GALVANIC CORROSION PROTECTION SYSTEM

Galvashield Tidal Plus Marine Jacket

 FOR PROTECTION OF PILES

Note To Specifier: This document is intended to aid in developing a specification for the installation of Galvashield® Tidal Plus Marine Jackets that utilize distributed zinc anodes, bulk aluminum anodes, and stay-in-place PVC modular / FRP formwork and should be modified as appropriate to accommodate project-specific conditions. For additional information, contact Vector Corrosion Technologies.

PART 1 GENERAL

* 1. DESCRIPTION

A. The work under this section consists of supplying, installing, and energizing a galvanic corrosion protection system, including required electrical connections, materials, and testing as detailed in the construction drawings.

* 1. REFERENCES
	2. ACI 222R Protection of Metals in Concrete Against Corrosion
	3. ASTM B6 Standard Specification for Zinc
	4. ASTM B418 Standard Specification for Cast and Wrought Galvanic Zinc Anodes
	5. MIL-A-24779 (SH)
	6. BID QUANTITY

Provide bids on a [lump sum] [per jacket] [square foot of jacket] basis. Pricing shall include all materials, testing, and incidental costs associated with construction means and methods.

* 1. SUBMITTALS

Cathodic protection specialist shall review and approve all submittal documents pertaining to the jacket system prior to submission for approval by the [Architect] [Engineer] [Owner]. Submit the following items for approval 30 days prior to jacket installation:

1. Cathodic Protection Specialist and Cathodic Protection Technician qualifications
2. Shop drawings indicating galvanic jacket locations, dimensions, and installation details including anode size and spacing, reinforcing connections, method of continuity correction, system wiring, stay-in-place jacket assembly, and methods of bracing during grouting operation.
3. Concrete or grout mixture proportions
4. Jacket installation quality control plan
	1. QUALITY CONTROL

Quality control for jacket installation shall be the responsibility of the Cathodic Protection Specialist (CPS). The CPS shall coordinate quality control testing activities as part of the overall project quality program. A Cathodic Protection Technician (CPT) working under the direction of the CPS may conduct site services such as testing and installation quality checks.

1. Qualifications:
	1. Cathodic Protection Specialist is an individual with certification from NACE International that has education, experience, and training in the design and installation of cathodic protection systems. The CPS shall be a currently licensed professional engineer in the state of [Select State] and shall provide evidence of at least 5 years’ experience in responsible charge of design and/or installation quality control of cathodic protection systems for reinforced concrete structures.
	2. Submit a CPS resume, NACE certificate showing current registration, current professional engineers license certificate with expiration date, and at least three project references.
	3. Project references shall include project name, project description, project construction cost, project location/address, reference’s name, address, phone number, and email.
	4. Cathodic Protection Technician qualifications shall include a resume and NACE certificate showing current registration.
2. The Jacket Quality Control Plan (QCP) shall be prepared by the CPS.
	1. The QCP shall identify the jacket installation sequence, and all pertinent testing hold points.
	2. The QCP shall identify the steps in the entire jacket installation sequence, equipment requirements, testing procedures, calibration requirements for embedded instrumentation, daily report templates, and shall describe the procedure for correcting non-compliant test results.
	3. Continuity bond procedures shall be included and submitted for approval prior to performing this work.
3. The CP Specialist shall prepare and submit a close-out commissioning report containing
	1. Photographs of the installation
	2. Daily CPT test reports
	3. Description of the instrumentation and procedures used for obtaining measurements
	4. All data collected during energizing including:
		1. Individual pile continuity checks
		2. Pile to pile electrical continuity between adjacent piles
		3. Individual pile structure potential measurements obtained prior to energizing
		4. Individual anode potential measurements obtained prior to energizing
		5. Mixed potential measured at least 24 hours after energizing
		6. Galvanic current measured at least 24 hours after energizing, if applicable
	5. Certification statement that the installation conforms to the plans and specifications

