

TECHNICAL MEMORANDUM
SOIL SAMPLING, TESTING AND LOGGING
ULOP GEOTECHNICAL EVALUATION
STAR BEND SETBACK LEVEE
Sutter County, California

Prepared by:

BLACKBURN CONSULTING
2491 Boatman Avenue
West Sacramento, CA 95691

May 2016

Prepared for:

Wood Rogers, Inc.
3301 C Street, Bldg. 100-B
Sacramento, CA 95816

West Sacramento Office:
2491 Boatman Ave. ▪ West Sacramento, CA 95691
(916) 375-8706 ▪ Fax (916) 375-8709



Main Auburn Office: (530) 887-1494
Fresno Office: (559) 438-8411
Modesto Office: (209) 522-6273

Geotechnical ▪ Geo-Environmental ▪ Construction Services ▪ Forensics

BCI File No. 3012.X
July 12, 2016

Mr. Jay Punia
Wood Rodgers, Inc.
3301 C Street, Bldg. 100-B
Sacramento, CA 95816

Subject: **Technical Memorandum**
 Soil Sampling, Testing and Logging
 ULOP Geotechnical Evaluation
 Star Bend Setback Levee
 Sutter County, California

Dear Mr. Punia,

Blackburn Consulting (BCI) prepared this Soil Sampling, Testing and Logging Technical Memorandum (TM) in accordance with our Subconsultant Agreement for the Star Bend ULOP Geotechnical Evaluation, dated April 1, 2016. This TM summarizes the soil sampling, testing and logging completed for the Star Bend Setback Levee design and construction.

Please contact us if you have questions or require additional information.

Sincerely,

BLACKBURN CONSULTING

Kristy Chapman
Project Engineer

Robert B. Lokteff, C.E., G.E.
Principal Geotechnical Engineer

**TECHNICAL MEMORANDUM
SOIL SAMPLING, TESTING AND LOGGING
ULOP GEOTECHNICAL EVALUATION
STAR BEND SETBACK LEVEE
SUTTER COUNTY, CALIFORNIA**

TABLE OF CONTENTS

1. PURPOSE1

2. SCOPE OF SERVICES1

3. PROJECT DESCRIPTION.....1

4. DOCUMENTATION OF ULOP COMPLIANCE.....2

4.1 Soil Sampling and Logging.....2

4.2 Laboratory Testing.....2

 4.2.1 Design2

 4.2.2 Construction.....3

4.3 Conclusions5

5. REFERENCES5

6. LIMITATIONS6

ATTACHMENT A – Compliance Statement Section 7.3 – Soil Sampling, Testing and Logging

FIGURE 1 – Vicinity Map

FIGURE 2 – Site Plan

FIGURE 3 – Surficial Geology Map

APPENDIX A – 2006 Geotechnical Report for Star Bend Setback Levee

APPENDIX B – 2007 Geotechnical Report for Star Bend Setback Levee Addendum No. 1

APPENDIX C – Subsurface Explorations by URS for Urban Levee Evaluation

APPENDIX D – Graphical Representation of Construction QA/QC Test Results

1. PURPOSE

Blackburn Consulting (BCI) prepared this Technical Memorandum (TM) for Wood Rodgers, Inc. (WR) to support their Urban Level of Flood Protection (ULOP) finding for the Star Bend Setback Levee located in Sutter County, California. This TM documents that the Star Bend Setback soil sampling, testing and logging performed for levee design substantially meet the May 2012 Urban Levee Design Criteria (ULDC), Section 7.3.

A Compliance Statement by the registered professional engineer in responsible charge of this work is provided in Attachment A.

2. SCOPE OF SERVICES

BCI performed the following to prepare this TM:

- Reviewed Star Bend Setback Levee construction documents. See Section 5 of this report.
- Reviewed the BCI Star Bend Setback Levee 2006 Geotechnical Report and 2007 Geotechnical Report Addendum No. 1 subsurface explorations and laboratory test data.
- Compared the reviewed soil sampling, testing and logging information to the May 2012 ULDC criteria.

3. PROJECT DESCRIPTION

BCI prepared the Star Bend Setback Levee 2006 Geotechnical Report and 2007 Addendum No. 1 to Geotechnical Report in accordance with the US Army Corps of Engineers (USACE) design criteria available at the date of the design. The design included a soil-bentonite (SB) slurry cutoff wall to mitigate underseepage deficiencies associated with a relatively impervious near-surface silt/clay “blanket” and underlying sand aquifer. The levee and cutoff wall construction were completed in 2009. BCI provided geotechnical engineering support during construction.

The levee is approximately 20 to 25 feet tall with 3:1 (horizontal to vertical) waterside and landside side slopes and a levee crest width of approximately 20 feet. The total length of the setback levee is approximately 3,300 feet. The levee embankment was constructed of soil that met the USACE criteria for compaction, moisture content, Plasticity Index, Liquid Limit and fines content. The SB slurry cutoff wall depth ranges from about 42 to 65 feet. The wall extends through the sand aquifer and terminates in a silt/clay layer underlying the aquifer.

