BENDWAY WEIRS, ROCK VANES, BANK BARBS, & J-HOOKS

{All are redirective methods}

BENDWAY WEIRS (BW):

Upstream angled, level-crested (flat, typical height is 1 ft above base flow), rock sills, designed to work as a system to realign the thalweg to a position off the stream ends of the weirs, & reduce flow velocities within the weir field.

ROCK VANES/ BANK BARBS

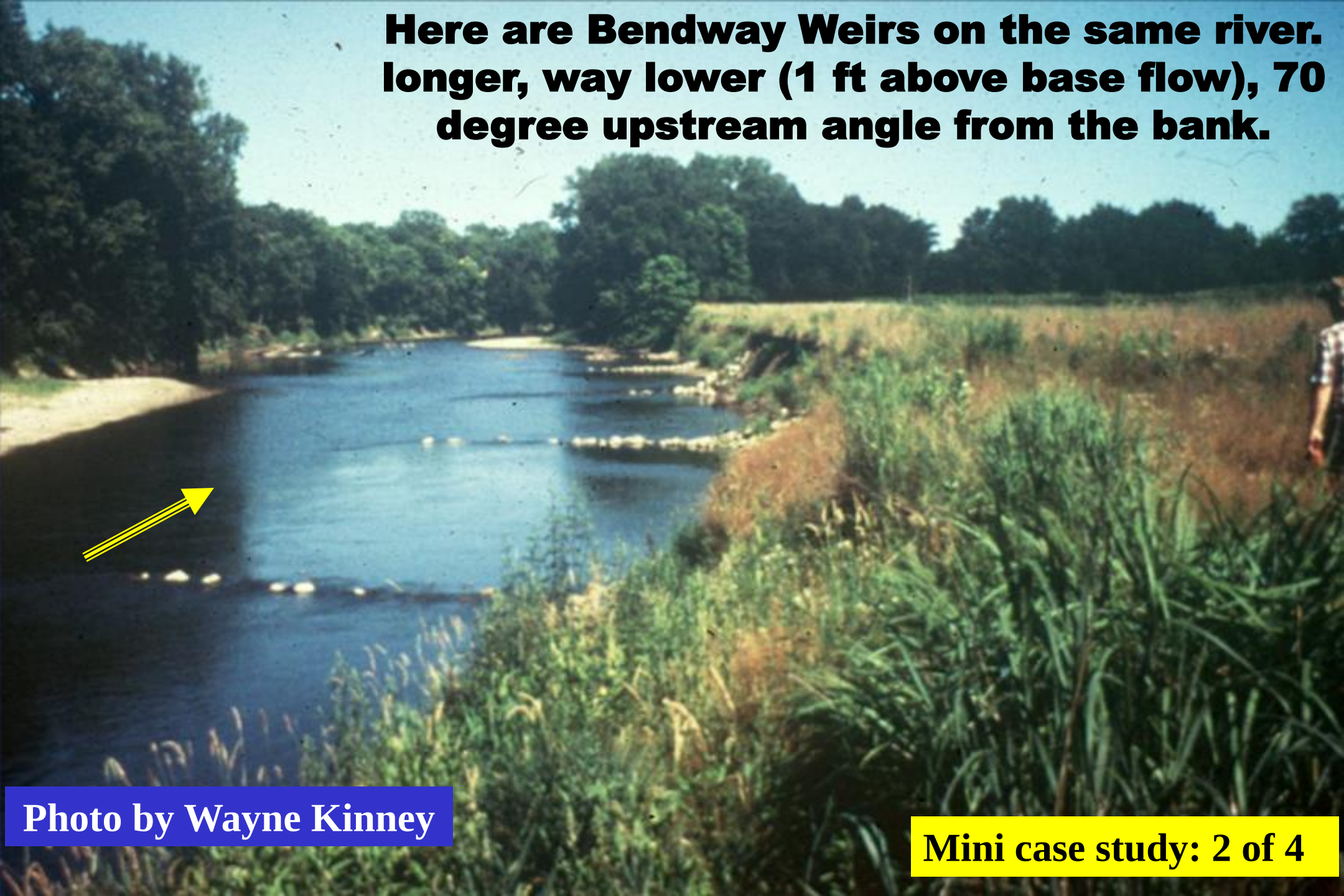
According to Janine Castro, who wrote the NRCS manual chapters on ROCK VANES & BANK BARBS, all specifications are exactly the same for both, except that ROCK VANES are constructed of extremely large boulders that do not adjust, and BANK BARBS are built using well-graded, self-adjusting stone.

Physical Differences Between Bendway Weirs & Rock Vanes/Bank Barbs

Differences between Bank Barbs & Bendway Weirs: pictured are Bank Barbs

Photo by Wayne Kinney

Mini case study: 1 of 4


Here are Bendway Weirs on the same river. longer, way lower (1 ft above base flow), 70 degree upstream angle from the bank.
Photo by Wayne Kinney
Mini case study: 2 of 4

BENDWAY WEIRS vs. ROCK VANES/ BANK BARBS

- **LEVEL-CRESTED** (flat)
- **ANGLED**-upstream 70 degrees from a line tangent to the bank
- **LENGTH**-determined by how much river flow needs to be controlled & by realigned thalweg location
- **HEIGHT**- lower than any flow that can erode the bank, usually 1 ft above the base flow (typical low-flow, or 80% excedence) water surface elevation

- **SLOPED**-Range 10 to 1, to 12 to 1
- **ANGLED**- upstream 30 degrees from a line tangent to the bank
- **LENGTH**-determined by height (crest) at bank end, vane slope angle, & bathymetry at river end of RV/BB
- **HEIGHT**- varies by designer, anywhere from 1/2 bank full stage to bankfull stage

Mini case study: 3 of 4

Rock Vanes (again)

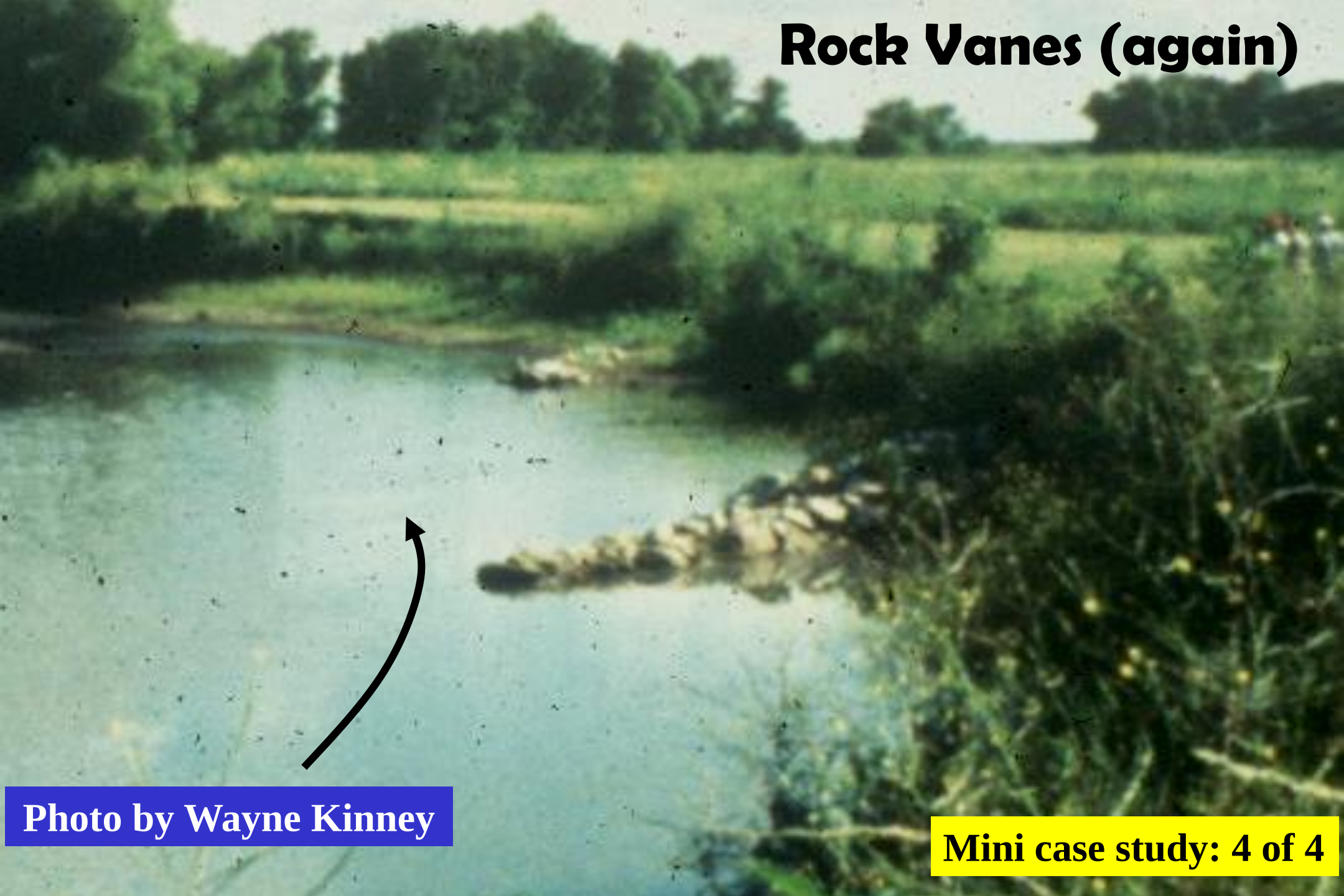


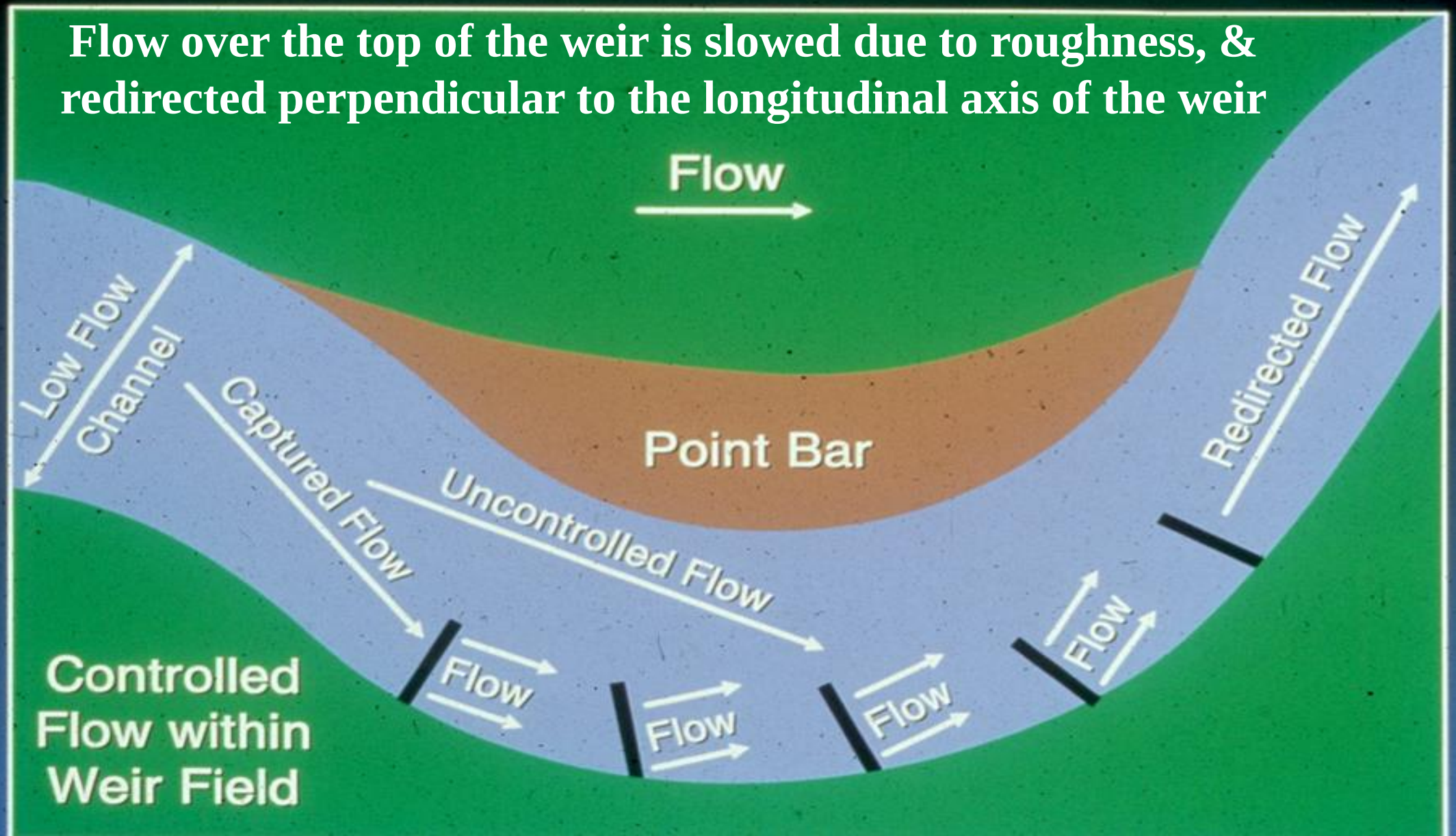
Photo by Wayne Kinney

Mini case study: 4 of 4

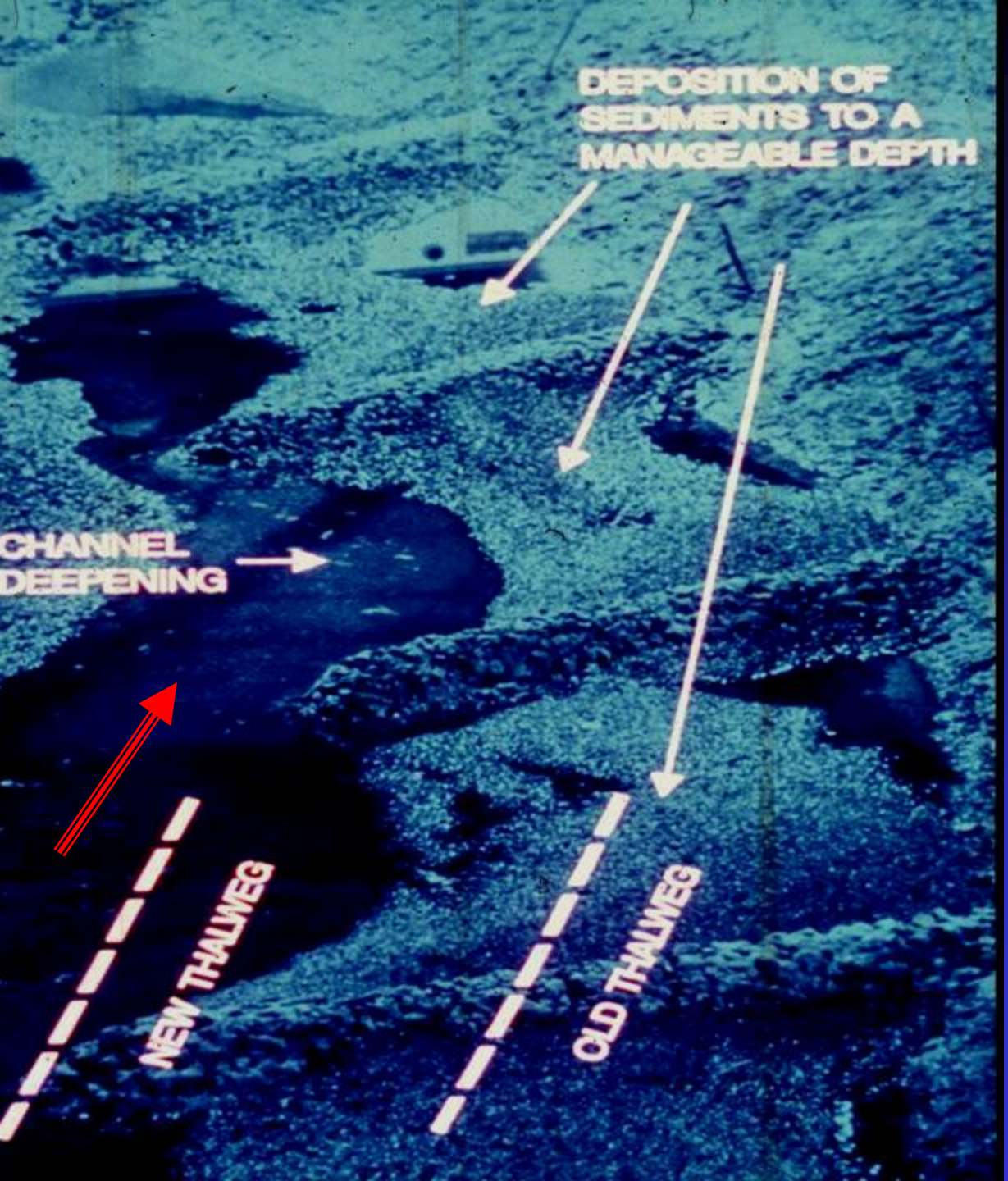
BENDWAY WEIRS

Bendway Weir Theory

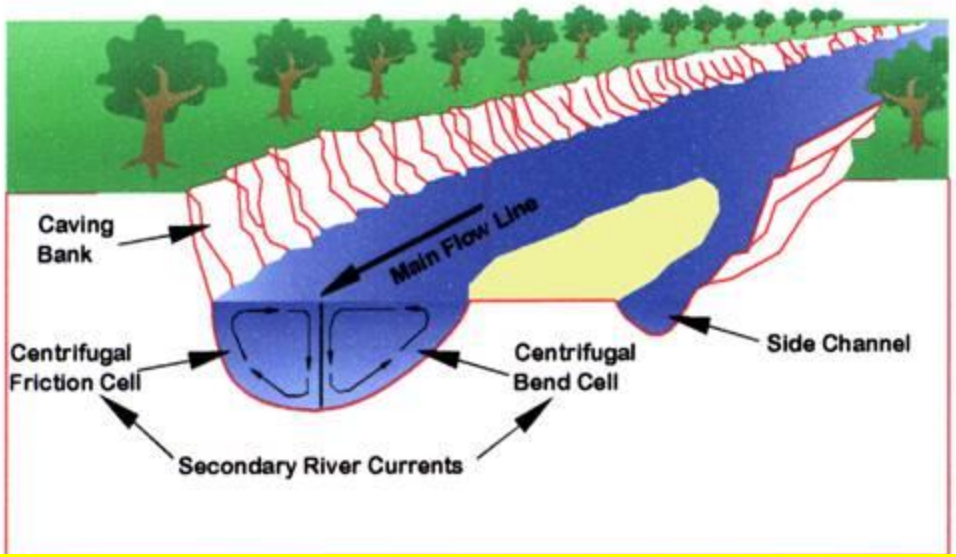
Flow over the top of the weir is slowed due to roughness, & redirected perpendicular to the longitudinal axis of the weir



Bendway Weirs were invented by Tom Pokrefke for use on large navigable rivers. Typical lengths used on Mississippi River navigation projects were 800 to 1,500 ft., constructed of 5,000 lb. graded stone. The crest elevation is set at -15 ft Low Water Reference Plane (LWRP), so that 9 ft draft tow boats can navigate over them.

