Canyon in a Box: Laboratory studies of sand entrainment and transport for a Grand Canyon sediment routing model

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Acknowledgements: Fine sediment modeling project participants

- **Steve Wiele (USGS)** – project leader, modeling of deposition in eddies, sand routing model
- **Jack Schmidt (USU)** – characterization of eddy sand storage environments
- **Josh Korman (Ecometric)** – biological linkages, integration with Grand Canyon Model (GCM)
- **Grams and Wilcock (JHU)** – sand entrainment component of sand routing model, laboratory testing of routing model

Why study the Colorado River in a 40 ft flume?

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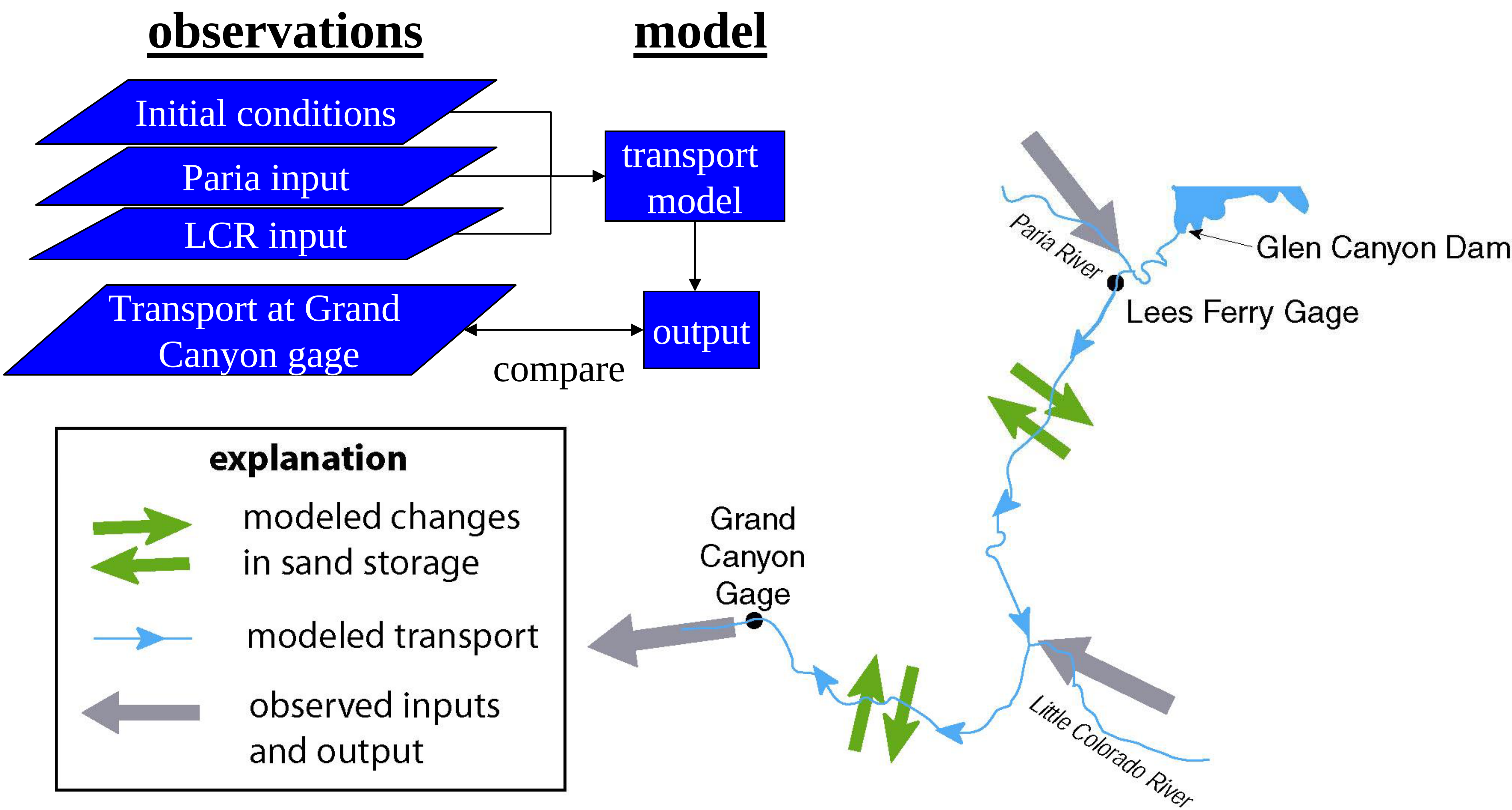
Why a sand routing model is needed

- Predict the fate of tributary sand
  - How fast does it move downstream?
  - Can it be stored on bed and/or channel sides?
- Observations may be made at particular locations for particular events;
  - *a model is needed to help explain the observations and predict response for conditions other than those directly measured*

