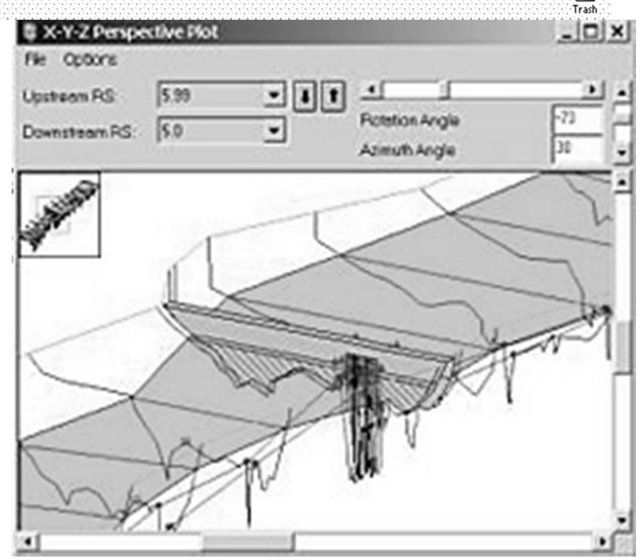
Introduction

- Uncertainty
  - The condition of being uncertain; doubt.
  - Something uncertain: the uncertainties of modern life.
  - Statistics
    - Estimated amount or percentage by which an observed or calculated value may differ from the true value

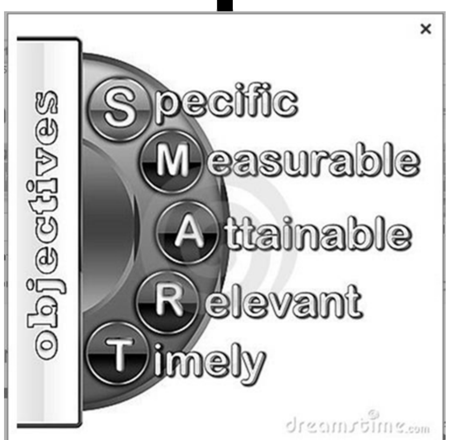
Sources of Uncertainty in Stream Restoration Design (SRD)

- Modeling
  - Design – quantify parameters (geometry, shear)
  - Response predictions – physical/ecological response to change (scour and fill)
  - ***Uncertainty***
    - Mathematical representation of complex systems
      - No full understanding of system
      - No model predicts everything
      - Work in one region but not another
    - Result → PRIMARY source of uncertainty in design



Sources of Uncertainty in SRD

- Restoration Objectives
  - Set so that purpose of project can be met
  - Vague – difficult to define specific, measurable objectives



What are some examples of SRD Objectives?

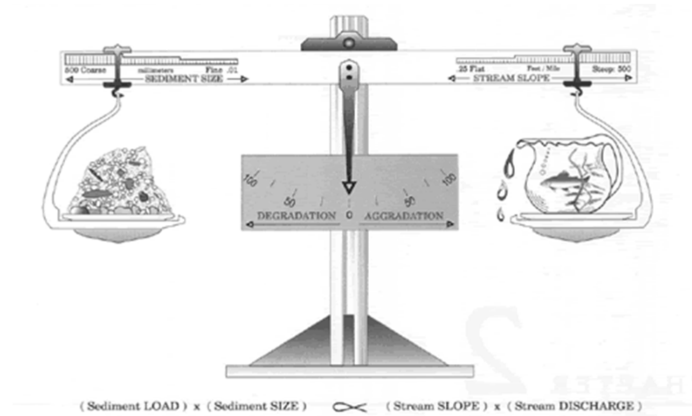
- Vague:
  - 1) Improvement of aquatic or riparian habitat
  - 2) improvement of the physical stability of stream
  - 3) Improvement of the aesthetic quality of stream
- How can we make these less vague?

