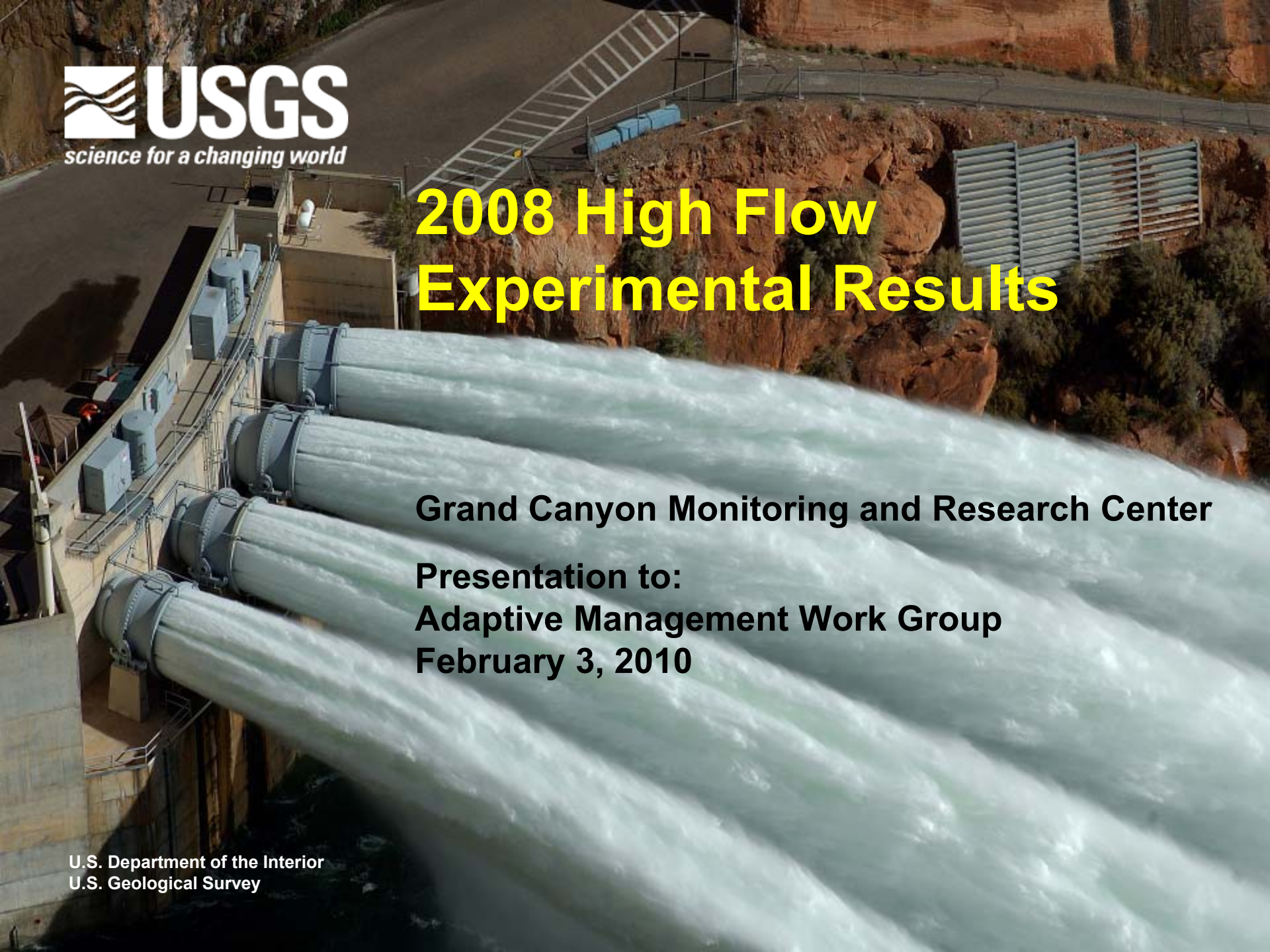

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2008 High Flow Experimental Results

Grand Canyon Monitoring and Research Center

Presentation to:
Adaptive Management Work Group
February 3, 2010

U.S. Department of the Interior
U.S. Geological Survey

2008 HFE Presentation Outline

- Background, objectives & science costs
- Status of 2008 HFE Reporting
- Overview of results of the 2008 HFE
- 2010 HFE summary/synthesis reporting
- Scientific basis for continued HFE testing

USGS

2008 HFE Presentation Outline

- Background, objectives & science costs
-
-
-
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USGS

Background, Objectives & Costs

Replicate of 2004 Hydrograph

- **peak = 41,500 cfs x 60 hrs**

Objective: Evaluate 2nd Sand Enriched HFE in context of ROD dam operations + steady flow test

- **MLFF flows followed the test**
- **Higher equalization flows began in mid April**
- **Steady flows began in Sept and October 2008**
- **Sand enrichment ~ 2.5X more than before 2004 HFE**

Science Budget: ~ $3,500,000

Glen Canyon Dam HFE release, March 6, 2008

Photograph courtesy of T. Ross, Bureau of Reclamation

USGS

Strategic Science Questions

- Based on AMWG concerns and AMP Goals

- Tier off strategic science questions in MRP
- Primary focus on sediment and humpback chub (backwaters habitats)

USGS

2008 HFE Presentation Outline

-
- Status of 2008 HFE Reporting
-
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USGS

14 HFE 2008 Publications – Topics/Author

1) Sand budgeting (Topping & others, in review – MAR 2010)
2) Sandbar modeling (Wright & Kaplinski, in revision – journal in 2010)
3) Sandbar changes (Hazel & others, 2010) *
4) Aeolian reworking (Draut & others, in press – MAR 2010)
5) Sandbar sedimentology (Draut & others, in revision – JUN 2010)
6) Backwater – formation & fate (Grams & others, FEB 2010)
7) Riparian vegetation (Ralston, 2010) *
8) Aquatic food production (Rosi-Marshall & others, FEB 2010)
9) Productivity of backwaters (Behn and others, FEB 2010)
10) RBT survival in Glen Canyon (Korman & others, FEB 2010)
11) Lees Ferry trout movement (Hilwig & Makinster, in press – MAR 2010)
12) Lake Powell quality of water (Vernieu, in revision – MAR 2010)
13) 2008 Weather & aeolian sand-transport data (Draut & others, 2009)*
14) USGS Fact Sheet (Melis & others, 2010) TODAY'S HANDOUT*

*, publication currently available at: www.gcmrc.gov & www.usgs.gov – other USGS reports will be electronically available in FEB & MAR 2010

USGS

9 HFE Preliminary Reports to TWG on January 20, 2010

Sand budgeting (Topping) – Project 1.A

Sandbar modeling (Wright) – Project 1.B

Sandbar changes (Grams) – Project 1.C

Backwaters– formation & fate (Grams) – Project 1.D

Riparian vegetation (Ralston) – Project 2

Aquatic food production (Kennedy) – Project 3

Rainbow trout growth & survival in Glen Canyon (Korman) – Project 4.A

Lees Ferry rainbow trout movement (Hilwig) – Project 4.B

Lake Powell quality of water (Vernieu) – Project 5

USGS

2008 HFE Presentation Outline

-
-
- Overview of results of the 2008 HFE
-
-

USGS

Project 1.A

"Sediment transport during three controlled-flood experiments on the Colorado River downstream from Glen Canyon Dam, with implications for eddy-sandbar deposition in Grand Canyon National Park"

David Topping and David Rubin and others

Draft USGS Open File Report (March 2010)

U.S. Department of the Interior
U.S. Geological Survey

Sand Budgeting – Project 1.A

Q: Was the net mass balance of sand following the 2008 HFE test net positive, negative, or neutral?

A: Sand Mass Balance was Neutral [RM 1 – 88] to Positive (RM 88 - 225) relative to December 2004-February 2008 antecedent accounting period.

