Watershed Analysis of the Mesoamerican Reef Region:

Application of the Nonpoint Source Pollution and Erosion Comparison Tool (N-SPECT)

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Outline

- Description
- Functions & Capabilities
- Applying to MAR
- Data Requirements
- Watershed Delineation
- NSPECT Analysis Concepts:
  - Runoff
  - Pollution
  - Erosion

Description (What is N-SPECT?)

- GIS-based tool for estimating and comparing nonpoint-source pollution and erosion.
- Extension compatible with ArcGIS 8.x and 9.x
- Public domain; developed by NOAA Coastal Change Analysis Program (CCAP), 2004.
- Initially developed for Wai'anae region, Oahu, Hawaii.
- Transferable – can be utilized in any location where input datasets are available.
- Flexible: adaptable to local areas, different time scales.
- Answers questions about effects of land cover change on water quality in watersheds.
- Relatively short processing times.

Functions & Capabilities

- Rainfall-runoff model
  - U.S. Soil Conservation Service (SCS) curve number technique
- Pollutant model
  - Concentration coefficients
- Sediment yield model
  - Universal Soil Loss Equation (USLE)
    - Modified (MUSLE)
    - Revised (RUSLE)

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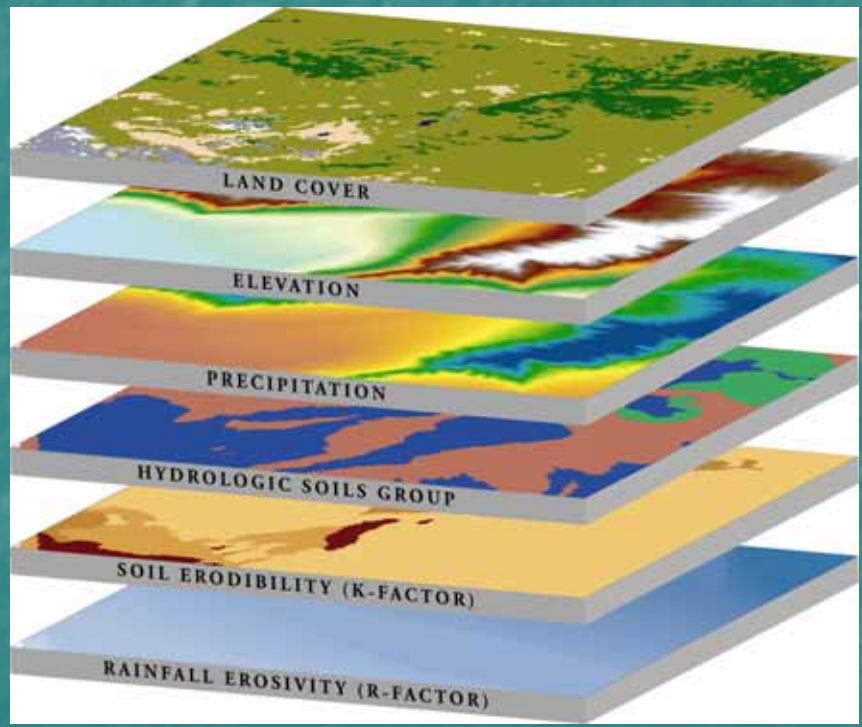
Data Requirements

- Land Cover grid
- Elevation (DEM)
- Precipitation grid
- Soils shapefile
  - Hydrologic soil group grid
  - Soil erodibility (K) grid.
- Rainfall Erosivity (R) Factor grid
- Pollutant/Nutrient Coefficients
- Water Quality Standards



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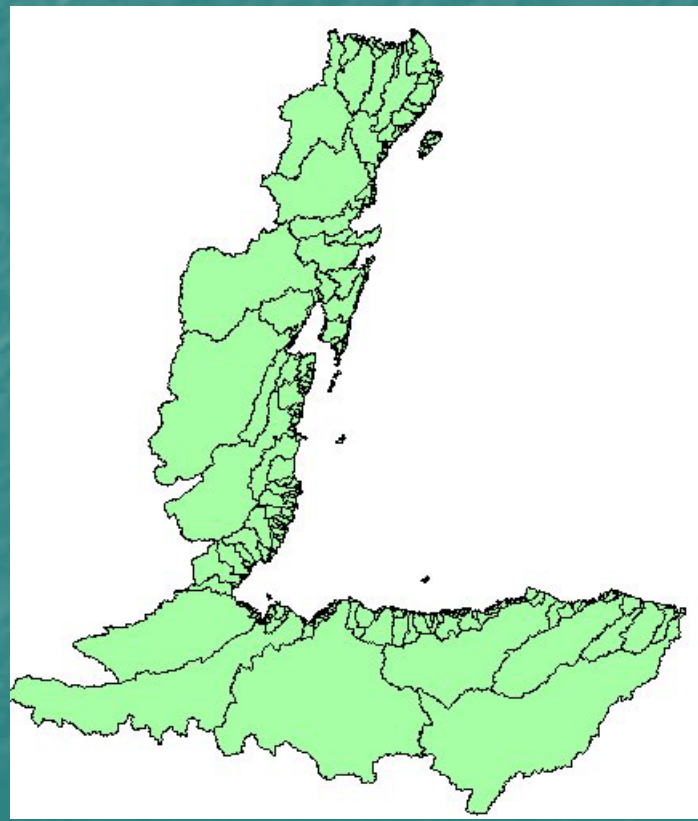
Applying N-SPECT to the MAR region

- Adapt model to the region (data needs)
- Run several analyses to predict water quality changes.
  - Annual Erosion/Sediment loads
  - Pollutant loads
- Extract outputs to pour points



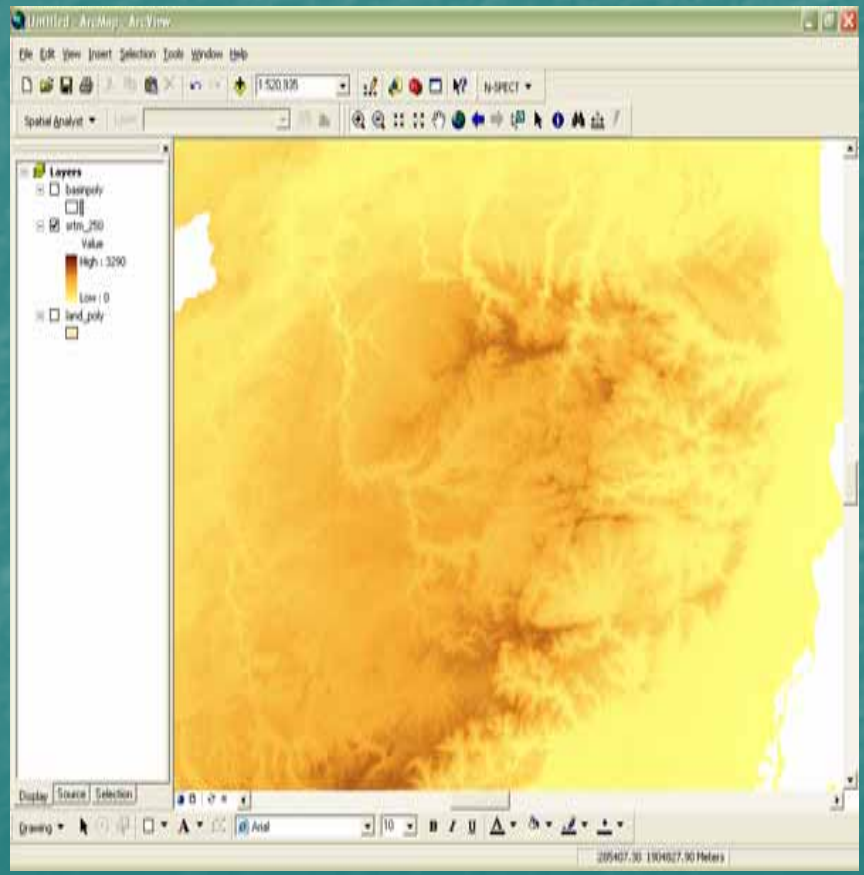
Performing Analyses with N-SPECT: Key Concepts

- Watershed Delineation
- Runoff volume
- Pollutants (accumulation & concentration.)
- Sediment Delivery (accumulation & concentration)

Photo: WWF, Sylvia Marin

Concept 1: Watershed Delineation in N-SPECT

- Why important? Topography (DEM)
- Other grids derived from DEM
- Analysis extent & overlay
- Watershed boundary shapefile the basic unit for all analyses



Watershed Delineation Process (in N-SPECT)

- N-SPECT requires its own delineation based on a user's Digital Elevation Model (DEM)
- Creation of basins polygon shapefile
- FILL command
- Determines flow direction to locate streams.
- BASIN command to delineate drainage basins based on ridgelines of DEM and pour points.
- Very small watersheds, problematic areas of very low relief aggregated into larger watersheds.

Watershed Delineation: DEM preparation

- First step: creating input DEM *(burn_20pos)*
- DEM developed from 90m resolution NASA SRTM data resampled to 250m; water bodies “burned” at -20m relative to surface of DEM
- NSPECT considers negative values sinks, so the DEM was raised 21m to eliminate all negatives and preserve the burn.
- NSPECT then fills in actual sinks.

