Introduction Watershed Management

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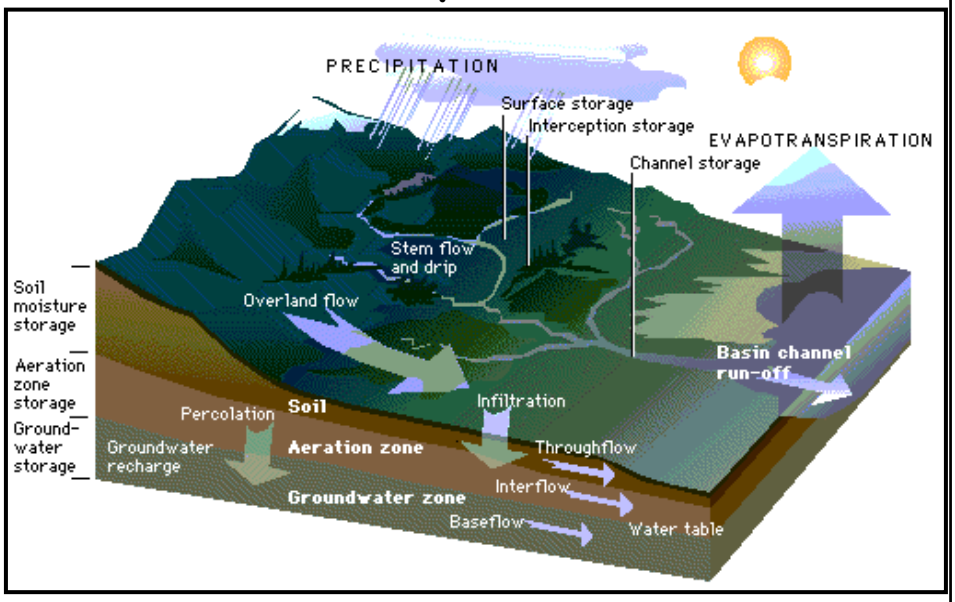
What is a Watershed?

A WATERSHED …

- Refers to a Particular Location and a Spatial Extent, Gravitationally Draining Through that Location.
- A Topographically Delineated Area that is Drained by a Stream System
- A Hydrological Unit used for Planning and Management of Natural Resources

Water Cycle



Watershed Management

✓**This is the PROCESS of GUIDING & ORGANISING,**

Land and Other Resource Usage in a Watershed

Ensuring the Sustenance of the Environment

(Mainly the Soil and Water Resources)

ie., need to recognise the interrelationships between,

LAND USE, SOIL-WATER, and SLOPE OF TERAIN

✓**Unifying Focus in watershed management is in how various human activities affect the relationship between water and other natural resources**

✓**Provides a basis for actions concerning the development and conservation**

Integrated Watershed Management

Real World > Dis-aggregated, Independent, Political Actions

The tendency or inclination > Implementation in an Independent Fashion with little or no regard to how they affect other areas.

However, Water Flows Down the Slopes and Ignores the Political or Administrative Boundaries

Therefore Upstream Activities by a Person or a Group of Persons Affect the Welfare of those in the Downstream

This Gives Rise to the Need of Bringing together THE PHYSICAL FACTORS of a watershed and

The SURROUNDING POLITICAL REALITIES

Watershed Management Concerns

- **PREVENTING deterioration of existing relationships between the use of natural resources within a watershed**
- **RESTORING sustainable relationships which had been destroyed due to actions in the past**

THERE BY ENSURE THE BEST USE OF RESOURCES IN A WATERSHED

Watershed Management Strategies

✓*PREVENTION STRATERGIES*
- Those Aimed at Preserving <u>Suitable</u> Existing Land Use Practices

✓*RESTORATIVE STRATEGIES*
- Those Targeting to Overcome Identified Problems or to restore conditions to a Desirable level both Environmentally and Politically

Problems Associated with Watersheds

- **Flooding**
- **.Unstable Slopes / Land Slides**
- **.Erosion from Denuded Land**
- **.Deficient Water Supplies**
- **.Energy Shortage**
- **.Food Shortage**
- **.Poor Quality Drinking Water**
- **.Polluted Streams / Reduced Fishing**
- **.Sedimentation of Navigation Tracks.**
- **.Timber Shortage (for Dwelling Purposes)**

Problems and Possible Interaction

Flooding Flood Control Reservoirs,
Construction of Levees
Flood Plain Management
Re-vegetation(Denuded Areas)