No reach of the ecosystem was forced into sand deficit during the 2008 HFE

USGS

Preliminary Results – Subject to Peer Review & Revision

Project 1.B

"Hydro-morphodynamics of two large eddies and associated sandbars along the Colorado River during high flow"

Scott Wright and Matt Kaplinski

Draft Journal Article, Spring 2010

U.S. Department of the Interior
U.S. Geological Survey

Main Findings – Project 1.B

Q: What is the minimum duration for high-flow experiments needed to build and maintain sandbars under sand-enriched conditions?

A: High elevation *deposition rates suggest that the flood duration was probably not too long and could perhaps have been longer*, i.e. deposition continued throughout the peak at both river mile 45 study sites where detailed measurements were made.

Key Finding: Compared to the surveys made at Eminence by Andrews in 1996, the 2008 HFE had ~ three times as much high elevation deposition with a peak duration ~ three times shorter. Also, net erosion in 2008 was substantially less than erosion on only the 1st day of the 1996 flood.

USGS

Preliminary Results – Subject to Peer Review & Revision

Project 1.C

"Sandbar Response Following the 2008 High-Flow Experiment on the Colorado River in Marble and Grand Canyons, Arizona"

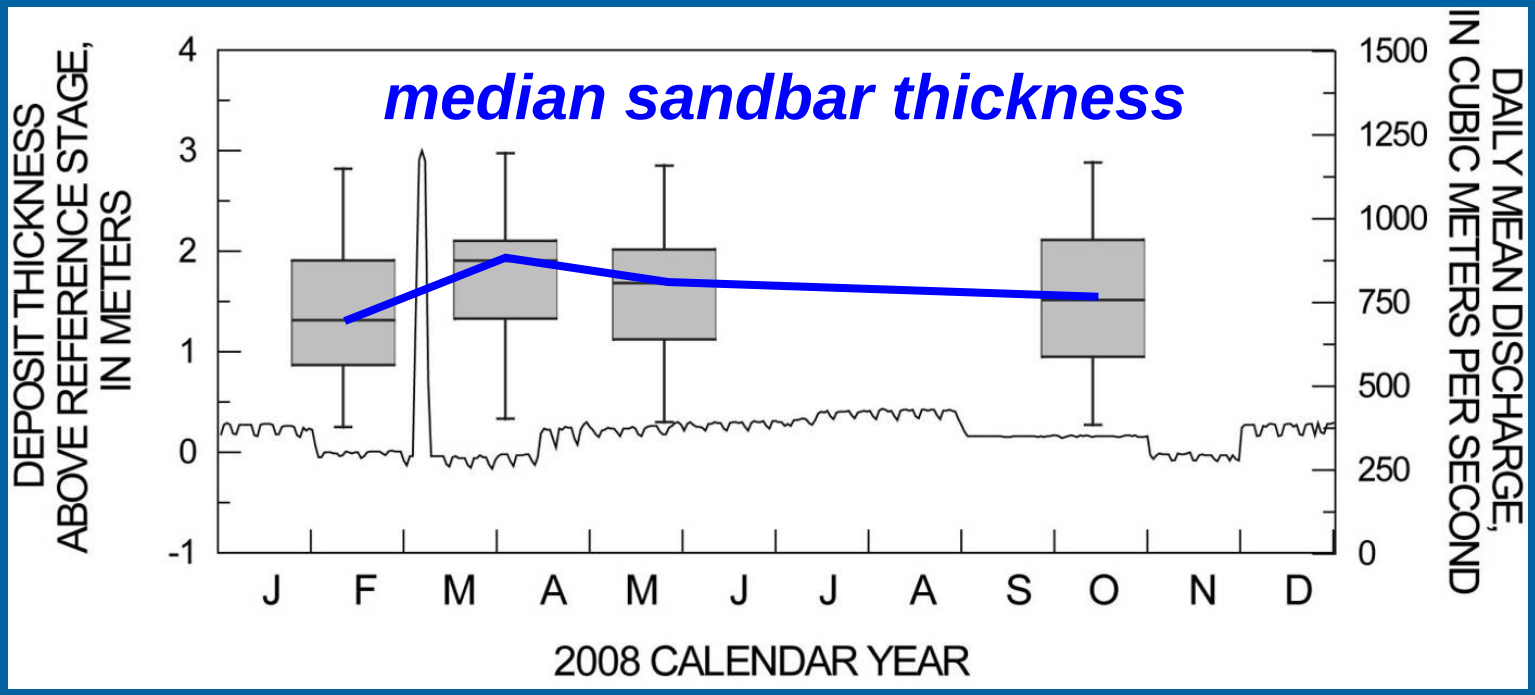
Joe E. Hazel, Paul E. Grams, John C. Schmidt and Matt Kaplinski

(USGS Scientific Research Investigations Report, 2010)

U.S. Department of the Interior
U.S. Geological Survey

Deposition of sandbars and subsequent erosion – Sandbars Were Built!

(after Hazel and others, 2010 – fig. 20, p. 29)



- *But , then the new sandbars eroded in the six-month period following the 2008 HFE; however, median sandbar elevation was still slightly greater in October 2008 than in February 2008*
- *Erosion rate was greatest between April and May.*
- *Erosion rate from May to October 2008 was lower.*

USGS

High flow Science Questions: Project 1.C (Sandbars) [Hazel and others, 2010]

Q: Following a high flow, how do ROD operations under 8.23-maf annual release volumes affect the persistence of sandbars and related backwaters compared to non-ROD operations that followed the 2004 high flow?

A: *Sandbar erosion rates were highest between April and May (following the onset of "equalization" release volumes under MLFF) but declined in the six month period after the HFE.*

This question cannot be completely addressed owing to the fact that repeat measurements were made in Water Year 2008 and it was not an 8.23 maf annual release year, but was higher owing to equalization requirements

USGS

High flow Science Questions: Project 1.C [Draut and others, 2009 & in press]

Q: Do sandbars deposited by high-flow experiments contribute to preservation of archaeological sites in the river corridor?

A: Draut and others (2009 & in press) process-based studies demonstrate that sand deposited by HFEs can be moved inland towards archaeological sites by wind.

Q: Do high-flow experiments contribute to added stability or erosion of archaeological sites located in close proximity to the river?

However, it is still not clear whether increased sand flux toward a site results in increased burial/preservation or perhaps increased site erosion and instability?

USGS

Project 1.D

"2008 High-Flow Experiment at Glen Canyon Dam: Morphologic Response of Eddy-Deposited Sandbars and Associated Aquatic Backwater Habitats along the Colorado River in Grand Canyon"

Paul E. Grams, John C. Schmidt, Matthew E. Andersen

(USGS Open File Report, in press)

U.S. Department of the Interior
U.S. Geological Survey

High Flow Science Questions: Project 1.D (Backwaters) [Grams and others, 2010]

Q: Do high flow tests result in creation of backwater habitats that may offer physical benefits to humpback chub and other native fishes?

A: High flows build sandbars that create backwaters (mostly).

One month after the 2008 HFE:

There were more backwaters &

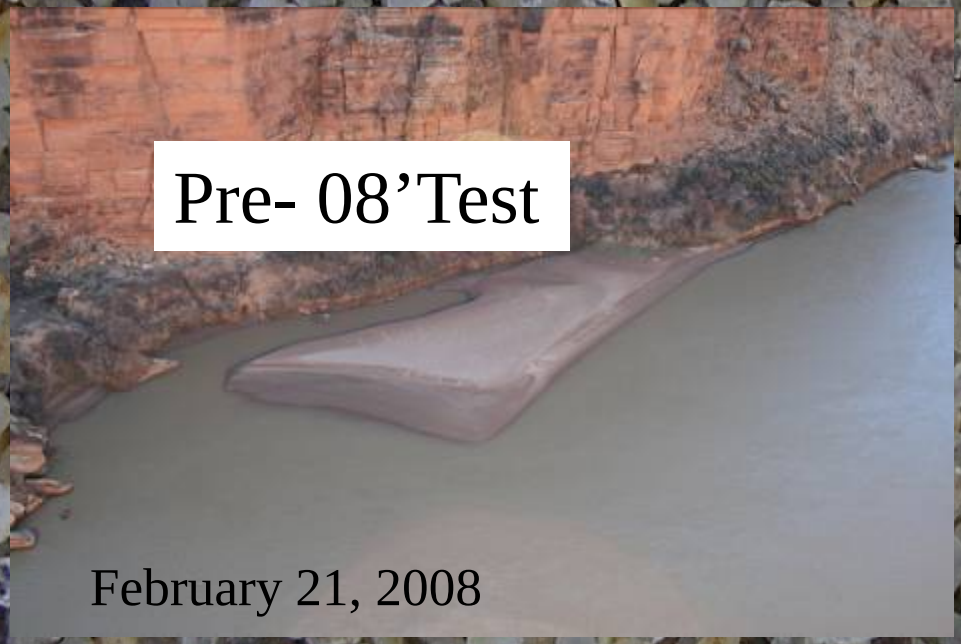
There was greater area and volume of habitat