PART 2 PRODUCTS

2.1 GALVANIC PILE JACKET SYSTEM

Galvanic pile jackets are a marine pile repair system intended to control corrosion. The system consists of galvanic anode units distributed around the pile surface, a stay-in-place form to contain a cementitious grout filler and a bulk anode(s) to provide protection to submerged pile sections. The encasement may also contain supplemental reinforcement as indicated on the plans. The galvanic pile jacket shall be Galvashield Tidal Plus Jacket system utilizing fabric wrapped zinc anodes with 25-lb bulk aluminum SilverBullet® anode(s) supplied by Vector Corrosion Technologies, [Lexington, KY +1 (813) 830-7566,] [Winnipeg, MB, +1 (204) 489-6300,] [www.vector-corrosion.com](http://www.vector-corrosion.com).

1. Distributed galvanic units shall be fabric-wrapped zinc strips containing a nominal 1.6 lb. of zinc per lineal foot of anode cast around two integral stainless steel lead wires of sufficient length to make connections between anodes and the reinforcing steel without splicing. The zinc anode shall be manufactured in compliance with ASTM B 418 Type II (Z13000) using zinc in compliance with ASTM B6 Special High Grade (Z13001) with iron content less than 15 ppm.
2. The wicking fabric material shall be a non-alkaline water transport medium that separates the zinc from the grout fill and causes upward transport of saltwater and direct wetting of the zinc anodes above the normal exterior water level. The fabric material shall be of sufficient length that a portion is exposed below the bottom of the jacket and in direct contact with seawater.
3. The stay-in-place forms shall be either PVC or fiberglass with minimum 1/8-inch thickness. Forms shall provide a minimum [2-6, if a structural cage is required include steel cage requirements] in. annular space around the existing pile and shall be of sufficient length to encase the pile from [at least 24 in. below mean low water or 1 foot below the mudline] extending up to the specified top elevation such that the galvanic jacket encases the entire area to be protected. If PVC stay-in-place formwork is to be used it shall consist of watertight, interlocking components with tensile strength greater than 6,500 psi and flexural strength greater than 12,000 psi. The formwork shall conform to NSF Standard 61 for use in potable water systems. Pumping ports shall be provided if the jackets are not filled from the top using the tremie method with pump tubes. If FRP stay-in-place formwork is to be used it shall be a minimum of 1/8 in. in thickness. Individual FRP sections shall be provided with tongue-and-groove joints that are sealed with 100% epoxy and non-metallic push pins during field installation. Pumping ports or integrated pump tubes shall be installed to fill the PVC / FRP jacket form with an approved concrete grout.

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Note to specifier: Bulk aluminum SilverBullet® anodes are an economical method to protect submerged pile sections. If bulk anodes are not required, edit the draft specification as appropriate. More than one SilverBullet® anode may be required for larger or longer piles for the underwater portion of the pile.

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1. The bulk anode(s) shall be 25-lb aluminum SilverBullet® anode with a steel strap core meeting the requirements of MIL-A-24779 (SH). SilverBullet® anodes shall be supplied with a 316 stainless steel band assembly with buckle to clamp the anode to the concrete pile below the jacket. A 3/8 in. diameter steel rod shall be welded to the anode’s steel strap core, and a No. 6 AWG stranded copper wire with red HMWPE insulation shall be brazed to the steel rod. The entire brazed connection shall be encased in a 1 ¼ in. (or larger) diameter PVC pipe filled with epoxy. Bulk anode(s) shall be provided by the galvanic jacket supplier with all attachments, electrical connections, junction boxes and sufficient wire required for field installation without splicing.

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Note to specifier: Electrical junction boxes are used to house electrical connections between the anodes and reinforcing steel, to allow disconnection of the sacrificial anodes for depolarization testing, to house instrumentation, and to conduct performance tests of the galvanic protection system. Most often tests are conducted to determine if the anodes are producing current and if the galvanic jacket assembly is providing cathodic protection to the pile. It is typically not necessary to test every pile on a structure to evaluate the system performance. If used for performance testing, a statistically significant sample size is recommended. Specifiers should note that pile reinforcing may be interconnected through the bent cap reinforcing. So, anodes placed on one pile in a multiple pile bent cap may deliver galvanic current to adjacent piles. If future performance testing is not required, electrical junction boxes are not necessary for direct-connect systems. Edit draft specification as appropriate.