Unstable Slopes / Land Slides
Slope Protection &
Drainage Structures

Erosion Erosion Control Structures
Contour Terracing
Re-Vegetation

Deficient Water Supplies
Storage Reservoirs
Water Harvesting
Vegetation Manipulation
Pumping of Deep Groundwater

Problems and Possible Interaction

Energy Shortage Fuel Wood Harvesting
Hydro-Power Development

Food Shortage Develop Agricultural Areas
Develop Agricultural Practices
Increase Livestock

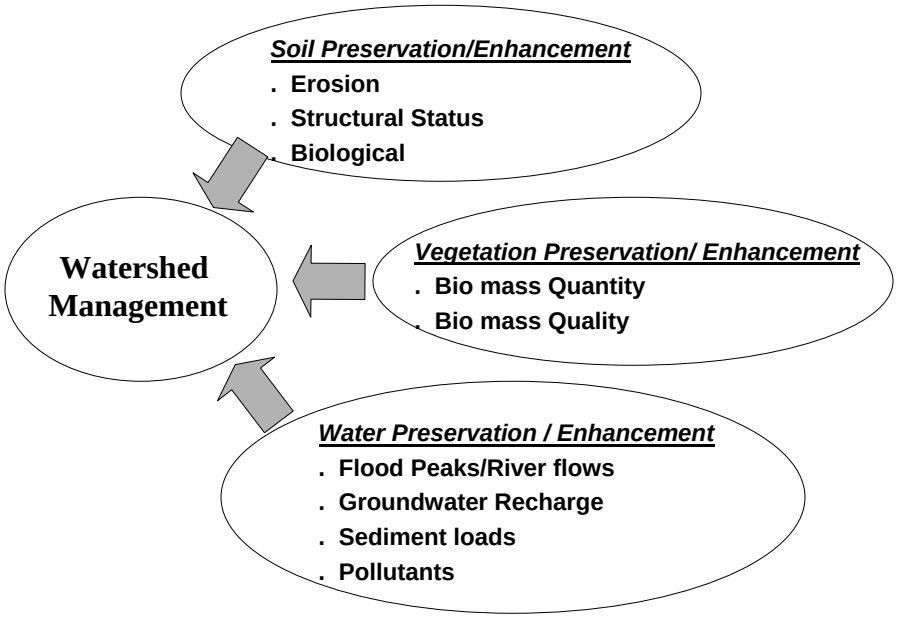
Poor Quality Drinking Water
Develop Wells and Springs
Treat Water

Polluted Streams / Reduced Fishery
Control Pollutant Entry
Treat Wastewater

Sedimentation of Navigation Tracks
Erosion Control Structures
Dredging and Mining

Timber Shortage - Timber Harvesting

Watershed Management Measures



Solution Associated with Watershed Management

Flooding	**Flood Control Reservoirs**	**Minimise sedimentation**
		Manage Land Cover
	Construction of Levees	**Minimise Sediments**
	Flood Plain Management	**Land use Zoning/Management**
	Re-vegetation	**Manage Land Cover**
Unstable Slopes / Land Slides		
	Slope Protection	**Structures for Stabilise Slopes**
		Manage Land Cover
		Restructure Slopes (Terracing etc.)
		Drainage Management
Erosion from Denuded Lands		
	Erosion Control	**Structures**
		Re-vegetation & Management
	Contour Terracing	**Re-vegetate, Mulching**
		Slope Stabilisation,
	Re-vegetate	**Protect and Manage Vegetative Cover**

Watershed Management Measures

Soil Preservation/Enhancement
- . Erosion
- . Structural Status
- . Biological

Vegetation Preservation/ Enhancement
- . Bio mass Quantity
- . Bio mass Quality

Water Preservation / Enhancement
- . Flood Peaks/River flows
- . Groundwater Recharge
- . Sediment loads
- . Pollutants

→ **Hydrology Related Factors**

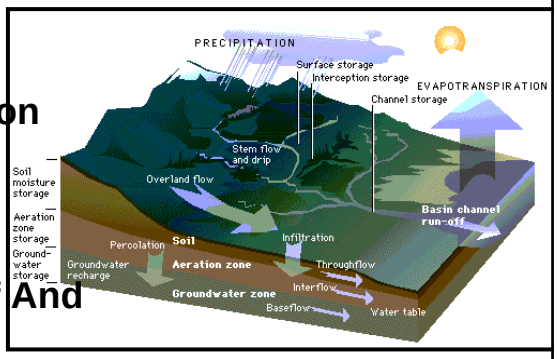
Hydrological factors in relation to Watershed Management

