Appendix B
Ecological Functional Loss Analysis

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Bay Habitat Mitigation Planning for Commercial Out Lease of a Floating Dry Dock at the MGBW Maintenance Piers in San Diego Bay, California

February 6, 2020

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Executive Summary

This document has been prepared in support of a floating dry dock construction project (Project) for Marine Group Boat Works, LLC (MGBW) at their National City facility. The Project will include dredging a 5.55-acre area and deploying a floating dry dock. The Project will include removal of marine debris, dredging 153,000 cubic yards of sediment to a maximum depth of -38 feet mean lower low water (MLLW), with a 2-foot overdredge allowance, construction of dry dock mooring and access structures, and installation and operation of the dry dock. By nature, a project of this magnitude includes an evaluation of impacts to habitat and the need to compensate for loss of natural resources. This document has been prepared to evaluate existing habitat at the site and develop science-based mitigation ratios to accommodate mitigation needs resulting from conversion of existing habitat types to a new range of habitat types at the Project site.

Existing marine conditions are predominantly soft-bottom shallow subtidal habitat; a small area of intertidal rip-rap armor lies in the southeast of the project area along the quaywall. The vast majority of the area consists of unvegetated subtidal habitat; however, the subtidal area includes 0.83-acres of eelgrass (*Zostera marina*) beds. The Project will convert existing habitat to deeper habitat (as a result of dredging) and add structural cover (predominantly over deep water).

The Project mitigation approach followed a systematic approach to evaluate 1) applicability of existing mitigation policies (i.e., for eelgrass), 2) assessment of Project benefits and *de minimis* impacts, and 3) development of science- and data-based ratios to mitigate for existing habitat values (i.e., those not regulated under established policy).

Mitigation need will be offset by utilizing credits from an established regional eelgrass mitigation bank. Thus, the basis for both in-kind mitigation of resources (i.e., eelgrass-to-eelgrass) and out-of-kind mitigation (e.g., soft-bottom habitat to eelgrass) will be eelgrass bank credits. This document includes the basis for out-of-kind mitigation. The findings are that if an existing eelgrass mitigation bank is used to offset Project impacts a total of 1.073 acre of credit would need to be used. The basis for this comes from the following impacts and associated mitigation:

- Altered depth impact of 45.7% ecological loss over 5.39 acres offset with 0.241 acre of eelgrass.
- Shading impact of 0.7% ecological loss over 5.39 acres offset with 0.004 acre of eelgrass.
- Impacts to 0.828 acre of eelgrass offset at 1:1 with 0.828 acre of eelgrass bank credits.
- Total proposed Project mitigation as eelgrass totals 1.073 acre of eelgrass bank credits.

The Project proposes to mitigate for all project related impacts using 1.073-acre worth of bank credits released from the U.S. Navy's San Diego Bay eelgrass habitat credits (per agreement with and at the discretion of the U.S. Department of the Navy).

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1 Introduction

This document has been prepared in support of a floating dry dock construction project (Project) at the Marine Group Boat Works, LLC's (MGBW) National City facility located at 1313 Bay Marina Drive, National City, CA 91950 (Facility). The Project site is located on the eastern shore of San Diego Bay at the southern end of Naval Base San Diego (NBSD) and to the north of the National City Marine Terminal ("Project Site," Figures 1; and Figure 2). MGBW currently operates a boatyard facility as a leaseholder of the San Diego Unified Port District. The Project will expand the operations both on land and on tidelands and will include a lease of U.S. Navy property. This document has been prepared in support of the installation of a floating dry dock and associated appurtenances at the Facility. The Project is anticipated to include dredging of approximately 153,000 cy from approximately 5.55 acres, installation of two mooring dolphins, installation of dry dock access facilities, and installation and operation of the dry dock.

1-1 Project Background

Naval Base San Diego (NBSD) is a major port for the United States (U.S.) Department of the Navy (Navy). NBSD is a port for U.S. Navy ships assigned to the Pacific Fleet and is the major West Coast logistics base for U.S. Navy surface forces. Activities at NBSD include continuous maintenance availabilities and loading/unloading of supplies for fleet vessels (U.S. Navy 2019). In a memorandum dated 16 January 2018, the Commander of the U.S. Pacific Fleet identified a current and projected shortfall of dry dock space necessary to support the U.S. Pacific Fleet's forecasted surface ship maintenance requirement (U.S. Navy 2019).

The Navy cannot accommodate the shortfall of dry dock space required for current and future maintenance of the U.S. Pacific Fleet. For this reason, the emplacement and operation of additional floating dry docks (including all required dredging as well as all required demolition and construction activities) has been proposed at two locations at NBSD within San Diego Bay, one of which is the MGBW Project. The proposed emplacement of additional dry docks within San Diego Bay will directly impact the biodiversity and habitat values of the San Diego Bay tidelands occurring within the anticipated project footprints, thereby requiring habitat mitigation action in compliance with California Eelgrass Mitigation Policy (CEMP) and U.S. Army Corps of Engineers (Corps) guidelines.

This habitat mitigation ratio planning document provides a thorough analysis of anticipated impacts occurring within the MGBW Project area and provides proposed ratios of mitigation based on respective habitat values. In turn, this information is used to determine appropriate mitigation need. Mitigation options may include creation of habitats that provide ecological lift or withdrawals of credits from the U.S. Navy's current eelgrass habitat mitigation bank (at the discretion of the U.S. Navy). Although this document is developed to specifically address alterations to habitats at MGBW in National City, California, the rationale and concepts provided can be utilized to assess mitigation need for similar projects.

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2 Project Description

2-1 Project Site Location and Conditions

The Facility is located approximately 3 miles southeast of the City of San Diego’s Central Business District in National City (Figure 1). The Facility faces San Diego Bay to the west, is bordered to the north and east by NBSD, and to the south by by the city of National City. The southern edge of the NBSD property boundary is located approximately 3,700 feet (0.7 mile) south of the Mole Pier and 1,220 feet (0.25 mile) south of Pier 13. Additionally, this location is approximately 500 feet south of the former Pier 14 site, which was previously used to berth shallow-draft vessels and was demolished by the Navy in 2008. The MGBW Facility is located to the south of the proposed Project site on Port of San Diego tidelands and includes two maintenance piers, which are approximately 15 feet wide and extend approximately 400 feet into south San Diego Bay. According to a recent Sediment Quality Survey Report, the existing water depth at this site ranges from approximately -9 to -17-feet MLLW (Mission Environmental 2018). The Project site includes the proposed 5.55-acre dredge area as well as a proposed 0.88-acre landside lease area.

2-2 Brief Description of Proposed Action

Emplacement of the proposed floating dry dock at MGBW would occur within San Diego Bay at the southern edge of the NBSD property boundary to the north of existing MGBW maintenance piers. For the purposes of this document, habitat mitigation ratios will be determined through relative valuation of habitats and anticipated Project impacts occurring within the Project area boundaries. The scope of the proposed actions addressed in this document includes all required dredging, as well as all required demolition and construction activities necessary to support the proposed emplacement and operation of a floating dry dock. Specifically, the scope of the proposed action addressed in this document includes the following:

1) Removal of marine debris at the site;
2) Dredging of approximately 153,000 cubic yards (cy) of sediment;
3) Installation of mooring and access structures; and
4) Emplacement and operation of a floating dry dock.

The floating dry dock would not be self-powered or capable of maneuvering without assistance from support vessels. Therefore, the floating dry dock would remain permanently berthed at the MGBW maintenance piers location. The floating dry dock would be in the ‘floating’ postion for the vast majority of time, and would be submerged only for loading or unloading vessels (U.S. Navy 2019).

Figure 1. Vicinity map for the Marine Group Boat Works Maintenance Pier Project in San Diego Bay, CA.

Emplacement of the proposed floating dry dock at the MGBW maintenance piers location would require dredging of a 5.55-acre area which defines the project area. Within the Project area, 2.14-acre area below the dry dock will dredged to -38 feet MLLW, with an additional 2-foot overdredge allowance (refer to Figure 2). According to a recent Sediment Quality Survey Report, the existing water depth near the existing MGBW maintenance piers ranges from approximately -9 to -17 feet MLLW (Mission Environmental 2018). As such, it is anticipated that dredging would involve removal of approximately 153,000 cubic yards of sediment using a mechanical barge-mounted clamshell dredge. Future maintenance dredging may be necessary to maintain the operational depth requirement (i.e., -38 ft MLLW). The frequency of maintenance dredging would depend on sedimentation patterns, and such maintenance dredging would be evaluated as a separate action and permitted with the appropriate regulatory agencies accordingly. However, maintenance dredging would not be subject to additional mitigation as described in this document since maintenance dredging would be used to maintain a condition, not convert existing habitat to a different habitat type.

The MGBW floating dry dock will be constructed of steel and would have a 9,000-ton vessel-lifting capacity. It would also be designed to meet the requirements of the Navy’s MIL-STD 1625D and American Bureau of Shipping Standards. The minimum dimensions for the floating dry dock are: 531.5-foot length, 154.2-foot outside width, a 120.08-foot inside width, a pontoon height of 10.2 feet, and a wing wall height of 42.85 feet above the pontoon deck (Navy 2019).

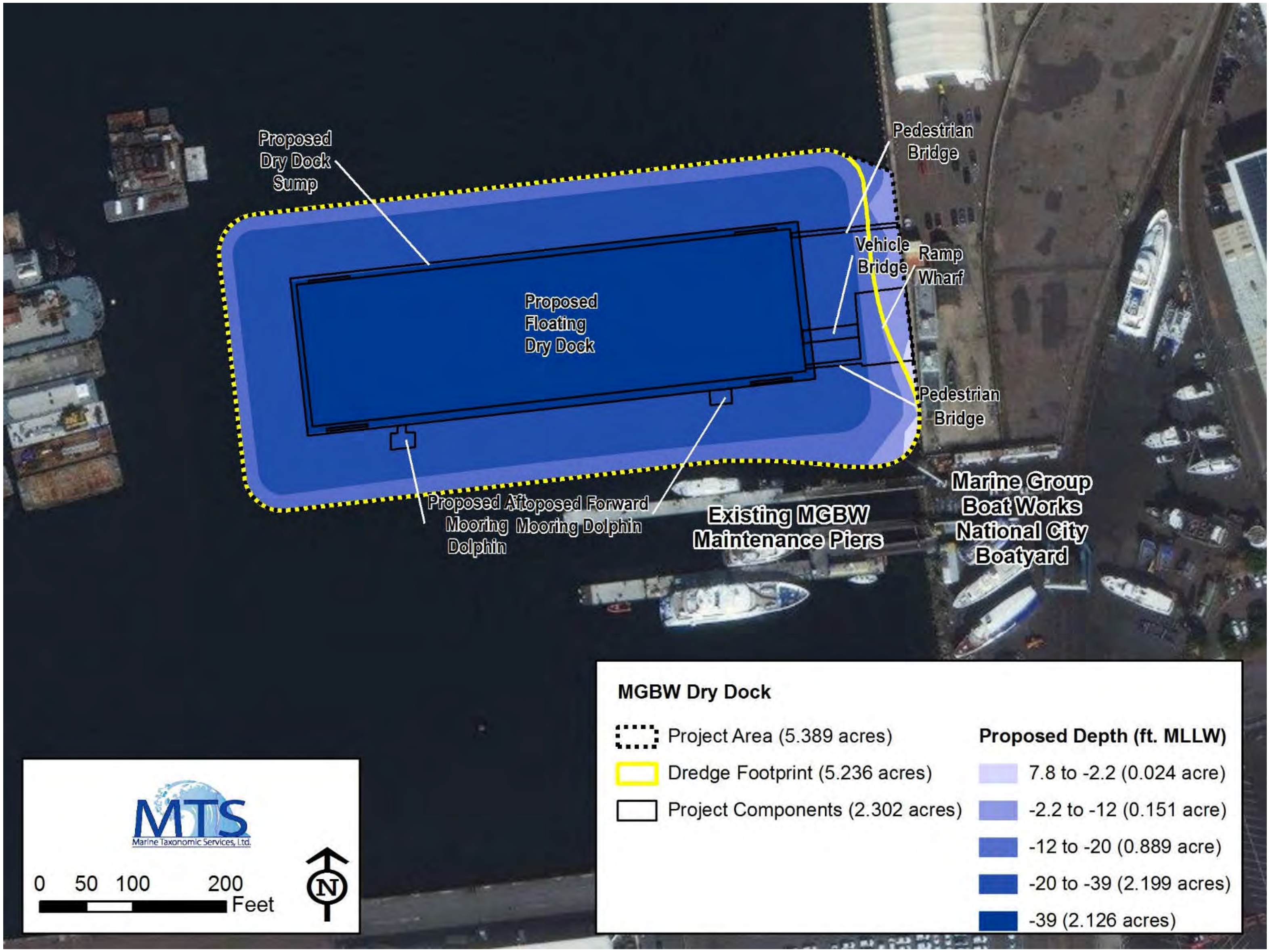

Figure 2. Preliminary Project design with post-construction bathymetry of the Project area. The Project's proposed dredge footprint is outlined in yellow, while area distinguished by habitat depth class are indicated as increasing shades of blue.

3 Methods

3-1 General Approach

At a high level, the Project will result in a transition of marine habitat that is relatively shallow and partially vegetated to one which is deeper and partially shaded. The habitat transition resulting from the project demonstrably results in an incremental change in San Diego Bay natural resources, and mitigation for that impact is required. The approach taken to determine appropriate mitigation need combines existing regulatory mitigation ratios that are derived from policy and additional mitigation calculated indirectly as functional equivalencies. For example, eelgrass mitigation is subject to a well-defined policy in the CEMP (NOAA Fisheries 2014), while out-of-kind mitigation for other types of impacts have no respective policy basis. Where policy guidance was lacking, the mitigation approach presented herein drew upon available data sources and knowledge of regional ecology to establish a defensible basis for out-of-kind mitigation.

Since eelgrass is present at the Project site, the CEMP was applied first. Second, the nature of the Project also justified several *a priori* components of this mitigation plan relating to specific demonstrable conditions or Project components. These components were evaluated individually, and mitigation assessed as described in detail below. The majority of the Project site subject to mitigation is comprised of non-vegetated soft bottom habitat which will be transformed to deeper habitat. The approach for these areas was to establish habitat values for soft-bottom habitat at various depths and calculate the loss of function as a result of the transformation to deep habitat, while also considering additional loss in function related to habitat shading.

Following establishment of mitigation need, the second component of mitigation is to establish the basis of mitigation credit. This mitigation program proposes to draw upon established mitigation bank credits in the form of established eelgrass habitat. Therefore, an additional set of calculations is presented to relate the loss in function of non-eelgrass habitats to the functional equivalent of eelgrass beds. The mitigation need is the sum of the individual habitat mitigation components assessed in this plan, expressed as an eelgrass bed functional equivalency.

3-2 Data Sources

Project design information was obtained from two sources. Recent existing bathymetry data was sourced from Orca Maritime as collected in July 2019 (Orca Maritime 2019). Project design information was provided by Triton Engineers, including the preliminary design drawings which will be used to contract infrastructure construction and dredging work at the site (Triton Engineers 2019). The preliminary design drawings were used to calculate Project dimensions (e.g. dredged area, dredged depths, shaded area) of the Project. Comparisons between the existing and future bathymetry (from the dredge plan) were used to evaluate changes of various habitat types resulting from the Project and form the basis of area-based mitigation calculations.

