Assessing the Effects of Change on Water and Soil Resources

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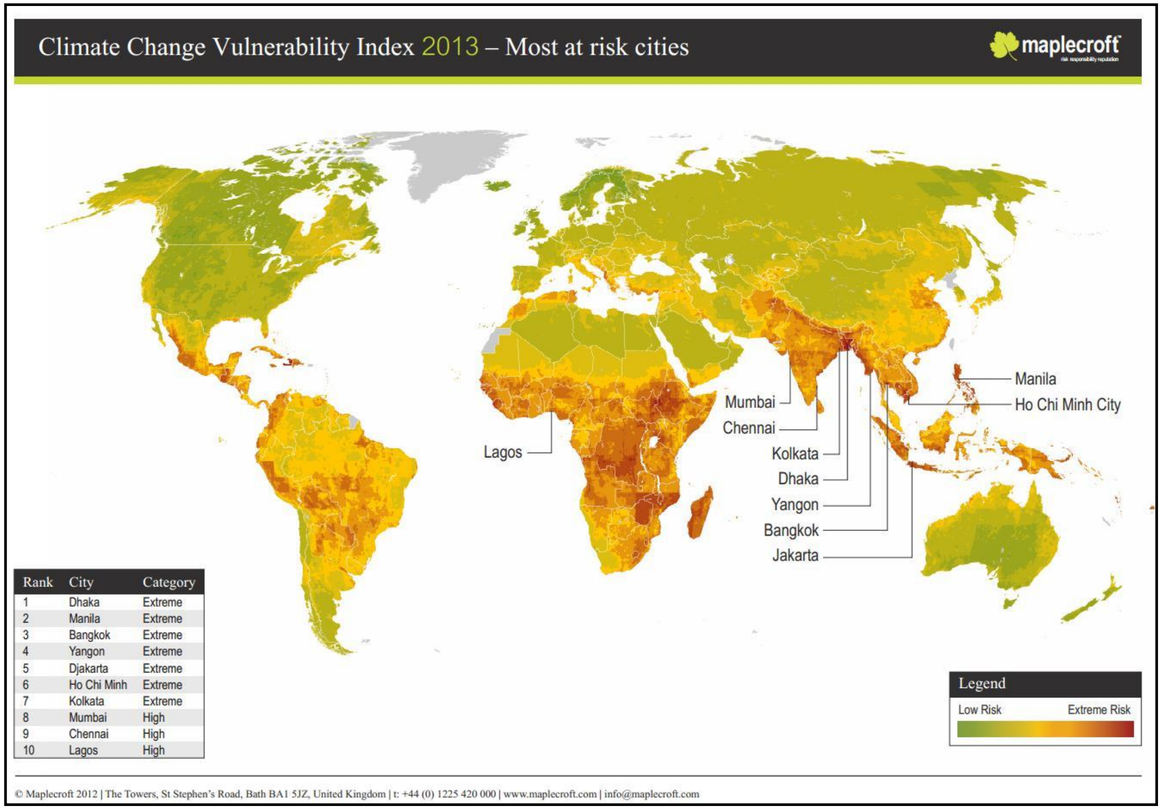
Presentation Outline

- Drivers of Change
- Modeling and Assessment
- Model Criteria
- Examples of Tools
- Questions

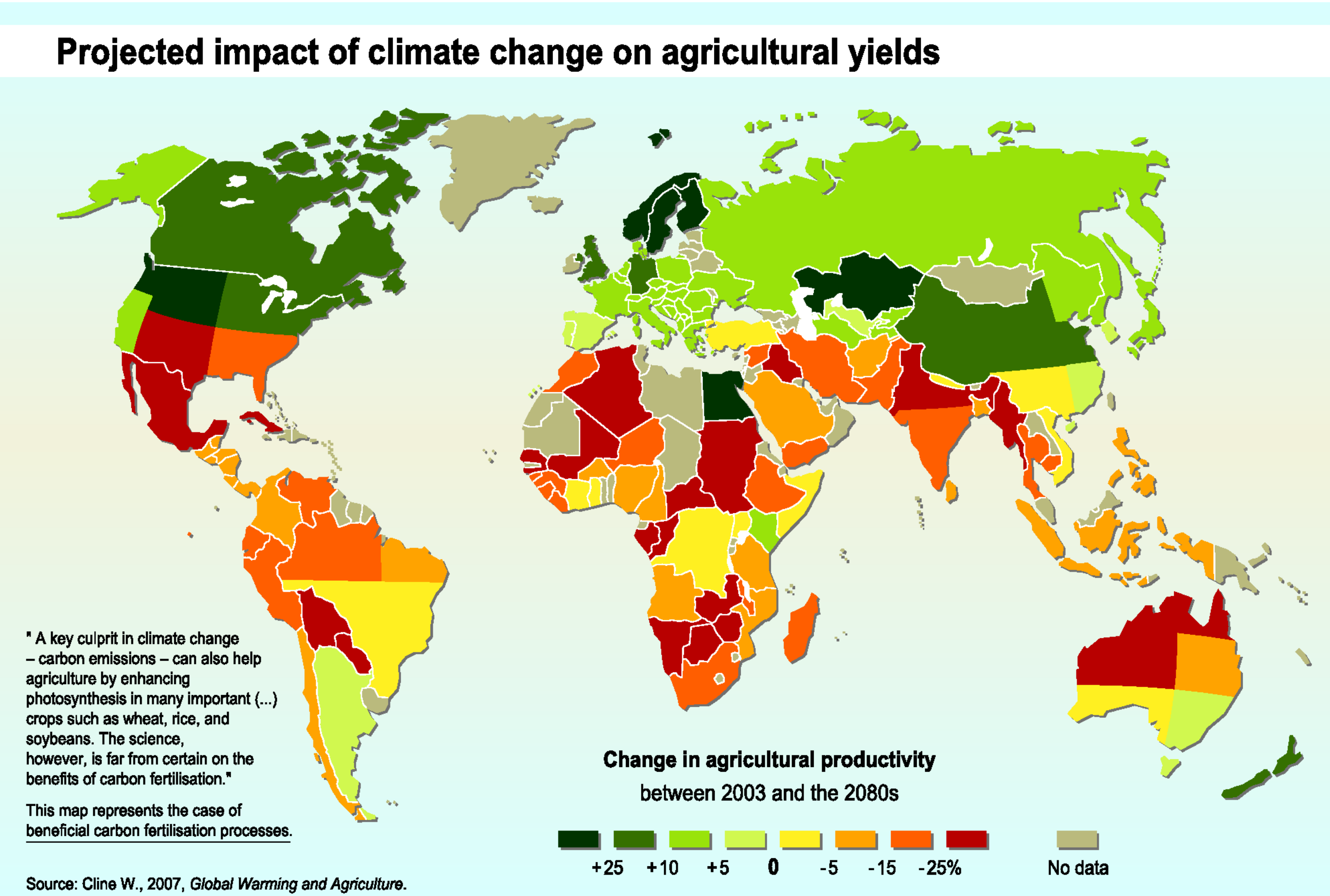


Rank	City	Category
1	Dhaka	Extreme
2	Manila	Extreme
3	Bangkok	Extreme
4	Yangon	Extreme
5	Djakarta	Extreme
6	Ho Chi Minh	Extreme
7	Kolkata	Extreme
8	Mumbai	High
9	Chennai	High
10	Lagos	High

Drivers of Change

- Growth (population and economic)
  - Development Impacts
  - Increase Demand for Agricultural Production
    - 8.3 – 10.9 Billion People by 2050 (UN Population Division)
  - Competition for Resources – Land and Water
    - Municipal Water Supply vs. Agriculture (Quantity and Quality)
    - Agriculture accounts of 70% of all water consumption
- Climate Variability and Associated Disturbances
  - Drought - Frequency and Duration
  - Consumptive Use of Water (increase in Evapotranspiration)
  - Water Supply - Increase Water Needs and Water Supply Conflicts
  - Raising Sea Levels – Force migration
  - Flooding
  - Erosion, Sediment Yield, Water Quality
  - Fire - Frequency, Extent and Severity
  - Insects and Pathogens
  - Vegetation Changes - Invasive Species

Effects of Climate Change will vary depending on location.



Assessment and Change

- Planning for growth and climate is confounded with uncertainty. We currently have limited capabilities for predicting long-term climate or growth change at the spatial scales needed by water managers. Watershed managers need to know what may happen at a field to watershed scale?
- Simulation models (e.g. hydrological and erosion models) are tools for assessing how watershed processes will respond to the Drivers of Change. They can be used to evaluate the implications of alternative actions, policies on future outcomes (scenario analysis).
- We can use model to start identifying the ranges of potential impacts and develop strategies for managing risk (e.g. increasing resilience).
- Given uncertainty, best to think about adaptation in the context of specific vulnerabilities. Identify what causes vulnerability. Identify areas with a high potential to change.

Model Criteria

- Physically-based models that can be parameterize based on physical, measurable watershed characteristics.
- Model only requires readily available data.
- Model is sensitive to the Drivers of Change
  - Land Cover/Land Use
  - Climate (temperature and precipitation)
- Model is sensitive to management alternatives.
- Model predicts desired end points (e.g. peak discharge, hillslope erosion).
- Model is appropriate for desired spatial (watershed size) and temporal (minute – daily) scales.
- Model is cost effective to use.

Example of Assessment Tools

- **Climate Assessment Tool (CAT) - Local Climate Change**
  - Based on the ROCKCLIM tool developed by Dr. William Elliot.
  - Modifies Historical Weather Records to Represent Different Climate Scenarios.
- **WEPPCAT - Field scale runoff and erosion modeling**
  - Link the Water Erosion Prediction Project Model and the CAT tool
  - Available online as stand-alone WEPP application for assessing sediment loss from agricultural fields.
- **Integrated Climate and Land Use Scenarios - Growth**
  - Developed by EPA-ORD and ICFI Consultants
  - Provides maps of land use change that include population growth and potential migrations as the result of climate change.
- **Automated Geospatial Watershed Assessment Tool**

  - Watershed scale runoff, erosion and water quality modeling
  - Developed by the USDA-ARS, EPA-ORD and University of Arizona.
  - GIS-based hydrologic and erosion modeling decision support tool.

Climate Assessment Tool (CAT)

- Developed by the USDA Agricultural Research Service in cooperation with the EPA Office of Research and Development.
- Uses statistics derived from weather station records to simulate 100 year time series using the CLIGEN stochastic weather generator.
- ROCKCLIM modifies Historical Weather Records to Represent Different Climate Scenarios. You can change:
  - Mean Month Minimum and Maximum Temperatures
  - Mean Month Precipitation
  - Number of Wet Days in a Month
  - Intensity Rainfall - **Greater fraction of rain falling in larger events**
- Provides input for WEPP and has been linked to Soil and Water Assessment Tool (SWAT) in the AGWA tool.
- Similar to the Climate Assessment Tool in EPA BASINS toolkit.

Over 2600 Weather Stations in US

If you have weather records (Daily Minimum Temperature, Maximum Temperature and Precipitation) you can create the required statistics to run the CLIGEN stochastic weather generator.

WEPPCAT Interface

Climate parameters for ALABAMA STATE FARM AL

34.68°N 86.88°W

600 feet elevation

Modify climate parameters below

34.68 °N 86.88 °W PRISM

(lat-long calculator) (degrees calculator)

600 ft elevation

Historical Record: Mean Maximum Temperature (°F)	Historical Record: Mean Minimum Temperature (°F)	Historical Record: Mean Precipitation (in)	Historical Record: Number of wet days	Month	User Values: Mean Maximum Temperature (°F)	User Values: Mean Minimum Temperature (°F)	User Values: Mean Precipitation (in)	User Values: Number of wet days
50.32	30.21	5.15	11.19	January	50.32	30.21	5.15	11.19
55.14	32.72	4.78	10.18	February	55.14	32.72	4.78	10.18
63.26	39.6	6.13	10.94	March	63.26	39.6	6.13	10.94
73.39	48.23	4.71	9.23	April	73.39	48.23	4.71	9.23
80.88	56.63	4.52	9.42	May	80.88	56.63	4.52	9.42
87.58	63.96	3.83	8.51	June	87.58	63.96	3.83	8.51
90.32	67.59	4.35	9.66	July	90.32	67.59	4.35	9.66
90.18	65.85	3.45	8.63	August	90.18	65.85	3.45	8.63
84.31	59.89	3.55	8.06	September	84.31	59.89	3.55	8.06
74.34	47.23	2.98	7.09	October	74.34	47.23	2.98	7.09
62.9	38.4	4.62	9.23	November	62.9	38.4	4.62	9.23
53.01	32.15	5.61	10.20	December	53.01	32.15	5.61	10.20
		53.68	112.34	Annual			53.68	112.34
Change entire column (enter 0 to reset) > >					+/- 0 °	+/- 0 °	+/- 0 %	+/- 0 %

Intensify Rainfall 0 (0.01 - 25%)

Adjust temperature for elevation by lapse rate

What is the most realistic way to change precipitation?

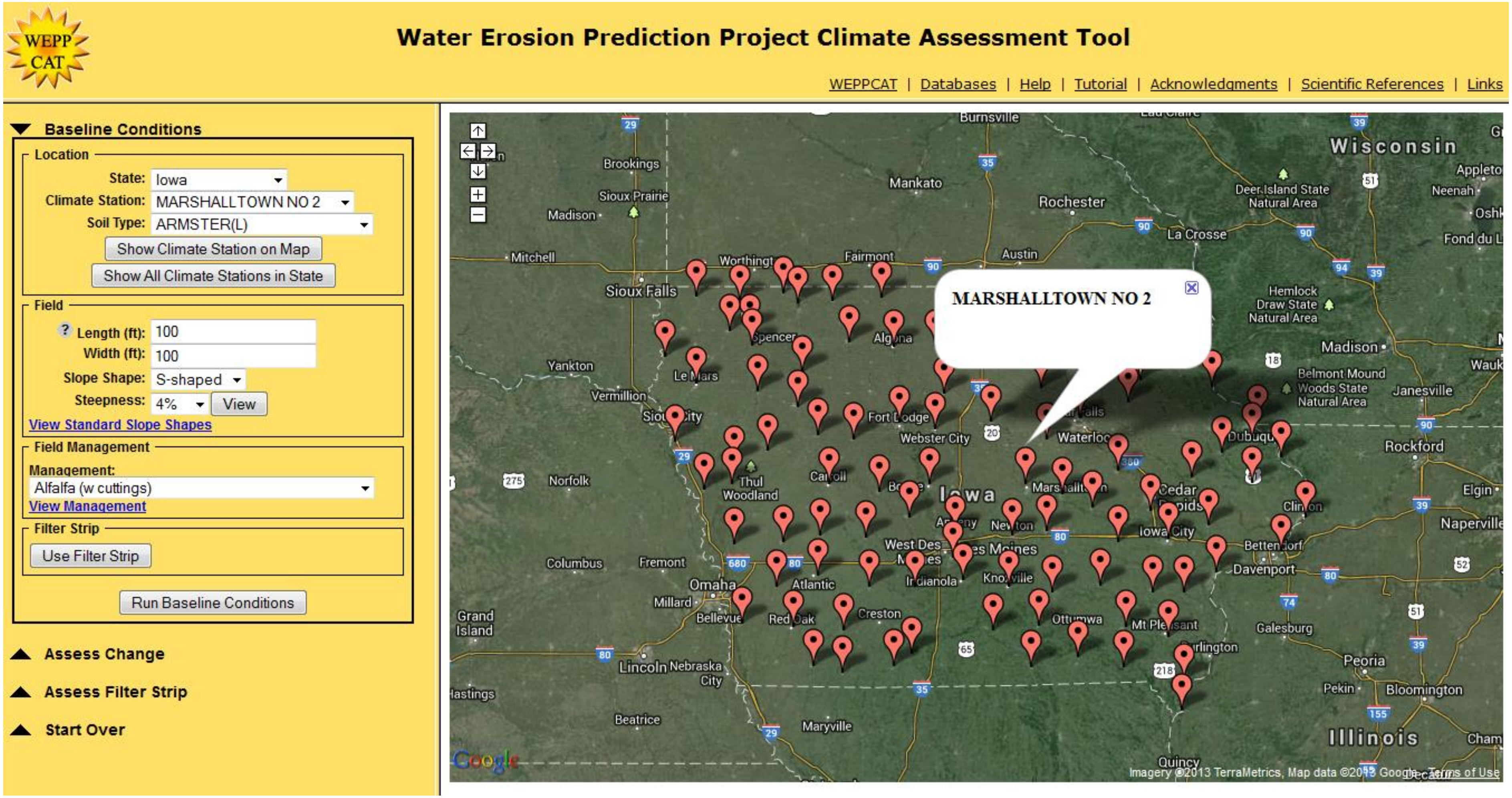
Scenario Analysis

- Global Climate Change Models provides relative estimates for potential change (e.g. 5% increase in average temperature) over a wide area.
- For precipitation a % change can take many forms, increase/decrease rain for each event, less/more events, or more large events.
- CAT allows you to modify local weather data so you can do “what if” analysis.

