TECHNICAL SPECIFICATIONS
L-31N SEEPAGE CONTROL PROJECT PHASE 1
CEMENT-BENTONITE SLURRY WALL

1.0 GENERAL

This Specification describes requirements for the construction of a Cement-Bentonite (CB) Slurry Trench Seepage Barrier (also termed CB wall) and related work, as indicated on the plans and project drawings and as hereinafter specified. The work consists of furnishing all labor, equipment, materials, and means of performing all operations, as required, for installing a CB wall. All references to the "Contractor" or "he" in this document refer to the company that will perform the operations for installing the CB wall.

The CB wall will have a minimum width of 32 inches and a minimum depth of 35 feet below ground surface as indicated on the plans and project drawings. The completed CB wall is intended to provide a partial barrier to groundwater and will have a permeability in the 10^{-6} cm/sec range and a minimum 28-day unconfined compressive strength (UCS) of 10 psi.

The CB wall will be constructed within a trench previously excavated in rock to the specified depth by others using an Austin Trencher Model AT 750 or equivalent mechanical drive chain trencher. The excavated trench will be backfilled to approximately ground surface using clean material less than 4 inches in maximum dimension excavated by the Trencher. The CB wall construction will involve re-excavation of the backfilled trench with simultaneous placement of CB slurry, as shown in the plans and project drawings and described in this specification.

Due to unique site conditions, and the importance of achieving satisfactory performance of the seepage barrier, Quality Control and Quality Assurance monitoring and testing will be exceptionally extensive and thorough. The first 1000' of trench construction will be a test section, with concentrated QA/QC testing to confirm that project specifications are being met, and satisfactory wall construction is being achieved. Results from the QA/QC testing in this section will be available while the contractor is proceeding with wall construction. If the results indicate unsatisfactory performance, construction will be suspended until an acceptable modification to the construction method can be implemented and tested. Any sections of constructed wall that do not meet specifications will be replaced.

The site is adjacent to Everglades National Park, which is a national treasure and environmentally sensitive. Precautions must be taken to avoid any on-site or off-site contamination. All areas disturbed by construction activities must be restored by the Contractor to pre-construction conditions.

1.1. Qualifications

The person responsible for the supervision and quality control of the CB slurry wall construction is designated as the CB Specialist. The CB Specialist shall be knowledgeable in all phases of CB wall construction including testing, inspection, quality control, and recordkeeping, and shall possess a minimum of five years experience including a minimum of five projects of similar size and scope, or larger. In particular, the CB Specialist shall be familiar with the means and

methods to perform the following: controlling composition, mixing, placing, cleaning, and maintaining slurry; supervising alignment and depth of slurry trenches; controlling mixing and placement of CB backfill, including backhoe operation and use of air lift. The CB Specialist shall be on the Site at all times during slurry trenching/backfill operations.

1.2. Characterization of Overburden Materials and Buried Utilities

A description of the typical strata through which the CB slurry wall is to be excavated is indicated by boring logs included in the plans and project drawings. In general, the slurry wall shall extend through the overburden and rock to a depth of 35 feet, which will penetrate lower permeability strata underlying the shallow Miami Oolite formation, as indicated in the plans and project drawings.

The CB wall is not expected to encounter buried utilities. Any known buried utilities will be identified by others prior to initial trenching by the Trenching operation, and any conflicts resolved prior to the start of CB work.

1.3. Reference Standards

Following is a list of standards, which will be referenced in this specification. Such referenced standards shall be considered part of this specification as if fully presented herein.

REFERENCE	TITLE OR DESCRIPTION
API Spec 13A	Specification for Drilling-Fluid Materials
API RP 13B-1	Recommended Practice Standard Procedure for Field Testing Water-Based Drilling Fluids
ASTM C 150	Standard Specification for Portland Cement
ASTM D 1633	Compressive Strength of Molded Soil-Cement Cylinders
ASTM D 4380	Density of Bentonite Slurries
ASTM D 4832	Preparation and Testing of Controlled Low Strength Material Test Cylinders
ASTM D 5084	Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

1.4. Submittals

A. Qualifications – The Contractor shall submit evidence that he is experienced and competent to construct a cement-bentonite slurry trench. The specialty slurry wall contractor shall have at least five years of prior experience in successful CB wall projects of similar size or larger.

The submittal shall include the qualifications of the CB Specialist who will supervise the construction, slurry preparation, and quality control, documenting at least five years of experience and at least five successful CB wall projects of similar size or larger during the past fifteen years.

