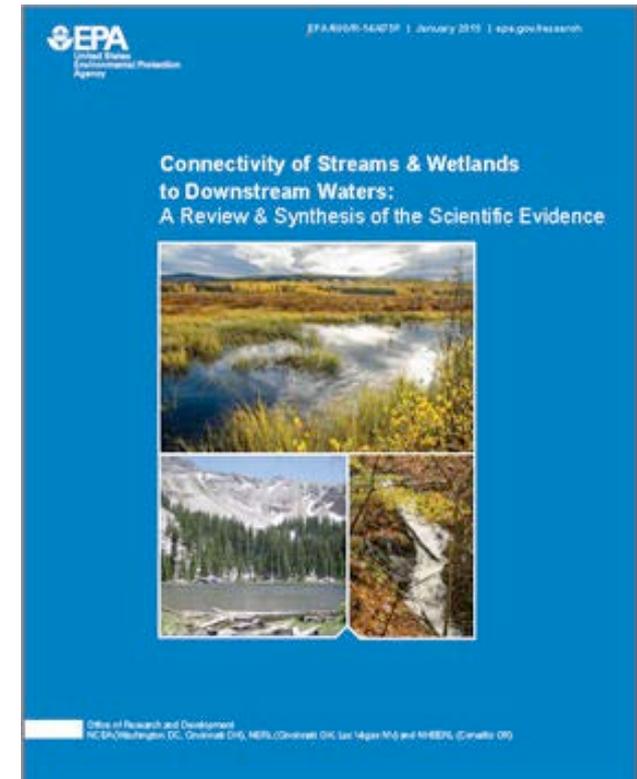
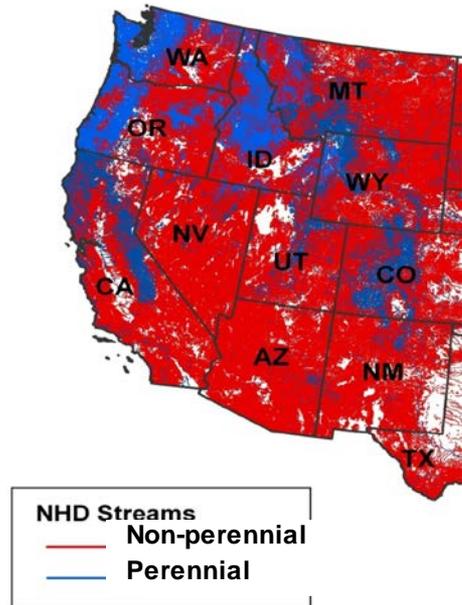


Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence



David Goodrich¹, Lainie Levick¹, William Kepner², Laurie Alexander² & 15 other Authors²

¹USDA-Agricultural Research Service

²US-EPA-Office of Research and Development



OVERVIEW

- **Background on Clean Water Act**
 - Judicial confusion
 - Reviews of scientific progress on stream connectivity
 - Definitions
- **Focus on Ephemeral & Intermittent (EI) streams in the SW**
- **Hydrologic characteristics**
 - Examples and video
- **Function of Ephemeral & Intermittent (EI) streams**
- **Examples of EI stream connectivity to downstream waters**
- **Conclusions**

Background – Clean Water Act (1972)

- To restore and maintain the chemical, physical, and biological integrity of the nation's waters
 - Applies to waters with a "significant nexus" to "navigable waters"
 - But also defines this term as "Waters of the US" including territorial seas (WOTUS)
 - Administered by EPA and Army COE
 - Some regulations interpreting the 1972 law have included water features such as intermittent streams, playa lakes, prairie potholes, sloughs and wetlands as "waters of the United States."

Background – Clean Water Act (1972)

- Supreme Court (4 – 1 - 4) decision in *SWANCC* (2001) and *Rapanos* (2006) raised questions about the scope of CWA



Alito Roberts Scalia Thomas Kennedy Breyer Ginsburg Souter Stevens

Government can regulate land that is adjacent to a "relatively permanent body of water" and has a "continuous surface connection with that water, making it difficult to determine where the water ends and the wetland begins."

FROM THE OPINION
BY JUSTICE
ANTONIN SCALIA

Government's reach extends to wetlands adjacent to "all identifiable tributaries that ultimately drain into large bodies of water," even temporary ponds and manmade drains.

FROM THE OPINION
BY JUSTICE JOHN
PAUL STEVENS

Agreed with the plurality to return the two cases to lower courts for further deliberation but disagreed that only "permanent bodies of waters" are subject to regulation. Also said that remote tributaries that have a "significant nexus" to a navigable waterway can be protected.

NYTimes,
20 June 2006

Background – Clean Water Act (1972)

- Post *Rapanos* (2006) lower court decisions were all over the map and resulted in further confusion on how to regulate WOTUS
- Conflicting Supreme Court opinions on stream *permanence*, the ephemeral ARS Walnut Gulch Experimental Watershed, and existing interagency work with ARS prompted EPA to work with ARS-SWRC to:
 - Review and summarize research on ephemeral and intermittent streams in the arid and semiarid SW
 - Levick, et al. (2008) The Ecological and Hydrological Significance of Ephemeral and Intermittent Streams in the Arid and Semi-arid American Southwest. U.S. EPA and USDA/ARS Southwest Watershed Research Center, EPA/600/R-08/134, ARS/233046, 116 pp.

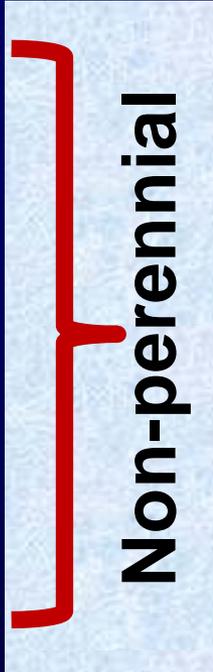
(www.tucson.ars.ag.gov/unit/Publications/PDFfiles/1981.pdf)

DEFINITIONS

EPHEMERAL STREAM: An ephemeral stream has flowing water only during, and for a short duration after, precipitation events in a typical year. ES beds are located above the water table year-round. Groundwater is not a source of water for the stream. Runoff from rainfall is the primary source of water for stream flow.

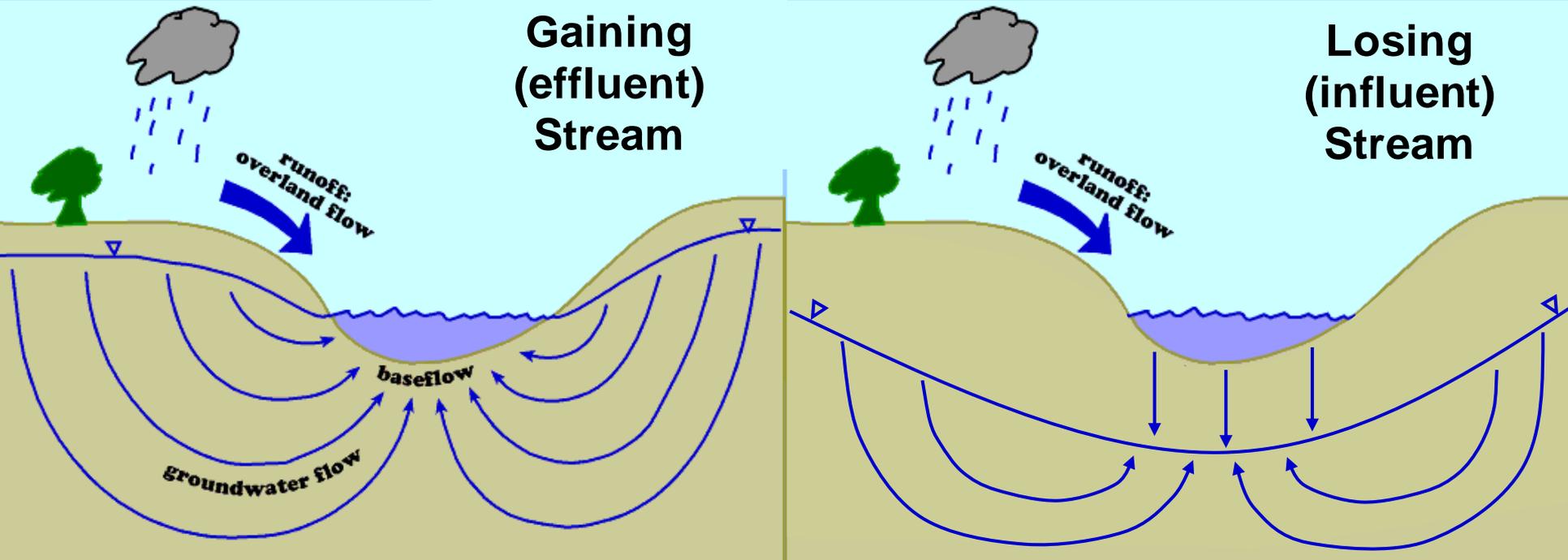
INTERMITTENT STREAM : An intermittent stream has flowing water during certain times of the year, when groundwater provides water for stream flow. During dry periods, they may not have flowing water. Runoff from rainfall is a supplemental source of water for stream flow.

PERENNIAL STREAM : A perennial stream has flowing water year-round during a typical year. The water table is located above the stream bed for most of the year. Groundwater is the primary source of water for stream flow. Runoff from rainfall is a supplemental source of water for stream flow.