3-3 Approach for Calculating Eelgrass Loss and Associated Mitigation

Vegetated shallows are recognized as a special status habitat and in southern California bay environments, eelgrass provides a multitude of ecological functions (NOAA Fisheries 2014). It is a unique and protected habitat and is subject to specific mitigation requirements under the CEMP (NOAA Fisheries 2014). Regarding the extent and nature of eelgrass (*Zostera marina*) at the project site, this report relies on a combination of previously collected data and literature and observations made during survey work performed by MTS staff Robert Mooney and Hannah Joss on October 28, 2019. Several eelgrass surveys have been conducted in San Diego Bay as part of the INRMP program (e.g., Port and Navy 2013). Results of several bay-wide surveys indicated that eelgrass was not consistently present at the site and suggested recent colonization of the area. The Environmental Assessment prepared by the Navy included results of a 2017 survey which reflected detection of a previously undetected eelgrass bed in the shallow southeast corner of the project area (M&A 2018 as cited in U.S. Navy 2019). The October 28, 2019 survey was performed at the direction of MGBW to validate and map the current presence of eelgrass (*Zostera marina*) in the project vicinity (MTS 2019). The 2019 survey is used in this document to preliminarily calculate mitigation need for vegetated eelgrass habitat per CEMP.

3-4 Approach for Assessing *de minimis* or Beneficial Project Impacts

Project data sources referenced above were also used to consider what Project elements might be considered to present positive or *de minimis* effects upon marine biological resources at the site, and therefore treated as neutral or beneficial impacts. Several components of the project fall into this category:

- Mechanical dredging techniques include generally accepted practical limitations of technology (e.g., the dredge permit ‘overdredge’ allowance). This project includes an overdredge allowance of 2 feet below the project depth. Above this overdredge prism (above -38 ft MLLW) are materials which must be dredged to meet project operational requirements. Below the overdredge limit (below -40 ft MLLW) lie sediments which are not authorized to be dredged. For purposes of assessing impacts of this project, a depth horizon one foot below the project depth (-39 ft MLLW) was chosen as the appropriate lower bathymetric boundary on which to model impacts.

- Removal of marine debris; marine debris is of unknown origin and/or character, and will be disposed of appropriately. This constitutes a project benefit, as debris removal is a restoration activity.

- An additional component of the project includes ongoing operations. Since sedimentation occurs in this part of the bay, it is presumed that future project maintenance dredging will be necessary to preserve the safe operation of the floating dry dock. Since maintenance dredging will restore the initial project condition at the bottom of the sump, and is well below the habitable zone for eelgrass (the only mitigation policy which might apply), maintenance dredging activities are appropriately considered *de minimis* with regards to impacting habitat in the future.

In summary, project elements of overdredging, debris removal, and maintenance dredging do not generate mitigation need.

3-5 Approach for Calculating Habitat Depth Conversion Impacts

Mitigation for non-eelgrass related habitat changes in areas encompassed by the Project are driven by a comparison of the existing habitat and their respective habitat values to the future post-implementation habitat conditions at the Project site. The purpose of this document is to ultimately determine mitigation required to account for bay habitats that will be permanently altered as a result of the proposed Project.

As a first step towards determining the habitat conversions, the current habitats within the project area were identified using the same classifications used by the Port of San Diego and the U.S. Navy within the San Diego Bay Integrated Natural Resources Management Plan (INRMP; U.S. Navy and Port of San Diego 2013). The INRMP defines bay habitat classes in terms of elevation as intertidal habitat (+7.8 to -2.2-feet MLLW), shallow subtidal habitat (-2.2 to -12-feet MLLW), moderately deep subtidal habitat (-12 to -20-feet MLLW), and deep subtidal habitat (depths greater than or equal to -20 feet MLLW). Additional features can be overlaid on these habitat classifications (e.g. vegetation, substrate type).

MTS used available pre-project (Orca Maritime 2019) and design depth data (Triton Engineers 2019) to classify depths within the above habitat classifications defined in the INRMP. One modification was made to the Orca Maritime (2019) data prior to analysis. There is a sunken vessel within the Project area which will be removed as marine debris. The area of the sunken vessel was cropped from the bathymetry data and contour lines redrawn to represent the existing bathymetry without the sunken vessel. Thus, the vessel itself is excluded from habitat impact analysis (see Section 3.4), while dredging the underlying bay bottom is considered part of the overall Project impact.

Depths were interpolated between the existing condition and the proposed Project dredged depth distribution to best represent the proposed depth distribution within the Project area,. This was necessary because the current Project plans are preliminary. However, due to favorable existing conditions (i.e., linear isobaths and/or flat bathymetry), the important design features causing habitat impacts are readily discernable (e.g. horizontal limit of dredged sump, maximum depth of the sump). Interpolation of depths across features allowed calculation of habitat change where the dredge limits abut existing conditions and the anticipated slope extending to the proposed -20-foot MLLW depth contour and beyond to the maximum Project depth (-39-ft MLLW used for analysis as noted above). Once the pre-Project and post-Project data were compiled, the two surfaces were converted to a 1-foot grid. Within the grid, the depth values were categorized based on habitat depth classifications defined in the INRMP and provided above. The surfaces were also subtracted to understand the area-based change in each 1-foot depth increment present at the Project site after construction.

Determining appropriate mitigation for the depth-based changes before and after construction meant that the habitats present before and after Project implementation needed to be quantitatively valued so that mitigation could be determined that adequately addresses the lost value. This was accomplished by applying the results of the Cabrillo Shallow Water Habitat (CSWH) Study (M&A 2019). The CSWH Study evaluated the effects of converting a formerly deep-water habitat in the Port of Los Angeles (San Pedro, California) to shallow water, including effects on benthic invertebrates. The CSWH Study found that converting deep water to shallow water improved the benthic macroinvertebrate community. In this assessment, the results of the CSWH Study are used to quantify the reverse process: converting a shallow water condition to deeper habitat.

The CSWH Study compared the benefit of converting soft-bottom habitat in the Port of Los Angeles based on infaunal invertebrate community metrics. The "ecological lift" determined from the CSWH Study was directly applied to depths at the Project area by applying a linear relationship to all subtidal depth classes for the pre- and post-Project configurations. The CSWH Study evaluated ecological lift between -51-feet MLLW and -15-feet MLLW. Since subtidal depths at the Project area extend to intertidal at approximately -2-feet MLLW, the results of the CSWH Study were extrapolated for subtidal depths above -15-feet MLLW.

The linear relationship from the CSWH Study was applied in two ways. First, application of the linear relationship was used to determine the relative lift of the average depth within each of the INRMP identified habitat depth classifications present within the Project area. The baseline depth from the CSWH Study (-51-feet MLLW) was subtracted from each of the median depths for each habitat depth classification identified in the INRP and the difference was then multiplied by the slope of the linear relationship between depth and ecological lift as determined by changed in the infaunal invertebrate community. That is, the impact for the Project relative to dredging was established for the incremental conversion of shallow to deep water, based on the slope of the linear relationship established in the CSWH Study. This provided the relative ecological lift moving from deeper to shallow water across the habitat depth classifications in a manner consistent with the CSWH study.

The difference between the ecological lift for each habitat depth classification was used to determine the relative value between the average depths for each habitat depth classification, and thus form a basis for determining mitigation ratios between the habitat depth classes. Mitigation ratios were standardized relative to one unit of the habitat being converted. Reciprocal values were also calculated to show the mitigation ratios when converting from deep to shallow.

The second application of the CSWH Study depth-ecological lift relationship was based on application of each foot of depth change within each of the one-square-foot grid cells as defined above to determine the lost ecological value associated with the Project on a Project specific depth change basis. This required the relative ecological lift associated with each foot of depth change to be calculated and then summed across all depth classes. The formula to calculate the lift difference is:

$$\sum_{i=1}^{N} DL_i \left(\frac{\mathrm{Ae}_i \quad \mathrm{Ap}_i}{A}\right)$$

Where:

Ae_i is the existing area within each depth class from 1 to *N.*
Ap_i is the proposed area within each depth class from 1 to *N.*
A is the total project area.
DL_i is the depth relative lift for each depth class from 1 to *N.*

The values used for DL are dependent upon the function used to determine lift. In the current calculation, the depth relative lift was calculated using the same linear function noted above from application of the CSWH Study data which had a slope of 0.0256. The lift was calculated starting at a relative depth of -51 feet with this maximum depth assigned a lift of 1. The formula for calculating depth relative lift for a linear function is:

$$DL_i = 1 + 0.0256(D_i \qquad 51)$$

Where:

D_i is the depth for each depth class from class 1 to *N*.

The range of depths chosen for the analysis were all of the subtidal depths within the range of the existing and proposed Project depth surfaces (from -39 to -2-ft MLLW). Note that application of the above formulas provides the depth relative lift standardized to the Project area. By the nature of this calculation, determination of any mitigation requires application of a mitigation ratio based on comparative habitat values to be multiplied by the mitigation area. The area of the depth relative lift must be equal to or larger than the area-adjusted ecological loss for mitigation to be deemed suitable.

3-6 Approach for Calculating Shading Impacts

Determining the lost ecological lift associated with shading requires two primary pieces of information. First, the extent of shading needs to be known. In the context of the Project, the extent of shading is clear: all structures placed over the water as part of the Project will shade the bottom. Second, an appropriate measurable factor (or suite of factors) must be evaluated to determine the level of impact associated with shading. Understanding the impacts associated with shading is more difficult and can arguably take many forms. In this analysis existing data were used to evaluate relative levels of photosynthetically active radiation (PAR) under future conditions with the Project fully implemented.

Shading impacts were determined using direct measurements of light intensity as a surrogate for measuring or evaluating biological value. Two datasets informed the determination of Project impacts to the light regime. First, M&A (2013) was reviewed to determine the extent to which light levels diminish under piers. Second, unpublished data supplied by Keith Merkel of Merkel & Associates documented the depth of the photic zone in southern California harbors. The depth-light relationship was sourced from investigations used to inform the extent of surveys for *Caulerpa taxifolia* in bays and harbors in southern California after the successful eradication of *Caulerpa taxifolia* (Anderson et al. 2005).

For the first study, M&A (2013) used PAR sensors to determine light attenuation under two piers in San Diego Bay relative to reference conditions away from the piers. The results of the study were used to estimate the average light attenuation associated with overwater structures. The level of attenuation moving from the edge to the mid-point of the pier was not linear; the area under the "curve" from the 3 monitoring points used in M&A (2013) was used to determine the average PAR reduction under a pier.

The second study included the depth-light relationship for a PAR sensor lowered through the water column in San Diego Bay (as provided by Merkel); attenuation was determined by plotting the light and depth, and modeling an exponential relationship via regression. The relationship was expressed as percentage of PAR light loss relative the surface condition of 100% available light.

In order to account for overwater shading impacts to bay habitats caused by the proposed Project, post-construction structures were used to calculate the areas within each depth classification that would occur underneath the proposed construction footprint. Each of the 1-foot depth classes were assigned a shading depth correction factor that was based on the potential light reduction associated with overwater cover relative to non-covered conditions. This was accomplished by combining the exponential loss of light with depth as previously measured in central San Diego Bay and the light attenuation data collected under two piers in San Diego Bay.

For purposes of this model, the two practical limitations were established: 1) shading impact due to pier shading could not be greater than the effect of unobstructed attenuation in the water column; and 2) an impact is not practically meaningful where light was attenuated to an extent that photosynthesis is below a *de minimis* level. Thus, the maximum shading depth correction factor was determined to be the depth value where the exponential loss of PAR through the water column was equal to the loss of light indicated by calculation of the area under the curve for light under piers observed in M&A (2013). Likewise, a minimum corrected depth value was set as the depth where the exponential light attenuation curve predicted light attenuation to 1% of surface light. This meant the maximum shading depth correction factor was used for all depths that were shallower than the difference between maximum shading depth correction factor and the minimum corrected depth value. As the depths to be corrected for shading fell below the difference between the two values, the shading depth correction factor was decreased to prevent the corrected depths from falling below the minimum corrected depth value.

The depth corrected values for areas of seafloor underneath structures were then used to correct the ecological loss associated with changing depths at the site. This was done by determining the shading depth relative lift lost for each adjusted depth category and standardizing that for the Project area so that it could be added to the lost ecological lift calculated for the site as a whole.

3-7 Approach for Calculating Value of Eelgrass Relative to Bare Bottom

Sections 3.5 and 3.6 outline the methodologies for assessing habitat impacts; this section presents the approach for establishing a mechanism to translate out-of-kind impacts to the proposed mitigation credits. Since the anticipated mitigation measure for the Project is to mitigate for lost ecological value using eelgrass bank credits owned by the U.S. Navy, eelgrass needed to be valued relative to unvegetated bay habitat.

The out-of-kind translation of habitat values drew upon available literature comparing seagrass-vegetated to similar unvegetated habitats (including eelgrass studies as a subset of seagrass studies) In keeping with the general methods used to value shallow water relative to deeper water, the potential increase in habitat value between seagrass-vegetated and unvegetated areas was evaluated by considering changes to the communities that inhabit seagrass beds. The primary focus was a review by Orth et al. (1984) that included summation of other work where fish and invertebrates were compared across seagrass and unvegetated areas. Unlike the CSWH Study, the review only provided results summarized by organism density. In addition to data summarized by Orth et al. (1984), four additional studies performed since Orth et al. 1984 were reviewed and used to provide additional data on the relative increase or decrease in the density of target organisms across eelgrass vegetated and unvegetated soft-bottom habitats.

The results of the literature review were listed and categorized by the seagrass studied. The results were compared for studies with *Z. marina*, other seagrasses, and all studies combined. Within each group, the density of target organisms in unvegetated habitat was subtracted from the density result for the same group of organisms within the studied seagrass habitat. Results were expressed as the percent increase or decrease of target organisms across the two habitats. The data were then summarized and graphed by providing the maximum observed difference, the minimum observed difference, the mean observed difference and the median observed difference for each of the seagrass study groups. The value of eelgrass relative to bare bottom was taken as the median for the *Z. marina* group of studies.

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4 Results

4-1 Existing Bathymetry

In order to analyze potential impacts caused by the proposed Project for the purpose of this report, anticipated changes to bathymetry within the proposed Project dredge footprint were mapped for comparison. Unlike post-dredging conditions as illustrated in Figure 2, the existing bathymetry does not contain deep subtidal habitat within the proposed Project footprint.

Pre-construction conditions mapped in Figure 3 were compared with post-construction conditions mapped in Figure 2 in order to quantify bathymetry changes resulting from the proposed Project. The results of this analysis are discussed below in Section 4-4 of this document.

4-2 Eelgrass Resources, Impacts, and Mitigation

The following sections provide the results of recent eelgrass monitoring and detail the anticipated Project eelgrass impacts and mitigation required to compensate for impacts to eelgrass.

4-2.1 Eelgrass Resources

Results of the October 28, 2019 eelgrass survey (MTS 2019) revealed that there were 36,081 square feet (0.828 acre) of eelgrass beds occurring within and immediately adjacent to the proposed Project area at the time of the survey (Figure 3). Several small patches of eelgrass were observed just outside of the Project area footprint (refer to Figure 3), but were included in the coverage estimate. However, eelgrass mapped outside of the Project area made up an extremely small portion of the total mapped eelgrass habitat.

4-2.2 Eelgrass Impact

All the mapped eelgrass is assumed to be impacted regardless of whether it occurs inside or immediately adjacent to the Project footprint. This determination is based on two lines of reasoning. First, the eelgrass outside of the Project footprint occurs immediately adjacent to the dredge footprint. It is possible that eelgrass in that area will be directly impacted by construction or indirectly by the new operational environment. Second, the amount of eelgrass is so small and isolated that it is arguably not worth monitoring for long-term impacts relative to simply assuming it will be impacted and including that impact in the mitigation.

4-2.3 Eelgrass Mitigation

If MGBW were to mitigate for all eelgrass currently on site through successful establishment of a new eelgrass mitigation site, the mitigation ratio specified in the CEMP is 1.2:1 in order to account for the direct impact as well as temporal disruption in habitat value. This would require successful establishment of 43,297 square feet (0.993 acre) of eelgrass. The CEMP suggests a conservative approach to mitigation that incorporates information on the expected successful eelgrass coverage within past restoration sites (eelgrass cover is not always 100%). The recommended planting ratio is 1.38:1. Hence, the CEMP recommends that for successful establishment of the required eelgrass mitigation, that a new mitigation site accommodate 49,792 square feet (1.143 acre) of eelgrass.

