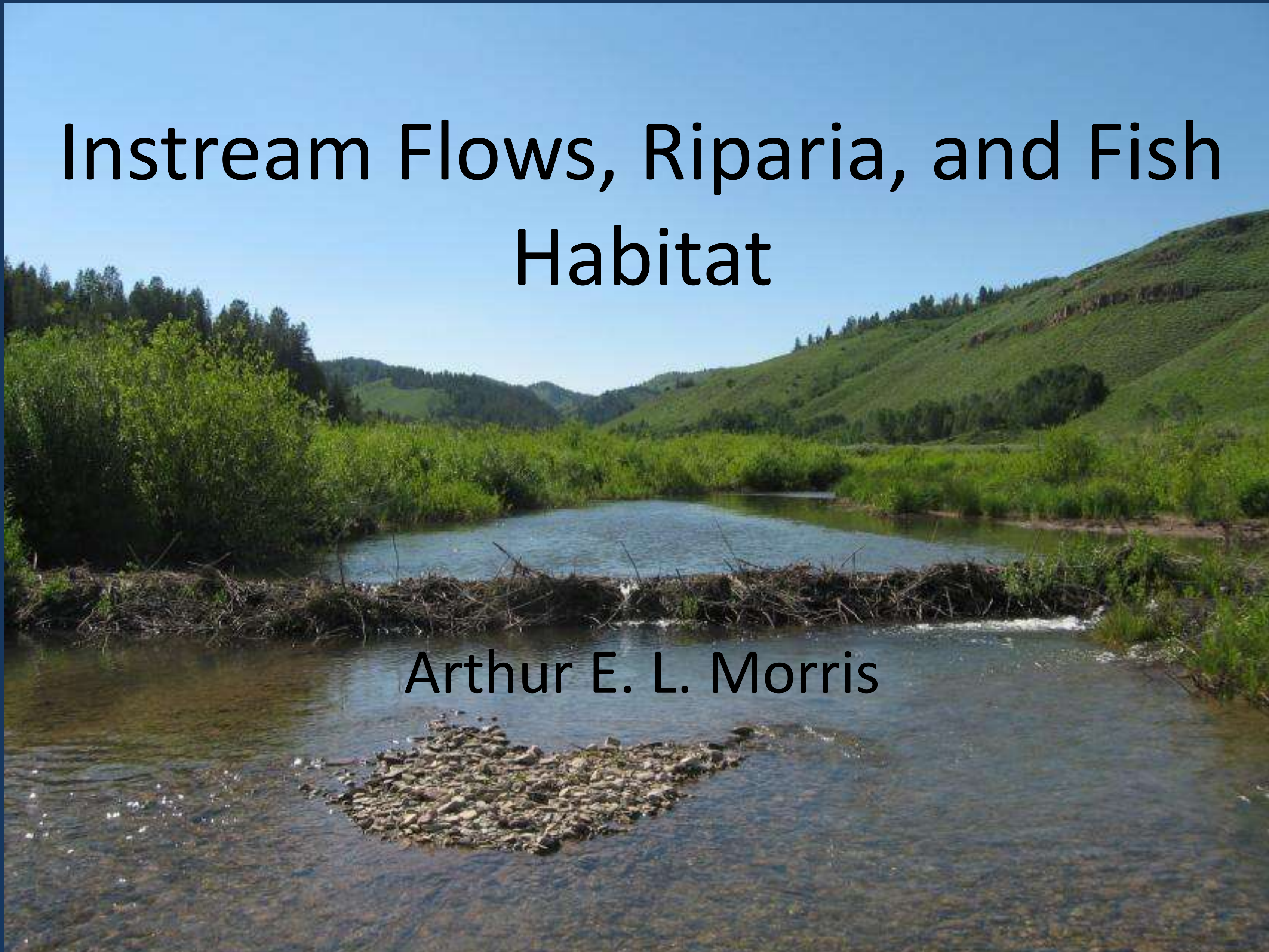
Instream Flows, Riparia, and Fish Habitat



Arthur E. L. Morris

I. Start with look at streams

Structures and functions of streams at different scales influence those of other scales

For example: climate, weather events, geomorphology, vegetation, and land-use at the larger scales influence in-stream flows that define the smaller scales.

Relatively small-scale features (e.g., log in the stream) can change channel form and size both upstream and downstream, influencing larger scale features.

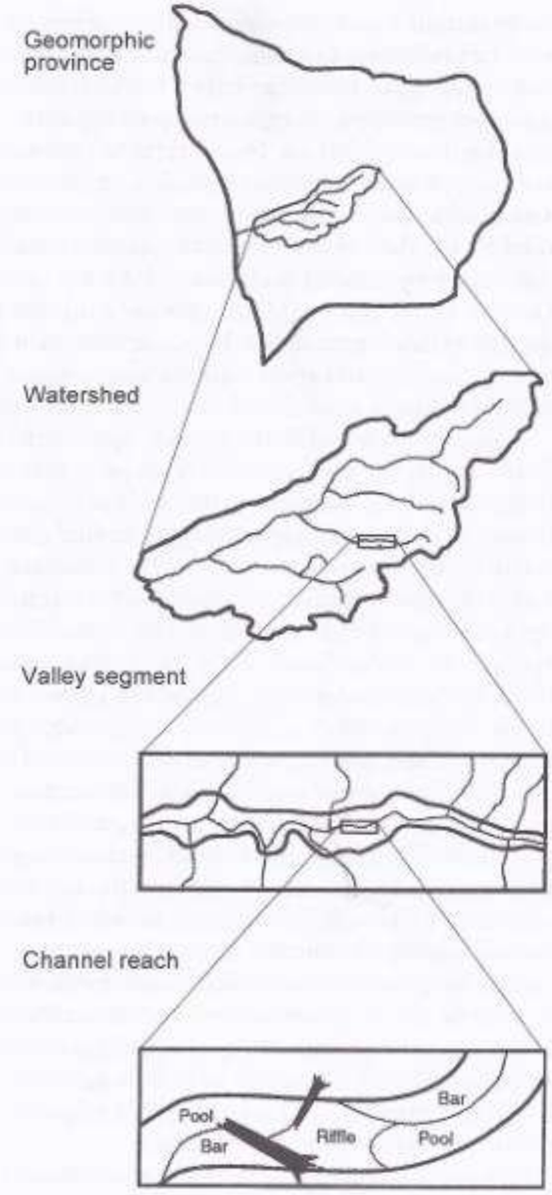


FIGURE 2.3. Geomorphic province, watershed, valley segment, channel reach, and channel unit (e.g., pools, bars, riffles) scales of classification illustrated for the Olympic Peninsula, Washington.

