Observations of sand dune migration on the Colorado River in Grand Canyon using high-resolution multibeam bathymetry

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Continuous monitoring of suspended sediment concentration, grain size, and flux
Total sediment flux = suspended flux + bedload flux

Bedload expressed as a constant proportion of suspended load
Based on measurements of bedform migration made at one discharge (595 m³/s) using rotating side-scan sonar (Rubin et al, 2001)

Features to note:
1. Dune size increased as discharge increased.
2. Superimposed dunes.
3. Spurs are oriented obliquely to dune crests.
4. Scour pits present in dune troughs.

Scale: 20 m diameter
Duration of observation: 8 hours, 10 minutes, with 2 gaps of approximately 20 minutes each
Time between images: 2 minutes 4 seconds
Date: September 25-26, 1998

Sonar data collected by Dave Rubin, George Tate, and Roberto Anima
Image processing by Dave Rubin
US Geological Survey
A NEW APPROACH

Over the past 15 years, GCMRC scientists have developed a suite of technologies that enable us to:

- Rapidly produce 3D maps large areas of the bed using multibeam bathymetry
- Simultaneously map bed sediments using multibeam sonar backscatter
- Measure sand grain size distribution using images acquired with a specialist underwater microscope
- Continuously measure of suspended sand concentration and grain size with increasing sophistication and accuracy
- Accuracy measure flow velocities using acoustic Doppler profilers
Can we develop relationships between measured discharge, suspended sediment flux, and bedload flux...

... that better predict bedload flux?

Objective: bedload flux as a function of routinely measured quantities
**DATA COLLECTION**

Bathymetry - Multibeam Sonar (Reson 7125, IxSea hydrins IMU & Heading, Trimble SPS930)

Current Velocity - ADCP (RDI workhorse)

Bed Grain Size - Underwater Camera (Buscombe et al., 2013)

Suspended Sediment – Acoustics samples @ 15 minute intervals, calibrated with D96 & P61 point samples from cableway
MULTIBEAM TRACKLINES
July 12, 2015 survey
20 survey lines
0.10 m cell size
20-30 soundings/cell
30-60 degrees beam angles
Mean cell standard deviation = 0.015 m
Cell Count = 119
MARCH 4, 2015

Dune height: 30 and 50 cm  
Dune length: 5 m  

Migration rate: ~1 m / hour

Fully capture dune migration  
using data collected at unprecedented temporal and spatial resolutions
JULY 12, 2015

Dune height: 75 and 130 cm
Dune length: 10-15 m

Migration rate: ~2 - 5 m / hour
Bedload flux calculations:

Translation only

1D only

Averaged over field of dunes (not calculated per dune)

Simons et al (1965) - mean sediment flux per unit bedform length

$q_0$ is a constant of integration (here set to 0 but a topic of research)
BEDLOAD CALCULATIONS

Bedload Rating Curve

- Bedload, Region 1
- Bedload, Region 2

Sediment flux vs. Water Discharge (m²/s)

% of Sand Flux as Bedload vs. Water Discharge (m³/s)

50 m scale

Region 1
Region 2
‘FLYING EYEBALL’ BED SEDIMENT CAMERA
BED SEDIMENT MEAN GRAIN SIZE WAS SLIGHTLY COARSER IN JULY
BUT LITTLE EVIDENCE OF GRAVEL IN TROUGHS

Hillshaded bathymetry

Acoustic backscatter sediment classification (Buscombe et al 2014)

Yellow = sand
SUMMARY (SO FAR)

- Dune dimensions (height and wavelengths) scale with discharge
- Dune translation speed increased with higher discharge
- Preliminary results would suggest that bedload is 10-15% of suspended load at discharges of 11-13,000 cfs (higher than currently implemented in flux-based sediment budget)
- and bedload is around 5% of suspended load at discharges of 17 – 21,000 cfs (in line with previous measurements and current predictions)
- However, these are likely to be conservative estimates given a possible contribution of ‘deformation flux’ (ongoing work)
- Bedforms are very ‘3 dimensional’, especially at larger discharges
- Bedload would appear to have a weak – moderate correlation with discharge
ONGOING AND FUTURE WORK

• Conduct mapping work at Diamond creek during the next HFE

• Start mapping work at other gage sites (starting at 30-mile gage in May 2016)

• Account for flux contribution (if any) of dunes changing shape as they migrate (Tom Ashley’s Masters thesis)

• As we acquire more data, develop and test relationships for bedload as a function of flow (velocity / discharge), grain size and suspended sediment

• Testing ways to autonomously and continuously monitor bedload
Thank You