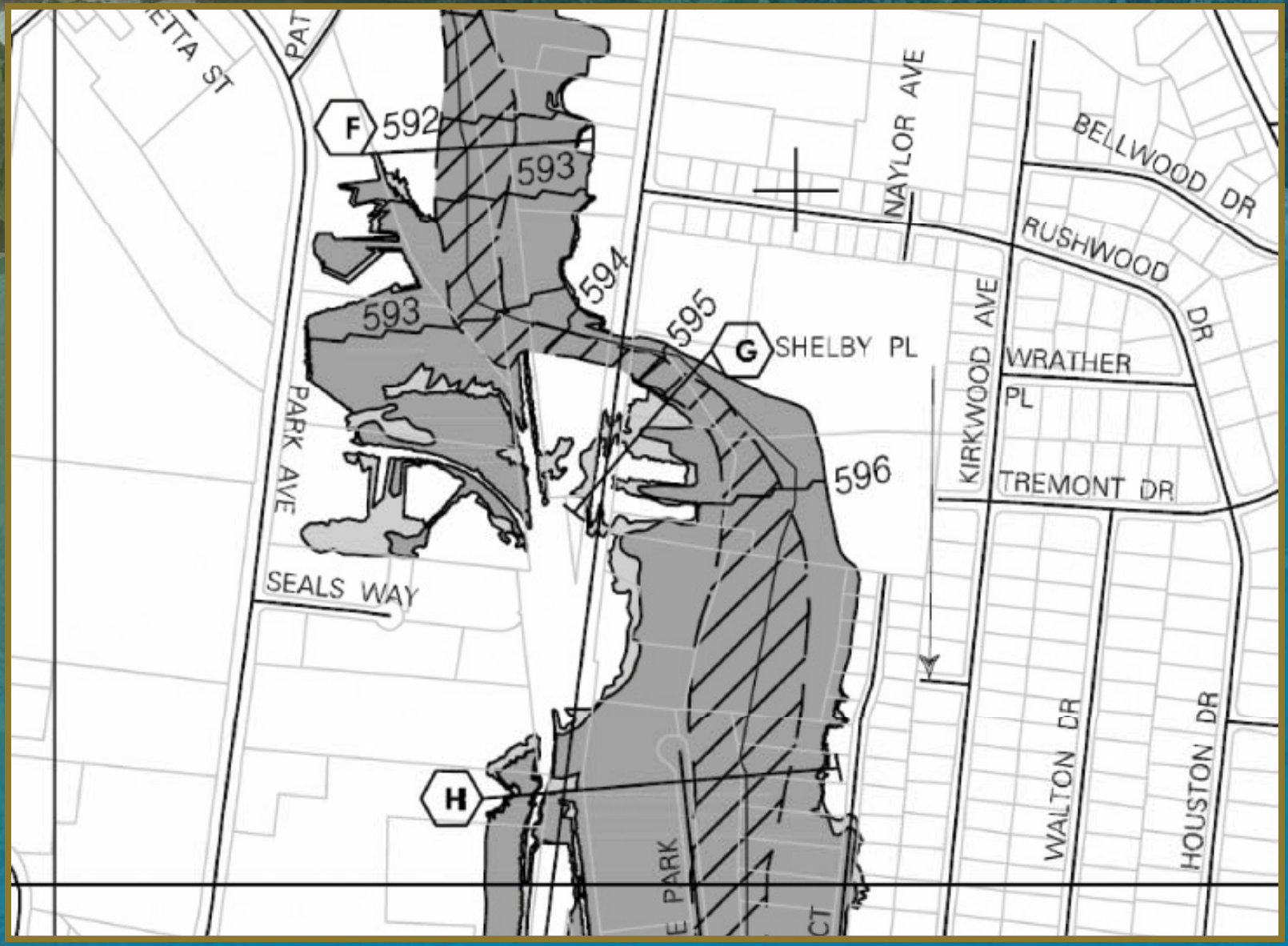
Hydraulics

- Choose analysis method
- Define input data & parameters
- Determine water surface elevations (WSELs)
- Define floodplain and floodway

