INTERNATIONAL WATERSHEDS COPING WITH CLIMATE HAZARDS

Twin-City Solutions at Ambos Nogales and San Diego–Tijuana

Presented at the University of Arizona's
Water Resources Research Center
June 17, 2021
12:00pm - 1:15pm MST

By Laura M. Norman, Ph.D.
US Geological Survey
Western Geographic Science Center

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- Bureau of Indian Affairs
- Bureau of Indian Education
- Bureau of Land Management
- Bureau of Ocean Energy Management
- Bureau of Reclamation
- Bureau of Safety and Environmental Enforcement
- Bureau of Trust Funds Administration
- National Park Service
- Office of Surface Mining Reclamation and Enforcement
- U.S. Fish and Wildlife Service
- U.S. Geological Survey

U.S. Department of the Interior
Stewarding Conservation and Powering Our Future

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DRIVERS OF LAND USE / LAND COVER CHANGE

Humans

- Urbanization
- Groundwater pumping
- Agriculture
- Cattle grazing
- Timber logging
- Mining
- Hunting, fishing, & trapping
- Fire suppression

Climate

- Winter vs. summer rainfall
- Drought→ Fire
- Monsoons→ Floods

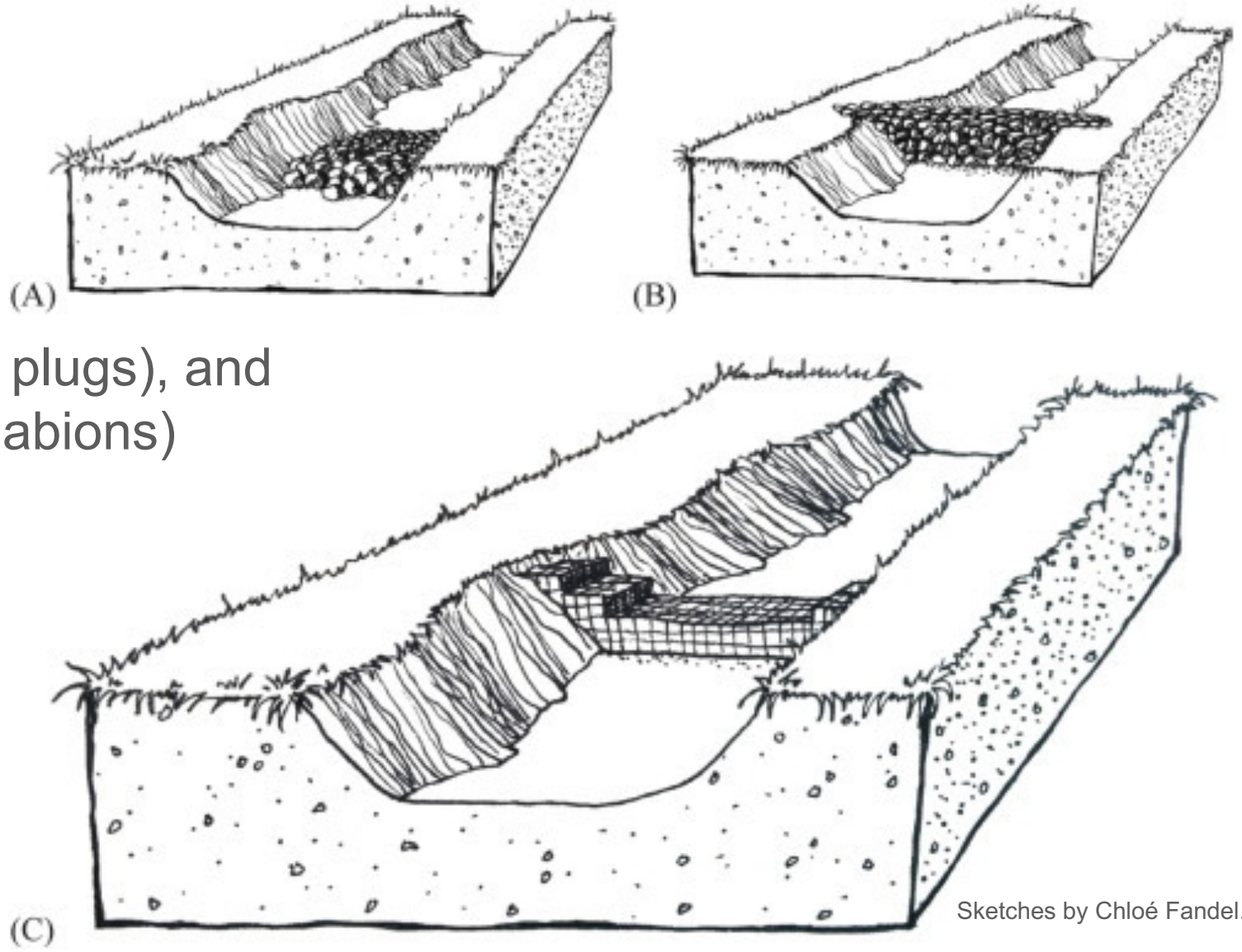
BEST MANAGEMENT PRACTICES (BMPS)

- Green Infrastructure
- Streambank Stabilization
- Floodplain Restoration
- Riparian Buffers
- Fencing
- Detention Structures


https://www.dep.state.pa.us/

DETENTION STRUCTURES

(A) spreader (or one-rock dam),
(B) loose-rock check dams (or gully plugs), and
(C) larger rock-filled wire baskets (gabions)
(D) beaver dam



Sketches by Chloé Fandel.

(D)

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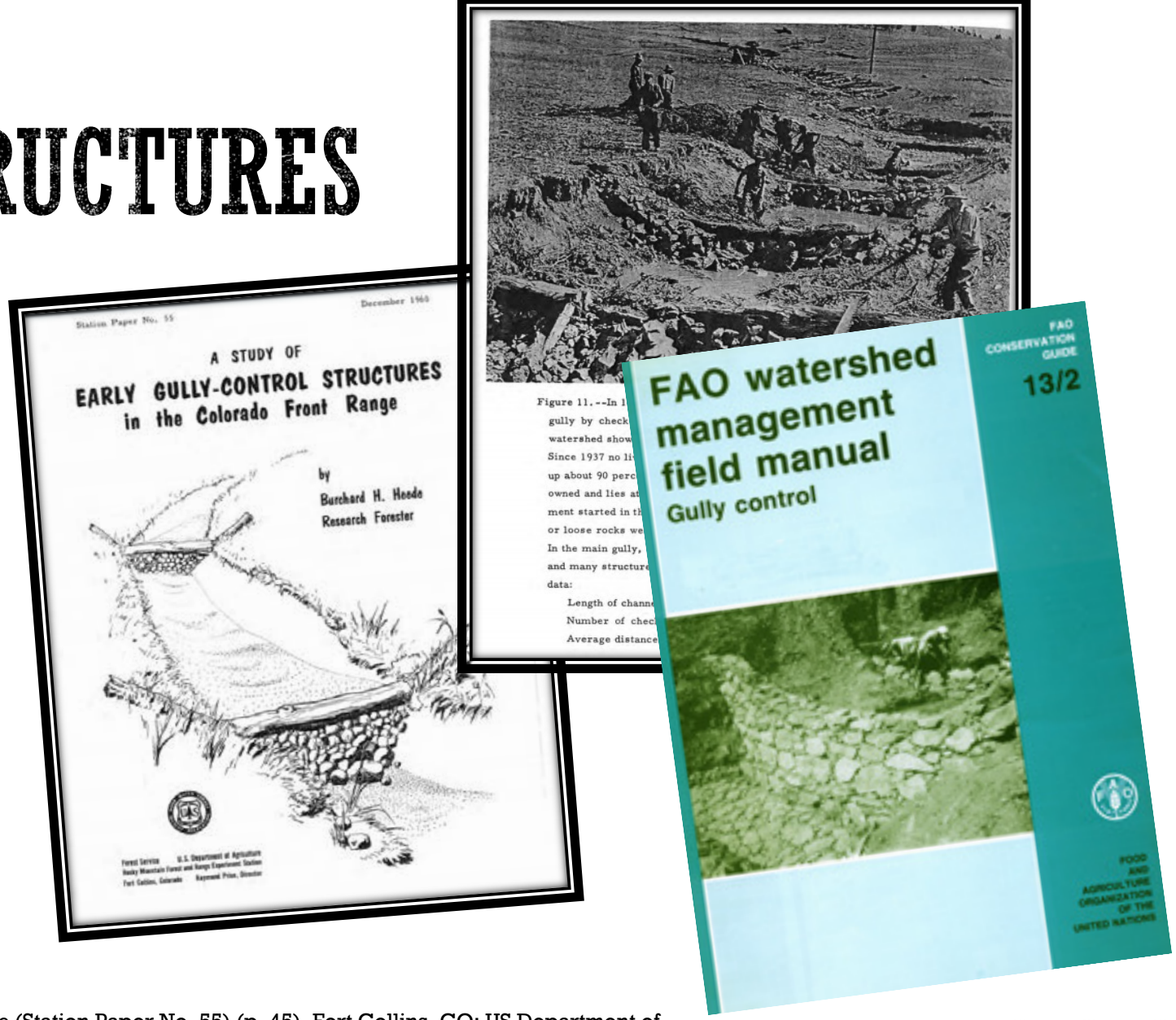
DETENTION STRUCTURES

Check dams and gabions



Heede, B. H. (1960). *A Study of early Gully-Control Structures in the Colorado Front Range* (Station Paper No. 55) (p. 45). Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. Retrieved from http://www.fs.fed.us/rm/pubs_exp_forests/manitou/rmrs_1960_heede_b001.pdf

Geyik, M. P. (1986). Gully Control. In *Watershed Management Field Manual* (Vol. 2). Rome: Food and Agricultural Organization of the United Nations. Retrieved from http://www.fao.org/docrep/006/ad082e/ad082e00.htm

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Land Change Science

ARIDLANDS WATER HARVESTING PROJECT

Water

Slow water & reduce floods

Support surface water & restore perennial flow

Increase infiltration & recharge the aquifer

Soils

Stabilize the soil & reduce erosion

Reduce nonpoint source pollution

Carbon sequestration

Vegetation

Encourage plant growth

Create habitat for animals

Determine efficacy of various Rock Detention Structures (RDS)

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2.) Work with partners to determine where new structures should be…..

- For flood prevention?
- For vegetation and habitat improvement?
- To "heal" the land?
- For groundwater recharge?
- For erosion control?
- For increasing water quality & quantity?
- To armor landscapes?
- For climate regulation?

ECOHYDROLOGY

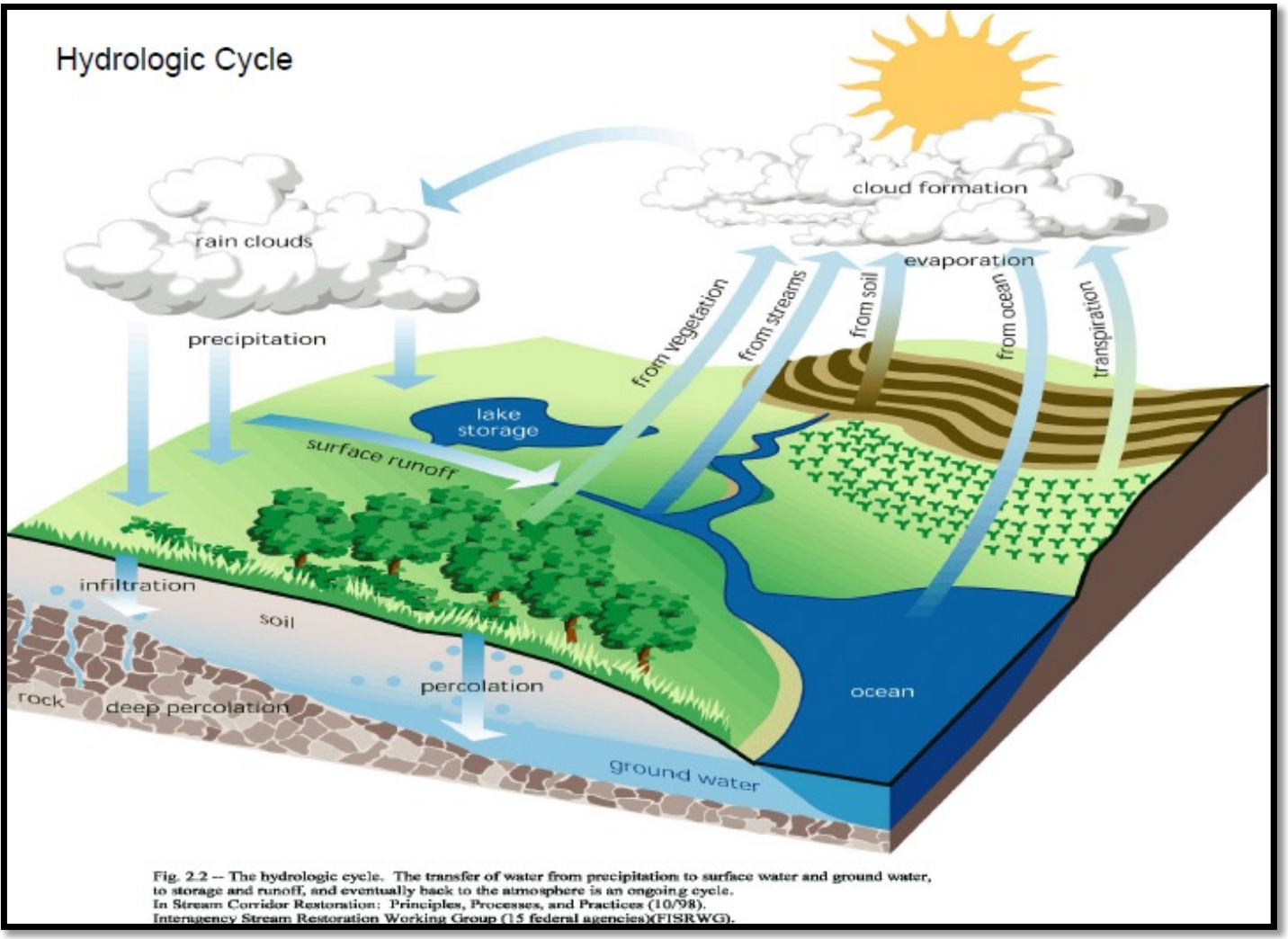
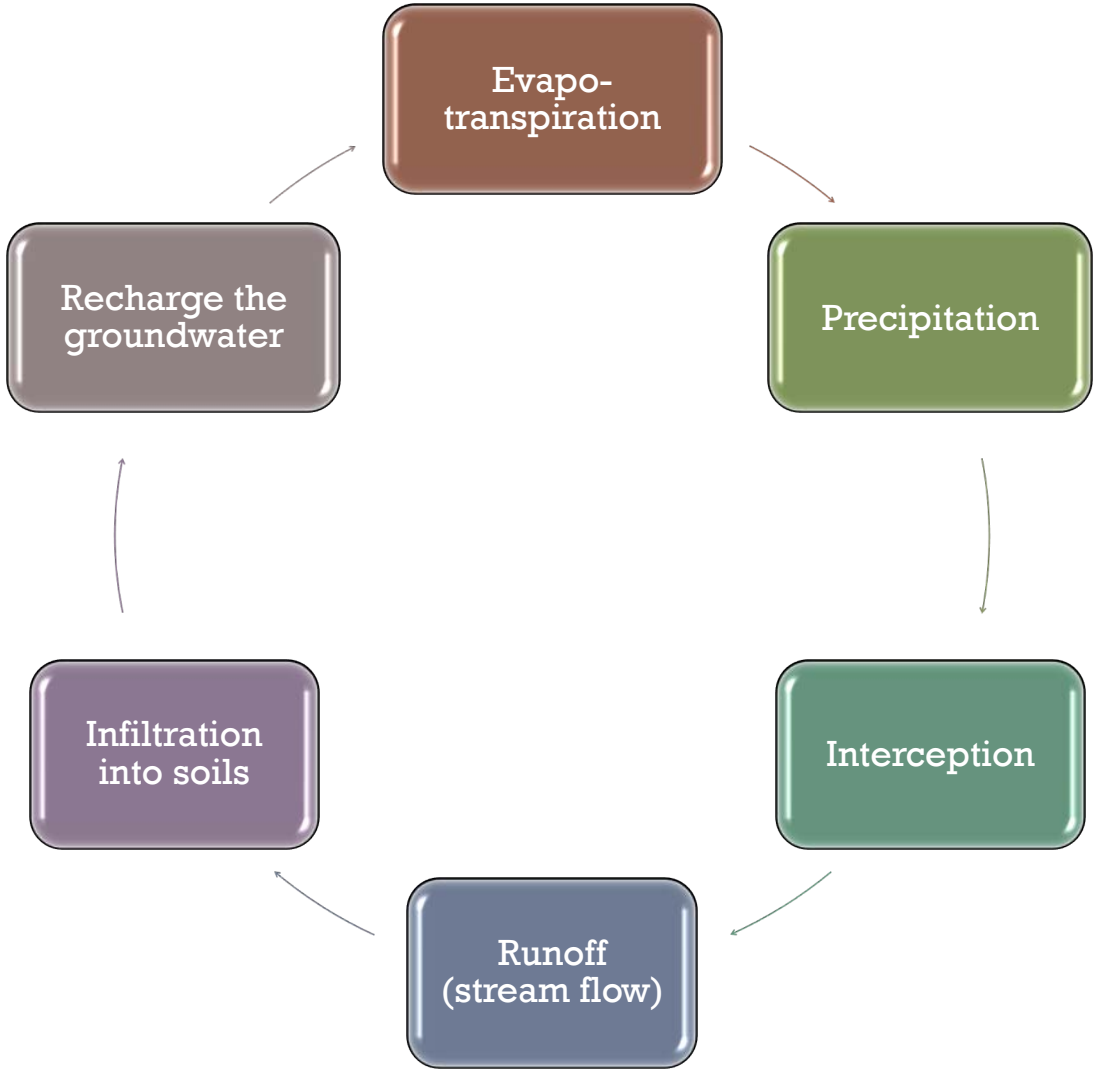


Fig. 2.2 -- The hydrologic cycle. The transfer of water from precipitation to surface water and ground water, to storage and runoff, and eventually back to the atmosphere is an ongoing cycle. In Stream Corridor Restoration: Principles, Processes, and Practices (10/98). Interagency Stream Restoration Working Group (15 federal agencies)(FISRWG).



Zalewski, M. (2011). Ecohydrology. In J. Gliński, J. Horabik, & J. Lipiec (Eds.), *Encyclopedia of Agrophysics* (pp. 235–237). Dordrecht: Springer Netherlands. Retrieved from https://doi.org/10.1007/978-90-481-3585-1_46

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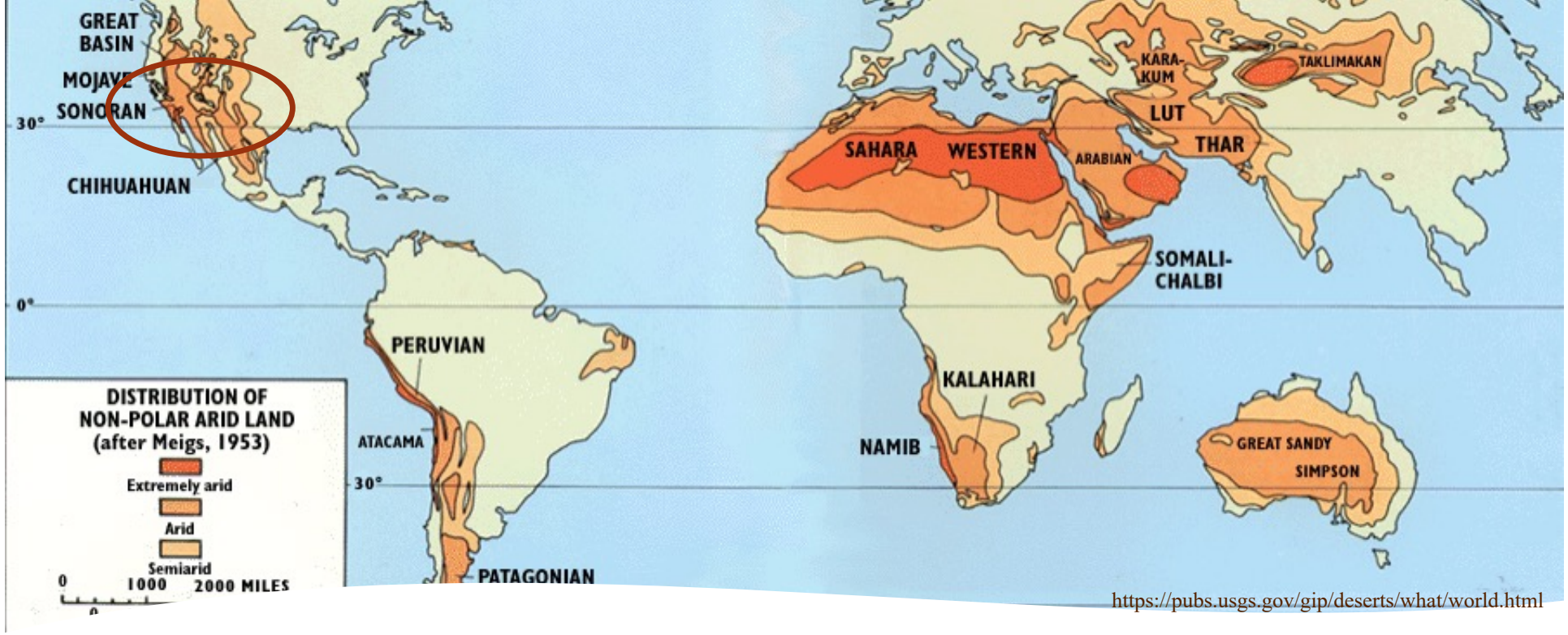

https://pubs.usgs.gov/gip/deserts/what/world.html

ARIDLAND HYDROLOGY

- Arid lands > terrestrial biome on Earth
- Arid: "*without moisture; extremely dry; parched*"
- Ephemeral streams only flow after rains
- Hydrology studies are challenging

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CLIMATE CHANGE

Southwest expected to get hotter, and experience more intense precipitation events with more variability

Science Contents News Careers Journals

SHARE REPORT

Large contribution from anthropogenic warming to an emerging North American megadrought

A. Park Williams[1], Edward R. Cook[1], Jason E. Smerdon[1], Benjamin I. Cook[1,2], John T. Abatzog...

+ See all authors and affiliations

Science 17 Apr 2020:
Vol. 368, Issue 6488, pp. 314-318
DOI: 10.1126/science.aaz9600

Article Figures & Data Info & Metrics eLetters PDF

This article has a correction. Please see:
Is corrected by - October 30, 2020

(Kerr, 2008)

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CLIMATE & ENVIRONMENTAL JUSTICE

- **Poor**, elderly, **marginalized**
- Children < 5 years old
- Those who depend on subsistence **farming** or traditional food sources
- Those with **weak health systems**
- Those living in **drought prone** regions
- **Socioeconomics**…

Norman, L. M., Donelson, A., Pfeifer, E., & Lam, A. H. (2006). Colonia Development and Land Use Change in Ambos Nogales, United States - Mexican Border. *U.S. Geological Survey*, *Open-File Report 2006-1112*, 121.

Norman, Laura M. 2010. "Urbanization and Environmental Health in Arizona Colonias." *In Donelson, A.J., and A.X. Esparza, (Ed.s). The Colonias Reader: Economy, Housing, and Public Health in US-Mexico Border Colonias*, 204–17. Tucson: University of Arizona Press.