WEPP Climate Assessment Tool (WEPPCAT)

- Available online as stand-alone Water Erosion Prediction Project model for assessing sediment loss from agricultural fields. Website: http://www.weppcat.net
- Create and run new meteorological time series (temperature and precipitation) using CAT.
  - Creates 100 year time series for a given climate scenario.
- Can address a wide range of “what if” questions about system response to climate change and adaptive agriculture management practices.
- Supports sensitivity analyses and scenario planning.
- Considers effects of agricultural soil conservation practices.

WEPPCAT Interface

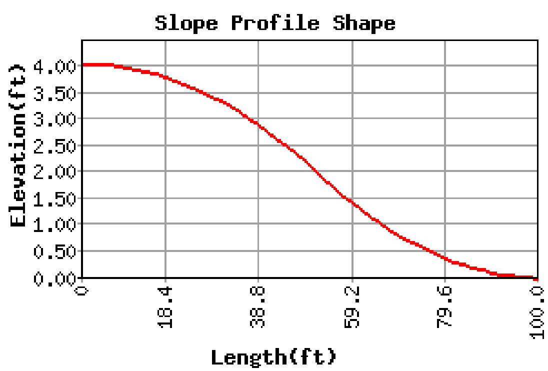


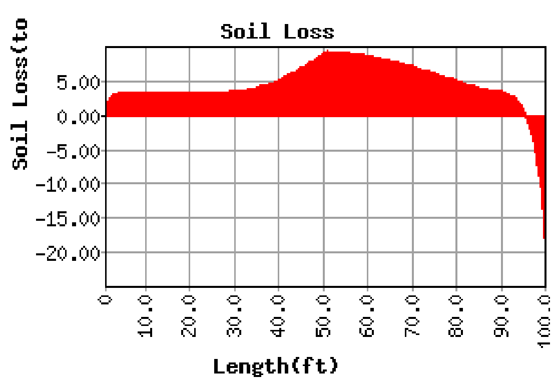
WEPPCAT Simulation Results

Scenario:	Baseline
State:	Iowa
Climate Station:	MARSHALLTOWN NO 2
Management:	Corn (fall mulch till)
Soil:	ARMSTER(L)
Slope Shape	S-shaped(4%)
Slope Length (ft):	100
Slope Width (ft):	100

Average Annual Precipitation (in/yr)	**33.8**
Average Annual Runoff (in/yr)	**4.7**
Average Annual Soil Loss (ton/A/yr)	**5.4**
Average Annual Sediment Yield (ton/A/yr)	**4.7**

Version Run on: October 14, 2013, 6:10 pm

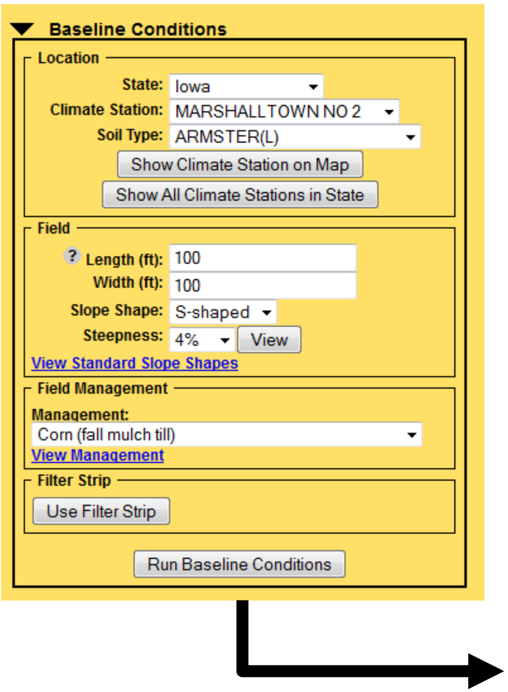


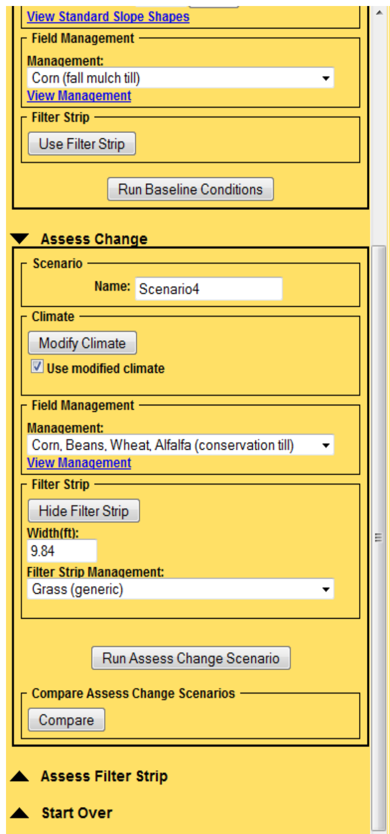


Creating Four Scenarios

- Baseline (Corn (fall, mulch, till))
- Increase Mean Precipitation by 5%
- Intensity Rainfall by 10%
- Corn, Bean, Wheat, Alfalfa (conservation till)
- Add 3 Meter Grass Buffer

Creating and Running Scenarios





Climate parameters for MARSHALLTOWN NO 2 IA

42.07°N 92.93°W

870 feet elevation

Modify climate parameters below ?

42.07 °N 92.93 °W PRISM

(lat-long calculator) (degrees calculator)

870 ft elevation

? Mean Maximum Temperature (°F)	? Mean Minimum Temperature (°F)	? Mean Precipitation (in)	? Number of wet days	Month	? Mean Maximum Temperature (°F)	? Mean Minimum Temperature (°F)	? Mean Precipitation (in)	? Number of wet days
28.79	14.21	1.12	5.90	January	28.79	14.21	1.18	5.90
32.93	16.28	1.09	5.73	February	32.93	16.28	1.14	5.73
45.28	25.13	2.17	7.75	March	45.28	25.13	2.28	7.75
60.56	37.48	3.12	9.75	April	60.56	37.48	3.28	9.75
72.3	48.6	4.18	10.99	May	72.3	48.6	4.39	10.99
81.39	58.33	4.55	10.12	June	81.39	58.33	4.78	10.12
86.37	62.37	3.81	8.65	July	86.37	62.37	4	8.65
84.1	59.77	3.74	8.49	August	84.1	59.77	3.93	8.49
76.04	51.23	3.82	8.68	September	76.04	51.23	4.01	8.68
64.53	39.71	2.39	7.25	October	64.53	39.71	2.51	7.25
47	26.82	1.79	6.38	November	47	26.82	1.88	6.38
32.75	17.03	1.19	5.67	December	32.75	17.03	1.25	5.67
		32.97	95.36	Annual			34.63	95.36
Change entire column (enter 0 to reset) > >					+/- 0 °	+/- 0 °	+/- 5 %	+/- 0 %

? Intensify Rainfall ? 10 (0.01 - 25%)

Adjust temperature for elevation by lapse rate

? What is the most realistic way to change precipitation?

Comparison of Assess Change Results

Scenario:	Baseline	Scenario1	Scenario2	Scenario3	Scenario4
State:	Iowa	Iowa	Iowa	Iowa	Iowa
Climate Station:	MARSHALLTOWN NO 2	MARSHALLTOWN NO 2	MARSHALLTOWN NO 2	MARSHALLTOWN NO 2	MARSHALLTOWN NO 2
Management:	Corn (fall mulch till)	Corn (fall mulch till)	Corn (fall mulch till)	Corn, Beans, Wheat, Alfalfa (conservation till)	Corn, Beans, Wheat, Alfalfa (conservation till)
Soil:	ARMSTER(L)	ARMSTER(L)	ARMSTER(L)	ARMSTER(L)	ARMSTER(L)
Slope Shape:	S-shaped	S-shaped	S-shaped	S-shaped	S-shaped
Slope Length (ft):	100	100	100	100	100
Slope Width (ft):	100	100	100	100	100
Filter Strip Width (ft):					9.84
Filter Strip Management:					Grass (generic)
Average Annual Precipitation (in/yr):	33.8	35.5	34.9	34.9	34.9
Average Annual Runoff (in/yr):	4.7	5.2	5.7	5.5	4.8
Average Annual Soil Loss (ton/A/yr):	5.4	6	6.7	5.3	5.3
Average Annual Sediment Yield (ton/A/yr):	4.7	5.2	5.8	4.2	2.4

Open as comma separated compare.csv file

Integrated Climate and Land Use Scenarios

- ICLUS was developed by the US EPA Office of Research and Development. Website: www.epa.gov/ncea/global/iclus/
- Bench land use change scenarios for the U.S. consistent with IPCC emissions storylines (A1, A2, B1, B2) for each decade from 2000 – 2100. Spatial outputs include:
  - House Density (1 ha resolution)
  - Impervious Cover (1 km resolution)
  - County-level demography
- Uses the SERGoM cohort-component model with a gravity migration model.
- ArcGIS tool allows users to run new scenarios reflecting different assumptions about population growth and development density.
- Use as input to hydrologic models and risk assessment tools.

SERGoM Spatial Model

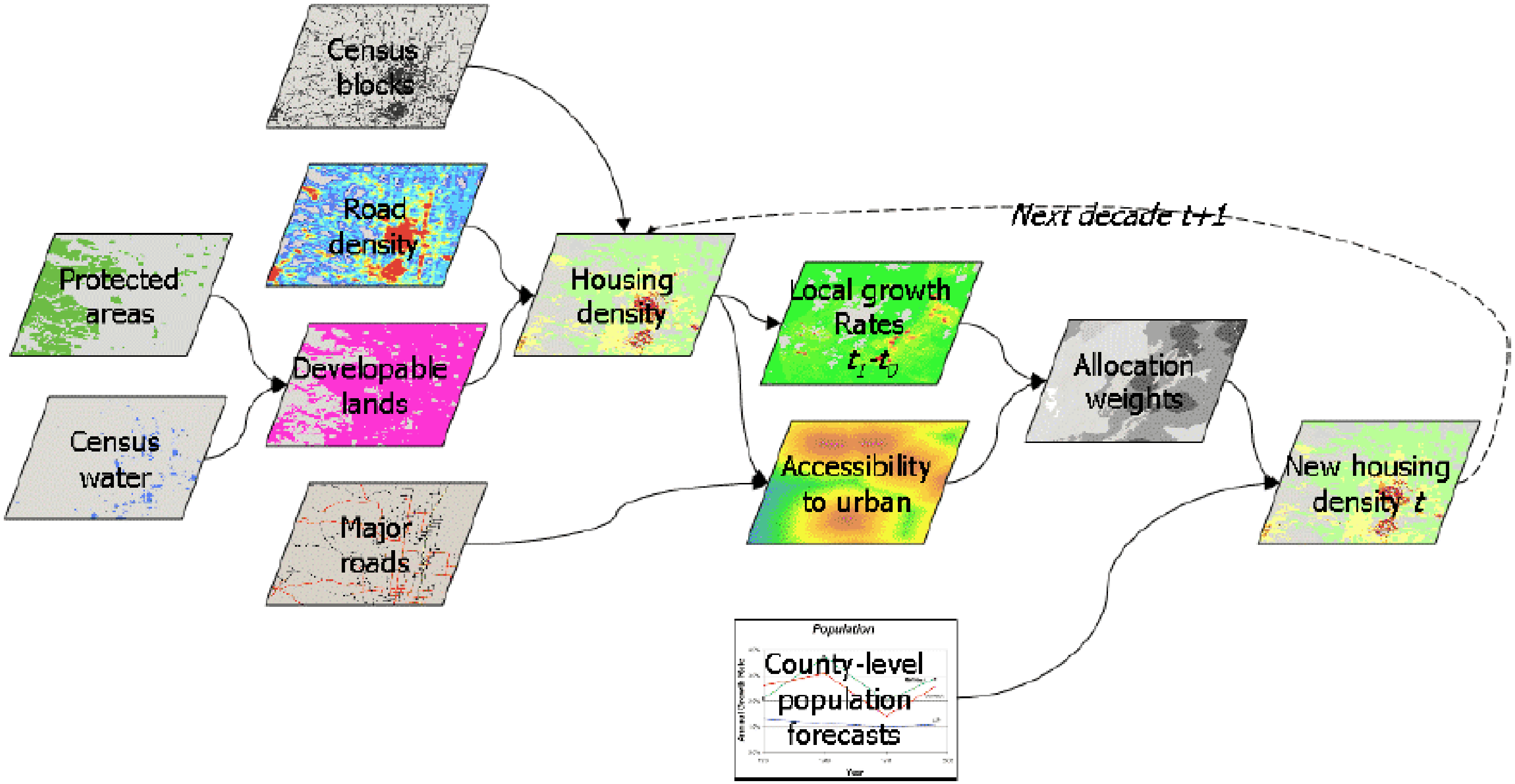
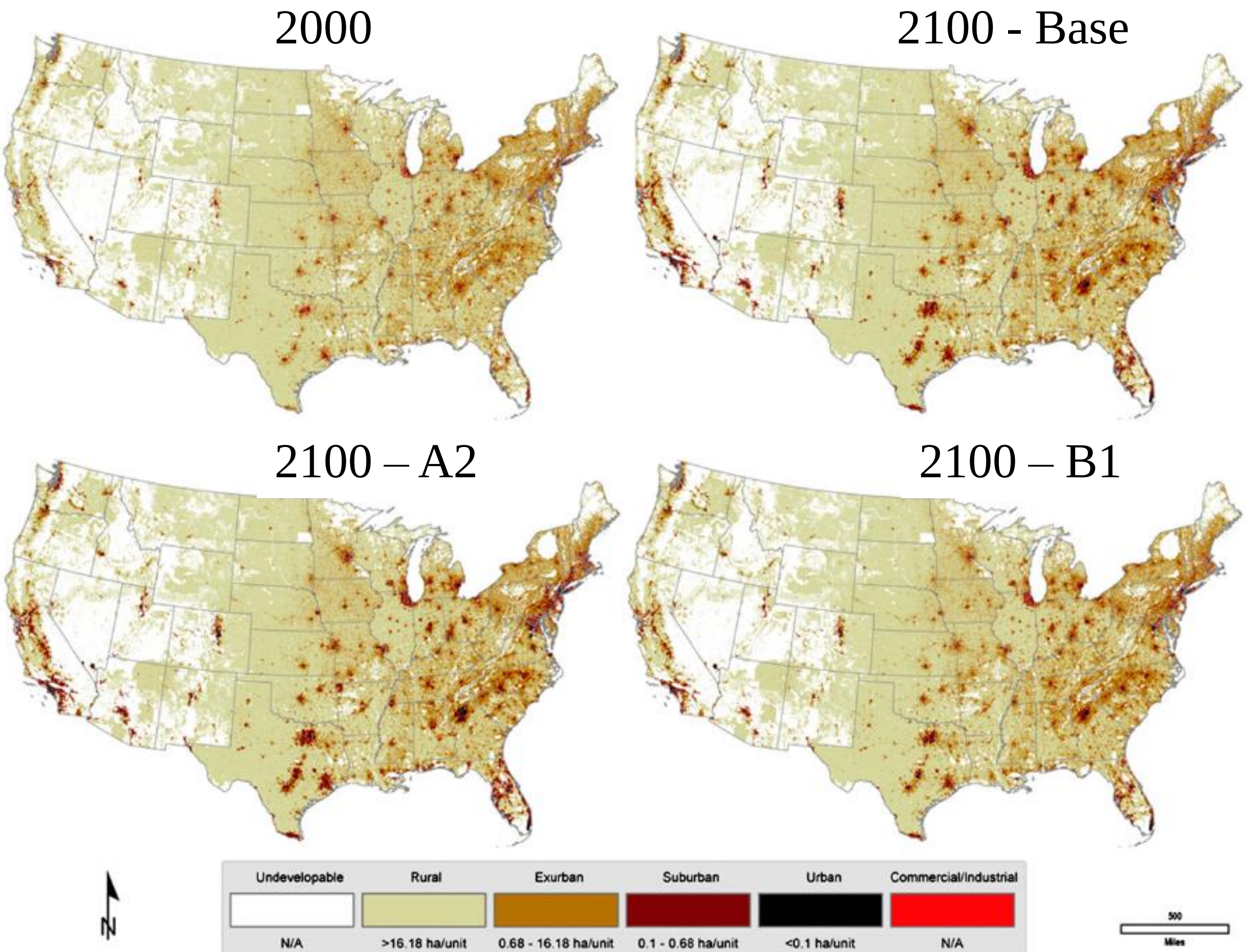


