Management of Reservoir Sedimentation

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Worldwide Office Locations
Design, Operation and Maintenance of Reservoirs

- Design Life Concept may not be valid

- Sustainability of Developed Resource:
  - Design
  - Operation
  - Management
Design Life Concept

- 30 to 50 year Design Life
- Engineering Economics
- Maintenance
- Refurbishment
Impacts of Sedimentation: Reliability of Yield
Sustainability: Reservoir Management

- Sediment Problem
- Sediment Management
Evaluation: Limitation of Engineering Economics

- Present Value of Distant Benefits diminishes
- Benefit Cost Ratio Reduces
Sustainability Criteria: Project Evaluation

- Role of Economic Analysis
- Comparison of Environmentally Acceptable Projects
- Comparison of Sustainable Projects
Sediment Yield
Reservoir Sedimentation: Capacity Reduction

- Average for world: 1% / year
- India: 0.5% / year
- Turkey: 0.4% to 2.4% / year
- China: 2.3% / year
Embalse el Camare, Venezuela

- Lack of Management
- Rapid siltation in a few years
- Complete collapse of agriculture
- Hauling of Drinking Water
Embalse el Camare, Venezuela
Sedimentation Management Techniques

- Reduction of Sediment Yield
- Mechanical Removal
- Sediment Routing
- Flushing
Mechanical Removal

- Dredging
- Hydro-suction / Syphoning
- Bypass Option
- Trucking
Hydrosuction / Syphoning
## Hydrosuction / Syphoning

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Period</th>
<th>Sediment Inflow</th>
<th>Sediment Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shiaohuashan</td>
<td>‘78-‘85</td>
<td>378,000</td>
<td>414,700</td>
</tr>
<tr>
<td>Yiuhe</td>
<td>‘80&amp;’83</td>
<td>442,300</td>
<td>268,100</td>
</tr>
<tr>
<td>Xihe</td>
<td>‘83&amp;’84</td>
<td>635,000</td>
<td>111,500</td>
</tr>
<tr>
<td>Tianjiawan</td>
<td>‘77-‘78</td>
<td>298,000</td>
<td>320,000</td>
</tr>
</tbody>
</table>
Bypass Option

Collection System

Siphon
## Routing vs Flushing: Difference

<table>
<thead>
<tr>
<th>Routing</th>
<th>Flushing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pass Incoming Sediment through</td>
<td>Remobilize Deposited Sediment</td>
</tr>
<tr>
<td>Total Load</td>
<td>Drawdown Flushing</td>
</tr>
<tr>
<td>Density Current</td>
<td>Emptying and Flushing</td>
</tr>
<tr>
<td>Venting</td>
<td>Flushing by Lateral Erosion</td>
</tr>
<tr>
<td>Bypassing of Flow</td>
<td></td>
</tr>
</tbody>
</table>
Conceptual Basics

Conventional Operation

Routing / Flushing

Outflowing Sediment

More Outflowing Sediment

Sediment

Sediment
Flushin

- Three Approaches
  - Drawdown Flushing
  - Emptying and Flushing
  - Flushing by Lateral Erosion
Drawdown Flushing

- Lower Water Surface Elevation
- Resuspend Deposited Sediment
- Examples: Noadehai & Guanting Reservoirs
Welbedacht Dam and Reservoir, South Africa

- Constructed: 1973
- Original Capacity: 114 million m³
- 1976 Capacity: 78 million m³
- 1991 Capacity: 17 million m³
Welbedacht Reservoir Long Section

- Position of Dam
- 1 in 5 Year Flood Level
- Stable Condition
- Position of Bridge
- 1988 Profile
- 1973 Profile
- Bed Profile
- Water Surface Profile

Elevation (m)

Section Number
Wepenaar Bridge
Welbedacht Flushing

FULL SUPPLY LEVEL = 1402.9 m

1991 BED BEFORE FLUSHING

SIMULATED BED PROFILE

1992 SURVEY OF BED

DAM

ELEVATION (m)

CHAINAGE (km)
Emptying & Flushing

- Favorable for use in small dams
- Most storage close to dam
- Sediment deposits scoured if gates open for several weeks
Emptying & Flushing