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1. Electrical
	1. Junction box shall be a 6 x 6 x 4-inch surface mount weather-proof enclosure with NEMA 4X rating. Enclosure shall be constructed of fiberglass, polycarbonate, or sunlight resistant PVC with a water-tight gasketed lid. Include weep holes or vents with openings no larger than 1/8-inch diameter.
	2. All fasteners and hardware shall be grade 316 stainless steel.
	3. Conduit and fittings shall be 1.5-inch diameter sunlight resistant PVC schedule 40 rigid electrical conduit.
	4. Wire shall be concentrically stranded copper with HMWPE or XLPE USE-2 insulation. Use the following color code:

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| --- | --- | --- |
| **Location** | **Size** | **Color** |
| Bulk Anode | 6 AWG HMWPE | Red |
| Embedded Anode | 12 AWG | Red |
| Structure  | 12 AWG | Black |
| Test (use with RE) | 12 AWG | Yellow or Green |
| Reference Electrode | 12 AWG | Blue |

* 1. Wire terminals shall be crimp-solder-heat shrink tinned copper ring terminals of the appropriate size for the wire. Stainless steel anode wires may be terminated with non-insulated high temperature ring terminals.

Note: Anode core wire is stainless steel and may be butt-spliced to copper wire or ordered with lead wire long enough to reach the junction box. If spliced, verify electrical continuity then seal splice with dielectric grease and medium-walled adhesive lined shrink tubing.

* 1. Bulk anode wire shall be terminated with an appropriately sized tinned copper compression lug. Solder and seal lug to wire insulation with medium wall adhesive-lined heat shrink tubing.
	2. Waterproof dielectric grease shall be used on all mating surfaces to minimize condensation corrosion inside the junction box.
	3. Buss bars, if used, shall be constructed of grade 316 stainless steel or titanium. Aluminum bus bars shall not be used in marine service.
	4. Shunts, if used, shall be either Holloway, Cott, Tinker Rasor, or MC Miller with a maximum resistance of 0.1 ohm and minimum current rating of 2 ampere.
	5. Permanent reference electrodes, if used, shall be silver-chloride electrodes manufactured for permanent immersion service with 30-year life.
	6. Epoxy shall be marine grade 100% solids paste.
1. Applications for approved equals shall be requested in writing two weeks before submission of project bids. Application for galvanic jacket equals shall include verification of the following information:
2. The embedded anode unit is constructed with special high purity zinc surrounded with a layer of water transport medium in contact with the anode and seawater.
3. The water transport medium shall demonstrate upward movement of seawater at least 4 feet above the normal water level and shall demonstrate direct wetting of the sacrificial anode.
4. Empirical evidence that the proposed alternate anode design causes the portion of the zinc anode above high tide to have substantially similar performance as the sections of the zinc within the tidal zone such that the galvanic anode will provide sufficient current flow to regions which would normally be too dry to receive sufficient current from a sacrificial anode.
5. Manufacturer shall have a proven track record of anode technology for reinforced concrete showing satisfactory field performance with a minimum of three projects of similar size and application.

2.2 CEMENTITIOUS GROUT

1. Grout mixture shall be portland cement concrete or cement-sand mortar of sufficient consistency to fill the jacket without voids or segregation.
2. The grout shall be proportioned to have the following properties:

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| ASTM C39 Compressive strength | >5000 psi |
| Maximum w/c | 0.40 |
| Air entrainment | [5% (+/-0.5%)] *{for non-freezing environments}*[8% (+/- 0.5%)] *{for freeze-thaw environments}* |
| ASTM C1611 Spread range | 22 to 26 |
| ASTM C1611 Visual Stability Index | ≤ 1 |

1. Aggregates shall meet gradation and durability requirements of ASTM C33. The maximum size aggregate shall be 3/8 in.
2. Grouts may contain anti-washout, water-reducing, and set control admixtures.
3. Admixtures containing chlorides or other salts corrosive to metals shall not be permitted.
4. Submit grout mixture proportions and mixture ingredient certifications to the Engineer for approval.