Non-perennial

Typical Perennial and Non-Perennial Channel Cross Sections



Perennial reaches of a stream can become non-perennial, and vice versa, in a very short distance, as a result of differences in geology along the river (prior definitions largely ignore the spatial context)

Stream Types in the Continental US

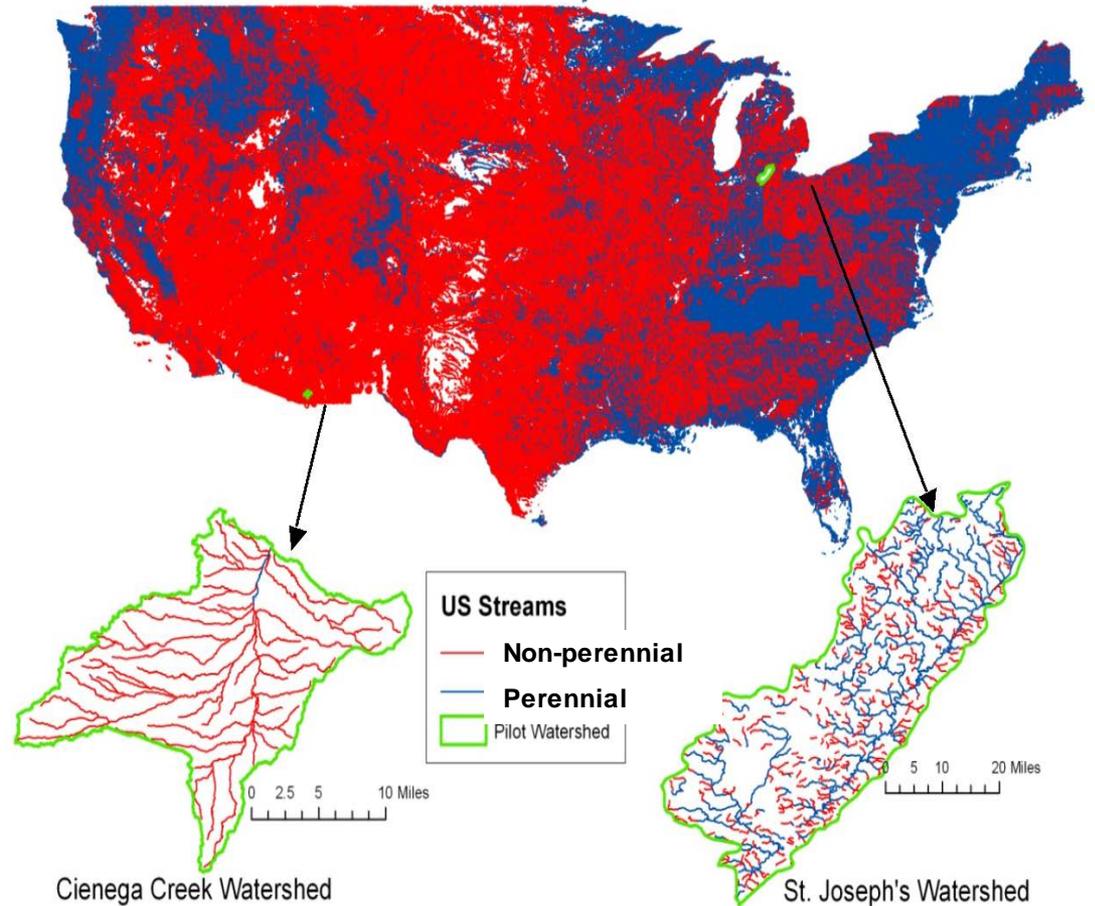
Percent Non-Perennial (Ephemeral & Intermittent)

| | |
|------------|------|
| Arizona | 94 % |
| Nevada | 89 |
| New Mexico | 88 |
| Utah | 79 |
| Colorado | 68 |
| California | 66 |
| Wyoming | 66 |
| Montana | 63 |
| Washington | 54 |
| Oregon | 51 |
| Idaho | 47 |

**** NHD stream segments are:**

- Based on 1:100,000 scale topographic maps
- Greater than 1 mile long

59% of the CONUS are Non-Perennial (EI)



Note: There are thousands of bridges / culverts on these non-perennial stream segments

The Ecological and Hydrological Significance of Ephemeral and Intermittent Streams in the Arid and Semi-arid American Southwest (Levick et al. 2008)

Primary Items Reviewed

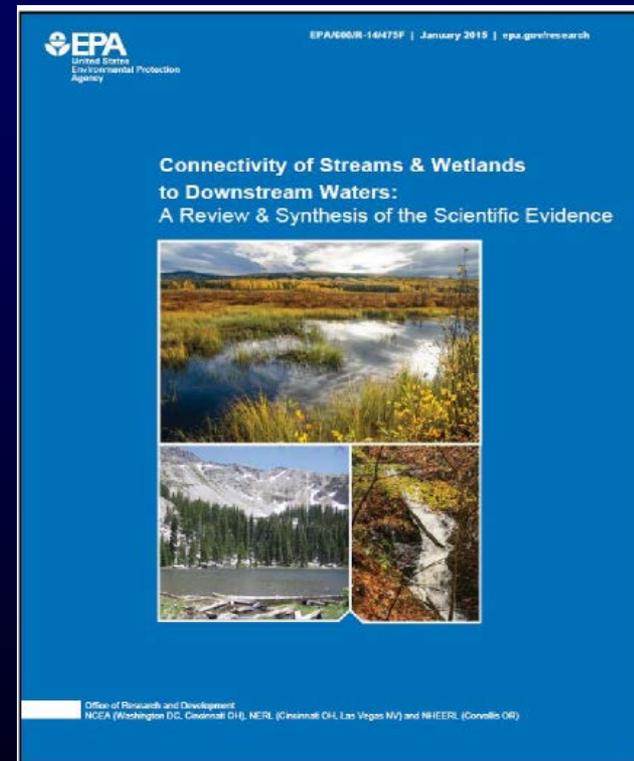
- **Location of Ephemeral and Intermittent Streams**
- **The Watershed Context**
- **Characteristics, Functions, and Ecosystem Significance**
 - **Hydrologic Features**
 - **Geomorphic Characteristics**
 - **Biogeochemical Functions**
 - **Plant Community Support**
 - **Faunal Support and Habitat**
 - **Synthesis of Functions**
- **Anthropogenic Impacts on Ephemeral / Intermittent Streams and Riparian Areas**

Over 310 publications reviewed



Background – National Level Review of Connectivity of WOTUS

- Continued confusion prompted requests by members of Congress, developers, farmers, state and local governments for more predictable methods to ID waters protected under the CWA that are consistent with peer-reviewed science
- Prompted a national effort along the lines of Levick et al. (2008) to review the current science on connectivity of streams & wetlands to downstream waters
- “Highly Influential Scientific Assessment”
- Synthesis of peer-reviewed literature
- Written for general audiences
- 1355 publications cited

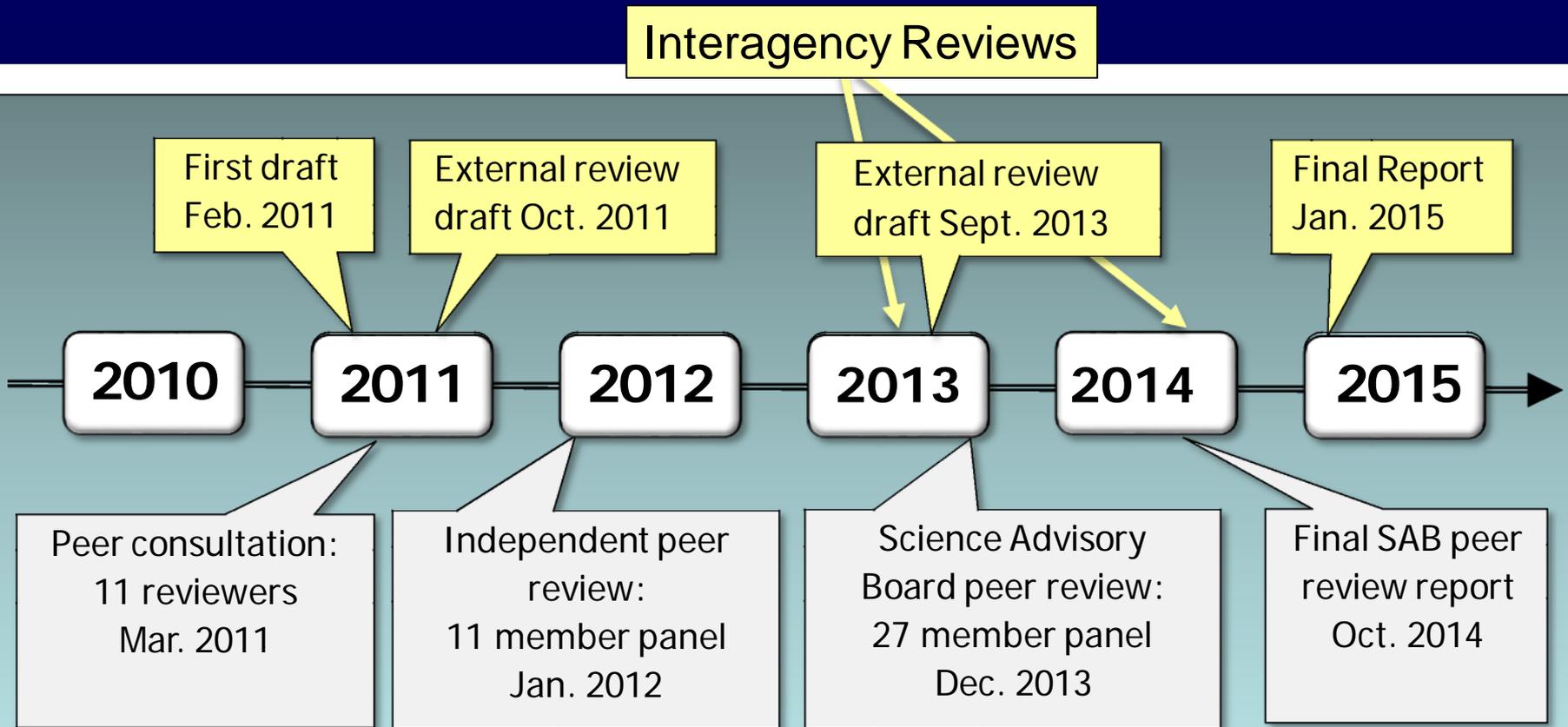


U.S. EPA. Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-14/475F, 2015.