Figure 2-1. Diagram of SERGoM data inputs and modeling process

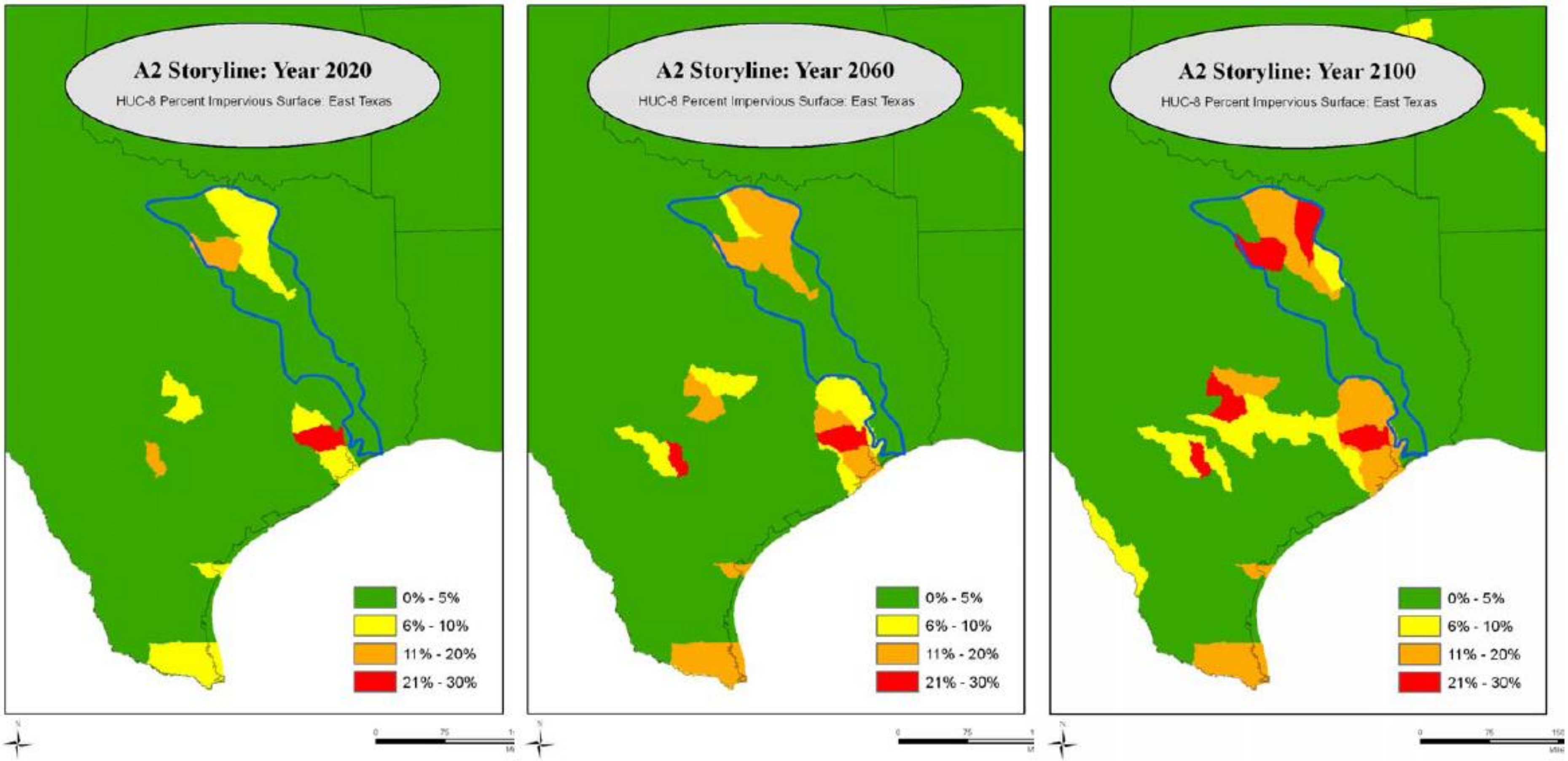
EPA – ORD, 2013

Examples of ICLUS Simulations



From: Bierwagen et al. 2010 – www.pnas.org/cgi/doi/10.1073/pnas.1002096107

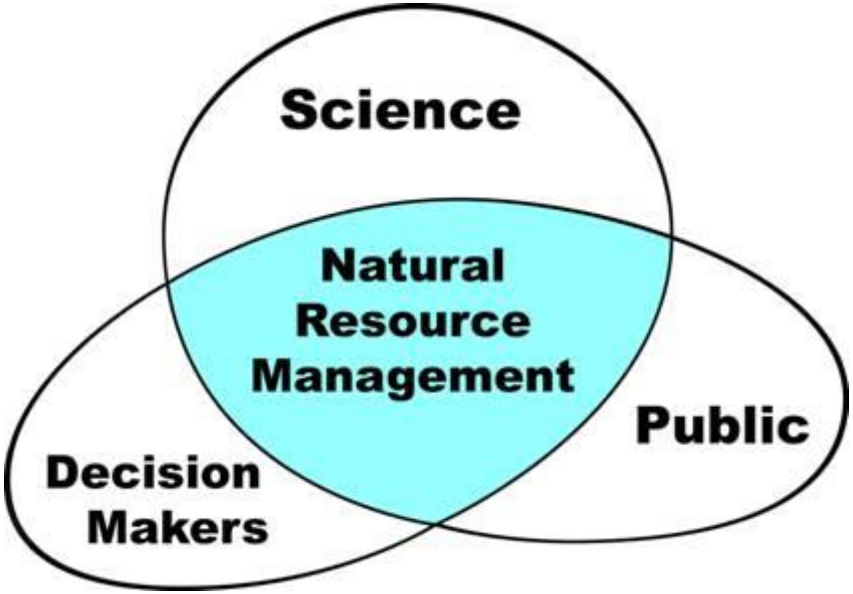
Emission Storyline A2
Projected Changes in Impervious Cover



EPA – ORD, 2013

AGWA

Automated Geospatial Watershed Assessment: GIS-based Hydrologic Modeling Tool for Watershed Assessment and Analysis



Research Objectives

- **Develop a reliable, <u>automated interface</u> to support hydrologic and erosion modeling.**
- **Applicable to ungauged watersheds**
  - **Model parameters based on soils, terrain, and land cover/land use.**
- **Investigate the impacts of land cover transitions on watershed hydrololgic response (runoff/erosion)**
  - **Historical and future changes**
  - **Identify sensitive, "at-risk", regions**
  - **Evaluate the impacts of management**
- **Better understanding of watershed processes, focus on spatial variability of cover**

How AGWA tools Fits into Comprehensive Watershed Assessments and Analysis

Impact of Historical Landscape Change (e.g. San Pedro/New York City)

Alternative Futures (e.g. San Pedro, Willamette River, South Platte)

AGWA (Runoff, Peak Discharge, Sedimentation, Nitrogen, Phosphorous)

Sub-catchments/Stream Segments at Risk to Increased Sedimentation and Run-off (e.g. 404q, 319)

Decision Support Tool for Watershed Assessment and Watershed-based Planning (e.g. GI, BMPs, Border 2020)

AGWA Goals

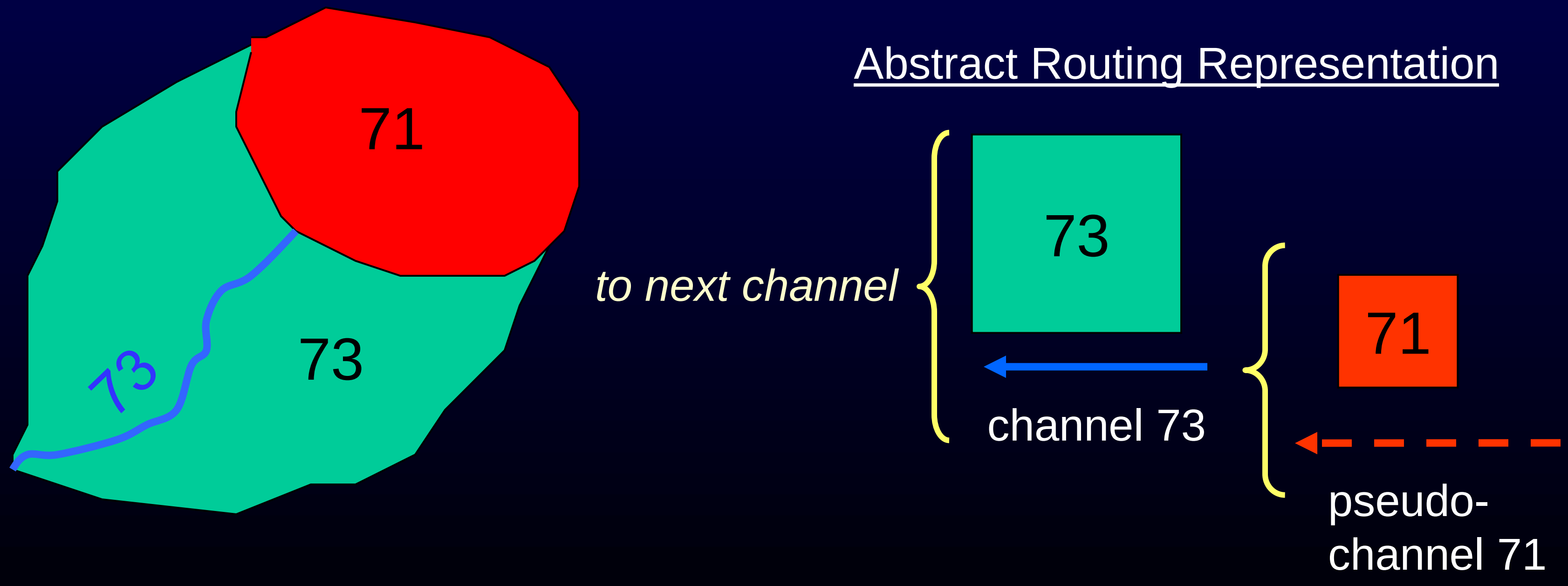
- Process-based tool to assess
  - Consequences of historical or future watershed changes
  - Identify locations for follow-up targeted ambient monitoring
  - Assist in stressor and source identification
  - Evaluate effectiveness of management actions
- Operate with readily available GIS data
  - USGS DEMs (DEMs in ESRI Grid Format)
  - STATSGO, SSURGO, FAO soils
  - NALC, NLCD, GAP land cover/use – users can define their own
- Applicable across a range of geographies
  - USA (AZ, UT, NM, ID, CA, NY, OR), Mexico, Kenya, Israel, S.Africa, Peru, Bulgaria
- Applicable to multiple spatial and temporal scales
- Both Stand-alone and Web application
- Target audience
  - Researchers
  - Resource Managers and Decision Makers
  - Community-based Stakeholders

AGWA – Basics

- Endpoints: volume & peak runoff, sediment, plus N and P
- Simple, direct method for model parameterization
- Provide repeatable results for relative change assessments
- Two hydrologic models to address multiple scales
  - SWAT for large basins, daily time steps
  - KINEROS for small basins, sub-hour time steps
  - Hillslope Runoff and Erosion Models (WEPP, RHEM)
- Basic GIS functionality
  - watershed delineation
  - watershed discretization
  - simple, direct method for model parameterization
  - execute the models
  - visualize results spatially and difference results across multiple simulations

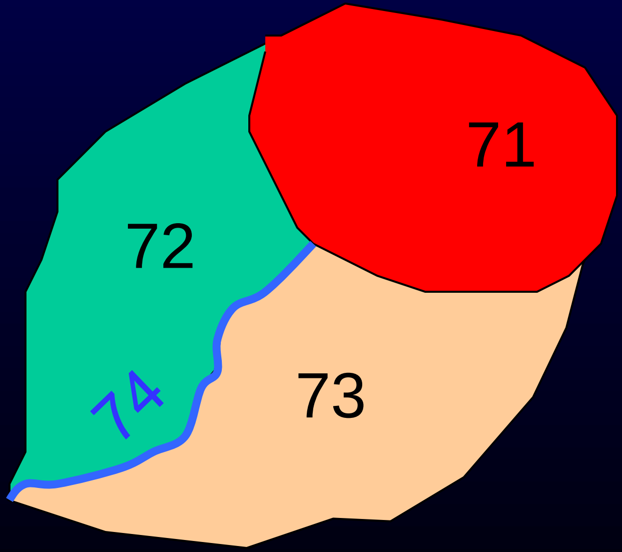
Soil Water and Assessment Tool (SWAT)

