Glen Canyon Physical Environment Update

Water Quality, Tributary Influences & Channel Analyses & Flows


Ted Melis

02:15 p.m. on January 21, 2015

Annual Reporting Meeting, Phoenix, AZ

USGS

RECENT QUALITY OF WATER

Glen Canyon Dam Tailwater Fishery

Water Years 2011 – 2014

“Era of RBT Natal Origins Project”

USGS

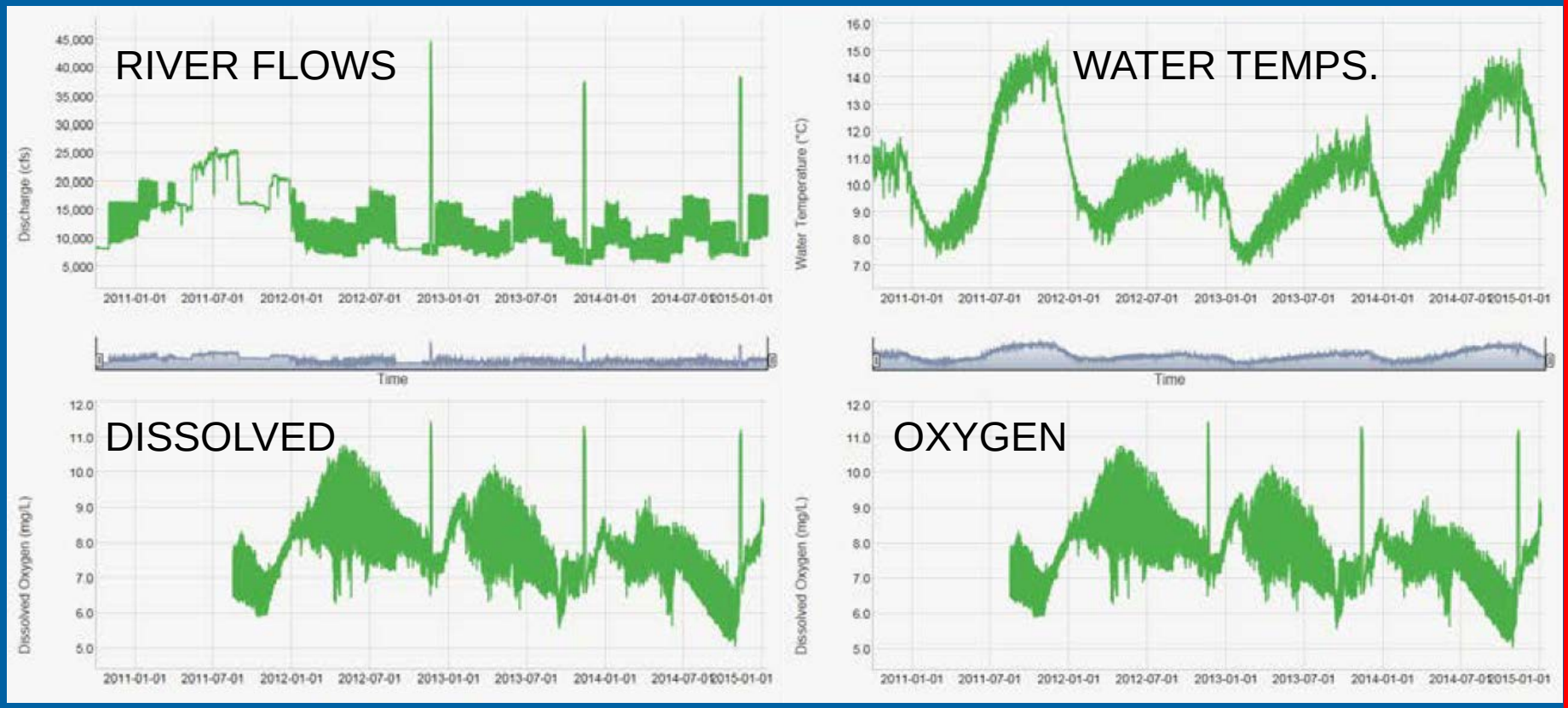
Glen Canyon *Temperature & Dissolved Oxygen*

WY 2011 through DEC 2014

[measured at Lees Ferry, AZ, station #09380000

http://www.gcmrc.gov/discharge_qw_sediment/station/GCDAMP/09380000]

Depressed Fall levels of DO prior to recent HFE releases



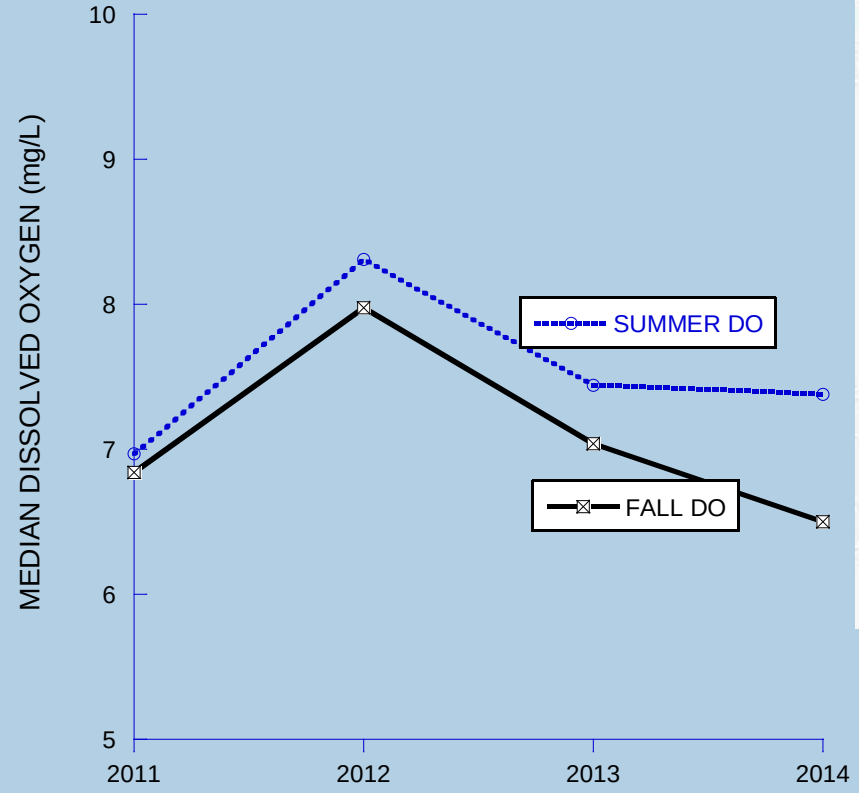
USGS

Dissolved Oxygen got lower ↓ in fall 2005 (3 to 4 mg/L [Vernieu written commun. USGS]

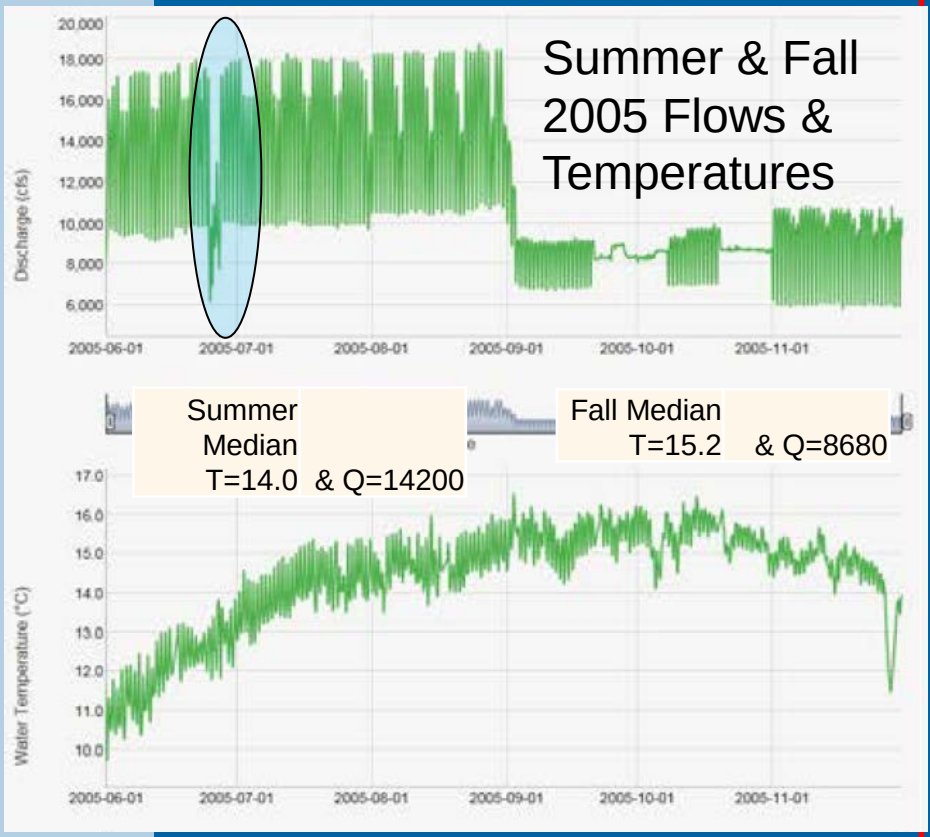
Night time "low flows" were tested in fall 2005 to elevate DO, and did

Median Summer & Fall Dissolved Oxygen @ Lees Ferry

[measured at Lees Ferry, AZ, station #09380000 accessed: http://www.gcmrc.gov/discharge_qw_sediment/station/GCDAMP/09380000]



[preliminary data, do not cite]