<http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=296414&CFID=44342430&CFTOKEN=33429607>

Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence

Development & Review Timeline



Three formal peer reviews, 48 Peer Reviewers, ~133,100 public comments received & addressed

OVERVIEW

- **Background on Clean Water Act**
 - Judicial confusion
 - Reviews of scientific progress on stream connectivity
 - Definitions
- **Focus on Ephemeral & Intermittent (EI) streams in the SW**
- **Hydrologic characteristics**
 - Examples and video
- **Function of Ephemeral & Intermittent (EI) streams**
- **Examples of EI stream connectivity to downstream waters**
- **Conclusions**

Hydrologic Characteristics

- High temporal variability
 - Flash floods are common from convective rainfall
 - Daily – seasonal – interannual – interdecadal (think episodic – not continuous)
- High peak to mean annual flow ratio (Graf 1988)
 - Pennsylvania (humid): 50-year return flood event is ~ 2.5 times the mean annual flow
 - Arizona (semiarid): 50-year return flood is about ~280 times the mean annual flow.
- Channel transmission losses (influent streams)
 - Runoff decreases with increasing drainage area but varies with geology

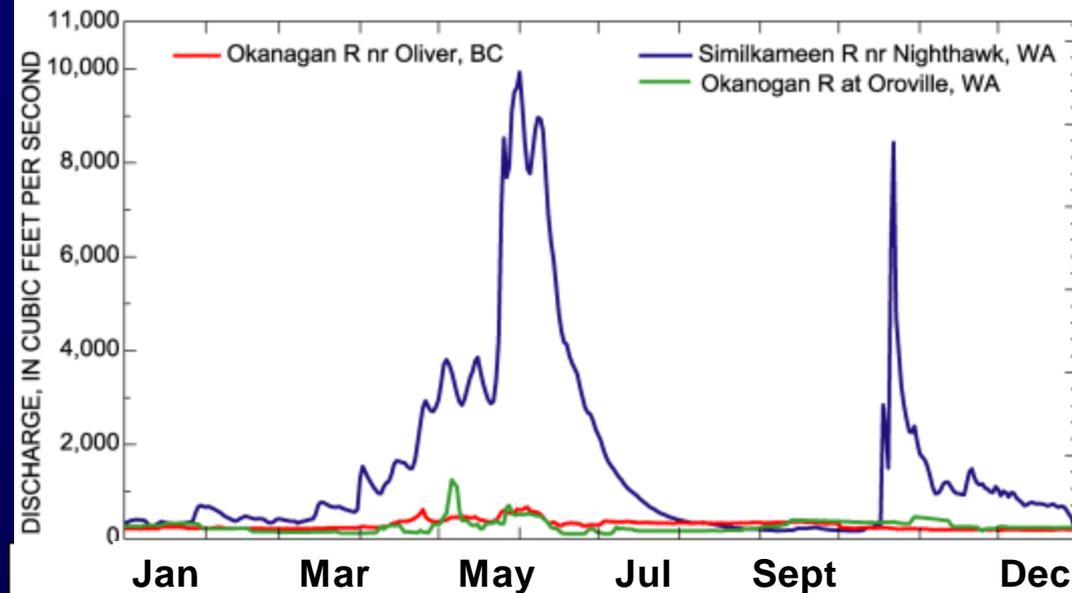
Annual Hydrograph 2003 Calendar Year

Eastern Washington

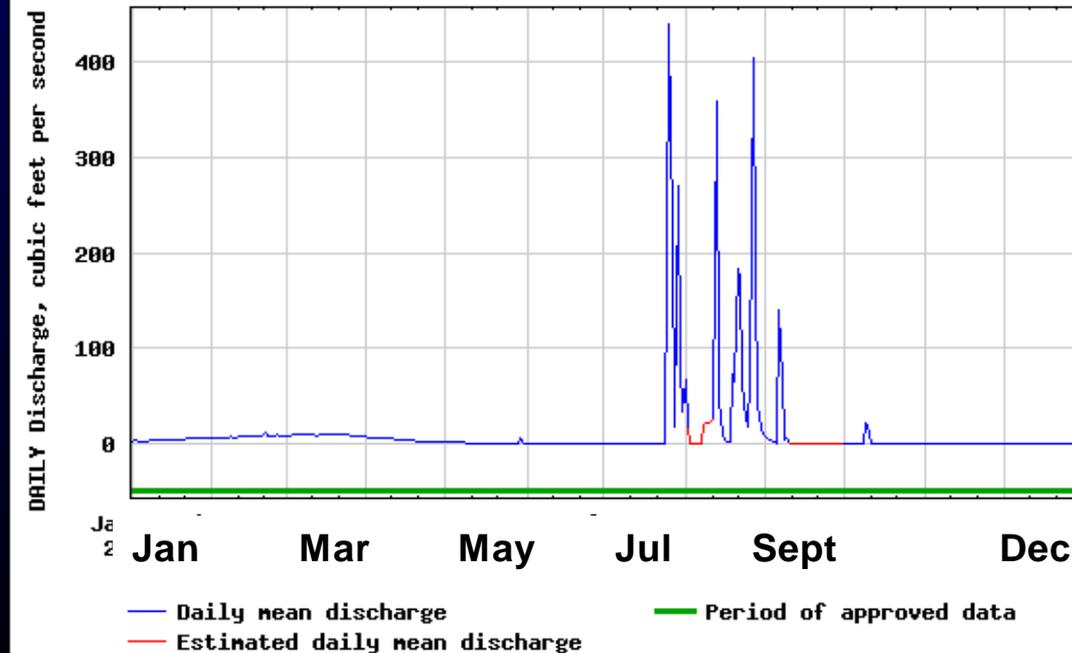
- Spring / Summer snowmelt
- Summer T-Storms
- Fall/Winter – Frontal storms

Southeast Arizona

- Summer thunderstorms
- Short duration

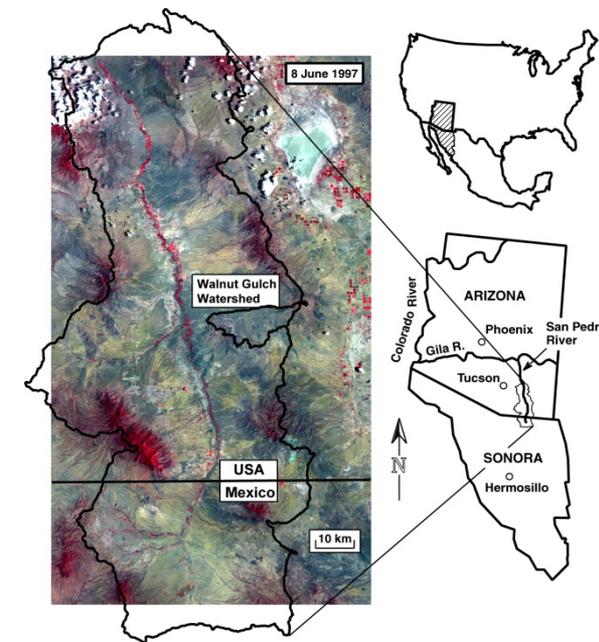
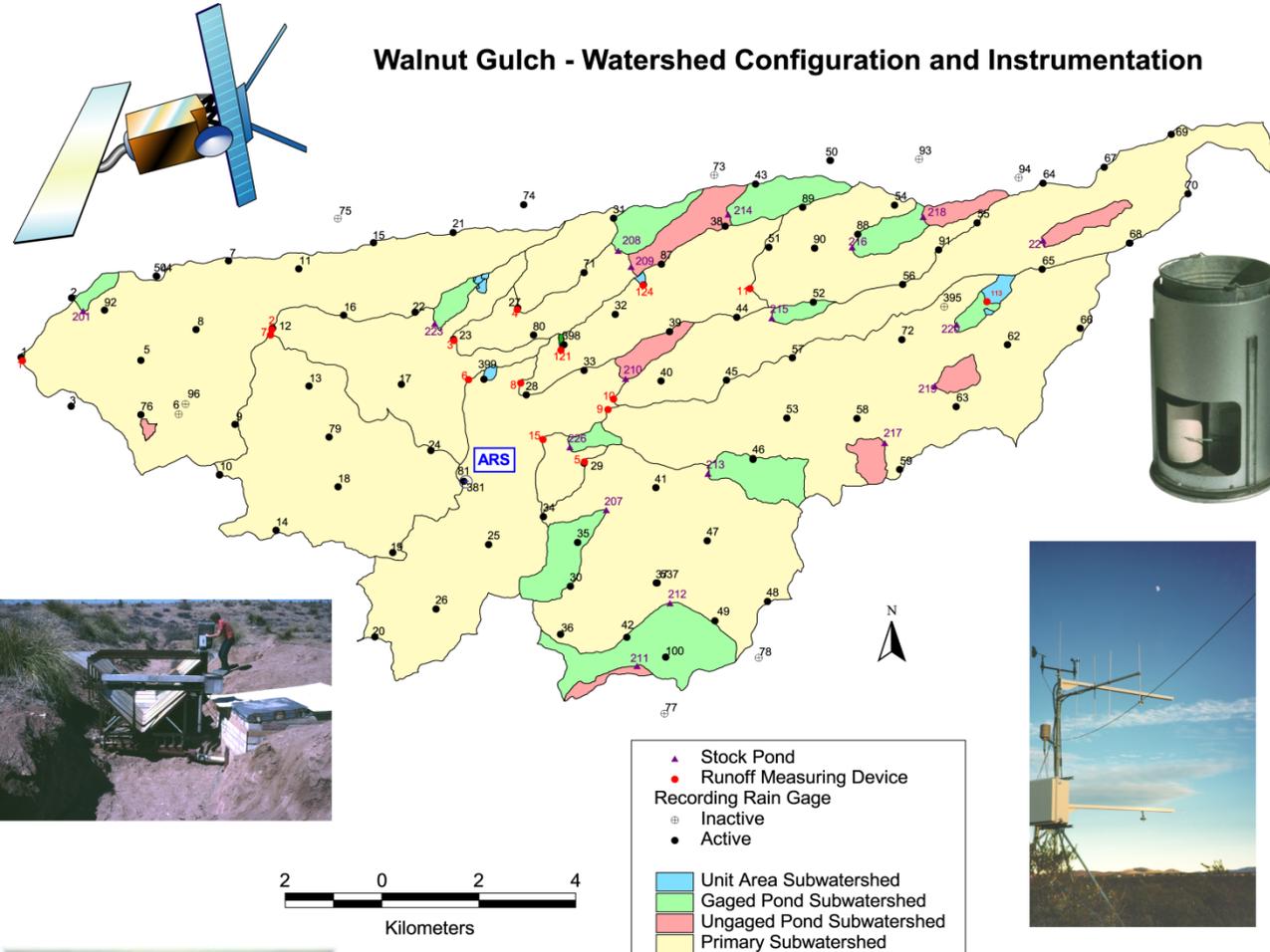