If eelgrass mitigation occurs through withdrawal of credits for an established eelgrass bank, the CEMP allows for use of existing credits at a 1:1 mitigation ratio. This ratio reflects that there was no temporal loss of the resource as the bank was established prior to the impact. Under this scenario, direct release of 36,081 square feet (0.828 acre) worth of eelgrass bank credit from the U.S. Navy's San Diego Bay eelgrass habitat credits (per agreement with and at the discretion of the U.S. Department of the Navy) could be used to mitigate for eelgrass impacts.

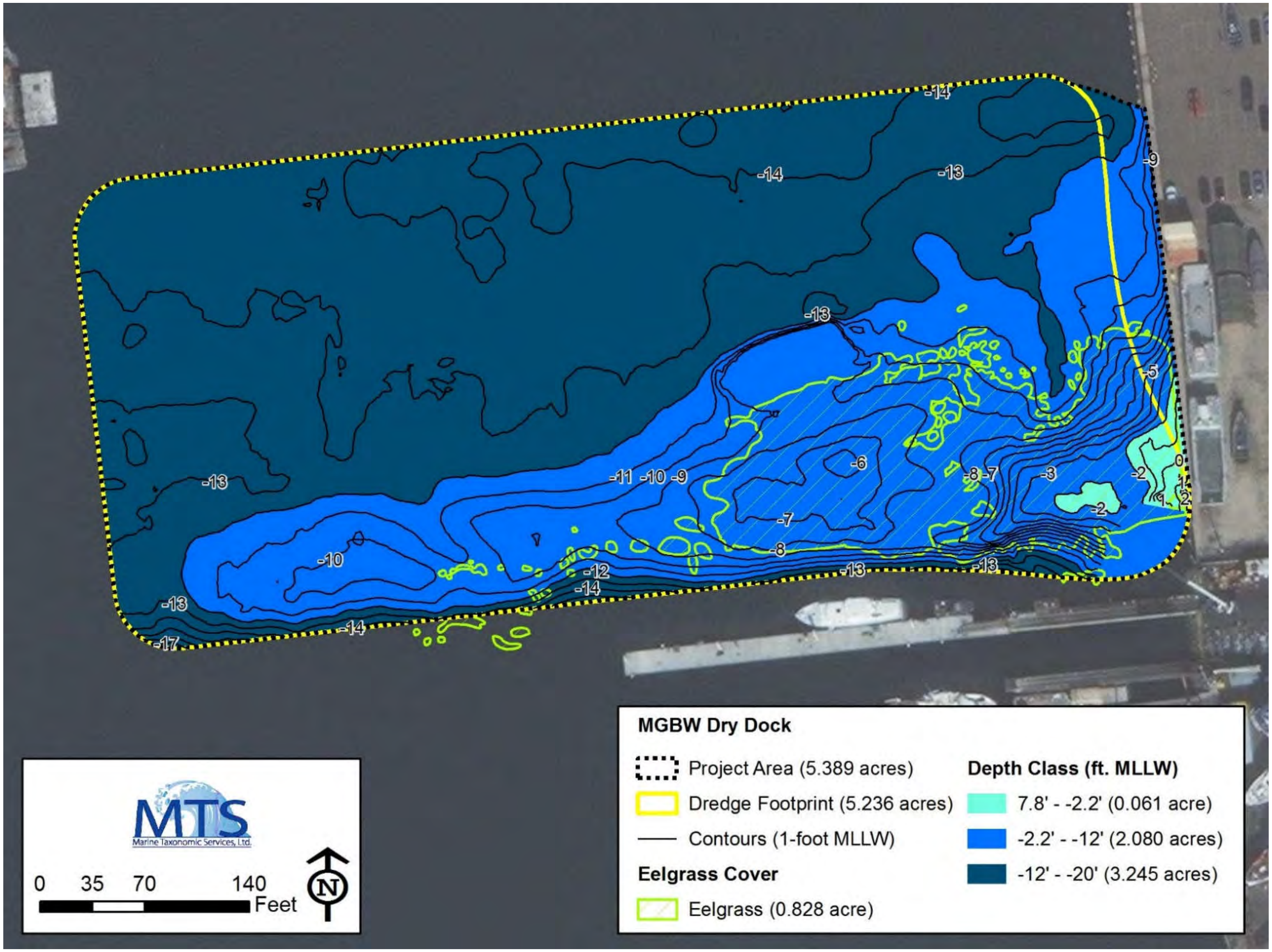

Figure 3. Pre-construction bathymetry of the proposed project Area. The Project’s proposed dredge footprint is outlined in yellow, while area distinguished by habitat depth class (intertidal, shallow subtidal, and moderately deep subtidal) are indicated in teal, blue, and purple, respectively.

4-3 Beneficial and *de minimis* Project Impacts

Any marine debris encountered as part of this project will be removed and disposed of appropriately. While some debris might be considered *de minimis* in nature, a substantial project effort is the removal of an existing wreck from the site, which is believed to constitute unpermitted fill. The wreck is of unknown precise origin (i.e., the date of wreckage is unknown), presides in the middle of the project site, and it is not known what conditions might be present in its vicinity. The removal of the wreck and associated sediments to a depth of 13.5 feet MLLW will be included in the dredge permit application as materials to be disposed of at an appropriate upland facility. As the wreck was not designed as an artificial reef (i.e., as defined in the Clean Water Act), removal of this marine debris constitutes an improvement in habitat. Removal of the marine debris constitutes a project benefit, and mitigation is therefore inappropriate. For purposes of determining mitigation need, the wreck itself has been excluded from calculations; however, the underlying bay bottom (based on bathymetry of the area immediately surrounding the wreck) has been included in the calculation of project impact, and thus is included in the mitigation calculation.

The project dredge application includes a 2-foot overdredge allowance across the dredge footprint, which is a standard component of projects resulting from the technological limitations of mechanical dredging. That is, the project description recognizes that there is a minimum 'design depth' of dredging which is necessary to accommodate future activities at the site, but the accuracy of mechanical dredging is such that additional incidental dredging is necessary to obtain the minimum design depth across the dredge footprint. Regulatory agencies have long accepted a 2-foot overdredge depth allowance to accommodate technological limitations; dredging deeper than the 2-foot overdredge depth allowance is specifically excluded from the permitted action. For the purposes of defining mitigation need, the 2-foot overdredge allowance is in many ways a contingency. For this project, the top foot of the overdredge allowance has been included in calculations of project impacts, while the bottom foot of overdredge allowance has been excluded from the calculations of mitigation need as a *de minimis* impact.

As stated above, future maintenance dredging has been excluded from consideration as an impacting activity since maintenance dredging restores a previously permitted condition and respective habitat values. In the case of this project, the maintenance dredging would occur at great depth relative to potential eelgrass habitat, and thus the CEMP would not apply.

4-4 Depth Conversion, Ecological Value, and Impacts

The determination of impacts associated with conversion of depths associated with dredging were determined by first evaluating the range of depth habitat classes being converted and then assigning an ecological value to the habitat depth classifications so that the relative ecological loss could be defined relative to change in depth and integrated across the Project area.

4-4.1 Depth Conversion

The result of the habitat conversion analysis generated the matrix below in Table 1. Areas of habitat types within the pre-construction Project area (vertical axis) were compared to areas of habitat types within the post-construction Project area (horizontal axis). The resulting areas generated inside the matrix quantify how much of each habitat depth classification within the pre-construction Project area will be converted to a different habitat depth classification as a result of the proposed Project. For example, Of the 2,314 square feet (0.053 acre) of intertidal habitat present within the proposed Project area, 226 square feet (0.005 acre) will remain as intertidal, 710 square feet (0.016 acre) will be converted into shallow subtidal habitat, 861 square feet (0.020 acre) will be converted into moderately deep subtidal habitat, and 517 square feet (0.012 acre) will be converted into deep subtidal habitat.

The proposed Project would predominately result in existing habitats within the Project area becoming deeper, as a result of dredging activity within the proposed dredge footprint. Each of the 3 habitat types found within the pre-construction Project area would persist, albeit at a smaller area. For example, only 1,615 square feet (0.037 acre) of shallow subtidal habitat would remain from the original 85,811 square feet (1.970 acre) of shallow subtidal habitat currently present and areas within existing depth classes would not necessarily share the same geospatial distributions between pre-construction and post-construction conditions.

It is important to note that the small change in area (400 square feet total) whereby shallower habitat is created, is the result of a bathymetric data gap which confounds conversion of GIS data into quantifiable changes in habitat types. Because the proposed Project involves dredging and no fill elements are proposed, habitat from pre-existing conditions can only stay the same, or get deeper. It is also important to note that the matrix in Table 1 does not provide for complete habitat conversion and lost ecological values. The matrix below, for example, doesn’t account for the area that would be shaded as a result of the proposed Project’s overwater structures. Furthermore, all existing eelgrass, and all unvegetated eelgrass habitat within the dredge footprint would be converted to bare bottom habitat as a result of the proposed Project. The impacts associated with loss of eelgrass and shading are provided in sections 4-1 and 4-5, respectively.

Table 1. Total area (in square meters) of impacts to habitat bathymetry as a result of the proposed Project. Habitat types are distinguished by occurrence at feet mean lower low water (MLLW), with Intertidal Habitat occurring between +7.8 to -2.2-feet MLLW, Shallow Subtidal Habitat occurring between -2.2 to -12-feet MLLW, Moderately Deep Subtidal Habitat occurring between -12 to -20-feet MLLW, and Deep Subtidal Habitat occurring at depths greater than or equal to -20-feet MLLW.

		Post-Construction Habitat			
	Habitat Type	**Intertidal (614 square feet)**	**Shallow Subtidal (2,347 square feet)**	**Moderately Deep Subtidal (40,623 square feet)**	**Deep Subtidal (188,422 square feet)**
Pre-Construction Habitat	**Intertidal (2,314 square feet)**	226	710	861	517
	Shallow Subtidal (85,811 square feet)	388*	1,615	11,862	71,946
	Moderately Deep Subtidal (143,882 square feet)	0	22*	27,900	115,960

*Map data artifact no fill proposed

☐	Habitat made shallower
░	Habitat depth class unchanged
▓	Habitat depth class made deeper

4-4.2 Subtidal Depth-Habitat Valuation

The review of the Cabrillo Shallow Water Habitat (CSWH) Study (M&A 2019) identified an ecological lift of 92% for shallow harbor soft-bottom habitat relative to deep harbor soft-bottom habitat (Figure 4). In other words, the valuation of shallow water was 92% higher than deep water. In the context of the CSWH Study deep water was -51-feet MLLW and shallow water was -15-feet MLLW.

As noted in the methods, the above relationship was assumed to be linear, with an equal ecological lift per unit of depth change. This allowed the slope of the line that expresses the linear relationship to be used as a conversion factor to determine the relative ecological lift between any two habitat depth classifications within the range of -15 to -51. For the purpose of this analysis, an assumption was made that the relationship could be extrapolated to -2-feet MLLW to encompass the range of subtidal elevations present within the Project site. The slope of the linear relationship was 0.0256 (2.56%).

Application of the linear relationship was used to determine the relative habitat value of the mean depth within each of the INRMP identified habitat depth classifications present within the Project area (Table 2). The baseline depth from the CSWH Study (-51-feet MLLW) was subtracted from each of the mean depths for each habitat depth classification identified in the INRMP and the difference was then multiplied by the 0.0256. This provided the relative ecological lift moving from deeper to shallow water across the habitat depth classifications in a manner consistent with the CSWH Study. The results show that deep subtidal habitat at the Project site provides 55% increased ecological lift relative to the -51-feet MLLW value in the CSWH Study. Moderately deep subtidal and shallow subtidal provide for 89% and 112% greater ecological lift relative to -51-feet MLLW, respectively (Table 2).

The difference between the ecological lift for each habitat depth classification provides the relative value between the mean depths for each habitat depth classification (Table 3). The differences form the basis for determining mitigation ratios between the habitat depth classes present on site independent of the CSWH Study depth values. The resulting mitigation ratios are simply standardized relative to one unit of the habitat being converted. Reciprocal values are provided to show the mitigation ratios when converting from deep to shallow.

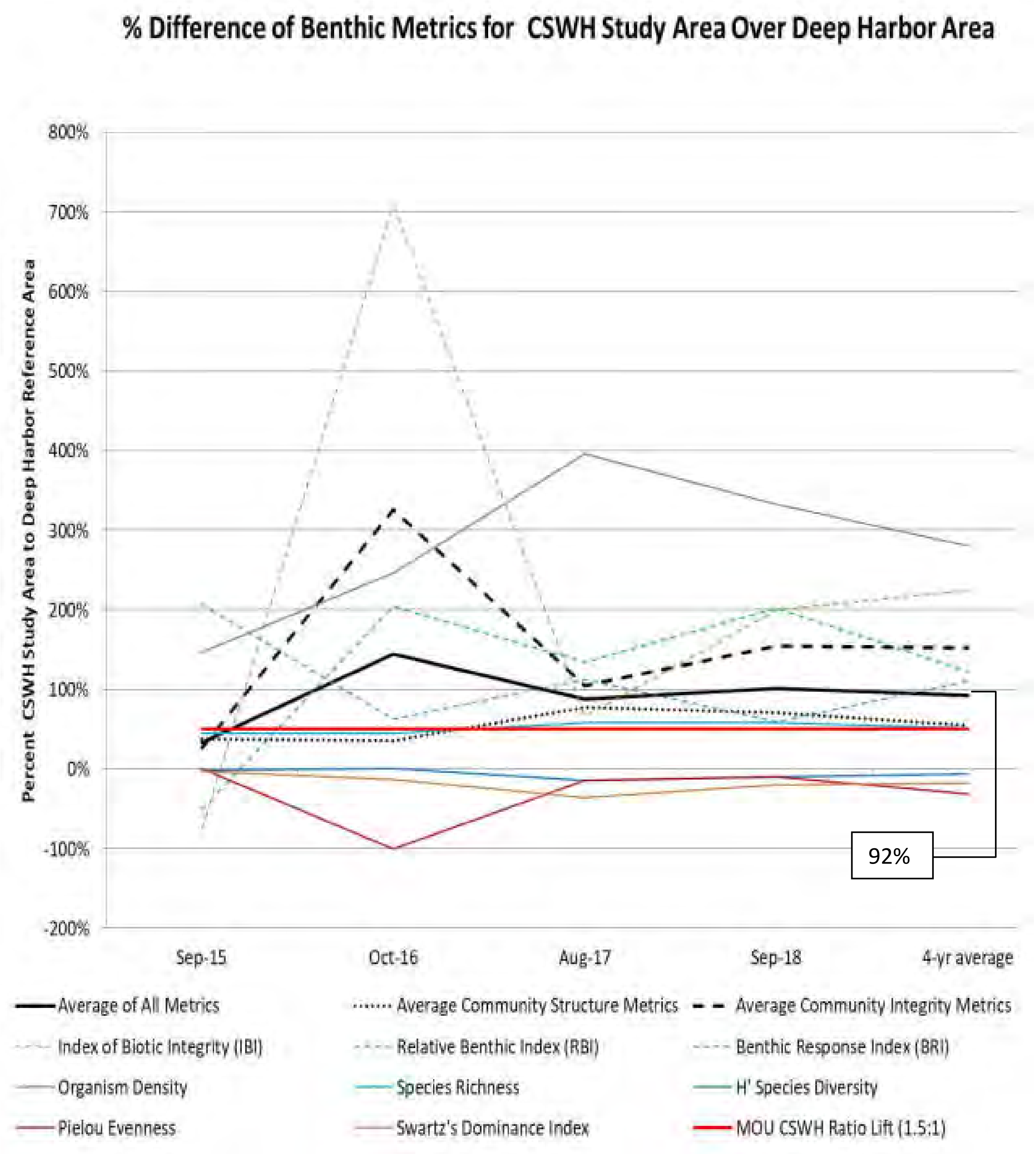

Figure 4. Functional lift in outer harbor habitat for Phase 4 of the Cabrillo Shallow Water Habitat. Figure adapted from M&A (2019).