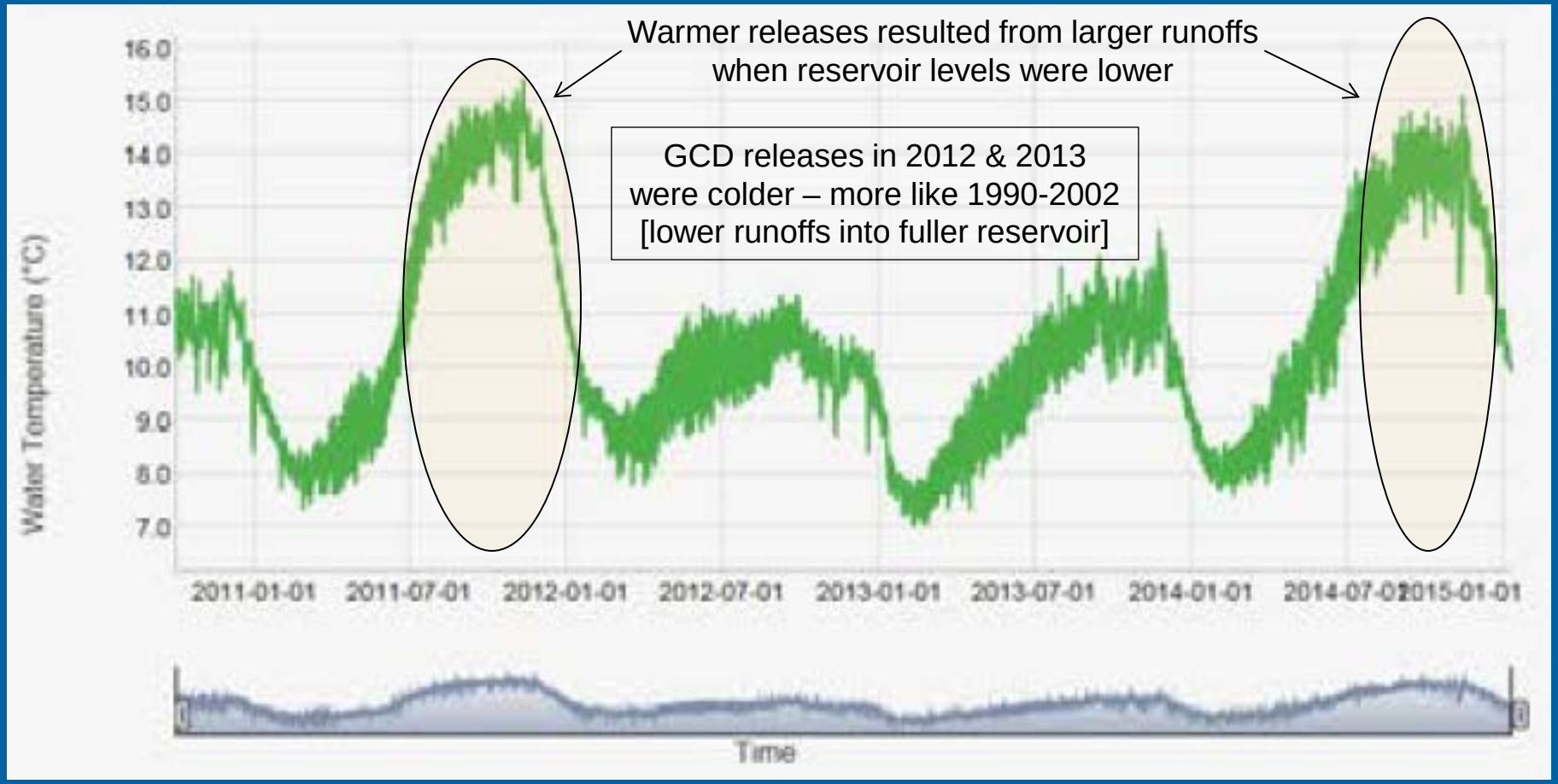
Dam releases had dissolved oxygen levels 5 – 6 mg/L in Fall 2014, but were as low as 3 – 4 mg/L in Fall 2005 (see:http://www.usbr.gov/uc/rm/amp/amwg/mtgs/06mar07/Attach_08.pdf)

(also during warmer releases shown above)

Note: June-timed emergency low-flow operations also occurred in 2005

Glen Canyon *Summer* Water Temperatures
WY 2011 through DEC 2014

[measured at Lees Ferry, AZ, station #09380000 accessed: http://www.gcmrc.gov/discharge_qw_sediment/station/GCDAMP/09380000]



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Water Temperatures were ***higher*** ↑ in summer 2005 (warmest)

When rainbow trout recruitment was Poor & abundance Falling

Median Summer and Fall Water Temperature @ LF

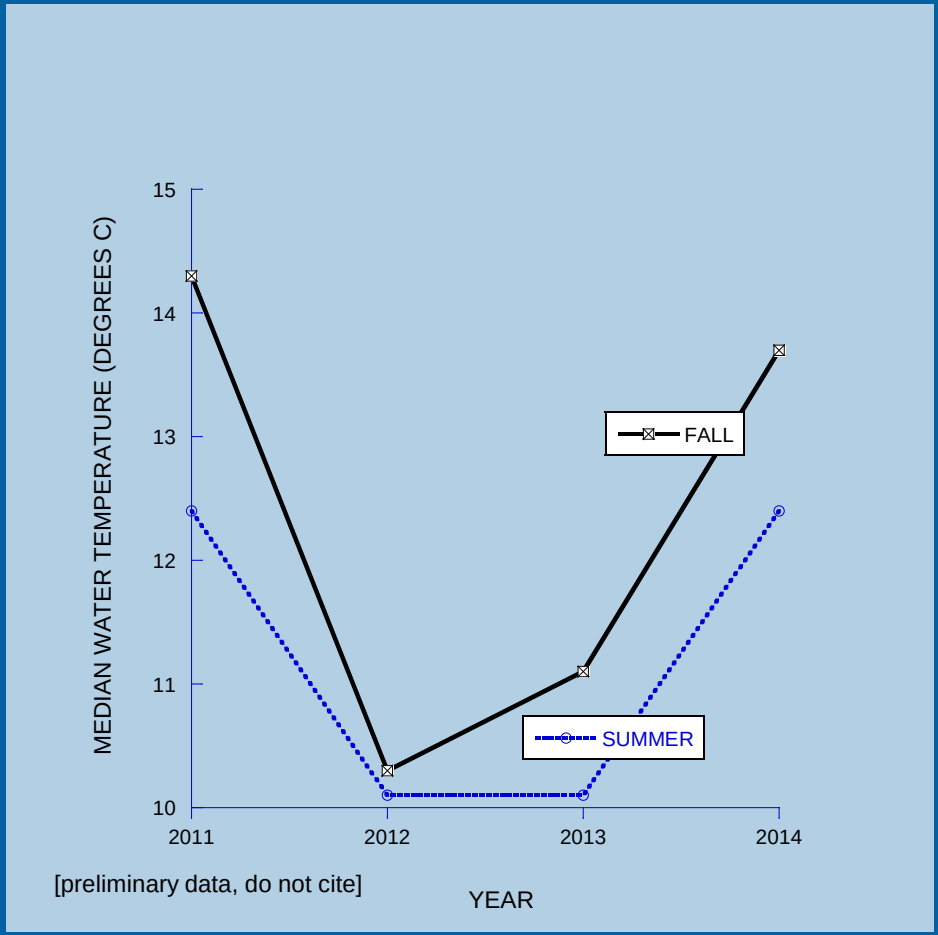
[measured at Lees Ferry, AZ, station #09380000 accessed: http://www.gcmrc.gov/discharge_qw_sediment/station/GCDAMP/09380000]

Median 2005 River Temperatures & DO

Fall = 15.2°C

Summer = 14.0°C

with Dissolved Oxygen in Fall dropping as low as 3 – 4 mg/L



TCD-like thermal regime treatment

Provided by

Annually Variable UCRB runoff

&

Lake Powell storage changes

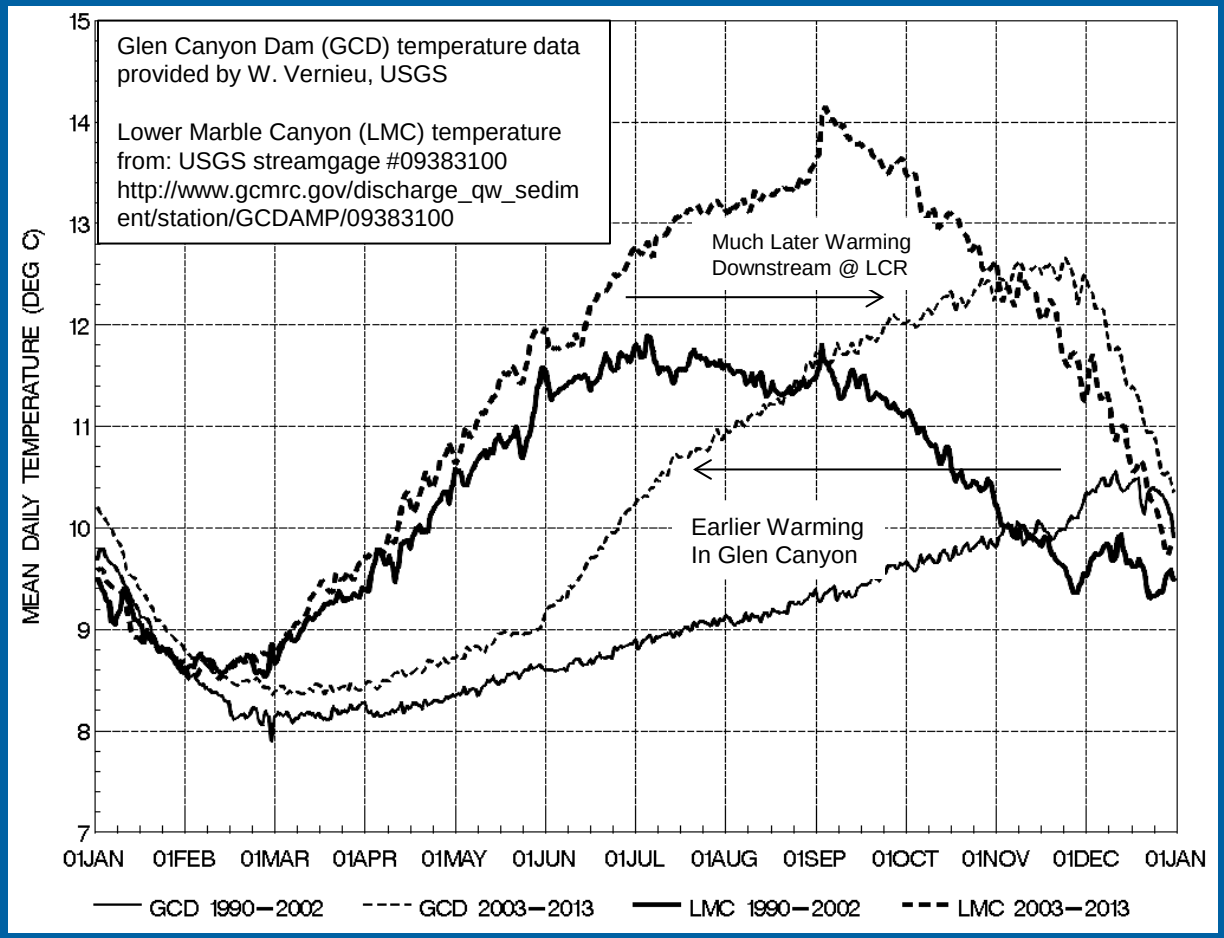
~1,200,000 RBT Recent RBT Decline **~200,000 RBT**