✓**Precipitation and Interception**

✓**Evapo-transpiration and Soil Moisture Storage**

✓**Infiltration Runoff And Stream flow**

✓**Groundwater**



Precipitation & Interception

✓**Affects the Amount, Timing and Spatial Distribution of Water Added to a Watershed from the Atmosphere**

✓**Precipitation is Largely beyond Human Control Land Use and Associated Vegetation Alterations affect the Deposition of Water by Changing Interception (Type, Extent, and Condition of Vegetative Land Cover Influence the Pattern and the Amount Reaching the Soil Surface)**

✓**Dense Coniferous Forests and Multi-Storied Canopies of Tropical Forests Intercept and Store Significant Quantities of Precipitation and a Substantial Quantity is Returned to Atmosphere as Evaporation (Approx 30%)**

Evapotranspiration & Soil Moisture

✓**Evaporation from Soils, Plants Surfaces, and Water Bodies together with Water Transpired through Plant Leaves is called Evapotranspiration**

✓**Larger Canopied Plants Transpire Larger Amounts compared to Bare Soil or Plants with Smaller Stature**

✓**ET affects the Water Yield, and Largely Determines the Proportion of Precipitation input becoming Streamflow**

✓**In Tropical Watersheds ET component Reaches upto 80%**

✓**Annual ET computations are through Water Balance Computations**

Comparison of Annual ET and RF

Country	Location	Annual Precipitation (mm)	Annual Evapotranspiration (mm)	ET as a % of RF
Thailand	N1	1337 (78-87)	725	54%
	P14	941 (78-87)	692	74%
	P21	935 (78-87)	676	72%
	X53	1799 (78-87)	534	30%
	X67	1803 (78-87)	1228	68%
	CT4	1219 (78-87)	943	77%
	N40	1387 (78-87)	10221	74%
	E54	1458 (78-87)	751	52%
	E29	1367 (78-87)	1064	78%
	M69	1591 (78-87)	950	60%
Malaysia	Lengkuas	2139 (61-67)	1643	77%
	Victoria	2578 (61-67)	1689	66%
	R.Panjang	2197 (72-79)	1412	64%
Sri Lanka	Peradeniya	2726 (69-80)	826	30%
	Putupaula	3480 (72-79)	795	23%
	Bopagoda	3324 (up to 96)	1952	58%
	Chilaw	1604 (up to 96)	536	33%
	Katharagama	1522 (up to 96)	1240	82%
	Dambulla	1278 (up to 96)	986	77%

Infiltration, Runoff & Streamflow

Rain Water Reaching the Ground, either

- ✓**Fills Depressions**
- ✓**Moves into the Soil or**
- ✓**Flows Over the Surface**

Water Which Enters the Soil, either

- ✓**Moves Downward to a Groundwater Aquifer or**
- ✓**Moves Downwards and Laterally to Stream Channels**

The Rate at Which Water Enters the Soil is Governed by

- ✓**Surface Conditions (Exposed, Compacted) & Land Cover (Vegetated,Impervious etc.)**
- ✓**Physical Conditions of Soil (Porosity, Hydraulic Conductivity, Current Moisture Content)**

Infiltration, Runoff & Streamflow

✓**Soil Covered with Vegetation Encourages Higher Infiltration than Bare Soils (Detainment)**
✓**Plants through Canopy Cover reduces the Rain Drop Impact which can seal the Surface by Displacing Tiny Particles into Soil Pores**
✓**Rainwater which flows over the surface and which flows laterally through the Soil becomes Streamflow**
✓**The Terrain Shape and Constituents determine the Time and Quantity of Streamflow Generated in a watershed**
✓**Watershed Characteristics such as, Shape, Size, Channel and Watershed Slope, Topography and Drainage Density, and the Presence of Wetlands and Reservoirs influence the Streamflow Response**

Infiltration, Runoff & Streamflow

Water Yield from a Catchments Usually Increases when,

✓**Forests are Clear Cut or Thinned**
✓**Vegetation converted from Deep Rooted to Shallow Rooted**
✓**Change of Plant Species with High Interception Capacities to Low Interception Capacities**