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ADDRESSING HIGH FLOWS OVERWHELMING SEWAGE TREATMENT SYSTEM AND MITIGATING CONTAMINATED SURFACE WATER

Source: GAO. | GAO-20-307

CLIMATE PRECIPITATION AVERAGES

	Nogales, Arizona	San Diego, California	Tucson, Arizona	Narragansett, Rhode Island	United States
Rainfall (in.)	17.8	11.7	12.3	51.0	38.1
Snowfall (in.)	0.8	0.0	0.4	30.2	27.8
Precipitation (days)	60.5	38.4	51.5	125.1	106.2

https://www.bestplaces.net/

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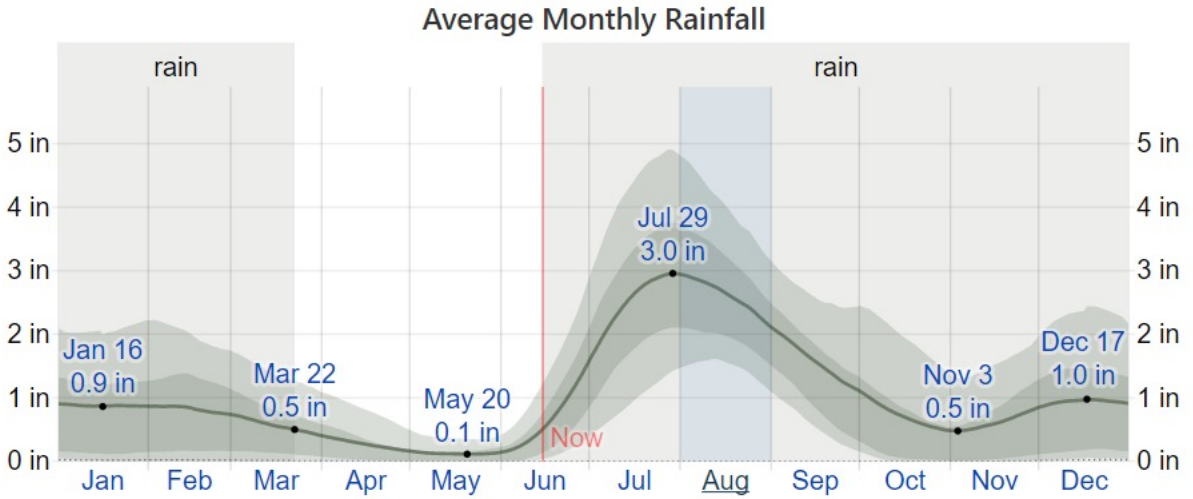
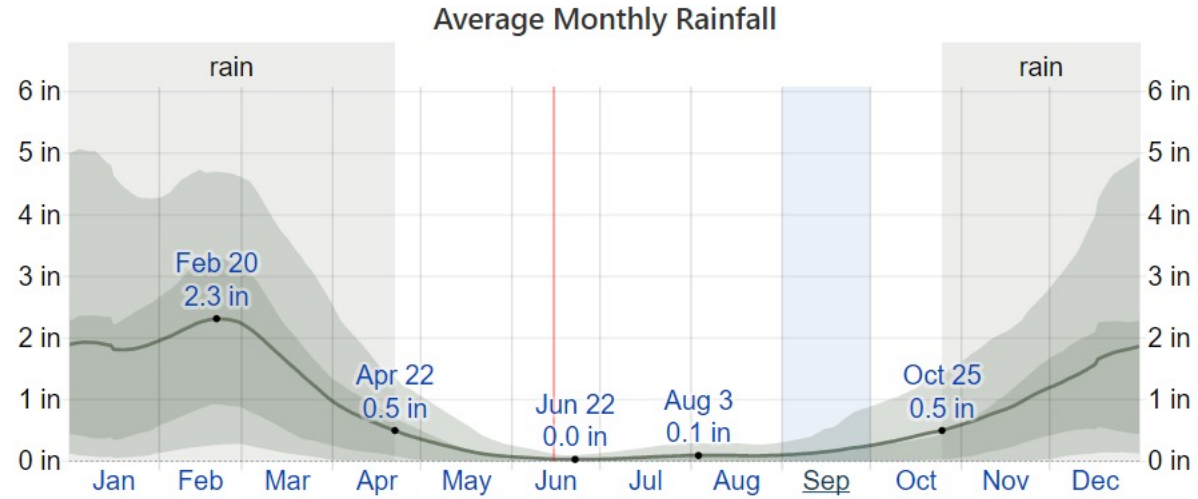
ARIDLANDS : DRYLANDS : US-MEXICO BORDERLANDS





- Ambos Nogales, Arizona/Sonora
  - *35°F* to *95°F*
  - Rainy season June 15 – March 22
  - "*Monsoon*" June 15 – September 30, with most rain ~July 29

- San Diego-Tijuana, California/Baja California
  - *50°F* to *77°F*
  - Rainy season October 25 – April 22
  - Most rain around February 20

https://weatherspark.com/

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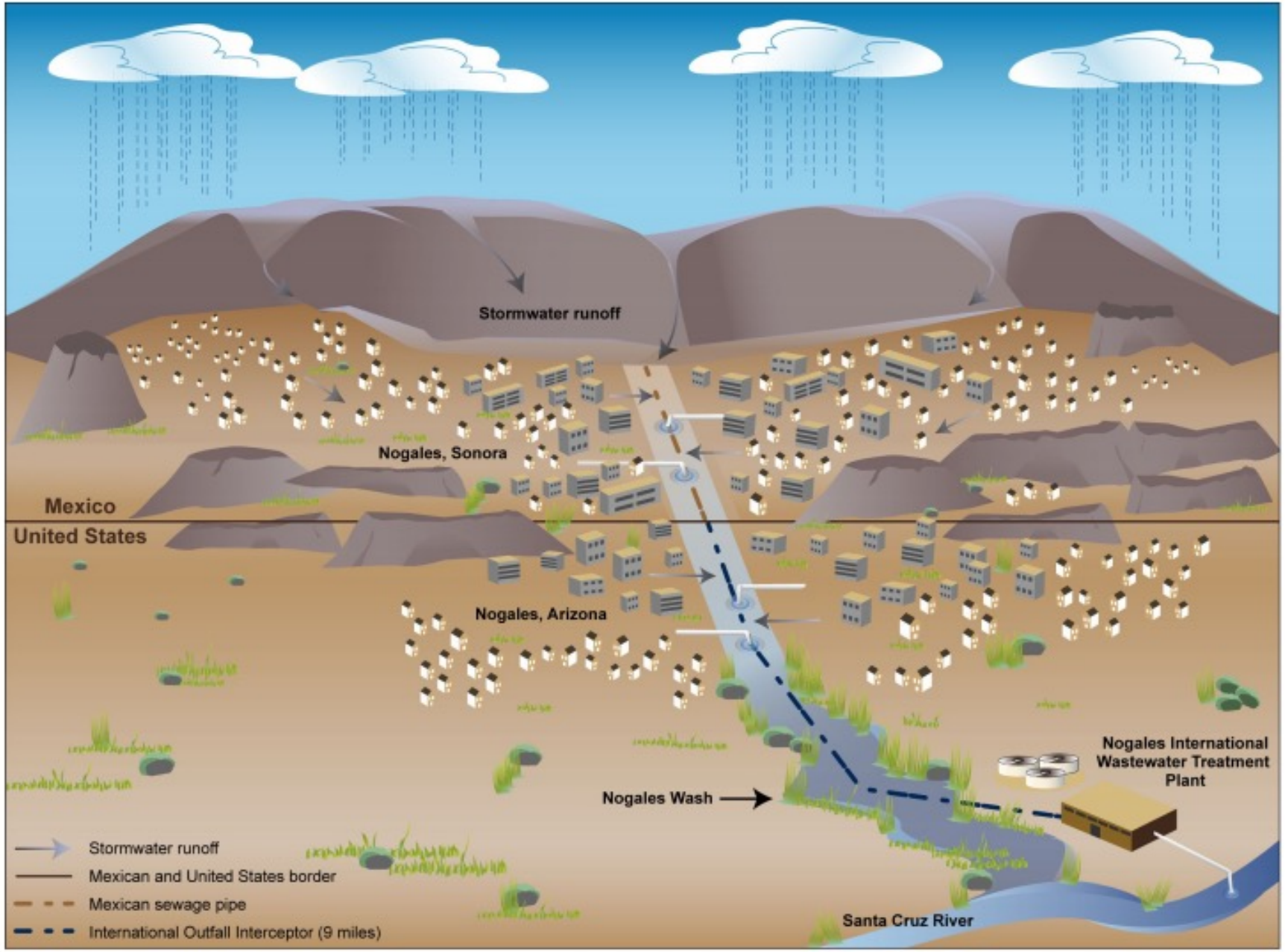
Figure 3: Nogales International Wastewater Treatment Plant



Source: GAO. | GAO-20-307

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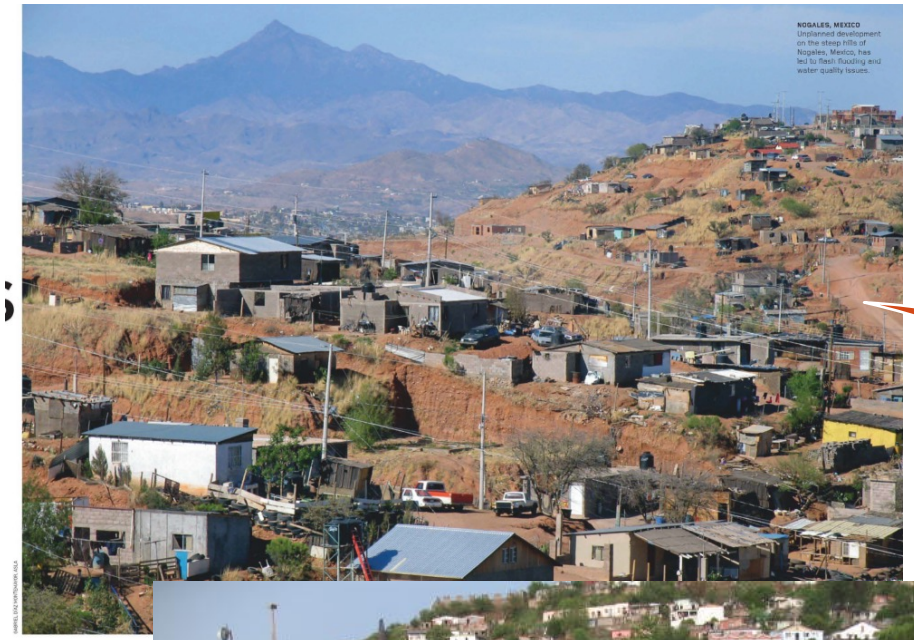
Nogales - Nogales



Norman, L. M., Villarreal, M., Niraula, R., Meixner, T., Frisvold, G., & Labiosa, W. (2013). Framing Scenarios of Binational Water Policy with a Tool to Visualize, Quantify and Valuate Changes in Ecosystem Services. *Water*, *5*(3), 852–874. https://doi.org/10.3390/w5030852

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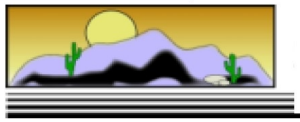
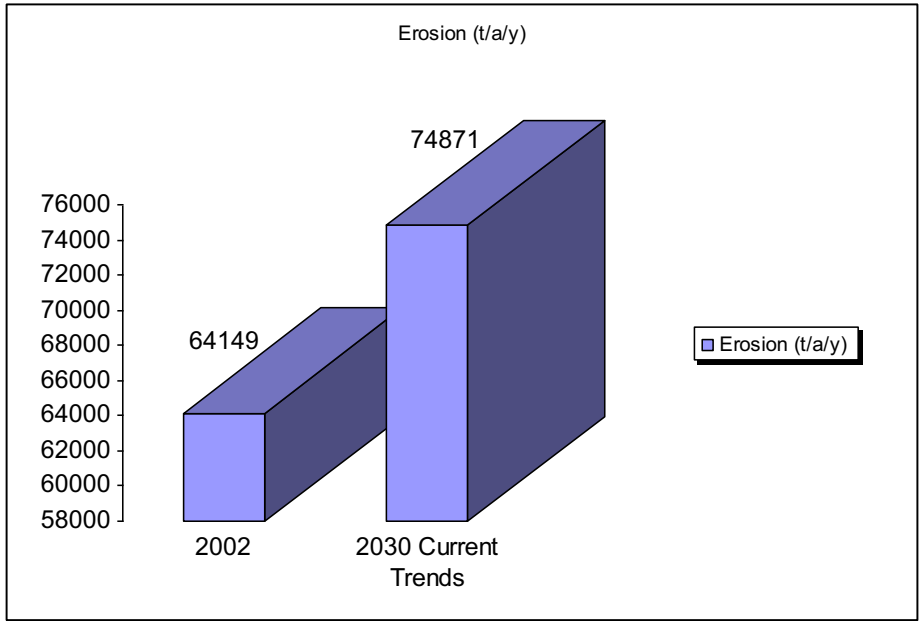
COLLABORATION IN AMBOS NOGALES

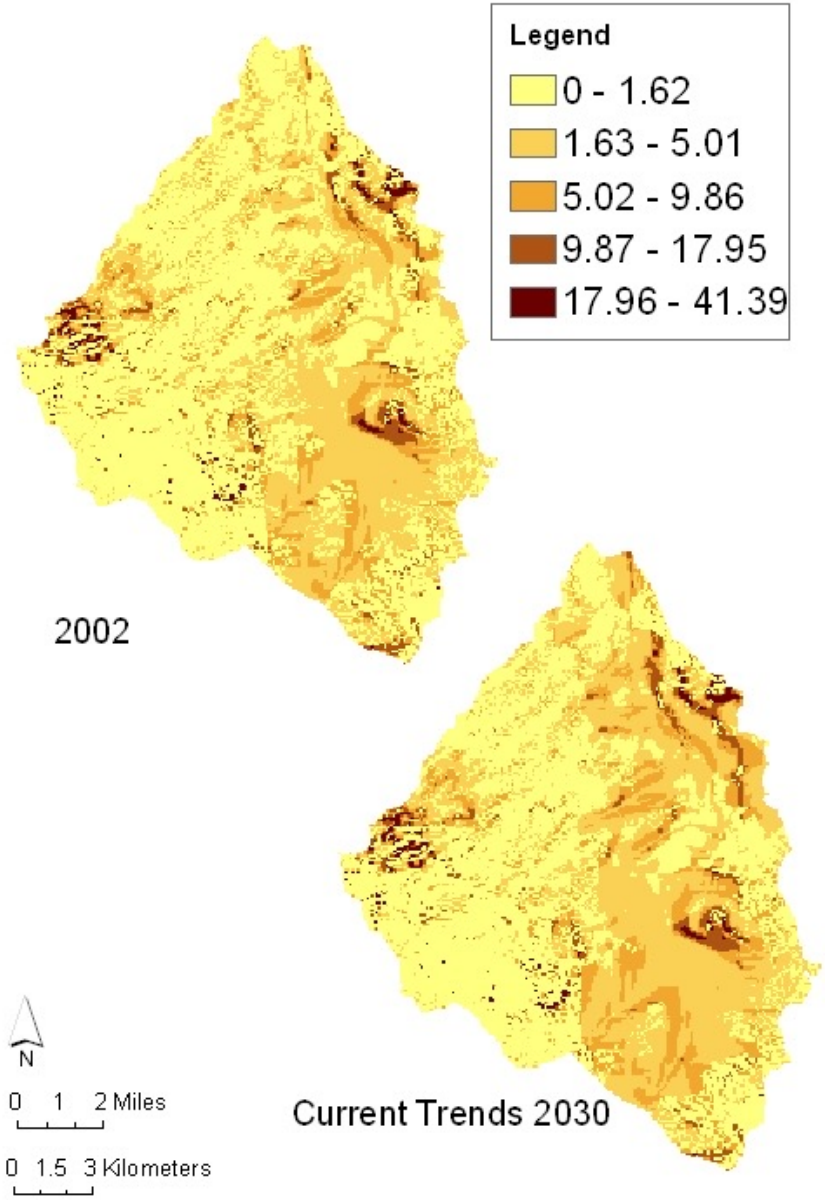
WATERSHED PLANNING



Erosion & Urban Growth

- Predicted urban development will *increase* erosion potential (+ ~11K tons/year).





Norman, L. M., Donelson, A., Pfeifer, E., & Lam, A. H. (2006). Colonia Development and Land Use Change in Ambos Nogales, United States—Mexican Border. *U.S. Geological Survey*, *Open-File Report 2006-1112*, 121.

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Sustainable Development

If Urban development occurs in sustainable development zone areas.
→**And** "Hot-spot" areas get excluded from growth and are planted with native grasses to reach at least an 80% cover of the surface
→**Then**, the erosion will d***ecrease*** in 2030 (- ~11K t/y) from 2002!!

Norman, L. M., Guertin, D., & Feller, M. (2008). A Coupled Model Approach to Reduce Nonpoint-Source Pollution Resulting from Predicted Urban Growth: A Case Study in the *Ambos Nogales* Watershed. *Urban Geography*, *29*(5), 496–516. https://doi.org/10.2747/0272-3638.29.5.496

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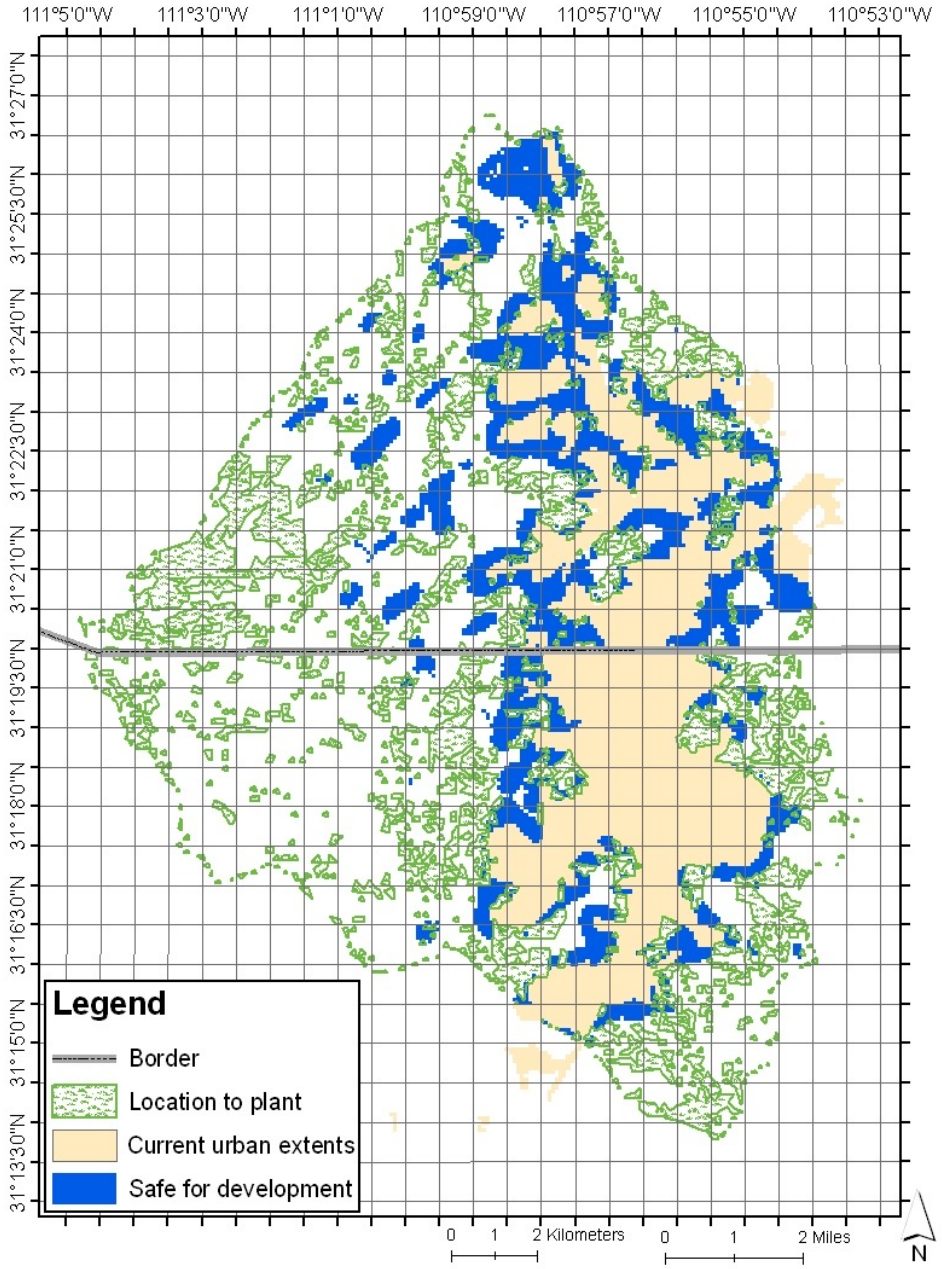
- Plant native grasses in areas identified as high-risk "hot spots"
- Allow (promote?) development in low-risk zones



Norman, L. M. (2005). ***Modeling land use change and associate water quality impacts in the Ambos Nogales watershed, United States-Mexico border.*** THE UNIVERSITY OF ARIZONA. Retrieved from http://phdtree.org/pdf/25545994-modeling-land-use-change-and-associate-water-quality-impacts-in-the-ambos-nogales-watershed-united-states-mexico-border/

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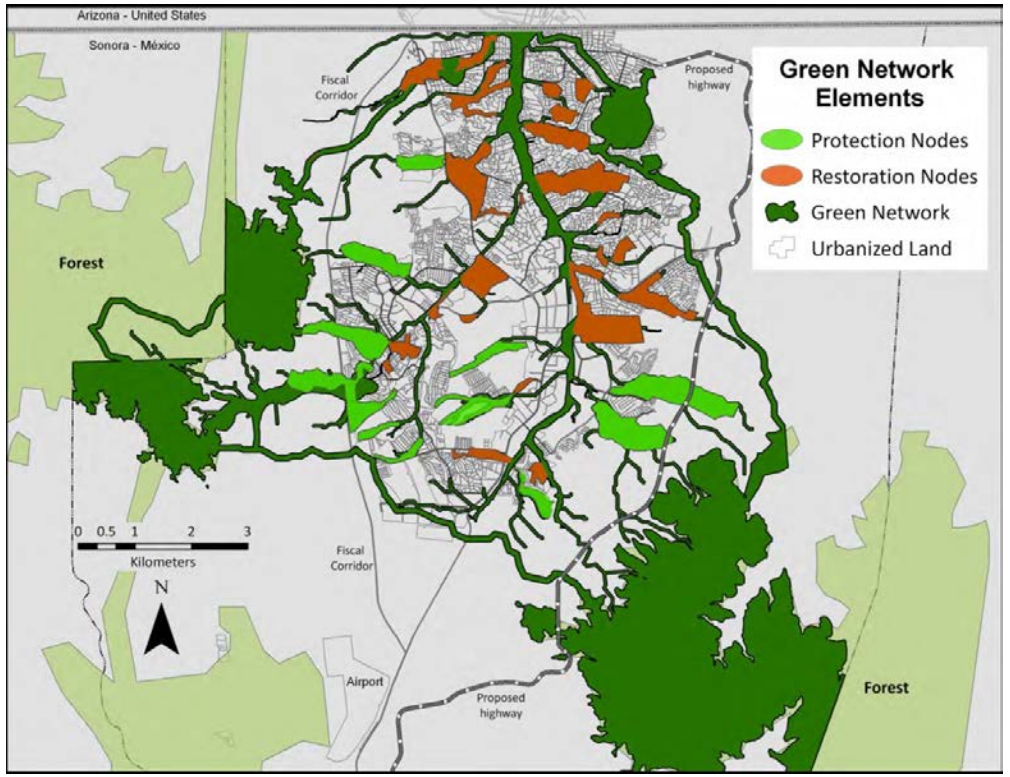
NOGALES, SONORA

Proposes the creation of a network of 35 potential locations for a city-wide green network.

