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The Shape of Streams to Come: New decision tools for assessing watershed sensitivity and ecological resilience in the Great Basin

Streams are the lifelines that flow across the arid and semi-arid landscapes of the Great Basin, an area that covers most of Nevada and extends into parts of Utah, Idaho, and Oregon. In a region where precipitation ranges from 6 inches to 27 inches annually, managing water resources in the face of climate-driven disturbances, including droughts, wildfires, and floods, is an increasing challenge. In addition, human activities such as road building or improper livestock grazing can jeopardize the ability of streams and riparian ecosystems to provide critical ecosystem services, such as water for downstream users, forage for livestock, and habitat for a large diversity of species.

Some stream systems experience little to no change in response to disturbance, while others experience significant stream channel degradation and changes in riparian vegetation. Understanding the processes that influence how watersheds recover after disturbance is key for making management decisions like where to place roads, stabilize streams, or focus conservation efforts.

“In order to understand what the recovery potential of a watershed or stream system is, we really need to know two things,” says Jeanne

Cassia Creek watershed in southeastern Idaho. Courtesy photo by Anna Knight, U.S. Geological Survey.

Chambers, research ecologist and senior scientist (emeritus) with the USDA Forest Service, Rocky Mountain Research Station based in Reno, Nevada. “One is its geomorphic sensitivity, and the other is its ecological resilience.”

Geomorphic sensitivity refers to the capacity of stream channels to absorb change and remain in a state of dynamic equilibrium over time. Ecological resilience refers to how much disturbance a riparian ecosystem can endure before it is transformed into an alternative stable state.

Assessing geomorphic sensitivity and ecological resilience provides measures of the recovery potential of stream and riparian ecosystems. The information allows managers to understand how watersheds have responded to disturbances in the past and how they are likely to respond in the future.

Chambers and geomorphologist Jerry Miller, a professor of environmental science at Western Carolina University in North Carolina, collaborated with scientists and managers to develop a new resource designed to help managers rapidly assess watersheds and categorize them based on sensitivity and resilience to disturbance. The new approach described in Geomorphic sensitivity and ecological resilience of Great Basin streams and riparian ecosystems Gen. Tech. Rep. RMRS-GTR-426 is intended to help managers determine and prioritize where management actions are most likely to succeed.

SUMMARY

Water is a precious resource in dryland regions of the western United States, including the Great Basin. Determining appropriate management strategies for stream and riparian ecosystems is challenging because Great Basin watersheds, stream systems, and associated riparian ecosystems have varying geomorphic and hydrologic conditions and support numerous different vegetation communities and animal species. These stream and riparian ecosystems show a wide variety of responses to both natural disturbances, such as floods, and human-caused disturbances, such as roads in the valley bottoms and improper livestock grazing. Decision support tools to manage and plan for disturbances that are increasingly amplified by climate change are imperative.

Assessing the geomorphic sensitivity of streams and the ecological resilience of riparian ecosystems provides the basis for understanding how they have responded to disturbances and management actions and how they are expected to respond in the future.

A collaborative group of managers and scientists led by Jeanne Chambers, research ecologist and senior scientist (emeritus) with the USDA Forest Service Rocky Mountain Research Station, and geomorphologist Jerry Miller, a professor of environmental science at Western Carolina University, developed a multiscale approach to help land managers rapidly assess watersheds and categorize them based on resilience and sensitivity to disturbance. The project was built on the long-term work of Chambers and her collaborators on Great Basin riparian ecosystems.

The new approach described in Geomorphic sensitivity and ecological resilience of Great Basin streams and riparian ecosystems Gen. Tech. Rep. RMRS-GTR-426 is intended to help managers determine and prioritize where management actions are most likely to be successful.

The approach is one part primer on the concepts and categories of sensitivity and resilience—the factors that drive stream and riparian ecosystem responses to disturbance and their capacity to absorb change and remain in a stable state. The concepts provide the basis for understanding and predicting how streams and riparian ecosystems are likely to respond to future disturbances. The second part encompasses a rapid assessment protocol for collecting and interpreting the information needed to determine the sensitivity and resilience categories and the

> *“In order to understand what the recovery potential of a watershed or stream system is, we really need to know two things: one is its geomorphic sensitivity, and the other is its ecological resilience.”*
>
> -Jeanne Chambers
> Research Ecologist/
> Senior Scientist (emeritus)
> Rocky Mountain
> Research Station

KEY FINDINGS

- Great Basin streams and riparian ecosystems vary spatially in their responses to both natural and anthropogenic disturbances with some systems experiencing little to no change and others experiencing both stream channel degradation and changes in riparian vegetation after disturbance.
- Understanding the factors that cause different responses to disturbance provides the basis for assessing the geomorphic sensitivity of stream systems and ecological resilience of riparian and meadow ecosystems.
- Watersheds can be categorized according to their geomorphic sensitivity and ecological resilience by assessing the characteristics of the watershed and its component stream systems and riparian vegetation.
- Stream systems with high sensitivity to disturbance typically experience large changes in channel pattern and form after disturbances; associated riparian ecosystems with low resilience often experience major changes in riparian vegetation after the same types of disturbances.

