USING RAINFALL-RUNOFF MODELS TO CHARACTERIZE FLOW REGIMES OF EPHEMERAL STREAMS IN THE DESERT SOUTHWEST

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Purpose

- Create a tool that can guide managers in planning base activities that disturb the landscape away from sensitive species habitat

- Develop a methodology that employs commonly available spatial datasets to characterize watersheds within large areas where observational data is lacking

Objectives

Characterize the hydrology of ephemeral and intermittent streams by:

1. Determining flow permanence using a continuous rainfall-runoff model
2. Estimating peak flows based on an event orientated rainfall-runoff model
3. Exploring flow regime changes under a warming climate scenario

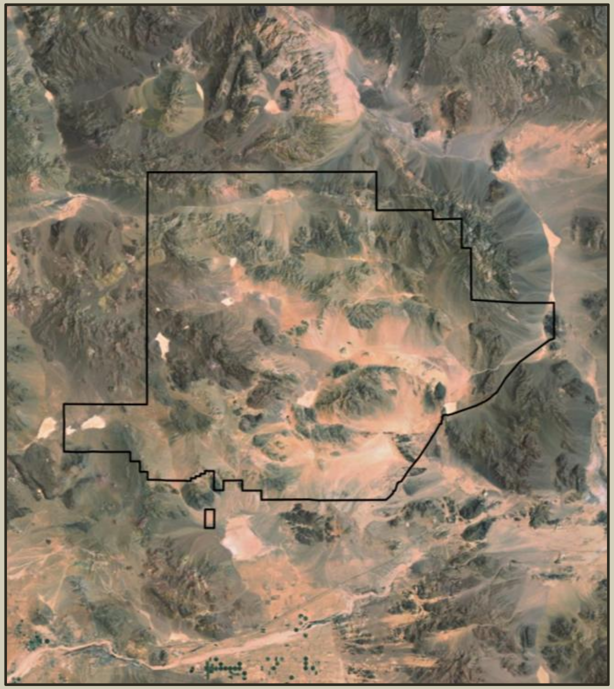
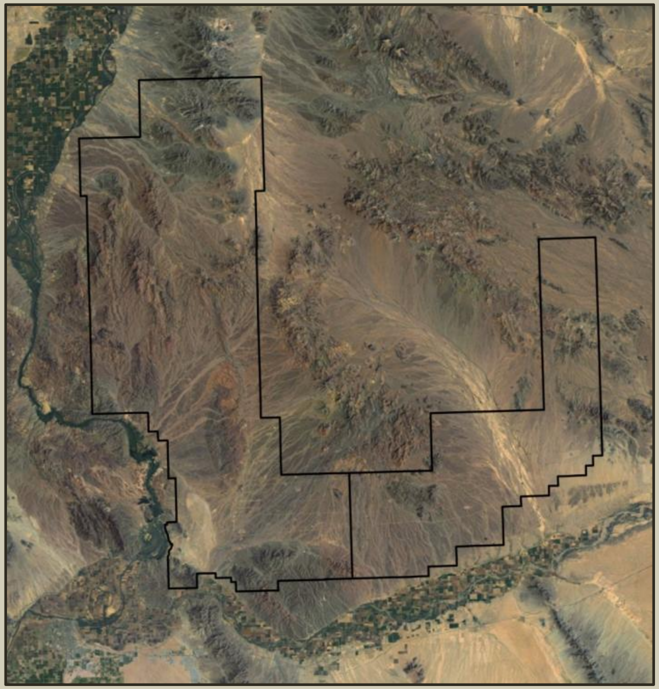
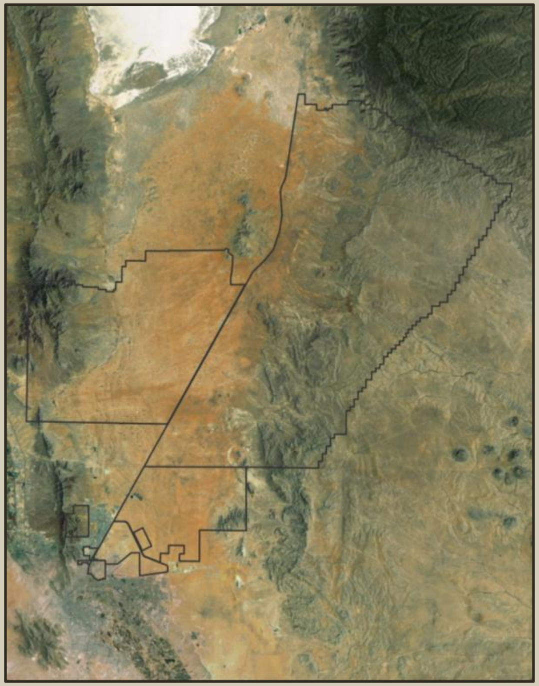
Presentation Outline

1. Study sites
2. AGWA tool
3. SWAT model
4. Flow permanence
5. KINEROS2 model
6. Peak flow
7. Climate change scenario
8. Errors and assumptions
9. Future development
10. Conclusions

Study Sites

Fort
Irwin
Mojave
Desert
Yuma
Proving
Ground
Sonoran
Desert
Fort
Huachuca
Fort
Bliss
Chuihuahuan
Desert
N
W
E
S
0 50 100
Km
1:5,000,000

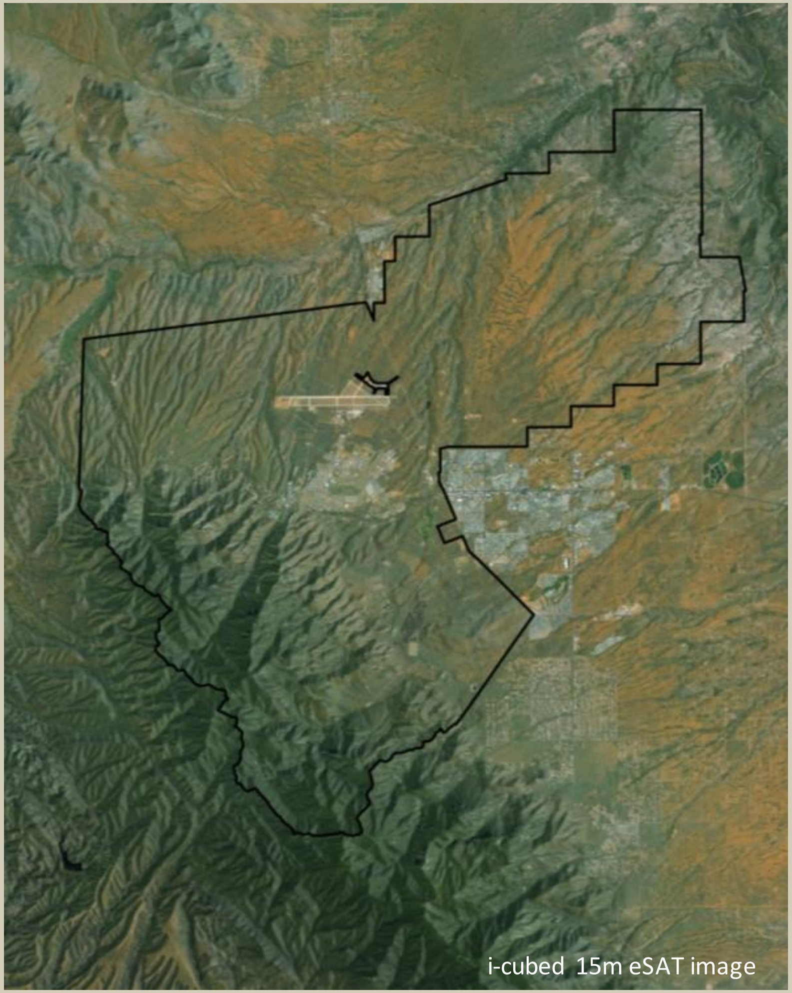
Study Sites

Ft. Irwin National Training Center	Yuma Proving Grounds Equipment Testing Center	Ft. Bliss Army Post
		

i-cubed 15m eSAT images

Area:	1,180 mi^2	1,300 mi^2	1,740 mi^2
Ave Annual Precip:	4.33 in (110 mm)	3.65 in (92.7 mm)	8.66 in (220 mm)

Ft. Huachuca



Area: 127 mi^2

Ave Annual Precip: 15.6 in (381mm)

Photo: Lainie Levick

Photo: Joel Murray

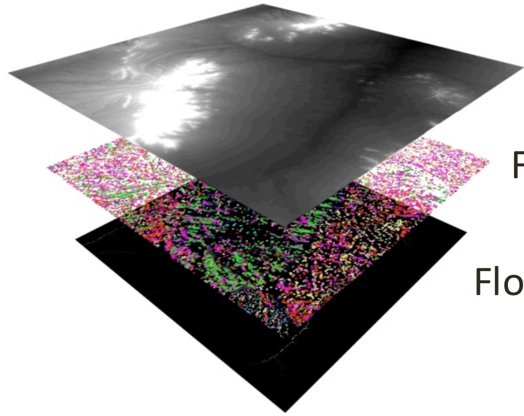
Automated Geospatial Watershed Assessment

- Developed by the USDA Southwest Watershed Research Center's Agricultural Research Station (ARS)
- Automates model setup and execution
- Models compute runoff and erosion rates
- Two separate rainfall-runoff models
  - KINEROS2-event specific
  - SWAT2000-continuous simulation
- Displays the results for visual analysis

Results

KINEROS	SWAT
Infiltration (mm; m^3/km)	Channel Discharge (m^3/day)
Infiltration (in; ac-ft/mi)	ET (mm)
Runoff (mm)	Percolation (mm)
Runoff (m3)	Surface runoff (mm)
Sediment yield (kg/ha)	Transmission loss (mm)
Peak flow (m^3/s)	**Water yield (mm)**
Peak flow (mm/hr)	Sediment yield (t/ha)
Sediment discharge (kg/s)	Precipitation (mm

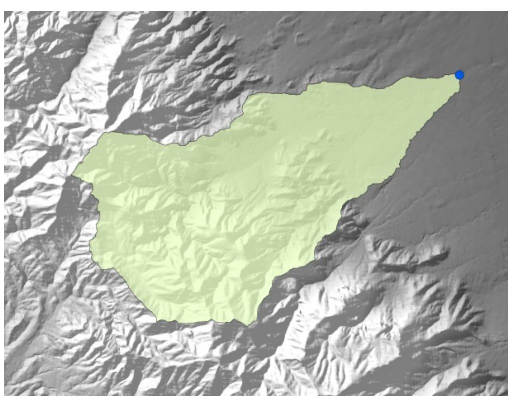
AGWA Workflow



10m Filled DEM

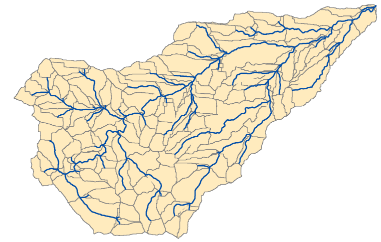
Flow Directional Grid

Flow Accumulation Grid

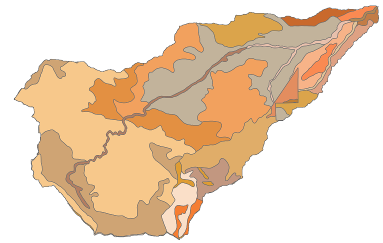


Watershed Outlet

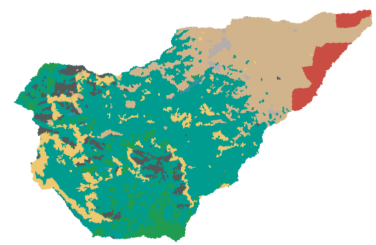
Watershed Delineation



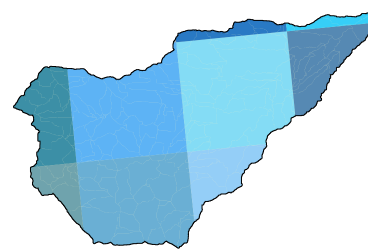
Subwatershed/Plane Discretization
CSA= 10,000m^2