[Korman and Yard, written commun., USGS 2015, preliminary data, do not cite]

USGS Median temperatures drop after 2011, then increase through summer & fall 2014 – temperatures increase right when food is less available…

Two Eras of the River's Thermal Regime

[1990-2002 versus 2003-2013, preliminary data, do not cite]



Dam releases reach 1990-2002 annual Temp. maxima 5 mos. earlier

2003-13 peak Temps ~2.5°C ↑

Thermal discontinuity distance below the dam has shortened over the last decade ??

USGS

Downstream average water temperature near LCR has not only been warmer since 2003, but warmer later into fall/winter (2011 is example)

TRIBUTARY INFLUENCES

Glen Canyon Tributaries & Tailwater Trout Fishery

USGS

Tributary Processes Can Influence CRe Shorelines and Channel Bed Textures

Repeat downstream views from river left above Waterholes Canyon confluence

- Can sediment inputs of this magnitude influence condition factor of RBT?
- AUG 2013 floods input fine sediment & gravel to lower Glen Canyon and have been reworked by a range of normal dam operations and 2 HFEs
- Waterholes Canyon bisects *Natal Origins study reach I* where rainbow trout have been repeatedly sampled in Jan, Apr, Jul, Sep, Oct, & Dec since 2012
- Integrated mapping studies of bed texture change and spatial analysis of fish monitoring data & shoreline types will attempt to answer the above question

USGS

Tributary Processes Can Influence CRe Shorelines and Channel Bed Textures

New 2013 Gravel Inputs from Waterholes Canyon

- Late summer 2013 floods input an unknown volume of gravel into channel areas already known to support large numbers of trout redds upstream of 3-Mile Bar
- Mapping studies of bed texture and analysis of fish & foodbase monitoring data & shoreline types are occurring to better understand possible influences on trout

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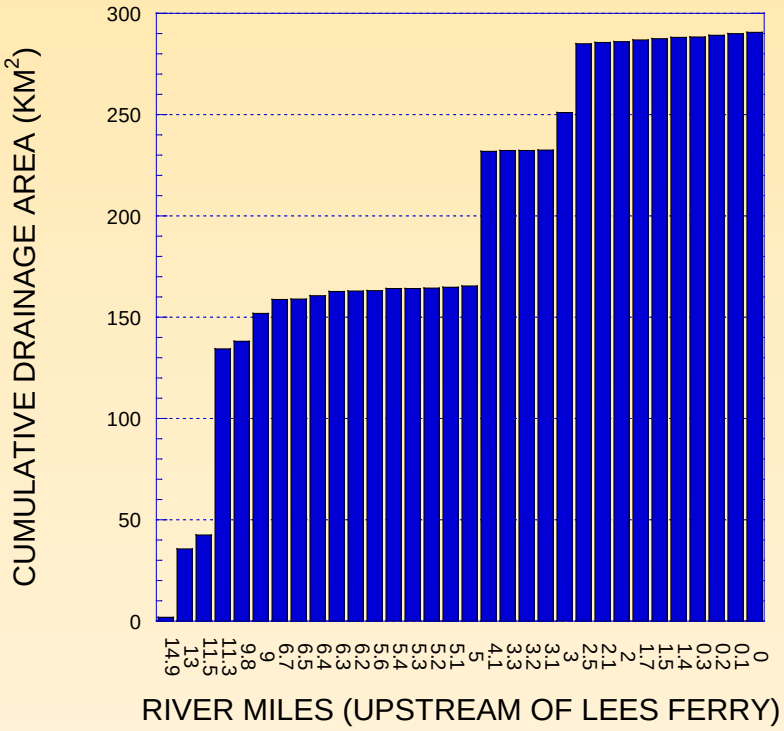
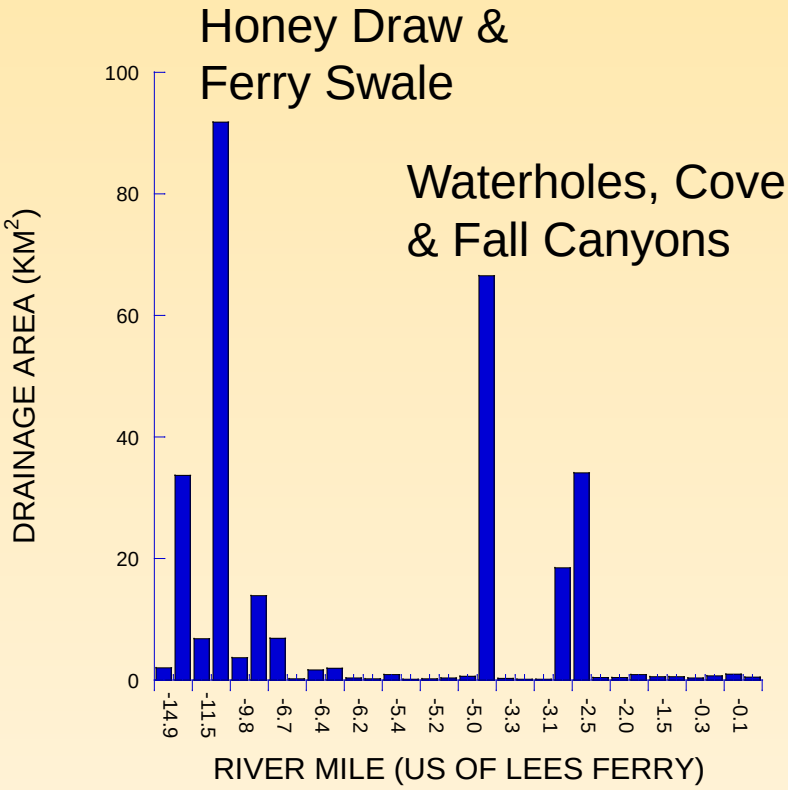
Cumulative Drainage Area between Glen Canyon Dam & Lees Ferry
[Total ~ 291 km^2, plus 31 km^2 of local shoreline area]

Contributing Drainage Area Increases Rapidly below GCD in the first 4 miles and then again between Waterholes and Fall Canyons





USGS

data from Webb et al. 2000
USGS WRIR 00-4055

Characteristics of Tributaries in Glen and Marble Canyons

- Drainage Area - Glen Canyon has about 1/10 area of ephemeral tributaries in Marble Canyon *(Not including Paria and Little Colorado Rivers)*

- Source Rocks - Glen Canyon tributaries drain softer Navajo SS, "mostly coarser sand" compared to Marble Canyon tributaries with harder rocks that contribute "less sand and more gravel/boulders"

- Glen Canyon – estimated total sediment input ~65,000 metric tons/yr. (Webb et al. 2000); sand inputs (but not gravel) are monitored in Waterholes

- Gravels - are coarse-grained inputs from the larger Marble Canyon tributaries altering channel depth and bed textures in CRe – *if yes, then so what?*

- Channel Depth (affects light penetration) & coarser bed-sediment tied to trout & benthic invertebrate production - Gravel inputs are not being measured, but repeat channel mapping likely to document changes.