- Hengshan Reservoir
  - Small, Gorge Type
  - Reservoir
  - 1 km long
  - 13 million m³ Storage
  - 69 m High Dam
  - 2.6m low level outlet
  - Loss of 3.2 million m³ in first 8 years
<table>
<thead>
<tr>
<th>Year</th>
<th>Duration</th>
<th>Sediment Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974</td>
<td>37 days</td>
<td>1,167,000 t</td>
</tr>
<tr>
<td>1979</td>
<td>52 days</td>
<td>1,247,000 t</td>
</tr>
<tr>
<td>1982</td>
<td>19 days</td>
<td>425,000 t</td>
</tr>
<tr>
<td>1982</td>
<td>36 days</td>
<td>749,000 t</td>
</tr>
<tr>
<td>1986</td>
<td>30 days</td>
<td>547,000 t</td>
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</tbody>
</table>
MBashe Hydroelectric Scheme, Transkei

- Diversion Structure
- One 2m x 3m Gate
- Complete Drawdown: Does not compromise project
- Sediment Concentration
Flushing by Lateral Erosion

- Low Dam
- Trench
- Sluice
- Dam
- Diversion Canal
# Flushing by Lateral Erosion

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Sediment Inflow/a (m³)</th>
<th>Time</th>
<th>Sediment Flushed (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heisonglin</td>
<td>530,000</td>
<td>'80-'85</td>
<td>816,000</td>
</tr>
<tr>
<td>Guanshan</td>
<td>120,000</td>
<td>'84-'88</td>
<td>344,000</td>
</tr>
<tr>
<td>Honggi</td>
<td>148,000</td>
<td>'88-'89</td>
<td>80,800</td>
</tr>
<tr>
<td>Shiaodaokeuo</td>
<td>415,000</td>
<td>'82</td>
<td>175,900</td>
</tr>
</tbody>
</table>
Sediment Routing
Routing: Bypassing of Sediment
Nagle Dam & Reservoir

- Flood Weir
- Flood Gates
- Mgeni River
- To Pietermaritzburg
First Falls Hydroelectric Scheme, Transkei

- Large Gates
- Critical Flow Conditions
- Routing and Flushing
- Wide Channel
Routing: Sanmanxia Reservoir

Large Reservoir

Combination of Techniques
- Sediment Flushing
- Sediment Routing
- Density Current
- Venting
Density Current Venting (Routing Technique)
## Density Current Venting

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>% of Density Current Sediment Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guanting</td>
<td>20% to 32%</td>
</tr>
<tr>
<td>Liujiangxia</td>
<td>52% to 87%</td>
</tr>
<tr>
<td>Sanmenxia</td>
<td>6% to 34%</td>
</tr>
<tr>
<td>Fengjiashan</td>
<td>23% to 65%</td>
</tr>
</tbody>
</table>
Cogwell Dam and Reservoir, California

- Flood Control and Environmental
- Previous Removal by Trucking: 3 mill cy
- Proposed Strategy: Trucking and Sediment Routing
Project Location

Devil's Canyon Branch of Cogswell Reservoir
Area = 11,041 acres

Cogswell Dam

Chileno Canyon
Area = 1913 acres

Little Mermaid's Canyon
Area = 4200 acres

Big Mermaid's Canyon
Area = 1370 acres

San Gabriel Branch of Cogswell Reservoir
Area = 14,068 acres

Glen Canyon
Area = 1147 acres

End of surveyed cross sections (Wild Trout Bridge)
Project Goal

Minimize Sediment Deposition in Reservoir

Maximize Environmental Benefit
Cogswell Dam and Reservoir Operating Strategy

- Sediment pass-through during Flood Season
- Use Low Level Gates
- Mechanical Removal Periodically
Sluice Gate Structure

- **Dimensions:** 6’ x 6’ Square Sluice
- **Free-flow Discharge Capacity:** 200 cfs
- **Sill Elevation:** 2171.0 ft
Simulated Sediment Outflow: Flood Season
Current Operating Policy

Sediment Outflow: 15-Oct to 14-Apr
Flood Season

Water Discharge (cfs)
Simulated Sediment Outflow: Flood Season
FAST - Policy 2

Water Discharge (cfs)

Sediment Outflow: 15-Oct to 31-Mar
Flood Season

Golder Associates
<table>
<thead>
<tr>
<th>Operating Policy</th>
<th>Percentage of Sediment Deposited</th>
</tr>
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<tbody>
<tr>
<td>Policy 1</td>
<td>72 %</td>
</tr>
<tr>
<td>Policy 2</td>
<td>54 %</td>
</tr>
<tr>
<td>Policy 3 (Current)</td>
<td>93 %</td>
</tr>
</tbody>
</table>
Cogswell: Economic Benefit

- Policy 3 (Current)
- Policy 1
- Policy 2
Summary

- Need for Sustainable Water Resource Development
- Management of Reservoir Sedimentation
- Variety of Techniques / Combination of Techniques
- Feasibility: International Experience