- Daily time step
- Distributed: empirical and physically-based model
- Curve-number based infiltration – USLE erosion
- Hydrology, sediment, nutrient, and pesticide yields
- Larger watersheds (< 1,000 km^2, up to a HUC 8)

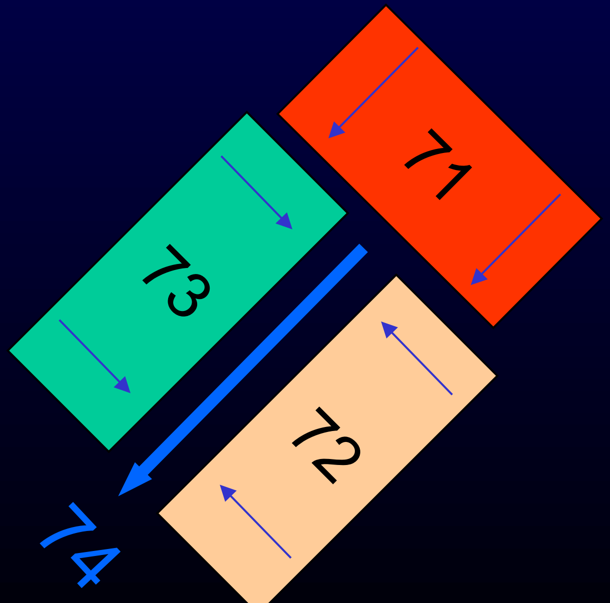


Kinematic Runoff and Erosion Model (KINEROS2)

- Event-based (< minute time steps)
- Distributed: physically-based model with dynamic routing – both for overland flow and erosion
- Has been used in urban environments
- Hydrology, erosion, sediment transport (plus N&P with OPUS version)
- Smaller watersheds (< 100-200 km^2, up to a HUC 10)

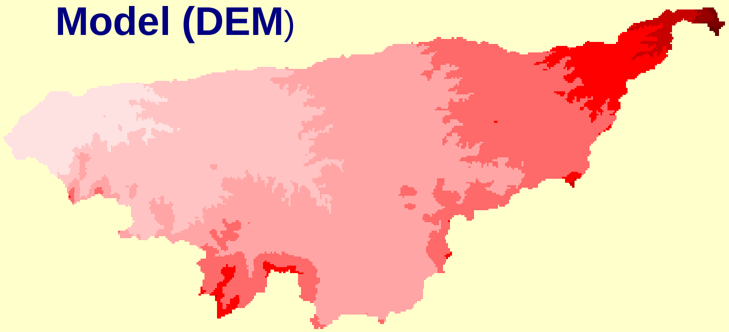


Abstract Routing Representation

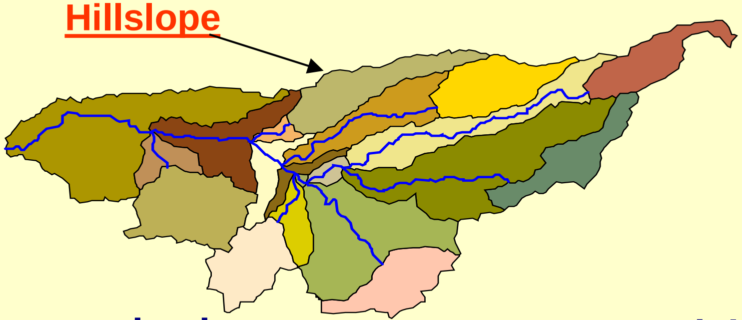


AGWA Conceptual Design: Inputs and Outputs

Watershed Delineation using Digital Elevation Model (DEM)



Hillslope



Watershed Characterization (model elements)

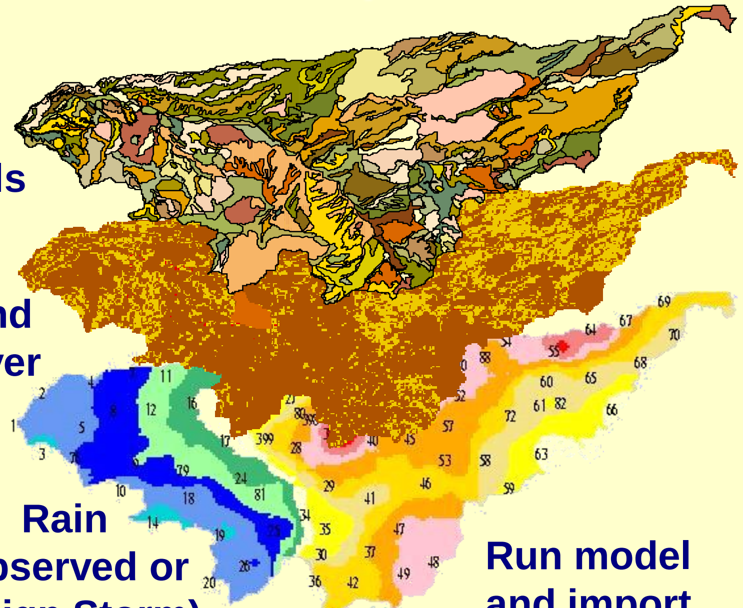
+

Intersect model elements with

Soils

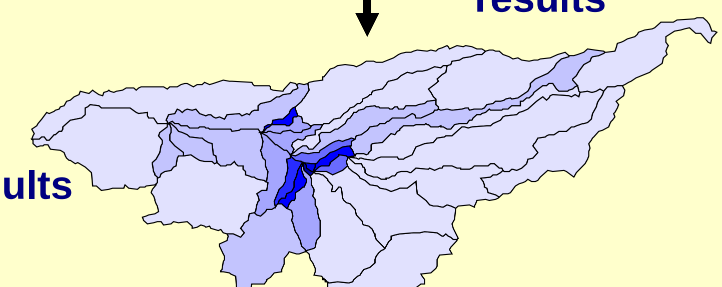
Land Cover

Rain (Observed or Design Storm)



Run model and import results

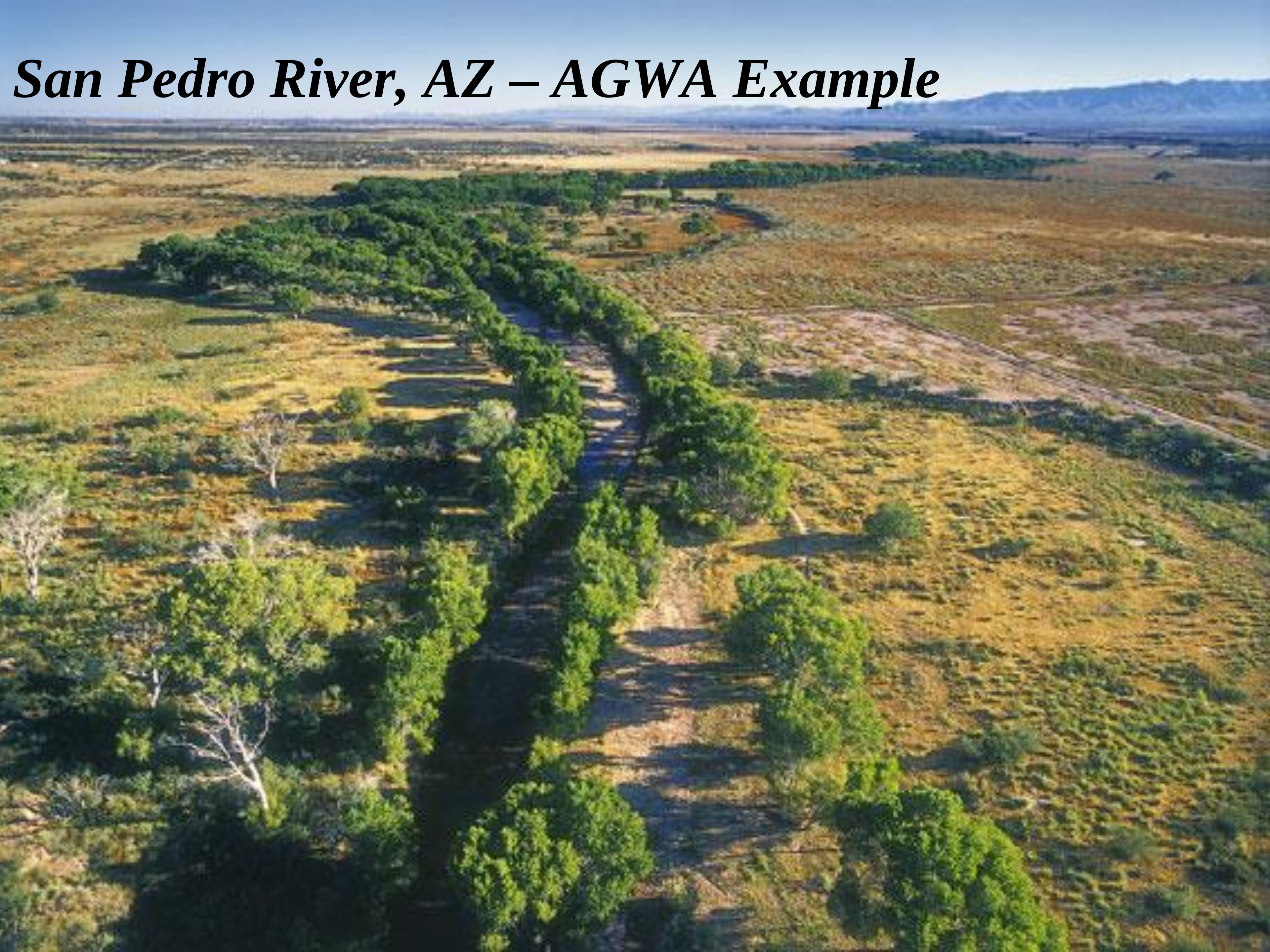
Results

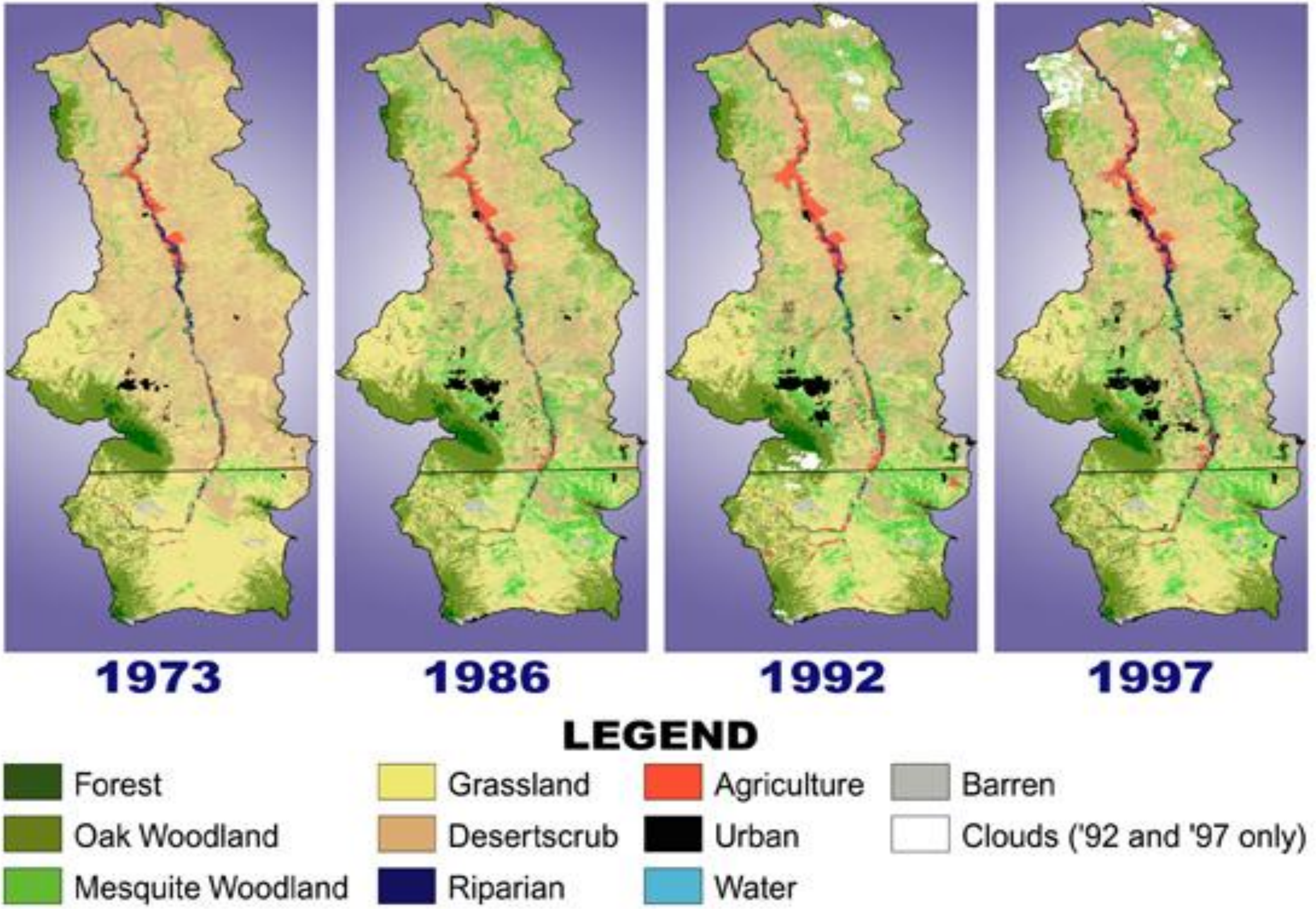


Output results that can be displayed in AGWA

KINEROS Outputs	*SWAT Outputs*
Channel Infiltration (m^3/km)	Precipitation (mm)
Plane Infiltration (mm)	ET (mm)
Runoff (mm or m^3)	Percolation (mm)
Sediment yield (kg)	Channel Disch. (m^3/day)
Peak flow (m^3/s or mm/hr)	Transmission loss (mm)
Channel Scour (mm)	Water yield (mm)
Sediment discharge (kg/s)	Sediment yield (t/ha)