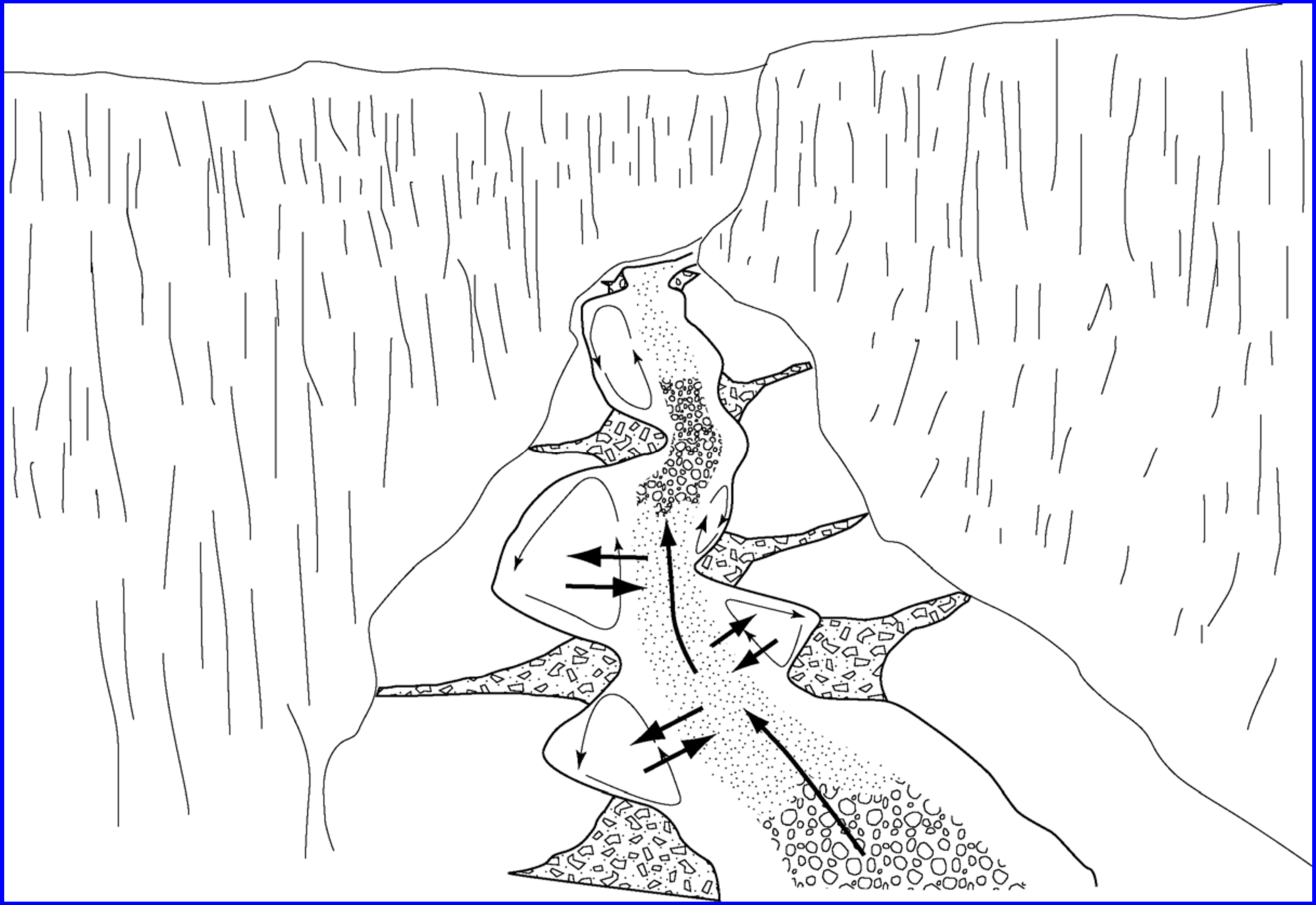
Management concepts the sand transport modeling will evaluate and apply

1. High flows will suspend sand and deposit some portion of it in eddies.
   - How fast will sand migrate?
   - How long will sand concentrations remain elevated?
   - What is the dependence on initial conditions?
2. Low flows will preserve tributary inputs.
   - How fast will sand migrate?
   - How low must flows be to store tributary inputs in upper Marble Canyon?

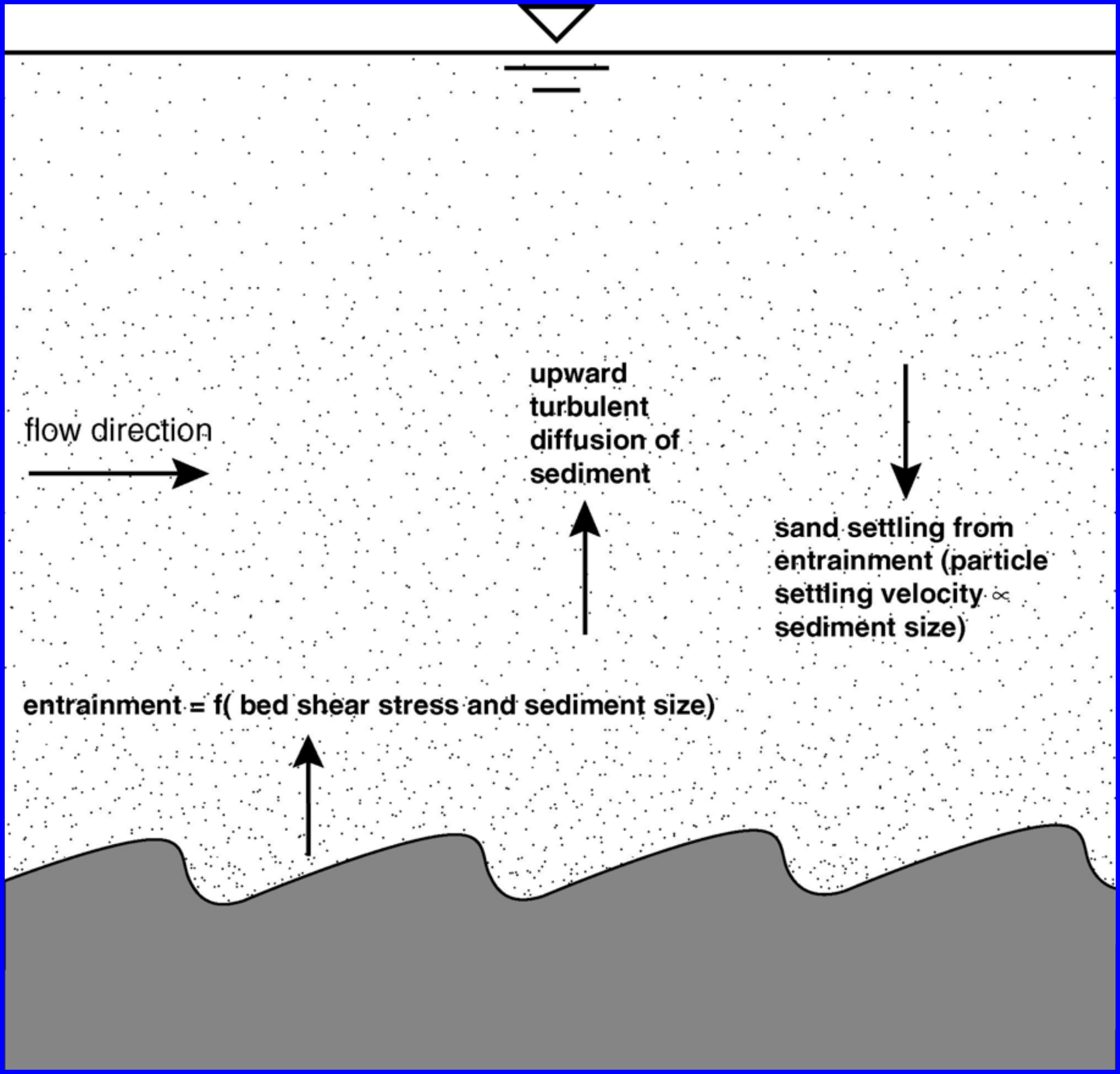
How can the sand routing model be tested?

