High-Resolution Monitoring of Suspended-Sediment Concentration and Grain Size in the Colorado River in Grand Canyon using a Laser-Acoustic System

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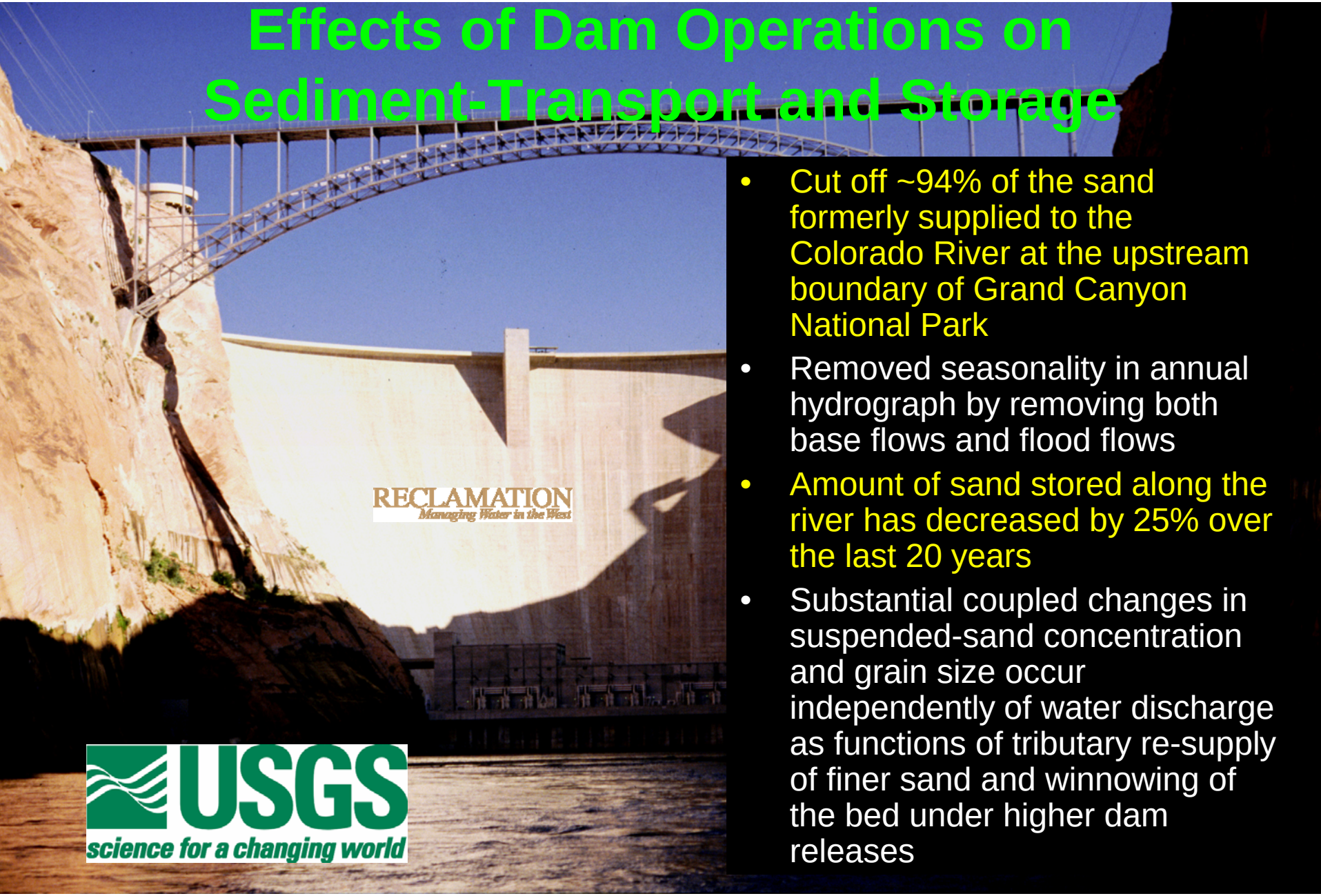
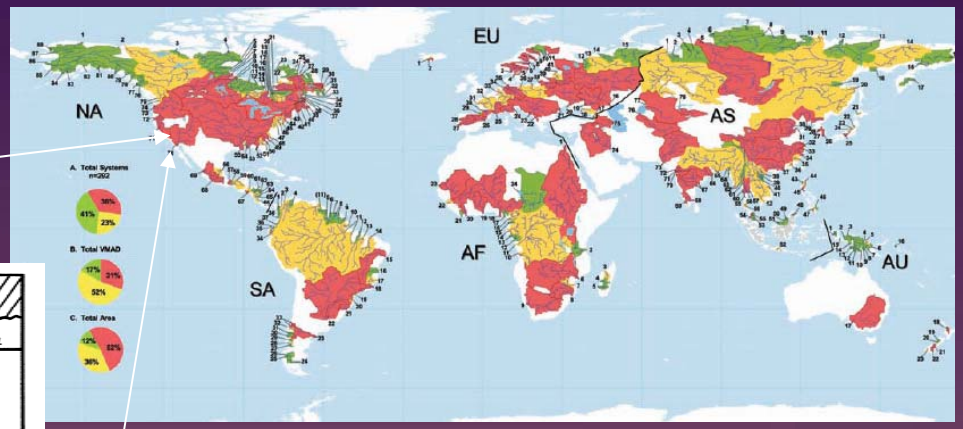
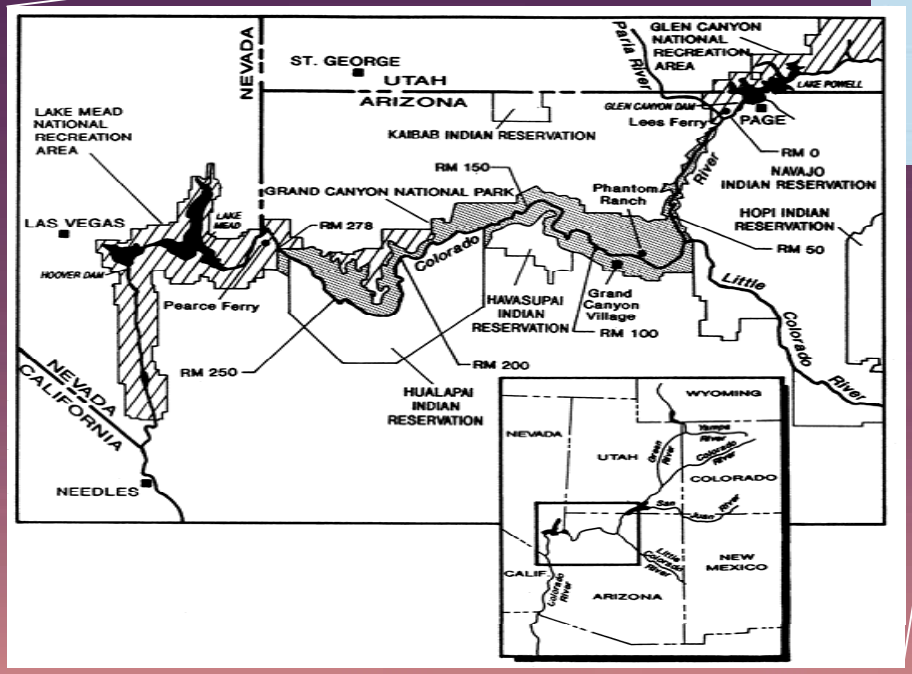
Effects of Dam Operations on Sediment-Transport and Storage



- Cut off ~94% of the sand formerly supplied to the Colorado River at the upstream boundary of Grand Canyon National Park
- Removed seasonality in annual hydrograph by removing both base flows and flood flows
- Amount of sand stored along the river has decreased by 25% over the last 20 years
- Substantial coupled changes in suspended-sand concentration and grain size occur independently of water discharge as functions of tributary re-supply of finer sand and winnowing of the bed under higher dam releases