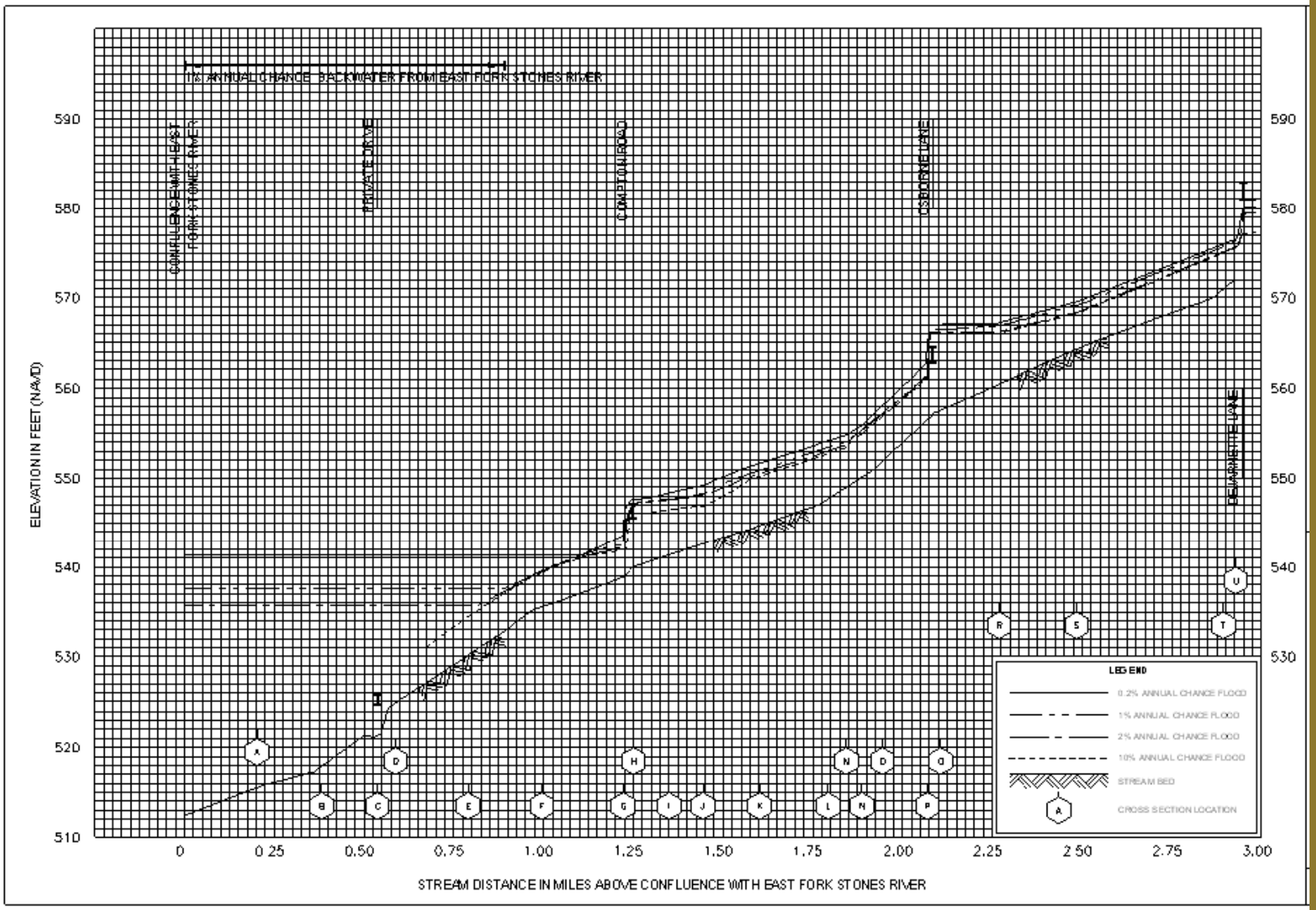
Hydraulics



Hydraulics


F
592
593
593
594
595
G
SHELBY PL
596
NAYLOR AVE
BELLWOOD DR
RUSHWOOD DR
KIRKWOOD AVE
WRATHER
PL
TREMONT DR
PARK AVE
SEALS WAY
H
WALTON DR
HOUSTON DR