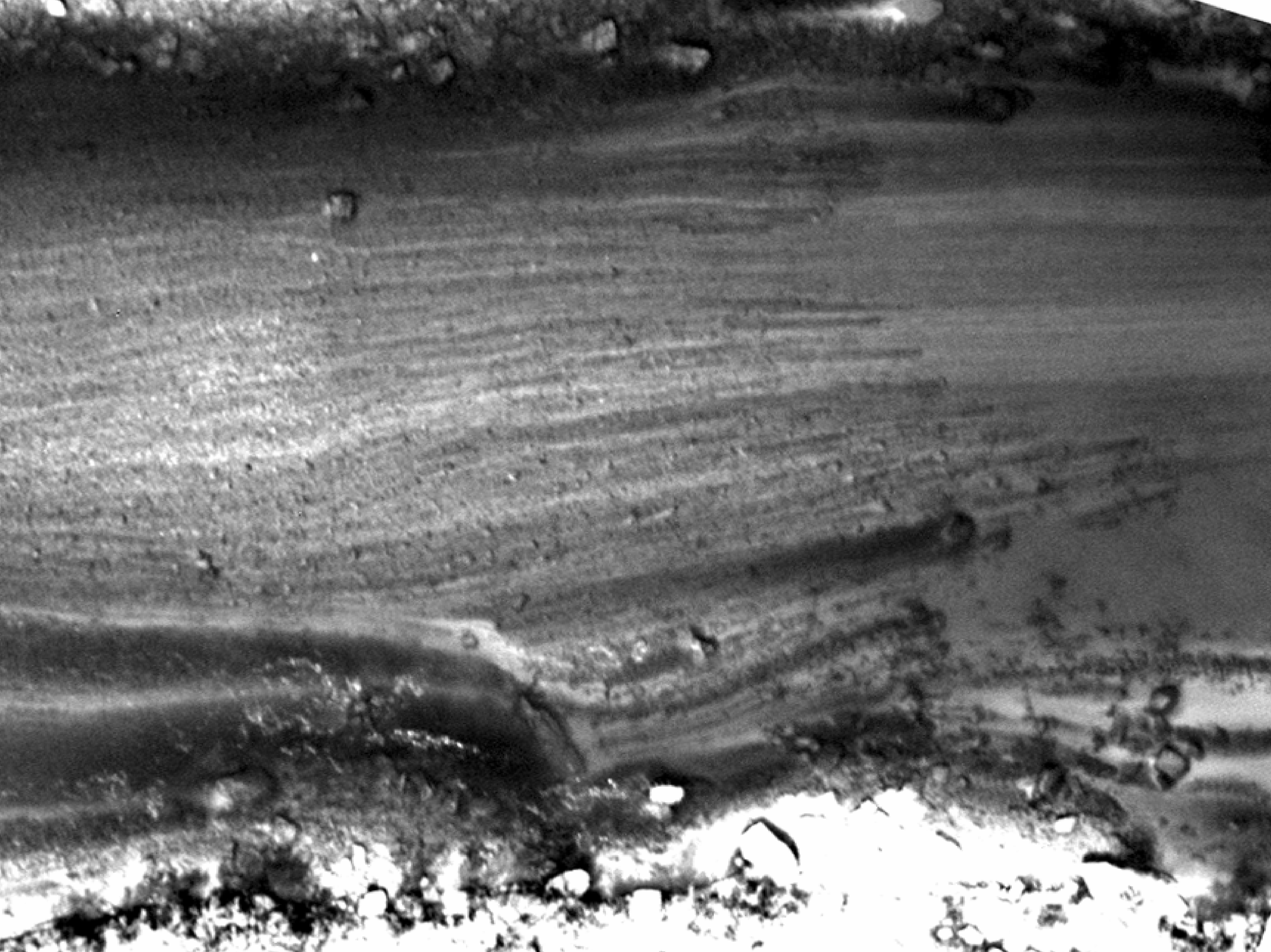


What does the sand routing model do?