NRCS Soil and State Surveys



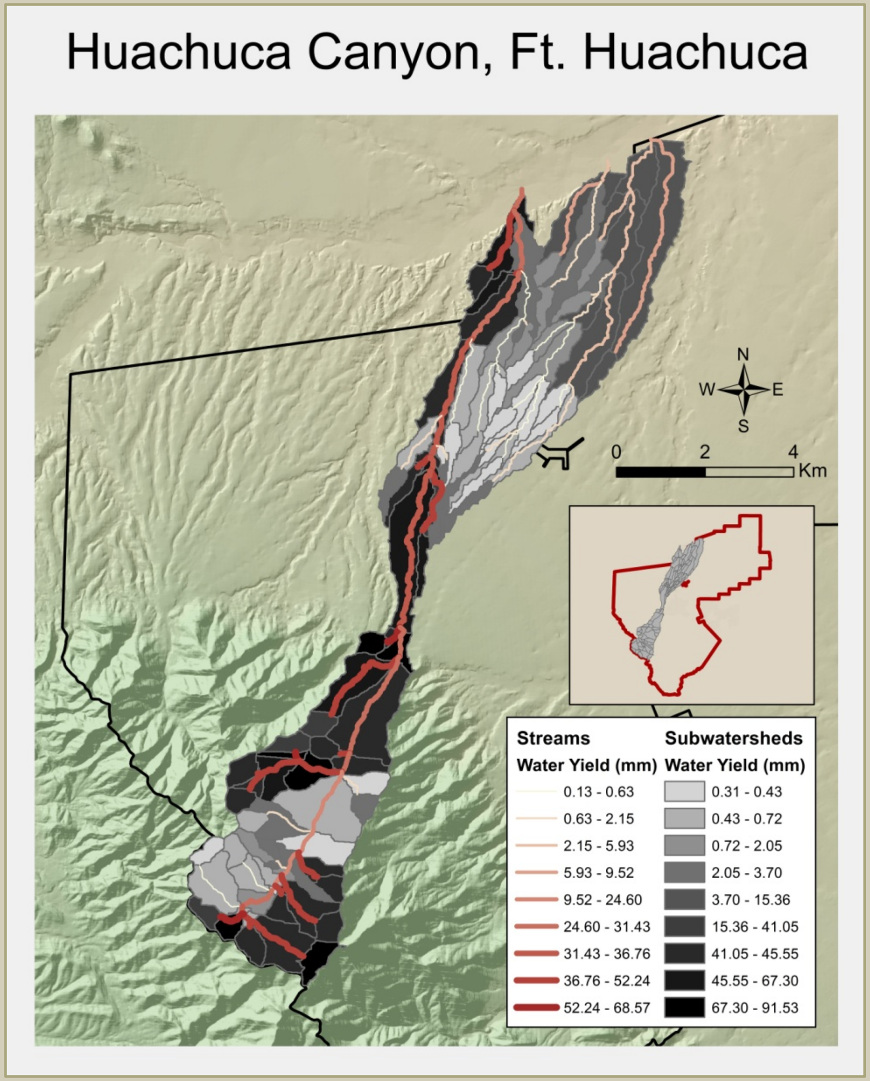
SWReGAP and GAP Landcover



Temp. and Precipitation data (Rain gauge, NEXRAD, Meteorological tower)

Soil and Water Assessment Tool (SWAT)

- Empirical & deterministic model
- Modified Curve Number methodology
- USLE for erosion
- Daily, monthly, & annual output
- Routes from adjacent planes and channels to downstream channel



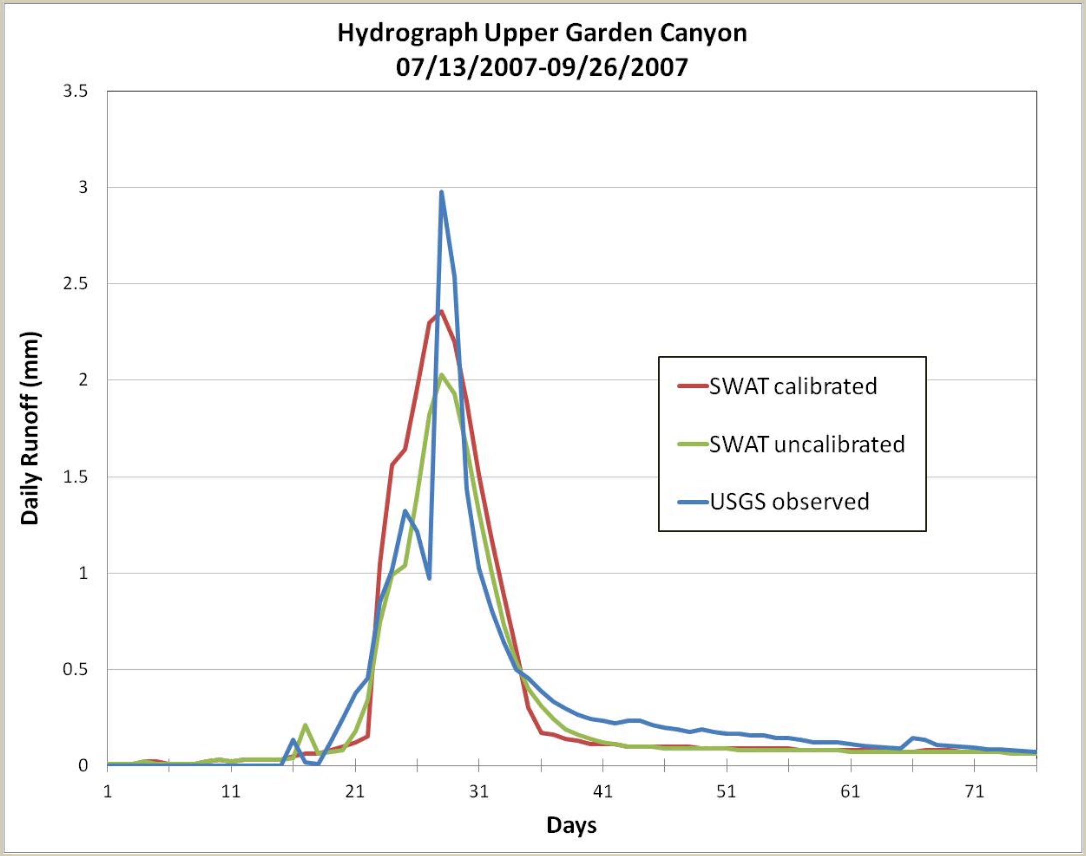
Calibration of SWAT

Calibrate surface runoff

- Reduce Curve Number (CN) 20%
- Increase Soil Available Water Capacity +0.08

Calibrate subsurface flow

- Decrease groundwater "revap" coefficient from 0.2 to 0.02



Model Assessment

- Paired T-test - tests equal mean hypothesis (α=0.05)
- Coefficient of Determination (R^2) - squared ratio between covariance and the multiplied standard deviation of the observed and predicted values (range: 0 to 1)
- Nash-Sutcliffe Efficiency (NSE) – one minus the sum of the absolute squared differences between the predicted and observed values normalized by the variance of the observed values (range: $-\infty$ to 1)

Upper Garden Canyon

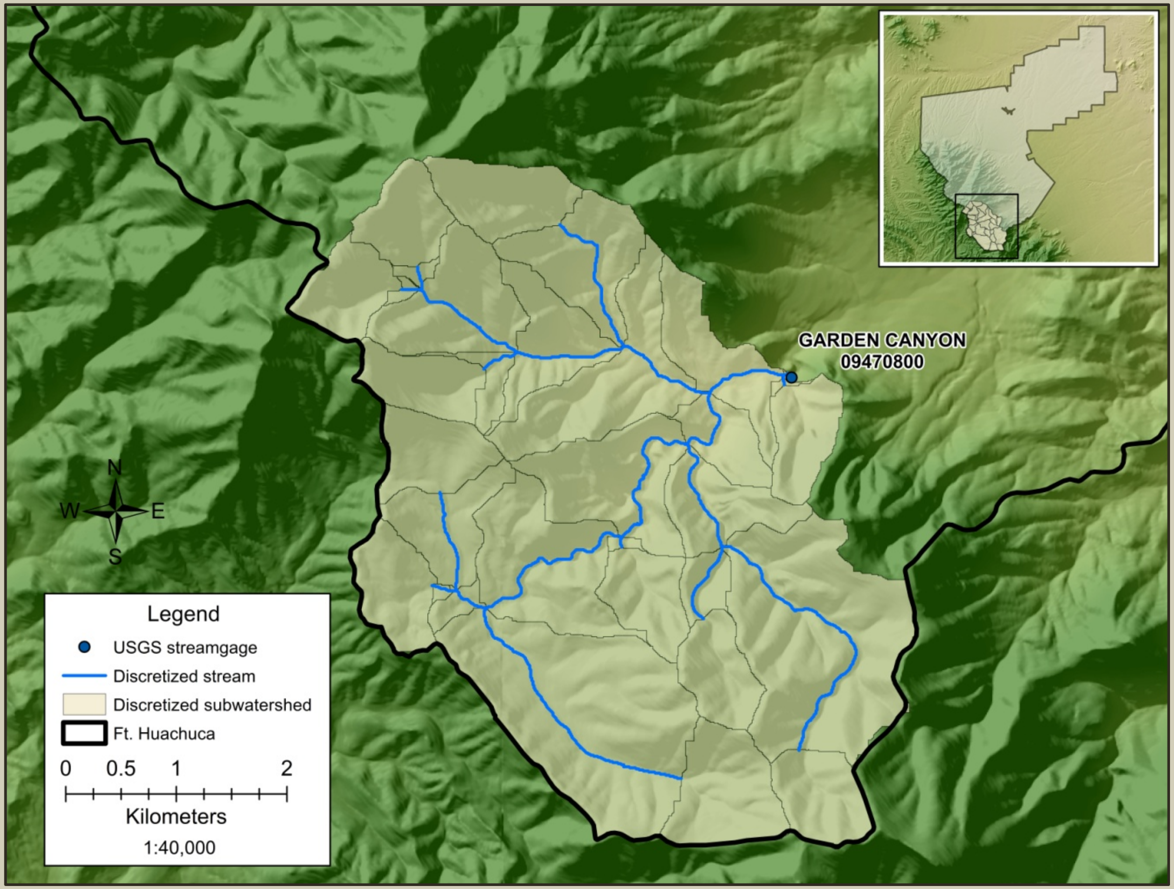
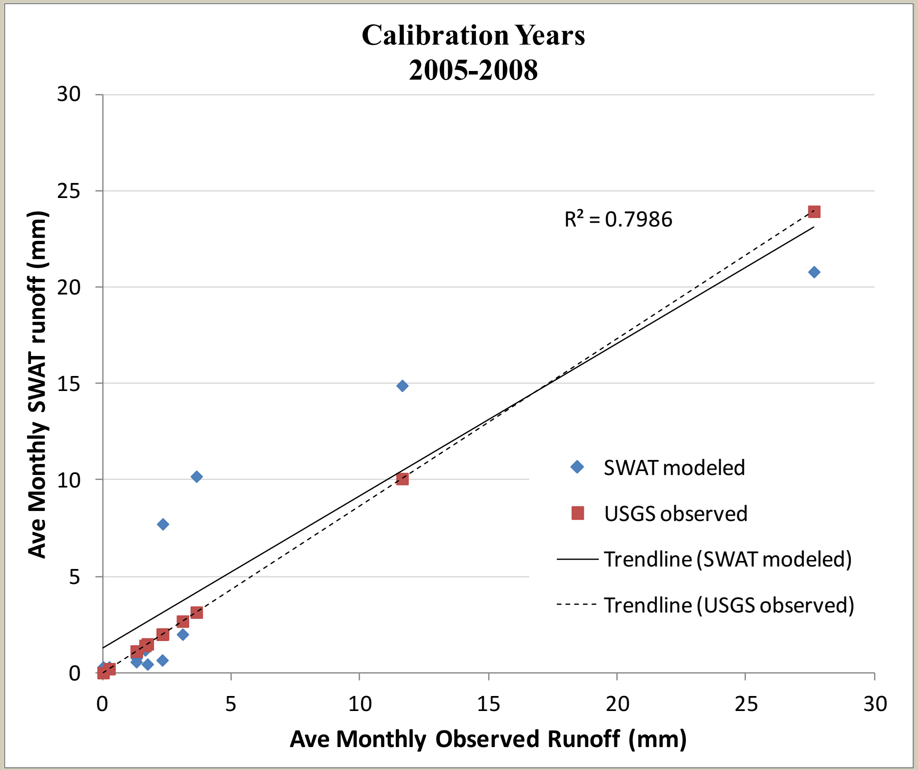
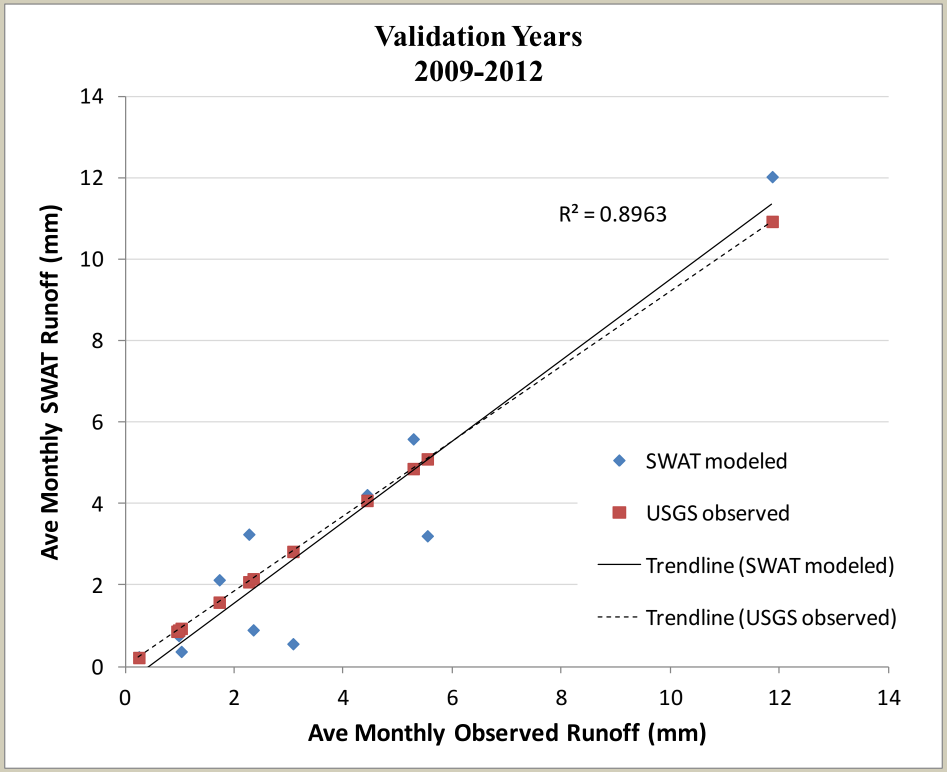