Green infrastructure strategies provide the city with environmentally responsible planning and design alternatives that can

i. reduce runoff volume,
ii. protect water resources,
iii. preserve riparian habitats, and
iv. offer the additional community benefit of creating more interesting places to live, work, and play!



Lara-Valencia, Francisco and Díaz-Montemayor, Gabriel, 2010, City of Green creeks: sustainable flood management alternatives for Nogales, Sonora http://virtual.cocef.org/Final_Reports_B2012/20044/20044_Final_Report_EN.pdf

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INSTITUTO MUNICIPAL DE INVESTIGACIÓN Y PLANEACIÓN DE NOGALES, SONORA.

4A **Nogales**

EL DIARIO DE SONORA
SÁBADO 4 de Diciembre de 2010

PRESENTAN PROYECTO

Ciudad de Cañadas Verdes

NOGALES

» Un manual elaborado por investigadores sobre cómo mejorar la ciudad fue entregado ayer

FORTUNATO LEAL
flea@eldiariodesonora.com.mx

El alcalde José Ángel Hernández Barajas recibió ayer de manos de investigadores de la Universidad del Estado de Arizona el manual denominado Ciudad de Cañadas Verdes: Alternativas para el manejo sustentable de inundaciones en Nogales, Sonora.

El Alcalde agradeció dicho manual y se comprometió a aterrizar el mayor número posible de los proyectos que esto enmarca, incluso señaló que hay noticias de recursos para aplicarse en algunas zonas que incluye este trabajo de investigación.

El manual es la compilación de investigaciones de campo, conjugadas con tecnología aplicada en otras ciudades del mundo y México, y que es factible para Nogales.

El doctor Francisco Lara, de la Universidad Estatal de Arizona, mencionó que el proyecto se realizó gracias al patrocinio de la Semarnat y la Agencia de Protección Ambiental (EPA por sus siglas en inglés).

Dijo que los apoyos bajaron a través de la Comisión de Cooperación Ecológica Fronteriza (COCEF), mediante el programa Frontera 2012.

"Este es un proyecto no sólo para tener una ciudad bonita, sino algo más entero, completo, donde se reconozca la importancia de la ecología y el medio ambiente, donde se promuevan acciones que eleven la calidad de vida de la población y que se resuelvan problemas crónicos como las inundaciones", expresó Francisco Lara.

Agregó que hay nuevas ideas y enfoques en el campo de la planeación urbana, que pueden servir para atacar simultáneamente diversos problemas y es lo que trataron de hacer con esta idea de una ciudad de cañadas verdes.

"Lo que estamos haciendo es pensar en acciones que puedan iniciarse tanto por el sector público, como el social y que sirvan para resolver problemas de inundación, que se creen espacios públicos abiertos y restablezca las funciones ecológicas básicas", señaló.

Mencionó el investigador de la Universidad Estatal de Arizona, que en esto participaron estudiantes, así como el Instituto Municipal de Investigación y Planeación (IMIP) que encabeza Claudia Gil Anaya.

FORTUNATO LEAL

El Alcalde recibió de manos de investigadores de la Universidad del Estado de Arizona el manual que propone una serie de obras.

Lara-Valencia, Francisco and Díaz-Montemayor, Gabriel, 2010, City of Green creeks: sustainable flood management alternatives for Nogales, Sonora http://virtual.cocef.org/Final_Reports_B2012/20044/20044_Final_Report_EN.pdf

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FLOOD HAZARDS

Normal rainfall has the potential of realizing *abnormal* runoff that augments:

I. loss of life and property through flooding
II. soil loss and watershed-capacity (denuding the landscape)
III. nonpoint-source pollution of shared drainages/ infrastructure (sediment, solid waste)

This puts public health and the environment at risk.

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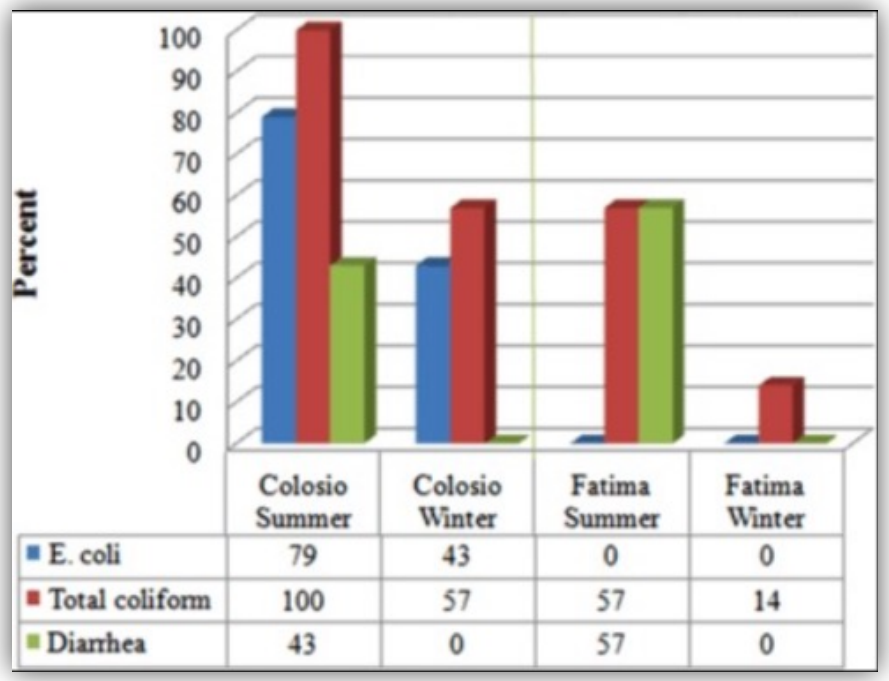
CLIMATE JUSTICE & ENVIRONMENTAL HEALTH

- Different socio-environmental vulnerability households
  - A. alternative water-delivery systems, (Colonia Luis Donaldo Colosio)
  - B. a colonia with access to piped water (Colonia Lomas de Fatima);
- Sample for microbes
  - *E.coli*
  - Total Fecal Coliforms
- Sample for metals
  - Arsenic, Mercury, Lead
- Survey
  - Quality of Life
  - Prevalence of diarrhea
  - Perceptions of Problems and Solutions

A. Colonia Luis Donaldo Colosio

B. Colonia Lomas de Fatima



	Colosio Summer	Colosio Winter	Fatima Summer	Fatima Winter
E. coli	79	43	0	0
Total coliform	100	57	57	14
Diarrhea	43	0	57	0

Felipe Caldeira

Norman LM, Caldeira F, Callegary J, Gray F, O' Rourke MK, Meranza V, Van Rijn S. Socio-Environmental Health Analysis in Nogales, Sonora, Mexico. Water Qual Expo Health. 2012 Jun;4(2):79-91. doi: 10.1007/s12403-012-0067-x. Epub 2012 Apr 12. PMID: 22719797; PMCID: PMC3375430.
Format:

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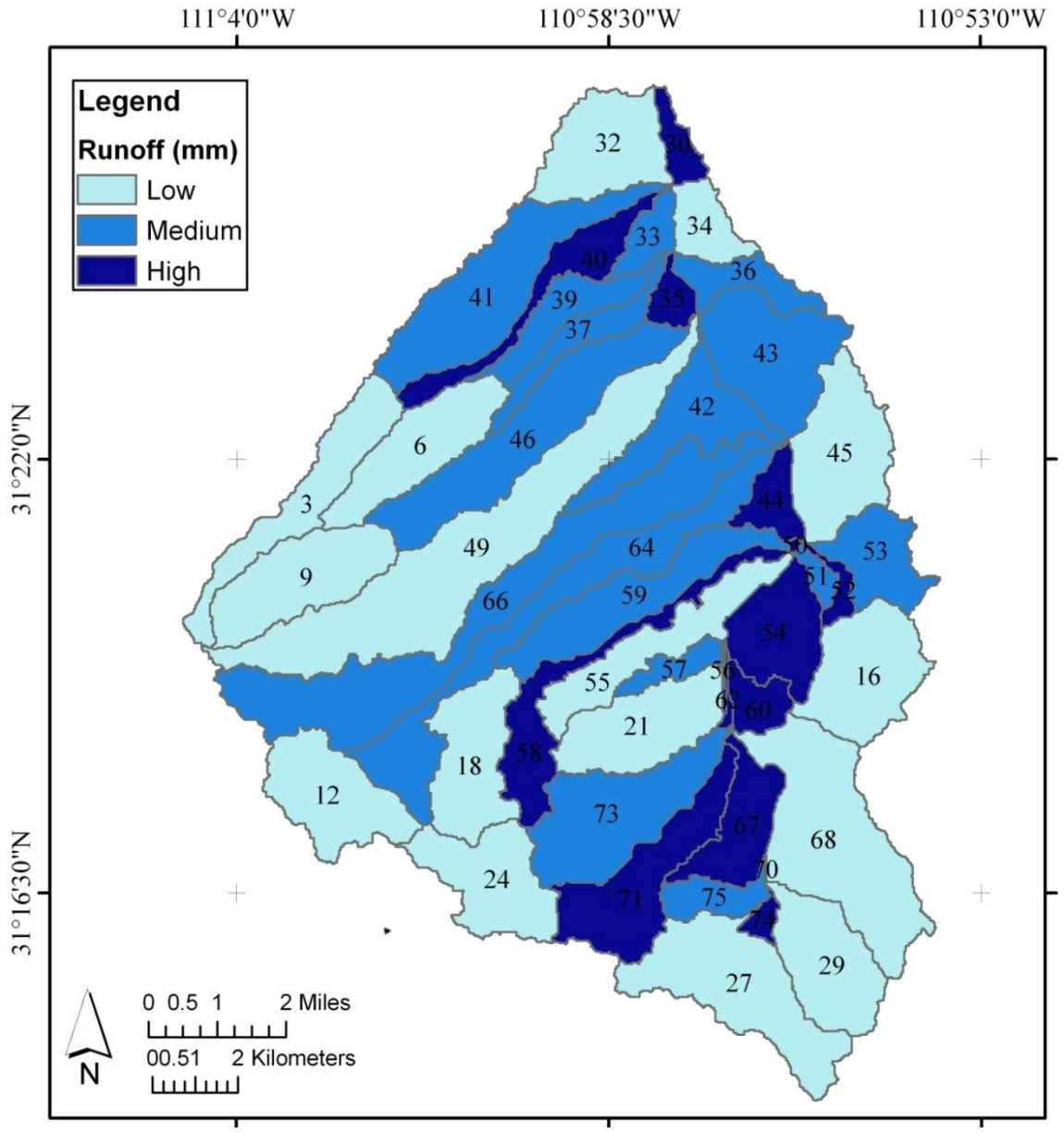
Flooding: Rainfall-Runoff Model

- Using a rainfall-runoff watershed model can help classify quantities of runoff into levels of risk
- This can be used to identify locations for potential human intervention
- Resulting map identified flood-prone areas and subwatersheds, based on 3 classes of risk



Norman, L. M., Huth, H., Levick, L., Shea Burns, I., Phillip Guertin, D., Lara-Valencia, F., & Semmens, D. (2010). **Flood hazard awareness and hydrologic modelling at Ambos Nogales, United States–Mexico border.** *Journal of Flood Risk Management*, *3*(2), 151–165. http://doi.org/10.1111/j.1753-318X.2010.01066.x

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INTERNATIONAL BOUNDARY AND WATER COMMISSION (IBWC/CILA)

- Began work in 2009
  → Looking at how to manage international flood hazards using gabions

- Norman, Laura M., Levick, L. R., Guertin, D. P., Callegary, J. B., Quintanar Guadarrama, J., Zulema Gil Anaya, C., … Octavio Gastelum Ceballos, F. (2010). Nogales flood detention study. *U.S. Geological Survey Open-File Report*, *2010–1262*, 112.
- Norman, Laura M., Villarreal, M. L., Wallace, C. S. A., Zulema Gil Anaya, C., Diaz Arcos, I., & Gray, F. (2010). A High-Resolution Land-Use Map: Nogales, Sonora, Mexico. *U.S. Geological Survey Open-File Report*, *2010–1156*, 28.

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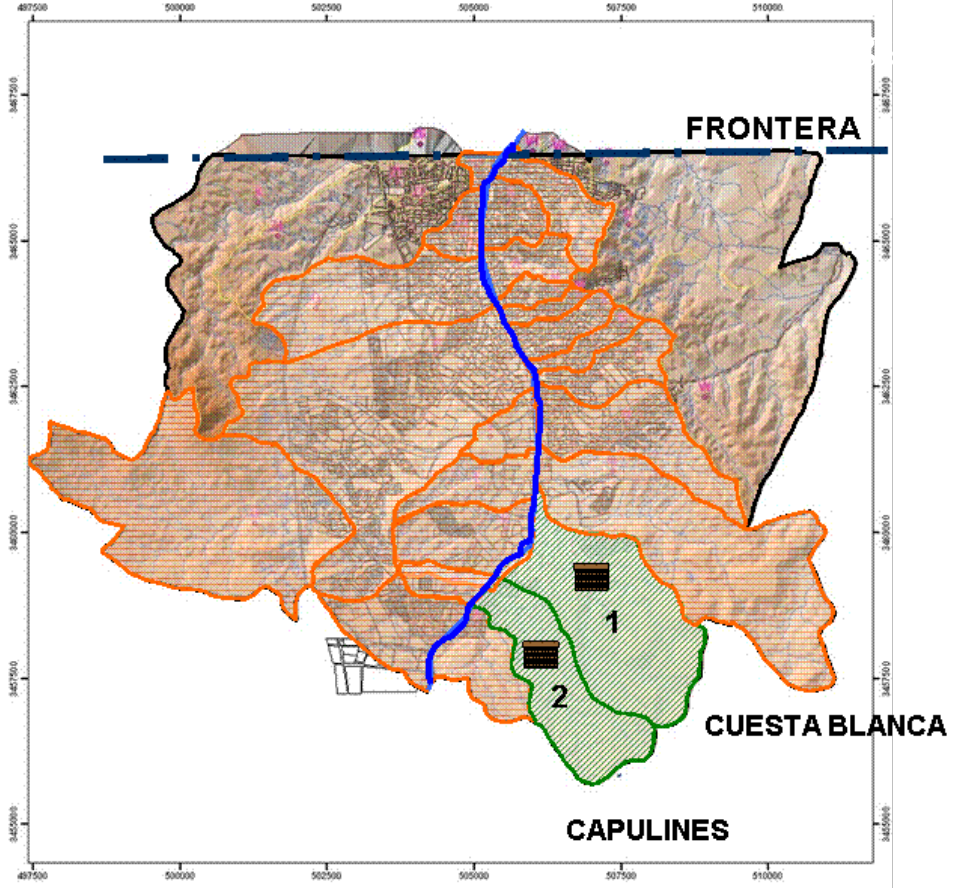

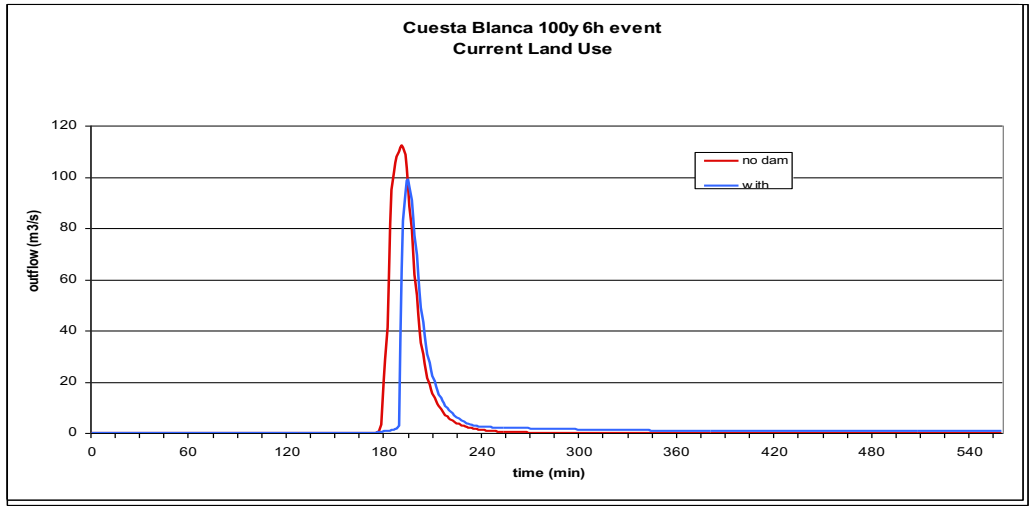

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Sediment yield (kg), 25 year, 6 hour event		
Channel Impacts	Cuesta Blanca	Capulines
w/out feature	8,518,604	9,268,617
w/ feature	2,964,995	3,869,279
Difference	5,553,609	5,399,338

Norman, L.M., Levick, L., Guertin, D.P., Callegary, J., Quintanar Guadarrama, J., Zulema Gil Anaya, C., Prichard, A., Gray, F., Castellanos, E., Tepezano, E., Huth, H., Vandervoet, P., Rodriguez, S., Nunez, J., Atwood, D., Patricio Olivero Granillo, G., and Octavio Gastelum Ceballos, F., 2010, **Nogales flood detention study**: U.S. Geological Survey Open-File Report 2010-1262, 141 p.

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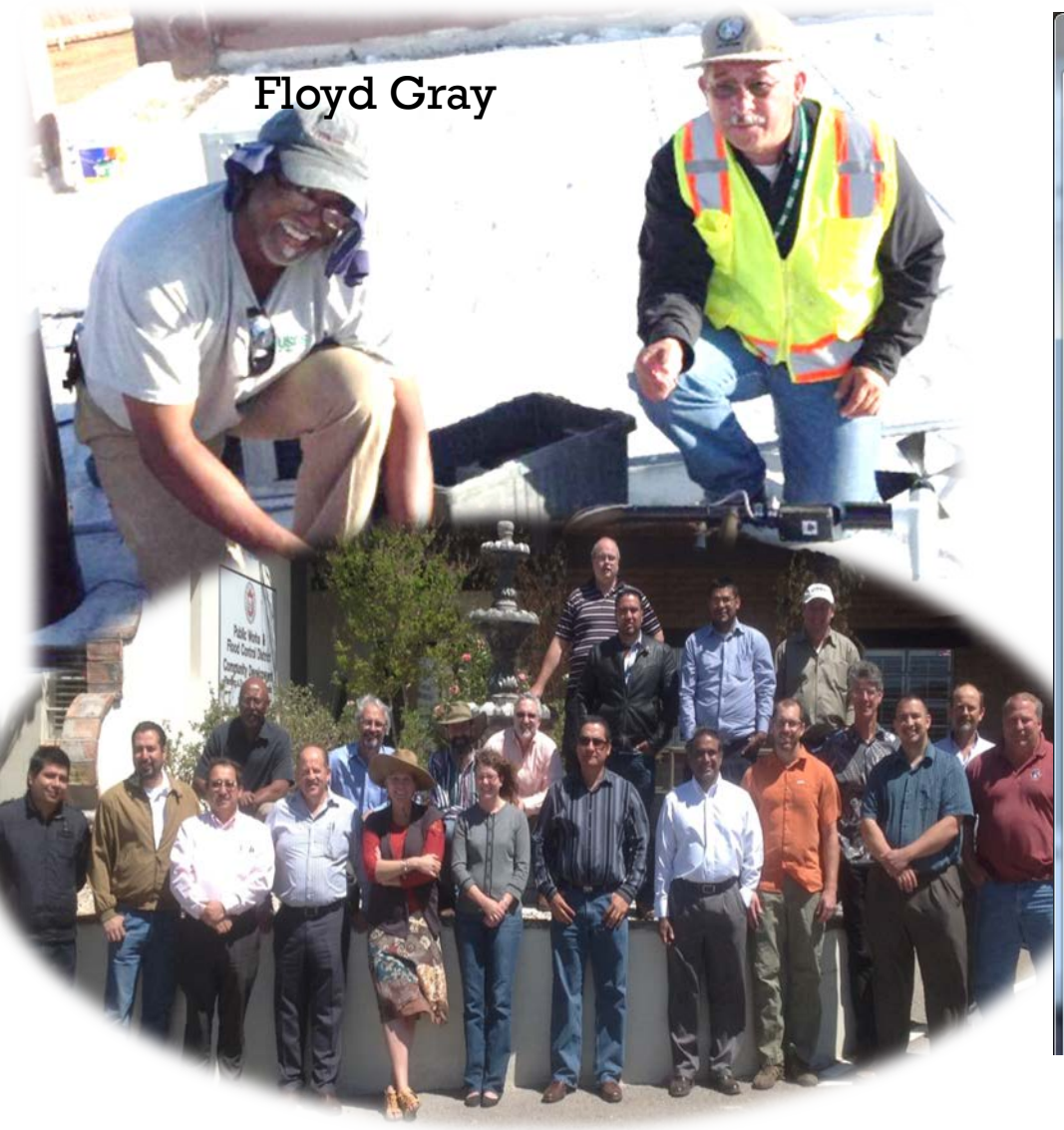
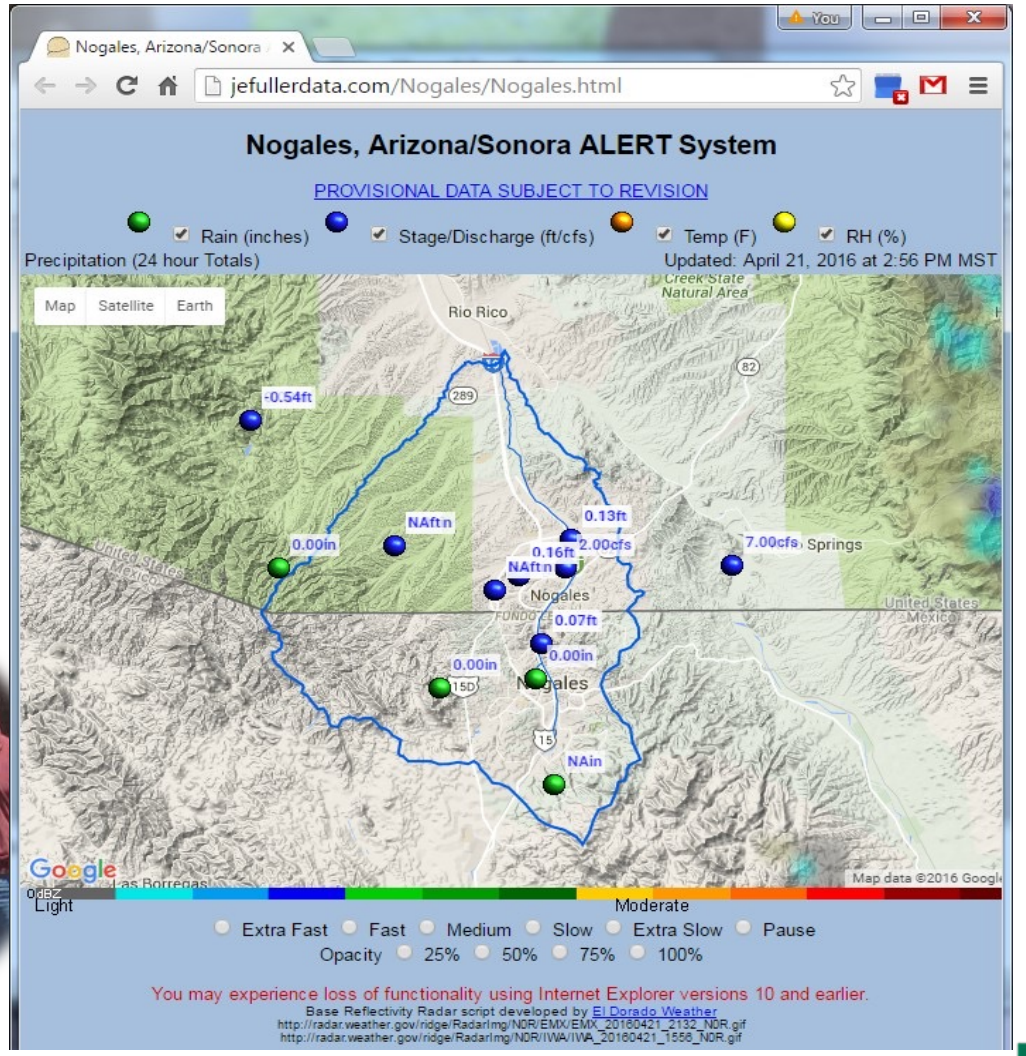
FLASH-FLOOD FORECASTING AT AMBOS NOGALES





(http://jefullerdata.com/Nogales/Nogales.html)

- Base Station
- 3 Weather Stations
- 1 Precip/Stream Station
- 1 Precipitation Station

Norman, Laura M. (2010). **Flash-Flood Forecasting at Ambos Nogales**, In the Border Climate Summary, Climate Assessment for the Southwest (CLIMAS) program, University of Arizona, Tucson, Ariz., http://www.climas.arizona.edu/files/climas/pdfs/periodicals/BorderClimateSummary_Jun10.pdf (NEWSLETTER)

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FLOOD RESILIENCE & RISK PERCEPTIONS

1. Previous experience of flooding heightens concern
2. Water in the streets and damage to vehicles priority
3. Women felt less prepared than men
4. Most felt not prepared for future floods
5. Resilience strategies should include:
   - *improved early warning systems,*
   - *green and gray infrastructure,*
   - *awareness and education campaigns, and*
   - *increased regulation and enforcement of development practices*.
6. Community fund and volunteer effort should focus on:
   - *Educational campaigns and*
   - *Green infrastructure demonstration projects*

Mr. Chris Freimund

Freimund, C. A., Garfin, G. M., Norman, L. M., Fisher, L., & Buizer, J. (2022 In Review). Flood resilience in paired US-Mexico border cities: A study of binational risk perceptions. *Natural Hazards*.