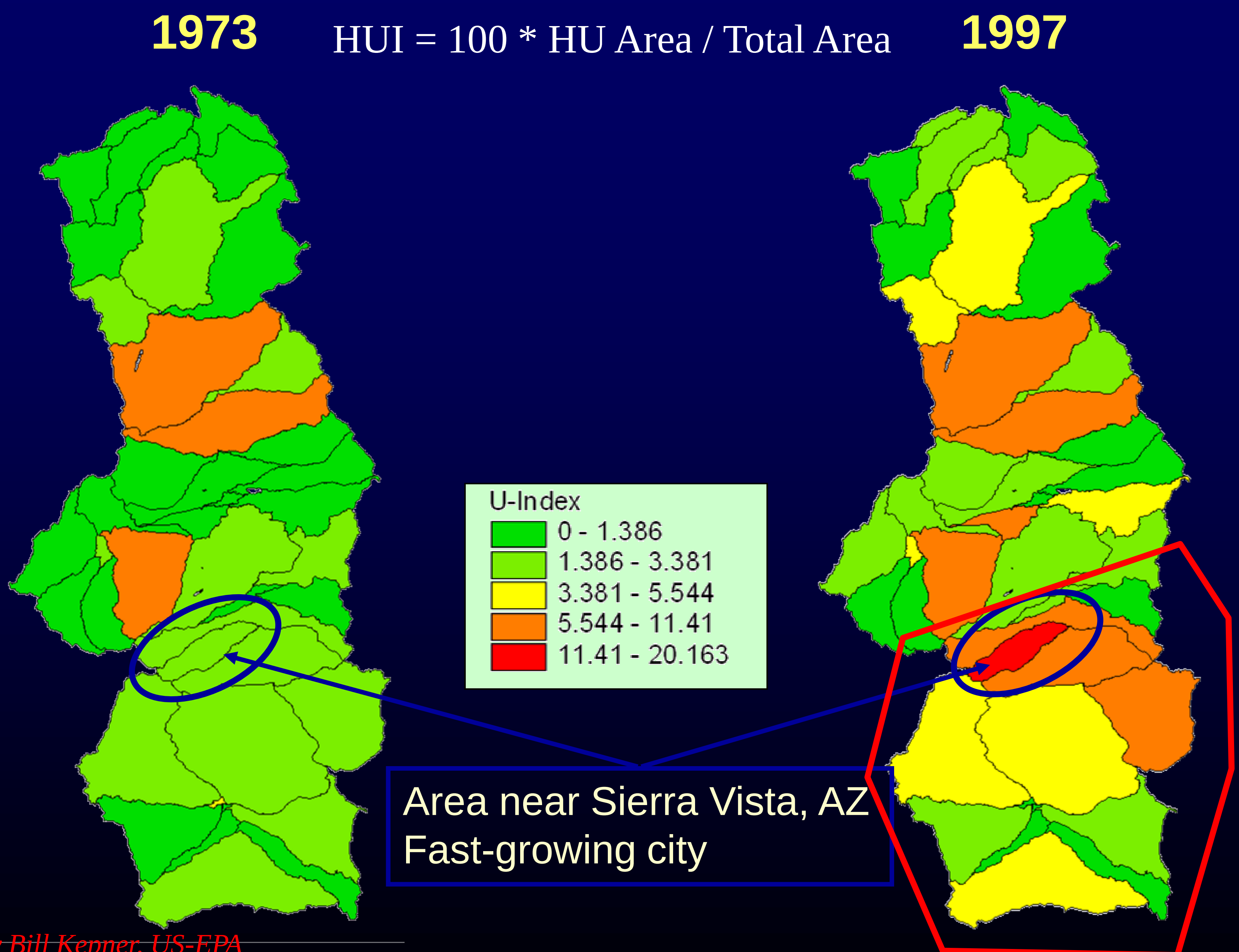
San Pedro River, AZ – AGWA Example





Kepner et al., EPA-NERL/ESD http://www.epa.gov/nerl1/land-sci/san-pedro.htm

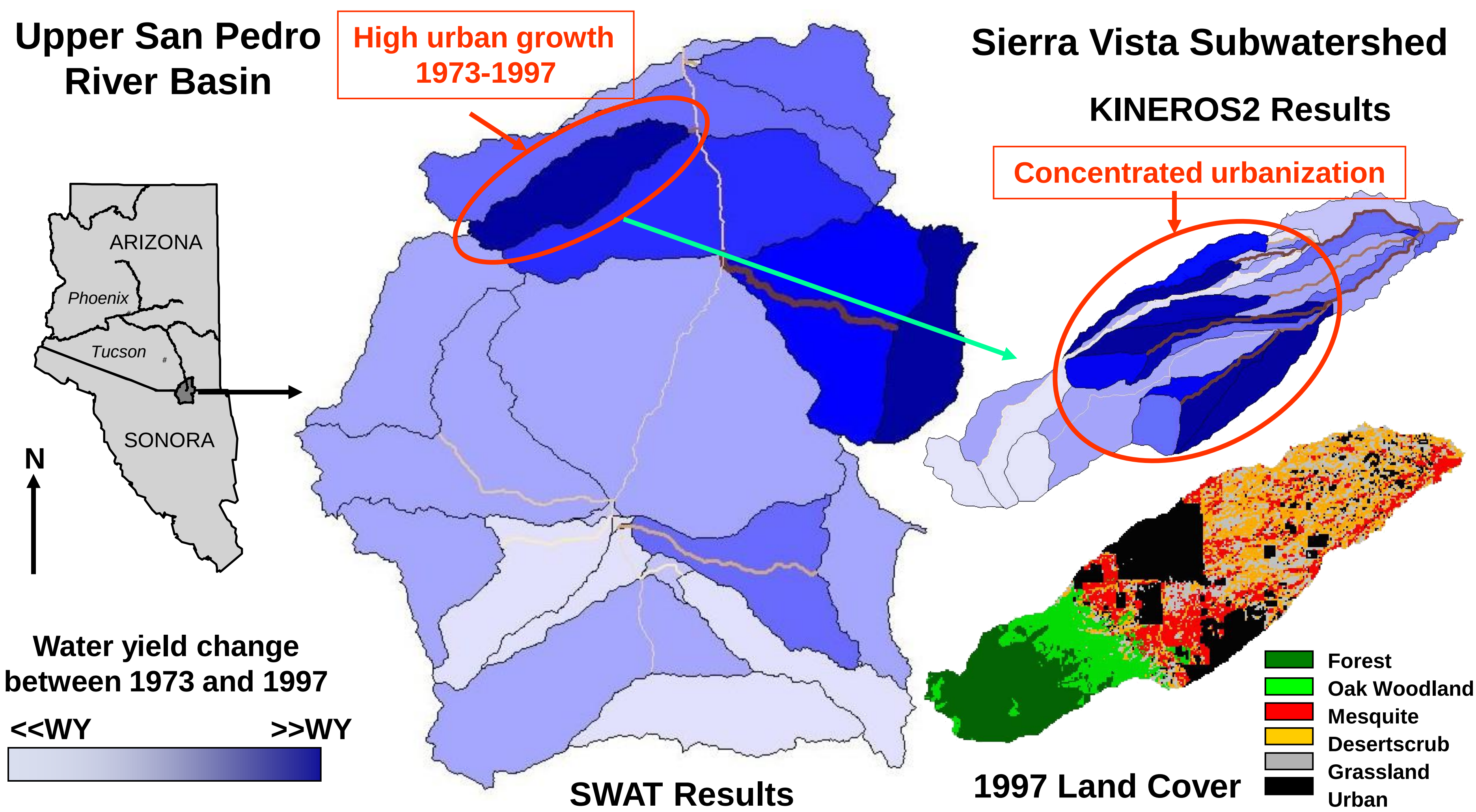
Human Use Index



Courtesy Bill Kepner, US-EPA

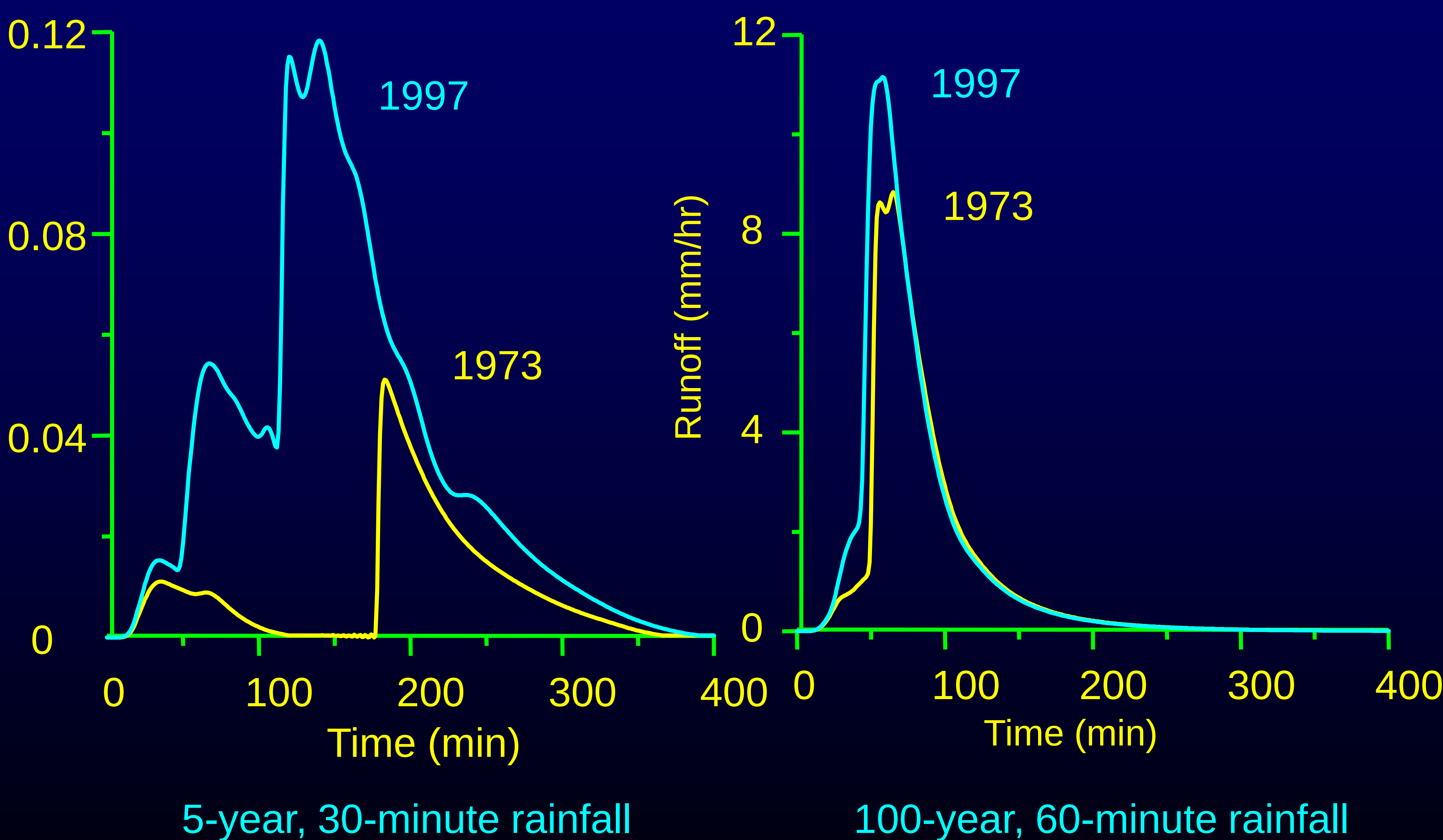
Spatial and Temporal Scaling of Results

- Using SWAT and KINEROS2 for integrated watershed assessment
- Land cover change analysis and impact on hydrologic response



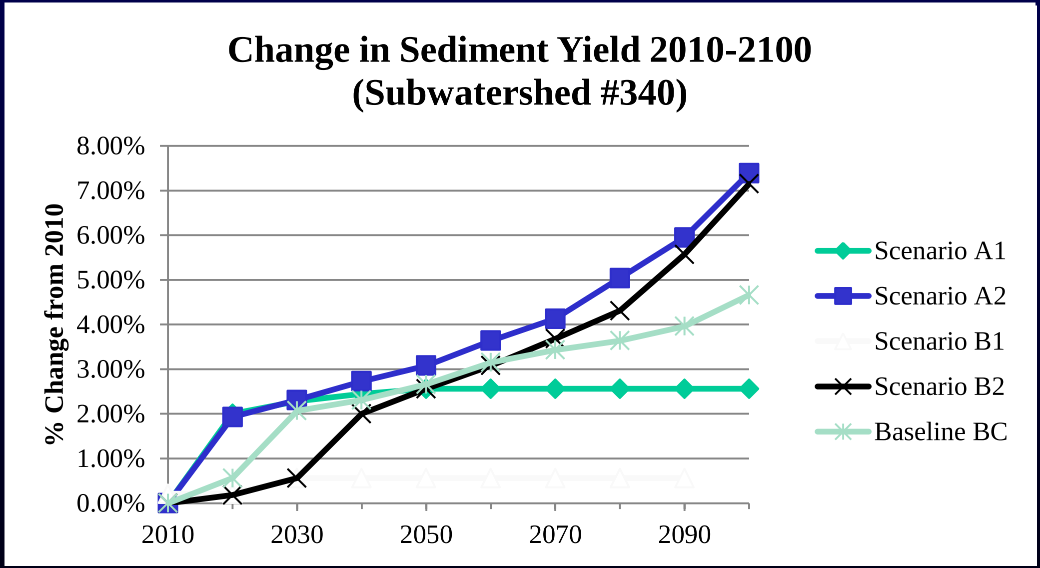
Simulated Runoff From the Small Watershed Near Sierra Vista

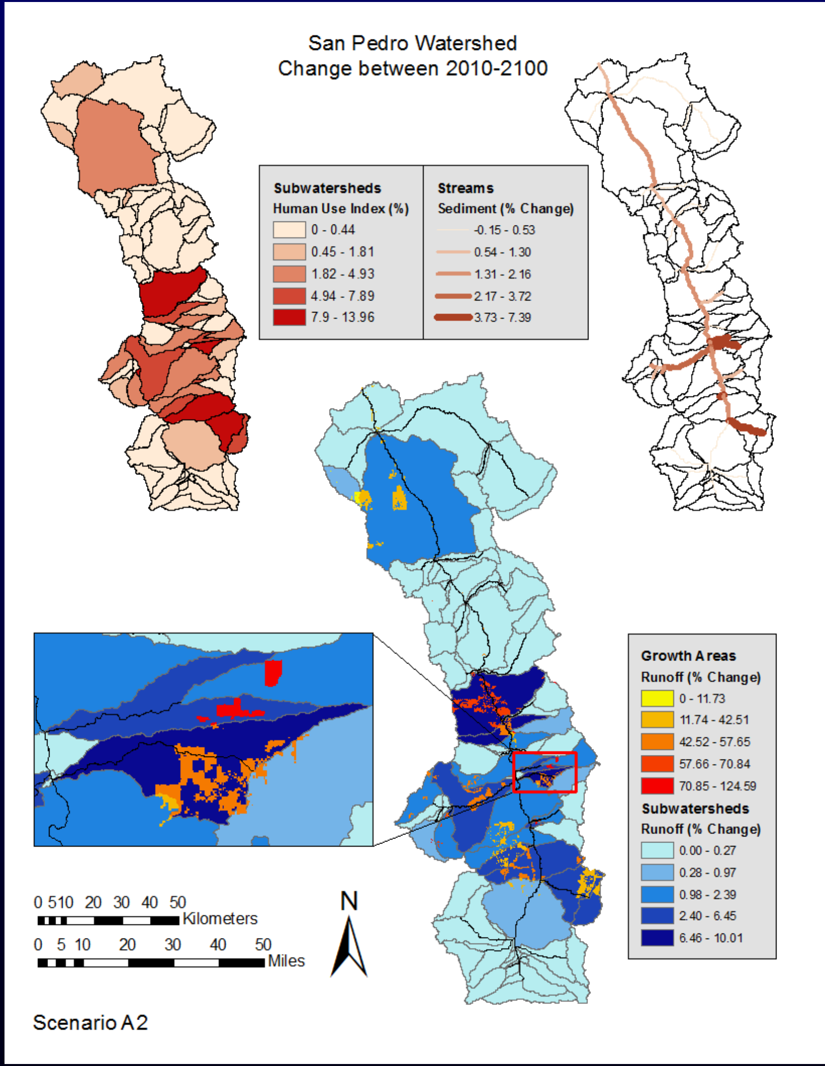
KINEROS model runs for rainfall events



Application of AGWA to assess impacts of growth

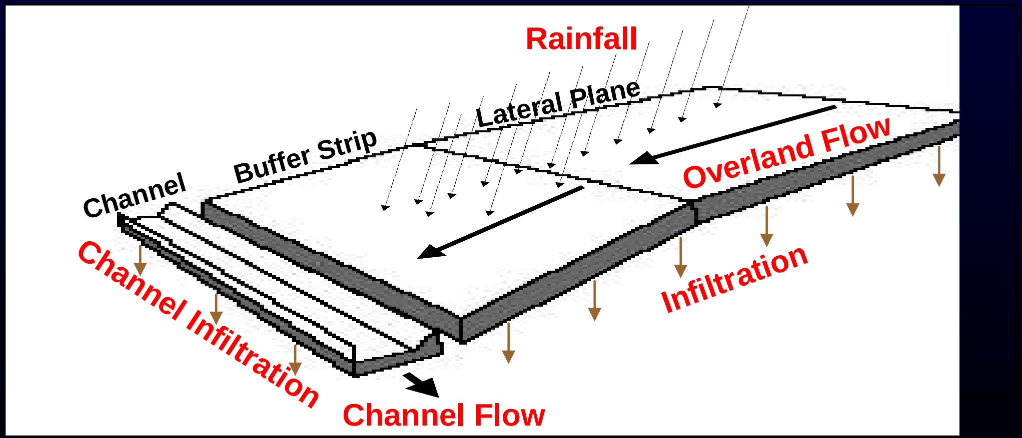
- Used USEPA Integrated Climate and Land Use Scenarios (ICLUS) to represent housing-density changes.
- Applied ICLUS scenarios to the San Pedro River.
- Application of AGWA's land use change tool.