Hydraulics


1% ANNUAL CHANCE BACKWATER FROM EAST FORK STONES RIVER
CONFLUENCE WITH EAST FORK STONES RIVER
PRIVATE DRIVE
CONCRETE ROAD
OSBORNE LANE
ELEVATION IN FEET (NAVD)
590
580
570
560
550
540
530
520
510
0
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
STREAM DISTANCE IN MILES ABOVE CONFLUENCE WITH EAST FORK STONES RIVER
LEGEND
0.2% ANNUAL CHANCE FLOOD
1% ANNUAL CHANCE FLOOD
2% ANNUAL CHANCE FLOOD
10% ANNUAL CHANCE FLOOD
STREAM BED
CROSS SECTION LOCATION

Hydraulics

Analysis Methods

- **Choose analysis method**
- **Define input data & parameters**
- **Determine water surface elevations (WSELs)**
- **Define floodplain and floodway**

- **Simplified or "Approximate" Methods**
  - **Manual Methods**
    - **Normal Depth Computations**
    - **FHWA Culvert Nomographs**
  - **Computer Methods**
    - **Quick-2**
    - **HY8**
- **Detailed Methods**
  - **Mathematical Models**

1-Dimensional

Steady Flow

- **Flow constant with time**
- **Single boundary condition**
- **Common Models:**
  - **HEC-RAS**
  - **HEC-2**
  - **WSPRO**

Unsteady Flow

- **Flow changes over time**
- **Multiple boundary conditions**
- **Common Models:**
  - **ICPR**
  - **SWMM**
  - **UNET**