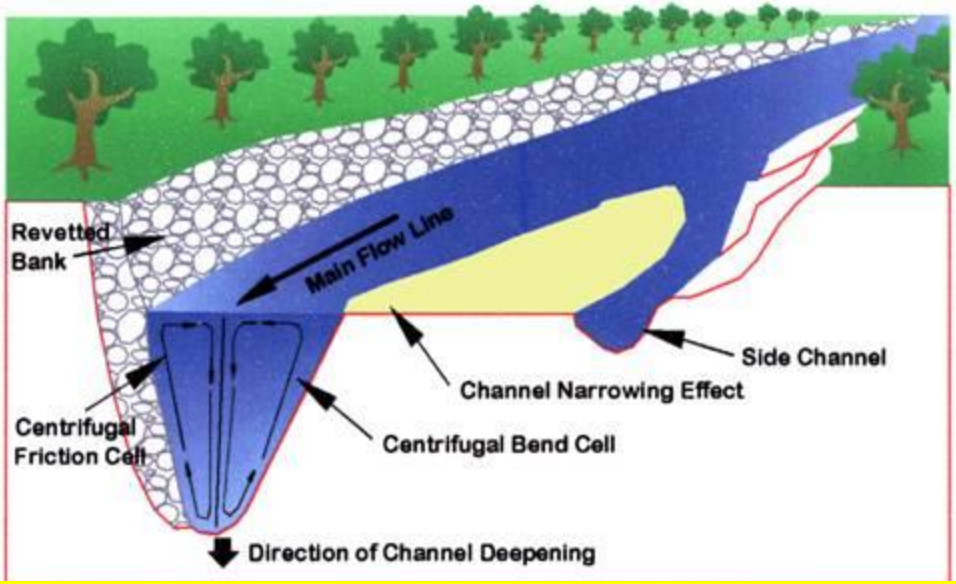


Looking DS at a partially drained movable-bed coal model of the Middle Mississippi River (Dogtooth Bend). Note new location of thalweg off the stream ends of the weirs.



1.

2.

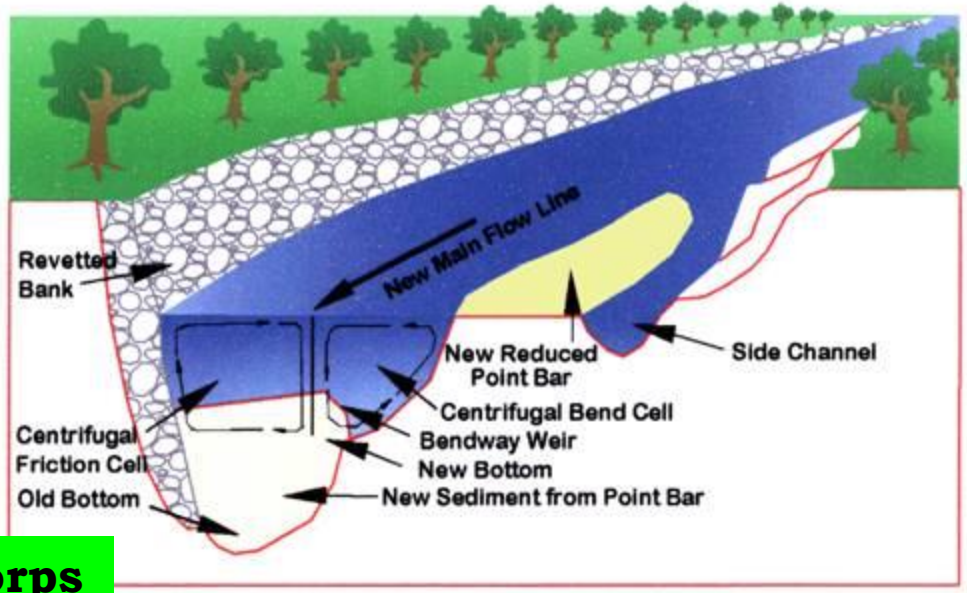


Unrevetted Bend | **Revetted Bend**

Bendway Weir installed | **Bendway Weir effects**

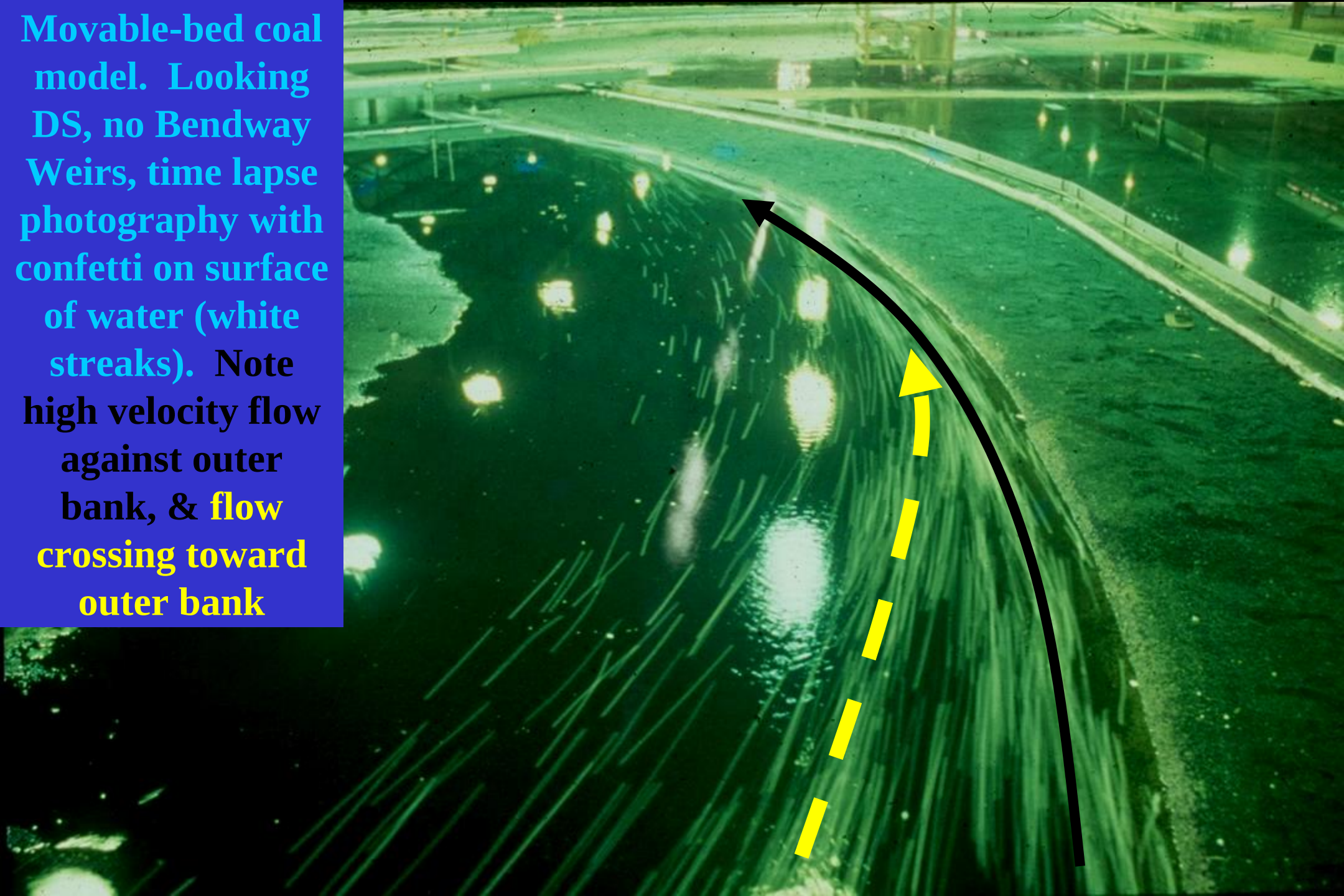
3.

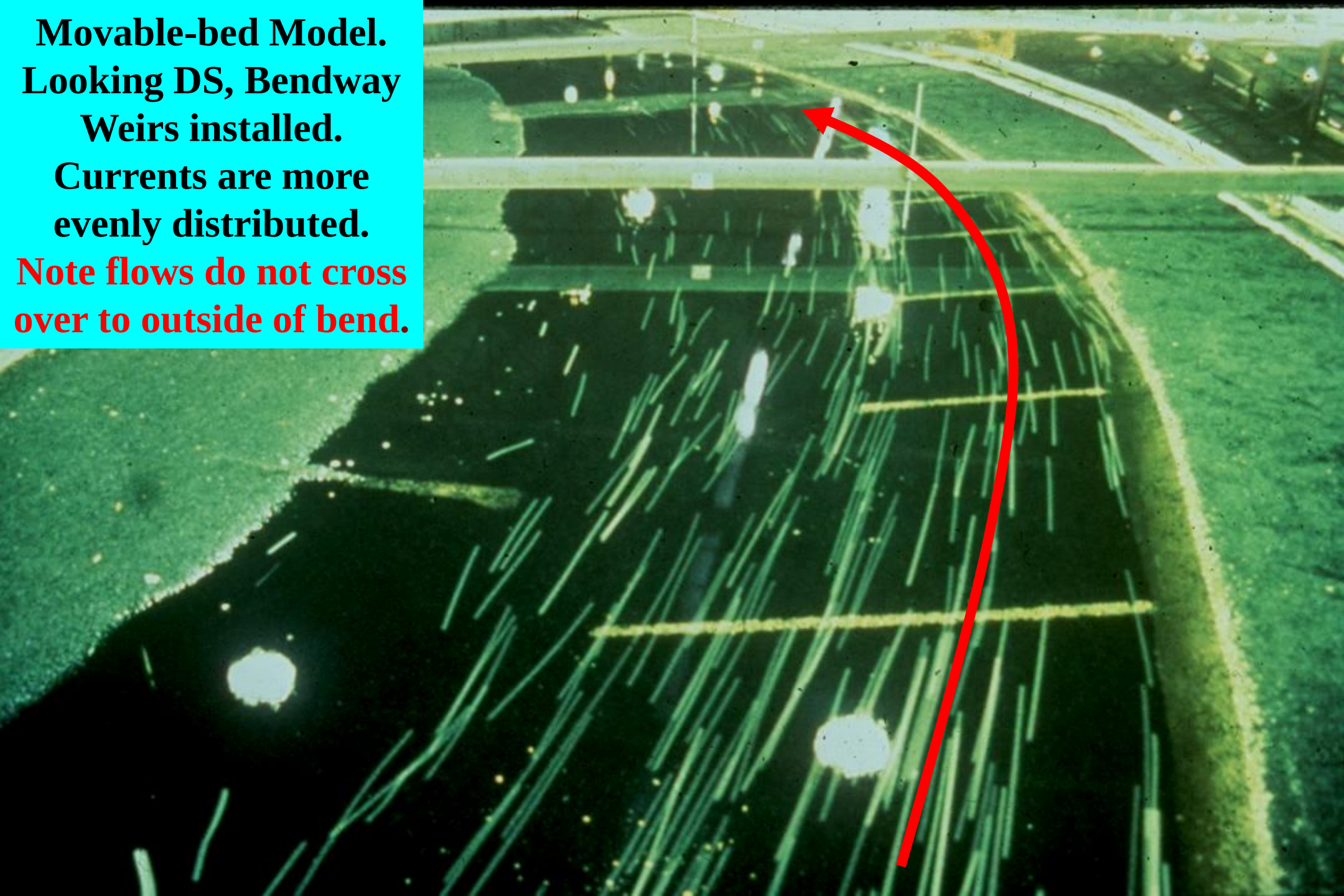
4.



From Rob Davinroy, St. Louis Corps

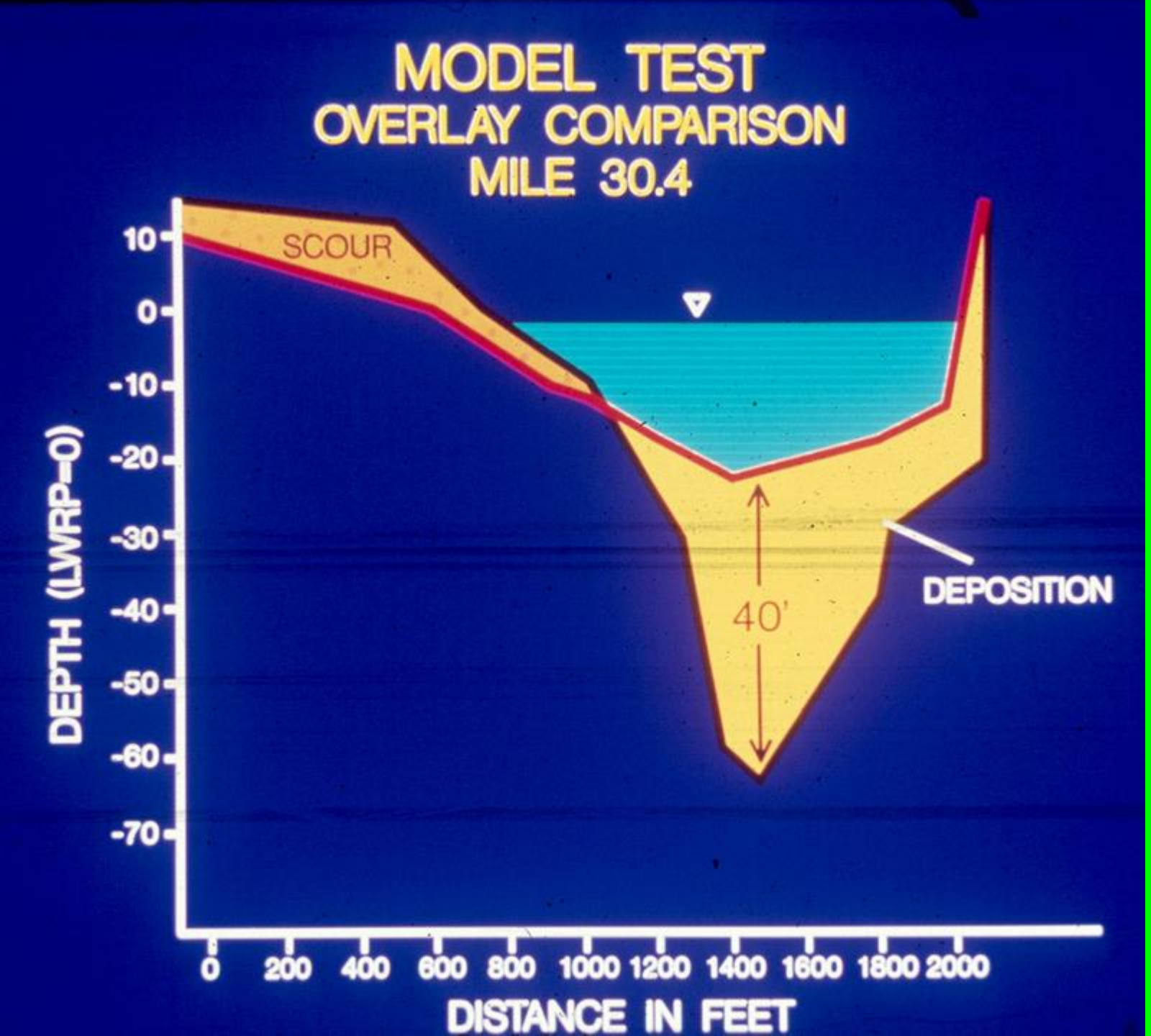
Movable-bed coal model. Looking DS, no Bendway Weirs, time lapse photography with confetti on surface of water (white streaks). Note high velocity flow against outer bank, & flow crossing toward outer bank




Movable-bed Model.
Looking DS, Bendway
Weirs installed.
Currents are more
evenly distributed.
Note flows do not cross
over to outside of bend.