The company name, key contact, and qualifications of the Contractor's Laboratory shall also be submitted. The laboratory shall have previous experience with CB slurry wall materials, experienced laboratory technicians, and permeability testing equipment meeting ASTM Standard D 5084.

B. CB Design Mix – At least two weeks prior to construction, the Contractor shall submit proportions and properties of the proposed CB design mix including cement, bentonite, additives, and water proportions; viscosity, density, Unconfined Compressive Strength, and permeability to the Owner's Representative for review and approval. A new project-specific laboratory design mix program is required.

The Contractor shall also perform a laboratory-scale test to verify that the CB design mix will meet the strength and permeability requirements of this Specification when diluted by a flowable sand-water mixture, in the ratio of 1 part sand-water to 3 parts CB slurry.. The diluted design mix will establish the maximum water content and minimum viscosity criteria for the wall construction.

The Contractor shall also submit the results of a laboratory test demonstrating the stability of the CB design mix when subjected to a standard Pinhole Dispersion Test (ASTM D4647).

C. Record Documents – Within thirty days after completing all field activities, Contractor shall submit a final report detailing mix proportions, testing data, daily logs, and all quality control records as specified herein.

The results of at least five laboratory tests shall be submitted demonstrating that the installed CB wall provides an Unconfined Compressive Strength within the range of 10 to 50 psi and a maximum permeability of 9×10^{-6} cm/sec.

D. Record Drawing – The Owner's Representative will make necessary surveys and measurements for "as-built" record drawings showing the actual depths and location of barrier wall together with any supplementary details at direction changes and other information as may be required to fully describe the installed Works.

2.0 CEMENT BENTONITE SLURRY

2.1 Materials

A. All materials used in the CB slurry wall will be subject to prior approval by the Owner's Representative. Owner, at his option, may provide suitable equipment and materials for Contractor's use.

B. Bentonite – Pulverized natural Wyoming sodium montmorillonite clay complying with American Petroleum Institute Specification API 13A, Section 9, 2004 edition.

C. Cement – ASTM C 150 Portland Type I or Type I-II.

D. Water – Water shall be clean, fresh, and free from excessive oil, acid, organic matter, or other deleterious substances. At the Contractor's option, water may be obtained from the adjacent L-31N canal, provided water quality requirements are met.

E. Additives –

- Additives of any kind must be approved by the Owner's Representative.
- Common water treatment additives may be used to correct water quality or enhance bentonite hydration and mixing. These additives may include soda ash, lime, or alum.
- Admixtures of softening agents, dispersants, retarders, or plugging or bridging agents may be added to the water or the slurry to permit efficient use of bentonite and proper workability of the cement-bentonite slurry.
- Retarders, thinners, and accelerators may be used to correct specific problems.
- Peptizing or bulking agents will not be permitted for mixing with slurry.

2.2 Delivery, Storage and Handling of Materials

A. Contractor shall make all arrangements for transportation, delivery, and handling of materials required for execution and completion of the CB wall. Owner, at his option, may provide equipment and materials for Contractor's use.

B. Materials shall be protected from moisture, spillage, and deterioration during transit to and storage at the Site.

C. For each shipment of materials, Contractor shall provide written certification of compliance from the manufacturer verifying that the materials meet the requirements of this Specification. Supplier's certified weight of each delivery of materials shall also be provided.

D. Any materials not meeting this Specification shall be promptly removed from the Site, and replaced with materials conforming to these requirements.

2.3 Mixtures

The proportions of the CB slurry shall be supervised by the Specialist. The Specialist may alter the proportions of the ingredients for workability or to provide greater strength where needed. The CB slurry shall harden to a material within the specified ranges of strength and permeability.

2.4 Panel Construction

CB wall construction is completed in discrete sections of backfilled trench known as panels. A portion of the CB slurry that hardens in the trench creates a vertical panel and the joined panels create the completed barrier wall. In general, each day's work, or separate portions of the day's work, may be considered a panel. Successful panel construction relies upon the proper placement of the CB slurry. The proper placement of CB slurry in panel construction includes the following:

A. Panel Construction – The slurry trench may be extended by alternating panels, by continuous excavation, or by a combination thereof provided the overlap requirements are met.

B. Overlaps – Panels are joined by excavating new panels into previously constructed panels, which is termed an overlap. Overlaps are generally limited to a distance of 2 feet as measured along the bottom of the slurry trench. Newly constructed panels shall not be disturbed, except for the jointing, topping-off, or capping, until the panel has hardened for a minimum of three days and demonstrates cement hydration. Untimely disturbing of a new panel may cause the panel to fail to harden properly.