USGS 09471550 SAN PEDRO RIVER NEAR TOMBSTONE, AZ



USDA-ARS Walnut Gulch Experimental Watershed near Tombstone, SE Arizona (since 1955)

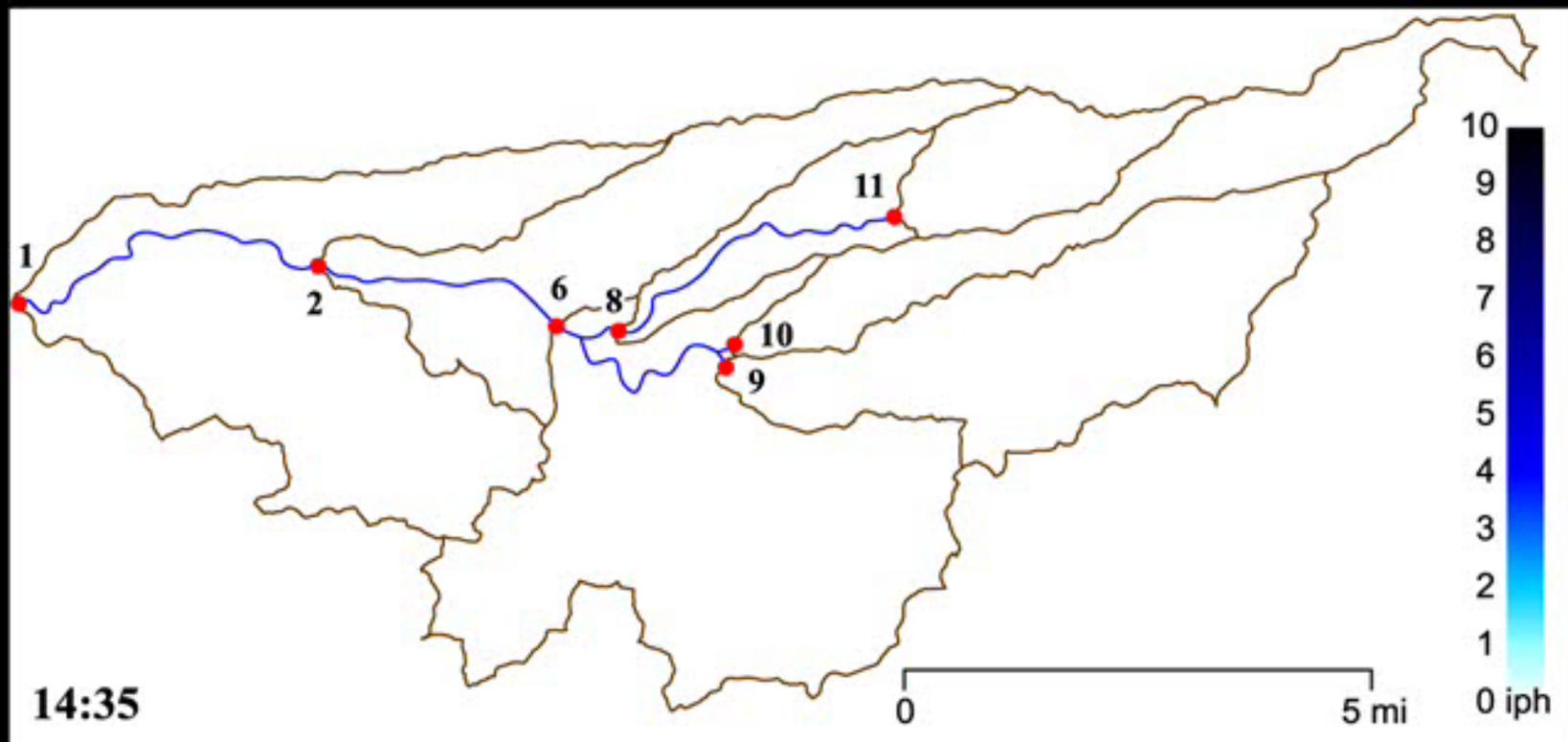
Walnut Gulch - Watershed Configuration and Instrumentation



- 60 sq. mi drainage
- 88 recording raingages
- 28 gaged subwatersheds
- Climate, sediment, carbon, vegetation, energy measurements



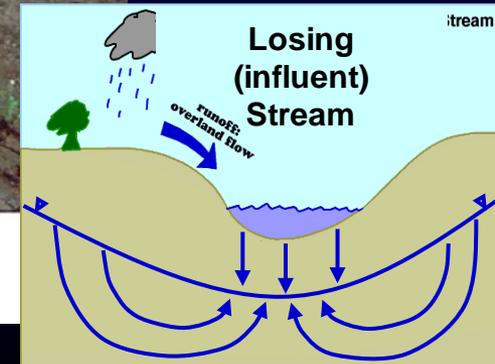
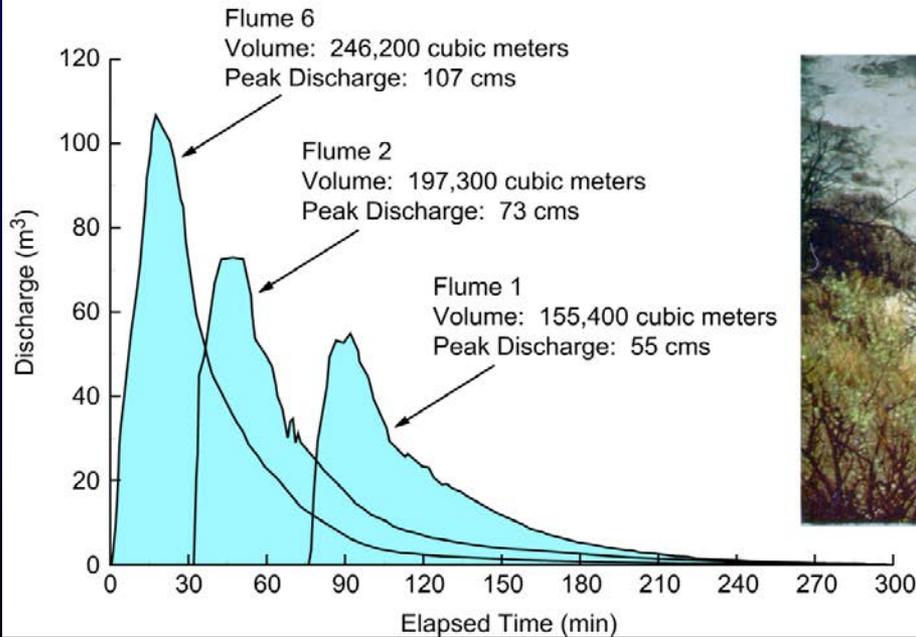
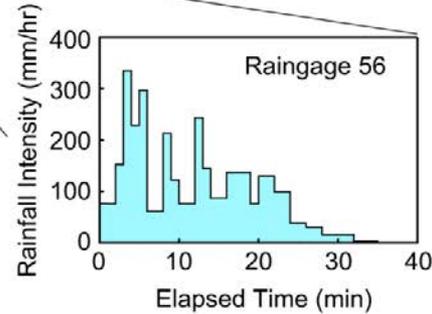
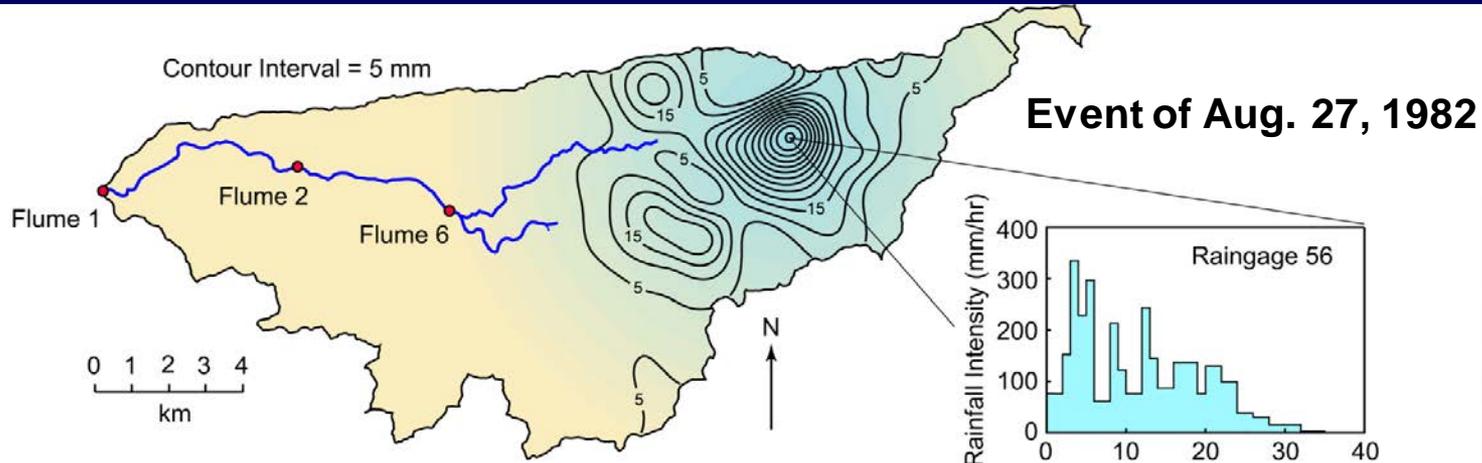
Storm, Runoff, and Channel Transmission Losses – Aug. 1, 1990