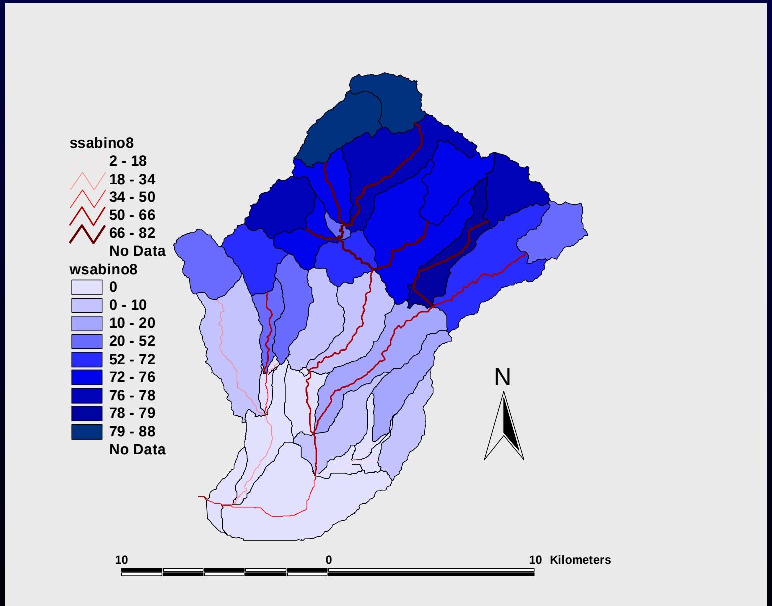




Management Toolkit

- Land Cover Modification Tool
  - ICLUS data used to change current land cover
- Livestock Management (fencing, water, stocking)
- Stock ponds/ reservoirs
- Buffer strips or filter strips (KINEROS)
- Post-Fire effects
- Multi-watershed analysis
- Low Impact Development BMPs

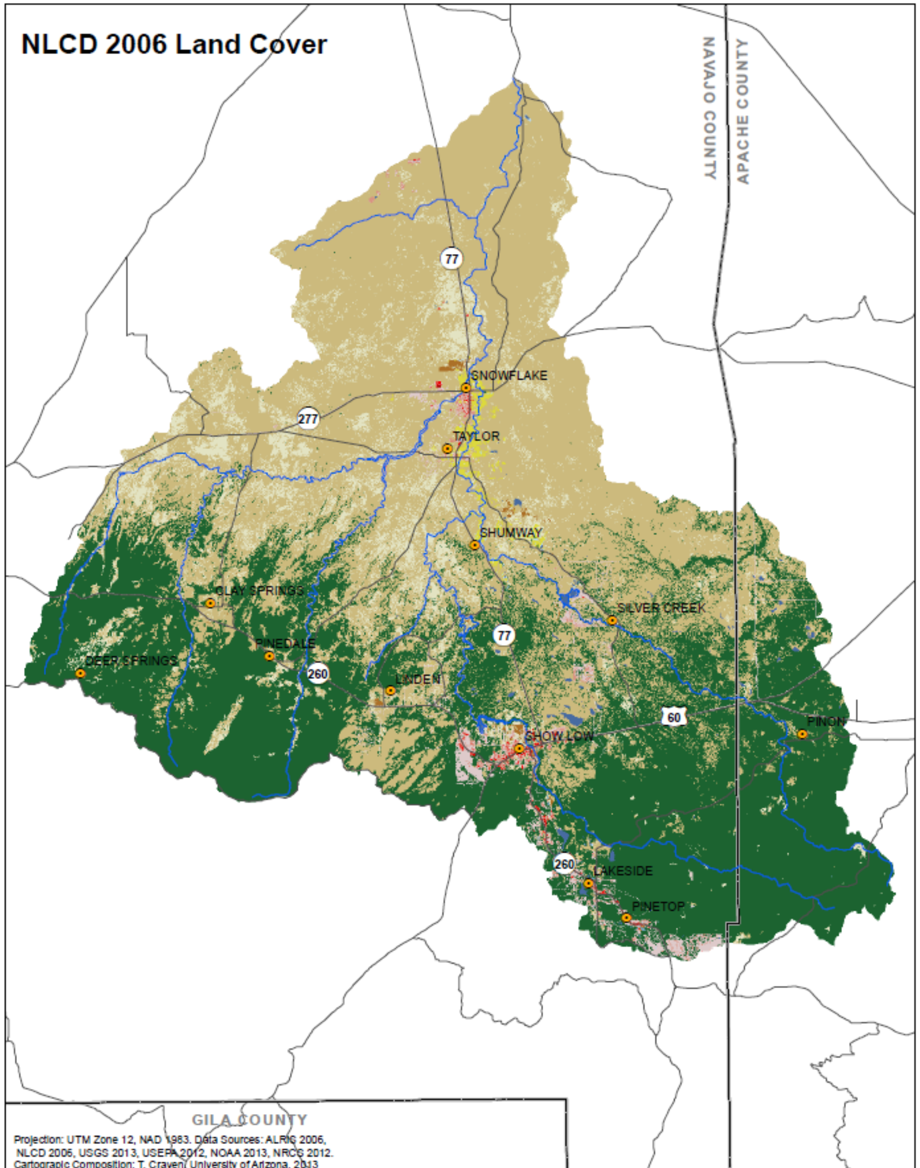


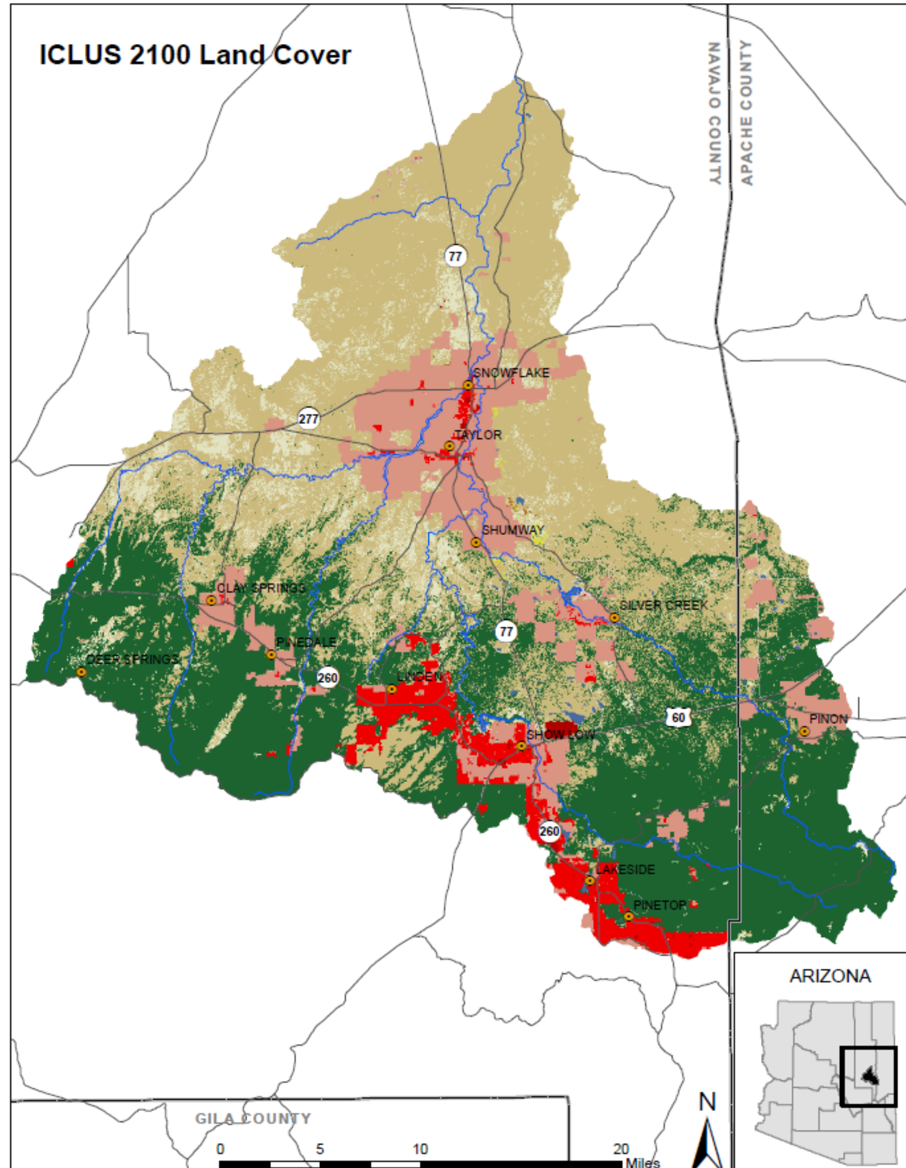


Assessing future impacts on water quality using AGWA and ICLUS

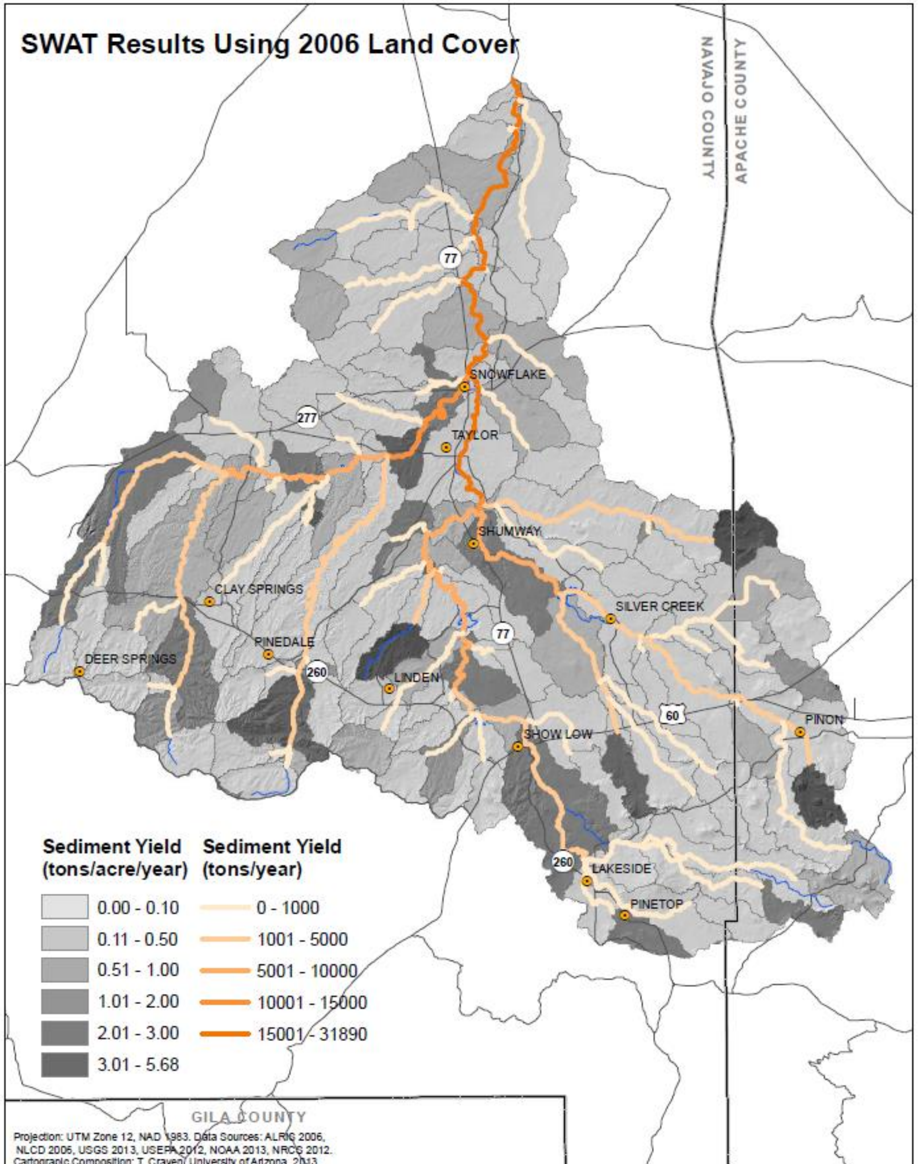
- Goal is to identify source areas for sediment under current and future conditions in the Silver Creek Watershed, Arizona.
- Used tools in AGWA to modify current Land Cover using the ICLUS dataset for represent future conditions.
- Used SWAT to identify “Hot Spots” for sediment and assess how the “Hot Spots” changed over time.
- Used KINEROS to identify “at risk” zones.