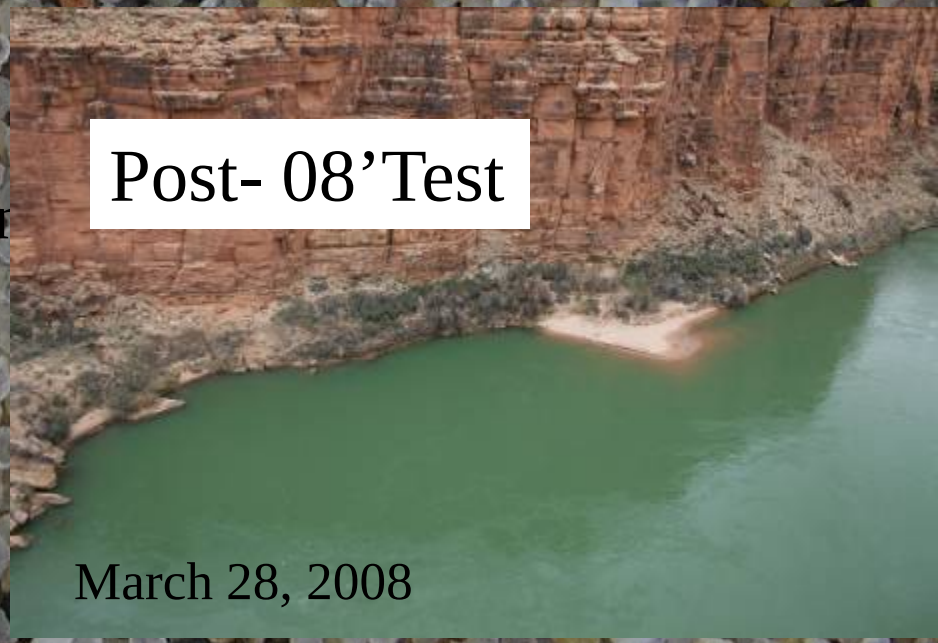
USGS

Photographic Data – RM 2

Sandbar and backwater loss

Above Cathedral Wash - River Left





Sandbars & backwaters in Upper Marble Canyon did not respond to the March 2008 HFE as positively as most other sites downstream

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Photographic Data – RM 3

Matched Photos – Above Cathedral Wash - River Left

This sandbar existed 24 years following dam closure, but was not rebuilt by the sand-enriched 2008 HFE

October 1987

March 29, 2008

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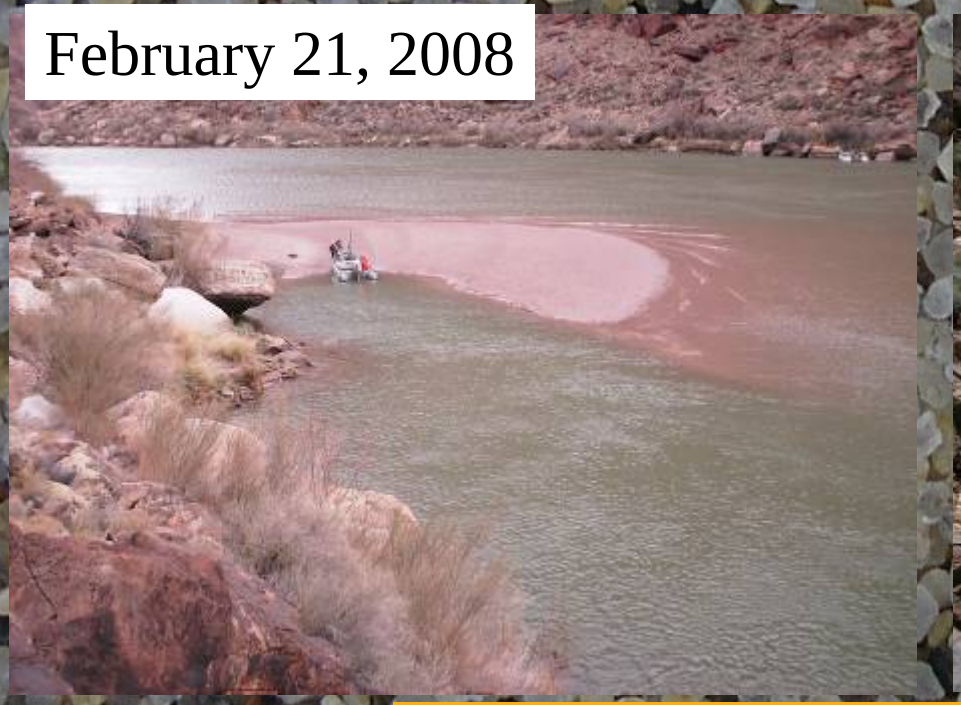
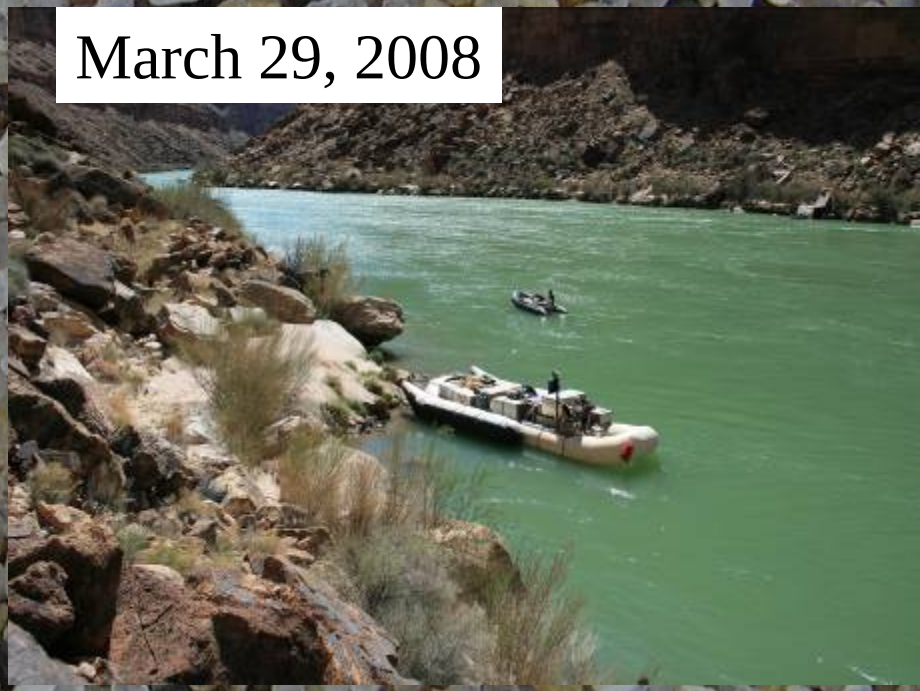
science for a changing world

Photographic Data – RM 6

Matched Photos – Below Six Mile Wash on River Left





Low-Elevation Sandbars in Upper Marble Canyon
Were Scoured – low flow backwaters supported by these bars were lost, but many backwaters built in downstream reaches