Sources of Uncertainty in SRD

- Vague Restoration Objectives
  - ***Uncertainty:***
    - Design success in achieving objectives is unknown
    - Clearly defined objectives needed for monitoring to assess success or failure

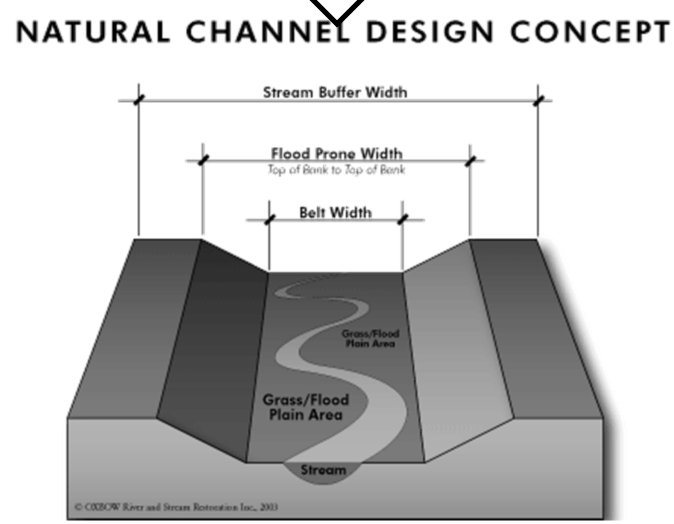
Sources of Uncertainty in SRD

- Vague Definitions
  - Defining stream condition
    - Stable Channel
      - "balance between erosion and deposition attained by mature rivers" (Davis 1902)
      - "one in which, over a period of years, slope is delicately adjusted to provide . . . just the velocity required for the transport of the load supplied from drainage basin." (Mackin 1948)
  - ***Uncertainty***
    - Inability to accurately and consistently define important terms that used to assess state of stream corridor



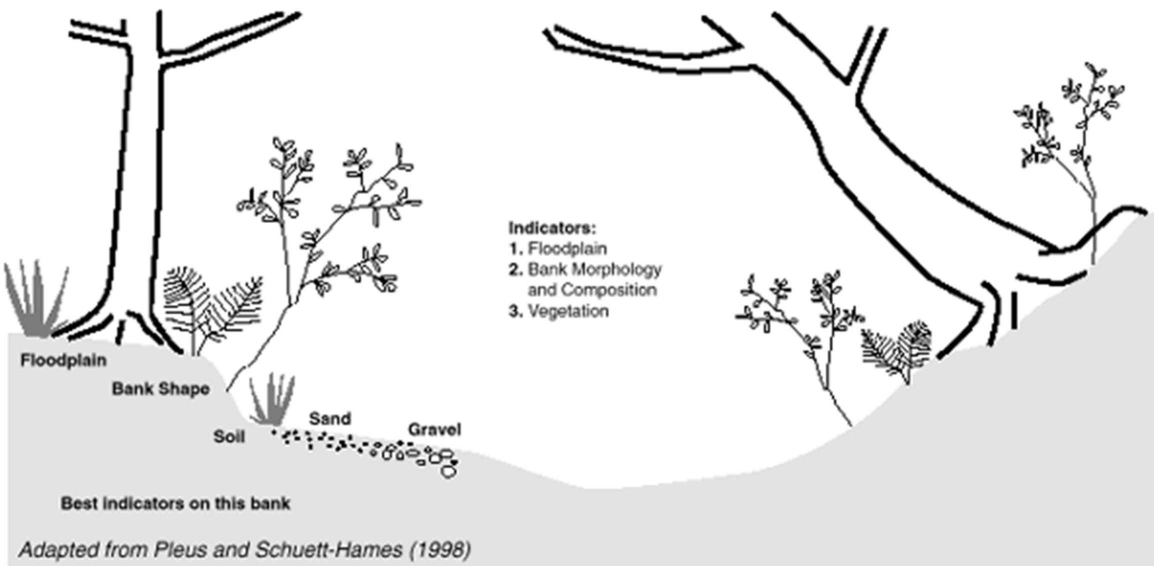
Sources of Uncertainty in SRD

- Vague Design Procedures and Guidelines
  - Vague guidelines and rarely differentiate between regions
    - Natural Channel Design → Urban Setting
  - ***Uncertainty***
    - Each project tends to be unique
    - Difficult to quantify system response to changes
      - Uncertainty comes from inability to incorporate experiential understanding of complex river systems into design guidelines