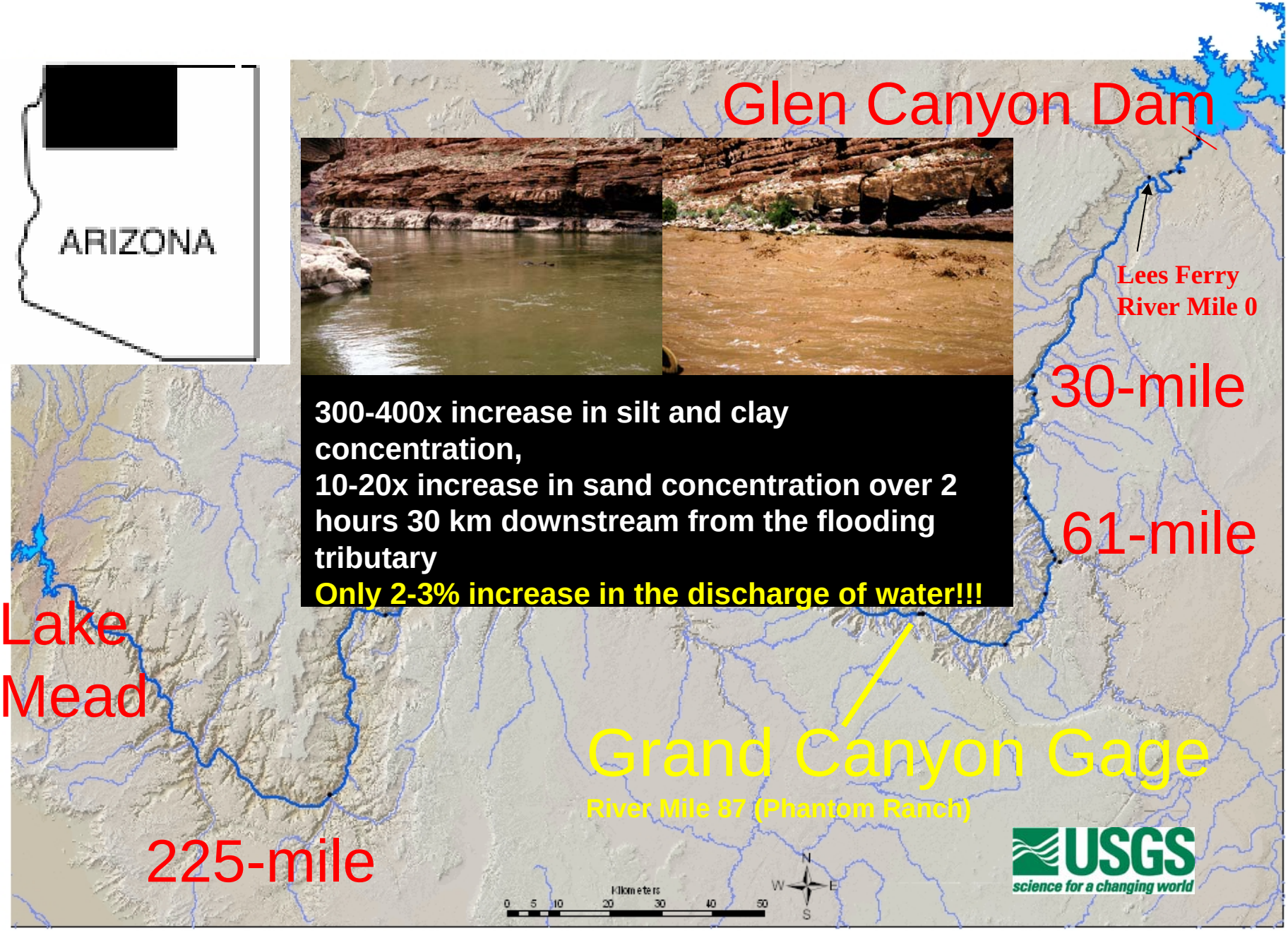
The Colorado River Ecosystem





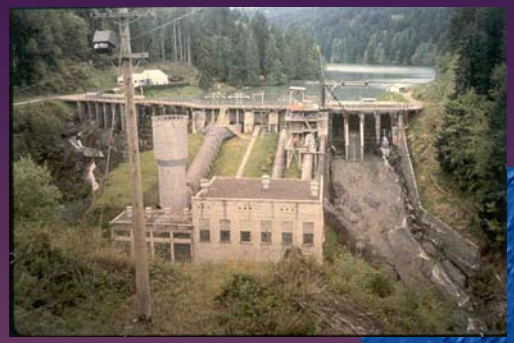
One of the Most Impacted Large River Systems of the World (from Nilsson et al. 2005)

Example of an "Exhausted River" similar to condition of Yellow River

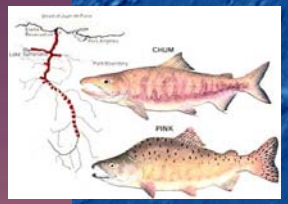


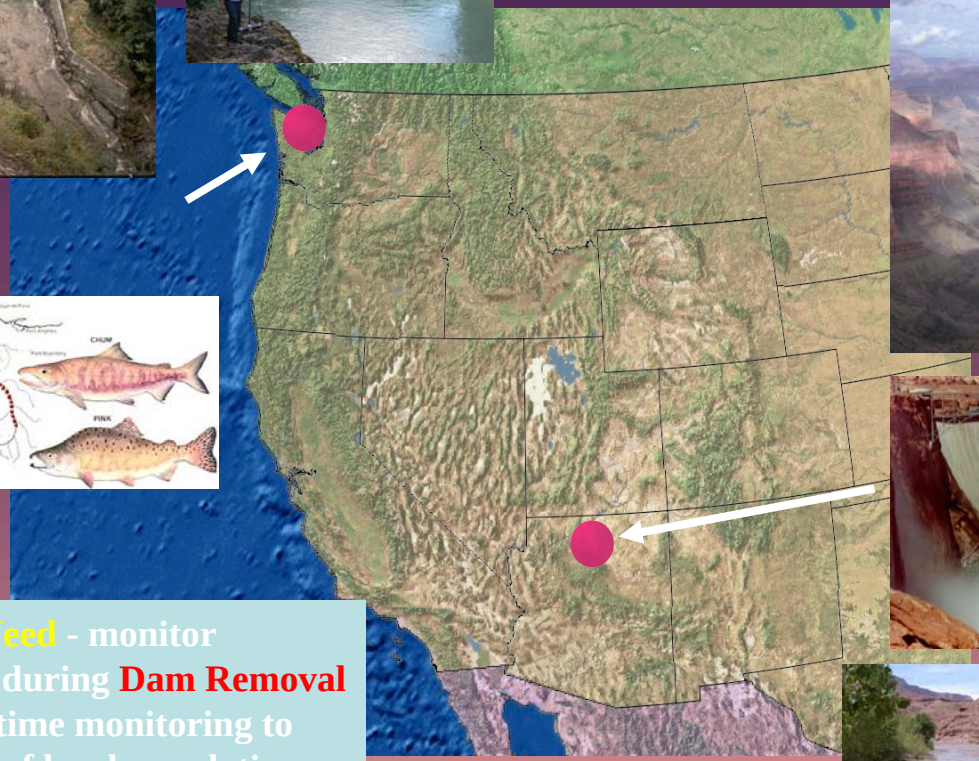
300-400x increase in silt and clay concentration,
10-20x increase in sand concentration over 2 hours 30 km downstream from the flooding tributary
Only 2-3% increase in the discharge of water!!!

Suspended-Sediment Monitoring in River Ecosystems of the Western U.S.



In **Grand Canyon (SW)** – **Need** - to support high-resolution **Sand Mass-Flux** for habitat restoration, **Challenge** - Mostly Logistics!



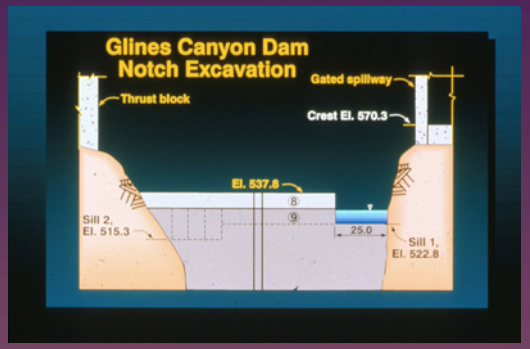


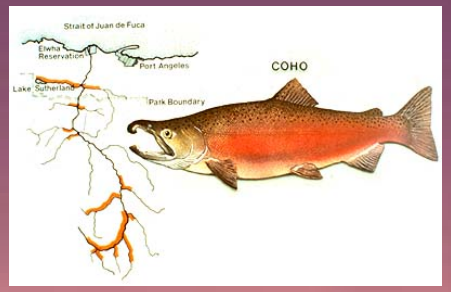
At **Elwha River (NW)** - **Need** - monitor concentration thresholds during **Dam Removal Project**, **Challenge** - real time monitoring to safeguard water supplies of local populations

Elwha River – Restoration of Fishery Stocks Proposed Through Removal of Two Large Dams

Removal of Glines and Elwha Dams is Intended to Restore Spawning Habitat For Native Fishes, but Must Be Done in a Manner that Protects Water Quality

Elwha River – Release of Reservoir Sediment Needs to Be Monitored During De-Construction





The Project Design Requires Systematic Removal of Concrete with “Natural” Evacuation of Sediment

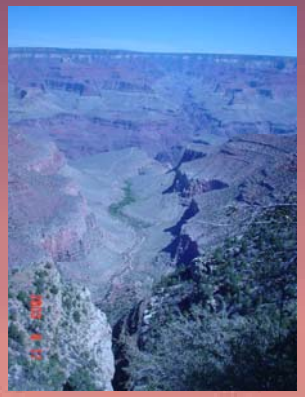
Paria River Provides Key Sand Inputs

- Inputs contain about 50% sand and 50% fines
- Concentrations as high as 1,000,000 mg/l
- Average Annual Sand Input ~1.4 million metric tons
- Median Sand Grain Size ~ 115 μm (fine)
- Located 15 Miles Below Glen Canyon Dam

Conventional Point & Isokinetic Sediment Samplers Have Been Used Historically to Monitor a Wide Range of Suspended-Sediment Concentrations in Rivers

However, Sample Resolution or Frequency is Limited by Access, Logistics, Cost & Time Needed for Laboratory Methods

As recently as 1998, only a few samples a year were collected at mainstem monitoring sites below Glen Canyon Dam

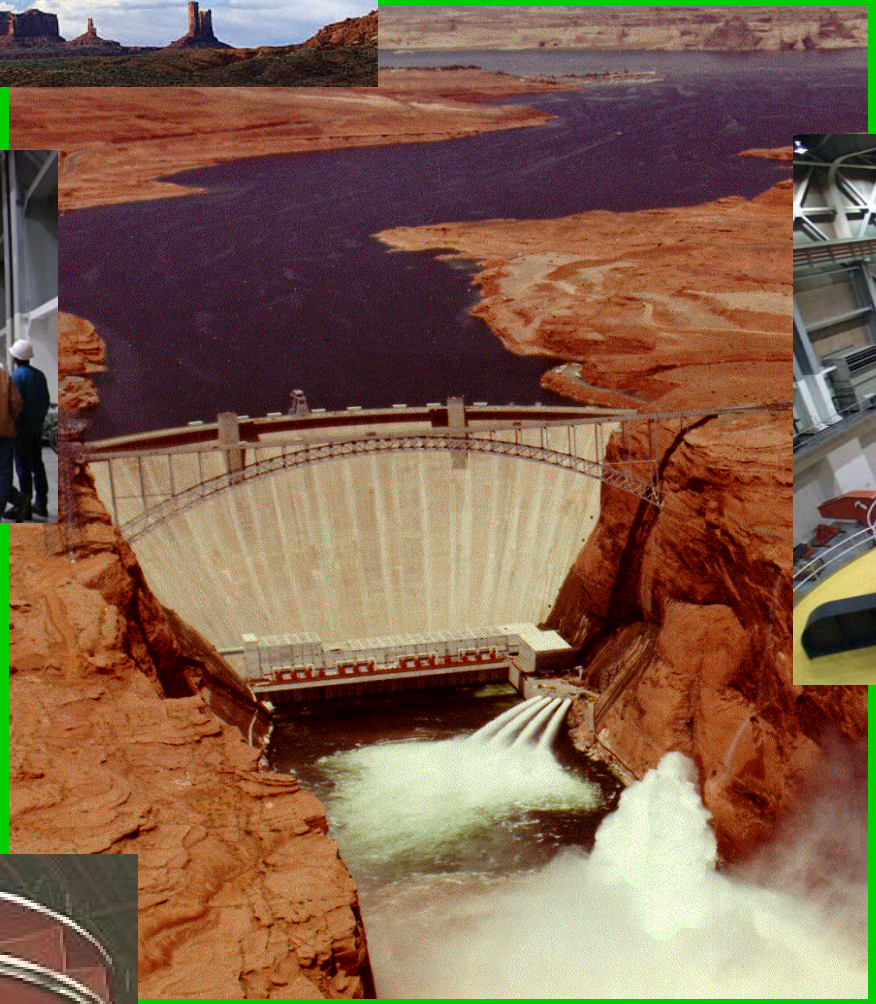


Acoustic & Laser Instruments May Provide Surrogate Data for SS Samples, But have a Limited Range for Monitoring Suspended-Sediment Concentrations in Rivers

These Limitations Mean That Vital Data on Sediment Transport During High-Transport "Events" Must Still Be Collected Using Conventional Methods – Adding Cost and Sample-Processing Delays

Assessing Glen Canyon Dam Operations

RECLAMATION
Managing Water in the West



Very little daily Suspended-Sediment transport data 1972-1999!