Table 2. Depth range, median depth and ecological lift relative to -51-ft MLLW for habitat depth classifications as defined in the INRP.

Habitat Depth Classification	Depth Range	Mean Depth	Relative Lift
Intertidal	+7.8 to -2.2	2.8	NA
Shallow Subtidal	-2.2 to -12.0	-7.2	2.12
Moderately Deep Subtidal	-12.1 to -20.0	-16.1	1.89
Deep Subtidal	-20.1 to -39.0	-29.6	1.55
CSWH	-51	-	1.00

Table 3. Mitigation ratios for conversion of depth habitat classifications based on changes in relative ecological lift.

Habitat Conversion	Depth Change	Lift Difference	Mitigation Ratio	Reciprocal Ratio
Shallow Subtidal to Moderately Deep Subtidal	-8.9	-0.23	1.00 : 1.23	0.81 : 1.00
Moderately Deep Subtidal to Deep Subtidal	-13.5	-0.35	1.00 : 1.35	0.74 : 1.00
Shallow Subtidal to Deep Subtidal	-22.4	-0.57	1.00 : 1.57	0.64 : 1.00

The results of the analysis find that conversion from shallow subtidal to moderately deep subtidal can be performed with a mitigation ratio of 1:1.23 (Table 3). That is for every unit of shallow subtidal converted to moderately deep subtidal an additional 0.23 units of moderately deep subtidal are required to offset additional ecological value associated with the single unit of shallow subtidal. If additional moderately deep subtidal habitat cannot be created, then out-of-kind mitigation options should be sought that provide for the lost value. Similarly, conversion of moderately deep subtidal to deep subtidal can be mitigated at a 1:1.35 ratio and conversion from shallow subtidal to deep subtidal is the sum of the intermediate values (1:1.57). These values only reflect conversion based on depth of unvegetated soft substrate, and cannot be used relative to Project elements that alter ecological value based on other features such as shading or loss of eelgrass habitat.

4-4.3 Project Depth Conversion Impact

The extent of mitigation required due to lost ecological value can be determined by combining the results of the habitat conversion matrix (Table 1) with the mitigation ratios provided in Table 3. However, this approach is built upon an assumption that the value associated with each of the habitat depth classes is centered around the mean value for the depth class. Given the approach taken to assign ecological lift is based on each foot of depth change, it is also possible to calculate the overall lost ecological value across the Project area as it relates to Project specific depth changes. This provides for a more refined, Project specific valuation that accounts for the actual depth changes across the Project area (i.e., with a specificity of 1-foot depth intervals as opposed to depth classifications).

The results of the habitat depth classification impact analysis used the formulas specified in the methods relative to the Project's proposed changes in depth per unit area (Table 4). The results show that the lost ecological value associated with making the site deeper is -0.457 (45.7%). This value is standardized for the area analyzed (234,753 square feet; 5.39 acres) and includes all the area shown as the "Project area" in Figure 2 and Figure 3. This value establishes the ecological value which must be replaced relative to depth changes at the site over an equal area at another site. It is possible to mitigate for this loss with creation or restoration of ecological value at different scales and with different values as long as the product of lost ecological lift (i.e., impact) and Project site (area) equals the product of the mitigation area and the gained ecological lift at the mitigation site.

4-5 Shading from Overwater Coverage and Impacts

Shading causes benthic impacts because it limits primary productivity over the area shaded. In the current context, this is specific to the microphytobenthos and does not include planktonic producers since tidal currents reduce residence time of phytoplankton to a *de minimis* level. Planktonic productivity at the scale of the Project relative to the surrounding waters is virtually non-existent, and is practically speaking immeasurable. However, microphytobenthos producers reside on the bay bottom surface, and are important to epibenthic and benthic infaunal communities. Primary productivity at the seafloor is likely an important driving force for increased ecological lift associated with benthic communities irrespective of the presence of larger macrophytes (but certainly not the only factor contributing to primary productivity).

The determination of shading impacts associated with Project structures was determined based on existing data collected under piers and observed attenuation rate of PAR in the water column. These data were combined to determine the water depth equivalent adjustment necessary to equate shading with decreasing the seafloor elevation. The below sections provide the results of the shading and light analysis and the results are related to potential impacts.

4-5.1 Light Monitoring Results from Existing Data

The results from M&A (2013) showed that light was attenuated by the presence of the "small" pier by 80% and a large pier by 78%. The study may be characterized as providing limited data regarding light attenuation under pier structures, but nonetheless provides data which informs modeling shading impacts on microphytobenthos. Observations suggest that at 50% under the pier, the sensor was at the mid-point under the pier and this represented the worst-case condition for shading. Regardless of the other differences between piers, once 25% and 50% of the way under the pier from the edge, the average attenuation was 96% and 98% of background, respectively. Results were relatively consistent regardless of depth in terms of percent of light diminishment relative to the reference condition (ambient light intensity away from pier).

Project Depth / Area Change				Depth Based Ecological Lift/Loss				Shading Adjusted Ecological Lift/Loss			
Elevation (Ft MLLW)	Area Proposed (sf)	Area Existing (sf)	Area Change (sf)	Depth Relative Lift	Area Adjusted Lift (proposed)	Area Adjusted Lift (existing)	Area Adjusted Lift Change	Area Shaded (sf)	Shading Depth Correction (ft)	Area Adjusted Shading Lost Lift	Depth & Shade Lift Change
-39	95510	0	95510	1.307	0.532	0.000	0.532	83111	0	0.00E+00	0.532
-38	4376	0	4376	1.333	0.025	0.000	0.025	165	0	0.00E+00	0.025
-37	4439	0	4439	1.358	0.026	0.000	0.026	165	0	0.00E+00	0.026
-36	4506	0	4506	1.384	0.027	0.000	0.027	213	0	0.00E+00	0.027
-35	4569	0	4569	1.410	0.027	0.000	0.027	222	0	0.00E+00	0.027
-34	4642	0	4642	1.435	0.028	0.000	0.028	198	0	0.00E+00	0.028
-33	4706	0	4706	1.461	0.029	0.000	0.029	143	0	0.00E+00	0.029
-32	4766	0	4766	1.486	0.030	0.000	0.030	150	0	0.00E+00	0.030
-31	4840	0	4840	1.512	0.031	0.000	0.031	108	0	0.00E+00	0.031
-30	4900	0	4900	1.538	0.032	0.000	0.032	65	0	0.00E+00	0.032
-29	4978	0	4978	1.563	0.033	0.000	0.033	70	0	0.00E+00	0.033
-28	5045	0	5045	1.589	0.034	0.000	0.034	71	-1	-7.74E-06	0.034
-27	5123	0	5123	1.614	0.035	0.000	0.035	65	-2	-1.42E-05	0.035
-26	5193	0	5193	1.640	0.036	0.000	0.036	69	-3	-2.26E-05	0.036
-25	5264	0	5264	1.666	0.037	0.000	0.037	72	-4	-3.14E-05	0.037
-24	5333	0	5333	1.691	0.038	0.000	0.038	70	-5	-3.82E-05	0.038
-23	5423	0	5423	1.717	0.040	0.000	0.040	68	-6	-4.45E-05	0.040
-22	5481	0	5481	1.742	0.041	0.000	0.041	112	-7	-8.55E-05	0.041
-21	5555	0	5555	1.768	0.042	0.000	0.042	246	-8	-2.15E-04	0.042
-20	6659	0	6659	1.794	0.051	0.000	0.051	245	-9	-2.40E-04	0.051
-19	8014	0	8014	1.819	0.062	0.000	0.062	241	-10	-2.63E-04	0.062
-18	7565	0	7565	1.845	0.059	0.000	0.059	243	-11	-2.91E-04	0.059
-17	6105	9	6096	1.870	0.049	0.000	0.049	245	-12	-3.21E-04	0.048
-16	4856	103	4753	1.896	0.039	0.001	0.038	239	-13	-3.39E-04	0.038
-15	3669	3991	-322	1.922	0.030	0.033	-0.003	244	-14	-3.73E-04	-0.003
-14	2417	38028	-35611	1.947	0.020	0.315	-0.295	246	-15	-4.02E-04	-0.296
-13	1280	78563	-77283	1.973	0.011	0.660	-0.649	246	-16	-4.29E-04	-0.650
-12	1052	28610	-27558	1.998	0.009	0.244	-0.235	243	-17	-4.50E-04	-0.235
-11	1055	20902	-19847	2.024	0.009	0.180	-0.171	247	-17	-4.58E-04	-0.172
-10	1023	15780	-14757	2.050	0.009	0.138	-0.129	248	-17	-4.60E-04	-0.129
-9	1012	13636	-12624	2.075	0.009	0.121	-0.112	252	-17	-4.67E-04	-0.112
-8	981	11977	-10996	2.101	0.009	0.107	-0.098	245	-17	-4.54E-04	-0.099
-7	856	7501	-6645	2.126	0.008	0.068	-0.060	244	-17	-4.52E-04	-0.061
-6	565	3170	-2605	2.152	0.005	0.029	-0.024	202	-17	-3.74E-04	-0.024
-5	464	1838	-1374	2.178	0.004	0.017	-0.013	141	-17	-2.61E-04	-0.013
-4	442	1607	-1165	2.203	0.004	0.015	-0.011	130	-17	-2.41E-04	-0.011
-3	437	2156	-1719	2.229	0.004	0.020	-0.016	119	-17	-2.21E-04	-0.017
-2	419	2961	-2542	2.254	0.004	0.028	-0.024	106	-17	-1.97E-04	-0.025
-1	407	1346	-939								
0	345	986	-641								
1	286	776	-490								
2	154	469	-315								
3	41	344	-303								
Totals	**234753**	**234753**	**0**	**NA**	**1.520**	**1.977**	**-0.457**	**89509**	**NA**	**-0.007**	**-0.464**

Table 4. The above table provides the ecological value lost associated with the Project's dredging and shading impacts.

These results mean that on average there was 21% of light available at the pier edge, 4% of light available when 25% under the pier and 2% of light available when at the mid-point (Figure 5). The area under the curve provides that the average condition under the piers was 7.8% of light available relative to the reference condition. The proportion of light available is generally independent of depth although the actual light available diminishes with depth.

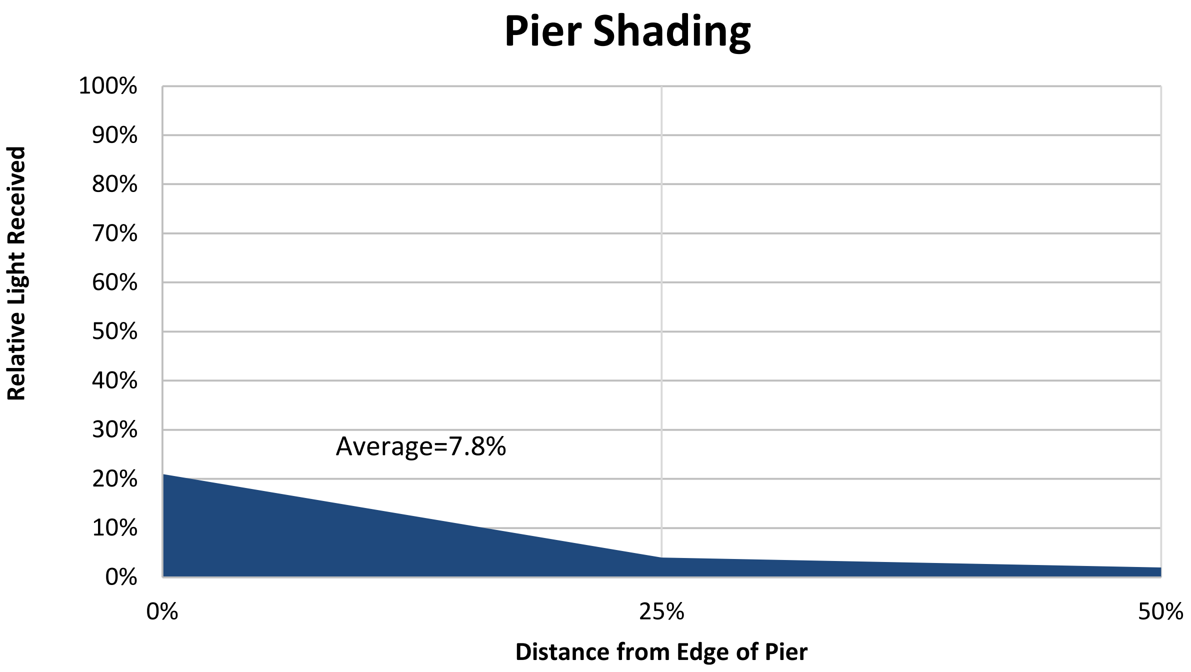

Figure 5. Summarized results from M&A (2013) showing the relationship between light levels relative to ambient conditions moving from the edge of a pier to the mid-point of a pier.

The results of lowering a PAR sensor through the water column in central San Diego Bay show the exponential light loss with depth (Figure 6). Fitting the data to an exponential curve show that light diminishes with depth according to the formula shown in Figure 6. The point in the water column where the percent of light remaining relative to the surface equals the relative incident light available under a pier (i.e., average value) is 16.7 feet. Stated another way, the light available at an unshaded depth of 16.7 feet is equivalent to the average light condition just below the water surface under a pier. At a depth of 28.6 feet light levels are 1% of surface. It should be noted that although these values are based on percentage change in light through the water column, the curve in Figure 6 was based on real data taken at a single point in time. If the water been more or less turbid at the time of monitoring, the curve might vary, and the referenced depths would be different. Nevertheless, these data provide relevant data and conceptual model on which to base shading impacts to microphytobenthos.

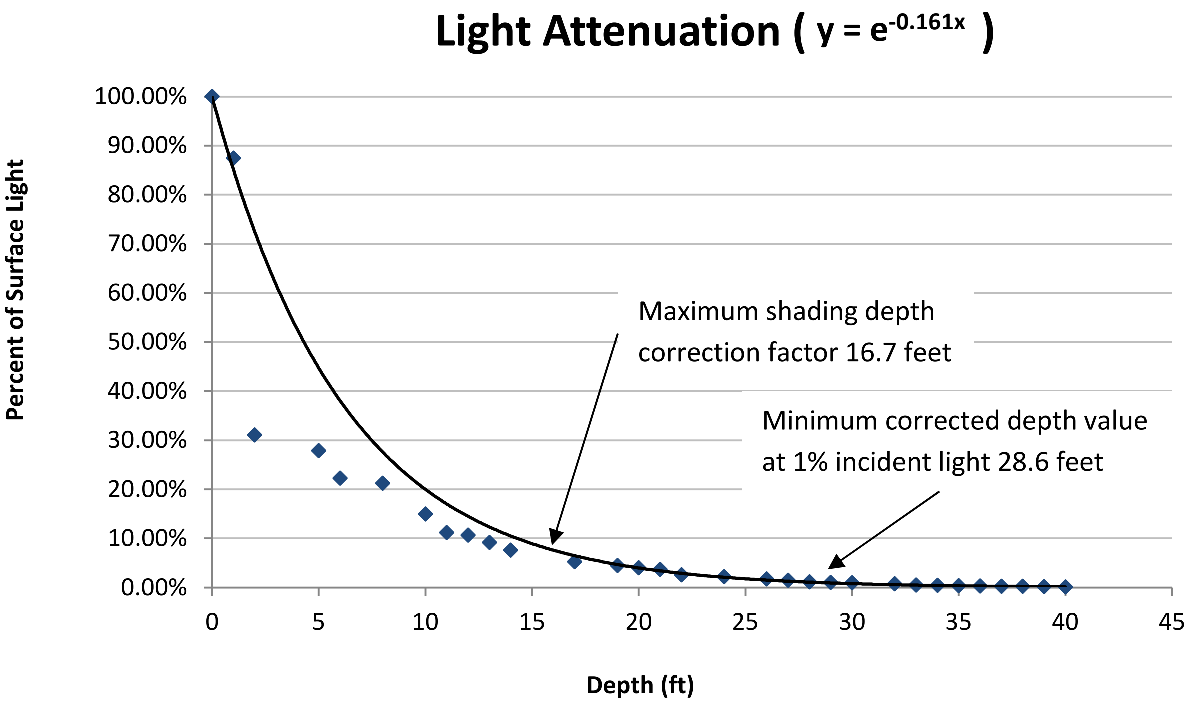

Figure 6. The observed relationship between light and depth in San Diego Bay expressed as a percentage of light available relative to surface light.