C. Topping Off – It is normal for the surface of the CB panel to shrink, settle, bleed, and crack as it hardens. Shrinkage and bleed shall not be greater than 10%, and cracking shall not extend to a depth exceeding 1 foot. After the CB has hardened, the panel shall be completed by filling with fresh CB. After final filling, the CB shall be covered and capped as shown in the project drawings using a soil and bentonite mixture in order to prevent desiccation and damage.

D. Overbreak – The CB slurry will fill voids in the trench walls, grout soil pores, and fill the trench. In addition, CB slurry will be wasted in creating overlaps and by normal spillage. The volume of CB used, compared to the neat volume of the trench, shall be calculated daily. The excess volume, known as the overbreak, shall be monitored by the CB Specialist to ensure quality control, minimize waste, and avoid environmental impact.

3.0 EXECUTION

3.1 Sequence of CB Wall Construction

A. As the trenching machine excavation proceeds, the Contractor shall backfill the trench using excavated sand and gravel. Any peat or organic deposits will be separated from the backfill and removed from the construction area. Any cobbles greater than 4 inches in maximum dimension shall be removed from the backfill material and hauled from the site by others after loading by Contractor.

B. A previously constructed test CB wall extends for 1000 feet between approximate Station 48+00 to Station 58+00 to an approximate depth of 18 feet below ground surface, as shown on the Project Plans. Before the trenching machine reaches this area, Contractor shall pre-excavate the test wall and place the excavated material into haul trucks for removal by others.

C. The CB wall will be constructed by continuous excavation to the extent practical. If alternating panels are constructed, they shall be tied together by overlap into adjacent previously constructed panels to provide a continuous watertight barrier.

3.2 Equipment Requirements

A. Trench Excavation Equipment – A hydraulic excavator or backhoe shall be used for excavation. The design of the bucket shall maintain the specified width of the trench and minimize raveling of the trench sides during use. Equipment shall be capable of excavating the minimum required width in a single pass.

B. Slurry Mixing and Placing Equipment.

- Colloidal Mixer – A high-speed/high-shear colloidal mixer or high-velocity/ high-pressure venturi jet mixer shall be used in conjunction with a high speed/high-shear centrifugal pump. The pump may be dedicated to mixing and/or can be used to mix and deliver CB slurry to the trench.
- Colloidal Mix Tank – The mix tank shall be equipped with a mechanically or hydraulically agitated sump including vanes, valves, hoses, and other equipment as required to prepare slurry mixtures.
- Slurry shall not be prepared or mixed in the trench.
- CB slurry that has been in the mixer for more than three hours shall be wasted and not used for trench fill.

C. Field Laboratory Equipment – The following equipment shall be provided:

- Marsh funnel and cup.
- Mud balance (direct reading of density).
- Slurry sampler (backhoe bucket may be used).
- Cylinders to mold laboratory samples (2 inches diameter x 12 inches long).
- Water test kit including hardness, pH and alkalinity.
- Thermometer to measure slurry temperature and ambient temperature.

D. Trench Bottom Preparation Equipment – After the final pass of the excavator bucket at each location, the trench bottom will be cleaned using an appropriate air lift. If loose sediments are detected after passage of the air lift, additional excavating and air lift will be conducted until the trench bottom is clean of sediment.

3.2 Working Platform

The slurry trench shall be installed from a prepared, level, and stable surface. The purpose of the working platform is to support the excavation and to ensure access for proper measuring and quality control of the work. The working platform shall be maintained in a condition that minimizes the potential for loose soils or debris falling into the completed trench.

The cement-bentonite wall will be installed from the working platform, which will be along the centerline of the trench excavated by others on the lines and grades shown on the project drawings.

3.3 Slurry Trench Excavation

A. Excavate the backfilled 32-inch minimum width trench to a minimum depth of 35 feet at all points along the centerline of the excavation. Excavate the trench from the working platform by the slurry method.

B. Maintain trench full of slurry for trench support. Do not excavate below the groundwater table without slurry.

C. Excavation shall proceed in panels. CB slurry shall be introduced into the trench during trenching and slurry shall be maintained in the trench during excavation.

D. Maintain the stability of the excavated trench at all times for the full depth.

E. Slurry shall always be at least 2 feet above groundwater level and not more than 3 feet below the top of trench during excavation.