DEM Setup: New Watershed Delineation menu

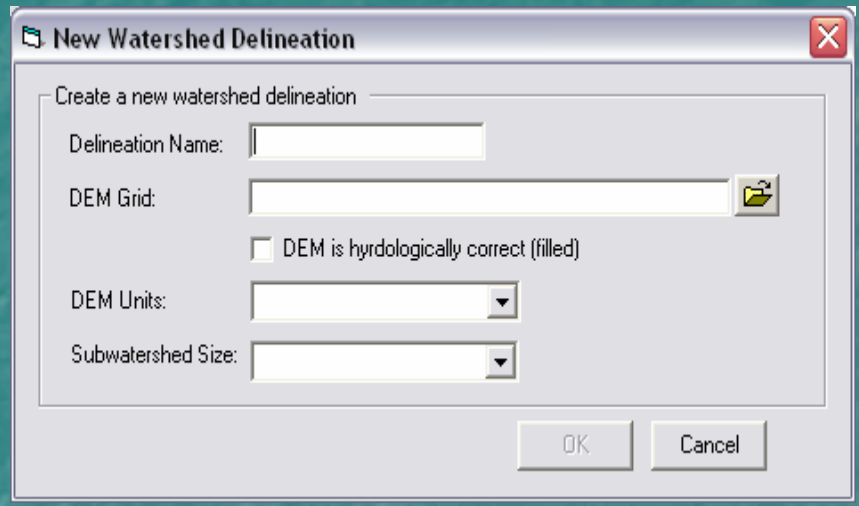
- 1st step = input DEM
- Hydrologically corrected?
- Units
- Subwatershed size: small, medium, or large.
  - Subwatershed size is relative to DEM based on flow accumulation.

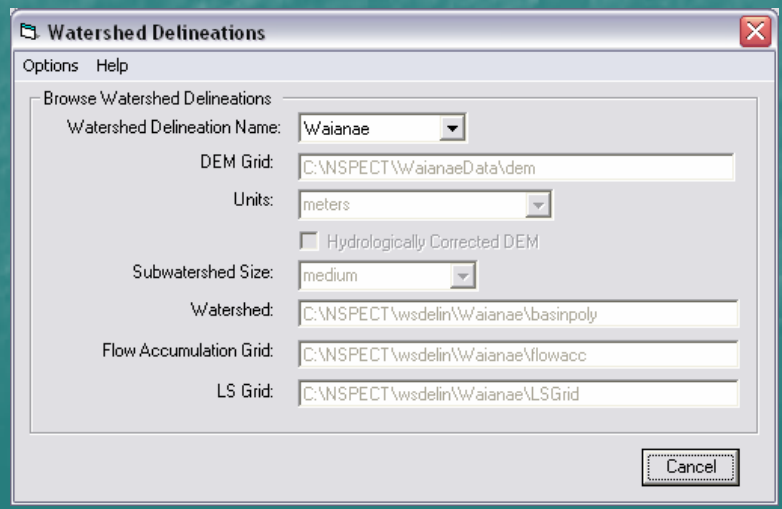
Based on the following conditions:

Small = 0.1% of max flow acc value

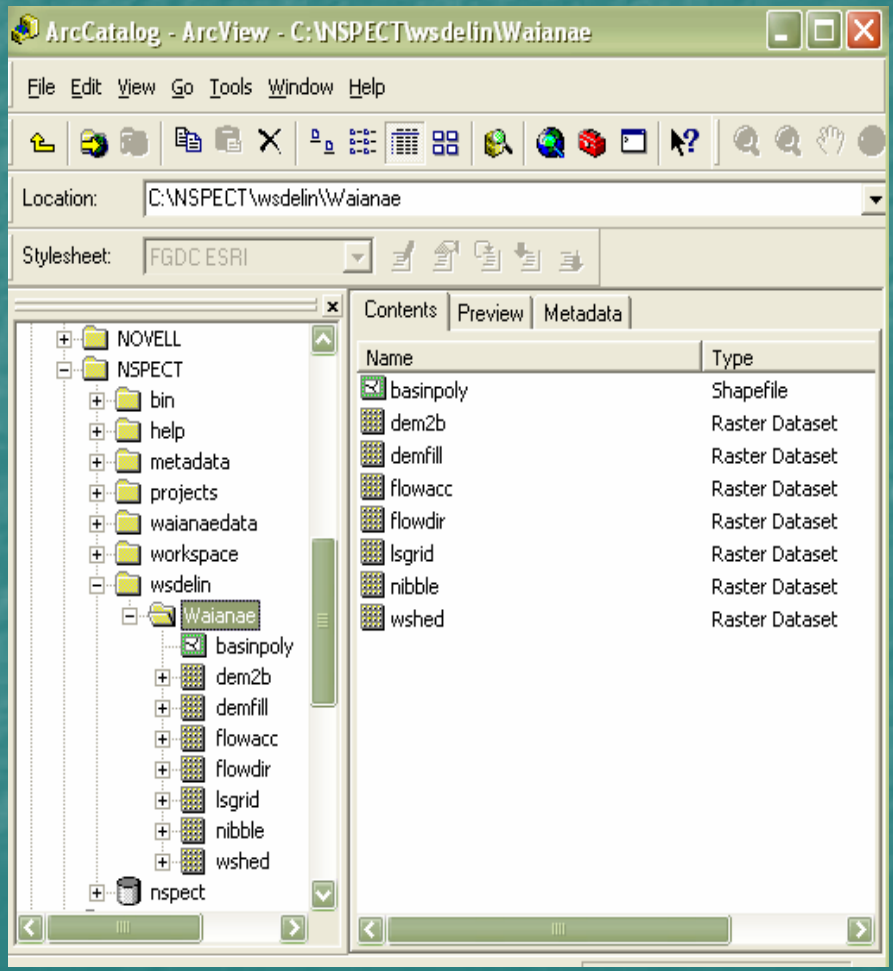
Medium = 1%

Large = 10%



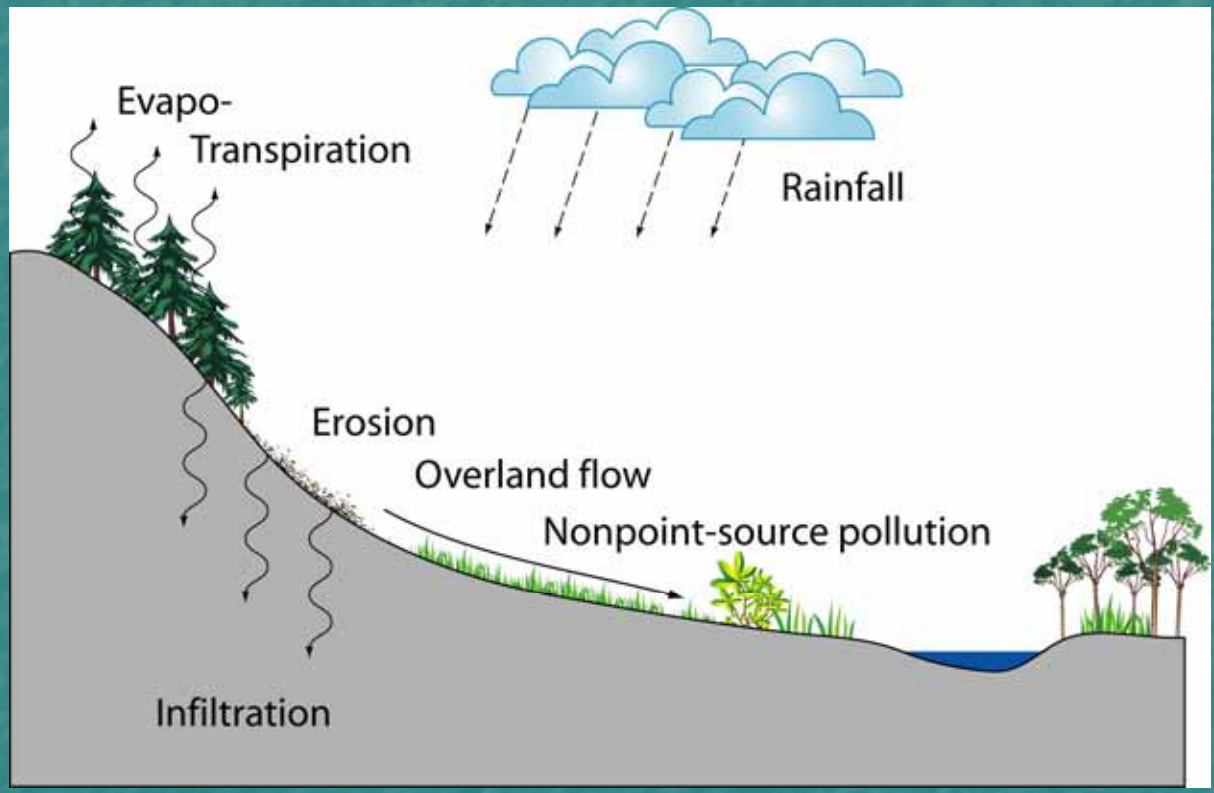


Watershed Delineation: Location & Key Output data



- Basin polygon shapefile
- Basin grid
- Flow direction grid
- Flow accumulation grid
- LS Factor grid