Studies on Downstream Impacts to River Since Early 70's

"When will you guys start answering our questions related to hourly to daily operations"

Grand Canyon gage
River Mile 87

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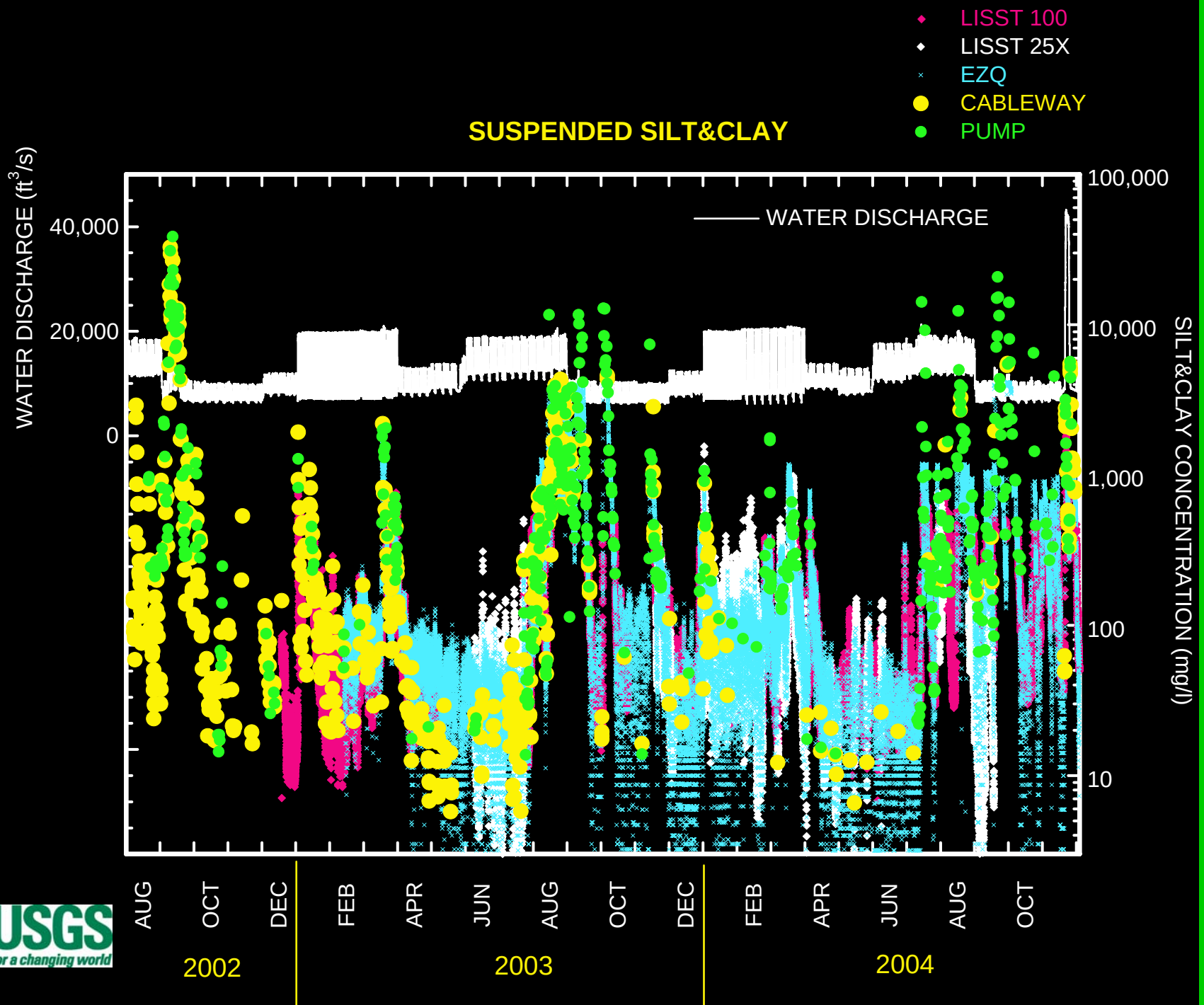
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WATER DISCHARGE (ft3/s)