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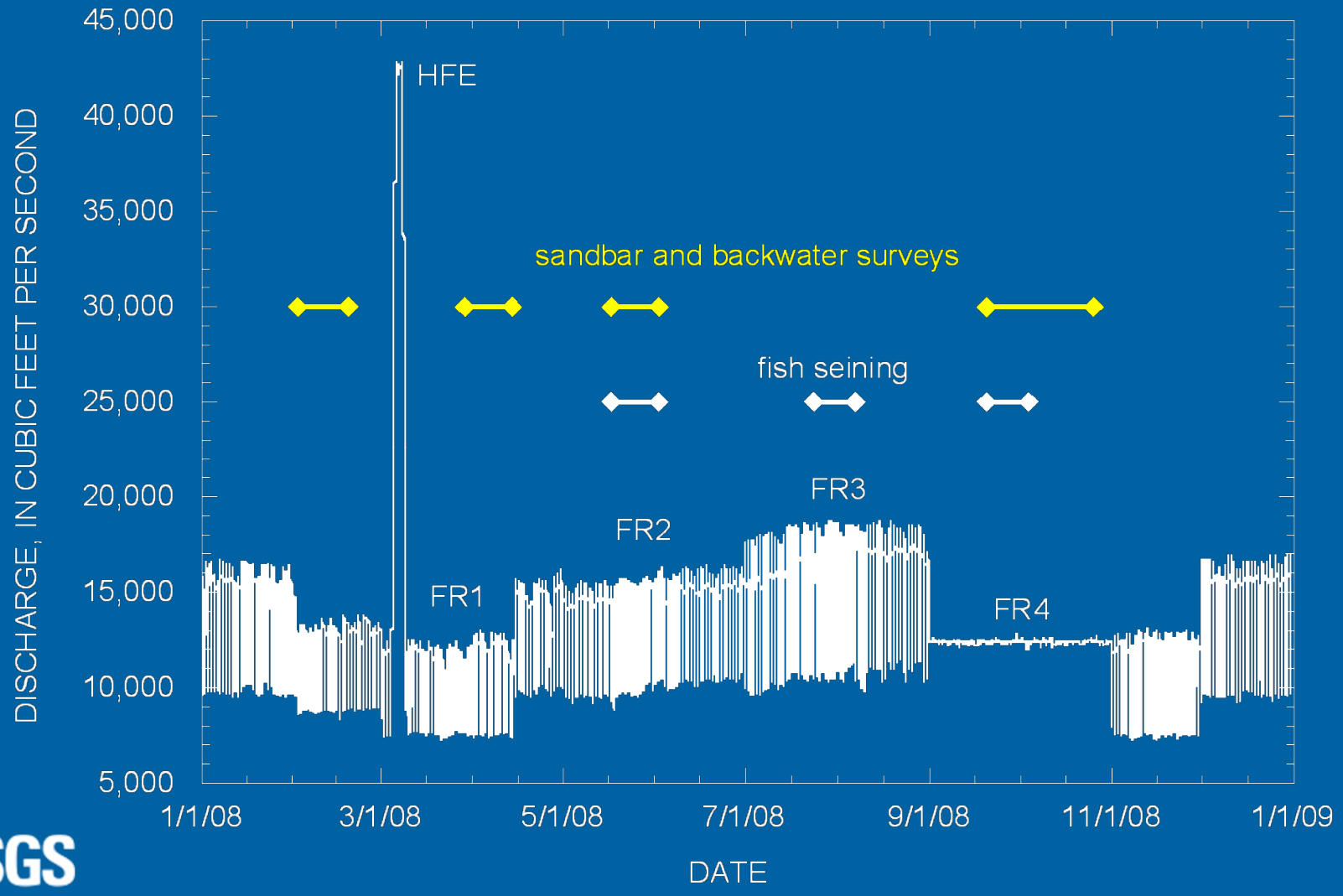
2008 Flows and Sandbar & Backwater Data Collection (Grams and others, in press)



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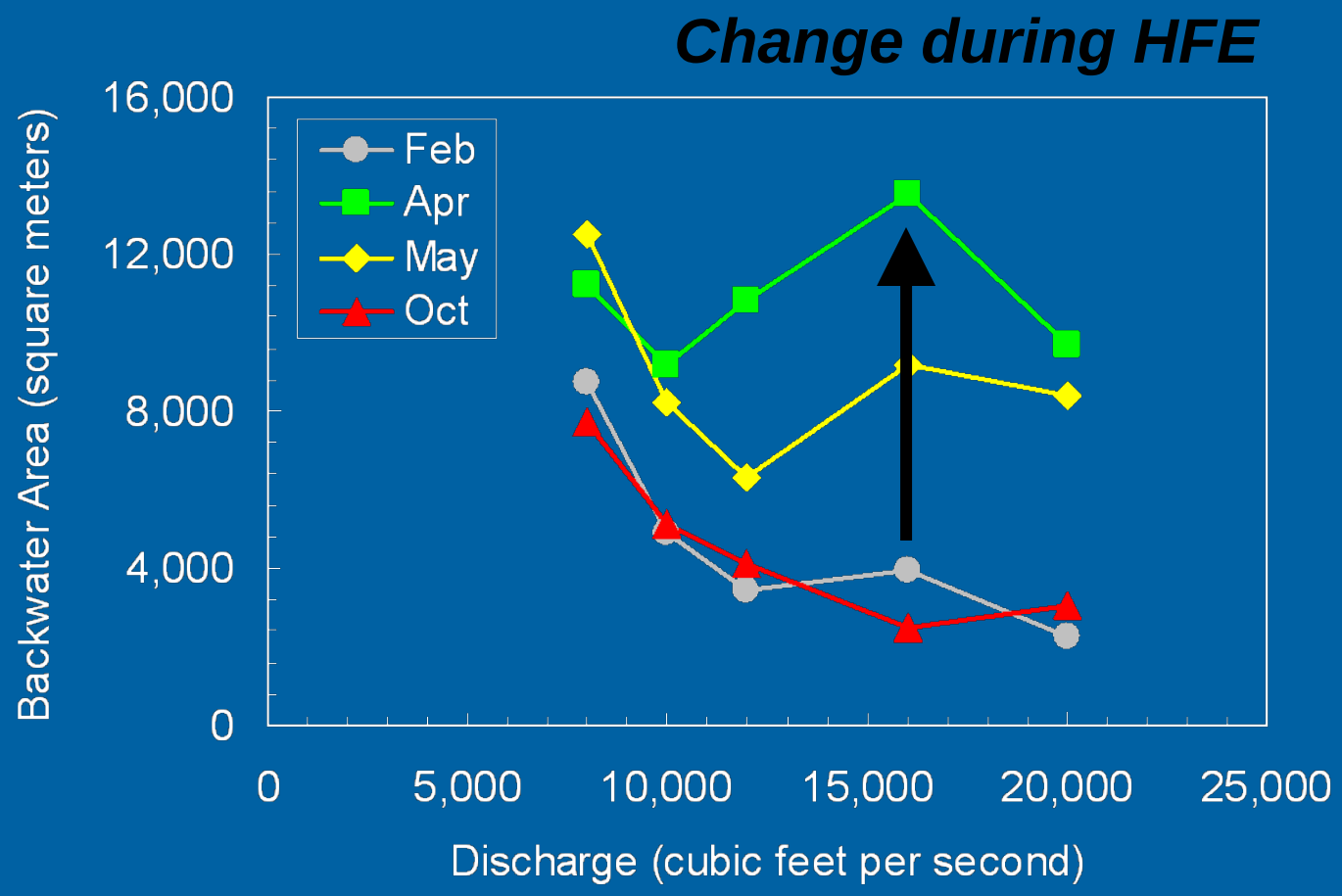
Backwater habitat area as a function of discharge (Grams & others, in press)