MANAGEMENT IMPLICATIONS

- Assessing geomorphic sensitivity and ecological resilience provides a measure of the recovery potential of streams and riparian ecosystems and allows managers to both predict likely responses to disturbance and determine effective management actions.
- The new approach categorizes watersheds into five types based on responses to disturbance and their relative sensitivity and resilience. For example, in fan dominated watersheds where accumulations of sediment from tributaries have created large side-valley alluvial fans, geomorphic sensitivity is low to moderate and ecological resilience is moderate to high.
- Understanding sensitivity and resilience offers a tool for prioritizing management actions in watersheds where they are most likely to be effective. A slow rate of incision in fan dominated systems means that restoration efforts are likely to succeed, whereas the highly dynamic nature of flood dominated watersheds makes restoration difficult.
- A rapid assessment protocol designed with managers in mind provides guidance and tools for collecting and interpreting watershed, stream system, and riparian ecosystem data.

appropriate management strategies. It includes a Great Basin Watershed Database containing a wide range of watershed-scale data for nearly 1,500 montane watersheds with perennial stream channels and an assessment of watershed characteristics. In addition, a companion website has been created that describes the two parts and has downloadable data forms.

Concerns about stream degradation

Chambers began working with Miller in the early 1990s to understand the geomorphology of the riparian ecosystems in the Humboldt-Toiyabe Forest in central Nevada.

"A primary concern at that time, which remains a critical issue today, is that certain types of stream systems were becoming entrenched by stream processes," says Miller, who was with the Desert Research Institute in Reno at the time.

Entrenchment, or incision, can alter stream and hydrologic processes, and in wet meadow systems it can lower groundwater levels creating ideal conditions for dryland vegetation to replace wet meadow and other riparian species. The effects can be devastating for species that depend on the stream and riparian ecosystems. Many of the streams support species of conservation concern, such as the Columbia spotted frog and the Lahonton cutthroat trout—the latter is listed as threatened under the Endangered Species Act of 1973.

Riparian ecosystems are equally important for upland species of conservation concern, such as the greater sage grouse whose populations have declined steeply in the last two decades, particularly in the Great Basin. During the summer, this iconic bird relies on access to water as well as the plants and insects found in meadow systems. "Meadow systems currently make up less than 4% of the landscape in the Great Basin and are highly valued by sage grouse," says Shawn Espinosa, upland game staff specialist with the Nevada Department of Wildlife.

"If a meadow system becomes dewatered through incision and becomes a shrubland," Espinosa

Natural and Human Caused Disturbances that Affect Streams and Riparian Ecosystems

HUMAN CAUSED DISTURBANCES

Improper livestock grazing

Improper timing, duration, or intensity of livestock grazing can result in:

- soil compaction, decreased infiltration, and increased runoff
- a decrease in riparian species with high wetland indicator status and an increase in species with low successional status as well as nonnative invasive species
- decreases in stream bank stability
- increases in bank erosion and changes in stream channel pattern and process.

Mining activity

Both current and historical mining activities can alter local groundwater flow systems.

Recreational activities

Recreational activities and their effects, such as developed and undeveloped campgrounds and trails, can result in surface disturbance, soil compaction, and decreased infiltration. They can impact stream bank stability and stream channels as well as the extent and composition of riparian vegetation.

Roads

Roads in the valley bottoms and stream crossings can alter the shape and pattern of the stream system, and consequently the response of the stream to high-flow events.

Human Developments

Development of land for housing and commercial enterprises generally increases the area of impervious cover, which can increase runoff while restricting sediment inputs to the channel.

Surface water manipulation or diversion

Rerouting of stream channels or diverting water from springs or stream channels with either ditches or flood irrigation can dewater riparian and meadow vegetation. It can also result in the development of headcuts and formation of gullies during high-flow events.

Wild horses

The effects are similar to those of improper livestock grazing when numbers are above appropriate management levels or animals concentrate in riparian areas.

Groundwater extraction

Water extractions via wells can dewater riparian and meadow vegetation, result in nonnative species invasions and degradation of species' habitats.

NATURAL DISTURBANCES

Floods

Floods resulting from high levels of precipitation with significant runoff are the primary driver of stream and riparian ecosystem change.