4-5.2 Shading Impacts

The result of the shading analysis was dependent upon application of the maximum shading depth correction factor and the minimum corrected depth value as determined from the methods provided above. The maximum shading depth correction factor was 16.7 feet as noted above, since this was equivalent to the maximum reduction in light observed as a result of shading under a pier. This value was rounded to -17 feet for the impact analysis. The minimum corrected depth value was 28.6 feet as noted above, since this was the depth at which light would be diminished to 1% of ambient light at the bay surface. This value was rounded to -29 feet for the impact analysis.

These parameters were used to assess shading effects beneath the drydock and ancillary structures (e.g., the dolphins and wharf). The results of the analysis show relatively minor impacts associated with shading when standardized across the Project area analyzed (234,753 square feet; 5.39 acres). The area adjusted lost ecological lift associated with shading calculated by the analysis was -0.007 (-0.7%) (Table 4). Although this value might seem relatively low considering the significant area of shading associated with Project structures, the mathematical driver is a function of the depths being shaded. Most of the shading is associated with the dry dock. Since the dry dock will be positioned over seafloor that is below the maximum shading depth correction factor, it is effectively removed from the analysis. The area remaining for analysis consisted of those areas shallower than -29-feet MLLW where shading occurred. Ultimately, the approach and results are appropriate if the lost productivity and ecological lift associated with depth is based on loss of primary productivity and its effect on secondary productivity of the invertebrate community. Under that conceptual model, impacts associated with depth conversion have already accounted for much of the lost primary productivity.

4-6 Relative Seagrass Valuation

Given that creation of eelgrass habitat is the proposed scenario for mitigation, valuation of eelgrass must be considered relative to unvegetated habitat. The ratio applied for this out-of-kind mitigation is considered below.

Seagrasses play many important roles in the systems they inhabit and are marine ecosystem engineers (Jones et al. 1994). They create physical structure forming habitat to the community of fishes and invertebrates that occupy seagrass beds or else live directly on the seagrass and they maintain the habitat they occupy through modification of physical processes. Seagrasses stabilize sediment and clarify water through sediment trapping and stabilization (de Boer 2007) and provide nutrient transformation and water oxygenation (Yarbro and Carlson 2008). Eelgrass serves as a primary producer in detritus-based food webs (Thresher et al. 1992) and is further directly grazed upon by invertebrates, fish, and birds (Valentine and Heck 1999), thus contributing to eco-system health at multiple trophic levels. Eelgrass is also a nursery area for many commercially and recreationally important finfish and shellfish (Heck et al. 2003), including both those that are resident within bays and estuaries, as well as oceanic species that enter the bays and estuaries to breed or spawn. Among local commercial and recreational important species, sand basses and lobster make use of eelgrass beds as habitat. Besides providing important habitat for fish, eelgrass and eelgrass-associated invertebrates provide important food resources that support migratory birds during critical life stages. In addition to their localized value, seagrasses are recognized as having globally significant contributions to carbon sequestration (Hoyt et al. 2014). The production or destruction of seagrass beds can have significant influence on atmospheric carbon dioxide levels.

The literature review summarizes a review by Orth et al. (1984) and includes results from four other studies performed since Orth et al. (1984) (Table 5). Unlike the CSWH Study which considered several ecological metrics, the seagrass literature review is focused on studies which measured organism density for several taxonomic groups. Table 5 provides the relative increase or decrease in the density of target organisms for each study.

The results of the comparisons of fish and invertebrate density inside and outside of various seagrass beds show that mean observed organism density increased by 1,280% and the median increase was 330% for all summarized studies (Table 5 and Figure 7). For studies focused on *Z. marina*, fish and invertebrate density changes revealed greater average increases; the eight studies that focused on *Z. marina* (or in one case a mixture of *Z. marina* and *Halodule wrightii*) showed an average and median increase in faunal density of 2,400% and 1,020%, respectively (Table 5 and Figure 7).

Table 5 Comparison of densities of animal communities associated with vegetated vs non-vegetated areas.

Localities	Seagrass	Faunal Assemblages--No. of Individuals Vegetated vs Nonvegetaded	Change (%)	Source
New York	*Zostera marina*	Fish 5.78 x 10^5 vs 5.45 x 10^5 per m^2	6.1%	Briggs and O'Connor 1971
Bermuda	*Thalassia testudinum*	Infauna 13,580 vs 3,145 per m^2	331.8%	Orth 1971
Florida	*Thalassia testudinum*	Polychaetes 33,485 vs 17,220 per m^2	94.5%	Santos and Simon 1974
North Carolina	*Zostera marina*	Macrofauna 923 vs 170 per m^2	442.9%	Thayer et al. 1975
Virginia	*Zostera marina*	Infauna 51,343 vs 1,771 per m^2	2799.1%	Orth 1977
North Sea	*Zostera noltii*	Infauna 2,035 vs 417 per 400cm^2	388.0%	Reise 1978
Virginia	*Zostera marina*	Mobile macroinvertebrates 13,032 vs 115*	11232.2%	Heck and Orth 1980b
Virginia	*Zostera marina*	Fish* 8,238 vs 303	2618.8%	Orth and Heck 1980
Florida	*Thalassia testudinum & Syringodium filiforme*	Macrofauna 3,185 vs 1,754 per m^2	81.6%	Stoner 1980c
California	*Zostera marina*	Bivalve-*Protothaca staminea* 20.4 vs 1.2 per m^2	1600.0%	Peterson and Quammen 1982
North Carolina	*Halodule wrightii*	Bivalves *Mercenaria mercenaria* 11.3 vs 0.4 per m^2 *Chione cancellata* 10.3 vs 0.4 per m^2	2725.0% 2475.0%	Peterson 1982
Australia	*Zostera muelleri*	Macrofauna 1,039 vs 156 per m^2	566.0%	Poore 1982
Belize	*Thalassia testudinum*	Macrofauna 12,167 vs 16,750 per m^2	-27.4%	Young and Young 1982
Florida	*Thalassia testudinum*	Macrofauna 654 vs 162 per 406 cm^2	303.7%	Lewis and Stoner 1983
Florida	*Thalassia testudinum & Halodule wrightii*	Macrofauna 17,479 vs 5,844 per m^2	199.1%	Virnstein et al. 1983
North Carolina	*Zostera marina & Halodule wrightii*	Macrofauna 3,223 vs 720 per m^2	347.6%	Summerson and Peterson 1984
California	*Zostera marina*	Fish** 1.70 vs 0.74 per m^2	217.5%	Hoffman 1986
Gulf of Mexico	*Thalassia testudinum*	Macroinvertebrates 296.9 vs 92.9 per m^2	219.6%	Valentine and Heck 1993
Gulf of Mexico	*Halodule wrightii*	Macroinvertebrates 274.2 vs 92.9 per m^2	195.2%	Valentine and Heck 1993
Malaysia	Mixed	Larval fish 79 vs 34 per 100 m^3	132.4%	Ara et al. 2011

*Trawl data. No estimates per m2. **Density estimate calculated from data provided in report.

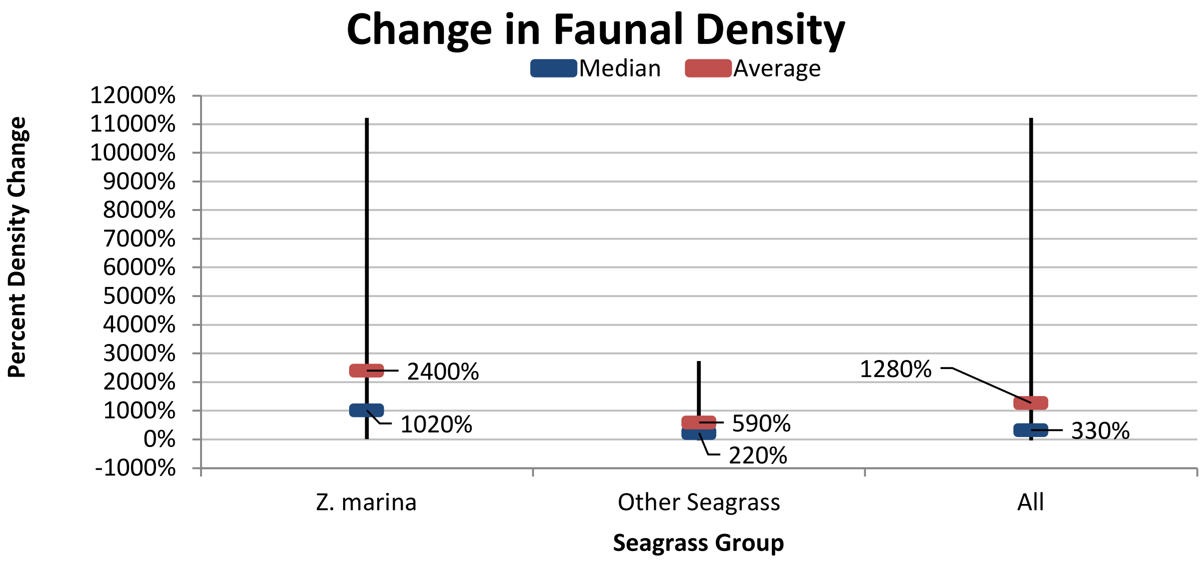

Figure 7. Summary of observed differences in faunal organism density between seagrass vegetated and non-vegetated reference areas using data provided in Table 5. Note that the study with mixed beds of *Z. marina* and *Halodule wrightii* is included in the *Z. marina* group. Bars represent minimum and maximum observed differences across studies.

The reviewed data show a high degree of variability in terms of how seagrasses affect the density of fish and invertebrate communities. Variation is particularly notable at the high end with 6 of the 21 studies showing increases greater than 1,000%, and a maximum of 11,232%. It is also notable that most of the studies showing the greatest lift are associated with *Z. marina*. Given variability at the high end, it is more conservative to utilize the median rather than the mean when evaluating the potential ecosystem lift of seagrass relative to comparative unvegetated habitat. The median organism density increases for eelgrass versus unvegetated areas are 220%, 330%, and 1,020% for studies of seagrasses other than *Z. marina*, all studies, and *Z. marina* studies, respectively. These can be directly translated into mitigation ratios of 2.2:1, 3.3:1, and 10.2:1.

Since the proposed mitigation is eelgrass habitat, the consensus of peer-reviewed literature supports a mitigation ratio for eelgrass relative to unvegetated shallow water of 10.2:1. This value reflects a conservative lift within the range of values of organism density change for those studies specific to *Z. marina*. Moreover, this value is conservative in that it does not account for larger-scale functions provided by seagrass beds in general. For instance, the reviewed data do not account for seagrass values associated with carbon sequestration (Hoyt et al. 2014), sediment stabilization (de Boer 2007), shoreline protection (Ondiviela et al. 2014), improved water quality (Yarbro and Carlson 2008), and conversion and export of productivity at higher trophic levels (Valentine and Heck 1999).

The results show that seagrass presence is important for multiple species. This effect is additive to any other value that can be associated with water depth as the studies reviewed generally controlled for other effects and were seeking to understand how seagrass presence interacts with faunal density. What this means in the current context is that it is appropriate to consider the additive effects of providing ecological lift by both making a site shallower, as well as by establishing eelgrass over that site. In southern

California, it is common practice to ensure the success of eelgrass transplants by filling areas too deep to support eelgrass to ensure a shallow habitat with a light regime sufficient to support eelgrass. While this pathway may be feasible at specific mitigation sites to achieve in-kind mitigation for impacts to eelgrass, the ecological lift provided by raising bathymetry alone, and thus providing an improved light regime and habitat benefits, is not typically included in habitat valuations. In this evaluation, any site that is created to support eelgrass is used to offset impacts through valuation of creation of a shallow site (and associated offsetting ecological lift) as well as credit for any eelgrass established per the CEMP.

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5 Mitigation Ledger

Project impacts to habitats outlined herein include direct impacts to eelgrass, alteration of the project footprint depth distribution, and shading. The ecological losses have been enumerated below, and are then offset using two scenarios 1) creation of shallow water habitat that is vegetated with eelgrass, and 2) withdrawing credits from an already established eelgrass mitigation bank.

Adequate mitigation is a balance of Project-related depth-associated ecological losses against ecological lift associated with mitigation. This requires that the Project area-adjusted loss equals the mitigation area-adjusted gain. As a formula, this is represented as:

$$A(EL_{\mathrm{P}}) = A_{\mathrm{M}}(GL_{\mathrm{DC}} + GL_{\mathrm{E}})$$

Where:

EL_{P} is the ecological loss for the Project,
A is the Project area,
A_{M} is the required mitigation area,
GL_{DC} is the gained ecological lift based on depth conversion (deep to shallow),
GL_{E} is the gained ecological lift based on eelgrass restoration.

Losses

Direct Eelgrass loss	0.828 acre (36,081 square feet)
Project area subject to ecological loss (A)	5.39 acres (234,753 square feet)
Project depth and shading ecological loss (EL_{P})	-46.4%

Gains

Mitigation via conversion of moderately deep subtidal to eelgrass vegetated shallow subtidal habitat.

Direct eelgrass loss mitigation (1.2:1)	0.993 acre (43,297 square feet); from CEMP
Mitigation area depth conversion lift (GL_{DC})	23%
Mitigation area eelgrass restoration lift (GL_{E})	1,020%
Mitigation area (A_{M})	0.240 acre (10,454 square feet); see formula above
Total required Project mitigation as eelgrass	1.233 acre (53,661 square feet)

Thus, if a Project specific mitigation site is constructed independently, the total required eelgrass mitigation is 0.993 + 0.240 = 1.233 acres. This amount offsets all depth, shading, and eelgrass related Project impacts.

Alternatively, if mitigation occurs through withdrawal of eelgrass from an existing eelgrass mitigation bank, the direct eelgrass losses would be mitigated at 1:1, no additional credit is applied to lift associated with depth changes that may have occurred for creation of the original mitigation site ($GL_{\mathrm{DC}} = 0$) such that the total required mitigation becomes 0.828+0.245 = 1.073 acre (46,740 square feet) of eelgrass bank mitigation credits.

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6 References

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February 8, 2020
M&A #14-075-38

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San Diego, CA 92132

RE: NBSD Mole Pier Floating Dry Dock Ecological Functional Loss Analysis and Potential for Offsetting Mitigation Employing the NEMS Bank, or New Eelgrass Restoration

Dear Sean,

This letter is to transmit information regarding the quantification of anticipated functional loss associated with the proposed Navy Base San Diego (NBSD) Mole Pier Floating Dry Dock Project, and to identify the means of offsetting the ecological impacts through eelgrass habitat development.