- ***Large increase in habitat from Feb to Apr***

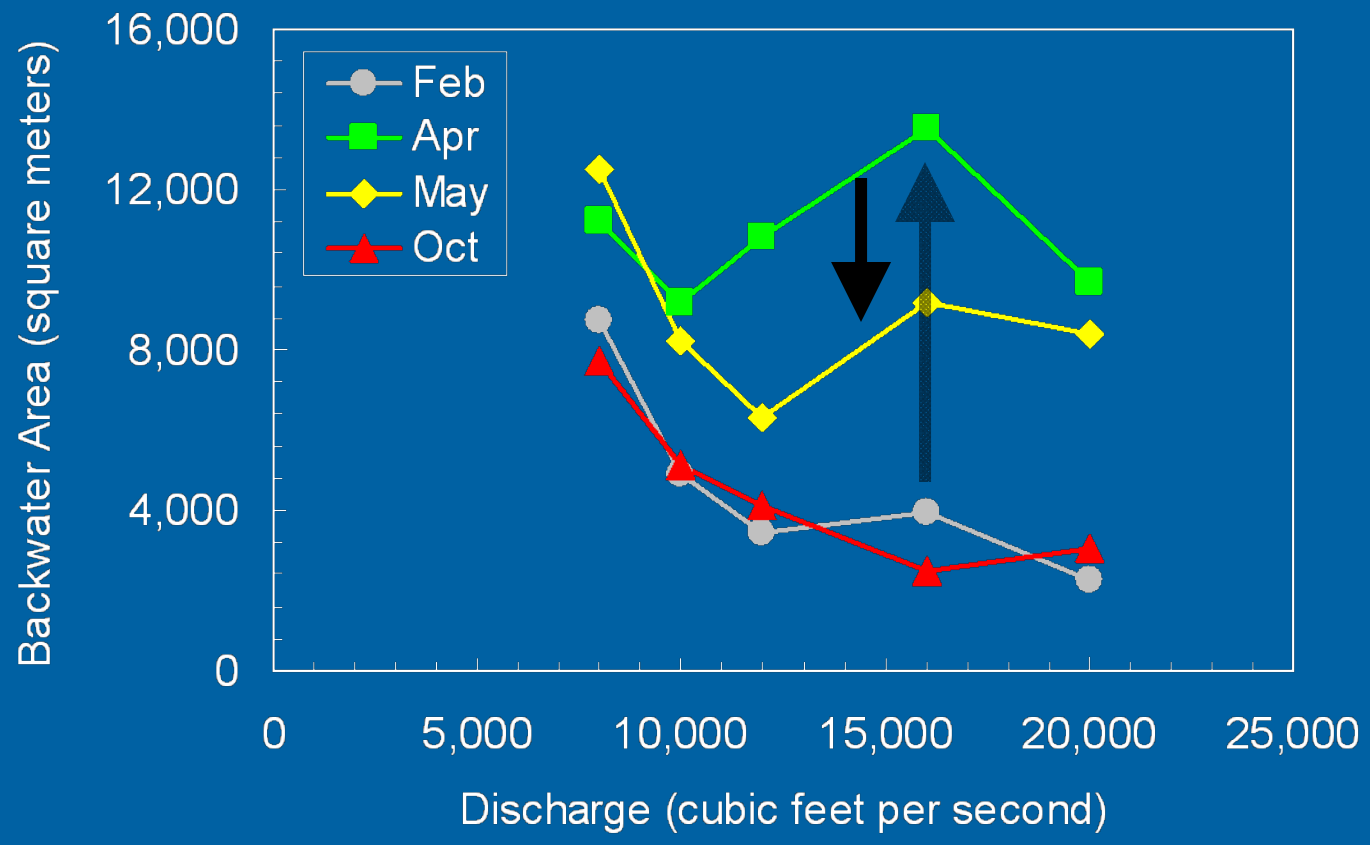


USGS

Backwater habitat area as a function of discharge (Grams & others, in press)

- *Large increase in habitat from Feb to Apr*
- ***Sandbar erosion and loss of habitat from Apr to May***

Change Post-HFE Apr. to May

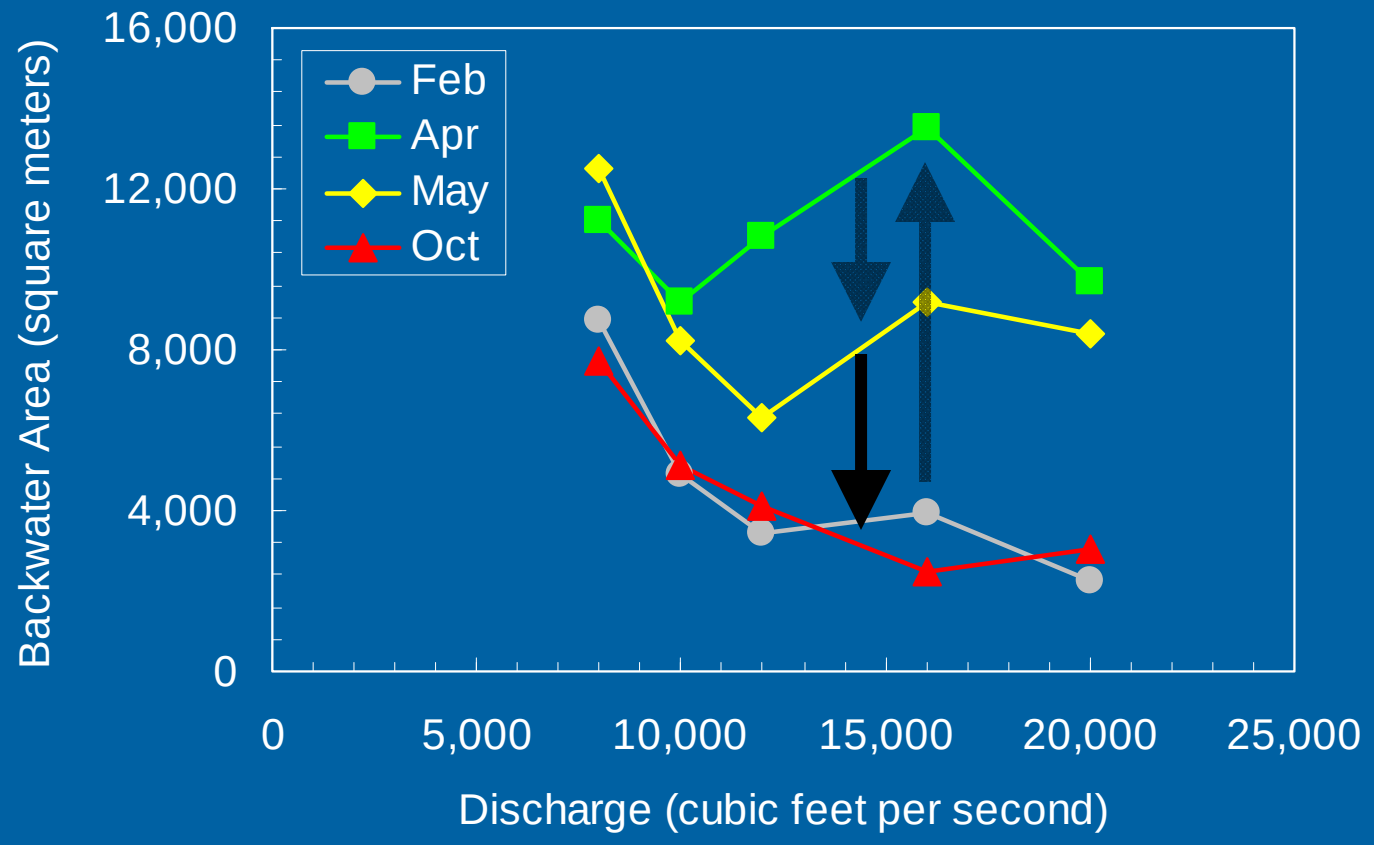


USGS

Backwater habitat area as a function of discharge (Grams & others, in press)

Change Post-HFE May to Oct.

- *Large increase in habitat from Feb to Apr*
- ***Sandbar erosion and loss of habitat from Apr to May***
- ***Continued erosion from May to Oct***



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- *Apr. and May have high habitat availability at all flows in range*
- *Feb. and Oct. have greatest habitat at low flows*

Humpback Chub Questions – Project 1.D

Strategic science question: How important are backwaters and vegetated shoreline habitats to the overall growth and survival of young-of-year and juvenile native fish?

2008 HFE science questions: Project 1.D

Q: Did the 2008 HFE test result in creation of backwater habitats that <u>may</u> offer physical benefits to humpback chub and other native fishes?

