Restoration of the Salton Sea

Volume 2: Embankment Designs and Optimization Study

Figures
"Baseline" Mid-Sea Dam Characteristics and Assumptions:
1. Dam crest at E1-223 ft.
2. Pre-dredge mudline at E1-268 ft.
3. Upstream pool at E1-228 ft.
4. Downstream pool at E1-268 ft.
5. Dredge existing Seafloor Deposits to E1-280 ft.

**Figure 1**
ALTERNATE TYPICAL DAM
CROSS SECTION
CONSTRUCTABILITY REVIEW
8/4/2005
*Baseline* Mid-Sea Barrier Characteristics and Assumptions:

1. Embankment crest at El -247 ft.
2. Pre-dredge mudline at El -268 ft.
3. Upstream pool at El -252 ft.
4. Downstream pool at El -257 ft.
5. Dredge existing Seafloor Deposits to El -280 ft.
7. No post-dredging ground improvement (contrary to what is shown on this illustration).

**Note:** Base drawing taken from Reclamation's Statement of Work, dated April 11, 2006.

**FIGURE 2**
ALT. BARRIER
TYPICAL CROSS SECTION

**LEGEND**

- ROCKFILL - 1'-4' HARD DURABLE QUARRY ROCK, DUMPED UNDERWATER.
- FINE ROCKFILL - 3'-12' HARD DURABLE QUARRY ROCK, DUMPED UNDERWATER.
- SEMI-PERVIOUS CORE - SAND AND GRAVEL, BUCKET PLACED IN LAYERS UNDERWATER.

**NOTES:**

1. IN THE SOFT LACUSTRIAN DEPOSIT, JET GROUT UPSTREAM AND DOWNSHORE ZONES AND CONSOLIDATE MIDDLE ZONE WITH WICK DRAINS. (SEE DRAWING)
2. IN THE UPPER ALLUVIAL DEPOSIT, JET GROUT UPSTREAM AND DOWNSHORE ZONES (SEE DRAWING).

**SALTON SEA RESTORATION PROJECT**

**Constructability Review**
8/4/2005
*Baseline* Ring / Perimeter Dike Characteristics and Assumptions:
1. Embankment crest at El -240 ft.
2. Pre-dredge mudline at El -280 ft.
3. Upstream pool at El -240.5 ft (0.5 ft freeboard).
4. Downstream pool at El -255 ft.
5. Dredge existing Seafloor Deposits to El -265 ft (west side) or to El -270 ft (east side).
7. Bottom of Upper Alluvium at El -275 ft (west side).
"Baseline" Habitat Pond Earthfill Embankment Characteristics and Assumptions:

1. Embankment crest at E1 -241 ft.
2. Pre-dredge mudline at E1 -250 ft.
3. Upstream pool at E1 -241.5 ft.
4. Downstream pool at E1 -250 ft.
5. Dredge existing Sessfloor Deposits to E1 -260 ft.
6. Embankment founded on 5 ft of Upper Alluvium, underlain by 5 ft of Stiff Lacustrine, underlain by additional Upper Alluvium.

TYPICAL EARTHFILL EMBANKMENT FOR HABITAT PONDS

(NOT TO SCALE)

LEGEND

EMBANKMENT FILL - COMPACTED (IN THE DRY) EARTHFILL (CLAY, SILT)
Notes:
1. Refer to Figure 2 for section locations.
2. The subsurface conditions illustrated were obtained by interpolation between widely spaced explorations. Information on actual subsurface conditions exists only at locations of explorations; conditions between explorations may vary from those depicted.
3. The discussions in the text of this report should be reviewed to obtain a proper understanding of the nature of the subsurface conditions.
4. Complete boring logs and CPT data are presented in the appendices of this report.