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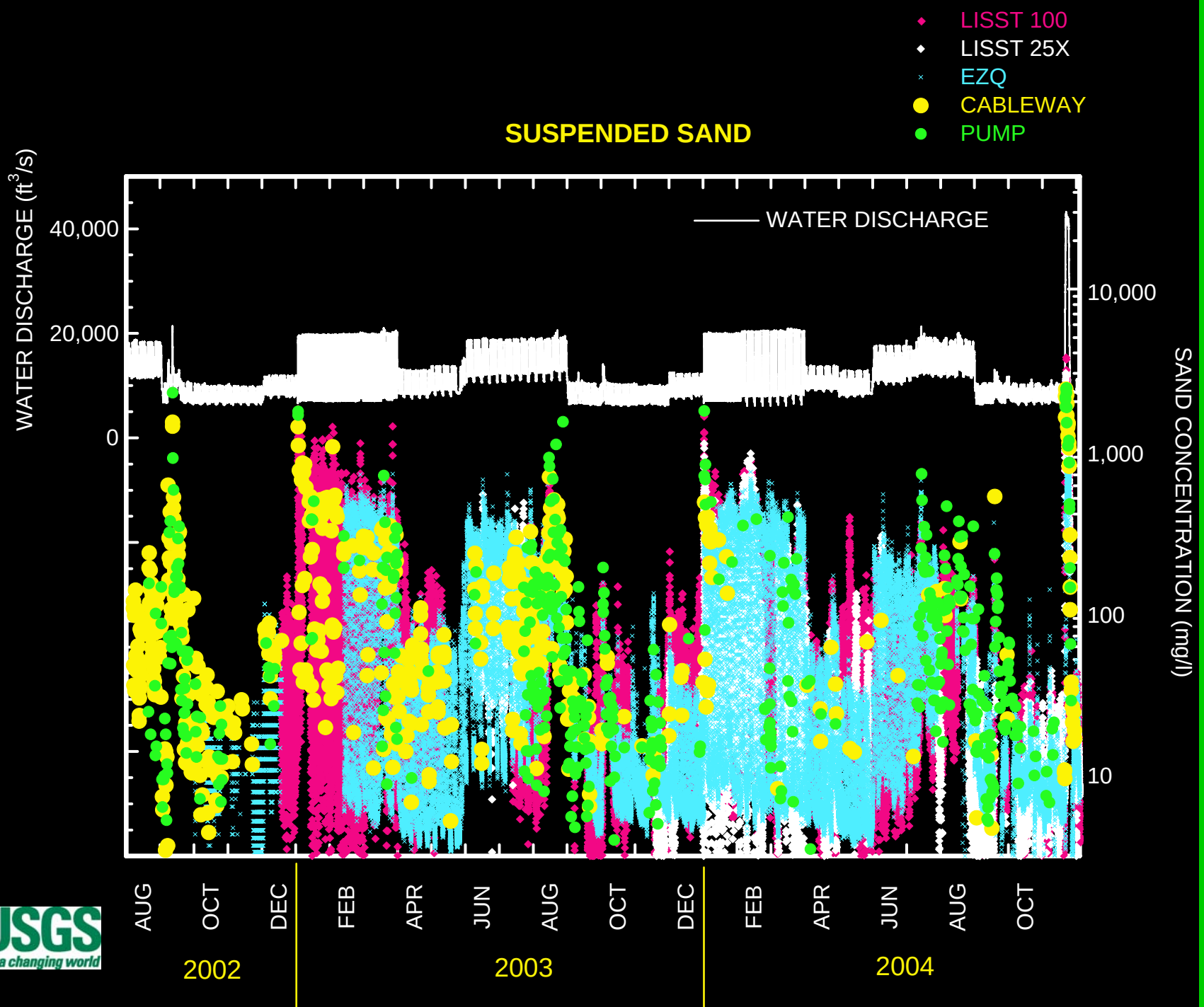
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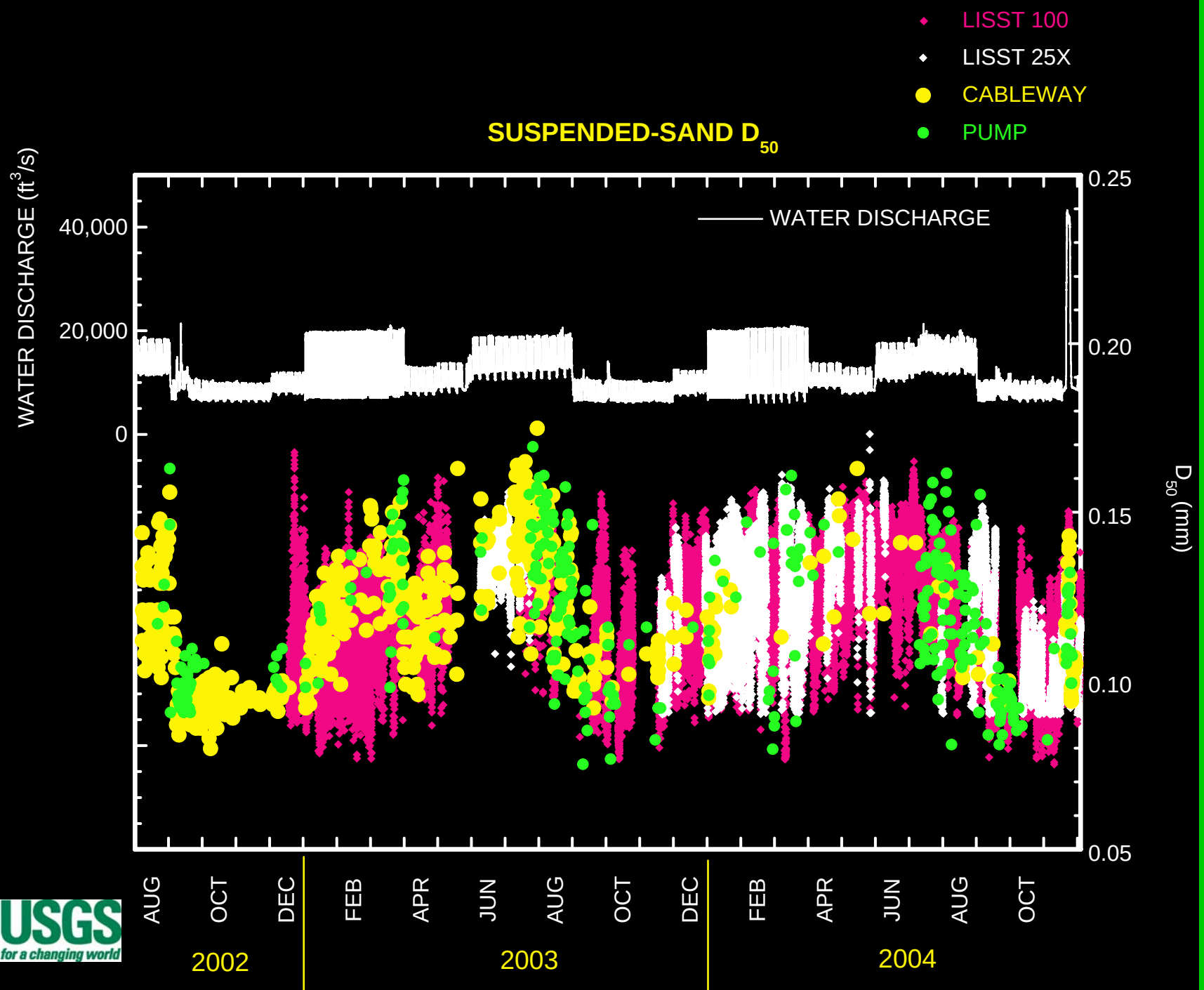
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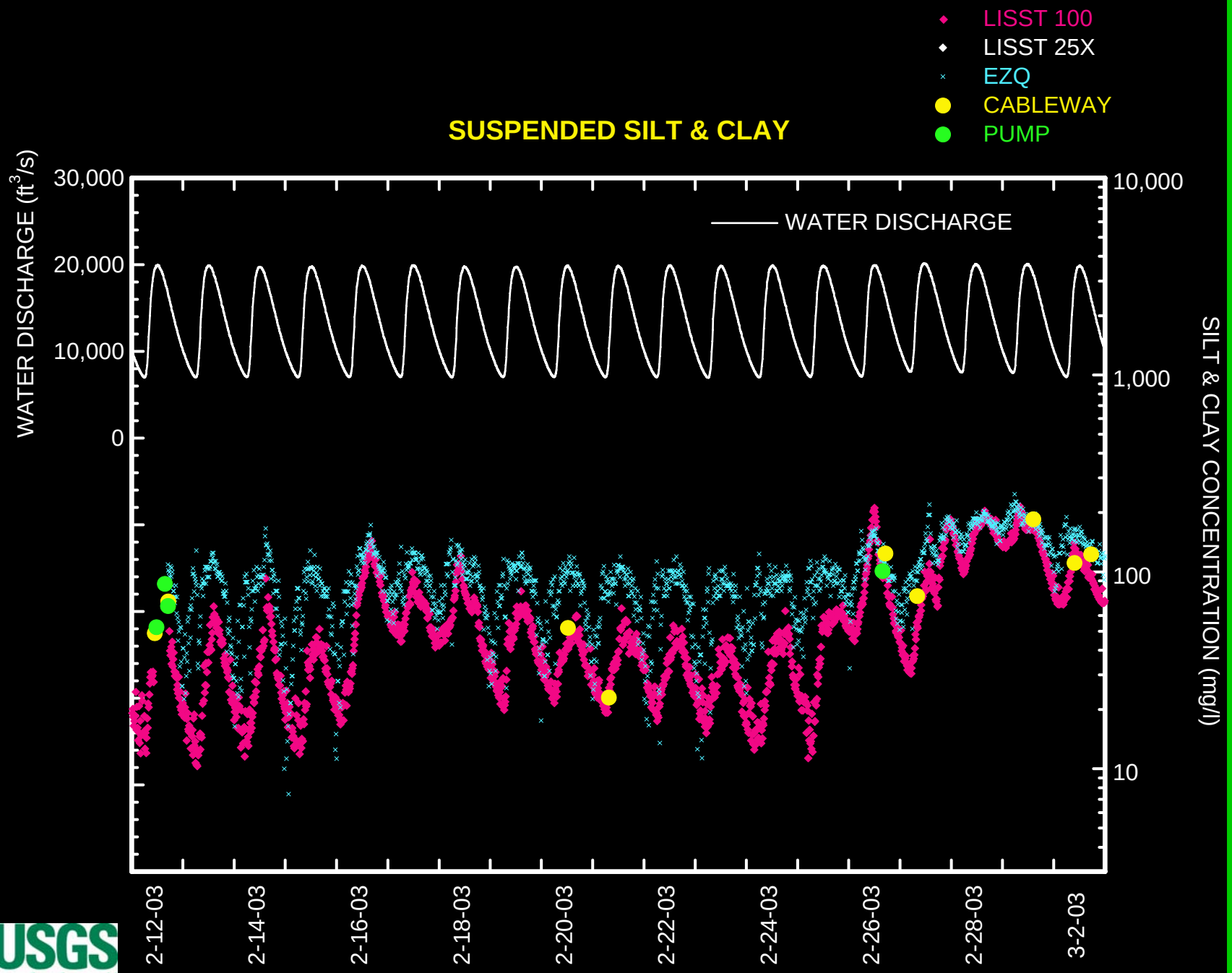