Sources of Uncertainty in SRD

- Parameter Uncertainty
  - Difficulty in estimating model parameters
    - E.g., Manning's n, Others??
    - Worksheet
  - ***<u>Uncertainty</u>***
    - Approximate or average values used for parameters which may lead to inappropriate or uncertain design



Sources of Uncertainty in SRD

- Parameter Uncertainty
  - Heil and Johnson (1995)
    - Uncertainty (COV) in bankfull discharge = 0.50-1.7
  - Johnson (1996)

TABLE 1. Uncertainty of Hydraulic Variables

Variable (1)	Coefficient of variation (2)	Distribution (3)	Reference (4)
Manning's *n*	0.1, 0.15	normal	(Cesare 1991)
Manning's *n*	0.2, 0.053	normal	(Mays and Tung 1992)
Manning's *n*	0.08	triangular	(Yeh and Tung 1993)
Manning's *n*	0.10, 0.055	triangular, gamma	(Tung 1990)
Manning's *n*	0.20 – 0.35	lognormal	(Hydr. Engrg. Center 1986)
Manning's *n*	0.28, 0.18	uniform	(present paper)
Channel slope	0.3, 0.068	normal	(Mays and Tung 1992)
Channel slope	0.12, 0.164	triangular	(Tung 1990)
Channel slope	0.25	lognormal	(present paper)
Particle size	0.02	uniform	(Yeh and Tung 1993)
Particle size	0.05	uniform	(Johnson and Ayyub 1992)
Friction slope	0.17	uniform	(Yeh and Tung 1993)
Sediment specific weight	0.12	uniform	(Yeh and Tung 1993)
Flow velocity[a]	$0.008x$[b]	triangular	velocity-meter manufacturer and this study
Flow velocity	$0.012x$[b]	uniform	velocity-meter manufacturer and this study

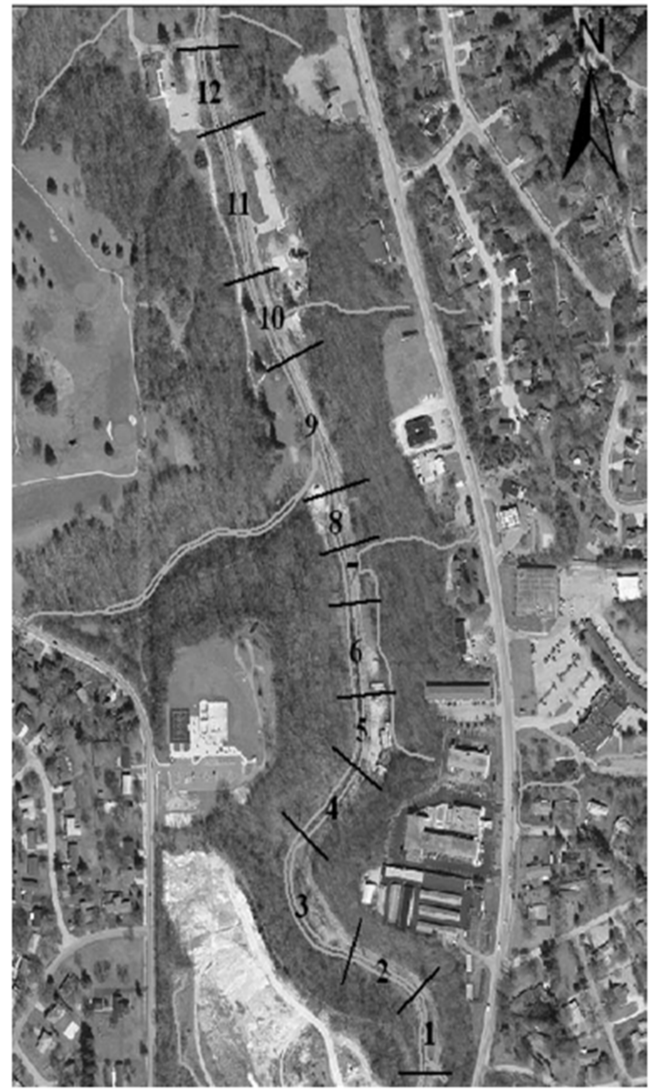
[a]Measured using electromagnetic meter.
[b]x = average velocity.