To view video of runoff open file:
Aug_1_1990_with_animation.wmv

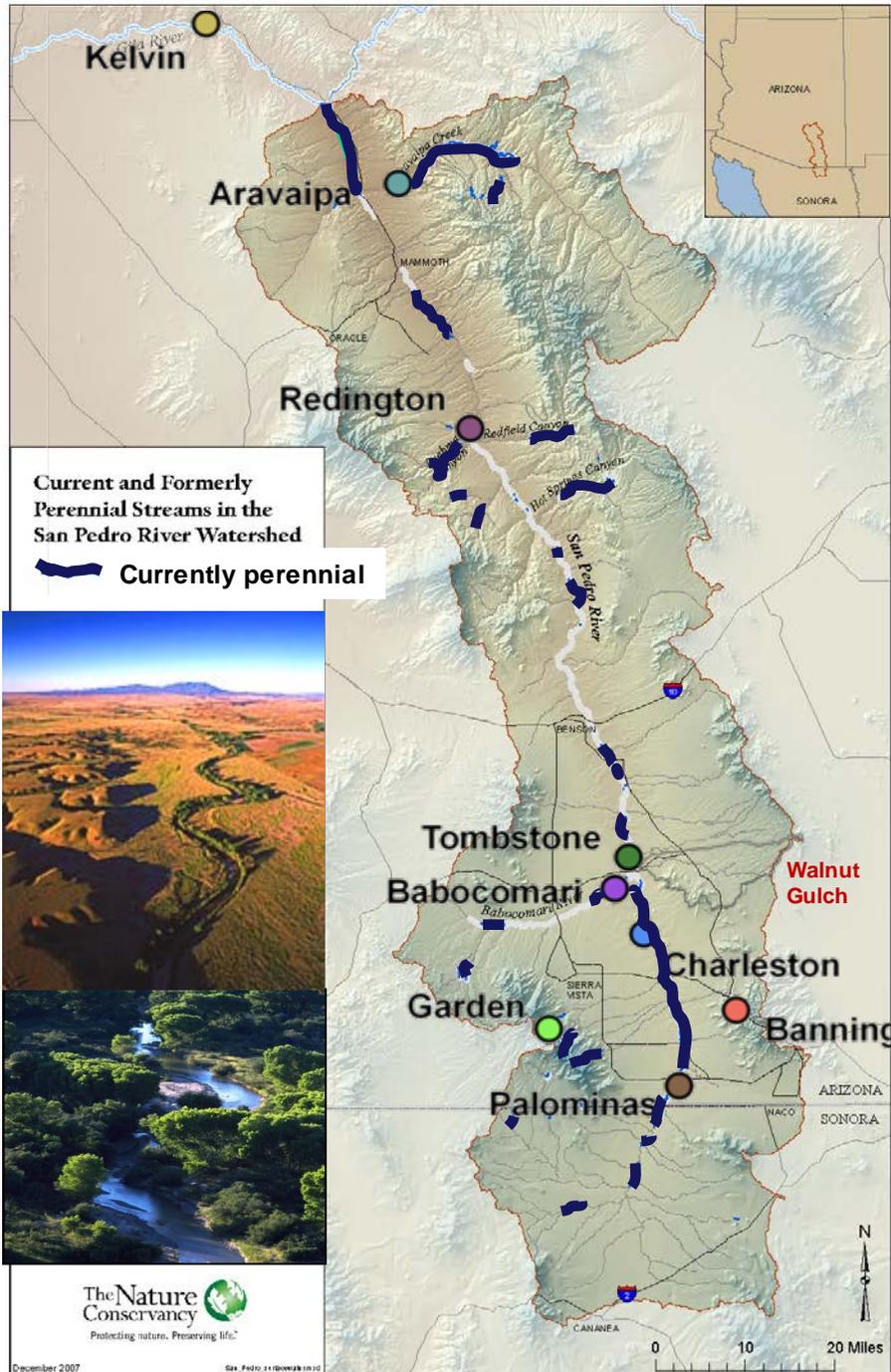
<http://www.tucson.ars.ag.gov/unit/WGWebcam/WalnutGulchWebcam.htm>

Runoff and Channel Transmission Losses



Spatial Context of Perennial Discontinuous Flow in the San Pedro (from low-flow surveys)

Perennial Streams Reaches (June '07) in the San Pedro Watershed



Function of Ephemeral & Intermittent Streams

- Like perennial streams, they are conduits for transferring water, sediment, energy, biota nutrients and pollutants through the watershed
 - Sediment mobilization, storage, transport and deposition
 - Energy dissipation of runoff
 - Biogeochemical activity & nutrient flux
- Alluvial aquifer recharge to maintain perennial flow
- Regional groundwater recharge
- Plant community support and associated species diversity
- Landscape and migratory connectivity



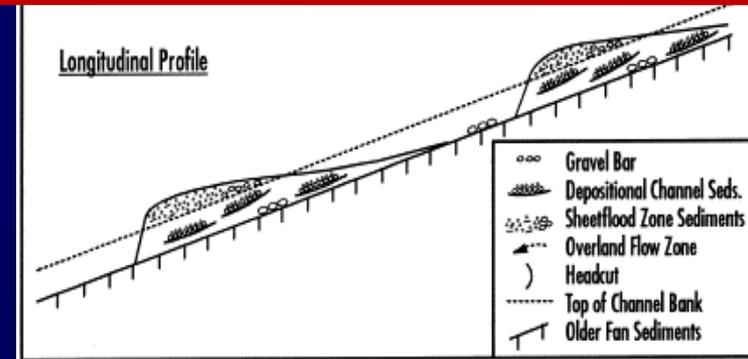
“Capillaries to Veins” analogy in watershed context



Opposite for alluvial fans

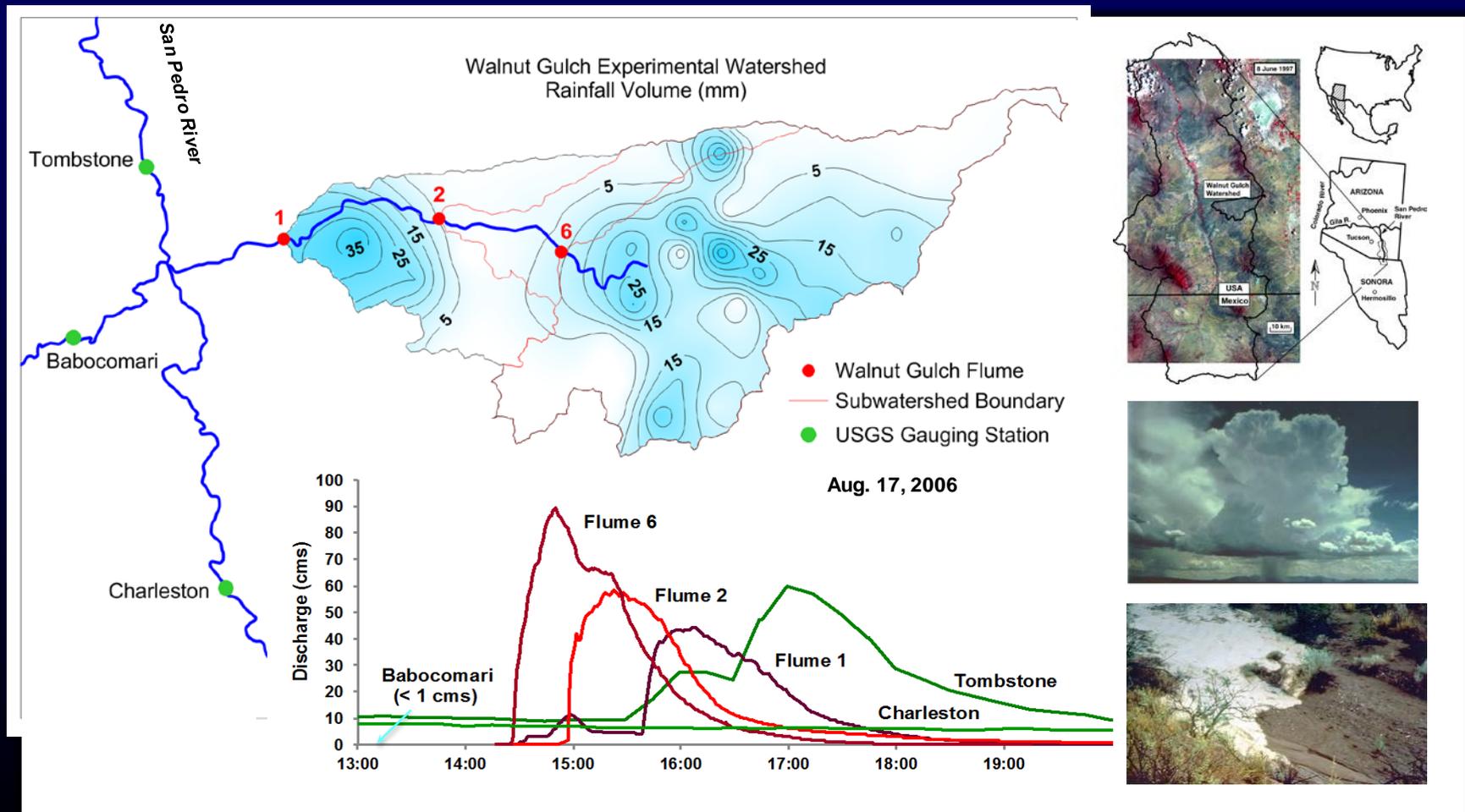
Sediment Storage, Transport, and Deposition

- Transport via episodic pulses
 - Due to short duration flash floods with transmission losses or infrequent multi-day floods
 - Sediment does not always reach the watershed outlet
 - It is remobilized during the next flow and redistributed within the watershed's channel network
 - Longer time scales need to be used in considering connectivity (e.g. WGEW study estimated sand transport of 401 and 734 m in 9 floods over two years)
 - Cumulative long-term effect is large sediment loads in downstream waters
 - Most of Southwest's impaired water designations are for sediment