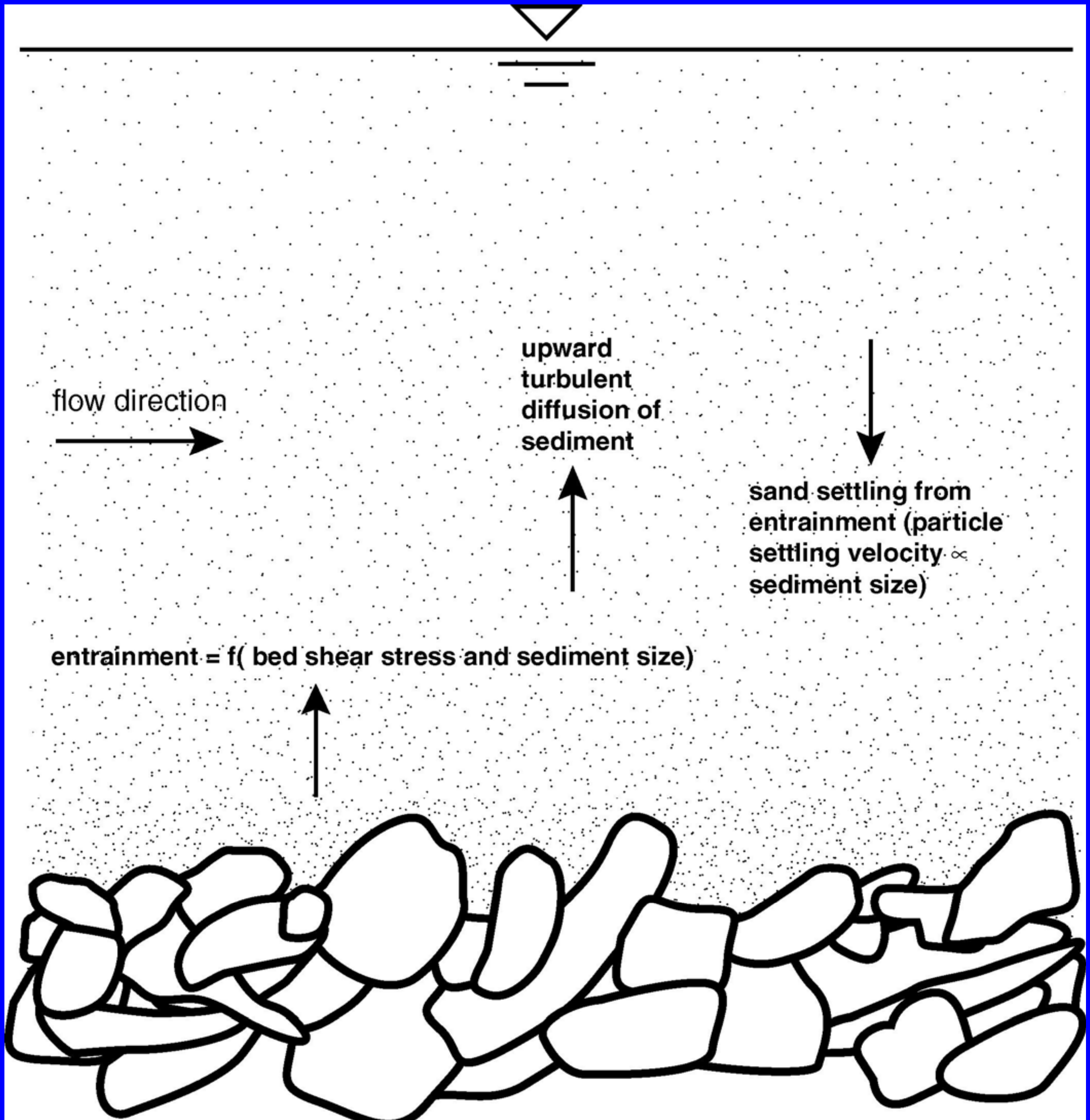
How does sand entrainment work?

