CAN WATERSHED MODELS GUIDE RIPARIAN RESTORATION EFFORTS IN THE BORDERLANDS?

Laura Norman, H. Ron Pulliam, Valer Austin, and David Seibert

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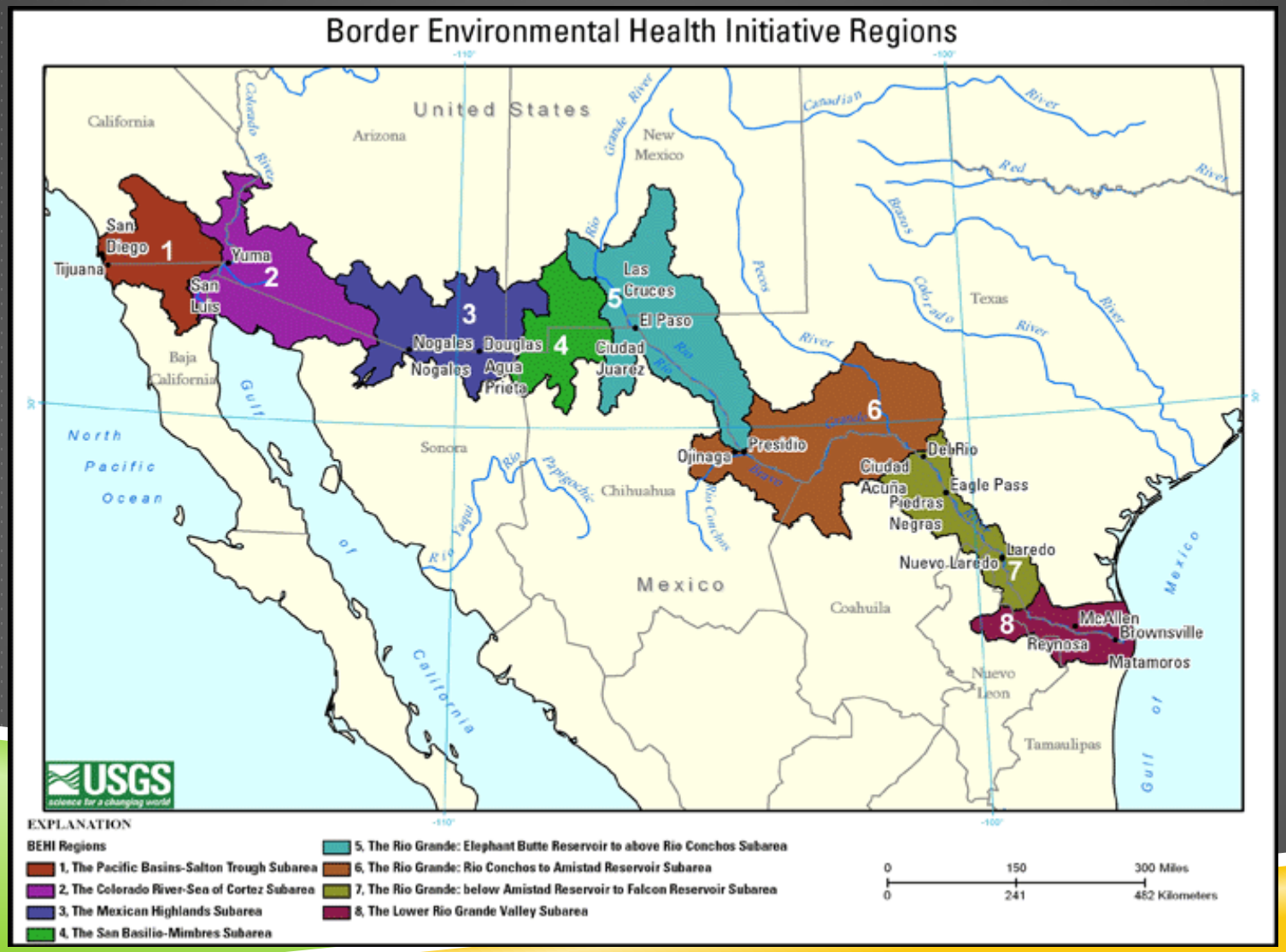
U.S. GEOLOGICAL SURVEY

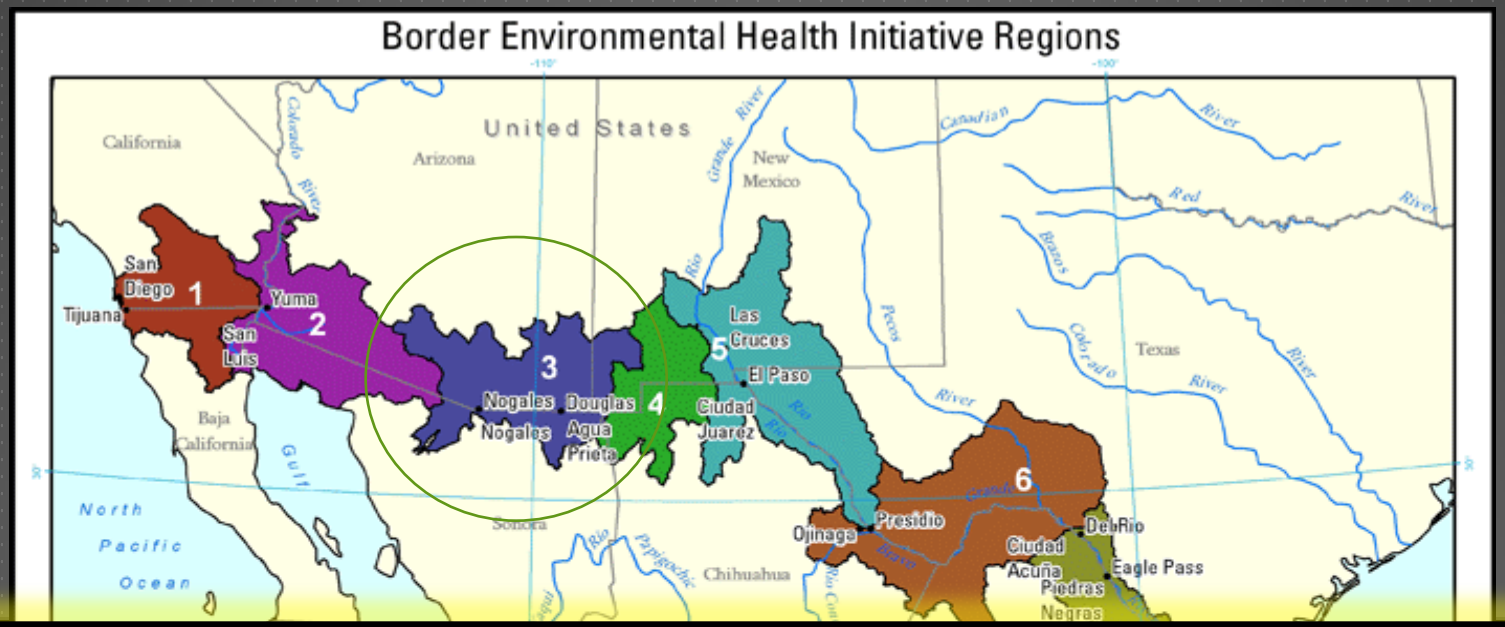
- As the Nation's largest water, earth, and biological science and civilian mapping agency, the USGS collects, monitors, analyzes, and provides scientific understanding about natural resource conditions, issues, and problems.

- The diversity of our scientific expertise enables us to carry out large-scale, multi-disciplinary investigations and provide impartial scientific information to resource managers, planners, and other customers.

U.S. - MEXICO
BORDER ENVIRONMENTAL HEALTH INITIATIVE (BEHI)



SUB-AREA 3: THE MEXICAN HIGHLANDS



The Mexican Highlands subarea, part of the Basin and Range physiographic province extends about 170 miles along the international border between US and Mexico. It is characterized by broad valleys or basins separated by steeply rising mountain ranges with independent hydrologic systems. The subarea contains 14 basins that drain to rivers in southern Arizona, southwestern New Mexico, northern Sonora, and the northwestern tip of Chihuahua--classified as desert but renowned for its lush vegetation and diverse aquatic habitats, remnants from a time when the area was **wetter.**

THE BORDERLANDS HABITAT RESTORATION INITIATIVE

Ron Pulliam, Gary Nabhan, & David Seibert

1. Restore hydrology and other physical drivers
   - focus on water and stream flow
2. Identify Gaps and Restore Food Chain
   - focus on nectar and fruit-producing species at base of the food chain
3. Reconnect People and Wildlife
   - involve local citizens in restoring ecosystem services in their own communities

discover the
MOUNTAIN EMPIRE
PATAGONIA SONOITA ELGIN

CUENCA LOS OJOS (CLO) FOUNDATION

"Cuenca los Ojos (CLO) is a leader in adapting to climate change. In a part of the world that has been drying up, CLO is reversing this trend by restoring habitat through an ancient tradition of slowing erosion and harvesting water -- water that would otherwise would rush over a desiccated landscape. Bringing water back to the land has resulted in remarkable vegetation changes, which in turn has increased populations across the animal spectrum."--http://www.cuencalosojos.org/

RESTORATION TECHNOLOGY

berm \ bərm \
earthen walls built with earth moving equipment to control erosion by reducing the rate surface runoff.

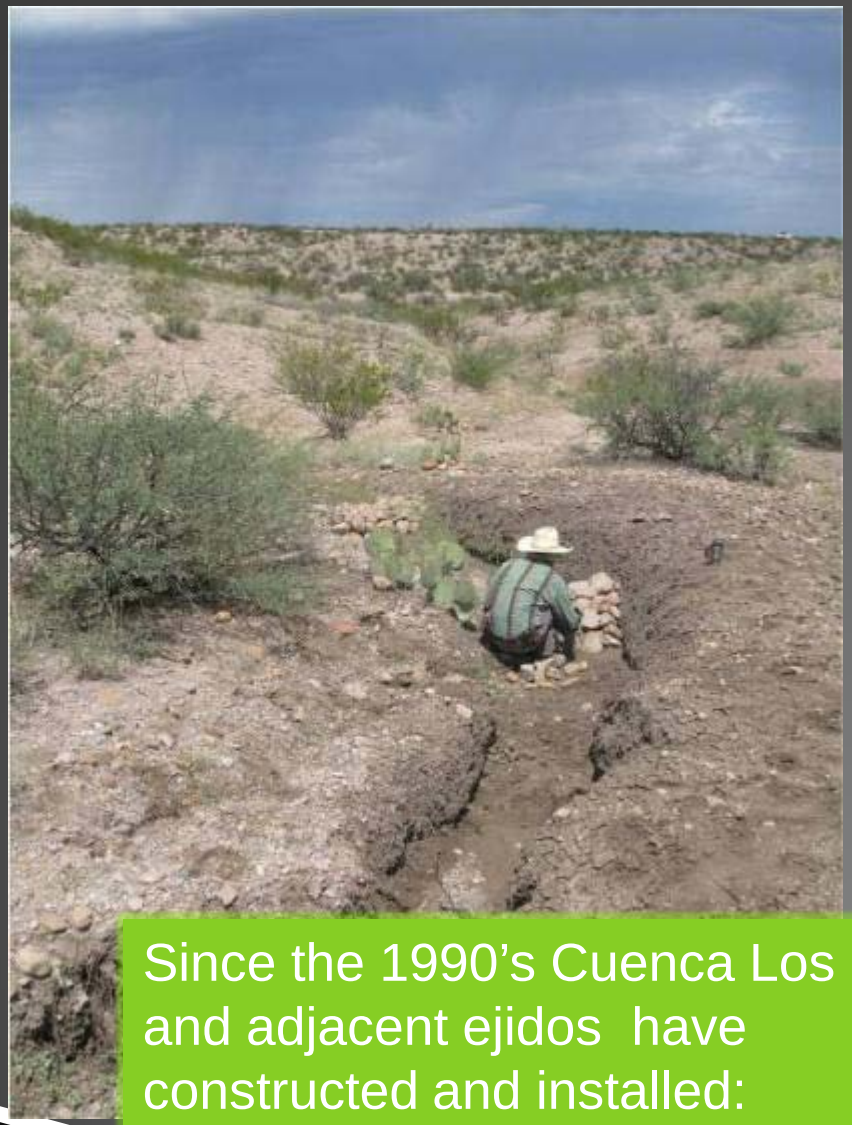
trincheras \ trin•che•ras \
rock retaining walls that are terraced up a hillside.