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"Sustainable Strategies for Stormwater & CSOs Control in Ambos Nogales"

CURRENT CONDITION

RETROFIT CONDITION

Terraced slopes for public space, retention gabion walls, trees and shrubs

- Rainfall/Runoff Modelling and Land Suitability Analysis
- Landscape Design
- Institutional Analysis
- Community Engagement and Awareness

CONACYT · El Colegio de la Frontera Norte · EPA United States Environmental Protection Agency · IMIP Nogales, Sonora · Frontera 2020 Border 2020 · Sonora · Arizona · University of Arkansas · Ecoparque · ADEQ Arizona Department of Environmental Quality · Nogales · ASU Arizona State University · USGS science for a changing world · Watershed Management Group

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MIDDLE SCHOOL STUDENT ARTISTS IN NOGALES ARE INVITED TO

NOVEMBER 18 Y 19 SUBMISSION DATE

ART CONTEST

THE RAIN AND MY CITY

¡SUBMIT YOUR ART WORK!

ART CONTEST

The Ambos Nogales Green Infrastructure Project and the Hilltop Gallery announce a call to middle school students from Nogales, Arizona for a juried art contest and exhibit of painting, drawing and mixed-media/3D allusive to the theme: **"The Rain and my City"**

Use your imagination to create an original piece of art expressing what you see, feel or experience when it is raining in your city, school, or neighborhood.

ART EXHIBIT

NOVEMBER 2020 **21**

PLACE

Las Lagunas de Anza located at Country Club Dr, Nogales, AZ 85621

IMPORTANT DATES AND EVENTS:

November 18-19, 2020 (12 - 3:30 pm):

Entries will be accepted at the Hilltop Gallery located at 730 North Hilltop Drive in Nogales, AZ.

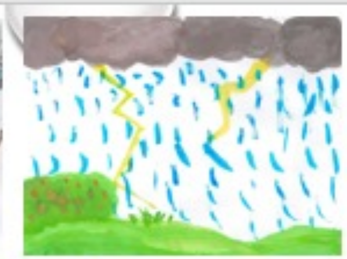
November 21, 2020 (9 am - 12 pm):

Art exhibit and community celebration (9 am to 12 pm): All entries will participate in a juried exhibit organized by the Hilltop Art Gallery and receive diplomas of participation. The three best artworks will receive a special prize.

A limited number of watercolor paint kits are available by request. If you need a kit, contact Hilda García (mhgarciaperez@colef.mx) of El Colegio de la Frontera Norte or Cesar López (clopez.arizona@gmail.com) of SEEDS Garden Crew.

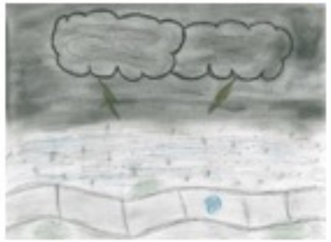
The exhibit will be held at the Mezquite Grove Outdoor Classroom at Las Lagunas de Anza (W. Country Club Dr, Nogales, AZ 85621).

This community event is sponsored by the Ambos Nogales Green Infrastructure Project, a binational collaboration of Arizona State University, the University of Arizona, El Colegio de la Frontera Norte, the University of Arkansas, the U.S. Geological Survey, the Arizona Department of Environmental Quality, SEEDS Garden Crew, and the Instituto Municipal de Planeación of Nogales, Sonora with the support of the Environmental Protection Agency, Border 2020 Program, and the North American Development Bank.























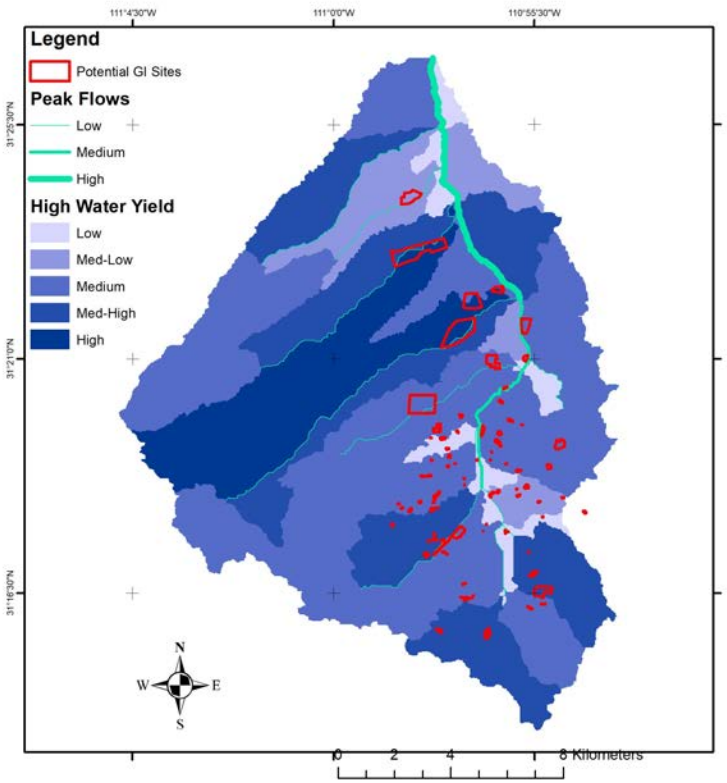


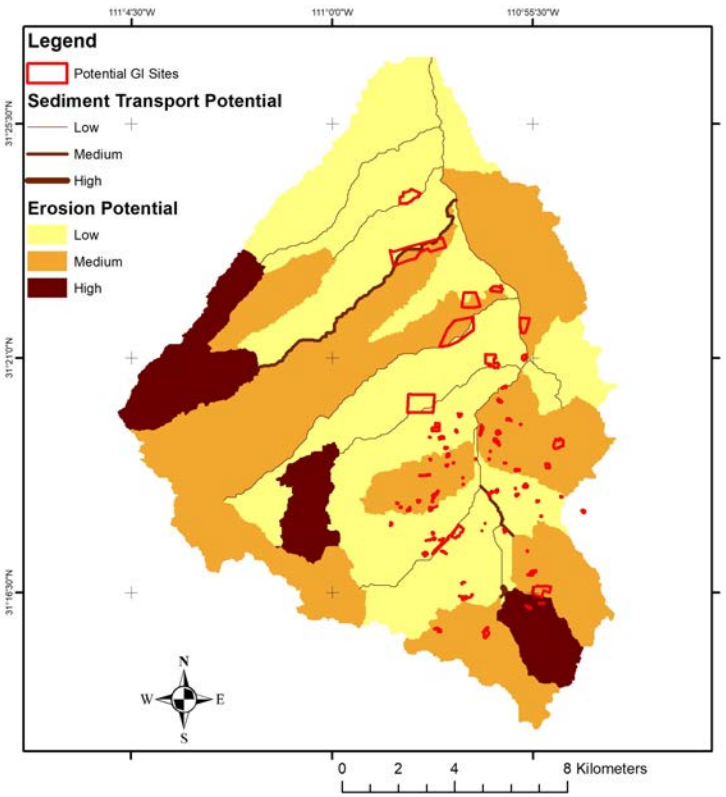


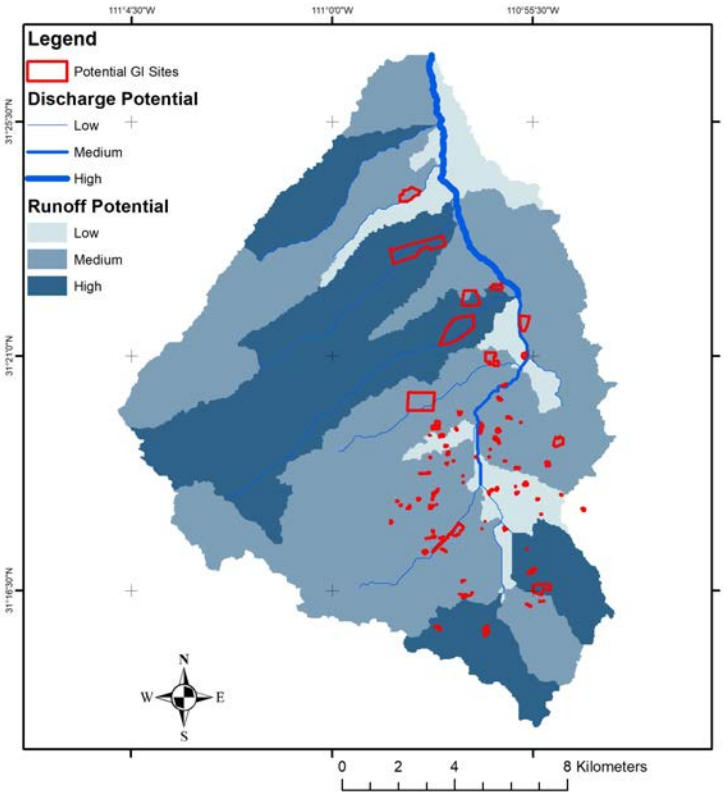


HYDROLOGIC MODELING

Alma Anides Morales







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CICLO: INFRAESTRUCTURA VERDE Y SALUD URBANA

Se invita a la comunidad de Ambos Nogales a participar como voluntariado en la construcción de jardines de lluvia y aprender sobre los beneficios de la infraestructura verde

28 DE MAYO 2021
Excavación y construcción de jardín
Escuela Secundaria General # 3
"Humberto Campos Varela"
9:00 a 15:00 hrs

29 DE MAYO, 2021
Plantación de árboles y arbustos
9:00 a 12:00 hrs

18 DE JUNIO 2021
Jardín de Lluvia
"Colonia Embarcadero"
Plantación de árboles y arbustos
8:00 a 15:00 hrs

Información y registro para voluntariado:

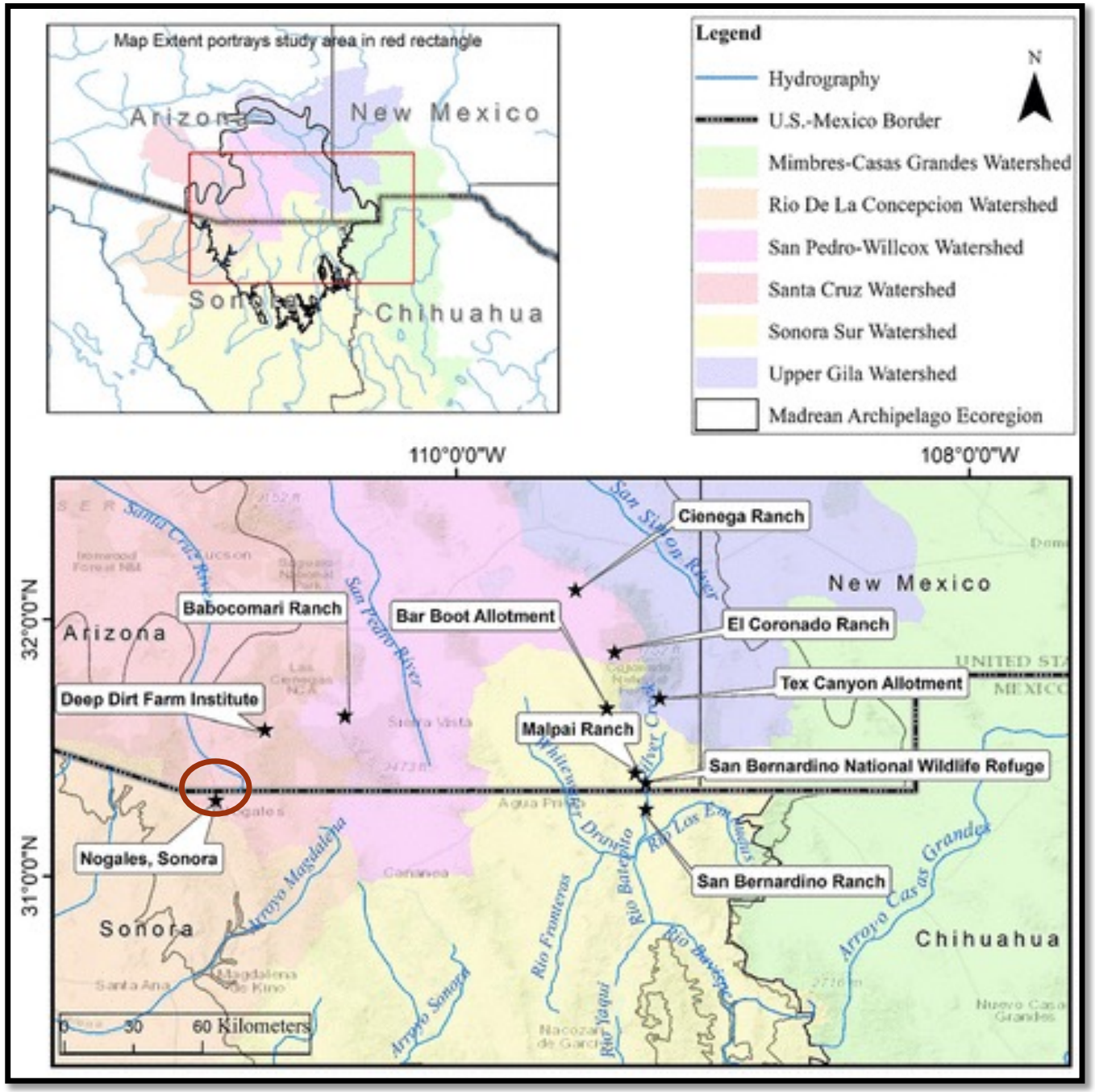
Nohemí Chávez
nohemi.fce@gmail.com

Ulises Hernández
uliprof923@colef.mx

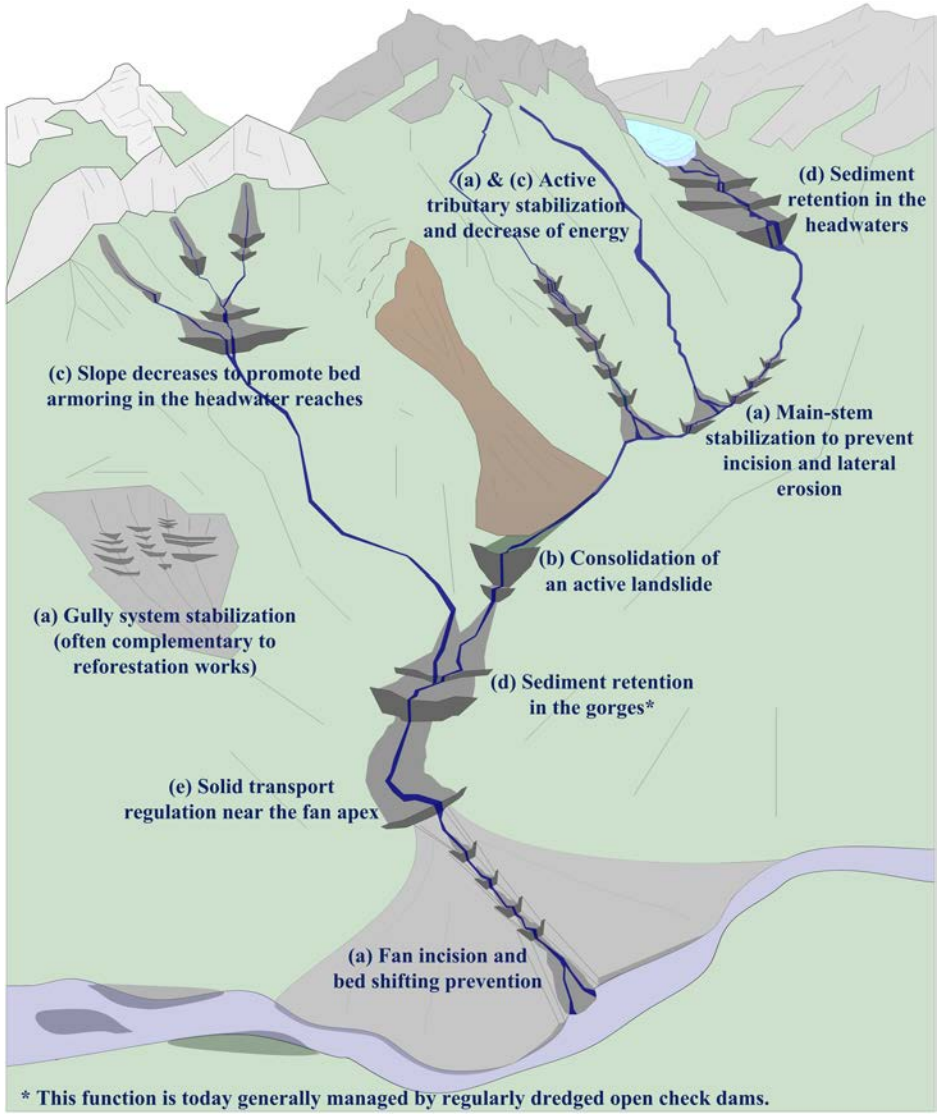
Este evento seguirá el protocolo de sana distancia y uso obligatorio de tapabocas que establecen las autoridades de salud, por lo que se integrarán grupos de trabajo en diferentes horarios.

Jardines de Lluvia
en Ambos Nogales

CONACYT · El Colegio de la Frontera Norte · EPA United States Environmental Protection Agency · IMIP Nogales, Sonora · Frontera 2020 Border 2020 · Seeds · Arizona · University of Arkansas · Ecoparque · ADEQ Arizona Department of Environmental Quality · Nogales · ASU Arizona State University · USGS science for a changing world · Watershed Management Group



http://geography.wr.usgs.gov/science/aridlands/



https://onlinelibrary.wiley.com/doi/pdf/10.1002/esp.3967

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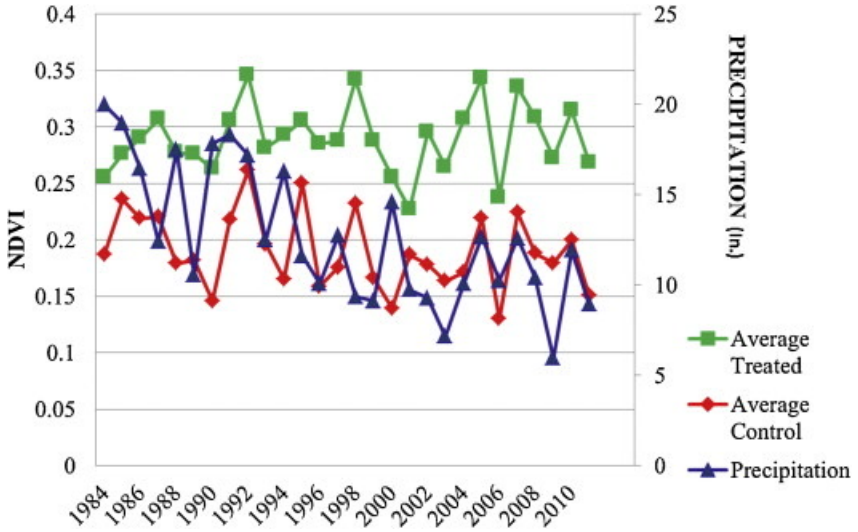
WETLAND RESTORATION: INCREASED VEGETATION

- Over a 27-year time period, we documented that vegetation is maintained and improved at structures, despite drought conditions, *and*

- This was evidenced extending up to 5km downstream and 1 km upstream!