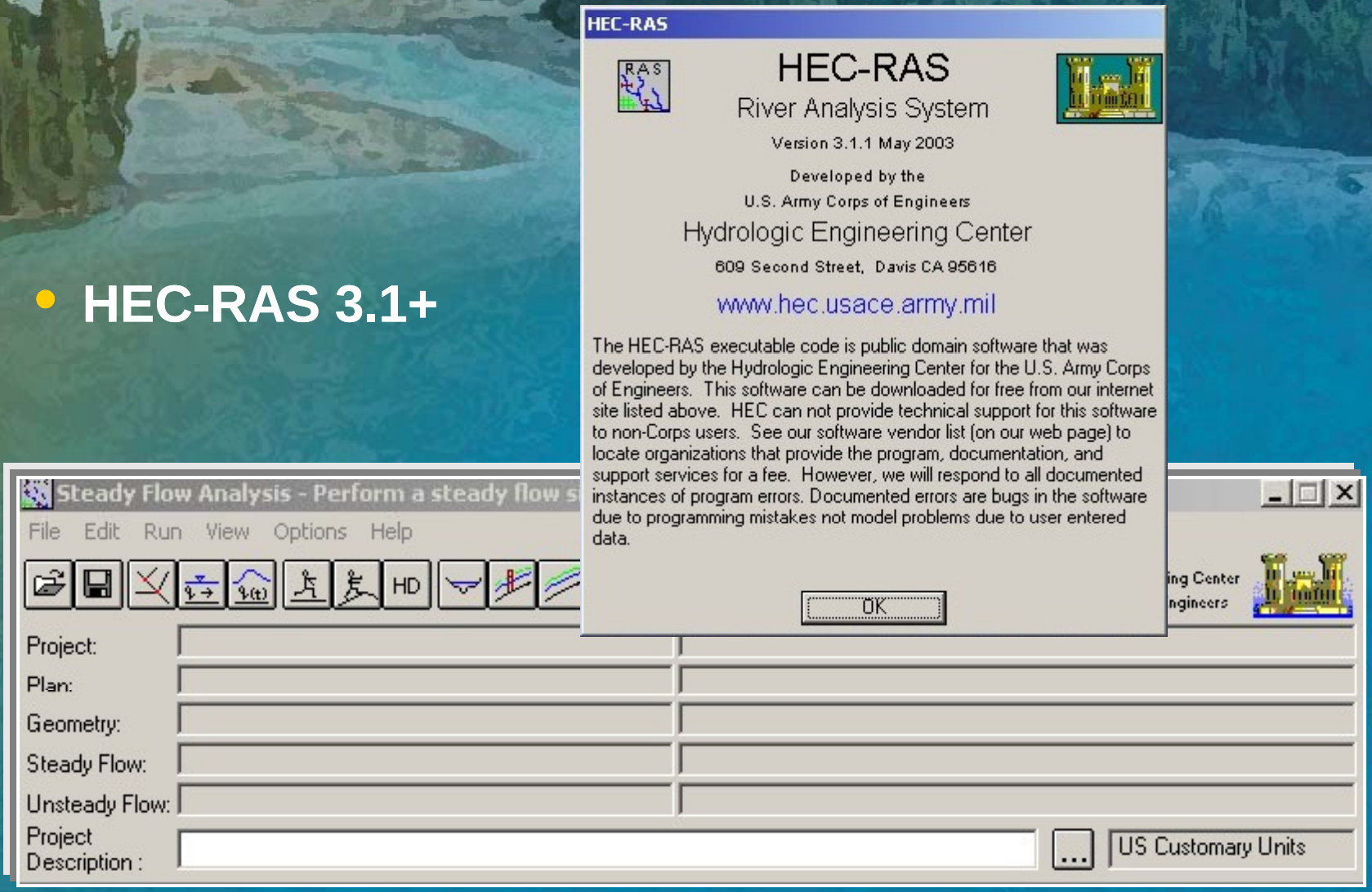
2-Dimensional Unsteady Flow

- **Flow changes over time**
- **Multiple boundary conditions**
- **Common Models:**
  - **FESWMS 2DH**
  - **FLO-2D**
  - **MIKE Flood**

Hydraulics

Analysis Methods

- **HEC-RAS 3.1+**



Hydraulics

Input Data

- Choose analysis method
- Define input data & parameters
- Determine water surface elevations (WSELs)
- Define floodway