Photo: Lainie Levick

Precipitation Data	Calibration					Validation				
	Time Period (years)	Daily		Monthly		Time Period (years)	Daily		Monthly	
		R^2	NSE	R^2	NSE		R^2	NSE	R^2	NSE
Nexrad-MPE	2006-2008	0.50	-0.01	**0.80**	**0.80**	2009-2012	0.57	-0.38	**0.90**	**0.86**
Rain gage	2000-2005	0.46	0.44	**0.95**	**0.92**	2006-2011	0.34	-0.24	**0.97**	**0.73**
Meterological Tower	2000-2004	0.02	-6.9	0.06	-0.3	2005-2008	0.37	-0.21	0.99	0.78

Upper Garden Canyon NEXRAD-MPE





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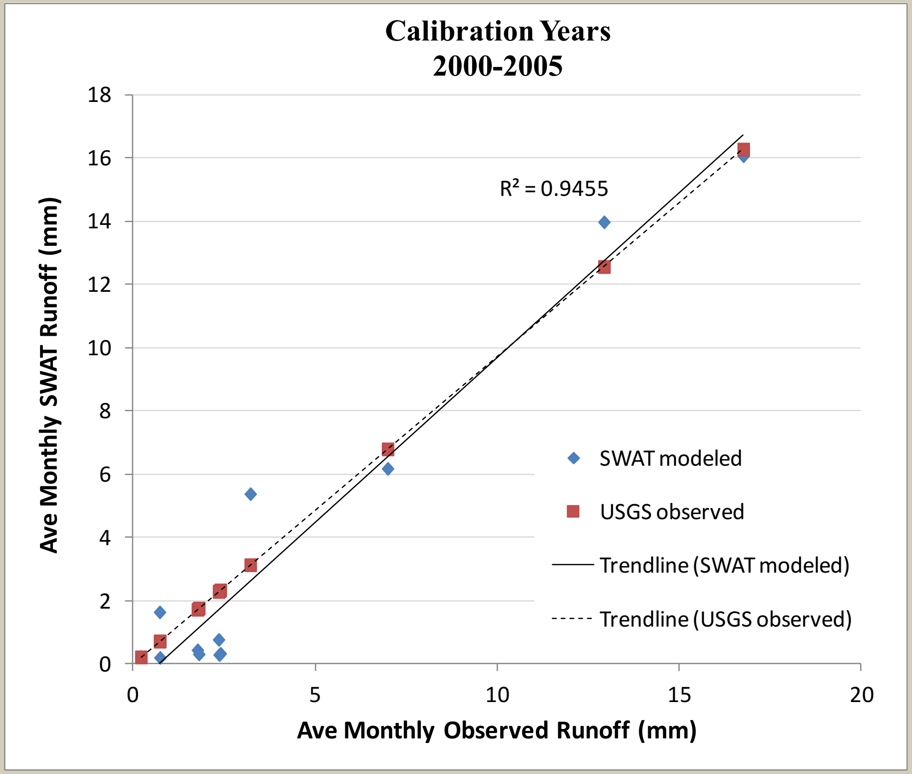
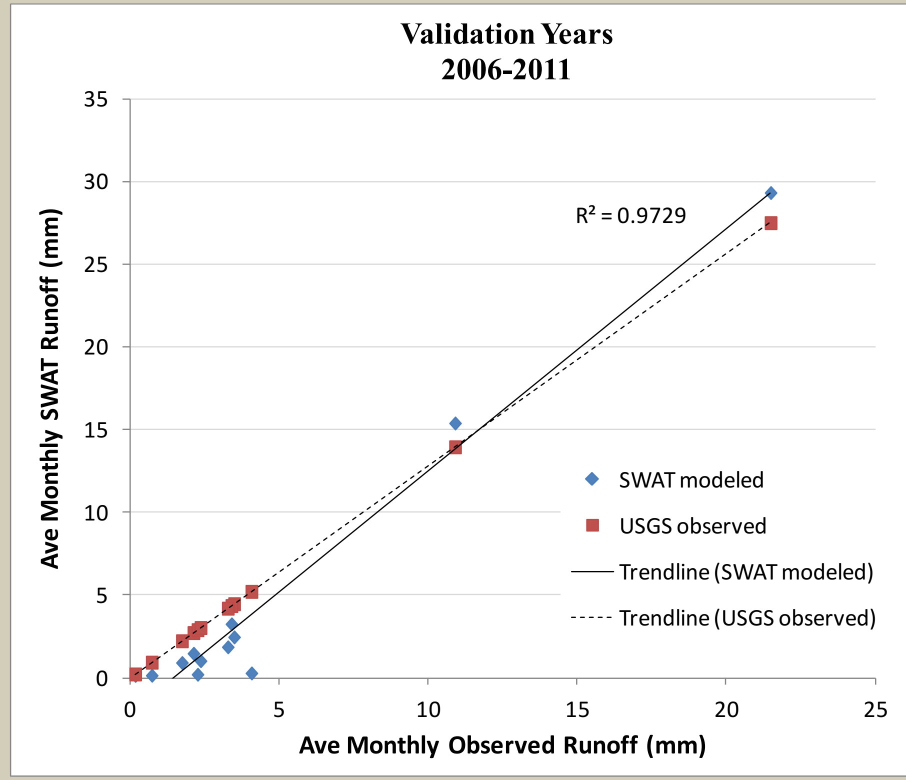
Upper Garden Canyon Rain Gauge





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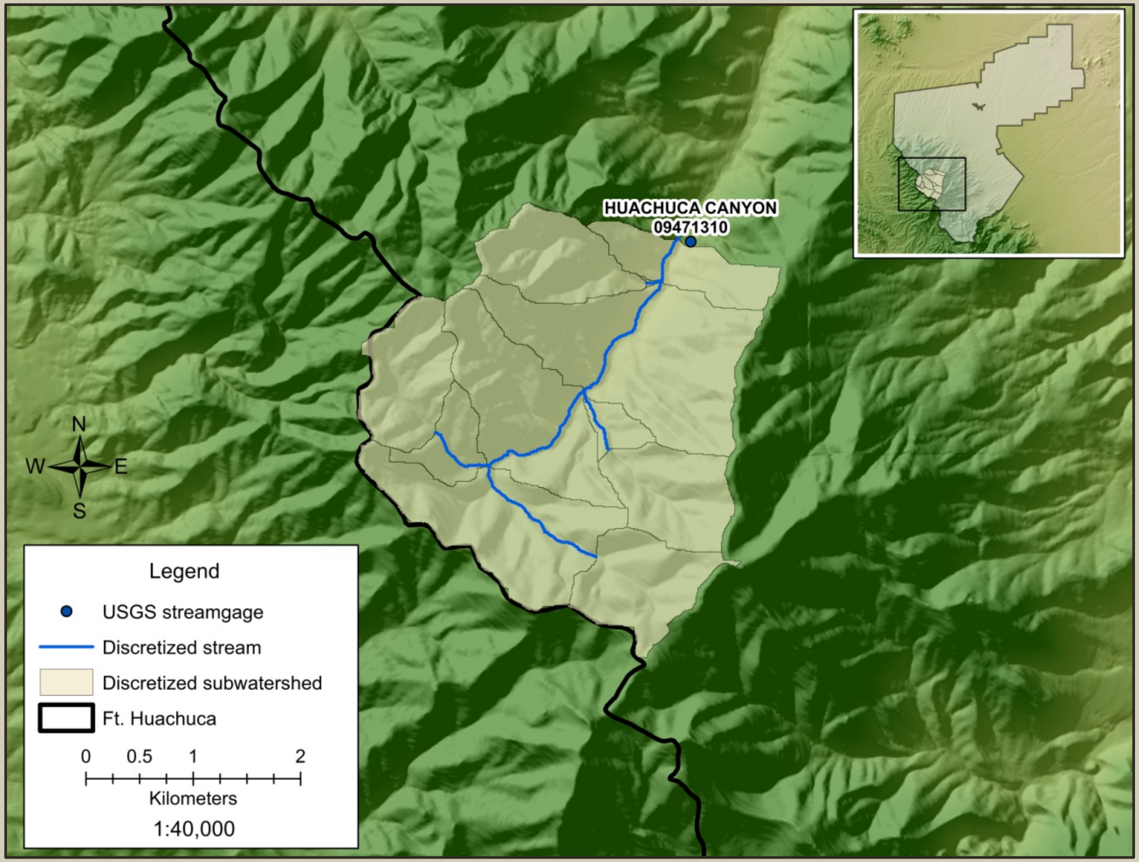
Upper Huachuca Canyon