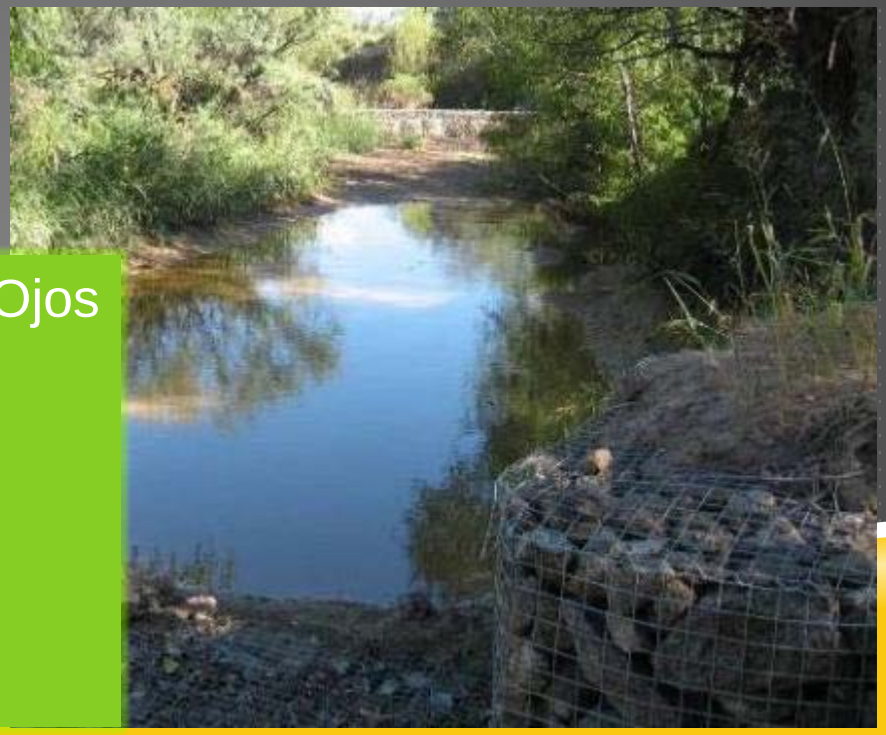
gabion \ gā•bē•ən \
wire cages filled with rock that are used for erosion control.

Check dams have been unearthed in Algeria, North Africa, from the Roman or possibly pre-Roman period **(27 BC–AD 1453**), an example of ancient measures for the conservation of water.

Figure 4. An Upstream View of a Series of Nearly Intact Check Dams in the Upstream Portion of the Channel along the Southern Edge of Site USFS 06-04-109

Prehistoric check dams in the San Francisco Valley, New Mexico, from between **A.D. 750 and 1000.**





Since the 1990's Cuenca Los Ojos and adjacent ejidos have constructed and installed:

- 500+ berms
- 30,000 rock walls
- 54 large wire gabions

Restoring over 12,500 acres!

DOCUMENTATION OF RESTORATION IMPACTS

→ Research being done by *Cindy Tolle*, *Steve Delong*, Susan Wethington, Bob Minckley, David Hodges & *Ron Pulliam*

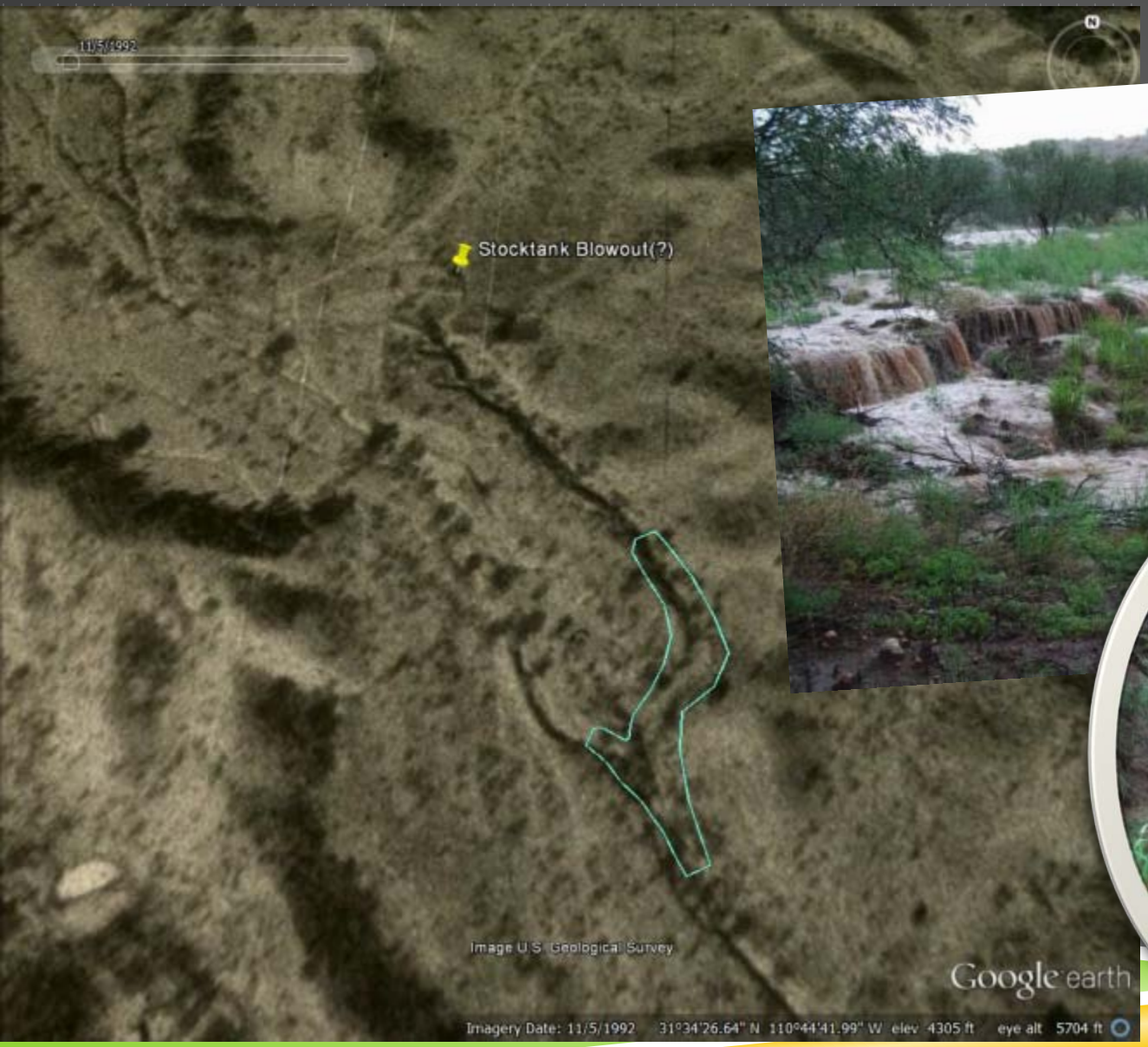
- Increased Stream Flow
- Increase in Riparian Vegetation
- Increase in Cienega Acreage
- Increase in Vertebrate Populations
- Only partial understory recovery
- Gaps in nectar and fruit producing species
- Slow recovery of animal-dispersed plants

PILOT STUDY AREA: DEEP DIRT FARM

- To use as an experimental watershed to share knowledge and begin working together
- Baseline information for monitoring in the future
- To make a difference

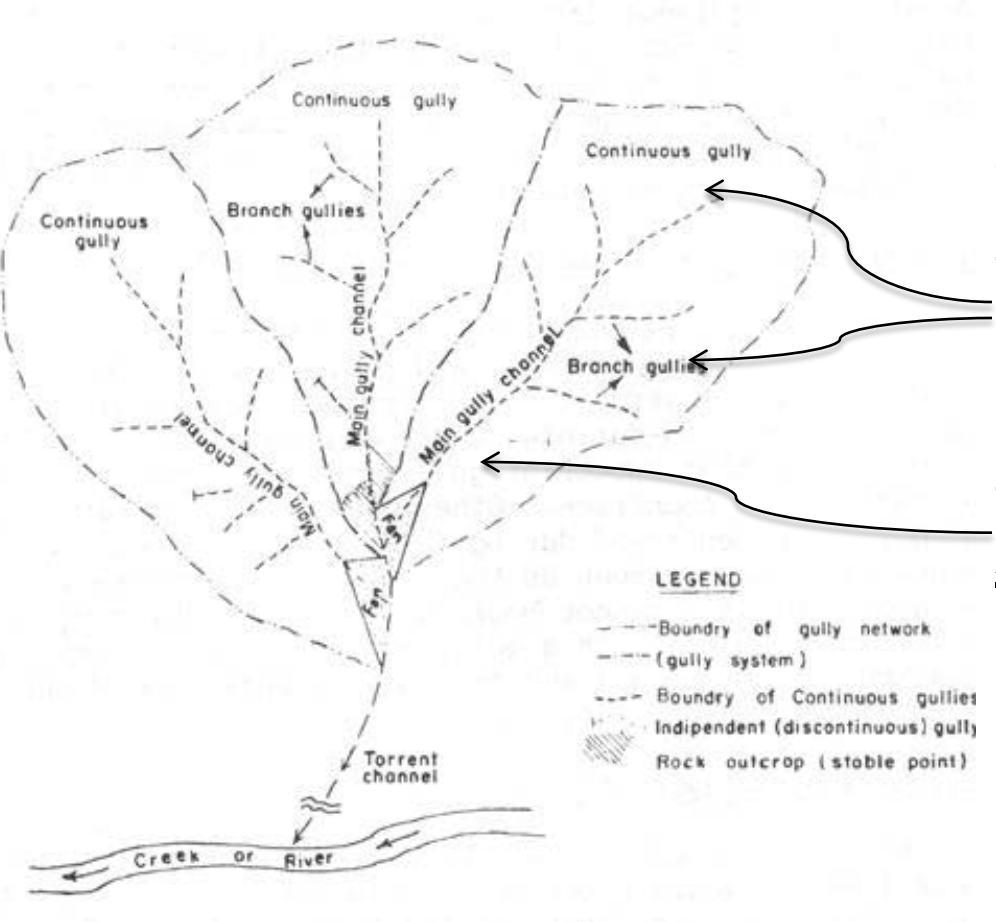
- "The Institute is located at Deep Dirt Farm, which comprises 34 acres with deep agricultural soils, bisected by an ephemeral stream/wildlife corridor.
- The farm lies within a folded topography of hills, small sheltered valleys & broad meadow."
- --http://www.facebook.com/DeepDirtFarmInstitute

HISTORICAL PHOTOS VIA GOOGLE EARTH SHOW CONDITIONS DATING BACK TO 1992 AFTER THE A STOCKTANK BLOWOUT THAT HAS CARVED A GULLY THROUGH THE FARM



1. How big do structures have to be here?
2. How much sediment might we expect for any given rainstorm?
3. And, how much runoff?
4. Where is the best place to put them?

CAN WATERSHED MODELS GUIDE RIPARIAN RESTORATION EFFORTS



For a continuous gully, the main criteria for selecting **structural control measures are based on:**

1. **the size of the gully catchment area,**
2. **the gradient, and**
3. **the length of the gully channel.**

The various portions of the main gully channel and branch gullies can be stabilized by ***loose-stone check dams.***

The lower parts are treated with ***loose-stone or boulder check dams***.

At a stable point in the lowest section of the main gully channel, for example, on a rock outcrop, a gabion check dam or cement masonry check dam should be constructed.

