Sediment and Temperature Modeling Update

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Annual Reporting Meeting
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Phoenix AZ

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

Project history and objectives

Project began in FY09 and is slated to end this year (though modeling has a long history in the program)

Objective statement (from the proposal): Development and application of numerical models of sand transport, sandbar evolution, and water temperature dynamics, leading to improved predictive capability of physical system attributes in response to changes in driving variables

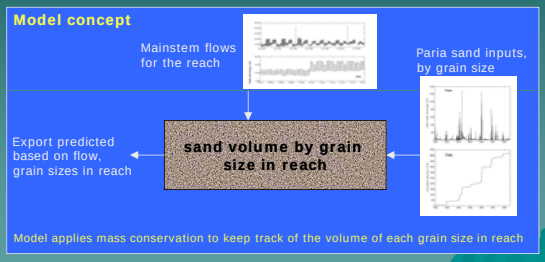
Proposal contains 5 science/management questions that the project is attempting to address

Progress update illustrated by 4 applications

- **Sand budgets: evaluate dam operations, flood trigger frequency**
- Temperature hindcasting: ecosystem modeling support
- Flood hydrographs: evaluate peak, duration, rise/fall rates
- "Habitat" modeling: nearshore ecology support

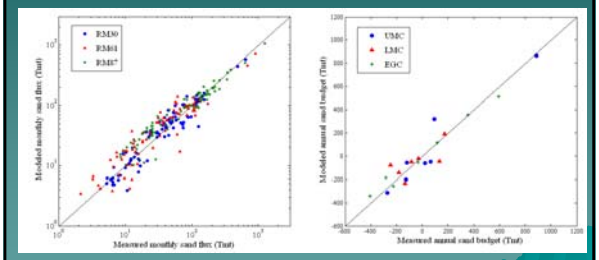
Sand budget modeling

We've developed a relatively simple "sand routing model" that can be used to forecast sand budgets in the 3 monitoring reaches, based on dam releases and tributary in puts



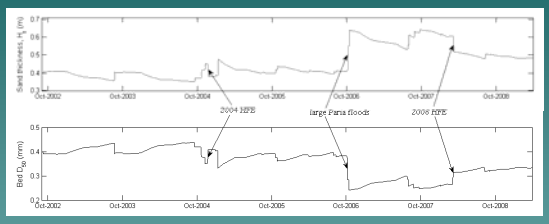
Model calibration and testing

The model has been calibrated using the sand flux monitoring data from Sep-2002 through Mar-2009 (Topping, next talk)



Model calibration and testing

The model is an advance over "stable" rating curves because the calculations are done by grain size, allowing the bed to fine and coarsen in response to tributary inputs and mainstem flows



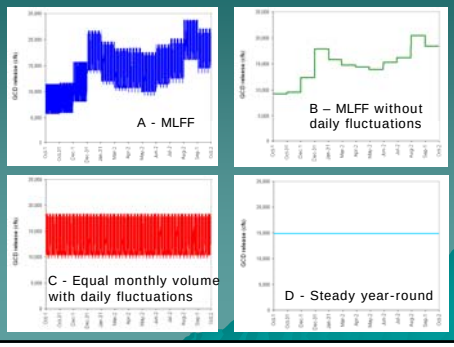
Wright, S.A., Topping, D.J., Rubin, D.R., and Melis, T.S., "A modeling approach for long-term sediment budgets in supply-limited rivers", USGS review completed, submitted to *Water Resources Research*, currently revising in response to reviews

Example – Evaluation of dam operations

The model can be used to compare various dam operations with respect to sand transport and budgets

4 example operations

10.8 MAF/yr (~average)



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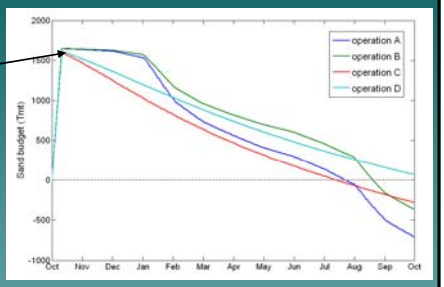
Example – Evaluation of dam operations

average Paria input at beginning of simulation (~1.5 million metric tons)



This is just one example, a more rigorous analysis that includes variability in tributary inputs and hydrology, and other operations, is possible