- Norman, L. M., Villarreal, M. L., Pulliam, H. R., Minckley, R., Gass, L., Tolle, C., & Coe, M. (2014). Remote sensing analysis of riparian vegetation response to desert marsh restoration in the Mexican Highlands. Ecological Engineering, 70C, 241–254. https://doi.org/10.1016/j.ecoleng.2014.05.012
- Wilson, N. R., & Norman, L. M. (2018). Analysis of vegetation recovery surrounding a restored wetland using the normalized difference infrared index (NDII) and normalized difference vegetation index (NDVI). International Journal of Remote Sensing, 39(10), 3243–3274. https://doi.org/10.1080/01431161.2018.1437297

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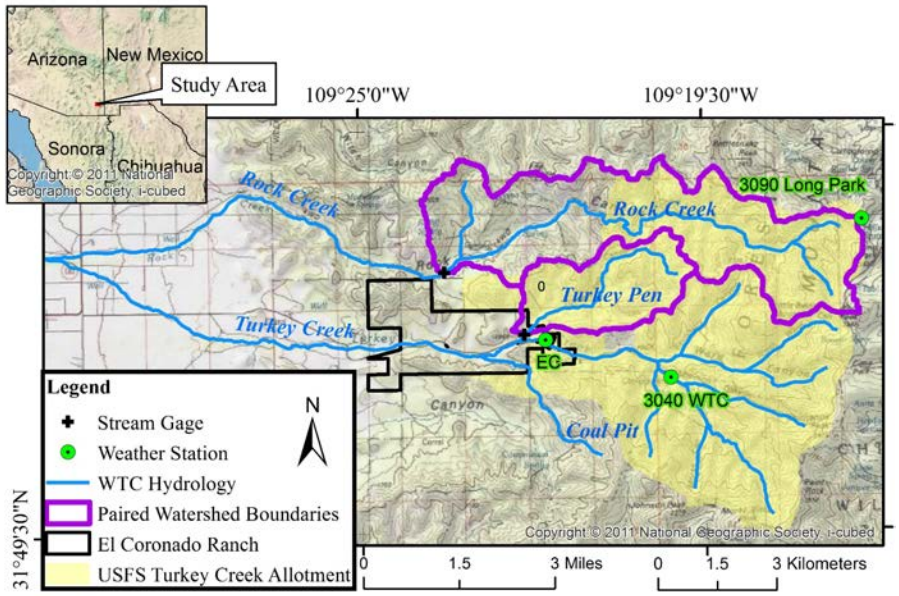
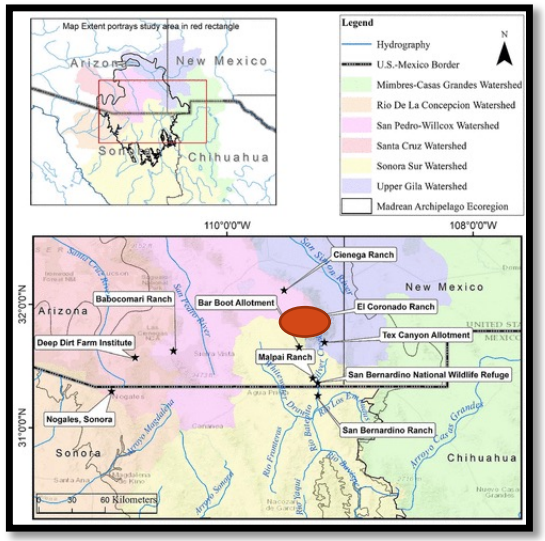
WATER REGULATION→ WATER PROVISIONING



	Untreated/Control (RC)		
	Q Volume (Total Cubic Meters)	Precipitation (Monthly total * Watershed Size, in Cubic Meters)	% Runoff
July	12,959 ↑	3,878,490	0.33
August	58,139 ↑	3,468,960	1.68
September	34,264 ↑	1,011,780	3.39 ↓
October	1,720 ↑	0	0
	Treated (TP)		
	Q Volume (Total Cubic Meters)	Precipitation (Monthly total * Watershed Size, in Cubic Meters)	% Runoff
July	0 ↓	1,238,090	0
August	18,561 ↓	1,107,360	1.68
September	27,560 ↓	322,980	8.53 ↑
October	855 ↓	0	0



Norman, L. M., Brinkerhoff, F., Gwilliam, E., Guertin, D. P., Callegary, J., Goodrich, D. C., Nagler, P. L., & Gray, F. (2016). Hydrologic Response of Streams Restored with Check Dams in the Chiricahua Mountains, Arizona. *River Research and Applications*, *32*(4), 519–527. https://doi.org/10.1002/rra.2895

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EROSION CONTROL → WATER PURIFICATION

Soil a
Assess
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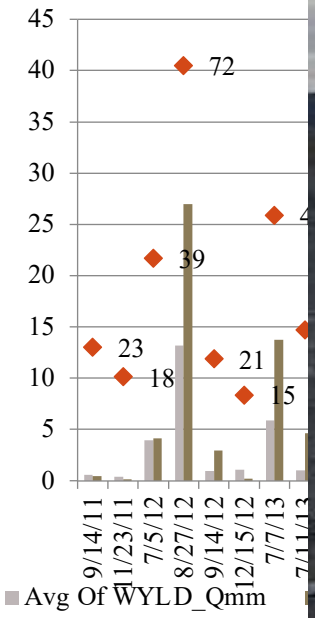

Norman, L. M., & Niraula, R. (2016). Model analysis of check dam impacts on long-term sediment and water budgets in Southeast Arizona, USA. *Ecohydrology & Hydrobiology*. http://doi.org/10.1016/j.ecohyd.2015.12.001

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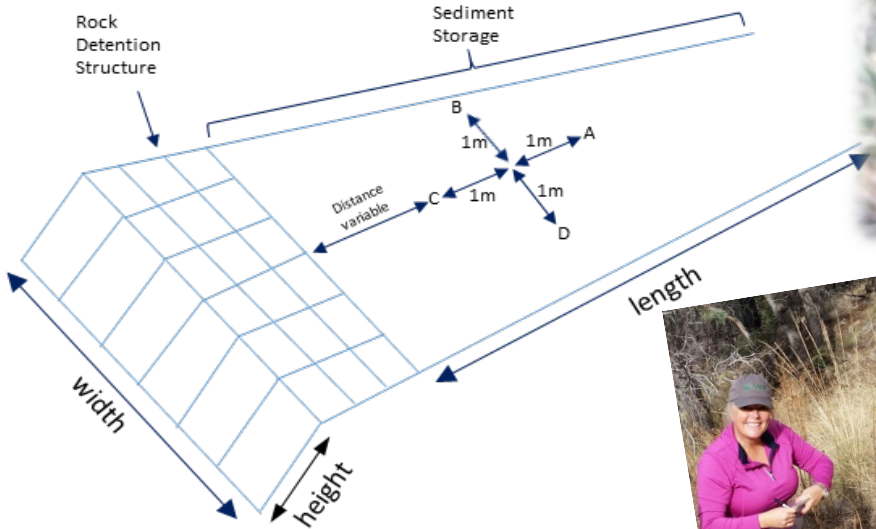
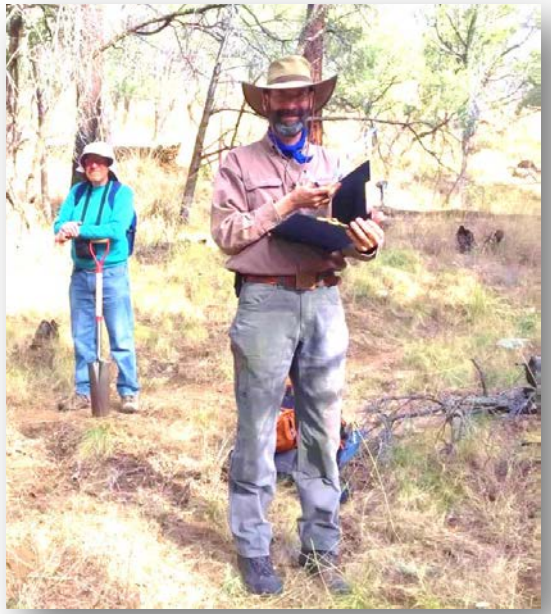
CARBON SEQUESTRATION AND STORAGE

Stable isotope ratios of carbon and nitrogen ($\delta\ ^{13}C$ and $\delta\ ^{15}N$)





James Callegary
USGS Hydrologist

Land Carbon

Callegary, J. B., Norman, L. M., Eastoe, C. J., Sankey, J. B., & Youberg, A. (2021). Post-Wildfire Carbon and Nitrogen Sequestration Potential in Entisols of Forest Ecosystems of Southwest USA. *Air, Soil and Water Research*, *13*. https://doi.org/10.1177/11786221201001768

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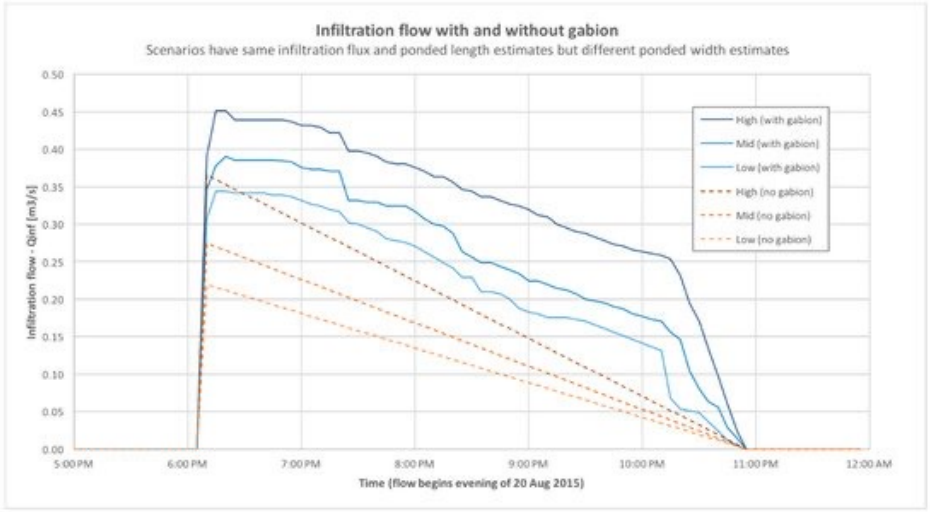
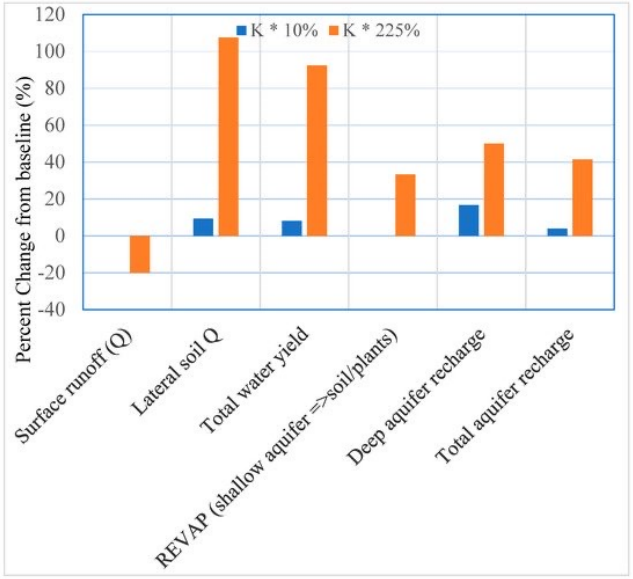
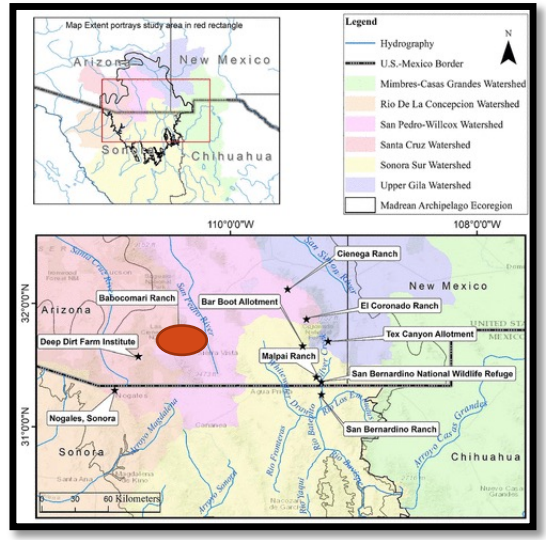
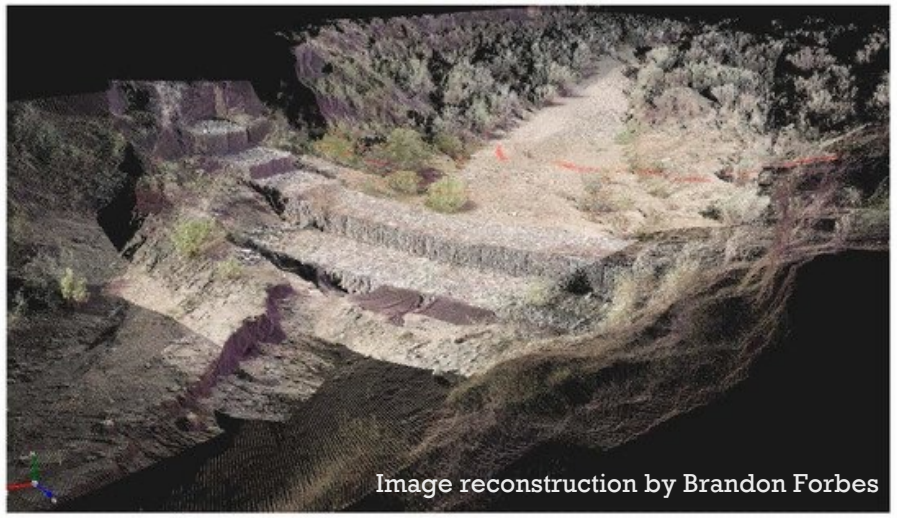
RECHARGE → WATER PROVISIONING









Norman, L., Callegary, J., Lacher, L., Wilson, N., Fandel, C., Forbes, B., & Swetnam, T. (2019). Modeling Riparian Restoration Impacts on the Hydrologic Cycle at the Babacomari Ranch, SE Arizona, USA. Water, 11(2), 381. https://doi.org/10.3390/w11020381

WALTON FAMILY FOUNDATION

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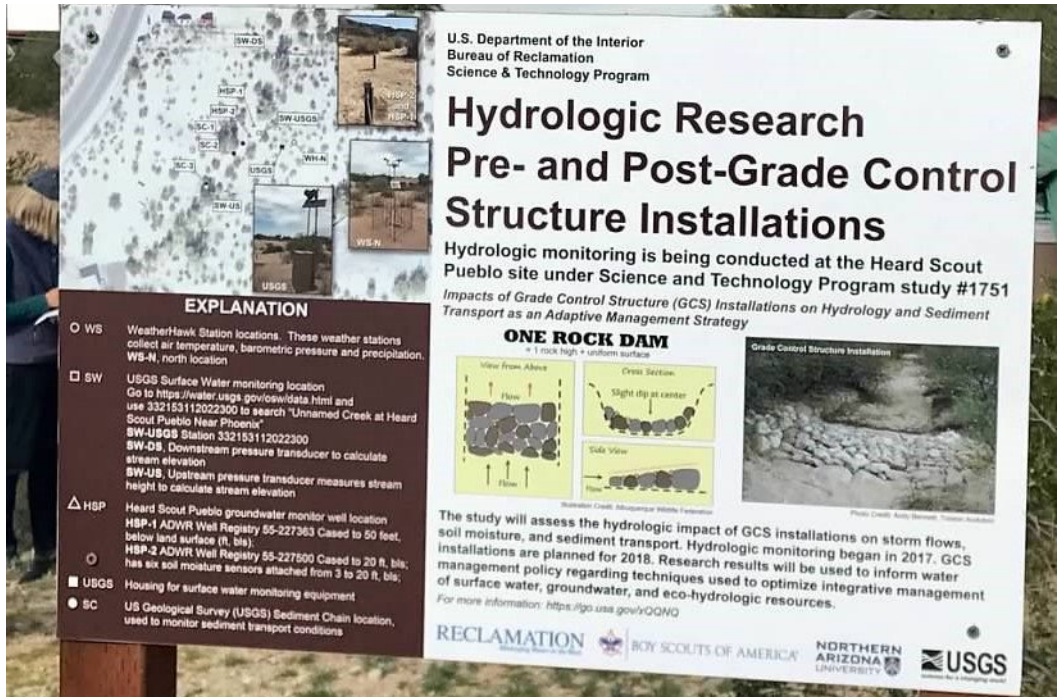
CLIMATE REGULATION

Deborah Tosline RG
Hydrogeologist
Bureau of Reclamation



Tosline, Deborah, Norman, L. M., Greimann, B. P., Cederberg, J., Huang, V., & Ruddell, B. L. (2020). *Impacts of Grade Control Structure Installations on Hydrology and Sediment Transport as an Adaptive Management Strategy* (Science and Technology Program Research and Development Office ST-2017-1751-01). Bureau of Reclamation. https://data.usbr.gov/catalog/4414/item/6298

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CLIMATE RELATED
ECOSYSTEM SERVICES OF ROCK DETENTION STRUCTURES








- ✓Flood regulation
- ✓Erosion regulation
- ✓Habitat Provisioning
- ✓Water regulation, purification, and provisioning
- ✓Carbon sequestration and storage
- ✓Social value
- ✓Climate regulation

Norman, L. M. (2020). Ecosystem Services of Riparian Restoration: A Review of Rock Detention Structures in the Madrean Archipelago Ecoregion. Air, Soil and Water Research, 13, 117862212094633.

Norman, L. M. (2020). Servicios de ecosistemas de restauración ribereña: revisión de estructuras de detención de rocas en la ecorregión del archipiélago Madrense. *Air, Soil and Water Research*, *13*, 117862212094633. https://doi.org/10.25384/SAGE.12780900.v1

Ver esta publicación en español

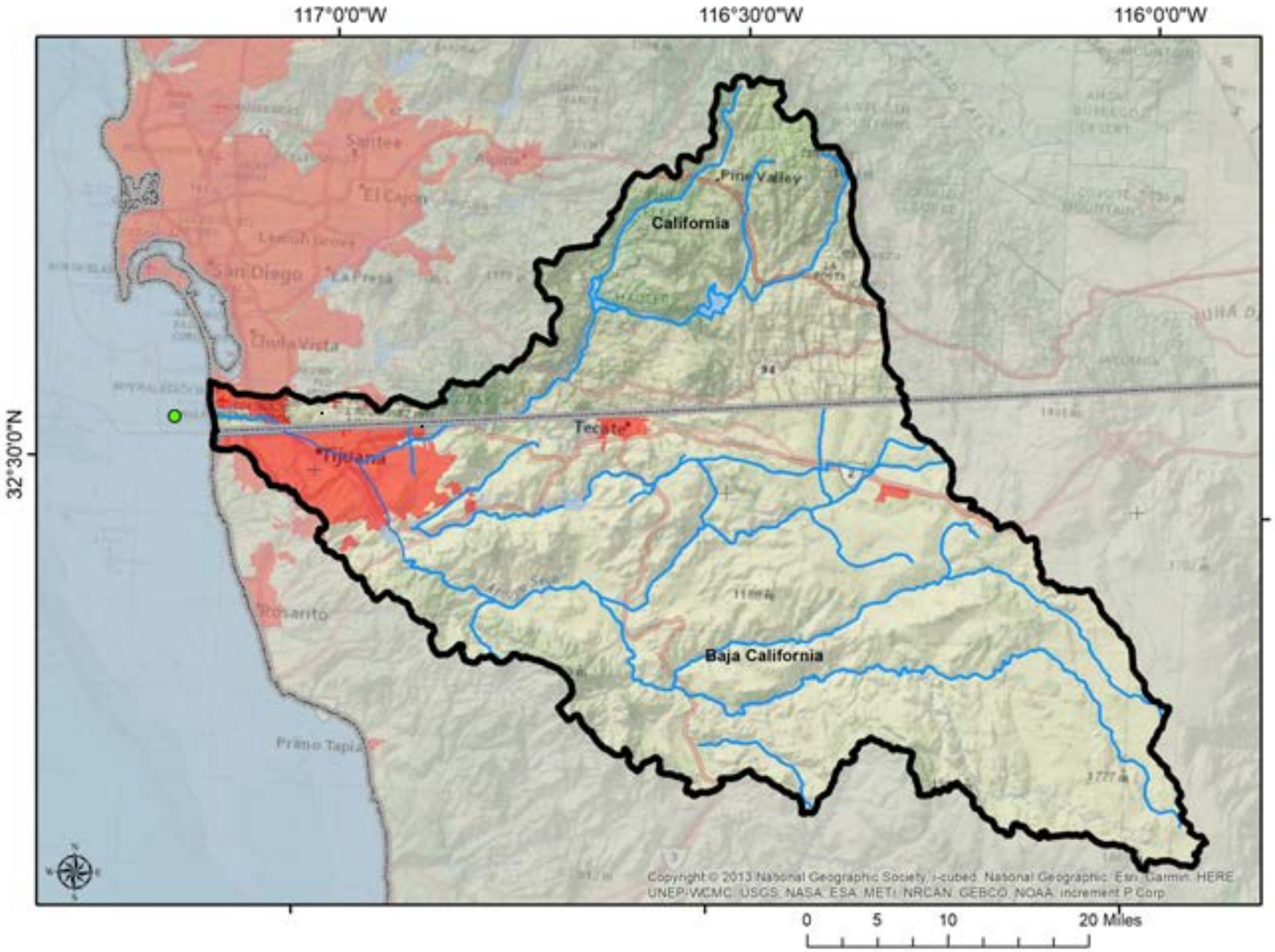

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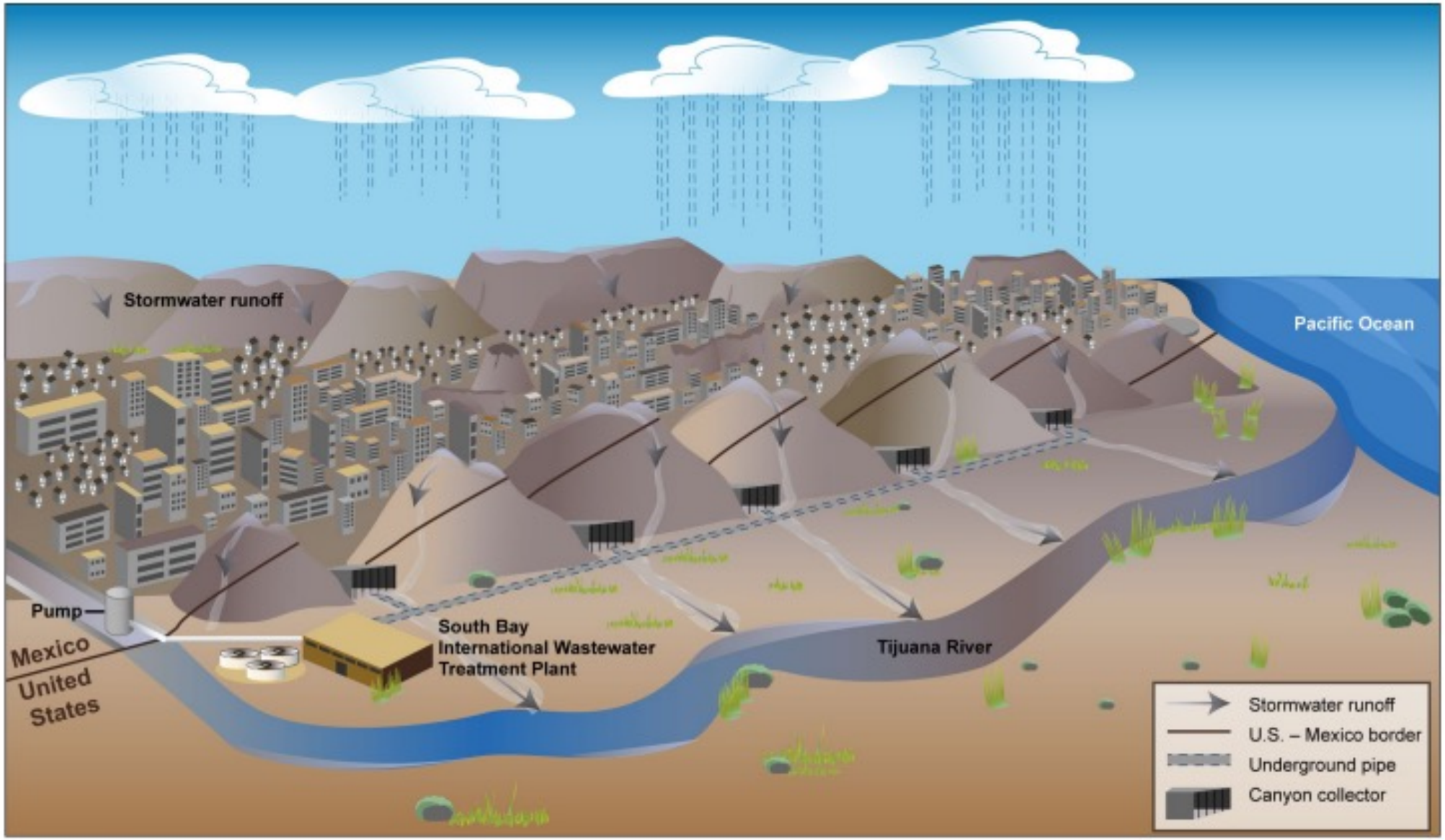
Figure 5: South Bay International Wastewater Treatment Plant



Source: GAO. | GAO-20-307

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San Diego - Tijuana

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Tijuana River National Estuarine Research Reserve

CICESE

US Army Corps of Engineers
Los Angeles District

El Colegio de la Frontera Norte

CALIFORNIA WATER BOARDS
San Diego - R9

SURFRIDER FOUNDATION

BECC
COCEF

CONAGUA
Comisión Nacional del Agua

WILDCOAST
COSTASALVAJE

Tijuana River Mouth State Marine Conservation Area
Southern California - Established January, 2012

& more!