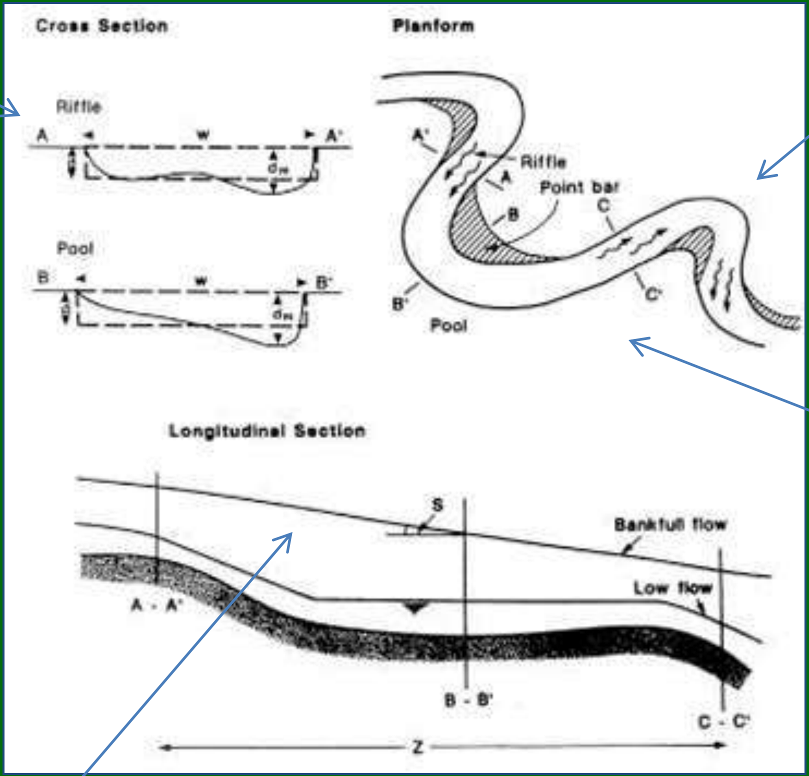
Naiman and Bilby 1998

Channel Structure

- Size of channel reflects the amount of water conveyed
- Shape of channel reflects the amount and size of transported sediments

Channel Structure

Deeper pools on on tighter bends

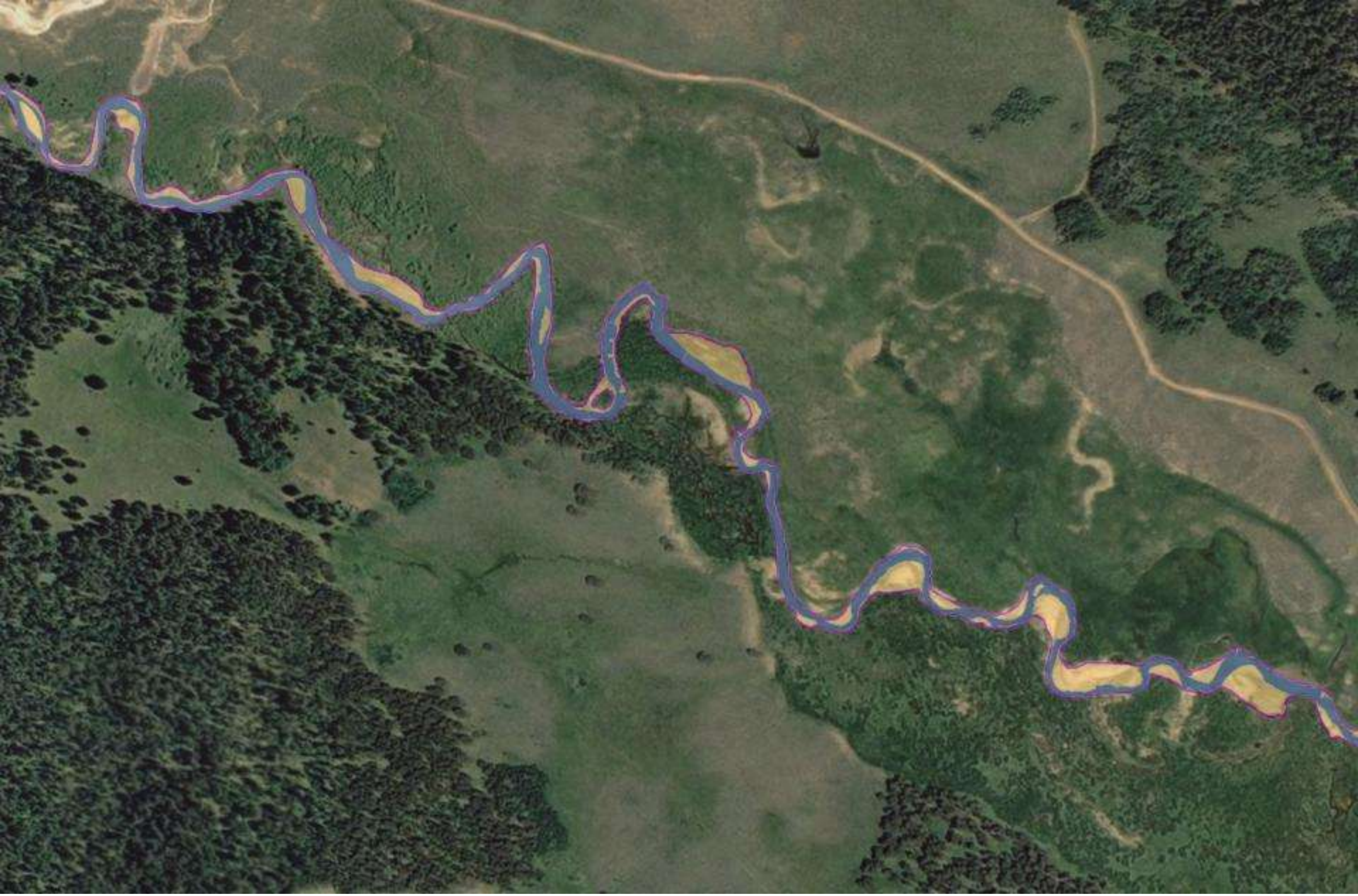


Sinuosity reflects deposition and erosion

Flood Area = flow outside of the channel

- -- Bankfull channel width: avg 1.5 year high-water width
- -- Mean annual flood: avg 2.33-year high-water width
- -- Other floods

Slope and streamflow are proportional to sediment load and size



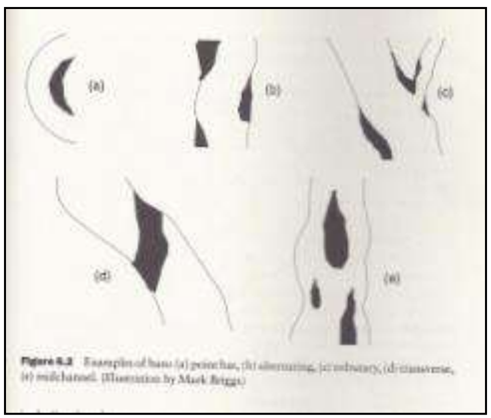
Highlighted meandering channel and depositional features. Stump Creek, ID