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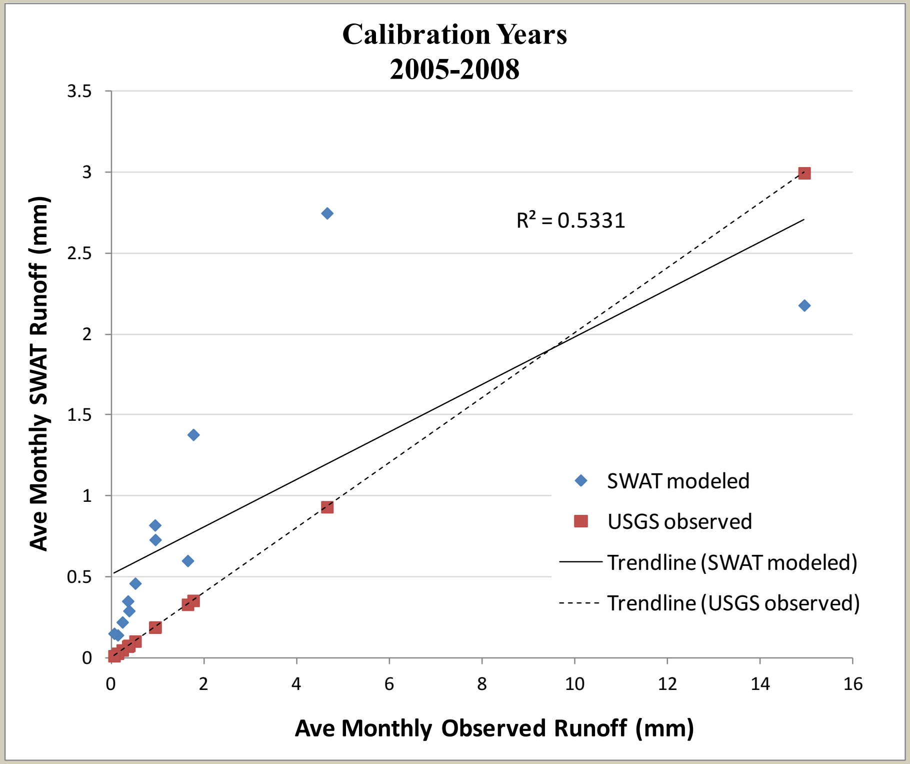

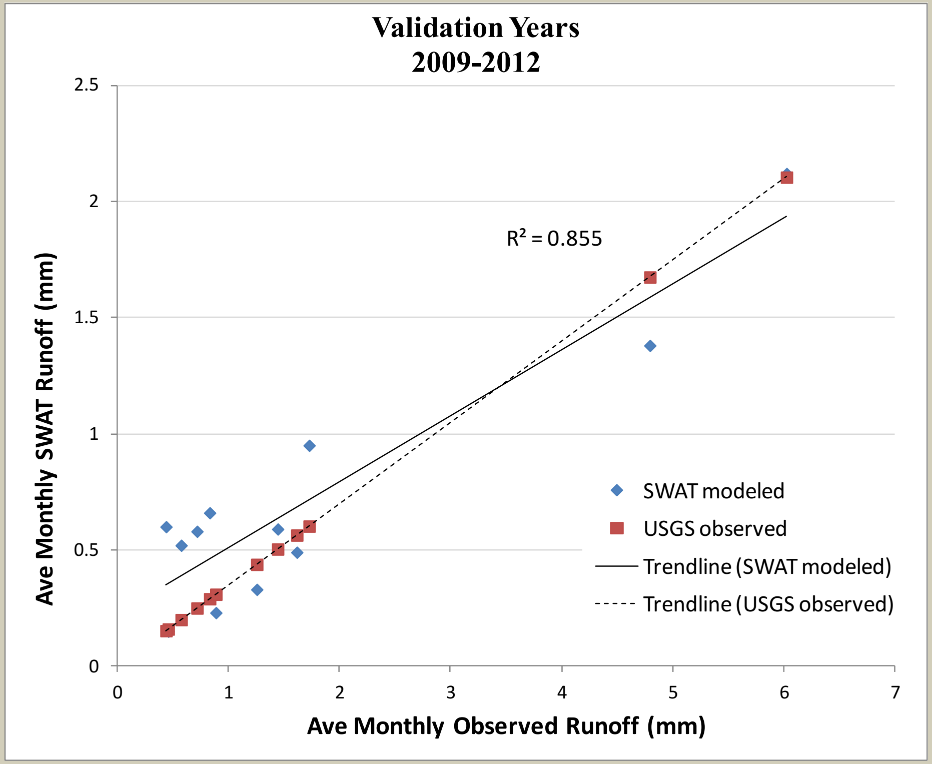

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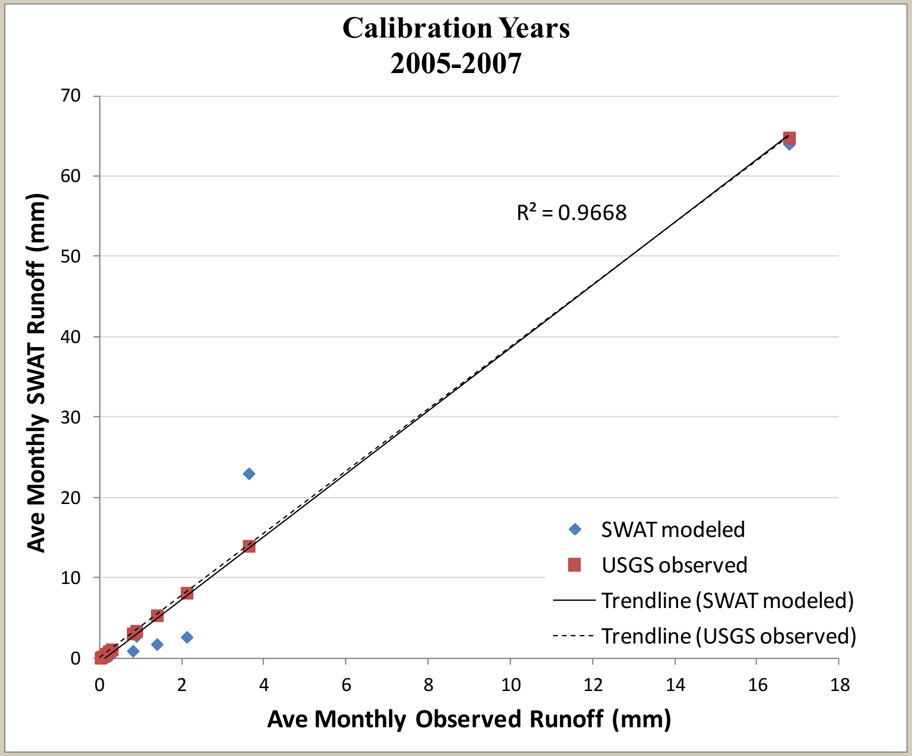

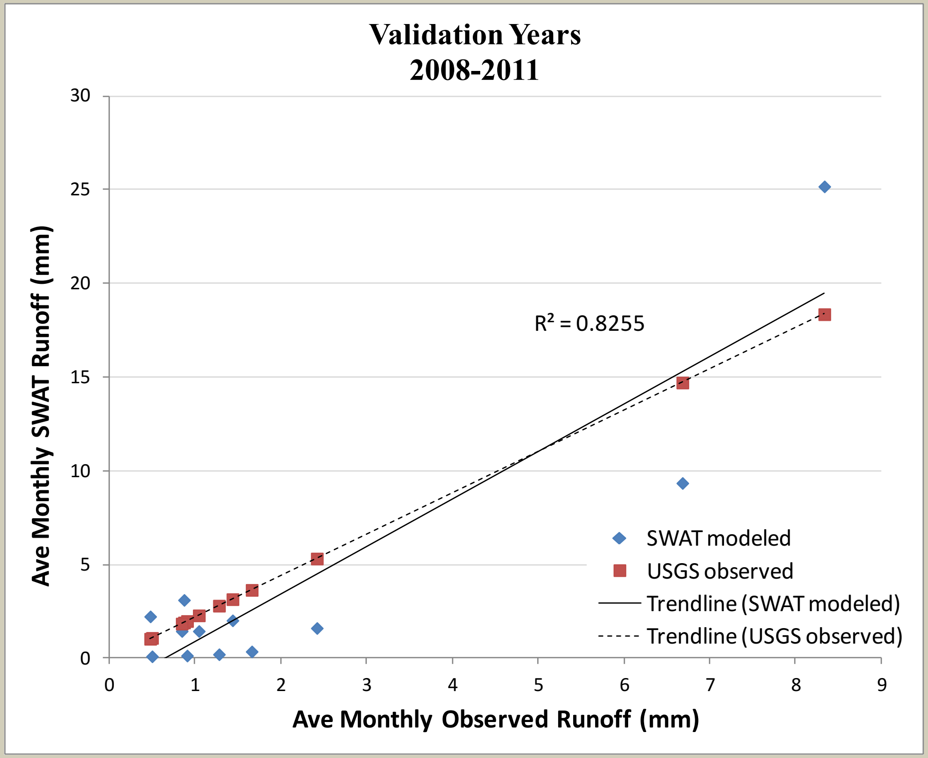

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Flow Permanence

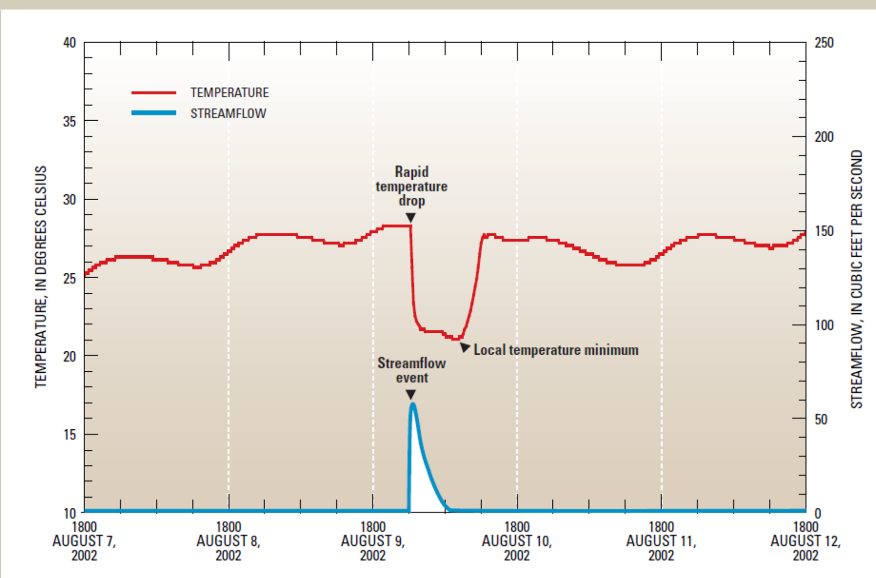
- Quantifies amount of time per year when surface flow is present
- Indicator of soil moisture/ biogeochemical reactions
- Used to describe hydrologic connectivity
- Possible to correlate with vegetation metrics
- Determined from SWAT daily output water yields