PART 3 EXECUTION

3.0 GENERAL DESCRIPTION

Pile jacketing is a means to repair concrete distress caused by reinforcement corrosion. Distressed piles are identified, cleaned of marine growth, and sounded to identify the extent of damaged concrete. The pile repair length is verified to ensure the jacket covers the entire damaged area. Damaged concrete is then removed in accordance with concrete repair procedures. The reinforcing steel is tested for electrical continuity, then electrical connections to the reinforcing steel are made inside the jacketed area and above the high tide elevation. A bottom form is installed below the low water line at the elevation shown on the drawing.

The galvanic corrosion protection system consists of fabric-wrapped high-purity zinc anode units and a bulk anode secured to the pile below the jacket bottom elevation. The anodes are either directly connected to the pile reinforcing steel or through wires routed through conduit to an electrical junction box.

After the anodes are installed, the stay-in-place form is placed around the embedded anode units and secured inside the bottom form. The stay-in-place form is braced to prevent bulging during concrete placement, and the bottom is sealed. The annular space inside the jacket is then filled with cementitious grout material from the bottom up using tremie or form and pump methods. After the grout has set, the bracing is removed, the jacket surface is cleaned, and the top of the annular space is sloped and coated.

Once grouting is complete, any wiring routed to a junction box is terminated, tests are conducted and recorded, the system is energized, and follow-up testing is conducted 24 to 72 hours afterwards.

3.1 MANUFACTURER TECHNICAL ASSISTANCE

* 1. The contractor will enlist and pay for the services of a NACE-qualified Cathodic Protection Technician (CPT) working under the direction of a NACE Cathodic Protection Specialist (CPS) for all duties defined in Article 1.5 Quality Control. The CPS or CPT shall not be employed by the jacket system Manufacturer.
	2. The galvanic jacket supplier shall provide shop drawings for the project.
	3. Manufacturer’s representative shall provide training and technical assistance during the installation of the galvanic pile protection system.
	4. The contractor shall coordinate its work schedule with the designated corrosion technician and Manufacturer’s representative for site support during project startup and initial anode installation.

3.2 SURFACE PREPARATION

1. All concrete surfaces within the jacketed area shall be thoroughly cleaned by abrasive blasting, water blasting, or similar approved methods to remove all oil, grease, dirt, loose concrete, marine growth, and any other material that would prevent proper bonding.
2. All concrete within the jacketed area shall be visually inspected and sounded to detect concrete damage. All spalled, cracked, or delaminated concrete shall be marked and then removed until solid concrete is encountered. Remove concrete from behind reinforcing bars to expose the entire perimeter of the bar and lock-in the repair in accordance with ICRI guideline 310-1R.
3. Chipping hammers shall be limited to 20 pounds.

3.3 ELECTRICAL CONTINUITY

1. All reinforcing steel within the jacketed area shall be electrically continuous prior to jacket installation. Any concrete demolition for continuity testing shall be performed inside the jacket limits.

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Note to specifier: Contact Vector for specific continuity testing methods for prestressed piles or for epoxy coated steel.

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1. The Cathodic Protection Technician shall confirm electrical continuity of the embedded steel within the pile using a high impedance voltmeter. Continuity measurements shall be conducted by the CPT by contacting two separate bars and measuring the resistance or voltage difference between each pair. Continuity is acceptable if the maximum DC resistance is less than or equal to 1.0 ohm or the maximum voltage difference is less than 1.0 mV. Resistance values shall subtract the lead resistance.
2. Any discontinuous steel shall be corrected by resistance welding a continuous 0.2-inch diameter solid steel wire (#9) or a small diameter reinforcing bar to continuous steel or by other means approved by the CPS.
3. After continuity has been verified, coat continuity welds with 100% solids epoxy.
4. Repair small concrete excavations with an approved portland cement mortar prior to installing the stay-in-place form as directed by the Engineer. Large excavations and spall areas shall be filled with the cementitious grout

3.4 REINFORCING STEEL CONNECTIONS

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Note to specifier: This section describes directly connecting the anode to the pile steel. This arrangement is used for installations where galvanic anode current output and depolarization testing is not required. Article 3.4.B is provided for applications where potential testing is desired. Delete if no post-installation monitoring is required. For bidding purposes, the contract documents should identify the quantity, dimensions, and location of all direct-connect pile jackets.