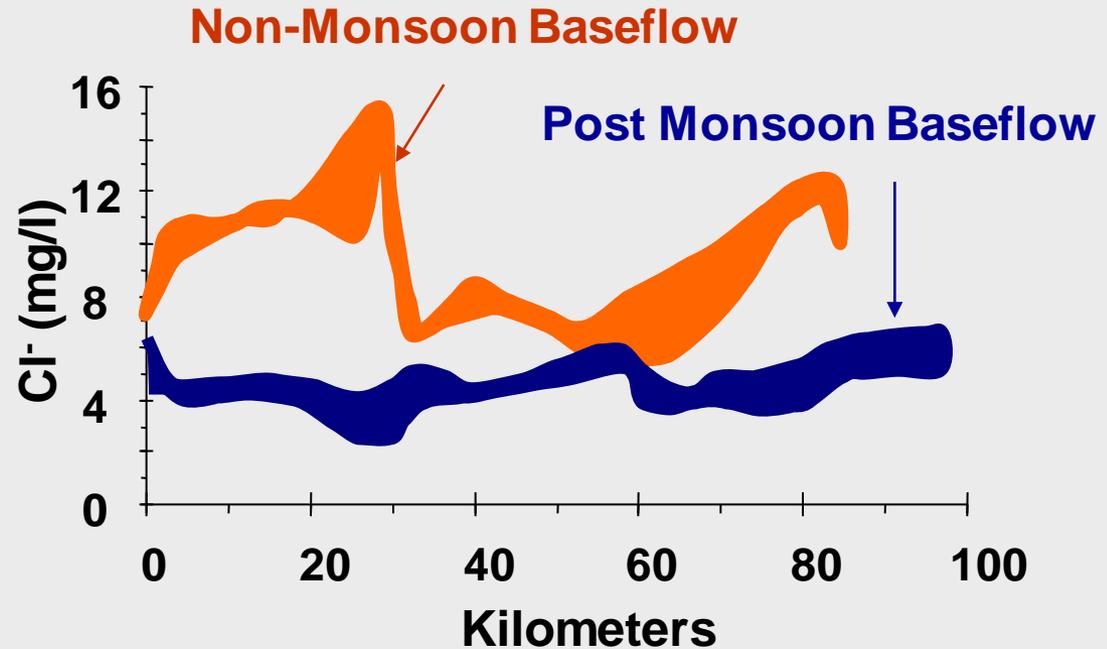
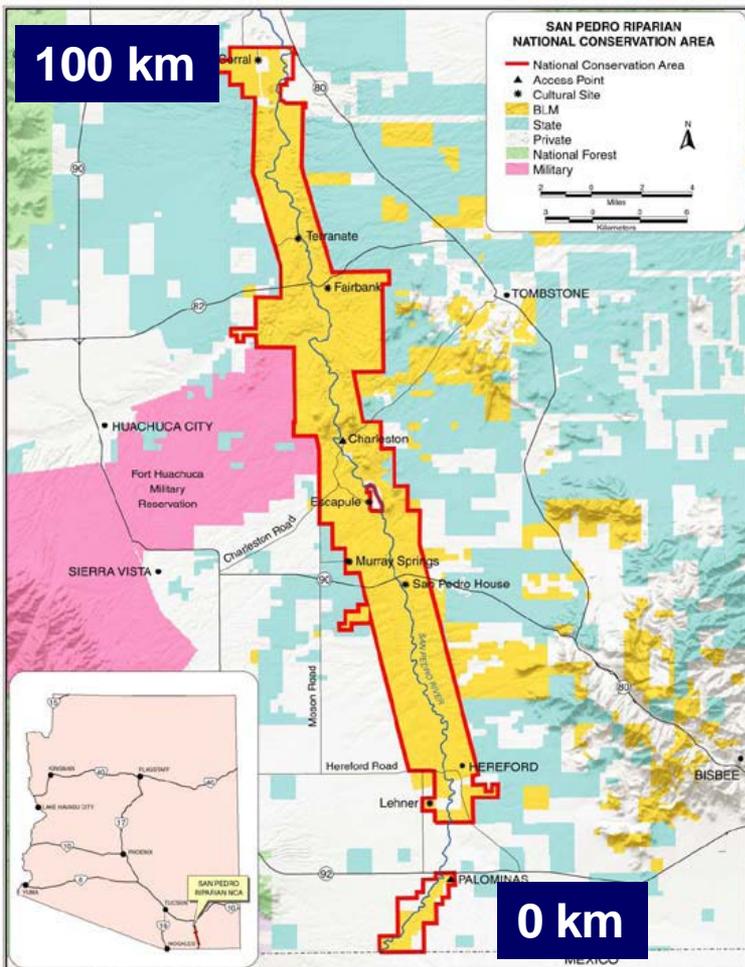
Examples on DS Connectivity from the SP

- Flow from the Walnut Gulch ephemeral tributary measurably affects flow in down stream Tombstone USGS gage
- In 2006, 4 of 23 runoff events detected at WG flume 1 had measureable impacts on flows at the downstream Tombstone USGS gage



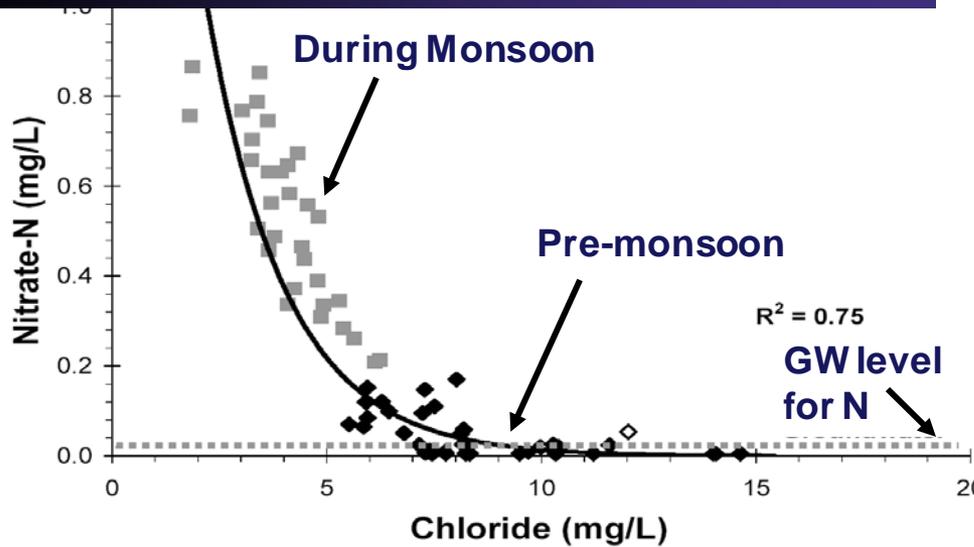
Biogeochemical Effects of Non-Perennial Tributary Runoff

Synoptic sampling of nutrients and chemicals along the San Pedro NRCA was conducted at multiple times during the year

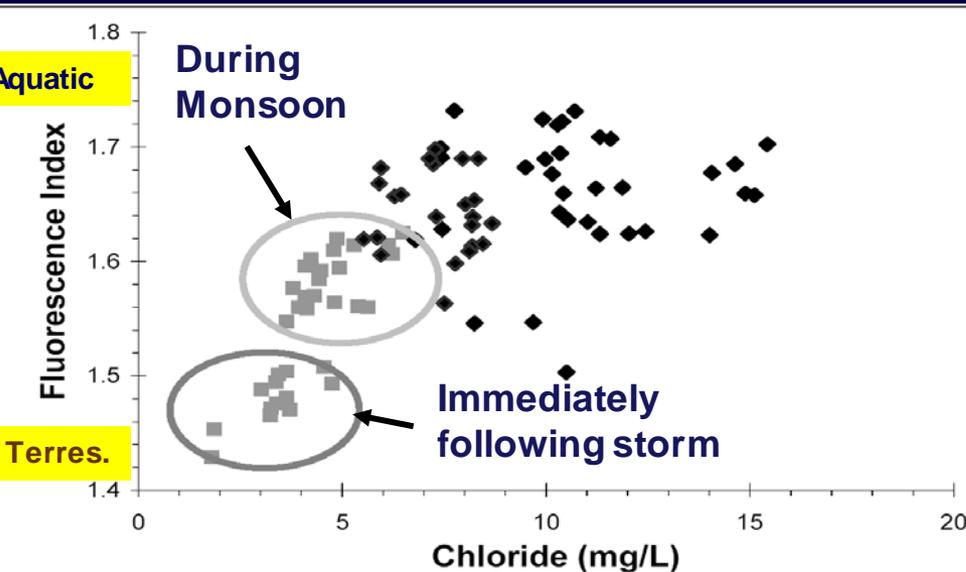


- Pre-Monsoon river disconnected
- Monsoon & Post Monsoon river connected – well mixed