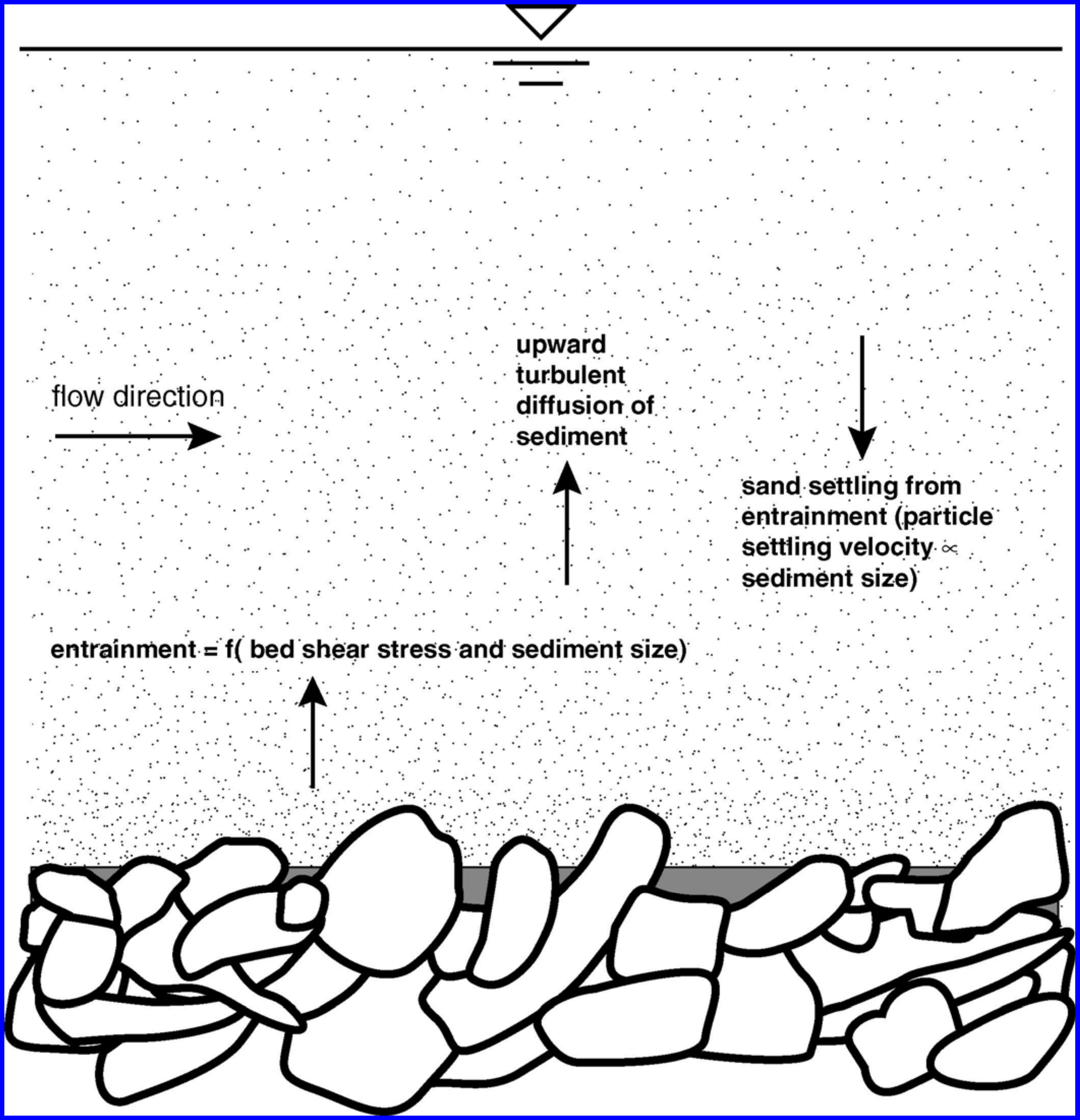




Underwater video camera


Hdg: 143.7
Speed: 4.3
21:23:22
07-12-03


flow direction
upward turbulent diffusion of sediment
sand settling from entrainment (particle settling velocity ∝ sediment size)
entrainment = f(bed shear stress and sediment size)



