PORT HOUSTON
Facilities Inspection and Condition Assessment Program ─ Corrosion Manual

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TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

1.1. Background

Port Houston is a 25-mile-long complex of 150-plus private and public industrial terminals along the 52-mile-long Houston Ship Channel. As of 2019, more than 200 million tons of cargo move through Port Houston each year, carried by more than 8,000 vessels and 200,000 barges.

Eight of the public terminals within Port Houston are owned, managed, and/or leased by the Port of Houston Authority (PHA) and include a wide variety of maritime assets. These maritime assets consist of cargo wharves; barge landing areas; small boat docks (fireboats and tour boats); bulkheads (unassociated with docks); riprap shoreline; and one vehicle bridge. These assets serve a variety of purposes, including handling of bulk materials, liquids, and containers; boat landing areas; boat docks; bulkheads for soil retention; and vehicle traffic. The age of these assets ranges from a few years to more than 100 years old, and they have been constructed with a wide range of structural systems and materials. A complete list of PHA maritime assets is provided in Appendix A.

1.2. Purpose of Inspection Program

The inspection and condition assessment of maritime assets is an essential part of asset management for Port Houston, as it provides the information necessary to:

- Define the condition of an asset at a point in time. This may be used for various purposes, including to define value, monitor ongoing deterioration or damage over time (when inspections are conducted at regular intervals), or to define baseline conditions for legal purposes such as change of ownership.
- Identify conditions that may compromise facility operations due to complete or partial structural failure or loss of functionality.
- Identify conditions that may lead to property or environmental damage.
- Evaluate the functional adequacy of the asset in terms of load rating and specific uses.
- Assess conditions that require maintenance, repair, or replacement to maintain or extend the useful service life of the facility.
- Program work in terms of allocating funds and assigning priorities.

To that end, in 2017, PHA produced the Maritime Facilities Inspection and Condition Assessment Program Manual (FICAP Manual) - heretofore referred to as the Maritime Structures Manual, which defines the requirements, documentation, and reporting for visual inspection and condition assessments of maritime assets at facilities owned or operated by the PHA. The scope of the Maritime Structures Manual applies to structural, berthing, shoreline, and ancillary components of maritime assets. The Maritime Structures Manual defines the element types applicable to each component category and provides visual inspection and condition assessment procedures and considerations to describe the existing condition of the elements and components of a particular asset. Component ratings are then used to determine an overall asset condition rating from which resource allocation decisions can be made based on the asset's existing condition.

This Corrosion Manual is intended to supplement the Maritime Structures Manual by providing a more complete indication of the current and future condition of maritime assets at Port Houston with a specific focus on corrosion protection components, which were excluded from the scope of the Maritime Structures

Manual, along with field measurements of the base metal elements those components protect. Whereas the Maritime Structures Manual was focused solely on *visual* inspection to evaluate the *existing* condition of applicable components of the asset, this Corrosion Manual includes *visual* and *non-visual inspection* (i.e. collection of field measurements) to evaluate the performance of corrosion protection components and to further evaluate the condition of the associated base metal elements. The field measurements will allow for a more in-depth assessment of existing conditions as well as estimations of future performance and associated corrosion rates of base metal elements. The field measurements will also provide suitable data for engineers to perform a remaining service life analysis of specific base metal elements should PHA elect to perform such analysis as part of a follow-up action.

When used in conjunction with the Maritime Structures Manual, this Corrosion Manual will provide additional inspection and assessment information appropriate for the use by PHA Asset Management, Project and Construction Management, and Maintenance Departments to better determine the need and timing of preventative or remedial action to maintain the desired level of service.

1.3. Corrosion Manual Basis and Objectives

As discussed above, this Corrosion Manual is part of the overall asset management program for PHA. The goal of this Corrosion Manual is to provide PHA with an estimation of the performance of corrosion protection systems and the associated impact on the current and future performance of the base metal elements they protect. PHA will be able to use the information provided through this program as part of an overall corrosion management system to help manage the negative consequences of corrosion for Port Houston. This Corrosion Manual follows the framework presented in NACE SP21430, *Standard Framework for Establishing Corrosion Management Systems*, and represents the corrosion-specific requirements for the PHA's asset management program. Where applicable, specific inspection and evaluation criteria follow available industry standards from AASHTO, ASCE, NACE, and ASTM as discussed herein. The referenced standards are included in Section 10.1.

The primary focus of this Corrosion Manual is to define the process, procedures, and requirements for completing inspections and condition assessments for corrosion protection components and base metal elements in a consistent manner and level of detail to meet the needs of PHA. The Manual is intended to be used by qualified professional engineers and inspectors. A Corrosion Manual Training Course offered by PHA supplements this Manual and is intended to aid engineers, inspectors, and facility managers in its use. Completion of the Training Course and adherence to the requirements of this Manual are required for performing corrosion inspections and condition assessments for corrosion protection components for the Port of Houston Authority.

This Corrosion Manual defines corrosion protection components and corresponding base metal elements in use on PHA maritime assets, and the standardized inspection and condition assessment procedures required to consistently characterize their current condition and expected future performance. Estimation of corrosion protection performance and the corresponding impact on the base metal elements they protect will assist PHA in making better-informed resource allocation decisions for maintenance and rehabilitation planning to ensure the expected corrosion protection is provided.

The strategy of this Corrosion Manual is to expand and integrate with the existing Maritime Structures Manual to identify and assess components and elements relating to corrosion protection and the corresponding base metal elements that are protected. In a general sense, this Corrosion Manual represents an expansion of the Maritime Structures Manual database to include corrosion protection components and elements and provides more complete information on the condition and expected rate of deterioration of base metal elements in maritime assets. The focus of the Corrosion Manual is on structural and fender components, as these are the typical elements with corrosion protection components, particularly cathodic protection systems. Typically, shoreline, ancillary, berthing, and mooring elements (other than dolphin piles) will not be included in the Corrosion Manual. These elements will be visually inspected as part of the Maritime Structures Manual. The data and information collected through the implementation of this Corrosion Manual will facilitate proactive corrosion management for PHA's maritime assets, including:

- Analysis of condition data and prediction of expected performance for corrosion protection systems (e.g., impressed current cathodic protection) will provide quantitative information to assess the cost-effectiveness of the different corrosion protection systems currently in use at Port Houston. This will identify systems that perform well, and those that do not, based on specific applications, elements protected, exposures, and maintenance.
- Assessment of performance via a corrosion damage (i.e. section loss) rating index will indicate whether an element or component will require maintenance, repair, or replacement within a certain timeframe. This information can be used in the scheduling and development of repair and rehabilitation designs for existing assets and in the development of corrosion protection plans for new assets.
- The analysis of condition data, prediction of performance, and assessment of risk will facilitate improved inspection planning. Specifically, inspection and condition assessment efforts (timing/frequency, methodologies, etc.) can be focused where needed to ensure the effectiveness of the corrosion protection systems and measures, and the overall durability of the asset.

1.4. Maritime Structures Manual Overview

The scope of the Maritime Structures Manual first published in 2017 includes the engineering requirements for conducting above water and underwater inspections and the associated condition assessment of the structural and non-structural components of the PHA's maritime assets. The Maritime Structures Manual provides the information necessary to:

- Provide structural engineering input into the overall decision regarding the current and future functionality of assets.
- Define the condition of an asset at a point in time. This may be used for various purposes, including to define the structural condition, monitor ongoing deterioration or damage over time (when inspections are conducted at regular intervals), or to define baseline conditions for legal purposes such as change of ownership.
- Identify conditions that may compromise facility operations due to complete or partial structural failure leading to loss of functionality.
- Identify conditions that may lead to property or environmental damage.
- Evaluate the functional adequacy of the asset in terms of load rating and specific uses.
- Assess conditions that require maintenance, repair, or replacement to maintain the life of the facility.
- Program work in terms of allocating funds and assigning priorities.

The Maritime Structures Manual addresses the following component types:

- Structural components (e.g., deck, superstructure, substructure, bulkhead)
- Berthing components (e.g., fender and mooring systems and hardware (cleats, bollards, and bitts))

- Shoreline components (e.g., unprotected and protected)
- Ancillary or other components (e.g., personal access systems (catwalks, ladders, and fall protection), guards (guardrails and wharf logs), crane tie-downs, crane and train rail supports, tracks and rails, utility systems supports, paints and markings)

The Maritime Structures Manual outlines the procedures for developing the asset condition rating (ACR), which reflects the general condition of the asset, and is based on the component ratings assigned to the structural and non-structural components of the asset. Among other utility, security, and mechanical operation components, the Maritime Structures Manual is not intended for use in the inspection and condition assessment of impressed current or sacrificial anode cathodic protection systems. These elements and components are not included in Maritime Structures and are not considered in the development of the ACR.

1.5. Corrosion Manual Scope

The scope of this Corrosion Manual includes the engineering requirements for conducting above-water and underwater inspections and condition assessments of the corrosion protection components and associated base metal elements of the PHA's maritime assets. This Corrosion Manual does not address specific safety requirements for the Inspection Team, nor does it address diving procedures and safety issues related to underwater inspections.

The scope of this Manual is limited to the following maritime assets with corrosion protection components:

- Cargo wharves (bulk, liquid, general cargo, and container)
- T-docks
- Boat and barge docks
- Bulkheads (not associated with wharves)
- Rail loading platforms
- Bridges (only those owned and maintained by PHA)

The maritime assets may be comprised of a range of corrosion protection components. This Manual addresses the following component types:

- Impressed Current Cathodic Protection components
- Sacrificial Anode Cathodic Protection components
- Surface Protection components (e.g. coating, wrap, and metalizing)

As with the Maritime Structures Manual, this Corrosion Manual is not currently intended for use in the inspection and condition assessment of:

- Utilities, such as mechanical, electrical, and plumbing systems
- Buildings, sheds, or other similar constructions
- Mechanical operation of crane and train rails (such as track switches)
- Wharf cranes and other mechanized equipment
- Security components (such as fences and cameras)

1.6. Element-Based Inspection and Condition Assessment Approach

The terms "inspection" and "condition assessment" refer to different but related activities. An inspection is an evaluation procedure in which a qualified team leader carries out or supervises the observation, classification, and documentation of the physical condition of a corrosion protection system or associated metal element. It may involve visual, tactile, and nondestructive testing methods, as well as material sampling and testing to determine the types, severity, and locations of deterioration or distress in the asset. The regular use of nondestructive and/or destructive measurement techniques is a distinguishing difference between inspections as part of the Corrosion Manual and Maritime Structures Manual.

A condition assessment is an evaluation of the inspection results considering the significance of observed and measured conditions. A condition assessment is based on engineering judgment considering qualitative and quantitative inspection findings and may be supplemented by engineering calculations. The outcome of a condition assessment is to determine the need and priority of maintenance, repair, or rehabilitation actions for a given component or asset. While this Manual discusses various inspection types and procedures, unless otherwise noted, corrosion inspections conducted for the PHA are expected to be included in condition assessments in the form of both (1) estimating the corrosion damage rating index for base metal components, and (2) calculating applicable component and overall corrosion ratings (discussed in the following sections).

The inspection and condition assessment process in this Manual uses an element-based approach. This approach is the same as the Maritime Structures Manual and is similar to that used for bridges as developed by AASHTO and presented by Ryan et al. (2012) and AASHTO (2013), and as used for waterfront facilities inspection. The general concepts and terms of this element-based approach are explained in the following sections of this chapter. Detailed procedures and guides for implementation are provided in subsequent chapters.

1.6.1. Hierarchy of Corrosion Manual Terminology

The premise of an element-based inspection and condition assessment approach requires the definition of a clear hierarchy extending from the PHA's properties and terminals down to the element level. This Manual uses the hierarchy shown in Figure 1.1, and the terms in this hierarchy are defined below. These terms are consistent with the approach in the Maritime Structures Manual, with the addition of the Corrosion Classification for Base Metal Components. An example of a hypothetical terminal using this hierarchy is shown in Figure 1.2. Element and component types are discussed in Chapters 3 and 4, respectively. In addition to the terms defined in these chapters, an extensive Glossary of Terms is provided in Appendix B.

Property or Terminal This is the highest level in the hierarchy from an inspection and condition assessment perspective (higher levels may be considered for asset management or other purposes). The property or terminal is typically comprised of a group of assets that taken together comprise a terminal or property. The property or terminal is normally defined by distinct property boundaries. A Terminal is used where the primary assets are a collection of cargo wharves, and a Property is used for other areas.

Maritime Asset Each property or terminal is normally divided into several maritime assets, each of which may serve a separate, similar, or common functional purpose. Asset types may include wharves, boat docks, bulkheads, or shore protection. The boundaries of each asset are determined primarily by asset type but may be defined based on factors such as functional use, original construction date, logical inventory, or maintenance considerations.

Corrosion Protection Component Each maritime asset may be comprised of a single or several corrosion protection components. Typical corrosion protection component types include impressed current cathodic protection systems, sacrificial anode cathodic protection systems, and surface protection systems. The Maritime Structures Manual lists the other structural or functional components that make up the remaining parts of the overall maritime asset.

Corrosion Protection Elements Each corrosion protection component is comprised of one or more elements. An element is an individual member of the corresponding system. Element types are defined by the component to which it belongs, its functional purpose, geometry, and material. Geometry includes the general shape and orientation of the element. Material for an element is defined generally and can include various metals, plastics, PVC, etc.

Base Metal Components For purposes of scoring the corrosion damage rating index on base metal elements, the Corrosion Manual classifies elements that are protected by the various corrosion protection components into Base Metal Components. Each base metal element in the Corrosion Manual is classified as either Critical, Typical, or Redundant as part of the Base Metal components.

Unlike other components, the Base Metal component is not a system of elements that make up the same structural or functional system on the asset. The Base Metal component classification is a way to organize elements based on their importance to the overall function of a given component or asset and are further defined in Chapter 2. The component classification impacts the deduction amount when calculating the overall corrosion condition rating of the asset as defined in Chapter 6.

Base Metal Element (from Maritime Structures Manual) The underlying elements of the Base Metal component are existing structural or functional elements in the Maritime Structures Manual that are protected by corrosion protection components. These elements are inspected with additional inspection methods (e.g. steel thickness measurements) beyond the visual observations of the Maritime Structures Manual.

Property or Terminal (typically consists of several maritime assets)	□	***Maritime Asset*** (e.g., wharf, T-dock, bulkhead)	□	***Corrosion Protection Components*** (e.g., Impressed Current Cathodic Protection System, Sacrificial Anode System, Surface Protection)	□	***Corrosion Protection Elements*** (e.g., Rectifier, Anode, Wiring, Coating..etc.)
			□	***Base Metal Components*** **Corrosion Classification** (e.g., Critical, Typical, Redundant)	□	***Elements (from Maritime Structures Manual)*** (e.g., Sheet Pile Wall, Fender Pile)

Figure 1.1: Hierarchy of Corrosion Manual Terms

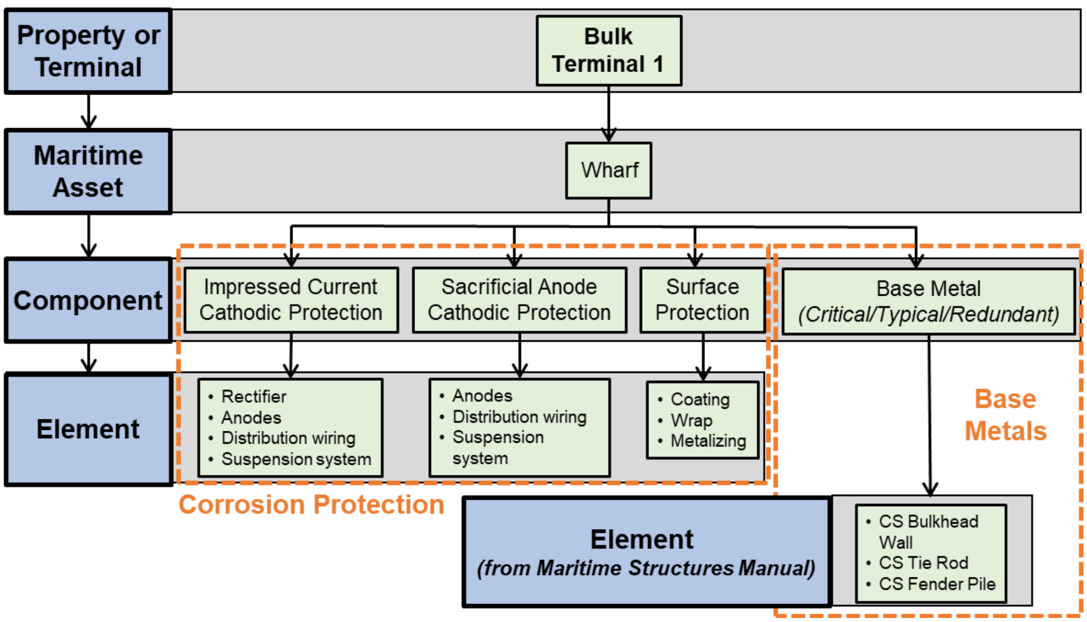


Figure 1.2: Corrosion Hierarchy Applied to Wharf with Corrosion Protection

1.6.2. Element-Based Inspection and Condition Assessment Approach

The inspection and condition assessment of an asset is a key component of an asset management program. The credibility of the inspection and condition assessment relies upon two equally important factors: 1) the experience and knowledge of the engineer(s) responsible for the assessment, and 2) the completeness and quality of the documentation of the condition of the asset determined during the inspection. The inspection findings should be observed, measured, and documented in a manner that provides the condition information necessary to facilitate a credible condition assessment and estimation of the corrosion damage rating index for each base metal element. Specifically, the inspection findings should be characterized and reported in terms of:

- Types of corrosion protection elements that may have damage, deterioration, or defects (observed conditions). This is needed to assess the overall implications of observed and measured conditions. It is generally more effective to characterize conditions according to element type as well.
- Type of observed condition (e.g., broken connection, missing anode, error in output display).
- Severity of observed condition (e.g., type and size of defects, severity of section loss).
- Scope or extent of observed condition (e.g., number of defects, area/length affected).

In order to provide the type and detail of condition information described above, an element-based inspection is necessary. The element-based inspection approach documents the visual condition of each inspected corrosion protection element (e.g., a single rectifier, wiring system, anode, or coating system with defined extents) of the asset. Element condition states are used to provide a clearly defined indication of the type, severity, and extent of the observed conditions (damage, deterioration, or defects) for a given element. An individual element may exhibit more than one type of condition and may also exhibit different levels of observed conditions. Accordingly, the element-based inspection requires quantification of each condition type, severity, and extent for a given element. Most corrosion protection elements are typically quantified per unit (each rectifier, anode, or wiring). For planar elements such as coatings, conditions are typically quantified by the area dimension (per square foot) of the overall member area. In all cases, the element condition states are assigned relative to the as-built or original condition of the element. The definition and use of condition states at the element level improve the objectivity and repeatability of the inspection and condition assessment.

In addition to visual inspection, the Corrosion Manual incorporates additional inspection techniques to verify the performance of the corrosion protection components, such as potential and current measurements of an impressed current cathodic protection (ICCP) component. These measurements are indicative of the overall component performance and are dependent on multiple elements of the component working properly. For example, a properly functioning ICCP component would require the rectifier, anodes, and wiring all to be functioning at certain levels to provide sufficient cathodic polarization. These measurements indicate the overall component performance and may or may not be reflective of a given element.

Additional elemental inspection methods are used for purposes of estimating the section loss and corrosion or consumption rates of the Base Metal and Corrosion components, such as ultrasonic thickness measurements of the base metal element, coating thickness measurements, and measuring the mass of sacrificial anodes. The specific inspection methods for a given asset are dependent on the corrosion components and elements that are present and are defined in an asset-specific Corrosion Inspection Plan, which is developed during the Baseline Inspection and can be updated as necessary following a given inspection.

The visual condition information collected through an element-based inspection, as well as the additional inspection techniques for the components and elements, provides the basis for the corrosion condition assessment. The inspection and condition assessment approach defined in this Corrosion Manual includes a condition assessment at both the component and asset levels and is described by component ratings and overall corrosion condition rating, respectively. Component ratings indicate the overall condition of a component (e.g., entire ICCP system, sacrificial anode system, coatings, base metal components, etc.) and are determined based on engineering interpretation of the inspection findings for the elements that make up the component. The purpose of the component rating is to provide a condition assessment for each component in an asset for use in assessing the overall corrosion condition and expected future performance of the corrosion protection and base metal components in an asset and to guide follow-up actions (e.g., need for further inspection, immediate repairs) and prioritize maintenance or repairs. The overall corrosion condition rating reflects the overall asset corrosion condition and is based on the component ratings assigned to the corrosion protection and base metal components of the asset. The outcome of the corrosion inspection and condition assessment process for a maritime asset is the overall corrosion condition rating along with a qualitative description, the component ratings, and the follow-up actions. The element-based inspection and condition assessment approach and its influence on component and overall asset ratings are summarized in Table 1.1. Element condition states are defined in detail in Chapter 3 of this Manual. The condition assessment approach using component and overall asset ratings is described in Chapter 6 of this Manual.

Table 1.1: Summary of Element-Based Approach

Level	Purpose	Comment
Asset	▪ Corrosion assessment for asset guides follow-up actions and asset management decisions.	▪ Overall corrosion condition rating (CCR) is a numerical rating and is supplemented by a qualitative (descriptive) assessment.
Component	▪ Component condition assessment indicates condition of corrosion protection or base metal components. ▪ Where appropriate, inspection measurements provide basis for overall component condition. ▪ Provide basis to determine overall corrosion condition.	▪ Numerical component rating is based on an engineering interpretation of the element condition states, inspection data, and their corresponding implication(s) on the functional condition of the component. ▪ Base metal component rating is based on the estimated corrosion damage rating index of critical, typical, and redundant elements.

Element	▪ Condition states document occurrence of damage, deterioration, or defects at time of inspection in terms of:
	  ▪ Type of condition(s) (i.e. damage mechanism)
	  ▪ Severity of defect (i.e. moderate, severe)
	  ▪ Extent of defect (i.e. localized or general)
	▪ Correlates conditions to element and material type.
	▪ Tracks conditions over time as indicated by inspections conducted at regular intervals.
	▪ Selective measurements of key parameters provide basis for corrosion damage rating index of overall component.
	▪ Provides basis for component rating.
		▪ Detailed visual inspections are conducted at the element level.
		▪ Element condition states are assigned based on predefined categories and quantified to define element condition.

1.6.3. Approach to Corrosion Damage Analysis

The Corrosion Manual uses the information collected during the inspection to estimate the current and future corrosion damage (i.e. section loss) of base metal components, using a corrosion damage rating index to develop the condition rating for each base metal component. Reference Section 6.2 for a complete discussion of component ratings. The purpose of using the corrosion damage rating index to develop the base metal component rating is to provide a scoring system that indicates both the existing condition and the rate of deterioration. This provides PHA with a scoring system that indicates future performance and provides a forward-looking planning tool for the time at which additional investigation, maintenance, or repairs will be required, which will facilitate long-term prioritizing and planning. As with other component ratings, a low base metal component rating indicates additional investigation, maintenance, repairs, or replacement will be required relatively soon, while a high base metal component rating indicates these activities will likely not be required in the short term.

The corrosion damage rating index is based on steel thickness measurements taken during inspections and section loss and corrosion rates calculated after the inspection. In order to provide reasonable and consistent corrosion damage ratings, steel thickness measurements are collected from base metal elements during Baseline and Routine Inspections. The type, amount, and location of the measurements are based on the Corrosion Classification for the element and are defined in the Corrosion Inspection Plan. Section loss is calculated relative to the as-built condition of the element, ideally represented by thickness measurements obtained during the Baseline Inspection after initial construction or during the next Routine Inspection after replacement. For existing structures without a Baseline Inspection after construction, the section loss is estimated based on the as-designed condition. The corrosion rate is calculated using the thickness measurements from the current inspection and the previous Routine Inspections. Higher corrosion rates and more section loss correspond to worse damage ratings and lower base metal component scores. Lower corrosion rates and less section loss correspond to better damage ratings and higher base metal component scores.

The corrosion damage rating index for a given base metal component is a broad summary of a set of elements experiencing various types of corrosion (e.g. uniform or pitting), severity of corrosion, and extent of corrosion damage between themselves and across their surfaces. The type, extent, and severity of corrosion will be controlled by the effectiveness of the corrosion protection systems, exposure severity, and material properties of the metals. As a result, a wide array of section loss measurements and corrosion rates are expected to be observed within the same base metal component. To manage this variability, the damage rating index is calculated for each exposure zone experienced by each element using the weighted averages of the section loss and estimated corrosion rate. This produces a consistent array of corrosion damage rating indices, which are combined using engineering judgment to produce an overall corrosion damage rating for the component.

Appendix H provides background information on the exposure zones and anticipated corrosion rates at the Port of Houston. As more measurements and corrosion data are collected as part of this program, specific corrosion rate classifications can be revised, cataloged, and documented for future reference and refining of the Corrosion Manual.

1.7. Corrosion Manual Overview

The primary scope of the Corrosion Manual consists of Inspection Planning, Baseline and Routine Inspections, and Corrosion Damage Analysis. Ongoing Functionality Checks may also be required to verify the operation of cathodic protection systems. Special Inspections may also be required on occasion at the discretion of PHA. Figure 2.1 illustrates the relationship between each of these program aspects. A written summary of each of these program aspects is described below:

Inspection Plan:	Prior to the Baseline Inspection, an asset-specific inspection plan is developed to define the requirements for a particular Baseline and Routine Inspection for the given asset. With the scope of the inspection and corrosion condition assessment process, the inspection process must be planned and implemented appropriately to collect the specific information required for the condition assessment and corrosion damage analysis.
Baseline Inspection:	Inspection to establish corrosion protection inventory information and provide a baseline condition assessment and corrosion damage analysis for new assets and for existing assets where no previous inspection exists.
Routine Inspection:	Regularly scheduled inspection to define asset condition at a point in time. These consist of Tier 1, Tier 2, or Tier 3 inspection tasks, which are defined in the Inspection Plan.
Functionality Checks:	Regularly scheduled checks to verify the ongoing functionality of cathodic protection systems. These checks are more frequent and simpler than Routine Inspections.
Corrosion Damage Analysis:	This analysis involves estimating the current section loss and corrosion rates of base metal elements using information collection during the Baseline and/or Routine Inspection. The corrosion damage analysis will provide more information regarding the current and future condition of the components in question and would be performed in conjunction with Baseline and/or Routine Inspections.
Special Inspection:	Inspection in response to specific situations, including Post-Event Inspection to assess condition after an extreme event (e.g., hurricane, vessel impact); Due Diligence Inspection to assess condition at times of change of ownership, lease, insurance, etc.; and In-Depth Inspection to determine the cause and significance of damage or deterioration and to provide the condition information necessary to complete designs for repair and/or strengthening.

Implementation of the Program involves conducting a Baseline Inspection of each maritime asset with corrosion protection in the PHA inventory, followed by regularly scheduled Routine Inspections at prescribed intervals to track changes in the asset's condition over time and provide regular updates on the corrosion damage of key components. Each asset will have a specific Corrosion Inspection Plan that can be updated as required over the life of the asset. If the conditions observed during a Baseline or Routine Inspection require further information or indicate that repairs may be required, an In-Depth Inspection (with a specific scope defined by the PHA based on inspection results and the PHA's operational priorities) may be conducted. Post-Event and Due Diligence Inspections are conducted as and when needed. Each inspection type is described in detail in Chapter 2 of this Manual.

1.8. Limitations of Corrosion Manual

The inspection and condition assessment methodologies presented in this Corrosion Manual are subject to the following limitations:

- The inspection and condition assessment methodology does not define all in-depth inspection methods, such as material sampling and coring, and non-destructive evaluation techniques including impact echo, impulse response, ground penetrating radar, radiography, infrared thermography, electrical resistivity, etc.
- This Manual is limited to procedures outlining Baseline and Routine types of corrosion inspection (see Chapter 2 for inspection types) and corrosion damage analysis of steel elements. The Manual does not define procedures or requirements for other inspection types (Post-Event, Due Diligence, or In-Depth Inspections) and refined engineering analysis, such as service life analysis or analysis for load rating structural components.

1.9. Manual Organization

The manual is organized into ten chapters:

- Chapter 1 describes the scope and purpose of this Corrosion Manual and inspection program.
- Chapter 2 describes the inspection types in terms of objectives and scope of work.
- Chapter 3 presents the corrosion protection element types encountered in PHA maritime facilities and discusses the element condition state descriptions used in this manual.
- Chapter 4 lists the corrosion protection and base metal component types encountered in PHA maritime assets. The component types are presented based on their functional purpose and the condition rating criteria used to assess the component condition are described.
- Chapter 5 describes the maritime asset types in the PHA inventory. This chapter is duplicated from the Maritime Structures Manual.
- Chapter 6 presents the assessment, corrosion damage analysis, and rating approach used for corrosion protection and base metal components and the overall corrosion condition of assets.
- Chapter 7 provides guidance on the recommended actions that may arise following a corrosion inspection and condition assessment.
- Chapter 8 describes the documentation and reporting requirements for corrosion inspections.
- Chapter 9 discusses administrative requirements associated with inspections, including inspection team qualifications, as well as safety, security, and insurance requirements. Limitations and responsibilities are also discussed.
- Chapter 10 lists the references cited in this report, as well as other references suggested to provide relevant background information on corrosion inspection and condition assessment of maritime assets.

CHAPTER 2: INSPECTION TYPES

2.1. Type of Inspection and Level of Effort

Given the overall objectives of the Corrosion Manual described in Chapter 1, the specific objectives, scope, and level of effort involved in a given inspection and condition assessment type may vary depending on the circumstances of a particular maritime asset.

2.1.1. Comparison with Maritime Structures Inspections

As described in Chapter 1, this Corrosion Manual is intended to supplement the Port's overall asset management program as well as the information provided by the Maritime Structures Manual by providing a more complete indication of the current and future condition of corrosion protection components and the base metals they protect. To achieve these objectives, additional inspections, condition assessments, and engineering analyses are required beyond the scope of the Maritime Structures Manual. In particular, additional inspection methods and measurements are necessary to properly evaluate corrosion protection components and estimate the corrosion damage rating index of steel elements.

The inspection and condition assessment approach in this Corrosion Manual goes beyond the visual observation methods presented in the Maritime Structures Manual. However, the overall elemental-based inspection approach, the relationship between components and elements, and the general pattern for assessing and providing condition ratings for components and the overall asset are similar to the Maritime Structures Manual. As such, the terminology, where appropriate, is similar.

For this Corrosion Manual, one distinguishing feature from Maritime Structures Manual is the testing and collection of data (e.g. steel thickness measurements, current output readings, potential measurements, or coating thickness measurements) during baseline and routine inspections. In this sense, the baseline or routine inspections for the Corrosion Manual are more "in-depth" than the Maritime Structures Manual baseline and routine inspections, which are visual only. Similarly, the scope and frequency of the baseline and routine inspections may be different.

As such, the terms "baseline," "routine," or "in-depth" in this Corrosion Manual should be understood relative to each other, and not relative to the Maritime Structures inspections.

2.1.2. Types of Inspection

This Manual defines four general types of inspections to address the range of objectives that may be desired. These inspection types are summarized below.

Baseline:

- Inspection to establish the baseline (initial) corrosion protection system inventory information and determine corrosion condition ratings for a new asset or for an existing asset where no previous record exists. As part of a Baseline Inspection, an asset-specific Corrosion Inspection Plan is developed that defines the specific inspection requirements for the asset.
- May involve above-water and underwater inspection.
- Part of primary scope of this Corrosion Manual.

Routine:	▪ Regularly scheduled inspection to define corrosion components and overall asset ratings, and element condition states at a point in time, and to allow tracking of conditions over time. ▪ May involve above-water and underwater inspection. ▪ May include Tier 1, Tier 2, and Tier 3 tasks at different inspection intervals. ▪ Part of primary scope of this Corrosion Manual.
Functionality Checks:	▪ Regularly scheduled checks to verify functionality of cathodic protection systems. ▪ More frequent intervals than Routine Inspections. ▪ Does not include underwater inspection. ▪ Part of primary scope of this Corrosion Manual
In-depth (Special):	▪ In-depth inspection to determine cause and/or significance of damage or distress, to aid in determining a suitable repair approach, to define quantities of repairs, or to provide additional information required to perform an Engineering Analysis. ▪ Not part of the primary scope of this Corrosion Manual; scope and objectives defined as needed and conducted under the direction of Port Houston.

The scope and content for each Baseline and Routine Inspection will be defined in the Inspection Plan and determined based on the type of corrosion protection systems and base metal components at a given asset. An asset-specific corrosion inspection plan is developed as part of the baseline inspection and is tailored to collect the information needed considering the specific corrosion protection and base metal elements at the specific asset (Section 2.2). This Corrosion Manual provides guidance and minimum requirements for identifying and prioritizing inspections of corrosion protection and base metal components for baseline and routine inspections.

2.1.3. Considerations for Level of Effort

The Corrosion Manual is mostly focused on inspecting and collecting data from readily accessible elements, which are those with the following characteristics:

- Exposed to either open water or open atmosphere.
- Do not require removal of overburden or other elements.
- Are not considered confined spaces.
- May be accessed by walking, boat, lift, scaffold, or diving.

If confined spaces are identified, the types of elements in the confined space should be identified. If one or more structurally significant elements can only be inspected from the confined space, a confined space entry may be required during the Baseline and Routine Inspections. The need for the confined space entry should be discussed with the PHA Project Manager.

Some elements may be temporarily obscured by cargo, debris, or similar obstructions. For Routine or Baseline Inspections, these areas may be considered temporarily inaccessible and may be skipped for one inspection cycle, provided that the total percentage of obscured areas does not exceed 10 percent of any component and no significant distress is suspected in the obscured area. These areas should be identified during the current Routine Inspection cycle and inspected on the next Routine Inspection cycle.

The Inspection Team may recommend the removal of overburden, inspection openings, or other more extensive measures to inspect permanently inaccessible elements for follow-up Special Inspections. These areas should be identified by a project-specific scope.

For some assets, it may become readily apparent during a Baseline or Routine inspection that the above-water portions of elements or corrosion protection systems are in very poor or likely unserviceable condition. In these circumstances, the above-water inspection may be truncated, or the underwater inspection may be deferred. Given the increased level of difficulty and cost associated with underwater inspections, it may be desirable to perform Baseline and Routine underwater inspections after the above-water inspections have been completed. In all cases, PHA approval is required to waive any portion of the above-water or underwater inspection based on observed above-water conditions.

The following sections describe the process for establishing and maintaining an Inspection Plan for each asset as well as the objective and scope of each inspection and condition assessment type.

2.2. Inspection Planning

Given the nature of corrosion protection systems and corrosion damage estimations, the implementation of an inspection and condition assessment program should be optimized considering the types of components to be inspected and their importance to the asset; expected design life; nature and severity of exposure; types of corrosion mechanisms; current condition; and likelihood of failure due to corrosion. The process for developing an optimized corrosion inspection plan that documents the specific requirements for Baseline and Routine Inspections for each asset is described in further detail below.

2.2.1. Identify Components and Define Classification for Base Metals

Identify component and associated base metal elements and classify importance

The first step of a corrosion condition assessment is to identify the corrosion protection components of the assets and the elements within each component. Element definitions for corrosion protection systems (e.g., impressed current and sacrificial cathodic protection systems, and surface protection systems) and further information on elemental descriptions for this Corrosion Manual is provided in Chapter 3.

Once the corrosion protection components have been identified, the corresponding base metal elements from the Maritime Structures Manual are identified and classified based on their importance to the overall function of the associated component or asset (critical, typical, and redundant), as described below. For the Maritime Structures Manual, elements are generally defined by their structural or functional purpose, geometry, and material. A comprehensive list of elements for structural, berthing, shoreline, and ancillary components is provided in Appendix C of the Maritime Structures Manual.

Note that only assets that include corrosion protection components or base metal elements are required to be inspected within the scope of the Corrosion Manual. All corrosion protection components are included in the Corrosion Manual, including corrosion protection components for reinforced concrete; however, the reinforced concrete elements themselves are excluded from baseline and routine inspections of the Corrosion Manual. Reinforced concrete elements are included as part of the Maritime Structures Manual and may also be inspected as part of a special inspection, as defined in Section 2.7.

Shoreline and ancillary components should generally be excluded from the scope of the Corrosion Manual. Mooring elements that are attached to the structure, such as cleats and bollards, are typically not included in the scope of the Corrosion Inspection Plan, as these elements are usually limited to atmospheric exposure and coating deterioration is driven primarily by use and wear, rather than corrosion. If warranted, cleats and bollards can be included as part of the inspection if the engineer determines corrosion will be a controlling mechanism for these elements during development of the inspection plan as part of the Baseline Inspection.

A three-category classification is implemented in the Corrosion Manual for elements in the base metal component. Because the structures under consideration are general civil/structural elements, consequences of failure relate primarily to load-carrying integrity or functionality. The three-tier classification is as follows:

- **Critical.** Loss of this element will likely significantly compromise the function and/or capacity of the associated component and/or other elements within the asset. This class is applicable to most substructure and superstructure elements, as well as bulkhead tie rods.
- **Typical.** Loss of this element may reduce the function or capacity of the associated component or asset, but the asset can remain in service (e.g., a through-thickness section loss in a portion of the sheet pile bulkhead wall). These include most typical bulkhead elements, deck elements, and fender or dolphin piles. This may also include substructure and superstructure elements with internal or external redundancy in quantity, such as multiple stringers within a given deck area, sheet pile retaining walls, or braces.
- **Redundant.** Multiple elements of this type may exist within the component to serve the same functional role. Loss of this element will not significantly compromise the function or capacity of the associated component (e.g., fender support framing or fender panels).

For purposes of this Manual, loss of an element refers to areas of complete through-section loss not necessarily the complete collapse of the element. The aforementioned element examples for each class are provided for guidance in developing the Baseline Inspection Plan. A complete list of base metal elements from the Maritime Structures Manual with typical class ratings is included in Appendix C. Deviating from these element classifications would require further review by a licensed structural engineer and approval from PHA staff. The review would include evaluating load paths and assessing redundancy through design document review and/or structural analysis or modeling. Different levels of inspection effort (e.g., inspection frequency, inspection area, required inspection methods) may be required for each element class, with more frequent and detailed inspections focusing on the Critical elements and on the corrosion protection components and elements associated with protecting these base metals, further described below.

Characterize exposure zones of components

The exposure conditions are defined for each asset at the global level to establish the environmental conditions as well as at the local level by identifying the exposure zones for each element. In some cases, more than one exposure zone may apply to a given element. The five typical classifications for exposure zones in maritime assets are briefly described below:

- **Atmospheric Zone.** Typical atmospheric conditions for the Houston Ship Channel include relatively high humidity levels and warm temperatures throughout most of the year along with consistent exposure to oxygen and UV. Additionally, precipitation in the area includes chlorides and other ions carried by mist from the nearby Gulf of Mexico.
- **Splash Zone.** In addition to the relatively high humidity levels and consistent exposure to oxygen and UV exposure as those in the Atmospheric Zone, elements in the splash zone are also subjected to

intermittent wet and dry cycles, which typically leads to increased ion concentration and corrosion rates. Corrosion rates are typically highest in the splash zone directly above the mean high tide as a result of the moist conditions and ready exposure to oxygen.

- **Tidal Zone.** Surfaces within the tidal zone remain saturated for a large portion of the year and can only dry at times of low tide; however, the typical high humidity of the area will result in typically low drying rates. Exposure to oxygen along the surface of an element varies as tidal movement occurs and during immersion oxygen levels are reduced. Because oxygen is a required constituent to support the corrosion process, elements within the tidal zone will see slower degradation rates.
- **Submerged Zone.** Exposure conditions for submerged elements differ from the tidal zone conditions primarily in the availability of oxygen since concentrations of dissolved oxygen in water are significantly lower than the oxygen concentration in the atmosphere. As a result, corrosion rates in the submerged zone are also lower than in the splash and tidal zone, but unprotected steel (steel without protective coatings or cathodic protection) can still corrode, though the risk is generally low at elevations below 3 ft below low tide.
- **Soils.** The risk for corrosion of steel elements buried in the soil is dependent on several factors, including the properties of the solid, water, and gaseous constituents of the soil and fluctuations in groundwater levels. All buried elements under consideration for the new wharf structures are typically surrounded by well-compacted soils or cementitious fill, which will limit the amount of oxygen and slow corrosion rates. The primary soil properties that influence the corrosion of buried steel include chloride content, pH, and electrical resistivity. Relatively high chloride ion concentrations and low resistivity in the soil may provide an environment in which corrosion is expected.

The environmental characteristics for each local exposure zone within the asset—atmospheric, splash, tidal, submerged, soil—may be established using previously collected data, if available. The local exposure zone is assigned for each base metal element and can help estimate the corrosion rate as part of the corrosion damage analysis. The exposure zone characteristics may be used to establish preliminary estimates of element corrosion rates for new construction and to assess the risk of future corrosion for existing elements. Since a single element may be exposed to multiple exposure zones, the inspection methods for data collection are performed not only at the element level, but also at the element-exposure zone sublevel, as defined below.

Characterize environmental conditions of an asset

In order to characterize the environmental or global exposure for a maritime asset, it is essential to understand the environmental conditions of the site's atmosphere, water, and soil. This information may be obtained from previous PHA studies and/or available data. This information is collected during the document review stage prior to a Baseline Inspection and is included on the Corrosion Inventory Record as described in Chapter 8. This information is useful when considering potential recommended follow-up actions or evaluating the overall severity of corrosion. The information provided may include the following:

- **Atmosphere Characteristics.** Monthly averages of temperature, relative humidity, and atmospheric chloride concentrations. These characteristics are already monitored near several Port Houston assets.
- **Water Characteristics.** Monthly averages of temperature (at various depths, if available), the concentration of chlorides and nutrients, resistivity, microbial activity, and flow velocity. Temperature, chlorides, nutrients, and resistivity are monitored near several Port Houston assets.
- **Soil Characteristics.** Includes soil resistivity, sulfate content, chloride content, and pH.

In many cases, it is reasonable to assume that the general site atmosphere, water, and soil characteristics at one location within an asset are similar to those at other locations within that asset. If an environmental survey and sampling are performed after the initial Baseline Inspection as part of an In-depth, Due Diligence, or Post-event Inspection, the environmental characteristics should be updated accordingly. Prior to the development of an inspection plan, environmental data, previous studies, and PHA records should be reviewed and used in developing each inspection plan. If additional sampling and testing are warranted, these recommendations can be included in the Follow-Up Actions.

Identify current age for all components and the design base metal thickness

Based on the available information, the original installation date (approximate age) of existing corrosion protection and base metal components should be identified and recorded on the inspection plan. In addition, the original design thickness or cross-sectional area of each base metal element in the Corrosion Manual should be recorded. If the available design documents indicate that a corrosion allowance was included in the design thickness of any base metal elements, the information should be recorded as well.

2.2.2. Inspection Scope and Frequency

All elements (or all portions of an element) may not need to be inspected in the same manner or at the same interval, depending on the characteristics of the corrosion protection system and the exposure zones for elements of interest.

The corrosion inspection plan should contain inspection tasks and a schedule to monitor identified corrosion mechanisms and the integrity of the element. The plan should:

- Define the type(s) of inspection procedures needed.
- Identify the next inspection date for each inspection type.
- Describe the inspection methods and NDE techniques.
- Describe the extent and locations of inspection and NDE.
- Describe any surface cleaning requirements that may be needed for each type of inspection.
- Describe any access requirements that may be needed for an inspection, above or below water line, etc.

Types of inspection procedures may include:

- Visual inspection
- Nondestructive evaluation techniques (e.g., ultrasonic thickness measurement)
- Coating thickness measurements and/or adhesion testing
- Sacrificial anode mass measurement
- CP system electrical performance

The inspection methods and the extent of NDE should be evaluated to assure they can adequately identify the corrosive mechanism and the severity of damage for the base metal elements in question at readily accessible exposure zones. All inspection procedures, except for visual inspection, should be performed in a manner to obtain data at locations representative of the condition of each element in a given exposure zone. The primary intent of acquiring and compiling elemental data is to track the global condition of that element and component over time, while localized conditions and/or distress will be noted and reported via visual inspection. As such, all testing locations should be well defined on the inspection plan and during the Baseline Inspection. Unless there is a specific reason to change, similar testing should be performed at the same locations during subsequent inspections. If additional or different test locations must be selected due to changes in available access, inspection requirements, or other reasons, these locations must be comparable to the initial locations and well-defined in the inspection summary.

Inspection frequency, which is the time interval between inspections, should be defined for each element considering the following:

- Type of corrosion damage (e.g., localized pitting or general wall thickness loss in steel elements).
- Location or zone of potential corrosion (e.g., atmospheric, splash, or submerged zone).
- Site environmental conditions.
- Rate of damage progression.
- Anticipated design life.
- Tolerance of the component or element to the corrosion damage (i.e., classification).
- Capability of the NDE program or methodology to identify the corrosion rates and related deterioration.
- Extent of inspection.
- Past and recent histories of operation, use, and inspection.

A Routine Inspection may require several tasks that are specific to a given component or element and relative to the specific exposure zone, which may warrant different frequencies for each task. For example, checking the current output of an impressed current rectifier should occur more frequently than an underwater observation of the associated anode, although both should occur regularly. In this sense, a Routine Inspection for the Corrosion Manual may warrant different inspection frequencies for various tasks. The inspection plan should identify the frequency for different tiers of tasks, identified as Functionality Checks, Tier 1 Inspections, Tier 2 Inspections, or Tier 3 Inspections. The defined frequency may be different for above-water and below-water inspections and can be different for different corrosion protection systems within the same asset. The frequency of the inspection for specific components or assets can also be adjusted based on the overall corrosion condition rating or corrosion damage rating index. Corrosion damage analysis is to be included in the Baseline Inspection and during each Routine Inspection, but not necessarily following each Functionality Check. The inspection plan should be updated, including scope and frequency, following each Routine Inspection, as required.

A guideline outlining recommended maximum time intervals between inspections for representative Functionality Checks, Tier 1 Inspections, Tier 2 Inspections, and Tier 3 Inspections, is provided in Table 2.1. A guideline with recommended NDE testing location intervals is provided in Table 2.2. Recommended frequencies and intervals outlined below may be adjusted in any inspection plan for a given element or asset dependent on the conditions discussed above.

Table 2.1. Guidelines for Maximum Inspection Intervals

Task Classification	Inspection Interval[Note 2]	Example Inspection Tasks [Note 1]
Functionality Checks [Note 3]	6 months	Verify functionality of ICCP system (current output, frequency, power consumption, shunts, etc.)
	1 year	Measure and record on/off structure-to-electrolyte potentials (and/or decay potentials) for cathodic protection systems
		Verify accessible negative lead-to-structure connections are intact
Tier 1 Routine Inspections	3 years	Perform above water visual assessment
		Obtain above-water thickness measurements of base metal elements
		Obtain above-water coating thickness and/or adhesion measurements
Tier 2 Routine Inspections	6 years	Level I underwater visual inspections of anodes
		Level II underwater cleaning and visual inspection of anodes and base metal elements
		Level III underwater cleaning and remaining thickness/weight measurement of base metal elements, coatings, and anodes
Tier 3 Routine Inspections	As Required[Note 4]	Visual inspection and thickness measurements of buried base metal elements or CP anodes

Note 1: Underwater inspection levels per ASCE 101

Note 2: Inspection interval for a particular asset is defined in the Inspection Plan. Interval may be reduced for assets with significant deterioration or where dictated by the type or priority of use. Interval may be increased for newly constructed assets or other assets at the discretion of the PHA.

Note 3: Typical functionality checks are as described in NACE SP0169 and SP0176. Note the frequency for Functionality checks has been modified from the referenced standards to meet the needs and desires of PHA.

Note 4: Inspection of buried elements will be as defined in the Inspection Plan. Initial inspection interval will be based on the age and visual condition of associated elements. The need and frequency of inspection for buried elements will be established based on subsequent inspections.

Table 2.2. Recommended Minimum NDE Testing Intervals

Element Classification	Exposure Zone	Test Intervals[Note 1, 2]
Critical	Atmospheric / Splash / Tidal	Base Metal Thickness: Every 50 LF or 20% of elements Coating Thickness and/or Adhesion: Every 50 LF or 20%
	Submerged	Base Metal Thickness: Every 100 LF or 10% of elements Coating Thickness and/or Adhesion: Every 100 LF or 10%
	Soil	As required
Typical	Atmospheric / Splash / Tidal	Base Metal Thickness: Every 100 LF or 10% of elements Coating Thickness and/or Adhesion: Every 100 LF or 10%
	Submerged	Base Metal Thickness: Every 200 LF or 5% of elements Coating Thickness and/or Adhesion: Every 200 LF or 5%
	Soil	As required
Redundant	Atmospheric / Splash / Tidal	Base Metal Thickness: Every 200 LF or 5% of elements Coating Thickness and/or Adhesion: Every 200 LF or 5%
	Submerged	Base Metal Thickness: Every 200 LF or 5% of elements Coating Thickness and/or Adhesion: Every 200 LF or 5%
	Soil	As required

Note 1: Individual repeated elements, such as piles, sampled on percentage basis. Large, solid-faced elements, such as bulkhead walls, measured based on plan length (linear foot = LF)

Note 2: A minimum of three test locations should be obtained for each element classification within each exposure zone, with a minimum of three individual readings at a given location (approximately 1 sq. ft.).

2.3. Baseline Inspection

The Baseline Inspection is asset-wide and includes both above-water and underwater inspections. At a minimum, a Baseline Inspection is the first inspection for an asset and may be considered the first routine inspection. The purpose of the Baseline Inspection is to:

- Develop an asset-specific corrosion inspection plan for the Corrosion Manual
- Develop a corrosion inventory record to be used as a point of reference for future inspections and condition assessments;
- Identify all corrosion protection components and elements within the scope of the inspection and condition assessment for the asset;
- Identify elements that are inaccessible or have special access requirements, including confined spaces;
- Assess current condition of each element and component; and
- Develop corrosion protection component and overall corrosion condition ratings as part of the condition assessment.

The Corrosion Inventory Record includes two primary items:

1. **Drawings and photographs** showing the current layout of corrosion protection components and elements. In particular, the documented asset layout should provide a clear delineation of corrosion protection elements, a labeling system for individual elements (i.e., assigning element numbering), and representative asset-type photographs (see Chapter 8 for reporting). The baseline drawings reflect a schematic "cumulative as-built" of the corrosion protection components and corresponding base metal elements, incorporating any modifications, extensions, or demolition which may have occurred since original construction. For existing assets, this may require an extensive review of records and field verification of items.
2. **Documented quantities of elements**. The baseline drawings include a listing of quantities for each of the elements included in the corrosion inspection. Using the established labeling system, the documented quantities of elements provide a means for future routine inspections to be conducted rapidly (i.e., all future inspection teams expect a certain number of anodes or a specified quantity of bulkhead).

With the corrosion protection component layout defined and an established labeling system, the remaining portion of a Baseline Inspection is to document any existing condition states using an element-based approach (discussed in Chapter 3) and develop corrosion protection component and overall corrosion condition ratings as part of the condition assessment based on the corrosion damage rating index estimation (discussed in Chapter 6). This portion is essentially the same scope as a Routine Inspection. It is important that the Baseline Inspection be comprehensive enough to provide a complete corrosion manual file for database purposes and to provide the basis for future inspections. A thorough and well-documented Baseline Inspection will facilitate time-efficient future routine inspections since inventory information and previous element-based inspection results will already be available as a starting point.

Ideally, a Baseline Inspection is performed before or soon after construction is completed for a new asset. Existing assets with no or limited inspection documentation will require a Baseline Inspection to fully document existing conditions. Baseline Inspections should also be performed after modifications or significant repairs are performed to either the asset or the corrosion protection systems.

Above water, the scope of a Baseline Inspection is a comprehensive visual inspection of all readily accessible corrosion protection and base metal elements in the entire asset as well as additional testing included in the defined inspection procedures in the inspection plan. The scope of the underwater inspection should be defined in the inspection plan and is limited to certain elements of the substructure, bulkhead wall, or fender system as covered in the scope of the Corrosion Manual. On certain assets, access to areas may be restricted by structure configuration, asset usage, or other concerns. In these areas, sonar imaging may be used to provide an inventory record of pile locations and bulkhead location. Note that Level 1 Underwater Diving Inspections per ASCE 101 are also required per the Maritime Structures Manual. If feasible, data from underwater inspections from the Maritime Structures Manual may be used in part or in full to provide the necessary information required by the Corrosion Manual.

After the Baseline Inspection is completed, corrosion damage analysis is performed, and recommended follow-up actions should be generated as warranted. While it is important to comprehensively inspect all corrosion protection and base metal components in a Baseline Inspection, if an element or component is not accessible due to temporary obstructions, a typical, recommended follow-up action is to flag the element for inspection on the next Routine Inspection. If the surrounding conditions of an obscured element indicate the element may have distress such that it affects the functionality and structural capacity of the asset, the temporary obstructions should be removed and the inspection completed as an immediate follow-up action.

Finally, the Baseline Inspection provides recommendations for the timing and frequency of Routine Inspections, discussed in more detail in the following section. It also provides needed information to assess the condition of elements in the scope of the Corrosion Manual and estimate the associated corrosion damage.

2.4. Routine Inspection

The Routine Inspection includes both above water and underwater inspections and is the most commonly performed inspection. Conducted at intervals defined in the corrosion inspection plan, the purpose of the Routine Inspection is to:

- Inspect readily accessible elements of the corrosion protection and base metal components. The scope of elements to be included is generally the same as in the Baseline Inspection; however, inspection frequencies may vary depending on element classifications.
- Update the inventory record with drawings/sketches/photographs documenting any changes in the corrosion protection components. Note that significant changes due to modification or repair should be previously identified in the asset file as part of either a previous Baseline Inspection or Routine Inspection inventory record or repair/rehabilitation record.
- Update the inspection forms with changed condition states (i.e., identify new conditions, verify old conditions remain unchanged, have been repaired, or have increased in severity or extent). This information should be detailed enough to properly scope special inspections or recommended follow-up actions, and to assist in assigning component and overall asset ratings as part of the condition assessment.
- Take additional measurements as defined in the corrosion inspection plan and update the corrosion damage rating index of base metal components.
- Update corrosion protection and base metal component ratings and the overall corrosion condition rating as part of the condition assessment.

The inspection interval for Routine Inspections may vary from asset to asset dependent on condition of the asset and corrosion protection systems. As described above, Routine Inspections may include Tier 1, Tier 2, or Tier 3 inspection tasks. The default inspection interval under the Maritime Structures Manual is a maximum of 3 years for above water and 6 years for underwater inspections. For components under the Corrosion Manual, the frequency of inspections would be defined in the asset-specific inspection plan. The default inspection interval is 3 years for Tier 1 tasks and 6 years for Tier 2 tasks. Tier 3 tasks are only performed on an as-needed basis. The outcome of an inspection and condition assessment may recommend more frequent inspections for particular elements based on observations of advanced or severe deterioration or results of corrosion damage analysis. More frequent inspections may also be recommended for assets where the type of use (e.g., heavy use, public access, high priority use) warrants a more frequent assessment. Less frequent inspections may be recommended for newly constructed assets or for assets where the condition or use warrants an increased inspection interval. The selection of inspection frequency for any structure will be recommended by the inspection firms and approved by PHA.

The above and below water inspection requirements are similar to those described for the Baseline Inspection. Above water, the scope of a Routine Inspection is a comprehensive visual inspection of all readily accessible elements for the corrosion protection components with additional testing related to corrosion protection or base metal elements as defined in the inspection plan.

After each Routine Inspection is completed, the component ratings are scored, including the corrosion damage rating indices for base metal components, as well as the overall corrosion condition rating. Recommended follow-up actions may include special inspections with prescribed levels of effort (optional) or increased inspection frequency or levels of effort for future routine inspections. If necessary, the inspection team can recommend modifying the inspection plan to accommodate a change in corrosion protection systems or a change in the corrosion damage estimation.

2.5. Functionality Checks

As discussed previously, some corrosion protection systems (e.g. impressed current cathodic protection systems) will require more frequent inspections to ensure ongoing functionality of the system. An example of these elements is the rectifiers in an impressed current cathodic protection system. These functionality checks can be performed during Routine Inspections but should also be performed at more regular intervals (every 2 months to 1 year, as defined in the Inspection Plan). These checks are analogous to ongoing maintenance inspections with very limited scope and a shorter time interval. After completing Functionality Checks, the inspector would not typically perform any updated component ratings or corrosion damage rating index. However, if a considerable change in the functionality of a corrosion protection system is identified, the inspection team can recommend follow-up actions or modify the component rating for the corrosion protection systems.

2.6. Example Inspection Plan and Commentary

For reference, a representative Corrosion Inventory Record and Routine Inspection Plan for Wharf 5 of Barbours Cut Terminal (BCT5) is provided in Appendix F. Construction of BCT5 was completed circa 1992 and consists of a reinforced concrete deck supported by reinforced concrete drilled shafts and beams beneath the topside crane rails. A landside steel bulkhead wall was installed circa 1990, prior to the construction of the wharf, and a steel-framed fender system is installed on the channel side. An ICCP system and surface protection coatings are installed to protect each of the three base metal element groups (bulkhead wall, fender piles, and fender support framing). PVC casings are used to protect the buried tie rods for the bulkhead. This section provides commentary regarding the BCT5 inspection plan, including tasks and inspection frequencies.

Functionality Checks - Tasks associated with routine functionality checks for the ICCP system include measuring and recording current and voltage output every six months for each rectifier and performing a visual inspection of the negative lead connections to the structure once each year. Current output can be measured at each rectifier, while connection inspections can be quickly performed by walking the topside (for the fender connections) and along the bulkhead beam (for the bulkhead wall connections) and these checks verify each unit is still turned on, working, and the structure is still receiving some level of protection from the installed system. In addition, structure-to-electrolyte potentials surveys will be performed annually to determine if CP is adequate based on the criteria of NACE SP0169. The minimum number and locations for measuring polarization decay are provided in the inspection plan to match the locations that were measured during the baseline inspection.

Tier 1 Inspection Tasks - The inspection frequency of Tier 1 inspection tasks is 3 years and includes the following tasks (described in further detail in the Routine Inspection Plan in Appendix F):

- Visual assessment of all accessible corrosion protection and base metal elements
- Thickness measurements of select base metal elements
- Coating thickness and adhesion measurements for select coating elements

Due to the age of the structure, some level of distress would be expected in both the corrosion protection systems and base metal elements. Tasks listed in Tier 1 require a higher level of effort than the functionality checks; however, these tasks should be performed on a regular basis. Visual assessment is the simplest way to identify and/or locate distress conditions within readily accessible portions of the corrosion protection systems and/or base metal elements and can be performed for the atmospheric, tidal, and splash zones. Lastly, gathering data to track deterioration rates and update the component rating results is critical and requires representative data regarding both steel and coating thickness.

Tier 2 Tasks - The inspection frequency of Tier 2 inspection tasks is 6 years and includes the following tasks (described in further detail in the Routine Inspection Plan in Appendix F):

- Level I underwater diving inspection to verify anode condition
- Level II underwater inspection and cleaning of anodes in five of the bays (approximately 10% of anodes)
- Level III underwater inspection and mass measurement of anodes in three of the bays (approximately 5% of anodes)
- Thickness measurement of applicable coating and base metal elements in upper portion of submerged zone in accordance with Table 2.2.

Inspection tasks outlined here have a longer recommended time between inspections for several reasons. First, the underwater inspection is more time consuming and costly, and the protection provided by the anodes can be verified through measured on/off potentials as part of the Tier 1 task. If these measurements are not indicating proper system performance, a more frequent underwater inspection may be warranted. Because of the increased effort for underwater inspection, coupled with the fact that the splash and tidal zone areas are being inspected every 3 years, a 6-year inspection frequency provides a reasonable time frame recognizing the slower deterioration rate of the exposure zone. If the section loss in the upper portion of the submerged zone indicates significant section loss, a more frequent measurement may be justified. The primary purpose of the first Level I and Level II underwater anode inspection is to identify ineffective or missing anodes and provide data related to any required maintenance and scheduling of anode replacement. Since the functionality checks and potential measurements (listed in Tier 1) indirectly measure the effectiveness of the anode groups as a whole, inspection intervals for these tasks can be longer.