Sources of Uncertainty in SRD

- Monitoring
  - Data collected defines degree of success
  - Questions:
    - What types of data?
    - How many data?
    - What locations should be monitored?
    - When should data be monitored (events)?
  - Disagreement in how long it takes a stream to "stabilize" following construction
    - Agencies suggest 3-5 years of monitoring
  - ***Uncertainty***
    - Vague monitoring program –uncertainty in assessing whether objectives are met and implementation of further remedies

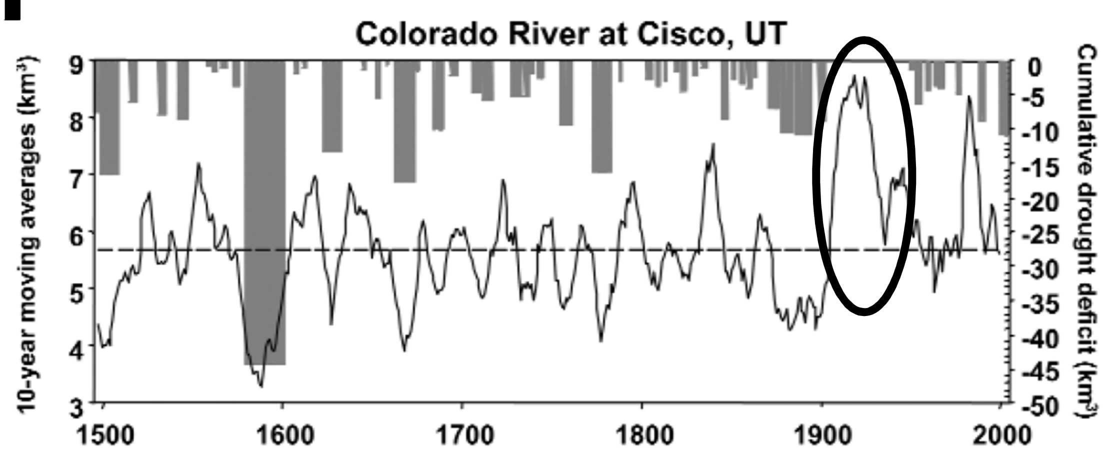
Sources of Uncertainty in SRD

- Scale
  - Two sources of ***Uncertainty:***
    - 1) Guidelines for small/moderate streams – application to large rivers questionable
    - 2) Reach scale design – reach length/proximity dictate success
      - optimum reach lengths/spacing unknown



Sources of Uncertainty in SRD

- Climate Change
  - Increase or decrease air temps and change in hydrologic regimes
  - ***<u>Uncertainty:</u>***
    - Direction and magnitude of changes unknown
    - How to incorporate changes in a project so that it continues to be self-sustaining over long-term



Sources of Uncertainty in SRD

- Land Use Changes
  - Changes in land use
    - change in boundary conditions
    - urbanizing ⇒
  - During or after implementation – failure?
  - ***Uncertainty***
    - What are future land use changes
    - How to incorporate them in design