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TIJUANA BASIN FLOODING AND POLLUTION SOLUTIONS

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Supervisory Research Physical Scientist
U.S. Geological Survey
Western Geographic Science Center
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Co-PI: Napoleon Gudino-Elizondo, PhD
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Graduate Student: Alma Anides Morales
Graduate Research Assistant
Dept of Environmental Science
The University of Arizona
aanides@email.arizona.edu

Co-PI: Ramon Macias
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Co-PI: Ing. Antonio Rascon Mendoza
Principal Engineer
la Comisión Internacional de Límites y Aguas (CILA)
Juarez, Chihuahua, Mexico
arascon@cila.gob.mx

U.S. CONSULATE
Tijuana

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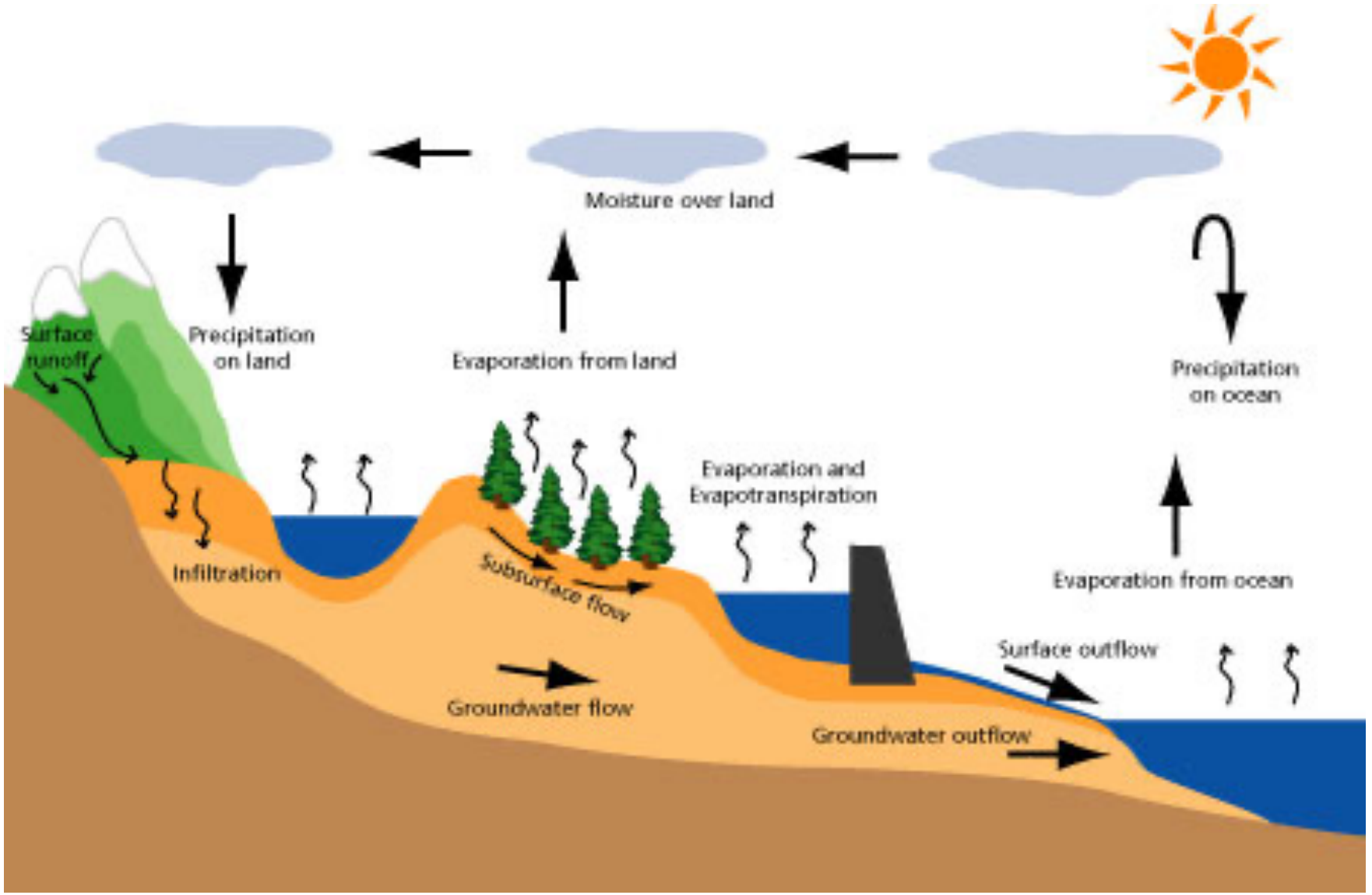
PROJECT GOAL

WATERSHED MODELLING



Typical Input

- **Topography**
- **Soil Characteristics**
- **Land Cover**
- **Land Use**
- **Meteorological Data**

Typical Output

- **Surface Runoff**
- **Streamflow**
- **Sediment Yield**
- **Subsurface Flow**
- **Percolation/Infiltration**

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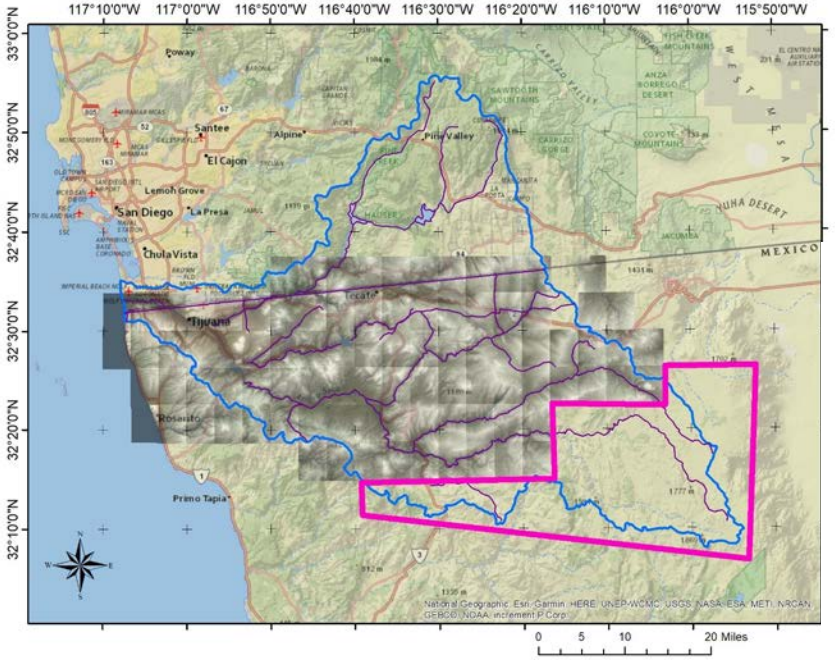
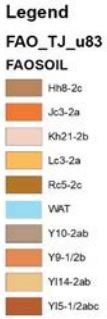
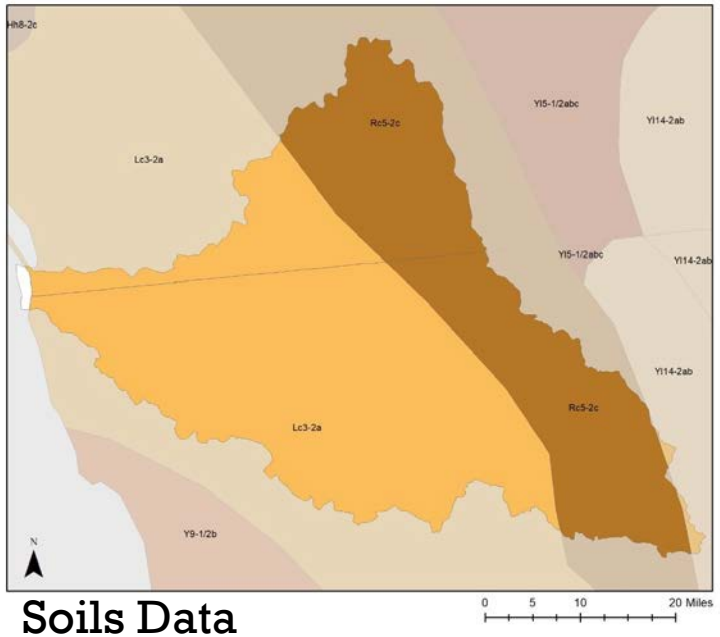
MODEL INPUTS (GEOSPATIAL DATA)



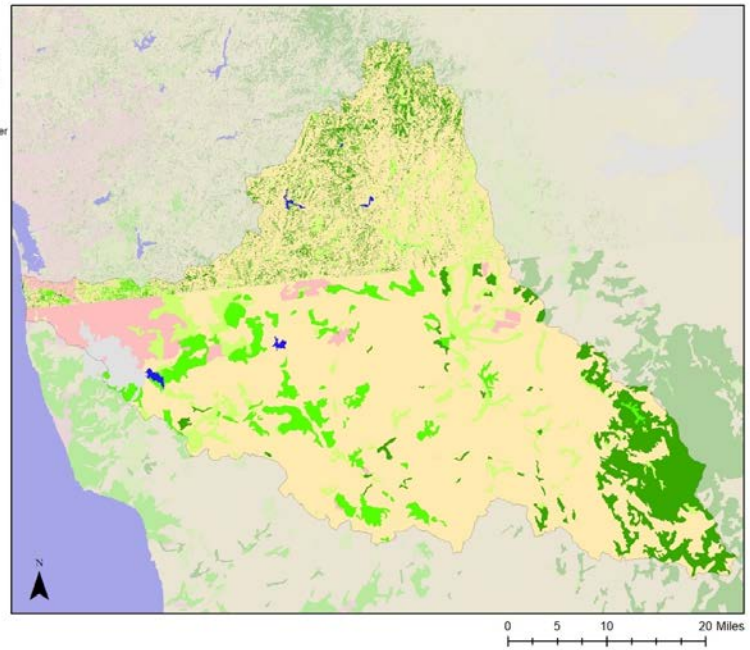
Digital Elevation Data





Soils Data

Land Use Data



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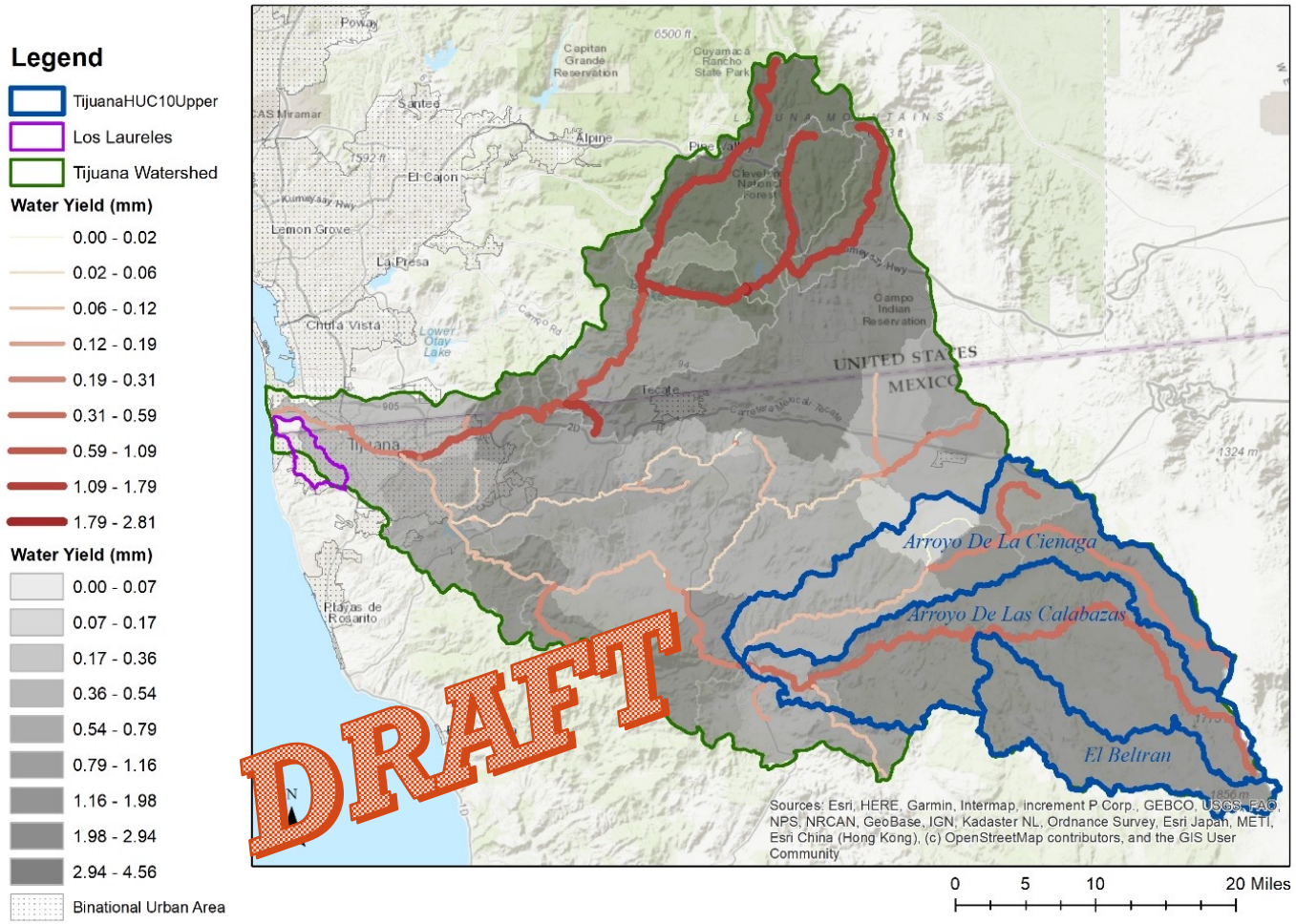
SWAT ITERATION RUN USING 30-M DEM OF WATERSHED, HISTORIC BEHI LAND USE, AND LOW-RESOLUTION FAO SOILS DATASETS



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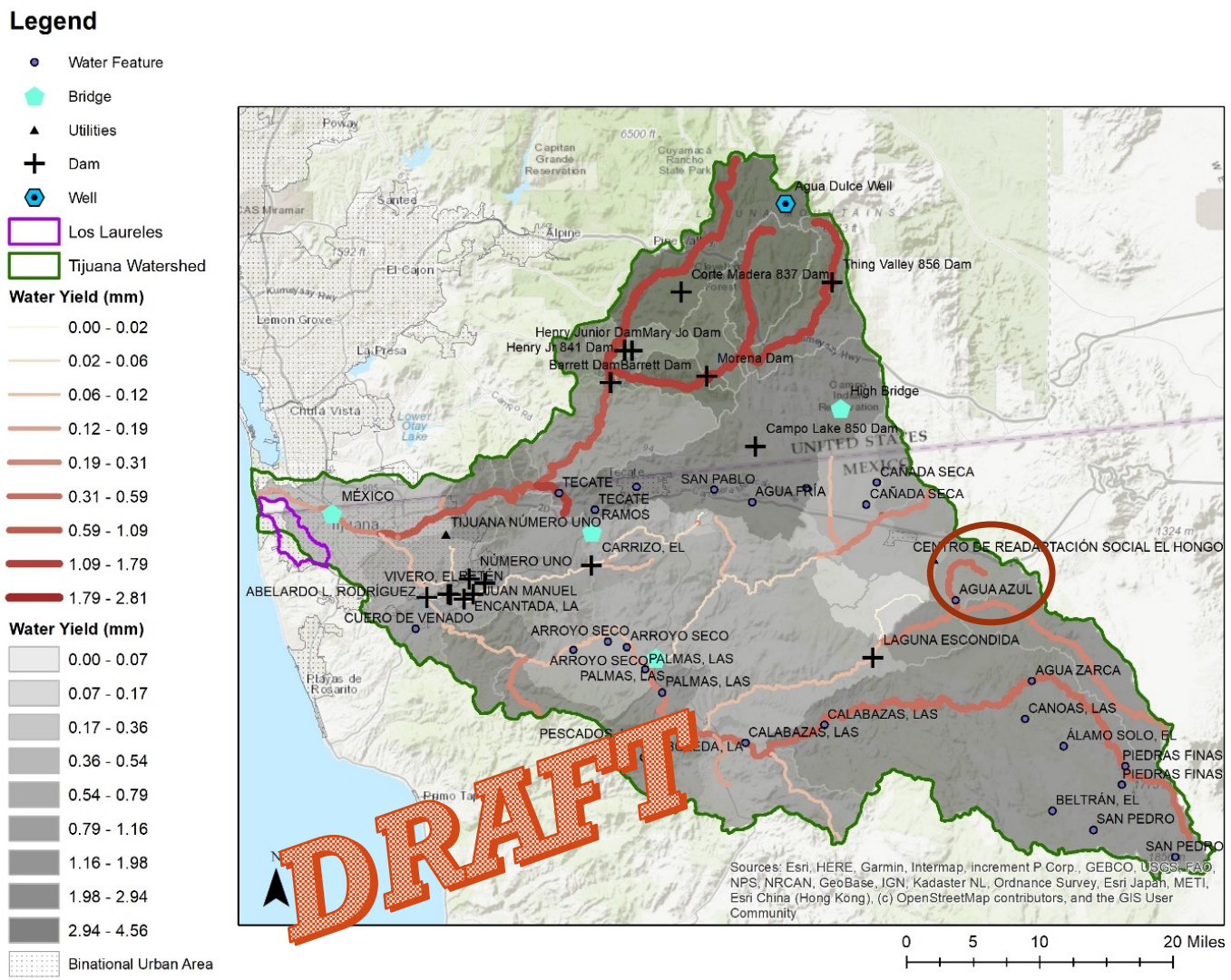
SWAT ITERATION RUN USING 30-M DEM OF WATERSHED, HISTORIC BEHI LAND USE, AND LOW-RESOLUTION FAO SOILS DATASETS



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GROUNDWATER MODEL UPDATE

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Search

California Water Science Center

San Diego Hydrogeology

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Regional Water-balance Model

A regional water-balance model can be used to partition runoff and recharge into streamflow components, base flow and spatially varying groundwater recharge on the basis of climate and streamflow measurements, and estimates of recharge.

A basin-scale approach for assessing water resources in a semiarid environment: San Diego region, California and Mexico

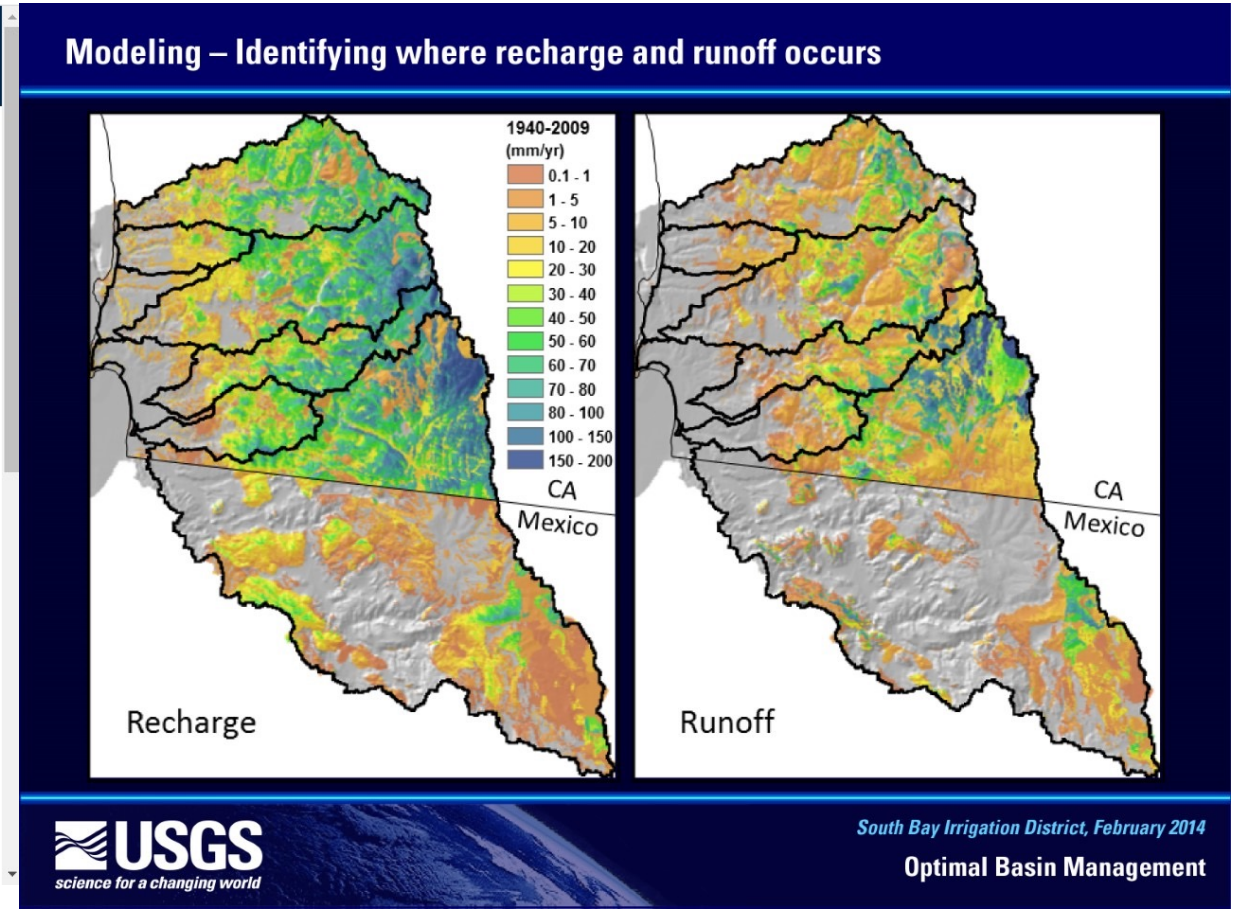
Many basins throughout the world have sparse hydrologic and geologic data, but have increasing demands for water and a commensurate need for integrated understanding of surface and groundwater resources. This paper demonstrates a methodology for using a distributed parameter water-balance model, gaged surface-water flow, and a reconnaissance-level groundwater flow model to develop a first-order water balance. Flow amounts are rounded to the nearest 5 million cubic meters per year.