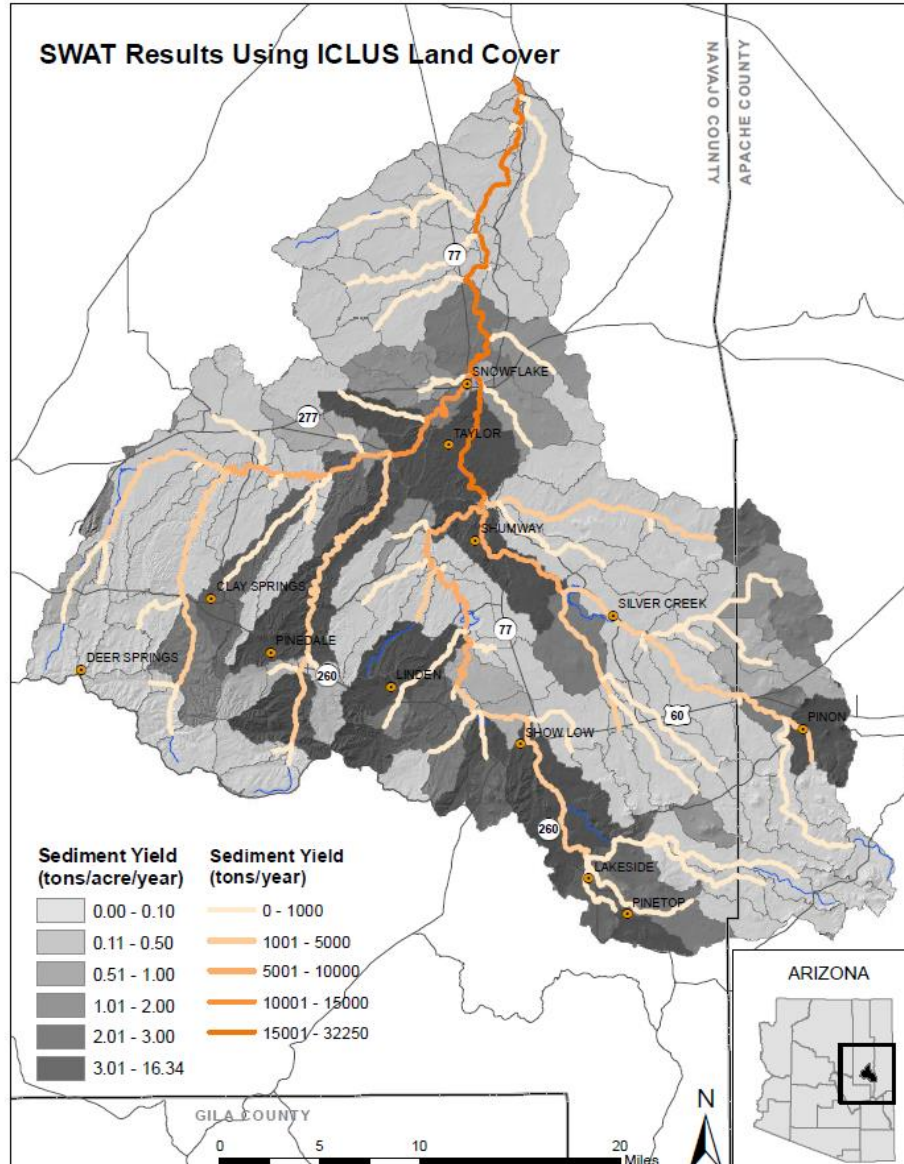
Silver Creek, Arizona
Water Quality Assessment using ICLUS data





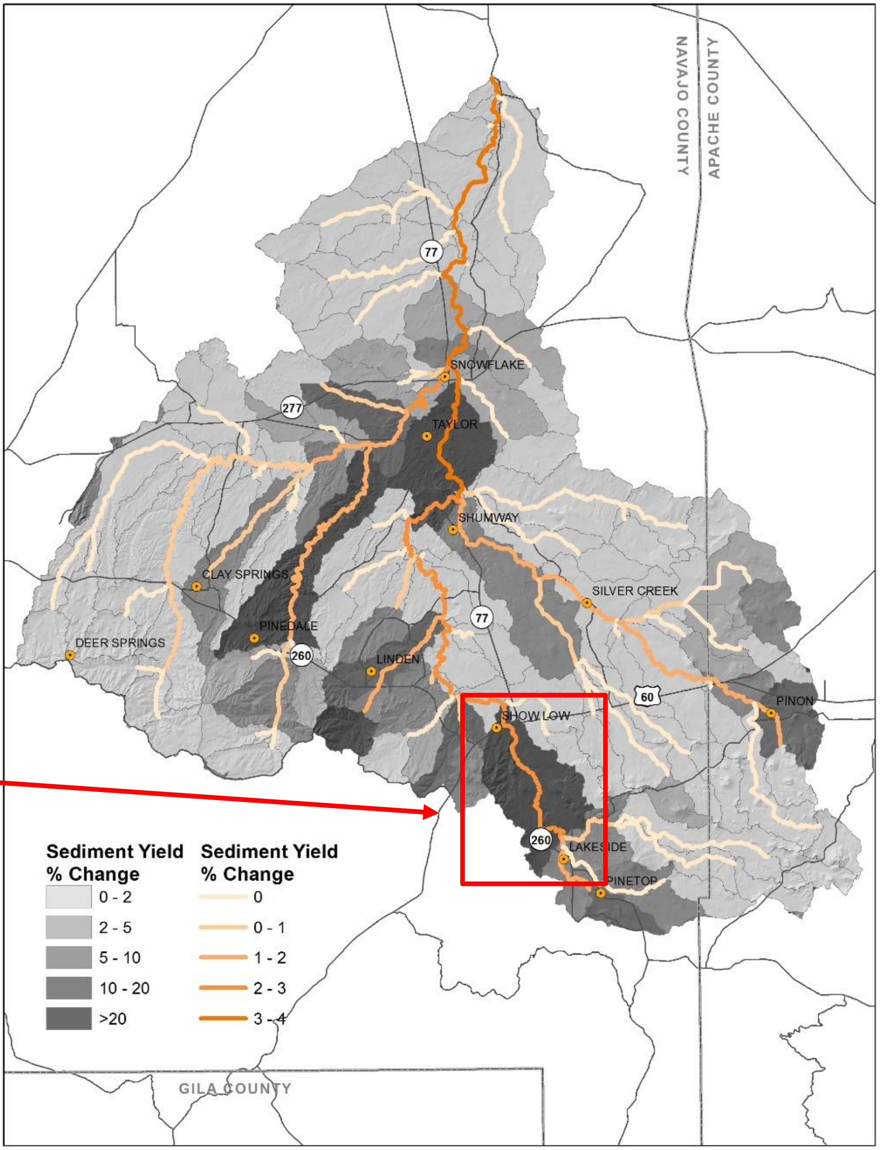
Silver Creek, Arizona
Water Quality Assessment using ICLUS data





Silver Creek, Arizona
Water Quality Assessment using ICLUS data

- Use AGWA Results View tool to create a Percent Change Map.
- Identify areas of high vulnerability.
- Use KINEROS2 to model "at risk" subwatersheds.



Silver Creek, Arizona
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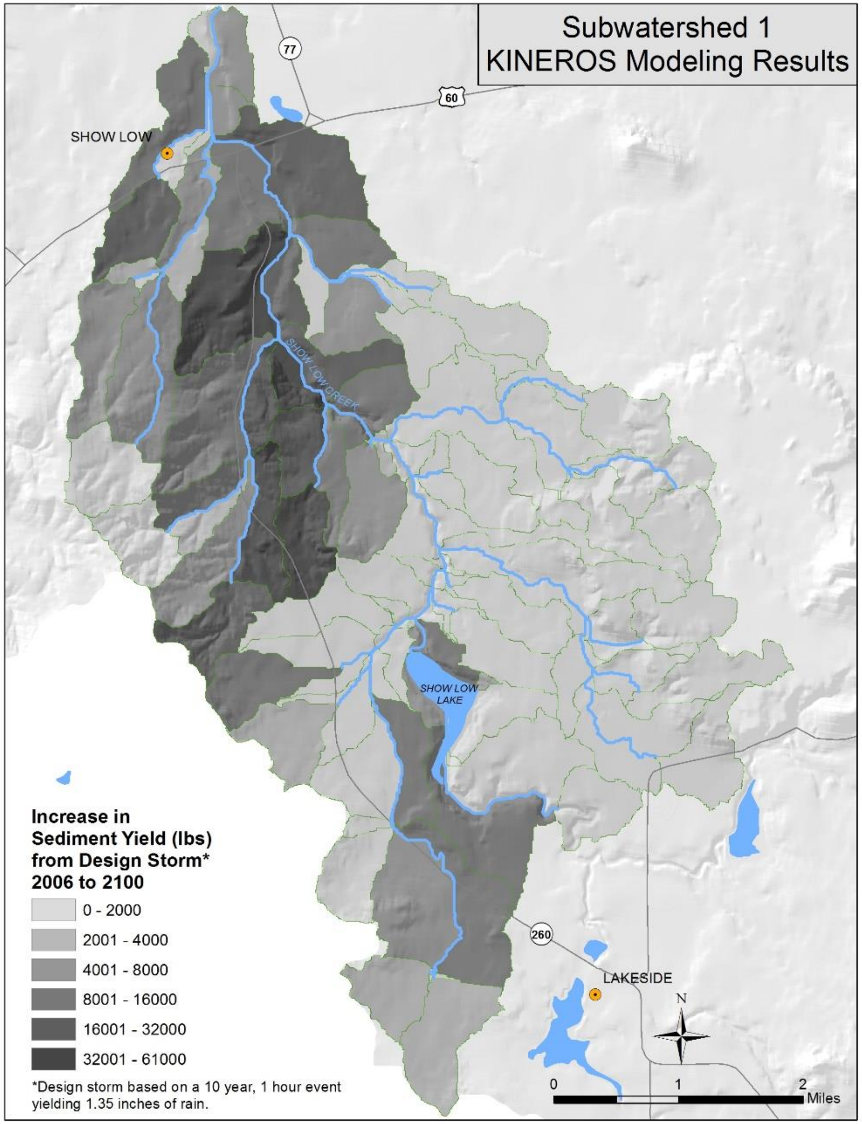
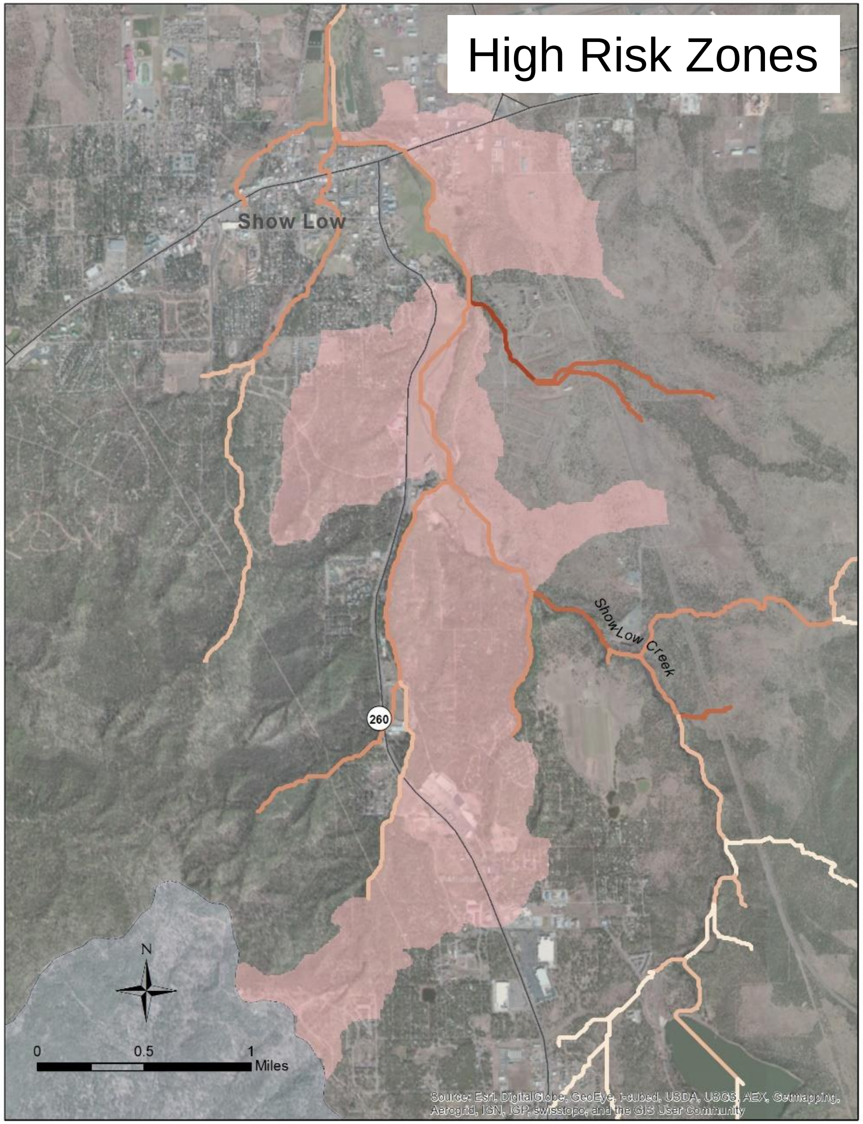
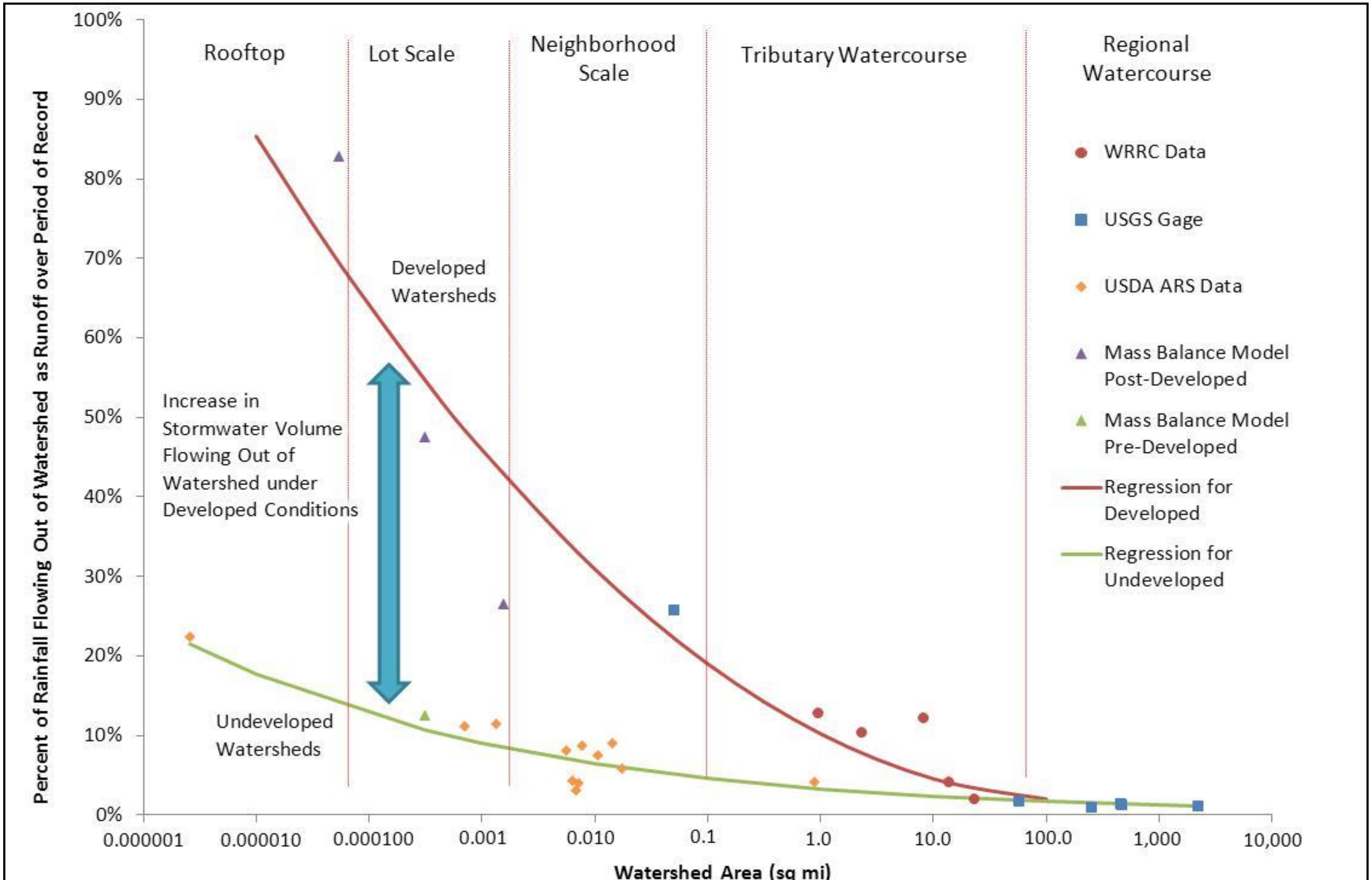




Adoptive Management Strategies

- The Southwestern United States is expected to get warmer and drier.
- Water Supplies will be limited.
- Conflict between agriculture and urban centers.
- Objective: Augment water supplies, and maintain quality of life, while protecting biological values.
- Management Strategy: Implement Low Impact Development (LID) practices to promote stormwater capture.