Legend:
- Stratigraphy:
  - Seafloor Deposits
  - Soft Lacustrine Deposits
  - Upper Alluvial Deposits
  - Upper Stiff Lacustrine Deposits
  - Lower Alluvial Deposits
  - Lower Stiff Lacustrine Deposits

Data Plotted Next to Exploration:
- For CPTs:
  - Qnt (ft):
    - 6 10 15 20 25 30
  - For Boreholes:
    - Wft 100

Source: URS, Figure 9, Date: 1-29-04.
Notes:

1. Refer to Figure 2 for section locations.
2. The subsurface conditions illustrated were obtained by interpolation between widely spaced explorations. Information on actual subsurface conditions exists only at locations of explorations; conditions between explorations may vary from those depicted.
3. The discussions in the text of this report should be reviewed to obtain a proper understanding of the nature of the subsurface conditions.
4. Complete boring logs and CPT data are presented in the appendices of this report.

Legend:

- Seafloor Deposits
- Soft Lacustrine Deposits
- Upper Alluvial Deposits
- Upper Silty Lacustrine Deposits
- Lower Alluvial Deposits
- Lower Silty Lacustrine Deposits

Data Plotted Next to Exploration:
For CPTs: 
Ωn (psf)
Ωm (psi)
Ωm (psi)

For Boreholes:
WCS
WCS

(VERTICAL SCALE = 400 X HORIZONTAL SCALE)
Notes:
1. Refer to Figure 2 for section locations.
2. The subsurface conditions illustrated were obtained by interpolation between widely spaced explorations. Information on actual subsurface conditions exists only at locations of explorations; conditions between explorations may vary from those depicted.
3. The discussions in the text of this report should be reviewed to obtain a proper understanding of the nature of the subsurface conditions.
4. Complete boring logs and CPT data are presented in the appendices of this report.

Legend:
Stratigraphy:
- Seafloor Deposits
- Soft Lacustrine Deposits
- Upper Alluvial Deposits
- Upper stiff Lacustrine Deposits
- Lower Alluvial Deposits
- Lower stiff Lacustrine Deposits

Data Plotted Next to Explanation:
For CPTs:

Qtn (tf)
0 90 100 150 200 250

For Borings:

WPF
0 10 100

Source: URS, Figure 11, Dated: 1-29-04.
Legend:

Stratigraphy:
- Seafloor Deposits
- Soft Locustine Deposits
- Upper Alluvial Deposits
- Upper Stiff Locustine Deposits
- Lower Alluvial Deposits
- Lower Stiff Locustine Deposits

Data Plotted Next to Exploration:
- For CPTs:
  - Qin (t-s) 0.5 120 360 180 50
  - For Boring:
    - NTX 0 100

Notes:

1. Refer to Figure 2 for section locations.
2. The subsurface conditions illustrated were obtained by interpolation between widely spaced explorations. Information on actual subsurface conditions exists only at locations of explorations; conditions between explorations may vary from those depicted.
3. The discussions in the text of this report should be reviewed to obtain a proper understanding of the nature of the subsurface conditions.
4. Complete boring logs and CPT data are presented in the appendices of this report.

(VERTICAL SCALE = 100 X HORIZONTAL SCALE)
Notes:

1. Refer to Figure 2 for section locations.
2. The subsurface conditions illustrated were obtained by interpolation between widely spaced explorations. Information on actual subsurface conditions exists only at locations of explorations; conditions between explorations may vary from those depicted.
3. The discussions in the text of this report should be reviewed to obtain a proper understanding of the nature of the subsurface conditions.
4. Complete boring logs and CPT data are presented in the appendices of this report.