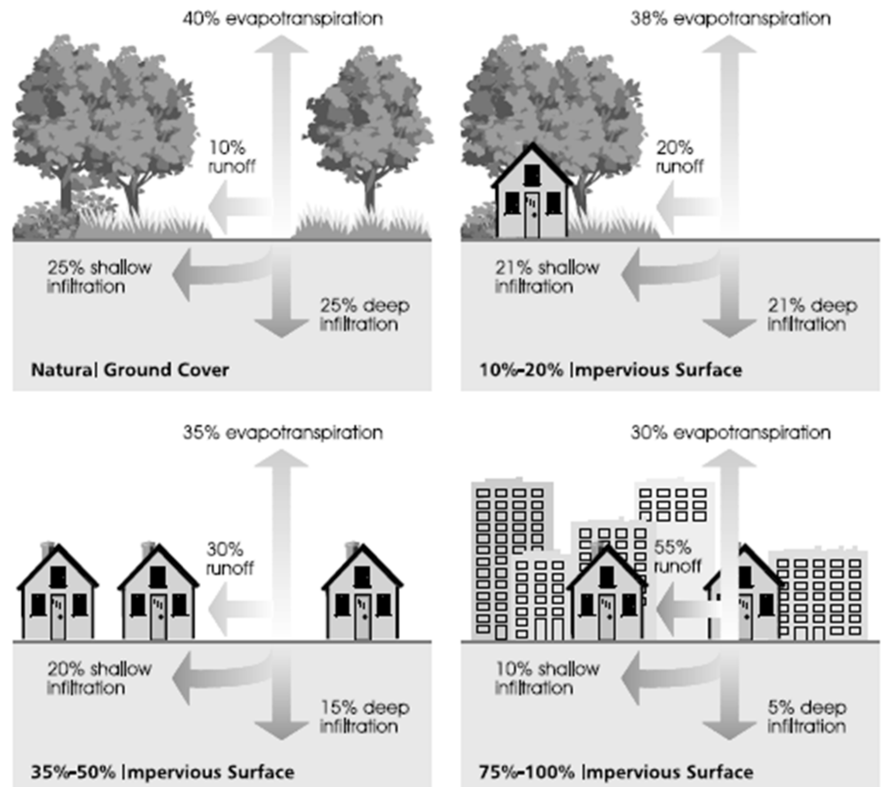


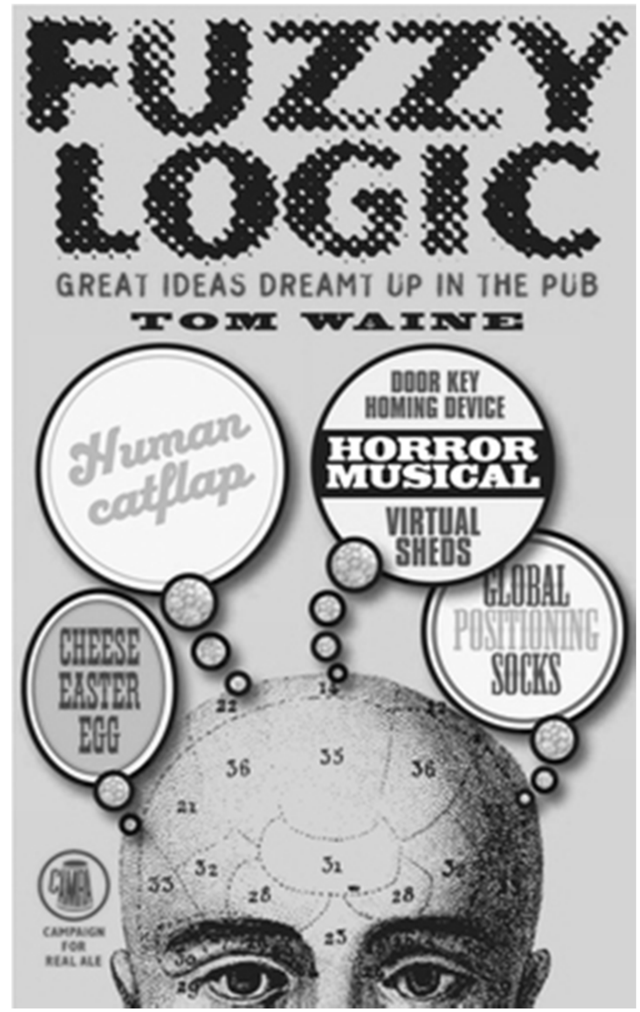
Figure 1.2. Runoff Variability with Increased Impervious Surfaces (FISRWG, 1998)