Tier 3 Tasks - No specific Tier 3 inspection tasks are included for BCT5 as part of the initial Inspection Plan. Bulkhead tie rods are the only buried (normally inaccessible) base metal elements as part of the corrosion inventory. Based on conversations with Port Houston, a future project is planned that will provide an opportunity for excavation and exposing the tie rods. Visual inspection and thickness measurements can be planned as part of that work when it occurs, rather than included as part of the routine inspection.

2.7. Other Special Inspections

The inspection types included in the primary scope of the Corrosion Manual are the Baseline and Routine Inspections, as well as Functionality Checks. In some situations, Special Inspections may be required outside of the regular inspection program. If necessary, three types of Special Inspections are defined in Chapter 2 of the Maritime Structures Manual: Post Event, In-Depth, and Due Diligence. These inspection types would be implemented as and when needed at the discretion of the PHA.

2.8. Refined Engineering Analysis or Other Corrosion Management Tasks

The primary scope of the Corrosion Manual does not include all of the potential refined engineering analyses or corrosion management tasks that could be performed as a result of Baseline or Routine Inspections. These analyses could include the following:

- Refined service life analysis.
- Life-cycle cost analysis to develop repair or corrosion protection solutions.
- Quantify structural effect of corrosion damage or other distress or defects.
- Evaluate need for repairs or supplemental corrosion protection.

An inspection may identify significant corrosion damage, defects, atypical conditions, or potential structural or functional concerns that may warrant a more refined engineering analysis. In these situations, the inspection and condition assessment team should include this finding in their recommended follow-up actions (see Chapter 7). These engineering analyses are considered outside the primary scope of the Corrosion Manual, and would be pursued at the discretion of the PHA.

2.9. Relationship between Inspection Plan, Inspection Types, and Refined Engineering Analysis

The relationship between Inspection types and Corrosion Damage Analysis of the Corrosion Manual is shown in Figure 2.1. The overall definition of the Baseline and Routine Inspections is the same as that under the Maritime Structures Manual, although the particulars (scope, timing, etc.) will be adjusted as needed in the asset-specific inspection plan to assess the unique features of corrosion protection systems.

The primary objectives of the Corrosion Manual are achieved by conducting a Baseline Inspection for each maritime asset followed by regularly scheduled Routine Inspections. A Baseline Inspection establishes the initial corrosion inventory information and component and overall corrosion condition ratings and is applied to every new asset and to existing assets where no previous inspection record exists. It may also be implemented after a major modification to an asset. A Routine Inspection defines the corrosion protection system and base metal conditions, corrosion and base metal component ratings, and overall corrosion condition ratings, and element condition states at a point in time and allows tracking of conditions over time. Corrosion damage analysis is performed based on the Baseline or Routine Inspections. The outcomes of a Baseline or Routine Inspection may include:

- No further action is required at this time; asset is scheduled for its next Routine Inspection.
- Modification to the corrosion inspection plan is recommend prior to next Routine Inspection
- More information is needed and/or repairs are required; conditions observed indicate that further investigation or repairs are required, prompting an In-Depth Inspection (defined in Maritime Structures Manual).
- Immediate action is required; observed conditions may compromise structural integrity or facility operations or may lead to property or environmental damage and require immediate attention.

The In-Depth, Due Diligence and Post-Event Inspections is not considered part of the regular Corrosion Manual of Baseline and Routine Inspections and are prompted by specific needs or implemented at the discretion of the PHA and when warranted by other inspections or situations. These inspections are defined in more detail in the Maritime Structures Manual.

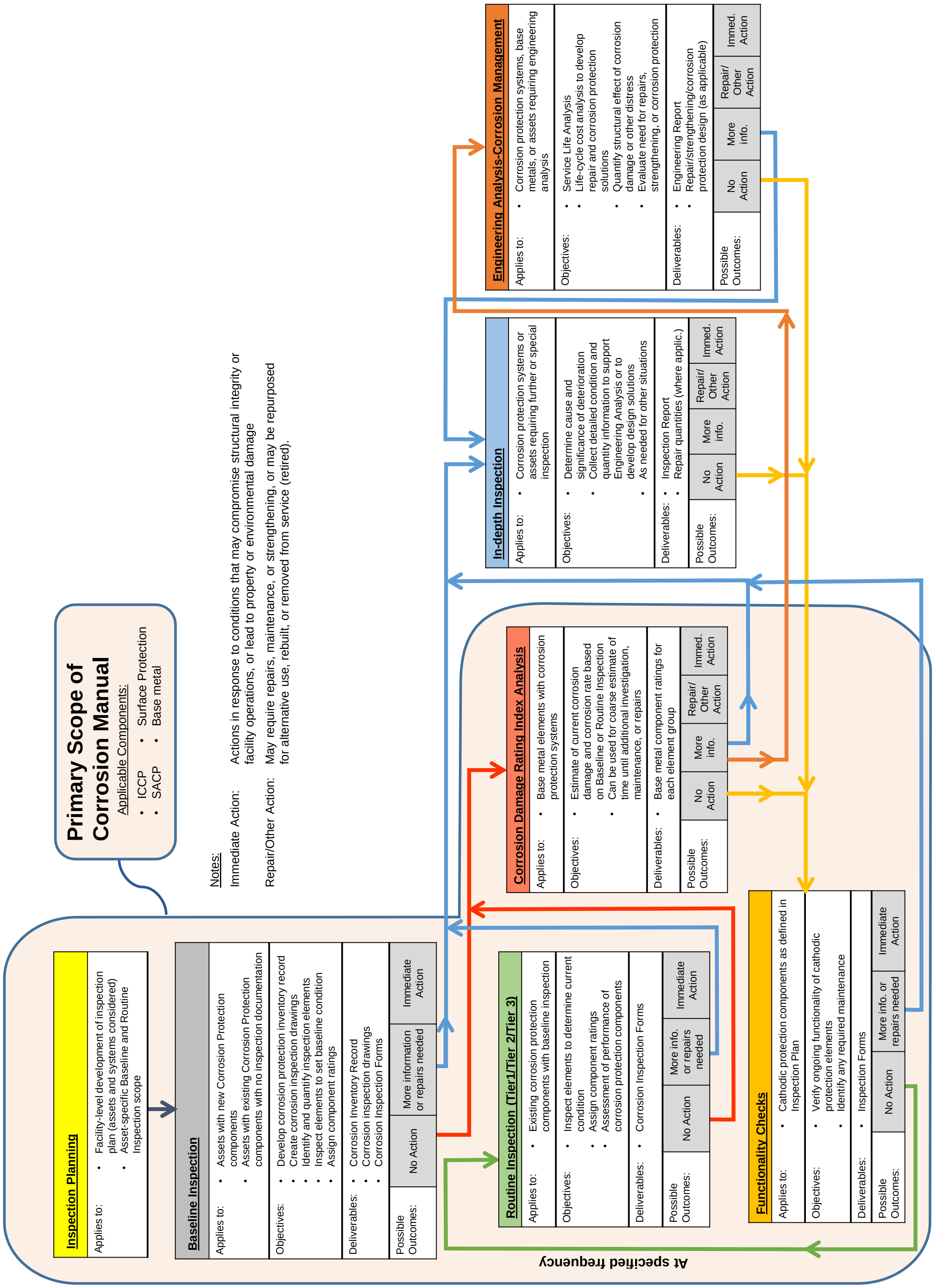


Figure 2.1. Relationship between Inspection Planning, Inspection Types, and Engineering Analysis.

CHAPTER 3: ELEMENTS AND ELEMENT CONDITIONS

3.1. General

The corrosion protection and base metal components within an asset consist of multiple individual elements, which may be corrosion protection related (e.g., rectifier, anodes, coating) or the corresponding base metal elements from the Maritime Structures Manual (e.g., bulkhead wall, fender pile, or whale beam). As discussed in Chapter 1, conducting the inspection on an elemental basis provides a systematic, objective, and comprehensive means of collecting inspection data. The following sections describe the elements that form a component, as well as how the condition of these individual elements is documented during an inspection using defined condition states.

3.2. Element Conditions and Condition States

Element conditions include potential damage, deterioration, or defects that may exist in an individual element. Some element conditions are element or material-specific (e.g., consumption of anode), while other element conditions may be experienced by several different elements (e.g., missing).

During a Baseline, Routine, or Due-Diligence Inspection, relevant conditions should be documented for each element using four standard, predefined condition states specific to the various conditions observed. The standard condition states range as follows: good (CS1), fair (CS2), poor (CS3), and severe (CS4). An example of selected element condition states that occur in bulk anodes is shown in Table 3.4. A complete list of typical conditions and their defined condition states is provided in Appendix D. Appendix E provides the same lists but arranged by element type for ease of use during an inspection (i.e., bulk anodes, power supply, monitoring equipment, coating, etc.)

Table 3.1. Example of Selected Condition States for Anodes

Code	Condition Name	Condition Definition	Condition States			
			CS1 (Good)	CS2 (Fair)	CS3 (Poor)	CS4 (Severe)
CNSM	Consumption	Consumption of anode.	<10% consumed by weight	10-50% consumed by weight	51-75% consumed by weight	>75% consumed by weight
CONA	Condition of Anode Connection	Condition of thermite weld connecting anode to the wiring.	No connection distress; connection is in place and functioning as intended.	Minor distress without distortion is present, but connection is in place and functioning as intended.	Cracked weld or damaged connection; assessment has determined electrical connection has not been compromised.	Cracked weld or failed connection resulting in electrical isolation of the anode.
MARG	Marine Growth	Organic growth on bulk and/or ribbon anodes.	No marine growth present.	Minor marine growth on anode.	Moderate marine growth on anode that may affect functionality.	Significant marine growth on anode affecting functionality.

Code	Condition Name	Condition Definition	Condition States			
			CS1 (Good)	CS2 (Fair)	CS3 (Poor)	CS4 (Severe)
MISS	Missing	Element intended to be in place is missing. Does not apply to elements that have been intentionally removed as part of a modification.	Element is present.	Parts of an element are missing, however does not affect functionality.	Element is missing but assessment has determined element is not needed for functionality.	Element is missing.
PASS	Passivation	Passivation of anode.	Passivation is not present	Passivation is less than 50%	Passivation of anode is 50%-80% (visual).	Passive film has built up on the anode, greater than 80% and affecting performance of CP system.

In order to provide a complete characterization of the element condition, three features of the condition should be established:

- Type of observed condition (e.g., broken connection, missing anode, error in output display).
- Severity of observed condition (e.g., type and size of defects, severity of section loss).
- Scope or extent of observed condition (e.g., number of defects, area/length affected). This is quantified by the length, area, or number of elements having the condition state in question. The quantity is associated with units listed for the element.

The process of providing this characterization is presented in the following section.

3.2.1. Documenting Element Condition States

The condition states provide a means for the Inspection Team to characterize and quantify any observable conditions exhibited by an individual element. As each element is inspected, the observed condition is categorized into one of the predefined condition states. An element may experience multiple conditions, even in the same location (e.g., on a DC Power Supply, the output display panels may be malfunctioning and the shunt may be missing). The extent of the condition is defined by recording the quantity of the condition state using the specified measured units defined for the element in Appendix C. Inspection records for data entry are discussed in Chapter 8.

The total quantity of each observed condition and corresponding condition state are rated for each element. The total quantity of observed conditions will add up to the total quantity for the element. If concurrent conditions are observed or measured for the same element, the highest (most severe) condition state is documented and quantified, and the lower (less severe) condition state is documented but the quantity is recorded in brackets to denote that the lower condition state is not considered in the total quantity. If no distress condition is observed, the element is considered a CS1. The total quantities for each type of element (element group) are also summed based on the condition state subtotals, irrespective of which type of condition was the cause of a condition state.

Table 3.2 provides an example of condition state data collected during a Routine Inspection. In this example, the element condition states for two coating elements are shown; only visual condition information is collected for these example elements. The Element ID is based on the naming scheme used to uniquely identify each element and is shown on the asset's corrosion inspection drawings, as described in Section 8.4.

Table 3.2. Example of Documenting Condition States for Corrosion Protection Elements

Element Location ID	**Element / Condition Code**	**Units**	**Total Quantity**	**In-accessible**	**Condition States (quantity [counted with other CS])**			
					CS1	**CS2**	**CS3**	**CS4**
CT 40-1	CT-EP	SF	230	165	0	35	30	0
	– PEEL	*SF*	*30*				*30*	*0*
	– CHLK	*SF*	*35*			*35 [25]*		
CT 40-2	CT-EP	SF	175	0	35	60	40	40
	– PEEL	*SF*	*80*				*40*	*40*
	– CHLK	*SF*	*60*			*60 [25]*		
Coating Subtotal	**CT-EP**	**SF**	**405**	**165**	**35**	**95**	**70**	**40**

The first coating element (labeled CT 40-1) is an epoxy coating (CT-EP) on a bulkhead wall (base metal element) with a total element quantity of 230 square feet. Inspection of this element determined that 165 square feet of the coating was below the waterline and not inspected. 30 square feet was categorized as CS3 because 30 square feet of CS3 peeling/cracking of the coating (PEEL) was observed. 35 square feet was categorized as CS2 because 60 square feet of a CS2 chalking of the coating (CHLK) was observed; however, 25 square feet of the chalking was observed within the same area of CS3 PEEL. These observations for CT 40-1 are recorded in Table 3.5 as follows:

- 30 SF of PEEL in CS3.
- 35 [25] SF of CHLK in CS2; the square bracket notation indicates that there is 60 SF of CHLK (CS2), but that 25 SF is concurrent with another more severe condition (PEEL in this case) and is recorded but is not counted in summations.
- 165 SF of Inaccessible; this is the total area of coating below the waterline.

The second coating element (labeled CT 40-2) is an epoxy coating on fender secondary framing (base metal element) with a total element quantity of 175 square feet. Inspection of this element determined that 40 square feet was categorized as CS4 peeling/cracking (PEEL), and 40 square feet was categorized as CS3 peeling/cracking. Note that within the 40 square feet of CS3 peeled area, 25 square feet of CS2 chalking area was also identified. An additional 60 square feet of CS2 chalking was also observed at other areas. The inspection observations for CT 40-2 are recorded in Table 3.5 as follows:

- 60 [25] SF of CHLK in CS2; the square bracket notation indicates that there is 85 SF of CHLK (CS2), but that 25 SF is concurrent with another more severe condition (PEEL in this case) and is recorded but not counted in summations.
- 40 SF of PEEL in CS3.
- 40 SF of PEEL in CS4.
- 35 SF of CS1; this is the total inspectable area of CT 40-2 without distress.

The total quantities in each condition state for a particular element group (e.g., epoxy coating, CT-EP) may be helpful in assessing the condition of the element group and related components. To report quantities for elements as a group, the quantities are summed based on the condition state subtotals, irrespective of which type of condition was the cause of a condition state. Using the example data in Table 3.5 for the hypothetical CT-EP coating group, this results in a total of 405 square feet of the possible coating surface, of which 35 square feet is CS1, 95 square feet is CS2, 70 square feet is CS3, and 40 square feet is CS4 (total of 240 square feet with an assigned condition state). The use of the square brackets to indicate areas of concurrent distress types is necessary to correctly arrive at these condition state totals for the coating element group. Portions of the element which were inaccessible for the inspection (165 square feet) are recorded separately and are not assigned a condition state.

For some elements, field measurements will be performed in addition to visual condition ratings to quantify and evaluate certain conditions (e.g., section loss on metals, coating thickness, anode mass, etc.). In these cases, the measured values are recorded and documented for data entry as discussed in Chapter 8. The measured values are used to evaluate the element condition and corresponding condition state for the measured element, as well as for purposes of assessing and rating the overall component. The quantity associated with the condition state (i.e., how much of a given element is represented by the measured data) corresponds to the units for the given element, even though the measured units may be different. For example, coating thickness may be measured in mils (1 mil = 0.001 inch), but the condition state is quantified based on SF. Field measurements such as coating thickness or section loss occur at distinct locations of given elements, but the condition states are quantified for the entire quantity of elements represented by the measurement. Visual observations are used to estimate the quantity of the element represented. For example, the condition state for the field measurement may be assigned a quantity based on the exposure zone quantity for the element (e.g., atmospheric, splash, tidal or submerged). As described above, if concurrent conditions are measured for the same element, the highest (most severe) condition state is documented and quantified, and the lower (less severe) condition state is documented but the quantity is recorded in brackets to denote that the lower condition state is not considered in the total quantity.

In addition to documenting the measured data in a tabular report as described in Chapter 8, the condition states and quantities associated with the measured data are also recorded in a detailed element condition summary along with the visual condition state ratings for the element in question. Table 3.6 provides an example of condition state data collected during a Routine Inspection of the coal-tar epoxy coating (CT-EP) surface protection system on support framing and fender pile of wharf CD 28, Bay 66. The example demonstrates how the condition states were defined and recorded for both visual observations and measured conditions. The coating element was quantitatively evaluated in terms of coating thickness (condition code THCK) and coating adhesion (condition code ADHS). The coating thickness was nondestructively evaluated using ultrasonic testing (UT). Up to ten UT measurements were taken on different exposure zones and the condition state (CS1 through CS4) in each zone was determined based on the criteria for THCK in Appendix D and E. The coating adhesion was evaluated using based on ASTM D3359 at up to five locations in different exposure zones and the condition state in each zone was determined based on the ADHS criteria in Appendix D and E. The coating was also evaluated visually. As a result, multiple condition states were recorded for each coating element and must be documented such that the total quantities in each condition state can be determined for the element group (e.g., CT-EP).

Table 3.3. Example of Condition States with Quantified Data for Corrosion Protection Elements

Element Location ID	Element / Condition Code	Exposure Zone	Units	Total Quantity	In-accessible	Condition States (quantity [counted with other CS])			
						CS1	CS2	CS3	CS4
CT 66-2	CT-EP		SF	450	0	0	403	12	35
(Base	*– PEEL*	*Splash*	*SF*					*12*	*35*
Metal ID	*– ADHS*	*Atmos.*	*SF*				*270*		
SF 66-1)	*– THCK*	*Splash*	*SF*				*133 [47]*		
CT 66-1	CT-EP		SF	100	60	0	0	30	10
(Base	*– PEEL*	*Atmos.*	*SF*					*5*	
Metal ID	*– PEEL*	*Splash*	*SF*						*10*
FP 66-1)	*– ADHS*	*Atmos.*	*SF*					*25 [5]*	
	– THCK	*Atmos.*	*SF*				*[30]*		
	– THCK	*Splash*	*SF*				*[10]*		
Coating Subtotal	**CT-EP**	**All**	**SF**	**550**	**60**	**0**	**403**	**42**	**45**

The coating element (CT 66-2) on support framing (SF 66-1) has a total element quantity of 450 square feet. Inspection of this element determined that 12 square feet was categorized as CS3 peeling/cracking (PEEL) and 35 square feet was categorized as CS4 peeling/cracking within the splash zone. Adhesion testing in the atmospheric zone was characterized as fair (CS2). Coating thickness measurements were performed in the atmospheric and splash zones, with condition states of CS1 and CS2, respectively. Note that the THCK condition state in the atmospheric zone does not need to be recorded here since it is CS1.

For this support framing, the atmospheric zone was assumed to be 270 square feet (60% of total area) and the splash zone was taken as 180 square feet (40% of total area). The CS ratings for THCK and ADHS are assigned quantities based on the exposure zone quantities where measurements were taken. The inspection observations for CT 66-2 are recorded in Table 3.6 as follows:

- 12 SF of PEEL in CS3; Splash zone
- 35 SF of PEEL in CS4; Splash zone
- 270 SF of ADHS in CS2; Atmospheric zone
- 133 [47] SF of THCK in CS2; Splash zone. The square bracket notation indicates that there is 180 SF of THCK (CS2), but that 47 SF is concurrent with another more severe condition (PEEL in this case) and is recorded but not counted in summations.

The coating element (CT 66-1) on the fender pile (FP 66-1) has a total element quantity of 100 square feet. Inspection of this element determined that 5 square feet was categorized as CS3 peeling/cracking (PEEL) within the atmospheric zone and 10 square feet was categorized as CS4 peeling/cracking within the splash zone. Adhesion testing in the atmospheric zone was characterized as CS3. Coating thickness measurements were performed in the atmospheric and splash zones, with condition states of CS2 in both zones. For this fender pile, the atmospheric zone was assumed to be 30 square feet (30% of total area) and the splash zone was taken as 10 square feet (10% of total area). The remaining element area (tidal and submerged) is taken as 60 square feet and was inaccessible during this inspection. The inspection observations for CT 66-1 are recorded in Table 3.6 as follows:

- 5 SF of PEEL in CS3; Atmospheric zone
- 10 SF of PEEL in CS4; Splash zone
- 25 [5] SF of ADHS in CS3; Atmospheric zone. The notation indicates that there is 30 SF of ADHS (CS3), but that 5 SF is concurrent with another more severe condition (PEEL in this case).
- [30] SF of THCK in CS2; Atmospheric zone. The notation indicates that the full 30 SF in the atmospheric zone is concurrent with a more severe condition (PEEL and ADHS in this case).
- [10] SF of THCK in CS2; Splash zone. The notation indicates that the full 10 SF in the splash zone is concurrent with a more severe condition (PEEL and ADHS in this case).

3.3. Element Type Descriptions

A broad range of corrosion protection element types may be encountered in maritime assets. Element types are primarily defined by their functional purpose and material type. Appendix C provides a list of element types arranged by the component with which it is associated. The terminology used in the element descriptions is defined in the Glossary (Appendix B). This list of element types contains the following information to describe each element:

- *Associated component.* This provides the component of which the individual element is a part.
- *Element code.* This code is used to indicate the element type and material for ease of documentation. The first two letters of the code are descriptive of the element type and the last two or three letters indicate the material type, as defined in Table 3.4.
- *Element descriptor.* A unique name is given for the individual element. Where applicable, the element name includes the material type, as defined in Table 3.4.
- *Element identification.* The element is described in the narrative for identification and categorization by the field inspection personnel. Multiple element types may share the same description but differ by material type.
- *Measured units.* This indicates the measurement basis by which an element's condition state is quantified (e.g., area units, linear units, or per-element occurrence).

While the element list in Appendix C is comprehensive, the list is not exhaustive and other elements may be present in some maritime assets within the PHA inventory. Table 3.5 provides an example of select element descriptions. The element types for a particular asset should be defined during the development of the Inspection Plan and confirmed as part of the scope of a Baseline Inspection and should be referred to for all subsequent routine or other inspections. Categorization of undefined element types should be discussed with the PHA Project Contact to ensure that naming is consistent with the PHA asset management system. For multiple-coat coating systems, the coating element material is categorized based on the primary protection system. For example, if a coating system includes an epoxy primer (2-3 mils), polyester barrier coat (16-18 mils) and a polyurethane topcoat (2-3 mils), the coating would be categorized as a polyester coating. If a given element has multiple types of coating systems, say the support framing for the fender includes some members with epoxy coating and some members with coal tar epoxy, then the coating element for the overall framing element would be categorized as "other."

Table 3.4. Materials for Corrosion Protection and Base Metal Elements

Element		Abbreviation	Description
Anodes	Aluminum	AL	Aluminum alloy anodes are used primarily in seawater applications and can be produced in a variety of alloys.
	Cast Iron	CI	Cast iron anodes can be used in fresh water, seawater, or underground applications. High-silicon cast iron is a commonly used alloy containing silicon, chromium, and iron.
	Dual	DL	Dual galvanic anodes can be made with a highly active anode metal casing (e.g. magnesium) and a less active core (e.g. zinc). These anodes are designed to provide a high initial current density to achieve initial cathodic polarization.
	Graphite	GP	Graphite anodes are used in soils, flowing seawater, and mud and are typically impregnated with a sealer to prevent failure from gas evolution in pores. Oftentimes used within anode wells.
	Magnesium	MG	Magnesium anodes are available as high-potential or low-potential alloys and are normally used in soils and fresh water.
	Zinc	ZN	Zinc anodes are available in two alloys; one for use in soils and the other for seawater application. Can be manufactured as a bulk anode or a mesh.
	Mixed Metal Oxides	MMO	Layer of precious metal oxide intermixed with titanium or tantalum oxide, on a titanium substrate. These anodes have a significantly lower consumption rate than typical galvanic anodes. Consumption rate in seawater can be as low as (0.5-1.0) mg/A-yr. Typical current capacity between 50-100 A
	Silicon/ Chromium/Iron	SCI	(FeSiCr) Similar functionality as MMO anodes, but semi-inert with greater consumption rates. Typically current capacity less than 30 A.
Cathodic Protection Jackets	Fiberglass	FG	Jacket encasements around structural elements constructed with fiberglass.
	Polyvinyl Chloride	PVC	Jacket encasements around structural elements constructed with PVC (polyvinyl chloride).
Coatings	Acrylic	AC	Acrylic coatings can be used as a topcoat in mild environments, typically installed on top of an inorganic zinc.
	Epoxy	EP	Epoxy-based coatings are commonly used as a primer, intermediate, or top coat within a steel coating system or as a sealer for a concrete coating system.
	Coal Tar Epoxy	CE	Two-component coal-tar-based epoxy used in marine or buried exposures. More typical of older structures.
	Polyurethane	PU	Polyurethane topcoats are a commonly used topcoat for steel elements in corrosive environments, especially where UV durability is a concern.
	Polyester	PE	Polyester coatings, with or without glass flake, are used on steel elements to form corrosion protection as barrier coatings.
Hot-Dip Galvanizing	Zinc	HDG	Sacrificial surface protection applied to carbon steel to provide sacrificial surface protection.
Metals[1]	Galvanized Steel	GS	Carbon steel that has been hot-dip galvanized with zinc.

Element		Abbreviation	Description
	Steel	CS	Carbon steel materials.
	Stainless Steel	SS	Stainless steel materials. Stainless steels have a minimum of 10.5 percent chromium and are available in various grades with varying corrosion resistance.
	Metals (all other)	MT	Metals that do not fall into any of the other categorized. Includes aluminum, cast iron, ductile iron, etc.
Other[1]	Other materials	OTH	All other materials that do not fit in any of the predefined categories. (Note if a material use is widespread and not defined in the Manual, consider defining new category and submitting to PHA for approval.)
Spray Metalizing	Aluminum	AL	Molten aluminum applied to steel or concrete elements as a corrosion protection method.
	Zinc	ZN	Molten zinc applied to steel or concrete elements as a corrosion protection method.
	Aluminum/Zinc	AZ	Typical composition (85% Zn / 15% Al) by weight. Zn is more anodic than steel and will provide cathodic protection. Al is an inert coating, creating a passive type protection to steel and slows down the zinc dissolution.
	Aluminum/Zinc/ Indium	AZI	(Al/Zn/In) Similar function to the (Al/Zn) metallizing with the addition of Indium, which helps activate the Al. Usually applied to locations where there is less moisture.
	Titanium	TI	Ti metalizing is used in an ICCP system and differs to Zinc in which it is not consumable. Typically a cobalt nitrate catalyst is used while Ti is used as the conductor for ionic current. The catalyst and Ti are not consumed.
Wraps	Polyvinyl Chloride	PVC	Wraps or jacket encasements around elements constructed with PVC (polyvinyl chloride) that do not include galvanic cathodic protection elements.
	High-Density Polyethylene	HDP	These systems typically form exterior barriers and often include seams that are bolted together. May or may not include an underlying layer of petrolatum tape.
	Petrolatum Tape	TP	Typically, a synthetic fabric carrier; fully saturated and coated with a petrolatum compound blended with inert fillers and corrosion inhibitors.
	Fiber - Reinforced Polymer	FRP	Wraps or jacket encasements around elements constructed with fiber-reinforced polymer (FRP) that do not include galvanic cathodic protection elements.
Supplementary Anode Materials	Carbon Backfill	CB	Carbon backfill is available as calcined petroleum or metallurgical coke, and coke breeze for ICCP systems in soil environments. Typically installed in deep anode wells in soil, coke breeze is used to decrease the anode-to-earth resistance.
	Calcium Sulfate	CSB	Typical mixture for galvanic anodes which includes: 75% powdered and hydrated gypsum, 20% bentonite clay, and 5% sodium sulfate. Reduces soil resistivity, increases anode life and current output.

Element		Abbreviation	Description
DC Power Supply	Batteries	BAT	Batteries can be used for CP systems that require small output current.
	Electric Circuit Breaker	EB	Circuit breakers are used to disconnect circuits and depower electric equipment. Only circuit breakers related to Power Supplies for CP systems (e.g. circuit breakers between AC power supply and transformer-rectifier units).
	Electric Panel	EP	Electric panels, typically operating at 240V or greater, are used to split and distribute AC to multiple transformer-rectifier units.
	Transformer-Rectifier Unit	TRU	Powered by an AC current, TRUs converts AC input to DC output current for use in the CP system.
Monitoring Equipment	External Coupon	EC	Weight-loss coupons that are the same metal as that of the protected structure and electrically connected, used to measure corrosion rate in terms of weight loss as a function time for the represented exposure.
	Junction Box	JB	Junction boxes house connections of the CP system wiring.
	Test Station	TS	Test stations can be installed for monitoring current and/or structure potentials for CP systems. They typically include a shunt resistor and may include a switch to disconnect the system and a connection to the lead wire to a permanently installed reference electrode.
Wiring and Protection	Copper	CU	Conductive and noble in comparison to carbon steel, encapsulated copper wiring can be used to make connections between the anode, structure, or rectifier, dependent on design of CP system. Encapsulation for copper wiring may be flexible or rigid.
	High-Molecular-Weight Polyethylene	HM	Wiring insulation typically used for direct burial cathodic protection systems for both anode and structure wiring.
	High-density polyethylene	HDPE	Installed around wiring, HDPE conduit can provide additional protection for wiring elements.
	Polyvinyl Chloride	PVC	Installed around wiring (typically copper), PVC conduit is sometimes filled with a non-conductive epoxy to protect wiring.
	Stainless Steel	SS	Conductive and noble in comparison to carbon steel, encapsulated stainless steel (typically Alloy 310) can be used to make connections between the anode, structure, or rectifier, dependent on design of CP system. Encapsulation of wiring may be flexible or rigid.

[1]*Repeated from Table 3.1 of the Maritime Structures Manual*

Table 3.5. Example Element Descriptions

Element Code(s)	Element Descriptor	Element Identification	Units[1]
Anodes (AN)			
AN-AL AN-CI AN-DL AN-GP AN-MG AN-ZN AN-MMO AN-SCI AN-OTH	AL Anode CI Anode DL Anode GP Anode MG Anode ZN Anode MMO Anode SCI Anode OTH Bulk Anode	Anodes are installed as part of galvanic and impressed systems. Galvanic anodes are more active metals with respect to the structure being protected and are designed to preferentially corrode. Impressed anodes are typically inert and do not corrode, but still provide protection to the structure through a power source. Anodes are typically installed in anode wells, soil, or underwater.	EA
Supplementary Anode Materials (SM)			
SM-CSB SM-CB	CSB Supplementary Anode Material CB Supplementary Anode Material	Underground CP backfill materials for impressed current anodes include a carbonaceous backfill such as coke breeze or petroleum coke. Backfill materials for galvanic current anodes include a mixture of calcium sulfate, bentonite clay, and sodium sulfate. These materials are used to decrease soil resistivity and to increase life of anodes and current demand	EA
DC Power Supply (PW)			
PW-BAT PW-CB PW-EP PW-TRU	BAT DC Power Supply PW DC Power Supply EP DC Power Supply TRU DC Power Supply	Electrical devices used to provide DC power for any impressed current CP system.	EA

[1]SF = square foot, LF = linear foot, EA = each
See Appendix C for complete list of element descriptions.

[1] SF = square foot, LF = linear foot, EA = each

CHAPTER 4: COMPONENT TYPES

4.1. General

A component is a group of elements that make up a particular corrosion protection system or a group of base metal elements with the same corrosion classification. Examples of corrosion protection component types are impressed current cathodic protection systems, sacrificial anode cathodic protection systems, and surface protection systems. The boundaries between corrosion protection component types are dictated by functional purpose within the overall asset. The base metal component types are classified as Class I - Critical, Class II - Typical, or Class III - Redundant and consist of metal elements from the Maritime Structures Manual, such as fender piles, steel whale beams, or bulkhead sheet pile walls.

Components can be grouped according to their function or purpose and based on the type of factors to be considered when determining ratings for the component. For the purposes of this Corrosion Manual, four components are categorized as listed in Table 4.1. The components in each of the four groups are defined in the following section.

Table 4.1. Component Descriptions

Component	Description
Impressed Current Cathodic Protection (ICCP) Component	A group of elements that comprise an impressed current cathodic protection system for the purpose of protecting structural or functional elements of a given asset. This may include anodes, wiring, power supply, monitoring equipment, supports.
Sacrificial Anode Cathodic Protection (SACP) Component	A group of elements that comprise a sacrificial anode cathodic protection system for the purpose of protecting structural or functional elements of a given asset. This may include bulk anodes, wiring, monitoring equipment, supports, cathodic protection jackets.
Surface Protection Component	A group of elements that are applied to the surface of existing structural or functional elements to mitigate or prevent corrosion of the underlying elements. These components include paints, epoxies, and other similar barrier coatings, as well as sacrificial coatings and thermal spray metalizing, or protective wraps. Each of these systems provides corrosion protection at the exterior surface of the element they protect.
Base Metal Components (Critical, Typical, Redundant)	A component defined in the Corrosion Manual to facilitate tracking of corrosion damage of base metal elements. by accounting for remaining section and expected corrosion rate based on exposure and status of other corrosion mitigation measures. The base metal elements are classified into components as Critical, Typical, or Redundant. The elements associated with these components are defined in the Maritime Structures Manual. Unlike other components, the Base Metal component is not a system of elements that make up the same structural or functional system on the asset. Rather, the Base Metal component is a group of elements with the same corrosion classification.

4.2. Elements Associated with Components

Commonly encountered corrosion protection component types for maritime assets are defined below within the groups described in the preceding section. Some of the component types are common to both ICCP and

SACP systems. This component list is not exclusive; other component types may be present in some maritime assets within the PHA inventory. The component types for a particular asset should be defined during the scope of a Baseline Inspection and should be referred to for all subsequent routine or other inspections. Categorization of undefined component types should be discussed with the PHA Project Contact to ensure that naming is consistent with the PHA asset management system.

Impressed Current Cathodic Protection (ICCP) Component Elements

Anodes (AN)	Anodes are installed as part of an impressed CP system. Impressed anodes are typically inert and do not corrode, but will provide protection to the structure through a power source. Some Impressed anodes may also be sacrificial. Anodes are typically installed in anode wells, soil, or underwater.
DC Power Supply (PW)	Electrical devices used to provide DC power for any impressed current CP system.
Supplementary Anode Materials (SM)	Underground CP backfill materials for impressed current anodes include a carbonaceous backfill such as coke breeze or petroleum coke. These materials are used to decrease soil resistivity and to increase life of anodes and current demand
Monitoring Equipment (ME)	Equipment or test coupons installed as part of impressed current cathodic protection systems used to monitor cathodic protection performance.
Wiring and Protection (WI & PR)	Wiring or conduit installed as part of impressed current cathodic protection systems. Includes cad weld connections, splices, caps, tape, insulation, and other miscellaneous materials associated with the wiring.
CP Supports (SI)	Elements such as hangers, clevises, straps, or accessories for the purpose of supporting wiring or other CP equipment. May also include hangar assemblies or baskets for anode elements.

Sacrificial Anode Cathodic Protection (SACP) Component Elements

Cathodic Protection Jackets (JA)	Systems encasing a structural or functional element consisting of a galvanic cathodic protection system, such as underlying zinc mesh embedded in a mortar cast against the structure being protected.
Anodes - Sacrificial (AS)	Anodes are installed as part of a sacrificial CP system. Galvanic anodes are more active metals with respect to the structure being protected and are designed to preferentially corrode. Anodes are typically installed in anode wells, soil, or underwater.
Supplementary Anode Materials (SE)	Underground CP backfill materials for sacrificial anodes include a mixture of calcium sulfate, bentonite clay, and sodium sulfate. These materials are used to decrease soil resistivity and to increase life of anodes and current demand
Monitoring Equipment (MS)	Equipment or test coupons installed as part of sacrificial anode cathodic protection systems used to monitor cathodic protection performance.
Wiring and Protection (WR & PT)	Wiring or conduit installed as part of impressed current cathodic protection systems. Includes cad weld connections, splices, caps, tape, insulation, and other miscellaneous materials associated with the wiring.
CP Supports (SI)	Elements such as hangers, clevises, straps, or accessories for the purpose of supporting wiring or other CP equipment. May also include hangar assemblies or baskets for anode elements.

Surface Protection Component Elements

Coatings (CT)	Coating systems serve to protect steel or concrete elements and may be applied in single-coat or multi-coat systems. The coating component encompasses paints, epoxies, and other similar barrier coatings.
Hot-Dip Galvanizing (HG)	Hot-dip galvanizing provides a sacrificial coating system by dipping the element in a molten bath of zinc during the fabrication process of the steel.
Metalizing (ML)	Metalizing may be applied to steel or concrete elements and is applied by spraying molten metal on the element. For reinforced concrete elements, connections to the steel reinforcement are required. These surface protection systems are sacrificial and may wear and be consumed from the surface inward.
Wraps (WP)	Wrap systems are generally composed of plastic, PVC sheet material, or mastic-coated tapes that are installed over structural or functional members. As with coatings, these products are used as a surface protection technique and provide protection against corrosion.

Base Metal Components Classifications and Corresponding Elements

Critical (BMC)	Loss of this element will likely significantly compromise the function and/or capacity of the associated component and/or other elements within the asset. This class is applicable to most substructure and superstructure elements, as well as bulkhead tie rods. Example elements from Maritime Structures Manual: DB, GI, GP, CO, PI, PB, PF, PC, TR, BT
Typical (BMT)	Loss of this element may reduce the function or capacity of the associated component or asset, but the asset can remain in service (e.g., a through-thickness section loss in a portion of the sheet pile bulkhead wall). These include most typical bulkhead elements, deck elements, and fender or dolphin piles. This may also include substructure and superstructure elements with internal or external redundancy in quantity, such as multiple stringers within a given deck area, sheet pile retaining walls, or braces. Example elements from Maritime Structures Manual: DT, SR, BR, RW, CF, BW, BP, BB, FP
Redundant (BMR)	Multiple elements of this type may exist within the component to serve the same functional role. Loss of this element will not significantly compromise the function or capacity of the associated component (e.g., fender support framing or fender panels). Example elements from Maritime Structures Manual: FL, SF

4.3. Link between Corrosion Protection Components and Maritime Structures Elements

Similar to the base metal components, each of the corrosion protection components (ICCP, SACP, and Surface Protection) are related to corresponding structural or functional elements in the Maritime Structures Manual. This relationship is enabled in the PHA master database where the Corrosion and Maritime

Structures databases are compiled (refer to Chapter 8 for more details on the database). The cathodic protection components (ICCP and SACP) are not directly linked to the individual Maritime Structures elements (e.g. Fender Piles). Whereas, each surface protection element will be linked to each Maritime Structures element, identified by inspectors. the corrosion classification for the base metal component will be linked to the corresponding Maritime Structures element with a matching element ID. This allows multiple components to be assigned and queried for a particular Maritime Structures element in the Maritime Structures and Corrosion databases. A hierarchy of Maritime Structures and Corrosion Manual terms is presented in Figure 4.1.

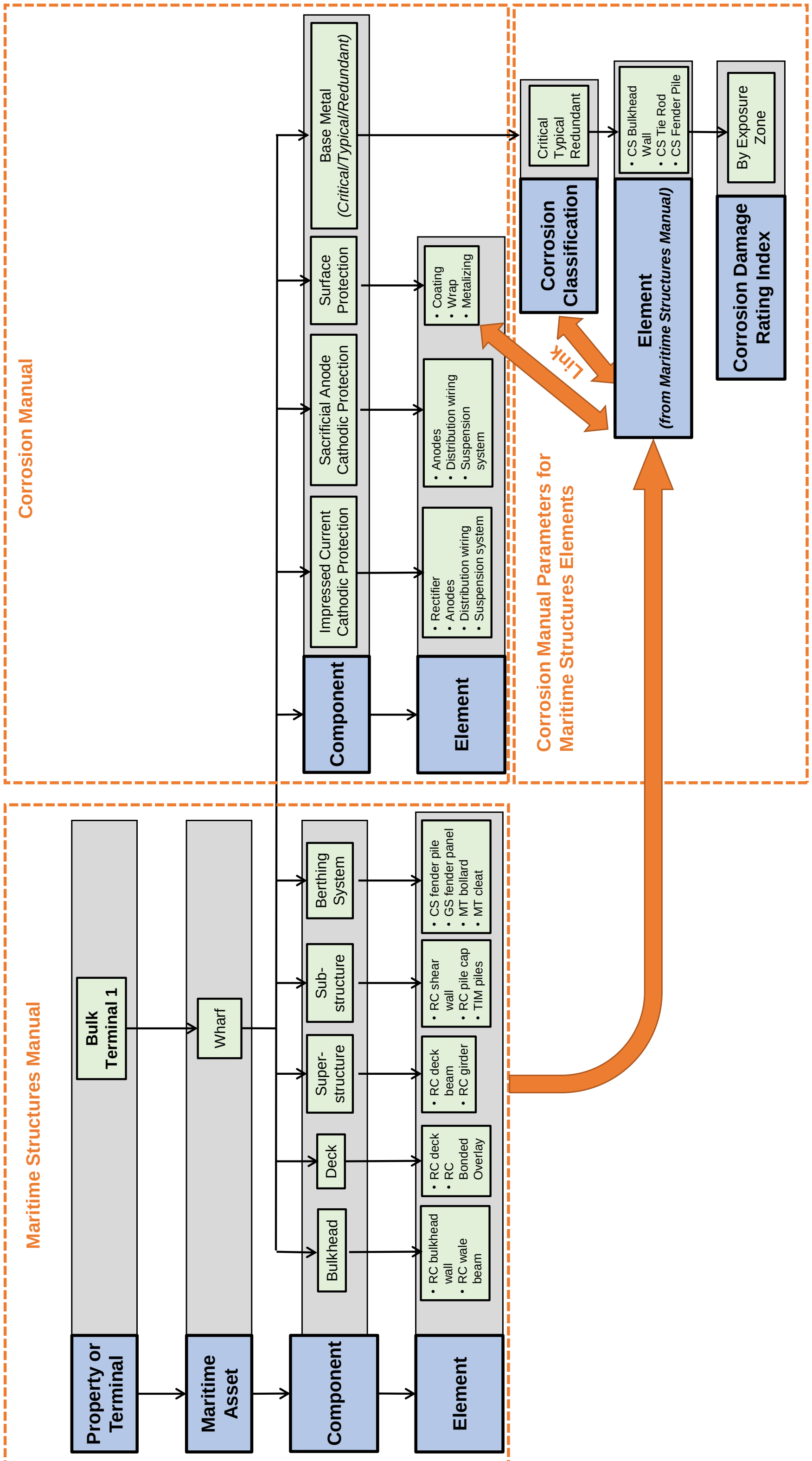


Figure 4.1. Hierarchy of Maritime Structures Manual and Corrosion Manual Relationships

CHAPTER 5: MARITIME ASSET TYPES

For the purpose of this Corrosion Manual, a maritime asset is a reporting unit that has a defined boundary and serves a functional purpose. Three primary asset types are considered: wharves, boat docks, and bulkheads. Shoreline is another asset type that typically does not include a corrosion protection component but has been included in this chapter as these assets are part of the PHA's asset management system through the Maritime Structures Manual. A complete list of PHA assets applicable to this Manual is included in Appendix A. The primary asset types are described in the following sections.

5.1. Wharves

Wharves are structures partially supported on land, and oriented parallel to the shore where ships can be moored at the offshore face. For this Manual, wharves are assets intended for the loading or unloading of cargo or personnel on large vessels (general cargo, break bulk, liquid, containers, cruise ships, etc.). Barge docks are also included as a subset of wharves. A single wharf structure consists of one or more types of structural systems, which are outlined in four major categories below.

1. **Open Platform with Open Structure.** This type of wharf has an underwater slope extending from the landside to the channel bottom. The wharf structure is supported over water by piles or drilled shafts, and water may freely move underneath. The wharf deck is supported either directly on the substructure elements or a series of superstructure elements. Soil on the landside of the structure is retained with either a curtain wall or a sheet pile bulkhead. The underwater slope may be protected or unprotected from erosion.
2. **Open Platform with Solid Structure.** This type of wharf is similar to the previous one in that water is free to move underneath the structure. The difference is that the deck is supported on fill, which is in turn supported on a structural platform slab. This platform slab is usually constructed above the water line, but on some older wharves, it may be below the water line due to settlement or subsidence.
3. **Solid Bulkhead.** This type of wharf has a vertical bulkhead from the face of the structure down to the channel bottom. The wharf structure behind the bulkhead consists of fill and may be topped by a concrete slab-on-grade. The bulkhead may be constructed by a continuous row of sheet piles (typically tied back to a deadman) or from a series of cells that rely on hoop stresses to resist lateral soil pressures.
4. **Solid Bulkhead with Relieving Platform.** This type of wharf is similar to the Solid Bulkhead but also has a buried supporting structure. This buried structure consists of a number of bearing piles connected by a relieving platform. Above the relieving platform are fill and a concrete slab-on-grade. This type of structure generally reduces earth pressures on the bulkhead by allowing surcharge loads to be carried by the bearing piles.

5.2. Boat Docks

Boat docks are similar to wharves but distinct in that they are not intended for the large-scale offloading of cargo or people. Also, unlike wharves, docks are self-supporting structures. The boats they serve are generally smaller than those berthed by wharves and so are subject to smaller berthing and mooring forces. They are often constructed from timber or steel framing. Three general categories of construction apply to boat docks.

1. **Open Platform with Open Structure.** See the description for wharves above.
2. **Solid Bulkhead.** See the description for wharves above.

3. **Floating Platform.** This type consists of a buoyant platform with a deck, anchored to either shore or the bottom of the channel. Buoyancy is achieved by either hollow or foam-filled elements. Floating platforms are free to move in elevation up and down with the change in tides.

5.3. Bulkheads

Bulkheads serve the purpose of separating the shoreline from the water with a vertical step in elevation. Some underwater slope may or may not be present between the bottom of the bulkhead and the main channel. Bulkheads are cantilevered, restrained by anchors at the top, or made of cellular structures. If a bulkhead is associated with a wharf or boat dock, it is considered a component. Where bulkheads are unassociated with a wharf or boat dock, they are considered an asset.

5.4. Shoreline

Shoreline assets are designated as unprotected shoreline or protected shoreline. The channel shoreline, if unimproved or unprotected, would form a natural slope to the bottom. Tides and waves can erode and move this shoreline where it is unprotected. Protected shoreline consists of supplemental material placed on the soil slope to protect it from erosion. This material can be natural stone (rip rap), concrete blocks, or other similar materials, and may or may not be stabilized with geotextile material.

CHAPTER 6: ASSESSMENT AND RATING APPROACH

6.1. General

As described in Chapter 1, this Manual employs an element-based inspection and condition assessment approach wherein inspections are performed at the element level and ratings are assigned at the component and asset levels. Based on the individual component ratings and the element-level inspection data, an overall corrosion condition rating is produced describing the overall asset corrosion condition.

Baseline, Routine, and Due Diligence Inspections involve a detailed inspection to categorize the condition states of individual corrosion protection and base metal elements. Using well-defined element condition states (as presented in Chapter 3) provides a justifiable, consistent, and comprehensive indication of element condition. The detailed element condition information and corrosion damage analysis facilitate an engineering evaluation of the implications of the element condition to provide a sound basis for rating each corrosion-related component of the maritime asset. The component ratings in turn allow conclusions to be made regarding the overall corrosion condition of the asset. The component ratings defined in Section 6.2 are applicable for Baseline, Routine, and Due Diligence Inspections and may be used for Functionality Checks and In-Depth inspections where appropriate.

As described in Chapter 2 of the Maritime Structures Manual, the objectives of a Post-Event Inspection are typically different from those of other inspection types. Given the circumstances of an extreme event, the Post-Event Inspection is intended to provide a more rapid condition assessment of a specific damage location in comparison to the more detailed element-based inspections. For this reason, the component ratings approach for Post-Event Inspections is defined differently than other inspections and is detailed in Section 6.3 of the Maritime Structures Manual.

The following sections define the condition rating process for components and overall asset corrosion condition for Baseline, Routine, and Due Diligence Inspections.

6.2. Component Ratings

This section defines the corrosion component condition assessment process for Baseline, Routine, and Due Diligence Inspections. It may also be applied to In-Depth Inspections, depending on their specific objectives and scope.

Upon completion of the element-based inspection, the condition assessment process involves determining ratings for each component. The corrosion protection component ratings are assigned relative to the assumed as-designed condition of the component and are intended to reflect the in-situ conditions including the effects of deterioration or damage on the current and future performance of the system. The base metal component rating is assigned relative to the corrosion damage rating index determined as part of the Baseline, Routine, or In-Depth Inspection, and does indicate the future performance of the base metal elements.

The element-based inspection and condition assessment approach defined in this Manual provide a quantitative evaluation of the element condition using the element condition states and quantities as described in Chapter 3. Although the element condition is quantitative, there is no direct (quantitative) relationship or formula to relate the element condition states to the component ratings, since the influence of the element conditions on the component condition depends on many complex factors. Instead of a formula-based approach, the component ratings are assigned by the engineer based on an interpretation of the influence of the observed element conditions on the component condition. Engineering judgment must be applied to determine the rating for a particular component. The factors to be considered include:

- Element condition state, defined in terms of:
  - Type of damage, deterioration, or defects (e.g., consumption of anodes, condition of elements, damaged or missing elements);
  - Severity of damage, deterioration, or defects (e.g., type and size of defects, amount of section loss);
  - Scope or extent of damage, deterioration, or defects (e.g., local or general in terms of number of defects, area/length affected);
- Implication of observed damage, deterioration, or defects on the corrosion performance of the affected elements

The component should generally be rated considering its overall condition, which may not necessarily reflect localized or element-level conditions. However, since both the severity and extent of the conditions should be considered, as well as the corrosion implications of the compromised condition, localized severe conditions in one element may have a negative effect on the overall performance of the entire component, thereby resulting in a lowered rating for the component. The component rating is selected by interpreting condition states that apply to a broad range of elements and materials. Accordingly, the engineer making the condition assessment should be qualified and have appropriate knowledge and experience in terms of the corrosion protection system, components, material types, and associated deficiencies.

The component ratings in this Manual are assigned on a scale from 1 to 6, ranging from critical to good condition, respectively. Different component rating criteria are defined for the different components defined in Chapter 4 and are presented in the following sections by component type.

The component ratings are accompanied by recommended follow-up actions, which are an important part of the inspection and condition assessment outcome. The follow-up actions provide guidance as to what actions may be required to address or further investigate the condition of a particular component or element. Any component with a rating of 3 (Poor) or less must be accompanied by a recommended follow-up action. Recommended follow-up actions are described in Chapter 7.

6.2.1. Ratings for Cathodic Protection Components

Component ratings for cathodic protection components are presented in Table 6.1 and Table 6.2. The ratings for cathodic protection components are divided into two rating categories: functionality ratings and visual condition ratings. The functionality rating provides an indication of the overall functionality of the corrosion protection system as a whole and is based on the criteria for cathodic protection established in NACE SP0176, *Standard Practice: Corrosion Control of Submerged Areas of Permanently Installed Steel Offshore Structures Associated with Petroleum Production;* NACE SP0169, *Standard Practice: Control of External Corrosion on Underground or Submerged Metallic Piping Systems; and SP0216-2016, Standard Practice: Sacrificial Cathodic Protection of Reinforcing Steel in Atmospherically Exposed Concrete Structures*. These criteria provide a reference for evaluating how the overall system is currently performing relative to established industry standards and whether the various elements within the cathodic protection system are working together to provide the intended protection. Typically, for ICCP systems functionality will be evaluated based on the negative voltage criteria using a current interrupter. For SACP systems, evaluation of the cathodic polarization (or decay) measurement may also be used. The visual condition rating is based on the observed condition of the various elements within the system and is not dependent on the functionality of the system. The functionality and visual condition scores could be the same or notably different from each other for a given cathodic protection system. For example, an impressed current cathodic protection system may not be delivering the intended protection if there is an error with the rectifier, but the remaining elements of the system could be in good condition (e.g. the wiring, connections, anodes.). In such a case, the functionality score would be low, but the visual condition score would be high. Similarly, if the system is providing adequate protection, but several elements within the system are worn, deteriorated, or missing, the visual condition rating may score lower than the functionality rating. The distinction between functional rating and visual condition rating is important since the ratings are weighted and scored differently when calculating the overall corrosion protection condition rating. For reinforced concrete cathodic protection systems, functional ratings are scored only when the appropriate monitoring stations are installed. If no monitoring stations are provided, the CP jackets or spray metalizing should be scored as indicated in Section 6.2.2. for surface protection components.

Table 6.1. Functionality Ratings for Cathodic Protection Components

Rating	Description
6 Good	One of the following criteria is met at all test locations: ▪ A negative (cathodic) voltage of -850 mV CSE (millivolt versus copper/copper sulfate reference electrode) or more negative between metal elements and the electrolyte, without risk of hydrogen embrittlement. ▪ A minimum of 100 mV of cathodic polarization, as measured by either polarization formation or decay. ▪ Test coupons are used to otherwise demonstrate adequate corrosion protection is being applied to the structure.* ▪ For reinforced concrete elements, the depolarized potential of the steel in wet saturated concrete is more negative than -720 mV CSE with the anode disconnected for a minimum of 24 hours, or a minimum of 100 mV of cathodic polarization, as measured by either polarization formation or decay
5 Satisfactory	One of the above criteria is met at least at 80 percent of the test locations. Damage, electrical malfunctions, or deterioration have affected the functionality of the ICCP or SACP system, such that the above criteria are not met at limited locations. Potential for overprotection or coating damage may be noted at some locations, but metals have low risk of embrittlement.
4 Fair	One of the above criteria is met for at least 50 percent of the test locations. The system is partially functional but may not be providing adequate corrosion protection to some base metal elements (or reinforced concrete elements, if applicable). Metals with high risk of steel embrittlement are subject to cathodic overprotection (instant off voltage more negative than - 1,000 mV CSE). Coatings with high risk of disbondment are subject to cathodic overprotection (instant off voltage more negative than -1200 mV CSE).
3 Poor	One of the above criteria are met at less than 50 percent of the test locations. Widespread performance deficiencies are observed for the cathodic protection systems.
2 Serious	One of the above criteria is met at less than 10 percent test locations. Evidence of nonfunctional cathodic protection system is noted at most locations.
1 Critical	ICCP or SACP system is not functional or is not providing corrosion protection at any test locations as intended.
Applicable Component Types: Impressed Current Cathodic Protection Systems, Sacrificial Anode Cathodic Protection Systems, Spray Metalizing with Monitoring Boxes	

*Reference NACE SP0104, *Standard Practice: The Use of Coupons for Cathodic Protection Monitoring Applications*. If corrosion rate is used as an evaluating metric, the corrosion rate should be no greater than 2 mpy to achieve a rating of 6- Good.

Table 6.2. Visual Ratings for Cathodic Protection Components

Rating	Description
6 Good	Very minor or no problems observed. Also applies to newly constructed or rehabilitated protective components.
5 Satisfactory	Limited minor defects, damage, or deterioration - not extensive to multiple elements.
4 Fair	Extensive minor or limited moderate defects, damage, or deterioration. All primary elements and their attachment to the asset are sound and functional purpose/use of the component is not affected. Minor repairs or maintenance may be required.
3 Poor	Extensive moderate defects, damage or deterioration that affects functional purpose/use of the component or compromises attachment of the component to the asset.
2 Serious	Defects, damage, or deterioration significantly affect functional purpose/use of the component.
1 Critical	Advanced damage or deterioration expected to result in failure(s) of component to provide adequate protection. The component can no longer serve its functional purpose/use and/or conditions are present that may lead to imminent failure of the ICCP system.
Applicable Element Types: Anodes, Supplementary Anode Materials, DC Power Supply, Monitoring Equipment, Wiring and Protection, Cathodic Protection Jackets, CP Supports	

6.2.2. Ratings for Surface Protection Components

The component ratings for surface protection components (coating, wrap, and spray metalizing) are presented in Table 6.3. Each of these components provides corrosion protection for steel and/or concrete substrates; spray metalizing does not include the necessary monitoring stations to perform measurements for cathodic polarization. If monitoring stations are present, the spray metalizing should be evaluated as part of the sacrificial anode system, with a functional and visual condition rating as discussed in Section 6.2.1.

Table 6.3. Ratings for Surface Protection Components

Rating	Description
6 Good	Very minor or no problems observed. Also applies to newly constructed or rehabilitated components.
5 Satisfactory	Limited minor defects, damage, or deterioration such as chalking, blushing, blistering, etc. - not extensive.
4 Fair	Extensive minor or limited moderate defects, damage, or deterioration. Coating, wrap, and/or metalizing may be peeling or missing in localized areas.
3 Poor	Extensive moderate defects, damage or deterioration. Coating, wrap, and/or metalizing may be peeling or missing in not more than 50 percent of coated surfaces.
2 Serious	Defects, damage or deterioration has significantly reduced protection of base steel elements. Coatings, wraps, and/or metalizing elements are only providing protection in localized locations.
1 Critical	Advanced defects, damage, or deterioration categorized as a systematic coating failure. Coatings, wraps, and/or metalizing elements do not protect base metal elements.
Applicable Element Types: Coatings, Wraps, and Spray Metalizing	

6.2.3. Ratings for Base Metal Components (Corrosion Damage Rating Index)

The defined ratings for base metal components are presented in Table 6.4. They are based on simultaneous consideration of both thickness measurements and an estimate of the corrosion rate, although visual inspection is important to ascertain representative locations are selected for measurement. The type, amount, and location of the measurements are based on the classification of the element and are defined in the Corrosion Inspection Plan as described in Chapter 2. As part of the Baseline or Routine Inspection, the remaining steel section thickness is measured for each base metal component in the accessible exposure zones. Some exposure zones, such as submerged or soil, may not have thickness measurements collected during each inspection. The corrosion damage rating index is intended to be calculated for the representative in-situ corrosion for the given element and exposure, and data representing atypical pitting or other isolated local corrosion should be avoided. If atypical corrosion mechanisms are significant enough to warrant concern, the Engineer can modify the corrosion damage rating of the component using their judgment, and provide a recommended follow-up action as discussed in Chapter 7.

The section loss is calculated as the percent decrease in thickness relative to the thickness recorded in the Baseline Inspection, or design thickness if the Baseline Inspection does not represent the initial as-built conditions after construction. The calculation is conducted as follows:

$$SL = \frac{(T_B - T_R)}{T_B} * 100$$

where SL is the section loss in percent, T_B is the initial as-built thickness (or design thickness if baseline information representing the original undeteriorated condition is not available), and T_R is the thickness measured in the most recent inspection. Section loss is averaged for each exposure zone. The engineer is expected to use engineering judgment when including measurements for purposes of calculating the average section loss. For steel shapes that include multiple exposed surfaces (e.g. H-pile with web and two flanges), the section loss should be calculated for the total section of the member. In the case of an H-pile, the average section loss for the web and each flange is to be considered.

The estimated corrosion rate is based upon engineering judgment of the available information at the time the inspection is completed. This can include information from previous Baseline and Routine Inspections, information related to the environmental conditions and exposure zone at each element, or information from Special or In-Depth Inspections. One such approach is to calculate the corrosion rate from the time of the previous Baseline or Routine Inspection, which can be calculated as follows:

$$CR = \frac{T_{R-1} - T_R}{I}$$

where CR is the corrosion rate in mils per year, T_R is the average thickness measured in the most recent inspection, T_{R-1} is the average thickness measured in the inspection conducted prior to the most recent inspection in mils, and I is the time interval between the most recent inspection and the previous inspection in years. The estimated corrosion rate is calculated for each exposure zone based on the available data. The inspector should consider the possibility that the corrosion process changes with the development of corrosion products with time, and that past corrosion rates may or may not be reflective of future corrosion rates.

The corrosion damage rating index is determined for the elements where measurements are collected in each exposure zone using the average section loss and average corrosion rate of the zone, which should be reported on the Corrosion Inspection Form. In practice, the section loss and rate will vary from point to point and will vary over time. The overall corrosion damage rating index for a base metal component is based on engineering judgment for the controlling exposure zone (Atmospheric, Splash, Tidal, Submerged, or Soil). The resulting damage rating index applies for critical, typical, and redundant components; the redundancy of a component is factored into the overall corrosion condition rating when considering the deductions for the component.