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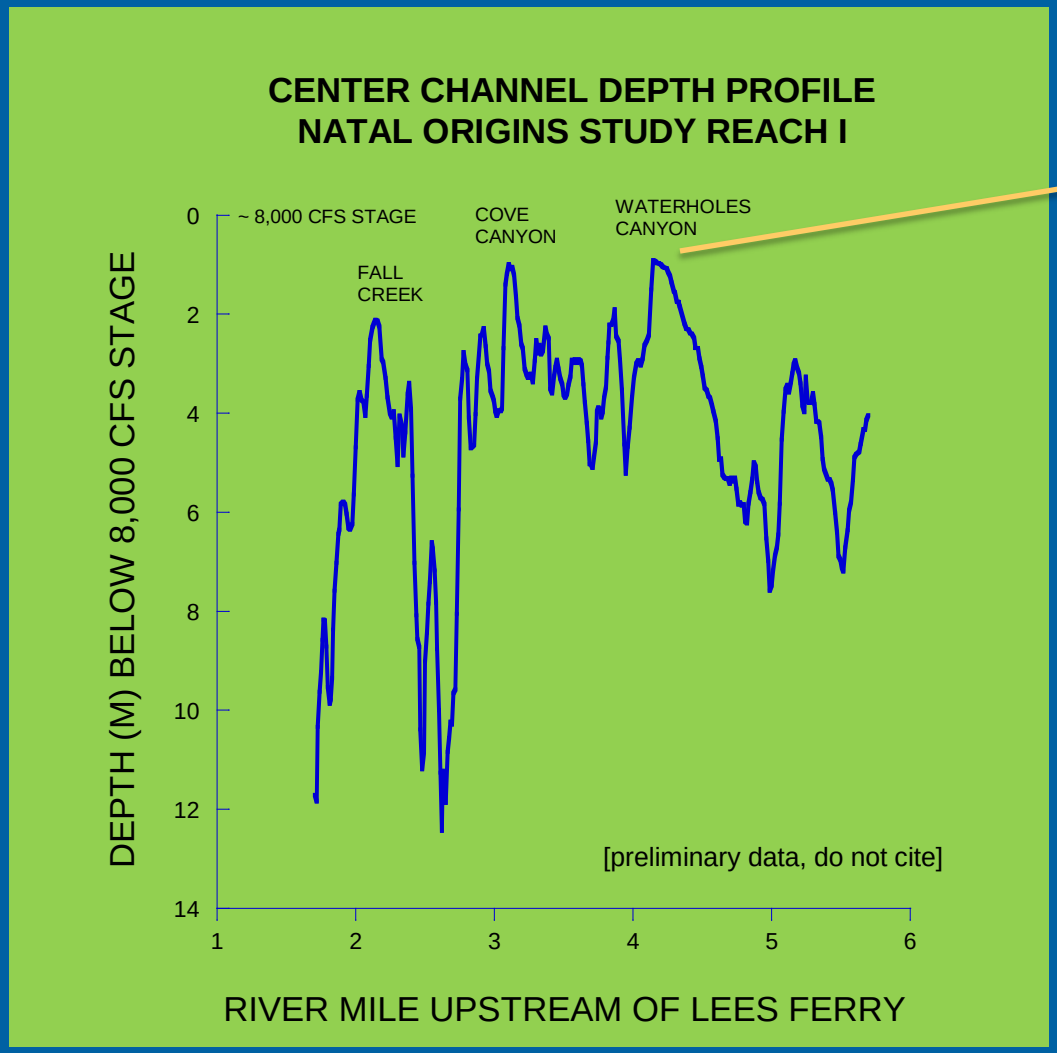
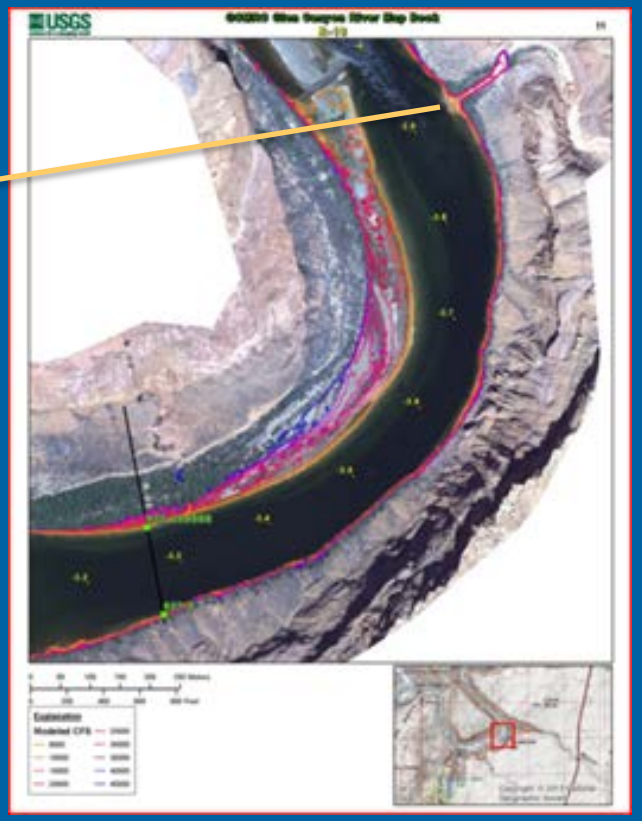
Localized Influence of Ephemeral Tributaries on Flow Depths

"Lower Glen Canyon"





How do tributary gravel inputs Influence *local channel depths* and *biological processes* over time under regulated flows?

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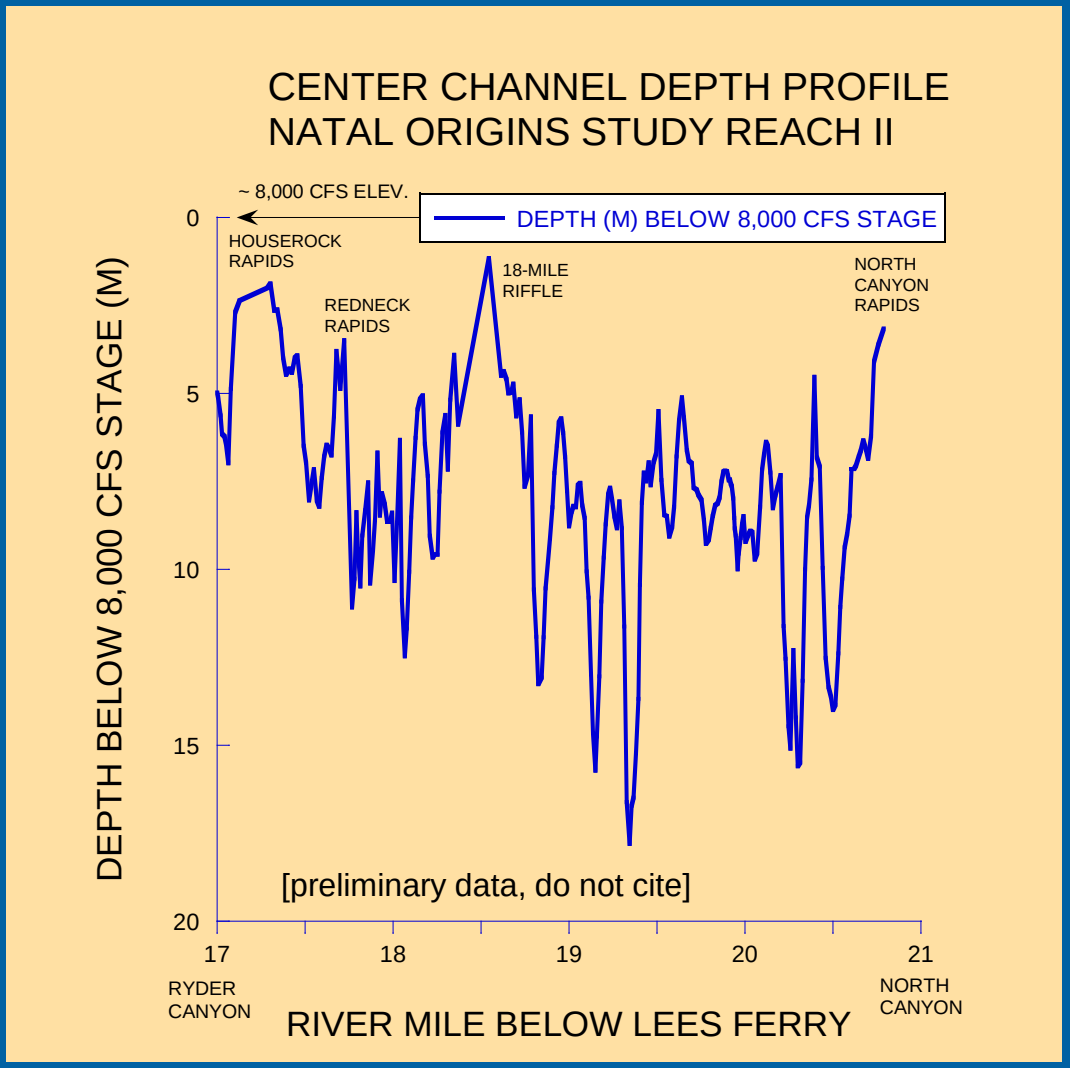
Evaluating Channel & "Hot Spots" (Food and Trout Condition Factor)

How about downstream in Marble Canyon?

Localized Influence of Ephemeral Tributaries on Flow Depths
"Upper Marble Canyon"



Rainbow trout condition varies by size classes within & between intensive NO fish sampling study reaches seasonally & across years of monitoring

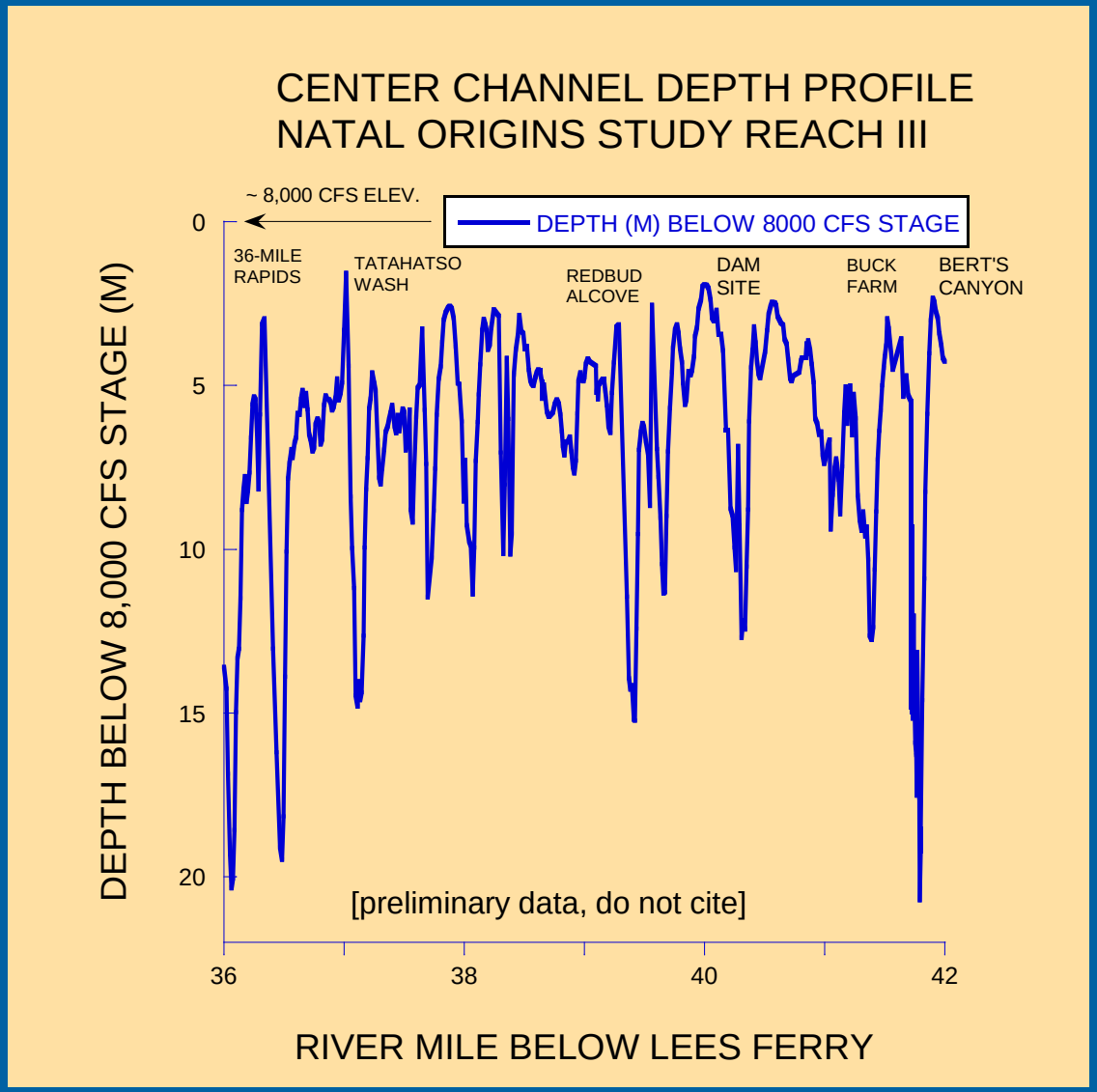
Question:

Are there spatial patterns relative to channel characteristics, such as (ave. depth, nearshore slope angle, bed texture & azimuth) & geomorphic framework controlled by ephemeral tributaries?