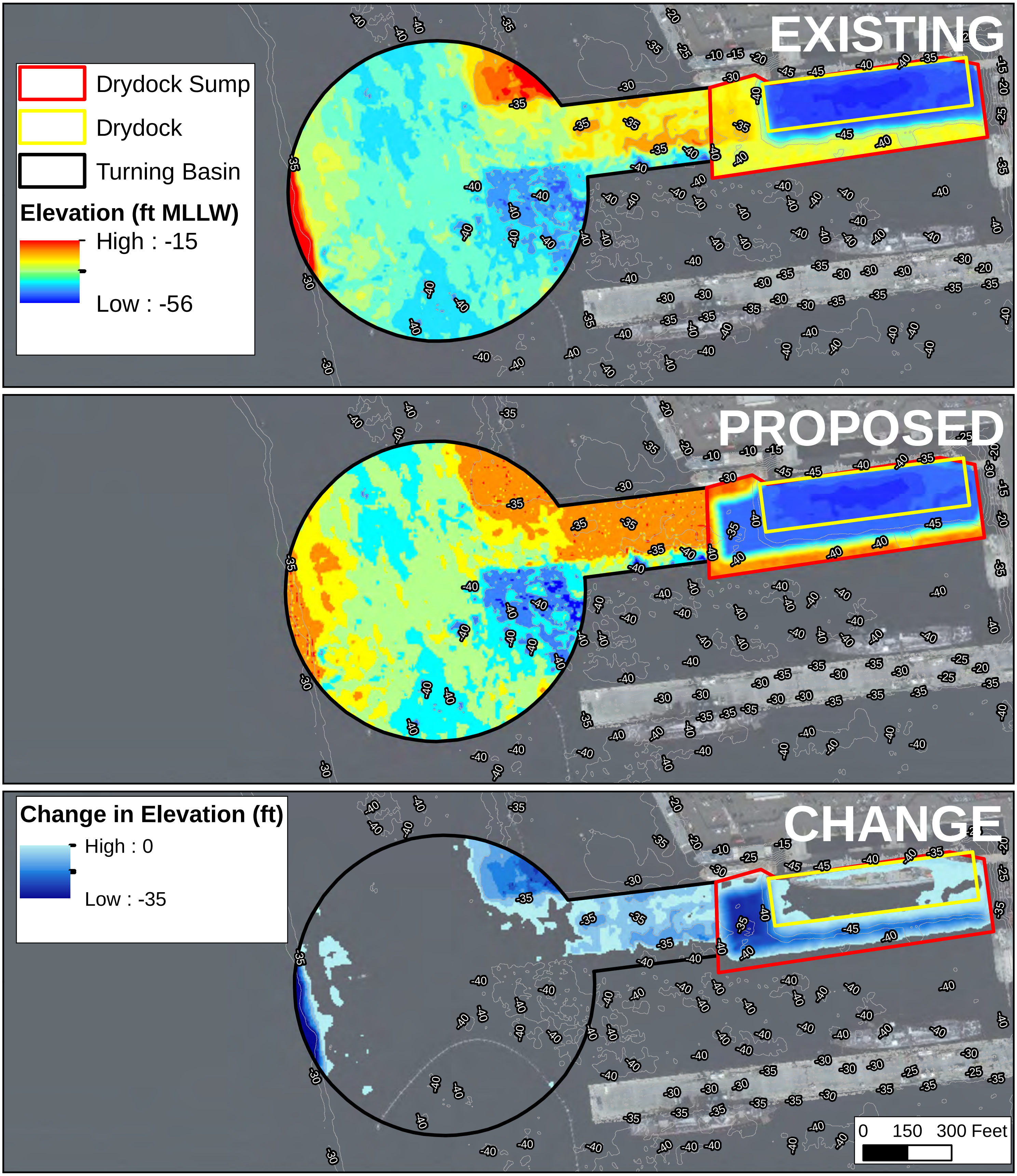
Background

The Navy is proposing the construction of a floating dry dock facility on the south side of the NBSD Mole Pier. This is the location of a prior dry dock, the "Steadfast" (AFDM-14). The Steadfast was a 528 foot long by 118 foot wide (1.43 acre) dry dock that was removed in 1998. The dry dock was positioned over a dry dock sump at the eastern end of the mole pier that allowed the dry dock to be submerged in place at the pier for loading and then raised in position.

"Steadfast" dry dock at NBSD Mole Pier prior to deactivation in 1998.

The Navy is proposing a new dry dock at the same location as previously used by the Steadfast. The new dry dock would be approximately 83 percent larger than the prior dry dock at a length of 700 feet and a width of 163 feet (2.62 acre). The positioning of the new dry dock would be similar to that of the "Steadfast" but would extend further to the west and south of the footprint of the prior dry dock. This would require expanding the scale of the dry dock sump through dredging, but the floor of the sump would remain comparable to the existing sump as a design depth of -53 feet MLLW.

To accommodate use of the dry dock, the existing approach channel and a turning basin in the main channel would need to be maintained. These areas are to be maintained to a depth of -37 feet MLLW. The depths in these areas are already predominantly at or below -37 feet and thus the work is principally of a maintenance nature. There are however a few portions of the outer radius of the turning basin that would extend into the shallower portions of the channel shoulders and may require original dredging. The existing, proposed design, and change in bathymetry required for the project are illustrated in Figure 1.



Mole Pier Drydock Habitat Change Analysis

Naval Base San Diego, San Diego Bay

Figure 1

Merkel & Associates, Inc.

Assessment Methods

Concurrent with the proposed Mole Pier Floating Dry Dock, the Navy is considering a commercial out lease floating dry dock at the Marine Group Boat Works (MGBW) Maintenance Piers at the south end of NBSD. This project is being led by MGBW and would bring a 531.5 foot by 154.2 foot dry dock to the site. An excavation of a dry dock sump to -38 feet MLLW would be completed. As the analysis for the MGBW dry dock commenced prior to the Mole Pier Floating Dry Dock, an assessment of ecological functional loss was undertaken to assess the effects of the MGBW dry dock project, prior to initiation of similar assessments for the present project. This work was undertaken by Marine Taxonomic Services (MTS) with input on evaluation methodology, underpinning theory, and data to support the analyses being provided by Merkel & Associates at the request of the Navy. The assessment methodology for the MGBW dry dock project has been articulated in a comprehensive report summarizing the overall approach, underpinning data supporting the analysis, and analytical methodology applied. The report also provides ecological functional loss conclusions and translation of losses into required scaling of eelgrass mitigation to offset the losses through ecological lift provided by eelgrass habitat, over similar unvegetated habitat (MTS 2020). Because, the approach taken for the analysis of the MGBW was developed with broader application in mind and has direct applicability to a second dry dock project, this approach has been fully adopted for the assessment of functional loss associated with the dry dock.

The analysis methodology applied focuses on the loss of habitat value with increasing depth within the shallow bay and incorporates bay coverage effects on reduction of benthic productivity based on diminished light levels. The loss of ecological value with depth has been noted in prior impact assessments and mitigation programs within developed bays. Differing value of habitat by depth range is also recognized in the San Diego Bay Integrated Natural Resource Plan (INRMP; U.S. Navy and Port of San Diego 2013). In most instances, the difference in value by depth is reflected as functional lift being generated by increasingly shallow submergence in subtidal environments. Thus, shallow water is considered to be of greater ecological value than deep water. This is principally related to increasing benthic primary productivity at shallow depths, increasing circulation due to wave and swell surge influence, and increasing temperature in shallow waters. For the change in ecological value with depth, a relationship was drawn from an ecological investigation conducted in at the Port of Los Angeles Cabrillo Shallow Water Habitat (CSWH) to explore the likely ecological lift garnered through raising the bay floor from -51 feet to an elevation of -15 feet MLLW (Merkel & Associates 2019) and then contemplating the reciprocal loss of ecological value as a result of deepening such an environment (MTS 2020). While the analysis is not perfect, in that it omits the value garnered through changing the nature of the substrate from mud to sand, this shortcoming is offset by applying a highly conservative simple linear relationship for value change over depth rather than a more likely exponential or power function that would be expected to show more pronounced loss of function with increasing depth in shallow waters and diminished difference in values expressed at the deeper harbor elevations involved in the dry dock project. To clarify this point further, the present analysis, the ecological value was calculated to be diminished by 2.56 percent for every foot of elevation loss (MTS 2020). Thus it is clear that with a change in elevation of 39 feet (100%/2.56%) all ecological value would be expected to be lost, irrespective of whether the change occurs between shallow water to deep water or deep water to deep water. As this is clearly not the case, a function that asymptotically approaches zero value would be a better fit to the ecological lift mode, but such a curve cannot be developed from the CSWH study structure as the study involved only two depths.

Concurrent with the reduction in value associated with increasing site depth, bay coverage diminishes light levels and would be expected to reduce productivity of a covered site where photosynthesis supports primary productivity. However, as light extinction occurs with increasing depth, eventually the photo-compensation point is reached where photosynthesis just balances respiration. Below this depth, the ambient light environment is too low to support photosynthetically derived primary productivity and increasing shading is no longer a factor relative to changing habitat function. MTS (2020) explored this relationship from photosynthetically active radiation (PAR) data collected in San Diego Bay by Merkel & Associates in 2004 and determined that light diminished along an exponential attenuation curve such that by 29 feet of depth in the central bay, light levels were less than 1 percent of surface light as measured at channel marker 28 approximately 0.9 miles from the Mole Pier Dry Dock location (Merkel & Associates, unpublished data). This is typically considered to be the approximate photo-compensation point below which photosynthesis would not be a factor to ecological function.

To evaluate the effects of bay coverage by the proposed dry dock on ecological function, the footprint of the proposed dry dock was overlain over the project design bathymetry to determine the additional impact of light reduction by shading that would be added to the impacts of the project that are associated with project deepening. The analysis is described in MTS (2020), however because all of the shaded area is deeper than -29 feet, the shading of the dry dock was determined to not further reduce ecological function. No direct eelgrass impact analysis was performed since no eelgrass occurs within the Mole Pier study area (Merkel & Associates 2018).

All change analysis has been based on comparison of the existing bathymetry derived from the 2014 condition survey (M&A and CLE Engineering 2015) and a bathymetric surface generated from the dry dock engineering study (GHD/COWI Joint Venture 2018). The subtraction of the existing and proposed bathymetric surfaces yielded the extent of elevational change anticipated as well as the area over which change would occur (Figure 1). The dry dock sump was examined separately from the approach and turning basin area surfaces since one area is dominated by new dredging, while the other area would be predominantly maintenance dredging. This approach allowed for independent calculation of functional loss in each area and a separate consideration of policy issues with respect to maintenance versus new construction activities. After developing the bathymetric surfaces and change data, a spreadsheet analysis was conducted following MTS (2020).

Impact Analysis Results

The Mole Pier Dry Dock project area totals 6.26 acres. The project work would result in a calculated 8.48 percent reduction in value of the dry dock area as a result of the proposed work. This would translate into a loss of function equivalent to 0.53 acres of unvegetated soft bay bottom (Table 1). The dry dock itself is 2.62 acres in size and would be located in waters ranging from -49 to -56 feet MLLW. Under the analysis conducted, impacts from shading would not amass in waters deeper than -28 feet MLLW. As a result, no additional ecological value is lost as a result of shading effects.

Within the turning basin and approach areas, deepening of the area would result in a functional loss of 0.78 percent over the 21.39 acres (Table 2). This translates into a functional loss equivalency of 0.17 acre. As noted previously, this is predominantly associated with maintenance dredging and thus may be reasonably treated differently from the dry dock project impacts which are considered to be new construction impacts.

Table 1. Mole Pier Dry Dock Functional Loss Analysis

Project Depth / Area Change				Depth Based Ecological Lift/Loss				Shading Adjusted Ecological Lift/Loss			Subtotal
Elevation (Ft MLLW)	Area Proposed (sf)	Area Existing (sf)	Area Change (sf)	Depth Relative Lift	Area Adjusted Lift (proposed)	Area Adjusted Lift (existing)	Area Adjusted Lift Change	Area Shaded (sf)	Shading Depth Correction (ft)	Area Adjusted Shading Lost Lift	Depth & Area Lift Change (%)
-58			0	0.821	0.000	0.000	0.00%		0	0.00%	0.00%
-57			0	0.846	0.000	0.000	0.00%		0	0.00%	0.00%
-56	90	59	31.12	0.872	0.000	0.000	0.01%	153	0	0.00%	0.01%
-55	19411	19364	47.16	0.898	0.064	0.064	0.02%	19485	0	0.00%	0.02%
-54	50094	50068	25.52	0.923	0.170	0.170	0.01%	49059	0	0.00%	0.01%
-53	100647	40166	60480.6	0.949	0.350	0.140	21.06%	37647	0	0.00%	21.06%
-52	9216	17098	-7882.24	0.974	0.033	0.061	-2.82%	5076	0	0.00%	-2.82%
-51	7047	8648	-1600.68	1.000	0.026	0.032	-0.59%	2295	0	0.00%	-0.59%
-50	5022	4828	193.84	1.026	0.019	0.018	0.07%	315	0	0.00%	0.07%
-49	4527	3423	1104.28	1.051	0.017	0.013	0.43%	72	0	0.00%	0.43%
-48	4059	2988	1071.48	1.077	0.016	0.012	0.42%		0	0.00%	0.42%
-47	3942	2660	1282.16	1.102	0.016	0.011	0.52%		0	0.00%	0.52%
-46	3897	2698	1198.76	1.128	0.016	0.011	0.50%		0	0.00%	0.50%
-45	3780	2714	1066.4	1.154	0.016	0.011	0.45%		0	0.00%	0.45%
-44	3861	2803	1057.8	1.179	0.017	0.012	0.46%		0	0.00%	0.46%
-43	3762	3011	751.44	1.205	0.017	0.013	0.33%		0	0.00%	0.33%
-42	3924	3116	808.48	1.230	0.018	0.014	0.37%		0	0.00%	0.37%
-41	3924	4029	-105.44	1.256	0.018	0.019	-0.05%		0	0.00%	-0.05%
-40	6021	8133	-2112.12	1.282	0.028	0.038	-0.99%		0	0.00%	-0.99%
-39	7182	14139	-6956.88	1.307	0.034	0.068	-3.34%		0	0.00%	-3.34%
-38	16191	36180	-19989.5	1.333	0.079	0.177	-9.78%		0	0.00%	-9.78%
-37	11925	21210	-9284.6	1.358	0.059	0.106	-4.63%		0	0.00%	-4.63%
-36	3078	10703	-7625.36	1.384	0.016	0.054	-3.87%		0	0.00%	-3.87%
-35	729	11003	-10273.9	1.410	0.004	0.057	-5.31%		0	0.00%	-5.31%
-34	162	3328	-3166	1.435	0.001	0.018	-1.67%		0	0.00%	-1.67%
-33	36	102	-66.4	1.461	0.000	0.001	-0.04%		0	0.00%	-0.04%
-32		13	-12.8	1.486	0.000	0.000	-0.01%		0	0.00%	-0.01%
-31		3	-2.56	1.512	0.000	0.000	0.00%		0	0.00%	0.00%
-30		5	-5.12	1.538	0.000	0.000	0.00%		0	0.00%	0.00%
-29		8	-7.68	1.563	0.000	0.000	0.00%		0	0.00%	0.00%
-28		3	-2.56	1.589	0.000	0.000	0.00%		-1	0.00%	0.00%
-27		3	-2.56	1.614	0.000	0.000	0.00%		-2	0.00%	0.00%
-26		0	-5.12	1.640	0.000	0.000	0.00%		-3	0.00%	0.00%
-25		0	-2.56	1.666	0.000	0.000	0.00%		-4	0.00%	0.00%
-24		5	-5.12	1.691	0.000	0.000	0.00%		-5	0.00%	0.00%
-23		3	-2.56	1.717	0.000	0.000	0.00%		-6	0.00%	0.00%
-22		0	-5.12	1.742	0.000	0.000	0.00%		-7	0.00%	0.00%
-21		5	0	1.768	0.000	0.000	0.00%		-8	0.00%	0.00%
-20		3	0	1.794	0.000	0.000	0.00%		-9	0.00%	0.00%
-19		0	-2.56	1.819	0.000	0.000	0.00%		-10	0.00%	0.00%
-18		5	0	1.845	0.000	0.000	0.00%		-11	0.00%	0.00%
-17		0	0	1.870	0.000	0.000	0.00%		-12	0.00%	0.00%
-16		0	0	1.896	0.000	0.000	0.00%		-13	0.00%	0.00%
-15		3	0	1.922	0.000	0.000	0.00%		-14	0.00%	0.00%
-14			0	1.947	0.000	0.000	0.00%		-15	0.00%	0.00%
Totals	**272527**	**272527**	**0**	**NA**	**1.035**	**1.119**	**-8.48%**	**114102**	**NA**	**0.00%**	**-8.48%**