Wildfire

Wildfire removes hillslope vegetation, which can decrease soil water storage and increase surface runoff and erosion. Large amounts of sediment can be delivered to the stream channels, affecting geomorphic processes. Resulting changes in riparian vegetation composition and extent may affect water quality and temperature.

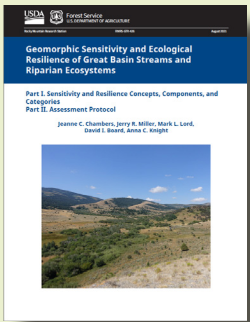
Beaver dams

Beaver dams can create a series of impoundments in streams that alter geomorphic and hydrologic processes as well as streamside and floodplain vegetation. The effects may be positive or negative depending on the riparian ecosystem and basin geomorphology.

Climate change

Changes in climate during the Holocene caused changes in vegetation types, soil erosion and sedimentation rates, flood frequencies, and stream incision rates. Ongoing and future climate change may have cascading, complex impacts on streams, groundwater, and riparian ecosystems.

What's in the Sensitivity and Resilience Toolbox?



The report

Geomorphic sensitivity and ecological resilience of Great Basin streams and riparian ecosystems Gen. Tech. Rep. RMRS-GTR-426

Part I: Components, Concepts, and Categories describes the concepts relevant to understanding geomorphic sensitivity and ecological resilience and defines the watershed categories.

Part II: The Rapid Assessment Protocol describes the three phases of work: collecting existing watershed information, conducting field studies, and interpreting results.

Appendices include a description of the Great Basin Watershed Database, information on the riparian vegetation types, complete lists of riparian and meadow species for the Great Basin, data forms, score sheets, examples of watershed types and more.

The website

Sensitivity and Resilience of Great Basin Riparian Ecosystems website

Part I: Components, Concepts, and Categories

Part II: The Rapid Assessment Protocol

Phase III: Interpretation

Additional supporting resources, including data collection and scoring forms, related publications, and links to the Great Basin Watershed Database

The database

The Great Basin Watershed Database available as an ArcGIS feature layer

Contains a wide range of watershed-scale data for nearly 1,500 montane watersheds with perennial stream channels, and an assessment of watershed characteristics.

For further guidance on implementing the approach, contact Jeanne Chambers or Jerry Miller.

says, "it has lost its value to sage grouse, which use meadows pretty extensively during the late brood-rearing life phase."

Developing an understanding of sensitivity and resilience

Chambers and Miller and their collaborators have long partnered to understand and document the variation that they observed and its effects on both streams and riparian ecosystems. In 2016, they assembled a team of nearly 20 scientists and managers from multiple agencies and universities to lay the groundwork for categorizing Great Basin watersheds according to their geomorphic sensitivity and ecological resilience, expanding the focus beyond central Nevada.

By investigating geomorphological processes of the past, the scientific team already knew that incision was driven largely by climatic changes that had occurred since about 2600 years ago. More recently, human activities such as road building and improper livestock grazing had also contributed to incision. Regardless of the cause, something else also stood out to the scientists.

"In some watersheds, incision was not very likely and had been pretty minimal, but other watersheds had really come unglued—a lot of impacts had taken place," Miller says.

Differences in how streams respond geomorphologically and how riparian ecosystems respond

Watershed categories. A summary of the responses of the five watershed types to disturbance, their relative sensitivity and resilience, and the primary management strategies for each type.

Dominant short-term processes	Geomorphic sensitivity	Ecological resilience	Management implications
Flood Dominated			
• Highly dynamic • Frequent avulsions and associated incision rework valley floor and channel • Riparian vegetation is adapted to the dynamic conditions	Low to moderate	Moderate to high	• Valley floor is highly unstable • Roads and infrastructure should be located off the valley floor • Maintaining bridges and road crossings may be difficult • Low potential for channel stabilization or restoration following disturbance
Armored			
• Incision common, but rate is limited by immobile bedrock or large clasts • Avulsion is typically absent • Woody vegetation types with meadow types in understory	Low	Moderate to high	• Disturbances are unlikely to have a significant effect on these systems • Excellent potential for stream restoration
Fan Dominated			
• Slow but continuous incision produces inset terraces, knickpoints, and lowered groundwater tables • Rare, localized avulsions occur upstream of the side-valley fans • Meadow types occur upstream, woody vegetation downstream • Incision and lowered water tables alter species composition	Low to moderate	Moderate to high	• Side-valley fans act as base-level controls • Upland disturbances and management treatments can influence groundwater hydrology of meadows • Slow rates of incision often result in significant restoration potential of meadows upstream of fans • Stabilizing channels adjacent to the fans can limit incision
Deeply Incised			
• Prone to rapid incision that lowers groundwater, reduces riparian corridor extent, and alters species composition • Deeply incised channels may be locally stable with inset floodplains • Avulsions are rare • Plant species composition depends on stream gradient, water table depth, and sediments	Incision: Moderate to high Avulsion: Low	Low to moderate	• Channels are prone to renewed incision given additional upland or channel disturbances • Channels, riparian ecosystems, and wet meadows are difficult to restore due to significantly lowered water tables and unstable and widening trench walls • Restoration potential depends on stream gradient, local groundwater conditions, and sediment size
Pseudostable			
• Stable channels with potential to undergo rapid, deep incision • Woody vegetation types with meadow types in understory • Avulsions are rare • Incision lowers groundwater, reduces riparian corridor extent, and alters species composition	Moderate to very high	Low	• Channels and riparian ecosystems prone to extreme change • Potential upland and channel disturbance should be minimized with aggressive management strategies • Very low potential for restoration of destabilized systems