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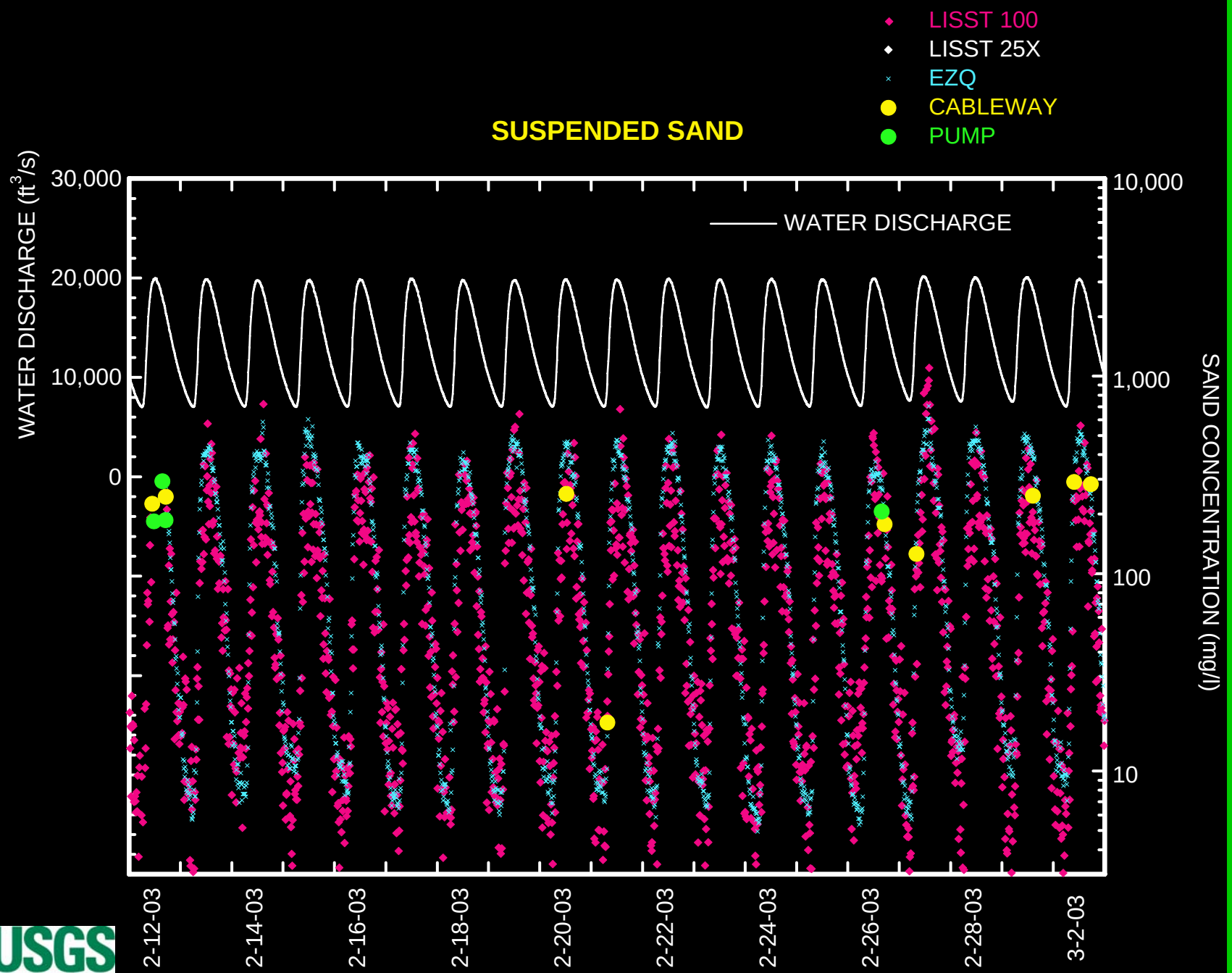
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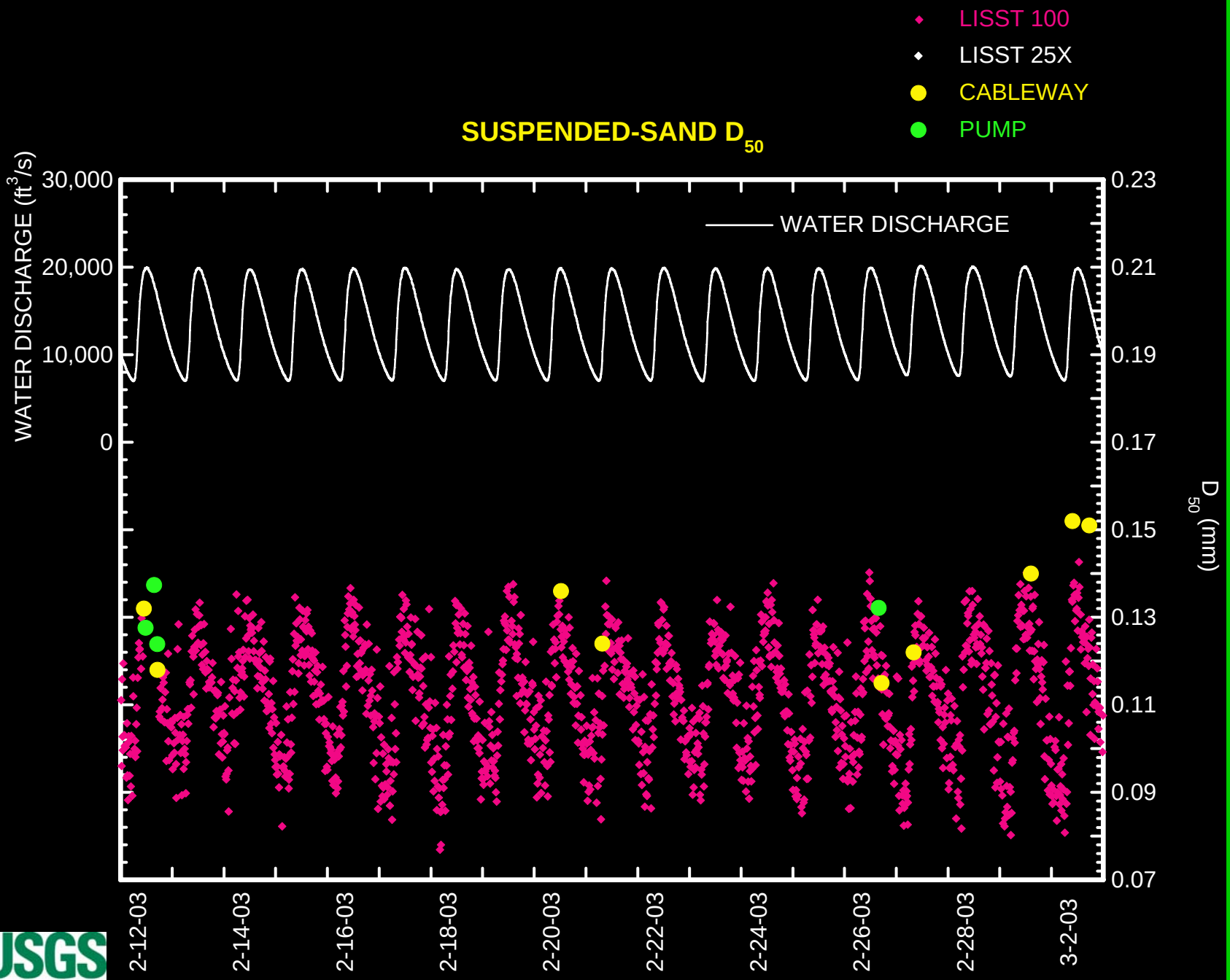
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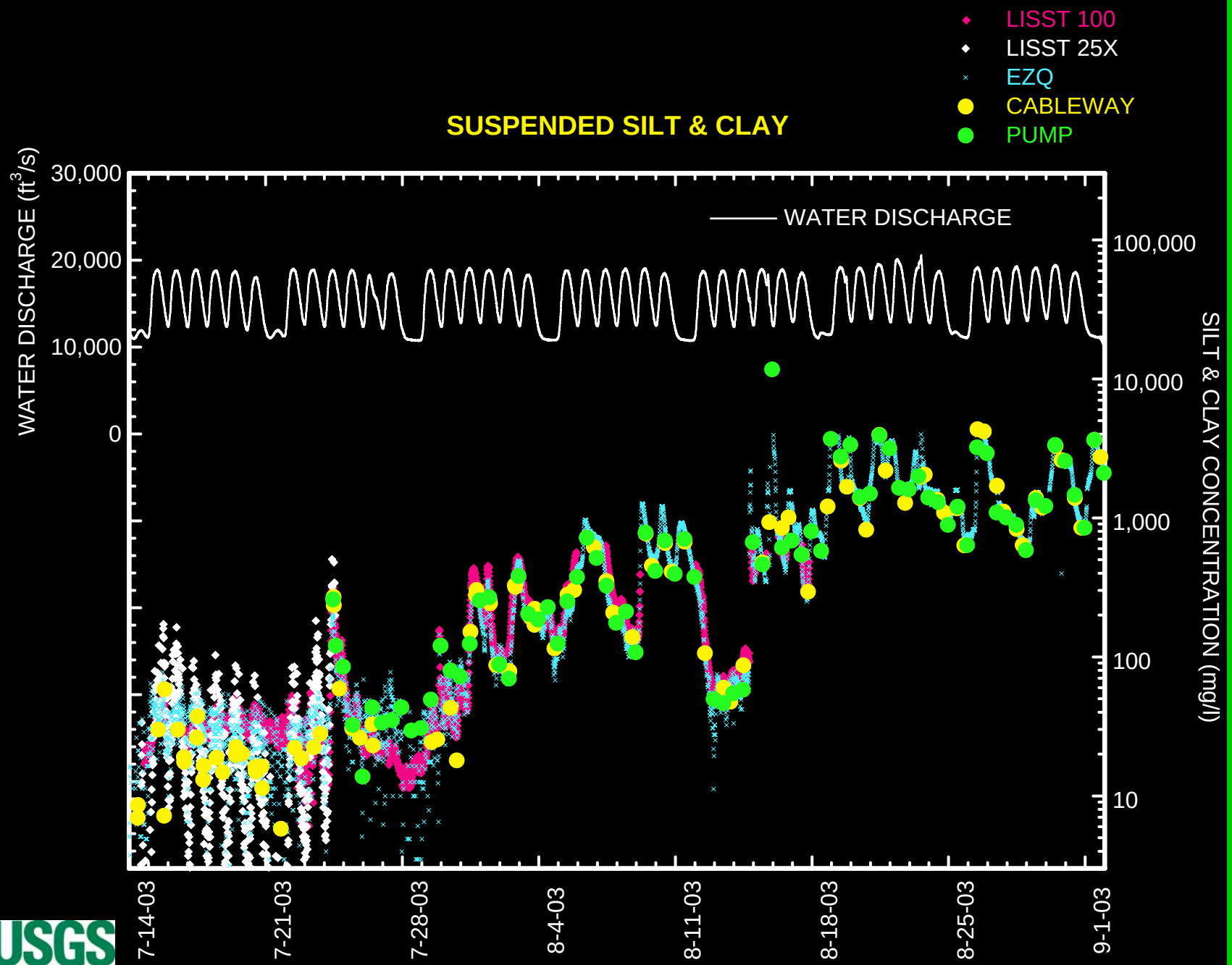
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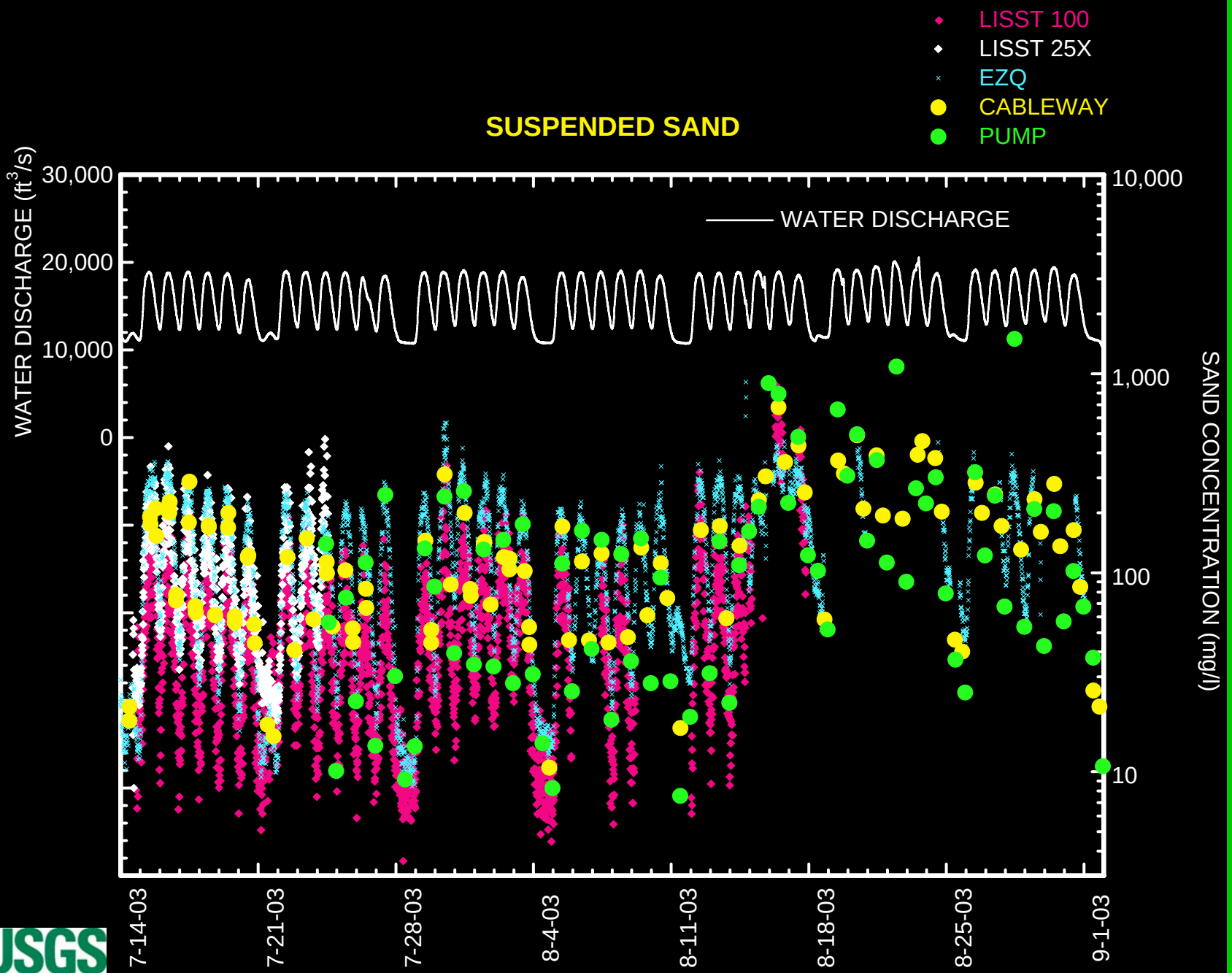