N-SPECT Concept: Runoff Estimation



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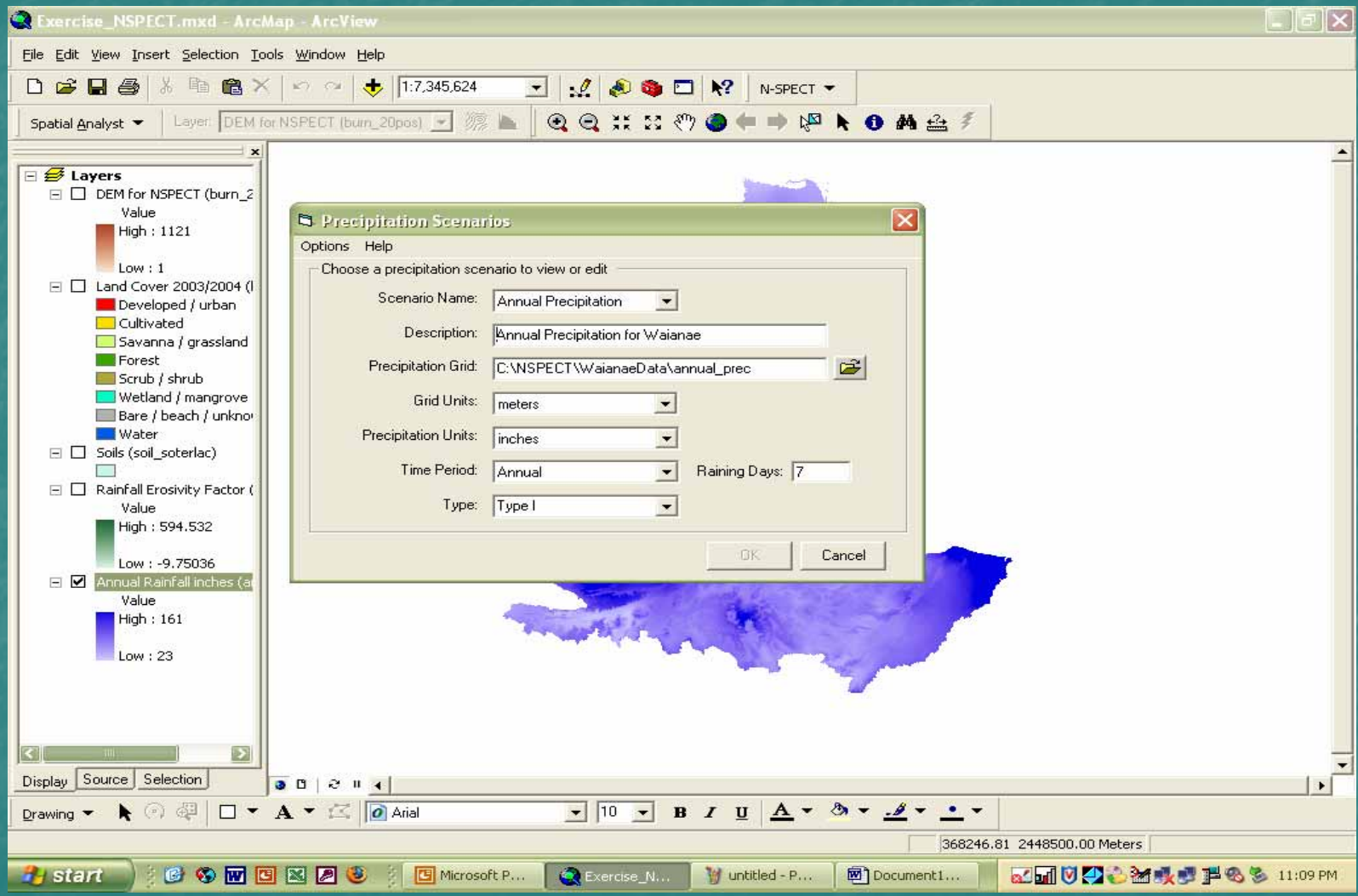
Soil characteristics, land cover, topography and *precipitation* determine **runoff**

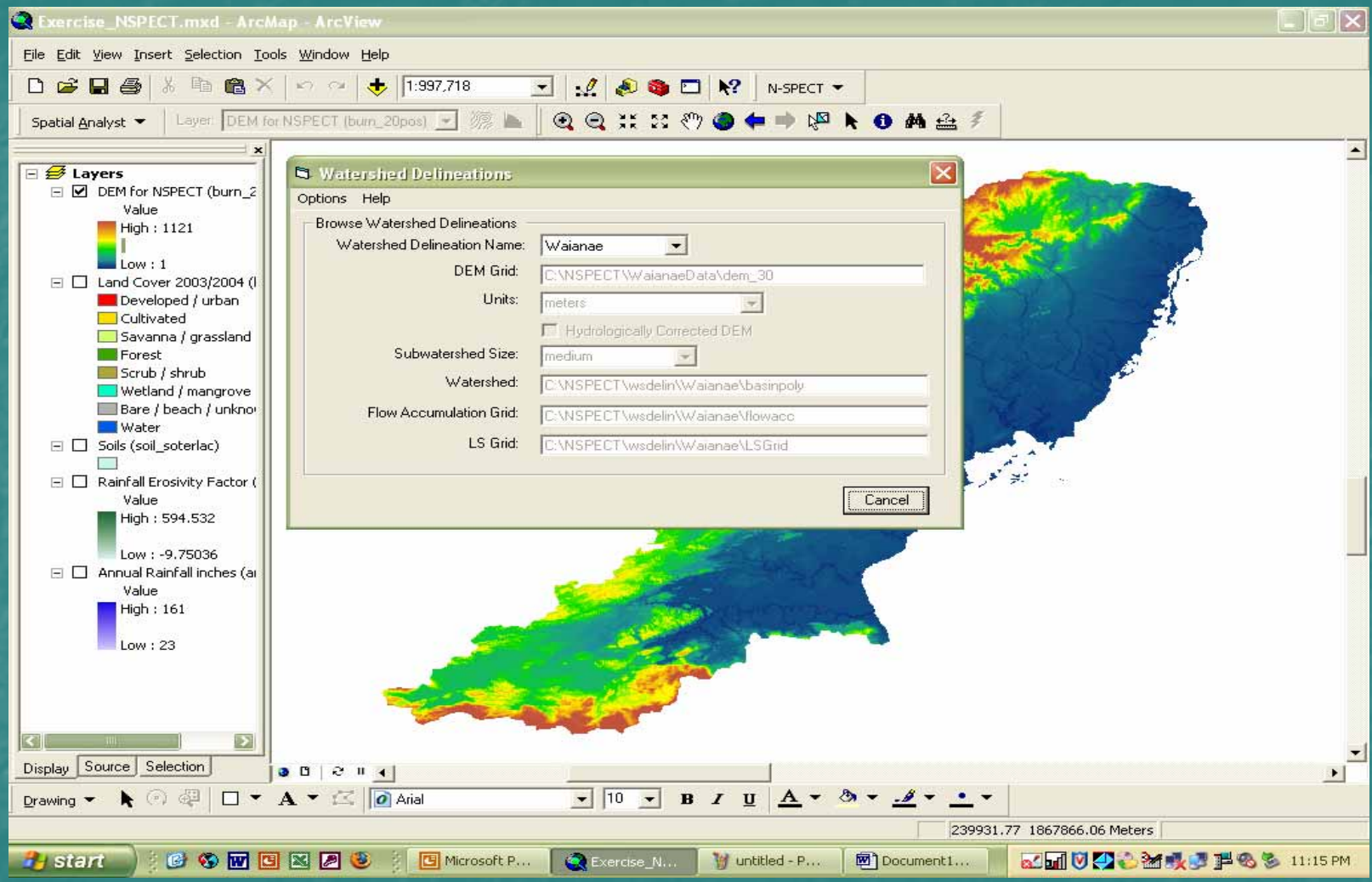
Runoff: Inputs required

- Rainfall grid (annual or event)
- Elevation (DEM)
- Runoff Curve numbers
- Soil (hydrological group)