Legend:

Stratigraphy:
- Seafloor Deposits
- Soft Lacustrine Deposits
- Upper Alluvial Deposits
- Upper Stiff Lacustrine Deposits
- Lower Alluvial Deposits
- Lower Stiff Lacustrine Deposits

Data Plotted Next to Exploration:
- For CPTs:
  - Gt (tbf)
  - 0 50 100 150 200
- For Springs:
  - 0 100

Source: URS, Figure 13, Dated: 1-29-04.
Approximately 5 feet of displacement

Displacement (mm) vs. $K_r$ (g)

- Surface-maximum
- Surface-mean
- Deconvolved-maximum
- Deconvolved-mean
- Model 1
- Model 2
- Model 3
- Model 4

Approximately 5 feet of displacement
TYPICAL CROSS-SECTION OF ROCKFILL DAM WITH JET GROUTED FOUNDATION

LEGEND

ROCKFILL: 1”-4” SOUND AND DURABLE QUARRY ROCK DUMPED UNDERWATER
FINE ROCKFILL: 5”-12” SOUND AND DURABLE QUARRY ROCK DUMPED UNDERWATER
TYPE A SAND/GRAVEL CORE: CLEAN SAND AND GRAVEL, BUCKET PLACED IN LAYERS UNDERWATER
FILTER BLANKET: LAYER OF TYPE A SAND/GRAVEL COVERED BY A LAYER OF FINE ROCKFILL, PLACED BY DUMPING UNDERWATER

SOIL-CEMENT-BENTONITE (SCB) SLURRY WALL (5’ WIDE)
BOTTOM OF WALL EL. ~350 OR 40 FEET BELOW SOFT/STIFF LACUSTRINE OR ALLUVIAL/STIFF LACUSTRINE INTERFACE

SEA FLOOR DEPOSITS (~268 TO ~280)
(TO BE REMOVED BENEATH DAM)

STIFF LACUSTRINE DEPOSITS (~305 TO UNKNOWN DEPTH)

SOFT LACUSTRINE AND/OR UPPER ALLUVIUM (~280 TO ~305)
TYPICAL CROSS-SECTION OF MODIFIED ROCK NOTCHES WITH MINIMUM FILTERS

Legend:
- **Rockfill**: 1"-4" sound and durable quarry rock dumped underwater
- **Fine Rockfill**: 3"-12" sound and durable quarry rock dumped underwater
- **Type A Sand/Gravel Core**: Clean sand and gravel, bucket placed in layers underwater
- **Filter Blanket**: Layer of Type A Sand/Gravel covered by a layer of fine rockfill, placed by dumping underwater

Sea Floor Deposits (~268 to ~280) (to be removed beneath dam)
Soft Lacustrine and/or Upper Alluvium Deposits (~280 to ~305)
Stiff Lacustrine Deposits (~305 to unknown depth)
TYPICAL CROSS-SECTION OF MODIFIED ROCK NOTCHES WITH MAXIMUM SEISMIC FILTERS

LEGEND:
- ROCKFILL: 1'-4" SOUND AND DURABLE QUARRY ROCK DUMPED UNDERWATER
- FINE ROCKFILL: 3'-6" SOUND AND DURABLE QUARRY ROCK DUMPED UNDERWATER
- TYPE A SAND/GRAVEL CORE: CLEAN SAND AND GRAVEL, BUCKET PLACED IN LAYERS UNDERWATER
- FILTER BLANKET: LAYER OF TYPE A SAND/GRAVEL COVERED BY A LAYER OF FINE ROCKFILL, PLACED BY DUMPING UNDERWATER
- SOIL-CEMENT-BENTONITE (SCB) SLURRY WALL (5'-8" WIDE), BOTTOM OF WALL EL. -350 OR 40 FEET BELOW SOFT/STIFF LACUSTRINE OR ALLUVIAL/STIFF LACUSTRINE INTERFACE
- WCK DRAINS (5'-FOOT CENTERS) IN SOFT LACUSTRINE
- DAM CREST ELEV. -225 MINIMUM 5.0' ABOVE NORMAL POOL
- SAND/GRAVEL CORE (TYPE A)
- DAM
- 30.0'
- 50.0'
- 280.0'
- 40.0'
- 20.0'
- 85.0'
- SOFT LACUSTRINE AND/OR UPPER ALLUVIUM DEPOSITS (-280 TO -305)
- SEA FLOOR DEPOSITS (-200 TO -280) (TO BE REMOVED BENEATH DAM) ALTERNATIVE NOTCH OUTLINE CONSIDERED IN STABILITY EVALUATIONS