LARGEST WATER YIELD OCCURS FROM CLEAR CUTTING OF FORESTS

Infiltration for Different Vegetation Conditions (Morocco)

	Heavily Grazed Palm Vegetation	Moderately Grazed Brushland	Ungrazed Afforested Pine
Vegetative Cover (%)	12.5	41.3	99
Slope (%)	0-10	5-25	5-40
Initial Infiltration Rate (mm/hr)	179	194	439
Infiltration Rate after 2hrs (mm/hr)	43	65	226

Increase of Water Yield with reduction in Vegetation Cover

Vegetative Cover Type	Increase in Water Yield per 10% Reduction in Cover		
	Average (mm)	Maximum (mm)	Minimum (mm)
Conifer & Eucalyptus	40	65	20
Deciduous Hardwood	25	40	6
Shrub	10	20	1

Ground Water

- **Groundwater is referred to as the water that is accumulated beneath the Soil Surface in Saturated Zones**
- **Groundwater is very important to maintain the Watershed Wetness but it Seldom Occurs where it is most needed**
- **Groundwater is often used as a Source of Fresh Water and important for vegetation sustenance and /or vegetation revival**
- **Groundwater that seeps into streams provides the Baseflow of Streams. Therefore any unmanaged use would create a heap of Environmental Problems.**
- **In most watersheds the use of Groundwater is limited by the Rate of Natural Replenishment. There are many places where Natural flood waters are used to replenish the Groundwater**

Soil Erosion and Sedimentation

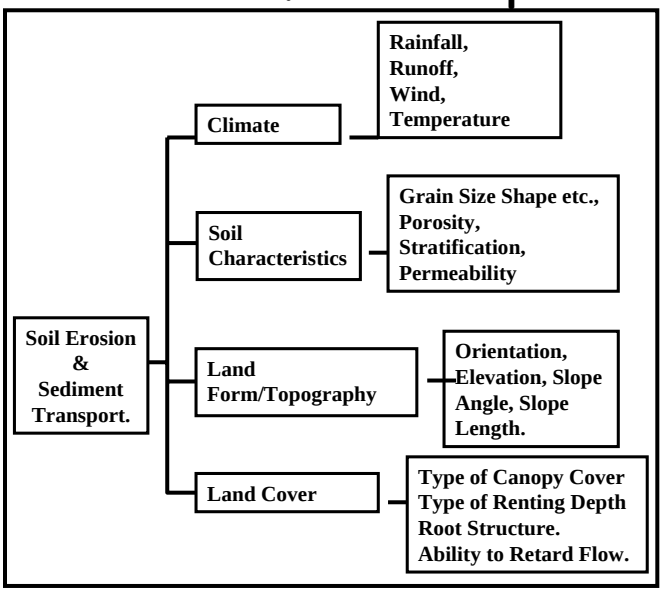
Soil Erosion

- **The Process of Dislodgement and Transport of Soil Particles by Wind and Water**
- **Factors affecting Soil Erosion are, Climate, Topography, Soil Characteristics, Vegetative Cover, Land Use etc.**
- **Concerns of Wind Erosion Significant only in Arid and Coastal Areas**
- **Major Concern throughout the World (Especially in the TROPICS) is the Soil Erosion by Water**

Erosion Rates

- **In Undisturbed Forests - 0.04 tons/ha/year**
- **Logging and Roads - in excess of 15 t/ha/yr**
- **Road Construction Sites - excess of 95 t/ha/yr**

Factors Associated with Soil Erosion & Sediment Transport



Estimation of Soil Erosion

Universal Soil Loss Equation: A = R K (LS) C P

A Soil loss in Tons per unit area

R A rainfall Erosivity factor for a specific area

K A soil erodibility factor for specific soil

LS Topographic factor (Dimensionless); A combination for watershed slope angle, and slope length. (L is compared with a 72.6 ft long slope, while C is compared with a slope of 9%)

C Dimensionless Crop Management Factor (Expressed as a ratio of soil loss from the condition of interest to soil loss from tilled continuous fallow

P Erosion Control Practice Factor. (Expressed as a ratio of the soil loss with the practices to soil loss with 1farming up and down the slope)