ecologically to disturbance of any cause, have everything to do with the type of watershed, stream characteristics, riparian vegetation types, and disturbance history.

For example, stream morphology and riparian vegetation interact to shape one another. The dominant geomorphic characteristics of a stream reach—the stream gradient, channel and bank substrate, and landforms that are present—influence the types of riparian vegetation that occur, as do water availability and soil characteristics. At the same time, riparian species that characterize a stream reach can affect geomorphic processes and resilience of the riparian ecosystem to disturbances, such as incision.

“We wanted to come up with a watershed categorization and a way of assessing the watershed categories that could help individuals prioritize areas for management and then determine appropriate management strategies,” Chambers says.

This is exactly the kind of approach to making management decisions that appeals to Espinosa.

“Is it worthwhile for us to spend dollars trying to restore an incised stream system,” he asks, “or just leave it as is and focus on where we might be able to make a greater difference with less money or less intensive work?”

For two years, Chambers and Miller spent focused time in the field with geomorphologists, hydrologists, and plant ecologists to evaluate watershed conditions across the entire Great Basin. The scientists explored a diversity of ecoregions that encompassed the major environmental characteristics, geologic and geomorphic characteristics, and vegetation characteristics of the watersheds across the region. They kept managers in mind as they collected field data to develop the watershed categorization and the assessment protocol.

The categorization of watershed sensitivity and riparian ecosystem resilience that they developed defines five categories based on the dominant processes at work and the potential for both geomorphic and vegetation change:

Flood dominated

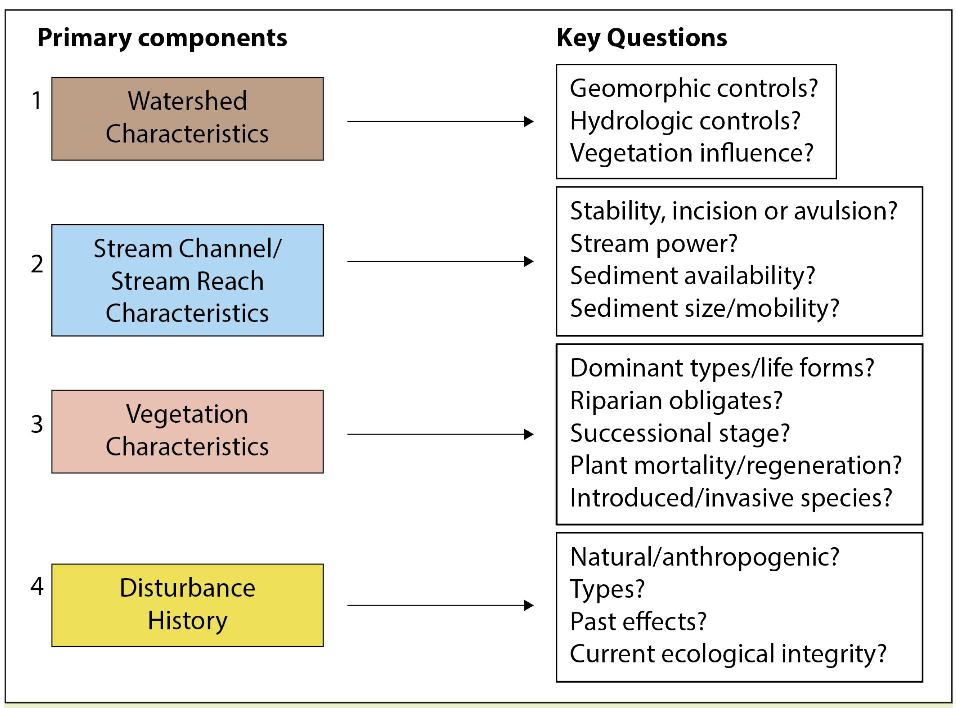
Armored

Fan dominated

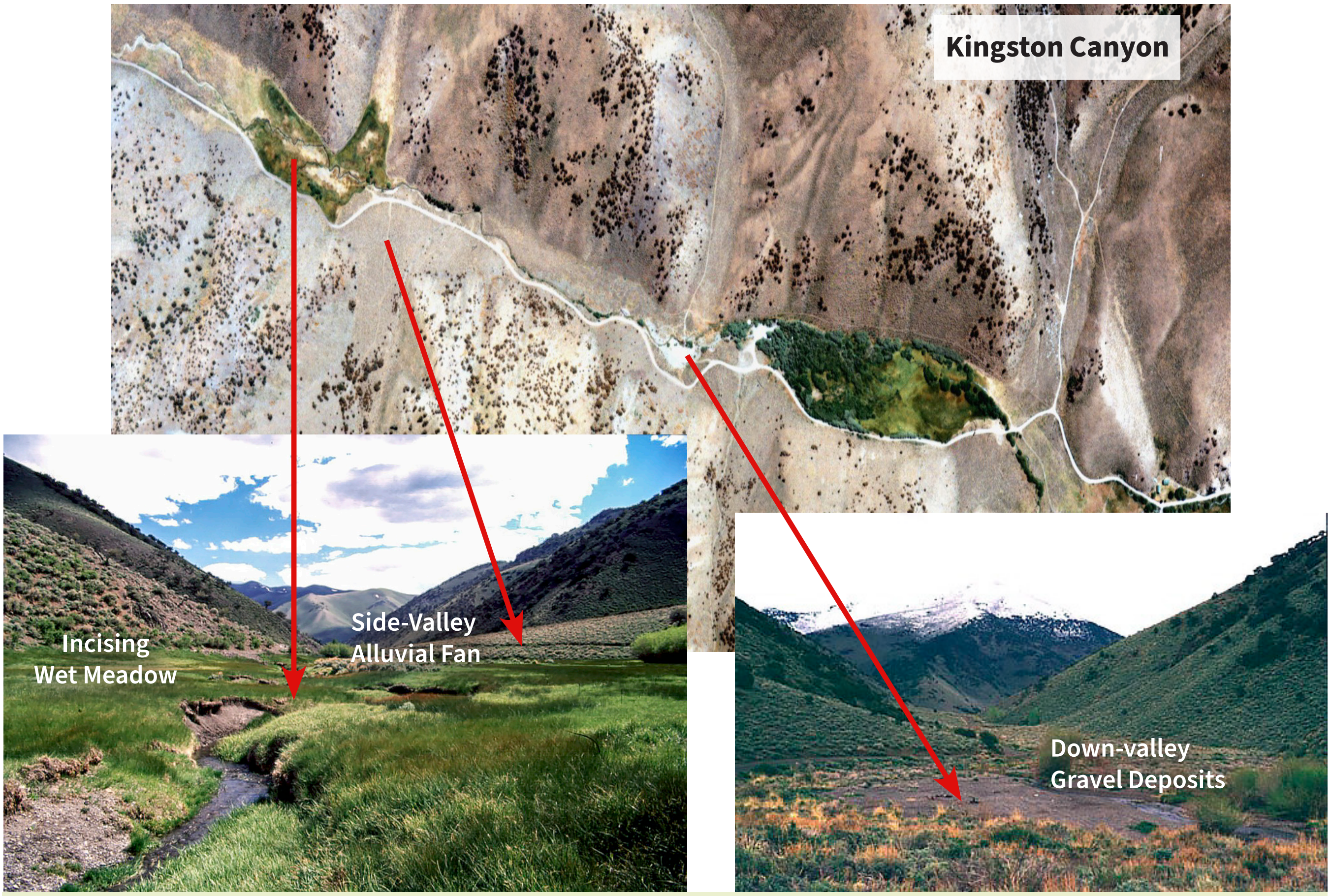
Deeply incised

Pseudostable

For example, the wet meadow ecosystems that sage grouse and other species depend on are often associated with fan dominated watersheds. In fan dominated watersheds where accumulations of sediment from tributaries have created large side-valley alluvial fans, geomorphic sensitivity is low to moderate and ecological resilience is moderate to high. This is because the large debris supplied to the channel by the



A set of key questions about four primary components are used to describe and evaluate sensitivity and resilience to disturbance of streams and riparian ecosystems within the Great Basin.



A fan dominated watershed in Upper Kingston Canyon, Nevada where geomorphic sensitivity is low to moderate and ecological resilience is moderate to high. Progressive incision can lower the water table and turn a wet meadow into a shrubland. However, a slow rate of incision indicates potential for successful restoration efforts. USDA Forest Service photos by Jeanne Chambers and Jerry Miller.

fan often results in channel bed armoring at the base of the meadow and inhibits erosion. Over time, progressive incision has the potential to lower the water table and turn a wet meadow into a shrubland. However, a slow rate of incision means that the potential for successful restoration efforts is significant.