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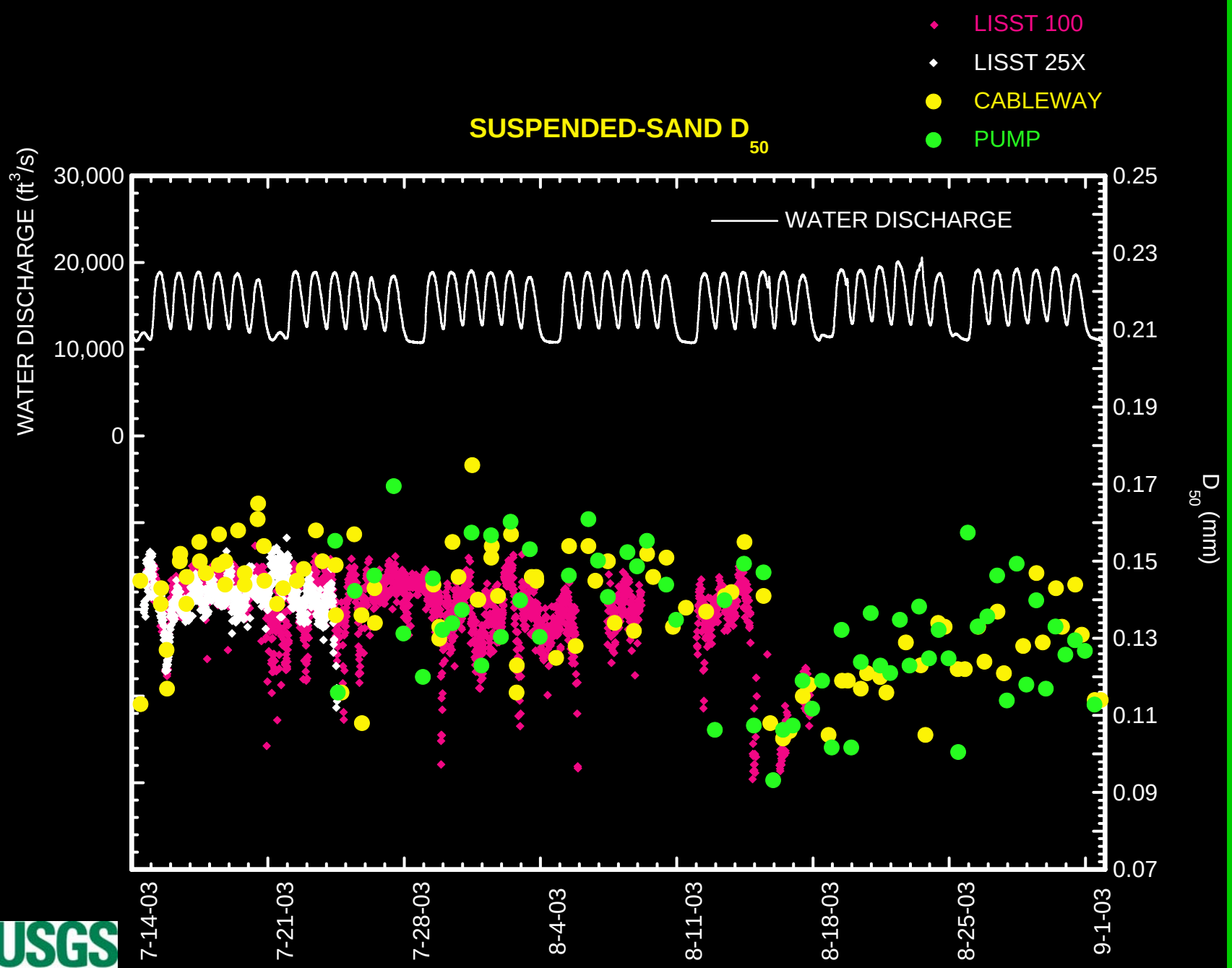
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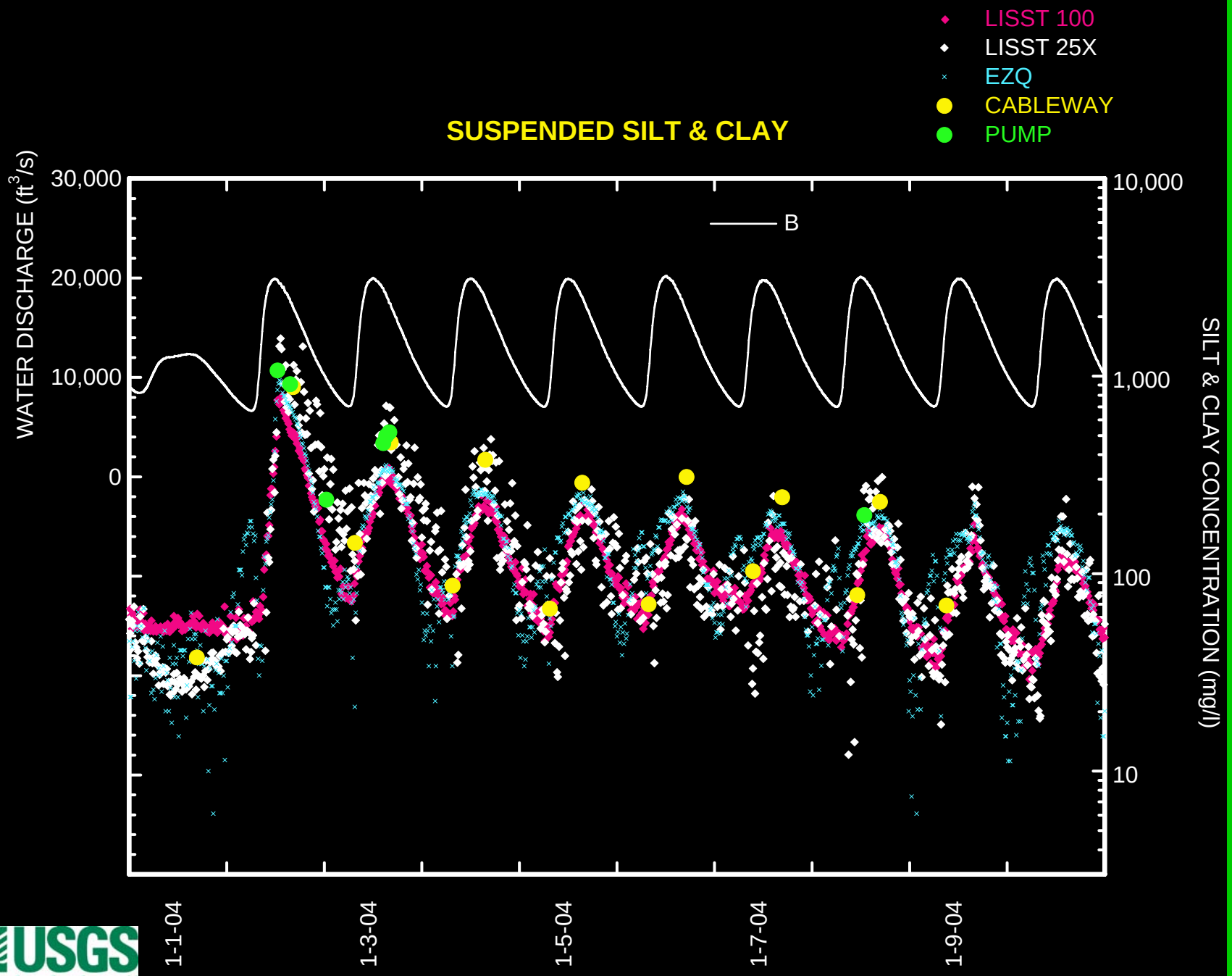
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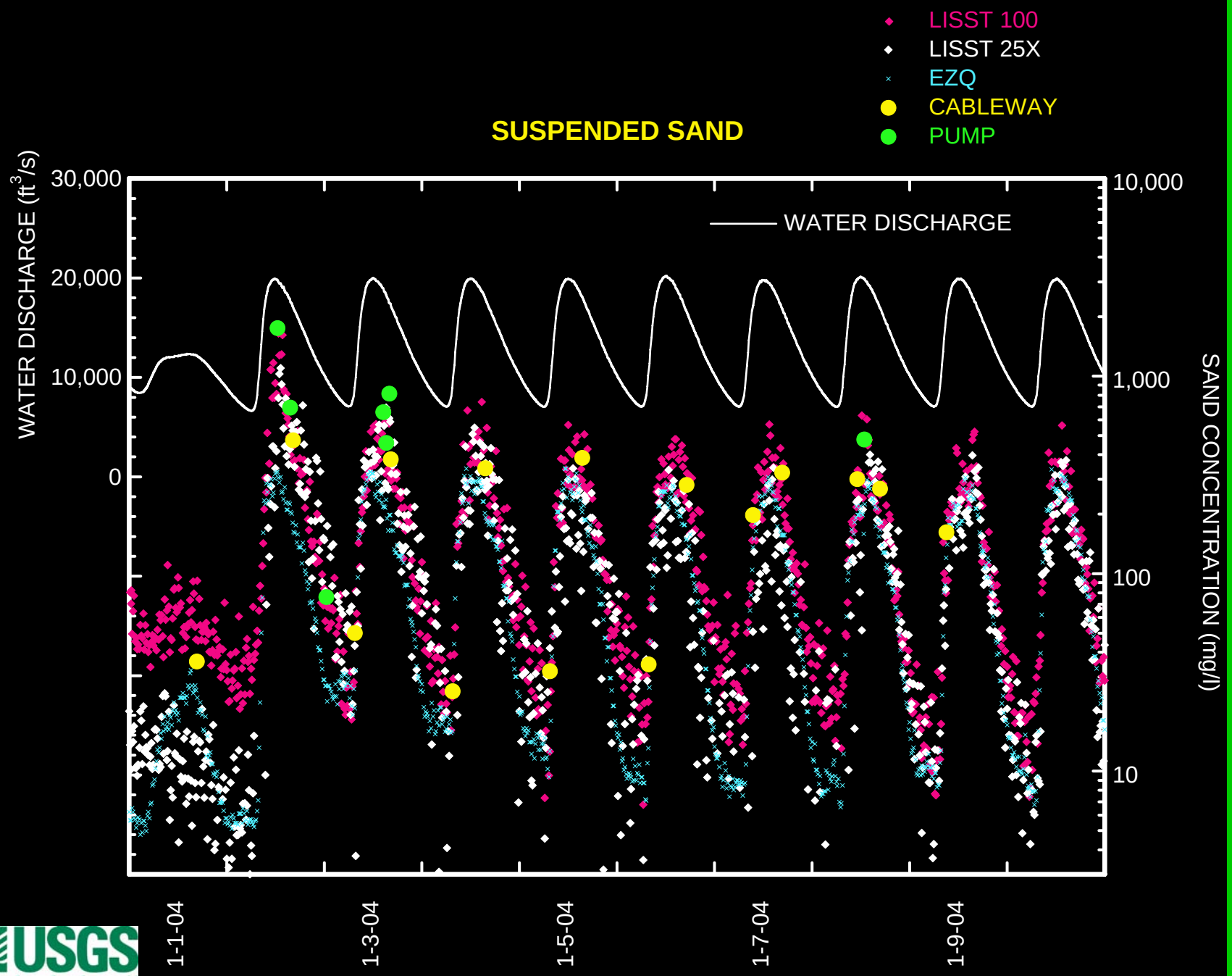
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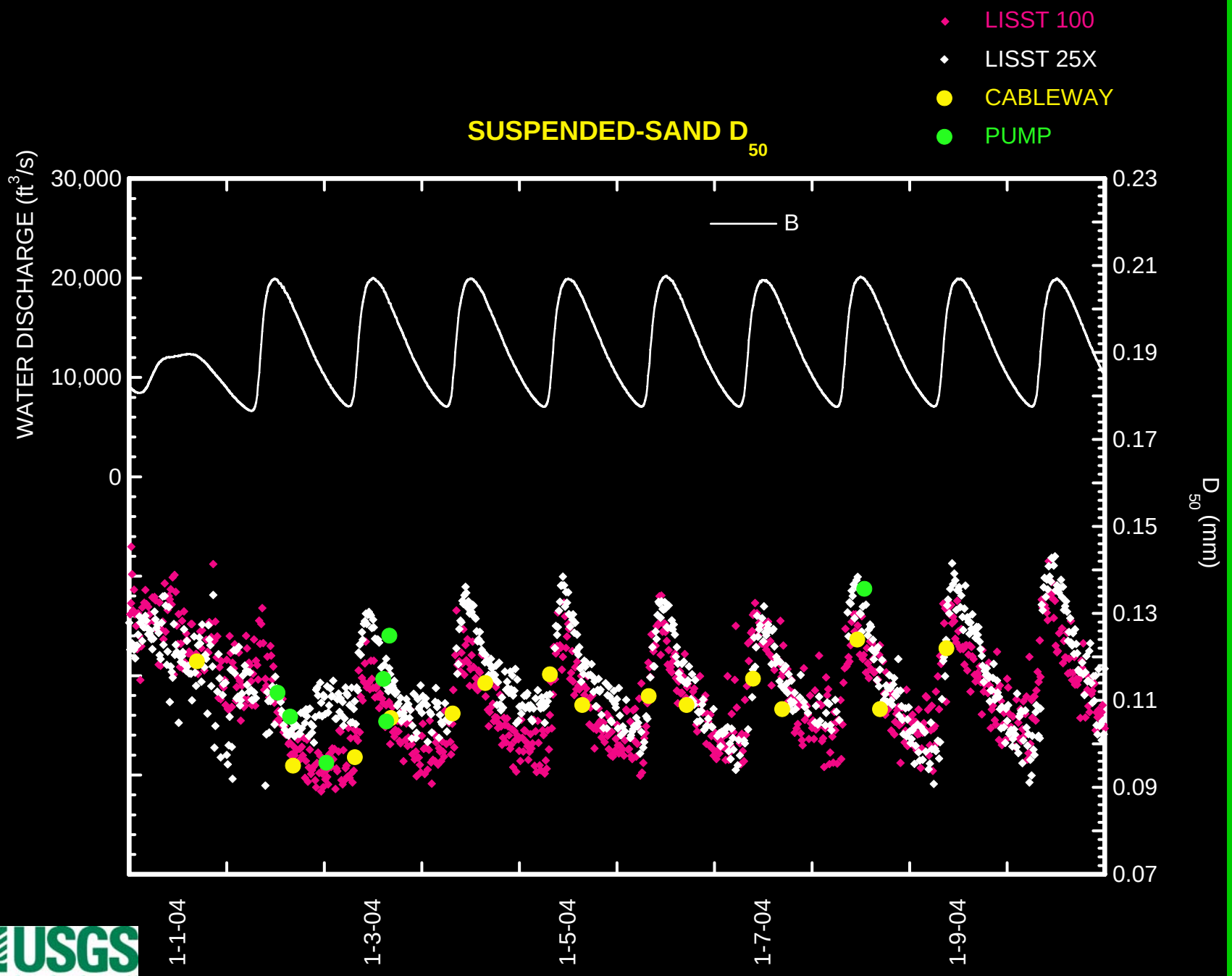