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1. Establish a steel connection for subsequent energized potential measurements above the top of the jacket such as a steel threaded rod or wire. Note the location of the connection on the daily log and as-built drawings.
2. Verify and note if continuity exists between the reinforcing in adjacent piles.
3. Prior to connecting any anodes to the pile reinforcing, measure and record the native structure potential of the in-situ pile reinforcing.
4. A minimum of two anode connection locations shall be established per pile within the jacketed area. It is preferred to provide redundant anode-to-reinforcing connections for each anode. This may be accomplished by electrically interconnecting all anodes and attaching the anode header to the reinforcing in two locations, preferably on opposite sides of the pile.
5. Directly connect internal anode wires to spiral or hoop ties by wrapping anode wire tightly to bare steel, brazing, drill and tap, welded stud, stainless steel split bolts, or other approved means detailed in the submittal.
6. Directly connect bulk anode wires by brazing, drill and tap, stainless steel split bolts, or other approved mechanical means detailed in the submittal.
7. Anode connections may be located at repair areas where reinforcing spiral or hoop ties are exposed after removal of damaged concrete. If no exposed ties or verticals exist after preparation of the pile, a small area of concrete shall be removed to expose reinforcing.
8. It is acceptable to connect the anodes inside a continuity groove with a small diameter steel rod (No. 9 wire) welded to all verticals.
9. Verify electrical continuity between each anode and the reinforcing network, then fully encapsulate the anode to reinforcing connection and cover all weld metal or fasteners in marine-grade epoxy.

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Note to specifier: This section describes connecting the anode to the pile steel through an electrical junction box which is placed above the jacket limits. Similar language can be used for monitoring boxes attached directly to the jacket. Contact Vector for more information on monitoring options. This setup can be detailed in the submitted shop drawings to be submitted if requested. For bidding purposes, the contract documents should identify the quantity, dimensions, and location of monitored piles.

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1. Establish a consistent accessible location for monitoring boxes above the top of the jacket.
2. Mount the monitoring station enclosure and conduit such that the conduit extends at least 4 inches into the grout inside the jacket.
3. Note the location of piles with monitoring stations on the as-built drawings.
4. A minimum of two reinforcing steel connection locations shall be established per pile within the jacketed area.
5. Establish two reinforcing connections on opposite sides of each pile by brazing, drill and tap, welded stud, stainless steel split bolts, or other approved means detailed in the submittal.
6. Reinforcing connections may be located at repair areas where reinforcing spiral or hoop ties are exposed after removal of damaged concrete. If no exposed ties or verticals exist after preparation of the pile, a small area of concrete shall be removed to expose reinforcing.
7. It is acceptable to connect structure wires in a continuity groove with a small diameter steel rod (No. 9 wire) welded to all verticals.
8. Verify electrical continuity between each wire and the reinforcing network, then fully encapsulate the reinforcing connection in marine-grade epoxy. Fully encapsulated means no exposed copper wire, no exposed fasteners, nor exposed weld metal.

3.5 GALVANIC ANODES

1. Distributed galvanic anode units shall be installed with an even spacing around the pile surface as indicated on the drawings.
2. The anodes shall be secured to the pile by strapping or other means to allow consolidation of grout over the anode.
3. Install the SilverBullet® bulk anode(s) a minimum of 1 foot below the bottom of the jacket.
4. Route bulk anode wiring inside the jacket to the reinforcing steel connection.
5. Secure anode wiring against the pile with strapping and protect wire ends from saltwater exposure.
6. Terminate wires as appropriate for direct-connect or monitored configuration.