Interplay

Backwater rearing habitat on Stump Creek, ID

Interplay

Example:



Briggs, 1996)

Variety of depositional and scouring patterns

Examples of mid-channel bars, pools, large-wood on Stump Creek, ID

Water Levels and Stream Corridor

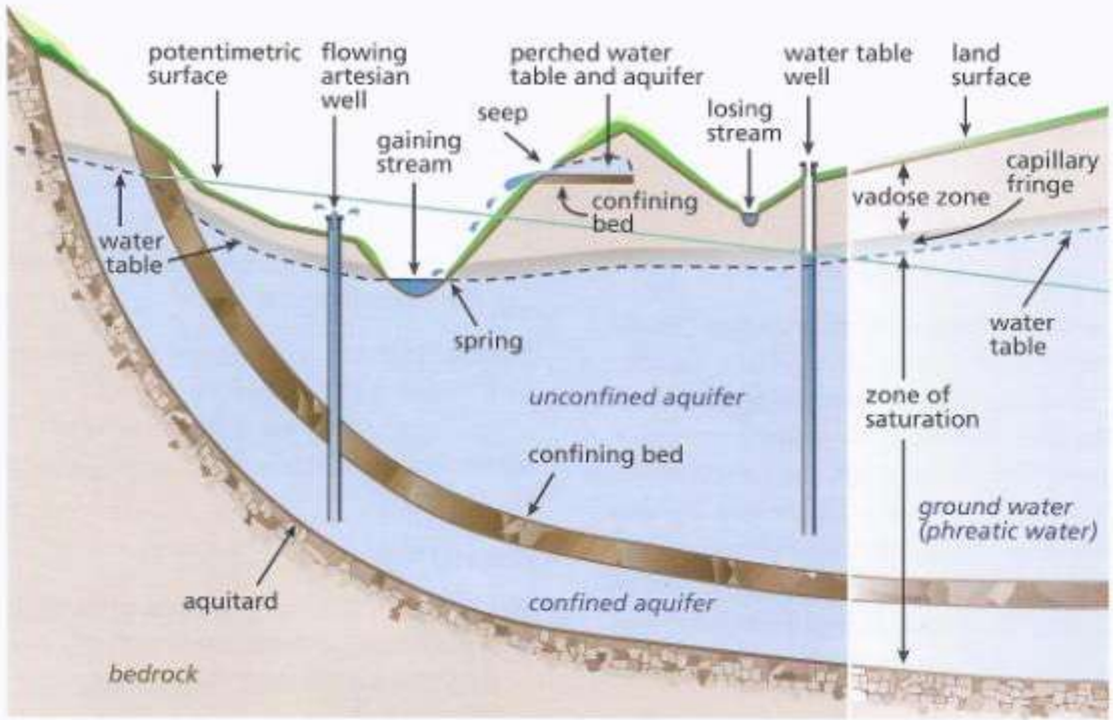


Figure 2.8: Ground water related features and terminology. *Ground water elevation along the stream corridor can vary significantly over short distances, depending on subsurface characteristics.* Source: USGS Water Supply Paper #1988, 1972, Definitions of Selected Ground Water Terms.

(FISRWG 1998)

What you see in the channel is not the only water in the stream system

Stream Water

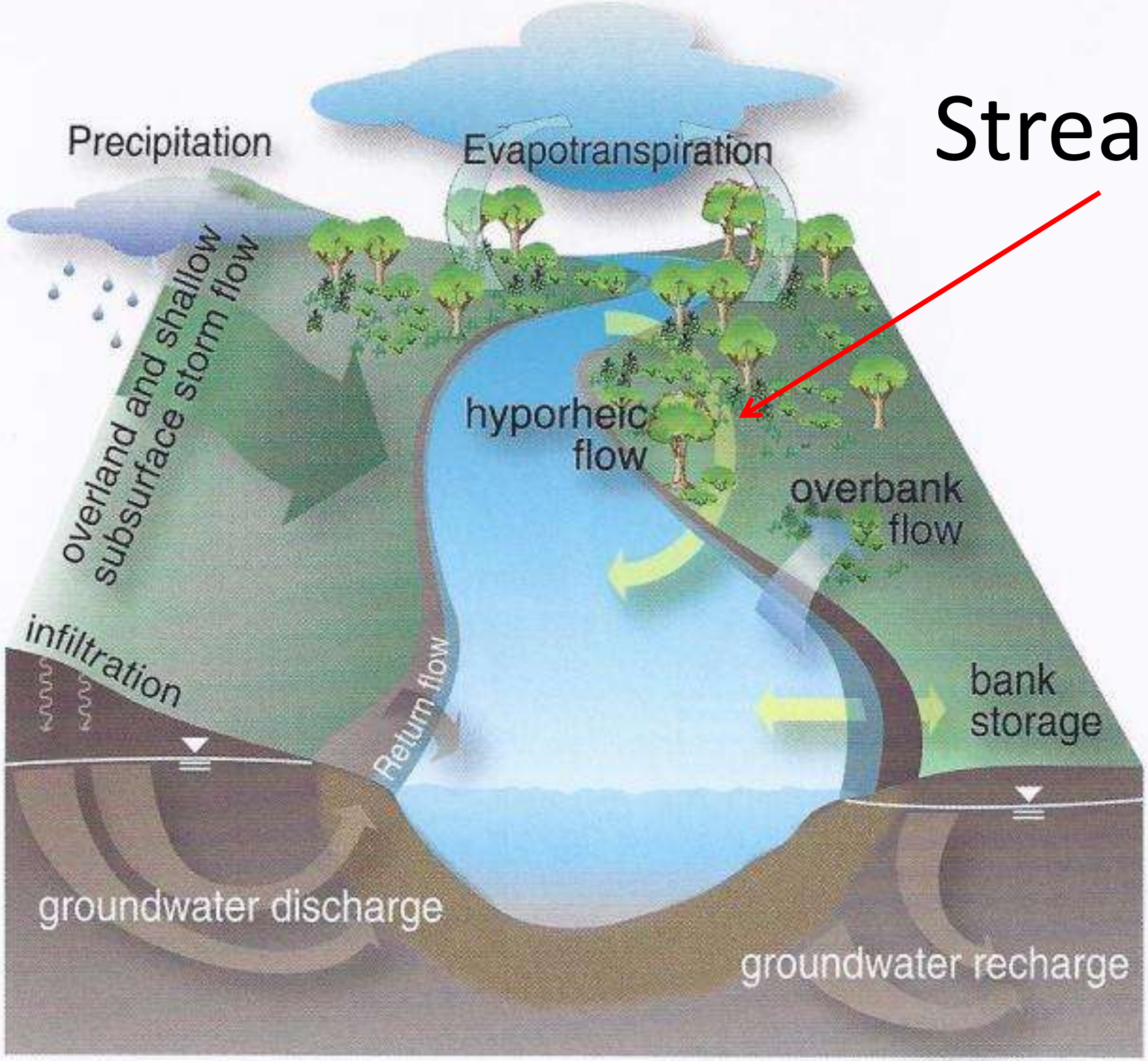


PLATE 2-1 Major pathways of water movement through riparian areas emphasizing (1) groundwater flow, (2) overland flow and shallow subsurface flow from adjacent uplands, and (3) instream water sources such as overbank flow, bank storage and hyporheic exchange. (FISRWG 1998)

Overbank flow wets soil. Phreatophytic plant roots follow descending water levels after floods.