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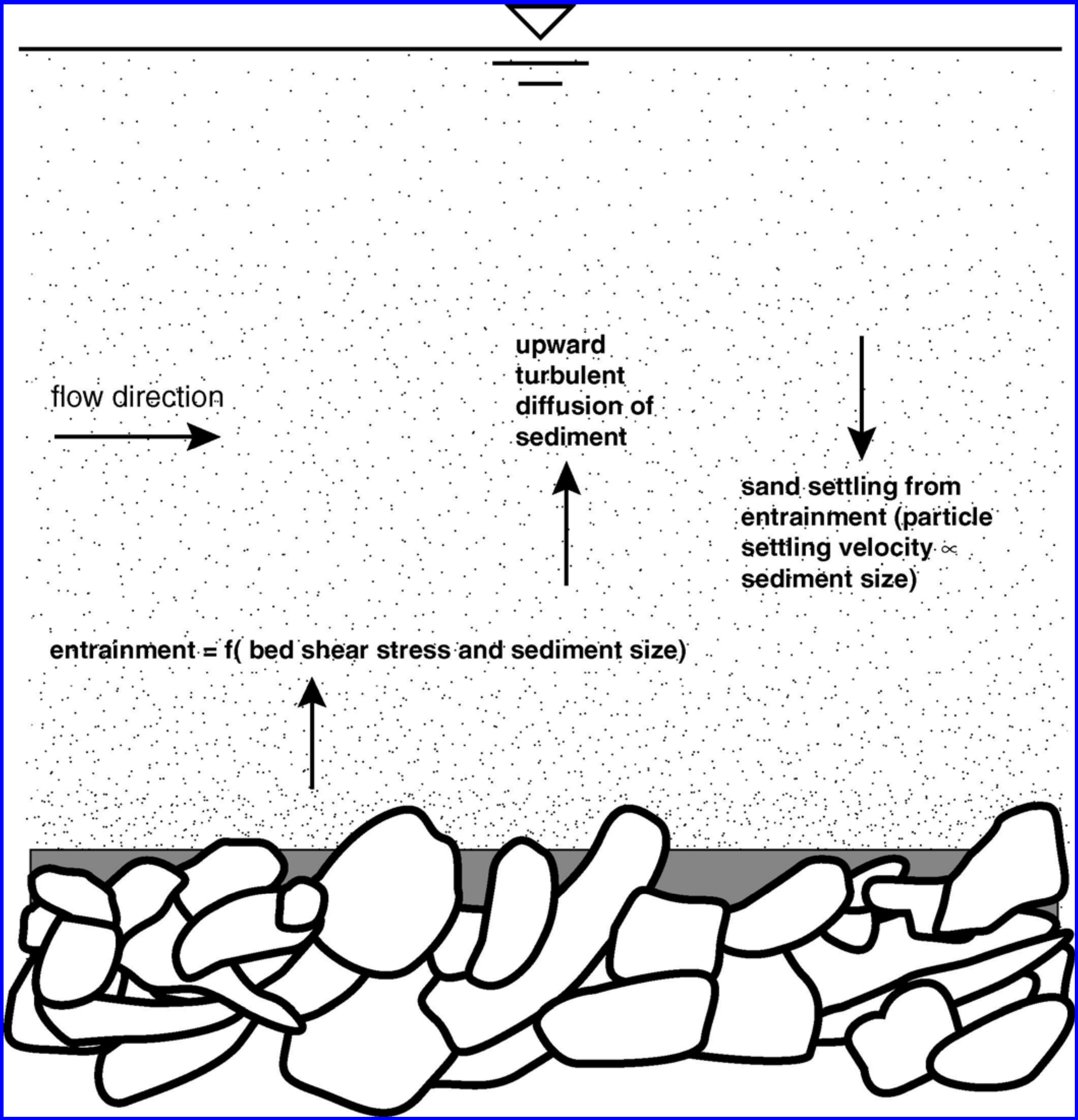
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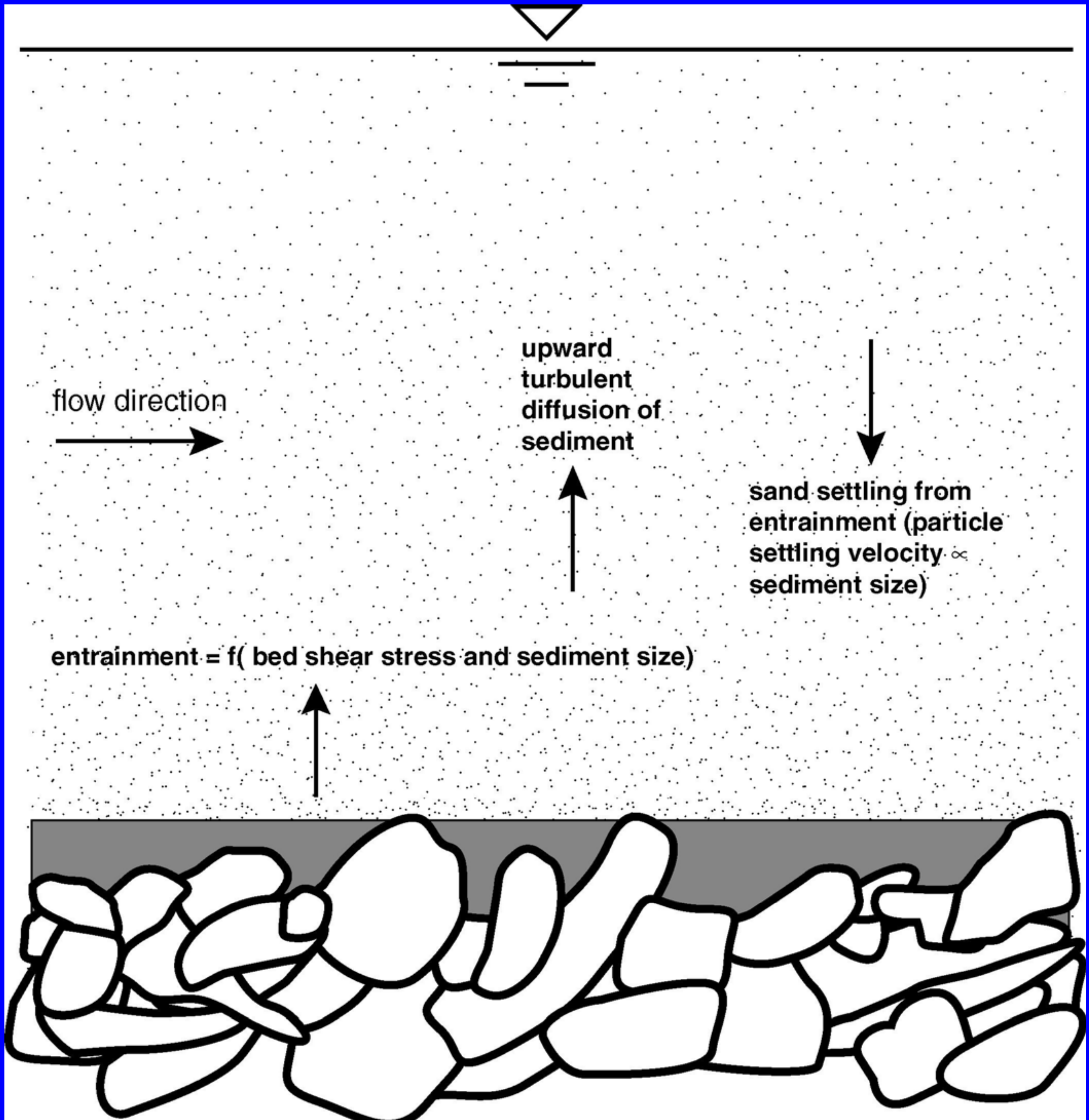
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