Precipitation



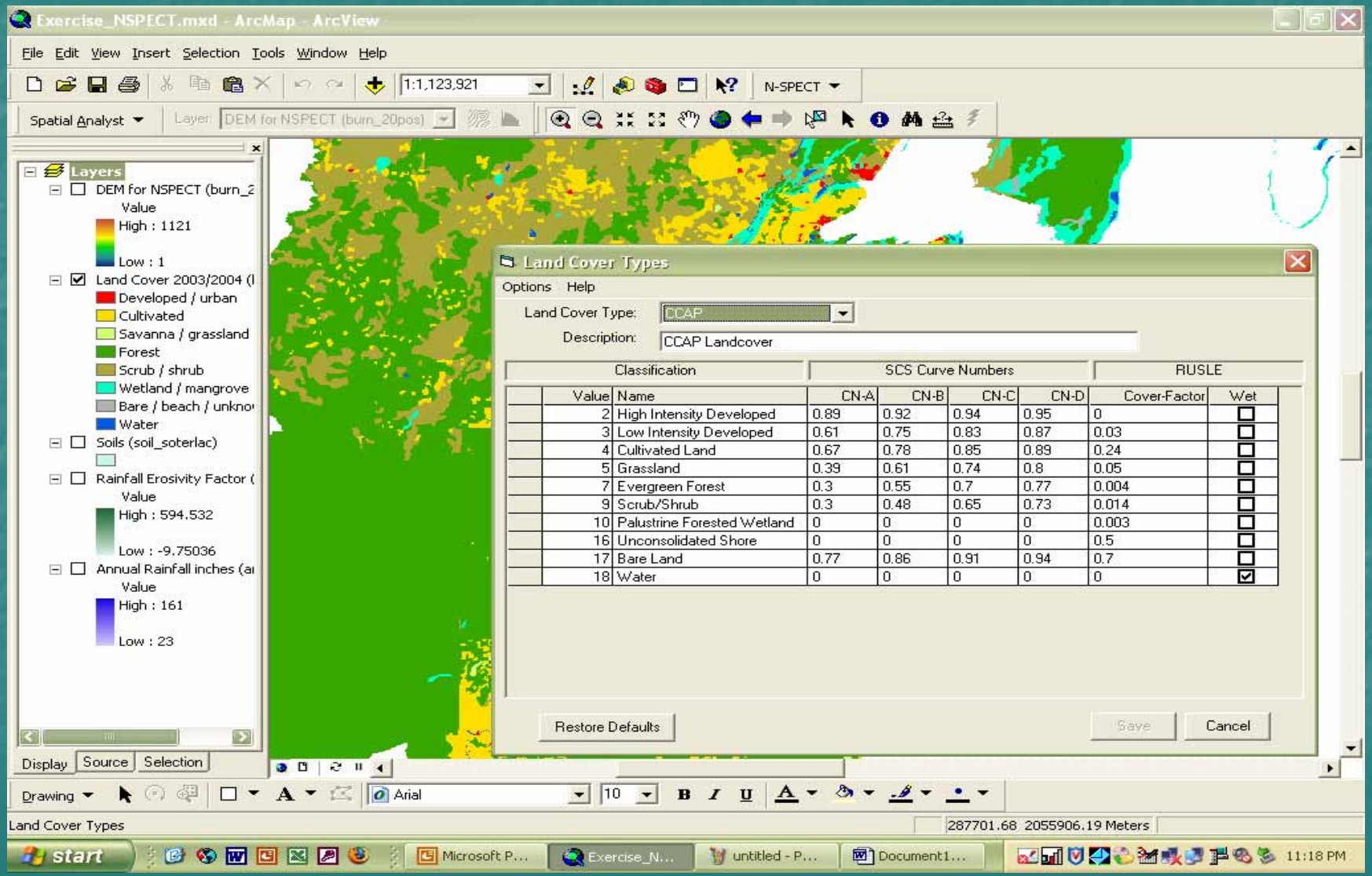
Elevation



Flow Direction & Accumulation

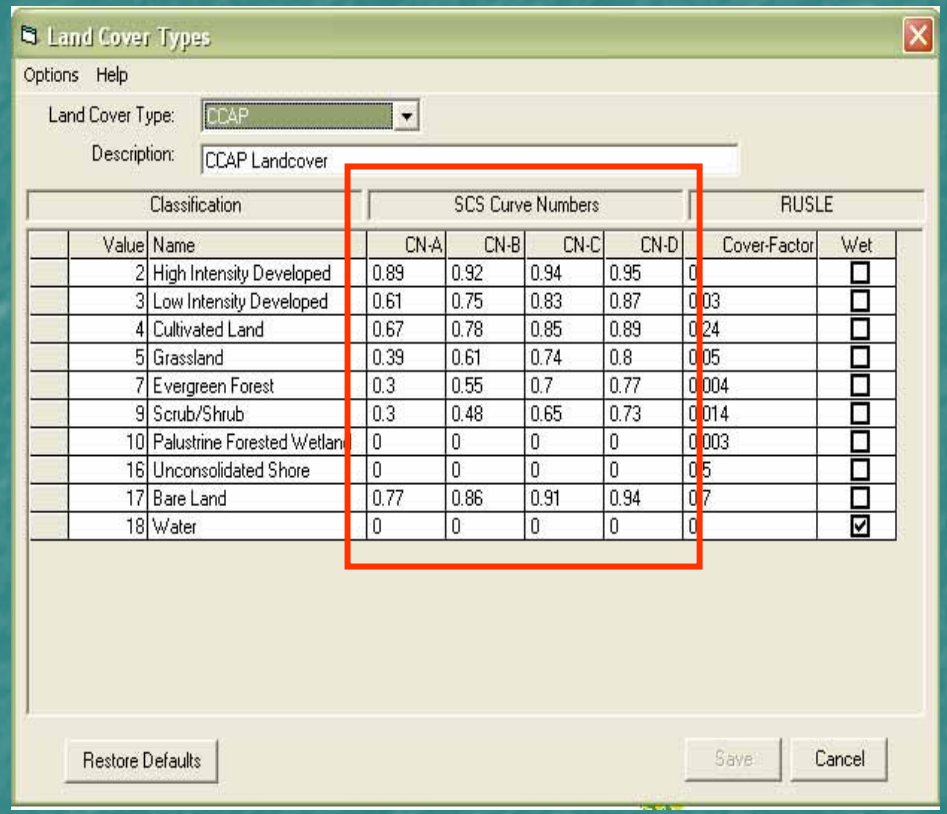
Resolution & processing time

Land Cover (Runoff Curve Numbers)

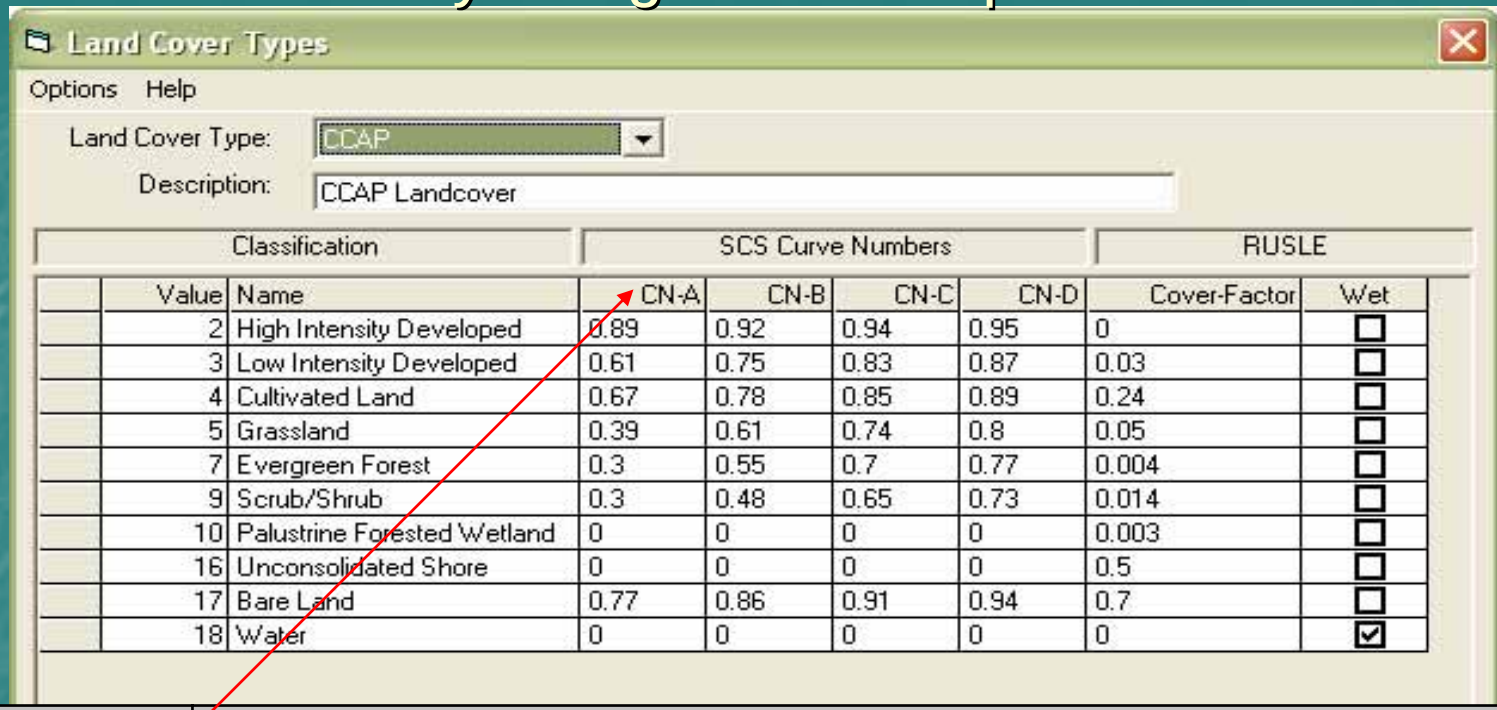


Runoff: SCS Curve Number method

- Developed by USDA-NRCS
- Curve numbers based on soil traits & represent permeability.
- Range: 0 (100% infiltration) to 100 (0% infiltration).
- Gridded by NSPECT, derived from land cover and hydrologic soil group.
- Runoff depth
- User-adjustable
- For more on actual processing equations, see tech guide.