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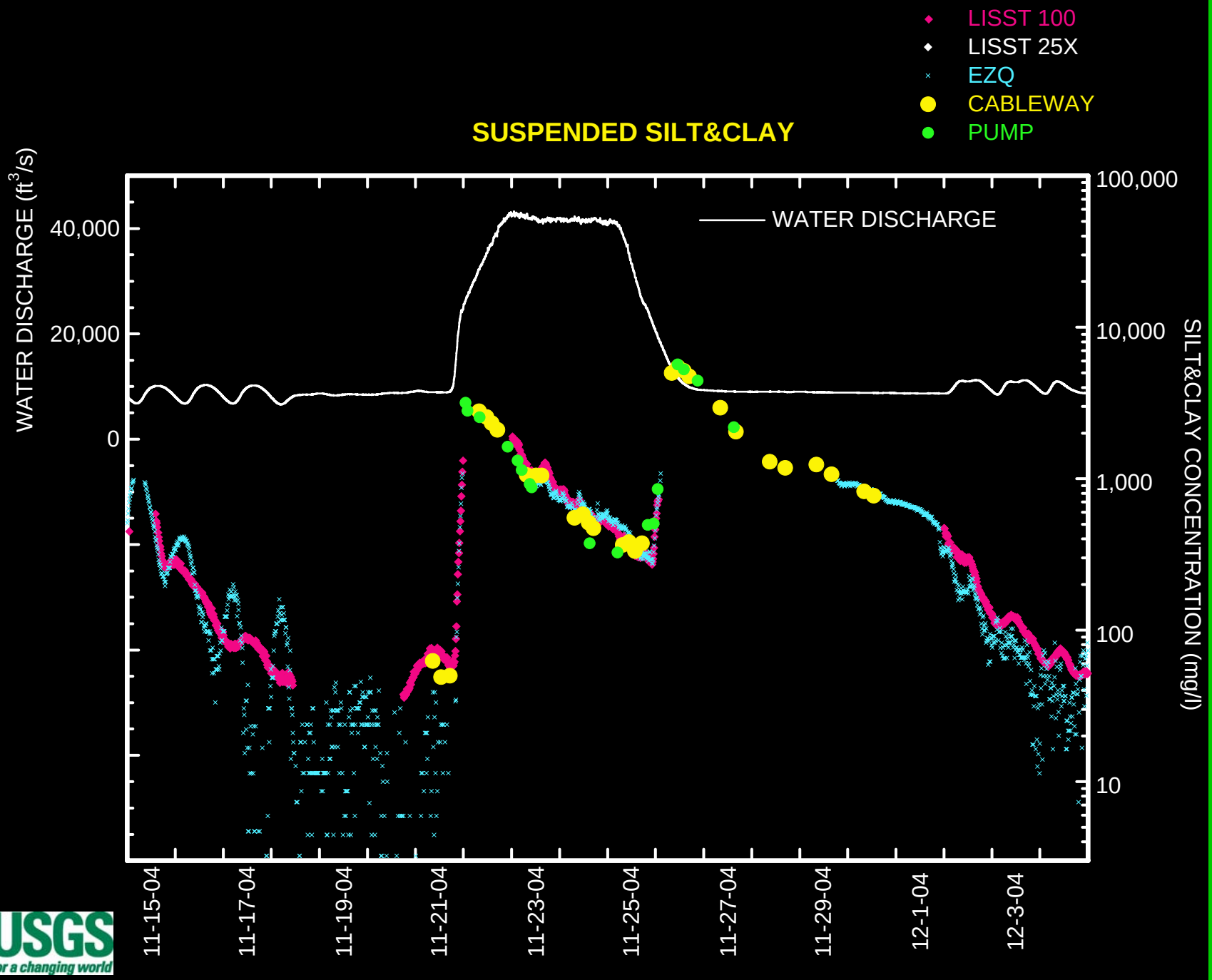
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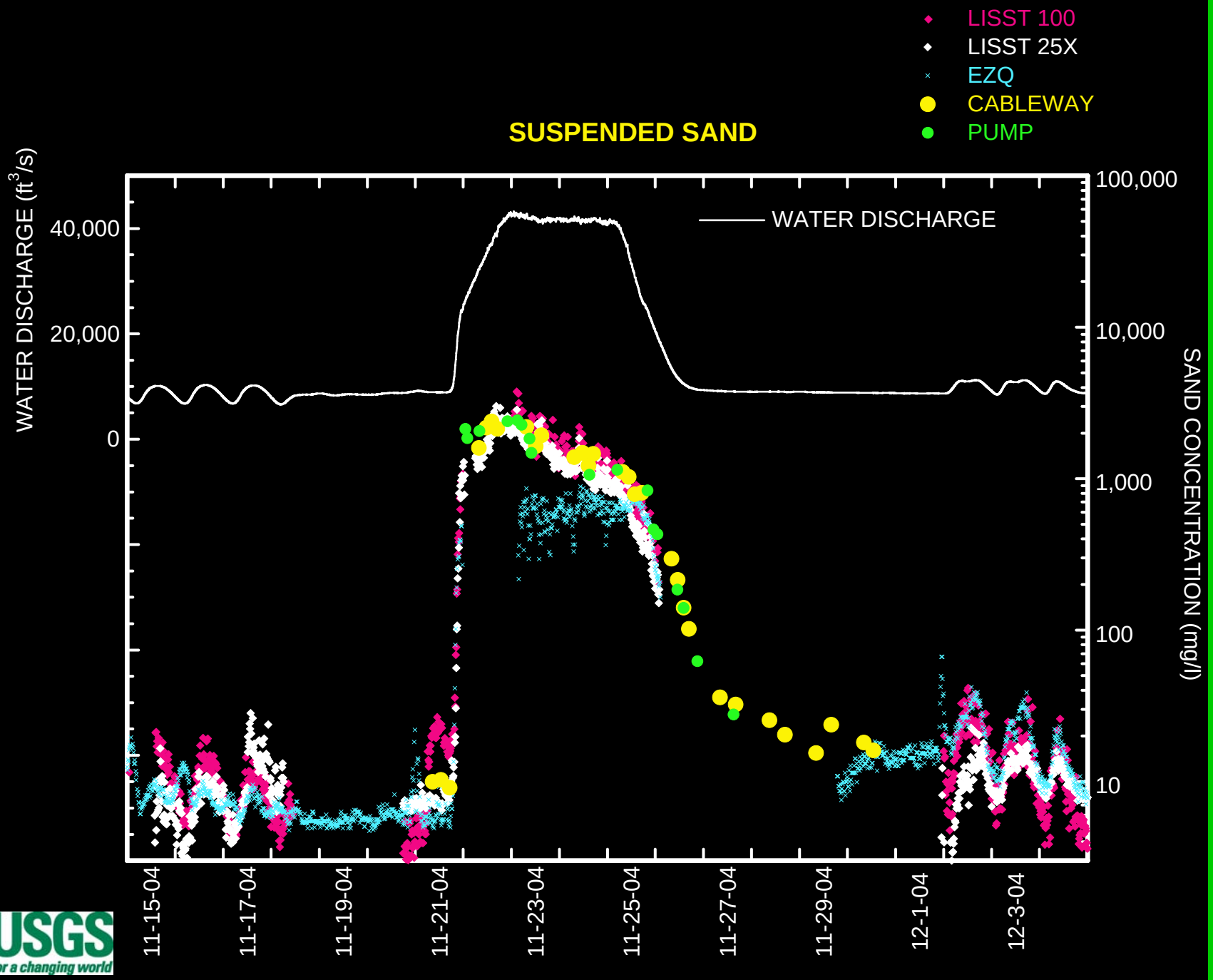
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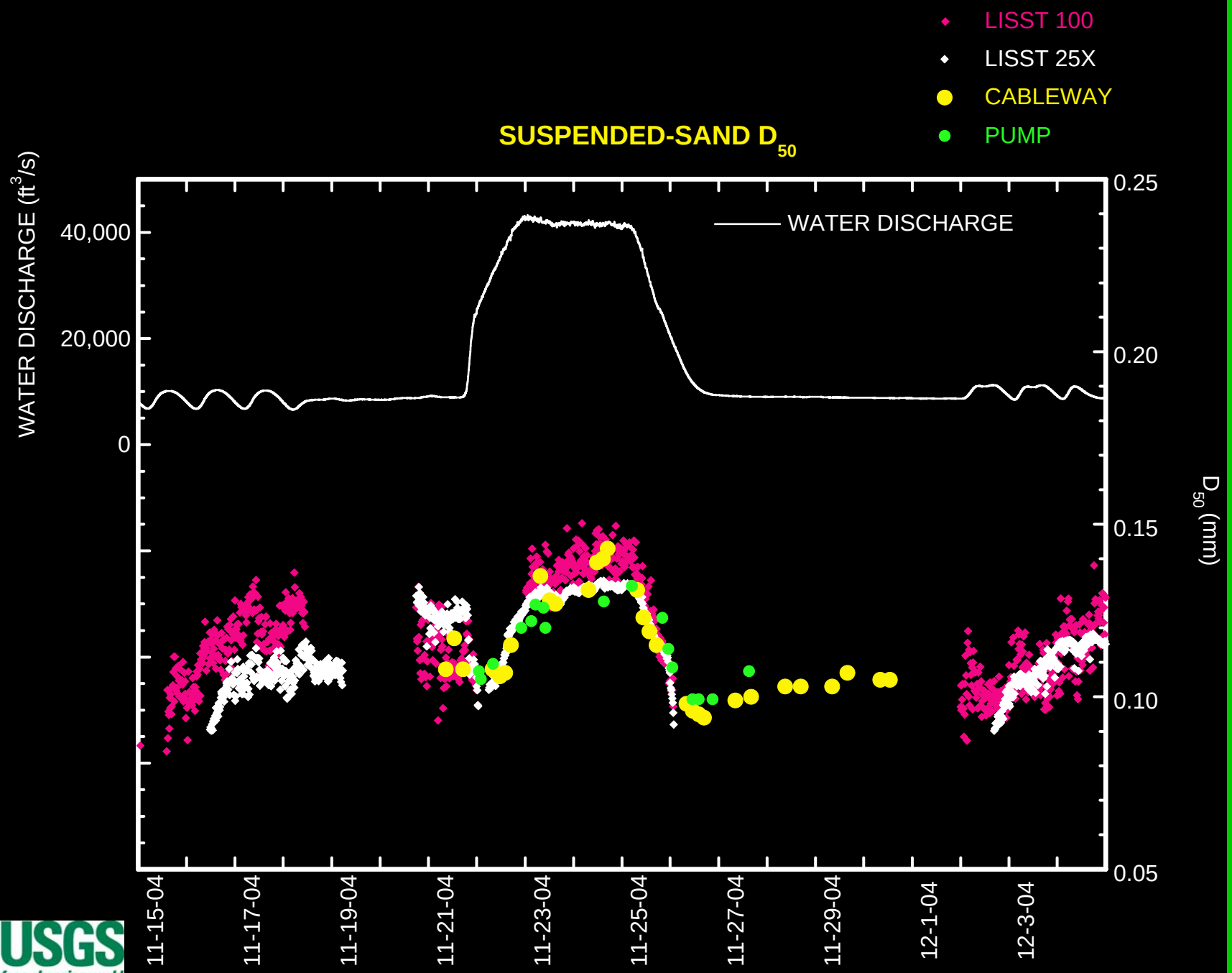