Hydraulics

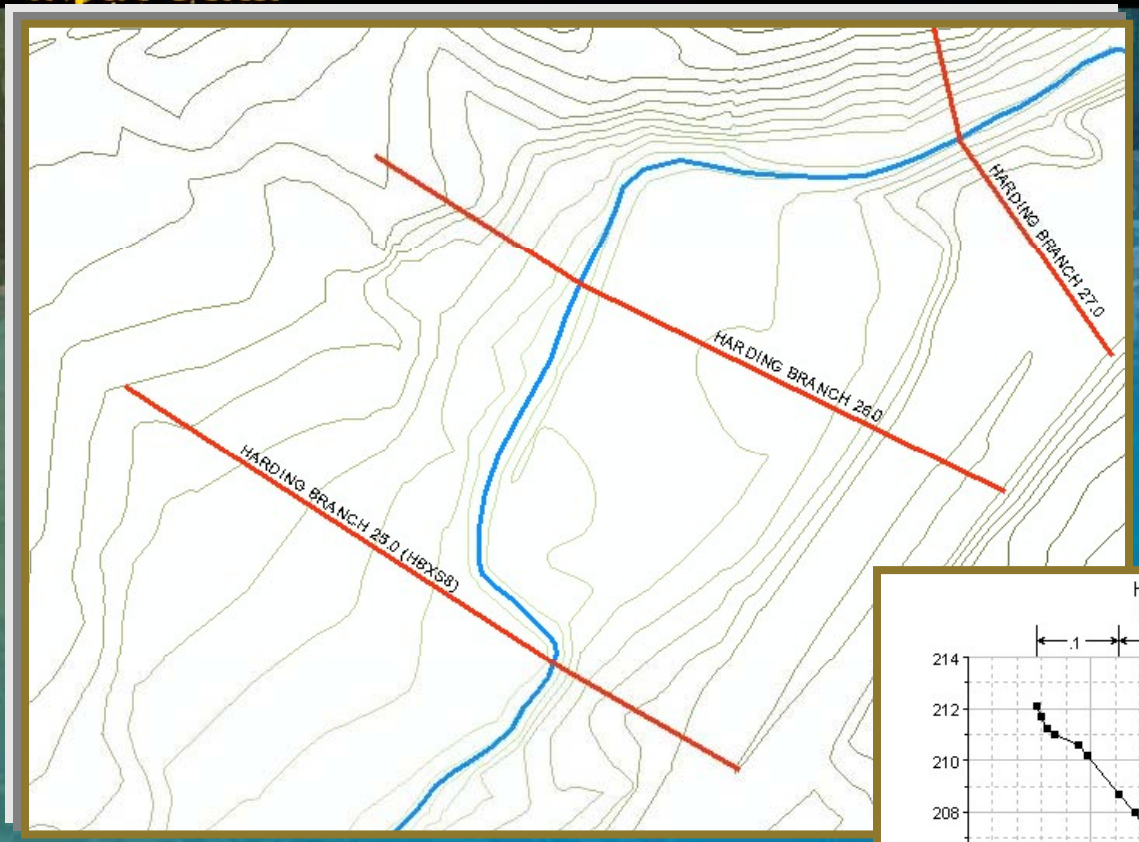
Input Data

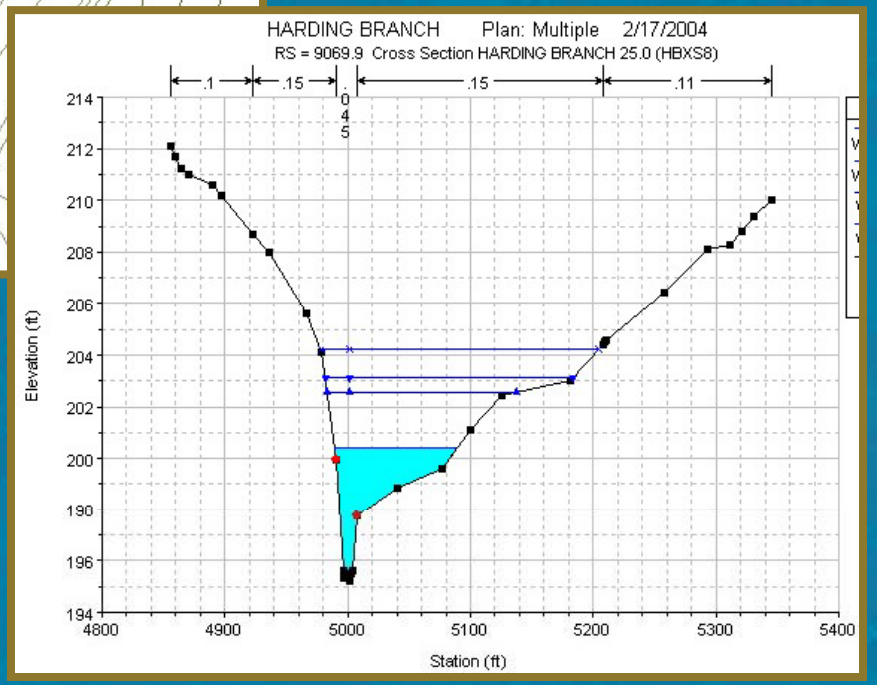
- Topography
  - Cross sections
- Coefficients
- Structures
  - Bridges, Culverts, Dams, Weirs
- Discharge (peak flows)
- Boundary conditions
- Calibration data, if available

- Cross Sections
  - Spacing
  - Orientation
  - Channel bank location
- Data Sources: Quads, GIS, Survey

Hydraulics

Input Data





Roughness Coefficients Manning's “n” values

- **Hydraulics reference books**
- **USGS Publications**
- **Table in HEC-RAS data editor**