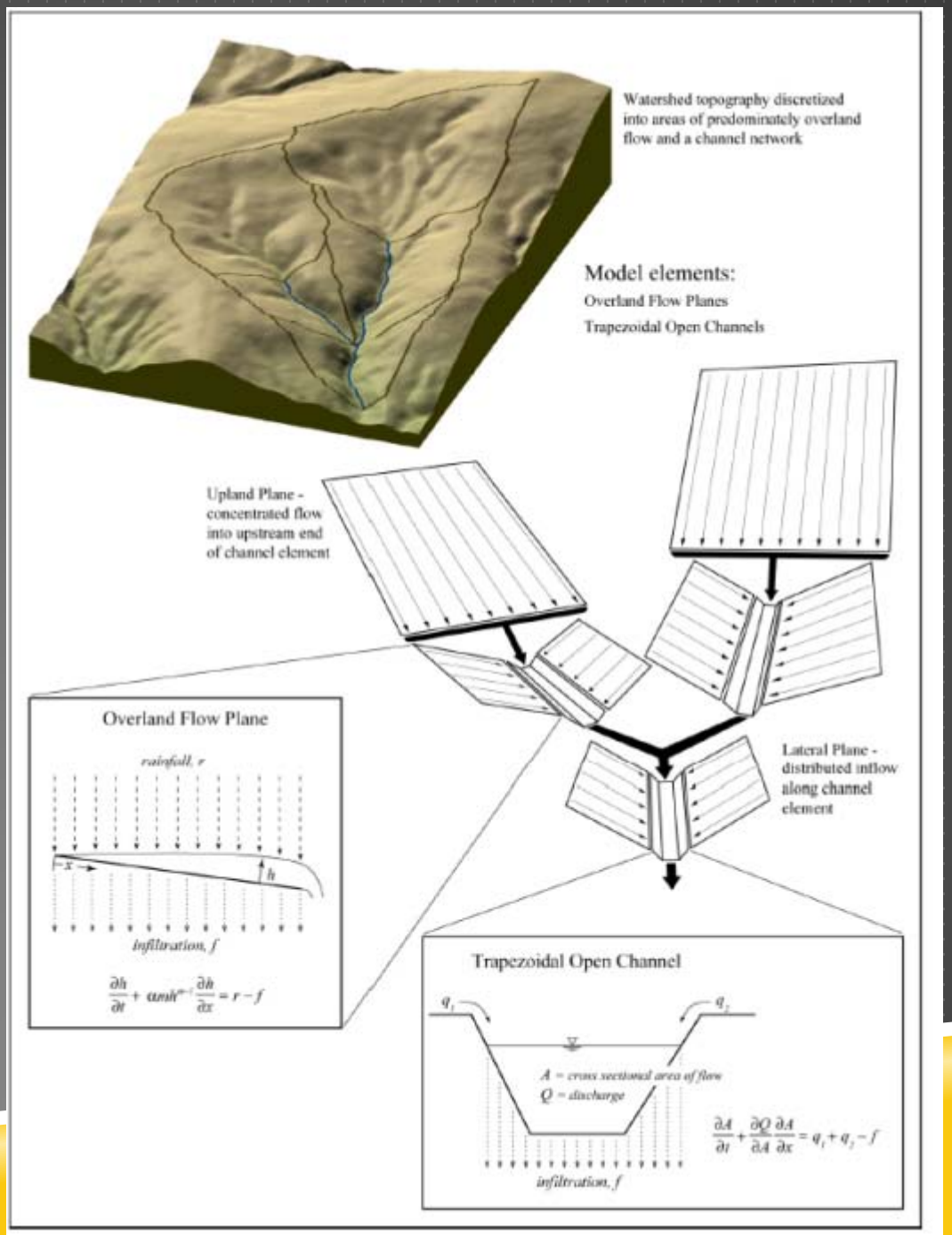
→If there is not a stable point, a ***counter-dam*** (gabion or cement masonry) must be constructed *in front of the first check dam*.

AUTOMATED GEOSPATIAL WATERSHED ASSESSMENT (AGWA) TOOL

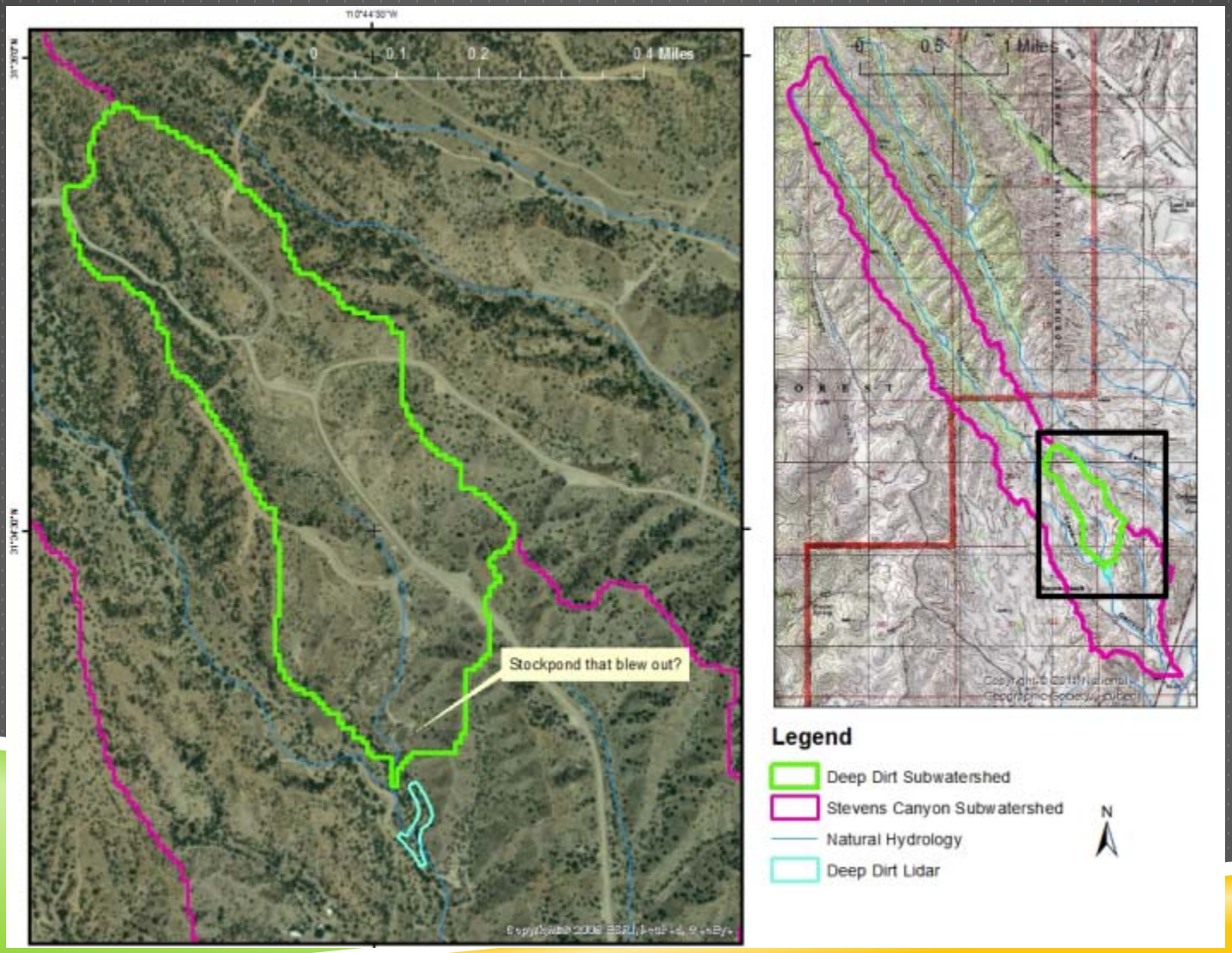
- The tool is a Geographic Information Systems (GIS) interface jointly developed by the U.S. Environmental Protection Agency, the U.S. Department of Agriculture (USDA) Agricultural Research Service, and the University of Arizona to automate the parameterization and execution of the **Soil Water Assessment Tool (SWAT)** and **KINematic Runoff and EROSion (KINEROS2)** hydrologic models.

In K2, the watershed is represented by a variety of spatially distributed model element types.

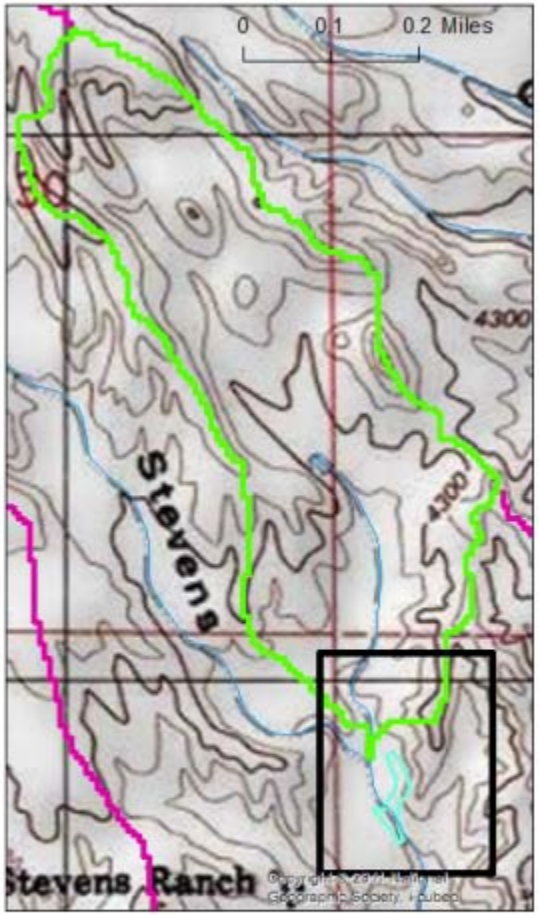
The model elements can be configured to effectively abstract the watershed into a series of shapes (rectangular overland flow planes, simple and compound trapezoidal channels, detention ponds, etc.), which can be oriented so that 1-dimensional flow can be locally assumed.



An outlet can be selected to delineate and discretize the watershed using a Digital Elevation Model (DEM); the Deep Dirt Sub-watershed (Bone Creek) is ~ 47 hectares, within the Stevens Canyon Sub-watershed (545 hectares)



FROM THE WATERSHED DELINEATION AND THE ELEVATION CHANGES WE SEE FROM THE 10-M. DEM, THE STOCKPOND THAT BLEW OUT MIGHT HAVE BEEN THE CIRCLE FEATURE IN THE OUTLET OF THE WATERSHED… THE BLOWOUT THEN LOOKS RESPONSIBLE FOR THE SURFACE FLOW DURING RAINSTORMS TO OCCUR



Legend

- Deep Dirt Subwatershed
- Natural Hydrology
- Deep Dirt Lidar

N

Surveying the longitudinal profile of the gully

1. The gully's longitudinal profile is an open traverse between the proposed first and last check dams.

2. Proceeding from the bottom to the top of the gully channel, the horizontal angles, vertical angles, and the ground distances between station points are measured with a hand compass, clinometer and 50 m tape, respectively.

3. While surveying the open traverse, materials available at the site should be noted, as this will play a part in determining what kind of check dams to build.

4. Horizontal and vertical distances between station points are computed first …→

Longitudinal profile of the gully : Surveyors:
: Location:
Survey of opened traverse : Date :

Left page — Right page

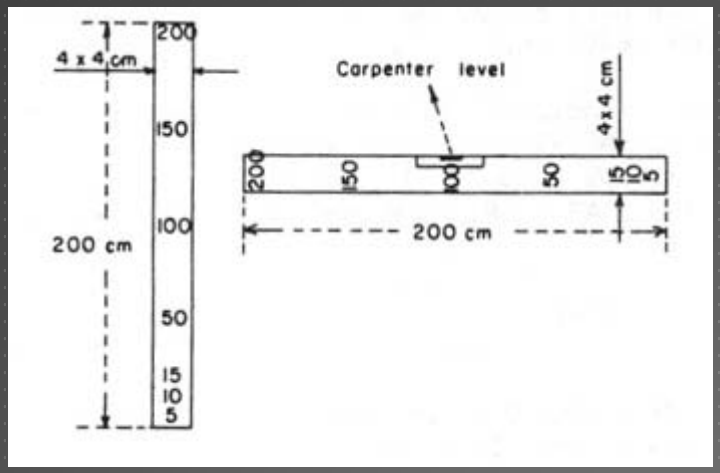
Field sketch

Station point	Shooting point	Horizontal Angle Degree	Vertical Angle Degree	Ground Distance m	Horizontal Distance (HD) m	Vertical Distance (VD) m
1	2	89	+ 12	50	48.90	10.40
2	3	89	+ 24	43	39.28	17.49
3	4	135	+ 16	47	45.18	12.95

Example: What are the vertical and horizontal distances between the points 1 and 2 ?