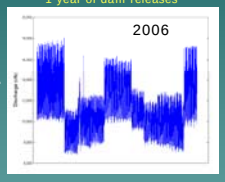
Example – Flood trigger frequency

The model can also be used to evaluate the frequency for which a given sediment trigger would me met, on average, based on historical data

21 years of tributary inputs

\+

1 year of dam releases



= 21 one-year scenarios for sand retention*

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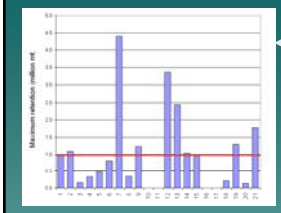
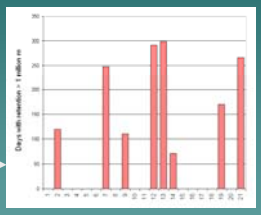
*Assumes tributary inputs and dam releases are uncorrelated

Example – Flood trigger frequency



Model predicts 10 out of 21 years with max retention of ~1 million mt or greater

Of these 10 years, 8 had retention >1 mmt for a significant period of time



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This approach could incorporate a range of hydrologic and operations scenarios, and evaluate various triggering criteria

Progress update illustrated by 4 applications

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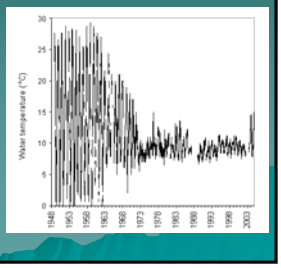
Temperature hindcasting: ecosystem modeling

Walters et al. are applying Ecopath/Ecosim to improve understanding of the controls on historical trends in native fish abundance

This requires basic information on historical trends in water temperature (e.g. on a monthly average basis)

To support this effort, we've applied our simplified water temperature model to hindcast historical conditions in various reaches



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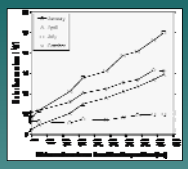
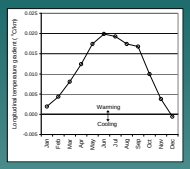
Monthly average temperature model

Temperatures typically warm downstream at ~constant rate





$$T = T_o + \frac{3.24\times10^{-5}\,X}{Q^{0.63}}\left(T_{air} + 7.44 - T_o\right)$$

distance d/s from GCD

temp at site

release temp

flow volume

air temp

release temp

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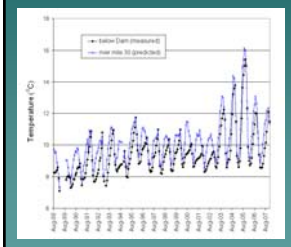
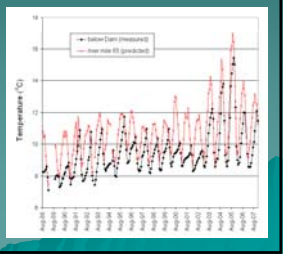
Wright, S.A., Anderson, C.R., and Voichick, N., 2009. "A simplified water temperature model for the Colorado River below Glen Canyon Dam", *River Res. Applic.* 25, 675–686

Example – Temperature hindcasting

Model was used to hindcast temperatures back to 1988 (when measurements began at GCD), for mid-Marble Canyon and below the LCR





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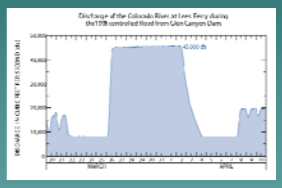
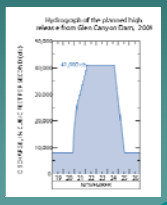
Flood hydrographs

What hydrograph shape (e.g. peak, duration) is most effective at building sandbars, for a given antecedent condition?





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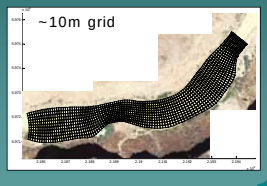
Sandbar morphology modeling

This requires fine scale models for simulating the detailed evolution of individual sandbars (or short reaches) over the flood hydrograph

Solve 3D mass and momentum conservation equations, for water and sediment, in a ~ meter scale grid

$$\frac{\partial u_i}{\partial x_i} = 0$$

$$\frac{\partial u_i}{\partial t} + u_j\frac{\partial u_i}{\partial x_j} = -\frac{1}{\rho}\frac{\partial p}{\partial x_i} + \nu\frac{\partial^2 u_i}{\partial x_j \partial x_j} + g_i$$