Table 6.4. Corrosion Damage Rating Index for Base Metal Components

		Estimated Corrosion Rate (mpy)			
		≤ 2	**2 < x ≤ 6**	**6 < x ≤ 11**	**>11**
Section Loss	**≤ 2%**	6 Good	6 Good	5 Satisfactory	5 Satisfactory
	>2% to ≤ 10%	5 Satisfactory	4 Fair	4 Fair	3 Poor
	>10% to ≤ 30%	3 Poor	3 Poor	3 Poor	2 Serious
	> 30%	2 Serious	2 Serious	1 Critical	1 Critical

6.3. Overall Corrosion Condition Rating

This section discusses the overall corrosion condition rating (CCR) for Baseline, Routine, and Due Diligence Inspections, which includes an overall corrosion condition rating (CCR) and a qualitative description of the corrosion condition of the asset. It may also apply to In-Depth Inspections depending on the objectives and scope of the In-Depth Inspection.

The overall CCR reflects the overall corrosion condition of the asset and is based on the component ratings assigned to the corrosion protection and base metal components of the asset. The overall corrosion condition rating is calculated as a score out of 100 as follows:

$$CCR = CP + BM \quad 0 \leq CCR \leq 100 \qquad \text{for all assets}$$

Where:

CCR = 100 corresponds to an asset with corrosion protection components with minor or no problems noted and base metal components with little to no section loss and a relatively low corrosion rate.
0 corresponds to an asset where the integrity of the corrosion protection components has been compromised and the base metal components have significant section loss and/or an aggresive corrosion rate.

CP = Corrosion Protection Component Combined Rating
= combined rating based on the condition of corrosion protection components with a maximum score of 60. Includes impressed current cathodic protection, sacrificial cathodic protection, and surface protection components.

BM = Base Metal Component Combined Rating
= combined rating based on the condition of base metal components with a maximum score of 40. Includes critical, typical, and redundant steel elements with corrosion protection systems.

The upper bounds on the CP and BM contribution to the overall CCR score reflect the relative importance of the corrosion protection and base metal components on the overall corrosion condition rating for the asset. The existing condition of the corrosion protection components have a higher weighting compared to the condition of the base metal components. CP and BM are determined based on the applicable component ratings (defined in Section 6.2) as described in the following sections.

6.3.1. Determining Corrosion Protection Component Combined Rating (CP)

The asset rating contribution from the corrosion protection components is determined as follows:

$CP = 60 - (ICF + ICV + SAF + SAV + SPR) \geq 0$ for assets with each corrosion protection system

$CP = 60 - 1.6 \times (ICF + ICV + SPR) \geq 0$ for assets with no sacrificial anode components

$CP = 60 - 1.6 \times (SAF + SAV + SPR) \geq 0$ for assets with no impressed current components

$CP = 60 - 3.6 \times (SPR) \geq 0$ for assets with only SPR components

Where ICF, ICV, SAF, SAV, and SPR are deductions based on their respective component ratings as defined in Table 6.5 below. The SPR deductions are based on combined ratings for the coatings, wraps, and metallizing components. If multiple impressed current or sacrificial anode systems are present, the ICF, ICV, SAF, and SAV deductions are based on combined ratings for each component type. The CP deductions are based on the significance of component to the corrosion protection of the asset, and the ease of maintenance, repair, and/or replacement of the component. CP is rounded to the nearest whole number.

Table 6.5: CP Deduction Table

Component Rating	CP Deductions by Component				
	ICCP Functionality (ICF)	ICCP Visual (ICV)	Sacrificial Anode Functionality (SAF)	Sacrificial Anode Visual (SAV)	Surface Protection (SPR)
= 1	30	10	30	10	30
= 2	15	5	15	5	15
= 3	8	3	8	3	8
= 4	4	2	4	2	4
= 5	2	1	2	1	2
= 6	0	0	0	0	0

6.3.2. Determining Base Metal Combined Rating (BM)

The asset rating contribution from the base metal components is determined as follows:

$$BM = 40 - (CR + TYP + RED) \geq 0$$

Where CR, TYP, and RED are deductions based on the component ratings as defined in Table 6.6 below. The deductions are based on combined ratings for the critical, typical, and redundant base metal components, respectively. The component rating used for this calculation is a combined rating from all elements within the component for the asset in question. The BM deductions are based on the same factors as described for the CP deductions, as well as the significance of the component to the structural and functional integrity of the asset. BM is rounded to the nearest whole number.

Table 6.6: BM Deduction Table

Component Rating	BM Deductions by Component		
	Critical Components	Typical Components	Redundant Components
	CR	TYP	RED
= 1	40	25	10
= 2	25	13	5
= 3	13	6	3
= 4	6	3	2
= 5	3	2	1
= 6	0	0	0

6.3.3. Example Calculations for Corrosion Condition Rating

Sample calculations to determine the CCR for four hypothetical assets are shown in Table 6.7. The left-hand portion of the table lists the Component Ratings for the assets. The Component Ratings have been assumed for the purposes of this example and would normally be assigned by the engineer as part of the corrosion assessment for the assets. Once the component ratings are known, the corrosion condition rating (CCR) is calculated.

Table 6.7: Sample Asset Condition Rating Calculations

Components		Component Ratings			
Component	Type	Asset 1	Asset 2	Asset 3	Asset 4
ICCP	ICCP Funct. (ICF)	3	6	6	1
ICCP	ICCP Visual (ICV)	3	4	5	2
SACP	SA Funct. (SAF)	6	NA	6	2
SACP	SA Visual (SAV)	5	NA	5	3
SPR	Surface Protection (SPR)	3	4	5	4
Base Metal (BM)	Critical (CR)	4	2	6	4
Base Metal (BM)	Typical (TYP)	4	4	5	2
Base Metal (BM)	Redundant (RED)	3	4	4	2
	Corrosion Condition Rating (CCR)	68	60	92	19

Note: NA = component type not applicable to asset.

	Deductions by Component			
	Asset 1	Asset 2	Asset 3	Asset 4
ICF	8	0	0	30
ICV	3	2	1	5
SAF	0	0	0	15
SAV	1	0	1	3
COA	8	4	2	4
CR	6	25	0	6
TYP	3	3	2	13
RED	3	2	2	5
CP =	40	50	56	3
BM =	28	10	36	16

The process of determining the component deductions, corrosion protection component combined rating (CP), and base metal component combined rating (BM) is illustrated below to calculate the CCR for Assets 1 and 2 from Table 6.7.

Calculation of CCR for Asset 1

The component ratings for the corrosion protection components are used to determine the corrosion protection component combined rating, CP. Using the component ratings for Asset 1 as listed in Table 6.7, the CP deductions are determined using Table 6.5 as follows:

Component	CP Deduction	Comments
Impressed Current Functionality:	For component rating of 3, ICF is 8	A component rating of 3 represents poor performance in a key corrosion protection component, resulting in a deduction of 8.
Impressed Current Visual:	For component rating of 3, ICV is 3	A component rating of 3 represents a poor condition; however, the deduction is less considering the repair to visual conditions is likely easier to implement than functional performance.
Sacrificial Anode Functionality:	For component rating of 6, SAF is 0	No deduction for a component in good performing condition.
Sacrificial Anode Visual:	For component rating of 5, SAV is 1	Minor deduction for component rating of 5 reflects satisfactory condition and limited expected impact on component function.
Surface Protection:	For component rating of 3, SRP is 8	A component rating of 3 represents poor condition of a key corrosion protection component, resulting in a deduction of 8.

Calculate CP:

$$
\begin{aligned}
CP &= 60 - (ICF + ICV + SAF + SAV + SPR) \geq 0 \\
&= 60 - (8 + 3 + 0 + 1 + 8) \\
&= 40
\end{aligned}
$$

The component ratings for the base metal components are used to determine the base metal component combined rating, BM. Using the component ratings for Asset 1 as listed in Table 6.7, the BM deductions are determined using Table 6.6 as follows:

Component	BM Deduction	Comments
Critical:	For component rating of 4, CR is 6	A component rating of 4 represents fair condition; however, the deduction is larger than the typical component given the importance of critical components on overall asset condition.
Typical	For component rating of 4, TYP is 3	A component rating of 4 represents a fair condition; the deduction is smaller given the less critical nature of these components.

Redundant	For component rating of 3, RED is 3	A component rating of 3 represents a poor condition; however, the deduction is minor given the redundant nature of these base metal components.

Calculate BM:

$$
\begin{aligned}
BM &= 40 - (CR + TYP + RED) \geq 0 \\
&= 40 - (6 + 3 + 3) \\
&= 28
\end{aligned}
$$

Calculate CCR:

$$
\begin{aligned}
CCR &= CP + BM \\
&= 40 + 28
\end{aligned}
$$

CCR = 68 for Asset 1

Calculation of CCR for Asset 2

Using the component ratings for Asset 2 as listed in Table 6.7, the CP deductions are determined using Table 6.5 as follows:

Component	CP Deduction	Comments
Impressed Current Functionality:	For component rating of 6, ICF is 0	A component rating of 6 represents a good-performing system, hence the deduction is zero.
Impressed Current Visual:	For component rating of 4, ICV is 2	While the functionality rating for the impressed current component was a 6, the visual condition rating represents a fair condition. Hence, a minor deduction.
Sacrificial Anode Functionality:	Not applicable	No sacrificial anode system present at Asset 2. Use modified CP equation.
Sacrificial Anode Visual:	Not applicable	
Surface Protection:	For component rating of 4, SPR is 4	A component rating of 4 represents a fair condition; hence, the deduction is relatively small.

Calculate CP using formula for when no sacrificial anode component is present.

$$
\begin{aligned}
CP &= 60 - 1.6 \times (ICF + ICV + SPR) \geq 0 \\
&= 60 - 1.6 \times (0 + 2 + 4) \\
&= 50 \text{ (round to nearest whole number)}
\end{aligned}
$$

Using the component ratings for Asset 2 as listed in Table 6.7, the BM deductions are determined using Table 6.6 as follows:

Component	BM Deduction	Comments
Critical:	For component rating of 2, CR is 25	A component rating of 2 represents a serious condition; given the importance of critical components on overall asset condition, the deduction is large.

Typical	For component rating of 4, TYP is 3	A component rating of 4 represents a fair condition; the deduction is smaller given the less critical nature of these components.
Redundant	For component rating of 4, RED is 2	A component rating of 4 represents a fair condition; however, the deduction is minor given the redundant nature of these base metal components.

Calculate BM:

$$
\begin{aligned}
BM &= 40 - (CR + TYP + RED) \geq 0 \\
&= 40 - (25 + 3 + 2) \\
&= 10
\end{aligned}
$$

Calculate CCR:

$$
\begin{aligned}
CCR &= CP + BM \\
&= 50 + 10
\end{aligned}
$$

CCR = 60 for Asset 2

6.3.4. Description of Overall Corrosion Condition

The numerical overall CCR may be used by the PHA to guide asset management and maintenance decisions. However, a single rating may not provide sufficient refinement or detail to properly guide decisions and recommended follow-up actions for all situations. Accordingly, the inspection and corrosion assessment deliverables must also include a qualitative description of the asset condition that addresses the following:

- Brief discussion of the ratings for all corrosion and base metal components of the asset;
- Discussion of the implications of the reported component ratings on the overall corrosion condition rating and recommended actions; and
- Discussion of recommended follow-up actions.

The combination of the corrosion condition rating and the narrative corrosion condition assessment will provide a complete evaluation of the overall current and future corrosion performance of the asset.

6.4. Relationship of Corrosion Condition Rating to Overall Asset Condition Rating

The CCR is a distinct numerical rating from the asset condition rating (ACR) that is developed through the Maritime Structures Manual. The ACR provides an indication of the existing condition of the structural and functional components of the asset and does not include corrosion protection systems nor an indication of their future performance. The CCR provides an indication of the existing condition of the corrosion protection systems, the base metals they protect, and a relative estimate of the rate of deterioration of the base metals. The ACR and CCR scores could be similar or notably different from each other for a given asset. For example, an asset may be in relatively good existing condition (higher ACR), but with poorly performing corrosion protection systems (lower CCR). Similarly, an asset may have a relatively poor existing condition (lower ACR), but the corrosion protection systems are performing well (higher CCR).

In general, a low CCR score would indicate that, without repairs or modification, the ACR score of the asset would be expected to decrease during upcoming routine inspections. While there may be a correlation between the existing condition and performance of the corrosion protection systems (i.e. if the corrosion protection systems are not working, the existing condition of the corresponding elements will likely be worse), this may not always be the case. Any correlation between the two scores is dependent on the condition of the various components and the implication of the underlying component ratings. For example, a lower ACR may be related to deck damage and superstructure conditions, which are parts of the asset that do not typically include corrosion protection systems. However, if a low ACR score is tied to corrosion of the bulkhead and fender system components, it is more likely that the CCR will also score relatively low. In this way, the ACR and CCR can be used in conjunction to prioritize corrosion-related conditions that may require maintenance, repair, or replacement to maintain or extend the useful service life of the base metals.

To synchronize the ACR and CCR where appropriate, the Team Leader for the Maritime Structures Routine Inspection should consider the results of the Corrosion Inspection (e.g., the Corrosion Inspection Summary and Corrosion Inspection Data) when calculating the ACR. If deemed appropriate based on engineering judgment, the component ratings should be adjusted accordingly by the Maritime Structures Team Leader when calculating the ACR for a Routine Inspection following a Corrosion Inspection. For example, if a bulkhead component would otherwise be scored poorly because of observed corrosion, but the Corrosion Inspection Summary and Corrosion Data indicate the Corrosion Damage Rating for the bulkhead is good or satisfactory, an improved component rating might be considered when developing the ACR score. Conversely, a decreased component rating might be considered if the Corrosion Damage Rating for the bulkhead is poor or serious. Any adjustments to component ratings made by the Maritime Structures Team Leader based on the findings of preceding Corrosion Inspections should be noted on the Structural Inspection Summary Report.

CHAPTER 7: RECOMMENDED FOLLOW-UP ACTION GUIDELINES

7.1. General

Deliverables from each baseline and routine inspections and condition assessments should include recommended follow-up actions as part of the inspection outcome. The recommended follow-up actions may include suggestions for maintenance or repairs, further investigation, or immediate actions to remedy or avoid conditions that may compromise the functionality of corrosion protection systems or the structural integrity of base metal elements.

The recommended follow-up actions for the Corrosion Manual are presented in the following sections using multiple categories, ranging from no action required (i.e., "do nothing at this time") to immediate (i.e., emergency) actions depending on the severity and implications of the conditions observed. More than one recommended action may arise from the inspection of a given asset. All actions should be prioritized consistently across all assets. In all cases, a brief justification should be provided for any recommended actions.

7.2. No Action Required

If the inspection does not indicate that any form of follow-up action (such as those described in the following sections) is required, the inspection recommendation is reported as "no action required at this time" until the next routine inspection on the Corrosion Inspection Plan (see Chapter 8). When no follow-up actions are recommended for a given asset, the current tasks and time intervals outlined in the Routine Inspection Plan for that asset are deemed sufficient based on the findings of the most recent inspection.

7.3. Priority or Routine Actions

The inspection and condition assessment of an asset may reveal conditions that require some form of follow-up action but do not represent an immediate action or emergency (see Section 7.6). These conditions or situations may include:

- Conditions requiring maintenance;
- Conditions requiring minor repairs;
- Conditions requiring replacement of one or more non-structural elements; and/or
- Elements where a condition state of CS4 (Severe) was assigned during the inspection.
- Corrosion protection systems for which functionality has been affected.

Element condition state CS4 (Severe) represents the most severe condition of the element for the condition type in question. The CS4 condition may correspond to a reduction in the structural capacity of a structural element, or a reduction in the functional performance of a non-structural element or corrosion protection system. Although the element condition state information is considered during the condition assessment process when assigning component ratings, the CS4 condition for an individual element warrants further review as a recommended follow-up action.

When a Baseline or Routine Inspection identifies conditions that require follow-up actions (other than Immediate Actions), the following information should be provided on the Follow-Up Action Form (see Chapter 8).

- Classify the recommendation as ***priority*** or ***routine***:
  - Priority: The action to address the observed condition should take precedence over other actions (e.g., routine maintenance), but the condition needing repair does not appear to immediately compromise the structural integrity. These conditions may affect the functionality of the asset, element, or corrosion protection system. Priority repairs may also be necessary to prevent further damage, deterioration, or defects from reaching the point at which future repairs become significantly more costly.
  - Routine: The action can be addressed as part of a routine maintenance program. Routine actions are those that can be scheduled in the future without compromising the structural integrity or functionality of the asset, and without significantly increasing the future cost of maintenance or repair.
- Provide a brief justification of the need for the action and the associated priority.
- Recommend whether or not an In-Depth Inspection (Section 7.4) is needed to properly identify the cause and implications of the damage, deterioration, or defects. The results of the additional inspection may be used to design an appropriate repair solution.

7.4. In-Depth Inspection

As discussed in Chapter 2, an In-Depth Inspection is not part of the scope of the Corrosion Manual. Rather, an In-Depth Inspection may be recommended as a follow-up action to a Baseline or Routine Inspection in order to obtain the information required for the preparation of repair design and construction documents, where atypical conditions have been identified that require more information to assess, or when functionality of corrosion protection systems have been compromised for reasons unknown based on the Routine Inspection. An In-Depth Inspection is warranted where an inspection was not able to identify the cause or significance of distress or deterioration. The recommendation for In-Depth Inspection should include:

- Description of the non-typical conditions and a brief written justification for the additional inspection, including an evaluation of its priority.
- Objective of the In-Depth Inspection. The objectives may vary, but some examples include:
  - Determine the cause or significance of deterioration or reduced effectiveness of corrosion protection system;
  - Collect detailed condition and quantity information necessary to develop repair design; and/or
  - Confirm element and component geometry, details, and material properties necessary to verify or determine as-built conditions (where no existing as-built information is available) for asset inventory purposes, or as needed to conduct an Engineering Analysis for the purposes of an upgrade or evaluating a corrosion protection system.

The In-Depth Inspection may involve material sampling and analysis, advanced cathodic protection evaluation techniques, nondestructive or destructive testing, and non-standard equipment and techniques beyond that used for Routine or Baseline Inspections. Specialized testing and engineering knowledge and experience may be required to develop the inspection plan and to conduct the needed inspection. For underwater inspections, the In-Depth inspection may require all three inspection levels summarized below and fully defined in ASCE 101.

- Level 1: Visual, tactile inspection
- Level 2: Detailed inspection with partial cleaning
- Level 3: Highly detailed inspection with Non-Destructive Testing (NDT) or Partially Destructive Testing (PDT)

When an In-Depth Inspection has been conducted with the intent of determining the cause or significance of damage, deterioration, or defects and collecting the information necessary for the preparation of repair documents, the inspection team should recommend repairs with the following actions:

- Recommend repair actions and classify the repair recommendations as ***priority*** or ***routine*** as defined in the preceding section.
- Provide an engineer's cost estimate for repair activities.
- If included in the scope, provide a set of repair documents suitable for bidding the repair work. This may also be performed as part of follow-up engineering work.

It is assumed that in most cases, the scope of work for the In-Depth Inspection will be such that the recommended actions listed above can be completed without the need to recommend an additional in-depth inspection. However, in some situations, the objectives or outcomes of the In-Depth Inspection may require an engineering analysis to supplement the In-Depth Inspection findings. In this case, a Refined Engineering Analysis may be recommended as a follow-up action to an In-Depth Inspection.

7.5. Refined Engineering Analysis

When an Inspection identifies significant damage, defects, atypical conditions, potential structural or functional concerns, or an ineffective corrosion protection system, a Refined Engineering Analysis may be recommended. The recommendation for a Refined Engineering Analysis should include:

- Brief written justification for the engineering analysis, including an evaluation of its priority.
- Objective of the engineering analysis, which may include any or all of the following:
  - Perform a structural evaluation (analysis) to quantify the structural capacity accounting for the effect of the observed defects or corrosion damage. This analysis may be required to determine if the structural integrity of the asset is at risk under the current conditions.
  - Provide a service life analysis for the base metal elements or corrosion protection systems.
  - Evaluate the need for repairs, replacement, or modification of the corrosion protection system.
  - Develop an appropriate repair, strengthening, or supplemental corrosion protection system solution.

The Refined Engineering Analysis will normally be performed considering the actual or anticipated loads on the asset, which may be different from the original design loading for the asset, and the exposure conditions on-site. The design loading and service life requirements (e.g. end-of-life criteria) should be determined in consultation with PHA and the PHA Engineering Design Guide. Note that the Baseline and Routine Inspections performed as part of the Corrosion Manual will provide the field data necessary to perform a refined service life analysis for the base metal and/or corrosion protection systems. The engineer should be able to use the field data collected (e.g. metal section loss, coating thickness) to evaluate the specific remaining service life until an established end-of-life criterion is met. In this case, the Refined Engineering Analysis will not require any additional fieldwork or field measurements, but only additional structural engineering analysis and calculation of the time until the end-of-life criteria are met. The end-of-life criteria will be established by PHA at the time of the analysis and might be the specific section loss until the element no longer satisfies the code-required factors of safety, or could be the section loss until predicted structural failure of the element or component occurs.

Note that a Refined Engineering Analysis is not part of the primary scope of the Corrosion Manual and is only conducted at the discretion and under the direction of the PHA. If included in the scope defined by the PHA, an Engineering Analysis may include the preparation of a set of repair documents suitable for bidding the repair work.

7.6. Immediate Actions

Immediate actions are required when an inspection identifies severe conditions that have occurred, or appear likely to occur, that have the potential for property or environmental damage, or that may affect the structural integrity or facility operations. Immediate actions are intended to be responses to an extreme condition or emergency and are not intended to apply to conditions requiring routine maintenance and/or repairs.

Upon identifying conditions that have the potential for property or environmental damage, or that may affect the structural integrity or facility operations, the inspection team shall take the following actions:

- The PHA Project Contact shall be notified immediately by phone with follow-up notification in writing to the PHA Project Contact within 24 hours.
- Provide PHA Project Contact a justification for the immediate response including a brief description, data, and/or photographs of the condition(s) of concern.
- An In-Depth Inspection (Section 7.4) or Engineering Analysis (Section 7.5) may be recommended to PHA Project Contact by the inspection team to further ascertain the extent and implications of the observed conditions, and to develop long-term repair and rehabilitation solutions to address the conditions and mitigate reoccurrence.

7.7. Inspection Plan Modifications

In addition to completing the Follow-Up Action Form with each identified follow-up action, the inspection team should use engineering judgment to determine appropriate tasks and/or task intervals for the subsequent Inspection Plan and update the plan, if needed. For low-priority (routine) actions, the Routine Inspection Plan should be updated with those actions (e.g. monitoring output current at more frequent time intervals). For high-priority immediate actions, the procedures in Section 7.6 should be followed.

Table 7.1 below provides the methodology for modification of the Inspection Plan(s) and/or assigning of additional inspections as a result of identified follow-up actions.

Table 7.1. Relationship Between Follow-Up Actions and Inspection Plans

Classification of Follow-Up Action Recommendation	Discussion
No Action Required	No modification of Routine Inspection Plan is required, and asset is scheduled for its next Routine Inspection.
Priority or Routine Follow-Up Actions	Conditions should be identified, classified as priority or routine, justification provided, and recommended actions to investigate and/or remedy the condition should be presented. For each condition identified, Inspection Plan(s) should be developed and/or modified, dependent on condition observed and severity: ▪ An In-Depth Inspection may be performed to obtain additional information (see Section 7.4) ▪ Tasks and/or task intervals may be updated in the Routine Inspection Plan for the subsequent Routine Inspection (see Section 7.7)
Immediate Actions	The PHA Project Contact shall be notified immediately by phone with follow-up notification in writing to the PHA Project Contact within 24 hours. For each condition identified, Inspection Plan(s) should be developed and/or modified, dependent on condition observed and severity, and immediate actions taken by PHA upon notification of condition: ▪ An In-Depth Inspection may be performed to obtain additional information (see Section 7.4) ▪ A Refined Engineering Analysis may be recommended to develop repair documents (see Section 7.5) ▪ Tasks and/or task intervals may be updated in the Routine Inspection Plan for the subsequent Routine Inspection (see Section 7.7)

CHAPTER 8: DOCUMENTATION AND REPORTING

8.1. General

This section describes documentation and reporting requirements for this manual, which supplement the existing FICAP documentation for each asset. Documentation and reporting are standardized to promote efficiency in inspection and reporting, enable comparison among assets, and provide for data storage and analysis via an asset database. A form-based reporting approach is used for most inspection types. Documentation begins with a standard asset description including the corrosion protection systems (Maritime Asset Corrosion Inventory Record, or "Corrosion Inventory Record Form"), and Standard Drawing Set. This information is intended to reflect persistent aspects of the asset, which would only change if significant repairs or modifications are performed to the asset. The inspection documentation consists of several standard forms to report element-based inspection condition states and quantities, report inspection notes and photographs, summarize the condition assessment, document follow-up actions, and update the inspection plan.

The following sections discuss the inspection forms and standard drawing requirements. Examples of an Inventory Record, Inspection Summary, Inspection History, Inspection Plan, Inspection Data, Elemental Form, and Follow-up Action Form are provided in Appendix F. Finally, deliverables for each type of inspection and general record-keeping requirements are defined.

8.2. Corrosion Inventory Record

The Inventory Record Form is a record document reflecting the as-built condition of the asset. The Inventory Record should be created as part of a Baseline Inspection and revised if changes are identified through a Routine or Special inspection. The Inventory Record should be updated after any modifications or significant repairs are performed.

The following information should be included as it pertains to each asset:

- **Identification -** Identification of the asset by the appropriate property/terminal and asset ID. These identifiers are coordinated with the Port of Houston Authority's GIS implementation.
- **Asset Classification and Type -** Categorization of the asset based on the asset type (e.g., wharf, boat dock, bulkhead, etc.). For wharves or boat docks, this also includes the generic type of construction (e.g. open or closed) and usage (e.g. break bulk, liquids, containers, etc.). Note that the usage information is coordinated with the PHA.
- **Original Date of Construction -** The year when the asset was originally constructed.
- **Date(s) of Rehabilitation or Modification -** Year(s) of significant rehabilitation or modifications. Significant modifications are defined as work that alters the asset's footprint or changes structural components; this definition applies regardless of the percentage of the asset being modified.
- **Date of Last Inventory Record Update -** The date when the asset was last inspected.
- **Geometric Data -** Pertinent asset dimensions, including plan dimensions, deck elevation, and channel depth.
- **Asset Corrosion Protection History -** A narrative describing the history of the asset construction, repairs, and modifications related to corrosion protection systems. If known, the reason for corrosion protection system modifications or repairs should be noted.

- **Reference Drawing List -** A list of existing drawings, titles, dates, and general scopes of work. At a minimum, drawing sets for original construction and any rehabilitation or major repairs related to corrosion management should be listed, if available.
- **Asset Exposure Zones -** A list of identified exposure zones at the site, specific height of the zones and exposure effects based on review of environmental conditions and data, as defined in Section 2.2.1.
- **Asset Environmental Conditions -** A list of environmental conditions to which the asset is exposed, including site, water, and soil conditions.
- **Components and Elements** – A list of components and elements comprising the corrosion protection systems and corresponding base metals for the asset. Components groups are categorized as impressed current corrosion protection, sacrificial anode cathodic protection, surface protection, and base metal. For each component, applicable element types should be listed and briefly described. Component descriptions should include the location and extent of component on the asset. Description of elements should include the material and typical geometric features, such as size, thickness, and span. If a standard component is not present on the asset, it should be listed with "none" as the description.
- **Figures** – Typical figures illustrating the location and configuration of the asset. At a minimum, these include the following: maps showing location of the facility relative to all PHA properties and a map marking the location of the asset within the facility; an aerial view illustrating the overall extent of the asset and marking adjacent assets; and a typical, annotated partial plan and section illustrating corrosion protection systems and protected components at the asset. Multiple typical partial plans or sections may be warranted for assets with multiple configurations.
- **Revision History** – A table logging revisions to the document. This table is included because the inventory record is intended to be semi-permanent. The table shows the revision number, person, and date of the revision author, the date and person responsible for verification of the revision, and comments describing the reason for the revision.

8.3. Corrosion Inspection Plan

The corrosion inspection plan summarizes the specific inspection tasks and associated scope and methods for a given asset. The listed methods are dependent on the corrosion components and elements that are present in that asset. The inspection plan may also list the frequency, location, and required size of data to be collected for corrosion testing tasks. The asset-specific inspection plan is developed prior to baseline inspection to collect the information required for the condition assessment and corrosion damage analysis. The tasks in the inspection plan and associated inspection frequencies should be updated after each inspection taking into consideration the recommended follow-up actions. Similar to the inventory record, revisions to the inspection plan should be logged in a revision history table at the end of the document.

8.4. Corrosion Inspection Drawings

Standard Inspection Drawings are created within the scope of the Baseline Inspection and are used as a reference for Baseline, and Routine Inspections. Drawings are important to present the layout of the structure, the naming of bays, and identify types and locations of elements within the scope of the corrosion management program. Furthermore, the drawings are used to develop the GIS database for Port Houston. Due to the long history of many of the maritime assets at Port Houston, the current configuration of a particular asset may be the result of multiple alterations performed over the years, which may have been recorded in multiple sets of construction drawings. Therefore, creating Standard Inspection Drawings has two main purposes. The first purpose is to create a schematic, cumulative as-built of the current configuration of the asset, which would then be verified as part of the fieldwork in the Baseline Inspection.

The second purpose is to define a consistent naming scheme for all corrosion protection elements of the asset, so that the Baseline Inspection and future inspections, modifications, and repairs can quickly and accurately identify and locate each element for documentation and reporting purposes.

Drawings should be created in accordance with the PHA CAD Standards in effect at the time of the Baseline Inspection. To provide uniformity between assets, the following should be used for plans and sections:

- Plans:
  - Orient asset with channel toward top of page, regardless of direction of true north.
  - Recommended scale: 1/8" = 1'-0"
  - In general, draw two plans: one upper-level plan and one lower-level plan.
- Sections:
  - Orient asset with channel on the right and landside on the left.
  - Recommended scale: 1/4" = 1'-0"
- Elevations:
  - Show elevation as viewed from water side.
  - Recommended scale: 1/8" = 1'-0"
  - Elevations are primarily intended to show berthing and fender system corrosion protection elements.

A Standard Inspection Drawing set consists of types of sheets shown in Table 8.1. A sample set of Standard Inspection Drawings, created for Wharf BCT 5, is included in Appendix G.

Table 8.1. List of Standard Inspection Drawings

Sheet Number	Sheet Description	Information Included
G-001	Title	Asset name PHA drawing number Date of drawing set Vicinity map Asset location map
G-002	Project Information	Sheet Index Key Plan, referencing asset plan sheets (i.e. G-1XX). The Key Plan should have notes/labels consistent with structure history on Corrosion Inventory Record form (i.e., indicate significant modifications, repairs, expansions, partial demolitions). List of Referenced Historical Drawings Definitions of Symbols Definitions of Abbreviations

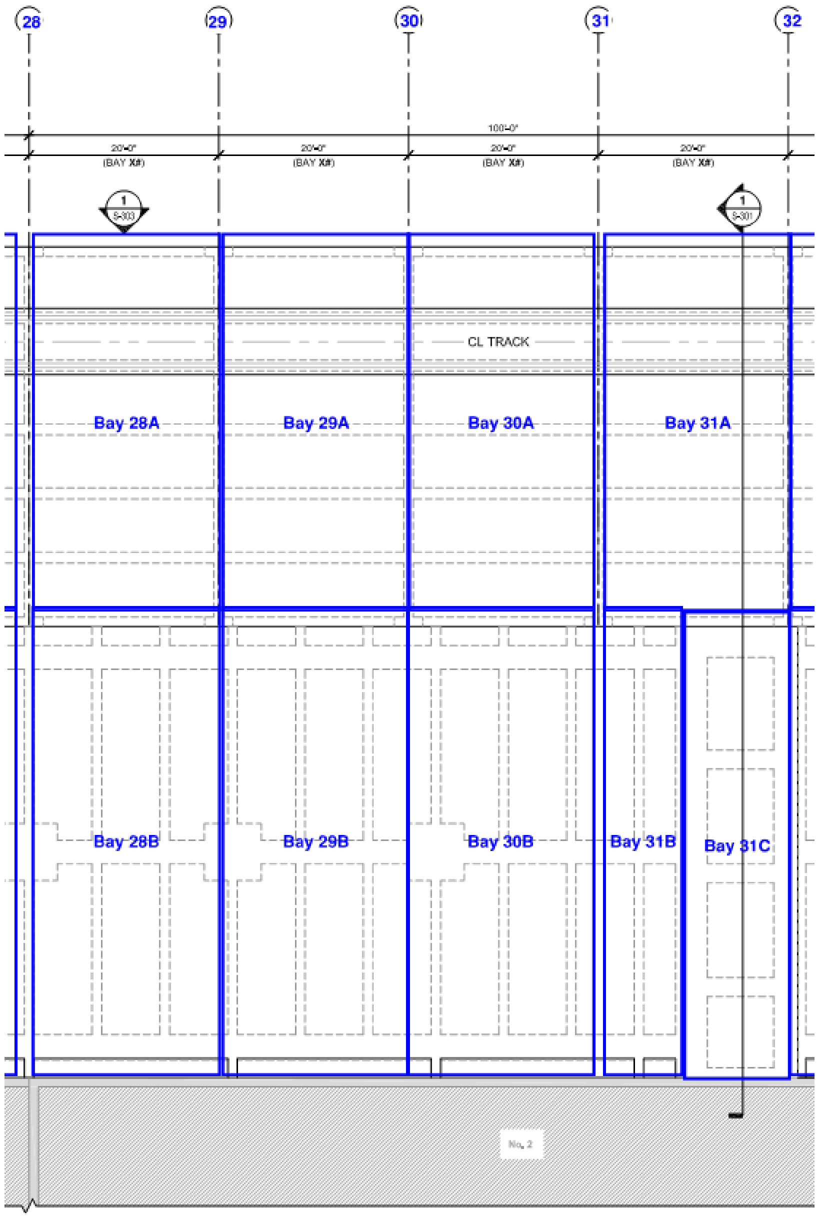
Sheet Number	Sheet Description	Information Included
G-10(x)	Bay Plan(s)	Plan view of topside of structure. Asset may be broken into multiple pages. Bays outlined and denoted per Corrosion Manual scheme (see Section 8.4.1). Grid lines, based on historic drawings if possible. Overall dimensions of bays. North Arrow Channel Designation
G-11(x)	Corrosion Protection Element Plan(s)	Corrosion Protection elements individually outlined and labeled.* Drawn as plan views. Applicable views may include the superstructure and deck elements cut at the structure topside and/or the substructure and fender elements cut below the deck level. Sheets to be ordered from Upper Plan to Lower Plan.
G-12(x)	Base Metal Element Plan(s)	Base Metal elements individually labeled.* Drawn as plan views. Applicable views may include the superstructure and deck elements cut at the structure topside and/or the substructure and fender elements cut below the deck level. Sheets to be ordered from Upper Plan to Lower Plan.
G-20(x)	Typical Sections	Cross-sections through representative portions of wharf. Include a separate cross-section for significant changes in structure configuration (e.g., change in pile type, arrangement of beams, width of structure, etc.). Provide elevations for Top of Deck; Mean Low Tide. Label typical elements with name and element code (e.g., Polyurethane Coating (CT-PU)).
G-30(x)	Typical Elevations	Elevation view of typical bay(s), as viewed from the channel. Include major corrosion protection and base metal Elements. Label typical elements with name and element code (e.g., Polyurethane Coating (CT-PU)).

* See Section 8.4.2 for Element labeling and identification scheme

8.4.1. Bay Numbering Scheme

Consistent with the bay numbering scheme for FICAP for inspections and condition assessments conducted for the PHA, bays are defined in the plan view as portions of the asset, typically extending from the waterfront to the landside, and extending between numbered rows of piles or drilled shafts (grid lines). Bays should be numbered sequentially from upstream[2] to downstream. Where possible, the bay numbers should correspond with historical designations[3] and grid line numbers; if historical designations are inconsistent or unclear, grid line and bay numbering should start at 1 at the upstream extent of the asset and continue downstream. Where the structural system or framing changes significantly, such as might occur between original and landside extensions, bays should be split into sub-bays, with a letter added to the end of the bay designation (i.e., 1A, 1B, 1C). Figure 8.1 shows an example of this numbering scheme.

[2] As defined in Appendix B, "upstream" is the direction against the primary flow of the ship channel excluding tidal variance, which is generally from Galveston Bay toward the Turning Basin or downtown Houston. In Bayport and Barbour's Cut Terminals (which do not have large net flows) upstream is oriented away from their individual turning basins to the east.
[3] Historically, many of the wharves were constructed in groups contemporaneously and grid lines continued numbering from one wharf to another.



Notes:
E-W extent of Bay defined by numbered Grid Lines

N-S extent of Bay defined by channel and landside

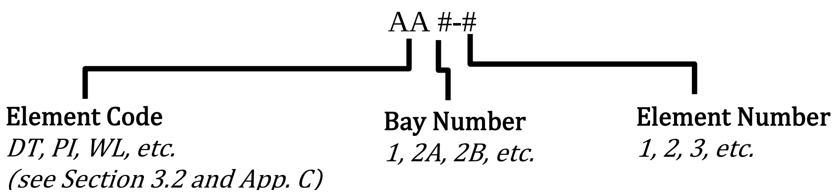
Bays are subdivided (A, B, C) based on changes in

Figure 8.1: Figure illustrating numbering of bays for CD 41, a structure with significant change in framing between the original (Bays -A) and landside extension (Bays -B and -C).

8.4.2. Element Labeling Scheme

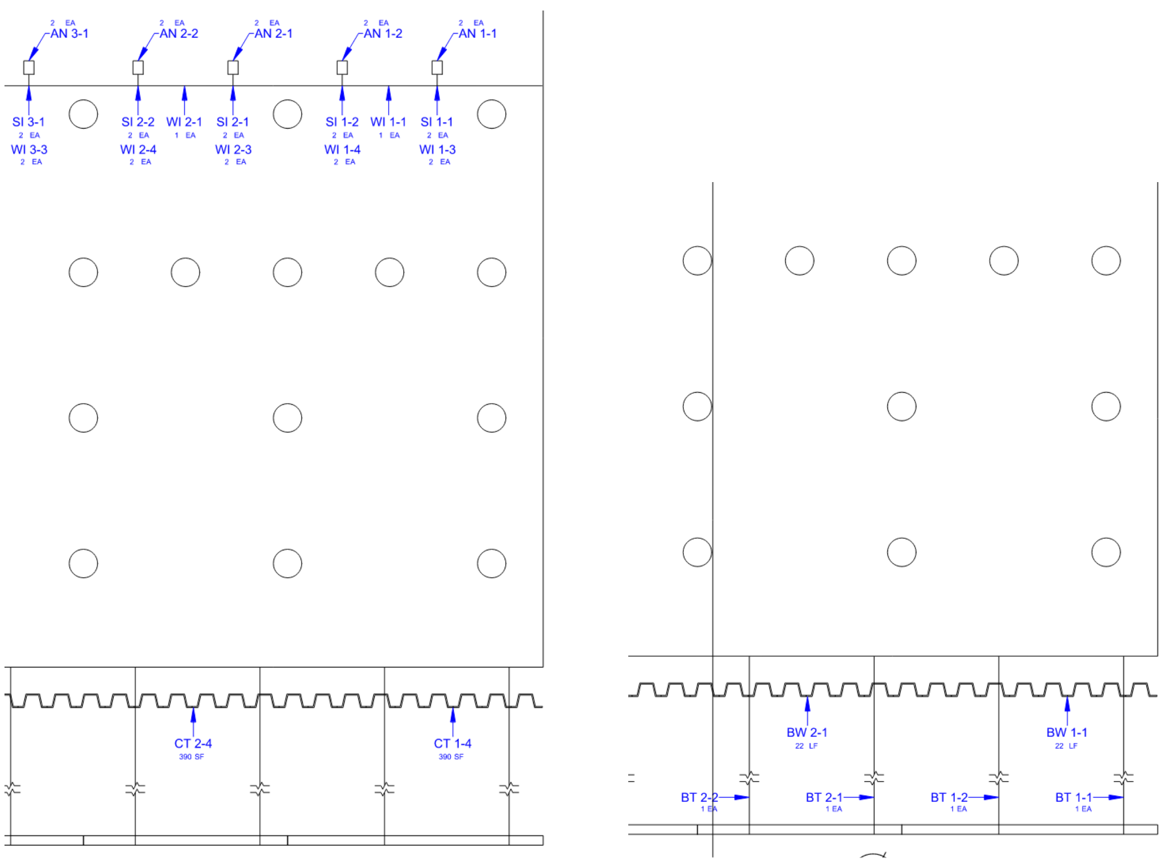
The nature of an element-based inspection and condition assessment approach is that each element of the asset that is included in a Baseline or Routine Inspection must be individually identified and labeled. A three-part Element ID labeling scheme has been developed to uniquely identifying each element on the Standard Inspection Drawings. The Element ID is also used on the Element Inspection Form and in the database.

The Element ID labeling scheme is as follows:



Elements should be numbered sequentially in each bay or sub-bay. Elements should start with 1 as the element closest to the upstream and waterfront and increase in number moving downstream and then away from the waterfront. If elements fall on a grid or bay line, they should generally be associated with the number of the bay or grid that is closer to the upstream end and waterfront. The bays furthest downstream and furthest land-side should include elements on their downstream and land-side ends, respectively. See Figure 8.2 for an example of this naming scheme as applied to corrosion protection and base metal elements.

The Element ID is supplemented by the Element Type Code presented in Chapter 3, where element types are defined by a two-part convention: AA-BB(B), where AA represents a two-letter element code, and BB(B) represents a two- or three-letter material type. This additional designation is used on the Element Inspection Form to indicate the material type.



a) Corrosion Protection elements *b) Base Metal elements*

Figure 8.2: Sample views of element designations from Wharf BCT5, showing definition for a) Corrosion Protection elements, and b) Base Metal elements.

8.4.3. Designation of Elevations

Due to subsidence in the general Houston region, the elevation of a structure relative to the ship channel water surface may have changed since its original construction. Consequently, historical drawings which made reference to Mean Low Water (MLW) or Mean Low Tide (MLT), Mean Sea Level (MSL), or other datums may no longer be accurate. The PHA publishes Wharf Characteristics regularly, which include elevations of each asset relative to MLW. This value shall be used for reference during inspections and shown on the Standard Inspection Drawings. If the value appears to be incorrect, a Follow-up Action should be created to re-survey the MLW elevation at the asset.

8.5. Corrosion Inspection Summary

The Corrosion Inspection Summary Form summarizes the findings of a Baseline or Routine Inspection, including the asset and component condition assessment findings. The Inspection Summary Form includes the following information:

- **Identification** – Identification of the asset by the property and asset ID. These identifiers are coordinated with the PHA's GIS implementation.
- **Inspection Information** – Type of inspection performed, date, scope, inspection firm(s), and personnel performing the inspection. Personnel performing the inspection should provide their qualifications in an attached roster.
- **Inspection Procedures** –Version of the Corrosion Management Manual used for the inspection and any variances from the defined procedures.
- **Certification –** Statement certifying compliance of inspection with this manual and applicable building codes, and seal of responsible Professional Engineer.
- **Overall Asset Corrosion Condition –** A narrative describing the asset's overall corrosion condition assessment and presenting the overall asset corrosion condition rating (see Section 6.3). Note significant areas of distress and reference action items for these as warranted. For Routine Inspections, note changes in condition from previous inspections. Representative conditions should be identified and shown in the attached figures.
- **Component Rating and Element Summaries –** Tables of ratings for each component and type of element. These tables match the components and elements provided in the Corrosion Inventory Record.
- **Figures –** Representative photographs or figures of conditions for various components. All photos provided should be referenced in the narrative.

8.6. Corrosion Inspection Data

The Corrosion Inspection Data Form summarizes the data collected during a Baseline or Routine Inspection. The form includes identification of the asset by the property and asset ID and inspection information, such as type of inspection performed, date, scope, inspection firm(s), and personnel reporting the data. Inspection Data collected for base metal and coating thickness measurements as well as test data specific to cathodic protection systems are reported. The inspection data section on the form can be customized based on the defined tasks in the inspection plan.

8.7. Corrosion Inspection History

The Inspection History is a log of the corrosion inspections that have been performed for the asset. All inspections meeting the criteria in this Manual should be logged. This form contains the following information:

- **Identification** – Identification of the specific component and asset by the property and asset ID.
- **Date** – The month and year when the inspection was performed.
- **Inspection Type** – Baseline, Routine, Post-Event, In-Depth, or Due Diligence.
- **Inspection Prime Firm** – The prime firm performing the inspection. Sub-consultants (if used) are not listed on this form.
- **Component Rating Summaries and Overall Corrosion Condition Rating**– A list of the component ratings resulting from the condition assessment and the overall corrosion condition rating. These values would only be entered for Baseline or Routine Inspections.

8.8. Corrosion Element Inspection Forms

Standardized Element Inspection Forms are applicable to Baseline and Routine Inspections. An example of these documents is provided in Appendix F. The use of these documents signifies that the inspection was performed in accordance with the inspection requirements of this Manual. Inspection Forms include the recorded observations on an element-level basis for the asset and are intended to be the archival version of the inspection's field notes.

It is anticipated that an element inspection form will be generated from the database sorted by each component as described in Section 8.12. Inspection Forms should include the following information:

- **Identification -** Identification of the specific component and asset by the property and asset ID.
- **Component Summary -** A sum of quantified condition states for each type of element in the component.
- **Elemental Record -** For each element, identification of the element type, location, total quantity, and conditions observed. For each type of condition, quantify the area or length for each condition state. Each entry should include a unique element identifier, referenced from the Standard Inspection Drawing.

Photographs specific to a particular element or condition should be uploaded to the database. Photographs are not required for each element or condition, but a sufficient number of photographs should be taken to show representative conditions. Photographs, however, are required for all observed conditions that would require a priority follow-up action. The photograph filename should be listed with the applicable element. Requirements for photographs submitted to the project database with the inspection forms are as follows:

- File Format: JPEG
- Size: 2048 pixels on longest edge

8.9. Follow-up Actions

The Follow-Up Action Form documents the recommended follow-up actions for Baseline, or Routine Inspections. Follow-up actions should be categorized as defined in Chapter 7 and should include a brief justification and a prioritization. Investigation Recommendations (as a follow-up action) may include maintenance or minor corrective actions that do not require an engineered design. An in-depth inspection or refined engineering analysis may be recommended as a follow-up action. The recommended follow-up actions should include photographs showing the conditions to be addressed where applicable. A sample Follow-up Action form is included in Appendix F.

8.10. Report Requirements

Baseline and Routine Inspections have defined deliverables with standardized methods of reporting. Expected deliverables for each are listed in Table 8.2.

Due Diligence and Post-Event Inspections are out of the scope of the Corrosion Manual and may have unique deliverables that do not fit standard templates. These deliverables may include technical reports, drawings, or other documentation. At a minimum, In-Depth Inspection deliverables should provide the following information:

1. Objective and scope.
2. Methodology, including reference to procedures or standardized test methods (e.g. ASCE, ASTM, AASHTO) as appropriate.
3. Record of observations and data, including field or laboratory data.
4. Interpretation of observations and data.
5. Recommendations.
6. Summary.
7. Seal of responsible Design Professional.

Table 8.2. Deliverables for Standard Inspections

Deliverable	Type of Inspection	
	Baseline	Routine
Corrosion Inventory Record	Yes. Includes initial generation of document.	Revise only if change identified
Corrosion Inspection Plan	Yes. Includes initial generation of document.	Update
Standard Corrosion Inspection Drawing Set	Yes. Includes initial generation of document.	No
Corrosion Element Inspection Forms	Yes. Includes initial generation of document.	Yes. Relies on inspection forms generated by Baseline.
Corrosion Inspection History	Yes. Includes initial generation of document.	Update
Corrosion Inspection Summary	Yes	Yes
Corrosion Inspection Data	Yes	Yes
Follow-Up Action Form	Yes	Yes
Submission into PHA database	Yes	Yes

8.11. Project Record Requirements

At the conclusion of the inspection, deliverable documents should be submitted to the Project Manager in electronic format[4] via the PHA's SharePoint system. After receipt and approval by the Project Manager, information from the Corrosion Inventory Record, Corrosion Inspection Forms (including referenced photographs), and Corrosion Inspection Summary should be entered by the inspection firm into the PHA Asset Database as described in Section 8.12.

The inspection firm should maintain electronic records of the deliverable documents for a minimum of 4 years after submission. Unused photographs, paper notes, or other documentation not included in the project deliverables may be discarded after submission.

8.12. Inspection Database Requirements

PHA has developed digital databases and corresponding GIS system to collect and report aspects of completed inspections from the Maritime Structures and Corrosion Manual. The inspections are to be submitted with a digital database template provided by PHA to the inspection firm, so that the digital data may be incorporated into the master database. The database template for corrosion inspections is different from that developed for the Maritime Structures Manual as it is customized for corrosion protection elements and condition state and accommodates corrosion test data entry.

As shown in Figure 8.3, the digital inspection system is comprised of three tiers. The master database is maintained by PHA. All digital inspection information is housed there for analysis and reporting, as well as the ability to provide the inspection firm's historical inspection information at the start of their inspections. Firms will be provided a digital inspection database template in SQL database format (e.g. Microsoft Access) with basic forms to allow for data entry. While the data is not required to be directly entered into the digital database template, submission to the port is required to be in the exact SQL structure provided, as the data will be digitally inspected and then imported into the master database. Detailed instructions for use of the system will be provided with the digital database template. The methodology of collecting data in the field is left to the inspection firm. Corrosion protection elements for surface protection and base metals are associated with the protected maritime structures elements in the master database for integrated inspection findings as discussed in Chapter 4.

[4] Format of electronic documentation should be PDF/A-1 as defined by ISO 19005-1.

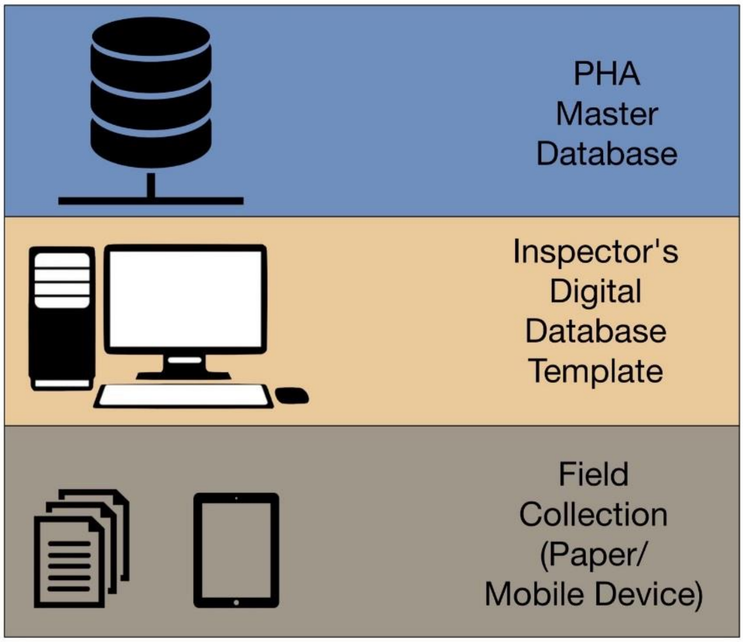


Figure 8.3. Digital inspection database hierarchy.

At the completion of the inspection, the inspection firm is required to transfer the required inspection documentation into the digital database template originally provided. This provides access to the required report forms to be submitted to PHA, as well as to attach photographs and drawings utilized for the inspection. Contractor's should print the Corrosion Inventory Record, Elemental Condition State Summary and Detailed Elemental Condition State Data, and review and certify that their findings are correctly entered. Printed versions of these forms should then be submitted as a part of the sealed engineering report.

CHAPTER 9: ADMINISTRATIVE REQUIREMENTS

9.1. Inspection and Corrosion Assessment Team Qualifications

The inspection and corrosion assessment of existing structures and the associated protection systems require specialized knowledge and experience to ensure that the results of the evaluation are credible and repeatable and provide the information necessary for the intended management purposes. The inspection and condition assessment of maritime or waterfront assets introduces additional complexities in terms of asset types and uses, exposure conditions, and the need for underwater inspection, and typically requires knowledge and experience different from that required for the evaluation of existing buildings, bridges, and other structures. Similarly, the inspection of associated corrosion protection systems introduces another level of complexity related to testing methods, performance requirements, and required knowledge and experience for the evaluation of corrosion protection systems, specifically for maritime conditions.

The inspection and condition assessment of corrosion management systems for maritime assets should be carried out by a team with the appropriate specialized knowledge and experience, including:

- Design, evaluation, and repair knowledge specific to corrosion management systems for maritime assets including:
  - Design requirements specific to cathodic protection and coating systems.
  - Understanding of corrosion processes and ability to interpret the significance of observed damage, deterioration, or other deficiencies on serviceability, structural performance, and integrity.
  - Understanding of corrosion protection performance criteria and methods of protection.
  - Repair methods for maritime components, elements, and corrosion protection systems.
- Visual, nondestructive, materials sampling, and testing techniques for assessing existing assets.
- Electrical testing techniques for cathodic protection systems.
- Underwater inspection techniques and requirements.
- Corrosion mechanisms for steel elements.
- Methods and requirements for characterizing and quantifying damage, degradation, and corrosion rates.
- Inspection and condition assessment documentation and reporting requirements.
- Safety requirements for conducting above-water and underwater inspections.

The scope and scale of an inspection and condition assessment of a maritime asset's steel elements and corrosion protection systems dictate that the work is conducted using a team approach. Each team member should have the training, knowledge, and experience necessary to conduct the aspects of the inspection and condition assessment for which they are involved or responsible. The intent of this document is not to dictate the specific makeup of an inspection and condition assessment team, but rather to propose a typical team structure and define the required minimum qualifications for team members.

The typical project team structure consists of an Inspection and Condition Assessment Project Manager who oversees an on-site inspection team and a team of engineers responsible for conducting the condition evaluation. The same personnel may be involved in both the inspection and condition assessment if their qualifications are appropriate, or the two teams may be separate. Similarly, the same personnel may be involved in both the FICAP and Corrosion Management scopes of inspections if their qualifications are appropriate.

The following sections present minimum qualification requirements for the on-site inspection team, the condition assessment team as a whole, and individual team members. The responsibilities and qualifications for the overall project manager are defined as part of the on-site inspection team, although this person is also responsible for the condition assessment portion of the project.

9.1.1. On-Site Inspection Team Composition and Qualifications

A typical organizational structure for an on-site inspection team is illustrated in Figure 9.1. Although the number of persons on a team may vary from project to project, the minimum number of personnel for the on-site inspection should be one Team Leader and one Team Member for safety and practical reasons. Most inspection types will include some degree of underwater inspection. For illustration purposes, the inspection team is split into the above-water and underwater groups, although in practice some personnel may take part in both aspects of the inspection. The on-site inspection team structure shown in Figure 9.1 may apply to teams consisting of PHA personnel, consultants, or some combination thereof.

Inspection and Condition Assessment Project Manager

- Responsible for overall direction and supervision of project team conducting inspection and condition assessment.
- Responsible for overall project scope, including:
  - On-site inspection activities (above and underwater);
  - Condition assessment and rating;
  - Documentation and reporting;
  - Recommendation of Follow-up Actions;
  - Updating Future Inspection Plans; and,
  - Establishing a quality assurance and quality control process for the inspection and condition assessment.
- Responsible for coordinating above-water and underwater inspection teams.
- Primary point of contact with PHA Project Manager.

Inspection Team Leader

- Responsible for planning, preparing, and performing inspections for above-water portion of project scope, including day-to-day inspection activities.
- Responsible for direction and supervision of Inspection Team.
- Responsible for communication with Project Manager.
- Must be on-site at all times during above-water inspection.
- Must inspect a minimum of 25% of above-water portion of asset.
- Must observe and evaluate all unusual structural conditions and problems, including those noted by Inspection Team Members.
- Must observe and evaluate all unusual conditions, problems, and/or questionable test results related to performance of corrosion protection systems noted by Inspection Team Members.

Underwater Team Leader

- Responsible for planning, preparing, and performing underwater inspections, including day-to-day activities.
- Responsible for direction and supervision of Underwater Inspection Team Members.
- Responsible for communication with Project Manager at regular intervals.
- Must be on-site at all times during underwater inspection.
- Must inspect a minimum of 25% of the underwater portion of the asset.
- Must observe and evaluate all unusual structural conditions and problems noted during underwater inspection, including those indicated by Underwater Inspection Team Members.

Inspection Team Member	**Underwater Team Member**
▪ Assists the Team Leader with some or all aspects of day-to-day inspection activities, including documentation and reporting.	▪ Assists the Underwater Team Leader with some or all aspects of day-to-day inspection activities, including documentation and reporting.

Figure 9.1: On-Site Inspection Team Composition and Responsibilities

The minimum qualifications for the members of the on-site inspection team (Figure 9.1) are defined below. The PHA Director of Project and Construction Management may set higher or lower qualification requirements on a project-specific basis. Post-event inspector qualifications will be at the discretion of the PHA Director of Project and Construction Management.

Inspection and Condition Assessment Project Manager	▪ A minimum of 10 years of experience in the inspection, design and/or construction of civil structures, including maritime or waterfront assets. Experience in the inspection, design, and/or construction of cathodic protection of civil structures counts towards this requirement. ▪ Successfully completed the Port of Houston Maritime Facility Corrosion Manual Training Course.* Plus ▪ Registered Professional Engineer licensed in the State of Texas specialized in civil, structural, or corrosion engineering. and ▪ Registered Corrosion or Cathodic Protection Technologist with AMPP/NACE International, or equivalent.
Inspection Team Leader	▪ A minimum of 5 years of experience in inspection of civil structures, including maritime or waterfront assets, and/or cathodic protection systems. ▪ Successfully completed the Port of Houston Maritime Facility Corrosion Manual Training Course.* Plus ▪ Registered Professional Engineer. or ▪ Registered Corrosion or Cathodic Protection Technologist with AMPP/NACE International.

Inspection Team Member	▪ Successfully completed the Port of Houston Maritime Facility Corrosion Manual Training Course.* Plus ▪ Graduate of a four-year engineering curriculum in civil, structural, or corrosion engineering and certified as an engineer-in-training (EIT) or ▪ A minimum of 2 years of experience in inspection of civil structures, including maritime or waterfront facilities. or ▪ Registered Cathodic Protection Tester with AMPP/NACE International. or ▪ Registered Basic Coating Inspector with AMPP/NACE International.
Underwater Inspection Team Leader	▪ Same minimum qualifications as defined above for Team Leader. Plus ▪ Hold diver certification from a recognized training organization (e.g., ADC accredited commercial, US Military, or PADI/NAUI dive school). ▪ At least 5 years of commercial underwater inspection experience under conditions similar to the inspection site, which may include low visibility, high currents, and confined spaces.
Underwater Inspection Team Member	▪ Same minimum qualifications as defined above for Inspection Team Member. Plus ▪ Trained commercial diver holding certification from a recognized training organization (e.g., ADC accredited commercial, US Military, or PADI/NAUI dive school).
Other Team Members	▪ Other personnel with lesser qualifications than those defined above may be present to perform manual tasks related to the above water inspection or to support diving operations.

*** Note:** Completion of the Port of Houston Corrosion Manual Training Course is valid for a period of five (5) years, after which time the Training Course must be retaken.

9.1.2. Corrosion Assessment Team Composition and Qualifications

The corrosion assessment requires an engineering interpretation of the on-site inspection findings and acquired data. Accordingly, the corrosion assessment team will largely consist of engineers. The structure of the corrosion assessment team is less formal than that of the on-site inspection team. The corrosion assessment team is led by the Inspection and Condition Assessment Project Manager as defined in the preceding section. All personnel involved with the corrosion assessment must have successfully completed the Port of Houston Maritime Facility Corrosion Management Inspection Training Program and be a registered Corrosion or Cathodic Protection Technician with NACE International, or have equivalent experience.

To determine the base metal component rating, base metal elements are classified into critical, typical, and redundant components. General classification by element type is provided in Chapter 2 as part of the inspection planning discussion. If these classifications were determined inappropriate for a given structure, revised element classes should be evaluated by a licensed professional engineer with structural expertise.