A Vicinity Map of the Star Bend Setback Levee is included as Figure 1. A Site Plan showing subsurface explorations and pre-construction topography is included in Figure 2. A Surficial Geology Map is included as Figure 3.

4. DOCUMENTATION OF ULOP COMPLIANCE

This section describes the quantity and type of subsurface explorations performed, the quantity and type of laboratory tests performed, and the type and general results of tests performed during the Star Bend Setback Levee design and construction.

1.1 Soil Sampling and Logging

BCI performed a total of 13 exploratory borings, 13 Cone Penetrometer Tests (CPTs), and 36 test pits for the Star Bend Setback Levee design in 2006 and 2007 to obtain subsurface soil and ground water information and samples for laboratory tests. An experienced BCI engineer/geologist logged the soils encountered in the exploratory borings and test pits consistent with the Unified Classification System (USCS) and BCI's field logging manual, and obtained pocket penetrometer measurements on fine-grained soil samples. BCI made ground water observations in the borings during drilling operations. Figure 2 presents the locations of the exploratory borings, CPTs, and test pits.

Appendix A and B contain the BCI Star Bend Setback Levee 2006 Geotechnical Report and 2007 Geotechnical Report Addendum No. 1, respectively. The documents include boring logs, test pit logs, CPT plots and sampling methodology for the design explorations.

Design explorations included:

- 11 exploratory borings and CPTs to depths of 61.5 to 105.5 feet below the ground surface (bgs) along the new setback levee alignment.
- 4 exploratory borings and CPTs to depths of 26.5 to 76.5 feet bgs waterside of the new setback alignment on the old, existing levee crown.
- 11 exploratory borings and CPTs to depths of 6.5 to 90 feet bgs landside of the new setback levee alignment.
- 9 test pits to depths of 5.5 to 13 feet bgs along the new setback levee alignment.
- 27 test pits to depths of 5 to 19 feet bgs in waterside borrow areas.

BCI also used 7 explorations performed by URS for the State of California, Department of Water Resources, Urban Levee Evaluation. These explorations along the old, existing levee crown (waterside of the new Setback Levee alignment) ranged in depth from 110 to 140 feet bgs. The explorations included 3 exploratory boring and 4 CPTs. Appendix C presents the exploration boring logs and CPT plots.

1.2 Laboratory Testing

1.2.1 Design

BCI performed laboratory tests on representative soil samples obtained from the exploratory borings and test pits. Tests included:

- Moisture content and dry unit weight (ASTM D2216) to estimate in-situ soil conditions and design parameters.
- Sieve analyses (ASTM D422) and percent finer than the No. 200 sieve (ASTM D1140) to estimate particle size distribution for hydraulic conductivity correlations and liquefaction analysis.
- Atterberg limits (ASTM D4318) to determine the liquid limit, plastic limit and plasticity index for hydraulic conductivity correlations and settlement parameter correlations.
- Optimum moisture and maximum density compaction curves (ASTM D698) to estimate parameters for remolded triaxial compression tests and stability analysis.
- Unconfined compressive strength (ASTM D2166) to estimate strength parameters for stability analysis and settlement parameter correlations.
- Consolidated undrained triaxial compression with pore-water pressure measurements (ASTM D4767) to estimate strength parameters for stability analysis.

BCI performed laboratory tests in accordance with current ASTM test methods. The 2006 Geotechnical Report in Appendix A and 2007 Geotechnical Report Addendum No. 1 in Appendix B contain the complete lab result reports. Table 1 presents the BCI Star Bend Setback Levee test quantities.

Table 1: Quantity of Geotechnical Laboratory Tests Performed for Design				
Moisture Content and Dry Unit Weight	Sieve Analyses	Atterberg Limits	Strength Tests (UC and CUw/PP)	Compaction Curves
42	29	56	11	4

1.2.2 Construction

The Star Bend Setback Levee embankment and slurry cutoff wall construction included Quality Control (QC) and Quality Assurance (QA) tests to document compliance with the contract plans and specifications. Tables 2 through 4 summarize the quantity of tests performed and test result statistics from the construction closeout report. Graphical representations of the results are included in Appendix D.