Biogeochemical Effects of Ephemeral Tributary Runoff



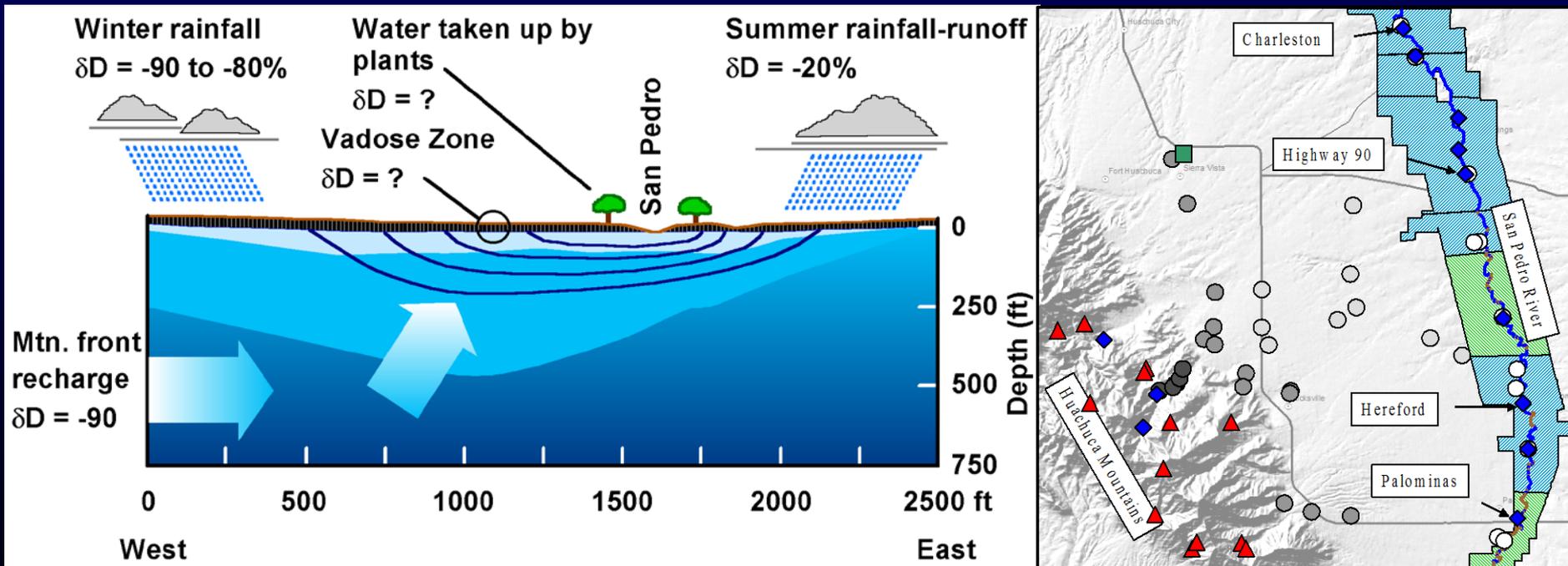
- Pre-Monsoon riparian river is low in nutrients
- Tributary inflow during monsoon causes concurrent increase in inorganic nitrogen
- Organic matter sourcing (FI) indicates nitrogen increase is caused by influx of terrestrial organic matter from tributary runoff



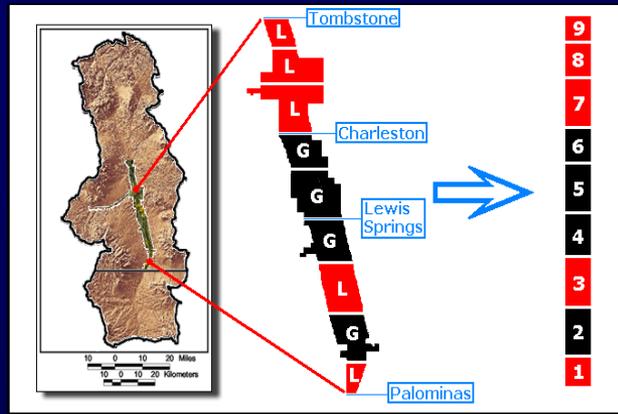
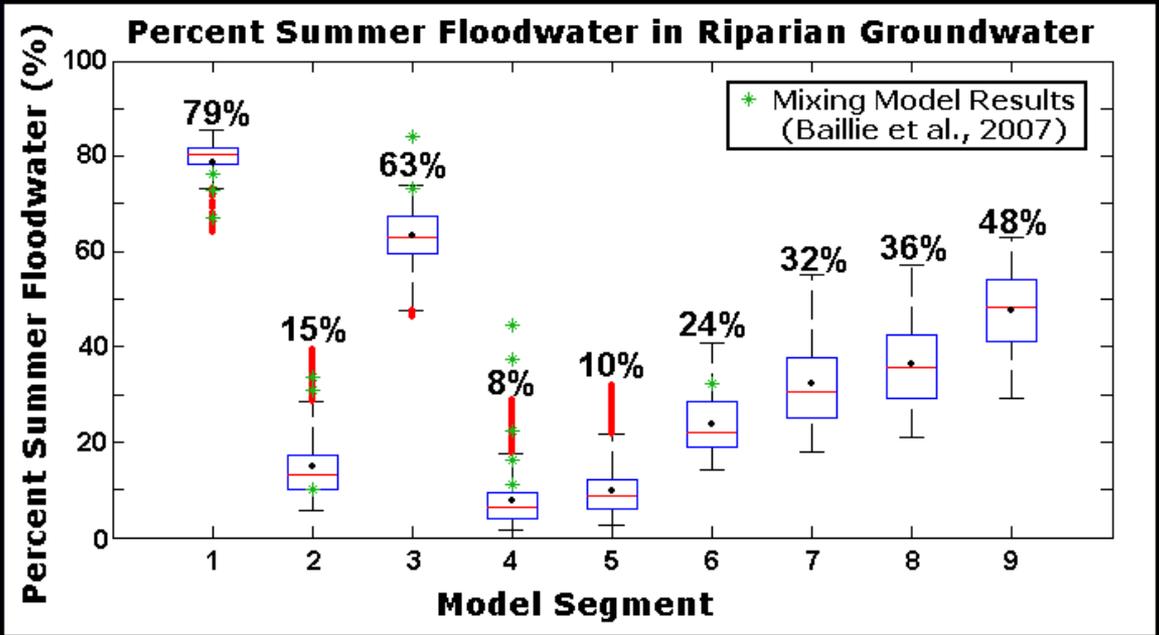
Monsoon tributary runoff supplies critical nutrients to the riparian ecosystem

What Water Maintains Perennial Flow ?

- Isotopes of hydrogen and oxygen and geochemistry can be used as tracers or fingerprints to identify water sources
 - Sample winter and summer precipitation
 - Sample across basin – mountain springs, deep basin wells, shallow riparian wells, and monsoon runoff

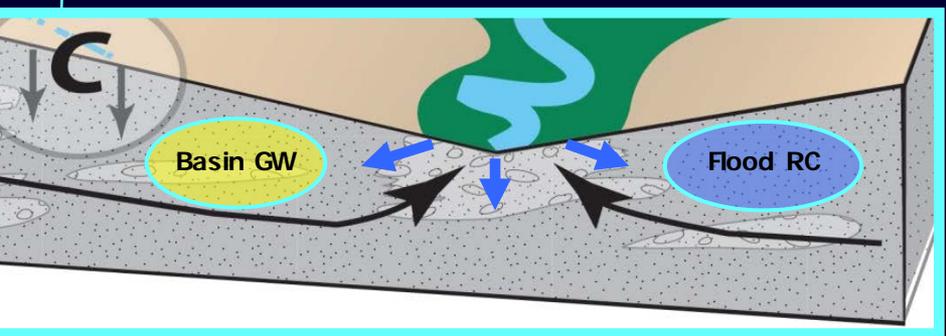


Alluvial Aquifer Recharge to Maintain Perennial Flow



L = losing reach
G = gaining reach

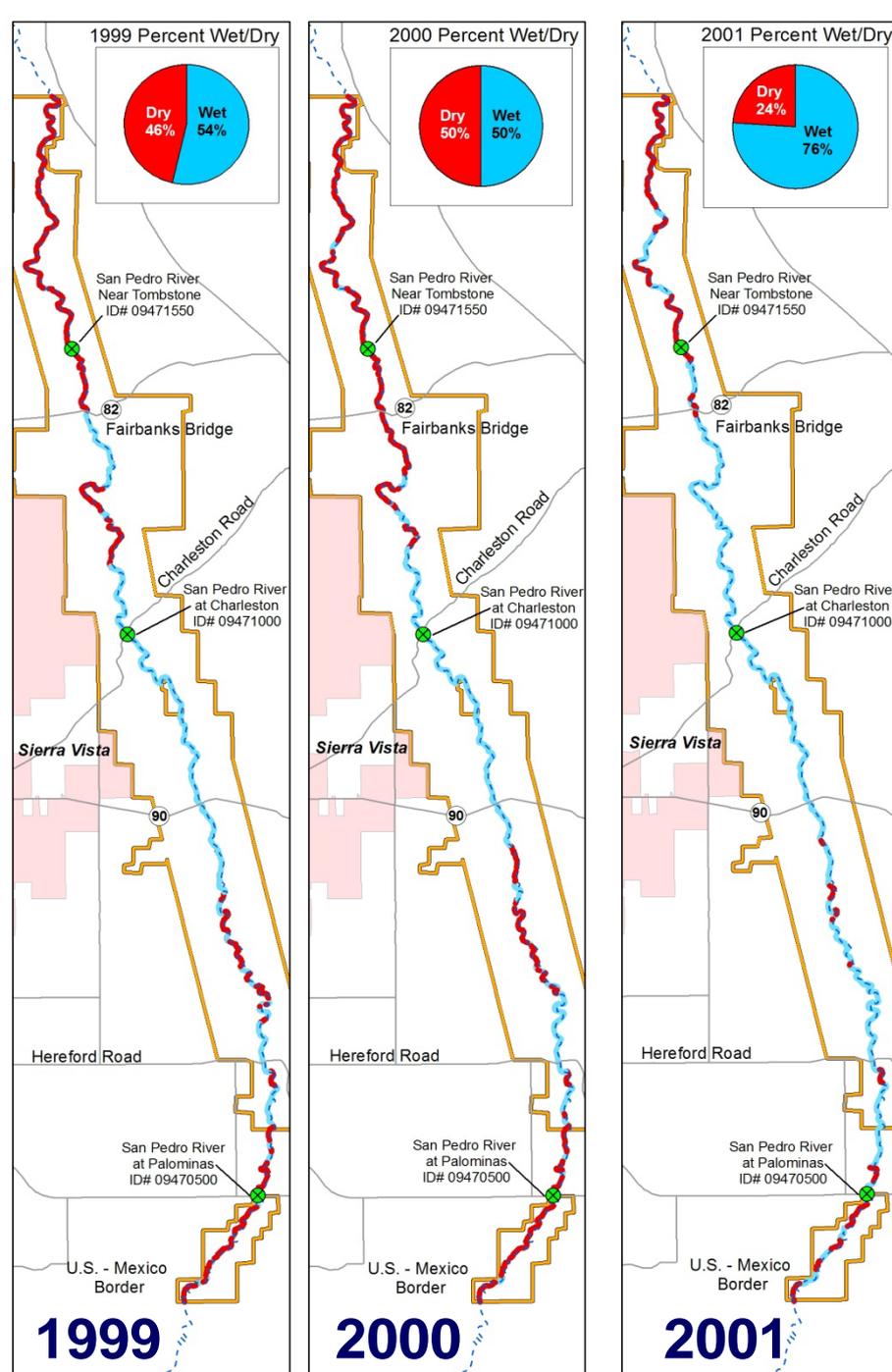
L G L G G G L L L



Result: Summer floodwater runoff from ephemeral tributaries is a significant source of alluvial aquifer recharge which maintains perennial flow in losing reaches