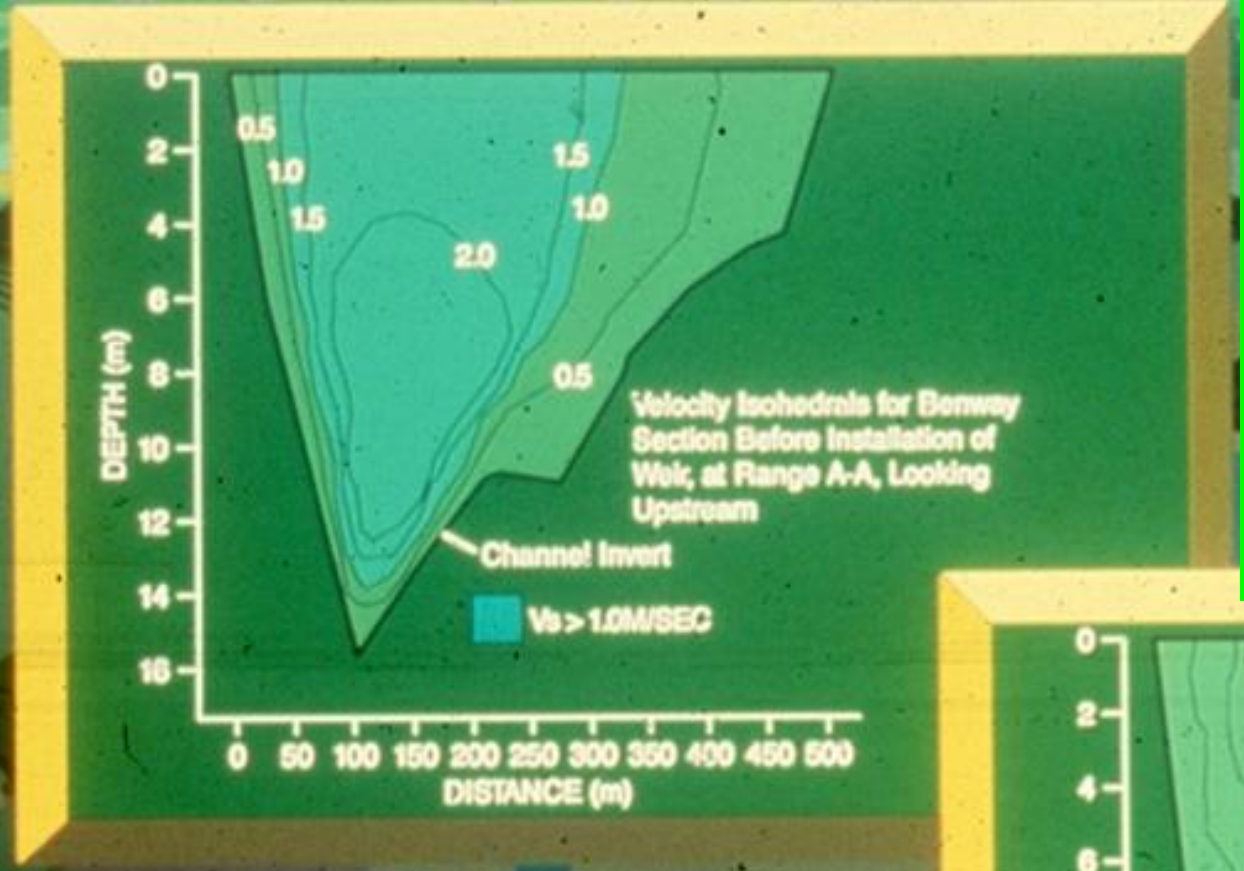
How Do Bendway Weirs Work?

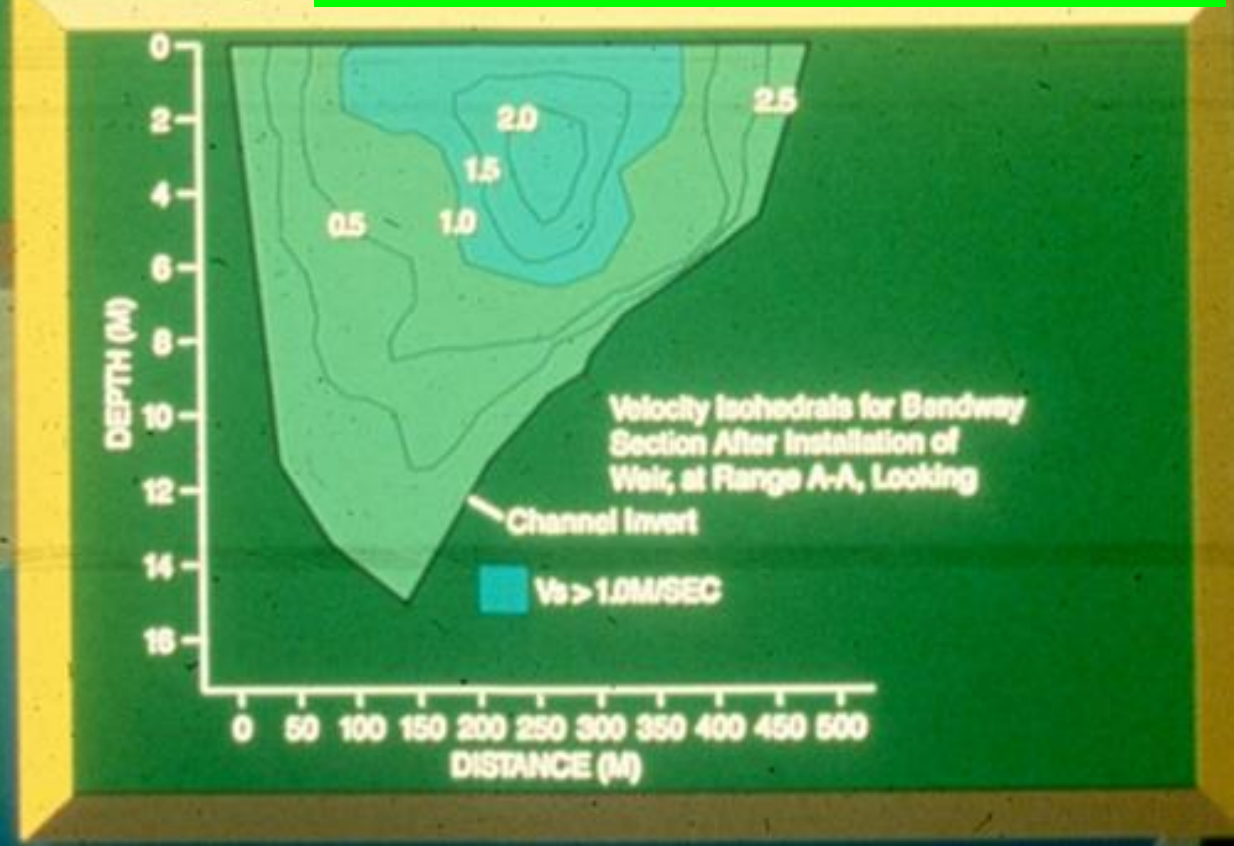
- Water flowing over the weir is redirected at an angle perpendicular to the longitudinal axis of the weir.
- With weirs angled upstream the erosive flow (energy) is directed away from the outer bank and toward the inner part of the bend.
- Strong secondary currents (helical flow) in bend are broken up. Roughness of the weir itself slows velocity of water traveling over the tops of the weirs by approximately 50%!!
- A set of weirs are designed to act as a system to capture, control, and redirect current directions and velocities through the bend and into the downstream crossing.
- Last weir in system can aim flow (and channel thalweg) where you need it.

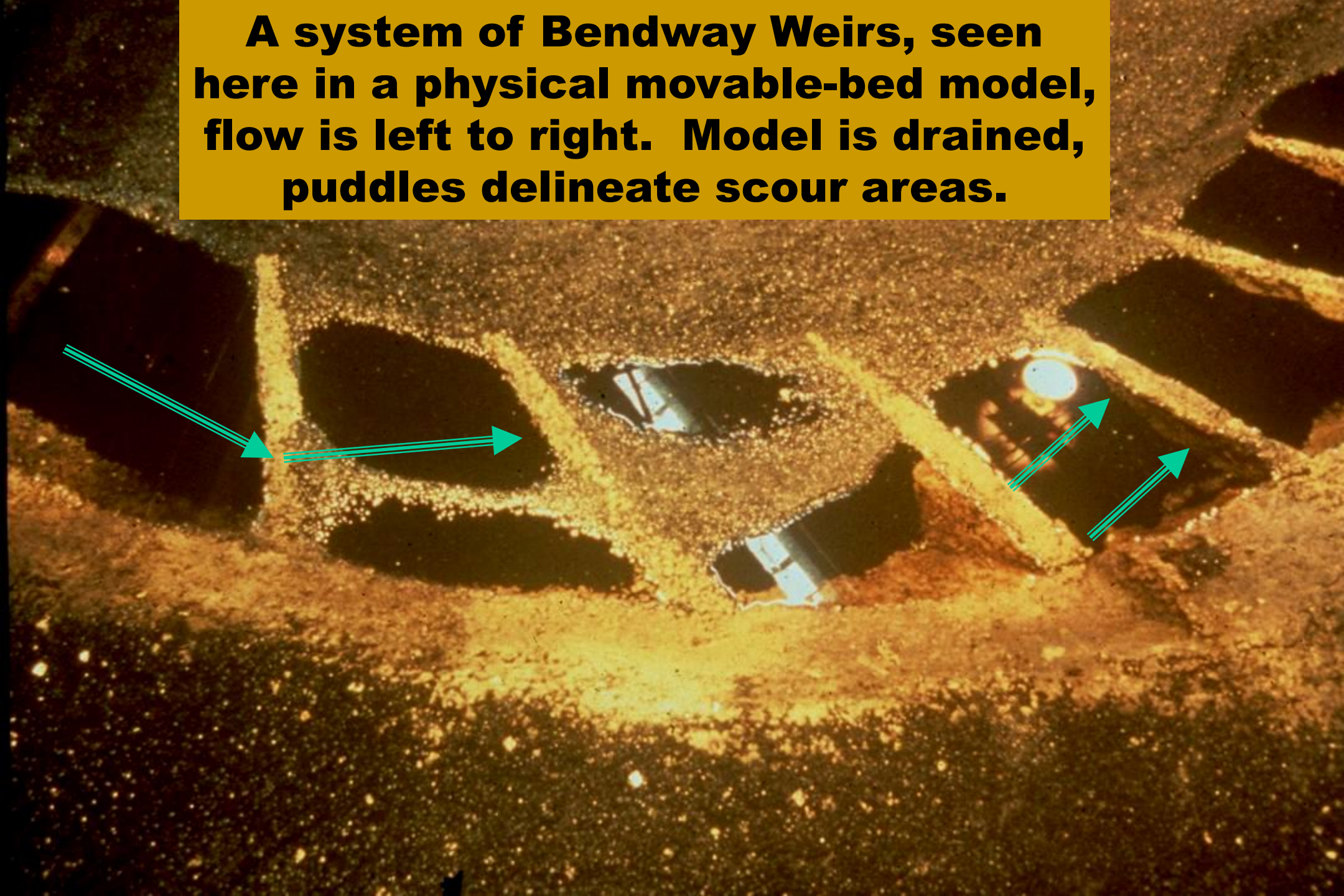


Mississippi River model test. Cross-section comparison shown here. 40 ft of deposition in the deepest part of the channel, scour on the inside of the bend

Velocities taken on the Mississippi River. Velocity isovels are in meters, not feet






A system of Bendway Weirs, seen here in a physical movable-bed model, flow is left to right. Model is drained, puddles delineate scour areas.

BENDWAY WEIRS ARE ENERGY MANAGEMENT & THALWEG MANAGEMENT TOOLS, THEY DO NOT PROVIDE TOTAL BANK STABILIZATION !!

BY THEMSELVES, NONE OF THE REDIRECTIVE RIVER TRAINING STRUCTURES PROVIDE TOTAL BANK STABILIZATION.

DURING EXTREME, LONG DURATION, HIGH ENERGY FLOW EVENTS SOME BANK SCALLOPING CAN OCCUR.

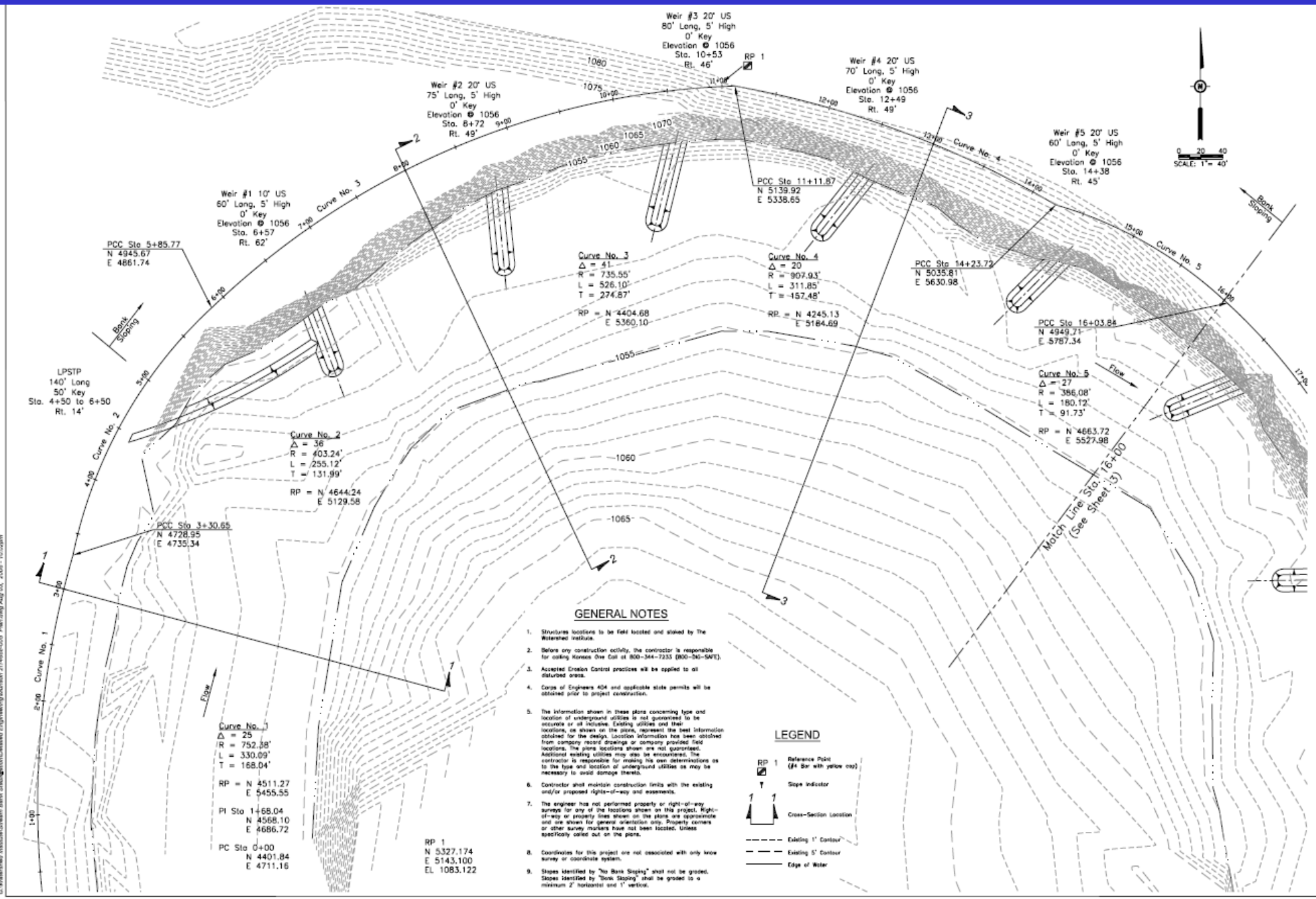
LITTLE BLUE RIVER, MARYSVILLE, KS.