Flow Cutoff Determination

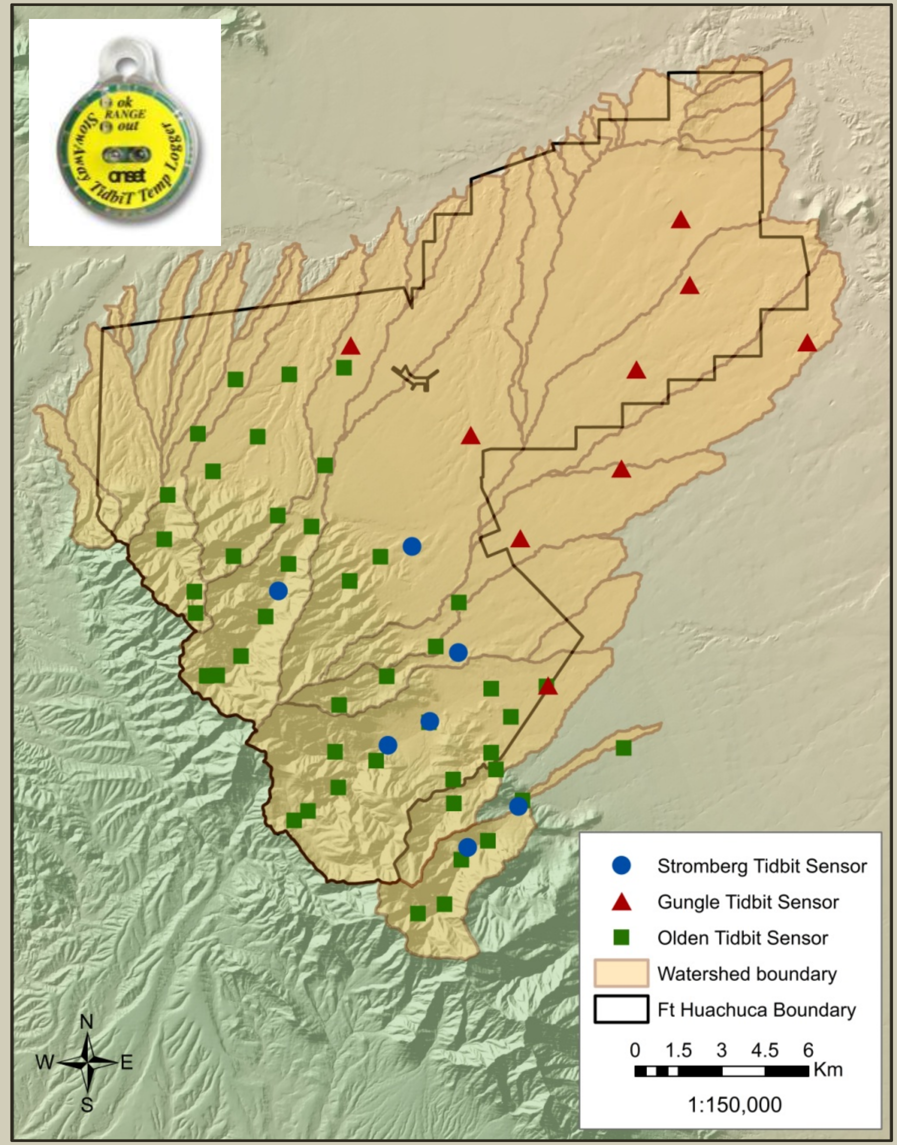
- SWAT poor at simulating zero-flow days
- Water yields (mm) function of area
- Flow cutoff based on contributing watershed area
- Use Tidbit Temperature data to establish area-flow cutoff relationships

Tidbit Temperature Logger

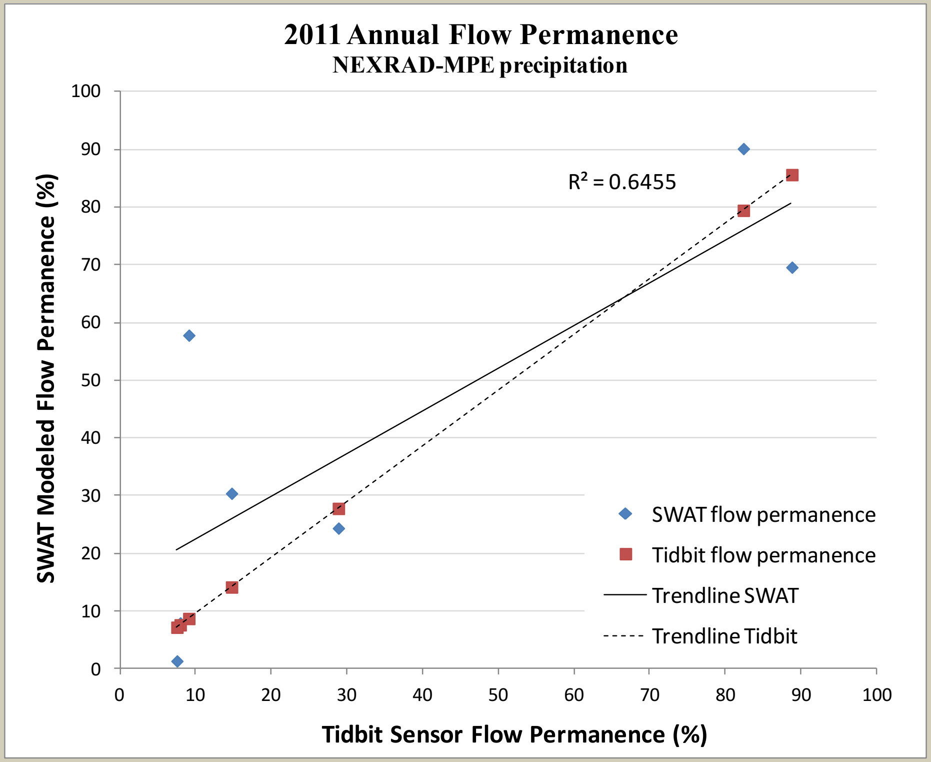
- Logs data at 15-minute intervals
- Detects onset and cessation of streamflow
- Thermograph interpretation technique

