Generalized Sediment Budget of the Lower Missouri River

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In cooperation with the U.S. Army Corps of Engineers
Impetus for Study

“Corps of Engineers and the U.S. Geological Survey scientists have been conducting valuable collaborative investigations of Missouri River sedimentary processes that should be used as the foundations for a more detailed and extensive sediment budget. Over time, continued collaboration may lead to a more formal program for data collection and evaluation. The Corps and the USGS should extend their collaborative efforts and develop a detailed Missouri River sediment budget for the headwaters to the river’s mouth, with provisions for continuing revisions and updates as new data become available.”

-National Research Council, 2011

Why is a Sediment Budget Important?

- The sediment budget of a reach determines physical channel form

\[(\text{Inputs} + \text{Gains}) - (\text{Outputs} + \text{Losses}) = \text{Residual}\]

- Residual $= 0$, Equilibrium
- Residual $< 0$, Degradating
- Residual $> 0$, Aggrading
Why is a Sediment Budget Important?
Why is a Sediment Budget Important?

- Quantifying sources of sediment in a budget also is a means of determining effectiveness of erosion and nutrient runoff reduction and targeting effective management activities.
Objectives of Study—A Starting Point

- Using existing information, establish the initial framework for a sediment budget with which to update the National Research Council (2011) conceptual sediment budget (Lower Missouri River, post-impoundment period).

- When and where possible, incorporate bedload transport into the generalized sediment budget.
Sediment Sample Collection

- **Objective** – Collect samples representative of sediment concentration over entire cross section
- Suspended sediment concentrations can vary 500 to 1000 percent from top to bottom and bank to bank
  - Equal-Discharge Increment samples
  - Depth-Integrated samples
Equal-Discharge Increment Sample Collection

- Discharge measurement needed
- Break up discharge into 4-7 equal increments
- Find horizontal center of each increment
- Collect depth-integrated sample at each increment center
### Sediment-Load Categories

<table>
<thead>
<tr>
<th>By origin</th>
<th>By transport</th>
<th>By sampling method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wash load</td>
<td>Suspended load</td>
<td>Suspended load</td>
</tr>
<tr>
<td>Bed-material load</td>
<td>Bed load</td>
<td>Unsampled load</td>
</tr>
</tbody>
</table>

- **Total sediment load**: Wash load and bed-material load combine to form the total sediment load.
- **Suspended load**: Represents more than 90% (70-90+%) of the total sediment load.
- **Unsampled load**: The unsampled load is also part of the total sediment load.

**Diagram**

- **Stream current**:
  - Stream current moving water and suspended load.
- **Solution load (dissolved)**:
  - Dissolved substances in the water flow.
- **Bed load**:
  - Sediment and bedload materials on the streambed.
- **Rolling grain**:
  - Sediment grains rolling along the bed.
- **Traction**:
  - Sediment grains moving due to water flow.
- **Saltation**:
  - Sediment grains bouncing off the bed.

**USGS**

- **Suspended load**:
  - Particles in suspension due to stream flow.
- **Unsampled Bedload**:
  - Bedload material not sampled in the study.
Sediment Budget—Temporal and Spatial Scales

- Geographic (reach, segment, basin)
- Temporal (daily, monthly, annual, long-term period of record)
Components of Sediment Budget

Equilibrium—input + gains = output + losses
Degradation—input + gains < output + losses
Aggradation—input + gains > output + losses
Suspended-Sediment Data Availability, 1968-2014