San Pedro River Wet/Dry Mapping: 1999 - 2001

- Monsoon runoff and a large tropical depression induced Aug. 2000 flood elevated baseflow and increased the extent of perennial flow a full 10 months later into June 2001
- Prior to this result it was accepted that low June base flows were solely maintained by the regional GW
- **Conclude:** Summer tributary runoff is a significant factor in sustaining perennial flow over longer stream reaches



Function of Non-Perennial Streams

- **Conduits for transferring water, sediment, energy, nutrients and pollutants through the watershed**
 - **Sediment mobilization, storage, transport and deposition**
 - **Energy dissipation**
 - **Biogeochemical activity and nutrient influx**
- **Alluvial aquifer recharge to maintain perennial flow**
- **Regional groundwater recharge**
- **Plant community support and associated species diversity**
- **Landscape and migratory connectivity**



CONCLUSIONS (E-I)

- **Ephemeral & Intermittent streams constitute the vast majority of drainage ways in the arid west**
- **They perform the same functions as perennial streams: Transport water, sediment, nutrients, biota, and pollutants, as well as, play an integral role in overall watershed function**
- **Flash floods, large transmission losses and high sediment loads are characteristics of SW arid and semiarid hydrology**
- **Biological processes, vegetation and wildlife communities are distinctly different in E-I riparian areas as compared to surrounding uplands (distinct habitat and micro-climate)**
- **The variability and highly episodic occurrence of runoff events requires that non-perennial streams be examined in a watershed context and over longer time periods**

Conclusions from National Synthesis

- **Science unequivocally demonstrates that streams, regardless of their size or frequency of flow, are connected to downstream waters and strongly influence their function.**
- **Clearly shows that wetlands in riparian areas are physically, chemically, and biologically integrated with rivers and function as buffers to protect downstream waters.**
- **Shows there is ample evidence that many wetlands/waters outside of riparian areas could affect downstream waters. Degree of connectivity is possible through case-by-case analysis.**
- **Variations in the degree of connectivity are determined by the physical, chemical and biological environment, and by human activities.**
- **Strongly supports the incremental contributions of individual streams and wetlands are cumulative across entire watersheds, and their effects on DS waters should be evaluated within a watershed context.**

Thank You !

July 31, 2006



October 2007



Rillito River, Campbell Ave. Bridge, Tucson, Arizona

Questions ?

ASSERTION

- **Non-perennial (ephemeral/intermittent) streams operate in a fundamentally different manner in the transport of water, nutrients, and sediment**
- **Assessing their role in maintaining the chemical, physical, and biological integrity of the nation's waters requires:**
 - **Longer time scales**
 - **A watershed perspective (larger spatial scales)**
- **Reach level assessments do not adequately capture the function of these systems**
- **They should be treated and evaluated in a different manner than perennial systems**

Other Important Waters of the US Common in the West “Isolated Waters”

- **Desert Springs**
- **Playa Lakes**
 - 20,000 in West Texas covering 200,000 ac
- **Terminal “Closed” Basins**
 - 66% of Nevada
 - 20% of New Mexico
 - Many contain perennial stream segments but are unconnected to TNW



STRENGTHENING THE SCIENTIFIC FOUNDATION FOR THE CLEAN WATER ACT THROUGH FEDERAL PARTNERSHIP AND TRANSDISCIPLINARY COLLABORATION

Laurie C. Alexander, William G. Kepner, and David C. Goodrich¹

Abstract—The U.S. Environmental Protection Agency’s Office of Research and Development (EPA/ORD) released a report, titled *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence*, that summarizes more than 1,200 studies from the peer-reviewed scientific literature on the structural and functional connectivity of streams and wetlands to downstream waters such as rivers, lakes, reservoirs and estuaries (<https://www.federalregister.gov/articles/2015/01/15/2015-00339/connectivity-of-streams-and-wetlands-to-downstream-waters-a-review-and-synthesis-of-the-scientific>). The evidence reviewed in this report spans many decades of research into aquatic ecosystems and watershed processes. It provides a scientific basis for the Clean Water Rule, which clarifies the definition of “waters of the United States” under the Clean Water Act and went into effect on 28 August 2015. As a technical review, the ORD report does not consider or set forth legal standards for CWA jurisdiction. Rather, it summarizes current scientific understanding of the hydrologic, chemical, and biological connections by which small or temporary streams, nontidal wetlands, and open-waters, singly or in aggregate, affect the integrity of waters protected by the Clean Water Act. It is the result of a multi-year collaboration by scientists working across disciplinary and organizational boundaries to synthesize the best available science in response to evolving policy needs.

INTRODUCTION

The objective of the Clean Water Act (CWA) is to restore and maintain the chemical, physical, and biological integrity of the nation’s waters. Supreme Court decisions in SWANCC (2001) and Rapanos (2006) raised questions about the scope of the CWA, and motivated new research into the connectivity of waters. In January 2015 the EPA ORD published a report (US EPA, 2015) to inform rulemaking by EPA and the U.S. Army Corps of Engineers on the definition of “waters of the United States” under the Clean Water Act (CWA). As a technical document, this report does not consider or propose legal standards or policy options for CWA jurisdiction. Rather, it evaluates, summarizes, and synthesizes the available peer-reviewed scientific literature to address questions about the physical, chemical, and biological connectivity and downstream effects of three categories of waters: ephemeral, intermittent, and perennial streams; riparian or floodplain wetlands and open waters; and wetlands and open waters in non-floodplain settings.

METHODS

This report is the product of a transdisciplinary collaboration of scientists in the EPA ORD National Center for Environmental Assessment, National Health and Environmental Effects Research Laboratory, National Exposure Research Laboratory, and the United States Department of Agriculture’s Agricultural Research Service. The authors reviewed and evaluated a large body of evidence from peer-reviewed sources that were published or in press by December 2014, including original research by scientists in federal agencies. The review synthesizes a total of 1,355 publications, which included 1,150 peer-reviewed journal articles, 120 scientific books or chapters, and 50 Federal reports. Following internal review by EPA and U.S. Army Corps of Engineers operational staff, drafts of the report were externally peer-reviewed by scientists in government, academic, nonprofit, and private industry organizations at three different levels: a peer consultation with 11 topic experts in February 2011, a contractor-led panel review by 11 independent peer reviewers in January 2012, and a review by the EPA Science Advisory Board (SAB), which

¹Laurie C. Alexander, Research Ecologist, U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C. 20460
William G. Kepner, Research Ecologist, U.S. Environmental Protection Agency, Office of Research and Development, Las Vegas, Nevada 89119
David C. Goodrich, Research Hydraulic Engineer, USDA-Agricultural Research Service, Southwest Watershed Research Center, Tucson, AZ 85719

Citation for proceedings: Stringer, Christina E.; Krauss, Ken E.; Latimer, James S., eds. 2015. Headwaters to estuaries: advances in watershed science and management—Proceedings of the Fifth Interagency Conference on Research in the Watersheds. March 2-5, 2015, North Charleston, South Carolina. e-Gen. Tech. Rep. SRS-211. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 302 p.

convened public meetings of a 27-member panel in 2013 and 2014. The level of peer review exceeded standards established by OMB (2004). All peer-review panels included Federal partners, who also provided comments during Interagency review. In addition, 133,100 comments from the public were received through the docket (Docket No. EPA-HQ-OA-2013-0582). Comments from all sources were considered and used to improve the clarity and scientific rigor of the document.

CONCLUSIONS

The final report contains five major conclusions, summarized here:

1. The scientific literature unequivocally demonstrates that streams, regardless of their size or frequency of flow, are connected to downstream waters and strongly influence their function.
2. The scientific literature clearly shows that wetlands and open waters in riparian areas (transitional areas between terrestrial and aquatic ecosystems) and floodplains are physically, chemically, and biologically integrated with rivers via functions that improve downstream water quality. These systems act as effective buffers to protect downstream waters from pollution and are essential components of river food webs.
3. There is ample evidence that many wetlands and open waters located outside of riparian areas and floodplains, even when lacking surface water connections, provide physical, chemical, and biological functions that could affect the integrity of downstream waters. Some potential benefits of these wetlands are due to their isolation rather than their connectivity. Evaluations of the connectivity and effects of individual wetlands or groups of wetlands are possible through case-by-case analysis.
4. Variations in the degree of connectivity are determined by the physical, chemical and biological environment, and by human activities. These variations support a range of stream and wetland functions that affect the integrity and sustainability of downstream waters.
5. The literature strongly supports the conclusion that the incremental contributions of individual streams and wetlands are cumulative across entire watersheds, and their effects on downstream waters should be evaluated within the context of other streams and wetlands in that watershed.

ACKNOWLEDGMENTS

This report was funded through the EPA ORD. It has been subjected to Agency review and approved for publication. We are indebted to the report co-authors and the many national experts who reviewed the drafts, provided comments and additions, and helped us in our effort to synthesize the best available science in response to evolving policy needs.

LITERATURE CITED

- Office of Management and Budget (OMB). 2004. Final information quality bulletin for peer review (Memorandum M-05-03). Office of Management and Budget, Washington, DC. (https://www.whitehouse.gov/omb/memoranda_fy2005_m05-03).
- Rapanos v. United States, 547 U.S. 715 (2006). <https://supreme.justia.com/cases/federal/us/547/715/>
- Solid Waste Agency of Northern Cook County (SWANCC) v. U.S. Army Corps of Engineers. 531 U.S. 159 (2001). <https://supreme.justia.com/cases/federal/us/531/159/case.html>
- U.S. Environmental Protection Agency (US EPA). 2015. Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence. EPA/600-R-14/475F, 408pp (<http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=296414>).