Sources of Uncertainty in SRD

- Construction and Implementation Practices
  - ***Uncertainty***
    - Troubleshooting in field
    - Human error in measurement, placement, and excavation
  - Experienced crew
    - Experiences lead to decision making on site to help solve problems and reduce uncertainty
    - New technology (GPS) – helps reduces human error component

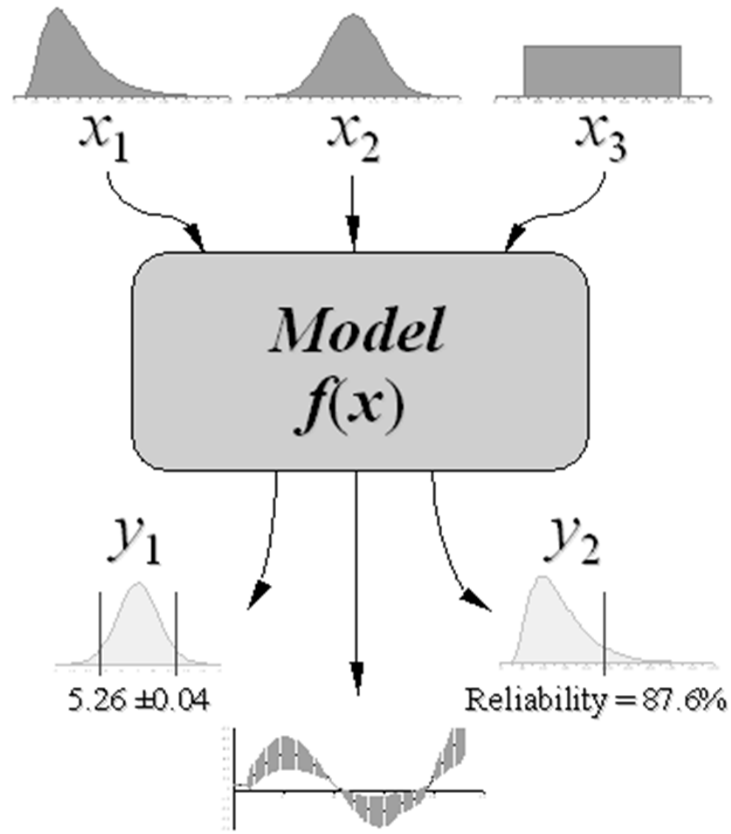
Incorporate Uncertainty in SRD

- Methods for Incorporating Uncertainty
  - Monte Carlo Simulations
  - Fault Tree Analysis
  - Neural Network Analysis
  - Fuzzy Logic
  - Failure Modes and Effects Analysis (FMEA)



Incorporating Uncertainty in SRD

- Monte Carlo simulation - Parameter Uncertainty
  - Mathematical model needed
    - Manning's Equation
  - Quantify statistics, probability distributions
    - Johnson (1996)



Incorporating Uncertainty in SRD

- Failure Modes and Effects Analysis

Qualitative procedure to systematically identify potential component failure modes and assess the effects of associated failures on operational status of the system

- Step 1: Describe Product or Process
- Step 2: Define Functions or components
- Step 3: Identify potential failure modes
- Step 4: Describe effects of failure
- Step 5: Determine causes
- Step 6: Identify detection methods
- Step 7: Calculate risk
- Step 8: Take action
- Step 9: Assess results

Design with Uncertainty

- Next Lessons:
  - Design Failure Modes and Effects Analysis
  - Case Study Application of DFMEA
  - Monte Carlo Simulation (depending on time)
  - Intro to Risk Quantification (depending on time)