"If you put even larger materials between the valley floor and the toe of the alluvial fan, then you can slow that erosion down even more," says Miller. "That was actually done on Kingston Creek as an experiment. Boulders were placed along the channel bed that serve as what we call local base-level control. They dictate how much erosion you can have upstream of that point."

Like fan dominated watersheds, flood dominated watersheds have low to moderate geomorphic sensitivity and moderate to high ecological resilience. However, the highly dynamic nature of flood dominated watersheds makes restoration difficult.

Flood dominated watersheds are characterized by large quantities of sediment that are highly mobile. High-magnitude floods frequently cause channel avulsion or the rapid abandonment of part of a stream channel and formation of a new channel in a different location. The riparian vegetation in these systems is adapted to the dynamic conditions and the riparian ecosystem is resilient to all but the most extreme floods.

In flood dominated watersheds, channel stabilization and restoration efforts may fail.

Maintaining bridges and road crossings may be difficult, and roads and other structures are best placed well above valley bottoms.

In contrast to fan and flood dominated systems, pseudostable watersheds have high geomorphic sensitivity. These systems are prone to rapid incision. Valleys are characterized by loose, sandy, permeable material, and hillslopes contain abundant fine-grained sediments. Because incision results in a lowering of the water table and a decrease in the extent of the riparian corridor, ecological resilience is low to moderate.

One example of a pseudostable watershed is Marshall Canyon in central Nevada which incised catastrophically during and after a heavy rainstorm in 1998. The valley floor was composed of easily eroded coarse sand and sediment that was transported downstream and redeposited over a three-month period after the rainstorm. The result was a trench roughly 20 to 30 feet wide and 20 feet deep which ended upstream in three amphitheater-like headcuts or areas of active erosion. The channel is now in the bottom of the trench, and the water table has dropped. Some riparian vegetation has reestablished along the new channel over time.

Because of the tendency for incision or widespread debris flows after disturbances, channels within these watersheds may be difficult to stabilize and manage. The potential for riparian and meadow restoration is determined

Catastrophic incision of the valley floor occurred in a pseudostable stream in Marshall Canyon, central Nevada, after a heavy rainstorm in 1998. Easily eroded valley fill and sediment were transported downstream through the stream system and redeposited downstream along the valley floor over a 3-month period. USDA Forest Service photos by Jeanne Chambers and Jerry Miller by substrate characteristics and local groundwater flow patterns. Recognizing that these conditions exist, preventing large-scale disturbance, and keeping roads out of the valley bottoms is key to preventing incision and maintaining ecological integrity in these watersheds.

The Assessment Protocol

The new assessment approach takes into account the factors that influence sensitivity and resilience at the watershed, watershed segment, and stream reach scales. The protocol is based on remote sensing information that is collected in the office and stream geomorphic and riparian vegetation data that are collected in the field. A summarization of the data is used to categorize the study watersheds.

The researchers estimate that most of the field data needed to understand how the streams and riparian ecosystems are responding to disturbance can be collected within a day.

“We didn’t want field studies to be so in-depth that nobody was going to do them,” Miller says.

To ensure that assessments are robust and reliable, the types of data to collect are based on scientific research. Nonetheless, the authors caution that it’s important to recognize that every stream is unique, and the response will not always be as anticipated.

Assessing the sensitivity and resilience of a system can help managers avoid costly mistakes as they make restoration decisions. Shawn Espinosa values the approach because it helps land managers recognize the underlying factors that shape a system before taking steps to improve it.

“I think this approach is going to be very useful for us and for other public land management agencies as well. It’s a great tool to help managers avoid mistakes and make the best decisions for corrective actions,” Espinosa says.

Now that the report is published, Chambers and Miller hope to work with the land management community to understand the sensitivity and resilience of their systems and to see how the approach can best be adapted for their purposes.

“It is extremely important that we maintain the ecological resilience of our stream systems so that they can continue to be a resource into the future,” Chambers says.

Assessment Protocol Tasks

Phase I. Preliminary work (office)

- Collect data on watershed characteristics and historical responses to disturbances
- Identify distinct watershed segments for field assessment

Phase II. Field data collection (field)

- Select reach-scale study sites within the watershed segments
- Collect reach-scale geomorphic, vegetation, and disturbance data

Phase III. Interpretation (office)