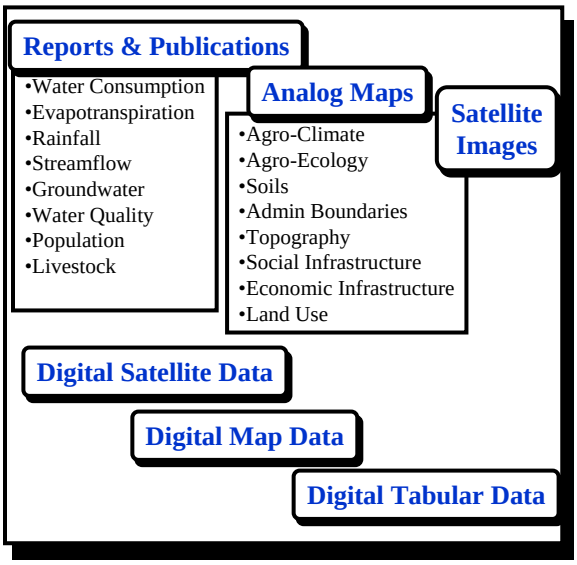
Estimation of Soil Erosion

Universal Soil Loss Equation: A = R K (LS) C P

USLE Estimates Sheet and Rill Erosion from uplands.
Does not include erosion from stream banks and eroded sediment deposited at the base of the slopes and at other reduced flow locations prior to reaching streams or reservoirs

Originally only for Agricultural Watershed
Now it is being applied to NON-Agricultural situations such as Construction Sites and Undisturbed Lands Including Forests and Range Lands with the use of a SUB FACTOR Method to Estimate the C-Factor

A general database for Reconnaissance Watershed Management Study



A general database for Reconnaissance Watershed Management Study

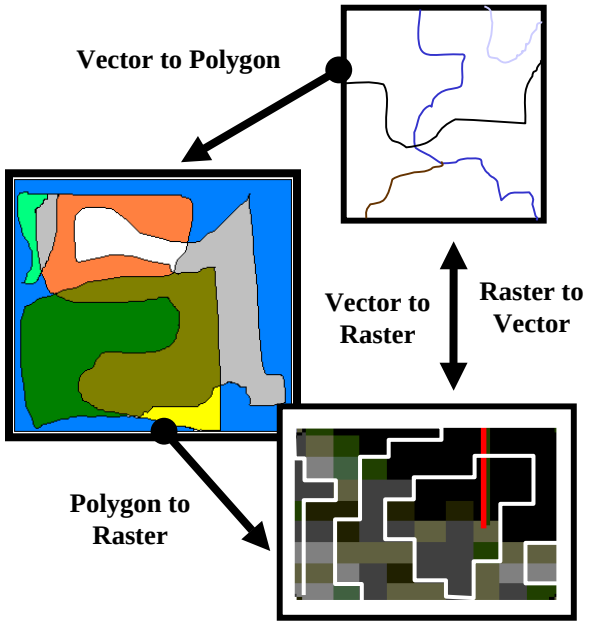
Data Acquisition & Management

- This Requires Most of the Effort
- Key Board Entry of Table
- Digitising of Maps
- File Transfers from Data
- Scanning and Automated

Watershed Management require Terrain Data i.e. Digital Image Processing Capability in GIS (Spectral Data to Terrain Data)

Watershed Management also Deals with Hydrological Time Series Data. GIS requires the pre-processing Capability for Consistency Checks, Graphical Inspection, Filling Missing Data, Applying Corrections etc.

Data Management



GIS Data Manipulation and Analysis

Single Data Plane

✓Interpolation of Point Data (rainfall & groundwater levels are in from rain gauges and from wells).

✓Creation of distances around points and lines (Useful in studying yield of wells in hard rock etc).

✓Interpolation and filtering (interpolation from digitised contours to obtain the DEM and filtered to obtain the slope map or a flow path map).

✓Interpolation and filtering is used for 2-D flow net construction of groundwater surfaces

✓Cover classification from remotely sensed data (a single plane is created from several data planes with spectral data).