USGS

If "Hot Spots" (Food and Trout Condition Factor) exist, then are they Linked with tributaries and channel morphology & sensitive to flows?

NO Reach III – “Middle Marble Canyon”



Recent Sandbar Mapping suggests

Sand exported from below River mile 30 in 2011 was mainly scoured from deeper areas of the main channel and not from eddies

(recall Grams sandbar mapping talk on TUE)

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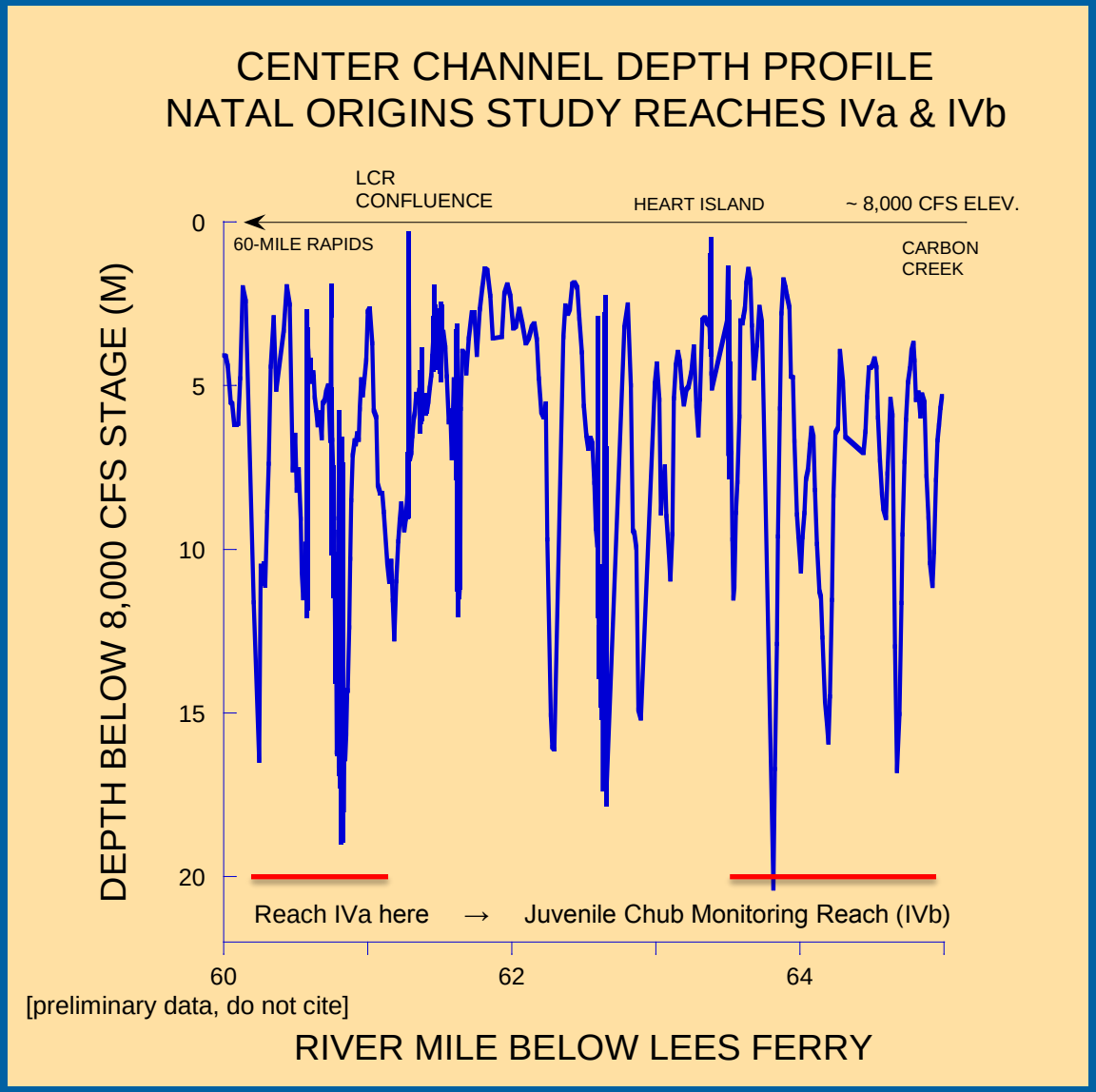
NO Reaches IVa & IVb – "Lower Marble & Eastern Grand Canyons"



Deeper Channel

"Plunge Pools below Rapids & Channel Constrictions"

most probable areas where recently identified trout production has occurred in Reaches III, IVa & IVb?

"redds" not generally observed in Marble Canyon ???

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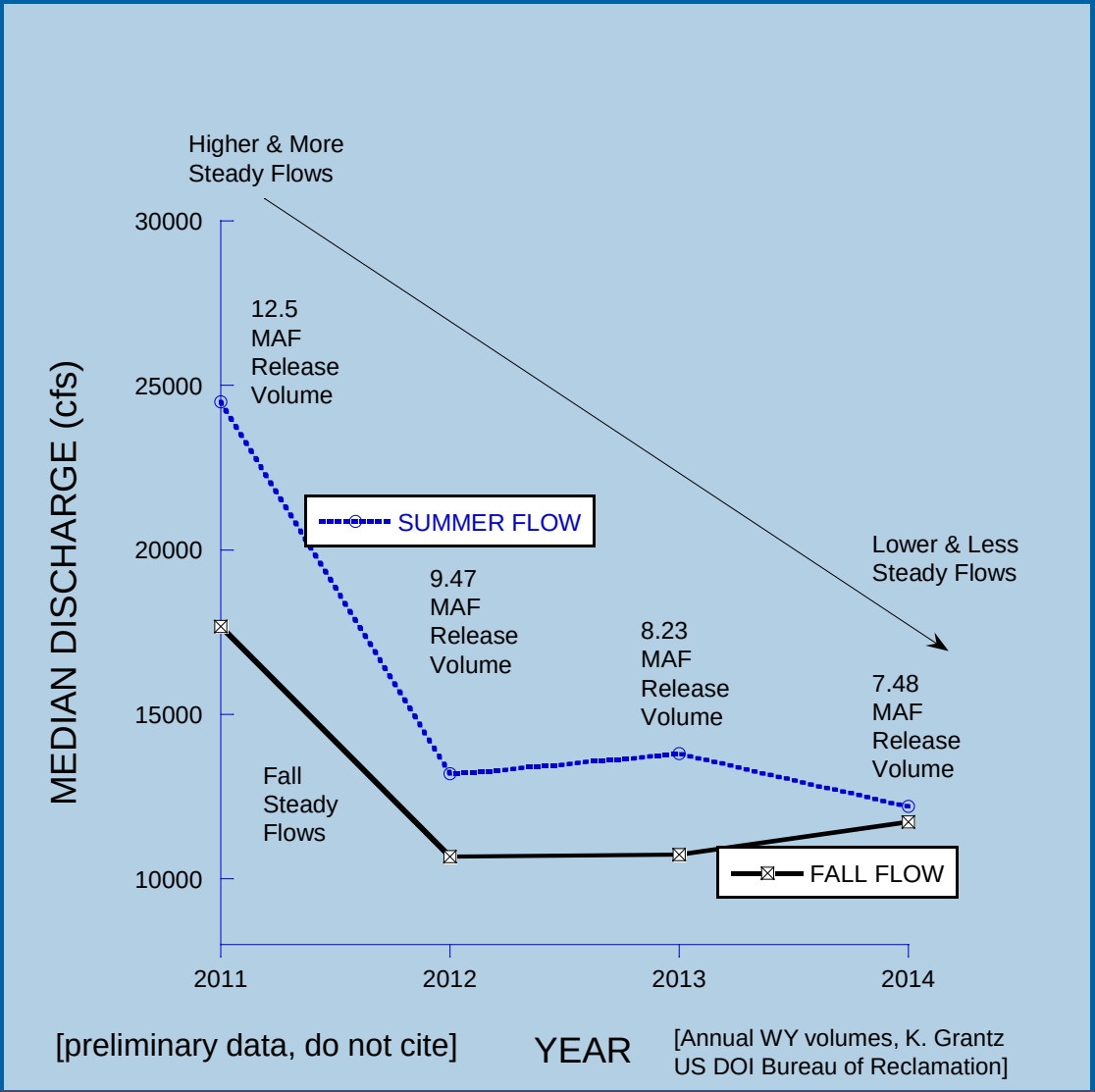
REVIEWING FLOWS

Dam Operations & Glen Canyon Rainbow Trout Fishery Responses

USGS

Median Summer and Fall Flow @ LF



Annual Release Volumes declined in each of the last 4 Years = lower flows

+

More frequent stable-flow periods in 2011-12 were followed by MLFF fluctuating-flow releases in 2013-14