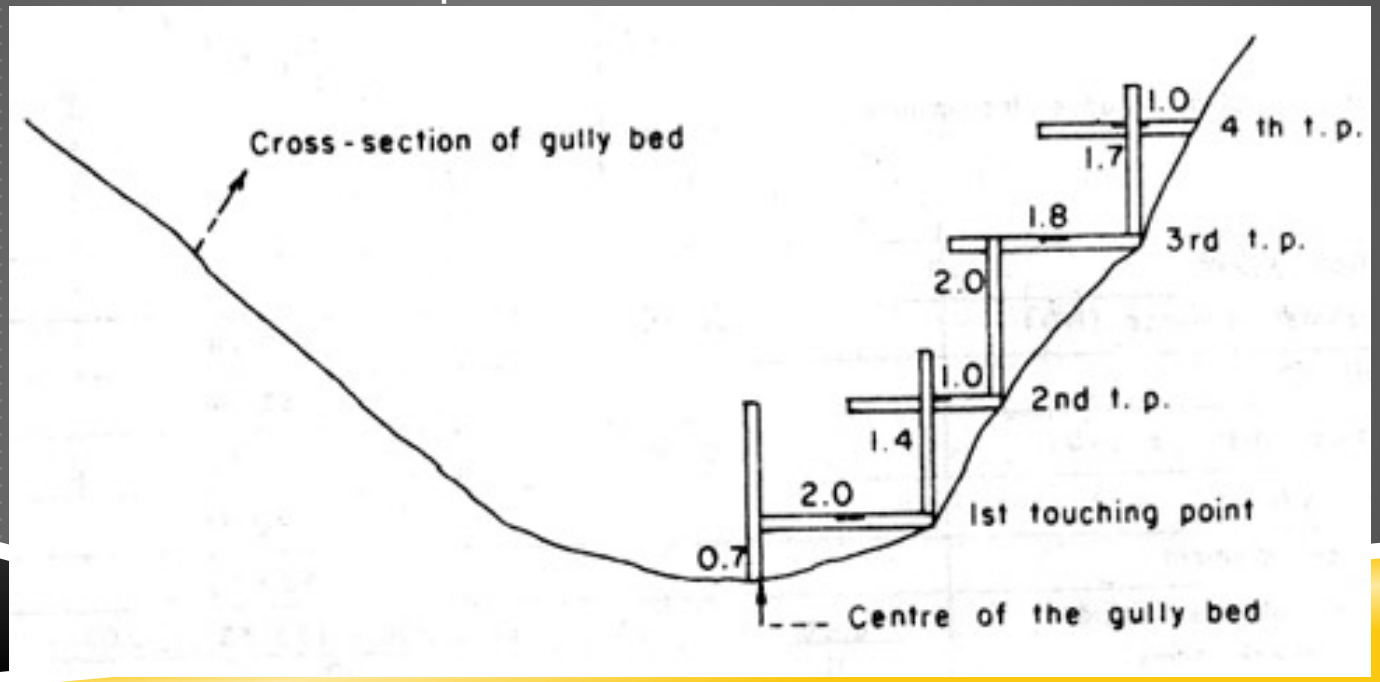
HD = GD x cos a
= 50 x cos 12
= 50 x 0.9781
= 48.91 m

VD = GD Sin a
= 50 Sin 12
= 50 x 0.2079
= 10.40 m



The cross-sections representing each portion of the gully bed can be measured with surveying rods

The average width of a gully portion is determined first; then the cross-section at this point is measured…



TERRESTRIAL LIGHT DETECTION AND RANGING (T-LIDAR) ACQUISITION

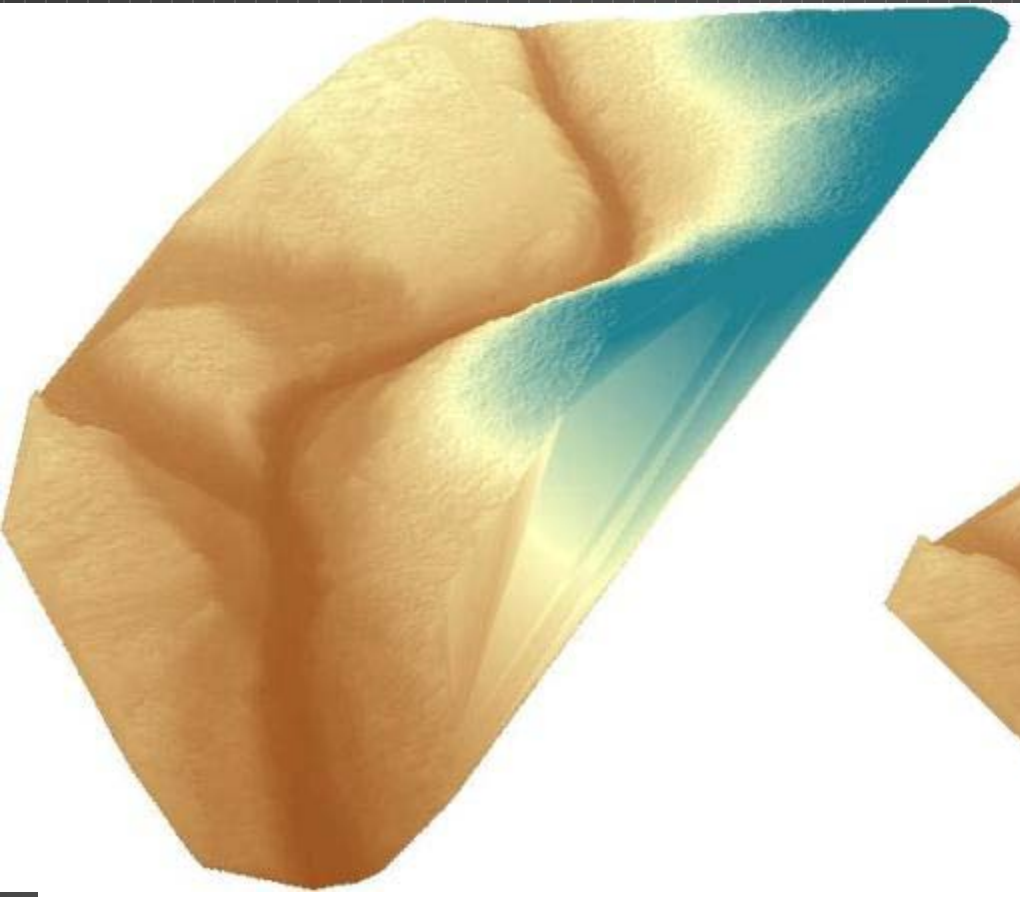
Scanner uses high-speed laser measurements to produce highly accurate three-dimensional maps of the riparian environment.

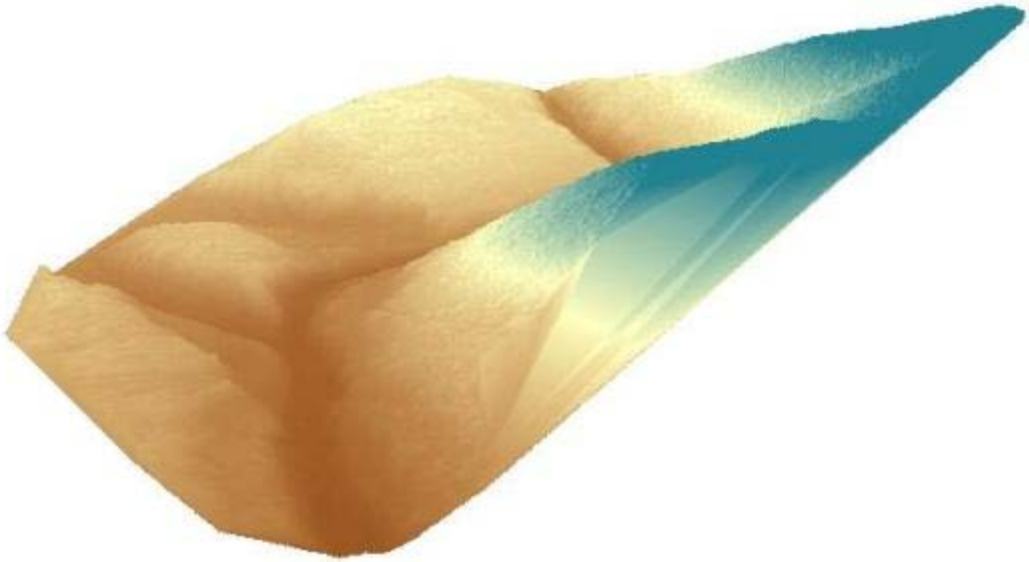
LIDAR FLY-THROUGH

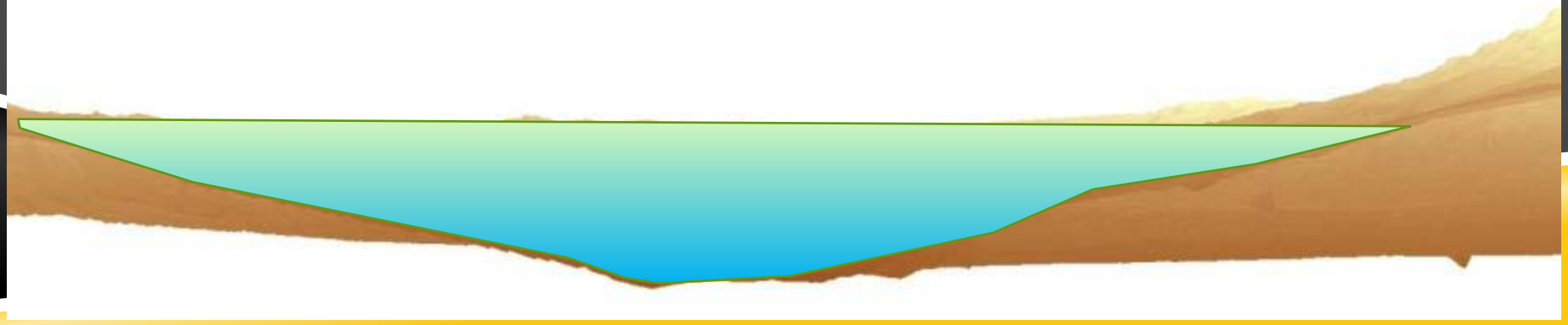
- This video shows a virtual fly-through of a detailed, highly accurate three-dimensional model of the study area

- Each of the millions of data points represents a discrete measurement with precise elevation and geographic position. Cobble bars, gravel beds, bluffs, riverside vegetation and man-made features are all visible in the data. Each feature can be queried for size, geographic position and precise elevation.