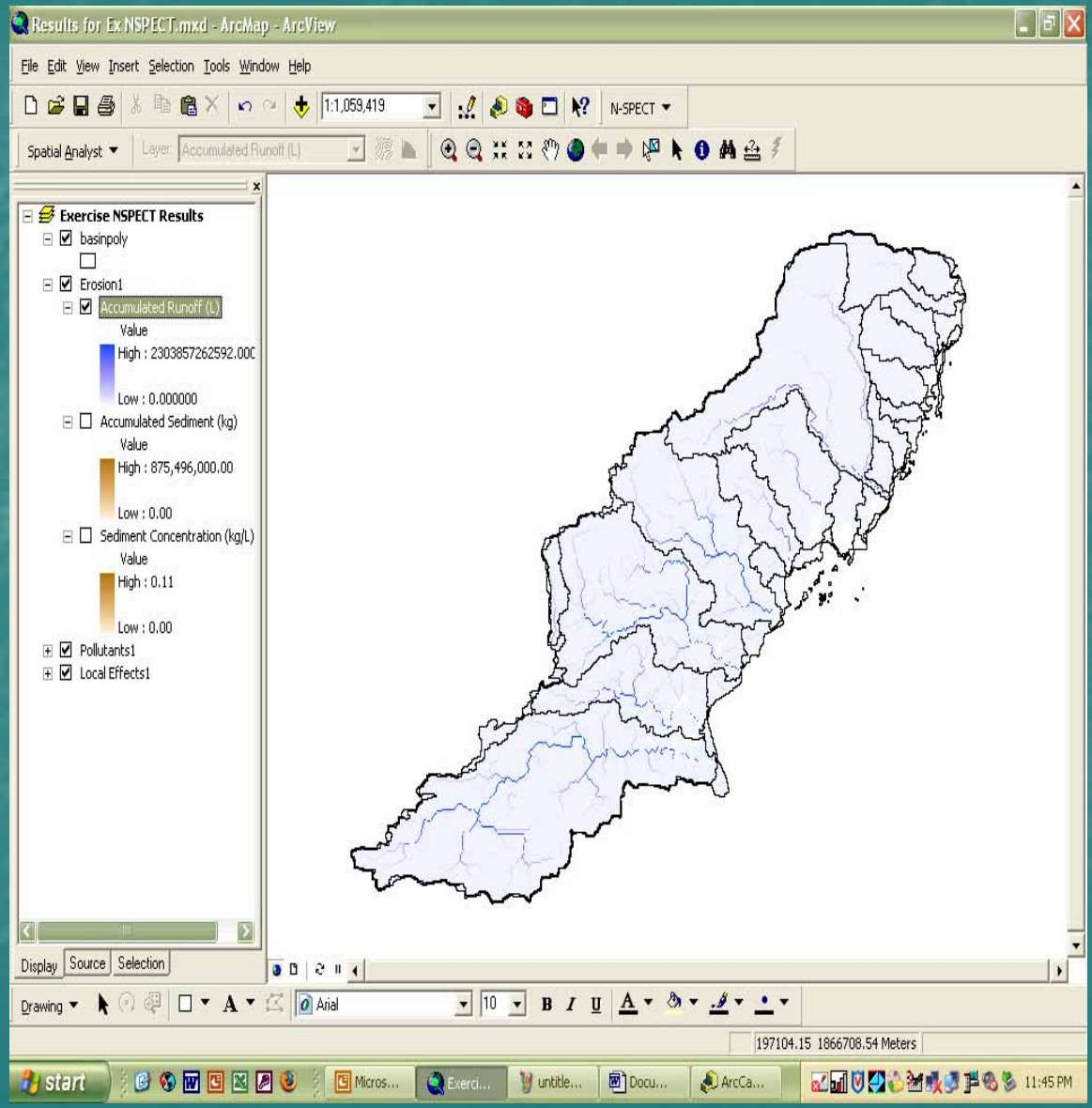
Hydrologic Soil Group



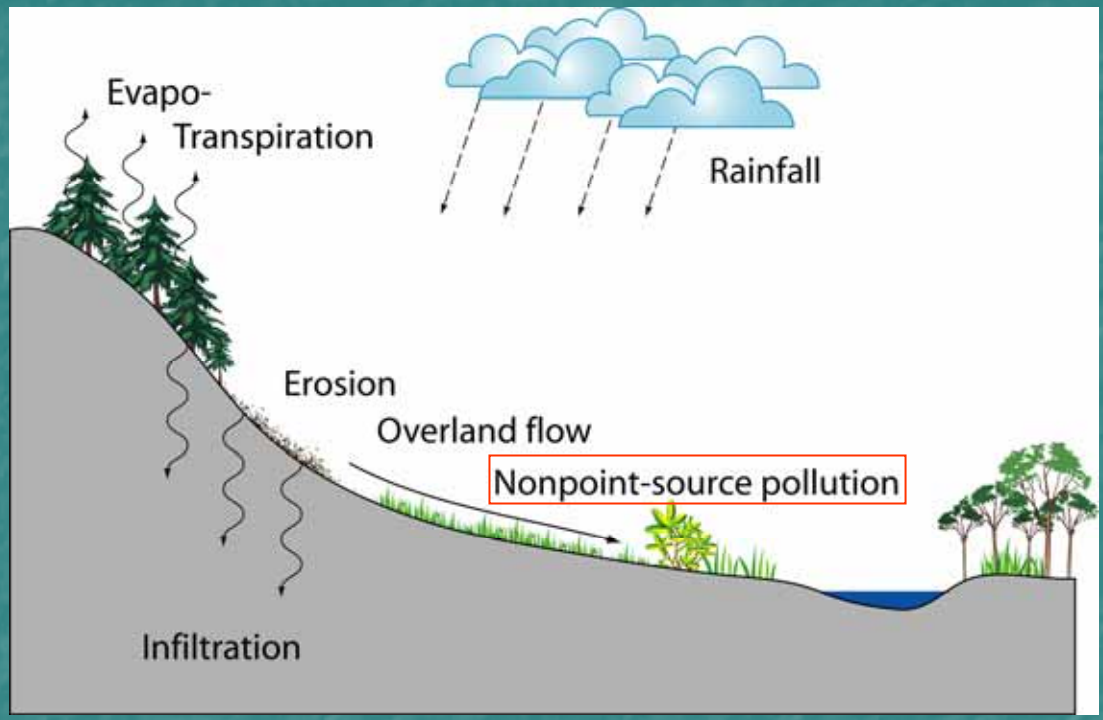
Hydrologic Soil Group	Soil Group Characteristics
A	Soils having high infiltration rates, even when thoroughly wetted and consisting chiefly of deep, well- to excessively-drained sands or gravels. These soils have a high rate of water transmission.
B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, and moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.
D	Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

Runoff: Outputs

- **Runoff volume (L)** (annual or event)
- *Runoff depth*
- *Runoff curve number grid*



N-SPECT Concept: Pollutants



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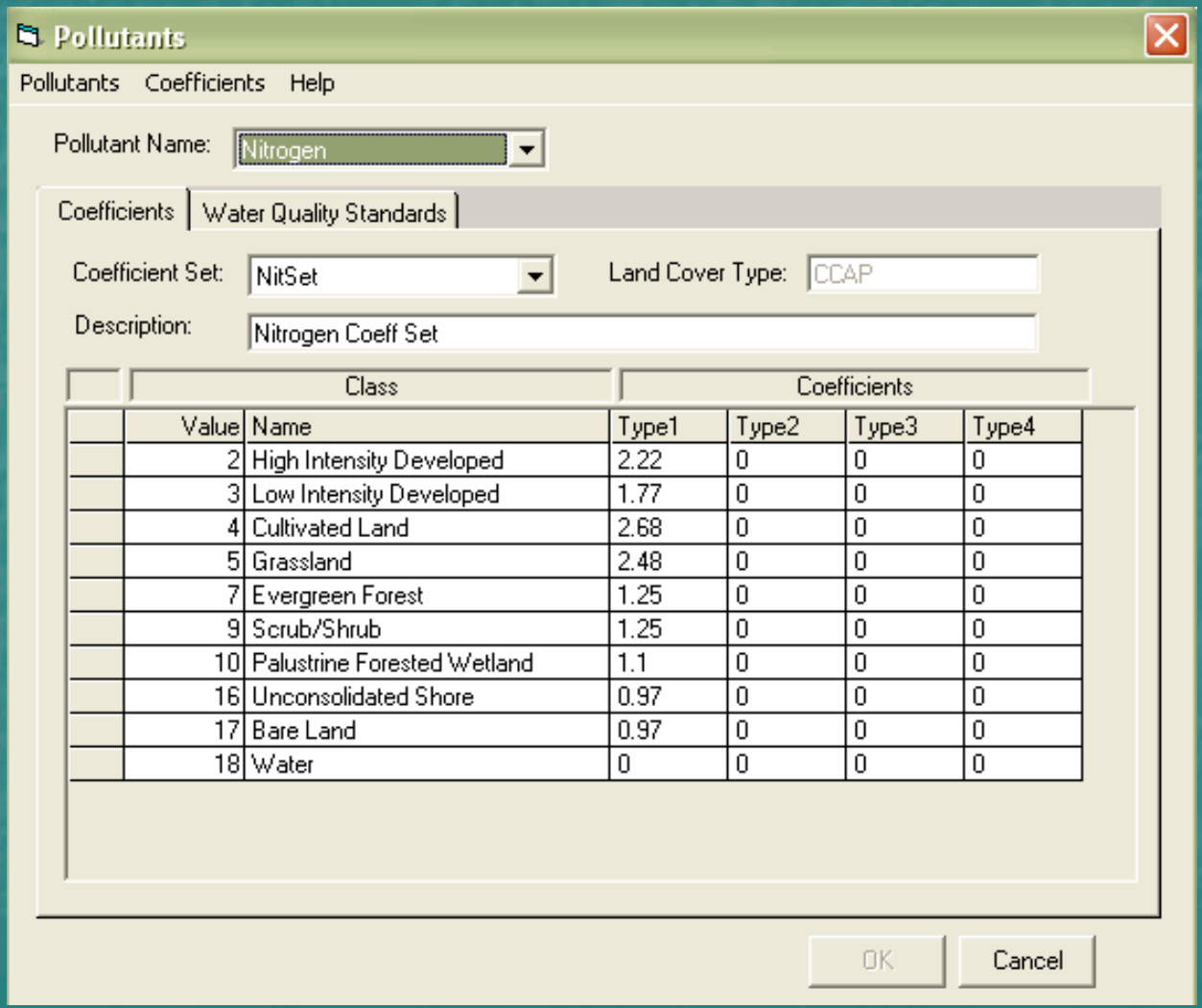
Eutrophication, algal blooms, closed beaches and shellfish beds, human health impacts through accumulation in food chain. (Arnold & Gibbons, 1996)

Runoff, land cover, topography and *pollutant coefficients* determine pollutant loads