Recall the warmer 2014 Temperatures

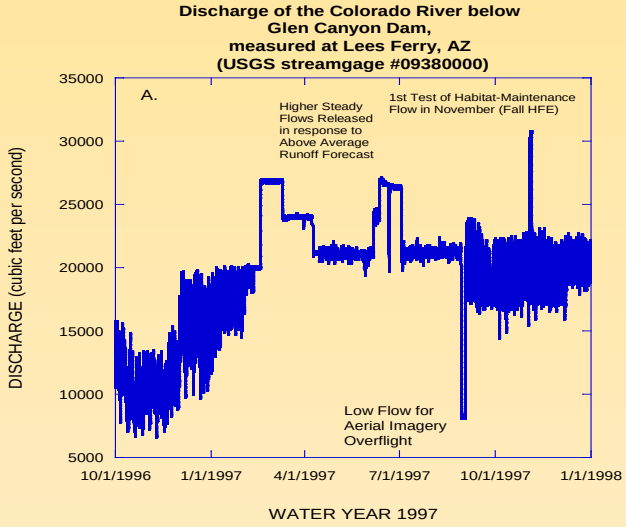
USGS

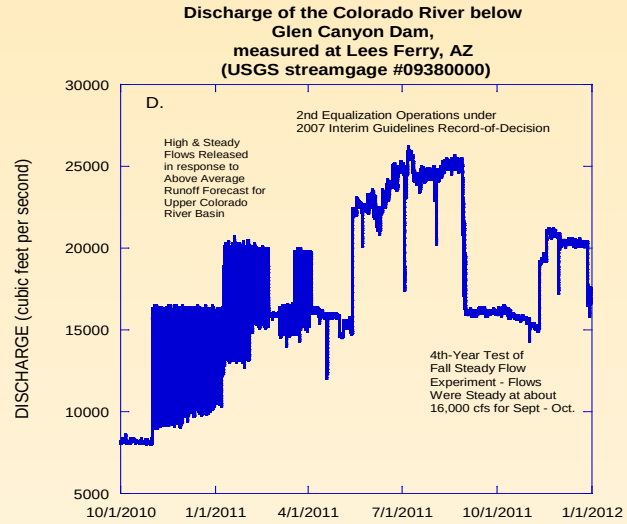
~1,200,000 RBT → **~200,000 RBT (see Yard and Korman talk to follow)**

RTELSS project reports elevated Redd Counts in 2013-14 following Fall HFEs (L. Avery, 2014 annual report, p. 60) , but limited trout recruitment reported (see Yard and Korman PPT)

Annual Dam Operations & Elevated Natural Trout Production in Glen Canyon

[1997, 2000, 2008 (Korman et al. 2012), 2009 (Melis et al. 2012) & 2011 (preliminary data, do not cite)]





HYDROGRAPH SUMMARY

4 out of 5 years included High Flow operations during *Spring*

All Years had Steadier flows in either Spring, Summer or Fall (some years in all 3 seasons)

4 out of 5 years had higher than minimum release volumes [ranging from ~9.0 to 12.5 MAF]

All 5 hydrographs had EXP flows of some type other than MLFF

2008 included 2 EXP flows (HFE & FSF), plus ***Equalization*** flows

Discharge data from: http://www.gcmrc.gov/discharge_qw_sediment/station/GCDAMP/09380000

Most Flow Treatments (* but not all) Seem to = ↑ ↑ ↑ RBT Responses

Summary History of MLFF, EXP Flows & Natural Rainbow Trout Production

Natural Glen Canyon Trout Production ↑ ↑ ↑ in 5 of 18 MLFF Water Years (28%) since GCD was re-operated and other flow EXPs began in WY 1997… Water Years since 2002

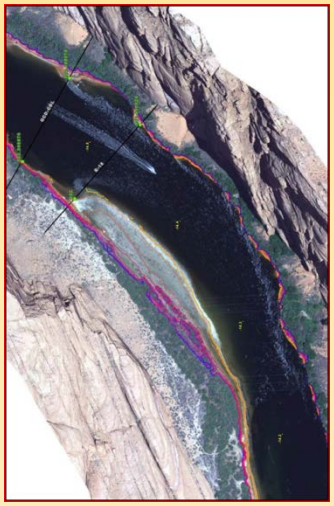
* When MLFF operations were **not** combined with ***other flow EXPs***, trout production apparently **not** elevated

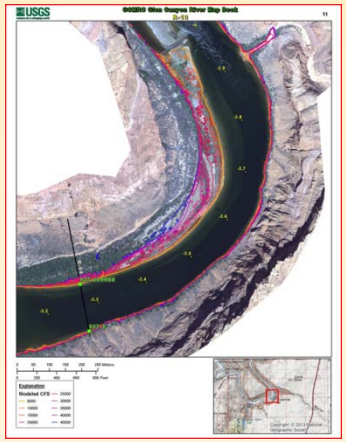
* Water Years when MLFF was combined with ***EXP winter season fluctuating flows*** were **not** associated with elevated Glen Canyon trout production

* Water Years in which MLFF was combined with ***Fall-timed HFEs***, were **not** associated with elevated trout production

* Several ***Greater-than-Minumum*** volume release years were **not** associated with elevated Glen Canyon trout production

Observations suggest that aquatic biology at least partly coupled to flow in GLCA





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See: Melis et al. 2012, Korman et al. 2012, Korman et al. 2011

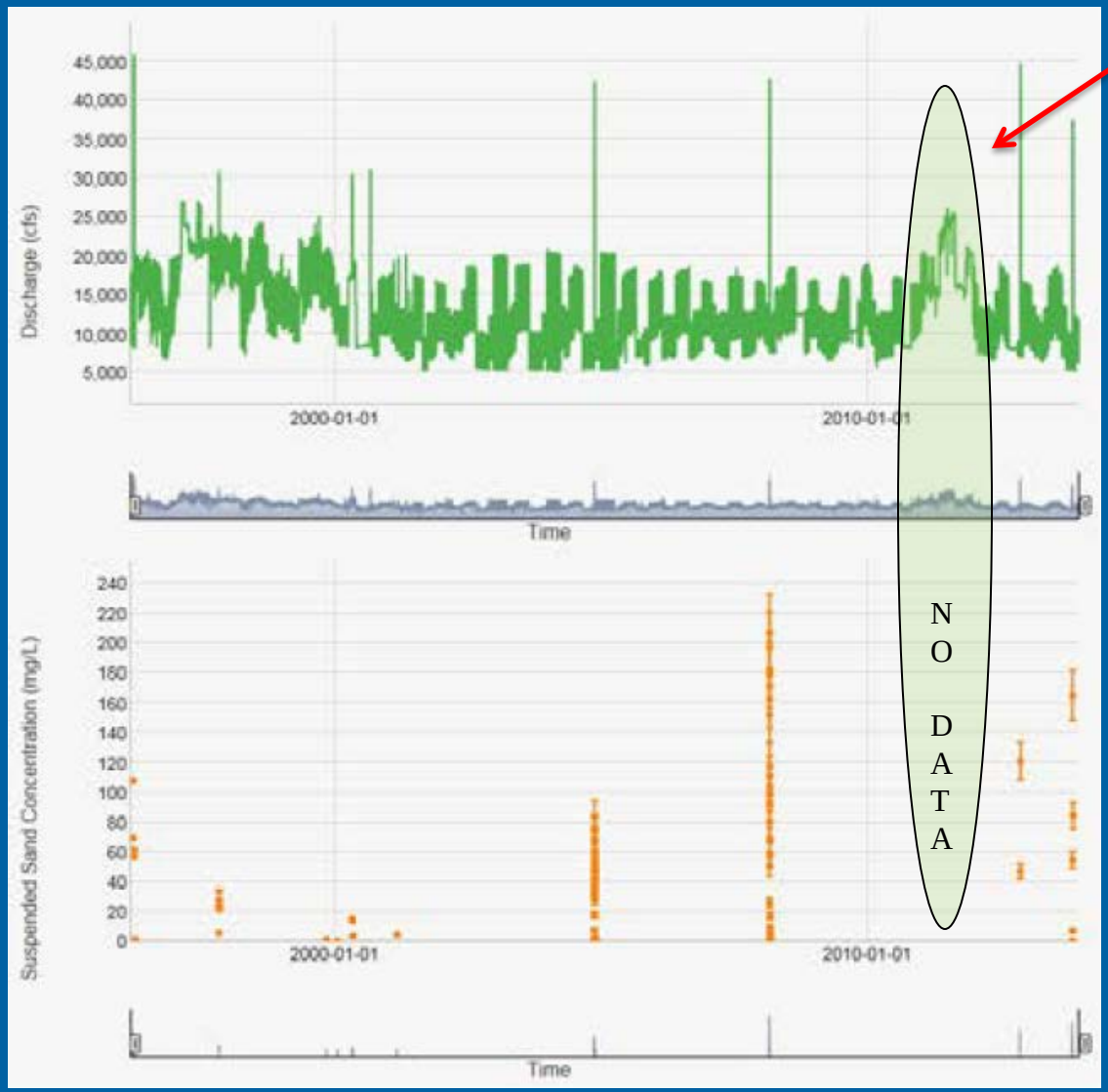
[preliminary , do not cite]

High-Flow Experiments & Export of Fine Sediment from Glen Canyon Tailwater Fishery

Review of Fine-Sediment Concentrations & Grain Sizes Exported as Suspended-Sediment Loads

USGS

Influence of HFEs on Fine Sediment in Glen Canyon?



Sand Export past Lees Ferry measured during all prior HFEs since 1996,

However, sand transport not sampled during other high-flow dam operations that may also influence channel-bed textures & *biological* processes relating to trout & foodbase responses

WY 2011 Operations tied to largest RBT cohort since 1990, but NO DATA…

Are more data needed to inform integrated studies during all spring high flows?

USGS

[measured at Lees Ferry, AZ, station #09380000

http://www.gcmrc.gov/discharge_qw_sediment/station/GCDAMP/09380000]

Some Take Aways

Glen Canyon Dam Tailwater Trout Fishery – perhaps better thought of as consisting of both Glen and Marble Canyons, perhaps 125 km or longer???