9.2. Safety Requirements

Inspection of an existing asset and corrosion protection systems presents numerous inherent safety risks for inspection personnel. Proper safety training and certification of inspection personnel is essential, as is continual awareness of safety concerns by all team members during the conduct of the inspection. Job safety must meet local and state regulations.

The Inspection Team Project Manager and the Inspection Team Leaders are responsible for providing safe working conditions during the inspection, including:

- Ensuring all Team Members have appropriate safety training in the application of safety procedures and use of safety equipment;
- Providing necessary safety equipment;
- Discussing safety procedures for each inspection task with Team Members; and,
- Enforcement of safety procedures and regulations.

Individual Inspection Team Members are responsible for their safety and the safety of others, including:

- Knowledge of safety rules and regulations;
- Use of appropriate personal protection equipment and clothing;
- Safety of other Team Members (warn others of unsafe actions);
- Recognition of personal limitations (lack of knowledge or skill, physical limitations);
- Maintaining appropriate attitude and awareness during inspection (avoiding distraction and boredom, ignoring or not recognizing hazards, etc.); and,
- Reporting of accidents and injuries.

9.2.1. Port of Houston Authority Safety Policy

The Project Manager and all members of the Inspection Team must be familiar with the Port of Houston Health and Safety Policy and must attend a Contractor and Consultant Safety Orientation before beginning work at Port Houston. Consultants and contractors shall abide by the tariff assigned to each terminal as outlined by the contract.

The Inspection Team is responsible for providing their personal protection equipment, including:

- High Visibility Vest - required inside the terminal or conducting work adjacent to a roadway.
- Hard Hats - required for work on the wharf, under wharf cranes, under Rubber Tire Gantry Cranes (RTG), in construction zones, or where an overhead hazard is present.
- Safety Footwear - required in a construction zone or where a foot hazard is present.
- Personal Floatation Device (Life Jacket) - required for work over, under, or near the water.
- Safety Glasses with ANZI Z87.1 rating with side shields - required for work in a construction zone or where an eye hazard is present.
- Proper electrical safety equipment - required when performing work on or around electrical equipment.

Additional safety-related requirements and practices will be addressed in the PHA Safety Orientation. In the event of a medical emergency, fire, vehicle incident, chemical spill, or chemical leak, the PHA Dispatch must be notified at 713-670-3611. Note that the current PHA Health and Safety Policy and the requirements of the PHA Safety Orientation will supersede the safety-related content in this Manual in the event of a discrepancy.

9.3. Other Administrative Requirements

Consultants and contractors shall comply with Security Requirements, Insurance, Limitation and Responsibility, and other issues as outlined by the contract.

CHAPTER 10: REFERENCES

10.1. Cited References

AASHTO. (2013). Manual for Bridge Element Inspection. Washington, DC: American Association of State Highway and Transportation Officials.

ASCE. (2001). Practice No. 101 Underwater Investigations Standard Practice Manual. (K. M. Childs Jr., Ed.) Reston, VA: American Society of Civil Engineers.

ASCE. (2015). Practice No. 130 Waterfront Facilities Inspection and Assessment. (R. E. Heffron, Ed.) Reston, VA: American Society of Civil Engineers.

NACE. (2019). SP21430, Standard Framework for Establishing Corrosion Management Systems. Houston, TX: NACE International.

NACE. (2016). SP0216, Sacrificial Cathodic Protection of Reinforcing Steel in Atmospherically Exposed Concrete Structures. Houston, TX: NACE International.

NACE. (2013). SP0169, Standard Practice Control of External Corrosion on Underground or Submerged Metallic Piping Systems. Houston, TX: NACE International.

NACE. (2007). SP0176, Standard Practice Corrosion Control of Submerged Areas of Permanently Installed Steel Offshore Structures Associated with Petroleum Production. Houston, TX: NACE International.

Port of Houston Authority. (2010). Engineering Design Guide. Houston, TX.

Port of Houston Authority. (2017). Maritime Facilities Inspection and Condition Assessment Manual. Houston, TX.

Ryan, T. W., Mann, J. E., Chill, Z. M., & Ott, B. T. (2012). Bridge Inspector's Reference Manual (BIRM). Arlington, VA: Federal Highway Administration.

10.2. Suggested References

The references below provide additional information on the subjects relevant to the FICAP program.

- Appendix B of ASCE 130: “Types and Causes of Defects and Deterioration”
- NACE/ASTM G193, Standard Terminology and Acronyms Relating to Corrosion
- NACE Publication 01105, Sacrificial Cathodic Protection of Reinforced Concrete Elements – A State of the Art Report
- NACE SP0290 (2007), Impressed Current Cathodic Protection of Reinforcing Steel in Atmospherically Exposed Concrete Structures
- NACE SP0408 (2014), Cathodic Protection of Reinforcing Steel in Buried or Submerged Concrete Structures
- NACE TM0497 (2012), Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems
- NAVFAC MO-322 (1993), Inspection of Shore Facilities
- NAVFAC MO-104.1 (1990), Maintenance of Fender Systems and Camels

APPENDIX A - MARITIME ASSET LIST

FICAP - Marine Facilities/Asset List

List starts upstream on Northside of channel to downstream on Northside, and then upstream on Southside to downstream on Southside

Property or Terminal	Description
Northside Turning Basin	Shoreline of 21.4 acre undeveloped property upstream of UP Rail Bridge
Northside Turning Basin	Shoreline UP rail Bridge to Sam Houston Boat dock
Northside Turning Basin	Sam Houston Tour Boat dock and bulkhead
Northside Turning Basin	Shoreline from Sam Houston Bulkhead to Wharf 8 bulkhead
Northside Turning Basin	Fireboat Dock
Northside Turning Basin	Wharf 8
Northside Turning Basin	Wharf 9
Northside Turning Basin	Bulkhead between CD09 and CD 10
Northside Turning Basin	Wharf 10
Northside Turning Basin	Wharf 11
Northside Turning Basin	Wharf 12
Northside Turning Basin	Wharf 13
Northside Turning Basin	Wharf 14
Northside Turning Basin	Wharf 15
Northside Turning Basin	Wharf 16
Northside Turning Basin	Wharf 17
Northside Turning Basin	Wharf 18
Northside Turning Basin	Wharf 19
Northside Turning Basin	Wharf 20
Northside Turning Basin	Wharf 21
Northside Turning Basin	Wharf 22
Northside Turning Basin	Wharf 23
Northside Turning Basin	Wharf 24
Northside Turning Basin	Wharf 25
Northside Turning Basin	Wharf 26
Northside Turning Basin	Wharf 27
Northside Turning Basin	Wharf 28
Northside Turning Basin	Wharf 29
Northside Turning Basin	Wharf 30
Northside Turning Basin	Wharf 31
Northside Turning Basin	Bulkhead between CD 31 and CD 32 (under 610 Bridge)
Northside Turning Basin	Wharf 32 and shoreline (from downstream bridge 610)
Northside Turning Basin	Shoreline between CD 32 and USCG Station (future wharf 33 & 34)
Woodhouse Terminal	Woodhouse T-head Grain Wharf and shoreline
Woodhouse Terminal	Shoreline Westside of WH slip
Woodhouse Terminal	Old WH FireBoat Dock ~110' x 15' wood (abandoned)
Woodhouse Terminal	Northside of WH Slip, roro platform, + Wharf H3
Woodhouse Terminal	Wharf H2
Woodhouse Terminal	Channelside WH wharf H1
Greens Bayou	Shoreline along GB dredge site to Bulkplant bulkhead (NE end) part used for barge fleeting
Bulk Materials Handling Plant	Ship dock with Bulk gantry crane
Bulk Materials Handling Plant	T head dock
Bulk Materials Handling Plant	Channel side shoreline (future wharf space)

FICAP - Marine Facilities/Asset List

List starts upstream on Northside of channel to downstream on Northside, and then upstream on Southside to downstream on Southside

Property or Terminal	Description
BW8	3750' of channelside shoreline
Care Terminal	Bulkhead from West side of property line to JP-4
Care Terminal	Care Wharf 1
Care Terminal	Care Wharf 2
Care Terminal	Undeveloped Shoreline JP-5 to Inbessa on Southside of JP Slip (future HFOTC wharf?)
Jacinto Port Terminal	JP Wharf 1 from Westside slip to JP-2
Jacinto Port Terminal	JP Wharf 2 (middle wharf)
Jacinto Port Terminal	JP Wharf 3, has four spiralveyors)
Jacinto Port Terminal	Rail loading platform w/ 2 Rail tracks (~200'x26') w/ Access bridge
Banana Bend	BB Shoreline
Channelview	Old Fireboat dock West of Lost Lake Placement Area (USED FOR BARGE FLEETING)
Lost Lake DMPA	--
Lost Lake Barge Fleeting Area	ACL Barge Fleeting area south east corner of Lost Lake DMPA
Goat Island	--
Hog Island	--
Atkinson Island DMPA	--
Midbay DMPA	--
Evvia Island	--
Bolivar DMPA	--
Boliver	14000' of shoreline on NW side of GIWW barge channel
END OF DOWNSTREAM ON NORTHSIDE	
Southside Turning Basin	PHA shoreline upstream of CD 4
Southside Turning Basin	Wharf 4W and 4E
Southside Turning Basin	Wharf 3W and 3E
Southside Turning Basin	Wharf 2
Southside Turning Basin	Wharf 1W
Southside Turning Basin	Wharf 1E T-head pipeline Wharf
Southside Turning Basin	Wharf 41
Southside Turning Basin	Wharf 42
Southside Turning Basin	Wharf 43

FICAP - Marine Facilities/Asset List

List starts upstream on Northside of channel to downstream on Northside, and then upstream on Southside to downstream on Southside

Property or Terminal	Description
Southside Turning Basin	Wharf 44
Southside Turning Basin	Wharf 45
Southside Turning Basin	Wharf 46
Southside Turning Basin	Wharf 47
Southside Turning Basin	Wharf 48
Southside Turning Basin	Shoreline 48 downstream to edge of PHA property
Southside near Brady's Landing	Shoreline by bridge Across from Brady's Island
Manchester Wharves	Bulk headed shoreline from 610 bridge to upstream M2
Manchester Wharves	Wharf M2 - pipelines only
Manchester Wharves	Wharf M3 - liquid U-head dock
Manchester Wharves	Shoreline downstream of M3 to edge of PHA property
Sims Bayou	Shoreline Pipeline and Rail bridge area
Sims Bayou	Shoreline from rail bridge to Barge wharf cut
Sims Bayou	Barge Wharf + Shoreline
Sims Bayou	Tanker Wharf ! U-Head Tanker Dock + Shoreline
Albemarle lease	Shoreline associated with 1.67 acres filled submerged tract across from BMHP
Vopak Lease	Shoreline on 13.77 filled submerged acre tract (Across channel from Care)
Peggy Lake DMPA	--
BOSTCO Lease	PHA Shoreline Northside of Barnes Island
BOSTCO Lease	PHA Shoreline Northside of Barnes Island
San Jacinto Barge Dock	Barge Dock and Shoreline (leased to Lyondell Bassell)
Alexander Island DMPA	
Dupont Liquid Bulk Terminal	Barge dock and Shoreline
Spilman Island	Shoreline South of old tunnel access road and bridge, NW of SH146
Spilman Island	Bridge ~166'x58' Old access to Baytown tunnel
Spilman Island	Shoreline NW side of Spilman from PHA bridge to SH146 bridge property
Spilman Island	G&H Tugboat Dock
Spilman Island	Shoreline on Southwest side of PHA bridge property is for access to Spilman
Spilman Island DMPA	--
Barbours Cut	BCT dock 8-Enterprise barge dock and shoreline (to be converted to ship wharf)
Barbours Cut	BCT Wharf 7 (from BCT8 to diagonal bulkhead West of BCT 6)
Barbours Cut	Bulk head between BCT 7 and BCT 6
Barbours Cut	BCT Wharf 6

FICAP - Marine Facilities/Asset List

List starts upstream on Northside of channel to downstream on Northside, and then upstream on Southside to downstream on Southside

Property or Terminal	Description
Barbours Cut	BCT Wharf 5
Barbours Cut	BCT Wharf 4
Barbours Cut	BCT Wharf 3
Barbours Cut	BCT Wharf 2
Barbours Cut	BCT Wharf 1
Barbours Cut	BCT East Roro
Barbours Cut	BCT LASH Dock and Basin
Barbours Cut	BCT Fire Boat Dock (berths fro two Fire Boats)
Barbours Cut	Shoreline along HSC from LASH Basin through Ballaster road
Barbours Cut	Shoreline from Ballaster road around corner of property (stabilized area)
Barbours Cut	Shoreline along Galveston Bay 31.27 acre tract
Bayport	Shoreline on Northside o channel from entrance to SanJac College property
Bayport	Shoreline Northwest corner of BPT Turning Basin
Bayport	Shoreline adjacent to PHA's Western first flush pond
Bayport	Future Bayport Wharf 7
Bayport	Future Bayport Wharf 6
Bayport	Bayport Wharf 5
Bayport	Bayport Wharf 4
Bayport	Bayport Wharf 3
Bayport	Bayport Wharf 2
Bayport	Future Bayport Wharf 1
Bayport	Bulkhead along BPT Channel North of Cruise
Bayport	Bayport Cruise Wharf
Bayport	Bayport Cruise Basin
Bayport	Shoreline South of Bayport Cruise along Galveston Bay
Pelican Island	Shoreline on West side of Pi just north of TAMUG
Pelican Island	Shoreline North of Sea Wolf Park
Pelican Island	Shoreline along Galveston Channel from Seawolf park to west end of shore property

APPENDIX B - GLOSSARY

Item	Definition	Alternate Names (deprecated)	Reference
Anode	The electrode of an electrochemical cell at which oxidation occurs. Electrons flow away from the anode in the external circuit. Corrosion usually occurs and metal ions enter the solution at the anode.		*NACE/ ASTM G193*
Apron	Portion of paved area adjacent to waterfront. For PHA assets, this may include both structural deck and slabs on grade.		
Backfill	Material placed in a hole to fill the space around the anodes, vent pipe, and buried components of a cathodic protection system		*NACE/ ASTM G193*
Beam	A structural member subjected primarily to flexure but may also be subjected to axial load.		*ACI CT-16*
– **Deck Beam**	Beam directly supporting or contiguous with wharf deck.	*Stringer*	
– **Frontal Beam**	The first beam at the front of the wharf, contiguous with the wharf deck.	*Spandrel Beam* *Marginal Beam* *Fender Beam*	
– **Wale Beam**	A horizontal member used for bracing the sheeting or trench, cofferdam, bulkhead, or similar structures	*Waler*	*ASCE 130*
Brace	An element, either horizontal or diagonally oriented, fastened across pile elements to provide lateral stability. Usually located in timber or steel maritime structures. For concrete structures, see also **strut**.		
Brace Wall	See **shear wall**		
Catalyst	A chemical substance, usually present in small amounts relative to the reactants, that increases the rate at which a chemical reaction (ex: curing) would otherwise occur, but is not consumed in the reaction		*NACE/ ASTM G193*
Cathode	The electrode of an electrochemical cell at which reduction is the principal reaction. Electrons flow toward the cathode in the external circuit.		*NACE/ ASTM G193*
Cathodic Disbondment	The destruction of adhesion between a coating and the coated surface caused by products of a cathodic reaction.		*NACE/ ASTM G193*
Cathodic Polarization	(1) the change of electrode potential caused by a cathodic current flowing across the electrode/electrolyte interface. (2) a forced active(negative) shift in electrode potential.	*Polarization*	*NACE/ ASTM G193*
Chalking	The development of loose, removable powder (pigment) at the surface of an organic coating, usually caused by weathering		*NACE/ ASTM G193*
Checking	The development of slight breaks in a coating that do not penetrate to the underlying surface		*NACE/ ASTM G193*
Channel Side	The side of the structure facing the ship channel.	*Harbor Side* *Water Side*	

Item	Definition	Alternate Names (deprecated)	Reference
Coating System	The complete number and types of coats applied to a substrate in a predetermined order. (When used in a broader sense, surface preparation, pretreatments, dry film thickness, and manner of application are included)		*NACE/ ASTM G193*
Concentration Cell	An electrochemical cell, the electromotive force of which is caused by a difference in concentration of some component in the electrolyte. (This difference leads to the formation of discrete cathodic and anodic regions)		*NACE/ ASTM G193*
Condition Assessment	An evaluation of inspection results to provide an appraisal of the significance of the observed damage and deterioration on the condition of the structure.		
Conductivity	(1) A measure of the ability of a material to conduct an electric charge. It is the reciprocal of resistivity. (2) The current transferred across a material (e.g., coating) per unit potential gradient.		*NACE/ ASTM G193*
Continuity Bond	A connection, usually metallic that provides electrical continuity between structures that can conduct electricity.		*NACE/ ASTM G193*
Corrosion Inhibitor	A chemical substance or combination of substances that, when present in the proper concentration and forms in the environment, reduces the corrosion rate.		*NACE/ ASTM G193*
Corrosion Rate	The time rate of change of corrosion. (It is typically expressed as mass loss per unit area per unit time, penetration per unit time, etc.).		*NACE/ ASTM G193*
Corrosion Resistance	Ability of a material, usually a metal, to withstand corrosion in a given environment.		*NACE/ ASTM G193*
Corrosiveness	The tendency of an environment to cause corrosion.		*NACE/ ASTM G193*
Curing	Chemical Process of developing the intended properties of a coating or other material (e.g., resin) over a period of time).		*NACE/ ASTM G193*
Current	(1) A flow of electric charge. (2) The amount of electric charge flowing past a specified circuit point per unit time, measured in the direction of net transport of positive charges. (In a metallic conductor, this is the opposite direction of the electron flow.)		*NACE/ ASTM G193*
Current Density	The current to or from a unit area of an electrode surface.		*NACE/ ASTM G193*
Defects	An anomaly in a material or element present since original construction.		

Item	Definition	Alternate Names (deprecated)	Reference
Depolarization	The removal of factors resisting the current flow in an electrochemical cell.		*NACE/ ASTM G193*
Deterioration	(1) Physical manifestation of failure of a material (for example, cracking, delamination, faking, pitting, scaling, spalling, and staining) caused by environmental or internal autogenous influences (2) decomposition of material during either testing or exposure to service.		*ACI CT-16*
Dissimilar Metals	Different metals that could form an anode-cathode relationship in an electrolyte when connected by a metallic path.		*NACE/ ASTM G193*
Distress	Deterioration, distortion, or displacement to an element as a result of external forces or material deterioration.		
Dock	A self-supporting structure for berthing and unloading cargo or passengers, typically for smaller vessels or barges. See also wharf.		
Dolphin	A free-standing, pile-supported or solid-filled structure used for mooring and berthing vessels, protection of the end of piers or wharves, turning ships, or protection of bridge structure.		*ASCE 130*
Downstream	The primary direction of the channel flow, excluding tide changes, which is toward Galveston Bay. In Barbour's Cut Terminal (which does not have a large net flow) downstream is oriented towards its turning basin and to the west in order to be consistent with original grid lines and naming schemes. Conversely, in Bayport Terminal, downstream is defined as to the east, also to be consistent with original grid lines. See also **upstream**.		
Electrode	A material that conducts electrons, is used to establish contact with an electrolyte, and through which current is transferred to or from an electrolyte.		*NACE/ ASTM G193*
Electrode Potential	The potential of an electrode in an electrolyte as measured against a reference electrode.		*NACE/ ASTM G193*
Electrolyte	A chemical substance containing ions that migrate in an electric field.		*NACE/ ASTM G193*
Embrittlement	Reduction of ductility, or toughness, or both, of a material (usually a metal or alloy)		*NACE/ ASTM G193*
Epoxy	Type of resin formed by the reaction of aliphatic or aromatic polyols (like bisphenol) with epichlorohydrin and characterized by the presence of reactive oxirane end groups		*NACE/ ASTM G193*
Erosion	The progressive loss of material from a solid surface due to mechanical interaction between that surface and a fluid, a multicomponent fluid, or solid particles carried with the fluid		*NACE/ ASTM G193*

Item	Definition	Alternate Names (deprecated)	Reference
Fender System	Devices used on the face of a pier, wharf, or dolphin to protect the ship and shore facility from damage due to contact between the two during berthing and mooring. Fenders may be energy-absorbing, or simply transmit forces directly to the structure behind. Fenders are usually designed for specific ranges of vessels. The fender system may be comprised of some or all of the pieces below.	*Fendering System*	
Facing	Sacrificial elements fastened to the harbor side of the fender system for the purpose of providing low-friction surfaces and protecting both ships and other fender elements from abrasion damage. Facing includes ultra-high molecular-weight (UHMW) panels, plastic rub strips, and timber logs.	*Rub Strips* *Lagging*	
Fender Unit	Energy-absorbing devices used on the face of a pier, wharf, or dolphin to protect the ship and shore facility from damage due to contact between the two during berthing and mooring.	*Damper*	
– Panel	A rectangular element oriented parallel to the fender system that increases the contact area of the fender system against the ship hull.		
Fittings	Elements used for mooring ships, including bitts, bollards, and cleats.		
Floor Beam	A beam element that carries vertical loads from a deck or system of stringers to a system of girders (typically perpendicular to the floor beam).		*BIRM*
Functionality	The use for which a particular element or component is designed. Functionality can usually be defined simply, such as “provide access to a lower level” (e.g., ladder), or “provide anchorage for mooring line and resist mooring force” (e.g. cleat)		
Galvanic Anode	A metal that provides sacrificial protection to another metal that is more noble when electrically coupled in an electrolyte. This type of anode is the electron source in one type of cathodic protection.		*NACE/ ASTM G193*
Girder	A large beam element, usually horizontal, that serves as a main structural member and usually supports one or more Beams. A large floor beam (i.e., depth greater than 36 inches) could also be considered a girder, particularly if it is a built-up section.		*ACI CT-16, BIRM*
Ground bed	One or more anodes installed below the earth's surface for the purpose of supplying cathodic protection.		*NACE/ ASTM G193*
Grid Line	A line used for layout on inspection drawings.	*Column Line*	
Half-Cell Potential	The potential in a given electrolyte of one electrode of a pair relative to a standard state or a reference state. Potentials can only be measured and expressed as the difference between the half-cell potentials of a pair of electrodes.		*NACE/ ASTM G193*
Houston Ship Channel	The navigable waterway existing from the Galveston Sea Buoy to the Houston Turning Basin		*Houston Pilots*

Item	Definition	Alternate Names (deprecated)	Reference
Hydrogen Embrittlement	Embrittlement caused by the presence of hydrogen within a metal or alloy.		*NACE/ ASTM G193*
Impressed Current	An electric current supplied by a device employing a power that is external to the electrode system.		*NACE/ ASTM G193*
Impressed Current Anode	An electrode, suitable for use as an anode when connected to a source of impressed current, which is generally composed of a substantially inert material that conducts by oxidation of the electrolyte and is not corroded appreciably.		*NACE/ ASTM G193*
Inspection	An evaluation procedure in which a qualified investigator observes, classifies, and documents the physical condition of a structure. It may involve visual, tactile, nondestructive testing and material sampling and testing methods to determine the types, severity and locations of deterioration or distress in the structure. An inspection is a key step in the condition assessment of a concrete structure		
Instant-Off Potential	The polarized half-cell potential of an electrode taken immediately after the cathodic protection current is stopped, which closely approximates the potential without IR drop (i.e., the polarized potential) when the current was on.		*NACE/ ASTM G193*
Land Side	The face of the structure parallel to and farthest away from the Ship Channel.	*Shore*	
Load rating	The load-carrying capacity of an existing structure determined in accordance with the governing code or standard for design or evaluation. Load rating is determined by analysis, and normally incorporates knowledge of the as-built condition and an evaluation of current structural conditions based on an inspection of the structure.		
Marine	Pertaining to the sea. For this manual, this includes the Ship Channel, which is brackish water.		
Maritime	Pertaining to structures on a shoreline, including rivers, bays, and oceans.		
Metallizing	The coating of a surface with a thin metal layer by spraying, hot dipping, or vacuum deposition		*NACE/ ASTM G193*
Overvoltage	The difference in potential of an electrode between its equilibrium and steady-state values when current is applied.		*NACE/ ASTM G193*
Oxidation	(1) Loss of electrons by a constituent of a chemical reaction. (2) Corrosion of a metal that is exposed to an oxidizing gas at elevated temperatures.		*NACE/ ASTM G193*
Passive	(1) the state of a metal surface characterized by low corrosion rates in a potential region that is strongly oxidizing for the metal. (2) the positive direction of electrode potential.		*NACE/ ASTM G193*

Item	Definition	Alternate Names (deprecated)	Reference
Pier	A structure that projects from the shore, oriented perpendicular, or at an angle to the shore. See also **wharf**.		*ASCE 130*
Pile	A vertical element that absorbs energy through bending of the member. Fender piles are typically driven into the channel bed and braced at their top.		
Pile cap	A member connecting pile heads and through which loads are transmitted to the piles		*ASCE 130*
Polarization	The change from the corrosion potential as a result of current across the electrode/electrolyte interface		*NACE/ ASTM G193*
Polarization Decay	The decrease in electrode potential with time resulting from the interruption of applied current.		*NACE/ ASTM G193*
Polarized Potential	(1) (general use) the potential across the electrode/electrolyte interface that is the sum of the corrosion potential and the applied polarization. (2)(cathodic protection use) the potential across the structure/electrolyte interface that is the sum of the corrosion potential and the cathodic polarization.		*NACE/ ASTM G193*
Property	The highest level in the hierarchy from an inspection and condition assessment perspective (higher levels may be considered for asset management or other purposes). It is typically comprised of a group of assets and is defined by distinct boundaries. A property is a collection of non-cargo assets. See also terminal.		
Reference Electrode	An electrode having a stable and reproducible potential, which is used in the measurement of other electrode potentials.		*NACE/ ASTM G193*
Repair	The action of replacing or correcting deteriorated, damaged, or faulty materials, components, or elements of a structure.		
Resistivity	The electrical resistance between opposite faces of a unit cube of material.		*NACE/ ASTM G193*
Secondary Framing	Includes bracing, struts, chocks, or other secondary structural framing members of a fender system. Secondary members generally add to the stability of the fender system and do not distribute berthing and mooring forces.		
Shear Wall	A wall, typically transverse to the front of the wharf, spanning between the **pile cap** and superstructure.	*Brace Wall*	
Stay Chains	Heavy-duty chains connecting between wharf structure and other fender elements. Chains types include weight chains (to restrain vertical movement), shear chains (to restrain lateral movement), tension chains (to restrain rotation in cantilevers), and keep chains (for lifting or replacing fender elements).		
Stringer	A beam element that carries vertical loads from a deck to a system of floor beams (typically perpendicular to the stringers).		*BIRM*

Item	Definition	Alternate Names (deprecated)	Reference
Structure -To-Electrolyte Potential	The potential difference between the surface of a buried or submerged metallic structure and the electrolyte that is measured with reference to an electrode in contact with the electrolyte.		*NACE/ ASTM G193*
Strut	A member spanning between piles or pile bents for the primary purpose of bracing the top of the piles or pile caps from lateral movement.	*Lower Beam* *Brace Beam* *Tie Beam*	
Terminal	The highest level in the hierarchy from an inspection and condition assessment perspective (higher levels may be considered for asset management or other purposes). It is typically comprised of a group of assets and is defined by distinct boundaries. A terminal is a collection of cargo-wharf assets. See also property.		
Tidal Datums	Standard elevation defined by a certain phase of the tide. Tidal datums are used as references to measure local water levels and should not be extended into areas having differing oceanographic characteristics without substantiating measurements. In order that they may be recovered when needed, such datums are referenced to fixed points. In the Houston Ship Channel, tide heights are mixed (both diurnal and semidiurnal). The tide cycles generally through a high and low twice each day, with one of the two high tides being higher than the other and one of the two low tides being lower than the other. See Figure 1 and Figure 2.		*NOAA*

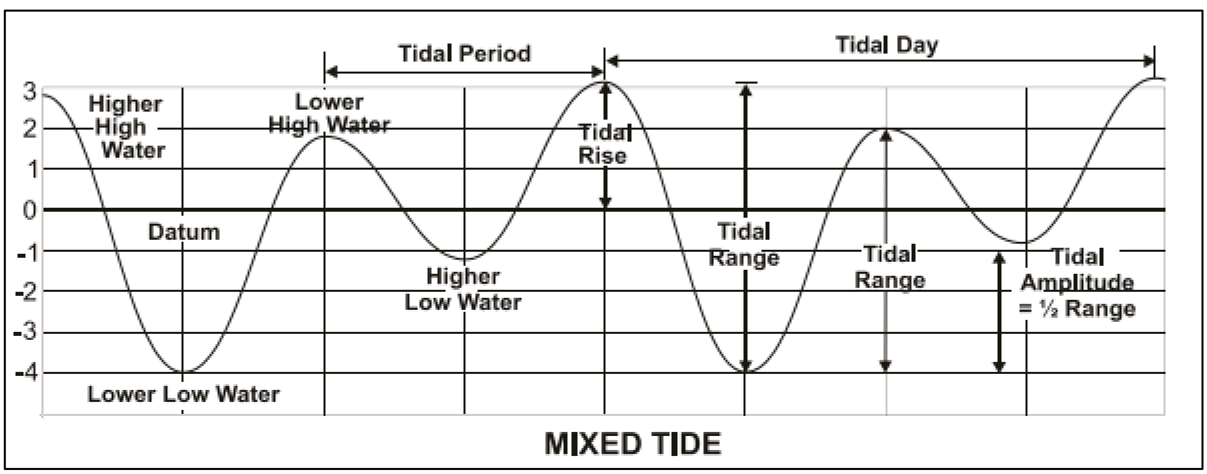


Figure 1. Schematic of tidal cycle with tidal terminology. The zero on the graph is illustrate of the relationship of tide to Mean Seal Level. Figure from NOAA Special Publication NOS CO-OPS 1.

Item	Definition	Alternate Names (deprecated)	Reference

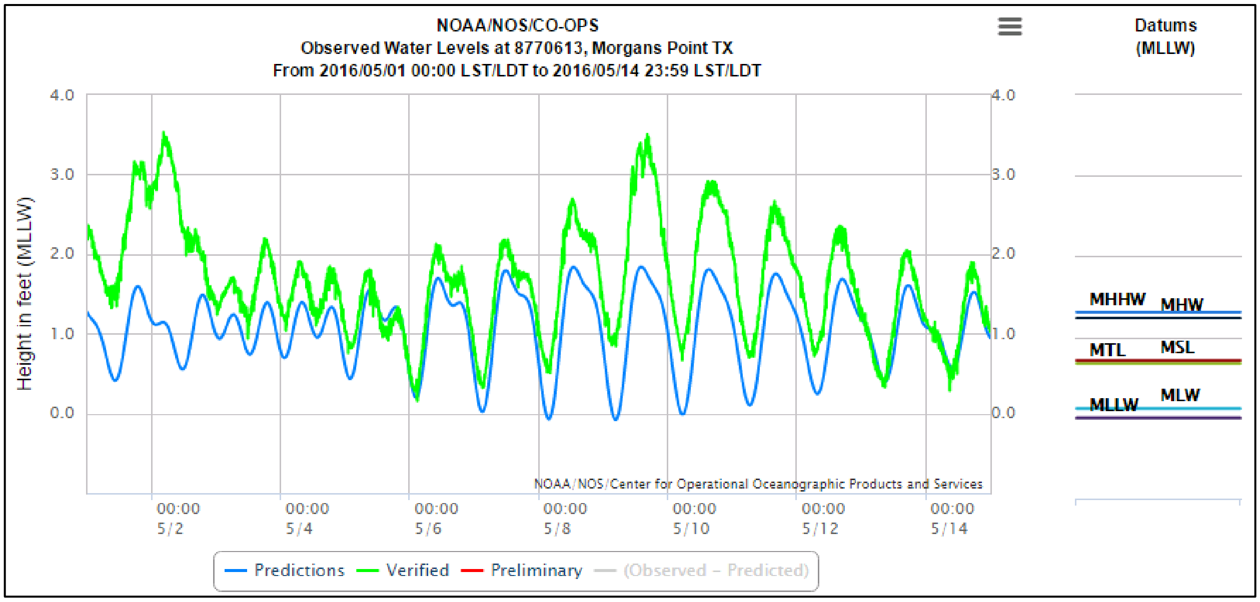


Figure 2. Example of observed and predicted water levels relative to MLLW at Morgans Point. Relative height of datums at this station are shown on the right.

– **MHHW (Mean Higher High Water)**	The average of the higher high water height of each tidal day observed over the **National Tidal Datum Epoch**.		*NOAA*
– **MHW (Mean High Water)**	The average of all the high water heights observed over the **National Tidal Datum Epoch**.	*MHT (Mean High Tide)*	*NOAA*
– **MLW (Mean Low Water)**	The average of all the low water heights observed over the **National Tidal Datum Epoch**.	*MLT (Mean Low Tide)*	*NOAA*
– **MLLW (Mean Lower Low Water)**	The average of the lower low water height of each tidal day observed over the **National Tidal Datum Epoch**.		*NOAA*
– **MSL (Mean Sea Level)**	The arithmetic mean of hourly heights observed over the **National Tidal Datum Epoch**. Shorter series are specified in the name; e.g. monthly mean sea level and yearly mean sea level.		*NOAA*
– **MTL (Mean Tide Level)**	The arithmetic mean of mean high water and mean low water.		*NOAA*

Item	Definition	Alternate Names (deprecated)	Reference
– **National Tidal Datum Epoch**	The specific 19-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken and reduced to obtain mean values (e.g., mean lower low water, etc.) for tidal datums. It is necessary for standardization because of periodic and apparent secular trends in sea level. The present NTDE is 1983 through 2001 and is actively considered for revision every 20-25 years. Tidal datums in certain regions with anomolous sea level changes (Alaska, Gulf of Mexico) are calculated on a Modified 5-Year Epoch.		*NOAA*
– **NAD27**	North American Datum of 1927		*NOAA*
– **NAD83**	North American Datum of 1983		*NOAA*
– **NAVD 88**	North American Vertical Datum of 1988		*NOAA*
– **N.D.D.**	Navigation District Datum; a historical Port of Houston Authority-defined datum, appearing on many historical drawings. Shown as +1.45’ relative to U.S.E.D. at Wharf 26 to 28 (ref C126-2 Sheet 3).		*NOAA*
– **Station Datum**	A fixed base elevation at a tide station to which all water level measurements are referred. The datum is unique to each station and is established at a lower elevation than the water is ever expected to reach. It is referenced to the primary bench mark at the station and is held constant regardless of changes to the water level gauge or tide staff. The datum of tabulation is most often at the zero of the first tide staff installed.		*NOAA*
– **U.S.E.D.**	Unknown abbreviation; appears on many historical drawings. Shown as -1.39’ relative to PHA datum on 1970s hand-drawn wharf plans.		
Tieback	A rod fastened to a deadman, a rigid foundation, or either a rock or soil anchor to prevent lateral movement of formwork, sheet pile walls, retaining walls, and bulkheads.		
Upstream	The direction against the primary flow of the **ship channel** excluding tidal variance, which is generally from Galveston Bay toward the Turning Basin or downtown Houston. In Barbour’s Cut Terminal, upstream is oriented away from its turning basin and to the east. Conversely, in Bayport Terminal, upstream is oriented toward its turning basin and to the west. In both of these terminals, these definitions allow for consistency with original grid line numbering. See also **downstream**.		*Upstream*
Wale Beam	A member that runs horizontally along the length of the fender system and distributes berthing and mooring forces to other elements.		

Item	Definition	Alternate Names (deprecated)	Reference
Wharf	A structure, partially supported on land and oriented approximately parallel to shore, where ships can be moored at the offshore face. See also **pier**.	*Quay*	*ASCE 130*

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APPENDIX C – ELEMENT DESCRIPTIONS

Table 3.1. Materials for Corrosion Protection and Base Metal Elements

Element		Abbreviation	Description
Anodes	Aluminum	AL	Aluminum alloy anodes are used primarily in seawater application and can be produced in a variety of alloys.
	Cast Iron	CI	Cast iron anodes can be used in fresh water, seawater, or underground applications. High-silicon cast iron is a commonly used alloy containing silicon, chromium, and iron.
	Dual	DL	Dual galvanic anodes can be made with a highly active anode metal casing (e.g. magnesium) and a less active core (e.g. zinc). These anodes are designed to provide a high initial current density to achieve initial cathodic polarization.
	Graphite	GP	Graphite anodes are used in soils, flowing seawater, and mud and are typically impregnated with a sealer to prevent failure from gas evolution in pores. Oftentimes used within anode wells.
	Magnesium	MG	Magnesium anodes are available as high-potential or low-potential alloys and are normally used in soils and fresh water.
	Zinc	ZN	Zinc anodes are available in two alloys; one for use in soils and the other for seawater application. Can be manufactured as a bulk anode or a mesh.
	Mixed Metal Oxides	MMO	Layer of precious metal oxide intermixed with titanium or tantalum oxide, on a titanium substrate. These anodes have a significantly lower consumption rate than typical galvanic anodes.
	Silicon/Chromium/Iron	SCI	(FeSiCr) Similar functionality as MMO anodes, but semi-inert with greater consumption rates.
Cathodic Protection Jackets	Fiberglass	FG	Jacket encasements around structural elements constructed with fiberglass.
	Polyvinyl Chloride	PVC	Jacket encasements around structural elements constructed with PVC (polyvinyl chloride).
Coatings	Acrylic	AC	Acrylic coatings can be used as a topcoat in mild environments, typically installed on top of an inorganic zinc.
	Epoxy	EP	Epoxy-based coatings are commonly used as a primer, intermediate, or top coat within a steel coating system or as a sealer for a concrete coating system.
	Coal Tar Epoxy	CE	Two-component coal-tar based epoxy used in marine or buried exposures. More typical of older structures.
	Polyurethane	PU	Polyurethane topcoats are a commonly used topcoat for steel elements in corrosive environments.
	Polyester	PE	Polyester coatings, with or without glass flake, are used on steel elements to form corrosion protection as barrier coatings.
Hot-Dip Galvanizing	Zinc	HDG	Coating element applied to carbon steel to provide sacrificial surface protection.
Metals[1]	Galvanized Steel	GS	Carbon steel that has been hot-dip galvanized with zinc.
	Steel	CS	Carbon steel materials.
	Stainless Steel	SS	Stainless steel materials. Stainless steels have a minimum of 10.5 percent chromium and are available at various grades with varying corrosion resistance.

Element		Abbreviation	Description
	Metals (all other)	MT	Metals that do not fall into any of the other categorized. Includes aluminum, cast iron, ductile iron, etc.
Other[1]	Other materials	OTH	All other materials that do not fit in any of the predefined categories. (Note if a material use is widespread and not defined in Manual, consider defining new category and submitting to PHA for approval.)
Spray Metalizing	Aluminum	AL	Molten aluminum applied to steel or concrete elements as a corrosion protection method.
	Zinc	ZN	Molten zinc applied to steel or concrete elements as a corrosion protection method.
	Aluminum/Zinc	AZ	Typical composition (85% Zn / 15% Al) by weight.
	Aluminum/Zinc/ Indium	AZI	(Al/Zn/In) Similar function to the (Al/Zn) metallizing with the addition of Indium, which helps activate the Al.
	Titanium	TI	Ti metallizing is used in an ICCP system and differs to Zinc in which it is not consumable. Typically a cobalt nitrate catalyst is used while Ti is used as the conductor for ionic current. The catalyst and Ti is not consumed.
Wraps	Polyvinyl Chloride	PVC	Wraps or jacket encasements around elements constructed with PVC (polyvinyl chloride) that do not include galvanic cathodic protection elements.
	High-Density Polyethylene	HDP	These systems typically form exterior barriers and often include seams that are bolted together. May or may not include an underlying layer of petrolatum tape.
	Petrolatum Tape	TP	Typically, a synthetic fabric carrier; fully saturated and coated with a petrolatum compound blended with inert fillers and corrosion inhibitors.
Supplementary Anode Materials	Carbon Backfill	CB	Carbon backfill is available as calcined petroleum or metallurgical coke, and coke breeze for ICCP systems in soil environments.
	Calcium Sulfate	CSB	Typical mixture for galvanic anodes whixh includes: 75% powdered and hydrated gypsum, 20% bentonite clay, and 5% sodium sulfate.
DC Power Supply	Batteries	BAT	Batteries can be used for CP systems that require small output current.
	Electric Circuit Breaker	EB	Circuit breakers are used to disconnect circuits and depower electric equipment. Only circuit breakers directly related to Power Supplies for CP systems (e.g. circuit breakers between AC power supply and transformer-rectifier units that are near the unit).
	Electric Panel	EP	Electric panels, typically operating at 240V or greater, are used to split and distribute AC to multiple transformer-rectifier units.
	Transformer-Rectifier Unit	TRU	Powered by an AC current, TRUs converts AC input to DC output current for use in the CP system.
Monitoring Equipment	External Coupon	EC	Weight-loss coupons that are the same metal as that of the protected structure and electrically connected, used to measure corrosion rate in terms of weight loss as a function of time, for the represented exposure.
	Junction Box	JB	Junction boxes house connections of the CP system wiring.
	Test Station	TS	Test stations can be installed for monitoring current and/or

Element		Abbreviation	Description
			structure potentials for CP systems. They may include a shunt resistor and a switch to disconnect the system and a connection to the structure or a permanently installed reference electrode.
Wiring and Protection	Copper	CU	Conductive and noble in comparison to carbon steel, encapsulated copper wiring can be used to make connections between the anode, structure, or rectifier, dependent on design of CP system. Encapsulation for copper wiring may be flexible or rigid.
	High-Molecular-Weight Polyethylene	HM	Wiring insulation typically used for direct burial cathodic protection systems for both anode and structure wiring.
	High-density polyethylene	HDPE	Installed around wiring, HDPE conduit can provide additional protection for wiring elements.
	Polyvinyl Chloride	PVC	Installed around wiring (typically copper), PVC conduit is sometimes filled with a non-conductive epoxy to protect wiring.
	Stainless Steel	SS	Conductive and noble in comparison to carbon steel, encapsulated stainless steel (can be used to make connections between the anode, structure, or rectifier, dependent on design of CP system. Encapsulation of wiring may be flexible or rigid.

[1]*Repeated from Table 3.1 of the Maritime Structures Manual*

Table C-1. Impressed Current Cathodic Protection (ICCP) Component Elements			
Element Code(s)	**Element Descriptor**	**Element Identification**	**Units[1]**
DC Power Supply (PW)			
PW-BAT PW-CB PW-EP PW-TRU	BAT DC Power Supply PW DC Power Supply EP DC Power Supply TRU DC Power Supply	Electrical devices used to provide DC power for any impressed current CP system.	EA
Anodes (AN)			
AN-AL AN-CI AN-DL AN-GP AN-MG AN-ZN AN-MMO AN-SCI AN-OTH	AL Anode CI Anode DL Anode GP Anode MG Anode ZN Anode MMO Anode SCI Anode OTH Bulk Anode	Anodes are installed as part of an impressed CP system. Impressed anodes are typically inert and do not corrode, but will provide protection to the structure through a power source. Some Impressed anodes may also be sacrificial. Anodes are typically installed in anode wells, soil, or underwater.	EA
Supplementary Anode Materials (SM)			
SM-CSB SM-CB	CSB Supplementary Anode Material CB Supplementary Anode Material	Underground CP backfill materials for impressed current anodes include a carbonaceous backfill such as coke breeze or petroleum coke. These materials are used to decrease soil resistivity and to increase life of anodes and current demand	EA
Monitoring Equipment (ME)			
ME-EC ME-JB ME-TS	EC Monitoring Equipment JB Monitoring Equipment TS Monitoring Equipment	Equipment or samples installed as part of an impressed current CP system used to monitor current and performance of such systems.	EA
Wiring and Protection (WI & PR)			
WI-CU WI-HM WI-OTH WI-SS	CU Wiring HM Wiring OTH Wiring SS Wiring	Wiring installed as part of an impressed current CP system. Includes cadweld connections, splices, caps, tape, insulation, and other miscellaneous materials associated with the wiring.	EA
PR-GRC PR-CS PR-HDPE PR-PVC	GRC Protection CS Protection HDPE Protection PVC Protection	Conduit used to provide additional protection for insulated or non-insulated wiring for CP systems.	EA

[1] SF = square foot, LF = linear foot, EA = each

Table C-1. Impressed Current Cathodic Protection (ICCP) Component Elements			
Element Code(s)	**Element Descriptor**	**Element Identification**	**Units**[1]
CP Supports (SI)			
SI-CS SI-GS SI-HDPE SI-OTH SI-PVC SI-SS	CS Supports GS Supports HDPE Supports OTH Supports PVC Supports SS Supports	Elements such as hangers, clevises, straps, or accessories for the purpose of supporting wiring or other CP equipment. May also include hangar assemblies or baskets for anode elements.	EA

Table C-2. Sacrificial Anode Cathodic Protection (SACP) Component Elements			
Element Code(s)	**Element Descriptor**	**Element Identification**	**Units[2]**
Cathodic Protection Jackets (JA)			
JA-FG JA-PVC	FG Cathodic Protection Jacket PVC Cathodic Protection Jacket	Systems serving to encase a structural or functional element, typically in conjunction with a galvanic cathodic protection system, such as underlying zinc mesh or an attached bulk anode.	EA
Anodes - Sacrificial (AS)			
AS-AL AS-CI AS-DL AS-GP AS-MG AS-ZN AS-MMO AS-SCI AS-OTH	AL Anode CI Anode DL Anode GP Anode MG Anode ZN Anode MMO Anode SCI Anode OTH Anode	Anodes are installed as part of a sacrificial CP system. Galvanic anodes are more active metals with respect to the structure being protected and are designed to preferentially corrode. Anodes are typically installed in anode wells, soil, or underwater.	EA
Supplementary Anode Materials (SE)			
SE-C SE-CB	C Supplementary Anode Material CB Supplementary Anode Material	Underground CP backfill materials for sacrificial anodes include a mixture of: calcium sulfate, bentonite clay, and sodium sulfate. These materials are used to decrease soil resistivity and to increase life of anodes and current demand	EA
Monitoring Equipment (MS)			
MS-EC MS-JB MS-TS	EC Monitoring Equipment JB Monitoring Equipment TS Monitoring Equipment	Equipment or samples installed as part of a sacrificial CP system used to monitor current and performance of such systems.	EA
Wiring and Protection (WR & PT)			
WR-CU WR-HM WR-OTH WR-SS	CU Wiring HM Wiring OTH Wiring SS Wiring	Wiring installed as part of a sacrifical CP system. Includes cadweld connections, splices, caps, tape, insulation, and other miscellaneous materials associated with the wiring.	EA
PT-GRC PT-CS PT-HDPE PT-PVC	GRC Protection CS Protection HDPE Protection PVC Protection	Conduit used to provide additional protection for insulated or non-insulated wiring for CP systems.	EA

[2] SF = square foot, LF = linear foot, EA = each

Table C-2. Sacrificial Anode Cathodic Protection (SACP) Component Elements			
Element Code(s)	**Element Descriptor**	**Element Identification**	**Units[2]**
CP Supports (SS)			
SS-CS SS-GS SS-HDPE SS-OTH SS-PVC SS-SS	CS Supports GS Supports HDPE Supports OTH Supports PVC Supports SS Supports	Elements such as hangers, clevises, straps, or accessories for the purpose of supporting wiring or other CP equipment. May also include hangar assemblies or baskets for bulk anode elements.	EA

Table C-3. Surface Protection Component Elements			
Element Code(s)	**Element Descriptor**	**Element Identification**	**Units[3]**
Coatings, Wraps, and Metalizing (CT, HG, ML, & WP)			
CT-AC CT-EP CT-CE CT-PU CT-OT	AC Coating EP Coating CE Coating PU Coating OT Coating	Coating elements serve to protect steel or concrete elements and may be applied in single-coat or multi-coat systems. Quantity is based on square foot of element.	SF
HG-HDG	HDG Galvanizing	Hot-dip galvanizing provides a sacrificial coating system by dipping the element in a molten bath of zinc during the fabrication process of the steel.	SF
ML-AL ML-ZN ML-AZ ML-AZI ML-TI	AL Metalizing ZN Metalizing AZ Metalizing AZI Metalizing TI Metalizing	Metalizing may be applied to steel or concrete elements and is applied by spraying molten metal on the element. For reinforced concrete elements, connections to the steel reinforcement is required. Quantity is based on square foot of element.	SF
WP-FRP WP-HDP WP-PVC WP-TP	FRP Wrap HDP Wrap PVC Wrap TP Wrap	These systems typically form jacket encasements or exterior barriers and often include seams that are bolted together. May or may not include an underlying layer of petrolatum tape, inert fillers, and/or corrosion inhibitors.	EA

[3] SF = square foot, LF = linear foot, EA = each

Table C-4. Base Metal Component Elements

Element Code(s)	Element Descriptor	Element Identification	Units[4]
Critical (BMC)			
TR-CS-BMC TR-GS-BMC	CS Tie Rod GS Tie Rod	A tension-only structural element. Includes elements used as bracing and those used as tie backs for retaining walls. Does not include rods used solely for railing.	EA
DB-CS- BMC DB-GS- BMC	CS Deck Beam GS Deck Beam	A structural element loaded perpendicular to its longitudinal axis that transmits loads directly from the deck to a girder or substructure element.	LF
GI-CS- BMC GI-GS- BMC	CS Girder GS Girder	A structural element loaded perpendicular to its longitudinal axis that transmits loads from a deck beam or stringer to the substructure. May also carry loads directly from a portion of the deck.	LF
GP -CS- BMC GP-WS- BMC	CS Gusset Plate WS Gusset Plate	A structural plate element that provides a connection between other structural elements. Constructed with one or more plates that may be bolted, riveted, or welded.	EA
CO-CS- BMC CO-GS- BMC	CS Column GS Column	A vertical prismatic element that transmits loads (vertical, lateral and/or bending) from the deck or superstructure into a substructure element.	LF
PI-CS- BMC	CS Pile	An axially loaded, vertical element that transmits loads from the deck, superstructure, or substructure into the ground via end bearing or friction. Piles are fabricated prior to installation and driven into the ground. Piles are considered deep foundation elements.	EA
PF-CS(S)- BMC PF-CS(C)- BMC	CS Sand-Filled Pile CS Concrete-Filled Pile	A type of pile that consists of a hollow steel pipe driven into the ground and then filled with material. Includes "Raymond Piles", which are concrete-filled pipes with tapered cross-sections.	EA
PC-CS- BMC	CS Pile Cap	A horizontally-oriented structural element that transmits loads from substructure or superstructure elements above to pile elements below.	LF
BG-CS- BMC	CS Closed Web/Box Girder	A hollow, four-sided structural element loaded perpendicular to its longitudinal axis that transmits loads from a deck beam or stringer to the substructure.	LF
BT-CS- BMC BT-GS- BMC	CS Bulkhead Tie Rod GS Bulkhead Tie Rod	A tension-only structural element, used to restrain the top of a bulkhead wall.	EA

[4] SF = square foot, LF = linear foot, EA = each

Table C-4. Base Metal Component Elements			
Element Code(s)	**Element Descriptor**	**Element Identification**	**Units[4]**
		Typical (BMT)	
AW-CS-BMT	CS Anchor Wall	A continuous buried wall element on the landside of a retaining wall or bulkhead. Used as anchorage for another element.	LF
BW-CS-BMT BW-GS-BMT	CS Bulkhead Wall GS Bulkhead Wall	A structural wall element that functions primarily as an earth retaining structure. Primarily subject to out-of-plane lateral loads. Bulkheads generally separate earth fill from water.	LF
DT-CS- BMT	CS Deck, open Grid	A horizontal, planar structural element that carries and distributes loads to superstructure or substructure elements. Observations specific to topside of element.	SF
SR-CS- BMT SR-GS- BMT	CS Stringer GS Stringer	A structural element loaded perpendicular to its longitudinal axis that transmits loads from the deck to a deck beam	LF
RW-CS- BMT	CS Retaining Wall	A structural wall element that functions primarily to retain soil. It may also carry vertical loads from elements above. Retaining walls are located above water level.	LF
CF-CS- BMT	CS Cofferdam	Single-cell or multi-cell structural elements used as a retaining, watertight structure.	EA
BB-CS- BMT	CS Bulkhead Wale Beam	A bulkhead element loaded perpendicular to its longitudinal axis that stiffens a bulkhead and is attached to tie rods or other anchorages.	LF
BC-CS- BMT	CS Bent Cap	A horizontally-oriented structural element that transmits loads from superstructure elements to column elements below.	LF
BR-CS- BMT BR-GS- BMT	CS Brace GS Brace	An element, often diagonally oriented, fastened across pile elements to provide lateral stability.	EA
PB-CS- BMT	CS Battered Pile	A type of pile that is driven at an angle, typically between 30 and 60 degrees from vertical. Battered piles provide lateral stiffness to the structure.	EA
FP-CS- BMT FP-GS- BMT	CS Fender Pile GS Fender Pile	A vertical element that absorbs energy through bending of the member. Fender piles are typically driven into the channel bed and braced at their top to form a propped cantilever.	EA

Table C-4. Base Metal Component Elements			
Element Code(s)	**Element Descriptor**	**Element Identification**	**Units[4]**
		Redundant (BMR)	
SF-CS-BMR SF-GS-BMR	CS Support Framing GS Support Framing	Secondary members generally add to the stability of the fender system and do not distribute berthing and mooring forces, but are lumped together with the primary-load carrying members for inspection purposes.	LF
DU-GS-BMR	GS Deck (stay-in-place form)	A horizontal, planar structural element that carries and distributes loads to superstructure or substructure elements. Observations specific to underside or full-depth of element.	SF
FL-CS-BMR FL-GS-BMR	CS Fender Panel GS Fender Panel	A rectangular element oriented parallel to the fender system that increases the contact area of the fender system against the ship hull.	EA

APPENDIX D - CONDITION STATES (ALPHABETICAL)

Code	Condition Name	Condition Definition	Condition States			
			CS1 (Good)	CS2 (Fair)	CS3 (Poor)	CS4 (Severe)
ABWJ	Abrasion/ wear	Abrasion or wear in jacket elements.	No abrasion or wear.	Localized or partial abrasion/wearing of the jacket shell.	Widespread abrasion/wearing of the jacket shell, or exposed annular grout.	N/A
ACIN	Error in AC Input	Incorrect AC input readings.	N/A	N/A	Error in AC input frequency.	No AC input voltage.
ADHS	Adhesion	Adhesion of protective coating on base metals based on measured inspection data, using ASTM D4541 or D3359 or equivalent.	Typical pull off testing values ≥200 psi. Adhesion test result classification of 5B.	Typical pull off testing values between 100 and 200 psi. Adhesion test result classification of 4B or 3B.	Typical pull off testing values between 50 and 100 psi. Adhesion test result classification of 2B or 1B.	Typical pull off testing values less than 50 psi. Adhesion test result classification of 0B.
BASK	Condition of Submerged Anode Baskets	Distress or damage to anode baskets.	No visible distress.	Minor distress or deterioration but no loss of support.	Moderate distress or deterioration resulting in the basket providing limited support for submerged anode.	Basket providing no support for submerged anode; anode is present and supported by lead wire.
BATT	Condition of Battery	Condition of CP battery.	No distress and proper output voltage measured.	Distress to battery and/or terminals that does not affect output voltage.	Distress to battery and/or terminals that reduces output voltage. May also include typical usage of battery.	Zero voltage output.
BSTL	Backfill Settlement	Settlement or improper compaction of anode well backfill.	No visible settlement.	Minor settlement observed.	Minor to moderate settlement or poor consolidation observed.	Moderate to major settlement or poor consolidation observed, affecting localized resistivity of the anode bed/well.
CHLK	Chalking	Chalking in metal protective coatings	No chalking.	Surface dulling.	Loss of pigment.	Loss of adhesion to structure resulting in disbondment of coating, structure becomes susceptible to corrosion.
CNSM	Consumption	Consumption of anode	<10% consumed by weight	10-50% consumed by weight	51-75% consumed by weight	>75% consumed by weight

Code	Condition Name	Condition Definition	Condition States			
			CS1 (Good)	CS2 (Fair)	CS3 (Poor)	CS4 (Severe)
CNSP	Connection / Splice Distress	Condition of coated or taped connections and splices of wiring.	No distress observed and functionality intact.	Minor distress observed but functionality intact.	Minor to moderate distress that may affect functionality of wiring.	Severe distress which affects functionality of wiring.
CONA	Condition of Connection	Condition of thermite weld connecting anode to the wiring.	No connection distress; connection is in place and functioning as intended.	Minor distress without distortion is present, but connection is in place and functioning as intended.	Cracked weld or damaged connection; assessment has determined electrical connection has not been compromised.	Cracked weld or failed connection resulting in electrical isolation of the anode.
CONS	Connection Distress to Structure	Connection distress support elements. Connections include items such as heavy hex structural bolts, post-installed anchors, through-bolts, anchor rods etc.	No connection distress; connection is in place and functioning as intended.	Loose fasteners or minor pack rust without distortion is present, but connection is in place and functioning as intended.	Missing fasteners; pack rust with distortion may be present; visible section loss on fastener of up to 20 percent OR assessment has determined connection's remaining capacity is not compromised.	Missing fasteners and/or pack rust cause translation and/or rotation preventing the connection from functioning as intended. Section loss on fastener in excess of 20 percent. Distress is significant enough to affect element's capacity.
CONW	Condition of Thermite Weld	Condition of thermite weld connecting anode to the wiring.	No connection distress; connection is in place and functioning as intended.	Minor distress without distortion is present, but connection is in place and functioning as intended.	Cracked weld; assessment has determined electrical connection has not been compromised.	Cracked weld resulting in electrical isolation of the anode.
CORR	Corrosion	Corrosion of metal and other material elements, excluding connections.	No corrosion observed.	Freckled rust or light pitting present; section loss is not evident.	Section loss is evident or pack rust is present, but assessment has determined element's functionality or capacity is not compromised.	Section loss is significant enough to affect element's immediate functionality or capacity Pack rust is causing element instability or prevents elements from functioning as intended.

Code	Condition Name	Condition Definition	Condition States			
			CS1 (Good)	CS2 (Fair)	CS3 (Poor)	CS4 (Severe)
CRKJ	Cracking	Cracking in jacket elements or infill grout	No cracking present.	Insignificant cracks or moderate-width cracks that have been sealed. Includes minor cracking of grout at top of jackets.	Wide cracks in jacket exposing infill material and/or anode.	Wide cracks resulting in affected functionality of CP system.
CRKP	Cracking of Conduit or Box	Cracking in PVC and/or HDPE protective conduit or junction box.	No cracking.	Insignificant cracks or moderate-width cracks that have been sealed.	Wide or unsealed cracks that do not affect functionality of wiring.	Wide or unsealed cracks that affect functionality of wiring.
DISJ	Jacket Distortion	Distortion from original location for any element, including delamination from infill grout.	No distortion present.	Elements have minor distortion, but translation or rotation is within the acceptable limits for the element. May include minor delamination.	Elements have moderate distortion or delamination, but translation or rotation is within the acceptable limits for the element OR a review has determined the functionality of the element's CP system is not compromised.	Elements have distortion or delaminated such that functionality of the element's CP system is compromised.
DISP	Error in Output Display Panels	Accuracy of rectifier output panels.	<5% measured error in current and/or voltage display panels	5 to 10% measured error in current and/or voltage display panels.	>10% measured error in current and/or voltage display panels.	Current and/or voltage display panels nonfunctional.
ELEC	Condition of Electrical Parts	Visual and functional condition of electrical components, including shunts, breakers, fuses, diodes…etc.	No distress observed and functionality intact.	Minor distress observed but functionality intact.	Minor to moderate distress observed but functionality intact.	Moderate to major distress observed with possibly impacted functionality.
FRPW	Fiber-reinforced polymer wrap	Condition of fiber-reinforced (Glass, Carbon, or other material) polymer permanently bonded to a member. Also may apply to unbonded plastic wrap, such as for piles.	No visible distress.	Minor bubbles or blisters. Minor abrasion to surface layer.	Delamination, gouges, holes, tears, or splits in material but assessment has determined capacity or functionality of wrap is not compromised.	Delamination, gouges, holes, tears, or splits in material that affects capacity or functionality of wrap.