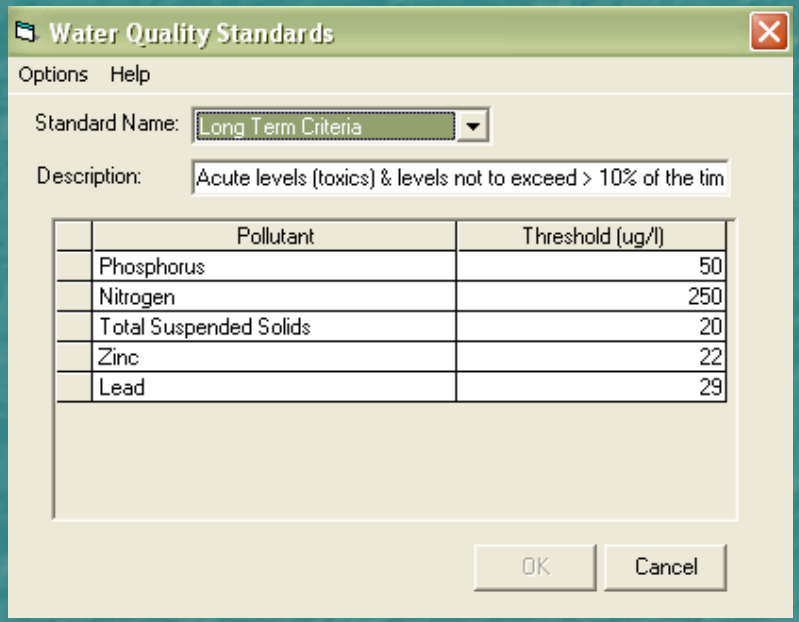
Pollutants: Inputs

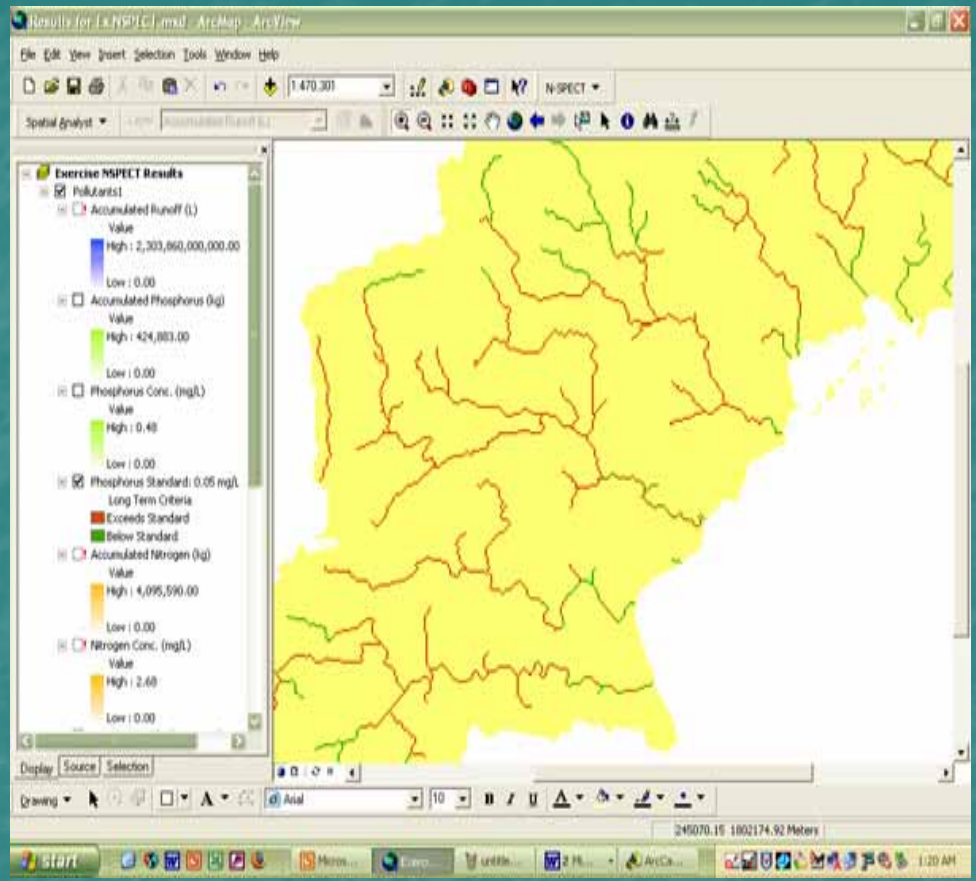
- Rainfall grid (annual or event)
- Elevation (DEM) derivatives
- Soil (hydrological group)
- Pollutant Coefficients
  - Expected pollutant mean concentration from each land cover type
  - Ideally, locally derived from WQ and land cover data.

Pollutants: Coefficient Method



Pollutants: Output



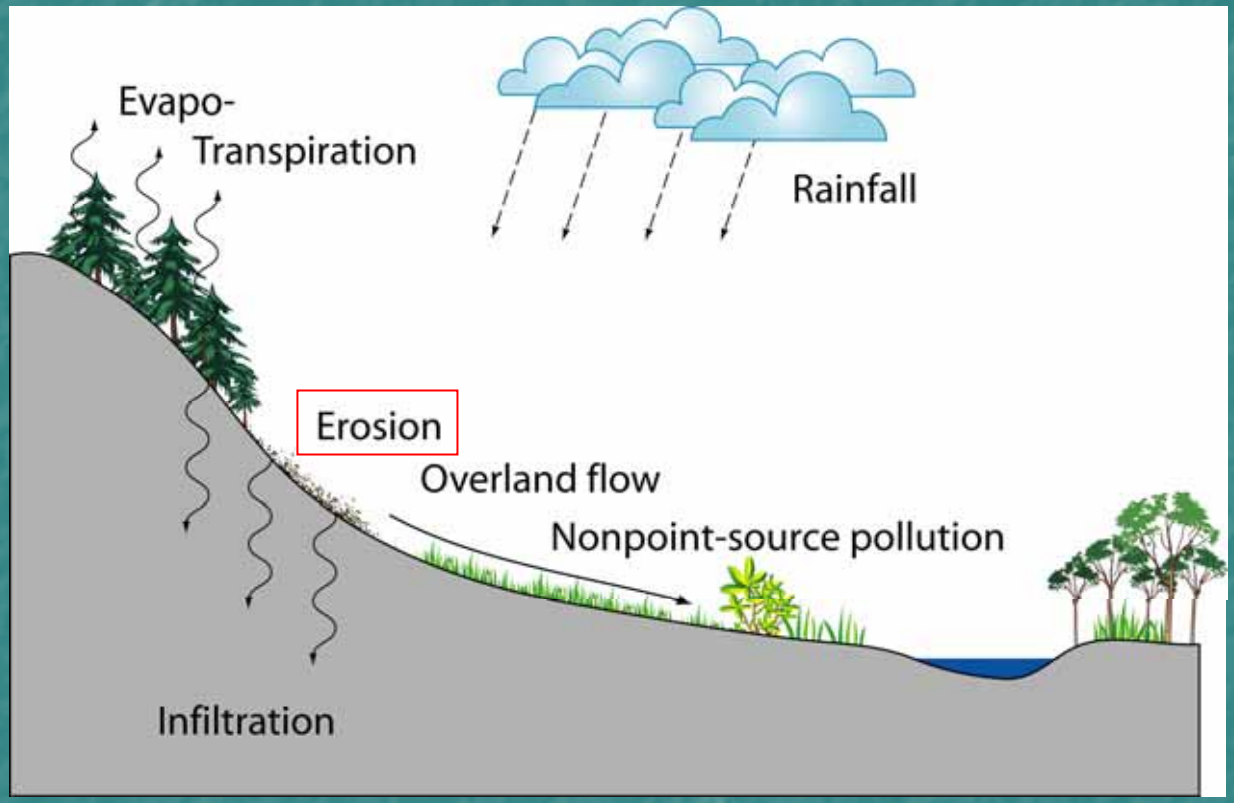


- Accumulated Pollutant (kg)
- Pollutant Concentration (mg/L)
- Comparison to water quality standard (exceeds or below standard)
  - Short, moderate, and long-term

Water quality standards

- Concentration output compared to local standards – meet or exceed criteria?
- Short, moderate, or long term.

N-SPECT concept: Erosion



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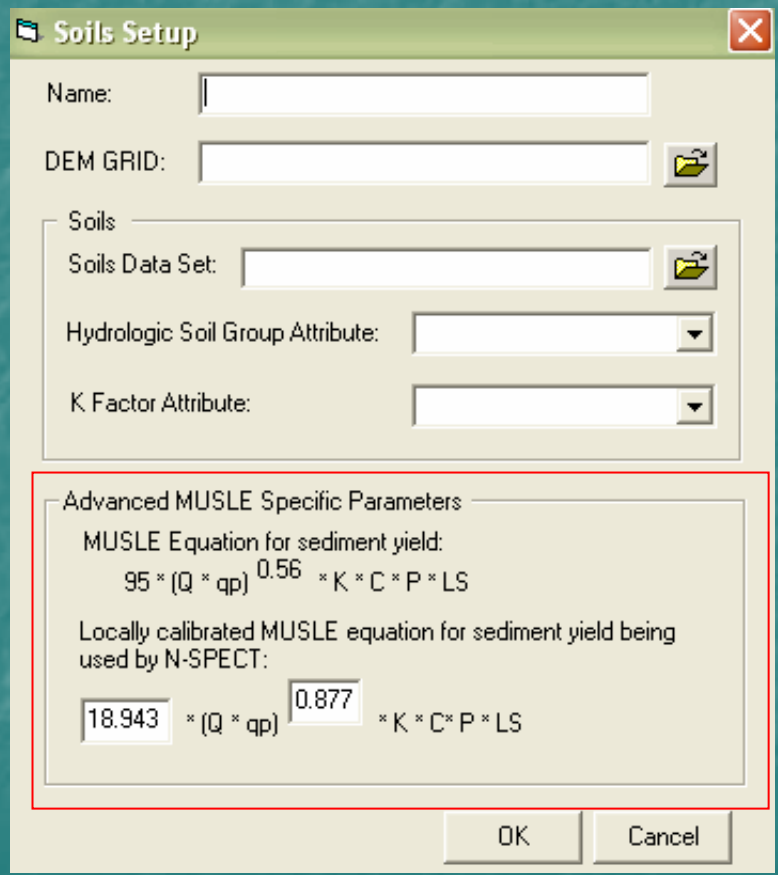
Runoff, topography, soil characteristics, and *land cover* determine sediment loads.

Erosion: USLE method

- Sediment yield & concentration
- Universal Soil Loss Equation
- Annual & Event (RUSLE & MUSLE)
- RUSLE: A = R * K * L * S * C * P
- Where:
  - A = avg. annual soil loss
  - R = rainfall/runoff erosivity factor
  - K = soil erodibility factor
  - L = slope length factor
  - S = slope steepness factor
  - C = cover management factor
  - P = supporting management practices factor

MUSLE method: Event based

- For single event precip scenarios
- Can locally calibrate equations for sediment yield.
- Q = storm runoff volume (acre-ft)
- q_p = peak runoff rate (ft^3/second)
  - "Maximum volume of flow attained at a given point in a stream during a runoff event."



Erosion Inputs

- DEM (LS Factor)
- Land cover grid (C Factor)
- Soils (K-factor) grid
- Rainfall grid
- Rainfall erosivity (R-factor) grid.