0 50 100 200 300
SCALE IN FEET

SALTON SEA RESTORATION PROJECT
Enhancement Designs and Optimization Study

OPTION D
MODIFIED ROCK NOTCHES/DAM WITH MAXIMUM SEISMIC FILTERS

KLEINFELDER

Project: 71930
By: KAV/SUMB
Date: August 2008
FIGURE 4.13
TYPICAL CROSS-SECTION OF "OPTIMIZED" SOUTH SEA DAMS WITH STONE COLUMNS

- Sand/Gravel Embankment Fill (Type A) with Stone Columns (Seismic Design)
- 3' Coarse Blanket Drain Layer (Type B)
- Sand/Gravel Embankment Fill (Type A) w/o Stone Columns
- 6" Thick Riprap Slope and Crest Protection
- Sand/Gravel Shell (Type B)

SOIL-CEMENT-BENTONITE (SCB)
Slurry Wall (3' wide) up to 30' into stiff lacustrine, depth determined with additional explorations during construction.

Wick Drains (5-foot Centers)

TYPICAL CROSS-SECTION OF SOUTH SEA DAM IN 6-MILE ZONE WHERE POTENTIAL FAULT RUPTURE MAY OCCUR

- 126.0' Stone Column Placement Platform
- CREST EL. -220 Minimum 10' above normal pool
- 2.5:1 Upstream and Downstream slopes

MULTIPLE SOIL-CEMENT-BENTONITE (SCB)
Slurry Walls (3' wide) up to 40' into stiff lacustrine, depth determined with additional explorations during construction. Total of 3 walls, side-by-side to be constructed.

Wick Drains (5-foot Centers)

FINE ROCKFILL
Sand/Gravel Embankment Fill (Type B)

SOIL-CEMENT-BENTONITE (SCB)

WICK DRAINS (5-FOOT CENTERS)

LEGEND
- Sand/Gravel Embankment Fill (Type A): Fine to Coarse Sand and Gravel, mix with maximum 3/4-inch gravel
- Sand/Gravel Shell (Type B): Fine to Coarse Sand and Gravel with Variable Fines Not Intended for Compaction with Stone Columns
- Stone Columns: 3' dia. Stone Columns, 10' on centers, installed in Type A Sand/Gravel (Triangular Pattern)
- Riprap Slope Protection: 1'-6" Diameter Sound and Durable Quarry Rock Dumped Underwater
- Fine Rockfill: 1'-6" Sand and Gravel

Project: 71932  By: KAF/CUMB  Date: August 2006  FIGURE 5.1
TYPICAL CROSS-SECTION OF NORTH SEA SAND DAM WITH STONE COLUMNS

NOTES
SOLID LINES SHOW THE IDEALIZED SECTION USED IN STABILITY AND SEEPAGE ANALYSES. DASHED LINES SHOW THE SECTION FOR CONSTRUCTION USING CONVEYOR PLACEMENT METHODS.

LEGEND
- SAND/GRAVEL EMBANKMENT FILL (TYPE A): FINE TO COARSE SAND AND GRAVEL, MIX WITH MAXIMUM 3/4-INCH GRAVEL SIZE AND MAXIMUM 10% FIES SUITABLE FOR COMPACTION WITH STONE COLUMNS
- SAND/GRAVEL SHELL (TYPE B): FINE TO COARSE SAND AND GRAVEL WITH VARIABLE FINES NOT INTENDED FOR COMPACTION WITH STONE COLUMNS
- TYPE A WITH STONE COLUMNS: 3' DIA. STONE COLUMNS, 10' ON CENTER, INSTALLED IN TYPE A SAND/GRAVEL (TRIANGULAR PATTERN)
- RR RAP SLOPE PROTECTION: 1'-4" DIAMETER SOUND AND DURABLE QUARRY ROCK DUMPED UNDERWATER