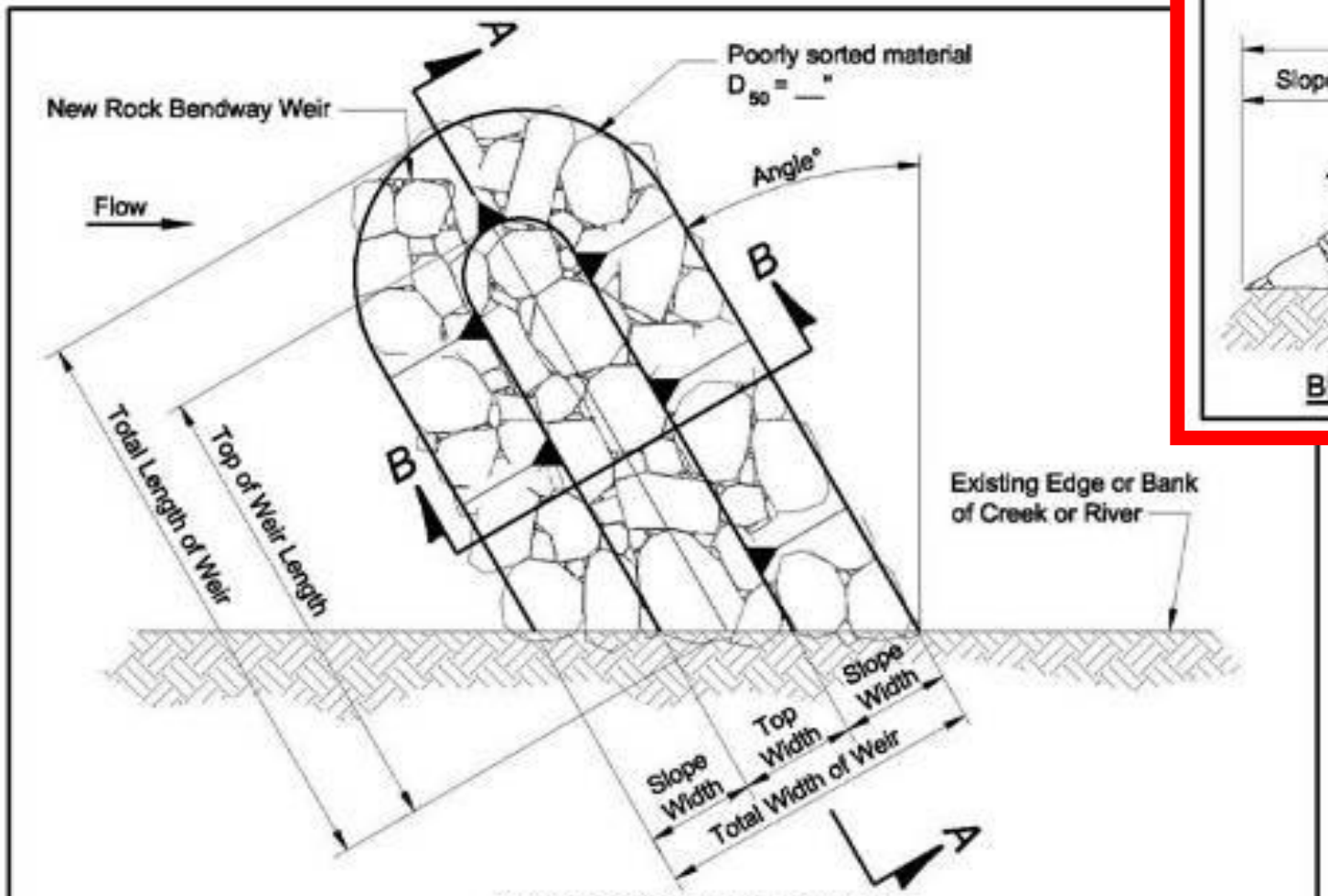
Martin - Jueneman Site

Over 9 miles of river constructed - 2000-2006

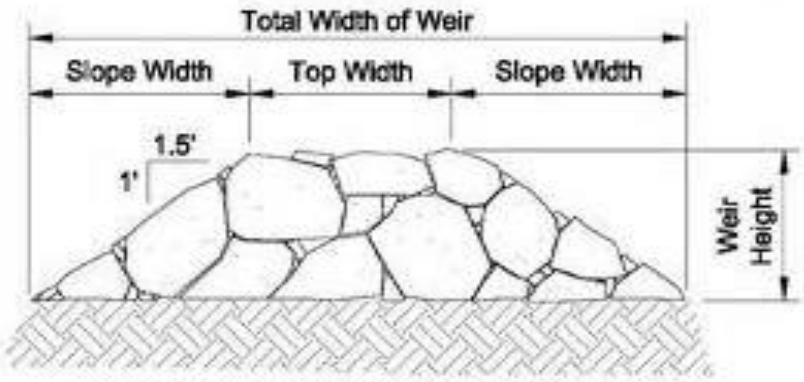
Using Bendway Weirs for thalweg realignment & to effectively reduce the river's width .to depth ratio by approximately 2/3 (from 75 to 1 to 25 to 1)

Plans & specs were developed for each site, typical Bendway Weir layout shown



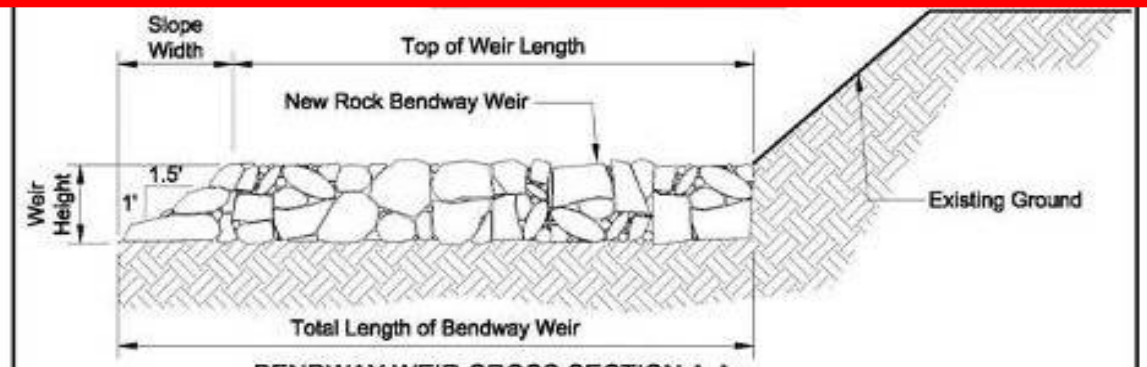


BENDWAY WEIR PLAN VIEW



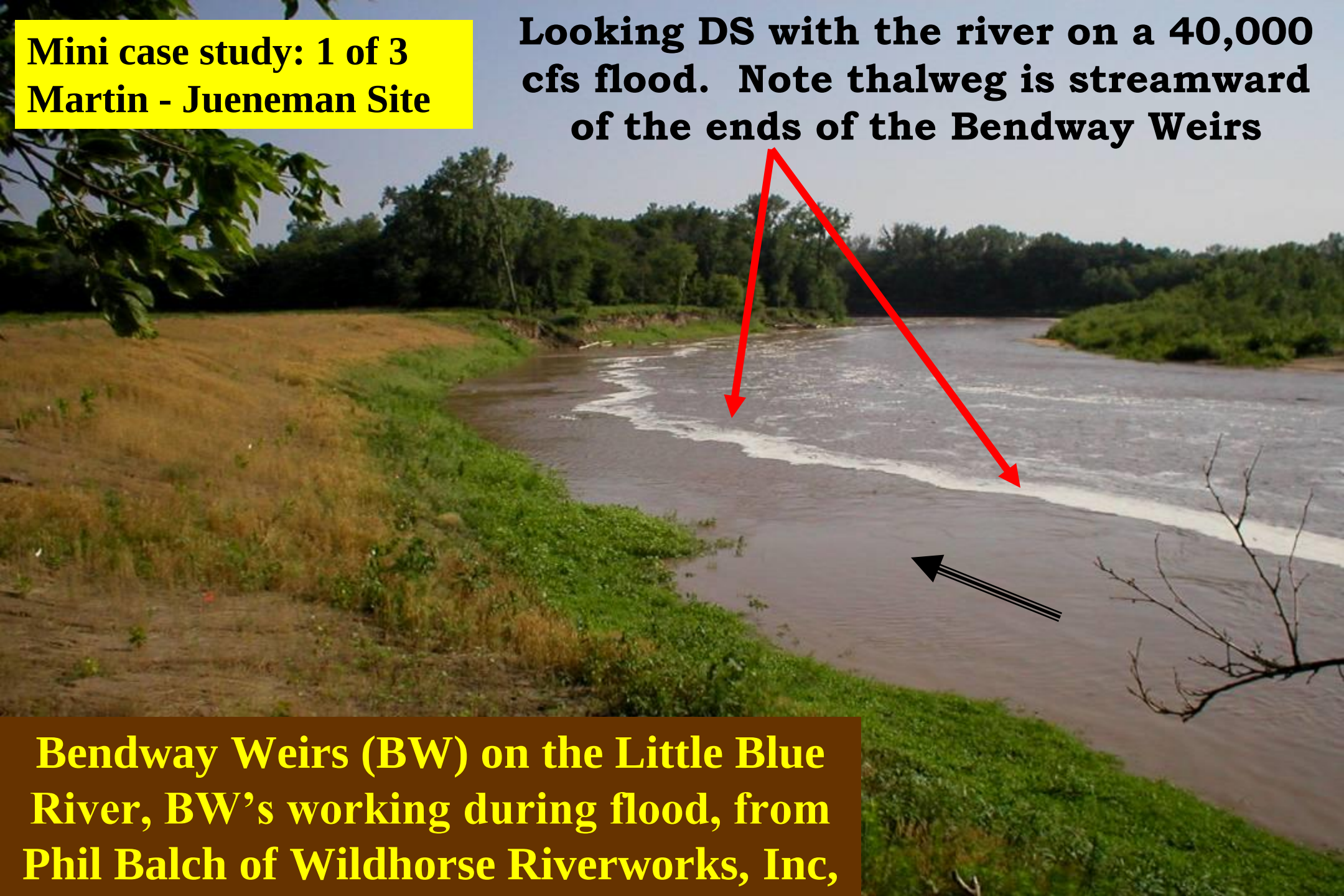
BENDWAY WEIR CROSS SECTION B-B

Bendway Weir details



BENDWAY WEIR CROSS SECTION A-A

Wildhorse Riverworks Inc.


Mini case study: 1 of 3
Martin - Jueneman Site
Looking DS with the river on a 40,000 cfs flood. Note thalweg is streamward of the ends of the Bendway Weirs
Bendway Weirs (BW) on the Little Blue River, BW's working during flood, from Phil Balch of Wildhorse Riverworks, Inc,

Deposition between Weirs from one bankfull flow 6/2002 on the Little Blue River, pix Phil Balch

Mini case study: 3 of 3 Martin - Jueneman Site

Natural Vegetation established on deposition 9/2002

FISH COMMUNITY RESPONSE TO BENDWAY WEIR INSTALLATION AT ONE SITE ON THE LITTLE BLUE RIVER, KS.

Pre-Project

2,000 feet long

16’ vertical banks

Soil loss 1977 – 2000 = 14.9 acres (461,542 tons)

Nitrates = 5,539 lbs

Phosphorus = 36,000 lbs

Potassium = 138,463 lbs

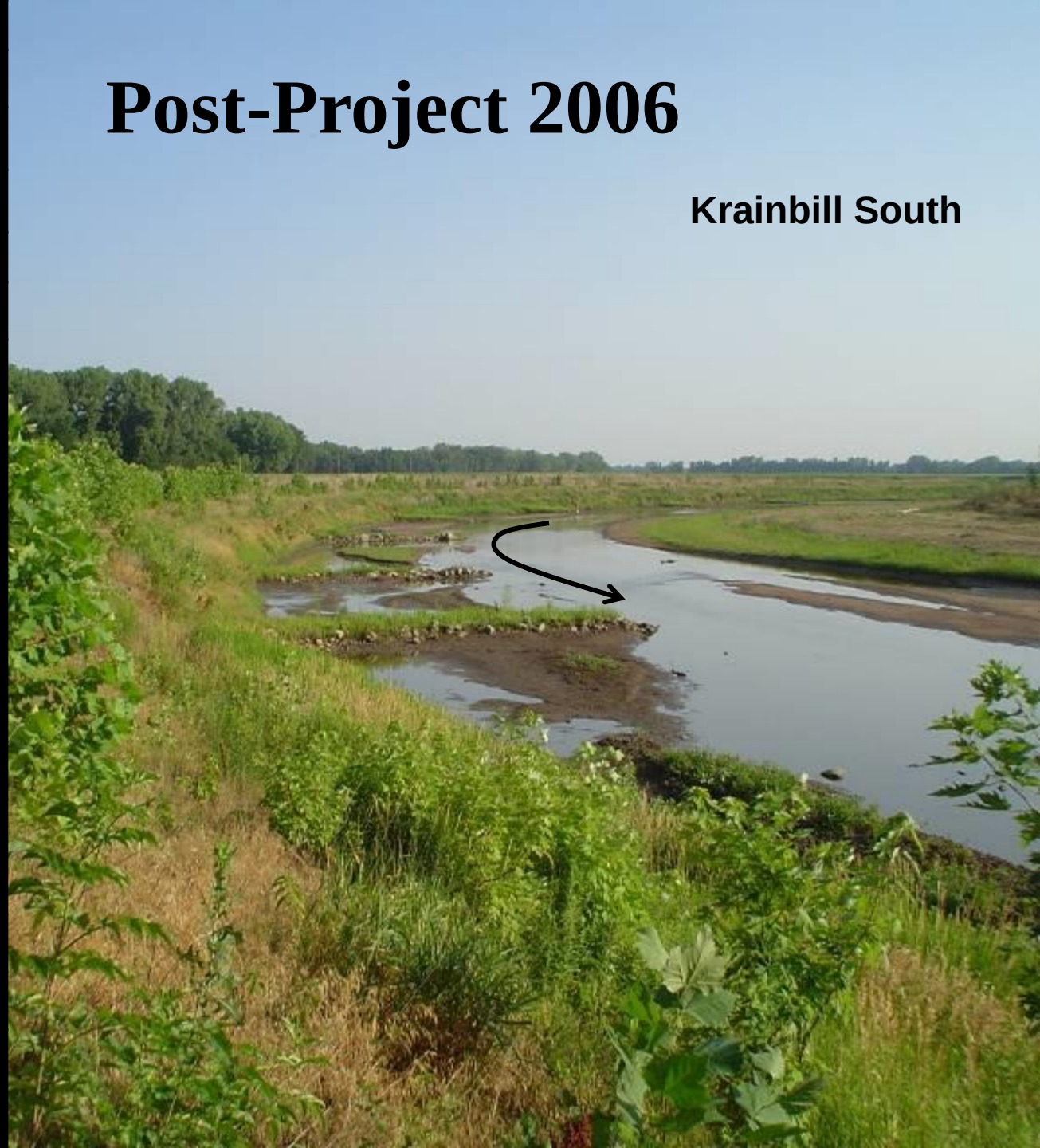
SPECIES	Number	CPUE
Longnose gar	1	1.16
River carpsucker	3	3.49
Channel catfish	1	1.16
Common carp	1	1.16
Smallmouth buffalo	1	1.16
5 Species, 7 Individuals		

Site 2 Krainbill South

Post-Project 2006

SPECIES	Number	CPUE
Longnose gar	6	5.8
River carpsucker	57	54.8
Channel catfish	47	45.2
Common carp	21	20.2
Flathead catfish	17	7.8
Freshwater drum	6	5.8
Quillback	12	11.5
Gizzard shad	145	139.4
Fathead minnow	1	0.9
Suckermouth minnow	42	40.4
Emerald shiner	32	30.8
Sand shiner	185	177.9
Red shiner	827	795.2
Bluntnose minnow	2	1.9
Bullhead minnow	295	283.7
Mosquitofish	1	0.9
Bluegill	3	2.9
Orangespotted sunfish	5	4.8