Dry Dock Sump Area	**6.26 acres**	**Dry Dock Area**	**2.62 acres**	**Total Loss**	
Change in Function	**-8.48%**	**Shading Based Change in Function**	**0.00%**	**Equivalency**	**-0.53**
Loss Equivalency	**-0.53 acres**	**Loss Equivalency**	**0.00 acres**	**Acres**	

Table 2. Turning Basin and Approach Channel Functional Loss Analysis

Project Depth / Area Change				Depth Based Ecological Lift/Loss				Shading Adjusted Ecological Lift/Loss			Subtotal
Elevation (Ft MLLW)	Area Proposed (sf)	Area Existing (sf)	Area Change (sf)	Depth Relative Lift	Area Adjusted Lift (proposed)	Area Adjusted Lift (existing)	Area Adjusted Lift Change	Area Shaded (sf)	Shading Depth Correction (ft)	Area Adjusted Shading Lost Lift	Depth & Area Lift Change (%)
-58			0	0.821	0.000	0.000	0.00%		0	0.00%	0.00%
-57			0	0.846	0.000	0.000	0.00%		0	0.00%	0.00%
-56			0	0.872	0.000	0.000	0.00%		0	0.00%	0.00%
-55			0	0.898	0.000	0.000	0.00%		0	0.00%	0.00%
-54			0	0.923	0.000	0.000	0.00%		0	0.00%	0.00%
-53			0	0.949	0.000	0.000	0.00%		0	0.00%	0.00%
-52			0	0.974	0.000	0.000	0.00%		0	0.00%	0.00%
-51			0	1.000	0.000	0.000	0.00%		0	0.00%	0.00%
-50			0	1.026	0.000	0.000	0.00%		0	0.00%	0.00%
-49			0	1.051	0.000	0.000	0.00%		0	0.00%	0.00%
-48			0	1.077	0.000	0.000	0.00%		0	0.00%	0.00%
-47			0	1.102	0.000	0.000	0.00%		0	0.00%	0.00%
-46			0	1.128	0.000	0.000	0.00%		0	0.00%	0.00%
-45			0	1.154	0.000	0.000	0.00%		0	0.00%	0.00%
-44			0	1.179	0.000	0.000	0.00%		0	0.00%	0.00%
-43			0	1.205	0.000	0.000	0.00%		0	0.00%	0.00%
-42	110	110	0	1.230	0.000	0.000	0.00%		0	0.00%	0.00%
-41	5181	5181	0	1.256	0.007	0.007	0.00%		0	0.00%	0.00%
-40	58620	58620	0	1.282	0.081	0.081	0.00%		0	0.00%	0.00%
-39	195015	195015	0	1.307	0.274	0.274	0.00%		0	0.00%	0.00%
-38	334244	334244	0	1.333	0.478	0.478	0.00%		0	0.00%	0.00%
-37	150781	145710	5071	1.358	0.220	0.212	0.74%		0	0.00%	0.74%
-36	183136	65692	117444	1.384	0.272	0.098	17.44%		0	0.00%	17.44%
-35	3776	59814	-56038	1.410	0.006	0.090	-8.48%		0	0.00%	-8.48%
-34	1093	33088	-31995	1.435	0.002	0.051	-4.93%		0	0.00%	-4.93%
-33	0	15506	-15506	1.461	0.000	0.024	-2.43%		0	0.00%	-2.43%
-32	0	8164	-8164	1.486	0.000	0.013	-1.30%		0	0.00%	-1.30%
-31	0	2796	-2796	1.512	0.000	0.005	-0.45%		0	0.00%	-0.45%
-30	0	1679	-1679	1.538	0.000	0.003	-0.28%		0	0.00%	-0.28%
-29	0	1500	-1500	1.563	0.000	0.003	-0.25%		0	0.00%	-0.25%
-28	0	1536	-1536	1.589	0.000	0.003	-0.26%		-1	0.00%	-0.26%
-27	0	1920	-1920	1.614	0.000	0.003	-0.33%		-2	0.00%	-0.33%
-26	0	1381	0	1.640	0.000	0.002	-0.24%		-3	0.00%	-0.24%
-25			0	1.666	0.000	0.000	0.00%		-4	0.00%	0.00%
-24			0	1.691	0.000	0.000	0.00%		-5	0.00%	0.00%
-23			0	1.717	0.000	0.000	0.00%		-6	0.00%	0.00%
-22			0	1.742	0.000	0.000	0.00%		-7	0.00%	0.00%
-21			0	1.768	0.000	0.000	0.00%		-8	0.00%	0.00%
-20			0	1.794	0.000	0.000	0.00%		-9	0.00%	0.00%
-19			0	1.819	0.000	0.000	0.00%		-10	0.00%	0.00%
-18			0	1.845	0.000	0.000	0.00%		-11	0.00%	0.00%
-17			0	1.870	0.000	0.000	0.00%		-12	0.00%	0.00%
-16			0	1.896	0.000	0.000	0.00%		-13	0.00%	0.00%
-15			0	1.922	0.000	0.000	0.00%		-14	0.00%	0.00%
-14			0	1.947	0.000	0.000	0.00%		-15	0.00%	0.00%
Totals	**931956**	**931956**	**1381**	**NA**	**1.338**	**1.346**	**-0.78%**	**0**	**NA**	**0.00%**	**-0.78%**

Dredge Area	**21.39 acres**	**Bay Coverage Area**	**0.00 acres**	**Total Loss**	
Change in Function	**-0.78%**	**Shading Based Change in Function**	**0.00%**	**Equivalency**	**-0.17**
Loss Equivalency	**-0.17 acres**	**Loss Equivalency**	**0.00 acres**	**Acres**	

Mitigation of Impacts

The mitigation for anticipated ecological function impacts is proposed to be addressed following the methodology outlined in MTS (2020). This mitigation is based on providing offsetting ecological lift equivalent to the quantified loss through replacement with eelgrass habitat either derived through the Navy Eelgrass Mitigation Bank (NEMS), or through new eelgrass habitat development.

As discussed in MTS (2020), eelgrass habitat is considered to provide 1020% (10.2 acres of unvegetated soft bottom equals 1 acre of eelgrass habitat) of the ecological function of similar unvegetated soft bottom habitat. This is based on the median value of studies documenting faunal organism density for *Zostera marina*. The logic to accepting the median value of studies over the mean value derived from the multiple studies evaluated is discussed in MTS (2020). To calculate the equivalent eelgrass habitat needed to offset project impacts, the area equivalency of impacted soft bottom has been divided by the difference in functional value between eelgrass and unvegetated soft bottom. The results of this analysis are summarized in Table 3.

Table 3. Eelgrass Habitat Equivalency to Functional Loss of Unvegetated Soft Bottom Habitat

Project Element Impact Location	Impact Functional Equivalency Loss (acres)	Eelgrass Habitat Equivalency (acres)
Dry Dock Basin and Shading	-0.53 acre	0.052 acre
Turning Basin and Approach Channel	-0.17 acre	0.016 acre
Total	**-0.70 acre**	**0.068 acre**

Because of the significant difference in ecological value associated with submerged aquatic vegetation and particularly eelgrass, the functional equivalency of ecological value loss as calculated in acres of unvegetated soft bottom habitat is off-set with relatively minor amounts of eelgrass habitat development. It is anticipated for the purposes of this analysis that mitigation would be derived through use of the NEMS mitigation bank. Adequate eelgrass exists in many of the individual sites to meet this mitigation need (U.S. Navy 2019). However, the project does include potential for opportunistic reuse of sediment to develop stand along mitigation for the impact concurrently with expanding the NEMS sites. Should this approach be taken, the time delay to habitat development would need to be factored in in accordance with the standards of the California Eelgrass Mitigation Policy (CEMP, NMFS 2014).

Please let me know if you need any additional information to support this effort. We appreciate the opportunity to assist you.

Sincerely,

Keith W. Merkel
Principal Consultant

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RE: Supplemental Analysis for Ecological Functional Loss
Associated with Water Column Shading by the
NBSD Mole Pier and MGBW Floating Dry Docks

Dear Sean and Nick,

This letter provides a brief supplement to the two prior documents prepared to quantify the reduced ecological function and appropriate scale of mitigation through eelgrass habitat for the Naval Base San Diego (NBSD) Mole Pier Floating Dry Dock (Merkel & Associates [M&A], Feb. 8, 2020) and the NBSD Commercial Out Lease Marine Group Boat Works (MGBW) Floating Dry Dock (Marine Taxonomic Services [MTS], Feb. 6, 2020). The supplement is in response to review and discussion garnered during a March 4, 2020 webinar presentation to Eric Chavez, National Marine Fisheries Service (NMFS), as well as Navy, MGBW and Mission Environmental staff. The supplement further benefited by subsequent discussions between Eric Chavez, Sean Suk of the Navy, Keith Merkel and Robert Mooney.

The assessment provides some clarifications that were provided in the webinar as well as transmitting additional requested analyses relative to water column impacts. Because of the parallel nature of assessment methods development for the two dry docks by MTS and M&A, this document has been collaboratively developed to provide a single supplement for both dry dock projects. The result is a compilation of written information addressing questions previously discussed verbally as well as transmittal of the methods of analysis for water column impacts and the resultant total impact and mitigation to offset impacts.

Clarifications of Initial Habitat Analyses

During the webinar, some clarifications were warranted based on the presentation of material in the two analyses (MTS 2020 and M&A 2020). First, the analyses reports address the methodology applied to the valuation based on scaled lost function with increasing depth intervals by one-foot depth bins. However, in the MTS document, the extent of net habitat change by habitat depth classes as defined under the San Diego Bay Integrated Natural Resource Management Plan (INRMP) was also provided. This inclusion led to some confusion as to whether the analysis was performed by depth steps or broader habitat type shifts. The habitat functional analysis was performed by one foot depth interval analyses.

A second substantive point of discussion had to do with the assumption of a linear decline in habitat value with depth rather than an exponential function. It is reasonable to assume that an exponential decay of habitat value occurs with depth in the photic zone. As was explained in the webinar, we concur with this assumption and have included text to this effect in the analyses. However, with only two data points used to develop the functional degradation relationship, only a linear function could reasonably fit the analysis. Because of the notable weakness of the curve, a brief analysis was undertaken to evaluate the likely outcome of applying an exponential curve rather than a linear fit. A more accurate curve would likely follow a light extinction type curve with a rapid loss in function occurring in the shallowest waters while losses of function by changing deep water to even deeper water would have limited effect on functions. This is because many important factors influencing ecological resources follow similar patterns of exponential decay with increasing depth (e.g., light transmission, wave energy, gas exchange). The point was made in the webinar, but not in the reports, that for the present projects the application of a linear decay curve would tend to over-estimate loss of function over the predominant range of depths present in the project area. However, for projects in shallower water, especially within very shallow water, the linear function could grossly underestimate functional loss. As a result, the application of this analysis approach should be carefully considered and potentially improved upon prior applying the methods to other projects. The application of the methods would certainly benefit by expanding the underpinning data from which to fit a better and more accurate functional loss curve.

An additional concern was raised about relating values to a depth step of -51 feet MLLW based on calibrating data as this depth falls outside of the elevation range for the MGBW dry dock and is near the bottom of the depth range for the Mole Pier dry dock. However, it was clarified that because the analysis is working based on the formula of curve, in this case the slope of a linear expression, it doesn't matter what depth step is set as the base value, the result will be the same. This was demonstrated by changing base value in the spreadsheet during the webinar and achieving the same impact and mitigation values.

Finally, it was noted that there are multiple assumptions that go into the analysis approach and that these may vary in validity depending upon project specific factors. In the present case, an assessment of the sensitivity of outcomes based on changing assumptions was undertaken. It was determined that the assumptions either led to a more liberal estimate of impact and conservative estimate of mitigation value relative to impacts. However, the assessment reports also point to factors that may influence outcomes under different circumstances and the high variability of data underpinning some of the value exchanges between unvegetated and vegetated bottom. While the analysis is considered the best available approach to completing this present valuation work, additional work on the development of the methods is warranted as is infilling some of the data gaps with bay specific information. For this reason, the present analysis should be viewed as a reasonable means to determine appropriate mitigation for the projects, but is also considered to be a good starting point for future assessments rather than a final methodology.

Water Column Eelgrass Functional Loss Analysis

Background on Analysis Framework

The principal function of this supplement is to capture a water column shading effect associated with the two floating dry docks. The water column element of the bay habitat was explicitly omitted from the prior analyses due to a consideration of the effect of a mobile water mass experiencing only transitory shading influence. This was believed to likely be *de minimis* compared to the benthic habitat effects. The prior determination to omit this element of the ecosystem from the analysis was further underpinned by a concern as to how ecotonal edge effects that tend to raise ecological functions around the overwater structures would be handled. In effect, edges of structures provide functional lift, while the shaded interior below structures degrades functions (Merkel & Associates 2013). As a result of the confounding ecological effects of structure edge versus interior, there is an expectation that small structures may provide a net ecological benefit (e.g., channel marker, sparse piles) while larger structures may have net negative ramifications to ecological function (e.g., large piers, dry docks). The principal complication is that it is not clear what factors play a role in dictating the shift between net positive and negative ecological effects. However, there are several elements that are known to contribute even though the point of ecological benefit to detriment is not precisely known. These include, but are not likely limited to, the ratio of edge to interior shading, the elevation of the structure off the water (allowing for both greater light penetration and surface mixing and gas exchange), the degree to which the structure disrupts circulation, and the residence time of water beneath the structure.

During the March 4 meeting, it was acknowledged by NMFS that water column impacts would likely be insignificant relative to the overall project ecological impact. However, the complete omission of the water column evaluation based on expected *de minimis* contribution was not justifiable, considering that the two dry docks were of a nature where the negative values of the structures were to be expected to outweigh the benefits of structures becuase they are larger features with low edge to interior area ratios and they sit on and into the water as opposed to over the water. Further, both sites are located away from the mouth of the bay, on the margins of a broadened and artificially deepened portion of the bay where residence time is expected to be moderately high based on model results from the San Diego Bay Integrated Natural Resource Management Plan (Navy and SDUPD 2013).

Through further discussions on how to determine water column functional loss, and many false starts down differing pathways of quantification, a methodology was developed to quantify effects of shading on the water column ecological resources. It is important to note that the methodology applied involves multiple assumptions. The assumptions are required due to a general paucity of data to support such an analysis. Most particularly, water column biological data tends to be presented in multiple incompatible formats with benthic data.

One potential evaluation approach was to compare water column and benthic fisheries data. However, water column fisheries sampling data are sometimes quantified by volumetric and sometimes spatial metrics, but most often by timed hauls or numbers of sets, without quantification of the amount of water sampled. Further, where reported volumetrically, there is often no means to determine the distribution of fish through the water column to evaluate whether deep water supports a greater abundance of fish than shallow water or whether fish are depth distributed. In addition, the fishing gear used to sample the water column has inherently different capture rates than gear used for sampling the bottom. These factors introduce complications with attempting to utilize fisheries data to relate water column and benthic functions.

In the case of fish, fish larvae, and other zooplankton the presence of overwater structures would not be expected to physically affect organisms to the point of detectable changes. While there is evidence that caged fish in the dark may suffer deleterious effects such as captive starvation, unrestrained fish have behavioral means of addressing shading. Sight foragers may move to the margins of a structure where they can forage within an enriched food environment or away from the structure, while entrainment foragers may benefit from larger foraging areas than afforded within cages. As such, it is unclear exactly what impact fish would suffer from the overwater structures, except that a redistribution of habitat utilization based on the fish ecology would be expected. For zooplankton, including fish larvae, entrained in the tidal currents, the duration of time spent in the shade of a structure would not be expected to result in detectible deleterious effects.