II. Fish Habitat

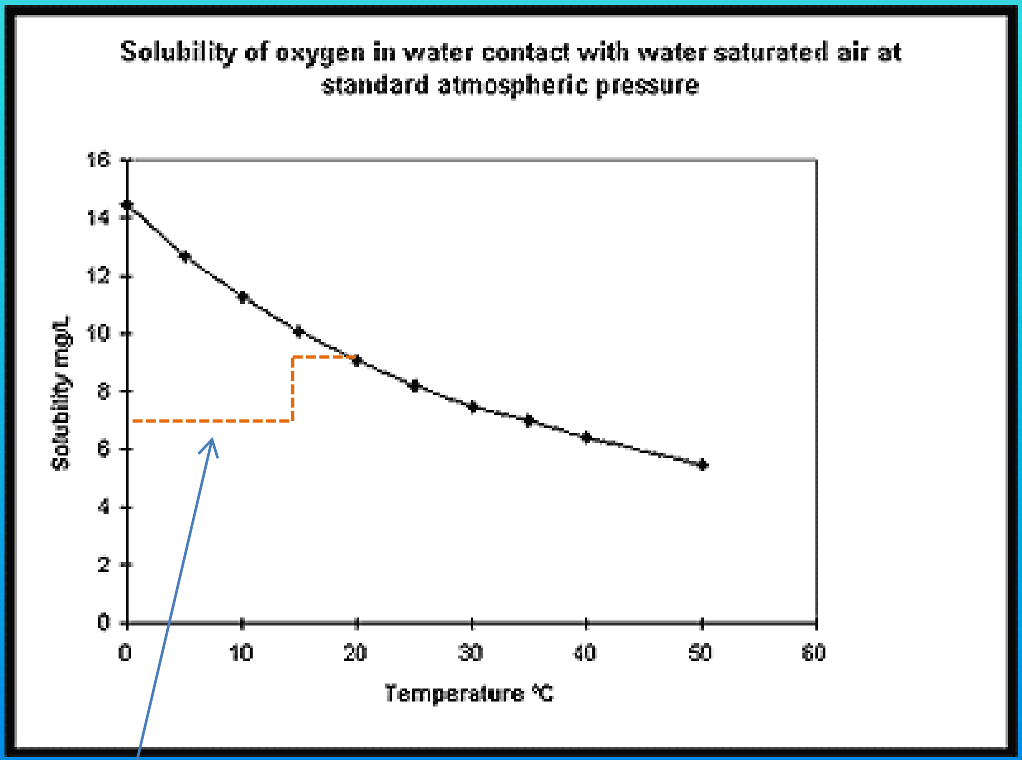
- Fish respond to external influences and their own instinctive and learned preferences
- Habitat preference is multi-faceted and involves feedbacks (e.g., presence of larger fish)
- Fish select habitat based on energetic and physical constraints and opportunities
- Presence of fish in a stream depends on a variety of factors including tolerance and selection.

Water

Fish: an aquatic animal…

Water needs to be chemically able to support fish. Some solutions of chemicals in an H_2O base won't work as the water part of fish habitat.

Dissolved Oxygen (DO)



http://www.eutechinst.com/techtips/tech-tips15.htm

DO

- Higher with lower water temperature.
- Higher with lower salinity.
- Higher with lower altitude (greater air pressure).
- Higher with aquatic photosynthesis.
- Lower with aquatic respiration.

Cutthroat Trout

- > 7 mg/l when water temp < 15 C (HSIM; Hickman and Raleigh 1982).
- > 9 mg/l when water temp > 15 C (HSIM; Hickman and Raleigh 1982).
- req'ts vary by age, activity, adaptation, etc. (HSIM; Hickman and Raleigh 1982).

DO & Instream Flow

Flowing water generally has higher DO than stagnant water

Process	Effect on DO
Internal mixing and turbulence*	Increase
Temperature*	Higher temperature decreases DO
Wind mixing*	Increases
Waterfalls, dams, and rapids*	Increase
Surface films*	Decrease
Water column depth*	Higher DO near surface
Aquatic photosynthesis	Increases
Respiration (bacteria, invertebrates, fish, etc.)	Decreases

* General contributors to reaeration listed in Stream Corridor Restoration: Principles, Processes, and Practices. 1998. Federal Interagency Stream Restoration Working Group

Temperature

Cutthroat Trout

- Optimal 12-15 C for adults (HSIM; Hickman and Raleigh 1982);
- < 10 C indicates lower probability for successful reintroduction (Harig and Fausch , 2002);
- Max about 26 C for short periods (HSIM; Hickman and Raleigh 1982).

Species	Max. Weekly Average Temp. for Growth (Juveniles)	Max. Temp for Survival of short exposure (juveniles)	Max. weekly average temp. for spawning	Max. temp. for embryo spawning
Atlantic salmon	20C(68F)	23C(73F)	5C(41F)	11C(52F)
Bluegill	32C(90F)	35C(95F)	25C(77F)	34C(93F)
Brook Trout	19C(66F)	24C(75F)	9C(48F)	13C(55F)
Common Carp	---	---	21C(70F)	33C(91F)
Channel catfish	32C(90F)	35C(95F)	27C(81F)	29C(84F)
Largemouth bass	32C(90F)	34C(93F)	21C(70F)	27C(81F)
Rainbow Trout	19C(66F)	24C(75F)	9C(48F)	13C(55F)
Smallmouth Bass	29C(84F)	---	17C(63F)	23C(73F)
Sockeye Salmon	18C(64F)	22C(72F)	10C(50F)	13C(55F)

(Brungs and Jones: 1977, http://www.epa.gov/volunteer/stream/vms53.html)

Food

- For energy and nutrients (No photosynthetic fish)
- Type and amount varies with species
- If energy gain > energy loss, then may survive.
  - Benefit from high-value food (high energy, nutritious)
  - Exploit areas where energy output is low relative to energy input
  - Exploit areas where foraging does not expose to predation

Cutthroat Trout

Fish, aquatic invertebrates, amphibians, etc.