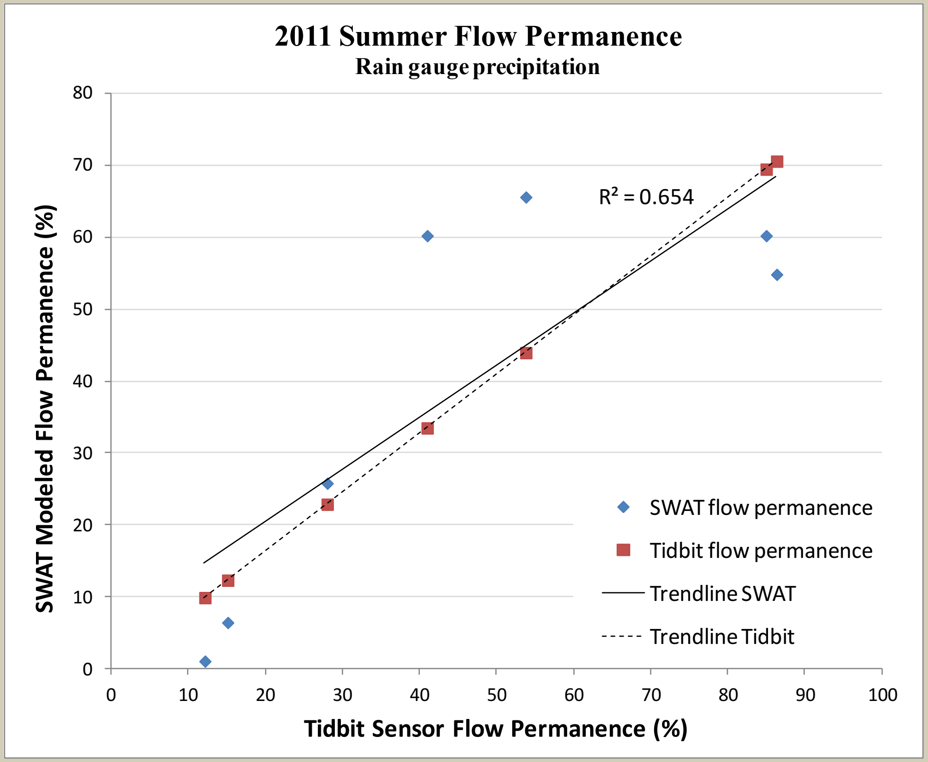


Gungle, 2005



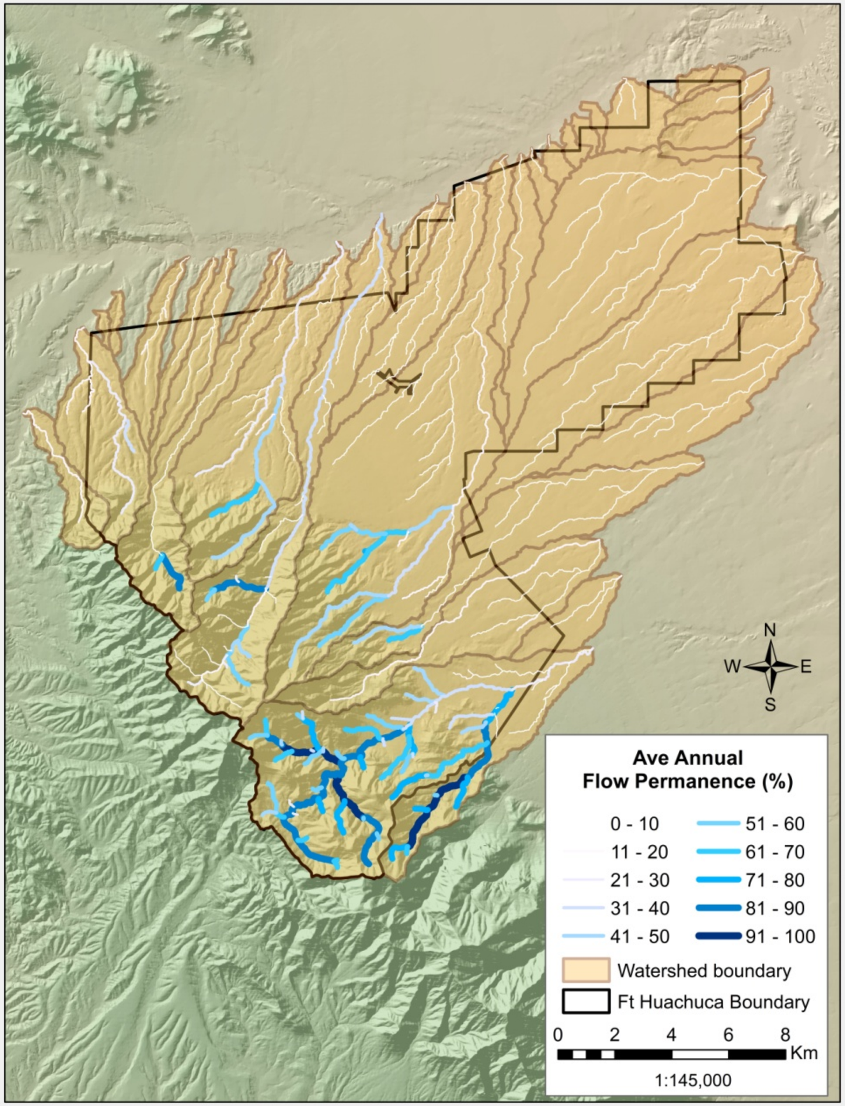
Flow Cutoff Analysis

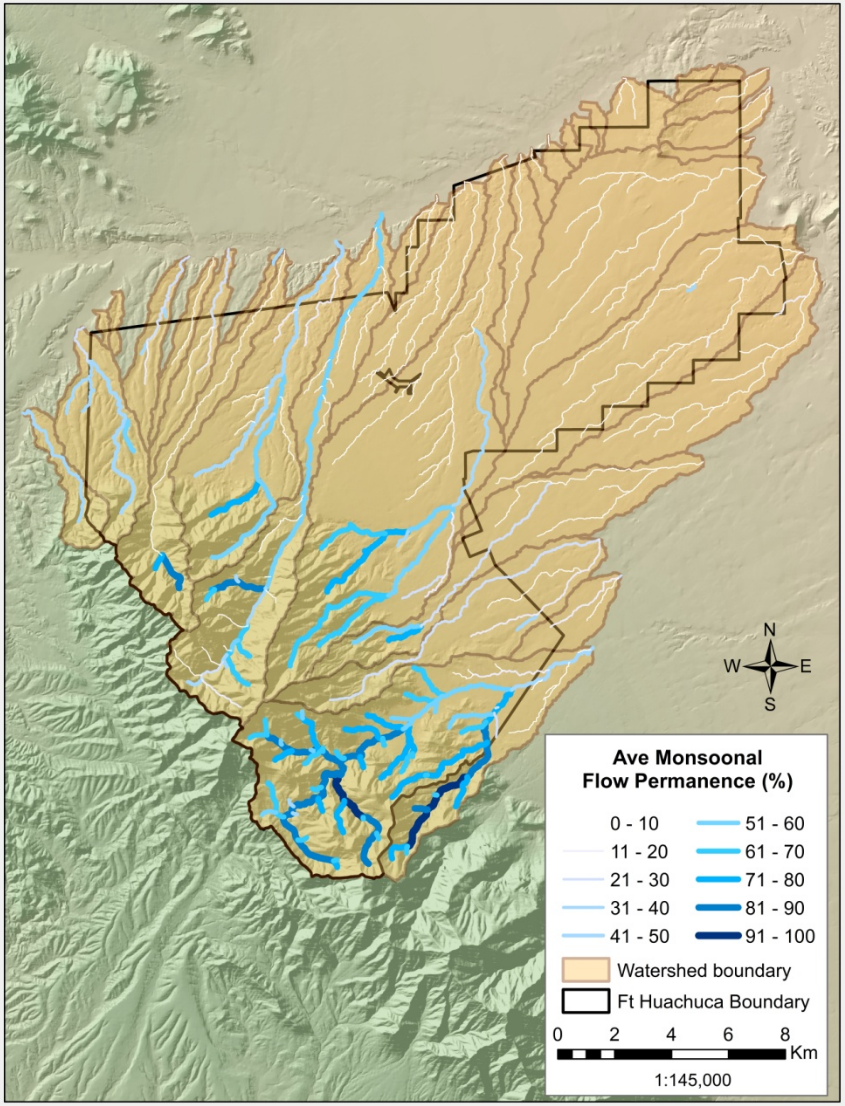




Watershed	TidBit Sensor			NEXRAD-MPE		Rain Gauge	
	Location ID	Annual %	Monsoon %	Annual %	Monsoon %	Annual %	Monsoon %
Buena School Area	GN	7.9	15.08	7.95	16.13	9.32	6.45
Soldier Creek	HN	7.47	12.12	1.37	4.3	0.27	1.08
Huachuca Canyon	HU	28.81	86.31	24.38	54.84	43.01	54.84
Garden Canyon	GU	88.74	84.95	69.59	74.19	56.71	60.22
Garden Canyon	GL	14.69	40.96	30.41	56.99	56.44	60.22
Ramsey Canyon	RU	82.33	53.76	90.14	82.8	71.78	65.59
Ramsey Canyon	RL	9.04	27.99	57.81	63.44	24.93	25.81

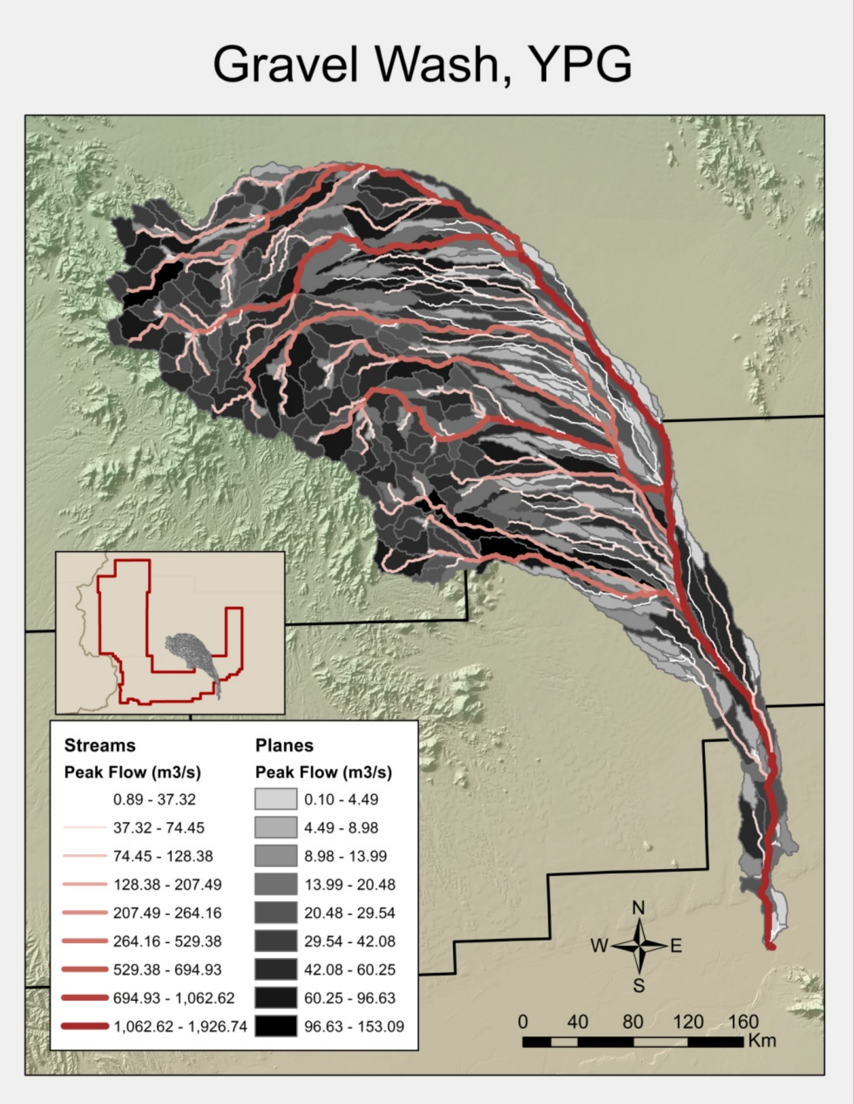
Ft. Huachuca Flow Permanence (NEXRAD-MPE)





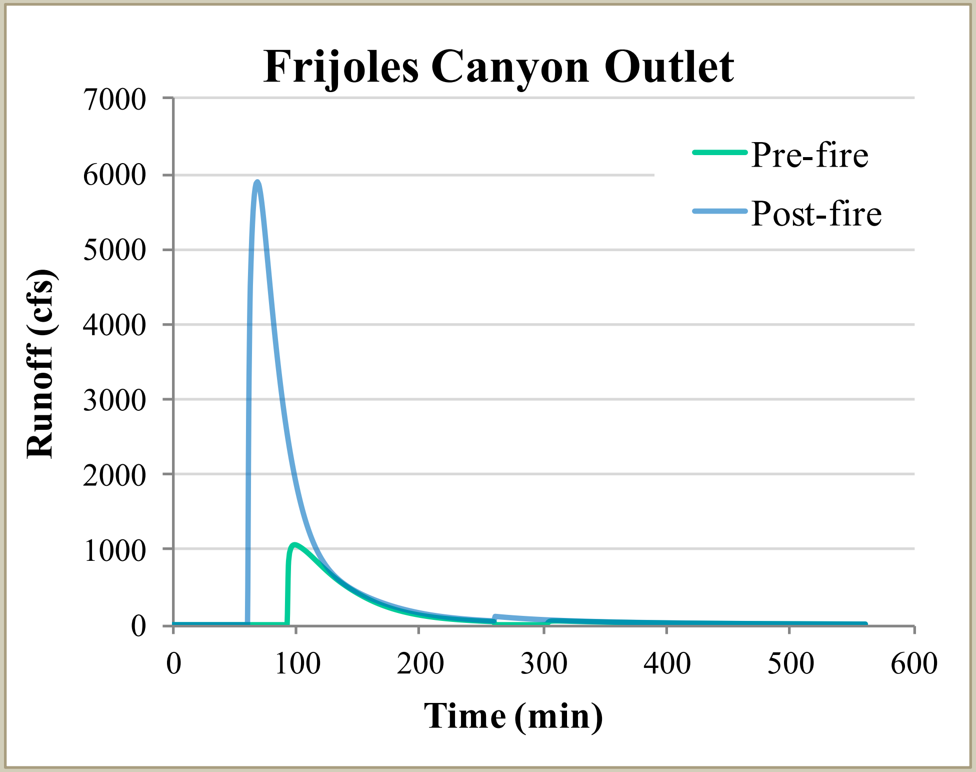
Kinematic Runoff and Erosion Model (KINEROS2)

- Short-term, event specific model
- Distributed, physically-based model with dynamic routing
- Routes flow from adjacent planes to corresponding channel before routing to downstream segment
- Calibration possible with met tower data



Peak Flow

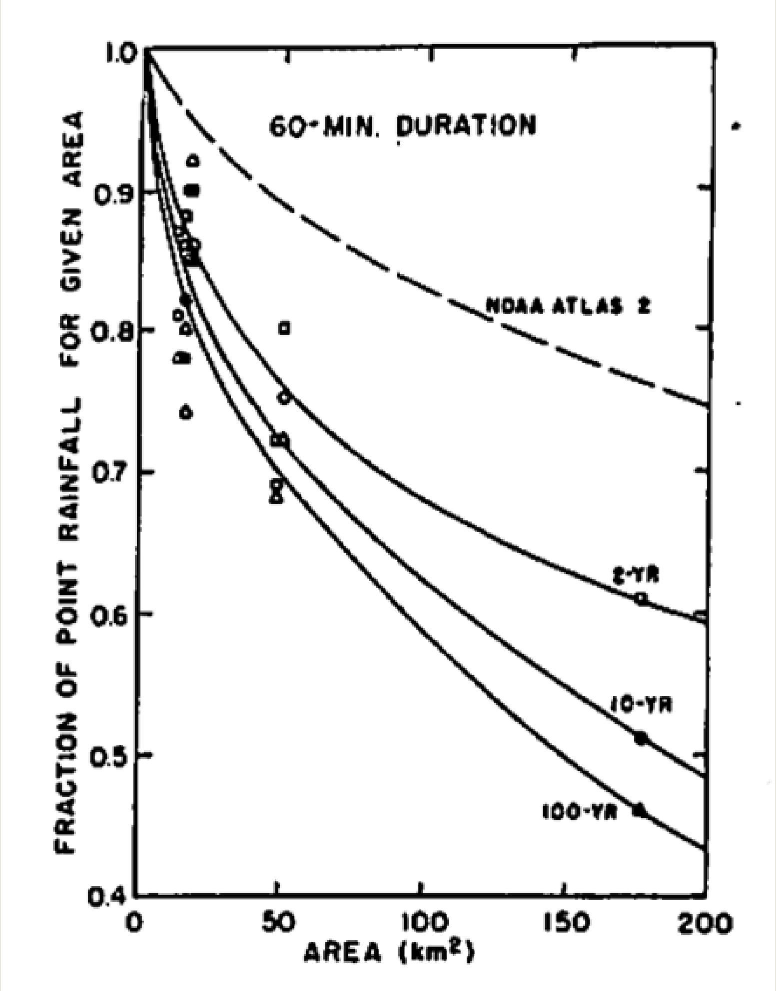
- Represents the highest point of discharge on a hydrograph
- Describes the magnitude of flow
- Measurement of watershed condition
- High peak flow events associated with sediment transport and channel formation