STATION (FT)

ELEVATION (FT, MSL)

0 50 100 200 300
SCALE IN FEET

SEA FLOOR DEPOSITS
(-264.9 TO -252.9)
(TO BE REMOVED
BELOW DAM)

STIFF LACUSTRINE DEPOSITS
(-305 TO UNKNOWN DEPTH)

SOIL-CEMENT-BENTONITE (SCB)
SLURRY WALL BOTTOM OF WALL EL.
-350 OR 40 FEET BELOW SOFT/STIFF
LACUSTRINE OR ALLUVIAL/STIFF
LACUSTRINE INTERFACE

STONE COLUMNS ON
10' CENTERS

50.0'

5.0'

5.0'

3.0' FILTER SAND BLANKET (TYPE A)

6.0' RIPRAP SLOPE PROTECTION

5' COARSE BLANKET DRAIN (TYPE B)

SAND/GRAVEL EMBANKMENT FILL (TYPE A)
WITH STONE COLUMNS (SEISMIC DESIGN)
W/O STONE COLUMNS (NON-SEISMIC DESIGN)

NORMAL POOL (EL. VARIES)

-223 MINIMUM 5' ABOVE NORMAL POOL.

WICK DRAINS (5-FOOT CENTERS)

WICK DRAINS (5-FOOT CENTERS)

STONE COLUMN PLACEMENT PLATFORM

DAM CREST ELEV.
TYPICAL CROSS-SECTION OF "OPTIMIZED" PERIMETER DIKE AND CONCENTRIC RING SAND DAMS WITH STONE COLUMNS (STATIC AND SEISMIC DESIGN CRITERIA ONLY)

NORMAL POOL
(EL. -230 OR LESS)

SOIL-CEMENT-BENTONITE (SCB) SLURRY WALL
(3' WIDE) UP TO 35' INTO UPPER STIFF LACustrine Depth determined with additional explorations during construction.

4'-THICK RIPRAP SLOPE AND CREST PROTECTION

75' STONE COLUMN PLACEMENT PLATFORM

Crest El. - 225
Minimum 5' Above Normal Pool

SAND/GRavel EMBANKMENT FILL (TYPE A)
WITH STONE COLUMNS (SEISMIC DESIGN)

SAND/GRavel EMBANKMENT FILL (TYPE A)

SAND/GRavel SHELL (TYPE B)

WICK DRAINS

3' COARSE BLANKET DRAIN LAYER (TYPE B)

SEA FLOOR DEPOSITS (-240 TO -243)
(TO BE REMOVED BELOW DAM)

SOFT LACustrINE AND/OR UPPER ALLUVIUM DEPOSITS (-243 TO -261)

STIFF LACustrINE DEPOSITS
(-261 TO UNKNOWN DEPTH)

46.0'

TYPICAL CROSS-SECTION OF "OPTIMIZED" PERIMETER DIKE AND CONCENTRIC RING SAND DAMS WITHOUT STONE COLUMNS (STATIC DESIGN CRITERIA ONLY)

NORMAL POOL
(EL. -230 OR LESS)

SOIL-CEMENT-BENTONITE (SCB) SLURRY WALL
(3' WIDE) UP TO 35' INTO UPPER STIFF LACustrine Depth determined with additional explorations during construction.