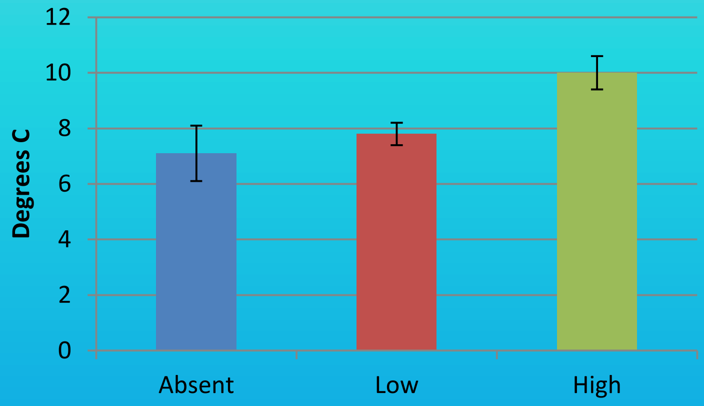
Shelter

- Shelter
  - From predation
  - From unfavorable temperatures, DO, chemicals
  - From energy expenses
  - From competition
  - From stochastic harm

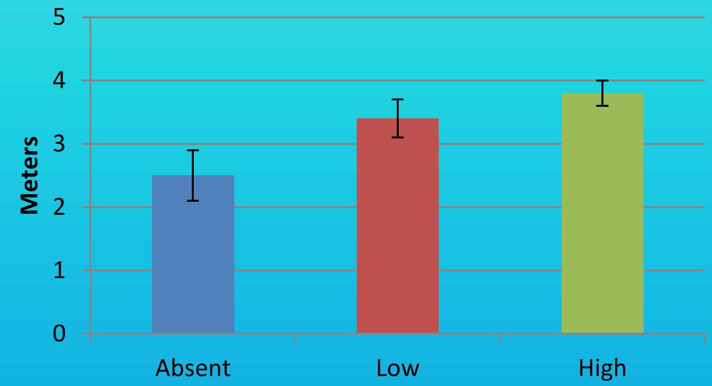
Cutthroat Trout: Best Predictors for Relocation Success in Small Streams

Harig and Fausch 2002; 27 small-stream sites in Colorado & New Mexico; greenback or Rio Grande cutthroat trout

Daily July Temperature

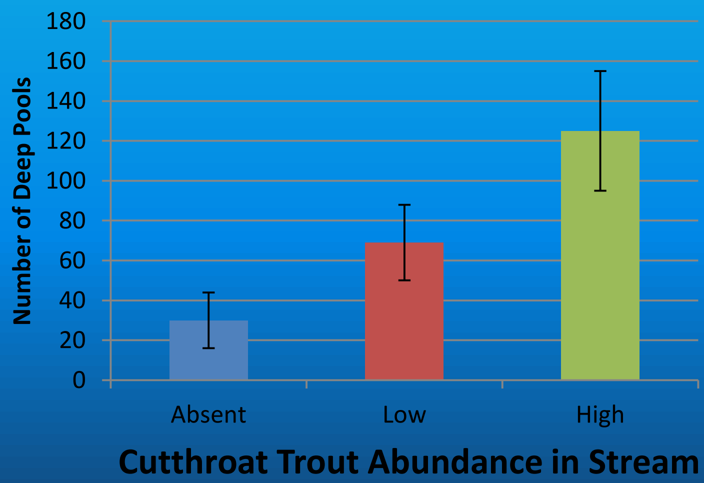


Mean Bankfull Pool Width

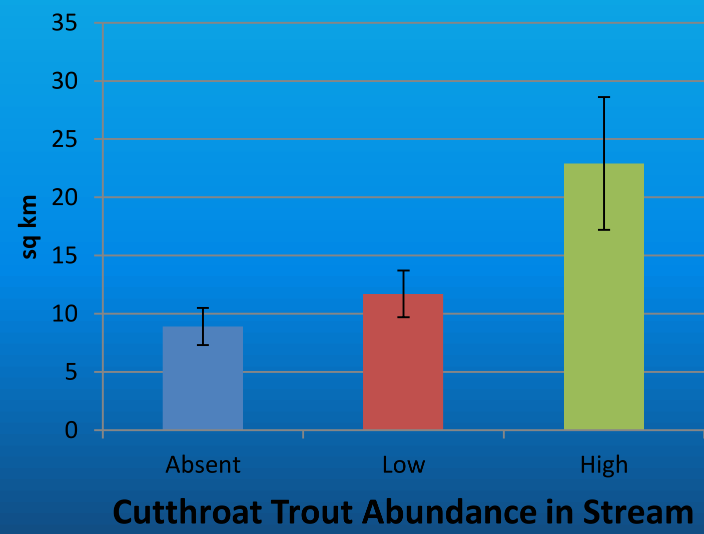


Number of Deep Pools

Residual Depth >= 30 cm



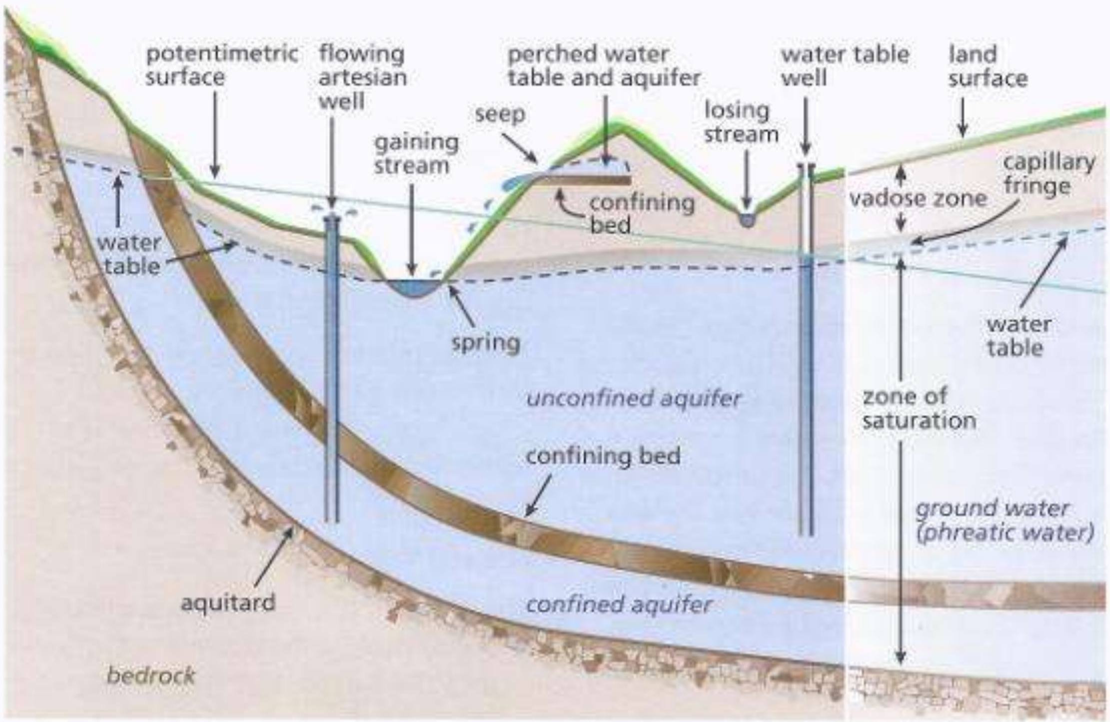
WatershedArea



"Salmonids favor pools created by large woody debris, boulders, or lateral scour beneath stream banks…" (Harig and Fausch 2002)