Geomorphic Framework – Glen and Marble Canyons are two different rivers influenced by operations of one dam, each has totally different sand and gravel budgets that are only partially known – inputs can alter geometry

Glen & Marble Canyon RBT Fishery – likely being influenced by sand & gravel inputs from tributaries and winnowing by dam operations through time

Physical/Biological Trout Responses & GCD – understanding requires fully integrated monitoring coupled to current ongoing QW & sediment work

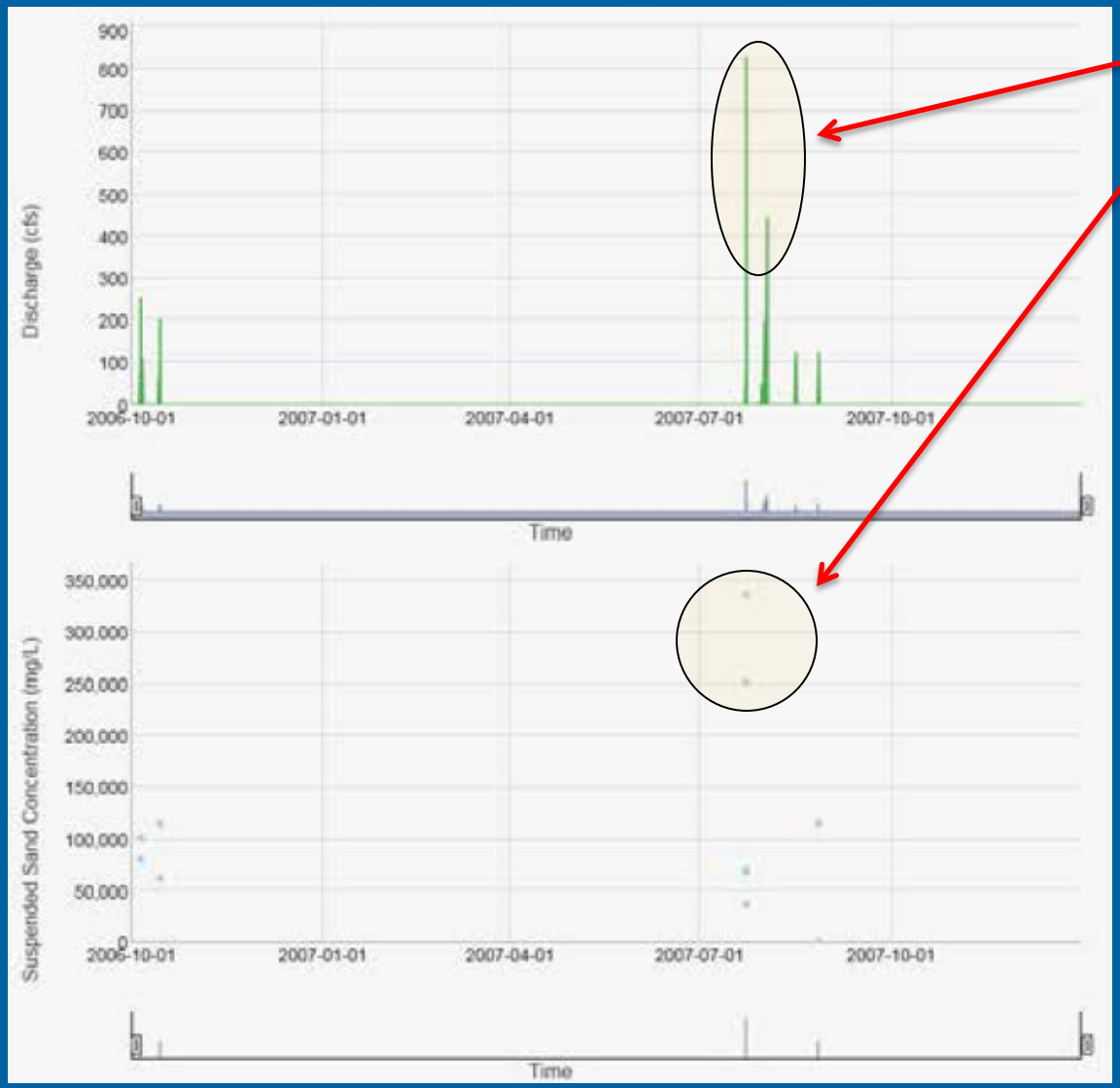
Thermal "Discontinuity Distance" - below dam has decreased under drier UCRB hydrology since 2002 – warmer water in Glen and Marble Canyons?

USGS

High-Flow Experiments & Export of Fine Sediment from Glen Canyon Tailwater Fishery

USGS

Waterholes Canyon Sand Inputs before Spring 2008 HFE



Summer 2007 floods in Waterholes Canyon had High sand concentrations

Sand loading from this and other tributaries may have set the stage for spring 2008 HFE influence on rainbow trout spawning and recruitment during the 2008-9 period

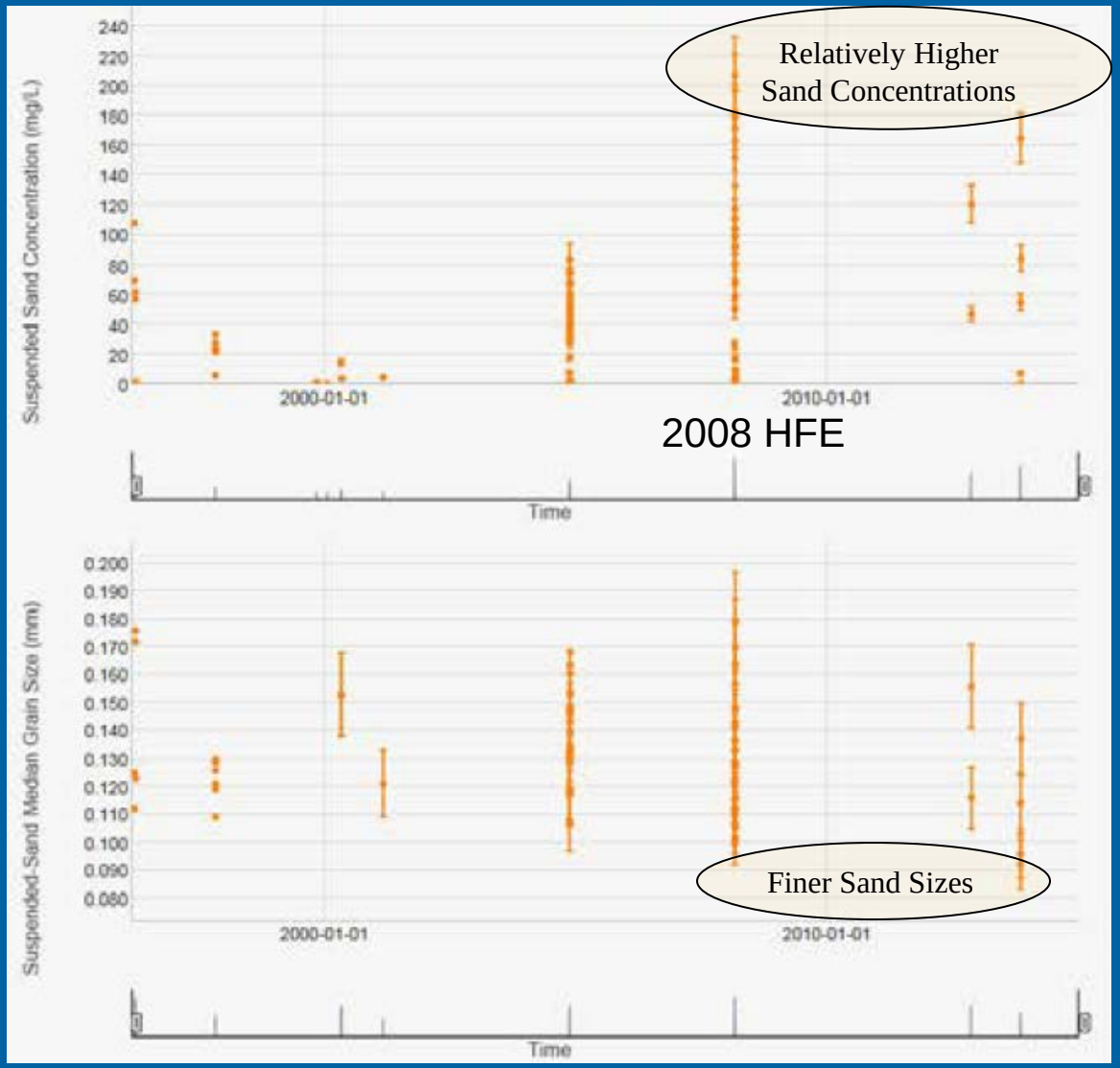
Recent fall-timed HFEs in 2012, 2013 and 2014 may be influencing trout spawning as *redd* counts in 2012-13 have been reported to be relatively higher, *but recruitment not increased*

[measured at Lees Ferry, AZ, station #09380000 http://www.gcmrc.gov/discharge_qw_sediment/station/GCDAMP/09380000]

USGS

Glen Canyon Tributary Sand Inputs of 2007 occurred about 6 mos. before the March 2008 HFE (channel cleaning → Bug ↑ & Trout ↑)

Sand Concentrations & Median Sand Grain Size for HFEs



Sand concentration highest during Spring 2008 HFE Even though 1996 peak was ~10% greater discharge

Finest sand grain sizes are Measured during 2008 & 2013 HFEs, suggests Influence of sand inputs to Glen Canyon in Falls of 2006-7 & summer 2013

Rapid sand concentration ↓ & grain size coarsening ↑ During HFEs suggests Efficient winnowing of channel bed & shorelines "*cleaning*"

[measured at Lees Ferry, AZ, station #09380000 http://www.gcmrc.gov/discharge_qw_sediment/station/GCDAMP/09380000]

USGS

Can repeat mapping of channel bed textures upstream discern Changes in fine sediments and gravel?