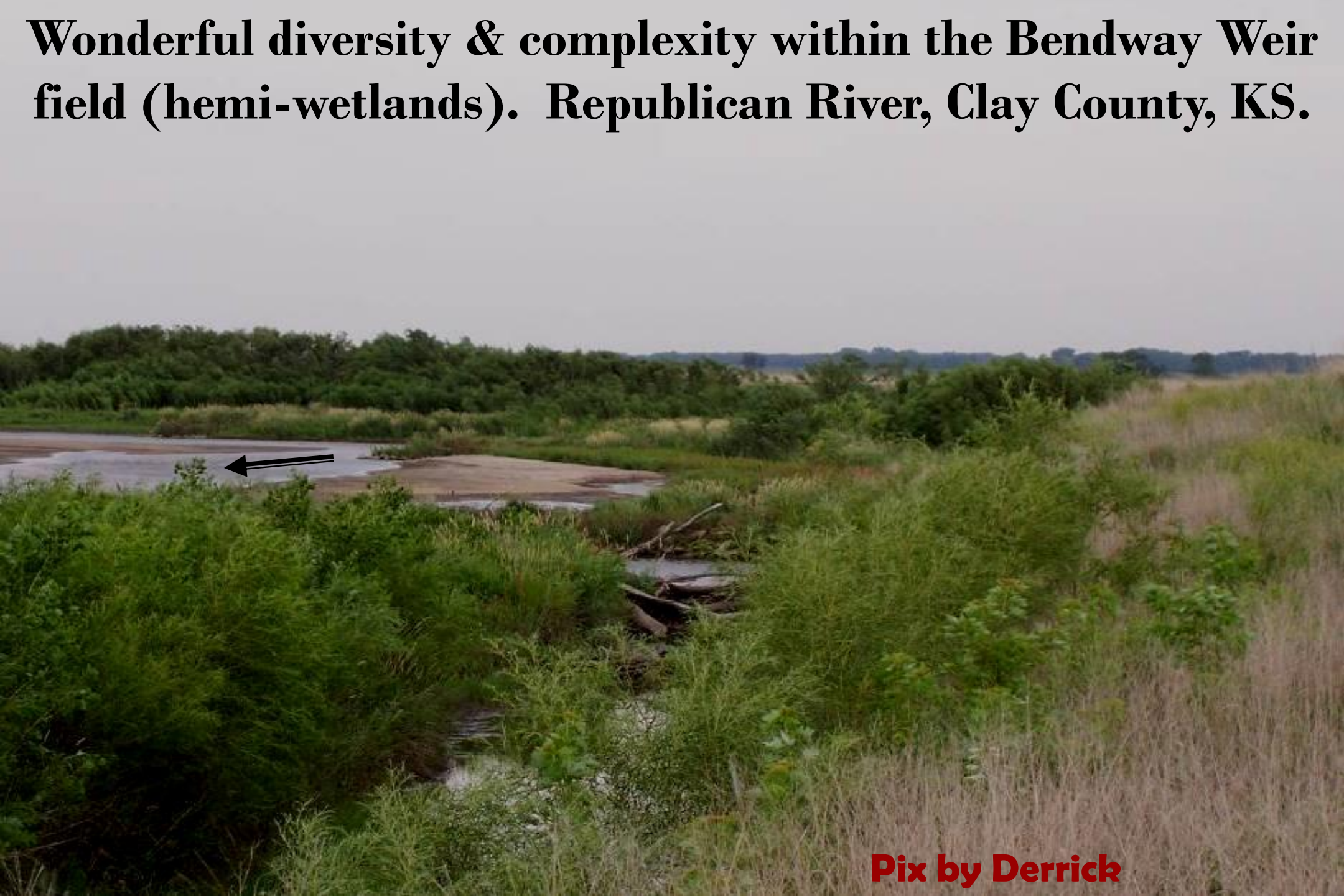
18 Species, 1704 Individuals



10 YEARS LATER-LTL BLUE R-HENNERBERG SITE- DERRICK–7/20/2012

HEMI WETLAND (HALF WET – HALF LAND) CREATION BETWEEN BENDWAY WEIRS ON THE REPUBLICAN RIVER

Wonderful diversity & complexity within the Bendway Weir field (hemi-wetlands). Republican River, Clay County, KS.



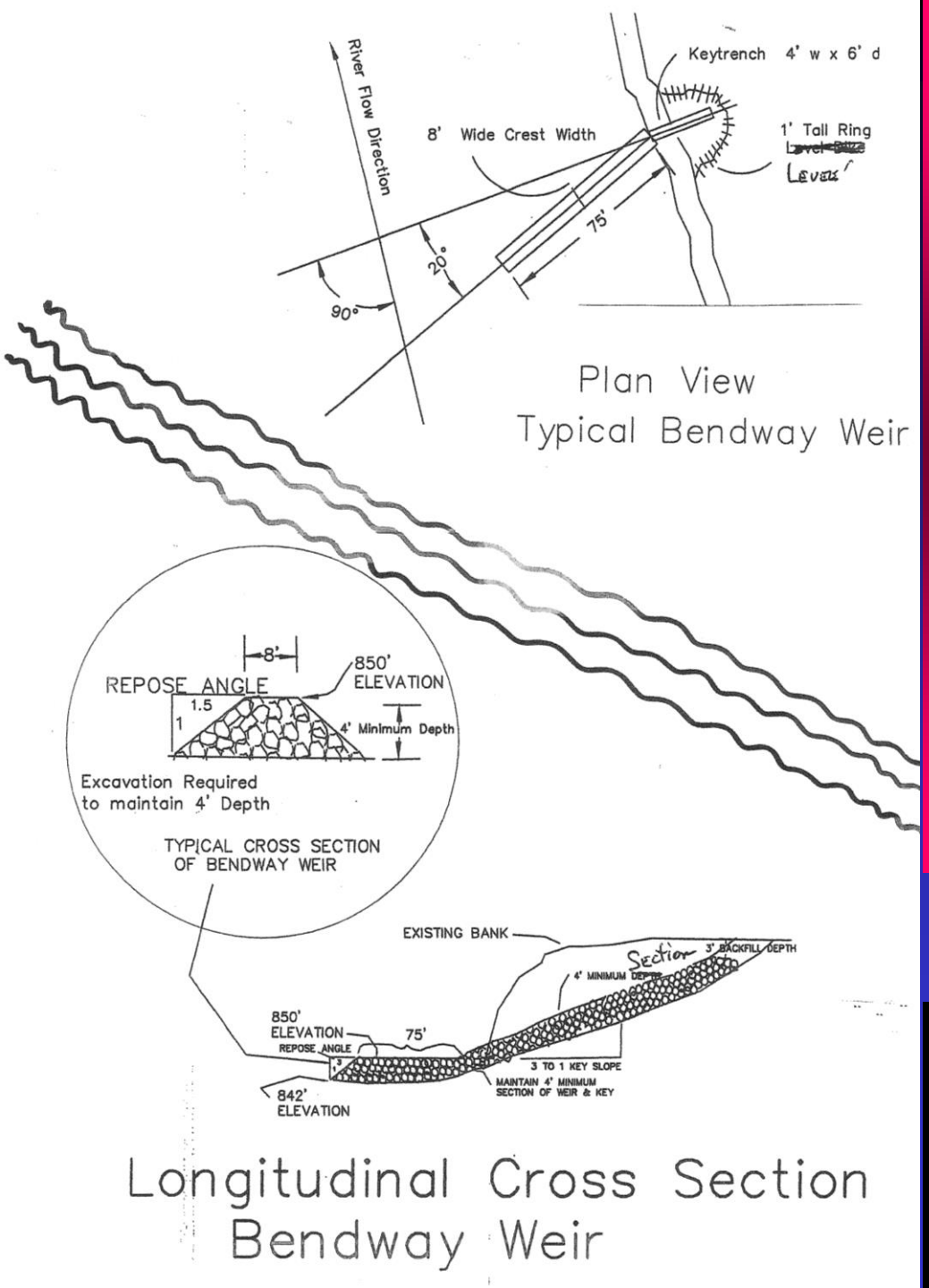
CASE STUDY- NEOSHO RIVER, ALLEN COUNTY, (MIKE GEFFERT'S PROPERTY) SOUTHEAST KANSAS

Constructed May-July 2000

Using Bendway Weirs for thalweg realignment & bank erosion reduction

Neosho River Project Specifications

- River is 260 ft wide, gravel-sand bed
- Project is 2,200 ft long, Outer bank is 25 ft tall, bank eroded 178 ft laterally in 6 years time
- 11 Bendway Weirs, are all 70 ft long, spaced 210 ft apart & constructed of “shot rock”, 400 lb max. weight ungraded stone
- First set of velocities (March 15, 2001) water was 6 ft over the weirs, second set of velocities (Mar 16, 2001) water was a measured 12 ft over the top of the weirs!!
- Velocities were measured with floating oranges



CONSTRUCTION DRAWINGS- Three views of a Bendway Weir & key (veg not shown).

CONSTRUCTION DRAWINGS FROM THE NEOSHO RIVER, KANSAS

Pre-Project. Looking upstream at the near-vertical eroded bank

PRE-PROJECT-NEOSHO RIVER @ GEFFERT'S-PIX BY PHIL BALCH 8/25/99

1 year later. Looking DS at the Neosho River on the flood

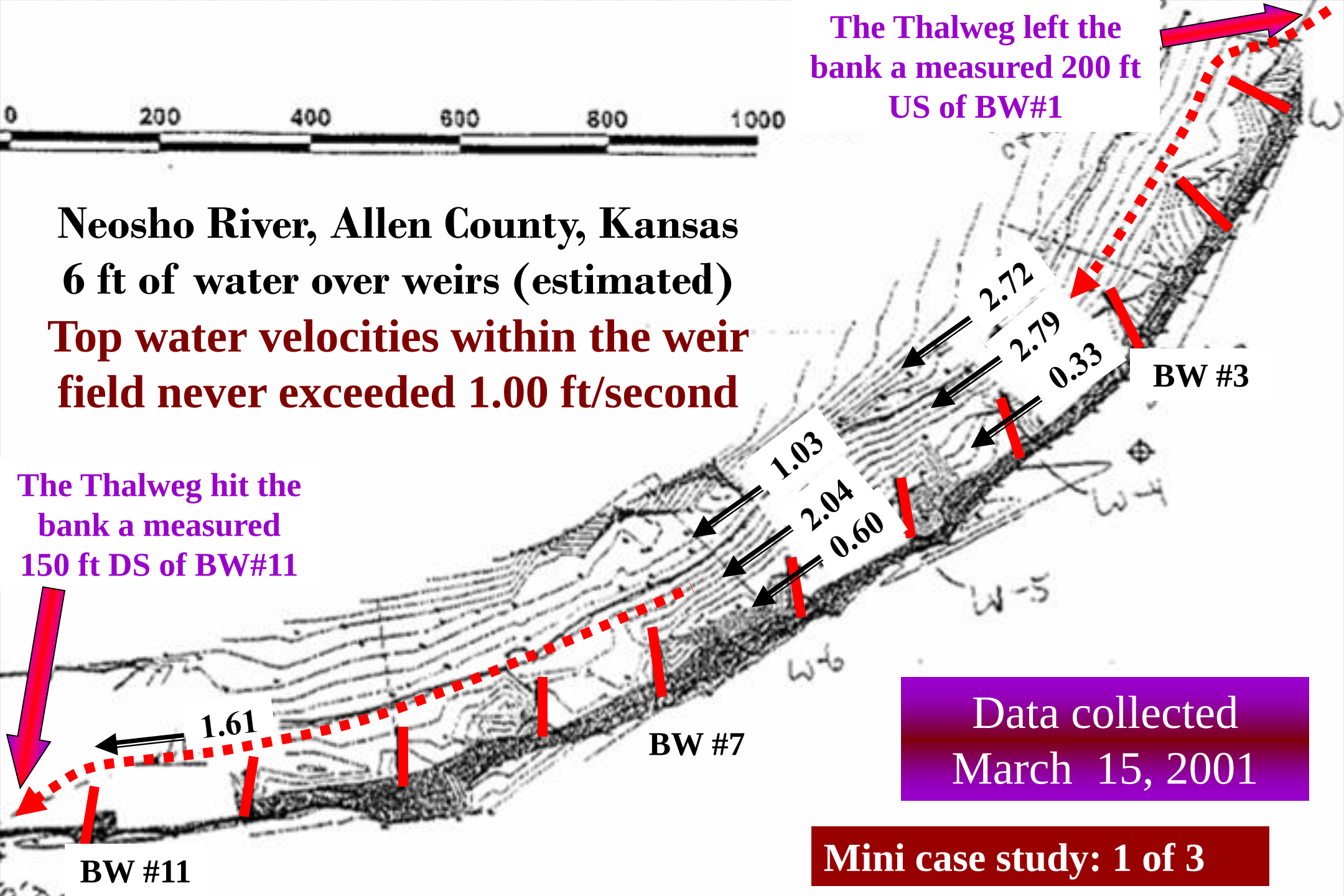
1 YEAR LATER-NEOSHO RIVER @ GEFFERT'S-PIX BY PHIL BALCH 5/01

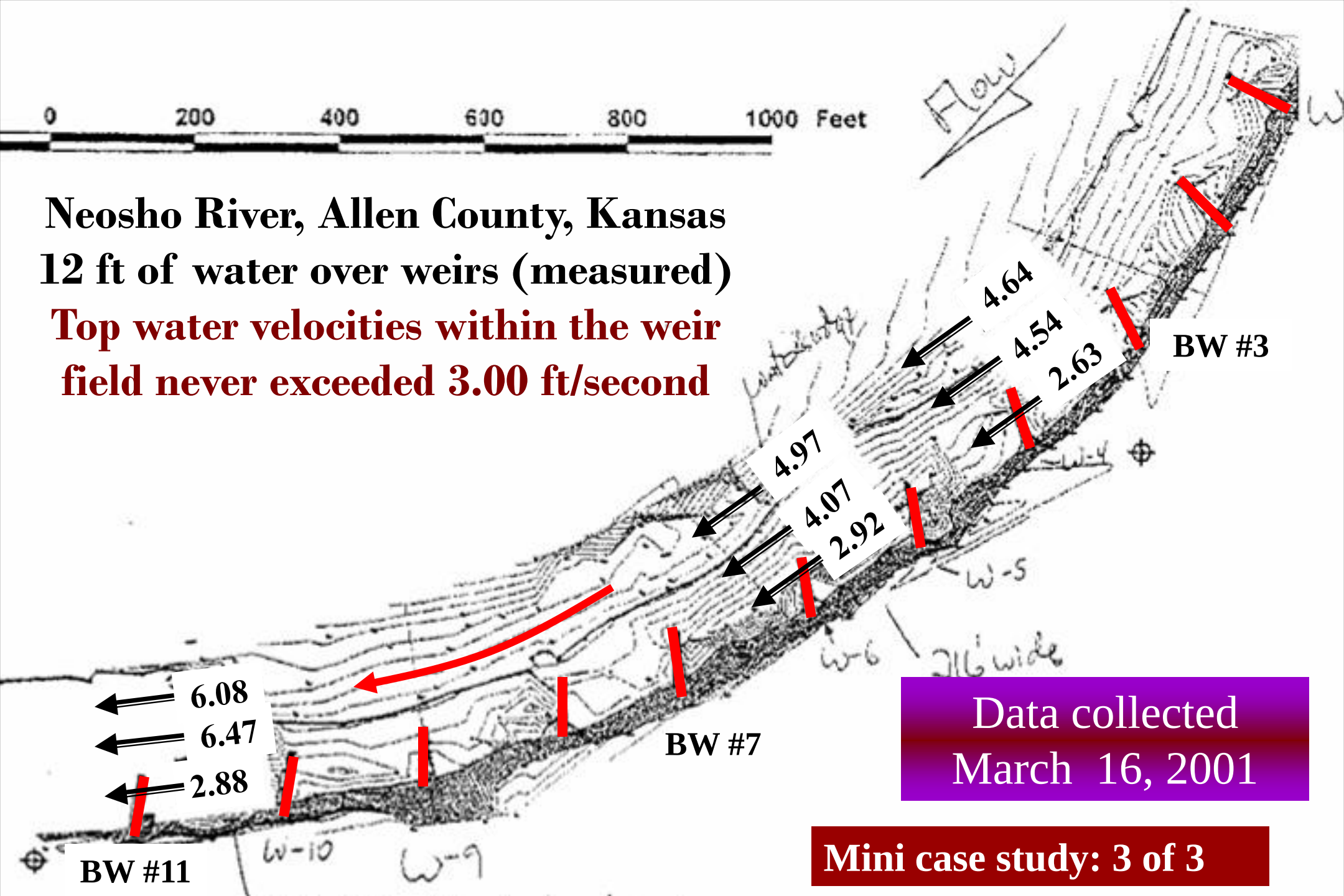
2 years later. Looking US @ Bendway Weirs & stable bank

2 YEARS LATER-NEOSHO RIVER @ GEFFERT'S-PIX BY PHIL BALCH 9/2002

HIGH WATER – LET'S GET SOME VELOCITIES

(We have a sack of oranges & time on our hands)


0
200
400
600
800
1000
The Thalweg left the bank a measured 200 ft US of BW#1
Neosho River, Allen County, Kansas
6 ft of water over weirs (estimated)
Top water velocities within the weir field never exceeded 1.00 ft/second
2.72
2.79
0.33
BW #3
1.03
2.04
0.60
The Thalweg hit the bank a measured 150 ft DS of BW#11
1.61
BW #7
BW #11
Data collected March 15, 2001
Mini case study: 1 of 3


0
200
400
600
800
1000 Feet
Flow
Neosho River, Allen County, Kansas
12 ft of water over weirs (measured)
Top water velocities within the weir field never exceeded 3.00 ft/second
4.64
4.54
2.63
BW #3
4.97
4.07
2.92
W-4
W-5
W-6
216' wide
6.08
6.47
2.88
BW #7
BW #11
W-10
W-9
Data collected March 16, 2001
Mini case study: 3 of 3

CATTARAUGUS CREEK @ SAVAGE ROAD – CONSTRUCTED OCT 2004


Bendway weirs are 24 ft long, spaced 80 ft apart.
Looking DS in project bend, high water on Catt Creek, 11/4/2004
8.0 ft/sec
Thalweg 6.4 ft/sec
Within the weir field 2.6 ft/sec
Slow water on the outside of the bend!!

SAME FLOW AS PREVIOUS BENDWAY WEIR PICTURE. Looking US at Rock Vane #2, high water, Catt Creek at Savage Rd. 11/4/2004. Rock Vane backs up water in the bend at this flow.