GIS Data Manipulation and Analysis

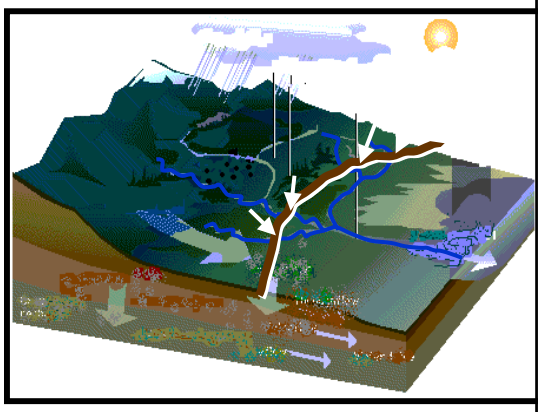
Combination of Two or More Data Planes – Overlay Analysis -

- **Well Defined Procedures**
  - Rational Formula for Peak Runoff Estimation
  - Universal Soil Loss Equation for Erosion Hazards
- **Judgemental: Semi-Quantitative Approach**
  - Classification of Thematic Maps into Classes or Parameters (involves judgement and uncertainty)
    - Runoff Curve Number Method in the USDA-SCS model
    - Classification of Remotely Sensed Data
- **Qualitative Approaches**
  - Used in Data-Scarce Regions where thematic data is lacking (inadequate rainfall and evaporation data, only a few or no groundwater well data, No soil maps etc.) Result will carry a bias and depend on the experience and familiarity with the region.

A Simple GIS Model to Compute Peak Runoff from Watershed

Watershed Management and Environmental Impact Assessment Exercises often require the estimation of Peak Flows at critical geographic locations

Example: For a Large Number of Catchments along a Planned Highway, it is necessary to estimate the adequacy of Drainage Structures Proposed by the Highway Developer



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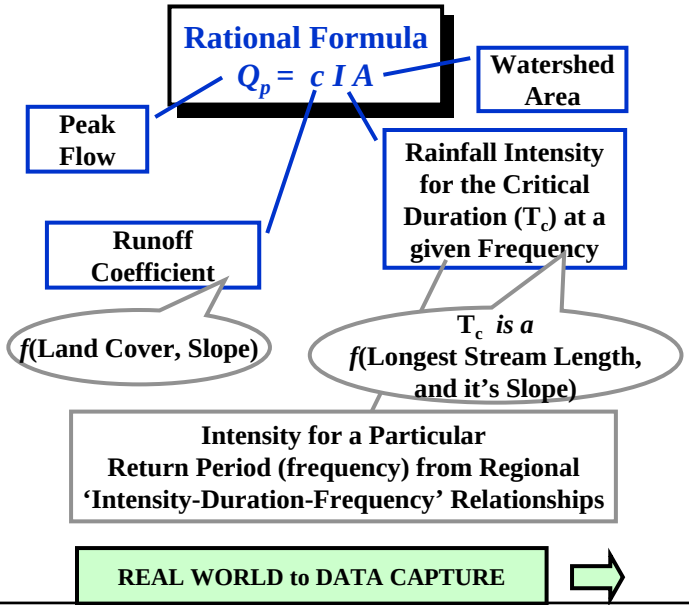

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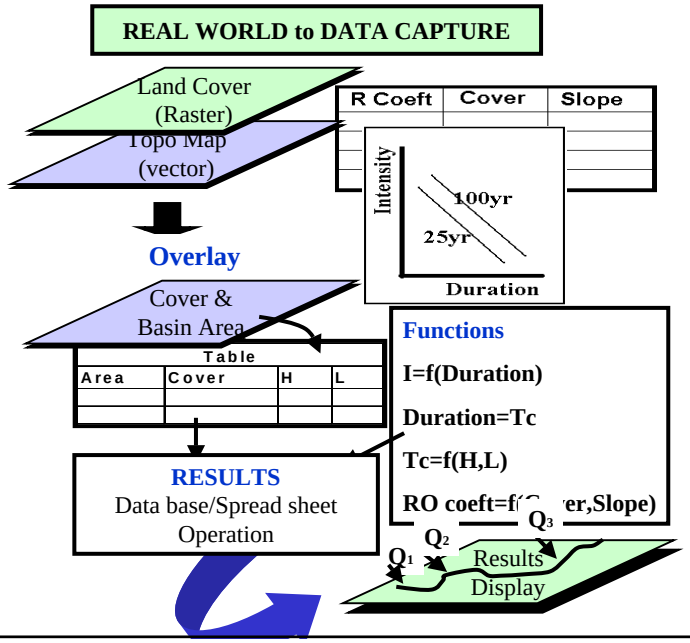

Watershed Management Potentials

Change Dike Failure Scenarios
Change Land Use Scenarios
Change Flood Event
Calculate Flood Damage

Establish Evacuation Routes
Relief and Medical Supply Paths, Stores Land Use Zoning
Reclamation Plans and Clearance
Establish Cost Curves
Incorporation of Mitigation Structures