III. In-Stream Flow & Riparian Areas

A. Water can enter streams from a variety of sources



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(FISRWG 1998)

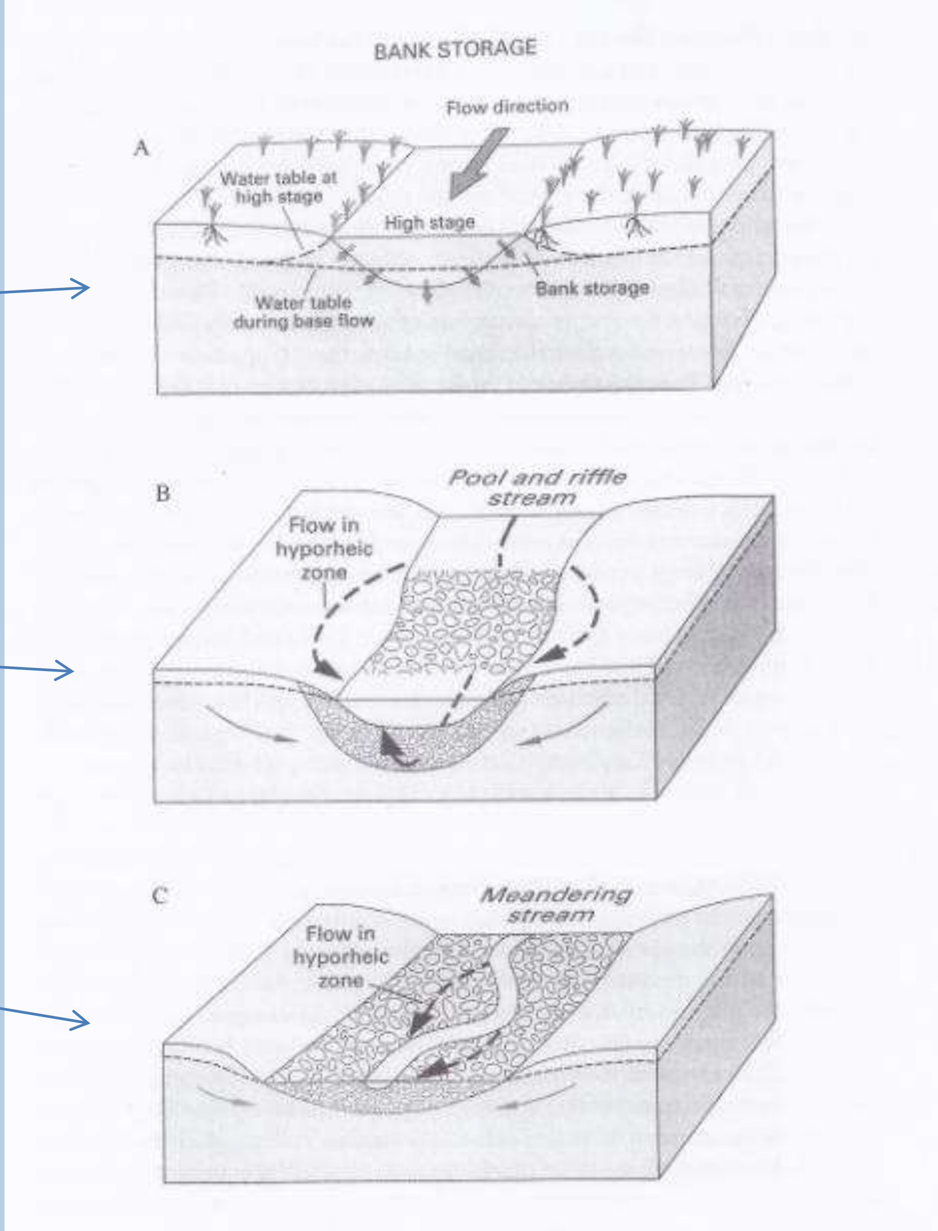
"Water exchange between channel and riparian areas caused by

(A) change in stream stage followed by bank storage,

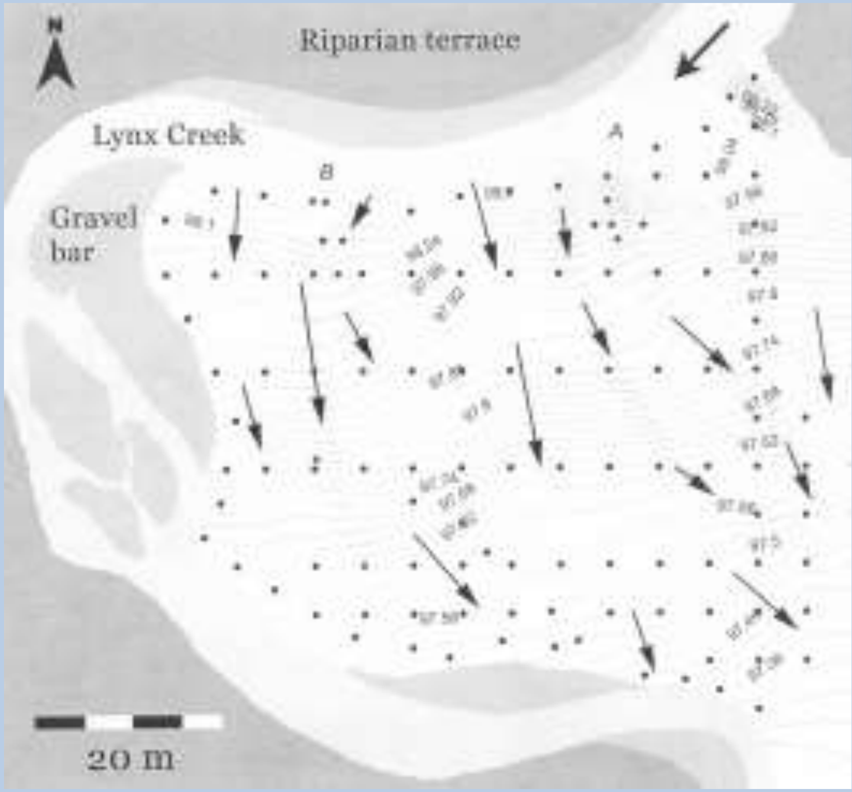
(B) streambed topography routing streamflow temporarily through subsurface (hyporheic) flow paths, and

(C) hyporheic flows through bends of meandering stream."