VIDEO

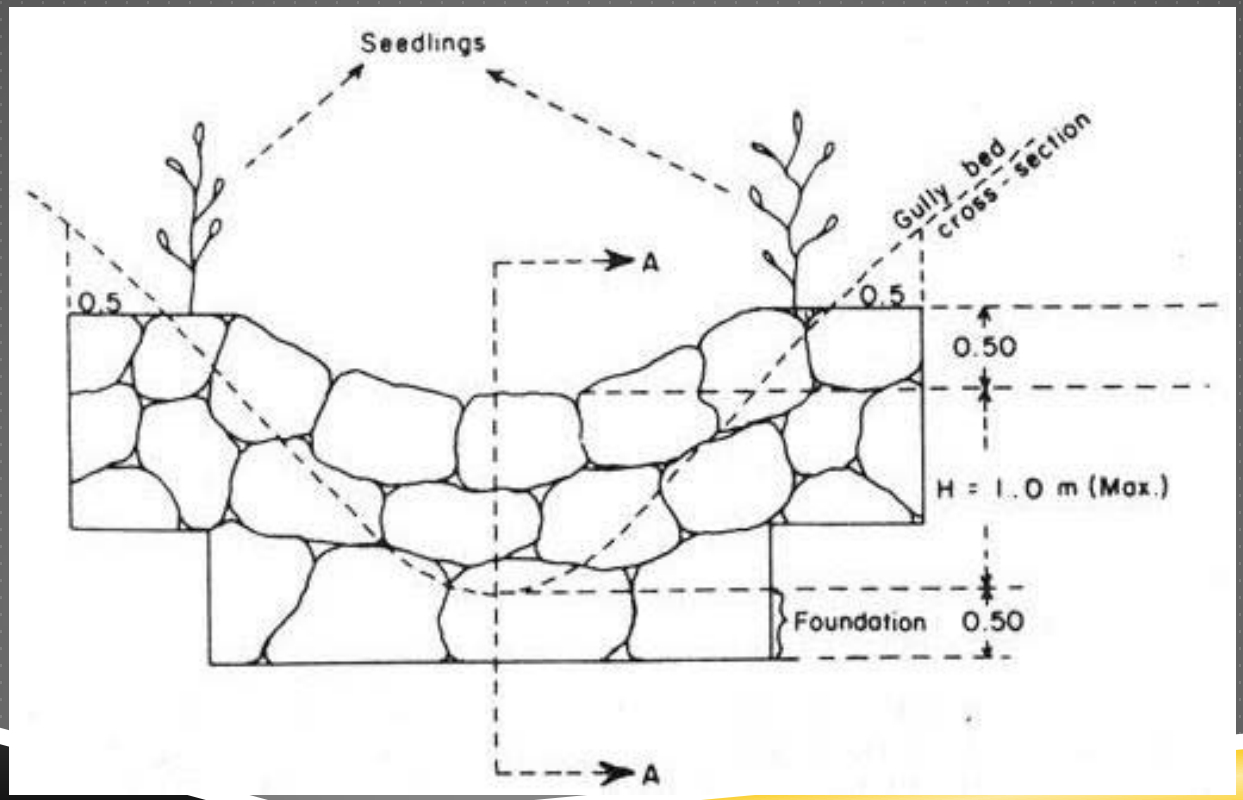






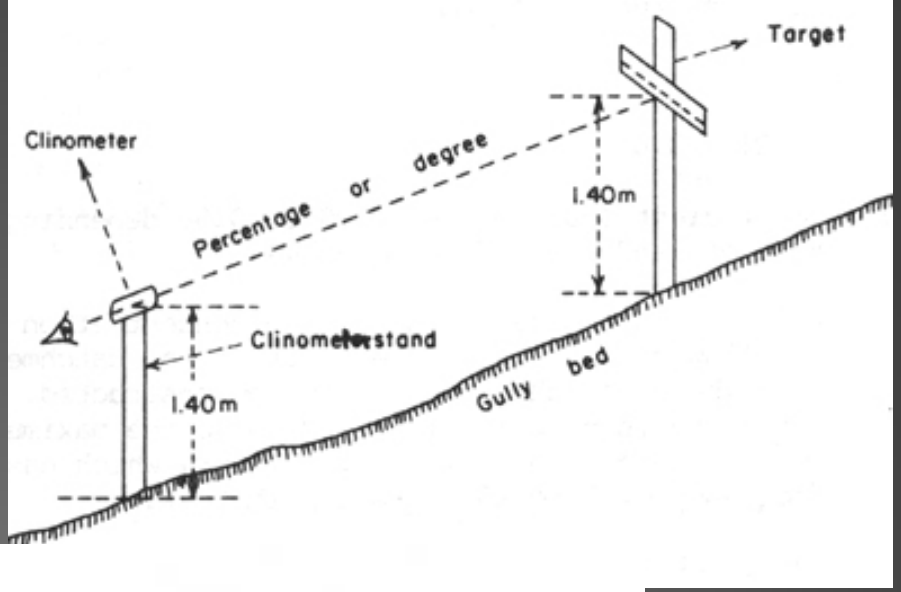
Design of check dams

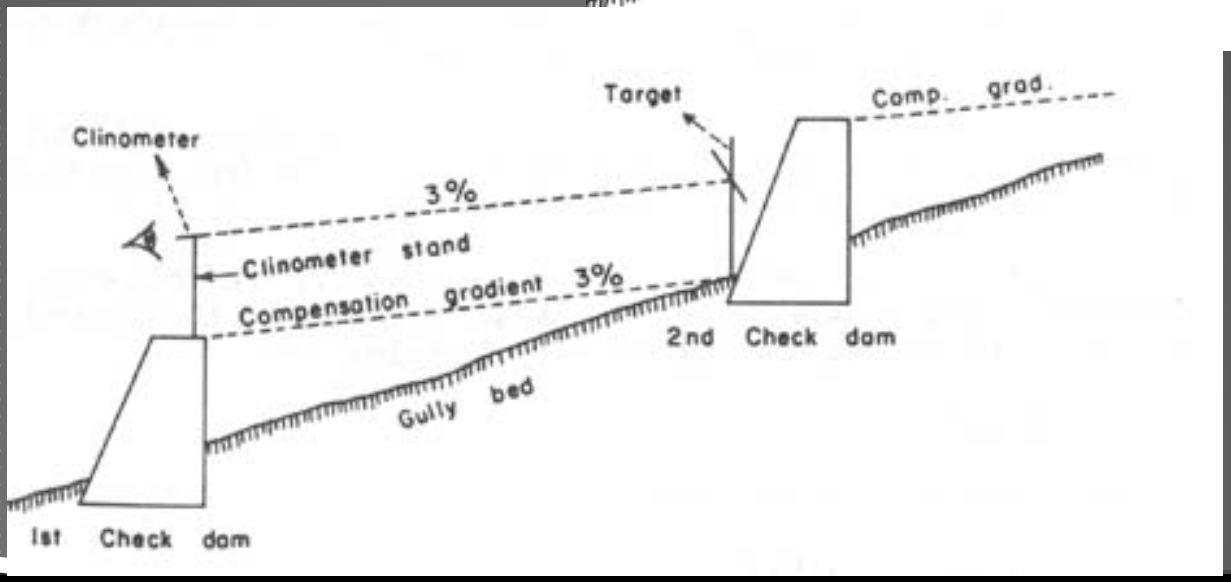
The cross-section for each portion of the gully bed is drawn to scale and the check dam is designed according to cross-sections based on the dimensions of the spillway, the thickness of the crest and base.



Check dams

Compensation gradient (3 percent) = the gradient between the top of the lower check dam and the bottom of the upper one (i.e. the future gradient of the channel





The distance between the first dam and the counter-dam must be at least two times the effective height of the first check dam.

Step I: Calculate peak discharge,
$Q = C*(A/100)^{3/4}$

Step II: Calculate peak runoff per running meter
$q = Q/L$ here L is length of the dam

Step III: Calculate depth of the flow considering peak discharge
$h = (q/1.71)^{2/3}$

Step IV: Calculate the hydraulic head (H_L),
$H_L = H + h$, here H is height of the dam

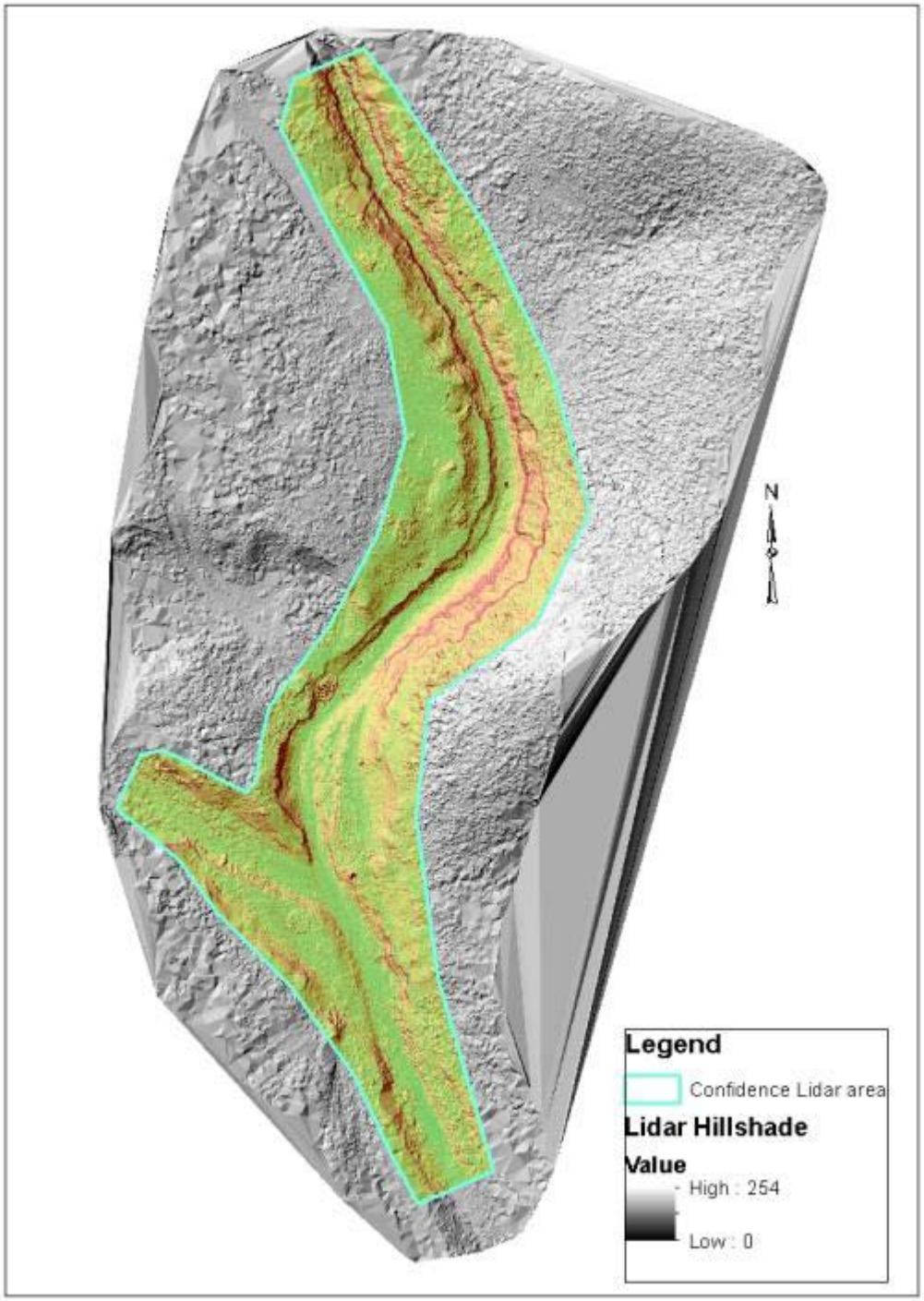
Step V: Calculate the top width of the dam (a)
$a = [H_L /(G+1)^{1/2}]$, here G is specific gravity of construction material

Step VI: Calculate the bottom width of the dam (b)
$b = [H_L /(G-1)^{1/2}]$, here G is specific gravity of the construction material

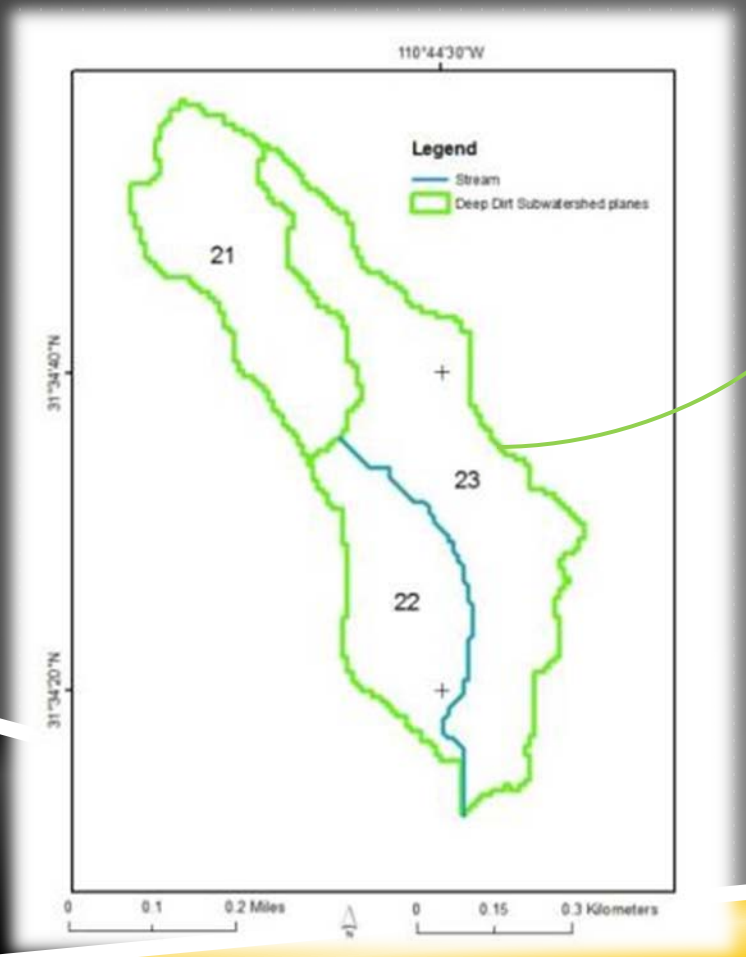
Step VII: Calculate the length of the downstream apron (L_a)
$L_a = 1.45 * K * (H_L /13)^{1/2}$, here K is coefficient of hydraulic gradient

Step VIII: Calculate the thickness of the downstream apron (t)
$t = 1.33 * [h/(G+1)]$, here G is specific gravity of the construction material

USING LIDAR TO RESAMPLE DEM



The watershed model elements are then intersected with soils and land cover data layers to derive the requisite model input parameters.