‘Harvestable’ Water (Rainwater/Stormwater) Potential to augment water supply



LID Planning Practices

GI/LID Non-Structural Practices / Benefits	Stormwater Runoff		Improves Community Livability			Regulatory
	Reduces Flooding	Improves Stormwater Quality	Reduces Urban Heat Island & Associated Energy Use	Can Provide Shade for Passive Recreational Use	Provides Wildlife Habitat	Riparian Protection*
Conserving or Restoring Sensitive Natural Areas	●	●	●	●	●	●
Preserving Natural Flow Paths	●	●	●	●	●	●
Preserving Natural Open Space	◒	◒	●	●	●	●
Minimization of Disturbed Areas and Soil Compaction	●	●	◒	◒	◒	◒
Disconnection of Impervious Areas	◒	●	○	○	○	○

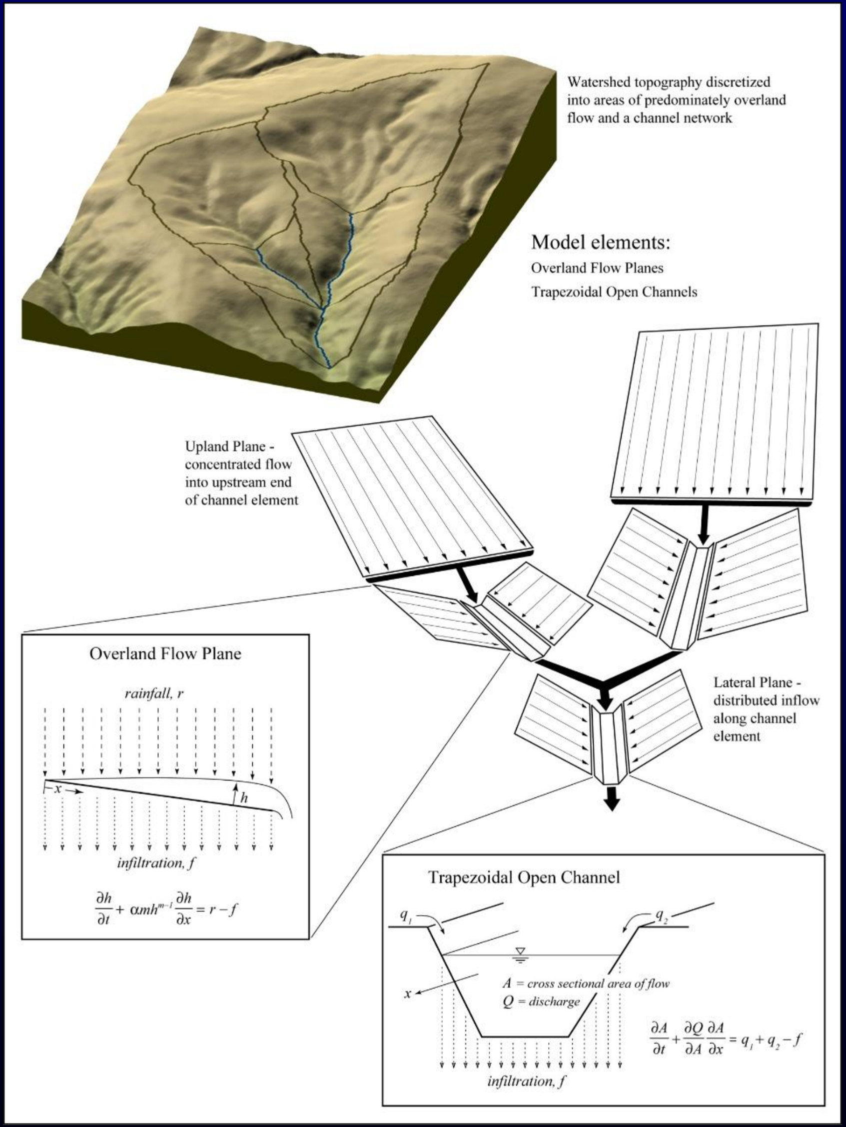
Based on Table from American Rivers, "The Value of Green Infrastructure", 2010.

● Yes ◒ In Some Cases ○ No

*Ordinance No. 2010 FC5 Title 16 Chapter 16.30

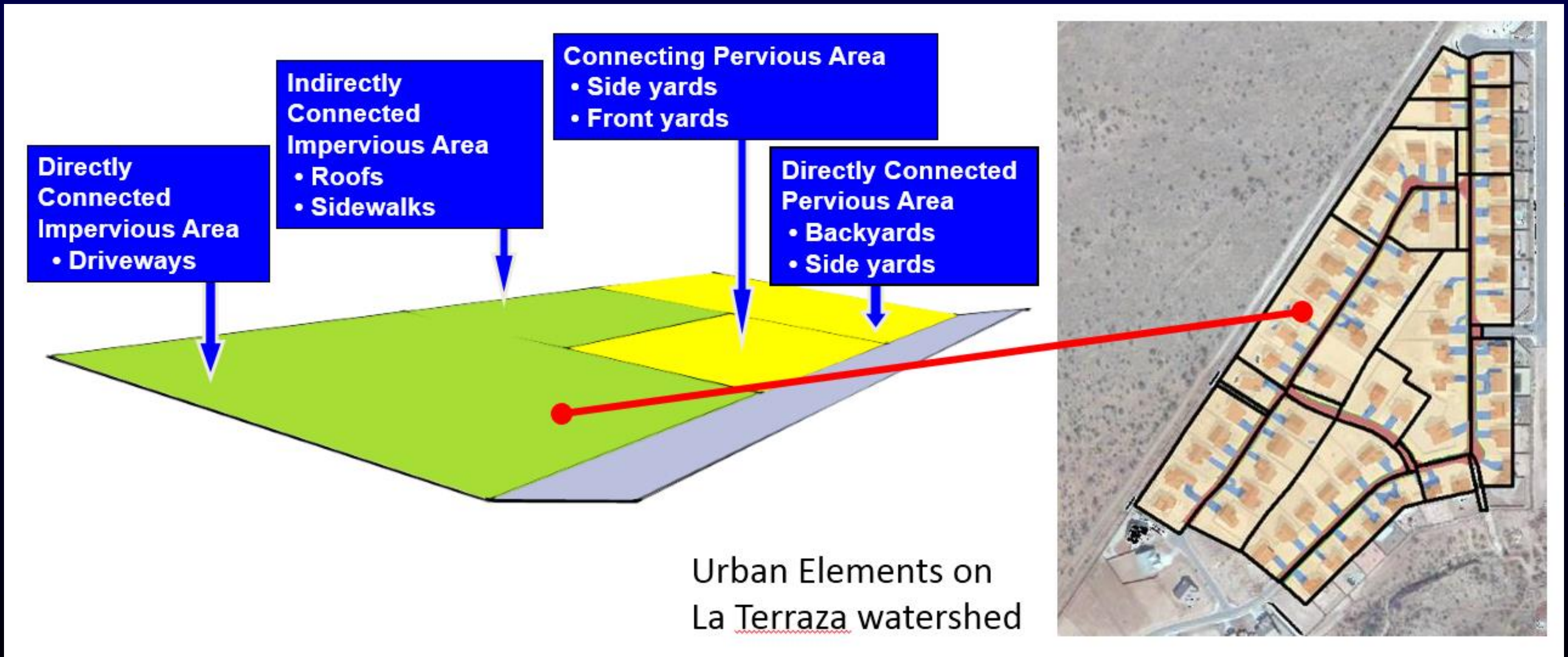
KINEROS2 (K2) Rainfall-Runoff-Erosion Model

- **K2 is an physically-based distributed, event model that is applicable from plot to watershed scales**
- **K2 estimates runoff, erosion and sediment transport in overland flow (hillslopes) and channel model elements**
- **K2 represents the watershed with a variety of spatially distributed model elements (hillslope, channel, injection, pipe, & urban**



K2 Urban Element

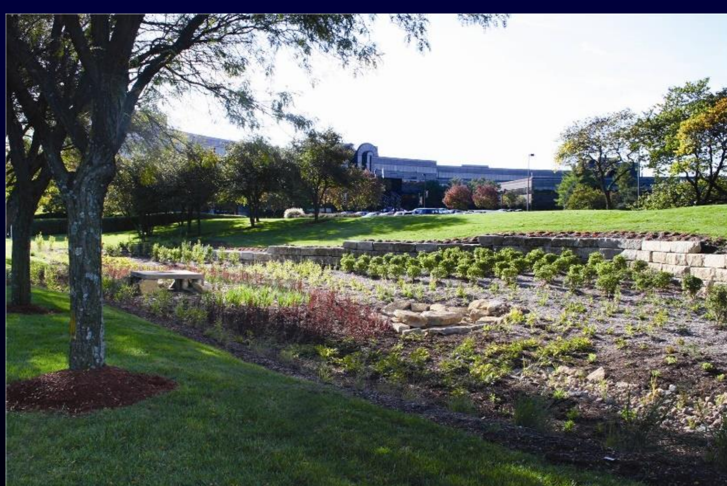
- **Represents a group of homes in a typical residential development in a simplified fashion grouping:**
  - **Impervious areas directly connected to the street (e.g. driveways)**
  - **Impervious areas that drain to a infiltrating area before draining to the street (e.g. roof to lawn)**
  - **Directly connected infiltrating area to street**
  - **Infiltration area draining to an impervious area to street (e.g. lawn to driveway)**



Fire

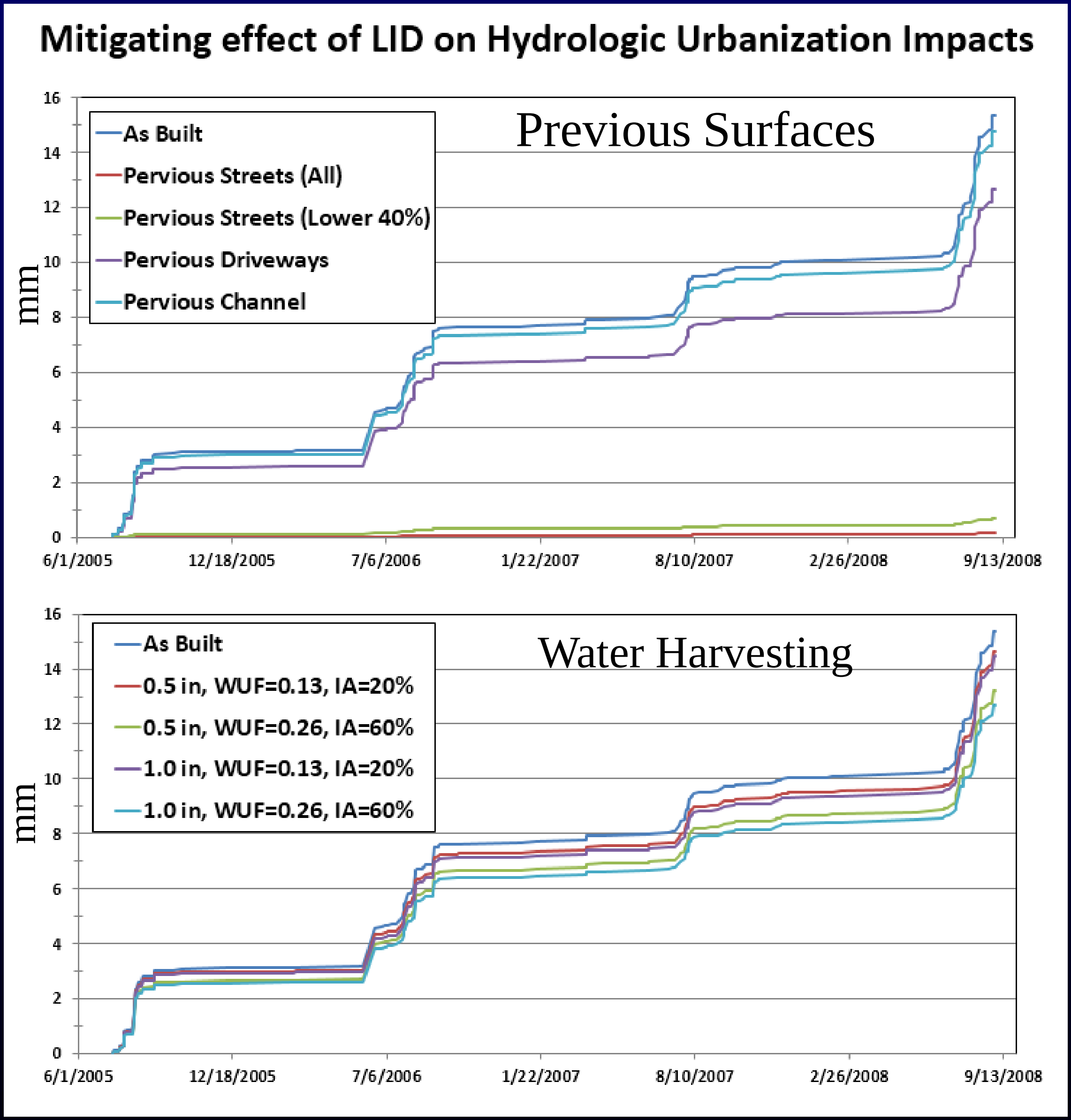
Low Impact Development Practices

- **Water Harvesting**
  - **Maximum Storage Capacity**
  - **Plant water use factor – daily water use**
  - **Irrigated area (fraction of total pervious area)**
- **Pervious Surfaces**
  - **Replace impervious streets, driveways and sidewalks with permeable pavers**
- **Bio-retention cells (Filter Strips)**
- **Variable Density Development**



ost-Fire

Sierra Vista La Terra Development



Using KINEROS2

Information

- AGWA Web Page: documentation, software, and publications:
  - http://www.tucson.ars.ag.gov/agwa/
  - Google: AGWA, Arizona
- Versions:
  - Arcview 3.x
  - ArcGIS 9.0,1,2,3
  - ArcGIS 10.0, 1
  - DotAGWA 1.x
  - Below MS-Win7

Google Analytics – visits to AGWA website since November, 2007

Closing Remarks

- Although uncertainty is high, we currently have enough knowledge on the Drivers of Change to start assessing potential impacts.
- Doing scenario analysis using our current tools (CAT, WEPPCAT, AGWA) we can start identifying the range of potential impacts.
- Spatial distributed data (ICLUS) and modeling systems (AGWA) can also identify watersheds and “hot spots” at are vulnerable.
- Strategies for managing risk at a field to watershed scale can be developed.

Questions?