Goodrich et al., 2012

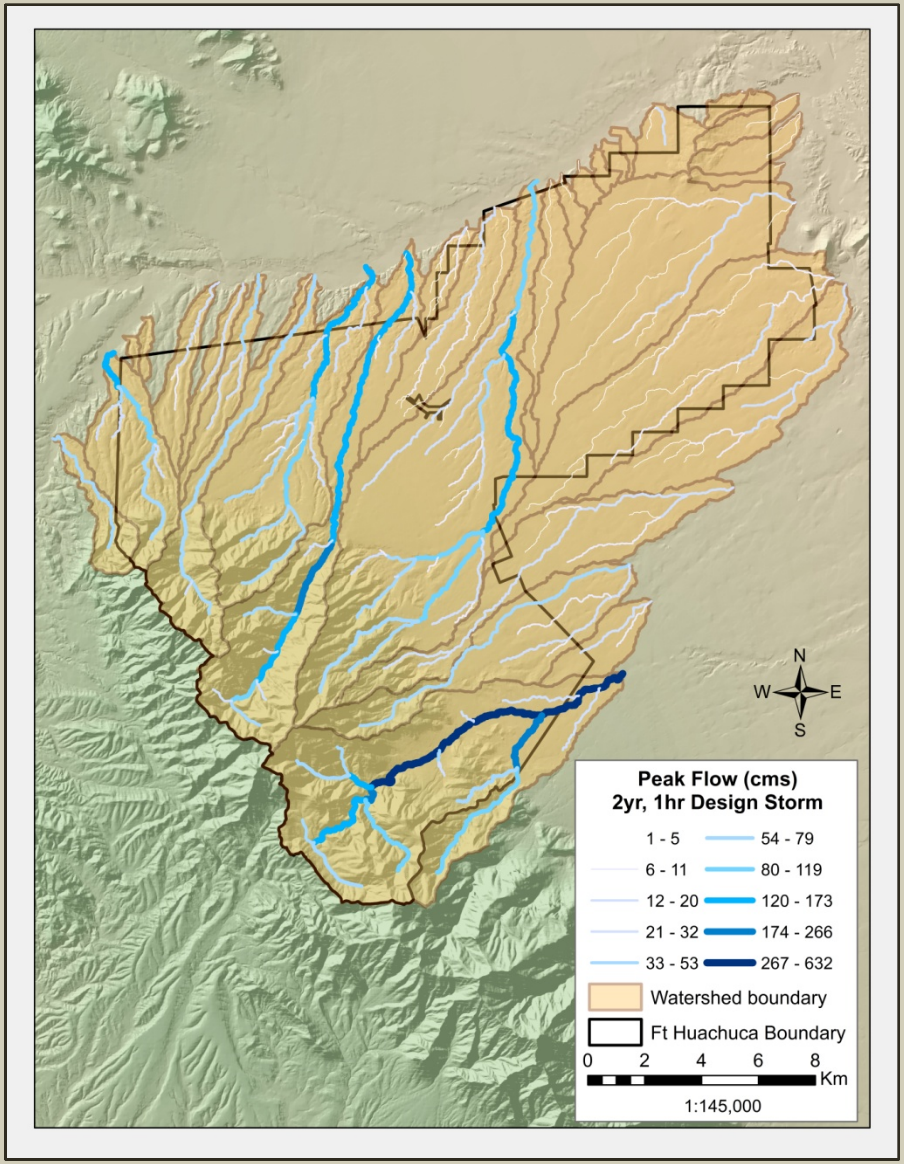
Areal Reduction Factor

- Accounts for applying equal precipitation depth across entire watershed
- Applied to point precipitation frequency depths
- Developed from paired rain gauge study at nearby Walnut Gulch Experimental Watershed
- Applied to design storm depths for 2, 10, and 100-yr; 1-hr events