Key RUSLE inputs: R-Factor

"Quantifies the effects of raindrop impact and amount and rate of runoff associated with the rain." - USDA

- Preferable to derive R-factor empirically from actual rainfall data. OK for U.S. but not always available in other places.
- Many studies in literature have derived region-specific equations incorporating precipitation or precipitation & elevation.
- Sediment load output from several R-factor regression equations compared statistically to each other and to a physical model at Texas A&M. (see documentation on cd for more info on R-Factor and MAR implementation).

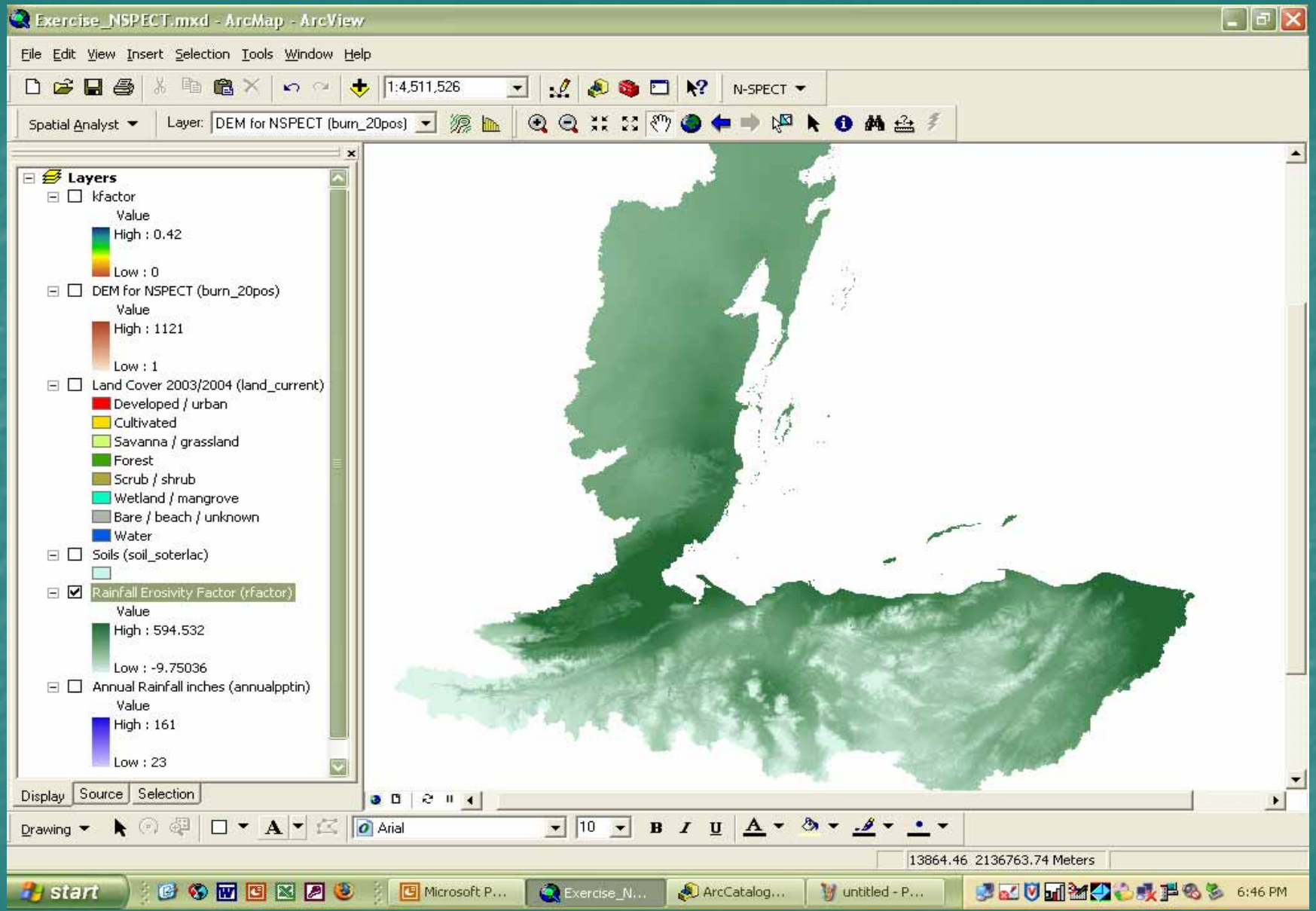
- Equation determined to be most appropriate for MAR region:
  - R = 3786.6 + 1.5679(Precip in mm) – 1.9809(Elevation in m)

- Erosivity grid for MAR generated from annual precip grid and DEM

R-factor conversion for N-SPECT

- R = 3786.6 + 1.5679 * (Precip in mm) – 1.9809 * (Elevation in m)
- Output in metric units *MJ * mm * ha^{-1} * h^{-1} * y^{-1}*
  (megajoule * mm / hectare * hour * year)
- However, N-SPECT requires US units:
  *hundreds of feet * tonf * inch * $acre^{-1}$ * $hour^{-1}$ * $year^{-1}$*
- Convert by Dividing by the conversion factor, 17.02.

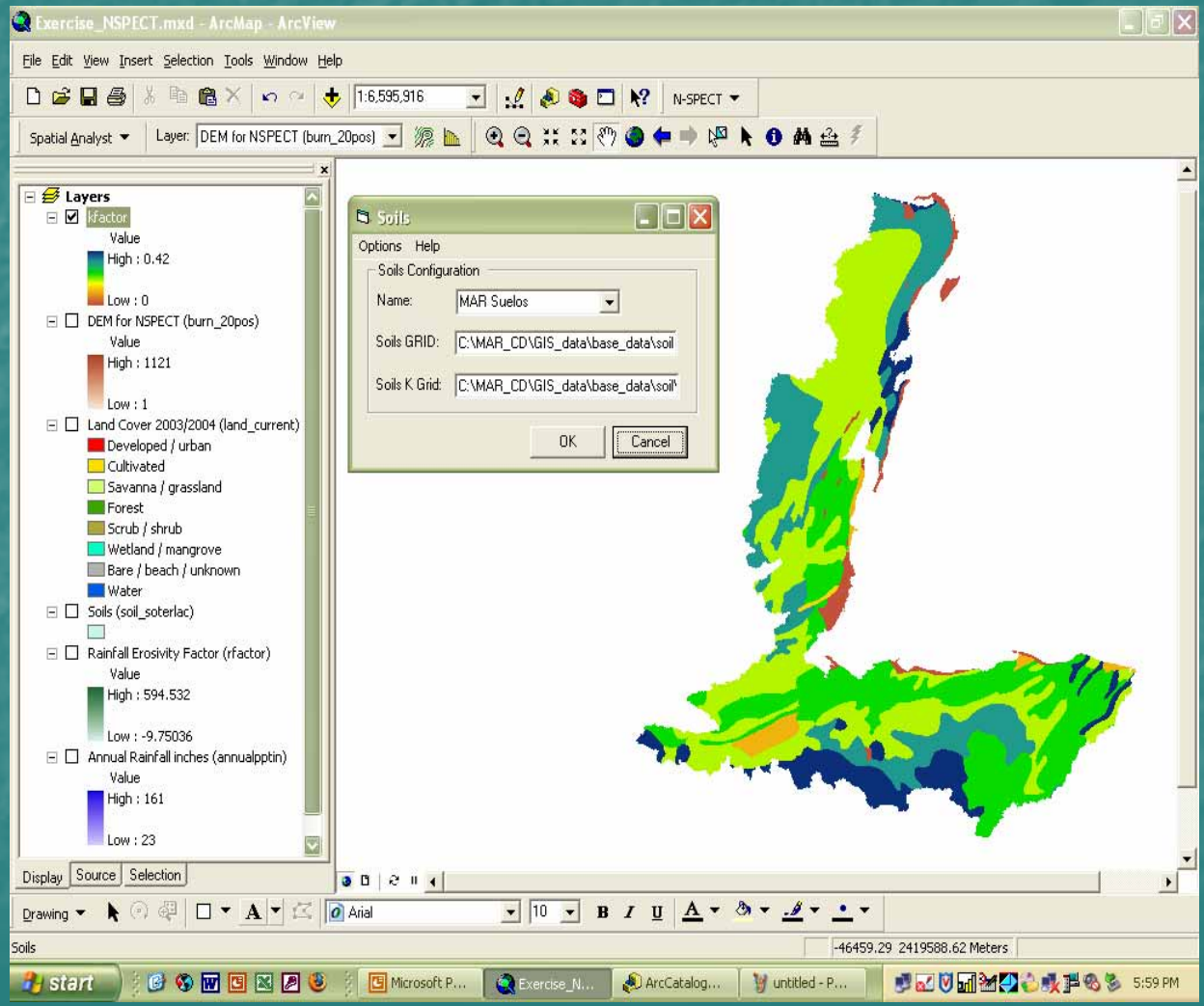
Reference: USDA-ARS Agriculture Handbook No. 703