4'-THICK RIPRAP SLOPE AND CREST PROTECTION

Crest El. - 225
Minimum 5' Above Normal Pool

SAND/GRavel EMBANKMENT FILL (TYPE A)
W/O STONE COLUMNS (NON-SEISMIC DESIGN)

SAND/GRavel SHELL (TYPE B)

4:1 V UPSTREAM AND DOWNSTREAM SLOPES

WICK DRAINS

3' COARSE BLANKET DRAIN LAYER (TYPE B)

SEA FLOOR DEPOSITS (-240 TO -243)
(TO BE REMOVED BELOW DAM)

SOFT LACustrINE AND/OR UPPER ALLUVIUM DEPOSITS (-243 TO -261)

STIFF LACustrINE DEPOSITS
(-261 TO UNKNOWN DEPTH)

46.0'

LEGEND

SAND/GRavel EMBANKMENT FILL (TYPE A): FINE TO COARSE SAND AND GRavel, Mix With MAXimum 3/4-INCH GRavel SIZE and MAXimum 10% Fines Suitable For Compaction With Stone Columns

SAND/GRavel SHELL (TYPE B): FINE TO COARSE SAND AND GRavel With Variable FinE Not IntEned for Compaction With Stone Columns

STONE Columns: 3' Dia. Stone Columns, 10' On Centers, Installed In Type A Sand/Gravel (Triangular Pattern)

RIPRAP SLOPE PROTECTION: 1'-4' Diameter Sound and Durable Quarry Rock Dumped Underwater

United States
Department of the Interior
Bureau of Reclamation

SALTON SEA RESTORATION PROJECT
Embayment Designs and Optimization Study
“OPTIMIZED” PERIMETER AND CONCENTRIC LAKES SAND DAMS (DIKES) WITH AND WITHOUT STONE COLUMNS

KLEINFELDER
Project: T1130
By: JAF/CJMB
Date: August 2008

FIGURE 5.3
LEGEND

FILTER/DRAIN BLANKET (TYPE A): FINE TO COARSE SAND AND GRAVEL, MIX WITH MAXIMUM 3/4-INCH GRAVEL SIZE AND MAXIMUM 10X MIXES.
Risk Estimates
Alternative No 1

Notes:
These values are estimated based on maximum APF for static and seismic FMIs for each structure in the alternative.
Risk Estimates
Alternative No 2

Notes:
These values are estimated based on maximum APF for static and seismic FMIs for each structure in the alternative.

Mid-Sea Barrier without stone columns would have APF 1.0E-02 and ALL 0.0E-00.
Risk Estimates
Alternative No 3

Annual Failure Probability, f

Loss of Life, N

- Static-Concentric Ring Dikes (outer rings), Underseepage
- Seismic-Concentric Ring Dikes (outer rings) with mitigation design features, Translation
- Total Static Risk Estimate
- Total Seismic Risk Estimate
- Total Probability of Failure - All Loadings

Notes:
- These values are estimated based on maximum APF for static and seismic FMs for each structure in the alternative
- Outer Concentric Ring Embankment without design features mitigating translation failure, would have APF of 1.0E-02 (failure by translation) and ALL of 0.0E-00
- Inner Concentric Rings not meeting seismic or seepage design criteria, would have APF 1.0E-02 (Overtopping) and ALL of 0.0E-00

SALTON SEA RESTORATION PROJECT
Embarkment Designs and Optimization Study

KLEINFELDER
Project: 71103  By: KAF/CLES  Date: August 2006

FIGURE 6.3
Risk Estimates
Alternative No 4

Notes:
These values are estimated based on maximum APF for static and seismic FMs for each structure in the alternative.

- Static-North-Sea Dam, Based on FM No 2
- Static-Habitat Ponds, Under Seepage
- Seismic-North-Sea Dam, Based on FM No 6
- Seismic-Habitat Ponds, Overtopping
- Total Static Risk Estimate
- Total Seismic Risk Estimate
- Total Probability of Failure - All Loadings
Risk Estimates
Alternative No 5

Notes:
These values are estimated based on maximum APF for static and seismic FM for each structure in the alternative.

- Static-Habitat Ponds, Under Seepage
- Seismic-Habitat Ponds, Overtopping
- Total Static Risk Estimate
- Total Seismic Risk Estimate
- Total Probability of Failure - All Loadings