Code	Condition Name	Condition Definition	Condition States			
			CS1 (Good)	CS2 (Fair)	CS3 (Poor)	CS4 (Severe)
GALV	Galvanized zinc coating	Condition of galvanized zinc patina on steel elements.	No white or red corrosion products. Surface may be bright and shiny, spangled, or matte gray.	White rust (zinc oxide) is visible on surface.	Red rust is visible through coating on less than 5 percent of the local area.	Red rust exceeds 5 percent of the local area.
IMPT	Impact Damage	Evidence of impact from large debris or floating matter.	No impact damage observed.	Elements have moderate damage, but a review has determined the functionality of the element's CP system is not compromised.	Elements have moderate damage, but the CP system is not compromised, however it is possible for inadequate performance in the future	Elements have severe damage such that functionality of the element's CP system is compromised.
INSU	Condition of Insulation	Condition of dielectric insulation surrounding wiring.	No damage to insulation	N/A	Minor to moderate distress that does not affect functionality of wiring.	Moderate to severe distress which may affect functionality of wiring.
LABL	Condition of Labels	Condition of labels unit and leads.	Easily legible.	Worn but legible.	Limited or no legible label information.	Labels for leads incorrectly labelled.
LEAD	Condition of Leads	Distress of input leads for junction boxes or electrical continuity leads for external coupons.	No distress observed.	Wear or minor distress of lead insulation.	Moderate distress of insulation or buildup of corrosion product at connections that does not affect electrical continuity.	Distress or buildup of corrosion product at connections that does affects electrical continuity.
MARG	Marine Growth	Organic growth on bulk and/or ribbon anodes.	No marine growth present.	Minor marine growth on anode.	Moderate marine growth on anode that may affect functionality.	Significant marine growth on anode affecting functionality.
MISS	Missing	Element intended to be in place is missing. Does not apply to elements that have been intentionally removed as part of a modification.	Element is present.	Parts of an element are missing, however does not affect functionality.	Element is missing but assessment has determined element is not needed for functionality.	Element is missing.

Code	Condition Name	Condition Definition	Condition States			
			CS1 (Good)	CS2 (Fair)	CS3 (Poor)	CS4 (Severe)
OUTP	DC Output	DC output readings.	DC output voltage and current.	N/A	Zero DC output current with DC output voltage	Zero DC output current and zero DC output voltage.
PASS	Passivation	Passivation of anode.	Passivation is not present.	Passivation is less than 50%	Passivation of anode is 51%-75% visual.	Passive film has built up on the anode, greater than 75% and affecting performance of CP system.
PEEL	Peeling/ bubbling/ cracking	Peeling, bubbling, or cracking in protective coatings or wraps	No peeling, bubbling, or cracking.	Finish coat exhibits peeling, bubbling, or cracking.	Finish and primer coats exhibit peeling, bubbling, or cracking.	Substrate is exposed.
PROT	Protection or Sleeve	Condition of Anode Protection or Sleeve	Protection or sleeve is not damaged	Minor distress, but remains functioning	Moderate distress that may affect functionality	Significant damage to protection or sleeve that affects functionality
REFE	Condition of Reference Electrode	Stationary reference electrodes for structure-to-electrolyte potential measurements.	Reference electrode operational.	Minor distress to reference electrode or wiring, including distress to lead wire insulation.	Internal resistance of reference electrode compromised and/or electrical continuity of lead wire inconsistent.	Reference electrode not functional or electrical continuity of lead wire lost.
SUPP	Condition of Support Elements	Distress of support elements such as hangers, clevises, straps, or accessories used to support CP wiring or equipment.	No visible distress.	Minor distress or deterioration but no section loss of base material.	Section loss or moderate distress is present but assessment has determined element's functionality or capacity is not compromised.	Section loss or severe distress is present and distortion or displacement is significant enough to affect element's immediate functionality or capacity
SXLS	Section loss	Section loss of base metal elements based on measured thickness during inspection.	$\leq$ 2% section loss	>2% to $\leq$ 10% section loss	>10% to $\leq$ 30% section loss	>30% section loss
THCK	Thickness	Thickness of protective coating on base metals based on measured inspection data.	$\geq$ 18 mils	$\geq$10 mils to < 18 mils	$\geq$ 5 mils to < 10 mils	<5 mils

Code	Condition Name	Condition Definition	Condition States			
			CS1 (Good)	CS2 (Fair)	CS3 (Poor)	CS4 (Severe)
VAND	Environmental / Vandalism	Deliberate or undeliberate destruction of PHA property by persons or environmental conditions.	No damage present	Potentially detrimental environmental conditions not yet resulting in damage (e.g. buildup of flammable material near electrical equipment).	Damage to equipment but functionality has not been diminished.	Damage to equipment resulting in reduced or eliminated functionality.
VENT	Condition of Well Vent	Distress or damage to anode well vent.	No distress.	Minor distress to vent.	Minor or moderate distress that may affect the ability of the pipe to vent gases properly.	Vent is damaged and/or filled so that immediate functionality has been compromised.
WEAR	Wear	Wear of protective coating. Includes wear from abrasion or weathering.	No wear.	Substrate not exposed, coating showing wear or abrasion.	Substrate is partially exposed; thickness of the coating is reduced.	Substrate exposed; protective coating is no longer effective.
WETH	Weathering Steel Patina [See Table Note 1]	Condition of weathering steel patina (oxide film).	Uniform color pattern, dark brown with some lighter reddish- or purple-brown spots. Patina is adhered.	Dark brown but with minor color variation. Small loose flakes on surface but underlying patina is adhered.	Dark brown with black blotches, non-uniform texture. Medium (up to 1 inch) sized flakes.	Dark brown, black patina with widespread blotchiness. Laminar sheets or large flakes. Patina is no longer effective.
WIRE	Condition of Wiring	Distress or damage to wiring used in CP systems.	No visible distress.	Insignificant distress, including exposed wire in good condition.	Distress such as visible section loss, cut strands, or fraying wire for which electrical continuity remains intact.	Distress such as visible section loss, cut strands, or fraying wire for which electrical continuity has been lost.

Table Notes

1. Weathering steel descriptions from Crampton, D.D., Holloway, K.P. and Fraczek, J., *Assessment of Weathering Steel Bridge Performance in Iowa and Development of Inspection and Maintenance Techniques*, Final Report SPR 90-00-RB17-012, February 21, 2013. Accessible at http://publications.iowa.gov/14956/1/Iowa_Weathering_Steel_Final_Report_2-21-2013.pdf.

APPENDIX E - CONDITION STATES (BY MATERIAL)

List of Condition States by Component and Element Type

Impressed Current Cathodic Protection (ICCP) Component Elements

DC Power Supply

Code	Condition Name
ACIN	Error in AC Input
BATT	Condition of Battery
DISP	Error in Output Display Panels
ELEC	Condition of Electrical Components
LABL	Condition of Labels
MISS	Missing
OUTP	Error in DC Output
VAND	Environmental / Vandalism

Sacrificial Anode Cathodic Protection (SACP) Component Elements

Cathodic Protection Jackets

Code	Condition Name
ABWJ	Abrasion/ wear
CRKJ	Cracking
DISJ	Jacket Distortion
IMPT	Impact Damage
MISS	Missing

Surface Protection Component Elements

Coatings, Wraps, and Metalizing

Code	Condition Name
ADHS	Adhesion
CHLK*	Chalking
GALV*	Galvanized Zinc Coating
FRPW*	Fiber-reinforced polymer / plastic wraps
PEEL*	Peeling/ bubbling/ cracking
THCK	Thickness
WEAR*	Wear
WETH*	Weathering Steel Patina

* Repeated from FICAP Maritime Structures Manual

Base Metal Component

Metal Material

Code	Condition Name
CORR	Corrosion (visual / qualitative)
SXLS	Section loss

ICCP and/or SACP Component Elements

Anodes

Code	Condition Name
CNSM	Consumption
CONW	Condition of Thermite Weld
MARG	Marine Growth
MISS	Missing
PASS	Passivation
PROT	Protection or Sleeve

Supplementary Anode Materials

Code	Condition Name
BSTL	Backfill Settlement
CNSM	Consumption
CONW	Condition of Thermite Weld
MISS	Missing
VENT	Condition of Well Vent

Monitoring Equipment

Code	Condition Name
ELEC	Condition of Electrical Components
LABL	Condition of Labels
LEAD	Condition of Leads
MISS	Missing
REFE	Condition of Reference Electrode
VAND	Environmental / Vandalism

Wiring and Protection

Code	Condition Name
CNSP	Connection / Splice Distress
CRKP	Cracking of Conduit
INSU	Condition of Insulation
MISS	Missing
WIRE	Condition of Wiring

CP Supports

Code	Condition Name
BASK	Condition of Submerged Anode Baskets
CONS	Connection Distress to Structure
MISS	Missing
SUPP	Condition of Support Elements

Type	Code	Condition Name	Condition Definition	Condition States			
				CS1 (Good)	CS2 (Fair)	CS3 (Poor)	CS4 (Severe)
Supplementary Anode Materials	BSTL	Backfill Settlement	Settlement or improper compaction of anode well backfill.	No visible settlement.	Minor settlement observed.	Minor to moderate settlement or poor consolidation observed.	Moderate to major settlement or poor consolidation observed, affecting localized resistivity of the anode bed/well.
	CNSM	Consumption	Consumption of anode	<10% consumed by weight	10-50% consumed by weight	51-75% consumed by weight	>75% consumed by weight
	CONW	Condition of Thermite Weld	Condition of thermite weld connecting anode to the wiring.	No connection distress; connection is in place and functioning as intended.	Minor distress without distortion is present, but connection is in place and functioning as intended.	Cracked weld; assessment has determined electrical connection has not been compromised.	Cracked weld resulting in electrical isolation of the anode.
	MISS	Missing	Element intended to be in place is missing. Does not apply to elements that have been intentionally removed as part of a modification.	Element is present.	Parts of an element are missing, however does not affect functionality.	Element is missing but assessment has determined element is not needed for functionality.	Element is missing.
	VENT	Condition of Well Vent	Distress or damage to anode well vent.	No distress.	Minor distress to vent.	Minor or moderate distress that may affect the ability of the pipe to vent gases properly.	Vent is damaged and/or filled so that immediate functionality has been compromised.

Type	Code	Condition Name	Condition Definition	Condition States			
				CS1 (Good)	CS2 (Fair)	CS3 (Poor)	CS4 (Severe)
DC Power Supply	ACIN	Error in AC Input	Incorrect AC input readings.	N/A	N/A	Error in AC input frequency.	No AC input voltage.
	BATT	Condition of Battery	Condition of CP battery.	No distress and proper output voltage measured.	Distress to battery and/or terminals that does not affect output voltage.	Distress to battery and/or terminals that reduces output voltage. May also include typical usage of battery.	Zero voltage output.
	DISP	Error in Output Display Panels	Accuracy of rectifier output panels.	<5% measured error in current and/or voltage display panels	5 to 10% measured error in current and/or voltage display panels.	>10% measured error in current and/or voltage display panels.	Current and/or voltage display panels nonfunctional.
	ELEC	Condition of Electrical Parts	Visual and functional condition of electrical components, including shunts, breakers, fuses, diodes…etc.	No distress observed and functionality intact.	Minor distress observed but functionality intact.	Minor to moderate distress observed but functionality intact.	Moderate to major distress observed with possibly impacted functionality.
	LABL	Condition of Labels	Condition of labels unit and leads.	Easily legible.	Worn but legible.	Limited or no legible label information.	Labels for leads incorrectly labelled.
	MISS	Missing	Element intended to be in place is missing. Does not apply to elements that have been intentionally removed as part of a modification.	Element is present	Parts of an element are missing, however does not affect functionality.	Element is missing and has negatively impacted functionality or capacity.	Element is missing and is preventing any functionality or capacity.
	OUTP	DC Output	DC output readings.	DC output voltage and current.	N/A	Zero DC output current with DC output voltage	Zero DC output current and zero DC output voltage.
	VAND	Environmental / Vandalism	Deliberate or undeliberate destruction of PHA property by persons or environmental conditions.	No damage present	Potentially detrimental environmental conditions not yet resulting in damage (e.g. buildup of flammable material near electrical equipment).	Damage to equipment but functionality has not been diminished.	Damage to equipment resulting in reduced or eliminated functionality.

Type	Code	Condition Name	Condition Definition	Condition States			
				CS1 (Good)	CS2 (Fair)	CS3 (Poor)	CS4 (Severe)
Anodes	CNSM	Consumption	Consumption of anode.	<10% consumed by weight	10-50% consumed by weight	51-75% consumed by weight	>75% consumed by weight
	CONA	Condition of Connection	Condition of thermite weld connecting anode to the wiring.	No connection distress; connection is in place and functioning as intended.	Minor distress without distortion is present, but connection is in place and functioning as intended.	Cracked weld or damaged connection; assessment has determined electrical connection has not been compromised.	Cracked weld or failed connection resulting in electrical isolation of the anode.
	MARG	Marine Growth	Organic growth on bulk and/or ribbon anodes.	No marine growth present.	Minor marine growth on anode.	Moderate marine growth on anode that may affect functionality.	Significant marine growth on anode affecting functionality.
	MISS	Missing	Element intended to be in place is missing. Does not apply to elements that have been intentionally removed as part of a modification.	Element is present.	Parts of an element are missing, however does not affect functionality.	Element is missing but assessment has determined element is not needed for functionality or capacity.	Element is missing.
	PASS	Passivation	Passivation of anode.	Passivation is not present.	Passivation is less than 50%	Passivation of anode is 51%-75% visual.	Passive film has built up on the anode, greater than 75% and affecting performance of CP system.
	PROT	Protection or Sleeve	Condition of Anode Protection or Sleeve	Protection or sleeve is not damaged	Minor distress, but remains functioning	Moderate distress that may affect functionality	Significant damage to protection or sleeve that affects functionality

Type	Code	Condition Name	Condition Definition	Condition States			
				CS1 (Good)	CS2 (Fair)	CS3 (Poor)	CS4 (Severe)
Cathodic Protection Jackets	ABWJ	Abrasion/ wear	Abrasion or wear in jacket elements.	No abrasion or wear.	Localized or partial abrasion/wearing of the jacket shell.	Widespread abrasion/wearing of the jacket shell, or exposed annular grout.	N/A
	CRKJ	Cracking	Cracking in jacket elements or infill grout	No cracking present.	Insignificant cracks or moderate-width cracks that have been sealed. Includes minor cracking of grout at top of jackets.	Wide cracks in jacket exposing infill material and/or anode.	Wide cracks resulting in affected functionality of CP system.
	DISJ	Jacket Distortion	Distortion from original location for any element, including delamination from infill grout.	No distortion present.	Elements have minor distortion, but translation or rotation is within the acceptable limits for the element. May include minor delamination.	Elements have moderate distortion or delamination, but translation or rotation is within the acceptable limits for the element OR a review has determined the functionality of the element's CP system is not compromised.	Elements have distortion or delaminated such that functionality of the element's CP system is compromised.
	IMPT	Impact Damage	Evidence of impact from large debris or floating matter.	No impact damage observed.	Elements have moderate damage, but a review has determined the functionality of the element's CP system is not compromised.	Elements have moderate damage, but the CP system is not compromised, however it is possible for inadequate performance in the future	Elements have severe damage such that functionality of the element's CP system is compromised.
	MISS	Missing	Element intended to be in place is missing. Does not apply to elements that have been intentionally removed as part of a modification.	Element is present.	Parts of an element are missing, however does not affect functionality.	Element is missing but assessment has determined element is not needed for functionality or capacity.	Element is missing.

Type	Code	Condition Name	Condition Definition	Condition States			
				CS1 (Good)	CS2 (Fair)	CS3 (Poor)	CS4 (Severe)
Monitoring Equipment	ELEC	Condition of Electrical Components	Visual and functional condition of electrical boxes and components.	No distress observed and functionality intact.	Minor distress observed but functionality intact.	Minor to moderate distress observed but functionality intact.	Moderate to major distress observed with possibly impacted functionality.
	LABL	Condition of Labels	Condition of labels unit and leads.	Easily legible.	Worn but legible.	Limited or no legible label information.	Labels for leads incorrectly labelled.
	LEAD	Condition of Leads	Distress of input leads for junction boxes or electrical continuity leads for external coupons.	No distress observed.	Wear or minor distress of lead insulation.	Moderate distress of insulation or buildup of corrosion product at connections that does not affect electrical continuity.	Distress or buildup of corrosion product at connections that does affects electrical continuity.
	MISS	Missing	Element intended to be in place is missing. Does not apply to elements that have been intentionally removed as part of a modification.	Element is present.	Parts of an element are missing, however does not affect functionality.	Element is missing but assessment has determined element is not needed for functionality or capacity.	Element is missing.
	REFE	Condition of Reference Electrode	Stationary reference electrodes for structure-to-electrolyte potential measurements.	Reference electrode operational.	Minor distress to reference electrode or wiring, including distress to lead wire insulation.	Internal resistance of reference electrode compromised and/or electrical continuity of lead wire inconsistent.	Reference electrode not functional or electrical continuity of lead wire lost.
	VAND	Environmental / Vandalism	Deliberate or undeliberate destruction of PHA property by persons or environmental conditions.	No damage present	Potentially detrimental environmental conditions not yet resulting in damage (e.g. buildup of flammable material near electrical equipment).	Damage to equipment but functionality has not been diminished.	Damage to equipment resulting in reduced or eliminated functionality.

Type	Code	Condition Name	Condition Definition	Condition States			
				CS1 (Good)	CS2 (Fair)	CS3 (Poor)	CS4 (Severe)
Wiring and Protection	CNSP	Connection / Splice Distress	Condition of coated or taped connections and splices of wiring.	No distress observed and functionality intact.	Minor distress observed but functionality intact.	Minor to moderate distress that may affect functionality of wiring.	Severe distress which affects functionality of wiring.
	CRKP	Cracking of Conduit or Box	Cracking in PVC and/or HDPE protective conduit or junction box.	No cracking.	Insignificant cracks or moderate-width cracks that have been sealed.	Wide or unsealed cracks that do not affect functionality of wiring.	Wide or unsealed cracks that affect functionality of wiring.
	INSU	Condition of Insulation	Condition of dielectric insulation surrounding wiring.	No damage to insulation	N/A	Minor to moderate distress that does not affect functionality of wiring.	Moderate to severe distress which may affect functionality of wiring.
	MISS	Missing	Element intended to be in place is missing. Does not apply to elements that have been intentionally removed as part of a modification.	Element is present.	Parts of an element are missing, however does not affect functionality.	Element is missing but assessment has determined element is not needed for functionality or capacity.	Element is missing.
	WIRE	Condition of Wiring	Distress or damage to wiring used in CP systems.	No visible distress.	Insignificant distress, including exposed wire in good condition.	Distress such as visible section loss, cut strands, or fraying wire for which electrical continuity remains intact.	Distress such as visible section loss, cut strands, or fraying wire for which electrical continuity has been lost.

Type	Code	Condition Name	Condition Definition	Condition States			
				CS1 (Good)	CS2 (Fair)	CS3 (Poor)	CS4 (Severe)
CP Supports	BASK	Condition of Submerged Anode Baskets	Distress or damage to anode baskets.	No visible distress.	Minor distress or deterioration but no loss of support.	Moderate distress or deterioration resulting in the basket providing limited support for submerged anode.	Basket providing no support for submerged anode; anode is present and supported by lead wire.
	CONS	Connection Distress to Structure	Connection distress support elements. Connections include items such as heavy hex structural bolts, post-installed anchors, through-bolts, anchor rods etc.	No connection distress; connection is in place and functioning as intended.	Loose fasteners or minor pack rust without distortion is present, but connection is in place and functioning as intended.	Missing fasteners; pack rust with distortion may be present; visible section loss on fastener of up to 20 percent OR assessment has determined connection's remaining capacity is not compromised.	Missing fasteners and/or pack rust cause translation and/or rotation preventing the connection from functioning as intended. Section loss on fastener in excess of 20 percent. Distress is significant enough to affect element's capacity.
	MISS	Missing	Element intended to be in place is missing. Does not apply to elements that have been intentionally removed as part of a modification.	Element is present.	Parts of an element are missing, however does not affect functionality.	Element is missing but assessment has determined element is not needed for functionality or capacity.	Element is missing.
	SUPP	Condition of Support Elements	Distress of support elements such as hangers, clevises, straps, or accessories used to support CP wiring or equipment.	No visible distress.	Minor distress or deterioration but no section loss of base material.	Section loss or moderate distress is present but assessment has determined element's functionality or capacity is not compromised.	Section loss or severe distress is present and distortion or displacement is significant enough to affect element's immediate functionality or capacity

Type	Code	Condition Name	Condition Definition	Condition States			
				CS1 (Good)	CS2 (Fair)	CS3 (Poor)	CS4 (Severe)
Coatings, Wraps, and Metalizing	ADHS	Adhesion	Adhesion of protective coating on base metals based on measured inspection data, using ASTM D4541 or D3359 or equivalent.	Typical pull off testing values ≥200 psi. Adhesion test result classification of 5B.	Typical pull off testing values between 100 and 200 psi. Adhesion test result classification of 4B or 3B.	Typical pull off testing values between 50 and 100 psi. Adhesion test result classification of 2B or 1B.	Typical pull off testing values less than 50 psi. Adhesion test result classification of 0B.
	CHLK	Chalking	Chalking in metal protective coatings	No chalking.	Surface dulling.	Loss of pigment.	Loss of adhesion to structure resulting in disbondment of coating, structure becomes susceptible to corrosion.
	FRPW	Fiber-reinforced polymer wrap	Condition of fiber-reinforced (Glass, Carbon, or other material) polymer permanently bonded to a member. Also may apply to unbonded plastic wrap, such as for piles.	No visible distress.	Minor bubbles or blisters. Minor abrasion to surface layer.	Delamination, gouges, holes, tears, or splits in material but assessment has determined capacity or functionality of wrap is not compromised.	Delamination, gouges, holes, tears, or splits in material that affects capacity or functionality of wrap.
	GALV	Galvanized zinc coating	Condition of galvanized zinc patina on steel elements.	No white or red corrosion products. Surface may be bright and shiny, spangled, or matte gray.	White rust (zinc oxide) is visible on surface.	Red rust is visible through coating on less than 5 percent of the local area.	Red rust exceeds 5 percent of the local area.
	PEEL	Peeling/ bubbling/ cracking	Peeling, bubbling, or cracking in protective coatings or wraps	No peeling, bubbling, or cracking.	Finish coat exhibits peeling, bubbling, or cracking.	Finish and primer coats exhibit peeling, bubbling, or cracking.	Substrate is exposed.
	THCK	Thickness	Thickness of protective coating on base metals based on measured inspection data.	≥ 18 mils	≥10 mils to < 18 mils	≥ 5 mils to < 10 mils	<5 mils
	WEAR	Wear	Wear of protective coating. Includes wear from abrasion or weathering.	No wear.	Substrate not exposed, coating showing wear or abrasion.	Substrate is partially exposed; thickness of the coating is reduced.	Substrate exposed; protective coating is no longer effective.

Type	Code	Condition Name	Condition Definition	Condition States			
				CS1 (Good)	**CS2 (Fair)**	**CS3 (Poor)**	**CS4 (Severe)**
	WETH	Weathering Steel Patina [See Table Note 1]	Condition of weathering steel patina (oxide film).	Uniform color pattern, dark brown with some lighter reddish- or purple-brown spots. Patina is adhered.	Dark brown but with minor color variation. Small loose flakes on surface but underlying patina is adhered.	Dark brown with black blotches, non-uniform texture. Medium (up to 1 inch) sized flakes.	Dark brown, black patina with widespread blotchiness. Laminar sheets or large flakes. Patina is no longer effective.
Metal Material	CORR	Corrosion	Corrosion of metal and other material elements, excluding connections.	No corrosion observed.	Freckled rust or light pitting present; section loss is not evident.	Section loss is evident or pack rust is present, but assessment has determined element's functionality or capacity is not compromised.	Section loss is significant enough to affect element's immediate functionality or capacity Pack rust is causing element instability or prevents elements from functioning as intended.
	SXLS	Section loss	Section loss of base metal elements based on measured thickness during inspection.	≤ 2% section loss	>2% to ≤ 10% section loss	>10% to ≤ 30% section loss	>30% section loss

Table Notes

1. Weathering steel descriptions from Crampton, D.D., Holloway, K.P. and Fraczek, J., *Assessment of Weathering Steel Bridge Performance in Iowa and Development of Inspection and Maintenance Techniques*, Final Report SPR 90-00-RB17-012, February 21, 2013. Accessible at http://publications.iowa.gov/14956/1/Iowa_Weathering_Steel_Final_Report_2-21-2013.pdf.

APPENDIX F - DOCUMENTATION AND REPORTING FORMS

- Corrosion Inventory Record
- Corrosion Inspection Plan
- Corrosion Inspection Summary
- Corrosion Inspection Data
- Corrosion Follow-up Actions
- Corrosion Inspection History

Maritime Asset
Corrosion Inventory Record

Property:	Barbours Cut Terminal	**Asset ID:**	BCT 5
Asset Type:	Wharf	**Year of Original Construction:**	1990
Wharf Type:	Open	**Year(s) of Significant Modifications or Repairs[1]:**	2002, 2004, 2008, 2011
Wharf Usage:	Containerized Cargo	**Date of Last Inventory Record Update:**	January 24, 2020

Asset Geometric Data

Area:	36 acres	**Deck Elevation above MLT:**	18 ft. 0 in.
Structure Length:	1000 ft.	**Channel Depth at Fender:**	44 ft. 6 in.
Structure Width:	Deck: 108 ft. 9 in.	**Channel Depth at Bulkhead:**	7 ft. 6 in.

Recommended Access: Pedestrian access to structure top side and landside bulkhead via catwalks; boat access required to channel-side of bulkhead wall (8-foot design clear span between drilled shafts).

Structure Corrosion Protection History

BCT 5 is located near the west end of the Barbour's Cut Terminal along the south side of the channel. The original structural drawings are dated 1989, and wharf construction was completed in 1992. Several noteworthy repairs and modifications performed at various times during the service life of the wharf include the following:

- 2002: Repair and localized recoating of fender system.
- 2004: Repair and localized recoating of fender system.
- 2004: Repair of the crane rail expansion joint.
- 2008: Repair and localized recoating of fender system.
- 2011: Repair and localized recoating of fender system.
- 2014: Coupon ladder testing program

Reference Drawing List

Drawing Set	Title	Date	Description
C107-3	Pavements and Utilities for Container Terminal No. 5 at Barbour's Cut - Phase I	27 Aug 1986	Phase 1 of Original Civil and Electrical Drawings
C107-4	Sheet Pile Bulkhead for Wharves Nos. 5 and 6 at Barbour's Cut Terminal	16 Feb 1988	Original Construction Drawings for Bulkhead
C107-5	Pavements and Utilities for Container Terminal No. 5 at Barbour's Cut - Phase II	24 May 1988	Phase 2 of Original Civil and Electrical Drawings
C107-6	Container Wharf No. 5 at Barbour's Cut Terminal	18 Jul 1989	Original Construction Drawings for Wharf
C107-5	Pavements and Utilities for Container Terminal No. 5 at Barbour's Cut - Phase II	20 Sept 1990	Modified Phase 2 of Original Civil and Electrical Drawings

[1] Significant modifications: Work that altered the structure's footprint, changes structural components, or adds/modifies a corrosion protection or coating system.
Significant repairs: Repair work in excess of 10 percent of the area or length of a structural component containing base metal elements or repair work to corrosion protection elements or coatings.

Drawing Set	Title	Date	Description
C107-12	Repair of Fender System at Wharf No. 5	5 Nov 2002	Fender Repair Drawings
C107-13	Repair of Fender System and Potable Water Line	23 Feb 2004	Fender and Utility Repair Drawings
C160-60	Crane Rail Repair	30 Aug 2004	Crane Rail Expansion Joint Repair Drawings
C60-D02-002	Fender System Maintenance at Barbours Cut Terminal	16 Oct 2008	Fender Repair and Maintenance Drawings
C60-D02-005	Annual Fender System Maintenance at Barbours Cut Terminal 2012	3 Oct 2011	Fender Repair and Maintenance Drawings

Asset Exposure Zones

The following exposure zones have been identified at this site, the specific height of the zones and exposure effects have been estimated based on review of environmental conditions and data.

Exposure Zone	Elevation versus MLLW	Elements
Atmospheric	+3.25 ft. or greater	CS Bulkhead Wall, CS Fender Piles, CS Support Framing
Splash	+1.25 to +3.25 ft.	CS Bulkhead Wall, CS Fender Piles, CS Support Framing
Tidal	+0 to +1.25 ft.	CS Bulkhead Wall, CS Fender Piles, CS Support Framing
Submerged	0 ft. or less	CS Bulkhead Wall, CS Fender Piles
Soil	Below the mudline toward the waterside of the bulkhead and below the pavement on the landward side of the bulkhead	CS Tie Rods, CS Bulkhead Wall, CS Fender Piles

Asset Environmental Conditions

Global Zone	Constituent	Values
Site	Temperature	January: 54°F, February: 57°F, March: 63°F, April: 70°F, May: 77°F, June: 82°F, July: 84°F, August: 84°F, September: 80°F, October: 72°F, November: 63°F, December: 56°F, Annual: 70°F
Site	Relative Humidity	Annual: 74%
Site	Atmospheric Chloride Concentration	5 to 10 kg / ha/ year
Water	Temperature	54°F - 86°F
Water	Chloride Concentration	4,000 - 6,000 ppm
Water	Additional Nutrients	Nitrite Plus Nitrate: 0 - 0.3 ppm, Sulfate: 0 - 1200 ppm
Water	Resistivity	No Data
Water	Microbial Activity	Negligible PCB Congener #52 and #191
Water	Flow Velocity	No Data
Soil	Resistivity	No Data
Soil	Sulfate Content	No Data
Soil	Chloride Concentration	No Data

Sources:

Consultant / Source	Title	Date	Description
National Atmospheric Deposition Program	Annual Precipitation - Weighted Mean Concentrations	Accessed 21 May 2019	Compiled Annual Data for Testing of Precipitation
National Weather Service	Houston Hobby Extremes, Normals, and Annual Summaries	Accessed 21 May 2019	Summary of Mean, Avg. High, and Avg. Low Temperatures for Houston
Texas Commission on Environmental Quality	Water Summary Report for Segment 2436 (Barbours Cut)	Various Dates	Summary of Water Testing Data for Barbour's Cut
Weatherbase	Monthly - Weather Averages Summary	Accessed 21 May 2019	Summary of Average Temperatures, Precipitation, and Humidity

Impressed Current Corrosion Protection Elements

Component / Element(s)	**Description**
Bulk Anode	Bulk anodes are installed as part of the ICCP system designed to protect both the fender piles and bulkhead wall.
– OTH Bulk Anode	Clusters of two bulk anodes are hung from the deck at approximately 35’ to the landside of the fender system at 10’ longitudinal spacing, totaling 200 anodes. Anodes are installed at Elev. -3.0 and -12.0’.
DC Power Supply	Three DC power supplies are installed to provide DC power for the ICCP system. Note: drawings indicate five rectifiers, but only three were installed.
– TRU DC Power Supply	Transformer-unit rectifiers are installed approximately 116-feet to the landside of the bulkhead wall adjacent to light poles 8 through 12.
Wiring and Protection	Wiring connects TRU DC Power Supplies with bulk anodes and the structure and is protected by PVC conduit to the landside of the bulkhead wall.
– CU Wiring	No. 6/7 copper wiring connects the corrosion protection system. Positive leads run to the bulk anodes and negative leads are connected to the fender system and bulkhead wall. Negative leads connect the copper conduit to the top fender wale beam and bulkhead wall in three and six locations, respectively.
– PVC Protection	Copper wiring is run through underground PVC conduit from the bulkhead wall to the five transformer-unit rectifiers.

Surface Protection Elements

Component / Element(s)	**Description**
Surface Protection	Coatings are used in conjunction with the ICCP system for protection of the bulkhead wall and fender system.
– PU Coatings	A three-coat system is used for protection of the fender system (Epoxy Low and Intermediate Coat with an Acrylic Urethane Topcoat).
– EP Coatings	An epoxy coating system is used for protection of the bulkhead wall (details unknown).

Base Metal Components and Elements

Component / Element(s)	Description
Critical	
– CS Tie Rod	Tie rods, 3-3/4 inch diameter, extending from bulkhead wale beam to dead man, spaced at approximately 15 feet on center and encased in Schedule 40 PVC Casings. • *Installed in 1990, no documented modifications or repairs.* • *Design Cross-Sectional Area = 11.0 in^2*
Typical	
– CS Bulkhead Wall	BZ-20 steel sheet piles extending from Elev. +14.65 to -58.00’. Mudline is shown at -5.00’. • *Installed in 1990, no documented modifications or repairs. BZ-20* • *Design Thickness = 0.551 in (flange), 0.394 in (web/wall)*
– CS Fender Piles	HP14x117 piles are extend from Elev. +16.0 to -69.0’ and are spaced at 10’-9” on center. • *Installed in 1990, no documented modifications or repairs.* • *Design Web/Flange Thickness = 0.805 in*
Redundant	
– CS Support Framing	Structural steel framing used to support the timber facing consisting of W21x111 top wales and W14x43 bottom wales. *Installed in 1990, modifications and repairs in 2002, 2004, 2008, and 2011.* • *Installed in 1990, modifications and repairs in 2002, 2004, 2008, and 2011.* • *Design Thickness: W14x43 (bottom)- web = 0.305 in, flange= 0.530 in W21x111(top)- web = 0.550 in, flange = 0.875 in HP14x117 (replacements) - web/flange = 0.805 in*

**Base Metal Components and Elements identified with FICAP labelling scheme*

Figures

Figure 1. Asset Location

Figure 2. Aerial view of asset and immediate vicinity.

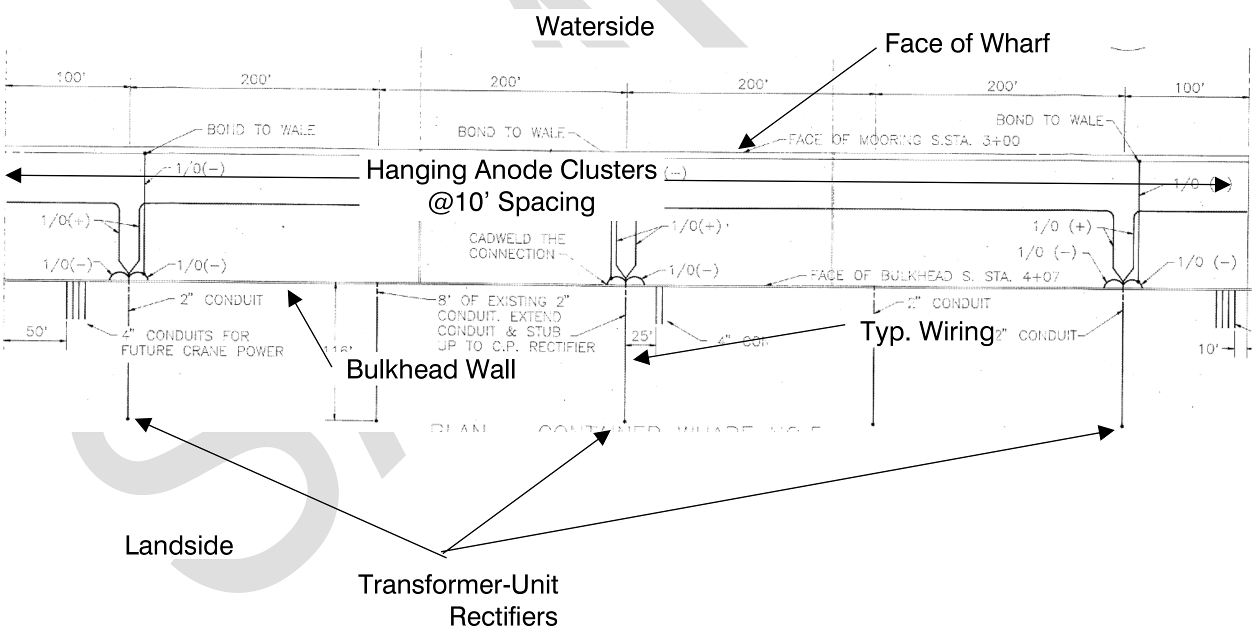

Figure 3. Typical Partial Plan of Structure.

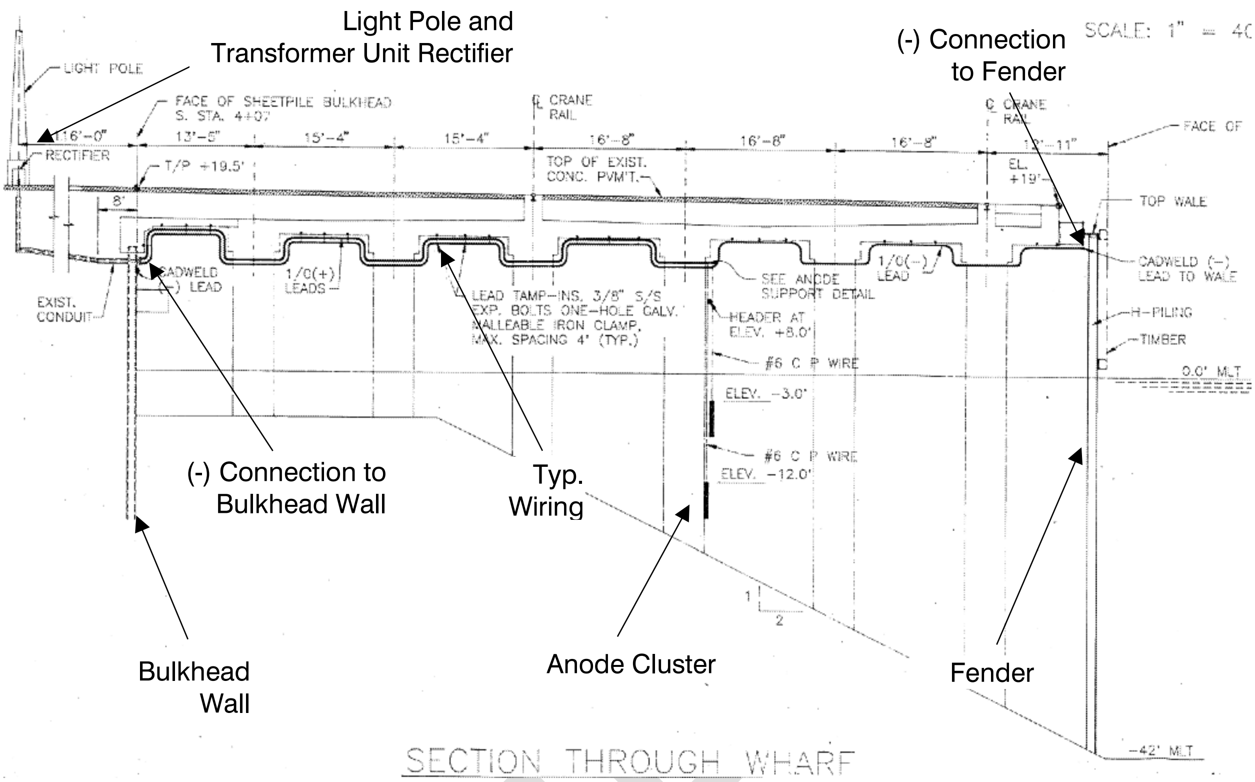

Figure 4. Typical Section through Structure.

Revision History

Rev. No.	Reported by:	Date	Verified by	Date	Comments
0	C. Jones	01/24/2020	S. Foster	01/24/2020	Baseline

Property:	Barbours Cut Terminal	**Asset ID:**	BCT 5
Asset Type:	Wharf	**Year of Original Construction:**	1990
Wharf Type:	Open	**Year(s) of Significant Modifications or Repairs[1]:**	2002, 2004, 2008, 2011
Wharf Usage:	Containerized Cargo	**Date of Most Recent Inspection:**	April 2020 (above-water) August 2020 (below-water)

Inspection Plan

Functionality Checks (Inspection Frequency = 6 months)

- Measure and record electrical measurements from (3) Transformer-Unit Rectifiers, which includes current output, voltage output, and functionality

Functionality Checks (Inspection Frequency = 1 year)

- Visual inspection of the nine weld connections between the negative leads and structure (3 to the fender wale beams and 6 to the bulkhead wall)
  - Terminal ring leads for structure and negative leads have good crimp connections
  - Inspect for loose or broken wires of structure and negative connections
  - Remove corrosion product from electrical connections if necessary to provide electrical continuity
- Measure and record on/off structure-to-electrolyte potentials to determine polarization decay of base metal elements in general accordance with Test Method 3 of NACE TM0497 to determine if CP is adequate to criterion in NACE SP0169.
  - At a minimum, testing should be performed at the same five locations during the Baseline Inspection:
    - Bays 5, 24, and 47 (near locations of negative structure connections)
    - Bays 14 and 33 (approximately midway between negative structure connections)

Tier 1 Tasks (Inspection Frequency = 3 years)

- Visual assessment of all accessible corrosion protection and bare metal elements
- Perform non-destructive measurements for elements as specified below. Measurement locations are recorded on Corrosion Element Inspection Forms. Readings should be obtained from same locations as those during the Baseline Inspection for comparable results.
  - UT Measurements: Prepare Uncoated Surfaces per SSPC- SP 3, SP 11, or as required per device manufacturer
  - Coating Thickness Measurements: Prepare Surfaces per SSPC-SP 1

Element	Exposure Zone	Required Inspections[1]
CS Tie Rod	Soil	Visually observe encasement concrete. Cracking may be indicative of corrosion distress of tie rod.
CS Bulkhead Wall	Atmospheric	Ultrasonic Thickness Measurements: 8 locations (each at flange and web) Coating Thickness and/or Adhesion Measurements: 8 locations
	Splash	Ultrasonic Thickness Measurements: 12 locations (each at flange and web) Coating Thickness and/or Adhesion Measurements: 12 locations
	Tidal	Ultrasonic Thickness Measurements: 12 locations (each at flange and web)

Element	Exposure Zone	Required Inspections[1]
		Coating Thickness Measurements: 12 locations
	Submerged (Tier 2)	Ultrasonic Thickness Measurements: 5 locations (each at flange and web) Coating Thickness and/or Adhesion Measurements: 5 locations
CS Fender Piles	Atmospheric	Ultrasonic Thickness Measurements: 8 locations (each at flange and web) Coating Thickness and/or Adhesion Measurements: 8 locations
	Splash	Ultrasonic Thickness Measurements: 12 locations (each at flange and web) Coating Thickness and/or Adhesion Measurements: 12 locations
	Tidal	Ultrasonic Thickness Measurements: 12 locations (each at flange and web) Coating Thickness and/or Adhesion Measurements: 12 locations
	Submerged (Tier 2)	Ultrasonic Thickness Measurements: 5 locations (each at flange and web) Coating Thickness and/or Adhesion Measurements: 5 locations
CS Support Framing	Atmospheric	Ultrasonic Thickness Measurements: 5 locations (each at flange and web) Coating Thickness and/or Adhesion Measurements: 5 locations
	Splash	Ultrasonic Thickness Measurements: 8 locations (each at flange and web) Coating Thickness Measurements: 8 locations
	Tidal	Ultrasonic Thickness Measurements: 8 locations (each at flange and web) Coating Thickness and/or Adhesion Measurements: 8 locations

[1]Test locations shall be representative of the condition of the given element within the entire bay. Unless specific conditions were noted during the visual survey or FICAP inspection that warrant acquiring data for specific bays, bays where data is to be acquired are listed below:

- 5 Locations: Bays 5, 14, 24, 33, and 43
- 8 Locations: Bays 3, 9, 15, 22, 29, 35, 41, and 47
- 12 Locations: Bays 1, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, and 46

Tier 2 Tasks (Inspection Frequency = 6 years)

- Level I underwater diving inspection of anodes as defined in ASCE 101
  - 100 percent verification of anode placement and connection of positive lead to each anode
- Level II underwater cleaning and inspection of anodes at 10% of anodes:
  - Bays 5, 14, 24, 33, and 43
- Level III underwater thickness and weight measurements of anodes:
  - Bays 5, 24, and 43
- Level III underwater thickness and weight measurements of base metal elements and coatings (shown in Table above)
  - Bays 5, 14, 24, 33, and 43

Tier 3 Tasks

- No planned Tier 3 inspections of buried tie rods unless warranted during future inspections.

Revision History

Rev. No.	Developed by	Date	Verified by	Date	Comments
0	C. Jones	01/27/2020	S. Foster	01/27/2020	Baseline
1	C. Jones	NA	S. Foster	NA	Routine inspection developed
2	S. Foster	10/11/2022		10/11/2022	Updated for 100% Manual

Property:	Barbours Cut Terminal	**Asset ID:**	BCT 5
Inspection Type	☒ Baseline ☐ Routine ☐ In-Depth	**Inspection Date(s):**	April 23-24, 2020 (above water) August 4-5, 2020 (under water)
Scope of Inspection	Entire Asset, Above Water and Under Water		
Inspection Firm(s):	**Prime**: Wiss, Janney, Elstner Associates, Inc.		
	Underwater: Rio Engineering, Inc.		
	Other (role): N/A		
Reported By:	S. Foster, P.E.	**Report Date:**	October 6, 2020
Corrosion Manual Version/Date:	Rev. 0, October 2022	**Variances from CM Procedure:**	N/A

Seal of Responsible Engineer

I hereby certify this inspection was performed under my direct supervision and control and to the best of my professional knowledge complies with the Corrosion Manual and applicable codes. Signed: ____________________ Name: Stephen Foster, PE____________________ Texas License No.:116280____________________ Date: 5-11-2021__________ Expires:9-30-21__________	Seal

Inspection Team Members

Project Manager: Stephen Foster
Inspection Team Leader(s): Stephen Foster
Inspection Team Member(s): Casey Jones, Kyle Myers, Lane Thompson

Underwater Team Leader: Joe Starkey
Underwater Team Member(s):

Overall Asset Condition

Overall, the base metal elements were in fair condition with minor to moderate measured section loss. The estimated corrosion rates for the bulkhead wall, fender piles, and fender support framing were all ranked with a damage index of fair to good. There are, however, several localized areas of distress that should be prepared and recoated to maintain the current condition of the assets.

The corrosion protection systems appeared to be functioning as intended for the bulkhead wall, but not the fender piles. Current output and structure-to-electrolyte potential measurements indicate that the system is operating as intended and providing sufficient cathodic protection to the bulkhead wall. The bond wires to the fender piles were all severed and non functional.

ICF (Functional) Component Rating = 4 (Deduction = 4)
ICV (Visual) Component Rating = 4 (Deduction = 2)
SPR Rating = 3 (Deduction = 8)
CP = 60 - 1.6 x (ICF + ICV + COA) = 60 - 1.6 x (4 + 2 + 8) = 38

CR Rating = 5 (Deduction = 3)
TYP Rating = 4 (Deduction = 3)
RED Rating = 4 (Deduction = 2)
BM = 40 - (CR + TYP + RED) = 40 - (3 +3 + 2) = 32

CCR = CP + BM = 38 + 32 = 70

The overall corrosion condition rating (CCR) for BCT 5 is 70.

Impressed Current Corrosion Protection Elements

Element(s)	Rating	Comments
Anodes	**4**	Limited moderate marine growth or section loss. Most elements and their attachment are sound and functional purpose/use of the component is not affected.
– OTH Bulk Anode	4	
DC Power Supply	**4 (Functional)** **4 (Visual)**	All three rectifiers are functional, proper gage readings and DC outputs were verified. PW5-1 was turned off upon arrival of the inspector, however, it was deemed functional when turned on. All six “on” potentials of the bulkhead wall were measured as more negative than -850 mV vs. CSE. All of the “Instant off” potentials were measured as more negative than -850mV vs. CSE and more positive than -1250 mV. Measured potentials at the fender did not meet any established criteria due to disconnection of the bond wires.
– TRU DC Power Supply	4 (Funct) 4 (Visual)	
Wiring and Protection	**3**	Wiring and protection was in satisfactory condition.
– CU Wiring	3	Negative lead wiring from the bulkhead wall appeared to be in satisfactory condition with minor corrosion at the connections. Positive lead wiring to the anodes exhibited

Element(s)	Rating	Comments
		minimal distress. Five bond wires in Bays 5, 14, 24, 37, and 43 intended to electrically connect the fender to the bulkhead wall had been cut at the fender, preventing cathodic protection of fender elements.
– CS Protection	4	Exposed carbon steel conduit extended through the bulkhead wall at locations where subgrade wiring was routed. Significant moisture discharge was observed in the Bay 5 wiring protection, evidence that the conduit had failed at some point along its length, allowing water and contaminants into the conduit, which can be seen in figure 9.

Sacrificial Anode Corrosion Protection Elements

None.

Surface Protection Elements

Element(s)	Rating	Comments
Surface Protection	**3**	The epoxy bulkhead wall coating was in fair condition, with Bays 1-3 recently recoated and in good condition. Multiple coating systems were observed on the fender system. The original coal tar epoxy coating was observed on the atmospheric exposure of the fender piles, as well as the upper horizontal framing members. Fender piles had been recoated in the tidal and splash exposure zones, presumably with a multi coat system. Four types of coating systems were observed on the lower horizontal fender framing members: zinc metalizing, coal tar epoxy (presumably the original coating), shop primer without a topcoat, and a complete shop coating with a polyurethane topcoat.
– CE Coatings	4	Coal tar epoxy was in satisfactory condition in the atmospheric exposure conditions of the fender piles and support framing, however, 4 lower horizontal framing members were coated with original coal tar epoxy, which was in poor condition.
– EP Coatings	3	The bulkhead wall coating appeared to be in fair condition, with varying degrees of peeling and blistering observed above the bulkhead beam. Bays 1 through 3 had been recoated as part of previous work scope. Measured adhesion values typically exceeded 800 pounds per square inch at discrete test locations.
– OTH Coatings	2	4 lower horizontal framing members appeared to have a red primer installed but was missing a topcoat. Surface protection provided to these beams was minimal and system details are unknown.

Element(s)	Rating	Comments
– PU Coatings	5	Recoated sections of the fender piles in the splash and tidal exposure zones exhibited minimal distress. Similarly, observed coatings on the 25 white shop-coated lower horizontal framing members were in satisfactory condition.
– ZN Metalizing	5	54 lower horizontal framing members were hot-dip galvanized. Observed metalizing was in satisfactory condition.

Base Metal Components and Elements

Element(s)	Rating	Comments
Critical	**NA**	Inaccessible. Rated as 5 for scoring purposes due to age.
– CS Tie Rod	NA	
Typical	**4**	
– CS Bulkhead Wall	5	The bulkhead wall was in satisfactory condition with minor corrosion at the seams and minimal general section loss, mostly in the splash and tidal zone. In 30 years of service, the average section loss was approximately 5 to 6%. *Section loss: (>2% to ≤ 10% satisfactory)* *Estimated Corrosion Rate: (Satisfactory <2mpy)*
– CS Fender Piles	4	Impact damage and corrosion of piles was observed near the waterline, with an average section loss of approximately 27% near the ends of the flanges. Webs typically have minimal section loss apart from stiffeners Overall, fair amount of section loss with estimated corrosion rate between 6 and 11 mpy. *Section loss: (Fair <10%)* *Estimated Corrosion Rate: (Fair, 6 < x ≤ 11 mpy)*
Redundant	**4**	
– CS Support Framing	4	Impact damage and corrosion of framing was observed near the waterline, particularly at connections. *Section loss: (>2% to ≤ 10%, Fair)* *Estimated Corrosion Rate: (2 < x ≤ 6 mpy, Fair)*

Figures

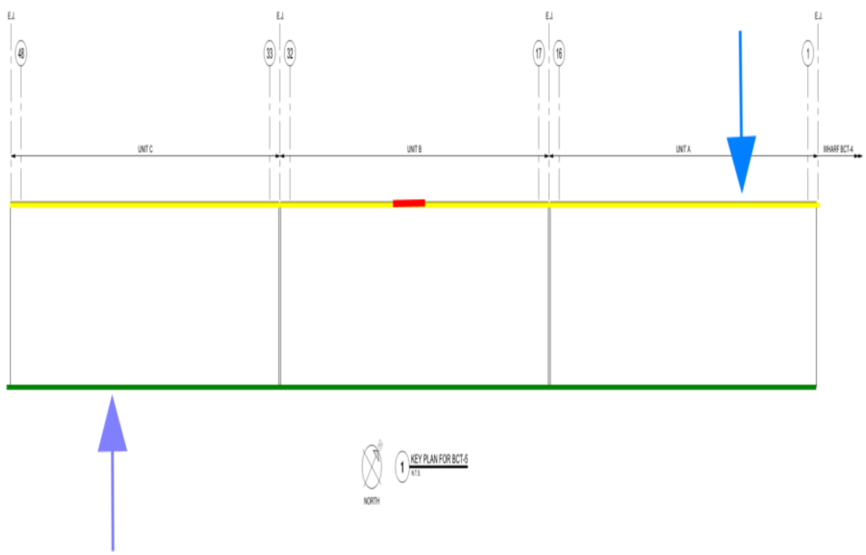

Figure 1. Visual representation of ICCP potential data from the bulkhead wall (blue arrow) and fender (purple arrow)
Green = adequate protection (-850 to -1200 mV vs. CSE)
Yellow = inadequate protection (>-850 mV vs. CSE)
Red = overprotection (<-1200 mV vs. CSE)

Figure 2. Elevation view of the wharf (looking west down the terminal).

Figure 3. Overall view of DC power supply, rectifier for BCT5

Figure 4. Electrical components of rectifier are in good condition without any significant distress.

Figure 5. Electrical connection to the fender pile with copper strands disconnected at the connection point

Figure 6. Broken electrcial connection between fender pile and the bulk head wall.

Figure 7. Connection bond from the bulk head wall to the fender piles, no major visible signs of corrosion or distress.

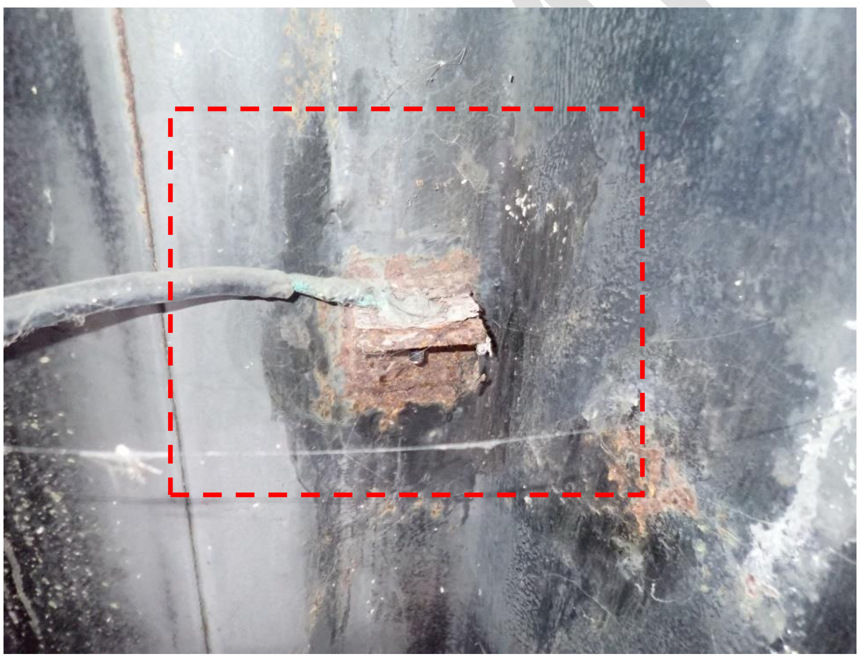

Figure 8. Negative wire connection from rectifier to bulkhead wall, showing visible signs of corrosion at connection point.

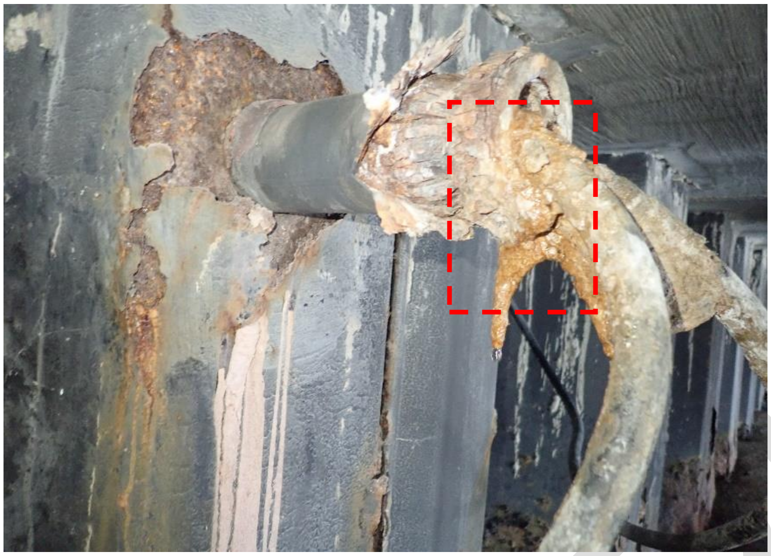

Figure 9. Condition of wiring conduit, carbon steel case severely corroded with protective wrapping peeled off from corrosion product. Moisture settling inside of conduit as shown within red boxed area.

Figure 10. Wrapping of electrical wires has failed, although wires are not exposed to the atmosphere and are still encased.

Figure 11. Evaluation of coatings along the support framing. Pull-off testing setup on framing shown in the red box.

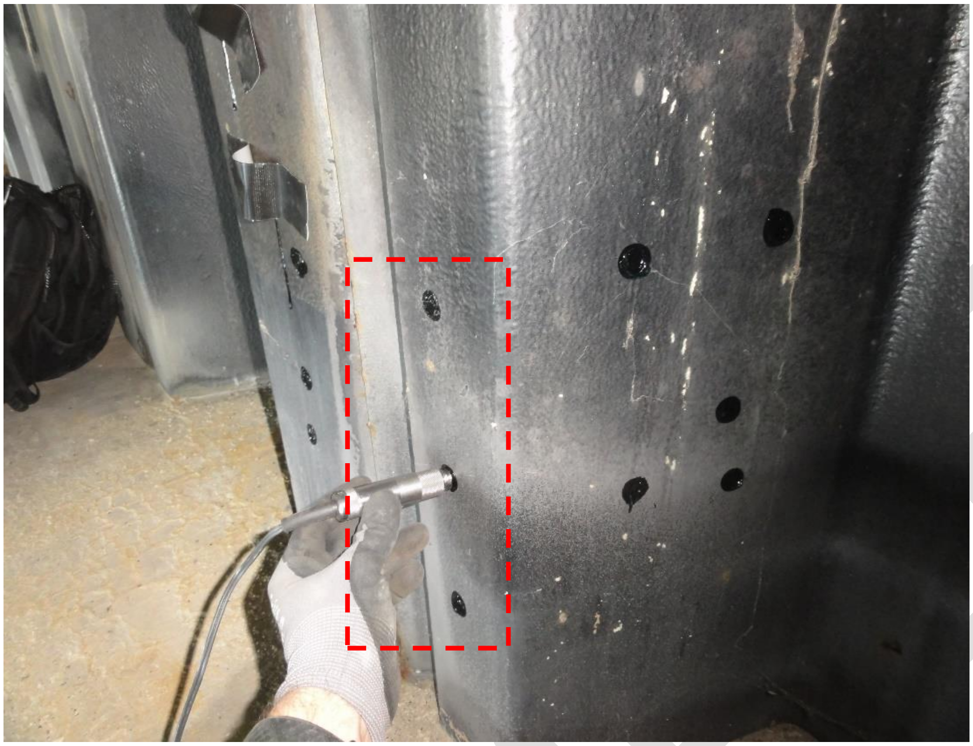

Figure 12. Typical condition of bulkhead wall coating is shown while UT measuremtns are being performed.

Figure 13. Different coatings can be visually seen from a yellow/white color that transitions to a dark grey color shown in the red box between the vertical red dashed line. The lighter coating is from bays 1-4.