$$R = 3786.6 + 1.5679(P) - 1.9809(E)$$

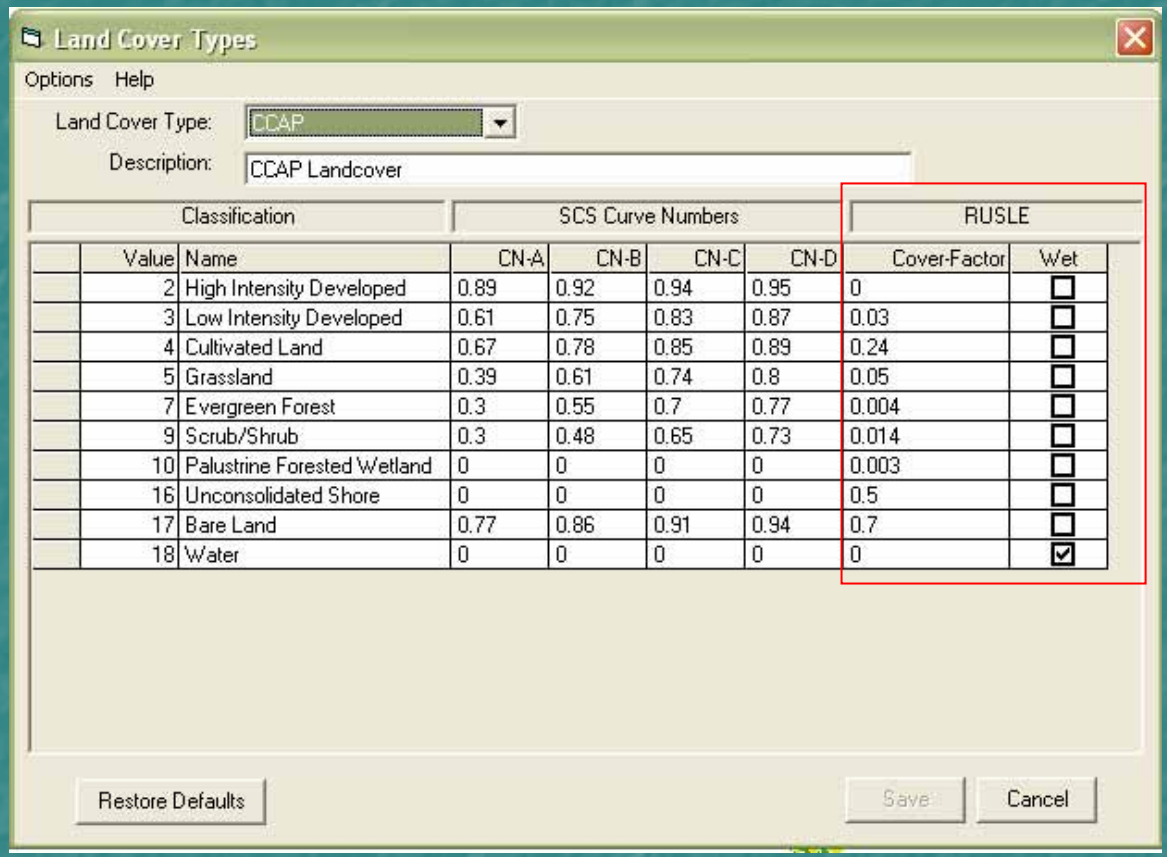
Key Input 2: K-factor

- Soil erodibility
- Average long-term soil response to stormwater erosion
- “Lumped” parameter. based on several different hydrologic soil processes.
- Contained in soil attribute table.



Ton * acre * hour / acres * tonf * feet * inch

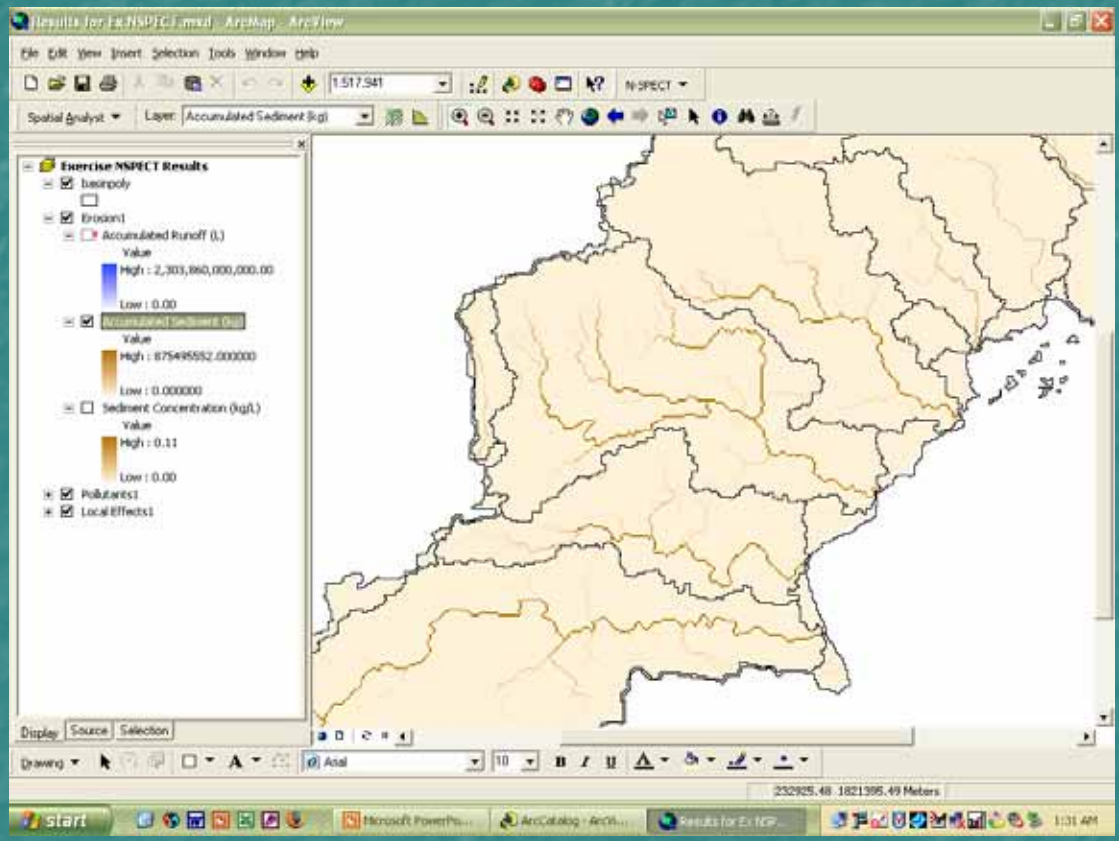
Land Cover (C) Factor



Value	Name	CN-A	CN-B	CN-C	CN-D	Cover-Factor	Wet
2	High Intensity Developed	0.89	0.92	0.94	0.95	0	☐
3	Low Intensity Developed	0.61	0.75	0.83	0.87	0.03	☐
4	Cultivated Land	0.67	0.78	0.85	0.89	0.24	☐
5	Grassland	0.39	0.61	0.74	0.8	0.05	☐
7	Evergreen Forest	0.3	0.55	0.7	0.77	0.004	☐
9	Scrub/Shrub	0.3	0.48	0.65	0.73	0.014	☐
10	Palustrine Forested Wetland	0	0	0	0	0.003	☐
16	Unconsolidated Shore	0	0	0	0	0.5	☐
17	Bare Land	0.77	0.86	0.91	0.94	0.7	☐
18	Water	0	0	0	0	0	☑

- Complex coefficient representing impact of land management/cover on soil loss.
- Higher value = higher level of soil loss

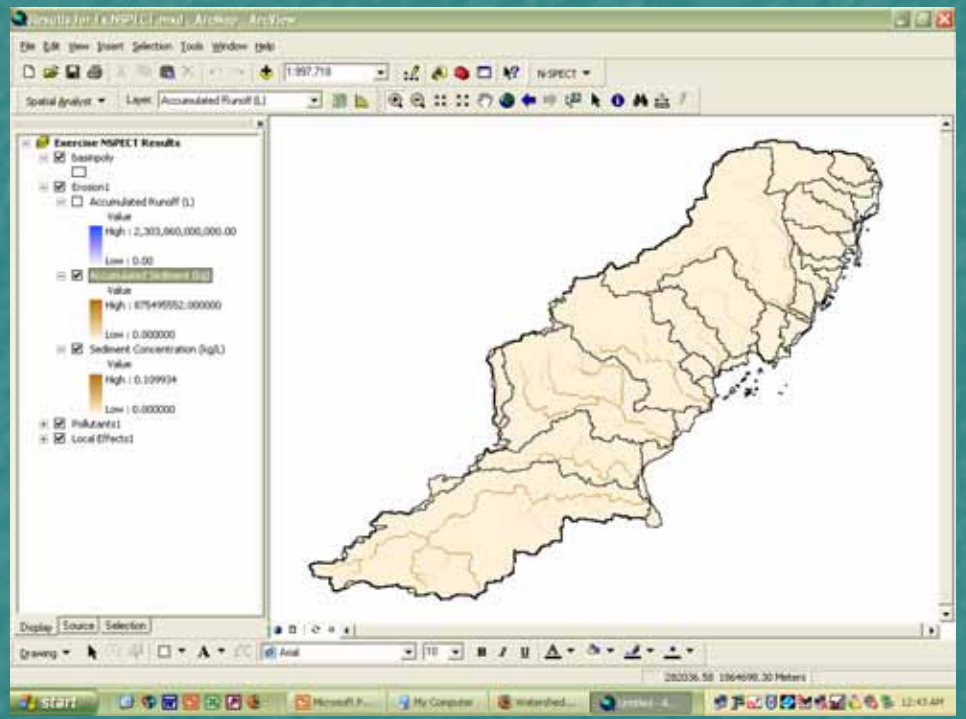
Erosion: Output GRIDs



- Accumulated Sediment (kg)
  - Total amount of sediment accumulated over a year's time
- Sediment concentration (kg/L)

Local Effects

- Contributions of single cells independent of upstream contributions through time.
- Pollution and erosion generated by single cells, groups of cells, with no input from upstream sources.



Land use & Management scenarios

- Not utilized for MAR region
- Allows you to overlay vector layers representing different land cover types and management scenarios.
- Compare effects of change on pollution and erosion.
- Additional training resources (Hawaii) available with N-SPECT.

Future improvement/adjustment

- Adapt to other regions
- Calibrate to real discharge and sediment
- Develop local pollutant coefficients
- Additional pollutants
- More detailed land cover/new curve #’s and cover factors
- Finer scale
- Locally accurate number of rainy days
- Higher res. Precip, DEM, & R-factor

N-SPECT Resources on CD

- Additional basic and advanced training exercises
- User's manual
- Technical guide

- Updates on web at http://www.csc.noaa.gov/crs/cwq/nspect.html