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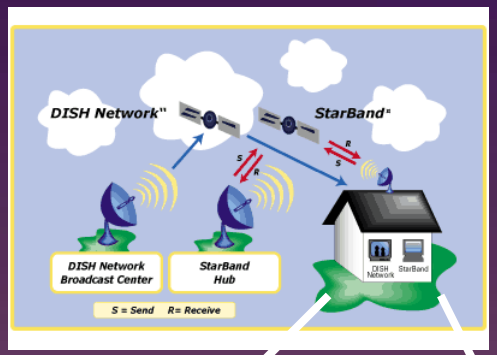
Remotely Controlled Operation

Colorado River of Grand Canyon, USA



River Not Even Visible From Rim!

12v PC & Power RUG

Commands & Programming

DATA Retrieval

Satellite Modem & Power Inverter

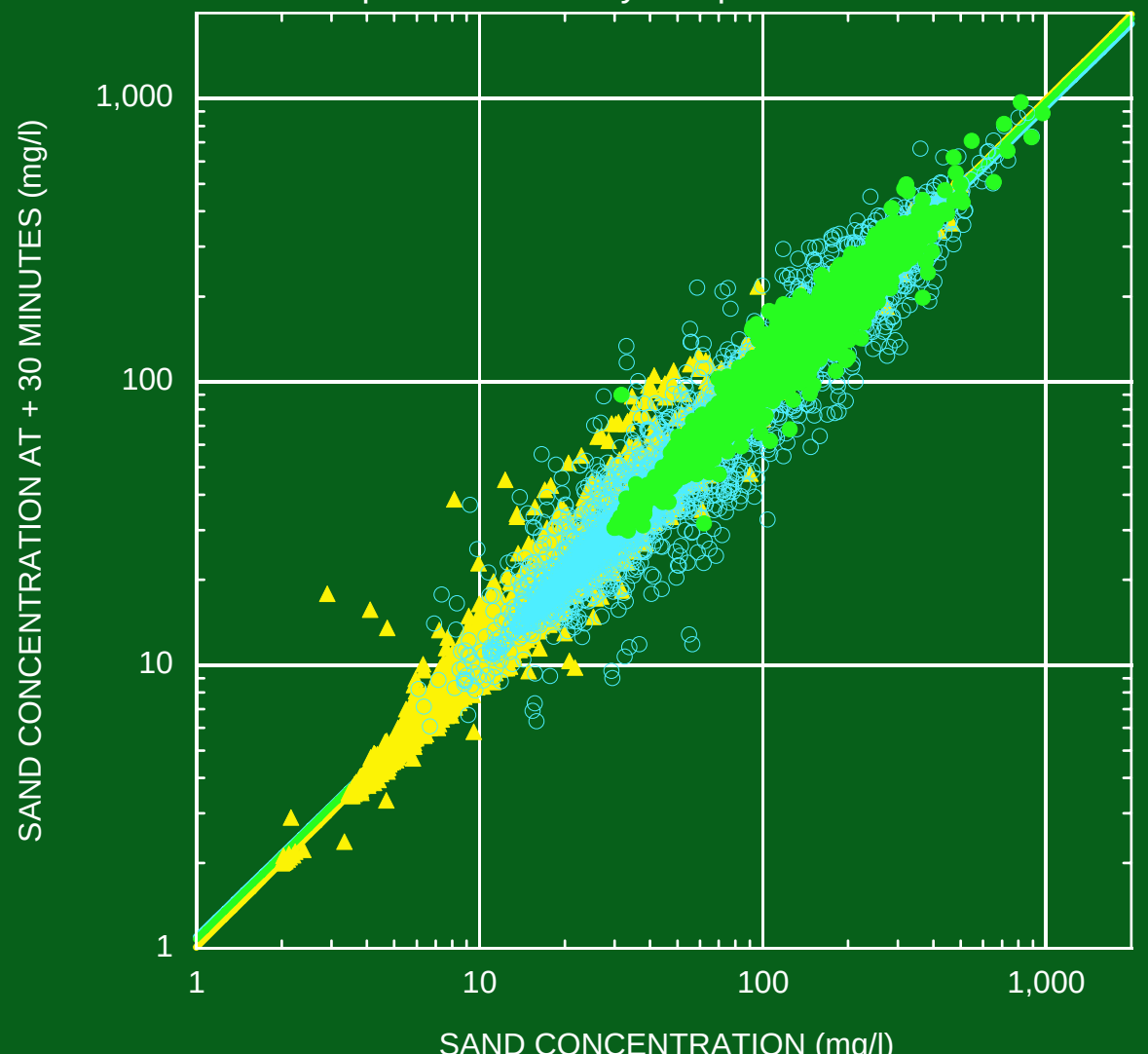
Some of the Sensors Currently Deployed Along the Colorado River in Grand Canyon

$EZQ_1 = 1.01 * EZQ_2\ 0.997$ $R^2 = 0.997$ n = 16,918

$lisst100_1 = 1.10 * lisst100_2\ 0.997$ $R^2 = 0.976$ n = 5,825

$lisst25X_1 = 1.08 * lisst25X_2\ 0.989$ $R^2 = 0.946$ n = 3,343

R^2 for sequential cableway samples is 0.669



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Which approach provides data most representative of conditions in the river?

- Cross-sectionally integrated samples collected with conventional samplers sample 10^0 to 10^1 liters of water over 30-45 minutes
- The EZQ effectively samples 10^8 liters of water over 30 minutes
- The LISSTs effectively sample 10^1 liters of water over 30 minutes

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The Value of Monitoring Data?

- **A Case Study from our Own 1995 EIS on Glen Canyon Dam Operations . . . .**
- **First Need to Collect the Data, then Interpret Them Relative to the Right Questions?**
- **Please Stay Tuned for Scott Wright's Talk (next)**

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