A: Yes, there were more backwaters & total habitat area and volume were increased in APR relative to FEB 2008

POINTS – Backwater Habitats Were Built throughout most of Marble and Grand Canyons

USGS

High Flow Science Questions: Project 1.D (humpback chub & other natives)

Q: To what extent are backwater habitats created by a high flow used by humpback chub and other native fishes?

A: Native fish were caught in backwaters created by the HFE.

- **Backwaters not "optimized" by the summer fluctuations**
- **Lower volume flows result in greater backwater availability**
- **Sep-Oct 2008 steady flows resulted in more *continuously available* backwaters than equivalent volume fluctuations**

POINTS – dam operations after the HFE mattered, both in terms of sandbar erosion and availability to fishes
-16,000 fish were seined in backwaters during 3 trips & majority were native species, including chub

USGS

Post-HFE sandbar erosion and backwater change: river mile 45 L

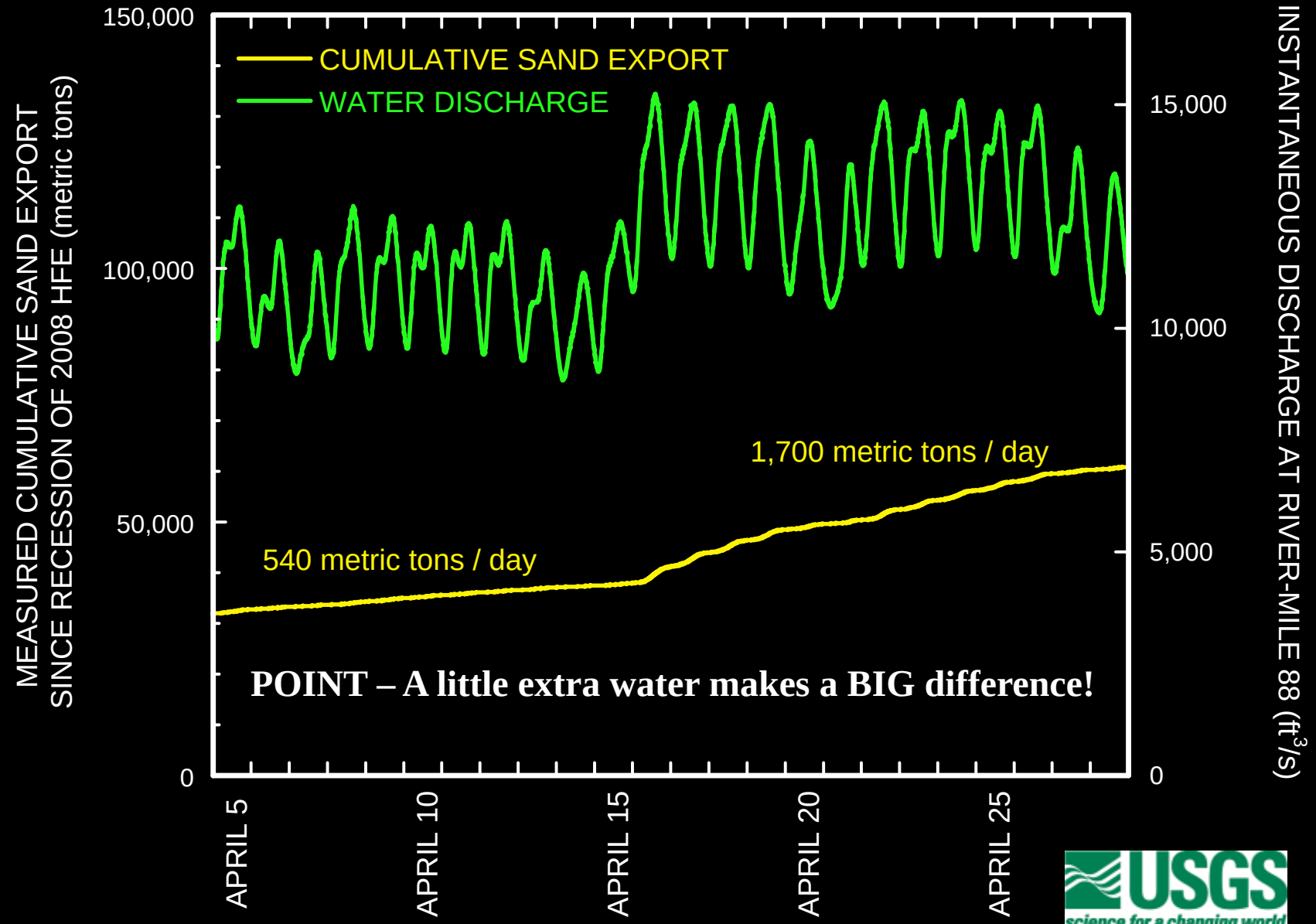
(from USGS FS 2010-3009)

POINTS – Sandbars are dynamic landforms and inherently unstable

However – they are most unstable under higher unsteady flows & more stable under lower steadier flows – it's about the physics

USGS

20% INCREASE IN DAM RELEASES RESULTS IN **~FACTOR OF 3 INCREASE** IN RATE OF SAND EXPORT AT RM 88



Preliminary Results – Subject to Peer Review & Revision

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Sandbars & Backwaters Summary

Q: Following a high flow, how do Record of Decision (ROD) operations under 8.23 million acre-feet annual release volumes affect the persistence of sandbars and related backwaters compared to non-ROD operations that followed the 2004 high flow?

Answers: BARS & BACKWATERS WERE BUILT

Sandbars eroded and backwater habitat declined in the six month period after the HFE.

Erosion rates were highest between April and May – the initial period of higher monthly volume fluctuations.

By October 2008, sandbars/backwaters (#'s, area & volume) decreased to levels only slightly greater than February 2008.

This question cannot be completely addressed owing to the fact that repeat measurements were made in Water Year 2008 and it was not an 8.23 maf annual release year, but was higher owing to equalization requirements

USGS

Moving On To Riparian Vegetation

Project 2 - Riparian Vegetation

"Riparian Vegetation Response to the March 2008 Short-Duration, High-Flow Experiment—Implications of Timing and Frequency of Flood Disturbance on Nonnative Plant Establishment along the Colorado River below Glen Canyon Dam"

Barbara E. Ralston

USGS Open File Report, 2010

U.S. Department of the Interior
U.S. Geological Survey

Fate of Sandbars following an HFE?

Initially sandbars are created at high elevations, but

then they are exposed to Aeolian Reworking

+

Erosion through river processes (as seen in previous slides)

but don't forget…

Substrate for vegetation

USGS

1,000,000 metric tons of sand = NFL gridiron stacked 44 stories high with Paria River sand (Dave Topping)

2008 HFE Science Questions: Project 2

Q: How does disturbance frequency within the riparian zone affect susceptibility to nonnative species establishment.

- Are open patches (areas of lower cover) more susceptible to exotic species colonization and establishment than sites with existing vegetation (greater cover) following a disturbance?

Q: How does timing of an HFE affect establishment success of nonnative species?

USGS

Riparian Vegetation Findings (Ralston, 2010)

- **Areas above power plant capacity stage elevations were little affected by 2008 HFE – existing plants at lower elevations were subject mostly to burial by HFE deposited sandbar deposits.**
- **Zones of intermediate disturbance and lower cover are more susceptible to nonnative plant establishment following an HFE.**
- **HFEs conducted in March reduce the likelihood of extensive tamarisk establishment (less than 2% of measured cover 6 months after the experiment).**
- **The coarser sandbars built by HFEs affect water holding capacity of substrates – favoring "clonal" species (arrowweed, seepwillow and common reed) – plants not dependent upon seed germination.**

USGS

POINT – Tamarisk didn't do too well, but "clonal" species increased cover in lower areas where burial occurred

Conclusions- Management Implications

Riparian community response to short duration HFEs and coarsening substrates (relative to pre-dam) favors:

- Plants adapted to partial burial – seepwillow, coyote willow, common reed
- Plants that grow and expand through vegetative reproduction rather than by seed (common reed, horsetails, arrowweed)
- Plants that can persist in coarser sediments (e.g., horsetails, common reed, arrowweed)

POINT – HFE Timing Matters!