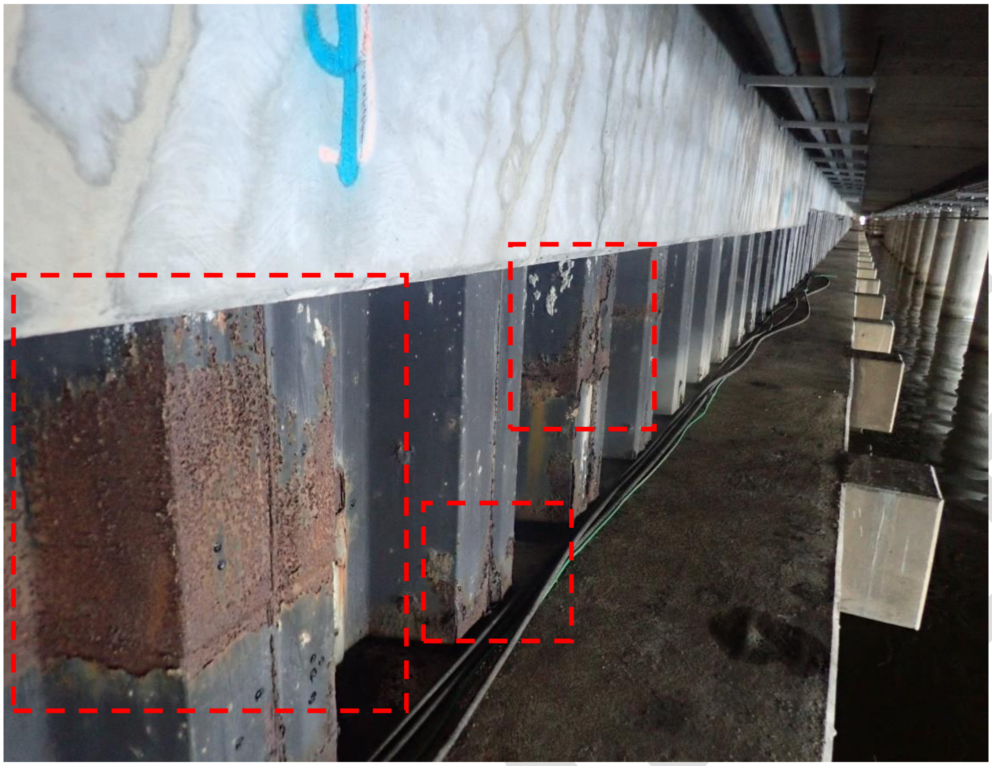

Figure 14. Locations of coating failures at the bulkhead wall, where corrosion has initiated.

Figure 15. Support framing with severely corroded connections and large amount of section loss

Figure 16.Support framing with newly installed galvanized bolts at the connection between the fender pile and a white coating.

Figure 17.Multiple support framing coatings were used, this picture illustrates a hot dipped galvanized support frame.

Figure 18. Multiple support framing coatings were used, this picture illustrates a red top coat used on the framing.

Figure 19.Coating condition of fender pile with corrosion along edges where the coating has failed.

Figure 20. Typical condition of fender pile at the submerged/tidal zone, showing coating disbondment and areas of corrosion.

Figure 21.Condition of fender pile in the submerged zone, showing significant corrosion, photo taken from underwater inspection.

Figure 22. Condition of bulkheadwall at the waterline, photo taken from underwater inspection.

Figure 23. Anode 5-1 is shown with marine growth on the surface of the anode casing.

Rating Definitions

Ratings tables below from PHA CM Manual Rev. **0**, dated **October 2022**

Table 6.1. Functionality Ratings for Cathodic Protection Components

Rating	Description
6 Good	One of the following criteria is met at all test locations: ▪ A negative (cathodic) voltage of -850 mV CSE (millivolt versus copper/copper sulfate reference electrode) or more negative between metal elements and the electrolyte, without risk of hydrogen embrittlement. ▪ A minimum of 100 mV of cathodic polarization, as measured by either polarization formation or decay. ▪ Test coupons are used to otherwise demonstrate adequate corrosion protection is being applied to the structure.* ▪ For reinforced concrete elements, the depolarized potential of the steel in wet saturated concrete is more negative than -720 mV CSE with the anode disconnected for a minimum of 24 hours, or a minimum of 100 mV of cathodic polarization, as measured by either polarization formation or decay
5 Satisfactory	One of the above criteria is met at least at 80 percent of the test locations. Damage, electrical malfunctions, or deterioration have affected the functionality of the ICCP or SACP system, such that the above criteria are not met at limited locations. Potential for overprotection or coating damage may be noted at some locations, but metals have low risk of embrittlement.
4 Fair	One of the above criteria is met for at least 50 percent of the test locations. The system is partially functional but may not be providing adequate corrosion protection to some base metal elements (or reinforced concrete elements, if applicable). Metals with high risk of steel embrittlement are subject to cathodic overprotection (instant off voltage more negative than - 1,000 mV CSE). Coatings with high risk of disbondment are subject to cathodic overprotection (instant off voltage more negative than -1200 mV CSE).
3 Poor	One of the above criteria are met at less than 50 percent of the test locations. Widespread performance deficiencies are observed for the cathodic protection systems.
2 Serious	One of the above criteria is met at less than 10 percent test locations. Evidence of nonfunctional cathodic protection system is noted at most locations.
1 Critical	ICCP or SACP system is not functional or is not providing corrosion protection at any test locations as intended.
Applicable Component Types: Impressed Current Cathodic Protection Systems, Sacrificial Anode Cathodic Protection Systems, Spray Metalizing with Monitoring Boxes	

*Reference NACE SP0104, *Standard Practice: The Use of Coupons for Cathodic Protection Monitoring Applications*. If corrosion rate is used as an evaluating metric, the corrosion rate should be no greater than 2 mpy to achieve a rating of 6- Good

Table 6.2. Visual Ratings for Cathodic Protection Components

Rating	Description
6 Good	Very minor or no problems observed. Also applies to newly constructed or rehabilitated protective components.
5 Satisfactory	Limited minor defects, damage, or deterioration - not extensive to multiple elements.
4 Fair	Extensive minor or limited moderate defects, damage, or deterioration. All primary elements and their attachment to the asset are sound and functional purpose/use of the component is not affected. Minor repairs or maintenance may be required.
3 Poor	Extensive moderate defects, damage or deterioration that affects functional purpose/use of the component or compromises attachment of the component to the asset.
2 Serious	Defects, damage, or deterioration significantly affect functional purpose/use of the component.
1 Critical	Advanced damage or deterioration expected to result in failure(s) of component to provide adequate protection. The component can no longer serve its functional purpose/use and/or conditions are present that may lead to imminent failure of the ICCP system.
Applicable Element Types: Anodes, Supplementary Anode Materials, DC Power Supply, Monitoring Equipment, Wiring and Protection, Cathodic Protection Jackets, CP Supports	

Table 6.3. Ratings for Surface Protection Components

Rating	Description
6 Good	Very minor or no problems observed. Also applies to newly constructed or rehabilitated components.
5 Satisfactory	Limited minor defects, damage, or deterioration such as chalking, blushing, blistering, etc. - not extensive.
4 Fair	Extensive minor or limited moderate defects, damage, or deterioration. Coating, wrap, and/or metalizing may be peeling or missing in localized areas.
3 Poor	Extensive moderate defects, damage or deterioration. Coating, wrap, and/or metalizing may be peeling or missing in not more than 50 percent of coated surfaces.
2 Serious	Defects, damage or deterioration has significantly reduced protection of base steel elements. Coatings, wraps, and/or metalizing elements are only providing protection in localized locations.
1 Critical	Advanced defects, damage, or deterioration categorized as a systematic coating failure. Coatings, wraps, and/or metalizing elements do not protect base metal elements.
Applicable Element Types: Coatings, Wraps, and Spray Metalizing	

Table 6.4. Corrosion Damage Rating Index for Base Metal Components

		Estimated Corrosion Rate (mpy)			
		≤ 2	**2 < x ≤ 6**	**6 < x ≤ 11**	**>11**
Section Loss	**≤ 2%**	6 Good	6 Good	5 Satisfactory	5 Satisfactory
	>2% to ≤ 10%	5 Satisfactory	4 Fair	4 Fair	3 Poor
	>10% to ≤ 30%	3 Poor	3 Poor	3 Poor	2 Serious
	> 30%	2 Serious	2 Serious	1 Critical	1 Critical

Maritime Asset
Corrosion Inspection Data Form

Property:	Barbours Cut Terminal	**Asset ID:**	BCT 5
Inspection Type	☒ Baseline ☐ Routine ☐ In-Depth	**Inspection Date(s):**	May 20, 2020 (abovewater) Aug 24, 2020 (underwater)
Scope of Inspection	Entire Asset, Above Water and Under Water		
Inspection Firm(s):	**Prime**: Wiss, Janney, Elstner Associates Inc.		
	Underwater: Rio Engineering, Inc.		
	Other (role): N/A		
Reported By:	S. Foster, P.E.	**Report Date:**	October 6, 2020
Corrosion Manual Version/Date:	Rev. 0, October 2022	**Variances from CM Procedure:**	N/A

Inspection Data

Transformer-Unit Rectifier Output Data

Rectifier ID	Voltage (V)	Current (amps)	Notes
PW 5-1	6.9	58	Was turned off
PW 24-1	7.1	72	
PW 43-1	5	31	

CP Potential Measurements (CS Bulkhead Wall)

Element Location	Near Waterline	
	On Potential	Off Potential
BW 5-1	-1200	-1080
BW 14-1	-1190	-1080
BW 24-1	-1470	-1132
BW 33-1	-1120	-1030
BW 37-1	-1200	-1090
BW 47-1	-1040	-920

[1] *Water only 2-4 feet deep at BW, all measurements taken near surface of water*
Units = mV vs. CSE

CP Potential Measurements (CS Fender Piles)

Element Location	Near Waterline		
	On Potential	Off Potential	Voltage Drop
FP 5-1	-725	NA	NA
FP 24-1	-720	-695	-25
FP 47-2	-795	-785	-10

Units = mV vs. CSE

Anode Mass Data

Element	Remaining Mass Anode 1 (lb/kg)	Remaining Mass Anode 2 (kg/lb)
AN 5-1*	15.5 lb (7.03 kg)	15.5 lb (7.03 kg)
AN 24-1	87.75 lb (38.89 kg)	87 lb (39.46 kg)
AN 43-1	110 lb (49.89 kg)	98.5 lb (44.68 kg)
Average		

**Different anode type than AN 24-1, AN 43-1*

Bulkhead Wall Metal Thickness Measurements

Exposure Zone	Element	Location Description	Thickness (in.)					Avg. Thickness (in.)
Atmospheric	BW 3-1	Flange	.534	.487	.538	.499	.535	.519
		Web	.393	.389	.388	.392	.390	.390
	BW 8-1	Flange	.533	.538	.535	.531	.537	.535
		Web	.387	.391	.354	.383	.385	.380
	BW 15-1	Flange	.525	.526	.538	.540	.527	.531
		Web	.391	.386	.390	.393	.389	.390
	BW 22-1	Flange	.544	.547	.518	.517	.543	.534
		Web	.375	.348	.375	.363	.371	.367
	BW 28-1	Flange	.551	.527	.557	.527	.535	.539
		Web	.391	.394	.386	.398	.391	.392
	BW 35-1	Flange	.551	.545	.511	.509	.540	.531
		Web	.375	.378	.396	.353	.371	.375
	BW 41-1	Flange	.512	.524	.505	.509	.529	.516
		Web	.385	.371	.363	.354	.359	.366
	BW 47-1	Flange	.536	.556	.553	.510	.509	.533
		Web	.393	.400	.384	.385	.378	.388
Splash	BW 1-1	Below wale beam	.530	.530	.530	.530	.530	.530
	BW 6-1	Below wale beam	.525	.525	.525	.525	.530	.526
	BW 10-1	Below wale beam	.535	.535	.535	.535	.535	.535
	BW 14-1	Below wale beam	.505	.505	.505	.505	.505	.505
	BW 18-1	Below wale beam	.525	.520	.520	.520	.520	.521
	BW 22-1	Below wale beam	.515	.515	.515	.515	.515	.515
	BW 26-1	Below wale beam	.520	.520	.520	.520	.520	.520
	BW 30-1	Below wale beam	.530	.525	.530	.530	.530	.529
	BW 34-1	Below wale beam	.535	.535	.535	.535	.535	.535
	BW 38-1	Below wale beam	.520	.520	.520	.520	.520	.520
	BW 42-1	Below wale beam	.535	.535	.535	.535	.535	.535
	BW 48-1	Below wale beam	.530	.530	.530	.530	.530	.530
Tidal	BW 1-1	Waterline	.530	.530	.530	.530	.530	.530
	BW 6-1	Waterline	.525	.525	.525	.525	.525	.525
	BW 10-1	Waterline	.540	.540	.540	.540	.540	.540
	BW 14-1	Waterline	.505	.505	.505	.505	.505	.505
	BW 18-1	Waterline	.525	.525	.525	.525	.525	.525
	BW 22-1	Waterline	.505	.505	.505	.505	.505	.505
	BW 26-1	Waterline	.520	.520	.520	.520	.520	.520
	BW 30-1	Waterline	.530	.530	.535	.530	.530	.531

Exposure Zone	Element	Location Description	Thickness (in.)					Avg. Thickness (in.)
	BW 34-1	Waterline	.535	.535	.535	.535	.535	.535
	BW 38-1	Waterline	.520	.520	.520	.520	.520	.520
	BW 42-1	Waterline	.545	.545	.545	.545	.545	.545
	BW 48-1	Waterline	.525	.525	.525	.525	.524	.525
	BW 5-1	Mudline	.545	.545	.545	.545	.545	.545
	BW 14-1	Mudline	.510	.510	.510	.510	.505	.509
Submerged	BW 24-1	Mudline	.520	.520	.520	.520	.520	.520
	BW 33-1	Mudline	.525	.525	.525	.530	.530	.527
	BW 43-1	Mudline	.385	.385	.385	.385	.385	.385

Bulkhead Wall Coating Thickness Measurements

Exposure Zone	Element	Location Description	Thickness (mils)					Avg. Thickness (mils)
	CT 3-4 (BW 3-1)	Above wale beam	56.4	54.4	44.8	66	59.4	56.2
	CT 9-4 (BW 9-1)	Web	11.6	10.3	21.2	9.8	17.6	14.1
	CT 15-4 (BW 15-1)	Atmospheric	36.9	33.9	43.8	39.5	37.5	38.3
Atmospheric	CT 22-4 (BW 22-1)	Above wale beam	30.8	26.2	30.5	21.9	19.7	25.8
	CT 28-1(BW 29-1)	Above wale beam	25.3	26.8	26	33.4	36.4	29.6
	CT 35-4 (BW 35-1)	Above wale beam	16.7	27.5	35.8	39	13	26.4
	CT 41-4 (BW 41-1)	Above wale beam	25.1	24.7	32.8	33.6	31.4	29.5
	CT 47-4 (BW 47-1)	Above wale beam	26.2	29.1	30.9	23.6	22.2	26.4
	CT 1-1 (BW 1-1)	Below wale beam	38	40.5	37.5	40.5	41.5	39.6
	CT 6-1 (BW 6-1)	Below wale beam	27.2	26.1	27.1	27	26.6	26.8
	CT 10-4 (BW 10-1)	Below wale beam	36.9	38.9	41.5	41.3	37.3	39.2
	CT 14-4 (BW 14-1)	Below wale beam	34.7	35.2	33.4	33.7	33.3	34.1
	CT 18-4 (BW 18-1)	Below wale beam	32.1	32.1	30.8	31.8	30.5	31.5
Splash	CT 22-4 (BW 22-1)	Below wale beam	30.2	31.3	31	32.5	32.5	31.5
	CT 26-4 (BW 26-1)	Below wale beam	21.5	20	20.4	21.2	20	20.6
	CT 30-4 (BW 30-1)	Below wale beam	26.6	30.1	30.1	29.2	30.2	29.2
	CT 34-4 (BW 34-1)	Below wale beam	35.9	37.6	37.2	37.2	35.7	36.7
	CT 38-4 (BW 38-1)	Below wale beam	33.4	32.7	34.4	32.1	31	32.7
	CT 42-4 (BW 42-1)	Below wale beam	31.1	30	31.1	30.9	32.6	31.1
	CT 48-4 (BW 48-1)	Below wale beam	34.3	40.1	38.5	36.3	33.6	36.6
	CT 1-1 (BW 1-1)	Waterline	44.5	45	44.5	46	45	45
	CT 6-1 (BW 6-1)	Waterline	25.6	24.6	24.8	24.4	26.1	25.1
	CT 10-4 (BW 10-1)	Waterline	35.2	33.9	35.2	34.6	32.7	34.3
	CT 14-4 (BW 14-1)	Waterline	32.4	30.9	31.6	30.5	31.6	31.4
	CT 18-4 (BW 18-1)	Waterline	27.4	27.2	30	28	25.2	27.6
Tidal	CT 22-4 (BW 22-1)	Waterline	34.6	37.9	36.3	36.6	34.8	36
	CT 26-4 (BW 26-1)	Waterline	17.1	17	17.1	17.4	16.7	17.1
	CT 30-4 (BW 30-1)	Waterline	28.1	28.9	25.6	33.6	27.2	28.7
	CT 34-4 (BW 34-1)	Waterline	39.1	37.8	37.2	37.8	38	37.9
	CT 38-4 (BW 38-1)	Waterline	28.2	32.3	35.6	36.8	31.2	32.8
	CT 42-4 (BW 42-1)	Waterline	31.8	37.3	40	39	35.9	36.8
	CT 48-4 (BW 48-1)	Waterline	41.6	39.1	36.8	38.5	40	39.2
Submerged	CT 5-4 (BW 5-1)	Mudline	35.1	32.5	33.1	41.1	40	36.4

Exposure Zone	Element	Location Description	Thickness (mils)					Avg. Thickness (mils)
	CT 14-4 (BW 14-1)	Mudline	26.7	28.9	25.8	23.9	32.9	27.6
	CT 24-4 (BW 24-1)	Mudline	34	36.2	34.5	26.1	27.6	31.7
	CT 33-4 (BW 33-1)	Mudline	20.1	20.7	19.5	21.8	18.6	20.1
	CT 43-4 (BW 43-1)	Mudline	9.3	11	11	10.5	8	9.9

Fender Pile Metal Thickness Measurements

Exposure Zone	Element	Location Description	Thickness (in.)					Avg. Thickness (in.)
Atmospheric	FP 3-1	5' above water	.790	.783	.790	.791	.793	.789
	FP 9-1	7' above water	.795	.795	.796	.799	.816	.800
	FP 15-1	6' above water	.765	.792	.790	.788	.789	.785
	FP 18-1	12' above water	.796	.799	.637	.676	.654	.712
	FP 22-1	5.5' above water	.814	.815	.814	.813	.814	.814
	FP 29-1	7' above water	.799	.818	.804	.799	-	.805
	FP 36-1	6' above water	.789	.798	.798	.807	.800	.798
	FP 41-1	6' above water	.829	.829	.831	.830	.831	.830
	FP 47-1	8' above water	.810	.798	.793	.803	.796	.800
Splash	FP 1-1	1' above water	.592	.648	.560.	.495	.471	.553
	FP 6-1	1' above water	.525	.600	.547	.539	.567	.556
	FP 15-1	1' above water	.466	.526	.359	.364	.321	.407
	FP 15-2	1' above water	.691	.677	.683	.709	.669	.686
	FP 22-1	1' above water	.373	.572	.459	.632	.580	.523
	FP 26-1	2' above water	.599	.602	.616	.579	.605	.600
	FP 30-1	1.5' above water	.796	.796	.788	.782	.779	.788
	FP 34-1	1.5' above water	.401	.476	.560	.411	.468	.463
	FP 35-1	2' above water	.655	.652	.663	.652	.667	.658
	FP 42-1	1.5' above water	.633	.681	.577	.6335	.642	.634
	FP 46-1	1' above water	.672	.582	.590	.626	.594	.613
Tidal	FP 1-1	W/L	.830	.835	.835	.835	.835	.834
	FP 6-1	W/L	.785	.785	.785	.785	.790	.786
	FP 10-1	W/L	.790	.790	.790	.790	.790	.790
	FP 14-1	W/L	.765	.770	.770	.770	.770	.769
	FP 18-1	W/L	.810	.815	.815	.810	.810	.812
	FP 22-1	W/L	.810	.810	.810	.810	.820	.810
	FP 26-1	N/A (See Notes)						
	FP 30-1	W/L	.790	.790	.790	.790	.790	.790
	FP 34-1	W/L	.775	.770	.775	.770	.775	.773
	FP 38-1	W/L	.795	.795	.795	.790	.790	.793
	FP 42-1	W/L	.800	.795	.795	.800	.795	.797
	FP 48-1	W/L	.805	.805	.805	.805	.805	.805
Submerged	FP 5-1	5' below water	.795	.795	.795	.795	.790	.794
	FP 14-1	5' below water	.800	.800	.800	.805	.805	.802
	FP 24-1	5' below water	.785	.785	.785	.785	.790	.786
	FP 33-1	5' below water	.790	.790	.790	.795	.795	.792
	FP 43-1	5' below water	.810	.810	.810	.810	.810	.810

Fender Pile Coating Thickness Measurements

Exposure Zone	Element	Location Description	Thickness (mils)					Avg. Thickness (mils)
	CT 3-1 (FP 3-1)	5.5' above water	26.7	24.7	26.6	29.5	25.1	26.5
	CT 9-1 (FP 9-1)	7' above water	36	29.2	33.3	29.5	27.7	31.1
	CT 15-1 (FP 15-1)	6' above water	18.3	17.1	20.8	20.2	21.9	19.7
	CT 12-1 (FP 12-1)	12' above water	34.8	44.2	40.4	37.1	35.4	38.4
Atmospheric	CT 22-1 (FP 22-1)	5.5' above water	31.8	33.9	33.2	33.9	32.5	33.1
	CT 29-1 (FP 29-1)	7' above water	21.9	24.5	23.1	23.5	23.7	23.3
	CT 35-1 (FP 35-1)	6' above water	21.7	19.1	25.1	23.7	23.6	22.6
	CT 41-1 (FP 41-1)	6' above water	20.4	17.1	14.9	14.4	17.7	16.9
	CT 47-1 (FP 47-1)	8' above water	23.9	25.9	29.1	26.8	26.5	26.4
	CT 1-1 (FP 1-1)	2' above water	32.4	36.5	30.7	32.4	31.9	32.8
	CT 6-1 (FP 6-1)	1' above water	34.5	30.9	30.9	33.6	31.2	32.2
	CT 15-1 (FP 15-1)	1' above water	28.4	24.2	24.2	26.6	27.2	26.1
	CT 15-3 (FP 15-2)	1' above water	27.3	25.4	24.6	30	22.5	26
	CT 22-1 (FP 22-1)	1' above water	32.1	33.1	34.4	34.8	34.7	33.8
Splash	CT 26-1 (FP 26-1)	2' above water	31.3	30.6	29.9	29.7	32.2	30.7
	CT 30-1 (FP 30-1)	1.5' above water	1.2	18.9	20	23.3	20.4	16.8
	CT 34-1 (FP 34-1)	1.5' above water	30.3	21.7	23.3	22.4	23	24.1
	CT 35-1 (FP 35-1)	2' above water	30.7	29.5	29.4	23.9	23.5	27.4
	CT 42-1 (FP 42-1)	1.5' above water	44.8	49.5	65.4	52.7	48.7	52.2
	CT 46-1 (FP 46-1)	1' above water	39.4	41.7	39.1	35.2	31.9	37.5
	CT 1-1 (FP 1-1)	1' above water	37.8	37.7	43.9	44	39.6	40.6
	CT 1-1 (FP 1-1)	W/L	25.3	27.5	26.1	28	25.8	26.5
	CT 6-1 (FP 6-1)	W/L	27.4	24.9	25.6	25.7	27.2	26.2
	CT 10-1 (FP 10-1)	W/L	28.4	27.4	24.4	27.1	28.5	27.2
Tidal	CT 14-1 (FP 14-1)	W/L	18.5	16.8	17	17.2	15	16.9
	CT 18-1 (FP 18-1)	Tidal	40.6	40	44.9	39.8	37.6	40.6
	CT 22-1 (FP 22-1)	5' below water	27.2	26.8	28.9	29.2	28.9	28.2
	CT 26-1 (FP 26-1)	1' above water	37.8	35.7	36.6	36.2	36	36.5
	CT 30-1 (FP 30-1)	W/L	30.2	28.6	28.8	28.9	28.7	29
	CT 5-1 (FP 5-1)	5' below water	29	29.7	31.5	30.1	28.2	29.7
	CT 14-1 (FP 14-1)	5' below water	22.1	20.1	19	11	13.2	17.1
Submerged	CT 24-1 (FP 24-1)	5' below water	22.6	23.4	23.1	23	23.1	23
	CT 33-1 (FP 33-1)	5' below water	19.2	19.6	21.1	21.2	21	20.4
	CT 43-1 (FP 43-1)	5' below water	23.1	23.7	25.6	24.8	24.8	24.4

Support Framing Metal Thickness Measurements

Exposure Zone	Element	Location Description	Thickness (in.)					Avg. Thickness (in.)
Atmospheric	SF 5-1	11.5' above water	.838	.842	.842	.839	.844	.841
	SF 14-1	12' above water	.833	.834	.834	.835	.848	.837
	SF 22-1	4.5' above water	.521	.533	.522	.531	.524	.526
	SF 33-1	12' above water	.862	.855	.860	.857	.858	.858
Splash	SF 3-1	3' above water	.534	.534	.532	.529	.520	.530
	SF 9-1	3' above water	.535	.536	.534	.536	.537	.535
	SF 14-1	3.5' above water	.516	.524	.517	.518	.519	.519
	SF 15-1	2' above water	.513	.514	.513	.514	.534	.518
	SF 22-1	3.5' above water	.802	.801	.801	.797	.799	.800
	SF 29-1	3' above water	.534	.563	.560	.558	.541	.551
	SF 38-1	1' above water	.507	.584	.765	.747	.566	.634
	SF 41-1	3' above water	.676	.718	.676	.737	.665	.694
	SF 43-1	1' above water	.538	.551	.536	.522	.521	.534
	SF 47-1	3.5' above water	.513	.514	.515	.515	.513	.514
Tidal	SF 3-1	1' above water	.203	.383	.206	.395	.278	.293
	SF 9-1	~ 1' above water	.515	.515	.515	.515	.515	.515
	SF 29-1	~ 1' above water	.515	.515	.515	.515	.515	.515
	SF 38-1	~ 1' above water	.555	.555	.555	.555	.555	.555
	SF 43-1	~ 1' above water	.540	.540	.540	.540	.540	.540

Support Framing Coating Thickness Measurements

Exposure Zone	Element	Location Description	Thickness (mils)					Avg. Thickness (mils)
Atmospheric	CT 5-2 (SF 5-1)	11.5' above water	13.5	12.9	13	12.6	13.5	13.1
	CT 14-2 (SF 14-1)	12' above water	14.2	14.1	14	12.3	12.4	13.4
	CT 24-2 (SF 24-1)	4.5' above water	12	10.6	10.3	14.2	10.2	11.5
	CT 33-2 (SF 33-1)	12' above water	13.4	13.7	13.4	13.5	13.7	13.5
Splash	CT 3-2 (SF 3-1)	3' above water	10	9.3	9.9	9.7	9.6	9.7
	CT 9-2 (SF 9-1)	3' above water	10.3	9.8	9.3	10.1	9.2	9.7
	CT 14-2 (SF 14-1)	3.5' above water	9.7	10	10.1	10.1	10.3	10
	CT 15-2 (SF 15-1)	2' above water	17	15.6	17.7	15.2	13.3	15.8
	CT 22-2 (SF 22-1)	3.5' above water	26.6	28.2	26.1	29.1	28.8	27.8
	CT 29-2 (SP 29-1)	3' above water	9.3	9.6	9	9.7	9.5	9.4
	CT 38-2 (SF 38-2)	1' above water	32.4	30.1	30.3	34.2	37	32.8
	CT 41-2 (SF 41-1)	3' above water	27.6	29.6	25.2	26.8	28.1	27.5
	CT 43-2 (SF 43-1)	1' above water	12	12.2	11.2	13.3	11	11.9
	CT 47-2 (SF 47-1)	3.5' above water	9.6	9.2	9.4	9.4	9.7	9.5
Tidal	CT 3-2 (SF 3-1)	1' above water	26.7	31.6	32.5	27.7	33.2	30.3
	CT 9-2 (SF 9-1)	~ 1' above water	28.6	27.2	26.7	27.2	28.4	27.6
	CT 38-2 (SF 38-2)	Galvanized (~ 1' above water)	9	9.2	8	8.4	8.6	8.6
	CT 43-2 (SF 43-1)	Galvanized (~ 1' above water)	10.7	11.2	10.6	10.3	11.2	10.8

Coating Adhesion Measurements

Element	Location Description	Adhesion (psi)			Avg. Adhesion (psi)	Notes
CT 22-1 (FP 22-1)	Atmospheric	917	808	670	798	4.5’ from high tide
CT 22-2 (SF 22-1)	Atmospheric	955	1084	1146	1062	3.5” from high tide
CT 31-1 (FP 31-1)	Atmospheric	1406	1375	1810	1530	4.5’ above high tide
CT 31-2 (SF 31-1)	Splash	1640	1059	1550	1416	2’ above high tide
CT 15-4 (BW 15-1)	Atmospheric	179	200	188	189	1.5’ below deck underside
CT 35-4 (BW35-1)	Atmospheric	360	289	346	332	4.5’ below deck underside

Property:	Barbours Cut Terminal	**Asset ID:**	BCT 5
Inspection Type:	☒Baseline ☐Routine ☐ Special	**Inspection Date:**	April 21-22, 2020 (abovewater) August 4-5, 2020 (underwater)
Scope of Inspection	Entire Asset, Above Water and Under Water		
Inspection Firm(s):	**Prime**: Wiss, Janney, Elstner Associates, Inc. (WJE)		
	Underwater: Rio Engineering, Inc.		
	Other (role): N/A		
Reported By:	C. Jones, WJE	**Report Date:**	October 6, 2020

Follow-up Actions

Item No.:	1	**Priority:**	☒Priority ☐Routine
Component:	Impressed Current Cathodic Protection System		
Element Type:	DC Power Supply	**Element ID(s):**	PW 5-1
Condition Identified:	Rectifier was turned off when the cover was initially opened. The time duration for which the rectifier was turned off is unknown.		
Reason for action:	ICCP system cannot function with rectifiers turned off.		
Recommended Action:	Routinely check rectifiers are turned on and functioning. NOTE: The rectifier was turned on and left running after completion of the inspection.		

Figure 1. As-found power switch of the landside rectifier in Bay 5 was turned off.

Item No.:	2	**Priority:**	☒Priority ☐Routine
Component:	Impressed Current Cathodic Protection System		
Element Type:	DC Power Supply	**Element ID(s):**	WI 5-3, 14-3, 24-3, 37-3, and 43-3
Condition Identified:	Bond wires intended to electrically connect the fender system to the bulkhead wall were severed at the fender.		
Reason for action:	Without the bond wiring electrically connecting the fender system to the bulkhead wall, ICCP is not being provided to the fender system. This was further evidenced with potential measurements of the fender system not meeting cathodic polarization requirements.		
Recommended Action:	Restore connections of the bond wires to the fender system to ensure ICCP is provided to the fender system as designed. After establishing these connections, perform CP measurements at the bulkhead wall and fender system to ensure protection of these elements is adequate.		

Figure 2. Severed connection of bond wire at fender (Bay 24 shown).

Item No.:	3	**Priority:**	☐Priority ☒Routine
Component:	Protective Coating		
Element Type:	Fender Coating	**Element ID(s):**	CT25-3, CT45-3, CT46-3, CT47-3
Condition Identified:	Lower horizontal framing members were missing a topcoat and steel exhibited significant section loss.		
Reason for action:	Apparent corrosion has resulted in loss of capacity of the base steel support framing members.		
Recommended Action:	Clean and coat these horizontal fender framing members. Alternatively remove and replace these members.		

Figure 2. Coating deterioration of steel structure elements

Item No.:	5	**Priority:**	☐Priority ☒Routine
Component:	Protective Coating		
Element Type:	Bulkhead wall coating	**Element ID(s):**	CT 1-4, 2-4, 3-4, 4-4, 5-4, 6-4, 7-4, 8-4, 9-4, 10-4, 11-4, 12-4, 13-4, 14-4, 15-4, 16-4, 17-4, 18-4, 19-4, 20-4, 21-4, 22-4, 23-4, 24-4, 25-4, 26-4, 27-4, 28-4, 29-4, 30-4, 31-4, 32-4, 33-4, 34-4, 35-4, 36-4, 37-4, 38-4, 39-4, 40-4, 41-4, 42-4, 43-4, 44-4, 45-4, 46-4, 47-4, 48-4
Condition Identified:	Failure of coating and underlying corrosion on bulkhead sheet pile wall.		
Reason for action:	Corrosion will continue to proceed and lead to additional section loss. Members and connections at whale beam may become non-functional.		
Recommended Action:	Clean and coat bulkhead wall.		

Figure 3. Protective coating failing leading to 50% consumption of bulk anode

Follow-up Actions Log

Item No.	Priority	Recommended Action	Assigned To	Assigned By	Date
1*	Priority	Turn on rectifier.	PHA/WJE	WJE	April 22, 2020
2	Priority	Restore connections of the bond wires to the fender system to ensure ICCP is provided to the fender system as designed.			
3	Priority	Repair fender coating system			
4	Priority	Repair bulkhead coating system			

* Documented for the purposes of showing when rectifier was turned on.

Maritime Asset Inspection History

Property:	Barbours Cut Terminal	**Asset ID:**	BCT 5
Asset Classification:	Wharf	**Year of Original Construction:**	1990
Inspection Frequency:	Ref. Inspection Plan	**Year(s) of Significant Modifications or Repairs:**	2002, 2004, 2008, 2011

Dates of Inspections, Asset, and Component Ratings

Date:	1/24/2020				
Inspection Type:	Baseline				
Inspection Status	Completed				
Inspection Firm: Above Water	WJE				
Inspection Firm: Underwater	Rio				
Corrosion Condition Rating (CCR)	**70**				
Corrosion Protection (CP)	**38**				
ICCP Functionality	4				
ICCP Visual	4				
SA Functionality	NA				
SA Visual	NA				
Surface Protection	3				
Base Metal (BM)	**32**				
Critical	5				
Typical	4				
Redundant	4				

APPENDIX G – CORROSION INSPECTION DRAWINGS

CONSULTANT:
WJE | ENGINEERS ARCHITECTS MATERIALS SCIENTISTS
Wiss, Janney, Elstner Associates, Inc.
9511 N. Lake Creek Parkway
Austin, Texas 78717
512.257.4800 tel | 512.219.9883 fax
TEXAS REGISTERED ENGINEERING FIRM F-0093
Headquarters & Laboratories: Northbrook, Illinois
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Honolulu | Houston | Los Angeles | Minneapolis | New Haven | New York
Princeton | San Francisco | Seattle | South Florida | Washington, D.C.

WJE PROJECT No.: 2018.6620.0

SEAL:

BASELINE DRAWINGS

NOT FOR CONSTRUCTION

PORT OF HOUSTON AUTHORITY · HOUSTON, TEXAS

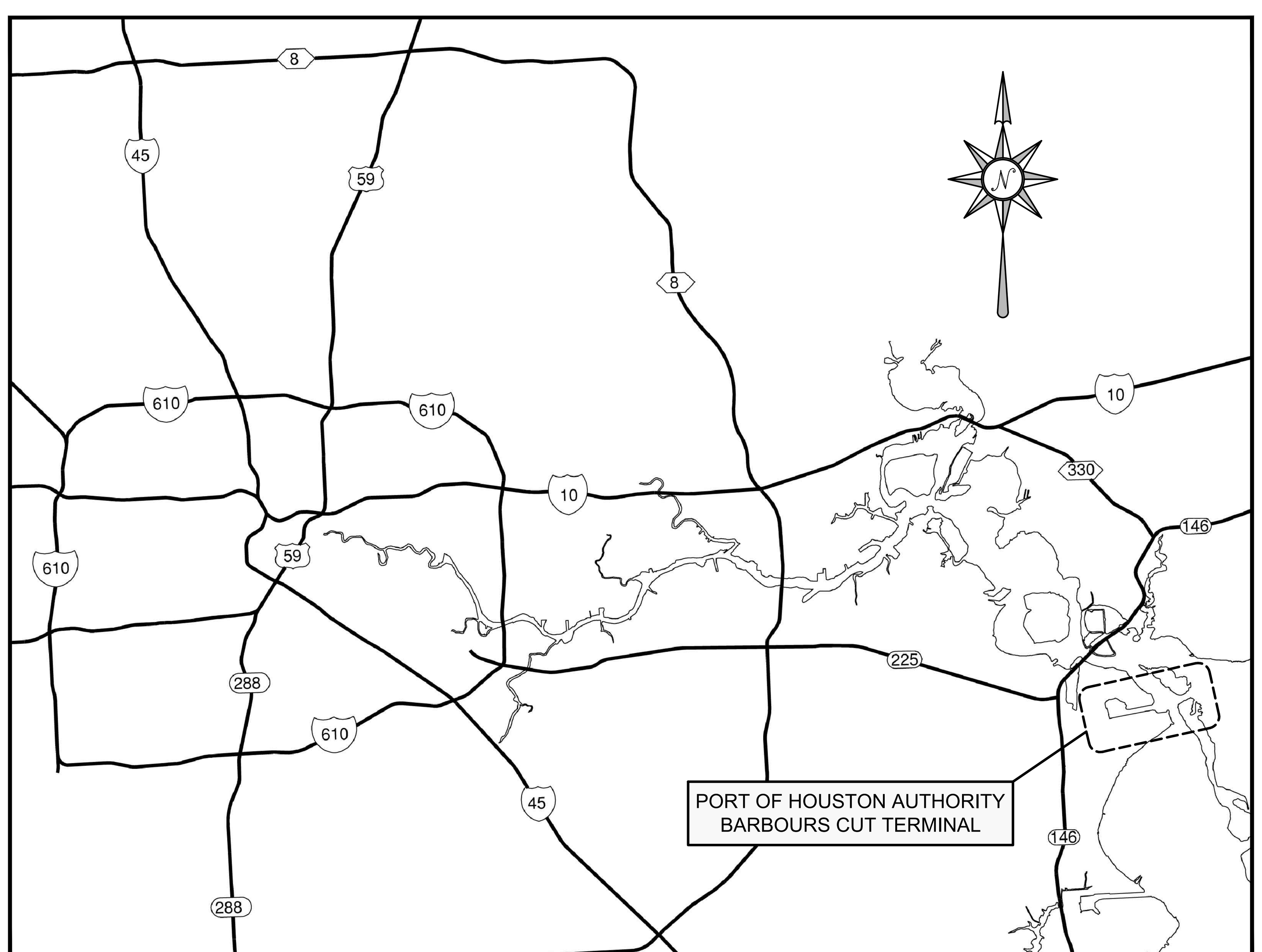
PORT OF HOUSTON AUTHORITY

FACILITY INSPECTION & CONDITION ASSESSMENT PROGRAM (FICAP)

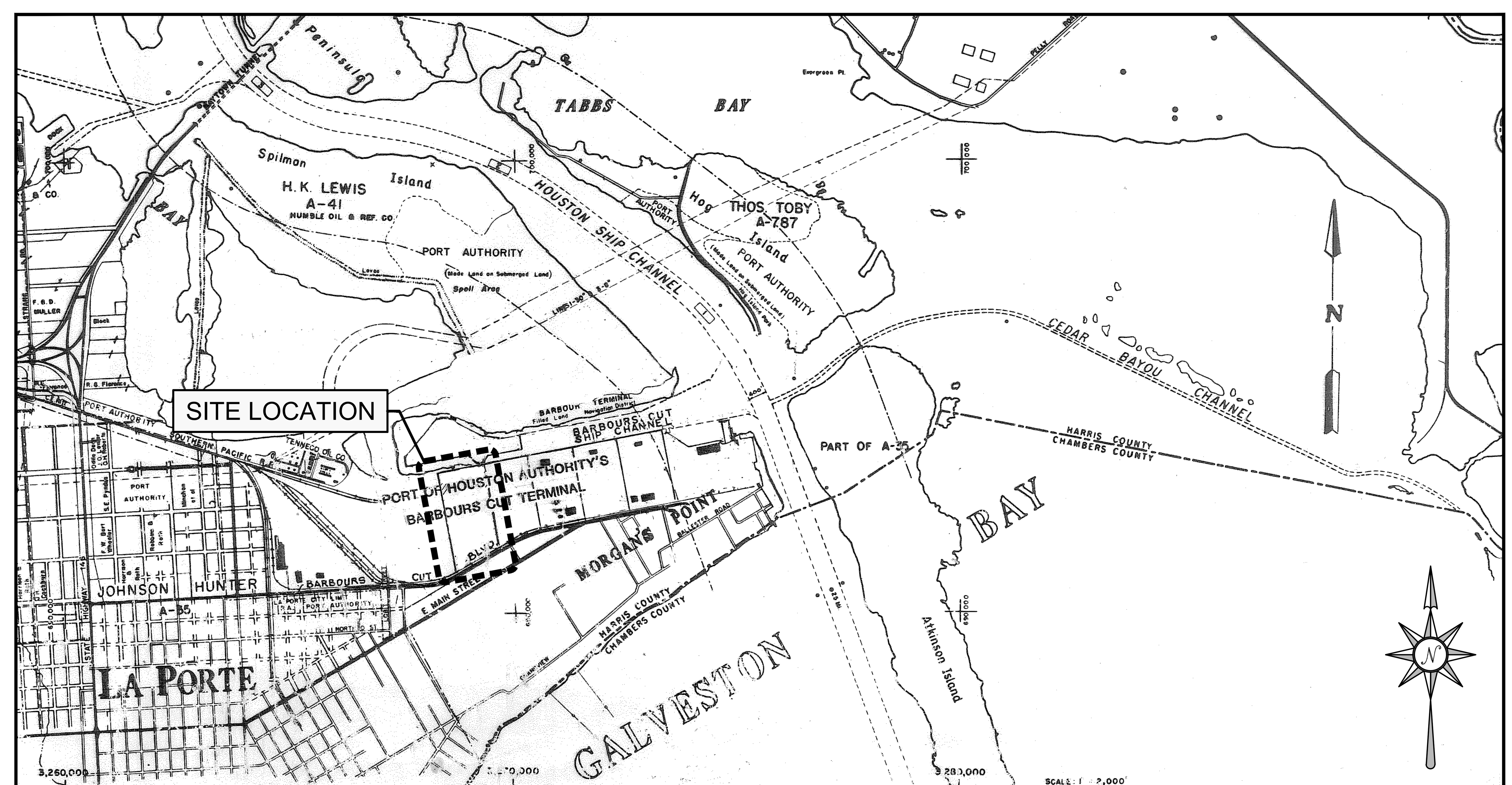
CORROSION INSPECTION DRAWINGS FOR WHARF No. 5 AT BARBOURS CUT TERMINAL

DWG NO. C60-D32-001

MAY 25, 2021



VICINITY MAP



LOCATION MAP

DRAWING No: C60-D32-001

SHEET No: G-001

REV. No:

REFERENCED HISTORICAL DRAWINGS

DRAWING SET	TITLE	DATE	DESCRIPTION
C107-3	PAVEMENTS AND UTILITIES FOR CONTAINER TERMINAL No. 5 AT BARBOUR'S CUT - PHASE I	8/27/1986	PHASE 1 OF ORIGINAL CIVIL AND ELECTRICAL DRAWINGS
C107-4	SHEET PILE BULKHEAD FOR WHARVES No.'S 5 AND 6 AT BARBOUR'S CUT TERMINAL	2/16/1988	ORIGINAL CONSTRUCTION DRAWINGS FOR BULKHEAD
C107-5	PAVEMENTS AND UTILITIES FOR CONTAINER TERMINAL No. 5 AT BARBOUR'S CUT - PHASE II	5/24/1988	PHASE 2 OF ORIGINAL CIVIL AND ELECTRICAL DRAWINGS
C107-6	CONTAINER TERMINAL No. 5 AT BARBOUR'S CUT PERMINAL	7/18/198	ORIGINAL CONSTRUCTION DRAWINGS FOR WHARF
C107-5	PAVEMENTS AND UTILITIES FOR CONTAINER TERMINAL No. 5 AT BARBOUR'S CUT - PHASE II	9/20/1990	MODIFIED PHASE 2 OF ORIGINAL CIVIL AND ELECTRICAL DRAWINGS
C107-12	REPAIR OF FENDER SYSTEM AT WHARF No. 5	11/05/2002	FENDER REPAIR DRAWINGS
C107-13	REPAIR OF FENDER SYSTEM AND POTABLE WATER LINE	02/23/2004	FENDER AND UTILITY REPAIR DRAWINGS
C160-60	CRANE RAIL REPAIR	08/30/2004	CRANE RAIL EXPANSION JOINT REPAIR DRAWINGS
C60-D02-002	FENDER SYSTEM MAINTENANCE AT BARBOUR'S CUT TERMINAL	10/16/2008	FENDER REPAIR AND MAINTENANCE DRAWINGS
C60-D02-005	ANNUAL FENDER SYSTEM MAINTENANCE AT BARBOUR'S CUT TERMINAL 2012	10/03/2011	FENDER REPAIR AND MAINTENANCE DRAWINGS

DRAWING SHEET INDEX

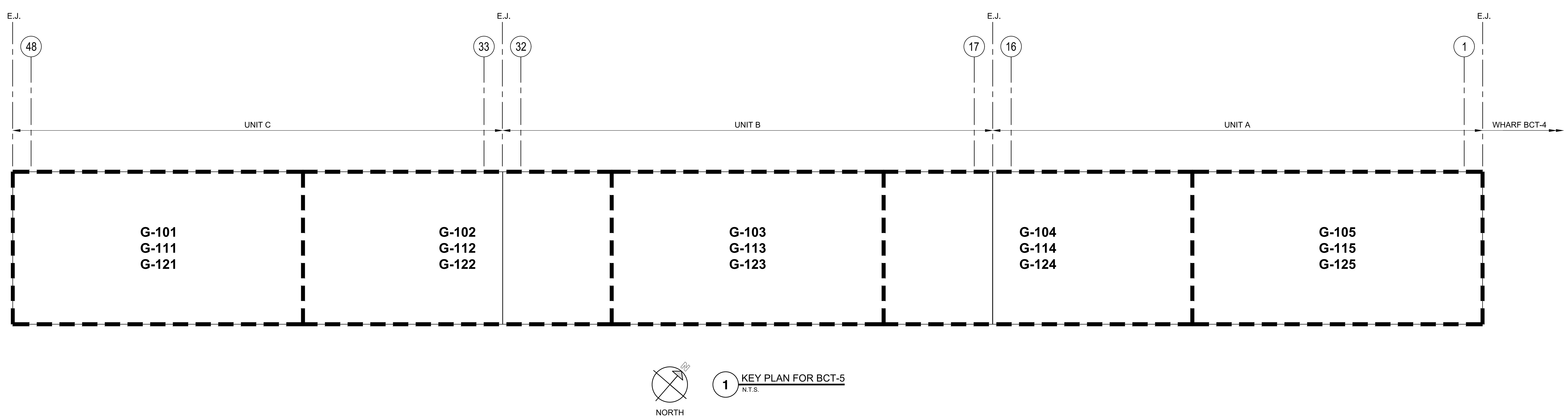
No.	SHEET TITLE
G-001	COVER SHEET
G-002	PROJECT INFORMATION
G-101	BAY DEFINITIONS PLAN - UNIT A
G-102	BAY DEFINITIONS PLAN - UNIT A / B
G-103	BAY DEFINITIONS PLAN - UNIT B
G-104	BAY DEFINITIONS PLAN - UNIT B / C
G-105	BAY DEFINITIONS PLAN - UNIT C
G-111	CORROSION PROTECTION ELEMENTS PLAN - UNIT A
G-112	CORROSION PROTECTION ELEMENTS PLAN - UNIT A / B
G-113	CORROSION PROTECTION ELEMENTS PLAN - UNIT B
G-114	CORROSION PROTECTION ELEMENTS PLAN - UNIT B / C
G-115	CORROSION PROTECTION ELEMENTS PLAN - UNIT C
G-121	BASE METAL ELEMENTS PLAN - UNIT A
G-122	BASE METAL ELEMENTS PLAN - UNIT A / B
G-123	BASE METAL ELEMENTS PLAN - UNIT B
G-124	BASE METAL ELEMENTS PLAN - UNIT B / C
G-125	BASE METAL ELEMENTS PLAN - UNIT C
G-201	TYPICAL SECTIONS
G-301	TYPICAL ELEVATIONS

SYMBOLS LEGEND

X DRAWING LABEL 1/4" = 1'-0"	-	PLAN / DETAIL NAME LABEL
# S-201	-	ELEVATION CALLOUT
# S-401	-	SECTION CALLOUT
# S-301	-	DETAIL / VIEW CALLOUT
XX-#	-	KEYED REPAIR / OBSERVATION
LEVEL-1 EL.= XX.XX'	-	ELEVATION MARKER
A — A	-	DRAWING MATCHLINE
X	-	STRUCTURAL GRIDLINE
N	-	NORTH ARROW

ABBREVIATIONS

&	AND
ADD'L.	ADDITIONAL
ALT.	ALTERNATE
APPROX.	APPROXIMATE
℄	CENTERLINE
C	STEEL CHANNEL SECTION
CJ	CONSTRUCTION JOINT
CONC.	CONCRETE
CONT.	CONTINUOUS
CL	COLUMN
CP	CATHODIC PROTECTION
DB	DECK BEAM
DBL	DECK BEAMLINE
DC	DECK COATING
DIAG.	DIAGONAL
DIA.	DIAMETER
DIM(S).	DIMENSION(S)
DS	DECK SLAB
EA.	EACH
EJ	EXPANSION JOINT
EQ.	EQUAL
EXP.	EXPANSION
FRP	FIBER REINFORCED POLYMER
FS	FENDER STEEL
FT	FENDER TIMBER
GALV.	GALVANIZED
H.S.	HIGH-STRENGTH
HORIZ.	HORIZONTAL
IJ	ISOLATION JOINT
K	KIP (1,000 POUNDS)
LF	LINEAR FEET
MAX.	MAXIMUM
MIN.	MINIMUM
MISC.	MISCELLANEOUS
MLT.	MEAN LOW TIDE
MPH	MILES PER HOUR
No. or #	NUMBER
ℙ	PLATE
PC	PILE CAP
PSF	POUNDS PER SQUARE FOOT
REQ'D.	REQUIRED
RSB	RAIL SWITCH BOX
SB	STRUT BEAM
SBL	STRUT BEAMLINE
SF	SQUARE FEET
SIM.	SIMILAR
SP	SHEET PILE
SW	SHEAR WALL
T.O.	TOP OF ......
TYP.	TYPICAL(LY)
U.N.O.	UNLESS NOTED OTHERWISE
VB	VALVE BOX
VERT.	VERTICAL
V.I.F.	VERIFY IN FIELD
W/	WITH
WP	WORKING POINT



1 KEY PLAN FOR BCT-5
N.T.S.

PORT OF HOUSTON AUTHORITY

CONSULTANT:

WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

Wiss, Janney, Elstner Associates, Inc.
9511 N. Lake Creek Parkway
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TEXAS REGISTERED ENGINEERING FIRM F-0093

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Honolulu | Houston | Los Angeles | Minneapolis | New Haven | New York
Princeton | San Francisco | Seattle | South Florida | Washington, D.C.

WJE PROJECT No.: 2018.6620.0

SEAL:

BASELINE DRAWINGS

NOT FOR CONSTRUCTION

PROJECT TITLE:

FACILITY INSPECTION & CONDITION ASSESSMENT PROGRAM (FICAP)

CORROSION INSPECTION DRAWINGS

SHEET TITLE:

BASELINE DRAWINGS FOR WHARF No. 5 AT BARBOURS CUT TERMINAL:

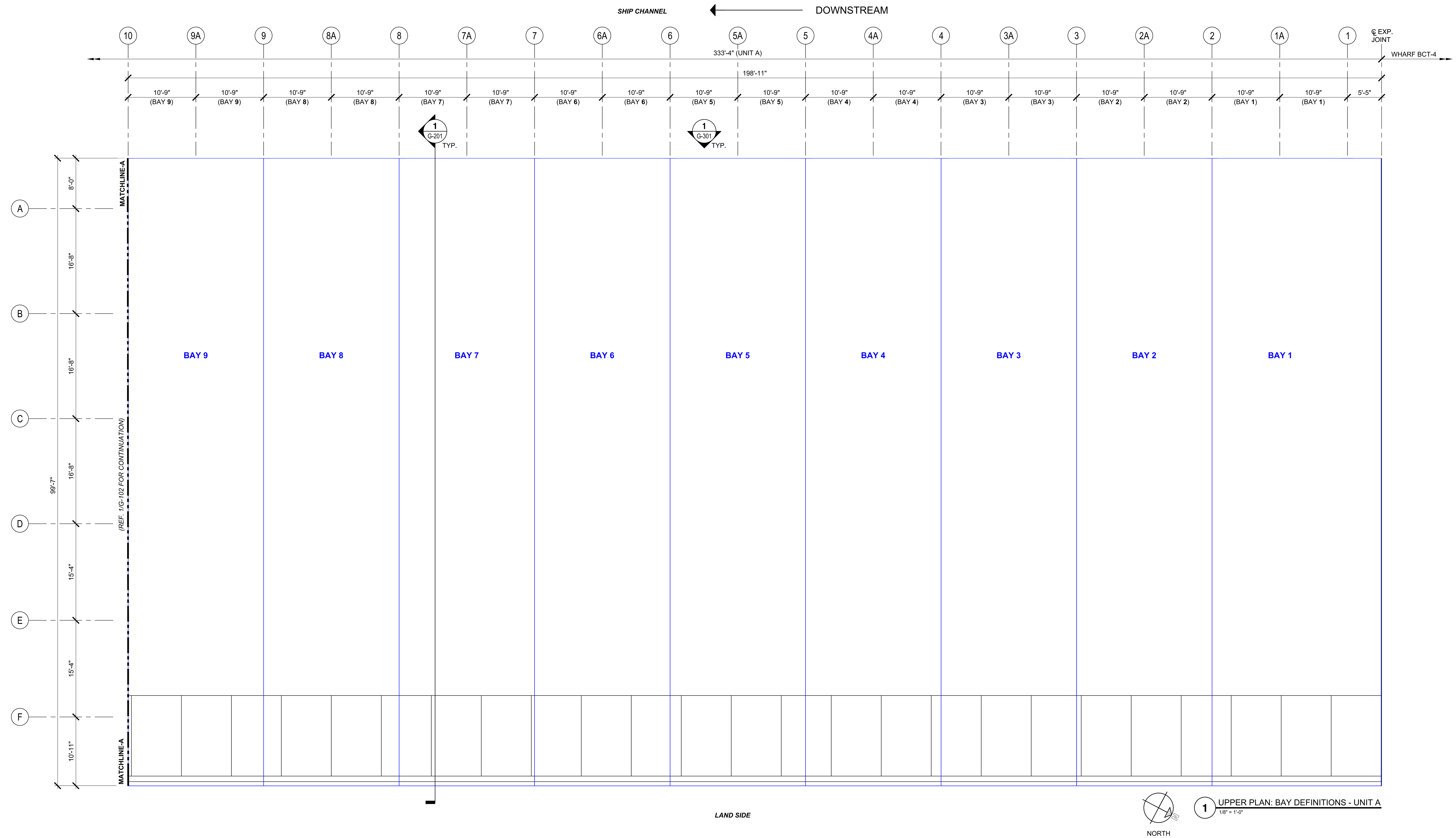
PROJECT INFORMATION

No.	DATE	DESCRIPTION

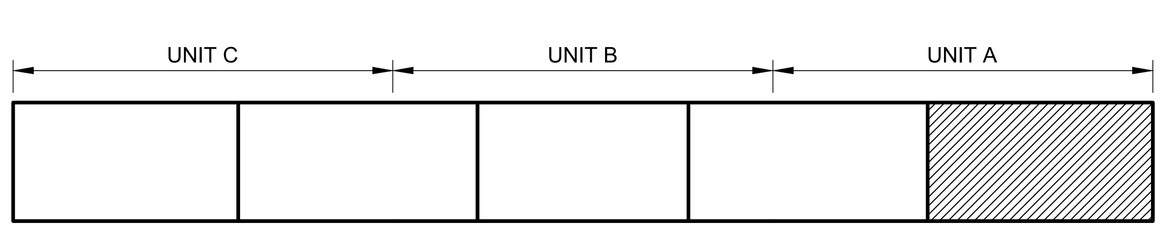
DATE:	05-25-2021
DESIGNER:	SWF
CHECKED BY:	CJL
CADD:	CLM
SCALE:	AS NOTED

DRAWING No: C60-D32-001

SHEET No: G-002 REV. No:



1 UPPER PLAN: BAY DEFINITIONS - UNIT A
1/8" = 1'-0"



KEY PLAN

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FACILITY INSPECTION & CONDITION ASSESSMENT PROGRAM (FICAP)

CORROSION INSPECTION DRAWINGS

SHEET TITLE:

BASELINE DRAWINGS FOR WHARF No. 5 AT BARBOURS CUT TERMINAL:

BAY DEFINITIONS PLAN - UNIT A

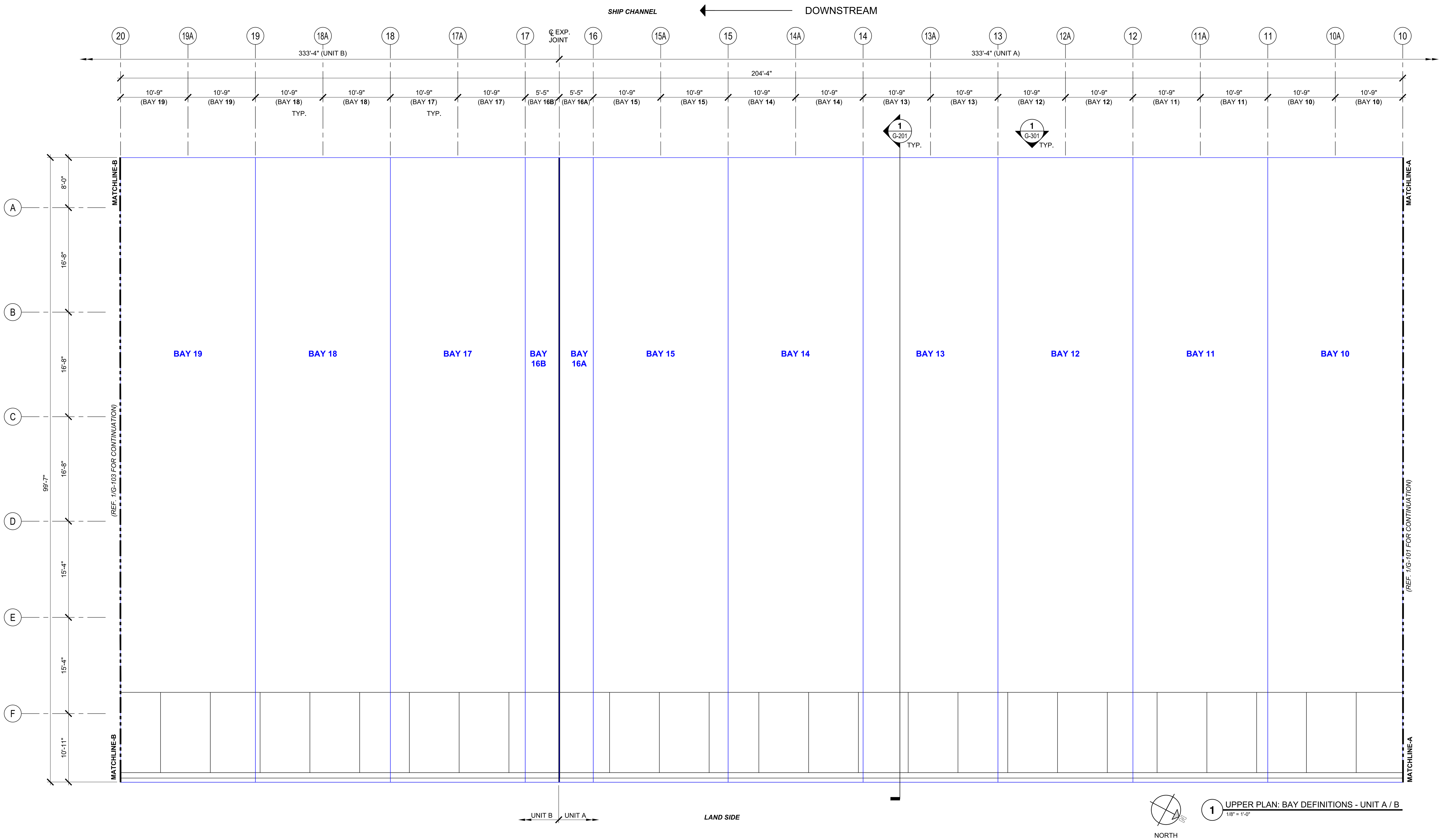
No.	DATE	DESCRIPTION

DATE:	05-25-2021
DESIGNER:	SWF
CHECKED BY:	CJL
CADD:	CLM
SCALE:	AS NOTED

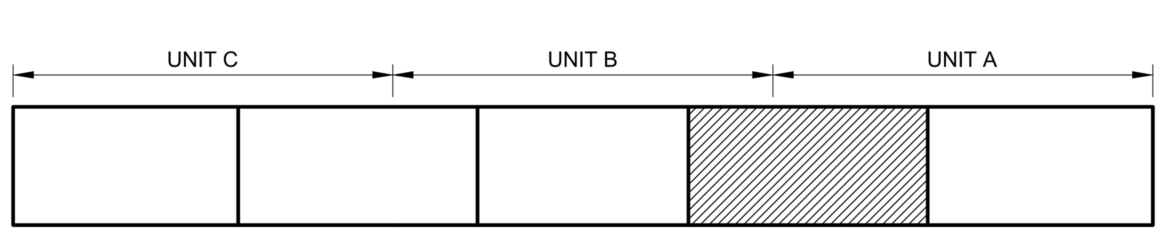
DRAWING No: C60-D32-001

SHEET No: G-101

REV. No:



1 UPPER PLAN: BAY DEFINITIONS - UNIT A / B
1/8" = 1'-0"



KEY PLAN

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SEAL:

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PROJECT TITLE:

FACILITY INSPECTION & CONDITION ASSESSMENT PROGRAM (FICAP)

CORROSION INSPECTION DRAWINGS

SHEET TITLE:

BASELINE DRAWINGS FOR WHARF No. 5 AT BARBOURS CUT TERMINAL:

BAY DEFINITIONS PLAN - UNIT A / B

No.	DATE	DESCRIPTION

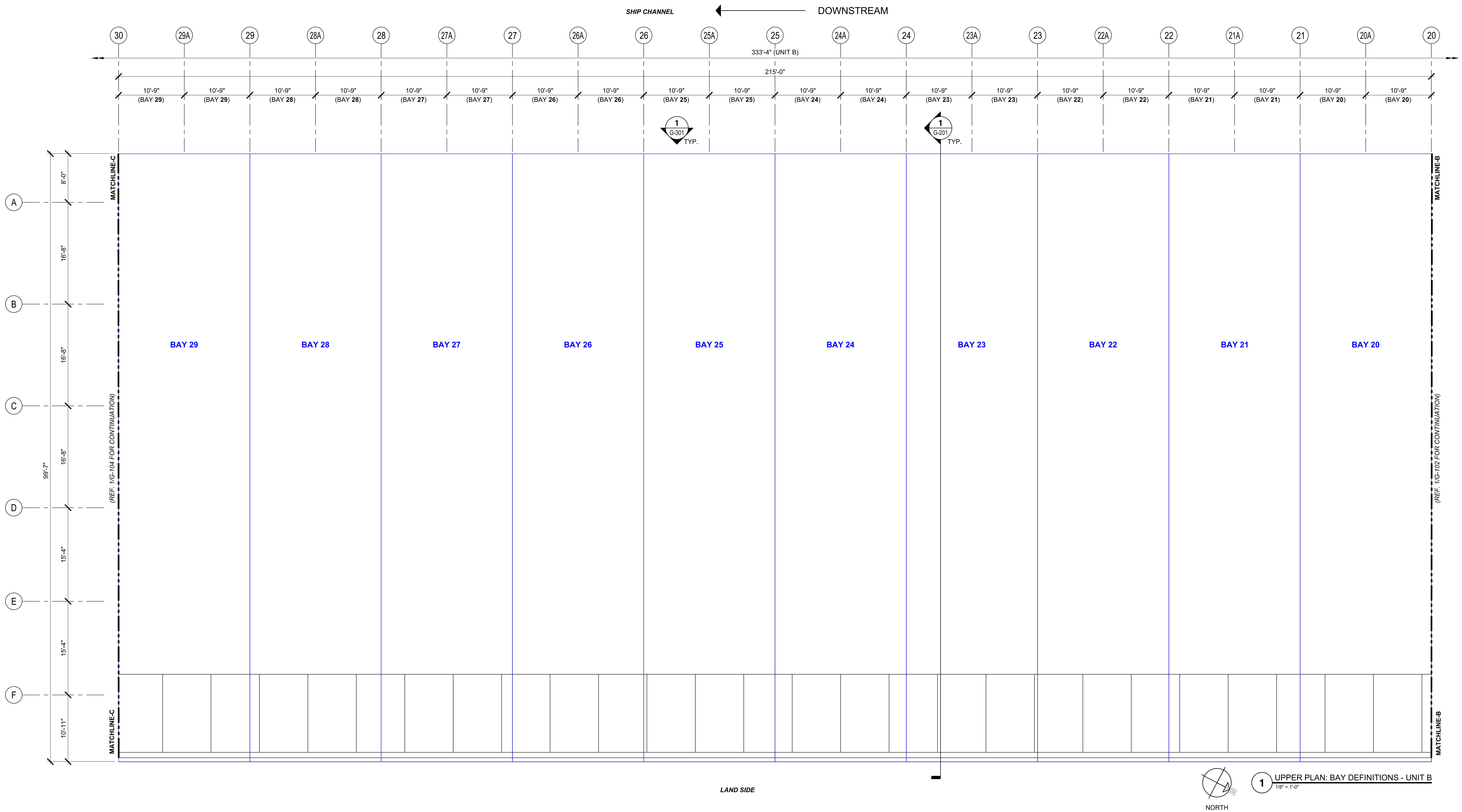
DATE: 05-25-2021
DESIGNER: SWF
CHECKED BY: CJL
CADD: CLM
SCALE: AS NOTED

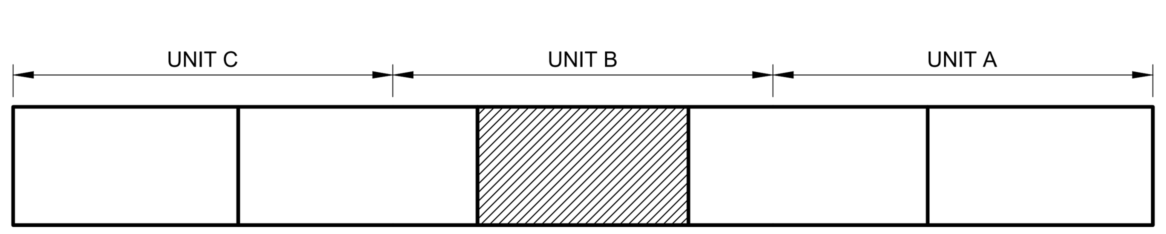
DRAWING No: C60-D32-001

SHEET No: G-102

REV. No:

PLOTTED BY: DiazPerezJr, Armando (10/19/2022 - 11:16 AM)
LAST SAVED BY: CJONES (9/7/2021 - 12:14 PM)
FILE LOCATION: \\wje.com\PA\US\2018\2018.6xxx\2018.6620.0 - PHA - CM SUPPLEMENT TO FICAP RFQ (SWF)\3 CAD\1-BCT5\Working Set





KEY PLAN

PORT OF HOUSTON AUTHORITY

CONSULTANT:

WJE | ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

Wiss, Janney, Elstner Associates, Inc.
9511 N. Lake Creek Parkway
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TEXAS REGISTERED ENGINEERING FIRM F-0093

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Princeton | San Francisco | Seattle | South Florida | Washington, D.C.