Rock Vane #2 dissipating energy, but consider the super-elevation of water upstream of the vane. 3/28/2006-Pix by Mayer

SINGLE STONE BENDWAY WEIRS

CHAUTAUQUA CREEK ICE DAMAGE REDUCTION PROJECT –Near its mouth @ Lake Erie, Westfield, NY.

- Severe scour from ice and high flow velocities on the right descending bank had resulted in an overwidened section of stream.
- Mid-channel sediment bars, mouth of creek @ Lake Erie clogged
- No holding areas or habitat for steelhead
- A heavily used public fishing section of the stream

DRILLING & PEGGING TOE STONES & SINGLE STONE BENDWAY WEIRS WITH METAL RODS INTO BEDROCK

Dave Spann of Chautauqua County Soil & Water Conservation District with a 7.5 ft long, 2.5 inch diameter bar. Dave did everything from writing the grant to providing extraordinary project management. On time and under budget!!!!


Construction
June 2006.
Drilling solid
stone
Pix by Joe Galati
JUN 9 2006

Looking upstream at the SINGLE-STONE BENDWAY WEIRS


Aug 31, 2006, looking US at two pegged to bedrock Single-Stone Bendway Weirs in the stacked stone wall section.
Pix by derrick

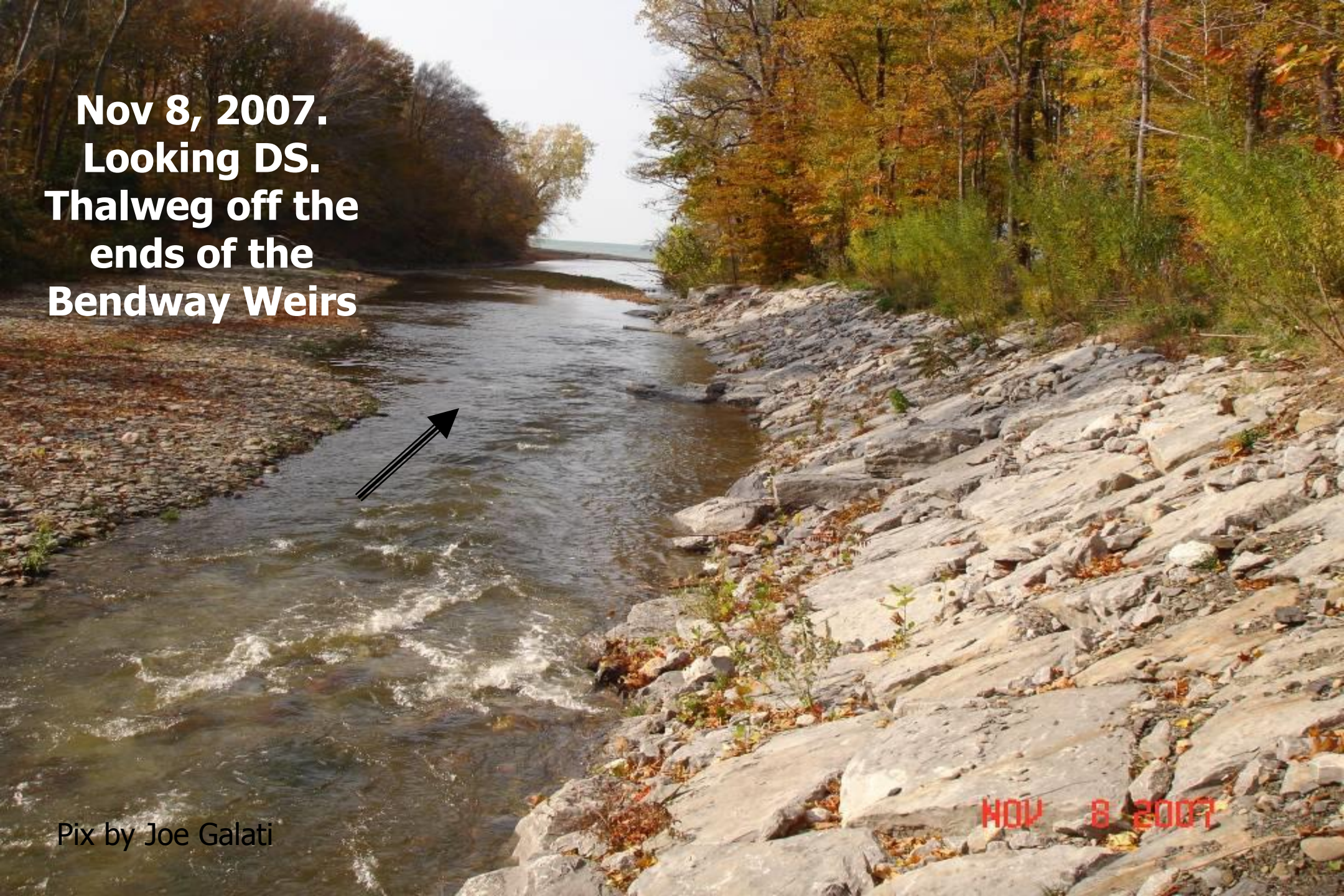
A high water flow event. Mar 14, 2007


Mar 14, 2006. Looking DS. Three submerged Bendway Weirs can be located due to surface disturbance
Pix by Joe Galati
MAR 14 2007

Mar 14, 2006. Looking DS. Close-up of two submerged Bendway Weirs

Pix by Joe Galati

16 MONTHS AFTER CONSTRUCTION NOV. 2007

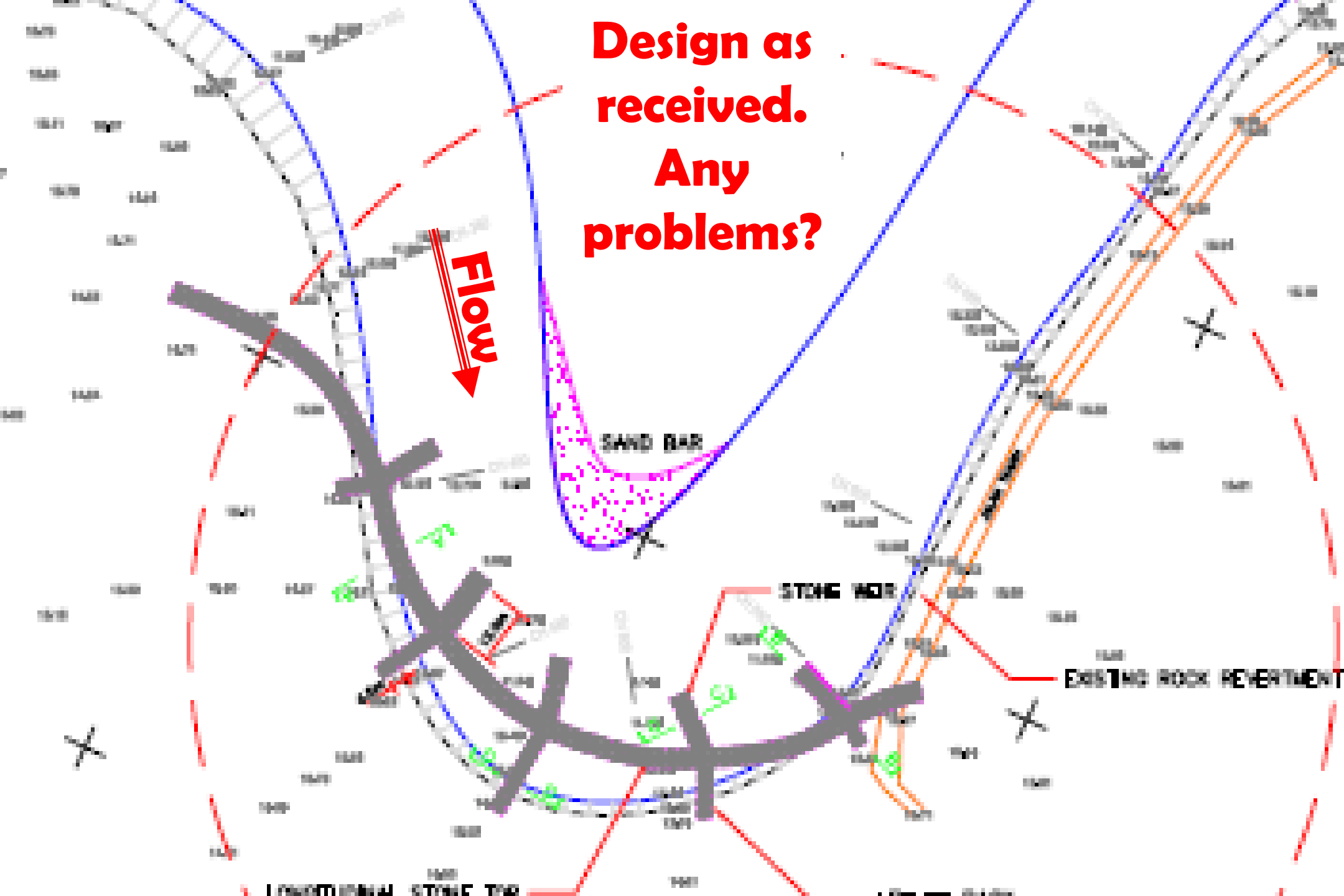

Nov 8, 2007.
Looking DS.
Thalweg off the
ends of the
Bendway Weirs
Pix by Joe Galati
NOV 8 2007

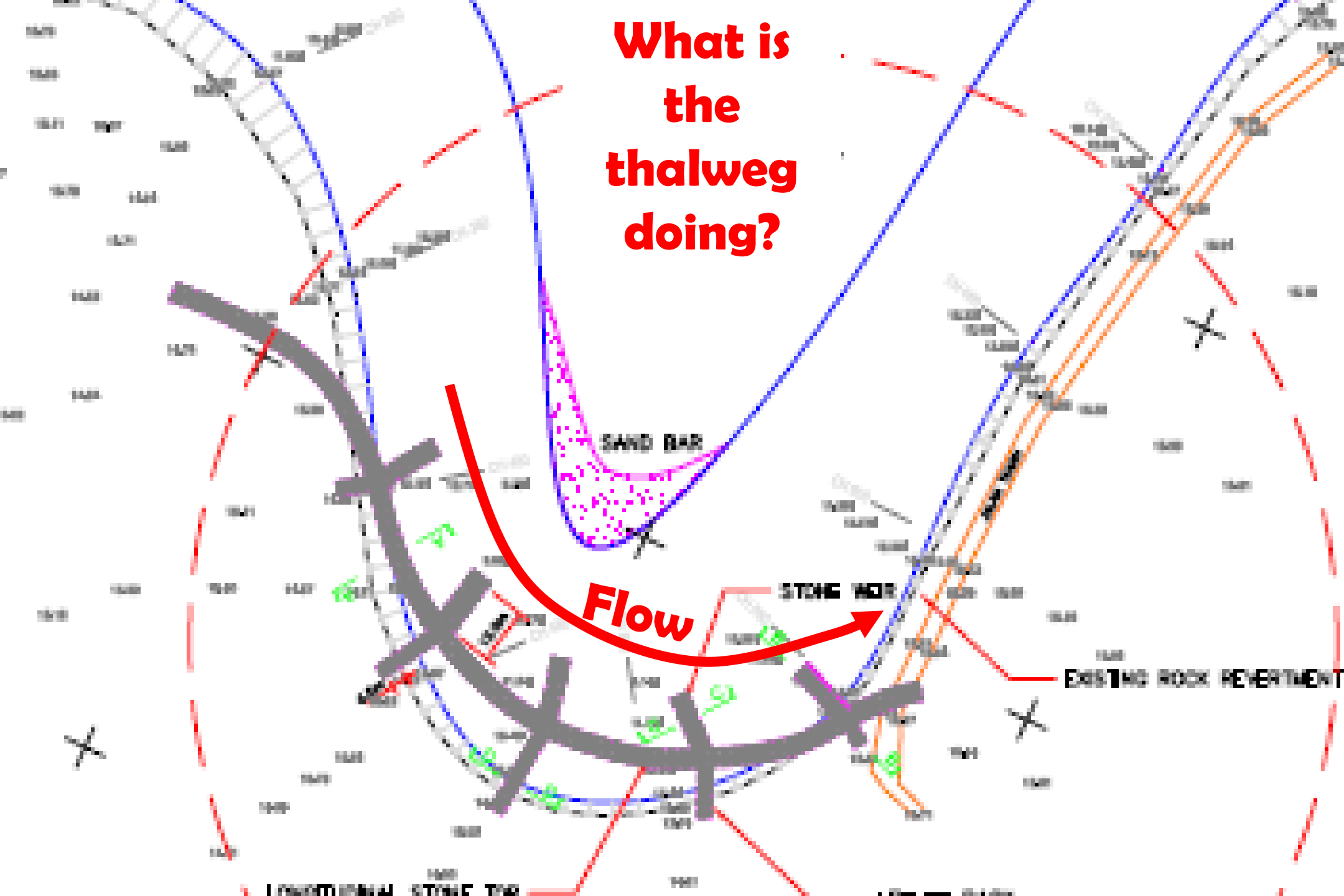
Hydraulic Improvements Due to Bendway Weirs

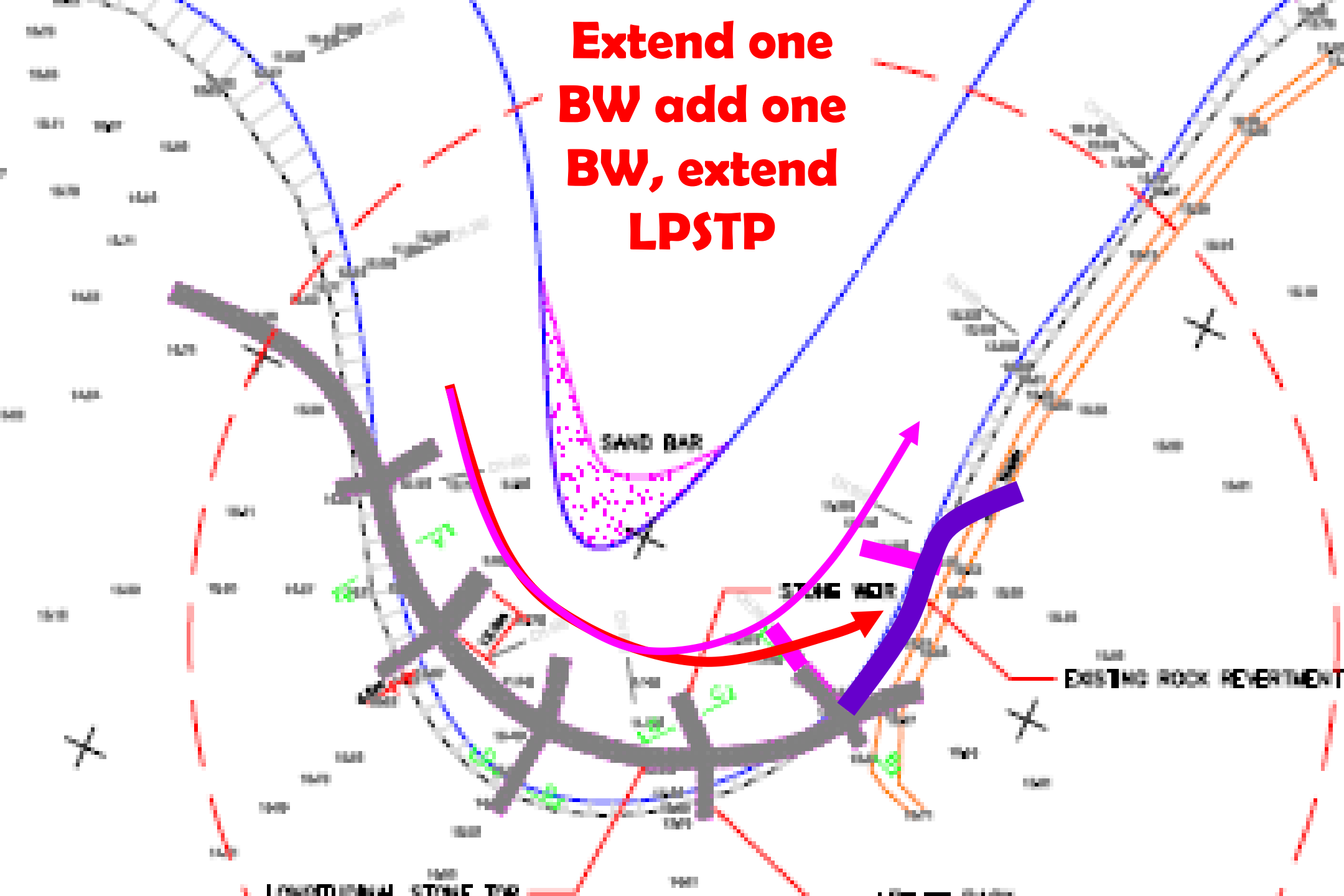
- Deposition occurs on the outer bank of the bend
- Velocities are reduced near the outer bank
- Flow is generally parallel with the outer bank of the bend
- The deepest section of the river (thalweg) is moved from the outside of the bend to an alignment off the stream ends of the Bendway Weirs

Looking US at two low Bendway Weirs on Irish Gulf (Boston, NY). Note cut bank on inside of bend