Aquatic Food Production – Project 3

"Short-Term Effects of a High-Flow Experiment on Macroinvertebrates in the Colorado River below Glen Canyon Dam"

Emma J. Rosi-Marshall, Theodore A. Kennedy, Dustin W. Kincaid, Wyatt F. Cross, Holly A.W. Kelly, Katherine A. Behn, Tyler White, Robert O. Hall Jr. and Colden V. Baxter

(USGS Open File Report, in press)

U.S. Department of the Interior
U.S. Geological Survey

HFE Science Questions – Project 3

Q: How will a future high flow affect food production and availability for rainbow trout in the Lees Ferry reach?

A: Total Aquatic Invertebrate Production ↓ but Quality ↑

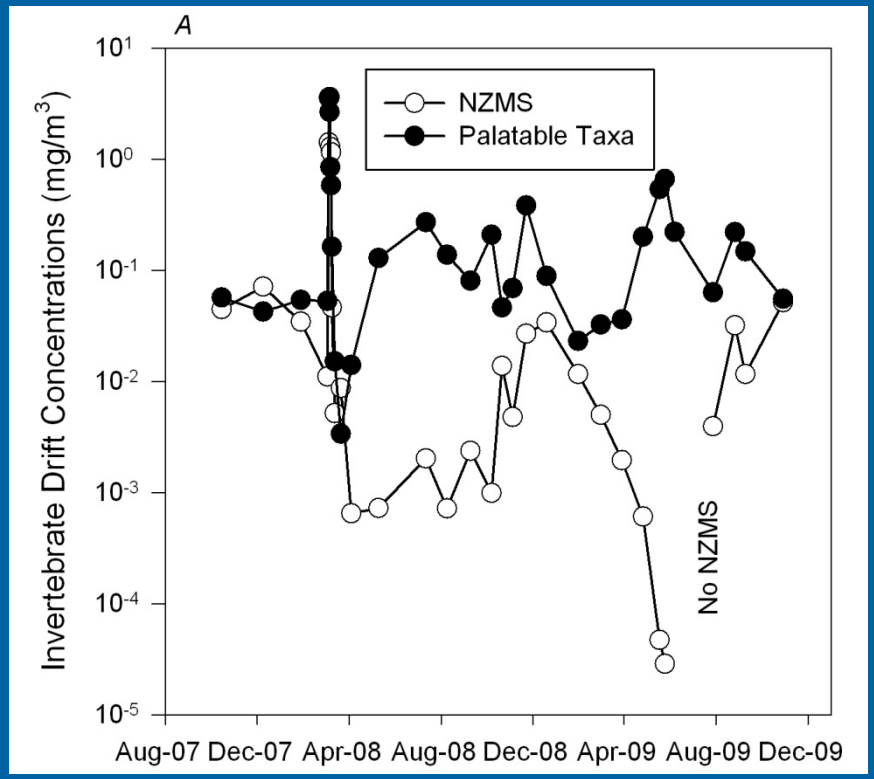
"… the relative quality of food sources increased because the HFE reduced the New Zealand mud snail population by about 80% and increased midges and black flies." (USGS FS 2010-3009)

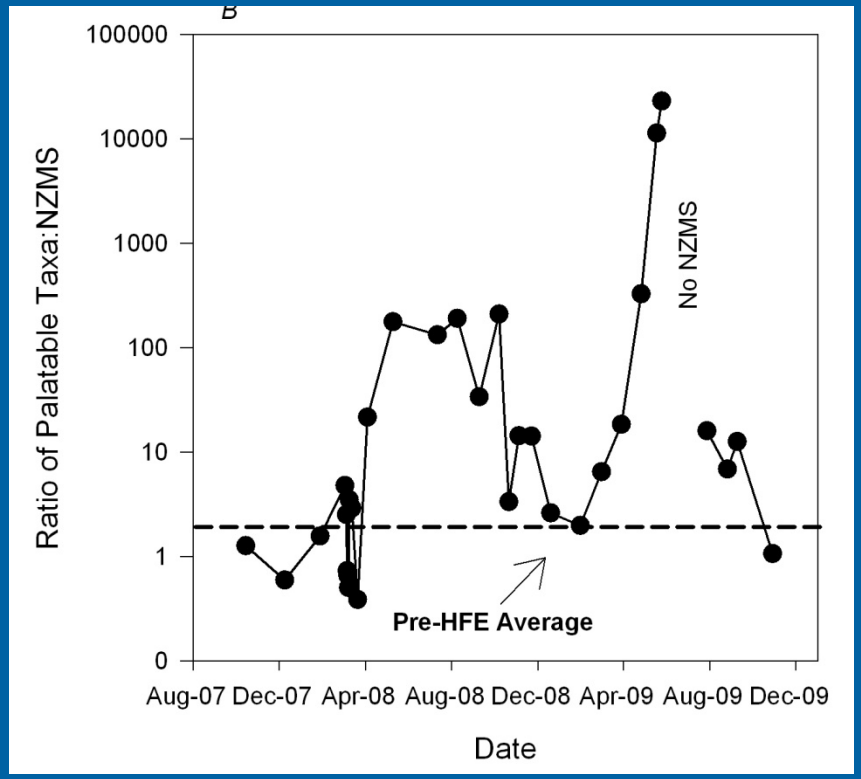
Q: What are the effects of high-flow experiments on aquatic food production?

A: No evidence of strong negative impacts at downstream locations

USGS POINT – Exotic New Zealand Mud Snails were BIG losers!

2008 HFE Improved the Quality of Drifting Food Resources – Project 3





POINT - Non-Digestible Mud Snails Were Reduced – Ratio of other digestible "Bugs" was increased proportionally following rebound by black flies and midges **(Rosi-Marshall and others, in press)**

Project 4.A – Trout Spawning & Survival

"Effects of High-Flow Experiments from Glen Canyon Dam on Abundance, Growth, and Survival Rates of Early Life Stages of Rainbow Trout in the Lees Ferry Reach of the Colorado River"

Josh Korman, Matthew Kaplinski and Theodore S. Melis

(USGS Open File Report, in press)

U.S. Department of the Interior
U.S. Geological Survey

Project 4.A - Conclusions

Rainbow Trout Spawning & Survival

"The March 2008 HFE resulted in a large increase in early survival of age-0 (fertilization to about 1 to 2 months from emergence) rainbow trout likely because of improved habitat conditions."

"Abundance of age-0 trout in July 2008 was more than four times higher than had been predicted."

"Trout abundance in 2009 was more than two times higher than expected given the estimated number of viable eggs deposited in that year, indicating that the effect of the high flows on young trout persisted for at least a year after the high flow."

(USGS FS 2010-3009)

USGS

POINTS – Rainbow Trout Production Was Way Up - Implications for both native & nonnative fisheries

Project 4.A - Conclusions

Rainbow Trout Spawning & Survival

"Trout abundance in 2009 was more than two times higher than expected given the estimated number of viable eggs deposited in that year, indicating that the effect of the high flows on young trout persisted for at least a year after the high flow." (USGS FS 2010-3009)

Rainbow Trout Growth after HFE

- Rates of growth were high despite high abundance

"Scientists think that the 2008 experiment increased the tiny spaces between gravel on the river bottom and improved availability of high-quality food." (USGS FS 2010-3009)

POINTS – More integrated Biological/Physical studies are needed
- HFE Bio-effects like these <u>may</u> persist over inter-annual timescales

USGS

Project 4.B – Rainbow Trout Movements

"Evaluating effects of an HFE on rainbow trout: Using acoustic telemetry and relative abundance measures"

Kara Hilwig and Andy Makinster

Proceedings of the November 2008 Colorado River Science and Resource Management Symposium – USGS Circular (in press)

U.S. Department of the Interior
U.S. Geological Survey

Project 4.B - Conclusions

Sonic Telemetry

- Majority of detected RBT did not displace downstream with HFE
- Movement not different among sex or size
- Documented RBT movement downstream of Paria River

Electrofishing

- Relative abundance in Lees Ferry reach did not change after HFE

POINT - "Data collected before, during and after the 2008 HFE indicate that trout did not move significantly as the result of the experiment." (USGS FS 2010-3009)

USGS

“Effects of 2008 High-Flow Experiment on Water-Quality in Lake Powell and Glen Canyon Dam Releases, Utah-Arizona”

William S. Vernieu

Draft USGS Open File Report

U.S. Department of the Interior
U.S. Geological Survey

Lake Powell questions - Project 5

Q: Did the operation of the river outlet works and the penstocks at capacity measurably alter Lake Powell hydrodynamics or stratification, or alter release water quality?