Bridges, Culverts, Dams

- 4 cross sections needed for HEC-RAS

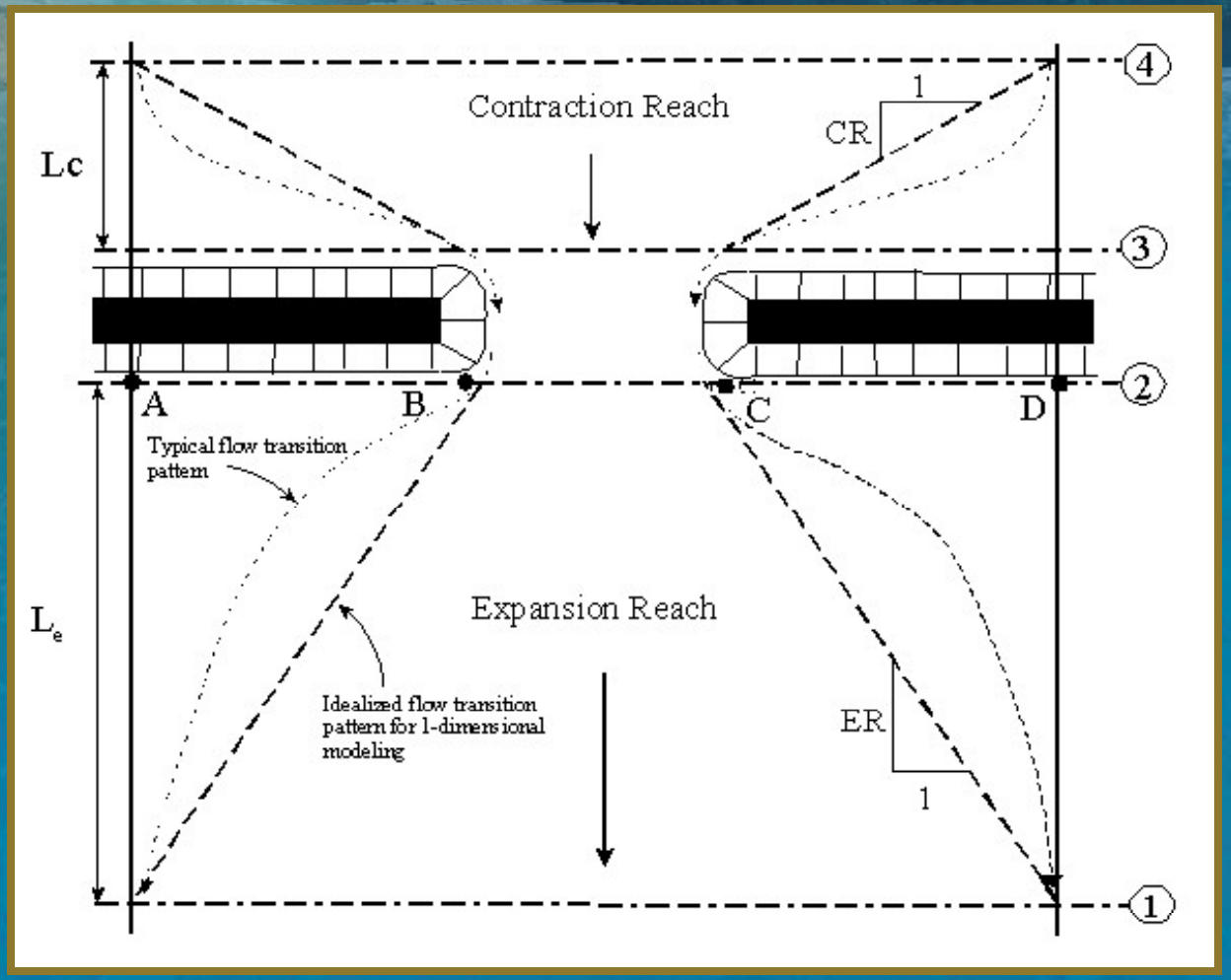


Figure from: Page 5-3, HEC-RAS River Analysis System, Hydraulic Reference Manual, Version 3.1, November 2002

Bridges, Culverts, Dams

- **Data Needed**
  - **Bridges**
    - **Opening, piers, rails, abutments, inverts**
  - **Culverts**
    - **Size, material, wingwalls/headwalls, inverts**
  - **Dams**
    - **Weir location & elevation, material, openings, if any**

Boundary Conditions

- **Starting Water-Surface Elevations**
  - **Known elevation, if tie-in necessary**
  - **Slope area method**
    - **Common for new studies**
    - **Computes normal depth given approximate slope**
    - **Estimate initial slope from channel slope**

Hydraulics

Determine WSELs

- Choose analysis method
- Define input data & parameters
- **Determine water surface elevations (WSELs)**
- Define floodway

Simulation Consists of:

- **Subcritical, step-backwater analysis**
- **Calibration**

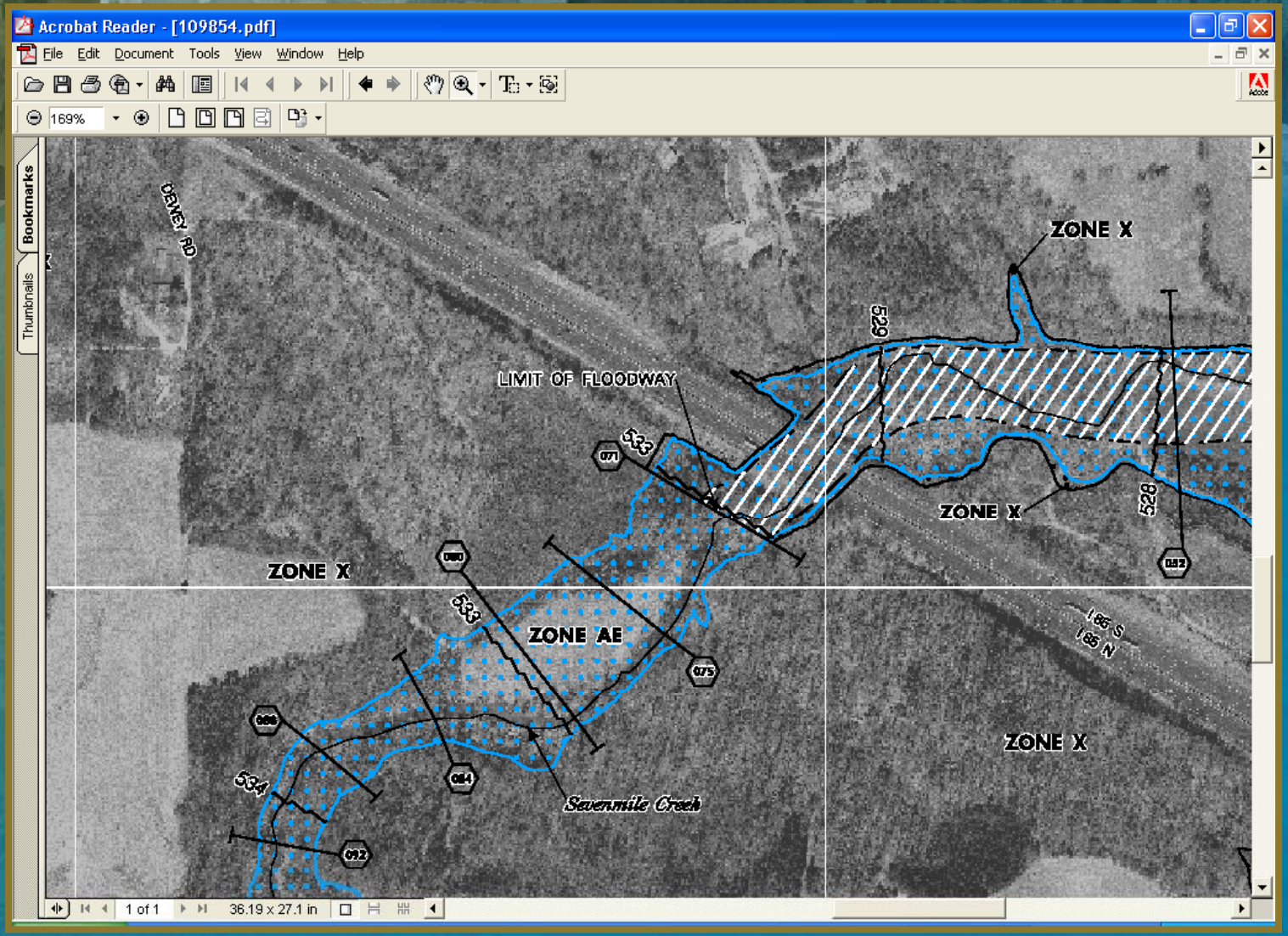
Calibration

- If data available
  - Adjust Manning's "n" values
  - Adjust ineffective flow areas in cross sections
- Computed WSELs must match HWMs within 0.5 foot
- Adjusted "n" values should not be outside range of published "n" values for the observed conditions

- Choose analysis method
- Define input data & parameters
- Determine water surface elevations (WSELs)
- **Define floodplain/floodway**