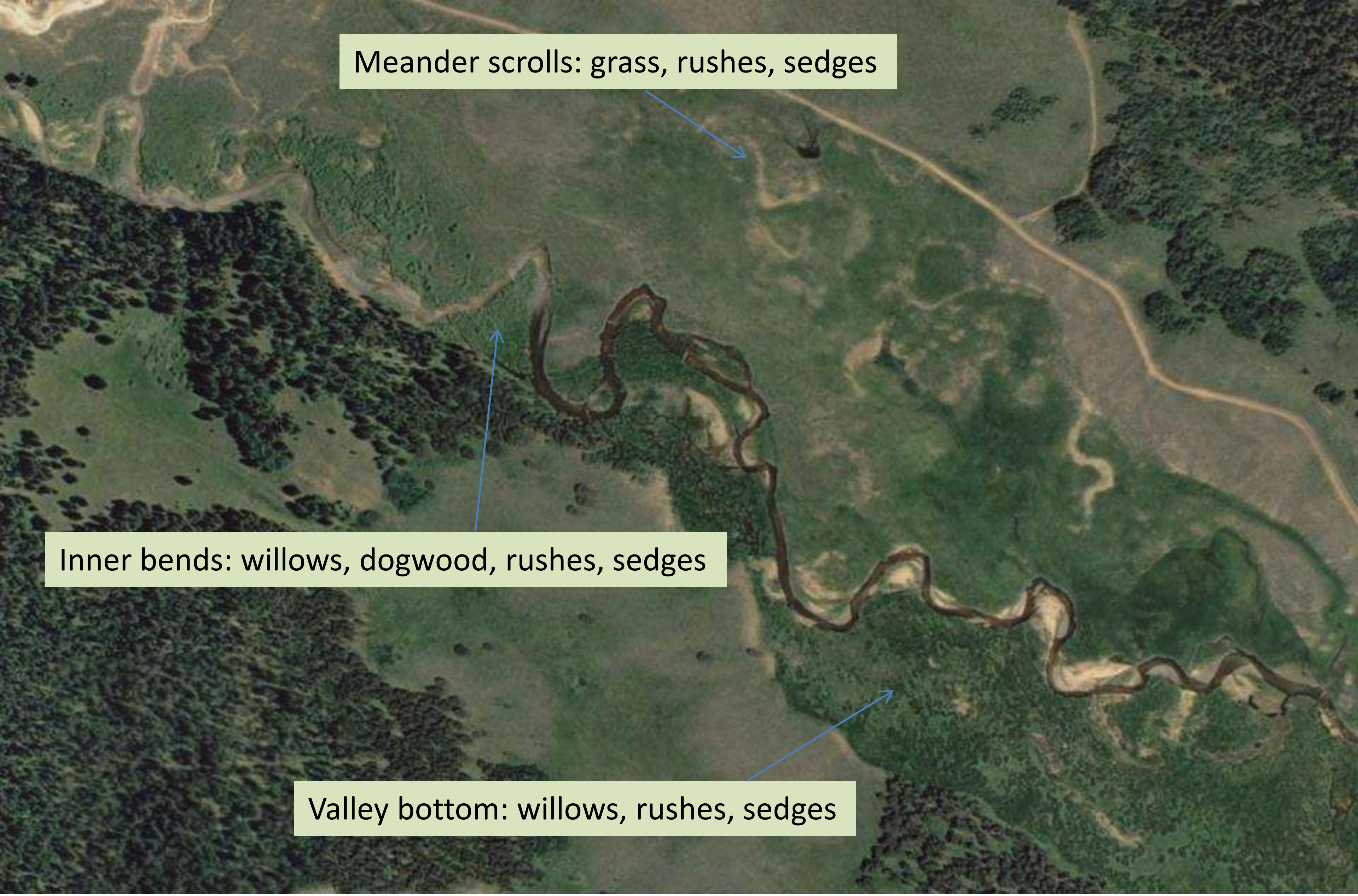
(NRC 2002, from Winter et al. 1998)



Example hyporheic flow



Alaska; O'Keefe and Edwards. 2002. American Fisheries Society Symposium 33:99–107



Example of riparian vegetation reflecting streamflow not visible in primary channel

Water

Riparian vegetation can help to trap and remove sediments, excess nutrients, and harmful chemicals.

Riparian soil-organism complexes can filter subsurface water.

Aquatic life-forms of terrestrial organisms can help to filter and purify water.

Riparian vegetation, organisms, and soil can improve water infiltration and moderate flood pulses, thereby reducing downstream sediment recruitment.

Oxygen

Riparian vegetation can help to cool streamwaters by providing shade in sunlit areas.

Riparian nutrient contributions to streams via litterfall, flooding, bank sloughing, etc., can help to support photosynthetic aquatic organisms.

Riparian materials such as wood pieces can directly and indirectly contribute to dams, waterfalls, and riffles that help to oxygenate streams.

Riparian materials can contribute to stream channel migration, leading to recruitment of other materials that influence re-aeration.

Food

Riparian communities support terrestrial organisms that become food for fish (primarily invertebrates, but also mammals, birds, reptiles, amphibians)

Riparian materials such as wood recruited to streams and streambanks provide temporally and spatially patchy habitat that supports aquatic organisms and trans-aquatic-terrestrial organisms such as caddisflies, stoneflies, and mayflies, which are prey for fish.

Wood in streams can provide complex, mid-column structure that readily contributes prey items to the drift.

Hyporheic flows can support aquatic organisms in near-stream soils; these organisms can become available as fish prey.

Shelter

Riparian vegetation can provide over-stream cover from aerial and bankside predators

Riparian vegetation and other materials can provide complex in-stream structure that provides both ambush and refuge cover, facilitates energetically-favorable feeding stations, and moderates competitive interactions

Riparian vegetation can stabilize banks so that they can be undercut, providing cover for fish

Reproduction

Riparian vegetation can contribute to environmental conditions appropriate for spawning and juvenile fish, such as by cooling summertime stream temperatures.

Riparian materials can contribute to spawning areas directly by creating riffles and forming spawning substrate, and indirectly by causing channel migration and alluvial deposition

Riparian vegetation helps to prevent extreme sediment loads by stabilizing stream banks and impeding and filtering surface runoff water.

Riparian wood recruited to streams provides feeding areas for juvenile fish.

Riparian wood recruited to streams and overhanging streams shelters juvenile fish from aquatic and terrestrial predators, including other fish.

Riparian wood can trap anadromous fish carcasses so that nutrients enter the stream, benefitting stream organisms that are prey for juvenile fish.

Riparian Relationships to Cutthroat Trout Relocation Success Factors

Relocation Success Factor (Harig and Fausch 2002)	Riparian Function
Warm enough water temperatures	Natural riparian systems generally do not increase temperatures; however, for many degraded stream systems, the challenge is decreasing water temperature to acceptable ranges.
Bankfull pool width of about 4 m	Large wood from riparian forests can function as pool-forming structure; riparian vegetation can help to prevent both extreme channel incision and widening.
Number of deep pools (residual depth >= 30 cm)	Large wood from riparian forests can function to create pools directly and to stabilize banks and channels so that deep pools can form; as the authors suggested, fish prefer pools with structure such as large wood.
Watershed area	Will not increase absolute watershed size, but the function of riparian systems is influenced by their large-scale extent.