Table 2: Levee Embankment Material						
	Liquid Limit	Plastic Limit	Plasticity Index	Passing No. 200 (%)	Max Dry Density (pcf)	Relative Compaction (%)
No. of Tests	1,262	1,262	1,262	1,259	901	901
Average Test Result	31	17	14	73	115	102
Median Test Result	31	17	14	72	115	102
Maximum Test Result	45	27	29	94	128	112
Minimum Test Result	22	12	7	22	102	94

Table 3: Soil Bentonite Cutoff Wall (42.1 ft) Station 11+16 to 30+00		
	Hydraulic Conductivity (cm/sec)	
	QC Testing	QA Testing
No. of Tests	38	9
Average Test Result	3.80E-08	4.38E-08
Median Test Result	3.64E-08	3.70E-08
Maximum Test Result	6.73E-08	6.70E-08
Minimum Test Result	2.32E-08	2.80E-08

Table 4: Soil Bentonite Cutoff Wall (65.0 ft) Station 29+50 to 46+00		
	Hydraulic Conductivity (cm/sec)	
	QC Testing	QA Testing
No. of Tests	33	7
Average	5.62E-08	6.64E-08
Median	5.87E-08	6.90E-08
Maximum	8.72E-08	8.40E-08
Minimum	3.07E-08	4.10E-08

1.3 Conclusions

BCI performed soil sampling, testing and logging during the Star Bend Setback Levee design in accordance with generally accepted geotechnical engineering principles and practices. These practices substantially meet the May 2012 ULDC, Section 7.3 criteria.

More specifically:

- BCI's soil sampling and logging procedures substantially comply with current USACE and DWR guidance documents.
- BCI's soil sampling, including soft soil sampling, for strength and deformation analysis are performed in a way that minimizes sample disturbance such as Shelby Tube sampling for soft soil.
- BCI used grain size analyses and correlations with the Sutter County USDA for hydraulic conductivity values. BCI compared these values with those used in the area for the Star Bend Setback Levee ULOP Underseepage Analysis for Intermittently Loaded Levees TM consistent with standard of care in the area for levee design.
- BCI performed the Star Bend Setback Levee settlement evaluation using estimated settlement parameters based on published correlations with in-situ test data and SPT data. No detrimental settlement has occurred since construction in 2009.
- BCI performed strength tests at appropriately low strain rates.
- BCI's field logging procedures substantially meet ASTM guidance as well as the DWR Manual.

Testing performed during construction documents that the materials used for the Star Bend Setback Levee embankment and slurry cutoff wall met the project specifications.

5. REFERENCES

Blackburn Consulting (BCI), October 2006, Geotechnical Report for Star Bend Setback Levee, Levee District No. 1, Sutter County, California, Prepared for Wood Rodgers, Inc. and Levee District No. 1.

Blackburn Consulting (BCI), November 2007, Addendum No. 1 to Geotechnical Report for Star Bend Setback Levee, Levee District No. 1, Sutter County, California, Prepared for Wood Rodgers, Inc. and Levee District No. 1.

URS, November 2008, Phase 1 Geotechnical Data Report (PIGDR) of the Sutter Study Area, prepared for the Urban Levee Geotechnical Evaluations Program (ULE)

MHM Incorporated, December 2010, Construction Completion Report for the Lower Feather River Setback Levee at Star Bend, Vol. 1, 2A, 2B and 3, Prepared for Levee District No. 1 Sutter County

Department of Water Resources (DWR), May 2012, Urban Levee Design Criteria (ULDC).

Department of Water Resources (DWR), November 2013, Urban Level of Flood Protection Criteria (ULOP).

6. LIMITATIONS

BCI prepared this TM for WR to support their ULOP finding report. This TM should not be used by others or for other projects without BCI's written permission.

The results and conclusions in this TM document substantial compliance with geotechnical aspects of design. This TM should not be interpreted as "certification" of the levee.

BCI performed services in accordance with generally accepted geotechnical engineering principles and practices currently used in this area. We do not warranty our services.

The analyses, results and recommendations presented in this TM are draft.

**TECHNICAL MEMORANDUM
SOIL SAMPLING, TESTING AND LOGGING
ULOP GEOTECHNICAL EVALUATION
STAR BEND SETBACK LEVEE**

FIGURES

Figure 1 - Vicinity Map

Figure 2 - Site Plan

Figure 3 - Surface Geology Map

**TECHNICAL MEMORANDUM
SOIL SAMPLING, TESTING AND LOGGING
ULOP GEOTECHNICAL EVALUATION
STAR BEND SETBACK LEVEE**

APPENDIX A

2006 Geotechnical Report for Star Bend Setback Levee

**TECHNICAL MEMORANDUM
SOIL SAMPLING, TESTING AND LOGGING
ULOP GEOTECHNICAL EVALUATION
STAR BEND SETBACK LEVEE**

APPENDIX B

2007 Geotechnical Report for Star Bend Setback Levee

Addendum No.1

**TECHNICAL MEMORANDUM
SOIL SAMPLING, TESTING AND LOGGING
ULOP GEOTECHNICAL EVALUATION
STAR BEND SETBACK LEVEE**

APPENDIX C

Subsurface Explorations by URS for Urban Levee Evaluation

**TECHNICAL MEMORANDUM
SOIL SAMPLING, TESTING AND LOGGING
ULOP GEOTECHNICAL EVALUATION
STAR BEND SETBACK LEVEE**

APPENDIX D

Graphical Representation of Construction QA/QC Test Results