F. Once the CB mix is introduced into the trench, excavation shall be continuous. If excavation is delayed for more than two hours, agitate the panel by other means or incorporate additives to prevent the slurry from setting. If slurry in the trench begins to set or becomes unworkable before excavation is completed, terminate the panel. Do not add water to the slurry in the trench. CB slurry that does not set shall be removed and replaced.

G. When a trench segment is extended, and the slurry in the previously excavated trench has taken an initial set, the excavation shall extend into the previously excavated trench to provide a minimum overlap distance of 2 feet at the bottom of the trench.

H. Take precautionary measures necessary to minimize damage to the work from groundwater and surface runoff water.

I. Maintain the cement-bentonite slurry at all times in a condition that meets the requirements of this Specification. Provide constant circulation for any slurry that is not pumped directly to the trench.

3.4 Trench Bottom Treatment

A. After the final pass of the excavator bucket at each location, the trench bottom will be cleaned using an appropriate air lift capable of lifting gravel to cobble size particles. The air lift shall follow as close as practical behind the excavator bucket. The air lift shall discharge at the top of the slurry, at a location and depth readily accessible for observation and sampling.

B. The volume displaced by the air lift shall be sufficient to maintain the bottom of the trench free from sediment.

C. The Contractor shall sound the trench at 10-foot intervals behind the air lift using a weighted tape to determine the depth of the slurry. If the sounding indicates inadequate excavation or sedimentation of sand/gravel, additional excavation and air lift shall be conducted until the sounding indicates full depth of CB slurry.

D. If sediment is detected at the bottom of the trench after passage of the air lift, the viscosity and density of the CB slurry will be measured at the discharge of the air lift and increased as necessary using additional cement and bentonite.

E. At any location where sediment is detected, excavation shall not proceed until uniform slurry with entrained sand/gravel is determined to exist from top to bottom of the trench.

F. As the excavation proceeds, soundings at 10-foot spacing shall be repeated at every 50-foot interval, starting at the beginning of the 50-foot interval. All depth soundings shall be recorded and compared with subsequent soundings.

G. If any of the repeat soundings indicate sedimentation of sand/gravel, a sample will be taken at the bottom of the trench using an appropriate thief or piston sediment sampler. All such samples taken shall be photographed and placed in a 2-inch diameter sample mold for laboratory testing Based on the viscosity, water content, and composition of the sample, the Owner's Representative will determine if the sample meets the diluted design mix acceptance criteria, or whether additional excavation, air lift operation, or change in design mix composition is required..

H. The final depth of the CB wall shall be measured and checked by the Contractor and approved by the Owner's Representative following excavation. Unless otherwise directed, the bottom of the slurry trench will be, at a minimum, the depth of excavation by the trenching machine.

3.5 Trench Top Treatment

After initial hardening of the CB slurry, the top of the completed trench shall be checked for free water or surface depressions. Any free water or cracked CB material shall be removed and the trench filled with fresh CB slurry to the elevation specified in the project drawings. Following initial set of this additional CB grout, the top of the trench shall be protected to prevent drying of the slurry by placing a minimum 6 inches of loose soil.

After the CB slurry strength achieves the minimum specified strength, a soil-bentonite mixture shall be placed in 6-inch maximum loose lifts and compacted to a minimum 90% of standard Proctor density. The final cover shall be at the same elevation as the natural ground surface.

3.6 Cleanup

A. Material excavated from the trench shall be disposed of in designated off-site disposal areas by others. The Contractor shall be responsible for loading the excess material onto haul trucks in a suitable condition for over-the-road transport. After completion of the CB wall, the work areas shall be cleared of excess slurry and excavated materials, and graded to restore the original topography.

B. Prior to demobilizing, all wastes and excess materials and equipment shall be removed and all disturbed surface areas restored to original condition. Disturbed areas shall be grassed as shown on the project drawings.

3.7 Environmental Requirements

A. Erosion and sedimentation controls shall be placed as shown on the project drawings. If additional controls are needed to prevent damage or runoff to surrounding areas, they shall be provided by the Contractor.

B. Dust and particulate emissions during construction shall be controlled in accordance with local and Federal laws.

C. Any spills or releases, whether on-site or off-site, shall be immediately reported to the Owner's Representative. Any emergency actions required to minimize potential damage or impacts shall be immediately initiated by the Contractor.

D. Until project completion and demobilization, the installed barrier wall shall be protected from damage caused by equipment, vehicles, and other possible damaging influences.