The San Diego River basin is 1 of 5 major drainage basins that drain to the San Diego coastal plain, the source of public water supply for the San Diego area. The distributed parameter water-balance model (Basin Characterization Model) was run at a monthly timestep for 1940–2009 to determine a median annual total water inflow of 120 million cubic meters per year for the San Diego region. The model was also run specifically for the San Diego River basin for 1982–2009 to provide constraints to model calibration and to evaluate the proportion of inflow that becomes groundwater discharge, resulting in a median annual total water inflow of 50 million cubic meters per year. On the basis of flow records for the San Diego River at Fashion Valley (US Geological Survey gaging station 11023000), when corrected for upper basin reservoir

Project Chief: Wes Danskin
Phone: 619-225-6132
Email: wdanskin@usgs.gov

Welcome to the United States Geological Survey (USGS) San Diego Hydrogeology project website, which provides geologic and hydrologic information for the transboundary San Diego–Tijuana area, USA and Mexico. This website provides background information about the project; a variety of news items; a large amount of data, in particular for USGS multiple-depth, monitoring-well sites; geologic and hydrologic models; and additional resources including photos, illustrations, and references. Last updated: April 2016

Some additional data may be



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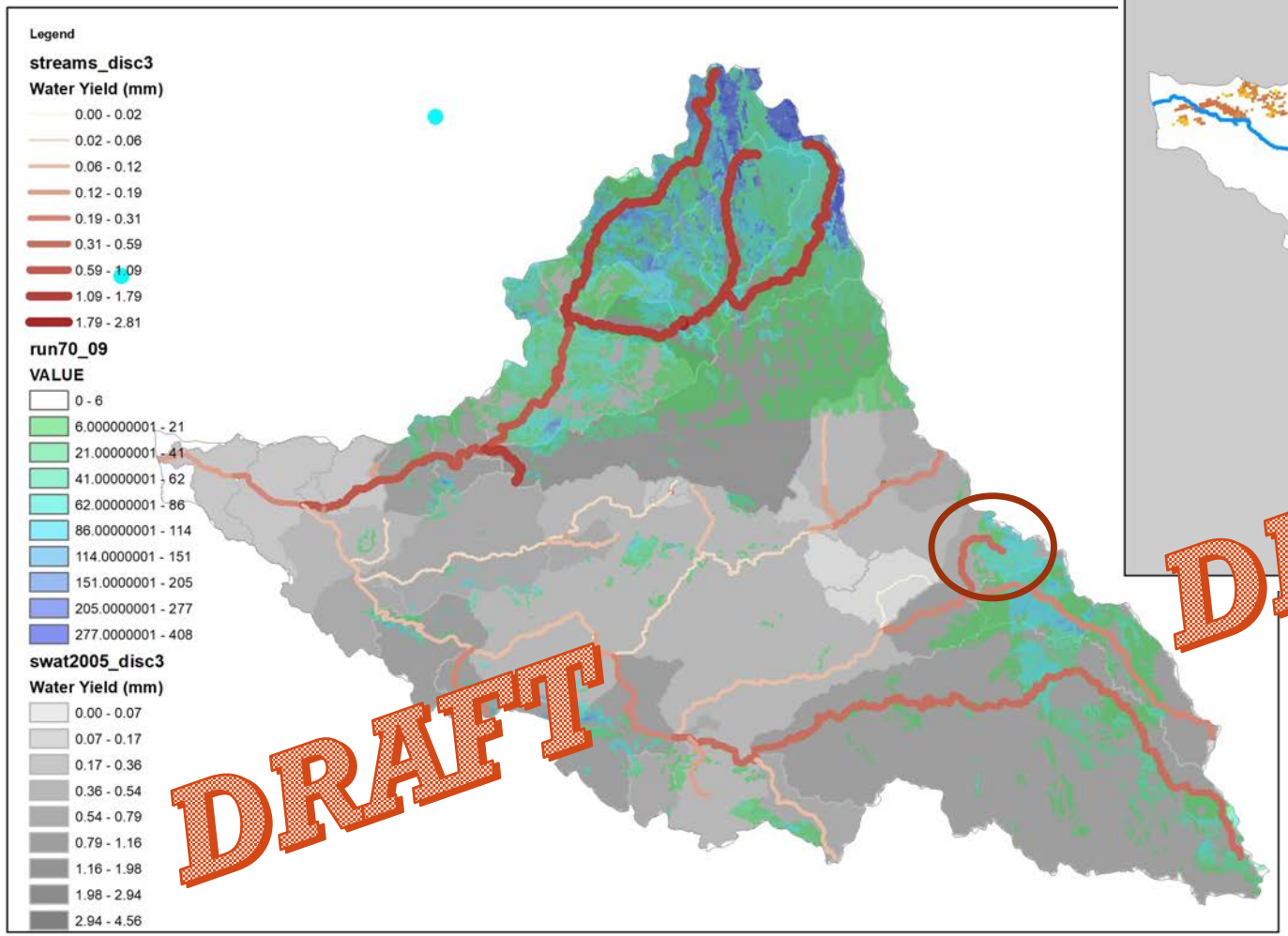
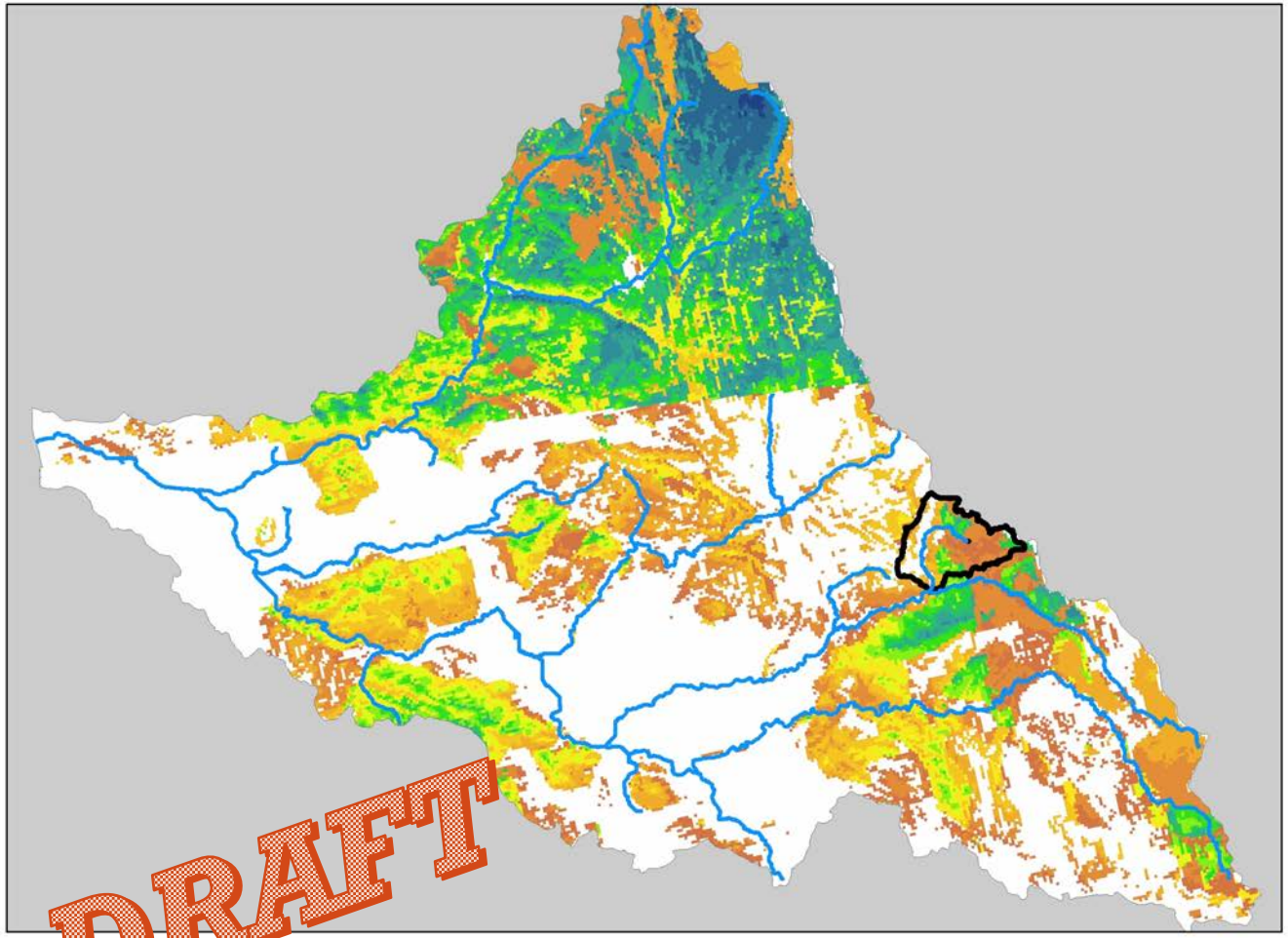
GROUNDWATER MODEL UPDATE BY CALIFORNIA WATER SCIENCE CENTER



RUNOFF



RECHARGE

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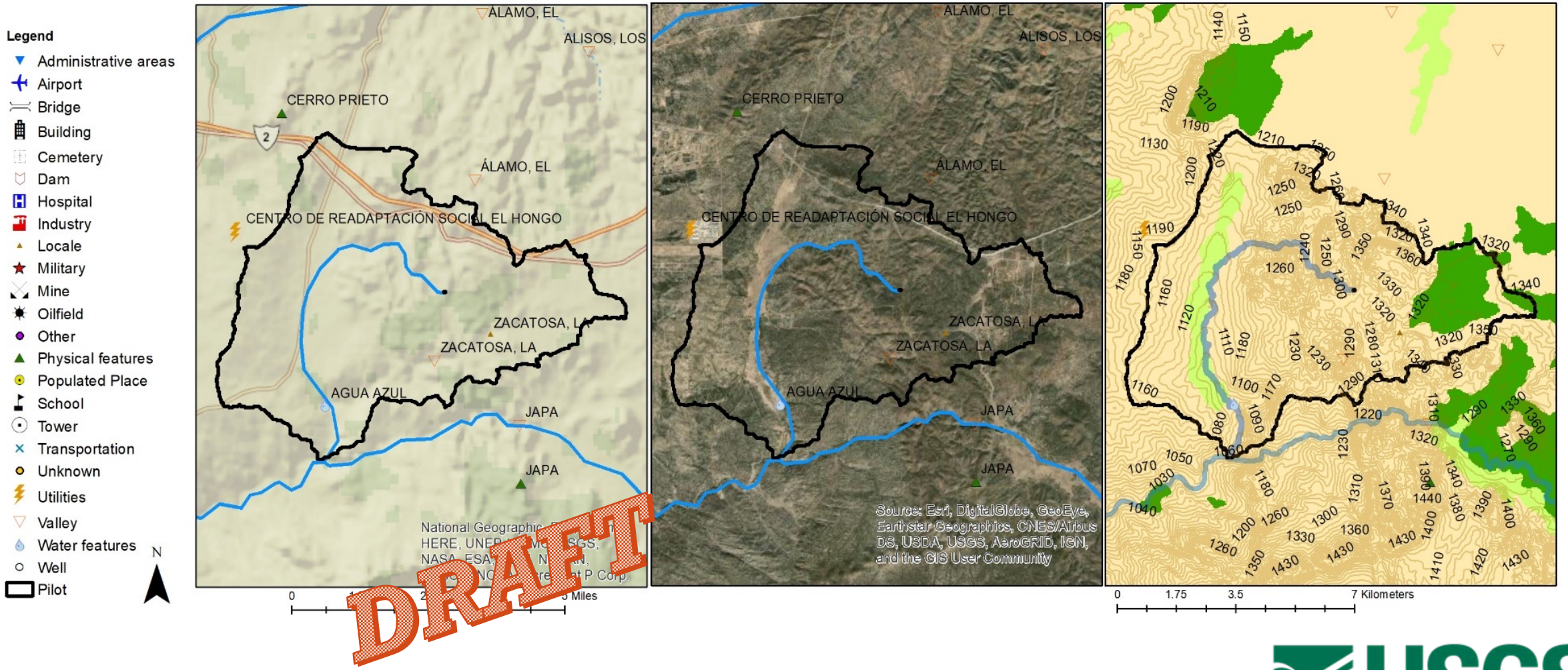
PILOT STUDY AREA: *AGUA AZUL*



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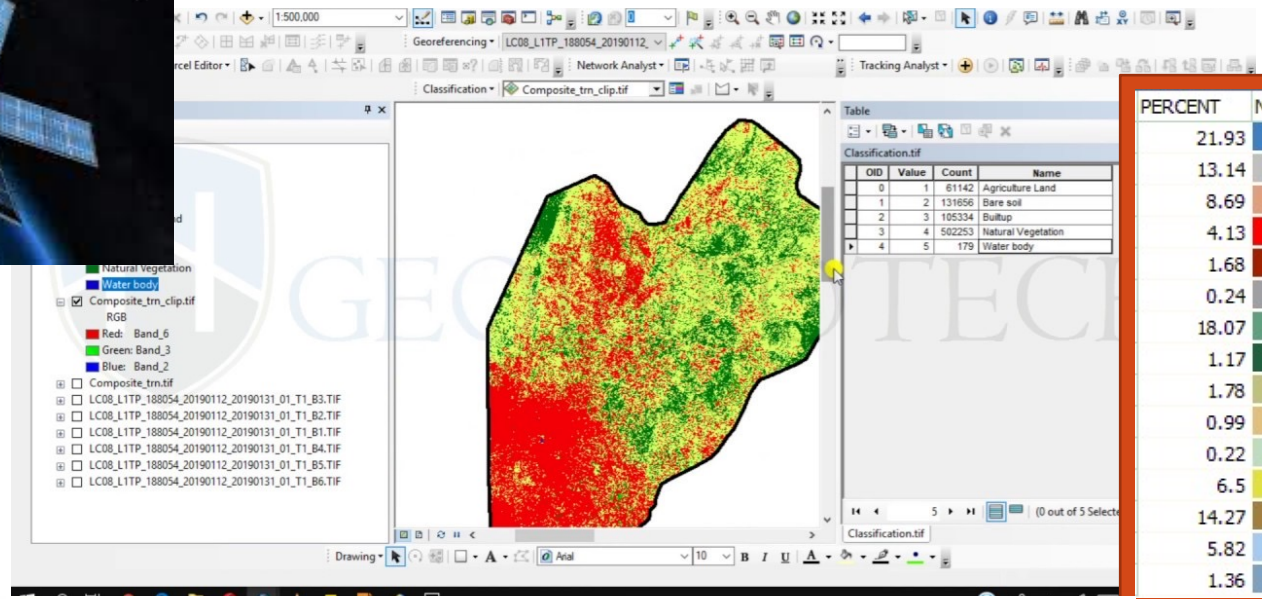
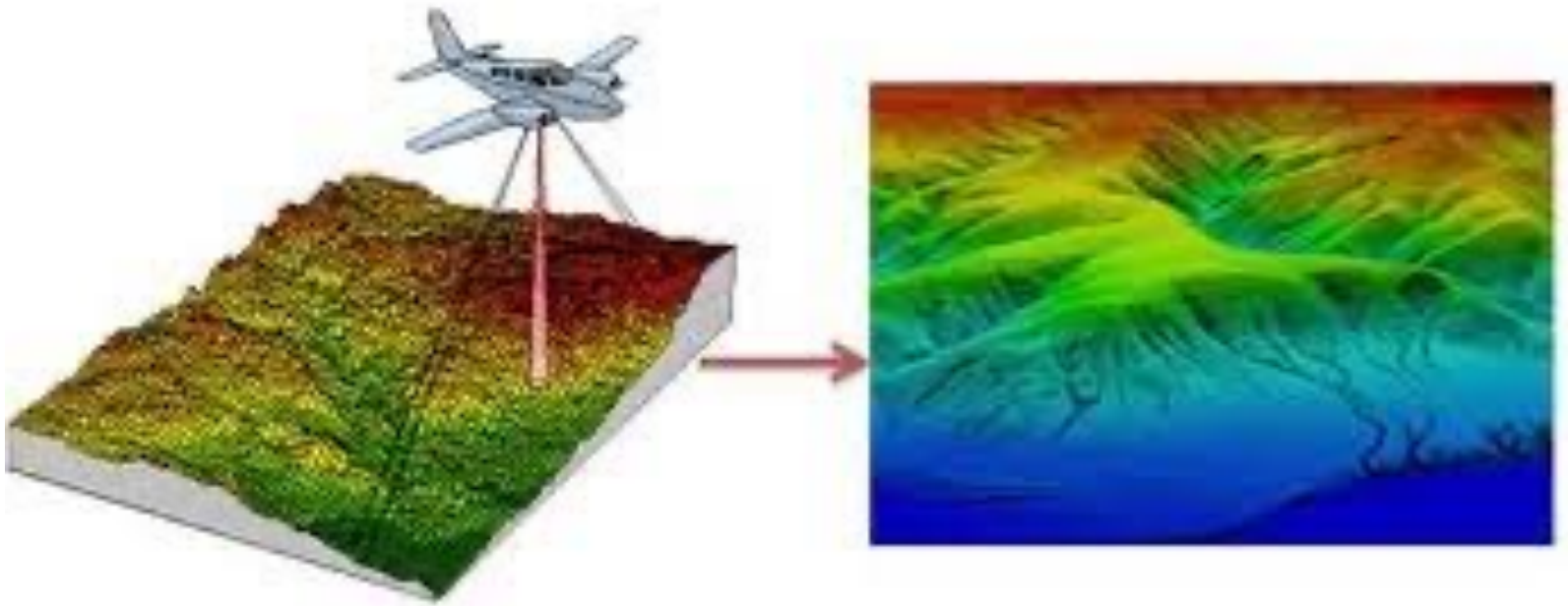
LAND USE / LAND COVER (LULC) & TERRAIN MAPPING





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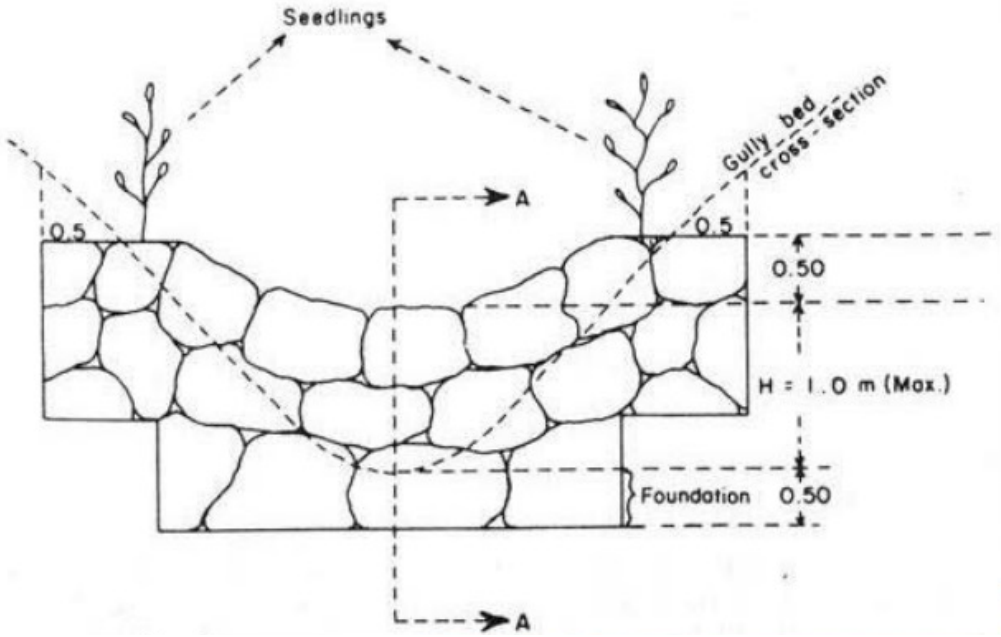

FAO (1986)

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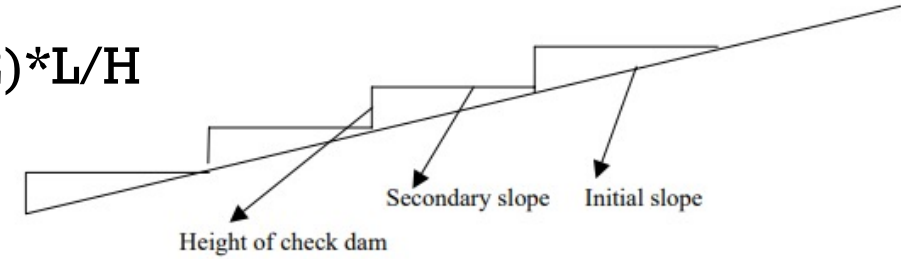
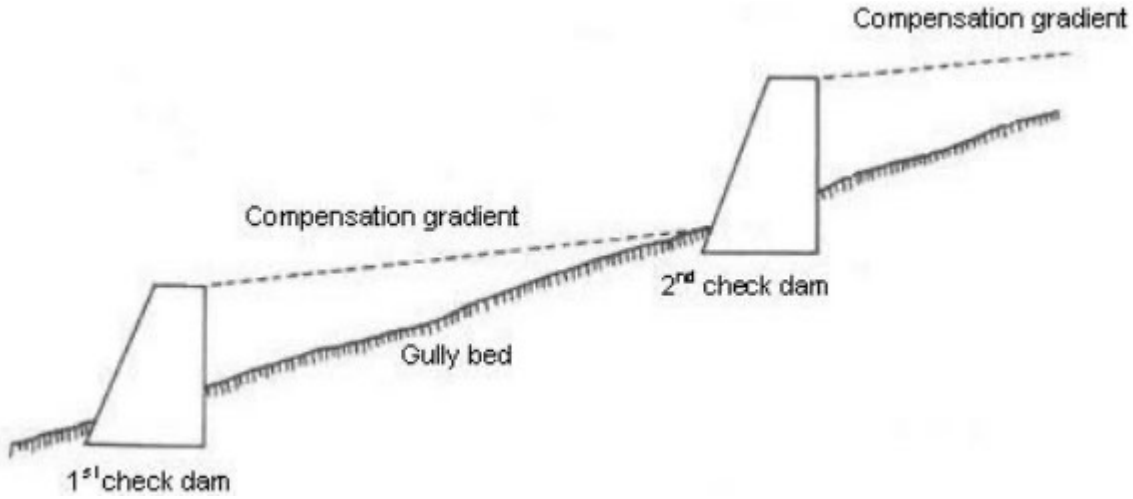
- **Number of check dams:**

N.O.C.D. = (S1-S2)*L/H



Where,
S1 = original slope%
S2 = secondary slope
H = height of check dams
L – length of channel

- **Spacing:**



FAO (1986)

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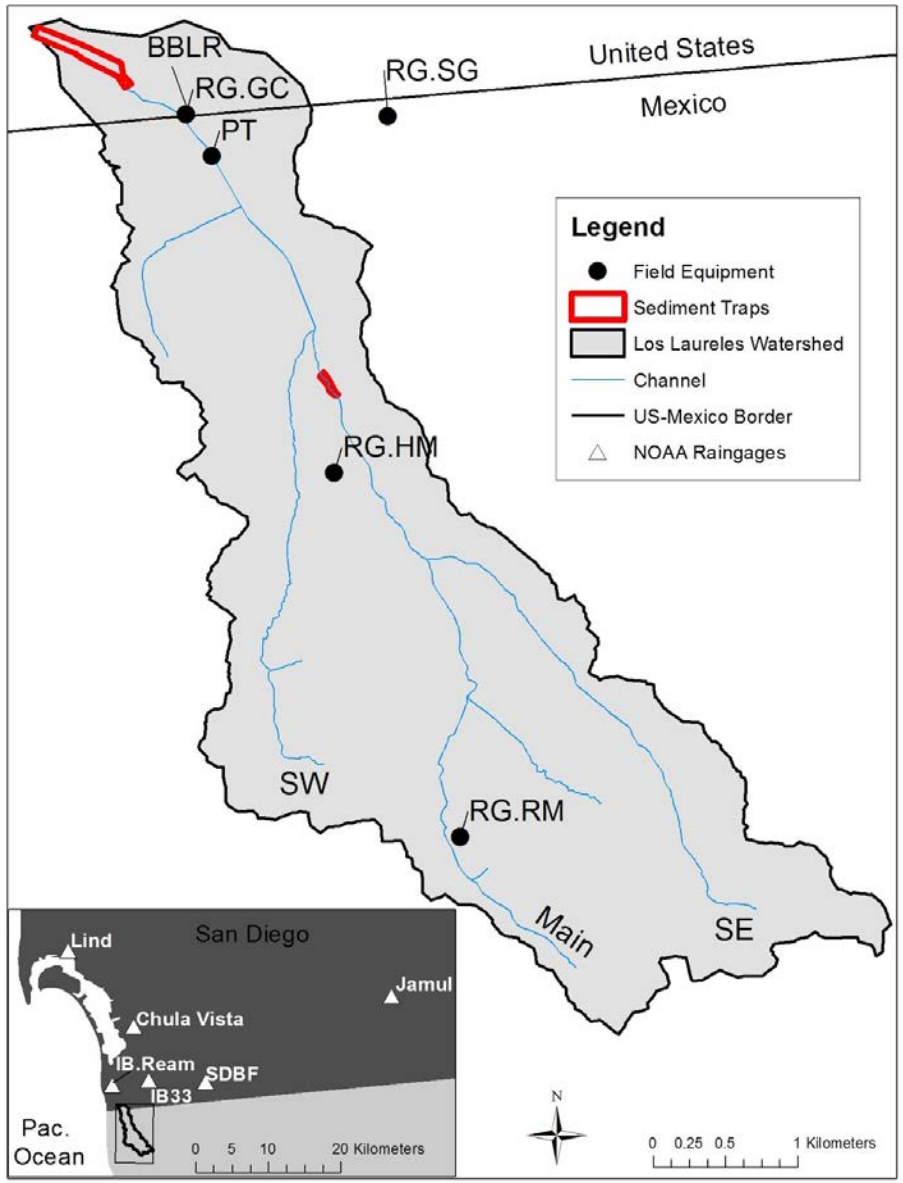
FIELD EQUIPMENT