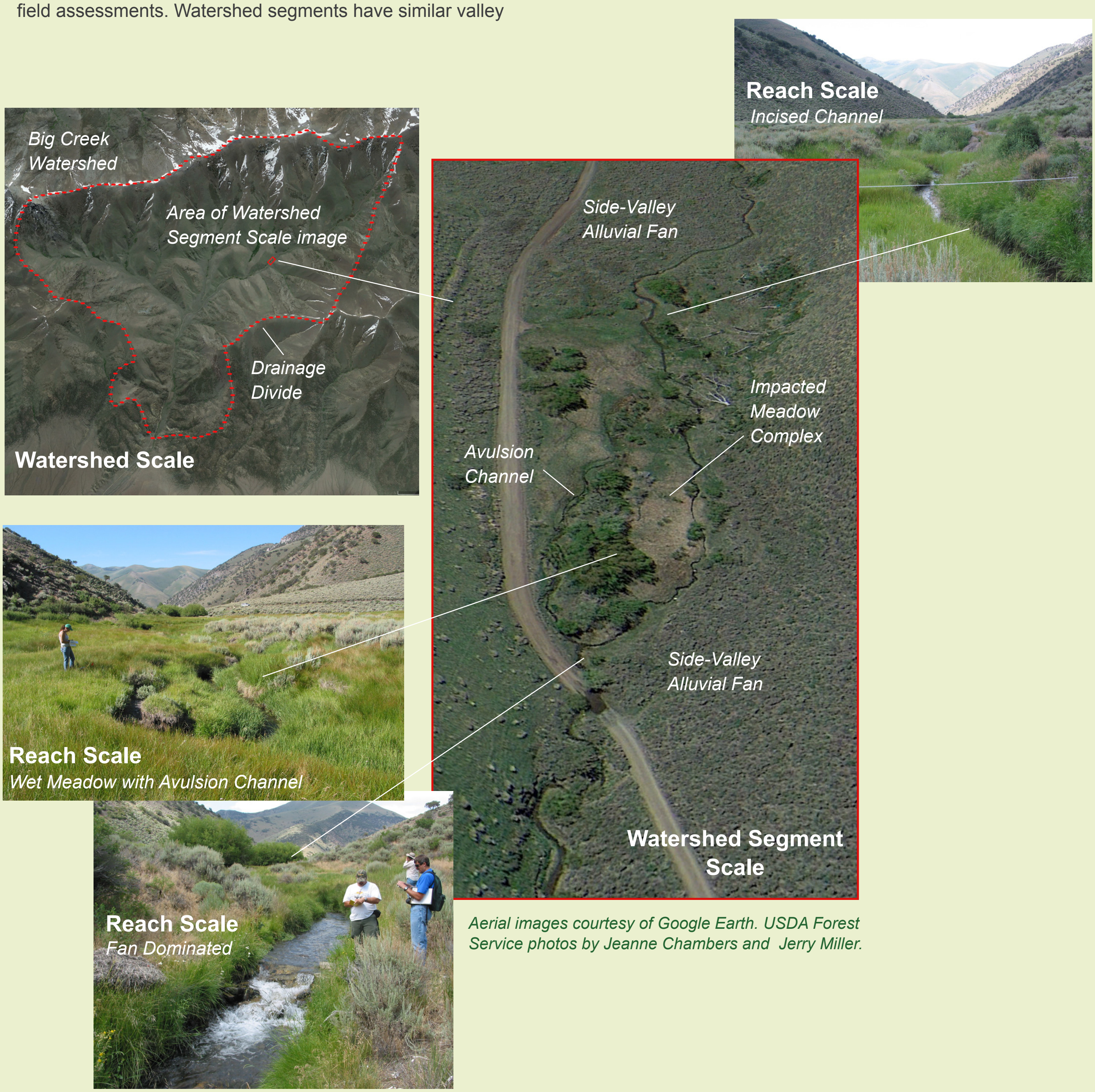
- Summarize the field data
- Determine the watershed sensitivity and resilience type and evaluate its ecological integrity

“I think this approach is going to be very useful for us and for other public land management agencies as well. It’s a great tool to help managers avoid mistakes and make the best decisions for corrective actions.”