4.0 QUALITY CONTROL

Quality control shall be the primary responsibility of the CB Specialist. The Specialist shall perform or supervise all operations, measurements, and tests. The Specialist shall prepare and maintain detailed records of the mixes, materials, tests, and excavation soundings. A summary of the required tests is shown in **Table 1**. The primary aspects of Quality Control include the following:

A. Maintain project quality control and quality control records. Perform quality control observations, measurements, and tests described in this Specification. Make quality control records, routine testing procedures, inspections, observations, and measurements. Quality Control testing methods and frequencies are shown in **Table 1**.

B. Obtain Certificate of Compliance from the material manufacturer for bentonite and cement.

C. Measure the viscosity, pH, and density of the bentonite slurry every shift, and each time the configuration of the plant is modified.

D. Measure the density of the cement-bentonite slurry at least four times per shift and any time sediment is detected at the bottom of the trench.

E. Measure the pH and the temperature of the CB slurry at the plant at least once per shift. Measure the pH and temperature of the CB slurry in the trench at least four times per shift.

F. Make molded samples of the fluid cement-bentonite slurry from the trench, two for each 100 lf of trench during the first 1000 lf of construction, and every 500 feet thereafter. The samples shall be properly cured and stored. One set of samples shall be delivered to the Owner's Representative. Any samples not destructively tested by the Contractor shall be retained for a minimum of ninety days. Additional samples that may be requested by the Owner's Representative shall be provided by the Contractor.

G. Excavation soundings shall be taken and recorded along the trench centerline at frequencies no greater than 10 feet apart, using a weighted tape, cable, or other suitable measuring device. Contractor shall place and maintain stakes, or other suitable reference points, at 20-foot intervals adjacent to trench, clearly indicating station and reference elevation on the stakes.

H. Records – Contractor shall maintain records of testing, measurements, and inspections performed to ascertain that the CB barrier wall construction meets the requirements of the Plans and Specifications. Contractor shall furnish reports, records, and documentation to Owner's Representative on a weekly basis during construction. Contractor shall maintain the following records:

- As-built profile of the trench bottom, including descriptions of typical materials encountered in the excavation, as determined from soundings.
- Results of construction control testing required by this Specification, including water tests, slurry tests, strength, and permeability tests. Records of observations, measurements, and tests shall be identified by Station No.
- Bentonite slurry and cement-bentonite grout mix quantities, and proportions of additives utilized, if any. Report any adjustments made to slurry mixes.
- Construction log of daily activities including delays encountered during construction, causes of delays, locations of affected areas, and extent of delays. Record unusual conditions or problems encountered and the dispositions made.

Table 1: Cement - Bentonite Slurry Trench Quality Control Testing Plan

Property	Requirement	Minimum Test Frequency	Test Method	Comment
Bentonite Powder				
a. Certification	By Manufacturer	1 per shipment	API 13A	Wyoming type (90 bbl/ton)
Cement Powder				
a. Certification	By Manufacturer	1 per shipment	ASTM C 150 ASTM C 989	Portland Type I or I-II GG BFS Grade 120I
Water for Slurry Mixing				
a. pH	6 to 9	1 per week	Hach Kit	Site Source
b. Hardness	< 250 ppm	1 per week	Hach Kit	
c. Alkalinity	< 250 ppm	1 per week	Hach Kit	
d. Total Dissolved Solids	< 1500 ppm	1 per source	Hach Kit	
Initial Bentonite Slurry				
a. Viscosity	> 30 sec.	1 per shift	API RP 13B-1	Each AM prior to Production
b. Density	> 1.025 gm/cc	1 per shift	API RP 13B-1	
c. pH of Slurry	> 7.5	1 per shift	Hach Kit	
d. Bentonite content	B/W > 4%	1 per batch	Record	Batch records
Cement-Bentonite Slurry				
a. Density	> 1.12 gm/cc	4 per shift	API RP 13B-1	
b. Viscosity	Record	2 per shift	API RP 13B-1	
c. pH of Grout	> 10	4 per shift	Hach Kit	
d. Temperature of Grout	<20^{o} above ambient	4 per shift	Thermometer	
e. Cement content	C/W > 15%	1 per batch	Record	Batch records
Hardened CB Grout				
a. Samples	Archive 90 days	2 per 100 ft	ASTM D4832	Backup
b. Bleed	< 10%	1 per shift	ASTM C292	Before top off
c. Permeability	< 9 x 10-6 cm/sec	1 per 100 lf	ASTM D5084	Reduce to 1 per 500 ft after initial 1000 ft of wall
d. UCS	Min. 10 psi	1 per 100 lf	ASTM D1633	

END OF SPECIFICATION