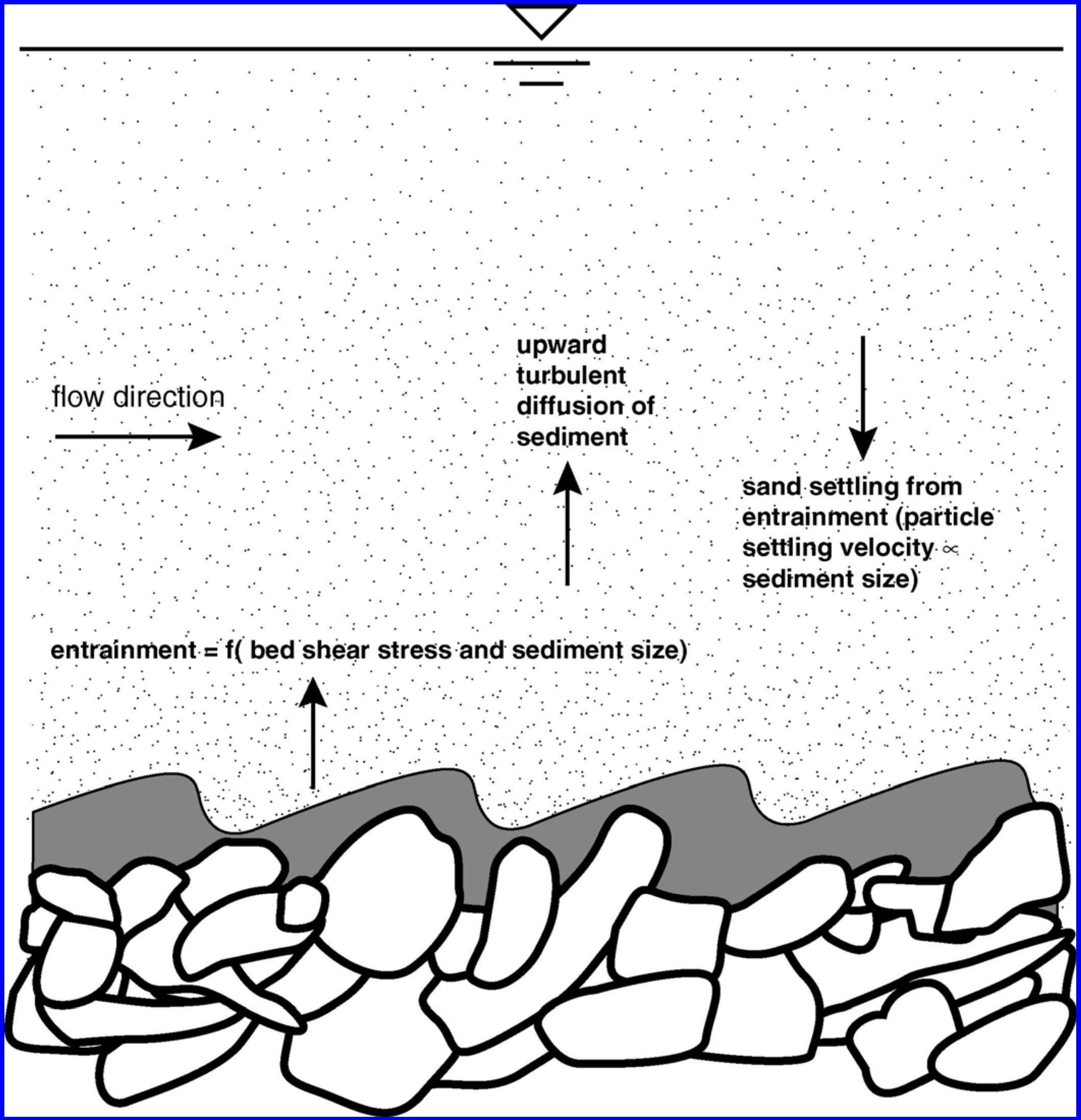
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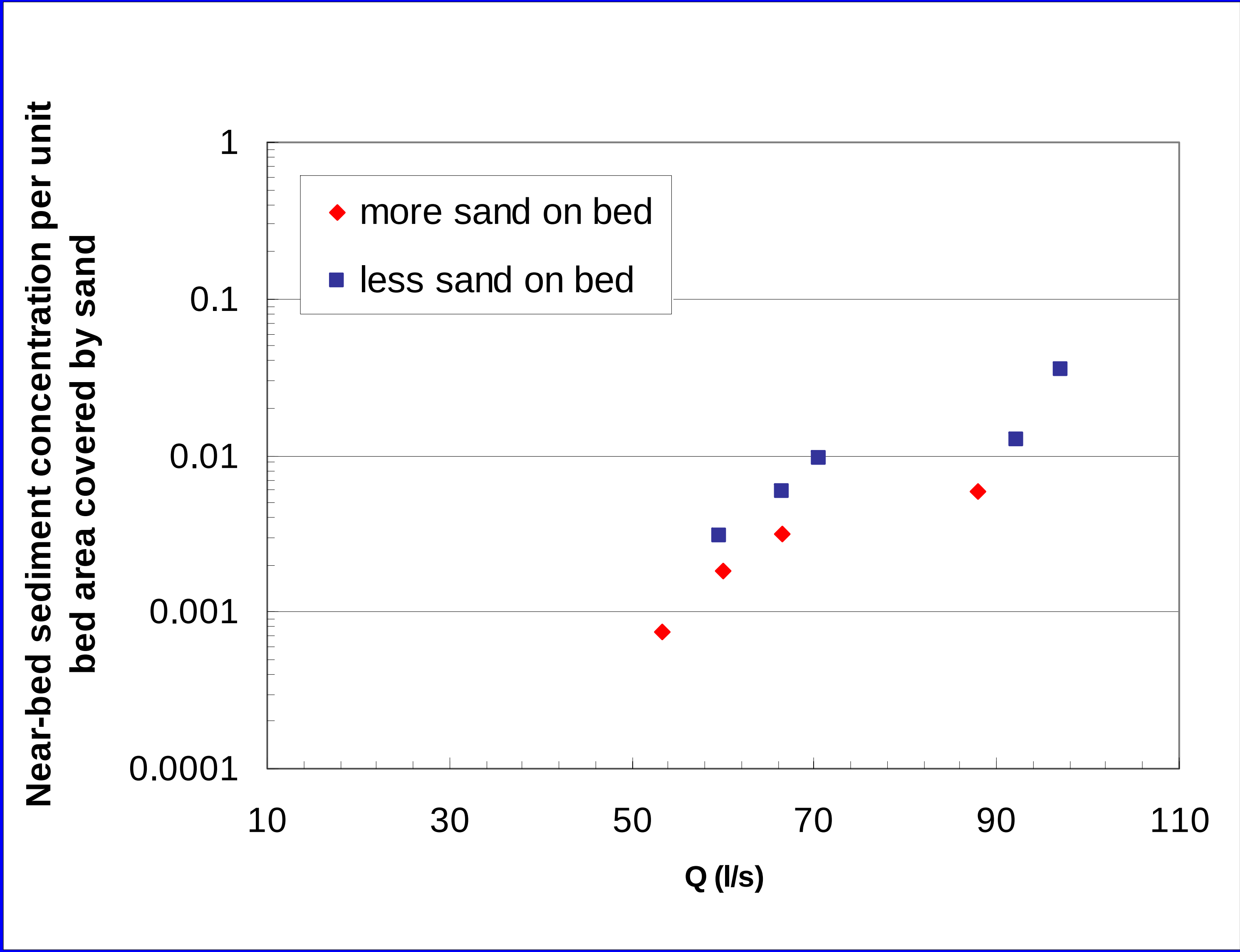
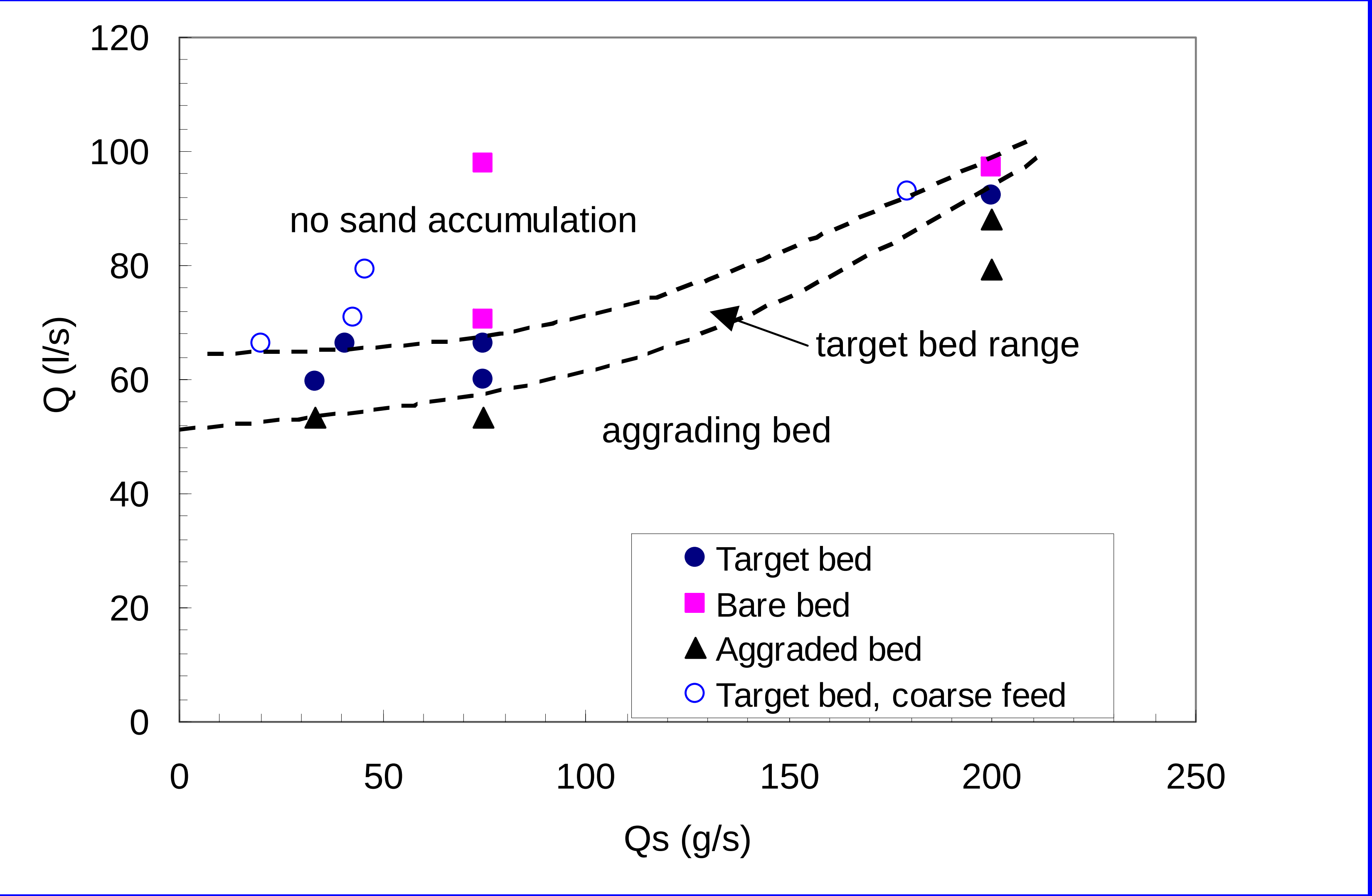
Flume studies – independent test of sand entrainment from coarse bed