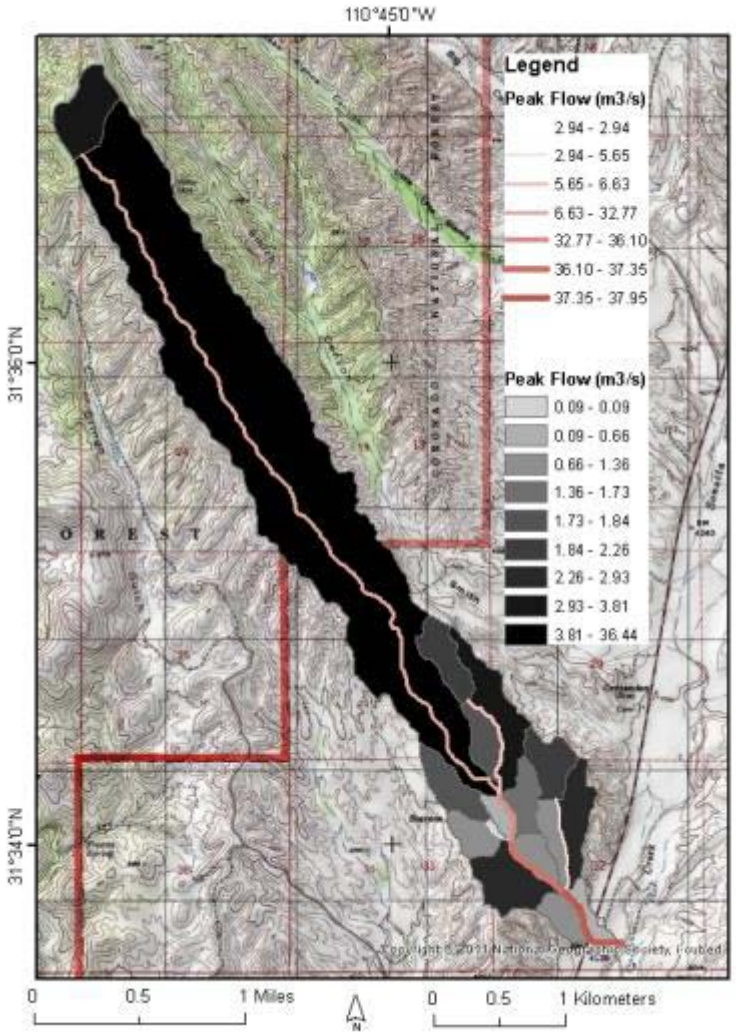


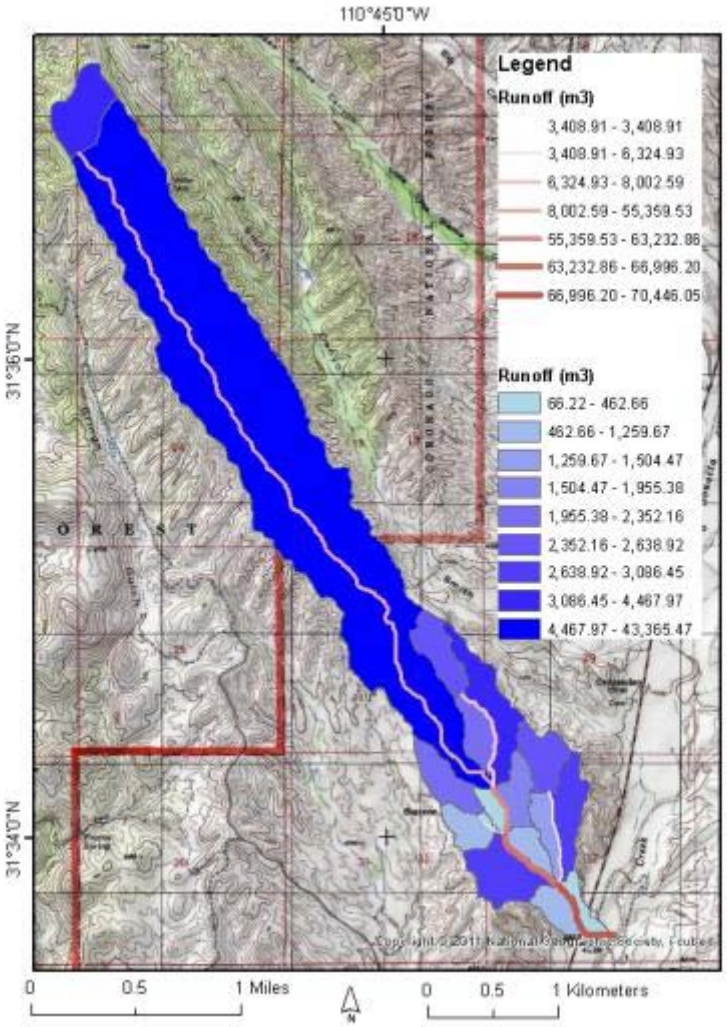
WS	21	22	23
Side		-1	0
MeanElev	1333.543823	1308.949707	1315.133057
AvgSlope	0.161222095	0.127483778	0.133424425
xCentroid	524134.6563	524428.6875	524517.625
yCentroid	3493861.5	3493230.75	3493452.5
Width	546.4470591	114.1032387	244.8918691
Length	251.165655	938.1517545	938.1517545
INT_	0.899999976	0.899999976	0.899999976
Cover	25	25	25
Mann_N	0.055	0.055	0.055
Pct_Imperv	0	0	0
TABID	4	14	15
Pave	0	0	0
Splash	33.70683371	32.46231296	33.98111249
Rock	0.463366129	0.434916398	0.460514333
Ks	4.754947482	4.758527905	4.898241557
G	209.9283406	197.8896222	209.1329165
Por	0.369026761	0.350472987	0.369151762
Smax	0.76274801	0.7241001	0.762831915
Cv	0.79590549	0.766369414	0.802294497
Fract_sand	0.60312336	0.603746944	0.603468835
Fract_silt	0.136246719	0.137493887	0.136937671
Fract_clay	0.260629921	0.258759169	0.259593494
Dist	0.356062982	0.337512803	0.355805108
Cohesion	0.002085054	0.002003819	0.002099538