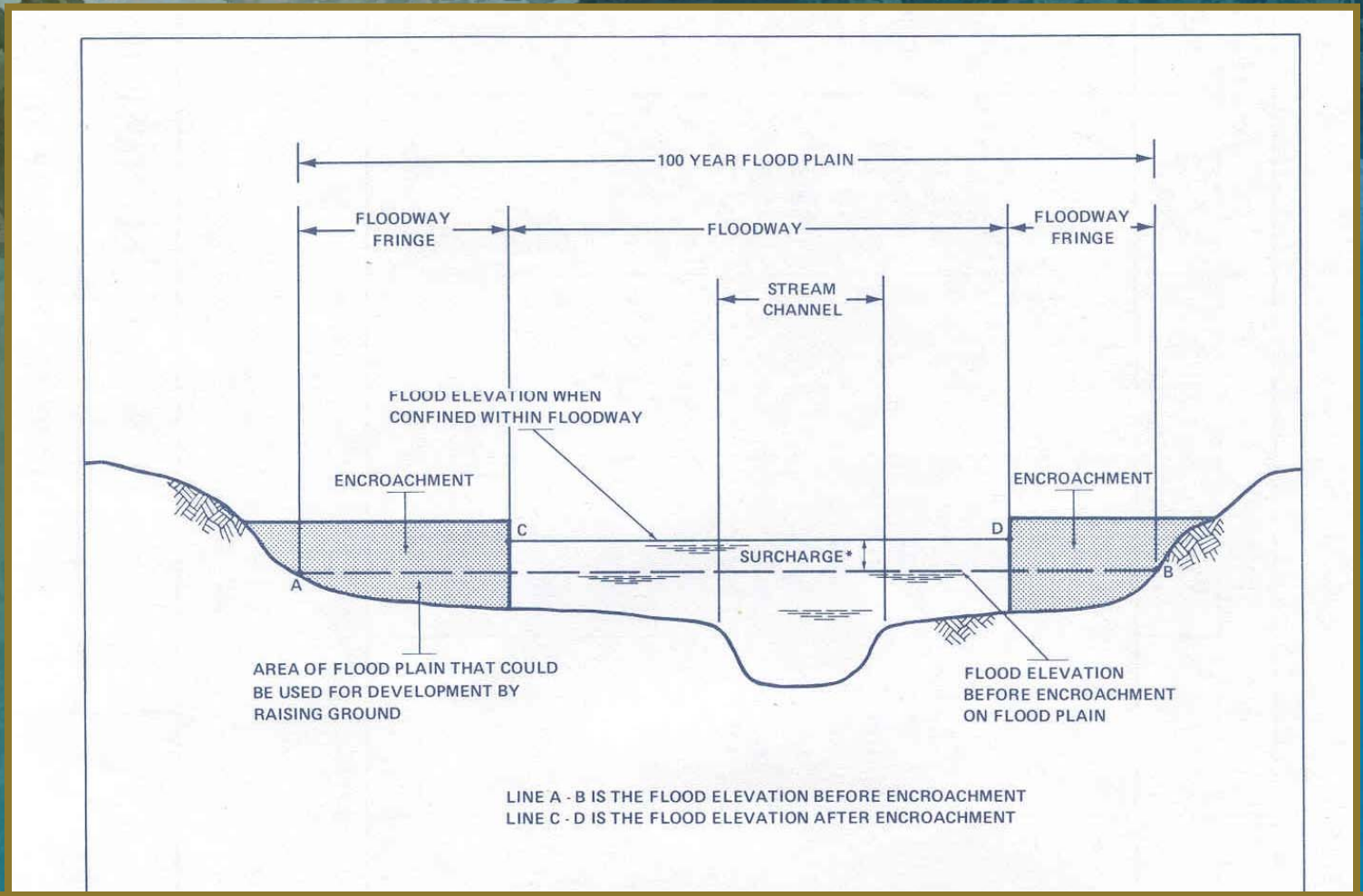
Hydraulics

Floodplain / Floodway



Hydraulics

Floodplain / Floodway



100-year floodplain: the channel of a river and the adjacent land areas that must be kept free of encroachment such that the 100-year flood can be discharged without cumulatively increasing the WSEL by more than the designated height.

Figure: Standard floodway schematic from FIS Report.

Floodways

- **FEMA set minimum standard of 1.0’**
- **States and communities have the option to define more stringent criteria**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