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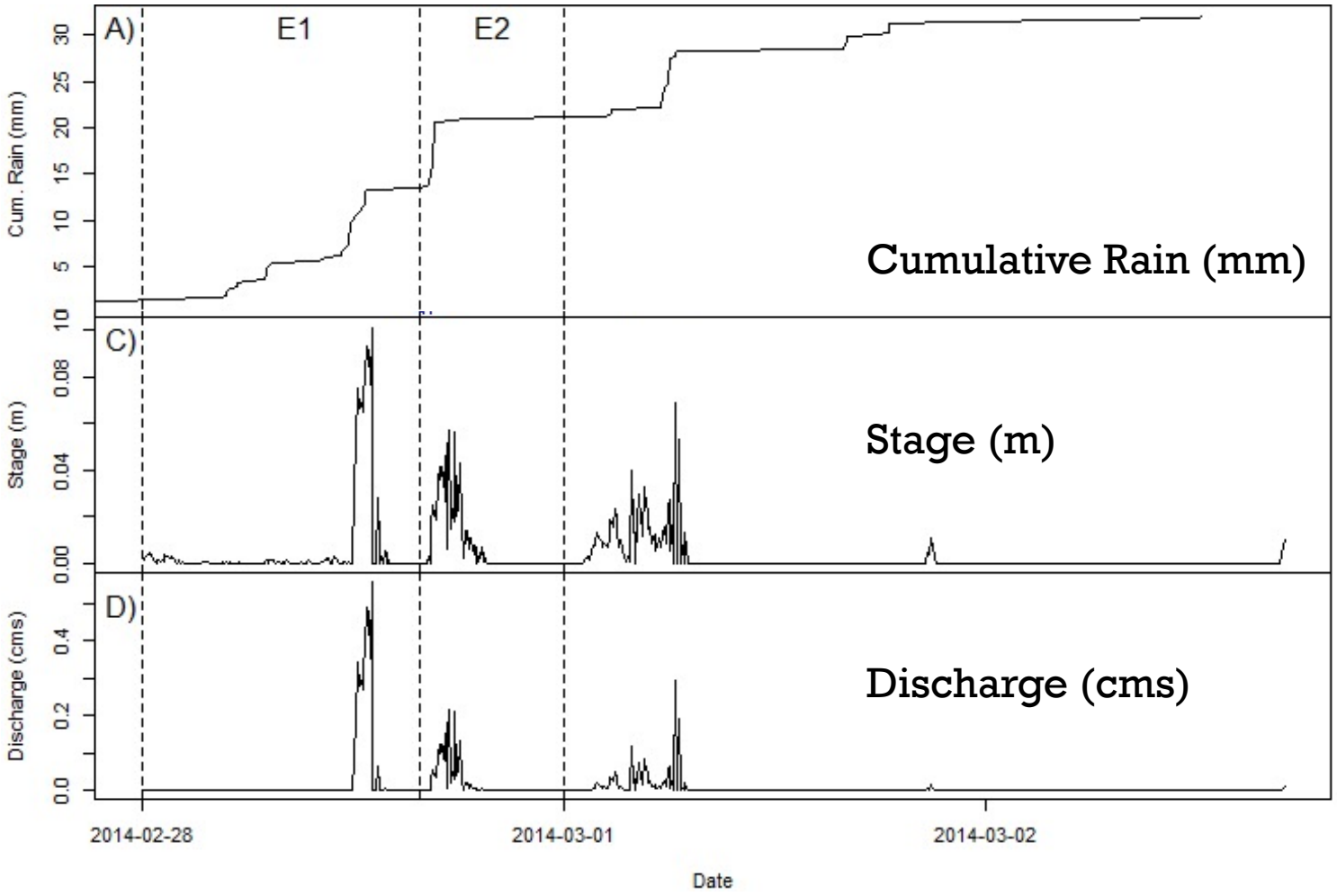
RAINFALL – RUNOFF

(CALIBRATION DATA)



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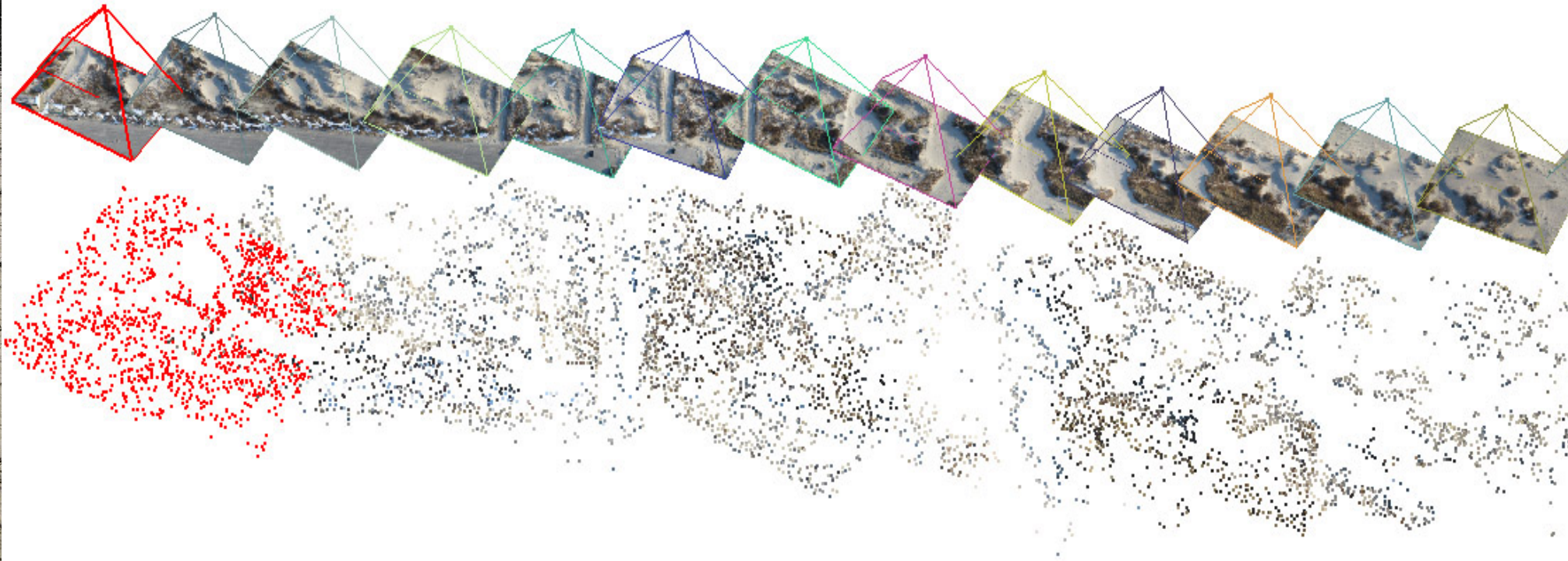
STRUCTURE FROM MOTION

(3D PHOTO-RECONSTRUCTION)

UAS (Drone)

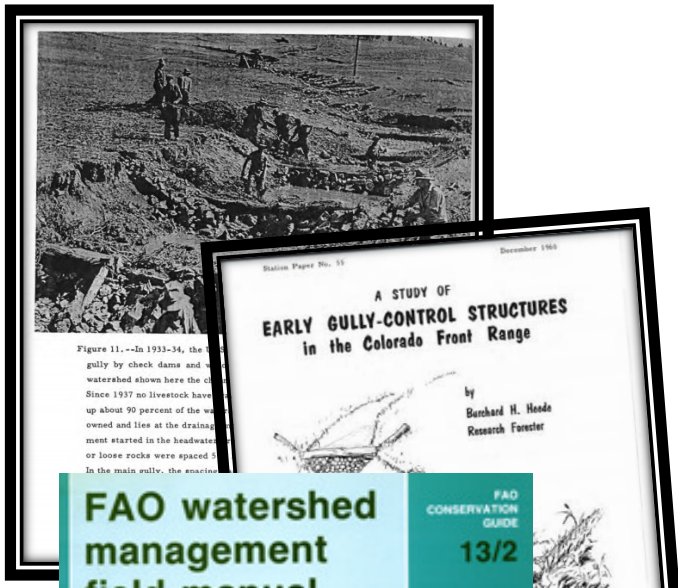
Ground Control Points dGPS

Point cloud (Agisoft)



CONTRACT CONSTRUCTION

Check dams and gabions



Training

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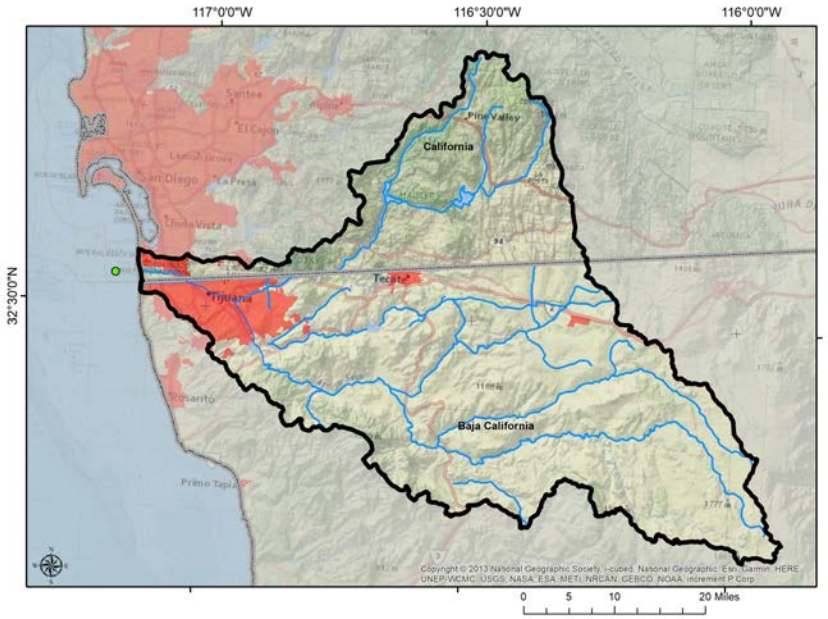
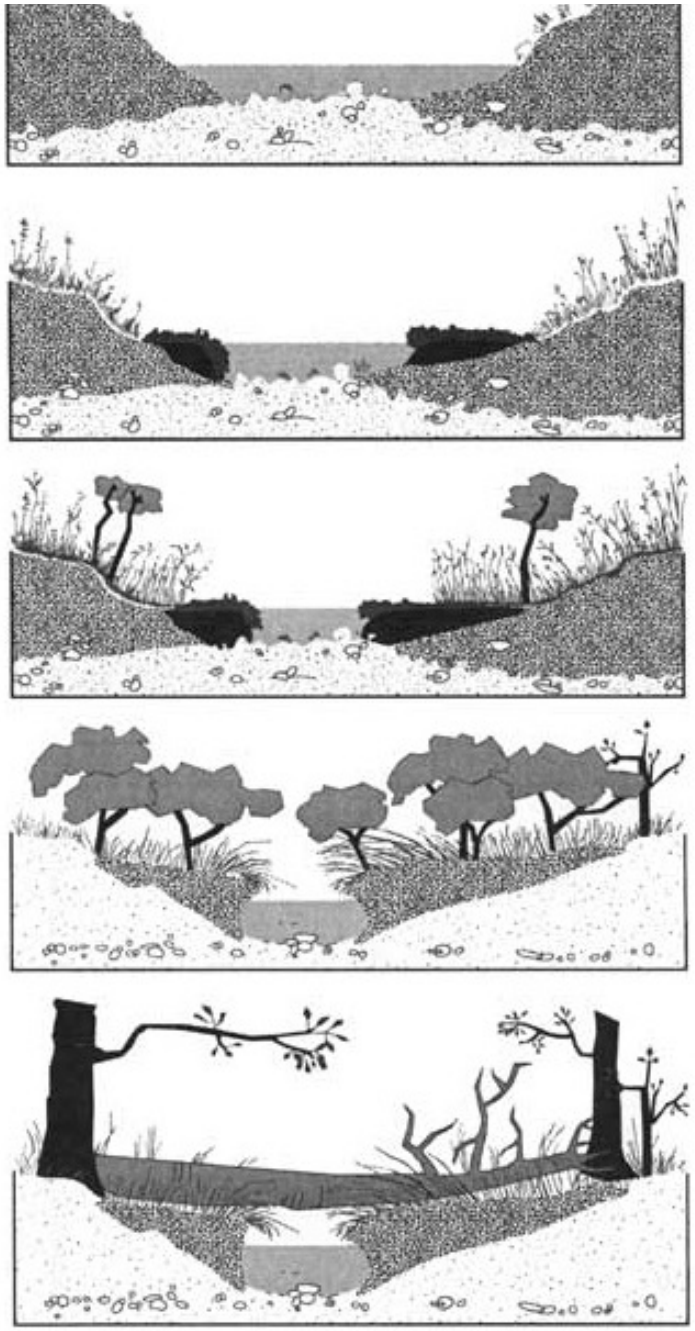
CAMARADERÍA





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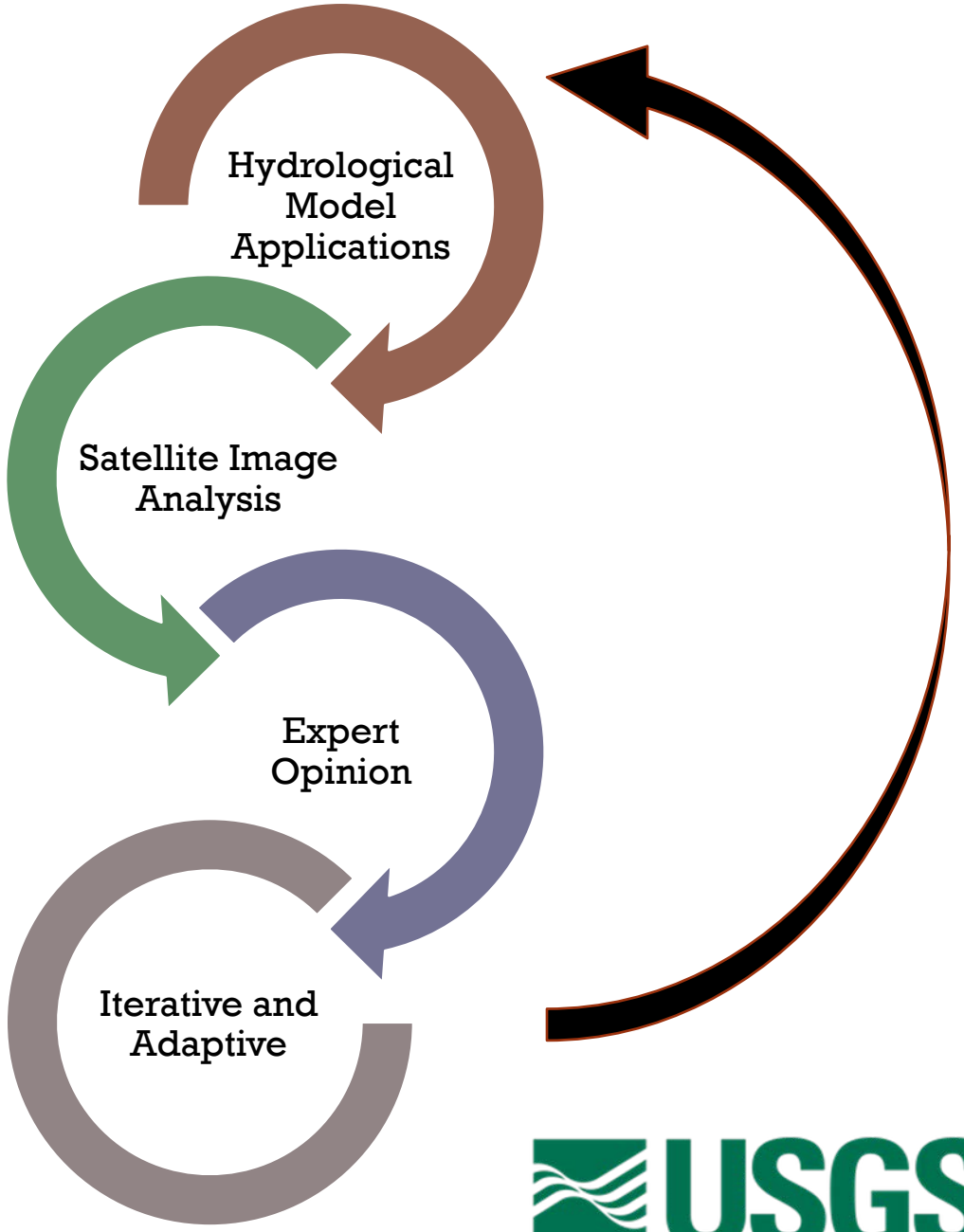
SCENARIOS… NEXT STEPS



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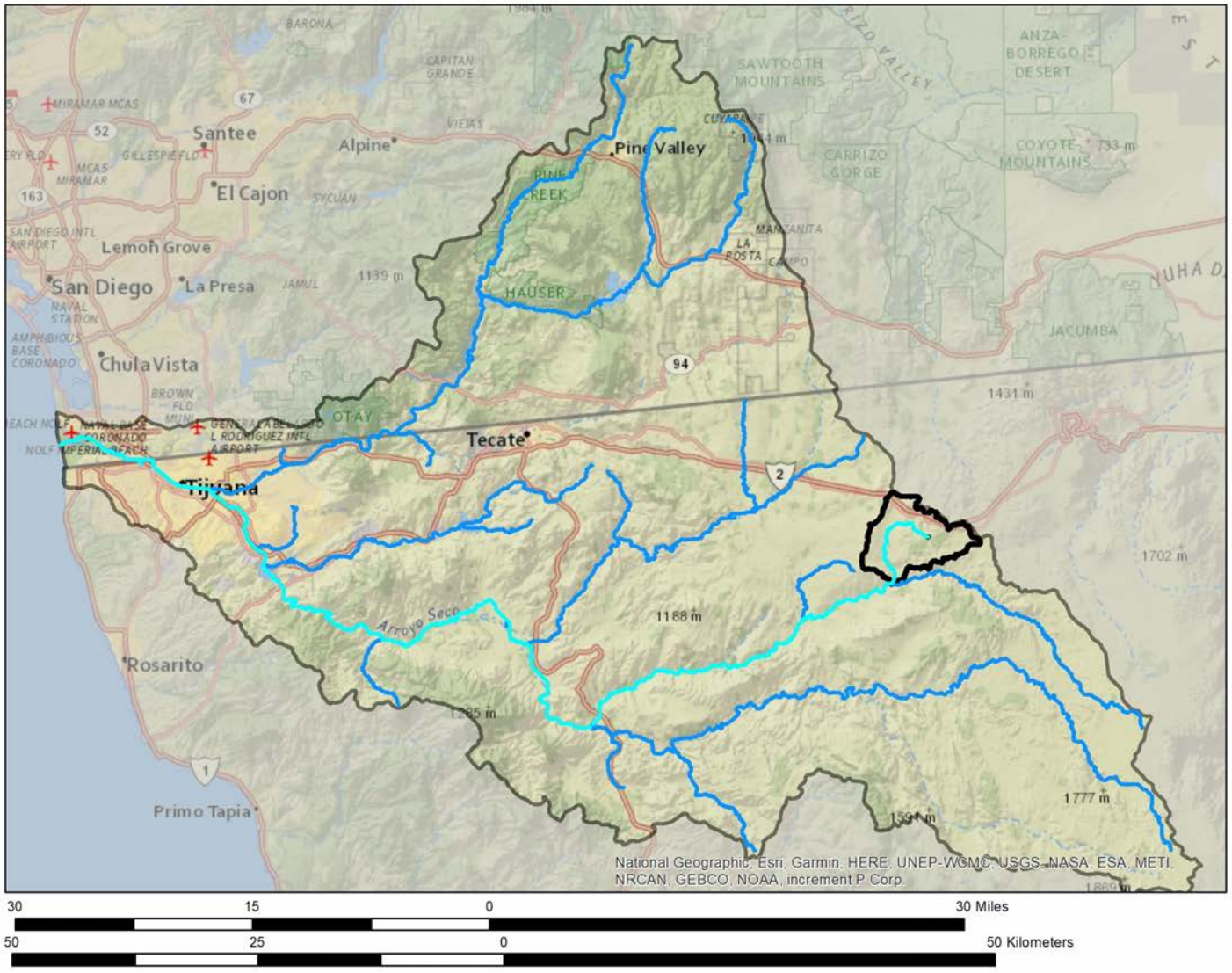
EXPANSION… NEXT STEPS



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TAKE HOME

- Managing water resources on a watershed basis makes sense—environmentally, financially, and socially.
- Watersheds models can span administrative boundaries and portray how actions throughout a transboundary watershed might impact communities and help them to become more climate resilient.
- Products of shared watershed analyses allow all stakeholders to envision future scenarios of management and identify mutual goals or strategies
- **Social relationships** promote success where the **institutional knowledge** can be shared for everyone's benefit

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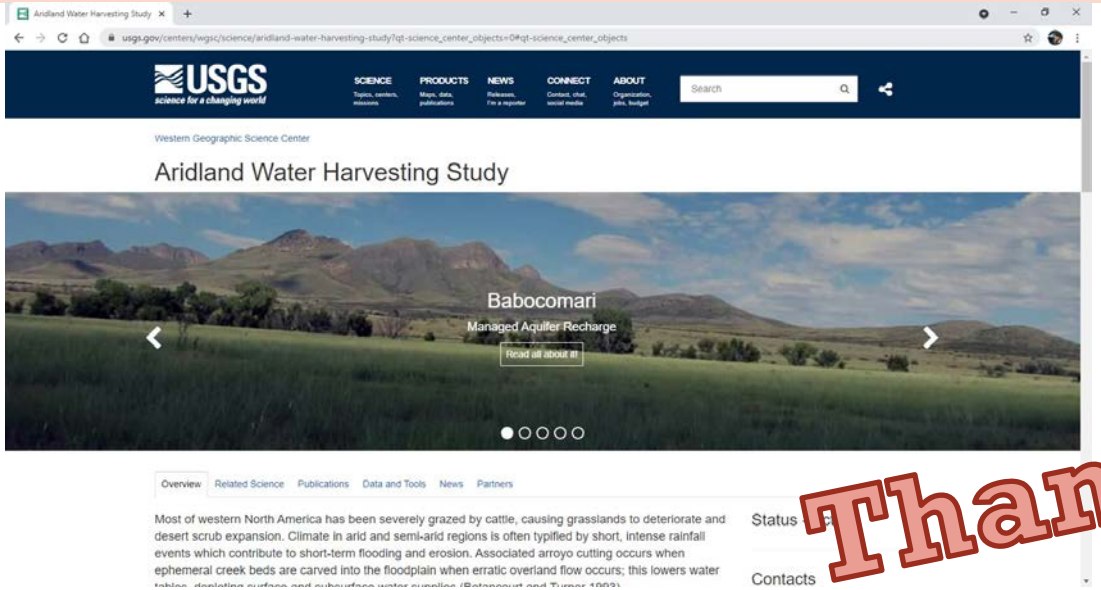
Land Change Science Program

Want to learn more about the USGS Aridland Water Harvesting Study?

https://usgs.gov/WGSC/Aridlands



Want to learn more about partnerships, people, & research in the Sky Islands?

USGS Public Lecture in March, posted online:
https://www.usgs.gov/media/videos/pubtalk-32021-a-jaguars-field-dreams

Thank you!

Want to find out more about what we're doing in Ambos Nogales?

Online Workshop ● July 8-9, 2021

"GREEN INFRASTRUCTURE IN AMBOS NOGALES: TODAY AND TOMORROW"

Contact francisco.lara@asu.edu for registration form.

Want to contact me or access publications?

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https://www.usgs.gov/staff-profiles/laura-m-norman