Compare High-Flow Data & Glen Canyon Sediment Export

Greatest "channel-cleaning" was accomplished in summer 1965, and allowed Glen Canyon Tailwater Rainbow Trout Fishery to be established (stocking)

Seasonal timing of floods (planned channel-cleaning flows associated with sediment predictions)	Total suspended-sediment load (million metric tons)	Peak flow (m^{-3} s) and duration (h)	High-flow release objective(s)
Spring (March through June) 1965	~5.0 (total sand, silt and clay) in sediment year 1965 (July 1, 1964 to June 30, 1965)* *	14 pulses ranging from ~500 to ~1600 m^{-3} s with varied durations (several hours to a ~week)	Engineering design and completion of hydropower plant
March 1996	0.06 ± 0.003 (sand) 0.01 ± 0.0002 (silt/clay)	~1270 m^{-3} s for 168 h	Sandbar research with multi-resource focus
November 2004	0.020 ± 0.001 (sand) 0.004 ± 0.0001 (silt/clay)	~1160 m^{-3} s for 60 h	Mainly sandbar research
March 2008	0.048 ± 0.002 (sand) 0.010 ± 0.0002 (silt/clay)	~1160 m^{-3} s for 60 h	Sandbar research with multi-resource focus

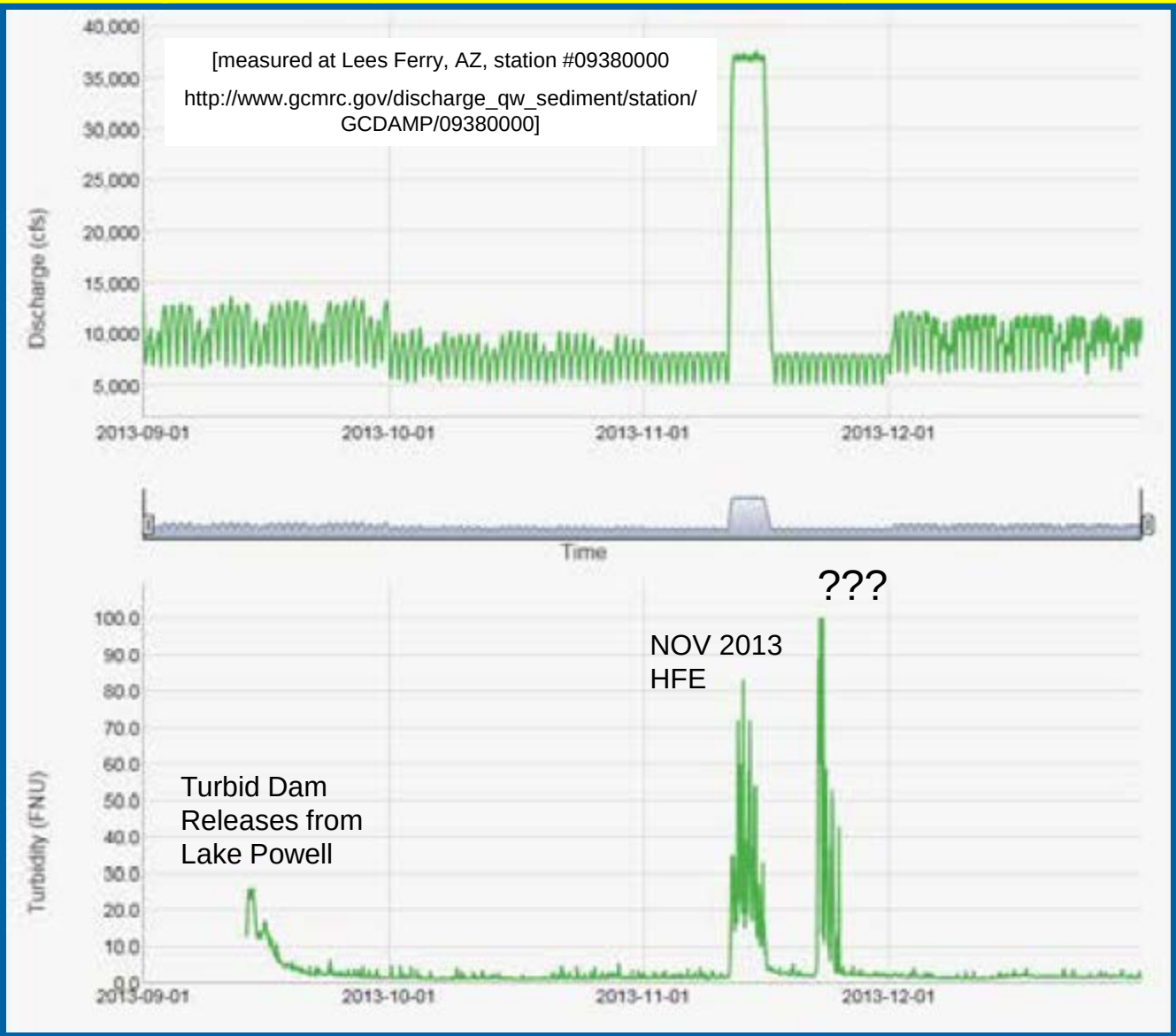
[from Melis et al. 2012]

WY 2011 - Suspended-sediment loads were measured and budgets were reported for all river segments below Glen Canyon, but the influence of high-flow operations that spring/summer on fine sediment in Lees Ferry segment (associated with large RBT response) is unknown?

USGS

*, For comparison, the average annual fine-sediment load measured at Lees Ferry during sediment years 1966–1970 was 240,000 (+/-10 000) metric tons

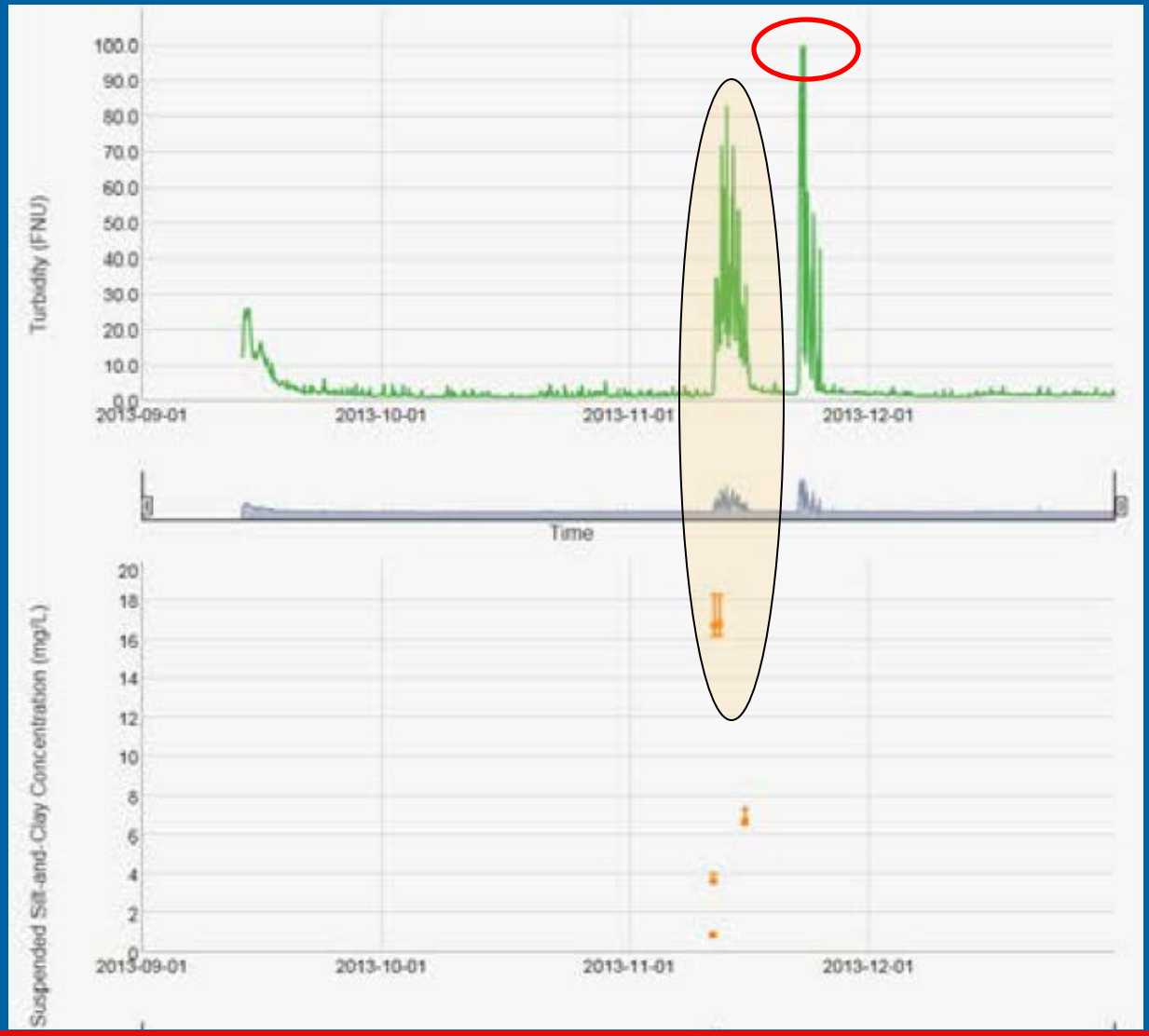
Monitoring Turbidity Events in Glen Canyon @ Lees Ferry



USGS Maintaining continuous turbidity data at Lees Ferry is challenging, but probe captured late November event from an unknown Upstream source

Turbidity & Silt/Clay Concentrations during Fall 2013 HFE

[measured at Lees Ferry, AZ, station #09380000 http://www.gcmrc.gov/discharge_qw_sediment/station/GCDAMP/09380000]



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Turbidity Spike of late NOV 2013 caused by relatively low Silt/Clay concentrations – unknown source(s) in Glen Canyon????

13th Biennial Conference of Science & Management on the Colorado Plateau & Southwest Region October 5-8, 2015 - High Country Conference Center - Flagstaff, AZ

Theme: **Multi-disciplinary Approaches to Assess and Respond to Climatic, Social, and Technological Changes**

Invited SPECIAL SESSION

Revisiting Science and Adaptive Management in the Federal Colorado River Programs

To submit a proposal or abstract, please visit http://nau.edu/Merriam-Powell/Biennial-Conference/.

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