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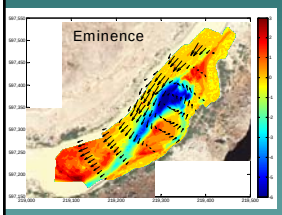
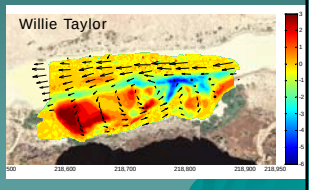
Sandbar morphology modeling

These models include a lot of physics, but some simplifications and assumptions are still required and therefore field-based calibration is necessary

HFE Project 1B (discussed in detail this afternoon) – Measurements of flow and bar morphology at two sites to support model calibration





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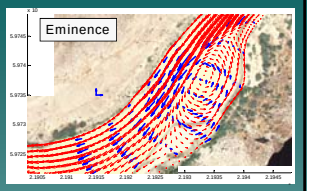
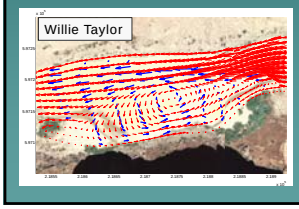
Sandbar modeling – calibration

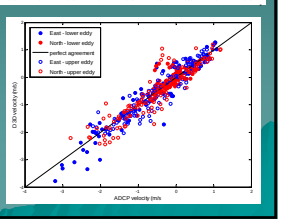
Using "Delft3D", a commercial, general-use, simulation package

Hydraulic calibrations (i.e. depth, velocity) were straightforward and are completed

Sand transport/morphology calibrations are more difficult and are still ongoing





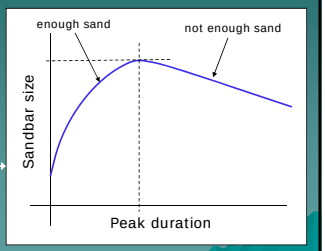


Example (future) application – flood peak duration

Once we are satisfied with the model calibration, a set of "quantification sites" will be used to evaluate various flood hydrograph shapes

For example, a range of peak durations could be evaluated with respect to the degree of sandbar-building achieved

It won't be this simple, but this is the idea



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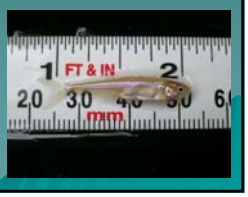
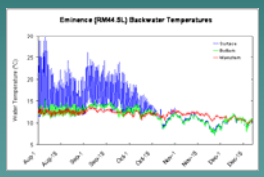
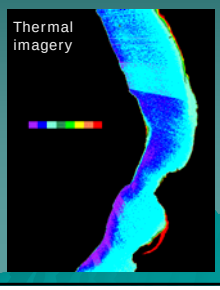


Habitat modeling – Nearshore ecology

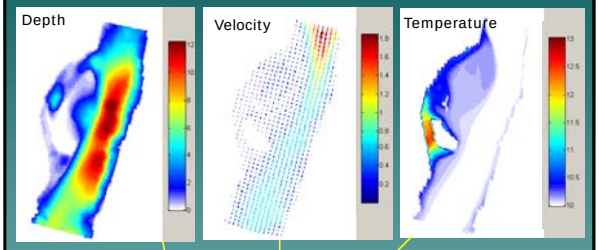
One of the goals of the nearshore ecology research project is to establish links between native fish presence and habitat conditions along the shorelines. But it's not possible to measure everything throughout the electrofishing reaches; modeling can be used to "fill in gaps"





Habitat modeling – Nearshore ecology

Preliminary model testing at Carbon (RM65)



Habitat suitability indices? Linked with fish data → Evaluate flow regimes

Summary

- The range of questions being asked by the program requires a range of modeling approaches. Input from resource managers is necessary regarding desired simulations (e.g. specifying dam operations to be compared)
- Progress has been made on several fronts over the past 1.5 years, but there will still be plenty to do when the project ends. Modeling is a component of data analysis and interpretation, so as long as research, monitoring, and adaptive management are continuing there will likely be a need for models
- Modeling tends to be most effective when it is directly integrated with other research and monitoring projects. Thus, projects that can benefit from modeling (e.g. sand mass balance, sandbar monitoring, nearshore ecology) should directly incorporate a modeling component, as opposed to having a stand-alone "modeling" project

Questions?

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