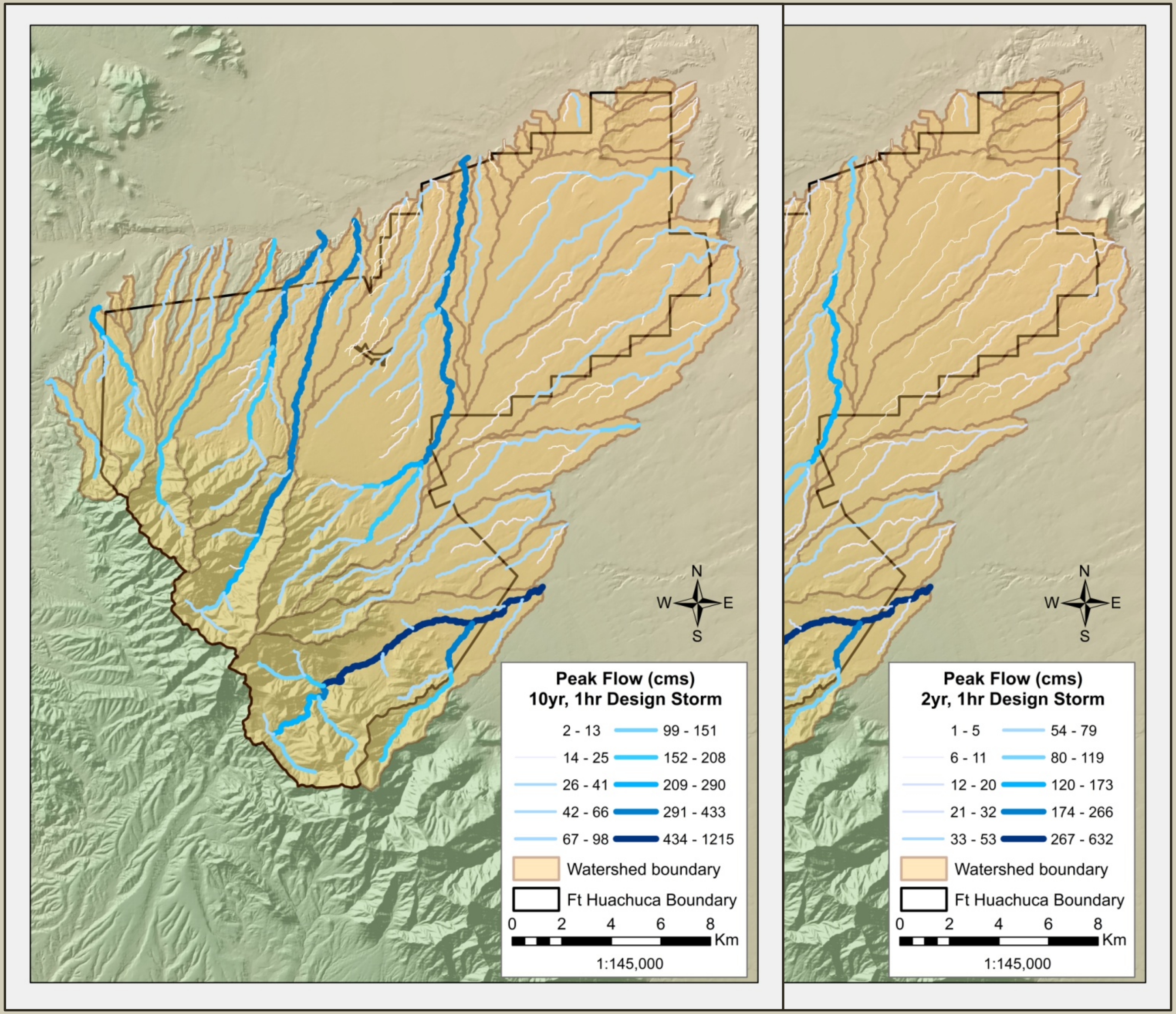


Osburn et al., 1980

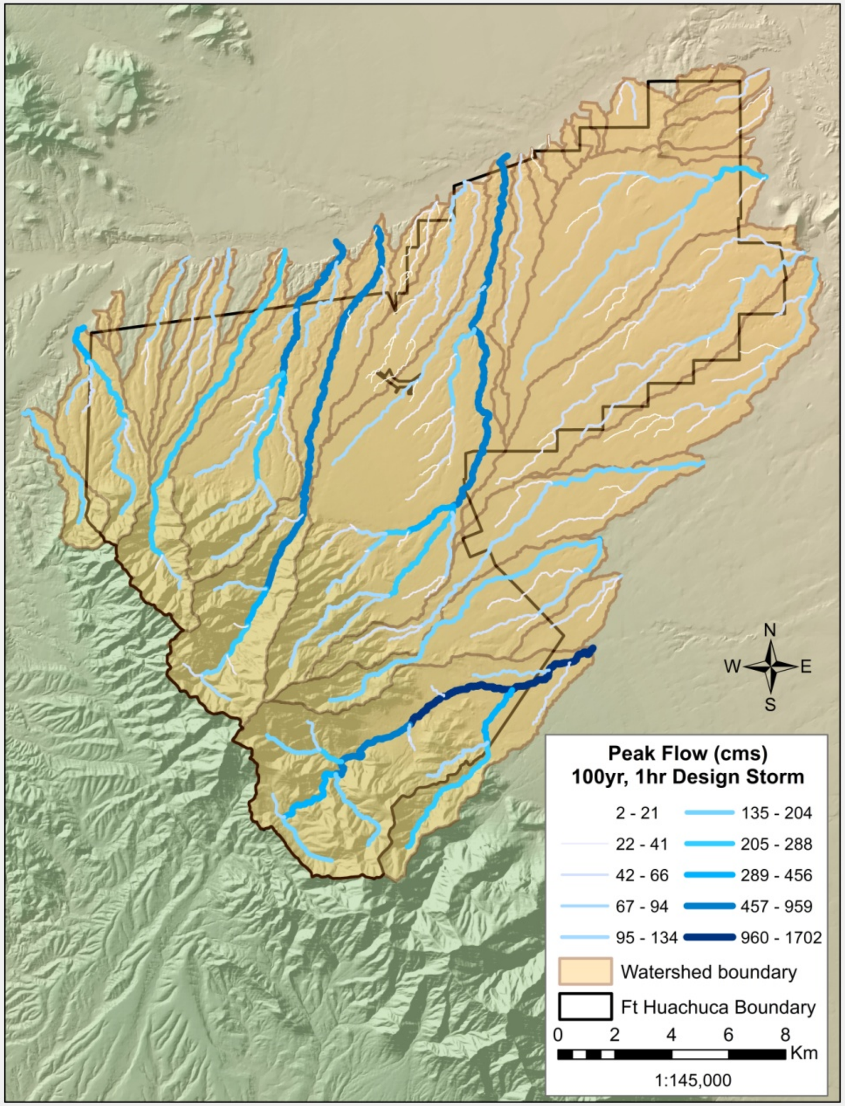
Peak Flow 2 year, 1 hour

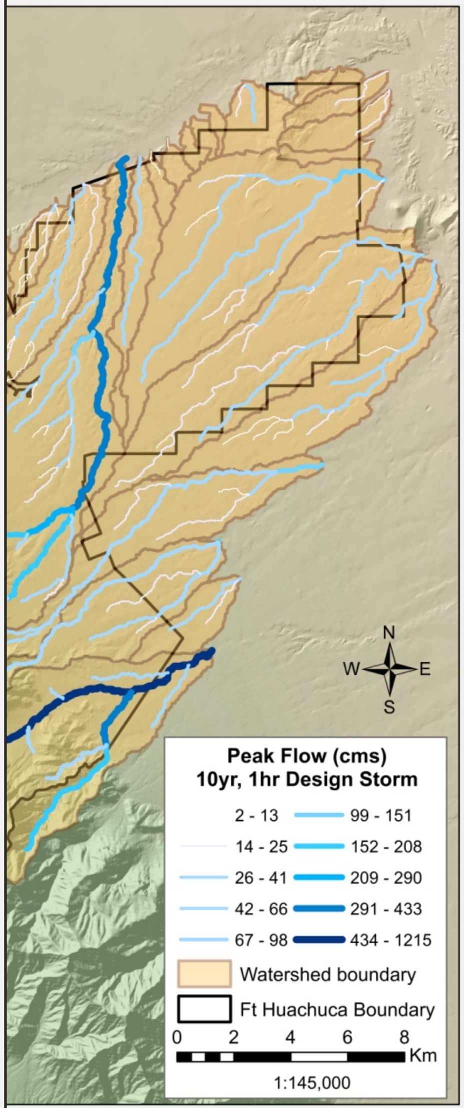


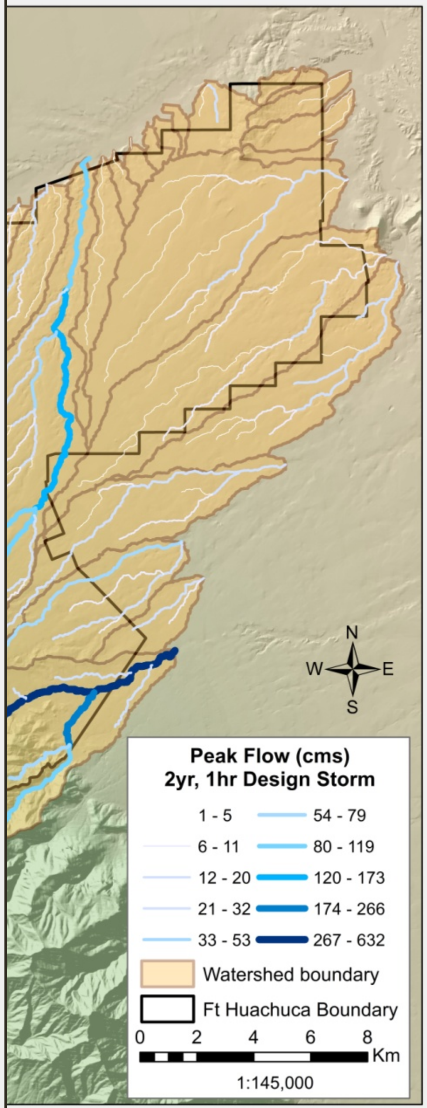
Peak Flow 10 year, 1 hour



Peak Flow 100 year, 1 hour



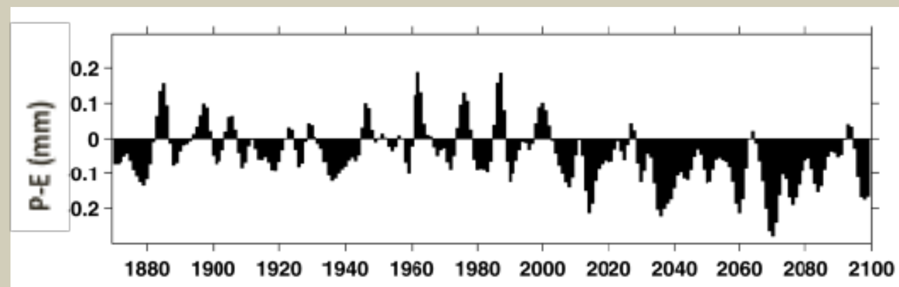




Climate Change Scenario

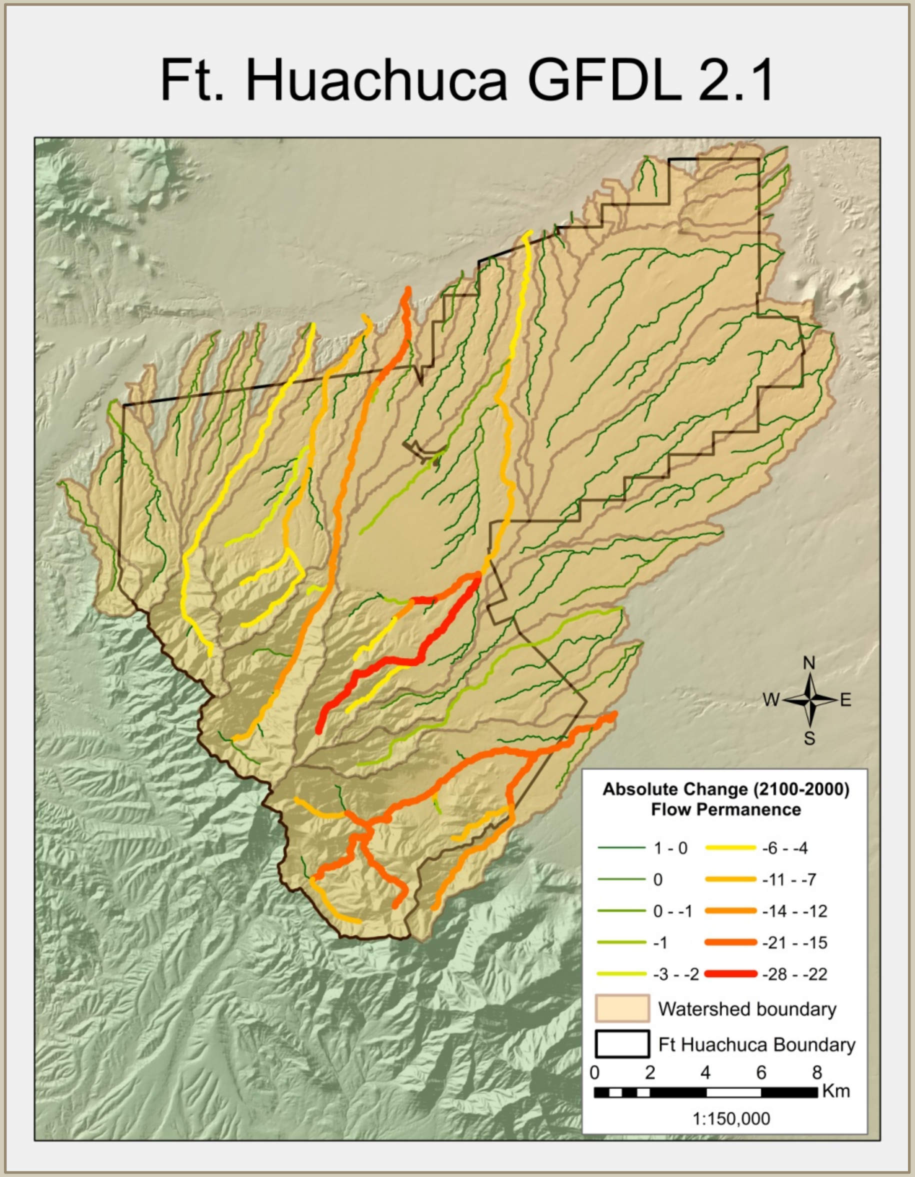
- NOAA's Geophysical Fluid Dynamics Laboratory Global Circulation Model 2.1
- Bias-corrected and downscaled climate and hydrology projections
- A2 scenario; global temp. increase 3.4° C by 2100
- Difference between SWAT simulations from 1981-2000 & 2081-2100

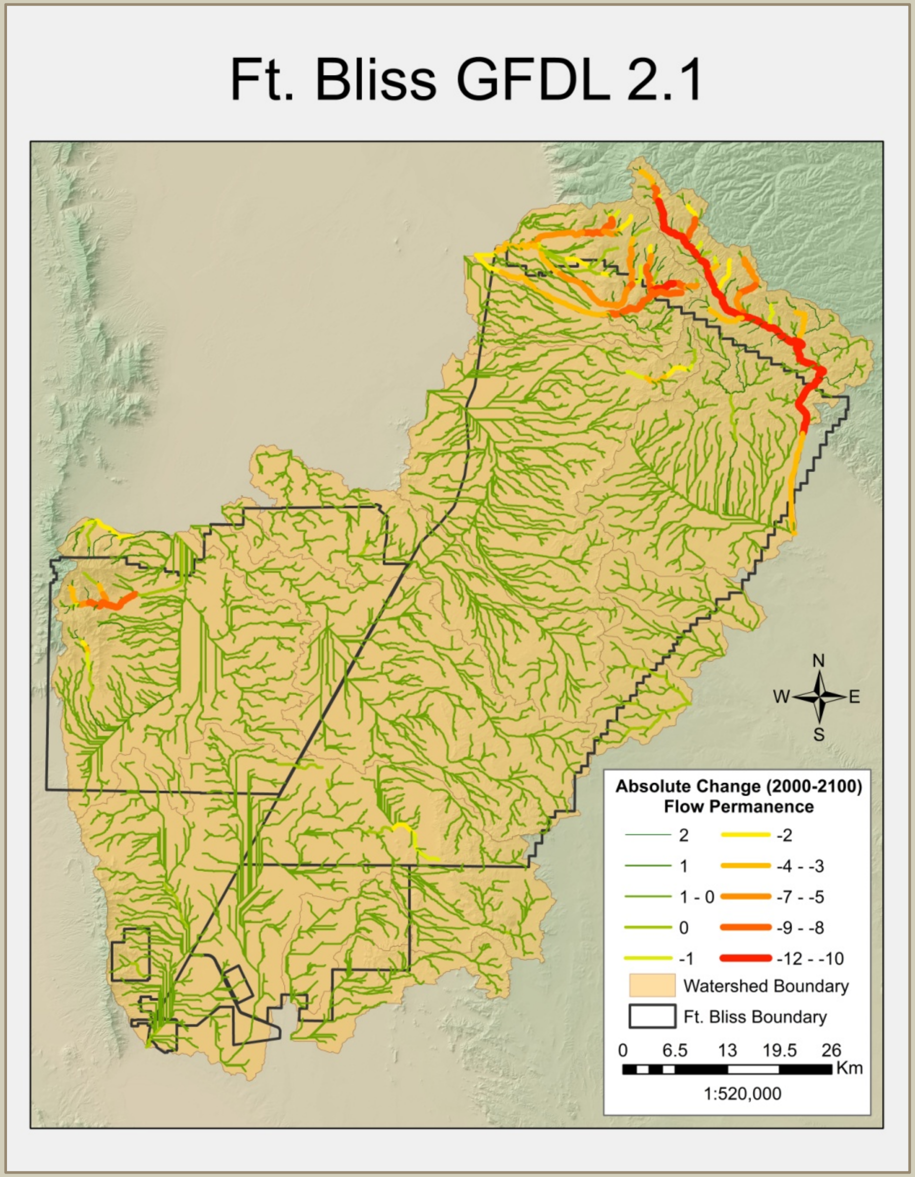
Changes in Precipitation-Evaporation



Seager et al. (2007)

Absolute Change Flow Permanence





Errors and Assumptions

- Accuracy of input data
- High spatial variability of summer thunderstorms
- Equipment failure
- Parameter changes unique to each watershed
- Tidbit sensor overestimation of flow permanence

Future Development

- Improve area-flow cutoff relationships
- Correlate hydrologic characteristics with vegetation and geomorphology
- Create ecohydrological classification
- Expand climate projection data to predict other hydrologic variables

Conclusions

- Rainfall-runoff models can accurately simulate hydrologic conditions.
- Relative differences between watersheds can be useful where calibration is not possible.
- Easy to assess large unmonitored areas
- Used to guide land disturbance activities away from ecologically sensitive areas.

Acknowledgements

- Strategic Environmental Research & Development Project
- University of Arizona's School of Natural Resources & Environment
- USDA Agricultural Research Station- Tucson
- Thesis Committee Members
  - Dave Goodrich
  - Phil Guertin
  - Lainie Levick
  - Shirley Papuga
- SERDP project team
  - Joel Murray
  - Sami Hammer
- Additional SERDP teams
  - Julie Stromberg, Hillary Nichols
  - Julian Olden, Kris Jaeger
- ARS
  - Shea Burns
  - Yoga Korgaonkar
  - Morgan Ross
  - Gabe Sidman

Questions/Comments

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