NLCD

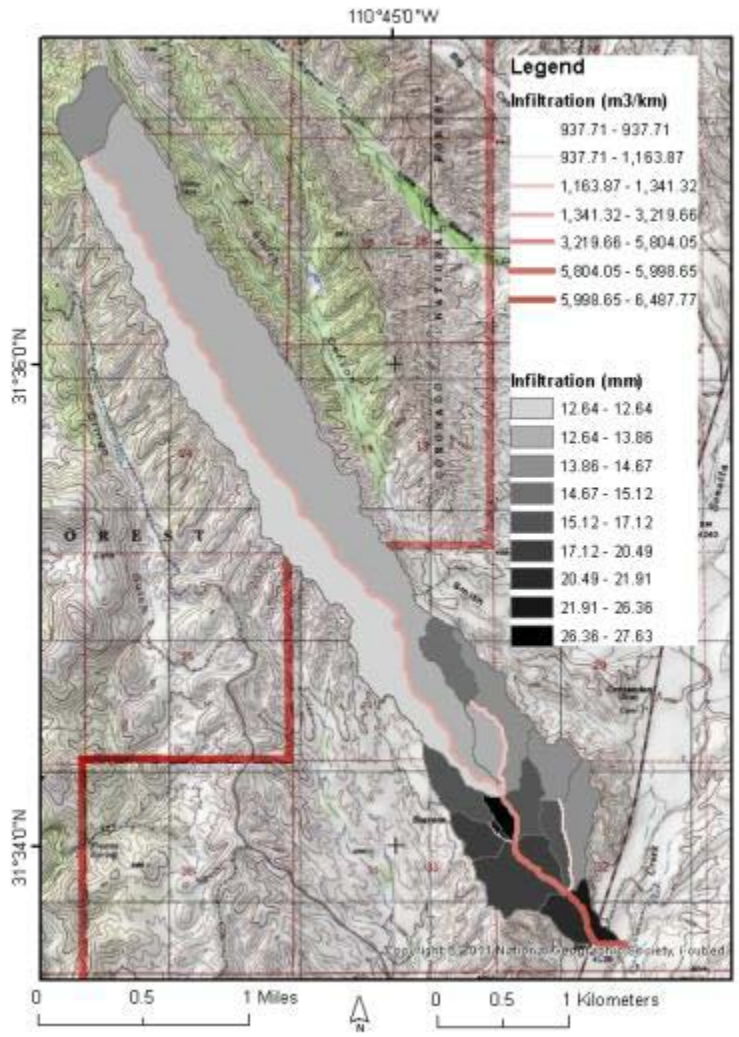
SSURGO

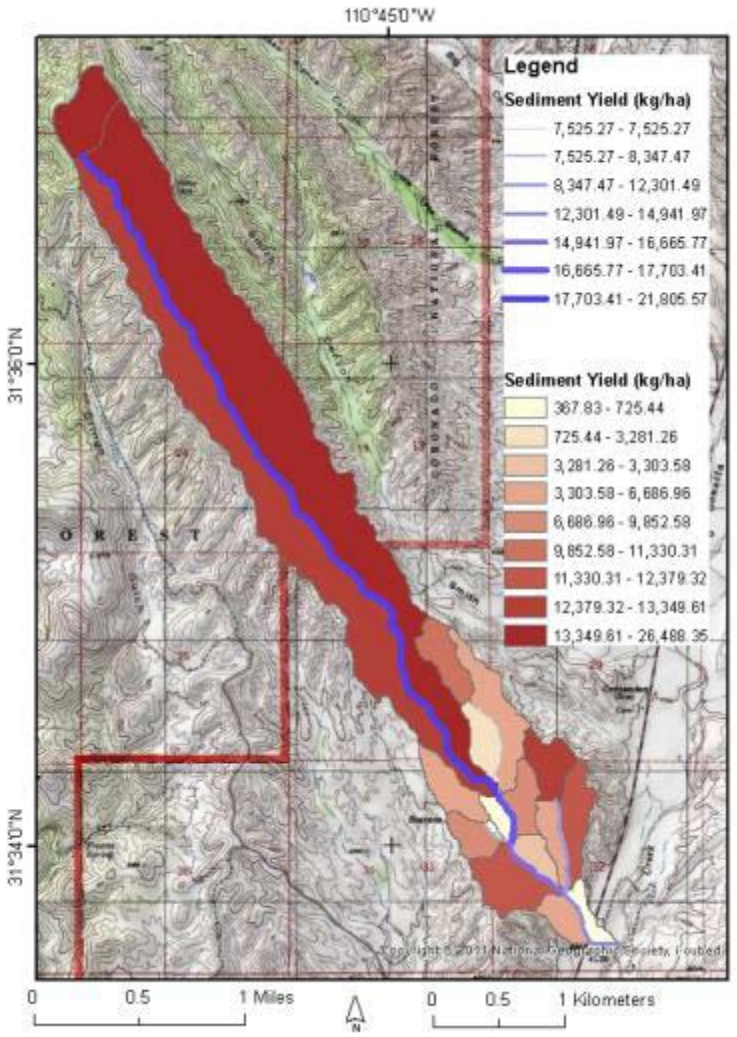
MODEL RESULTS: PEAK FLOW & RUNOFF



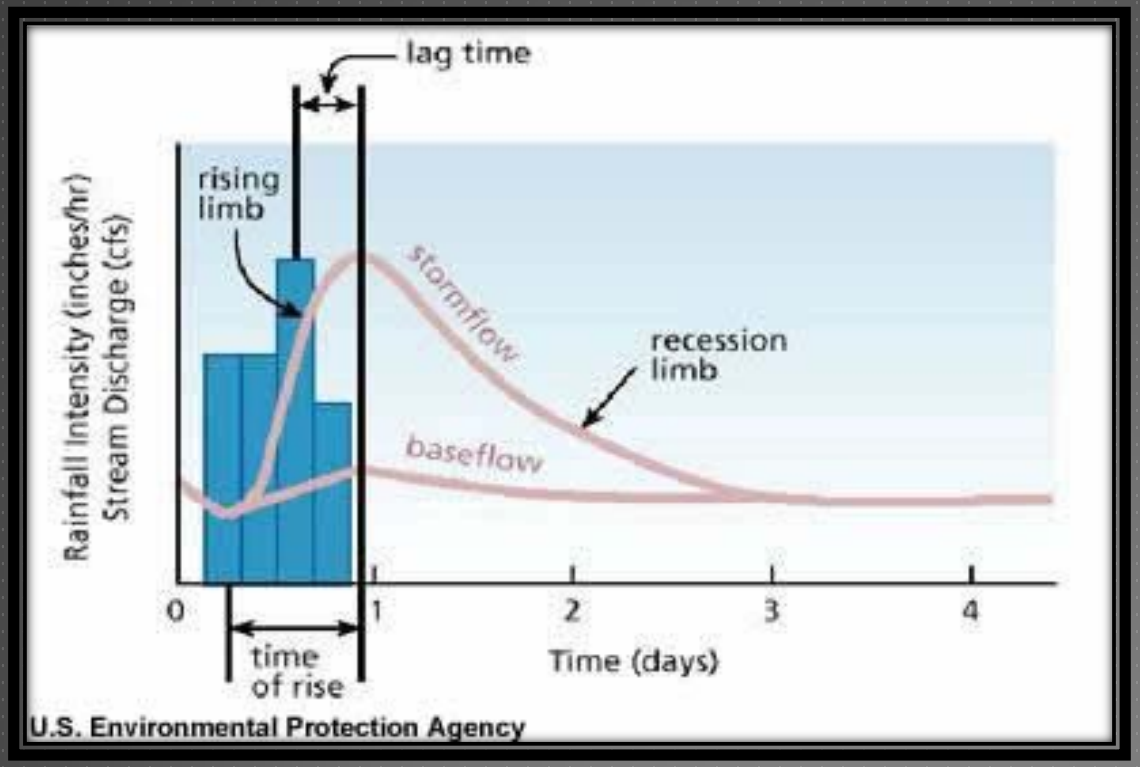


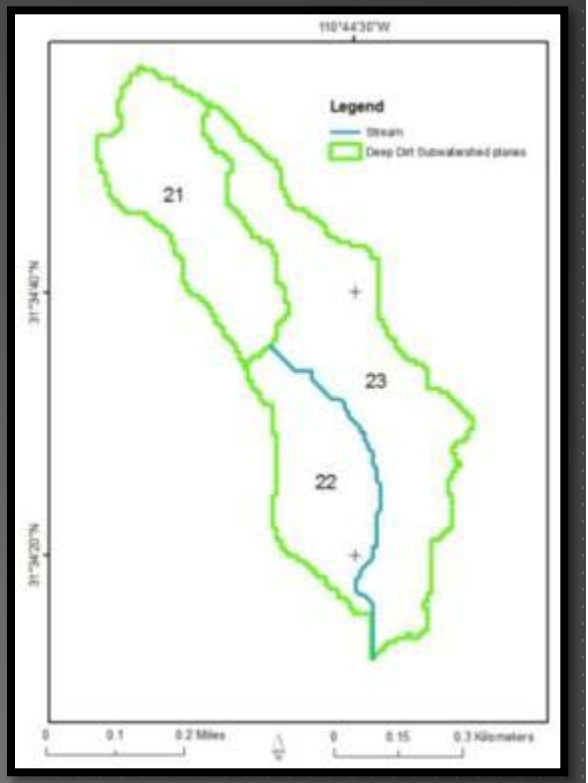
MODEL RESULTS: INFILTRATION & SEDIMENT YIELD





Stream flow over time: Hydrographs

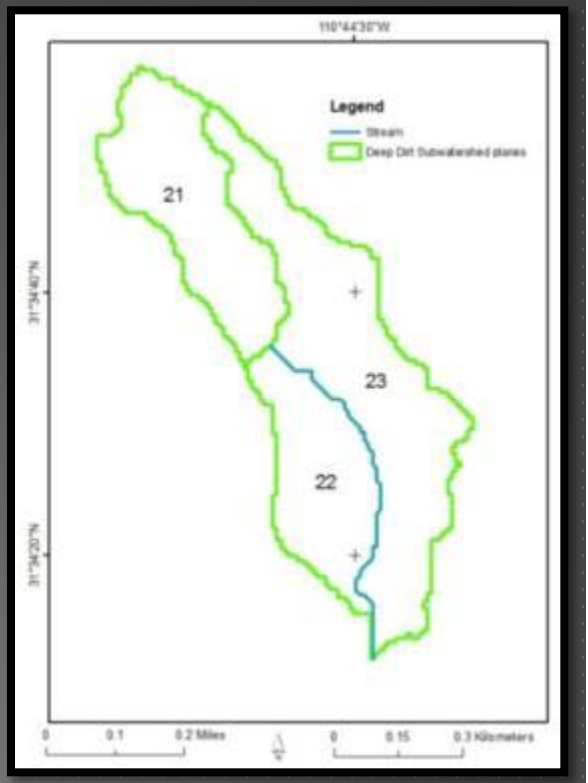


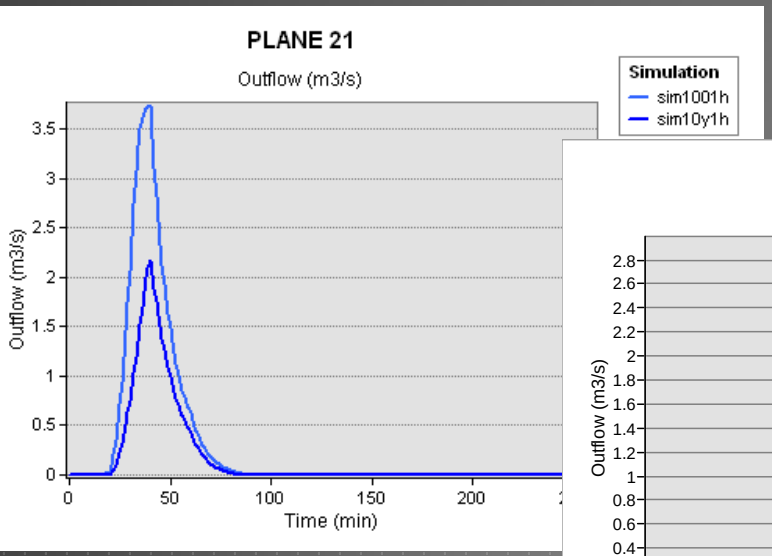


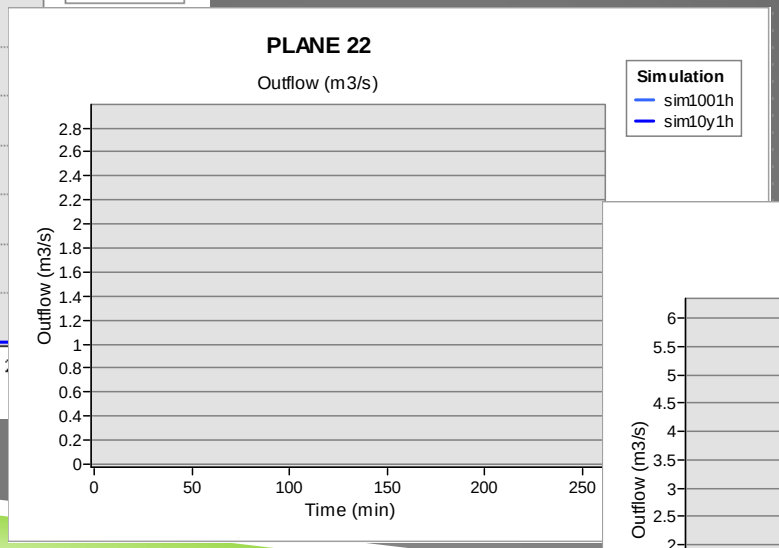
****Peak Flow:** the highest point on the hydrograph when the rate of discharge is greatest

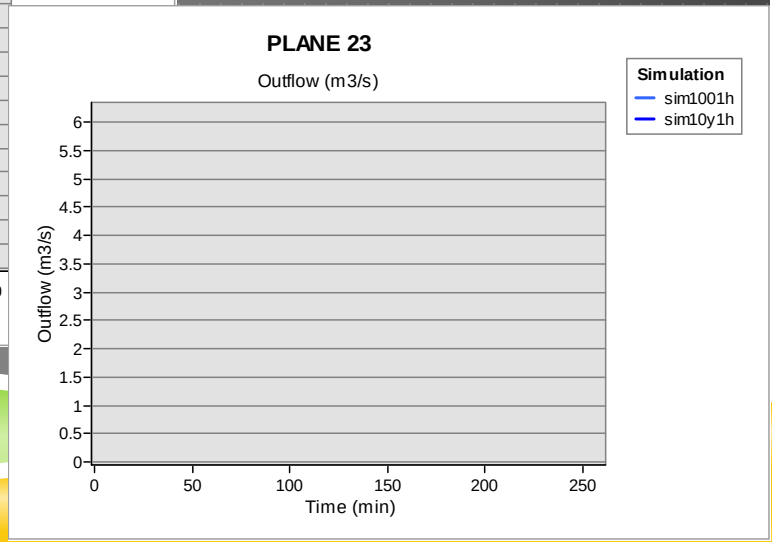
Runoff Hydrographs

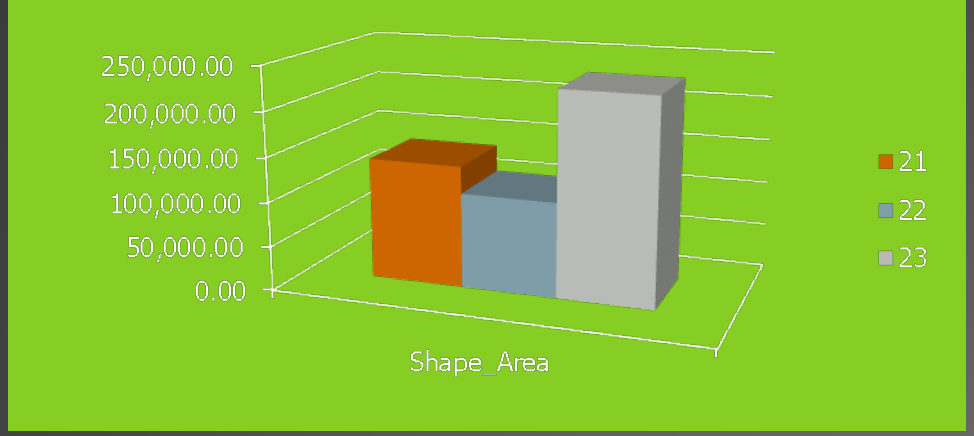
Model results for a rainfall event lasting 1 hour, for a 10-year flood (~1.35 inches) and a 100-year flood (2.04 inches), evenly distributed in the watershed….