-Shawn Espinosa, Nevada Department of Wildlife

Key Aspects of Assessing Sensitivity and Resilience

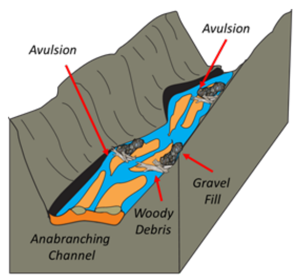
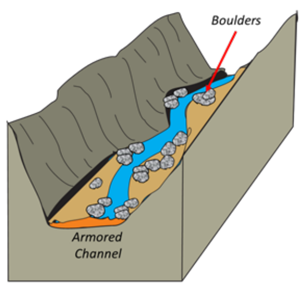
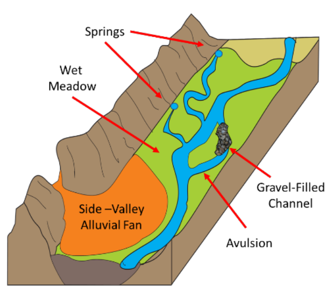
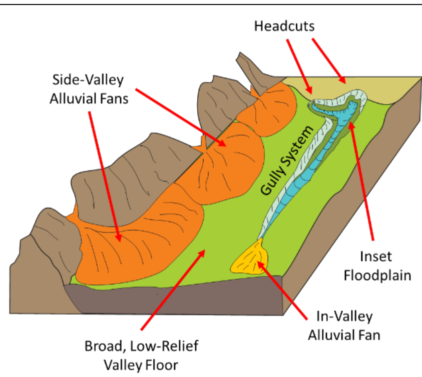
Multiple scale approach. In the assessment, information is collected on the factors that influence sensitivity and resilience at the watershed, watershed segment, and stream reach scales. Watersheds are divided into one or more basin types, and then basin types are divided further into watershed segments and stream reaches for more-detailed field assessments. Watershed segments have similar valley geologic materials, morphology, landforms, and vegetation types. Stream reaches make up watershed segments and have homogeneous channel and valley floor landforms (e.g., terraces, floodplains), channel bed features (e.g., pools and riffles, steps and pools, bars, knickpoints), sediment sizes, and riparian vegetation.



Aerial images courtesy of Google Earth. USDA Forest Service photos by Jeanne Chambers and Jerry Miller.

Key Aspects of Assessing Sensitivity and Resilience (continued)

Basin morphology. Basin type (A, B, or C) is defined according to the underlying geology, topography, landscape morphology, and geomorphic and hydrologic processes. Variations in basin types provide important insights into watershed dynamics. The general relief, valley width, and the frequency and size of side-valley alluvial fans indicate how dynamic a watershed has been over thousands of years and is likely to be at present.

Basin Type	Common Traits	Characteristics
Type A1		-Steep slopes, narrow valley floors, high channel gradients, and high relief -Readily transported, coarse sediment, lack side-valley fans -Local deposition producing channel avulsions -Anabranching channels
Type A2		-Steep slopes, narrow valley floors that typically lack side-valley fans -Large bed material and low sediment transport -Avulsion and incision are rare -Relatively immobile channels -Often associated with glaciated basins, or resistant bedrock with local colluvial sediments
Type B		-Large side-valley alluvial fans and wet meadow complex -Stepped longitudinal profile across toe of fan -Sediments periodically mobilized during extreme events, resulting in incision -Rare avulsions upstream of fan -Variable channel characteristics
Type C		-Broad, low-relief and low gradient valley floors -Deep alluvial fill in valley underlying valley floor -Fans may occur but have little influence on channel form -Unincised reaches have shallow or no channels -Incised reaches possess discontinuous inset floodplains and terraces -Gully systems, once formed, terminate upstream in headcuts -Often possess large wet meadow complexes

Components and guiding questions: see p. 5.
Watershed categories: see p. 7.

FURTHER READING

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SCIENTIST AND MANAGER PROFILES

The following individuals were instrumental in the creation of this Bulletin.

JEANNE CHAMBERS is a Senior Scientist (emeritus) with the Rocky Mountain Research Station located in Reno, Nevada. Her research focuses on (1) developing an understanding of the factors that determine ecological resistance to invasive species and that affect ecological resilience to disturbance, and (2) using that information to develop effective management and restoration approaches. She works in alpine ecosystems, arid and semi-arid shrublands and woodlands, and riparian ecosystems.

JERRY MILLER is the Whitmire Distinguished Professor of Environmental Science at Western Carolina University in North Carolina. His research during the past 25 years has focused on the development of geomorphic and hydrologic tools to establish effective watershed and water resources management programs including river and riparian ecosystem restoration. His work has also documented the transport and fate of contaminants in rivers and lakes, and the analysis of hydrologic and geomorphic responses of streams to natural and anthropogenic disturbances.

SHAWN ESPINOSA is an Upland Game Staff Specialist with the Nevada Department of Wildlife (NDOW) in Reno, Nevada. He has served NDOW in this capacity for 16 years and has been involved with Greater sage-grouse conservation and research work for the past 19 years. His efforts have focused primarily on sagebrush ecosystems, aspen woodlands, montane conifer woodlands and riparian systems due to the associations and dependencies of various upland game species on these communities and habitat types.

WRITER'S PROFILE

SYLVIA KANTOR is a science writer for the Rocky Mountain Research Station in Fort Collins, Colorado, as well as the Pacific Northwest Research Station in Portland, Oregon. She has a master's degree in forestry from the University of Washington and lives in Seattle, Washington. Her portfolio is available at www.sylviakantor.com.

About the
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The purpose of SYCU is to provide scientific information to people who make and influence decisions about managing land.

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