REAL WORLD DESIGN REVIEW #1

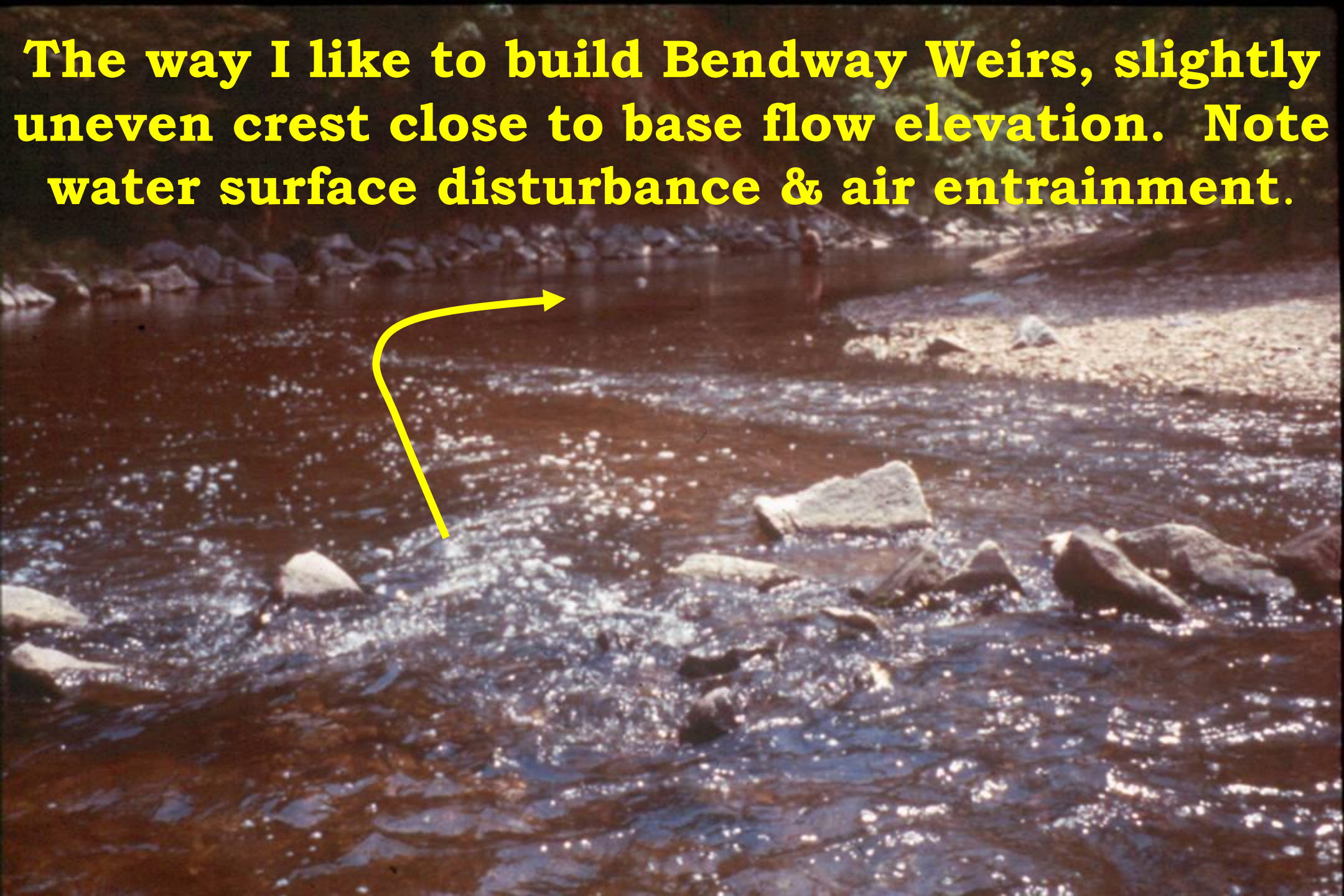

Design as received. Any problems?
Flow
SAND BAR
STONE WEIR
EXISTING ROCK REVETMENT


What is the thalweg doing?
SAND BAR
Flow
STONE WEIR
EXISTING ROCK REVETMENT


Extend one BW add one BW, extend LPSTP
SAND BAR
EXISTING ROCK REVETMENT

Functions of Bendway Weirs

- One of the few bank protection methods that changes direction of flow and that flow redirection can be predicted (even DS of the project).
- The reduction in stream forces within the weir field usually results in some sediment deposition within the weir field.
- The reduction in stream forces immediately adjacent to the bank, combined with sediment deposited on the outer bank, can benefit volunteer or bioengineered vegetation.
- Bank erosion is usually reduced, but not completely. Some species will use bare and vertical bank surfaces (both aquatic and terrestrial). A well-vegetated stable bank is not always the natural condition in many stream systems.
- Aquatic diversity and complexity is increased (depths, substrates, velocities), edge length is increased. Dr. Fischenich stated the most diverse bathymetry he had ever witnessed from man-made structures (Harland Creek 1994)
- LWD can be naturally recruited (or placed) between Bendways, and especially immediately DS of the last Bendway Weir in a series
- Costs are competitive or lower than many traditional methods.
- Blends well with other bank protection methods.
- Weirs can at times be retrofitted to existing projects to reduce concentrated flow.


The way I like to build Bendway Weirs, slightly uneven crest close to base flow elevation. Note water surface disturbance & air entrainment.

Possible Bendway Weir Applications

- Where current sets, and possibly the thalweg, must be realigned (typically flow into a bridge opening or hydraulic structure).
- The stream needs to be realigned to reduce impacts of stream energy on downstream objects/bends. Even small "bank sags" or "elbows" can be mitigated with short Bendway Weirs.
- Where the thalweg needs to be moved from its present location (excessive scour at the toe of a continuous structure).
- Where the hydraulic width to depth ratio (W/D) of a stream needs to be reduced in an economical & environmentally compatible manner (to improve sediment transport, reduce existing channel overwidening).
- Can be retrofitted into an existing project to solve specific local problems and/or increase overall project performance.

Ways To Construct Stone Bendway Weirs

On Larger Rivers:

- From barges (2 methods)

  - Use bottom dump barge (hinged in middle)

  - Use bulldozers or dragline to push rock off barge and into river

- End dump method (build key, then dump rock off key into river forming a wide "road like" weir)

On Streams and Smaller Rivers:

- Machine-built (2 methods)

  - Build “road-like” key from top bank, then working from key, construct remainder of weir.

  - Working from point bar, dig key, construct key, then weir

Indicators That a System of Bendway Weirs Are Working

- Outer bank between weirs is stable and vegetated
- Failed material is not removed from base of eroded bank
- Sediment is deposited on outer bank after high flow events
- "Dogbone" shaped depositional patterns formed between midpoints of weirs at the upper end of the weir field
- Typically deeper pools are found between weirs at the lower end of the bend
- Point bar scoured, and at times a vertical face scoured on the point bar (usually from mid-bend to downstream end of bend)
- In some cases low-elevation mud flats are deposited between bank ends of weirs

Where Bendway Weir Use Could Prove Problematic

- In cobble or gravel bed streams the redirective effects of Bendway Weirs are limited in the downstream direction due to the resistance of the bed materials not allowing the channel thalweg to be relocated by stream energy redirected by the weirs (which is a main objective of Bendway Weir use).
- In tight radius bends, caution is advised when radius to width (R/W) is less than 4 to 1!!!
- In bends with an arc angle greater than 60 degrees (LPSTP) might have to be placed between BW)
- In narrow streams (base-flow water width is less than 20 ft).
- Where point bars are tall and built of cobble or gravel
- Very few Bendway Weir projects in high velocity, supercritical flow, or steep-sloped stream systems.

Some Bendway Weir Design Rules of Thumb

- No impinging flow into the proposed area of the weir field.
- A defined channel crossing is usually required upstream of the project bend. The upstream bend should be stable.
- Must have the "Luxury of Space" between the eroding riverbank and the object to be protected
- Bendway Weir crest height can typically be set equal to 1 ft above the water surface elevation at base flow (typical low flow) with a tolerance of plus or minus one foot
- Need to lay out the thalweg relocation required for the project throughout entire project and US and DS of the project. This "smoothed" thalweg alignment should be based on project performance goals
- Stream ends of Bendway Weirs should be just short of the anticipated relocated thalweg alignment

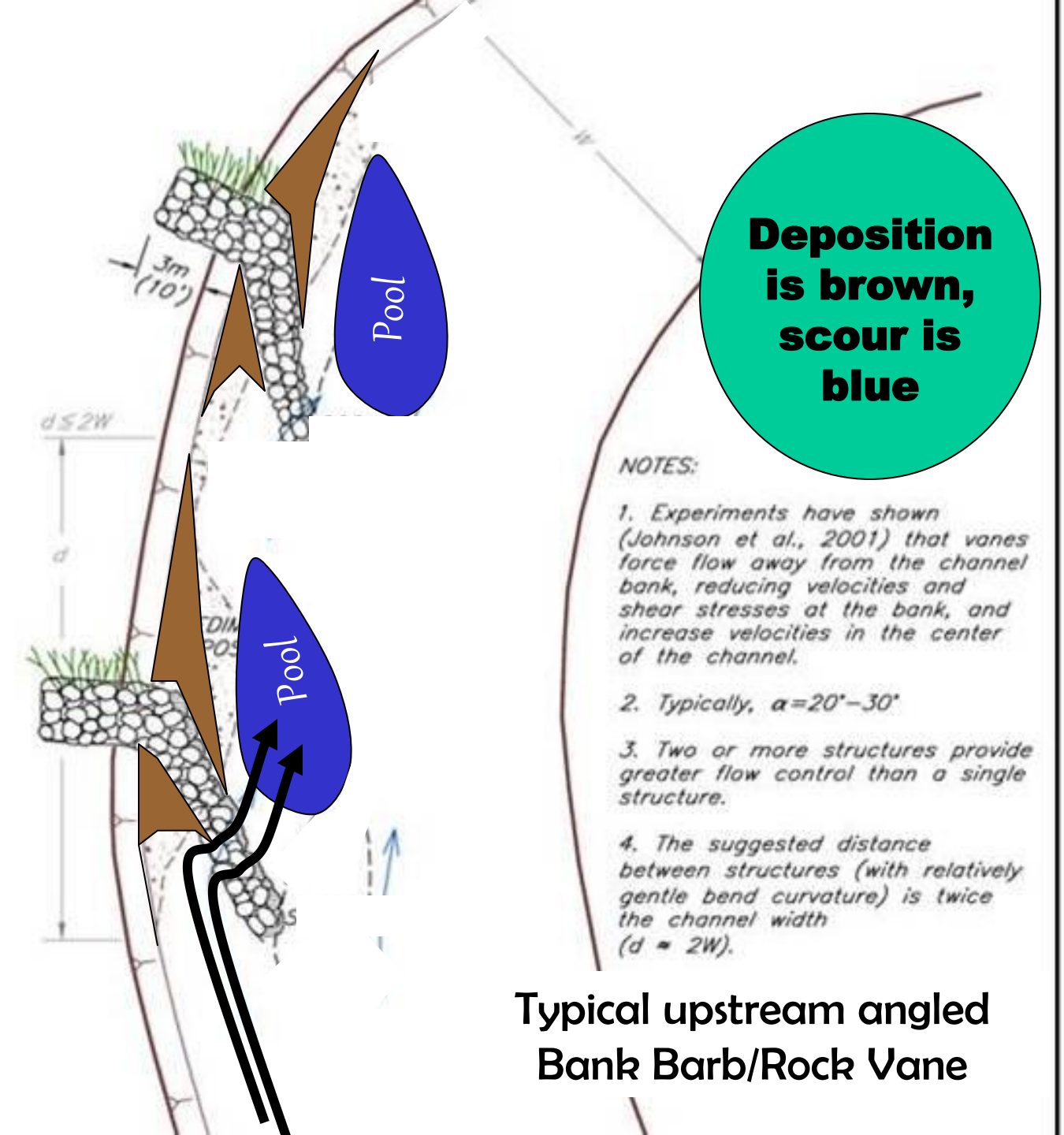
BANK

BARBS

LITTLE BLUE RIVER, MARYSVILLE, KS.

Elva Hynek Site

Using Bank Barbs for near-bank velocity reduction & to effectively reduce the river's width to depth ratio by approximately 2/3 (from 75 to 1 to 25 to 1)