3.6 STAY-IN-PLACE JACKET

1. Install a bottom form capable of supporting the full weight of the wet grout.
2. The bottom form shall contain a lip to support the bottom edge of the jacket.
3. The bottom form shall contain a seal to retain the grout inside the form.
4. Place the jacket around the pile and insert into the temporary bottom form.
5. Center the jacket around the pile and secure in place. The use of spacers or centralizers is recommended to prevent the form from shifting during grouting operations.
6. Support the forms as needed to hold the jacket shape, prevent bulging, or separation during grout placement.
7. Pumping ports, if specified, shall be spaced one foot above the bottom of the form, one foot below the top of the form, and at intervals no more than four feet apart between the top and bottom ports. Ports shall be placed on alternate sides.
8. Pumping ports shall be fitted with a means to retain the fluid grout such as slide gates or ball valves.
9. Jackets may be filled without pumping ports by filling from the bottom up or filling with integrated pump tubes.

3.7 GROUTING

1. Fill the annulus between the pile and the stay-in-place form within 72 hours of placing the jacket around the pile in accordance with the approved quality plan, the drawings, the specifications, and the grout manufacturer's instructions, and jacket manufacturer’s instructions.
2. The grouting mixture may be pumped through the installed ports or tremie from the top assuring that no segregation or air voids exist after concrete placement.
3. Grout placed through multiple ports on a single pile shall start from the bottom port and move to the next port after grout rises to that level.
4. The contractor shall control and prevent excessive form pressures by controlling the rate and method of grout placement.
5. Discharge or retain any residual water contained in the forms in accordance with environmental permit requirements.
6. After the concrete has sufficiently cured, all temporary form support and/or bracing shall be removed from the piles, and the jacket surface shall be cleaned of any hardened grout.
7. Fill the top of the jackets by hand with cement-based mortar to create a 45-degree chamfered edge

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3.8 COMMISSIONING TESTS

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Note to specifier: This section describes commissioning tests for directly connected pile jacket systems.

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1. Prior to connecting any anodes to the pile reinforcing, measure and record the native structure potential of the in-situ pile reinforcing.
2. Measure and record the energized potential of each completed galvanic pile jacket after grouting.
3. Obtain the energized potential within one week after grouting, but at least 24 hours after grouting operations are completed.
4. Calculate and report polarization as the difference between the energized potential to the native structure potential for each pile.

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Note to specifier: This section describes connecting the anode to the pile steel through an electrical junction box which is placed above the jacket limits. Contact Vector for more information on monitoring options. This setup can be detailed in the submitted shop drawings to be submitted if requested. For bidding purposes, the contract documents should detail the number and location of monitored piles.

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1. Measure and record the native potential of each pile’s reinforcing prior to energizing.
2. Measure and record the native potential of each anode prior to energizing.
3. Verify and note if continuity exists between the anode and structure prior to energizing.
4. Verify and note if continuity exists between the reinforcing in adjacent piles.
5. Terminate structure wires using marine-grade crimp-solder-heat shrink ring terminals and connect to the bus, bolt, or stud inside the monitoring station using waterproof contact grease on mating surfaces.
6. If a shunt is incorporated in the monitoring station, connect shunt wire to the structure bus using marine-grade crimp-solder-heat shrink ring terminals and waterproof contact grease.
7. Terminate anode wires using marine-grade crimp-solder-heat shrink ring terminals. Connect wires to the anode bus and shunt, if used, using waterproof contact grease on mating surfaces. The galvanic system is now energized.
8. Obtain and record the energized potential within five minutes after energizing. This is termed the Initial Potential.
9. Obtain and record the galvanic current as the voltage drop across the shunt within five minutes after energizing. Calculate the current by dividing the voltage drop by the shunt resistance. This is termed the Initial Current.
10. Obtain and record the energized potential and galvanic current within one week, but at least 24 hours after energizing.
11. Calculate and report polarization as the difference between the energized structure potential to the native structure potential for each pile.

\*\*\*END OF SPECIFICATION\*\*\*