WJE PROJECT No.: 2018.6620.0

SEAL:

BASELINE DRAWINGS

NOT FOR CONSTRUCTION

PROJECT TITLE:

FACILITY INSPECTION & CONDITION ASSESSMENT PROGRAM (FICAP)

CORROSION INSPECTION DRAWINGS

SHEET TITLE:

BASELINE DRAWINGS FOR WHARF No. 5 AT BARBOURS CUT TERMINAL:

BAY DEFINITIONS PLAN - UNIT B

No.	DATE	DESCRIPTION

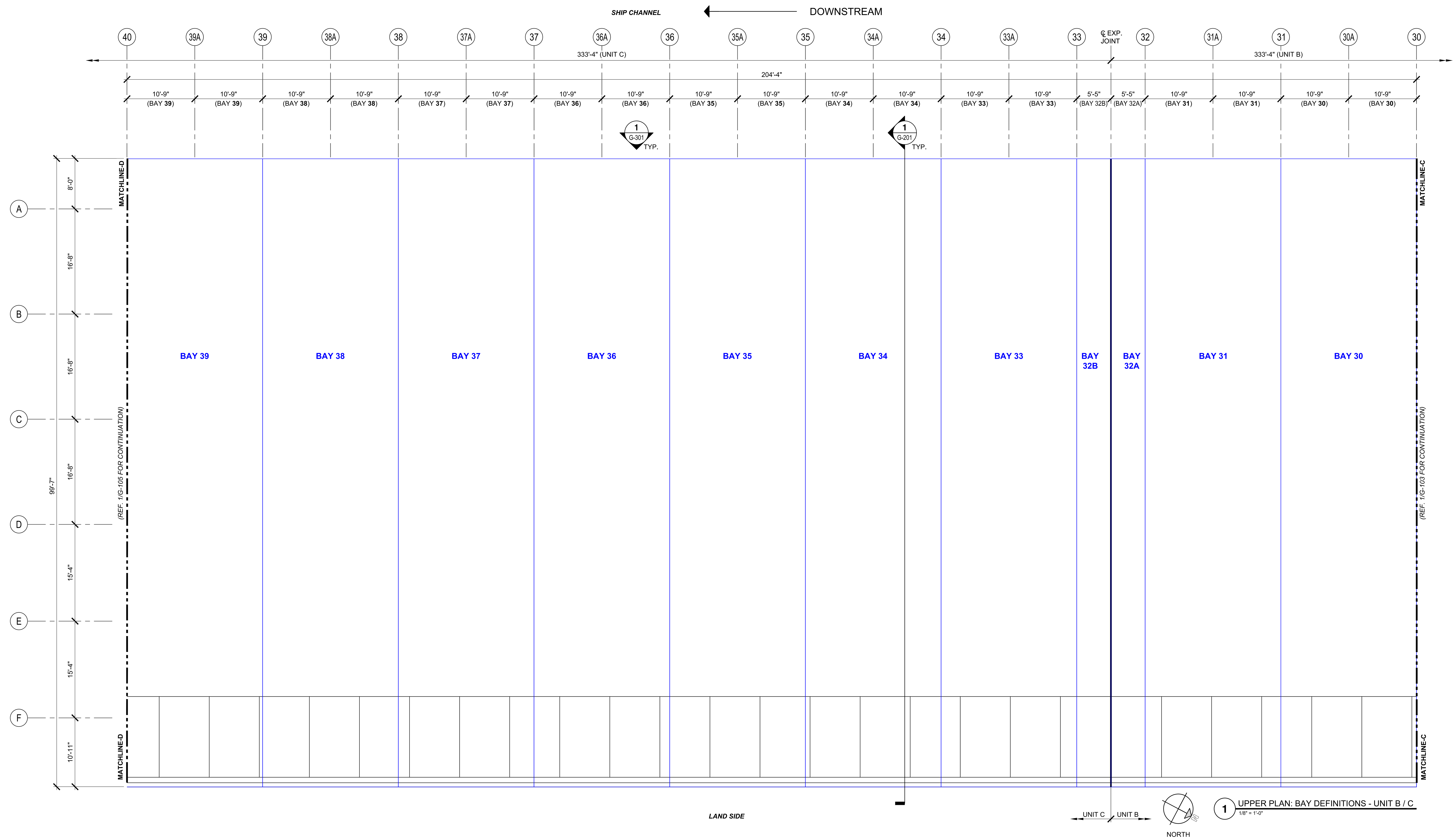
DATE:	05-25-2021
DESIGNER:	SWF
CHECKED BY:	CJL
CADD:	CLM
SCALE:	AS NOTED

DRAWING No: C60-D32-001

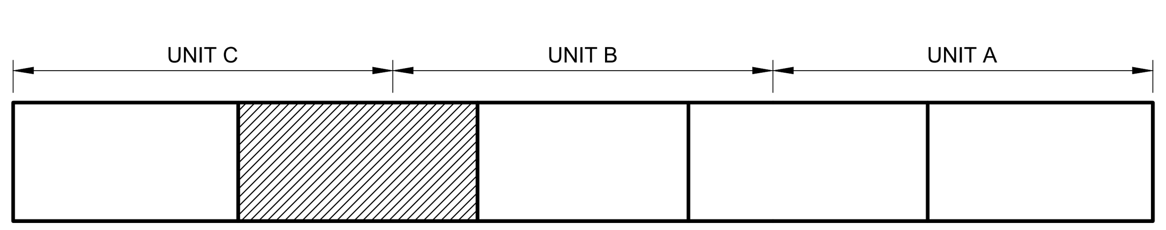
SHEET No: G-103

REV. No:

PLOTTED BY: DiazPerezJr, Armando (10/19/2022 - 11:16 AM)
LAST SAVED BY: CJONES (9/7/2021 - 12:14 PM)
FILE LOCATION: \\wje.com\P\AUS\2018\2018.6xxx\2018.6620.0 - PHA - CM SUPPLEMENT TO FICAP RFQ (SWF)\9 CAD\1-BCT5\Working Set



1 UPPER PLAN: BAY DEFINITIONS - UNIT B / C
1/8" = 1'-0"



KEY PLAN

PORT OF HOUSTON AUTHORITY

CONSULTANT:

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WJE PROJECT No.: 2018.6620.0

SEAL:

BASELINE DRAWINGS

NOT FOR CONSTRUCTION

PROJECT TITLE:

FACILITY INSPECTION & CONDITION ASSESSMENT PROGRAM (FICAP)

CORROSION INSPECTION DRAWINGS

SHEET TITLE:

BASELINE DRAWINGS FOR WHARF No. 5 AT BARBOURS CUT TERMINAL:

BAY DEFINITIONS PLAN - UNIT B / C

No.	DATE	DESCRIPTION

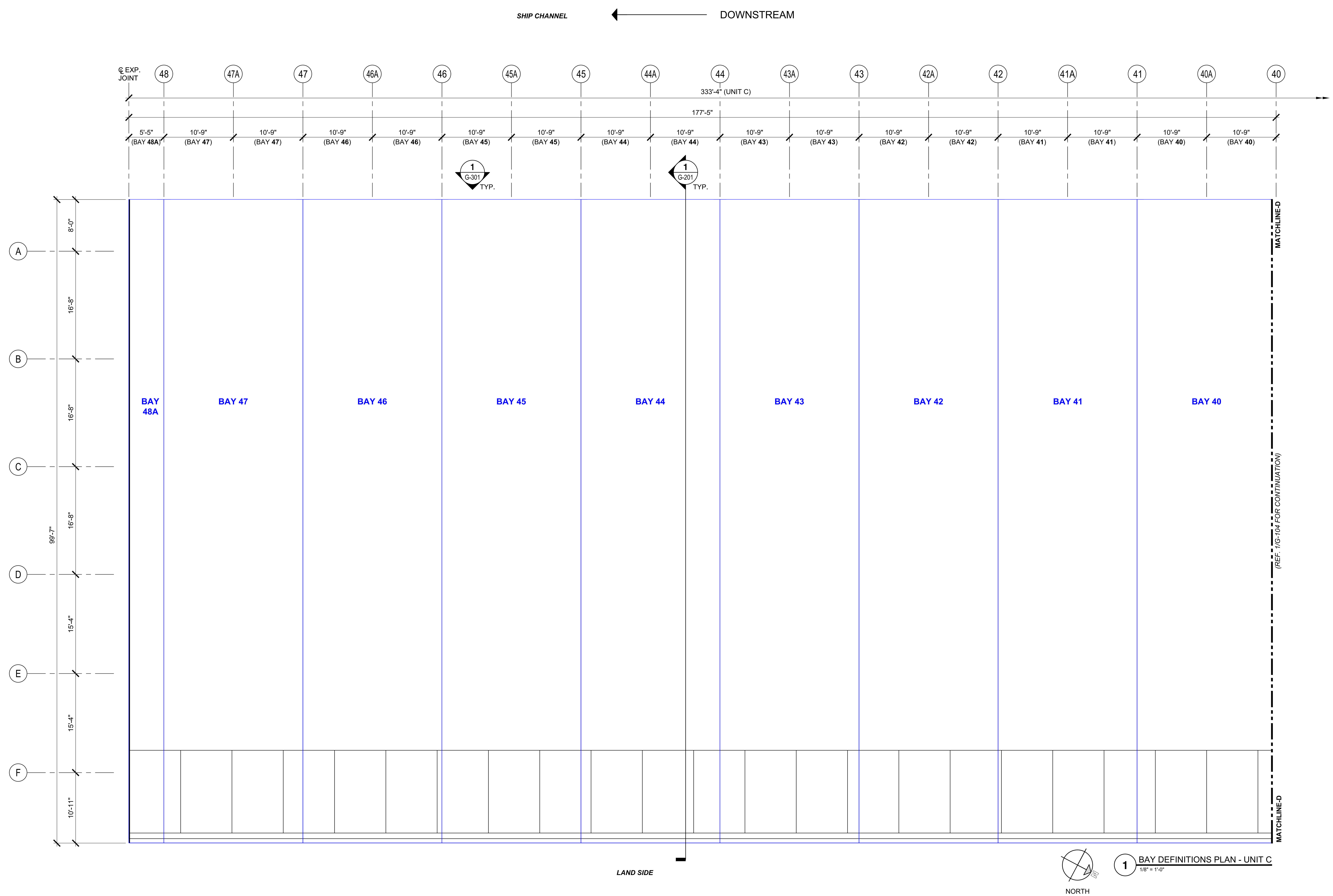
DATE:	05-25-2021
DESIGNER:	SWF
CHECKED BY:	CJL
CADD:	CLM
SCALE:	AS NOTED

DRAWING No: C60-D32-001

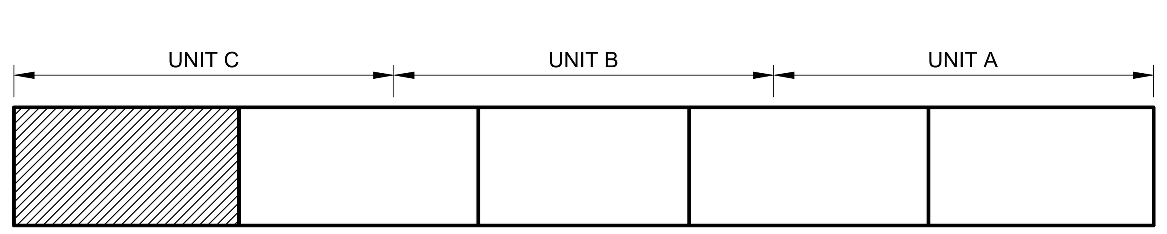
SHEET No: G-104

REV. No:

PLOTTED BY: DiazPerezJr, Armando (10/19/2022 - 11:16 AM)
LAST SAVED BY: CJONES (9/7/2021 - 12:14 PM)
FILE LOCATION: \\wje.com\PA\US\2018\2018.6xxx\2018.6620.0 - PHA - CM SUPPLEMENT TO FICAP RFQ (SWF)\9 CAD\1-BCT5\Working Set



1 BAY DEFINITIONS PLAN - UNIT C
1/8" = 1'-0"



KEY PLAN

PORT OF HOUSTON AUTHORITY

CONSULTANT:

WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

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TEXAS REGISTERED ENGINEERING FIRM F-0093

WJE PROJECT No.: 2018.6620.0

SEAL:

BASELINE DRAWINGS

NOT FOR CONSTRUCTION

PROJECT TITLE:

FACILITY INSPECTION & CONDITION ASSESSMENT PROGRAM (FICAP)

CORROSION INSPECTION DRAWINGS

SHEET TITLE:

BASELINE DRAWINGS FOR WHARF No. 5 AT BARBOURS CUT TERMINAL:

BAY DEFINITIONS PLAN - UNIT C

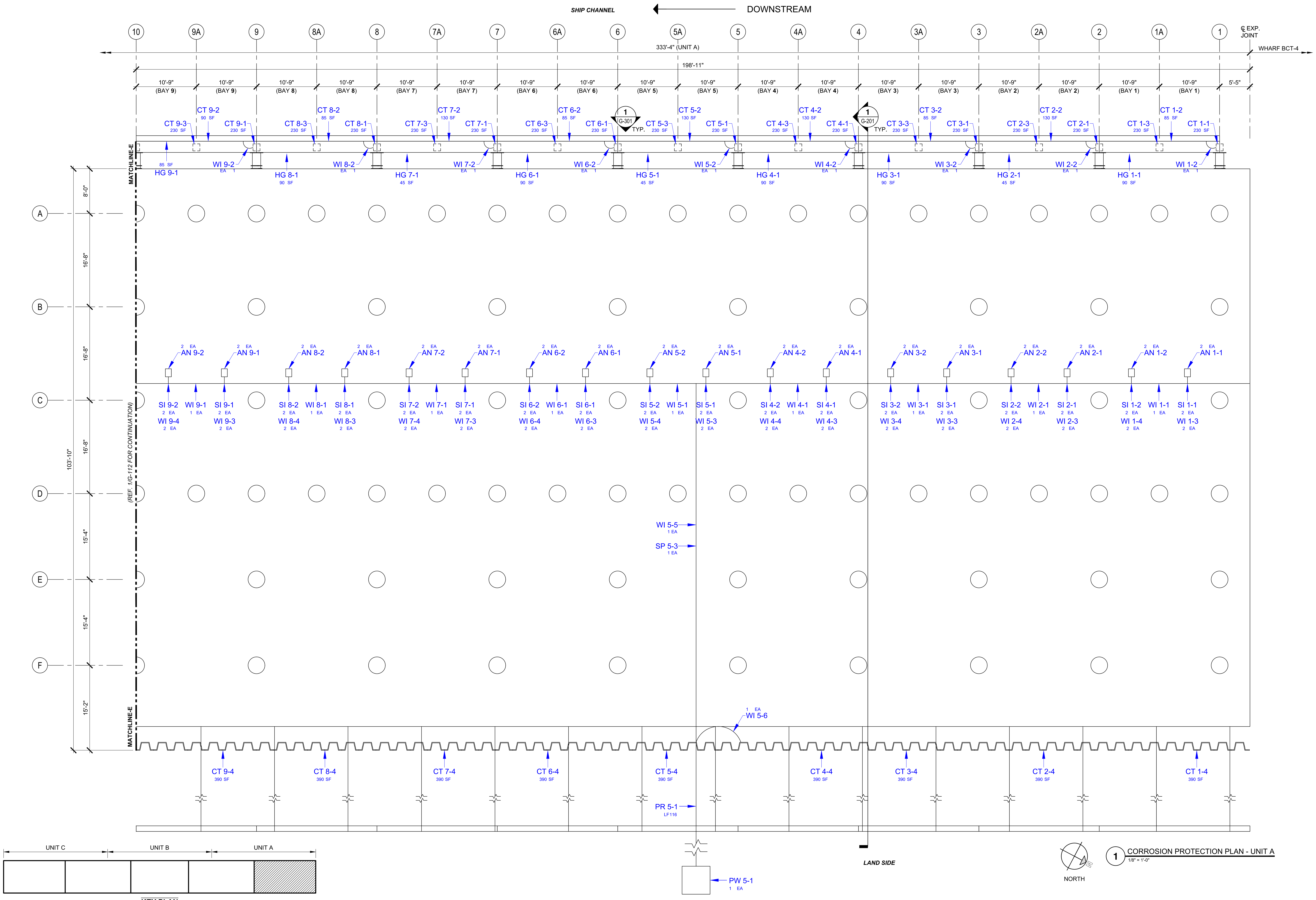
No.	DATE	DESCRIPTION

DATE:	05-25-2021
DESIGNER:	SWF
CHECKED BY:	CJL
CADD:	CLM
SCALE:	AS NOTED

DRAWING No: C60-D32-001

SHEET No: G-105

REV. No:



1 CORROSION PROTECTION PLAN - UNIT A
1/8" = 1'-0"

PORT OF HOUSTON AUTHORITY

CONSULTANT:

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WJE PROJECT No.: 2018.6620.0

SEAL:

BASELINE DRAWINGS

NOT FOR CONSTRUCTION

PROJECT TITLE:

FACILITY INSPECTION & CONDITION ASSESSMENT PROGRAM (FICAP)

CORROSION INSPECTION DRAWINGS

SHEET TITLE:

BASELINE DRAWINGS FOR WHARF No. 5 AT BARBOURS CUT TERMINAL:

CORROSION PROTECTION PLAN - UNIT A

No.	DATE	DESCRIPTION

DATE:	05-25-2021
DESIGNER:	SWF
CHECKED BY:	CJL
CADD:	CLM
SCALE:	AS NOTED

Drawing No: C60-D32-001

Sheet No: G-111

Rev. No:

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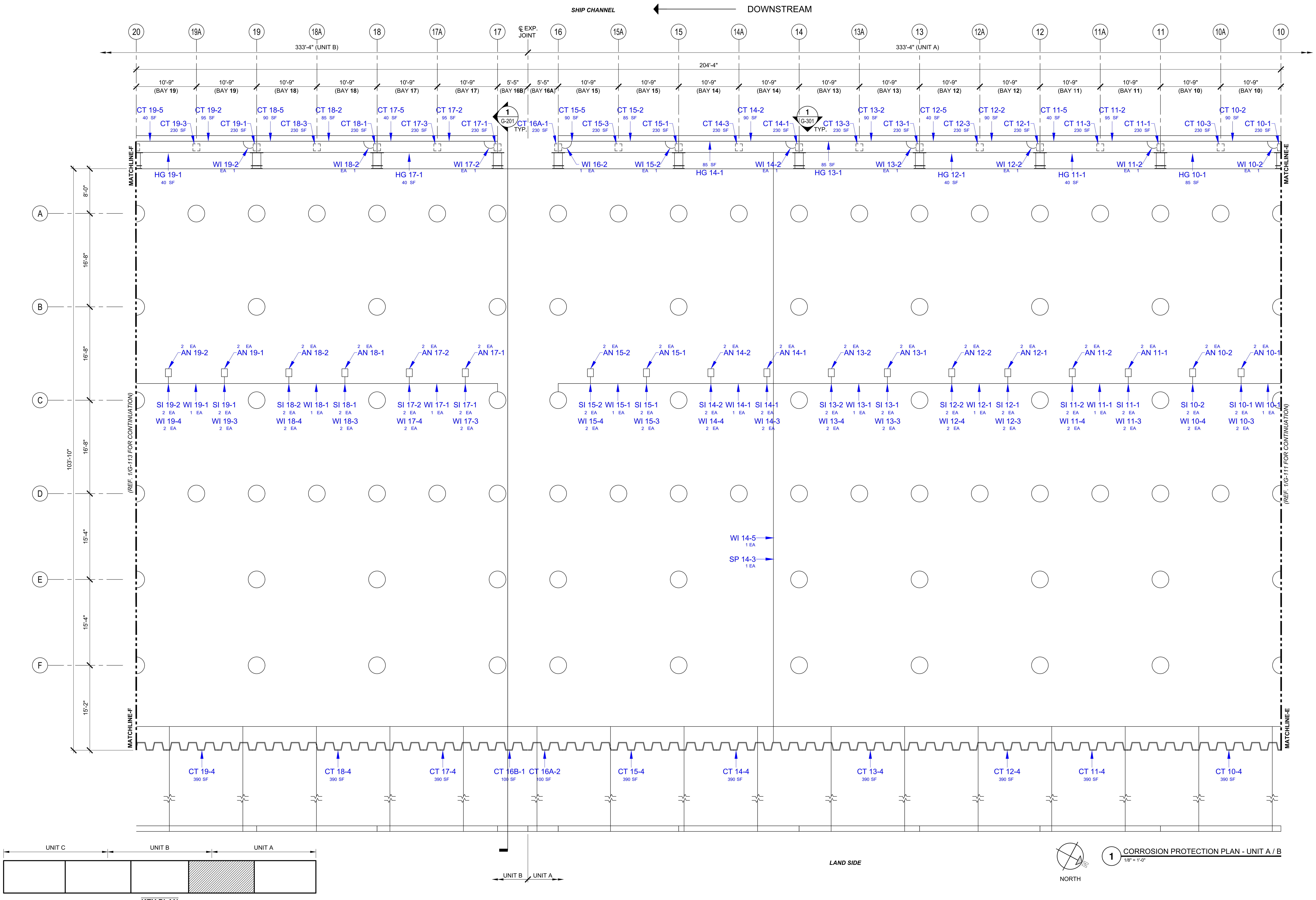

1 CORROSION PROTECTION PLAN - UNIT A / B
1/8" = 1'-0"

PORT OF HOUSTON AUTHORITY

CONSULTANT:

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TEXAS REGISTERED ENGINEERING FIRM F-0093

WJE PROJECT No.: 2018.6620.0

SEAL:

BASELINE DRAWINGS

NOT FOR CONSTRUCTION

PROJECT TITLE:

FACILITY INSPECTION & CONDITION ASSESSMENT PROGRAM (FICAP)

CORROSION INSPECTION DRAWINGS

SHEET TITLE:

BASELINE DRAWINGS FOR WHARF No. 5 AT BARBOURS CUT TERMINAL:

CORROSION PROTECTION PLAN - UNIT A / B

No.	DATE	DESCRIPTION

DATE:	05-25-2021
DESIGNER:	SWF
CHECKED BY:	CJL
CADD:	CLM
SCALE:	AS NOTED

DRAWING No: C60-D32-001

SHEET No: G-112

REV. No:

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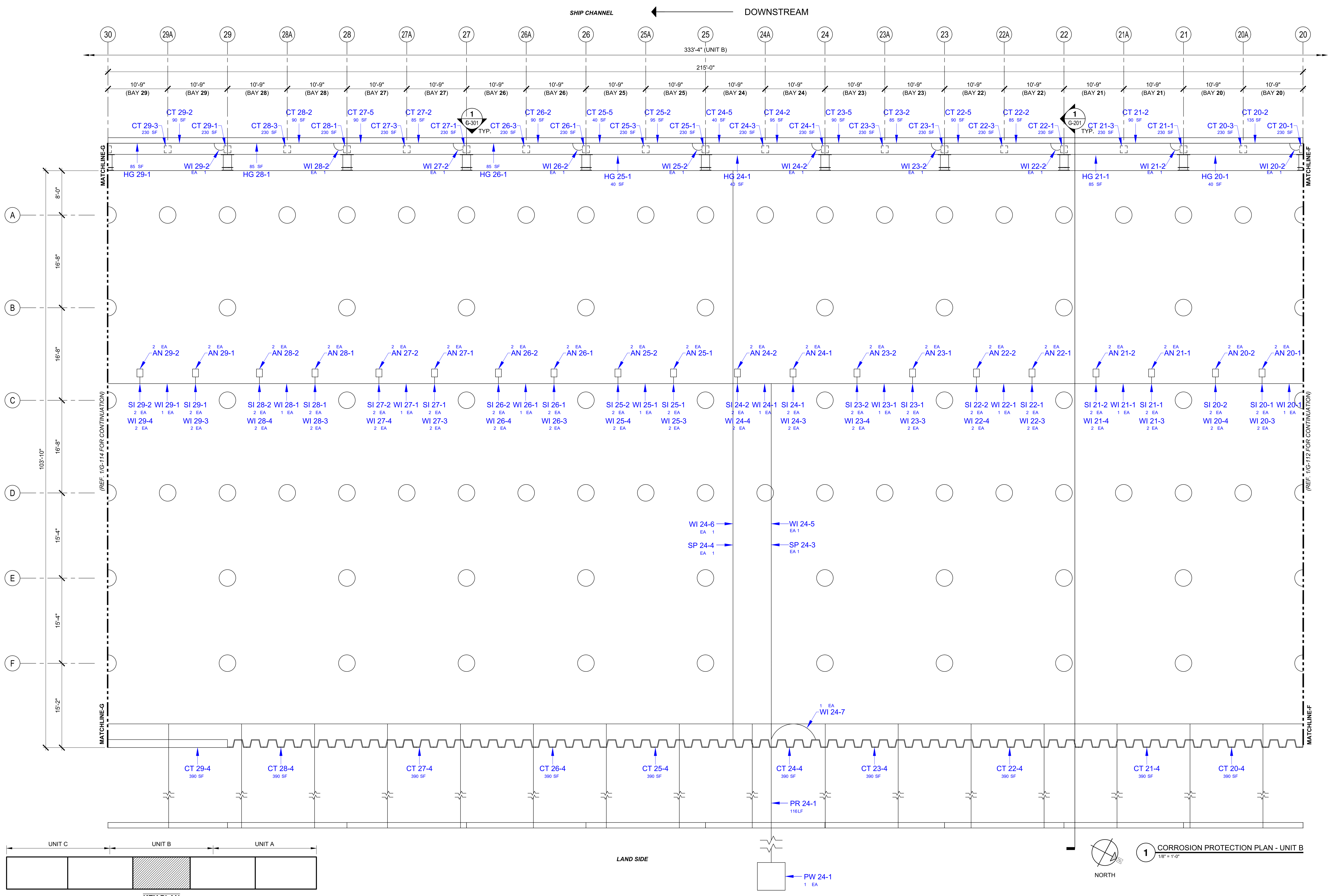

PORT OF HOUSTON AUTHORITY

CONSULTANT:

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WJE PROJECT No.: 2018.6620.0

SEAL:

BASELINE DRAWINGS
NOT FOR CONSTRUCTION

PROJECT TITLE:

FACILITY INSPECTION & CONDITION ASSESSMENT PROGRAM (FICAP)

CORROSION INSPECTION DRAWINGS

SHEET TITLE:

BASELINE DRAWINGS FOR WHARF No. 5 AT BARBOURS CUT TERMINAL:

CORROSION PROTECTION PLAN - UNIT B

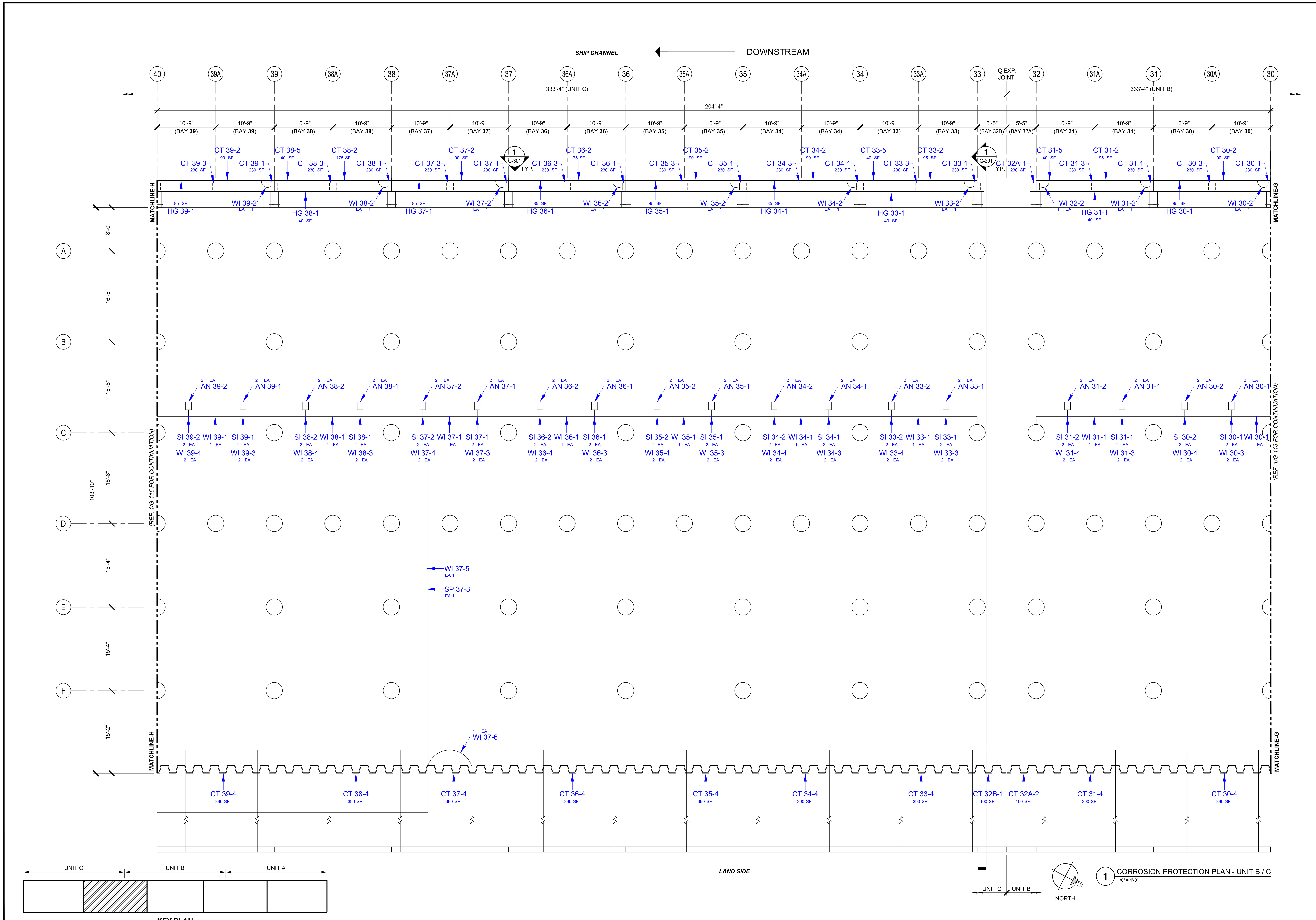
No.	DATE	DESCRIPTION

DATE:	05-25-2021
DESIGNER:	SWF
CHECKED BY:	CJL
CADD:	CLM
SCALE:	AS NOTED

DRAWING No: C60-D32-001

SHEET No: G-113

REV. No:



PORT OF HOUSTON AUTHORITY

CONSULTANT:

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WJE PROJECT No.: 2018.6620.0

SEAL:

BASELINE DRAWINGS
NOT FOR CONSTRUCTION

PROJECT TITLE:

FACILITY INSPECTION & CONDITION ASSESSMENT PROGRAM (FICAP)

CORROSION INSPECTION DRAWINGS

SHEET TITLE:

BASELINE DRAWINGS FOR WHARF No. 5 AT BARBOURS CUT TERMINAL:

CORROSION PROTECTION PLAN - UNIT B / C

No.	DATE	DESCRIPTION

DATE:	05-25-2021
DESIGNER:	SWF
CHECKED BY:	CJL
CADD:	CLM
SCALE:	AS NOTED

DRAWING No: C60-D32-001

SHEET No: G-114

REV. No:

PLOTTED BY: DiazPerezJr, Armando (10/19/2022 - 11:16 AM)
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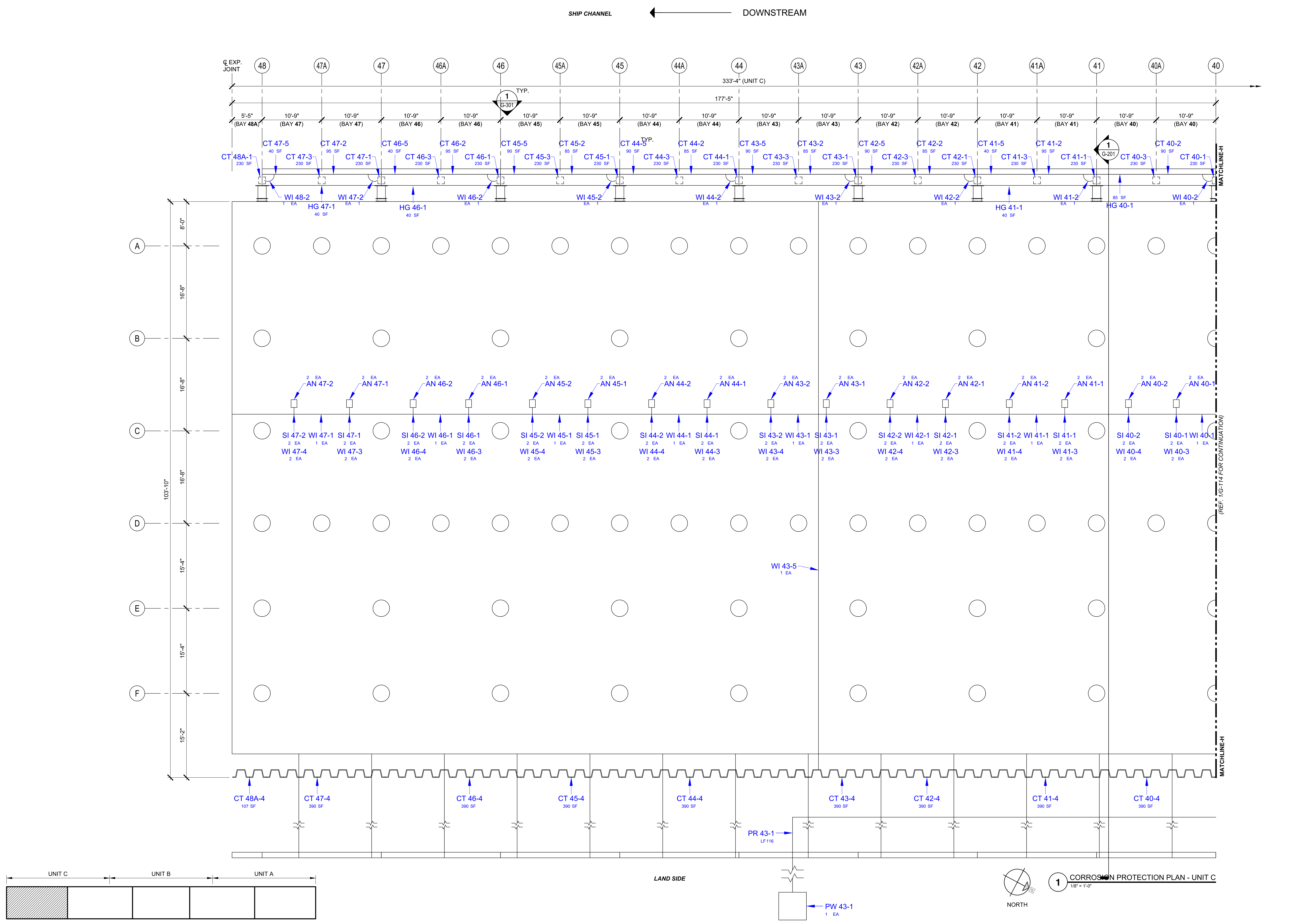

PLOTTED BY: DiazPerezJr, Armando (10/19/2022 - 11:16 AM)
LAST SAVED BY: CJONES (9/1/2021 - 12:14 PM)

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WJE PROJECT No.: 2018.6620.0

SEAL:

BASELINE DRAWINGS

NOT FOR CONSTRUCTION

PROJECT TITLE:

FACILITY INSPECTION & CONDITION ASSESSMENT PROGRAM (FICAP)

CORROSION INSPECTION DRAWINGS

SHEET TITLE:

BASELINE DRAWINGS FOR WHARF No. 5 AT BARBOURS CUT TERMINAL:

CORROSION PROTECTION PLAN - UNIT C

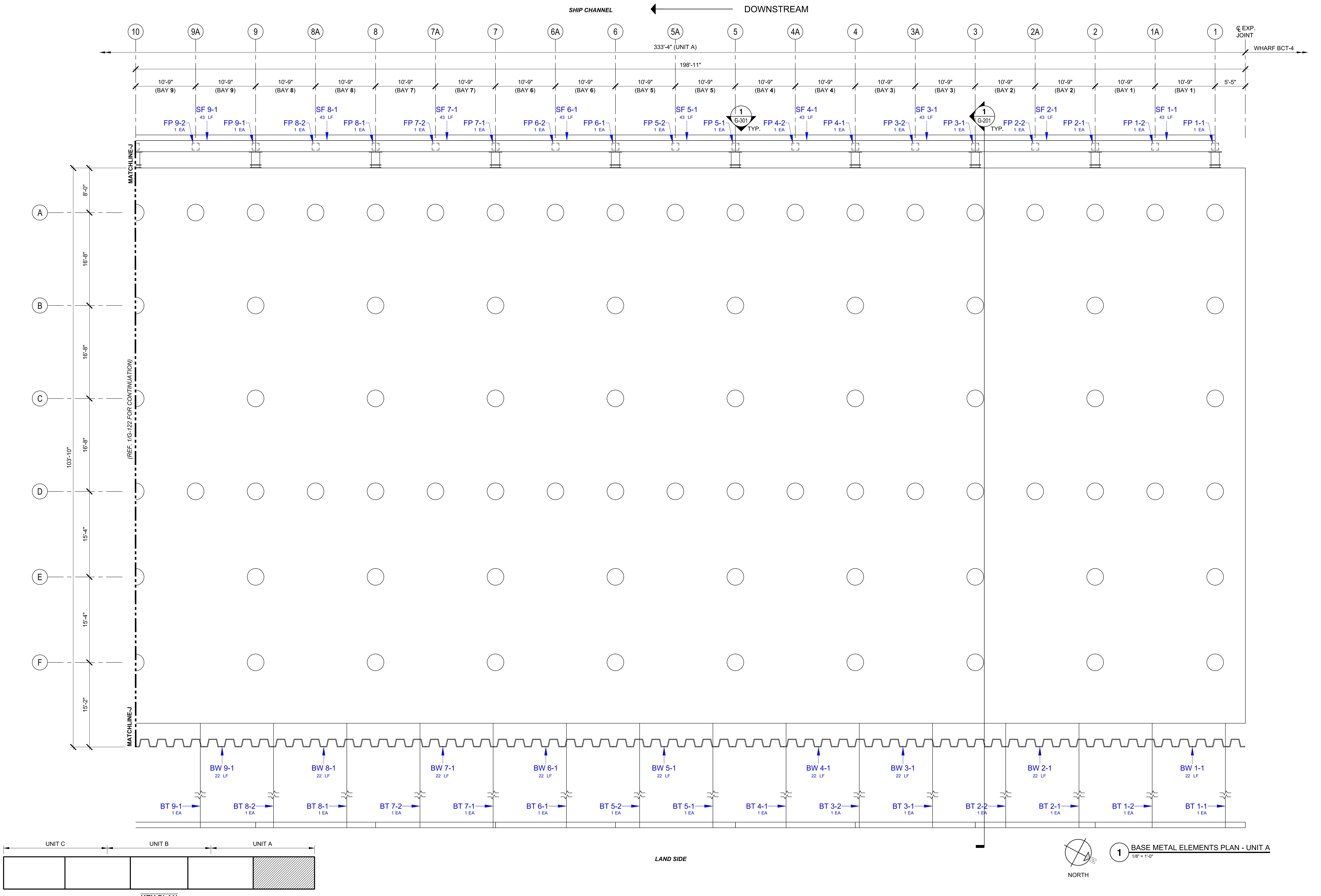
No.	DATE	DESCRIPTION

DATE:	05-25-2021
DESIGNER:	SWF
CHECKED BY:	CJL
CADD:	CLM
SCALE:	AS NOTED

DRAWING No: C60-D32-001

SHEET No: G-115

REV. No:



1 BASE METAL ELEMENTS PLAN - UNIT A
1/8" = 1'-0"

PORT OF HOUSTON AUTHORITY

CONSULTANT:

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WJE PROJECT No.: 2018.6620.0

SEAL:

BASELINE DRAWINGS

NOT FOR CONSTRUCTION

PROJECT TITLE:

FACILITY INSPECTION & CONDITION ASSESSMENT PROGRAM (FICAP)

CORROSION INSPECTION DRAWINGS

SHEET TITLE:

BASELINE DRAWINGS FOR WHARF No. 5 AT BARBOURS CUT TERMINAL:

BASE METAL ELEMENTS PLAN - UNIT A

No.	DATE	DESCRIPTION

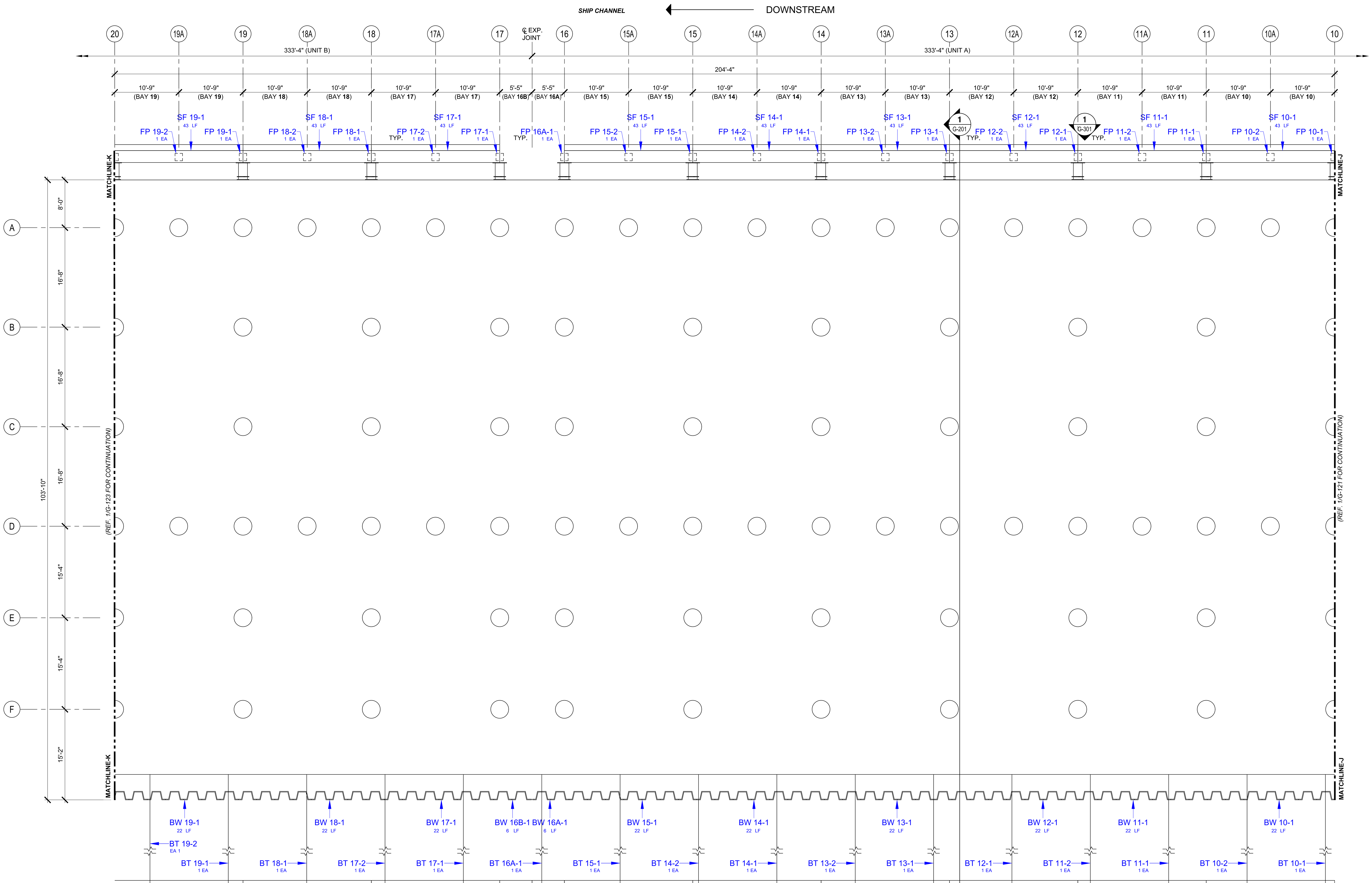
DATE:	05-25-2021
DESIGNER:	SWF
CHECKED BY:	CJL
CADD:	CLM
SCALE:	AS NOTED

DRAWING No: C60-D32-001

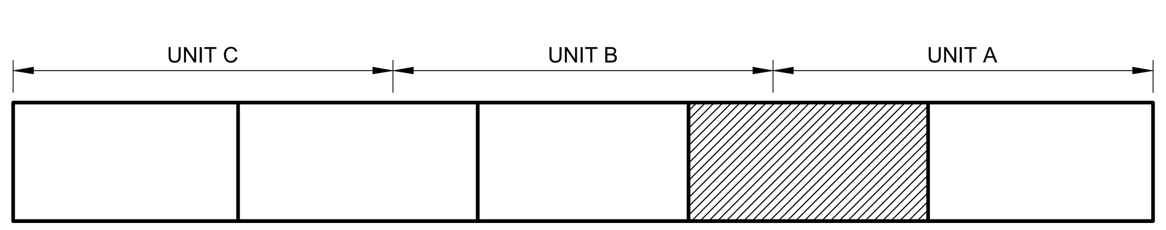
SHEET No: G-121

REV. No:

PLOTTED BY: DiazPerezJr, Armando (10/19/2022 - 11:16 AM)
LAST SAVED BY: CJONES (9/1/2021 - 12:14 PM)



1 BASE METAL ELEMENTS PLAN - UNIT A / B
1/8" = 1'-0"



KEY PLAN

PORT OF HOUSTON AUTHORITY

CONSULTANT:

WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS
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9511 N. Lake Creek Parkway
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TEXAS REGISTERED ENGINEERING FIRM F-0093

WJE PROJECT No.: 2018.6620.0

SEAL:

BASELINE DRAWINGS
NOT FOR CONSTRUCTION

PROJECT TITLE:

FACILITY INSPECTION & CONDITION ASSESSMENT PROGRAM (FICAP)

CORROSION INSPECTION DRAWINGS

SHEET TITLE:

BASELINE DRAWINGS FOR WHARF No. 5 AT BARBOURS CUT TERMINAL:

BASE METAL ELEMENTS PLAN - UNIT A / B

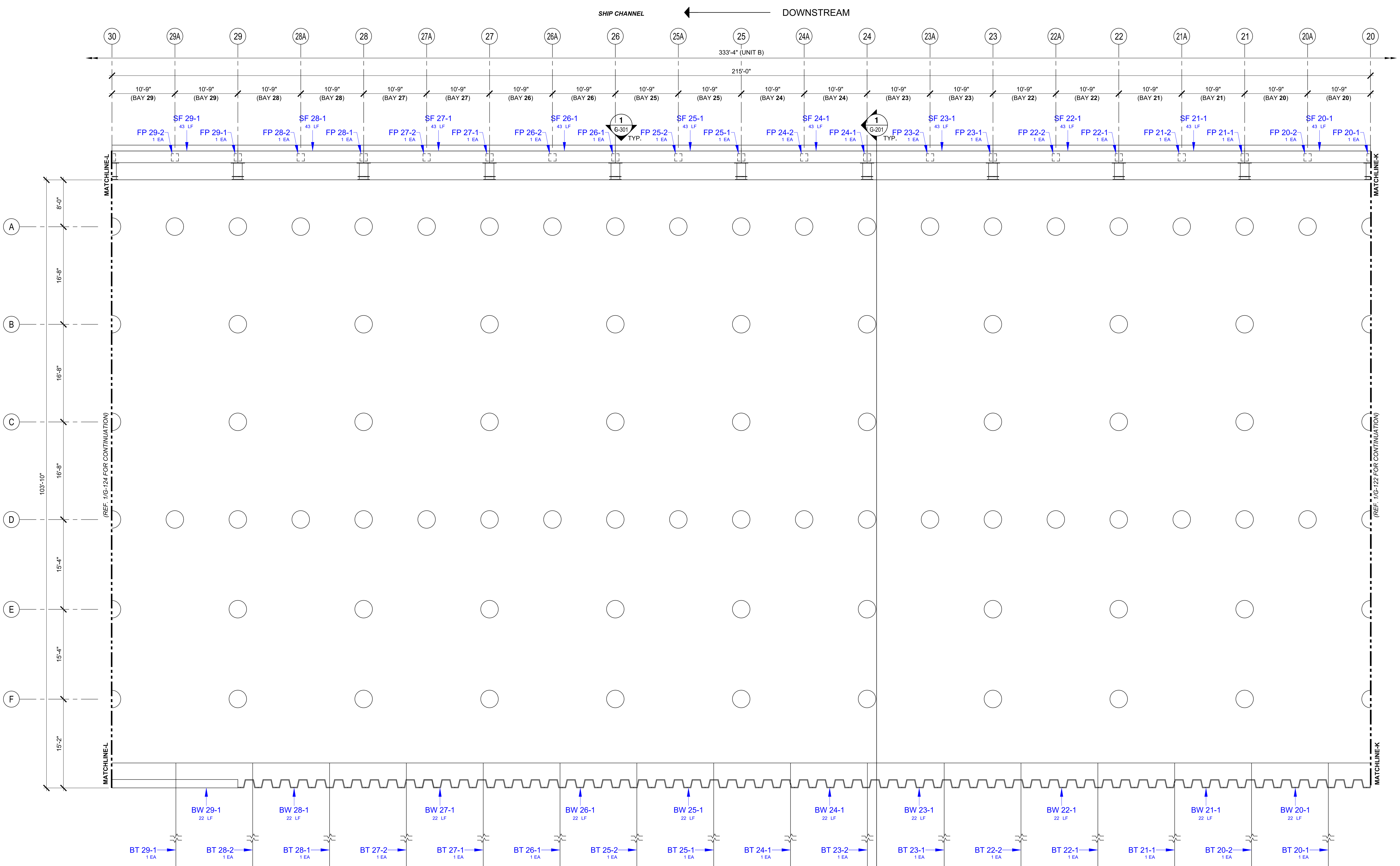
No.	DATE	DESCRIPTION

DATE:	05-25-2021
DESIGNER:	SWF
CHECKED BY:	CJL
CADD:	CLM
SCALE:	AS NOTED

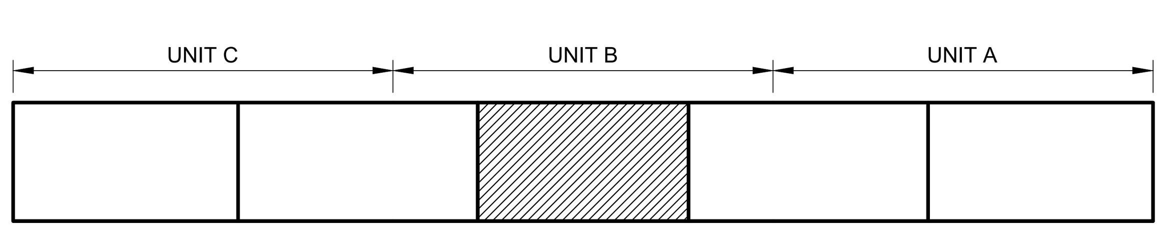
DRAWING No: C60-D32-001

SHEET No: G-122

REV. No:



1 BASE METAL ELEMENTS PLAN - UNIT B
1/8" = 1'-0"



KEY PLAN

PORT OF HOUSTON AUTHORITY

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WJE PROJECT No.: 2018.6620.0

SEAL:

BASELINE DRAWINGS

NOT FOR CONSTRUCTION

PROJECT TITLE:

FACILITY INSPECTION & CONDITION ASSESSMENT PROGRAM (FICAP)

CORROSION INSPECTION DRAWINGS

SHEET TITLE:

BASELINE DRAWINGS FOR WHARF No. 5 AT BARBOURS CUT TERMINAL:

BASE METAL ELEMENTS PLAN - UNIT B

No.	DATE	DESCRIPTION

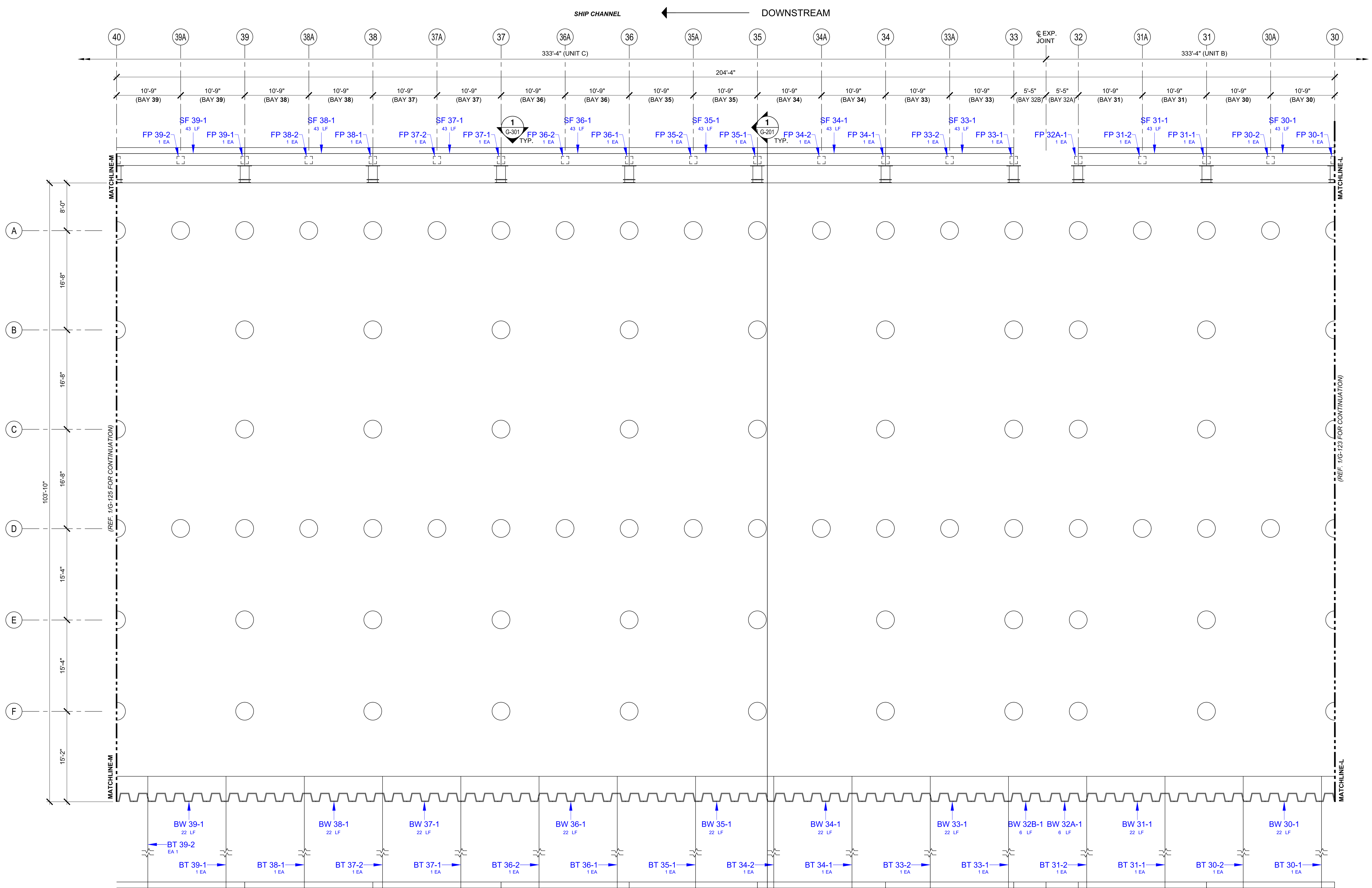
DATE:	05-25-2021
DESIGNER:	SWF
CHECKED BY:	CJL
CADD:	CLM
SCALE:	AS NOTED

DRAWING No: C60-D32-001

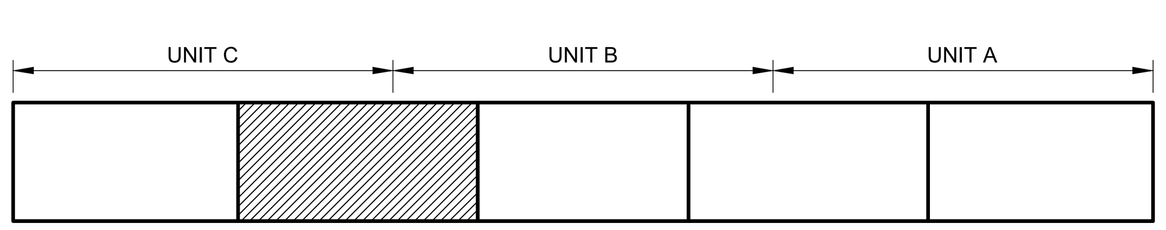
SHEET No: G-123

REV. No:

PLOTTED BY: DiazPerezJr, Armando (10/19/2022 - 11:16 AM)
LAST SAVED BY: CJONES (9/7/2021 - 12:14 PM)
FILE LOCATION: \\wje.com\FPAUS\2018\2018.6xxx\2018.6620.0 - PHA - CM SUPPLEMENT TO FICAP RFQ (SWF)\9 CAD\1-BCT5\Working Set



1 BASE METAL ELEMENTS PLAN - UNIT B / C
1/8" = 1'-0"



KEY PLAN

PORT OF HOUSTON AUTHORITY

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TEXAS REGISTERED ENGINEERING FIRM F-0093

WJE PROJECT No.: 2018.6620.0

SEAL:

BASELINE DRAWINGS

NOT FOR CONSTRUCTION

PROJECT TITLE:

FACILITY INSPECTION & CONDITION ASSESSMENT PROGRAM (FICAP)

CORROSION INSPECTION DRAWINGS

SHEET TITLE:

BASELINE DRAWINGS FOR WHARF No. 5 AT BARBOURS CUT TERMINAL:

BASE METAL ELEMENTS PLAN - UNIT B / C

No.	DATE	DESCRIPTION

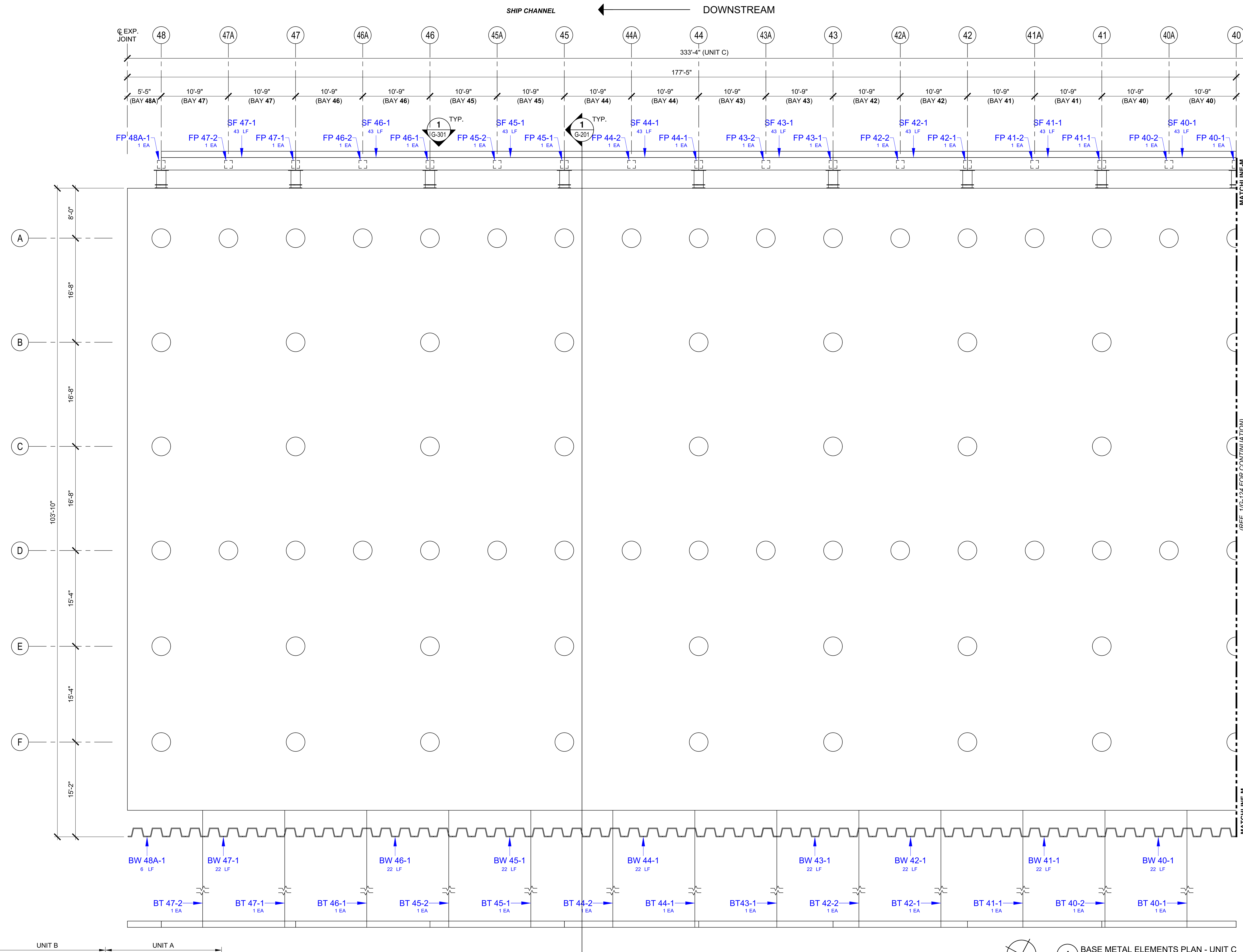
DATE:	05-25-2021
DESIGNER:	SWF
CHECKED BY:	CJL
CADD:	CLM
SCALE:	AS NOTED

DRAWING No.: C60-D32-001

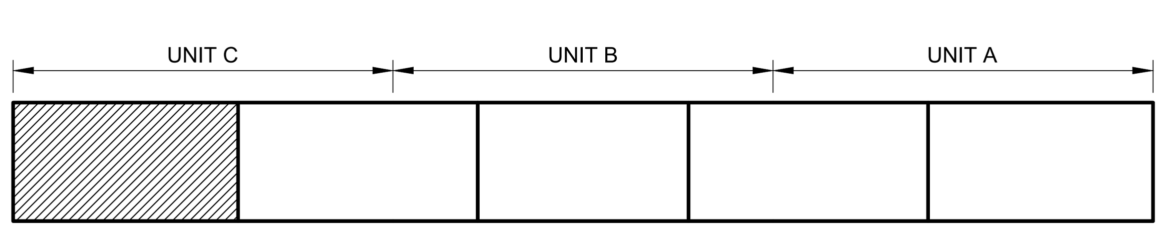
SHEET No.: G-124

REV. No.:

PLOTTED BY: DiazPerezJr, Armando (10/19/2022 - 11:16 AM)
LAST SAVED BY: CJONES (9/17/2021 - 12:14 PM)
FILE LOCATION: ...2018.6620.0 - PHA - CM SUPPLEMENT TO FICAP RFQ (SWF)\9 CAD\1-BCT5\Working Set



1 BASE METAL ELEMENTS PLAN - UNIT C
1/8" = 1'-0"



KEY PLAN

PORT OF HOUSTON AUTHORITY

CONSULTANT:

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WJE PROJECT No.: 2018.6620.0

SEAL:

BASELINE DRAWINGS

NOT FOR CONSTRUCTION

PROJECT TITLE:

FACILITY INSPECTION & CONDITION ASSESSMENT PROGRAM (FICAP)

CORROSION INSPECTION DRAWINGS

SHEET TITLE:

BASELINE DRAWINGS FOR WHARF No. 5 AT BARBOURS CUT TERMINAL:

BASE METAL ELEMENTS PLAN - UNIT C

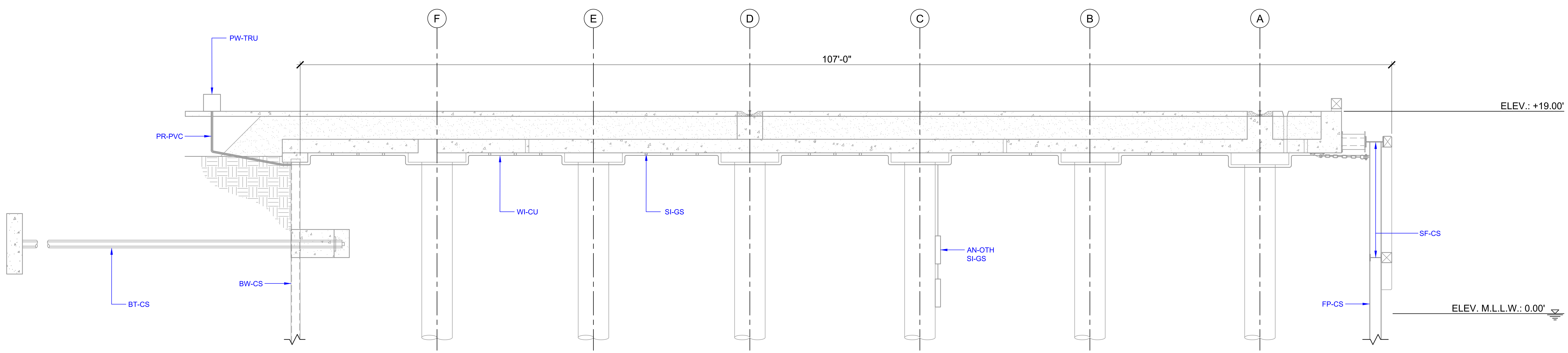
No.	DATE	DESCRIPTION

DATE:	05-25-2021
DESIGNER:	SWF
CHECKED BY:	CJL
CADD:	CLM
SCALE:	AS NOTED

DRAWING No: C60-D32-001

SHEET No: G-125

REV. No:



1 TYPICAL SECTION THROUGH WHARF & FENDER
3/16" = 1'-0"

PORT OF HOUSTON AUTHORITY

CONSULTANT:

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WJE PROJECT No.: 2018.6620.0

SEAL:

BASELINE DRAWINGS

NOT FOR CONSTRUCTION

PROJECT TITLE:

FACILITY INSPECTION & CONDITION ASSESSMENT PROGRAM (FICAP)

CORROSION INSPECTION DRAWINGS

SHEET TITLE:

BASELINE DRAWINGS FOR WHARF No. 5 AT BARBOURS CUT TERMINAL:

TYPICAL SECTIONS

No.	DATE	DESCRIPTION

DATE:	05-25-2021
DESIGNER:	SWF
CHECKED BY:	CJL
CADD:	CLM
SCALE:	AS NOTED

DRAWING No: C60-D32-001

SHEET No: G-201

REV. No:

PLOTTED BY: DiazPerezJr, Armando (10/19/2022 - 11:21 AM)
LAST SAVED BY: CMUSCA (3/6/2021 - 10:27 PM)
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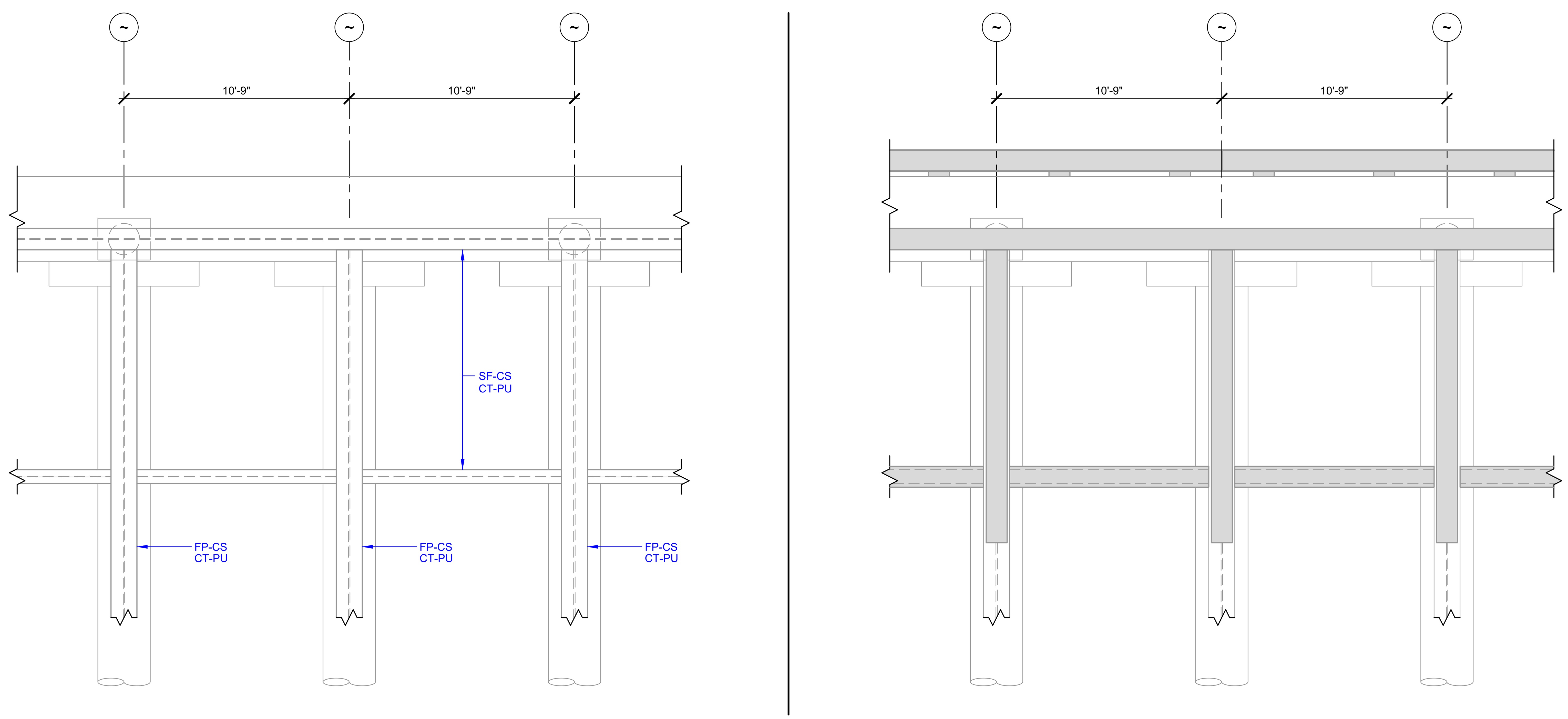

2A: STEEL FRAMING

2B: TIMBER FACING

1 TYPICAL BAY: FRONT ELEVATION
1/4" = 1'-0"

PLOTTED BY: DiazPerezJr, Armando (10/19/2022 - 11:22 AM)
LAST SAVED BY: CMUSCA (1/24/2020 - 12:41 PM)
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Princeton | San Francisco | Seattle | South Florida | Washington, D.C.
WJE PROJECT No.: 2018.6620.0

SEAL:
BASELINE DRAWINGS
NOT FOR CONSTRUCTION

PROJECT TITLE:
FACILITY INSPECTION & CONDITION ASSESSMENT PROGRAM (FICAP)
CORROSION INSPECTION DRAWINGS

SHEET TITLE:
BASELINE DRAWINGS FOR WHARF No. 5 AT BARBOURS CUT TERMINAL:
TYPICAL ELEVATIONS

No.	DATE	DESCRIPTION

DATE:	05-25-2021
DESIGNER:	SWF
CHECKED BY:	CJL
CADD:	CLM
SCALE:	AS NOTED

DRAWING No: C60-D32-001
SHEET No: G-301
REV. No:

APPENDIX H – REFERENCE INFORMATION

CORROSION MECHANISMS IN MARINE ENVIRONMENTS

Port Houston properties under consideration for this program include maritime structures along the 52-mile-long Houston Ship Channel. The considered structures consist of cargo wharves, barge landing areas, small boat docks (fireboats and tour boat), bulkhead (unassociated with docks), and one vehicle bridge. These assets are located on the water and thus see a variety of exposures that are unique to marine environments.

NACE International (NACE) defines corrosion as, "the deterioration of a substance, usually a metal, or its properties because of reaction with its environment." The likelihood of a material to corrode in a particular environment (i.e., corrosivity) is dependent on a number of localized factors. Taking these factors into account is important from a corrosion management perspective to ensure that sufficient corrosion mitigation strategies are being applied and also that overly-aggressive and costly protection is not performed. This balances the cost of corrosion-related losses with the cost of corrosion mitigation methods. Parameters that influence the corrosivity of the local environment around the Port properties are discussed in the sections below.

Corrosion Mechanisms for Steel

Steel components and elements at the Port Houston facilities are generally exposed to a marine environment where atmospheric and aqueous corrosion are the primary degradation mechanisms. The aqueous corrosion process requires the following factors:

- Ions are involved and need an electrolyte to move in (usually water)
- Oxygen is involved and needs to be supplied
- The metal has to be willing to give up electrons to start the process
- A new material is formed and this may react again or could provide protection of the original metal
- A series of simple steps are involved and a driving force is needed to achieve them

Interfering or controlling these factors allows the corrosion reaction to be stopped or slowed to a manageable rate.

Atmospheric Corrosion

Atmospheric corrosion is the deterioration of a metal properties due to electrochemical as well as the other reactions of its surface with the constituents of the atmosphere surrounding the material. Generally, atmospheric corrosion is due to the presence of moisture due to fog, dew, precipitation, and relative humidity. Salts of sulfur and chlorine can aggravate corrosion by forming electrolytes in industrial atmospheres. Ambient temperature and air pressure also affect corrosion.

Concentration Corrosion

Concentration cell corrosion is the deterioration of parts of a metal surface at different rates, due to the parts of the surface coming into contact with different concentrations of the same electrolyte. The different concentrations can result in some parts of the metal exhibiting different corrosion rates. Differential aeration corrosion occurs when the oxygen concentration varies over the metal surface. A partially submerged metal is subject to differential aeration corrosion because the oxygen concentration in the water is typically different from the oxygen concentration in the atmosphere. This typically occurs in steel regions below mean low tide.

Uniform Corrosion

Uniform corrosion occurs over the majority of the surface of a metal at a steady and often predictable rate. Uniform corrosion causes regular, uniform consumption of material from the surface. This occurs where the environment has consistent exposure to the material surface and the metal is uniform. Uniform corrosion is a potential deterioration mechanism where metallic surfaces are exposed to a marine atmosphere.

Pitting Corrosion

Pitting corrosion is highly localized corrosion occurring in a confined area that results in pits or cavities. Pitting may be initiated by localized damage in a protective coating or the presence of non-uniformities on the metal surface. Pits may penetrate deeply into the material and may be difficult to detect and/or measure.

Crevice Corrosion

Crevice corrosion is localized attack of a metal surface at, or immediately adjacent to, the crevice formed between two mating surfaces. It is a form of concentration corrosion due to a difference in concentration of chemical constituents, typically oxygen. Crevice corrosion is a potential concern in an element where two metals or a metal and a non-metallic element are clamped together and exposed to moisture or liquid.

Filiform Corrosion

Filiform corrosion is a particular form of crevice corrosion that occurs underneath a breach in a protective coating. Small breaches, or holidays, in the coating allow moisture to penetrate and proceed along tunnel-like paths under the coating surface. Coated elements can be more susceptible to these breaches at fastener penetrations and material edges.

Microbiologically Influenced Corrosion (MIC)

Microbiologically influenced corrosion is the deterioration of metals as a result of the metabolic activity of micro-organisms. Sulfate reducing bacteria (SRB) is anaerobic and is generally responsible for many instances of accelerated corrosion damage to submerged structures. Some studies have also identified the contribution of sulfur oxidizing bacteria (SOB) that can increase the corrosion damage of SRB.[x].

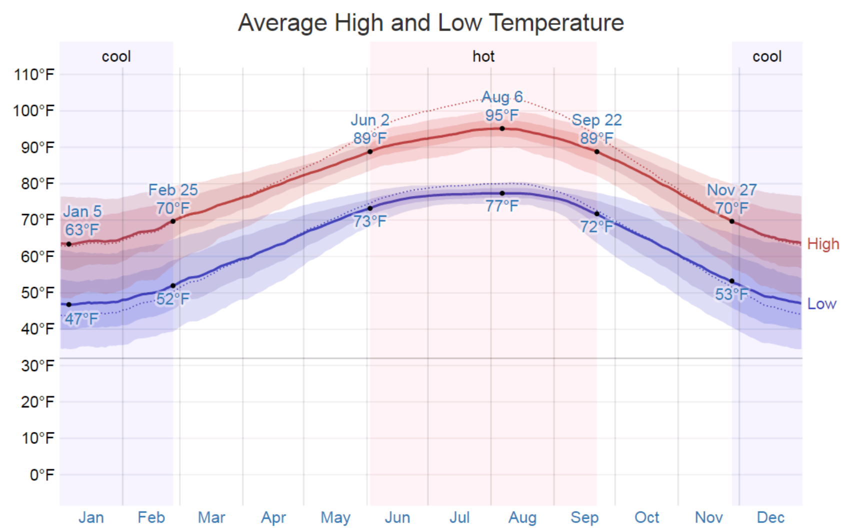
Galvanic Corrosion

Galvanic corrosion is an electrochemical process in which one metal corrodes preferentially when it is in electrical contact with another, in the presence of an electrolyte. Electrochemically negative, or anodic, materials will corrode or donate electrons to electrochemically positive, or cathodic, materials. Galvanic corrosion is accelerated when the area of the anodic material is small relative to the area of the cathodic material.

Exposure Conditions

The gulf coast climate is normally warm and humid for the majority of the year. Mean monthly temperatures range from 54 degrees Fahrenheit (°F) in January to 84 °F in August and mean relative humidity exceeds 70 percent year-round.[1,2] The average daily high and low temperature in Houston is shown in *Figure H.1*.

[1] Source: https://www.weather.gov/hgx/climate_hou_normals_summary, accessed April 18, 2018
[2] Source: https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,houston,United-States-of-America, accessed April 18, 2018



The daily average high (red line) and low (blue line) temperature, with 25th to 75th and 10th to 90th percentile bands. The thin dotted lines are the corresponding average perceived temperatures.

Figure H.1. Daily average high and low temperature in Houston. [3]

Houston Ship Channel Water Quality

Port Houston properties include eight public terminals among other docks and shorelines along the 52-mile-long Houston Ship Channel. The ship channel flows from the Buffalo Bayou and San Jacinto River down through Galveston Bay as shown in Figure H.*2*. The channel has a mix of seawater and fresh water that fluctuates in composition as tidal and stream flows vary. Data on the quality of the ship channel water is available through the state's surface water quality monitoring program by Texas Commission on Environmental Quality (TCEQ). The TCEQ divides the Galveston Bay and Houston Ship Channel System (HSC) into designated water quality segments, each of which include a number of monitoring stations as shown in Figure H.*3*.

The measured chloride contents in samples collected on the ship channel segments around the public terminals (segment IDs: 1007, 1006, 2436, and 2438) are shown in Figure H.*4*. The data shows lower chloride content in the upstream portion of the channel, increasing as the channel flows toward Galveston Bay. A list of the Port Houston terminals around each of these segments and the annual average measured chloride contents are listed in Table H.**1**. Average measured chloride content in the water ranges from a 1,600 mg/l in the upstream end near the Turning Basin Terminal to 7,800 mg/l in Galveston Bay near Bayport Terminal. For reference, typical seawater has a chloride content of 19,400 mg/l, and freshwater is normally considered to have a chloride content of less than 250 mg/l (often termed the "salt line" in tidal estuaries[4]). The measured chloride levels indicate that channel water is about one-tenth to one-half the salinity of sea water.

[3] The daily average high (red line) and low (blue line) temperature, with 25th to 75th and 10th to 90th percentile bands. The thin dotted lines are the corresponding average perceived temperatures.
Source: https://weatherspark.com/y/9247/Average-Weather-in-Houston-Texas-United-States-Year-Round#Sections-Humidity , accessed April 18, 2018
[4] Definition of salt line: http://www.state.nj.us/drbc/hydrological/river/salt-line.html, retrieved April 24, 2018

Figure H.2. Overall map of Port Houston properties. The Houston Ship Channel is outlined in dark blue.

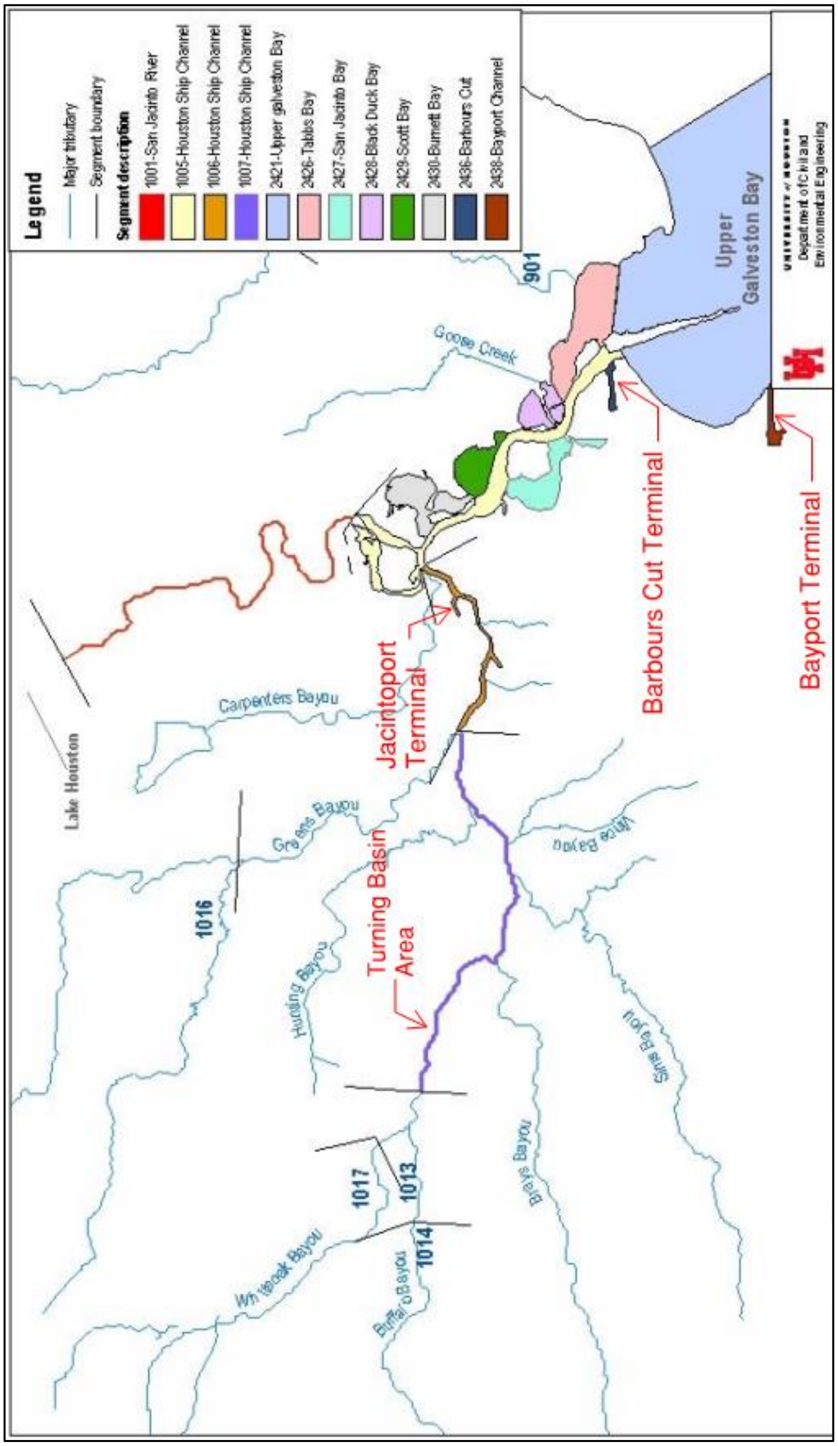


Figure H.3. Houston Ship Channel segment description per TCEQ.[i]

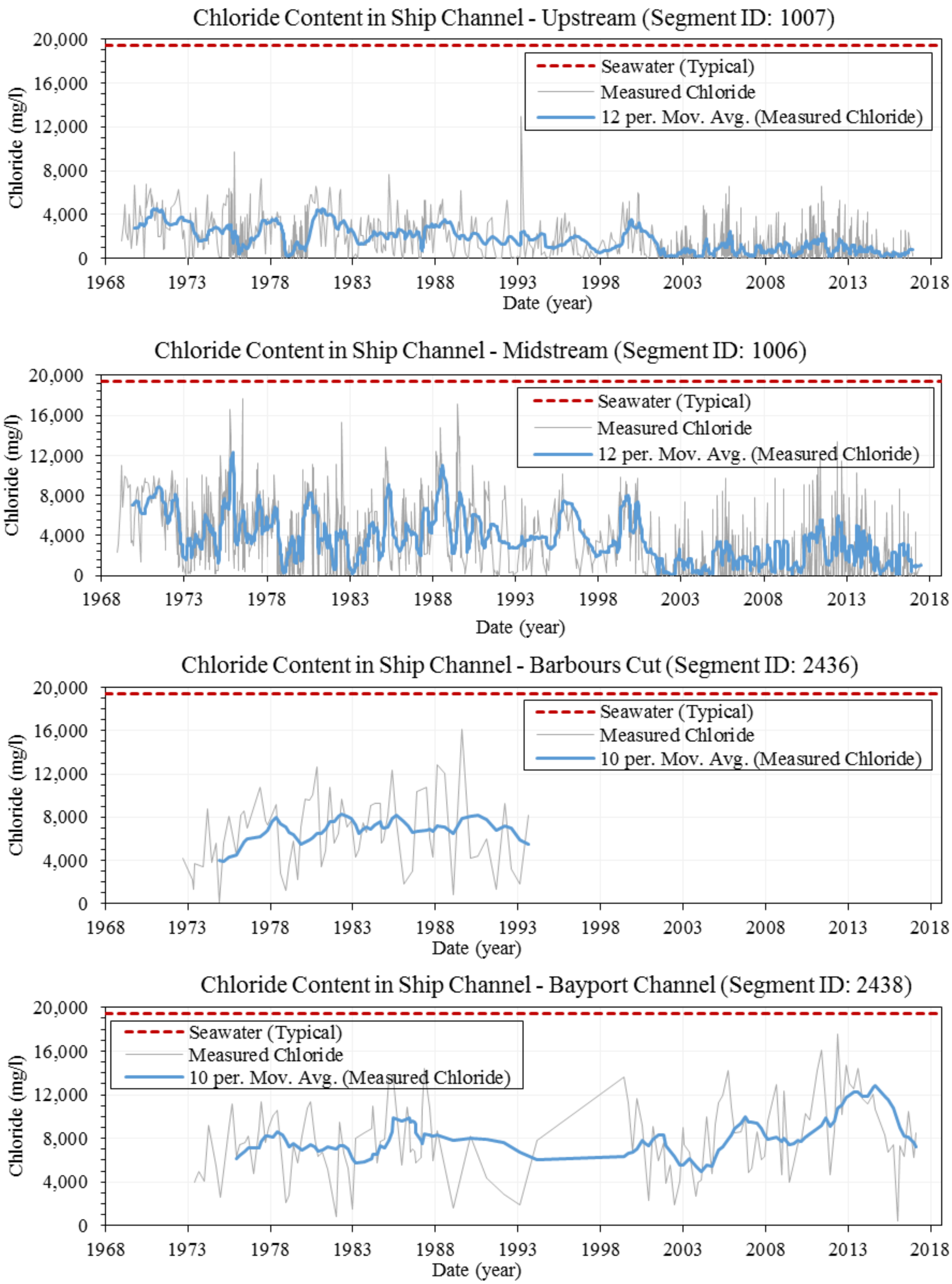


Figure H.4. Chloride content at different segments of ship channel. [5]

Table H.1. Annual Average Chloride Content in the Ship Channel, per TCEQ

	HSC Upstream	HSC Midstream	Barbours Cut	Bayport
Segment ID	1007	1006	2436	2438
Segment Name	Houston Ship Channel/Buffalo Bayou Tidal	Houston Ship Channel Tidal	Barbours Cut	Bayport Channel
Terminals included	▪ Turning Basin ▪ Southside Wharves ▪ Industrial Park East ▪ Woodhouse Terminal ▪ Manchester Wharves	▪ Bulk Materials Handling Plant ▪ CARE Terminal ▪ Jacintoport Terminal	▪ Barbours Cut Terminal	▪ Bayport Terminal
Range of annual average Chloride content (mg/L)	350-4,500	500-8,900	2,500-10,100	4,100-14,000
Average measured chloride content (mg/L)	1,600	3,250	6,500	7,850
Monitoring period	1969-2017	1969-2017	1973-1994	1973-2017
Average Number of measurements /year	75.7	37.7	3.2	3.8

Water Elevations

The National Oceanic and Atmospheric Administration (NOAA) collects and provides water level data near the entrance to Barbour's Cut Terminal at Station ID 8770613 [6] and near Manchester and Turning Basin Terminals at station ID 8770777 [7]. Water level data is available at these station from 1993 to the present and from 1998 to present, respectively. Datums for water elevation are shown on the graphic in Figure H.5 measured relative to the internal station datum. Definitions of datums and their abbreviations are listed below:

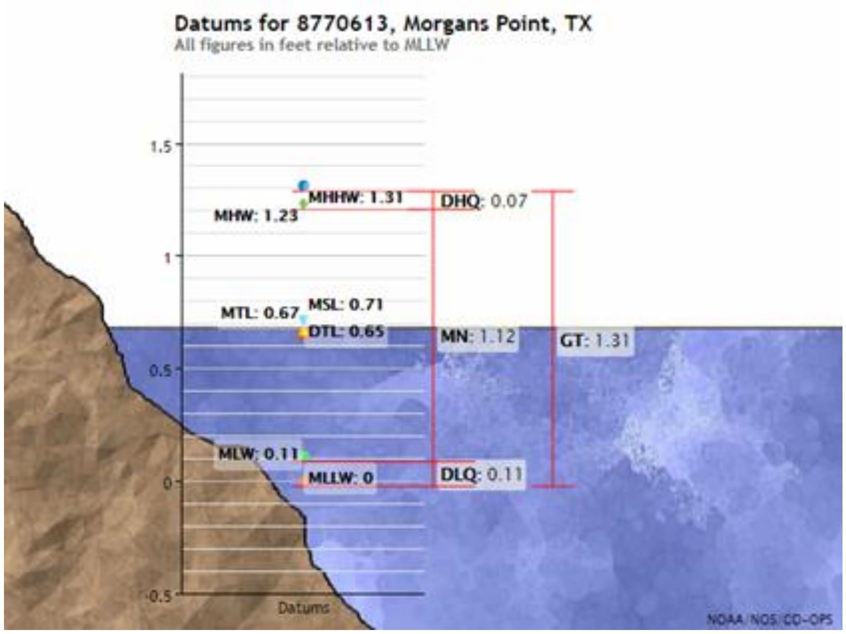
- **MLLW:** mean lower low water. The average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch.
- **MLW:** mean low water. The average of all the low water heights observed over the National Tidal Datum Epoch.
- **MSL:** mean sea level. The arithmetic mean of hourly heights observed over the National Tidal Datum Epoch.
- **MHW:** mean high water. The average of all the high water heights observed over the National Tidal Datum Epoch.
- **MHHW**: mean higher high water. The average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch.

[5] Per TCEQ, water quality data: https://www80.tceq.texas.gov/SwqmisPublic/public/default.htm. Last accessed April 17, 2018

[6] Station data available at https://tidesandcurrents.noaa.gov/stationhome.html?id=8770613. Last accessed April 18, 2018

[7] Station data available at https://tidesandcurrents.noaa.gov/stationhome.html?id=8770777. Last accessed April 18, 2018

Note that because these locations have semidiurnal tides (two low tides and two high tides, each at different heights), the mean values of the lowest low tides and all low tides is different. Similar logic applies to MHHW and MHW.

(a)


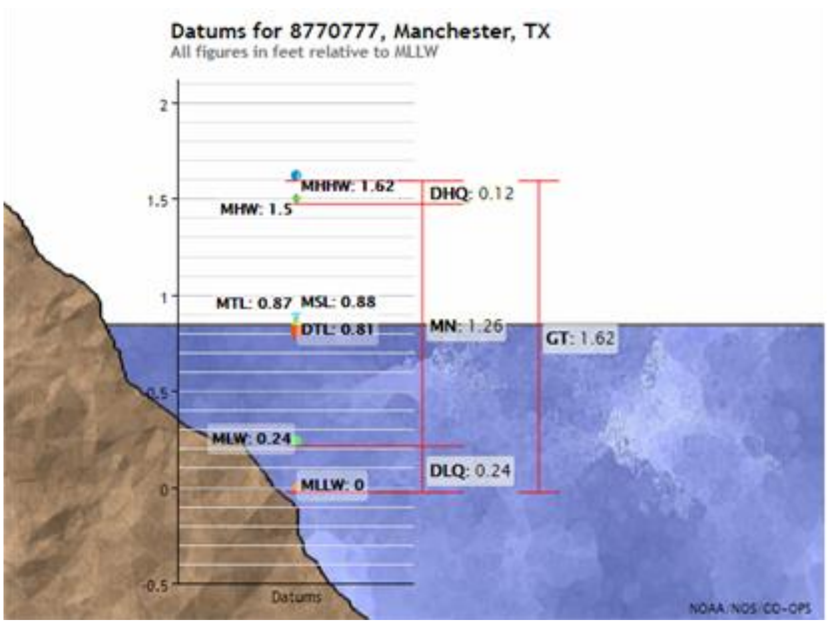
(b)


Figure H.5. Datums for: (a) Station 8770613, Morgans Point, and (b) Station 8770777, Manchester. [8]

[8] Retrieved from https://tidesandcurrents.noaa.gov/datums.html?id=8770613 and https://tidesandcurrents.noaa.gov/datums.html?id=8770777. Last accessed April 18, 2018.

Current practice at Port Houston is to report water level heights at wharves relative to MLLW. In addition to semidiurnal water level changes, the mean water levels fluctuate throughout the course of the year. Based on the reported data from 1993 to 2018, water levels reach maxima in May and September/October and minima in January and July. This data is plotted versus MLLW in Figure H.*6* for Morgans Point and Manchester stations, respectively. Stations datums relative to MLLW are shown in Table H.**2** and Table H.**3**. Note that the diurnal range of tides is greater when accounting for the month-to-month variation that occurs over the course of the year.

Table H.2. Annual and Monthly Average Datums
Station 8770613, Morgans Point

Datum	Height vs. MLLW, (ft.)		
	Annual Average	**Monthly Maximum (September)**	**Monthly Minimum (January)**
MLLW	0.00	0.57	-0.50
MLW	0.11	0.73	-0.45
MSL	0.71	1.26	0.27
MHW	1.23	1.72	0.84
MHHW	1.31	1.81	0.89
Great diurnal range: MHHW - MLLW	1.31	2.31 (Sep. - Jan.)	

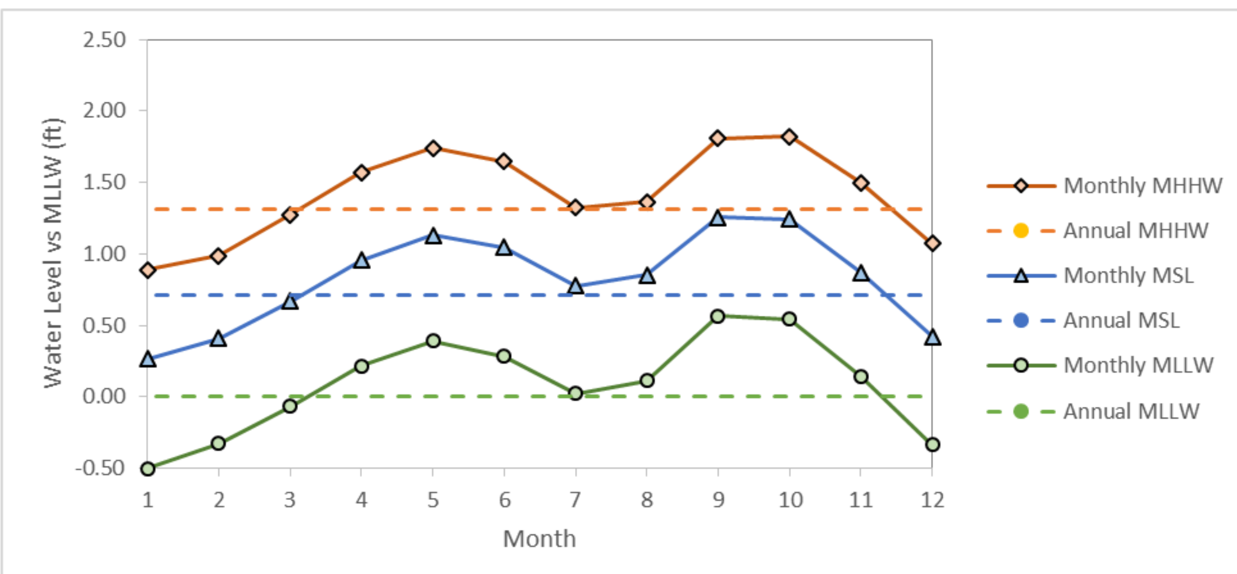


Figure H.6. Plot of monthly MHHW, MSL, and MLLW for Station 8770613 (Morgans Point) from 1993 to 2018.

Table H.3. Annual and Monthly Average Datums- Station 8770777, Manchester

Datum	Height vs. MLLW (ft.)		
	Annual average	Monthly maximum (October)	Monthly Minimum (January)
MLLW	0.00	0.72	-0.41
MLW	0.24	0.94	-0.14
MSL	0.88	1.56	0.5
MHW	1.50	2.16	1.15
MHHW	1.62	2.27	1.23
Great diurnal range: MHHW - MLLW	1.62	2.68 (Sep. - Jan.)	

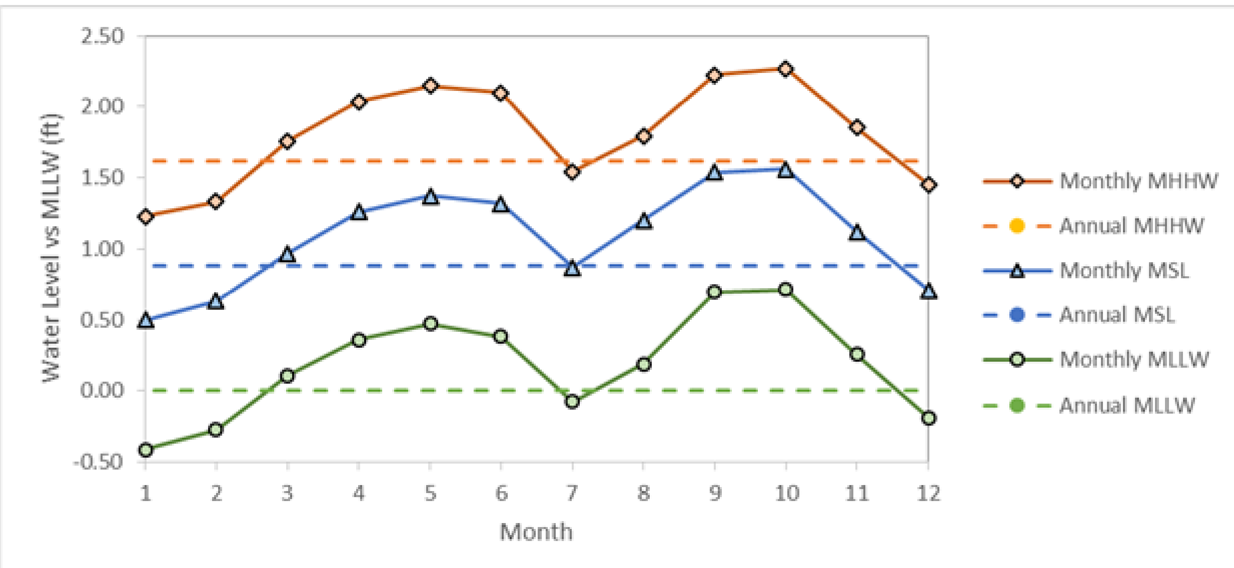


Figure H.7. Plot of monthly MHHW, MSL, and MLLW for Station 8770777 (Manchester) from 1998 to 2018.

Exposure Zones

The exposure conditions are expected to vary based on the distance from, and the exposure to, the channel water. The landside elements are fully buried and thus in direct contact with soil for their full height. These elements may also be exposed to ground water, depending on the element depth versus groundwater table elevation. Waterside elements are exposed to soil, ground water, or channel water, of which the specific exposure will vary based on the elevation of the element's surface versus tidal water levels. The specific height of the zones and exposure effects are usually calibrated based on field investigation and/or laboratory studies of samples extracted from the structure. The exposure conditions for elements at Port Houston properties can be classified into five zones as follows.

Atmospheric Zone

Elements within the atmospheric zone are exposed to relatively high humidity levels and warm temperatures throughout most of the year, along with consistent exposure to oxygen and UV exposure.

These conditions provide an environment at which several degradation mechanisms may occur. In addition, precipitation in the area includes chloride and other ions due to inclusion of fine chloride-laden mist from the nearby Gulf of Mexico. Based on 2015 data from the nearest monitoring site in the National Atmospheric Deposition Program (NADP: site TX10, located near Sealy, Texas), precipitation in the area contains 0.5 to 1.0 mg/l of chloride, or considering the volume of rainfall, approximately 5 to 10 kg/ha/year.[9] These exposure conditions indicate some risk of corrosion for unprotected steel elements and steel reinforcements with shallow concrete cover.

A corrosivity classification system is described by ISO 9223[ii] for metals and alloys under atmospheric conditions. This international standard defines five corrosivity categories by the first-year corrosion rate of standard specimens. The corrosivity category can be determined based on one-year corrosion losses measured with standard metal specimens or estimated through measurements of environmental parameters. Three environmental parameters are used—the time of wetness (TOW), which is estimated from temperature-humidity complex, and the level of two corrosive impurities—sulfur dioxide (SO2), and airborne salinity contamination (Cl−). Classifications are defined based on these measurements, which can be used to estimate the corrosivity category using lookup tables for specific metals. ISO 9224[iii] provides guiding corrosion rate values for each of these categories for the standard metals, which can be used to predict the extent of corrosion attack in long-term exposures. This comprehensive classification system of atmospheric corrosivity can be used to evaluate environmental stress and consequently facilitate the selection of anticorrosion measures or estimation of service life.

Splash Zone

The splash zone starts with the baseline exposure of the atmospheric zone but is also subjected to intermittent wet and dry cycles. The splash zone is the area of the structure that is frequently wetted due to waves and tidal variations. Wind and water spray are also often responsible for wetting the elements and components in this zone.

Tidal Zone

Tidal zone exposure conditions vary from splash zone conditions in several ways. Firstly, concrete surfaces remain saturated for the majority of the year and can only dry at times of low tide. Because the relative humidity in Houston exceeds 70 percent on average year-round, drying rates will be slow at times of low tide. Consequently, the concrete in the tidal zone can be expected to remain saturated and result in chloride transport largely dominated by diffusion. This saturated concrete also limits the rate of oxygen transport from the atmosphere to the bar levels. Secondly, as tidal fluctuations occur, exposure to oxygen along the surface of an element varies. Oxygen is required to support corrosion process. When an element is submerged for extended periods of time, oxygen levels are significantly reduced, generally resulting in slower degradation rates during immersion; however, severe localized steel corrosion may initiate in submerged conditions if small regions of steel are coupled with passive steel.[iv]

Submerged Zone

Exposure conditions for submerged elements differ from the tidal zone conditions primarily in the availability of oxygen. Oxygen concentration in the atmosphere is approximately 21 percent (210,000 ppm), whereas dissolved oxygen in water is on the order of 10 ppm or less. Dissolved oxygen concentrations within water typically decrease with water depth.

[9] Source: NADP website: http://nadp.sws.uiuc.edu/nadpdata/annualReq.asp?site=TX10, retrieved Feb. 22, 2018.

In concrete, this low oxygen availability limits the rate that oxygen can reach corrosion cells and suppresses the cathodic reaction for steel corrosion in concrete. For steel elements, corrosion rates in the submerged zone are also lower than in the splash and tidal zone, but unprotected carbon steel (steel without protective coatings or cathodic protection) can still corrode.

Macrocell coupling may form between reinforcing steel in the submerged and tidal/splash zones. As steel reinforcement in the tidal and splash zones typically begins to corrode earlier in the structure's life, coupling between the corroding steel above the waterline and non-corroding steel below tends to make the potential of the submerged steel more negative, essentially raising the corrosion threshold and slowing or preventing the initiation of corrosion in the submerged steel.[v] This phenomena, however, may work to the opposite effect should corrosion initiate below the waterline prior to the tidal or splash zones.

Soil Zone

The risk for material degradation for elements submerged in soil are dependent upon several factors, including the properties of the solid, water, and gaseous constituents of the soil and fluctuations in groundwater levels.

The primary soil properties that influence corrosion of buried steel include resistivity, pH, and chemical and microbial composition of the soil. Measurement of redox potentials can also provide a secondary indication of corrosivity, as shown in Table 2.4 . Geotechnical data for soil properties should be collected through testing of soil samples at various depths. Generally, high chloride ion concentrations and low resistivity in the soil provide an environment in which corrosion is expected. The degree of corrosivity can be estimated using chloride and sulfate concentrations and the soil pH, as presented in Table H**.5**. ANSI/AWWA C105[vi] also describes a point system for evaluating soil corrosivity to ductile iron pipes based on soil test results including resistivity, PH, redox potential, sulfides, and moisture.

Water-soluble sulfates found within the soil or the groundwater may lead to chemical attack of the cement within the concrete, potentially leading to concrete degradation and, in turn, a reduction in the protection of the underlying reinforcing steel.

Geotechnical data provided by Lymon C. Reese & Associates in their report "Geotechnical Investigation Report for Wharf 3 Upgrade at the Barbours Cut Terminal" stated a mean sulfate content of 4,060 ppm (water-soluble SO_4^{2-}) in Barbours Cut area, indicating severe exposure to sulfates within the soil, per ACI 201.2R-16, "Guide to Durable Concrete."

Table 2.4. Soil Redox as an Indicator for Soil Corrosivity [vii]

Redox Potential (vs. SHE*)	**Aeration**	**Soil Corrosivity Category**
Negative	Not Aerated	Extremely Severe
0-100 mV	None to Weak	Severe
100-200 mV	Weakly Aerated	Moderate
200-400 mV	Aerated	Slight
Above 400 mV	Strongly Aerated	Noncorrosive
* Standard Hydrogen Electrode		

Table H.5. Effect of Resistivity, Chlorides, Sulfates, and pH on Corrosion of Buried Steel [viii,ix]

Parameter	Value	Influence on Corrosivity
Resistivity (Ω · cm)	> 20,000	Essentially Noncorrosive
	10,000 to 20,000	Mildly Corrosive
	5,000 to 10,000	Moderately Corrosive
	3,000 to 5,000	Corrosive
	1,000 to 3,000	Highly Corrosive
	< 1,000	Extremely Corrosive
Chloride Content (ppm)	> 5,000	Severe
	1,500-5,000	Considerable
	500-1,500	Corrosive
	<500	Threshold
Sulfate Content (ppm)	> 10,000	Severe
	1,500-10,000	Considerable
	150-1,500	Positive
	0-150	Negligible
pH	<5.5	Severe
	5.5-6.5	Moderate
	6.5-7.5	Minor
	>7.5	None (Alkaline)

Exposure Zone Corrosivity for Steel

The five exposure zones are classified as atmospheric, splash, tidal, submerged, and soil (or below the mudline). These zones each represent different environmental exposure conditions that affect the potential corrosion rates of unprotected steel components and elements.

Atmospheric Zone

This zone is above the splash zone and is therefore not constantly wetted or affected by the rise of tidal waves, i.e., it is not exposed to an electrolyte. The corrosive conditions are typically most severe in areas sheltered from direct rainfall and sunlight but freely exposed to sea spray and condensation that accumulates sea salts and moisture. Other elements in the atmospheric zone are exposed to relatively high humidity levels and warm temperatures, along with consistent exposure to oxygen and UV. The most common types of corrosion anticipated in this zone are general section loss and/or localized pitting corrosion. Steel corrosion rates will be affected by metal composition and quality, temperature, humidity levels, and air quality or pollution. Corrosion rates of unprotected carbon steels in the atmospheric zone are generally low, less than 100 µm/year or 4 mil/year (mpy).

Splash Zone

Uncoated steels experience the high corrosion rates in this zone due to the ample supply of oxygen and water. Wave impingement can also erode coating systems. Corrosion rates of unprotected carbon steels in the splash zone are generally the highest of all zones and can be greater than 500 um/year or 20 mpy.

Tidal Zone

The tidal zone is below the splash zone and is considered to be submerged or wet a majority of the time. This zone has the potential to be dry at times of low tide. Steels in the tidal zone can benefit from the application of cathodic protection. Corrosion in the tidal zone is generally low, less than 50 um/year or 2 mpy.

Submerged Zone

The submerged zone has two general areas—an area of potentially higher corrosivity near the surface, and an area of lower corrosivity below. The high corrosivity area is where Accelerated Low Water Corrosion (ALWC) has been reported in the region 1-1/2 to 3 feet below the mean low water level.[x] ALWC corrosion is attributed to a potential combination of factors that include oxygen differentials, microbial influenced corrosion (MIC), and water pollution. ALWC rates of corrosion can be rather high, greater than 300 µm/year or12 mpy.

A zone of reduced corrosivity zone starts approximately 1 meter below the mean low water level (MLWL) and extends into the mudline. This zone generally exhibits lower corrosion rates due to the reduced availability of oxygen. MIC is also possible in the lower submerged zone and mudline, resulting in localized pitting or preferential weld attack. Corrosion rates are expected to be less than 100 µm/year or 4 mpy.

Buried Zone

The aggressiveness of soil to buried steel is normally minimal. Corrosion of buried steel occurs primarily only in aerobic (oxygen-rich) conditions, usually only existing above the lowest design ground water level. The aggressiveness normally comes from organic soil, fillings, sulfur clay, or contaminated ground water. Soils with low specific resistivity and low pH can be especially aggressive. Moisture content, organic content, acidity, resistivity, soil particle size, and the composition and location of the ground water affect soil corrosivity.

Early research by the National Bureau of Standards (NBS) and recent research are consistent in that corrosion is absent when steel is below the water table and in undisturbed soils even when soils are corrosive.[xi] Significant corrosion of the steel casing or of the embedded reinforcing steel is not expected below the water table due to the lack of oxygen needed to support the corrosion cell; since oxygen concentrations are low, differential aeration cells do not develop. However, corrosion can occur above the water table where oxygen is available to support the corrosion reactions. When most of the casing is below the water table, the cathode (oxygen-rich) area above the water table is small, and the anodic area below the water table is large, so corrosion will be slow, even above the water table. In one Army Corp of Engineers Report,[xii] corrosion attack of steel piles was low where the majority of the pile was below the water table, even when the area above the water table contained corrosive soils.

Undisturbed soils, even above the water table, tend to be less corrosive than disturbed soils, especially disturbed soils containing man-made products such as slag or cinders. Severe corrosion can occur in stratified soils of clay (moist and oxygen deficient) and sand or silt (porous with oxygen available). Soil testing provides indicators of the corrosivity of the soil that can be used to estimate service life, but the large number of factors affecting corrosion makes this estimate only generally reliable.[xi]

The corrosivity of a generic soil can be assessed by a combination of soil resistivity, chloride content, sulfate content, pH, redox potential, and moisture conditions, as listed previously in Table 2.4 and Table H.**5**. In soils containing high contents of sulfur, slow microbiological corrosion may occur. Soils with high sulfates can support the growth of sulfate-reducing bacteria, which can lead to MIC. These microbes do not directly attack metal but may generate an acidic environment that can promote corrosion.

In addition to the parameters listed above, corrosion of steel in soil is dependent upon a few other factors. The nature of the soil is important; for example, undisturbed soil is usually less corrosive than disturbed soils or fill. In addition, stray currents from adjacent cathodic protection systems can cause local accelerated areas of corrosion if the currents are not controlled.

With these considerations above, general rates of corrosion remain low in the buried zone. Typical rates are 25 to 115 µm/year or 1 to 4.5 mpy.[xiii]

Summary Table

The typical corrosion rates for unprotected steel are summarized in Table H.**6**. The corrosion rates listed in this table represent the highest values observed in historical data for ordinary steel in seawater.

Table H.6. Corrosion Rates of Unprotected Steel by Exposure Zone[xiv]

Exposure Zone	Corrosion Rate	Comments
Atmospheric Zone	Up to 100 µm/year (4 mpy)	Varies with exposure to moisture, salts, pollution, and air temperature.
Splash Zone	Up to 500 µm/year (20 mpy)	High corrosion rates observed in this zone at or above the mean high tide mark.
Tidal Zone	Up to 50 µm/year (2 mpy)	Low corrosion rates in upper portion of tidal zone.
Submerged Zone	Up to 300 µm/year (12 mpy)	ALWC in region below mean low tide. Driven by concentration corrosion and/or MIC.
Submerged to Mudline	Up to 100 µm/year (4 mpy)	Low oxygen levels minimize corrosion potential.
Buried Zone	Up to 115 µm/year (4.5 mpy)	Rates depend on a large number of soil parameters and are higher in disturbed soil.

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