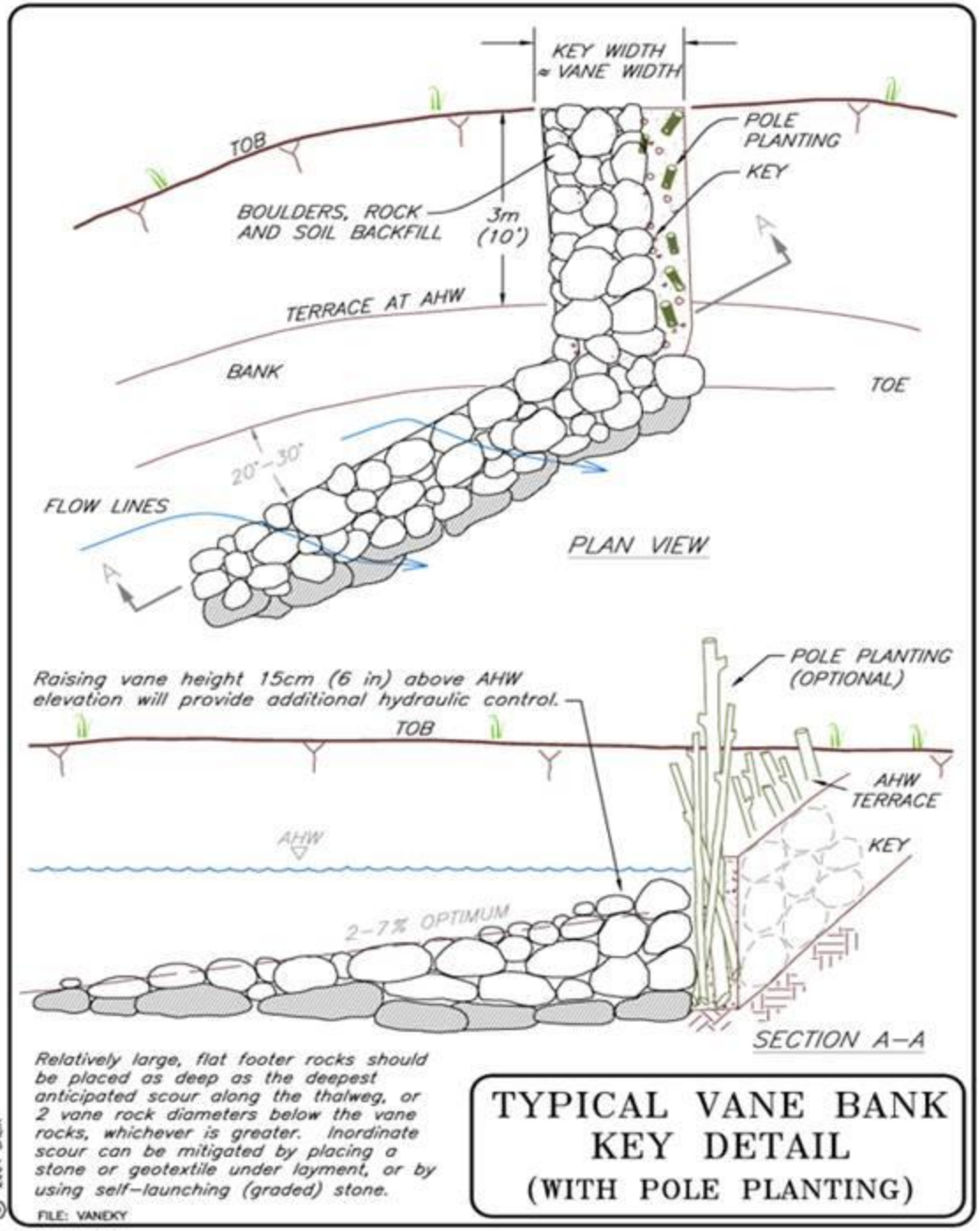


Typical upstream angled Bank Barb/Rock Vane

from John McCullah's

www.E-Senss.com

Salix Applied Earthcare



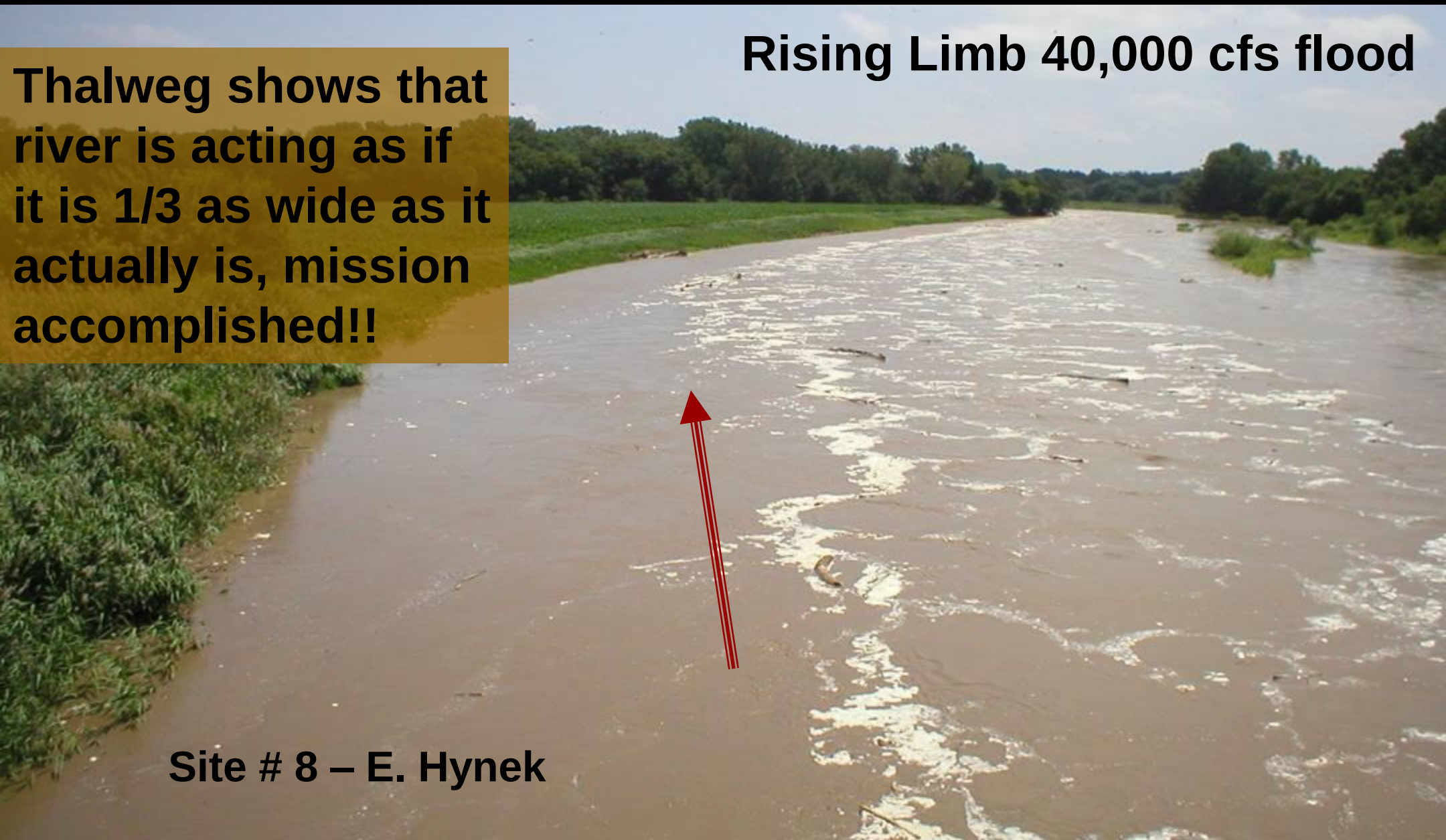
from John McCullah's

E-Senss.com

Salix Applied Earthcare

UPSTREAM ANGLED BANK BARBS

UPSTREAM ANGLE BANK BARBS



UPSTREAM ANGLED BANK BARBS

ROCK VANES

ROCK VANES WITH STONE TOE PROTECTION ON THE SALMON RIVER, PULASKI, NY.

2 YEARS OLD

DESIGNED BY CARL SCHWARTZ, U.S. FISH & WILDLIFE SERVICE

Photos by Dave Derrick

APRIL 13, 2010

Looking DS @ a properly functioning Rock Vane (RV). Thalweg leaves the bank US of the US end of the RV. Note calm water in "elbow" of Rock Vane.

2 YEARS OLD - SALMON RIVER, PULASKI, NY - PIX BY DERRICK 4-13-2010

Looking DS @ calm water & deposition in “elbow” of Rock Vane.

2 YEARS OLD - SALMON RIVER, PULASKI, NY - PIX BY DERRICK 4-13-2010

Looking US @ calm water in "elbow" of Rock Vane. Note thalweg location.

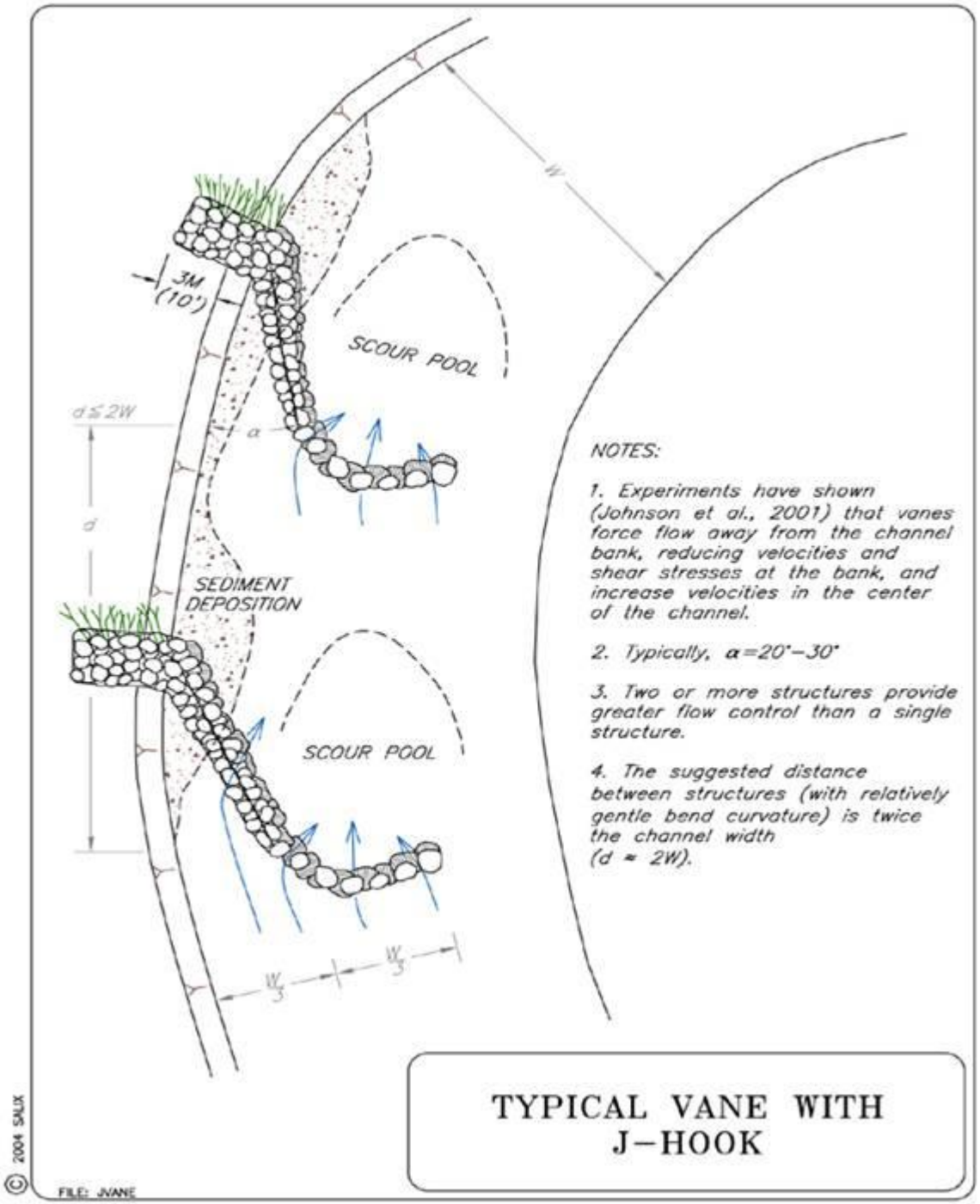
2 YEARS OLD - SALMON RIVER, PULASKI, NY - PIX BY DERRICK 4-13-2010

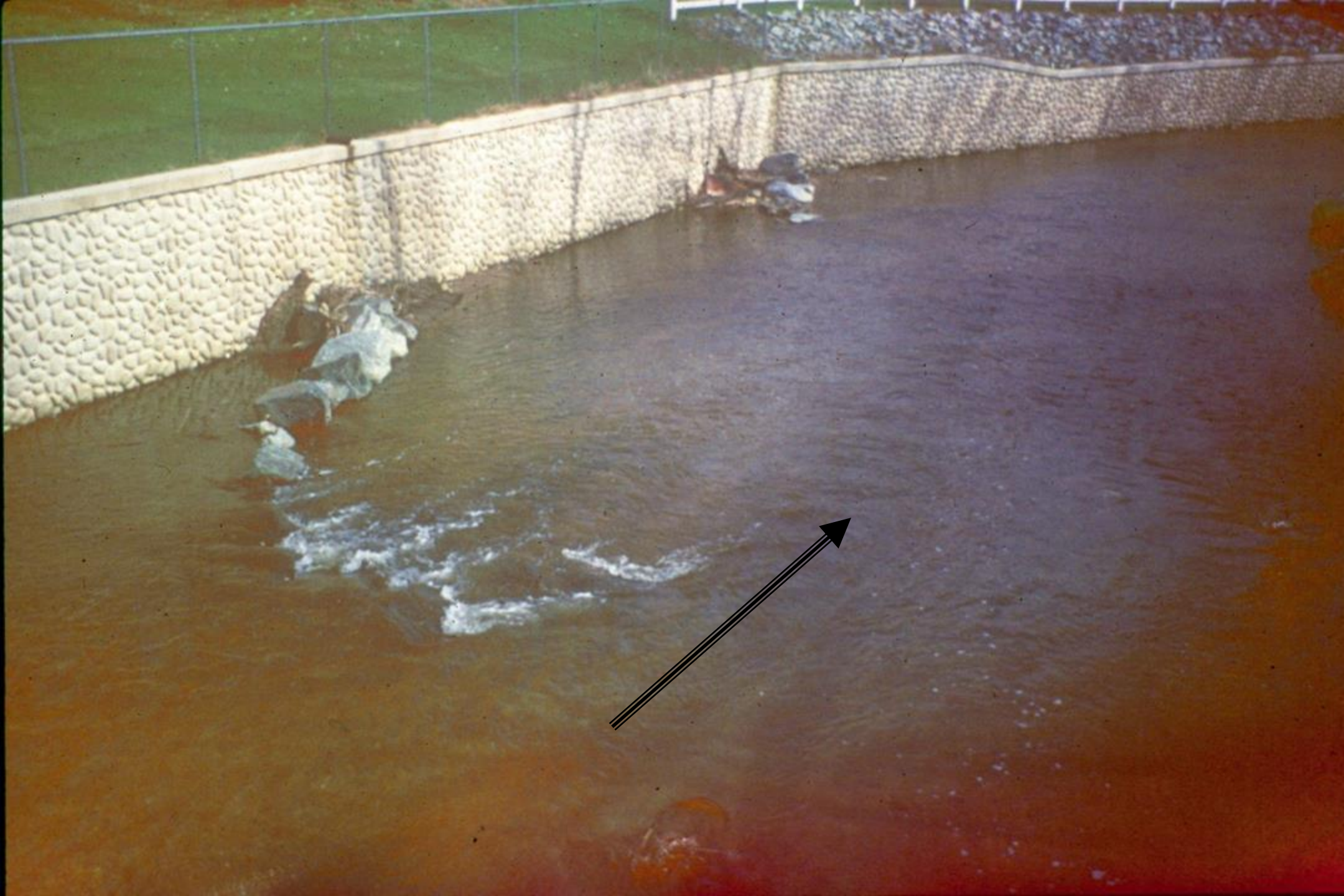
J-HOOK VANES

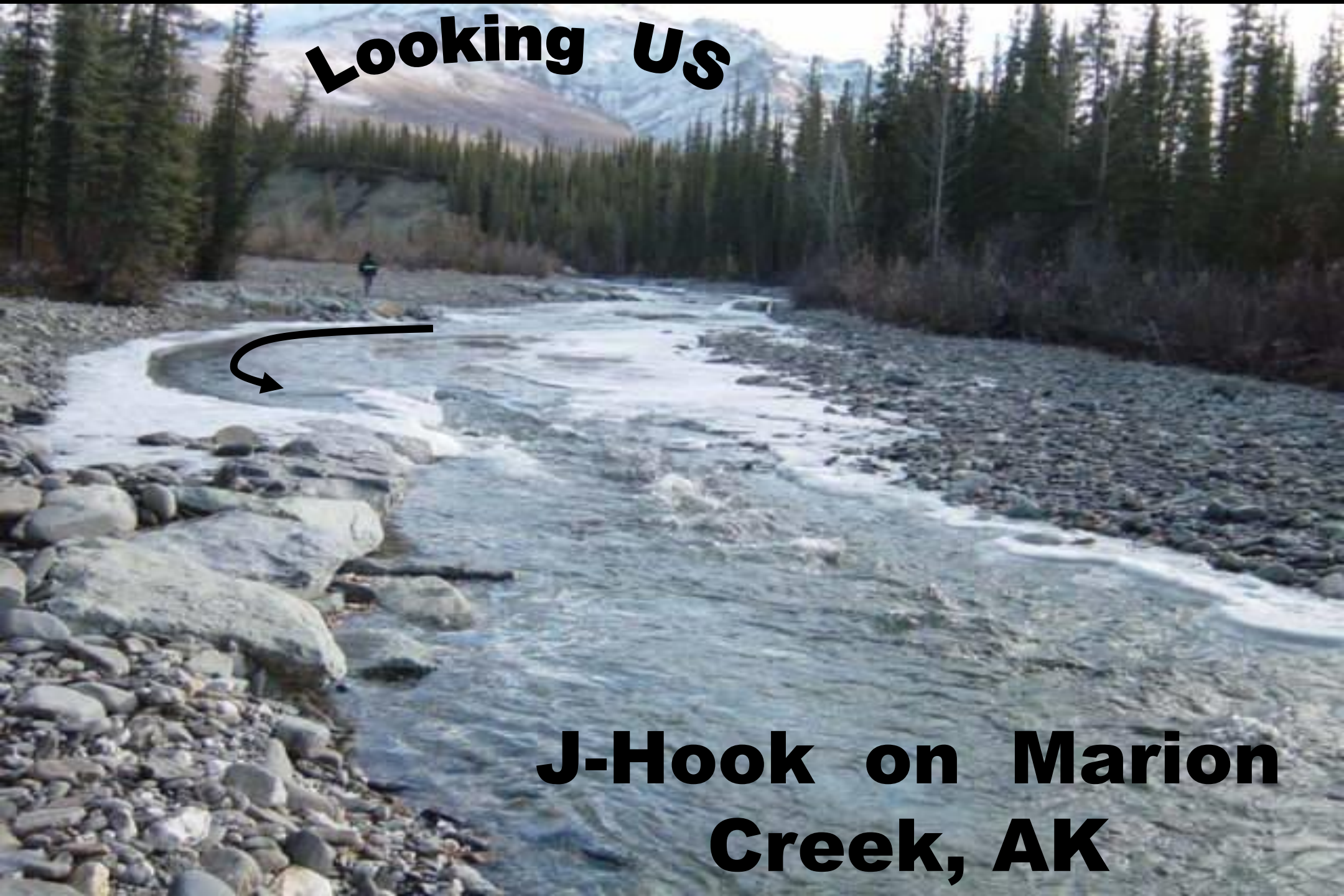
J-HOOK VANES

- A Dave Rosgen invention, named due to the overall plan view shape of the structure
- The "J" section is a semi-circular flow concentrator designed to provide a plunge-scour pool for habitat for salmonids, has nothing to do with bank protection.
- Plunging flow into pool dissipates energy, entrains air, & provides hydraulic cover (surface disturbance)

Neil Young, no John McCullah






Looking Us
J-Hook on Marion
Creek, AK

Comparison of cost, spacing, function, & durability between Bendway Weirs & Rock Vanes

In my experience, in the same stream, similar bends, same length of bend, compared to Bendway Weirs, the Rock Vanes cost three times as much & take three times longer to install. Larger stone in RV also tends to be more expensive to haul.

BW are more durable, very very few repairs needed!! The large stones in RV need to be in compression (imbricated). If not, stone tends to get moved during higher flows resulting in partial failure of the structure.

Hydraulically, Bendway Weirs & Rock Vanes/Bank Barbs function completely differently.

The BW control & realign the thalweg much better, & slow water down within the entire weir field, even with 12 ft of water over the BW.

RV/BB act as a hydraulic brake, slowing the water down more (especially within the angle of the RV), & if spaced correctly will form nice deep pools between RV. With RV/BB the thalweg is kicked away from the bank, but then heads toward the bank again, & if spaced correctly, is kicked out again. If spaced too far apart, the thalweg can hit the bank & flank the downstream RV/BW.

Spacing is more critical with Rock Vanes/Bank Barbs, if they are spaced too close together, I have seen the scour pool from the upstream RV/BB destroy the downstream RV/BB. If Bendway Weirs are spaced too close together, bad things do not happen, except a little stone was probably wasted!!

This PowerPoint presentation was developed & built by Dave Derrick.

Any questions or comments, call my personal cell @ 601-218-7717, or email @ d_derrick@r2d-eng.com

Enjoy the information!!

Does your mind look like this?
GOOD, my work is done.
QUESTIONS???