Restoration

- Without in-stream flows, restoration of riparian systems will not be effective in places where those flows provide riparian water.

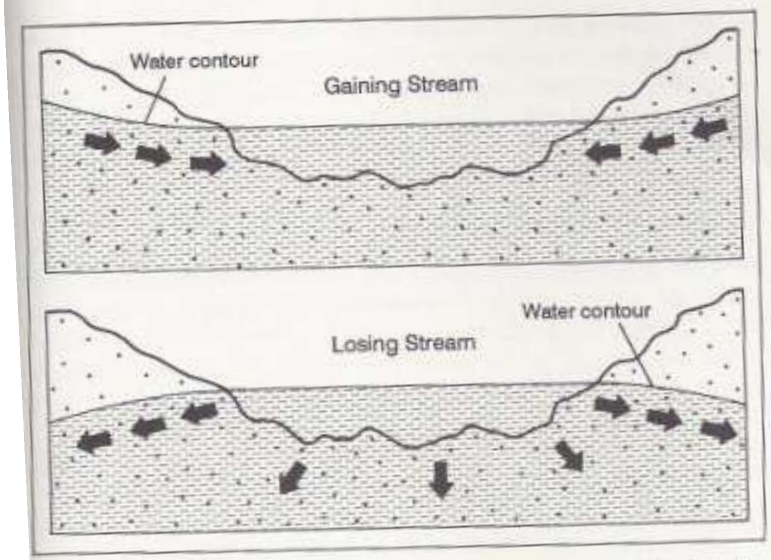


Figure 5.2 Comparison of water contours and groundwater flow directions for gaining and losing streams. (Illustration by Mark Briggs)

(Briggs 1996)

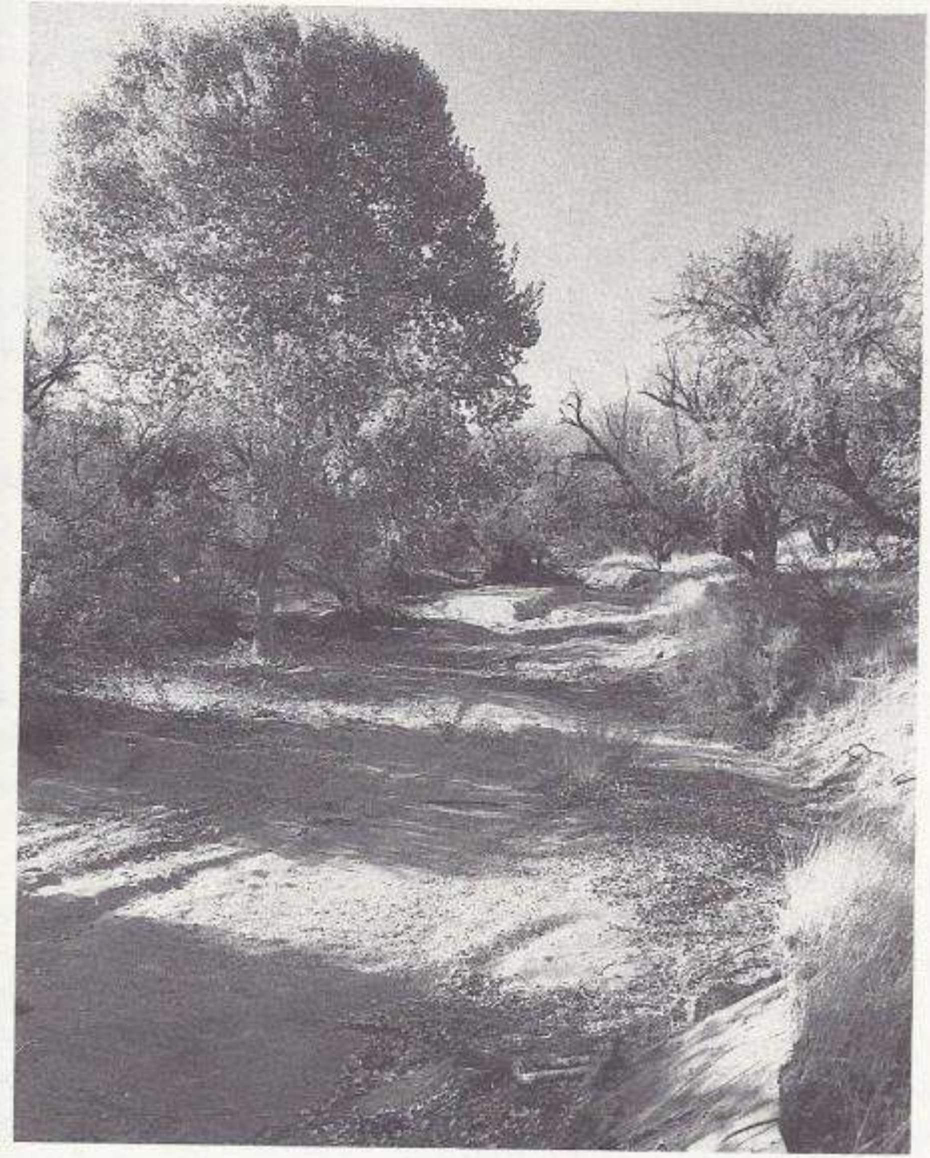


Figure 5.1 At a revegetation site called Box Bar along the lower Verde River, Arizona, only those seedlings planted in the secondary channel survived. Despite extensive irrigation, those planted on the upper terrace (on the right) did not survive. (Photograph by Liz Rosan, Sonoran Institute)

(Briggs 1996)

Assess Riparian Water Availability

- Hydrologic modelling (combine with seed source analysis)
- Historical and existing vegetation community species and growth (on-ground, remote)
- Direct groundwater measurements (well, piezometer)

In-Stream Effects on Riparia Highlight Needs for Advanced In-Stream Flow Needs (IFN) Assessments

- IFN assessment method should consider more than how much of the channel is “wet” or the availability of in-channel habitat under different flow regimes. (Anderson et al. 2006)
- “Tools that lack dynamic feedbacks among physical and biological components of the river environment are unlikely to provide sufficient descriptions of how population or community viability will respond to changes in the flow regime.” (Anderson et al. 2006)

Instream Flow Regimen Generalities

Example: (Tennant 2011)

- 10% Minimum for short-term survival
- 30% Good survival conditions
- 60% Excellent to outstanding habitat for most aquatic life forms and general recreation.

Advantages: Simple, Easy, Heuristic

Disadvantages: Focused on aquatic organisms alone – neglects riparian and other terrestrial organisms related to fish habitat; May miss site-specific needs (e.g., rearing habitat); May miss hyporheic and groundwater connections.

A Few Suggestions

- Measure and consider hyporheic flow and groundwater in stream management and restoration projects.
- Avoid conceptually separating riparian areas from streams when considering IFN.
- Advance in-stream flow maintenance possibilities to benefit fish, birds, riparian diversity, etc.