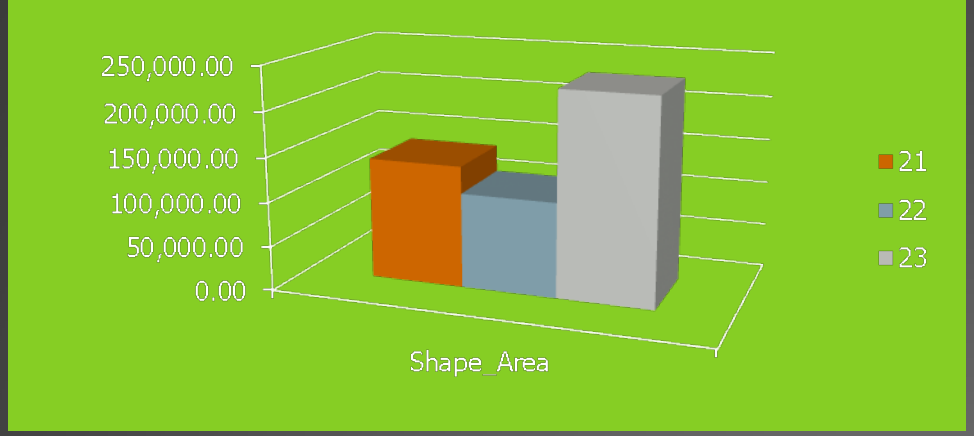




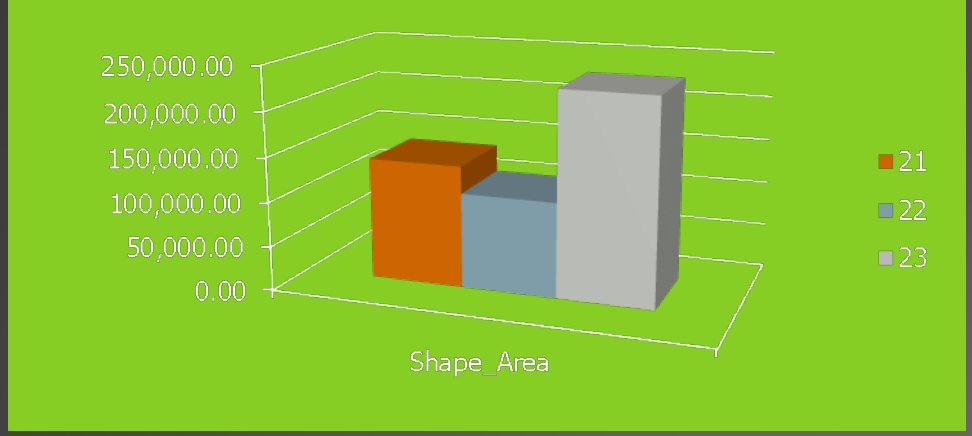




WS_	21	22	23	SUM	AVERAGE
Infilt_mm	15.12	13.35	14.52	42.99	14.33
Infilt_in	0.60	0.53	0.57	1.69	0.56
Runoff_mm	18.75	20.62	19.45	58.82	19.61
Runoff_m3	2,573.62	2,207.35	4,467.97	9,248.94	3,082.98
Sed_kg_ha	11,330.31	3,281.26	5,341.98	19,953.56	6,651.19
QP_m3_s	2.16	1.83	3.81	7.80	2.60
QP_mm_hr	56.78	61.40	59.74	177.92	59.31
SedP_kg_s	153.56	33.26	125.31	312.13	104.04
Pct_Error	-0.14	-0.02	-0.03	-0.19	-0.06

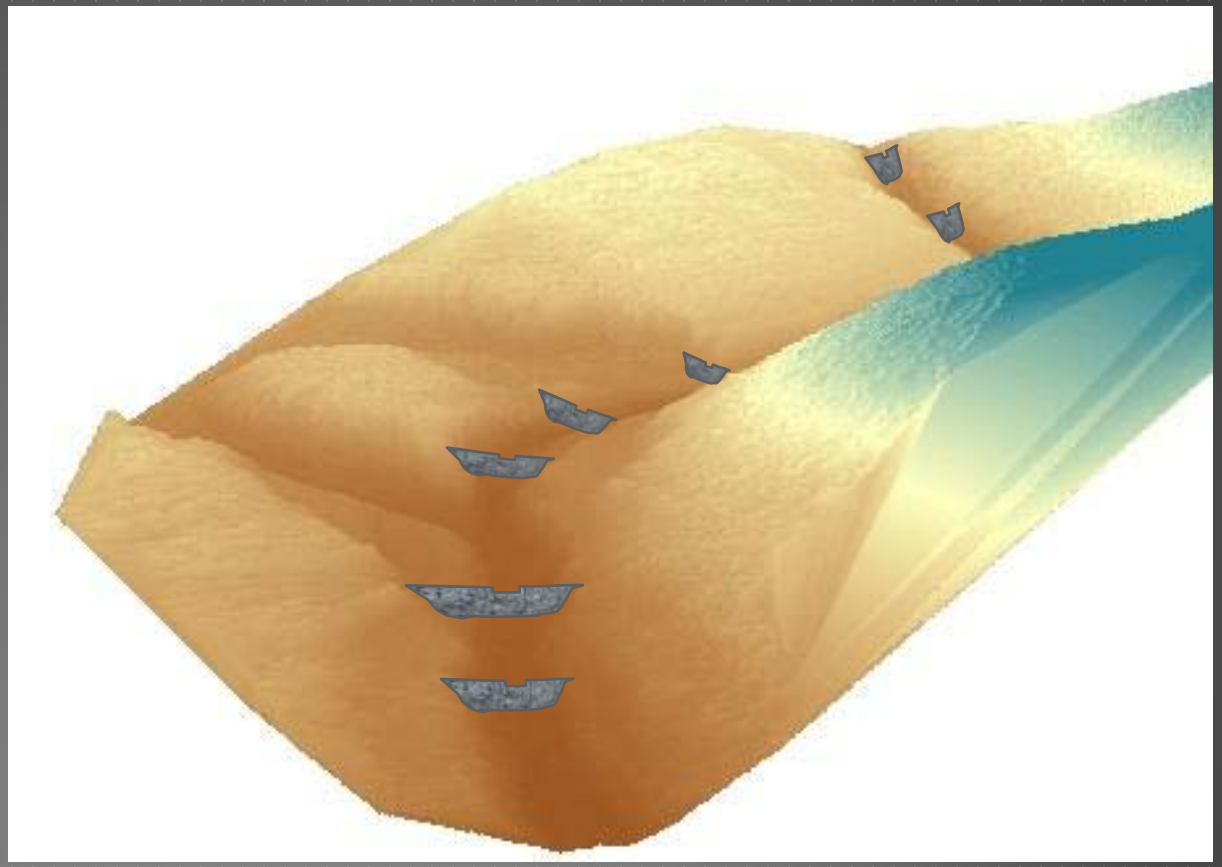


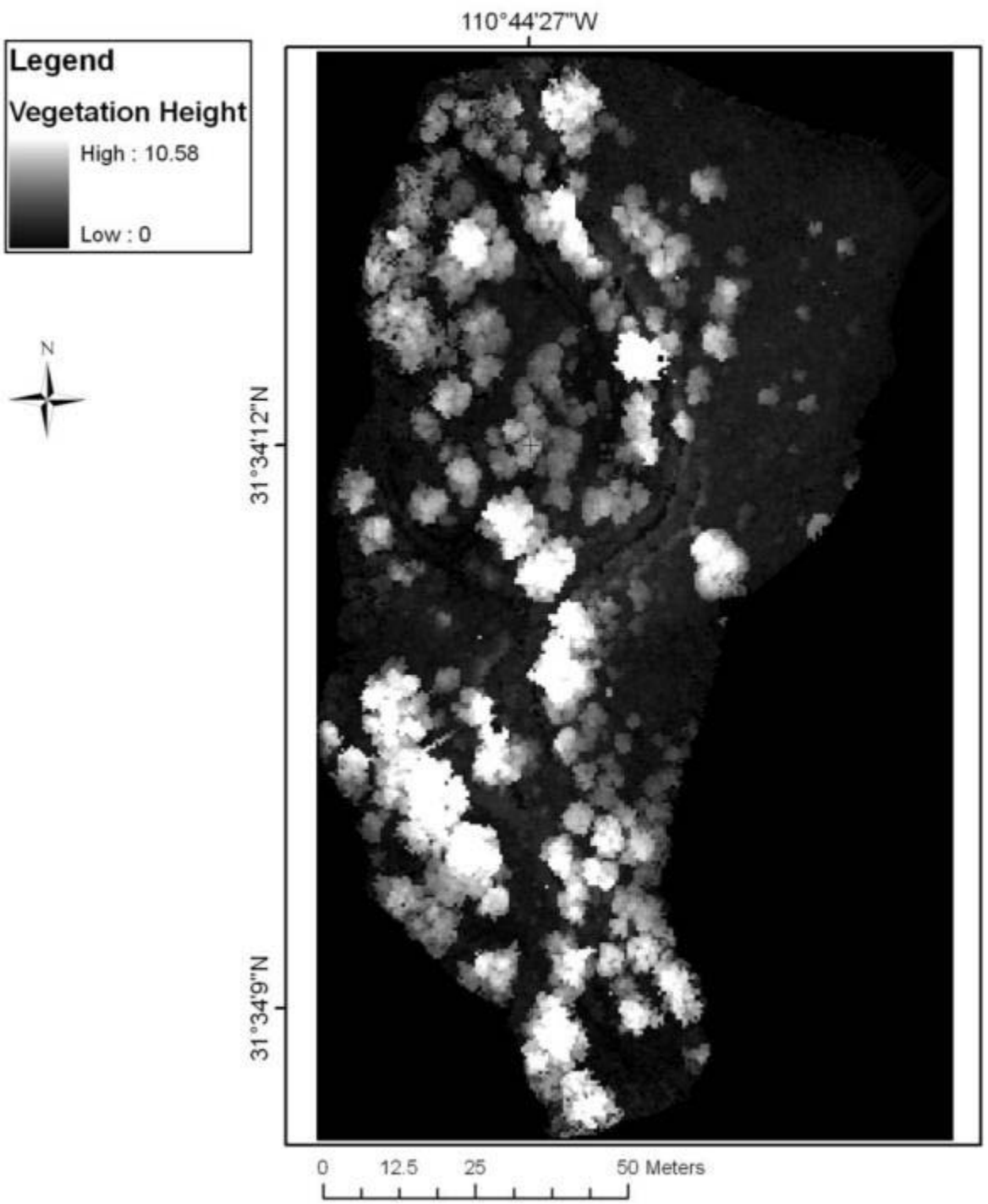
WS_	21	22	23	SUM	AVERAGE
Infilt_mm	15.12	13.35	14.52	42.99	14.33
Infilt_in	0.60	[illegible]	0.57	1.69	0.56
Runoff_mm	[illegible]8.75	20.62	[illegible]	58.82	19.61
Runoff_m[illegible]	2,573.62	2,207.35	4,467.97	[illegible]8.94	3,082.98
Sed_kg_ha	11,330.31	3,281.26	5,341.98	19,953.56	6,651.19
QP_m3_s	2.16	1.83	3.81	7.80	2.60
QP_mm_hr	56.78	61.40	59.74	177.92	59.31
SedP_kg_s	153.56	33.26	125.31	312.13	104.04
Pct_Error	-0.14	-0.02	-0.03	-0.19	-0.06



WS_	21	22	23	SUM	AVERAGE
Infilt_mm	15.12	13.35	14.52	42.99	14.33
Infilt_in				1.69	0.56
Runoff_mm		2[illegible]	19.45		19.61
Runoff_[illegible]	2,573.62	2,207.35	[illegible]7.97	9,248.94	[illegible]8
Sed_kg	11,330.31	3,281.26	[illegible]1.98	19,953.56	6,6[illegible].19
QP_m3_s	2.16	1.83	3.81	7.80	2.60
QP_mm_hr	56.78	61.40	59.74	177.92	59.31
SedP_kg_s	153.56	33.26	125.31	312.13	104.04
Pct_Error	-0.14	-0.02	-0.03	-0.19	-0.06

Can watershed models guide riparian restoration efforts in the Borderlands?



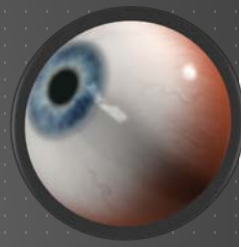

110°44'27"W
Legend
Vegetation Height
High : 10.58
Low : 0
N
31°34'12"N
31°34'9"N
0
12.5
25
50 Meters

Joel Sankey

WHAT'S NEXT?

…trying to create an "*expert system*" for riparian restoration…

1. Using Remote Sensing, GIS, and Watershed Models to mimic, capture, and simulate the judgment and behavior of a human or an organization that has expert knowledge and experience.



2. We hope to use this research to develop a protocol for similar restoration activities—to reduce trial and error, and save time, energy, and money.

The Mexican Highlands

THANK YOU!

- Caleb Weaver
- Cindy Tolle
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- Helen Raichle
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- Pankaj Jamwal
- Pete Hawkins
- Shinji Carmichael
- Steve Buckley
- Steve DeLong
- Van Clothier
- Whitney Henderson