- **Annual loads**

6 sites with complete record

22 stations <50% record

1. Missouri River at Yankton, SD
2. James River at Scotland, SD
3. Vermillion River at Vermillion, SD
4. Big Sioux at Akron, IA
5. Missouri River at Sioux City, IA
6. Floyd River at James, IA
7. Monona-Harrison Ditch at Turin, IA
8. Little Sioux at Turin, IA
9. Soldier River at Piegah, IA
10. Boyer River at Logan, IA
11. Missouri River at Omaha, NE
12. Platte River at Louisville, NE
13. Missouri River at Nebraska City, NE
14. Nishnabotna River at Hamburg, IA
15. Little Nemaha at Auburn NE
16. Big Nemaha River at Falls City
17. Nodaway River at Clarinda, IA
18. Missouri River at St. Joseph, MO
19. Platte River at Sharps Station, MO
20. Kansas River at DeSoto, KS
21. Missouri River at Kansas City, MO
22. Blue River at KC, MO
23. Grand River at Sumner, MO
24. Chariton River at Prairie Hill, MO
25. E FK Little Chariton nr Huntsville, MO
26. Blackwater River R + Lamire R
27. Missouri River at Boonville, MO
28. Moreau River nr Jefferson City, MO
29. Osage River at St. Thomas, MO
30. Gasconade R abv Jerome, MO
31. Missouri River at Hermann, MO
32. Missouri River at St. Charles, MO
33. Mississippi River at Grafton, IL
34. Mississippi River at St. Louis, MO

Upstream:
- 33 stations
- 8 Missouri River main stem
- 23 tributaries
- 2 MS River stations

Downstream:
Suspended-Sediment Data Availability

- **Daily loads**

![Graph showing suspended-sediment data availability over time for various locations.](image-url)
Sediment Data Availability

- Bedload
Sediment Budget, 1968-2014, Yankton to Sioux City

Inputs
- 330,800 tons
  + Gains
  1,000,000 tons
  - Losses
  - Output
  11,200,000 tons

(Inputs + Gains) – (Loss + Outputs)
- 9,806,000 tons/yr,
  - 87.8% of Sioux City load

Bedload: ? No data

Residual < 0, Degrading
Stage Trends-Gavins Point Dam Tailwaters

-7 feet downstream of Gavins Point Dam between 1968-2012
Sediment Budget, 1968-2014, Omaha to Nebraska City

Omaha
18,800,000 tons

Platte R
11,100,000 tons

Inputs + Gains – Outputs+Losses
-513,000 tons/yr, -1.7%

Bedload?

MRRP (2000-09)
+137,000 tons/yr

Nebraska City
30,200,000 tons

Other Losses?
## Long-term (1968-2014) Budget Residuals

<table>
<thead>
<tr>
<th>Reach</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Gavins Point to Sioux City</td>
<td>-87.8%</td>
</tr>
<tr>
<td>2 Sioux City to Omaha</td>
<td>-9.2%</td>
</tr>
<tr>
<td>3 Omaha to Nebraska City</td>
<td>-1.7%</td>
</tr>
<tr>
<td>4 Nebraska City to St. Joseph</td>
<td>4.0%*</td>
</tr>
<tr>
<td>5 St. Joseph to Kansas City</td>
<td>-4.9%*</td>
</tr>
<tr>
<td>6 Kansas City to Hermann</td>
<td>0.1%*</td>
</tr>
<tr>
<td>7 Hermann to St. Louis</td>
<td>-6.9%</td>
</tr>
</tbody>
</table>

*Includes bedload estimate
Annual Variability in Sediment Budget Residuals, Omaha to Nebraska City, 1968-2014
Daily Variability in Sediment Budget Residuals, Omaha to Nebraska City, 1968-1976
Sediment Budget Data Gaps

- Bedload?
- Tributary sediment loads
- Bank erosion/channel storage?
- Flood-plain erosion/storage?

Flood-plain/Channel storage losses?

Sediment gains from bank erosion?
Surrogates and Technological Advancements in Sediment Monitoring

Continuous turbidity

Figure 1. Three self-cleaning nephelometric turbidity sensors—A, YSI Incorporated (Yellow Springs, Ohio) model 6136 turbidity sensor, B, Hydrolab (Loveland, Colorado) self-cleaning turbidity sensor, and C, Forest Technology Systems (Blaine, Washington) model DTS-12 turbidity sensor.

LISST-SL (real time particle size)
Time-lagged Multi-beam Surveys for Determining Bedload Transport

Huizinga (2015)
Questions?

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