A: Unlike 1996, there was no measurable effect on lake structure from the 2008 HFE, other than a decrease in reservoir elevation of 2.6 ft

POINT – Antecedent reservoir condition & HFE volumes matter in terms of possible "Lake Structure" effects

2008 HFE Presentation Outline

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-
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- 2010 HFE summary/synthesis reporting
-

USGS

HFE Synthesis: Scope & Schedule For 1996, 2004 and 2008 results

Background: Full reporting was required by 2008 EA & in 2008 HFE science plan

Editorial Team: Jack Schmidt, Rich Valdez and Ted Melis

Focus: Ecosystem responses as well as key resources of interest to GCDAMP

Report Type: USGS Circular - Dec 2010

Use: Will Inform next knowledge assessment & long term experimental planning

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2008 HFE Presentation Outline

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-
- Scientific basis for continued HFE testing

USGS

The Overarching Sandbar Question?

Consensus of Sediment Researchers - None of the 2008 HFE sediment results refute any of the previously published sediment findings (Rubin & others, 2002; Topping & others, 2007; Melis & others, 2007; Wright & others, 2008)

"It may not be possible to rebuild and maintain sandbars over the long run solely through the manipulation of Glen Canyon Dam operations. Long-term experimentation that includes multiple, more frequent HFEs following tributary floods and that incorporates ongoing monitoring of intervening dam operations is required to resolve this question." (USGS FS 2010-3009)

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POINT – Physics govern river processes – hence, there are no easy answers or solutions for sandbars

The Overarching Sandbar Question?

Continued

"Frequent short-duration controlled floods under sand-enriched conditions could result in the downstream propagation (into the downstream half of Marble Canyon and into Grand Canyon) of the gains in total eddy-sandbar area and volume observed in the upstream half of Marble Canyon during the 2004 controlled-flood experiment." (Topping and others, 2006)

POINT – A long term experimental sediment triggering approach is required to answer the strategic sandbar question

USGS

The Overarching Sandbar Question?

Continued

"It is still unclear whether controlled floods will provide a sustainable strategy for longer term habitat restoration and maintenance using only sand supplied by the remaining tributary sources of sand below the dam. *This will require integration of the results described in this report with results from other studies and continued experimentation, monitoring, and evaluation*." (Hazel and others, USGS Scientific Investigations Report, 2010)

POINT – Since the EIS sediment paradigm shifted following the 1996 High Flow Experiment – the story has not really changed all that much . . . .

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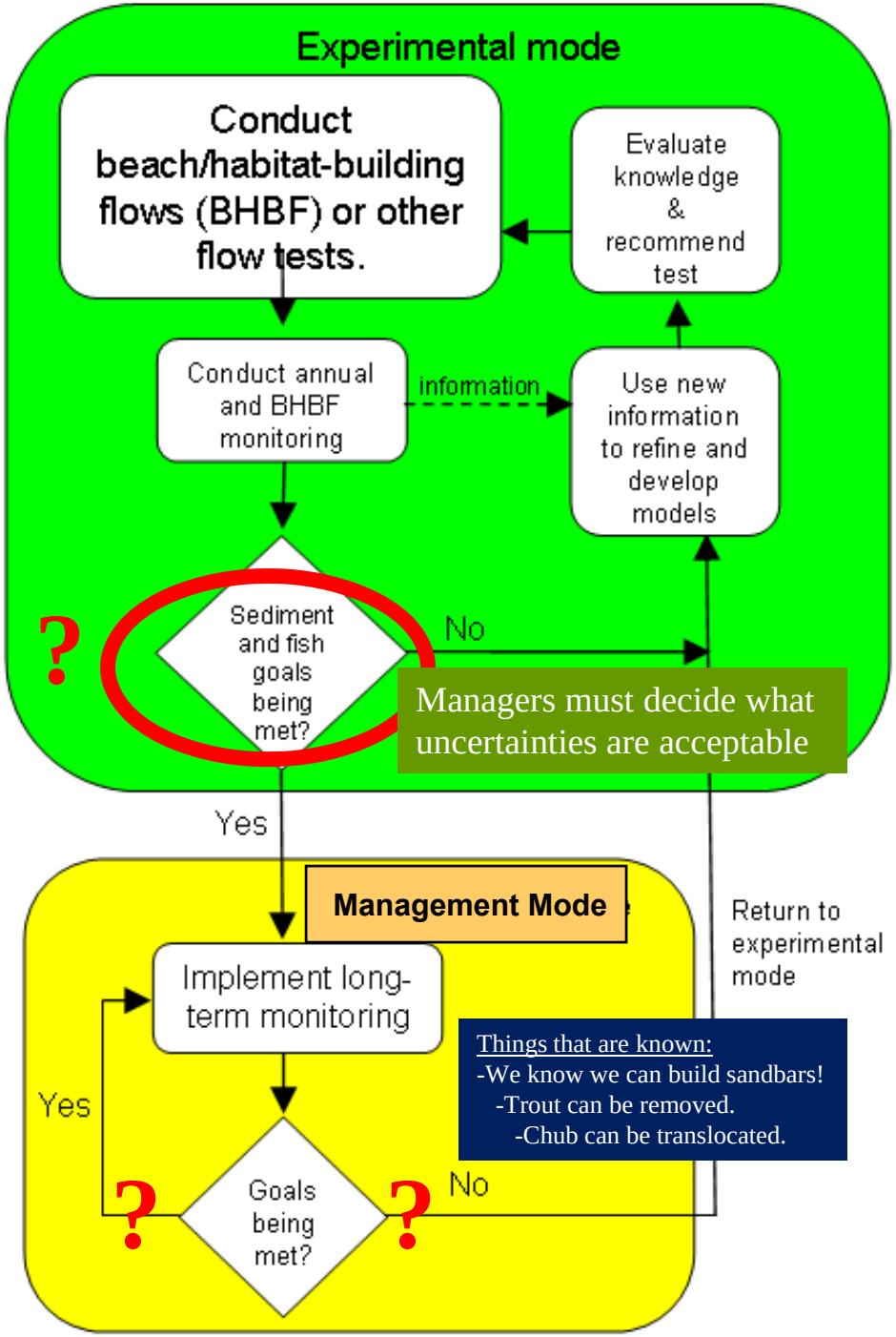

Long-Term HFE Strategy

Several HFEs may be required:

- **Sand supplies are limited**
- **High Flow events are relatively inefficient**
- **Intervening flows export sand and erode sandbars**
- **Effectiveness is based on cumulative effects of multiple events**
- **Effectiveness varies under different flow regimes and natural conditions**

Modeling <u>may help inform HFE planning process</u> – HFE triggering, duration, etc.

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Acknowledging Science Cooperators

- National Park Service (permitting, outreach & education)
- Bureau of Reclamation (NEPA compliance & dam releases)
- U.S. Fish & Wildlife Service (NEPA compliance)
- AZ Game & Fish Department (Makinster, Sorensen and others)
- Utah State University (Schmidt and others)
- Northern Arizona University (Parnell and others)
- Native American Tribal representatives
- Loyola University (Rosi-Marshall and others)
- University of Wyoming (Hall and others)
- USGS - AZ, CA & WA Water Science Centers (Hart, Fisk, Hornewer, Wright, Konrad and many others)
- USGS Marine Geology Team (Rubin, Draut and others)
- Humphrey Summit Support (logistics)
- Many others…

USGS