- 18 experimental runs
- Constant flow depth
- 10 cm diam. bed roughness
- Two grain sizes
  - Fine (~ Paria inputs)
  - Coarse
- Range of flow and feed rates

Lower sand-bed elevation augments near-bed sand concentration



Sharp threshold exists between sand-covered and evacuated bed



How do tributary sand inputs move downstream?

- Sand wave hypothesis
  - Sand moves downstream as waves that lengthen and become sorted with respect to grain size
- How do the sand waves migrate under different flow scenarios?
- How well can the process of sand wave migration be represented in the sand routing model?

Flume studies II

Nonuniform transport – introduce a sand wave

- Test sand wave migration and sorting in lab
- How well does the routing model and transport algorithm perform?
  - What conditions are needed to preserve the sand wave
  - What happens when flow increases (BHBF)

Flume studies II
Nonuniform transport – introduce a sand wave

- Experimental plan – four runs each started with uniform transport and spatially uniform bed
  - Run 1. *Uniform transport followed by evacuation*.
  - Run 2. *Uniform transport followed by interval of increased sand feed rate*.
  - Run 3. *Uniform transport followed by increase in sand grain size*.
  - Run 4. *Uniform transport followed by increases in both the sand feed rate and grain size*.

Flume studies II
Nonuniform transport – introduce a sand wave

- Main channel at Saint Anthony Falls Hydraulic Laboratory
  - Channel specifications
    - 84 m long, 2.75 m wide, 1.8 m deep
  - 0.5 m flow depth
  - Approximately same roughness and sand as in previous experiments
  - Concentrations ~ 1200 mg/l at 750 l/s (26 cfs)
    - ~25 tons of sand

Conclusions

- The sand routing model is being developed as a tool to aid in predicting the fate of tributary sand inputs
- Experimental studies provide essential independent tests of routing model components
- Future experimental studies will test the application of the sand routing model to conditions of nonuniform transport in a controlled experiment