Least Tern Island Project
Endangered Engineering

Design Team
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Sponsor

The U.S. Army Corps of Engineers ®
Tulsa, Oklahoma District
The U.S. Army Corps of Engineers
Project Proposal

• Create a method for establishing an ideal Least Tern habitat
• Must be cost effective
• Create little impact to the natural surroundings
• Provide long term sustainability
Least Tern Habitat Preferences

• 10% to 0% vegetation cover
• Sandy, sloping beaches
• Large island
  • Greater than one acre

Adult Interior Least Terns
Island Requirements

- Island must be at a height in which vegetation can be scoured off by flooding
- Maintain a constant flow on all sides
  - Keep out predators and recreational vehicles
  - Prevent land bridging
- Island Area should be about 2 to 3 acres
Flow Requirements

- **1 year flood flow** – 40,000 cfs
  - Scour vegetation from the top of the island
- **Average flow** – 25,000 cfs
  - Maintain proper scour around the island
  - Island visible above waterline
- **Minimum flow** – 2,000 cfs
  - Prevent land bridging
Island Flow and Stage Comparison

- 10 ft: 40,000 cfs
- 8 ft: 25,000 cfs
- 1.5 ft: 2,000 cfs
Location Specifications

- Straight reach immediately upstream and downstream
- Proper flows available
- Stable banks
- Large sediment transport capabilities
- Between Keystone Dam & Muskogee, OK
- Tributaries immediately upstream and/or downstream
Army Corps Arkansas River Inspection

- Jerry Sturdy, Army Corps Biologist, conducted the inspection
- Air boat tour of the Arkansas River - Jenks Bridge to just past Bixby Bridge
- Observed examples of both good and bad island habitats

U.S. Army Corps Air Boat
Proposed Design Top View

Flow

1/2 River Width

Riprap

Dimensions & quantity of riprap will depend on flow rate.
Proposed Design Side View

Top View
Flow
Cut Location

Cross Section View at Cut Location
Flow
Stream Bed

Dimensions & quantity of riprap will depend on flow rate.
ARS Hydraulics Lab

- Adjacent to Lake Carl Blackwell, Stillwater, OK
- Contributing ARS Personnel – Kem Kadavy, Sherry Britton, and Darrel Temple
- Physical scale model
  - Concrete flume
  - Regime theory
Concrete Flume

- 90ft x 6ft x 10ft
- Flow rate available – 3 cfs
  - Measured by a 4 inch orifice and manometer
- Concrete sand as bed material
  - $D_{50} = 0.6 \text{ mm (0.024 in)}$
- Various sizes of gravel utilized for island structure material
  - Diameter 4 to 1 in
Regime Theory

- **Width** $\propto Q^{1/2}$
  - Scaling factor $= 1000/6 \approx 165$
- **Depth** $\propto Q^{1/3}$
  - Scaling factor $= 40$
- **Bed material of model = bed material of river**

<table>
<thead>
<tr>
<th>River Flow (cfs)</th>
<th>River Depth (ft)</th>
<th>Model Flow (cfs)</th>
<th>Model Depth (in)</th>
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<td>25,000</td>
<td>8</td>
<td>.92</td>
<td>2.4</td>
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ARS Concrete Test Flume
Model Construction

Prepare Level Bed

Prepare Structures Using Template
Bed and Water Surface Profile
Week 1

Flume Profiles

- Channel Bed
- Q=2.17
- Q=1.49
- Q=0.98

Steel Channel Iron @10.2
Tarp Board @ 72.1
Tailwater Control Area
Concrete Floor
Velocity Analysis with Confetti

Week 2

0 seconds
3 seconds
6 seconds
10 seconds

Flow
Final Design
Units in inches

Side View of Island Structures

Flow →
Flume Surface Graph

Station Perpendicular to Flume (ft)

Station Parallel to Flume (ft)

- 1.5-1.6
- 1.4-1.5
- 1.3-1.4
- 1.2-1.3

Station Perpendicular to Flume (ft)
Flume Surface Results

<table>
<thead>
<tr>
<th>Station Perpendicular to Flume (ft)</th>
<th>Station Parallel to Flume (ft)</th>
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<tr>
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Legend:
- Pink: 1.45-1.5
- Dark Blue: 1.4-1.45
- Light Blue: 1.35-1.4
- Blue: 1.3-1.35
- Red: 1.25-1.3
- Dark Red: 1.2-1.25
- Light Green: 1.15-1.2
- Pale Green: 1.1-1.15
- Yellow: 1.05-1.1
- Red Brown: 1-1.05
- Purple: 0.95-1.05
- Brown: 0.9-1.05
- Orange: 0.85-1.05
- Light Brown: 0.8-1.05
- Light Orange: 0.75-1.05
CCHE2D Computer Model

- Developed at the National Center for Computational Hydroscience and Engineering, University of Mississippi
- 2-D depth-averaged mass & momentum governing equations
Bed Shear for Flume Data
Velocities for Arkansas River Data
Design Verifications

- Flume modeling
  - Favorable amount of scour/deposition in appropriate areas
  - Stagnation of velocities behind structures

- Computer modeling
  - Stagnation of velocities behind structures
  - Low velocities area ~ 8 acres during Arkansas River simulation
  - Increase of velocities around structures

- Velocity calculations
  - Velocities are great enough to scour vegetation during flow rates greater than 40,000 cfs
Riprap Calculation

- Colorado State University (CSU) Procedure as reported by Simons and Senturk (1977, 1992)
  - Safety Factor (SF) = 1.3
  - $D_{50} = 2.5$ ft (30 in)

\[
\eta = \frac{21 \tau_{\text{max}}}{\gamma (SG - 1) D_{50}}
\]

\[
\eta' = \eta \frac{1 + \sin(\lambda + \beta)}{2}
\]

\[
SF = \frac{\cos \alpha \tan \phi}{\eta' \tan \phi + \sin \alpha \cos \beta}
\]
Construction for Full Scale Prototype

- Full Scale Riprap Structures
  - Based on an estimated $50/yd$^3$
  - $270,000 for material and construction
- Located in a straight reach within 1-2 miles of Polecat Creek (South of Jenks)
- Suggest stabilizing banks adjacent to the island with riprap
Arkansas River Prototype Side View

Flow
Stream Bed

5 ft
30 ft

300 ft
180 ft
10 ft
Arkansas River Prototype Top View
Recommendations

- Construct prototype during low flow periods
- Confirm design by constructing a small prototype
  - Riprap – $10,000
    - Front – 43ft x 10ft x 3ft
    - Rear – 56ft x 10 ft x 3ft
  - Quikrete® – $10,000
    - Front – 30.5ft x 7ft x 2.5ft
    - Rear – 40ft x 7ft x 2.5ft
  - Stabilize an existing island
Visit our website at

http://biosystems.okstate.edu/seniordesign/envr/