Phytoplankton, which forms the lowest trophic level in the water column, would be affected by shading of an over water structure. An argument can be reasonably made that the degree to which plankton are adversely effected is limited as the plankton are entrained in tidal currents and the effect of the structure would be comparable to that experience by passing clouds where photosynthetic productivity was diminished for a brief period. This is a reasoned view where the interest is in the individual organism. However, for the purposes of the present analysis, phytoplankton is being viewed as trophic support for the water column community. With this broader view, the effect of shading on plankton would be viewed as photosynthesis foregone. While each phytoplankter passing beneath the dry docks would suffer a limited reduction in normal growth, the cumulative effects across all phytoplankton passing under the structure would be equal to the loss of all phytoplankton within the water column beneath the structure at a single point in time. As such, the dynamic component of residence time is removed from the analysis when the metric of interest is not individual plankter survival, but rather contribution to the food-web.

For the present analysis it was assumed that the effects to standing stock at lower trophic levels would translate upward in a similarly scalable manner to higher trophic levels across habitat types. Most specifically, it was assumed that the influence of the projects on the biomass of phytoplankton would have a similarly translatable effects to the rest of the system as biomass of eelgrass. This assumption oversimplifies ecosystem dynamics in that the biomass of eelgrass, in addition to supporting a detrital based food web, also provides multiple habitat structural benefits that feed multiple trophic sub-complexes that are not found within the water column.

Conversely, the trophic complexity of eelgrass cannot be fully decoupled from the water column contributions to a bed. In any case, this assumption was necessary for the analysis completed to provide an estimator of ecological functional equivalency between the water column shading and eelgrass habitat. However, the equivalency metrics are believe to be conservative relative to mitigating impacts because they under value the ecosystem structuring benefits of eelgrass and thus would result in an over-estimate of the extent of eelgrass required to balance water column ecological functions.

Determining the biomass of water column phytoplankton has been a challenge resulting from transient sampling data, extremely seasonally variable phytoplankton abundance, and the lack of systematic sampling within San Diego Bay. An initial attempt to determine plankton biomass was undertaken by querying available satellite imagery data for which multiple models have been developed to quantify plankton and development of estimates of biomass. Seasonal phytoplankton net primary productivity (NPP) estimates for San Diego Bay were sought by using MODIS (Moderate Resolution Imaging Spectroradiometer) Ocean Color satellite imagery data (NASA; https://oceancolor.gsfc.nasa.gov/atbd/) and derived algorithmic products provided by Oregon State University's Ocean Productivity Lab (http://sites.science.oregonstate.edu/ocean.productivity). Specifically, NPP calculated on the basis of the Carbon, Absorption, and Fluorescence Euphotic-resolving (CAFÉ) Model 4-km resolution raster grids integrated over monthly time intervals (CAFÉ Model; Silsbe et al. 2016), were assessed. However, the very coarse data set does not extend into San Diego Bay, remaining in the nearshore coastal waters. The CAFÉ algorithm calculates NPP on the basis of absorption of photosynthetically active radiation and the efficiency at which absorbed energy is converted into carbon. The low spatial resolution of the imagery and lack of explicit coverage of bay waters makes it challenging to draw site-specific conclusions for the waters of the bay.

Only one long-term monitoring study was identified that collected robust phytoplankton data within San Diego Bay. This was the monitoring of the South San Diego Bay Coastal Wetland Restoration and Enhancement Project (Nordby Biological Consulting and Tijuana River National Estuarine Research Reserve 2013). In this study, continuous monitoring data of chlorophyll concentrations were collected on 15-minute intervals for a year within the restored Pond 11 and the Otay River estuary in south San Diego Bay. Because of the continuous collection nature of the sampling and the known shallow nature of the sampling sites, it was possible to determine an estimated annual biomass for phytoplankton present at the two sampling stations by converting chlorophyll concentration in micrograms per liter (µg/L) to grams of carbon per cubic meter (g C / m^3). The conversion was performed using a rudimentary relationship for phytoplankton of 40 g C to g chlorophyll-a (Lorenzen 1968). This method was chosen over empirical models such as Cloern et al. (2014) that require more input variables such as temperature, daily irradiance, and nutrient limited growth rates. After conversion of an annual average chlorophyll concentration for the two sites to carbon equivalence, the higher average annual concentration of 0.15 g C / m^3 present in Pond 11 was accepted as a water column representation of phytoplankton in San Diego Bay. Further, because Pond 11 and the Otay River are very shallow environments, this concentration is considered a surface concentration not depleted by light limitation through the photic zone.

It bears noting that the application of shallow south bay marsh channel plankton sampling as a surrogate for central bay surface water algal concentrations is a significant extrapolation of the data; however, it represents the best available data at the present time. Further, it is expected that phytoplankton concentrations within shallow waters around the mouth of a riverine estuary would be higher than within the clear deeper bay waters of the south-central bay ecoregion of San Diego Bay where the dry dock projects occur. For future applications of this methodology, expanded data on phytoplankton concentrations through the bay would be highly beneficial. It is also important to note that Cloern et al. (2014), a widely cited paper and from authors focusing on bay and estuary phytoplankton ecology have indicated that phytoplankton concentrations may vary up to 10-fold within estuaries and 5-fold from year to year, going even further noting that "this is probably an underestimate". This further supports the need for more extensive phytoplankton information to base future assessments such as the present.

Phytoplankton g C / m^2 for surface water covered by the projects was calculated by integrating all concentrations of phytoplankton (g C / m^3) through the water column to the bottom of the photic zone, defined as -29 feet MLLW as explained in MTS (2020) based on prior empirical data collection that follows diminishing light levels in accordance with Beer's Law.

To relate the water column carbon to eelgrass carbon, a literature search was completed to identify carbon stores in above ground, below ground, and whole plant eelgrass. This literature review yielded multiple estimates of carbon stores across a wide geography and number of studies. In some instances, biomass was reported as grams ash free dry weight per square meter (g DW / m^2). These values were converted using the ratio of g C: 0.36 g DW to calculate g C / m^2 from g DW / m^2 (Duarte 1990) (Table 1).

Water Column Functional Loss Calculation Methods

Once it was determined that balancing the lost standing stock of phytoplankton within the areas shaded with eelgrass restoration was appropriate to determine mitigation, a spreadsheet was developed to balance the impact and the mitigation. The impact was calculated by determining the average loss of the phytoplankton standing stock as g C / m^3 from a surface concentration estimated at 0.15 g C / m^3 with diminishing cumulative concentrations based on light reduction downward through the photic zone. Light reduction curves derived from M&A unpub. data are presented in MTS (2020). These component factors, along with the coverage by dry dock structures and existing bay bathymetry were used to calculate the shaded volume of water and determine the standing stock biomass within that volume of water.

The shaded volume of water was determined for each 1-foot depth interval under project structures by clipping the existing bathymetry by the footprint of the proposed dry dock and support structures. The existing pre-project bathymetry was used because both projects under consideration only propose to make the bottom deeper. Using the existing bathymetry ensures that impacts are not ascribed to that volume of water which is created by the project actions. Only the prism of existing water that will be shaded is considered to be impacted and no uplift was ascribed to structure edge conditions. The clipped bathymetry was then used to determine the volume of water within each 1-foot depth bin above the existing benthic surface. Volume was determined to a high elevation of -2-ft MLLW to prevent having to consider the temporal water volume change due to tides.

Table 1. Eelgrass biomass estimates from multiple studies

Location	Biomass (g C / m^2)*			Source	Notes
	Above Ground	Below Ground	Whole Plant		
San Quintin Bay BC, Mex	14.4			Cabello-Pasini et al. 2003.	
Ojo de Liebre Lagoon Baja	3.204			Cabello-Pasini et al. 2003.	
San Ignacio Lagoon Baja	4.932			Cabello-Pasini et al. 2003.	
Great Harbor, Mass	115			Dennison and Alberte 1985	40-190 range
Puget Sound	45			Thom and Albright 1990	5-85 range
Padilla Bay, WA	56			Bulthuis 1995	12-100 range
Beaufort, NC	61			Fonseca and Bell 1998	
Bahia San Quintin	51.5			D. Ward Unpub. 2011-2012	16-87 range
Gulf of AK	146.9			D. Ward Unpub. 2007-2015	1-768 range
Bering Sea AK	147.2			D. Ward Unpub. 2007-2015	1-774 range
Humboldt Bay (south)	234			Moore and Black 2006	234±123
Ave. 10 Denmark sites	52.2	53.28	105.48	Rohr et al. 2016	52.20±17.87, 53.28±48.41, 105.48±56.13
Ave. 10 Finland sites	36.36	28.44	64.8	Rohr et al. 2016	36.36±11.16, 28.44±18.55, 64.80±26.15
Ave. 6 Clayoquot Sound, BC	16.98	5.76	22.74	Postlethwaite et al. 2023	16.98±11.20, 5.76±2.74, 22.74±13.86
Mean g C / m^2	**72.68**	**29.16**	**64.34**	* Conversion from ash-free dry weight to g C/m2 following Duarte 1990	
Median g C / m^2	**48.60**	**28.44**	**64.80**		

Once the volume of water to be shaded under the proposed structures was determined, the plankton stock within each cubic foot of water by depth bin was calculated. This required using the estimates previously described for the surface plankton stock. This value was then corrected moving deeper through the water column by reducing the plankton stock with the same light degradation curve that was used to determine benthic impacts associated with shading. The logic to diminishing plankton concentration with reduced light through the photic zone is supported by the empirical model of Cloern et al. (2014). Once the plankton stock was estimated by depth using this relationship, the loss of that plankton was calculated by multiplying each depth bins plankton stock estimate by the volume of water within each of the corresponding depth bins. The sum of products for each depth bin provided the total lost phytoplankton stock through the water column irrespective of water depth thus allowing the phytoplankton stock within the shaded areas of the project to be presented as g C / m^2.

To compensate for the lost phytoplankton stock the previously provided estimates of *Z. marina* standing stock in g C / m^2 were used to determine the amount of eelgrass habitat that would be necessary to compensate for the phytoplankton losses within each depth bin. The sum of the estimates of eelgrass necessary for losses in each depth bin were then summed to determine the total required compensatory offset required. As with prior literature reviews relating seagrass functions to those of unvegetated bay environments the biomass estimates from the fourteen data sets reviewed ranged widely from a low for above ground biomass of 3.2 g C / m^2 in Ojo del Liebre Lagoon, Baja to a high of 234 g C / m^2 in south Humboldt Bay, California (Table 1. Few studies explored below ground biomass resulting in only three studies providing estimates for whole plant biomass ranging from 22.74±13.86 g C / m^2 at British Columbia sites to a high of 105.48±56.13 g C / m^2 at Denmark sites. Those studies that included whole plant biomass were all from substantially higher latitudes than San Diego and may substantively miss the range of local eelgrass. For this reason, it was determined better to explore impact to mitigation ratios using a broader representation of eelgrass carbon stores based on above ground biomass only. This would under-estimate the total carbon and thus would skew results towards requiring a greater amount of eelgrass to offset water column impacts. The mean (72.68 g C / m^2) and median (48.60 g C / m^2) carbon stores were calculated for above ground biomass for all studies. From this calculation, the lower yield median value was applied to eelgrass as an offsetting balance to water column losses.

Cumulative Impact Analysis Summary

The results of the analysis are presented for the MGBW floating dry dock (Table 2) and the Mole Pier floating dry dock (Table 3). The carbon concentration assumptions in each of these is a surface phytoplankton of 0.15 g C / m^3 wherein the concentration is flattened by factoring in the full water column depth and an eelgrass carbon concentration of 48.60 g C / m^2.

The analysis indicates a low supplemental mitigation need associated with water column shading effects would be required in addition to that already quantified in the MTS (2020) and M&A (2020) analyses previously prepared. Specifically, for the MGBW floating dry dock the supplemental eelgrass from a mitigation bank required would total 458.1 ft^2 (42.6 m^2) (Table 2). For the larger Mole Pier dry dock located in deeper water, the requirement supplemental mitigation would be 715.0 ft^2 (66.4 m^2) (Table 3).

Table 2. Summary of MGBW Floating Dry Dock Water Column Functional Loss Calculations

Elevation (Ft MLLW)	Area Existing (sf)	Area Existing Shaded (sf)	Volume Shaded (ft^3)	Depth Corrected Volume Shaded (ft^3)	Light Decay	Plankton Stock (g C/ft^3)	Plankton Loss (g C)	Equivalent Z. marina (ft^2)
3	344							
2	469							
1	776							
0	986							
-1	1346							
-2	2961	287	287	89302	1	0.004	379.312	84.010
-3	2156	314	628	89015	0.8512922	0.004	321.868	71.287
-4	1607	374	1122	88701	0.7246983	0.003	273.037	60.472
-5	1838	521	2084	88327	0.61693	0.003	231.454	51.262
-6	3170	597	2985	87806	0.5251877	0.002	195.873	43.382
-7	7501	1379	8274	87209	0.4470882	0.002	165.611	36.680
-8	11977	3517	24619	85830	0.3806027	0.002	138.754	30.731
-9	13636	8501	68008	82313	0.3240041	0.001	113.280	25.089
-10	15780	4233	38097	73812	0.2758221	0.001	86.475	19.152
-11	20902	5364	53640	69579	0.2348052	0.001	69.394	15.369
-12	28610	15780	173580	64215	0.1998878	0.001	54.520	12.075
-13	78563	42426	509112	48435	0.1701629	0.001	35.007	7.753
-14	38028	6009	78117	6009	0.1448584	0.001	3.697	0.819
-15	3991	0	0	0	0.1233168	0.001	0.000	0.000
-16	103	0	0	0	0.1049786	0.000	0.000	0.000
-17	9	0	0		0.0893675	0.000	0.000	0.000
-18	0	0	0		0.0760778	0.000	0.000	0.000
-19	0	0	0		0.0647645	0.000	0.000	0.000
-20	0	0	0		0.0551335	0.000	0.000	0.000
-21	0	0	0		0.0469347	0.000	0.000	0.000
-22	0	0	0		0.0399551	0.000	0.000	0.000
-23	0	0	0		0.0340135	0.000	0.000	0.000
-24	0	0	0		0.0289554	0.000	0.000	0.000
-25	0	0	0		0.0246495	0.000	0.000	0.000
-26	0	0	0		0.020984	0.000	0.000	0.000
-27	0	0	0		0.0178635	0.000	0.000	0.000
-28	0	0	0		0.015207	0.000	0.000	0.000
-29	0	0	0		0.0129456	0.000	0.000	0.000
-30	0	0	0		0.0110205	0.000	0.000	0.000
-31	0	0	0		0	0.000	0.000	0.000
-32	0	0	0		0	0.000	0.000	0.000
-33	0	0	0		0	0.000	0.000	0.000
-34	0	0	0		0	0.000	0.000	0.000
-35	0	0	0		0	0.000	0.000	0.000
-36	0	0	0		0	0.000	0.000	0.000
-37	0	0	0		0	0.000	0.000	0.000
-38	0	0	0		0	0.000	0.000	0.000
-39	0	0	0		0	0.000	0.000	0.000
Totals (ft^2)	**234753**	**89302**	**960553**	**960553**	**NA**	**NA**	**2068.3**	**458.1**
Totals (ac.)	**5.389**	**2.050**						**0.011**

Table 3. Summary of Mole Pier Floating Dry Dock Water Column Functional Loss Calculations

Elevation (Ft MLLW)	Area Existing (sf)	Area Existing Shaded (sf)	Volume Shaded (ft^3)	Depth Corrected Volume Shaded (ft^3)	Light Decay	Plankton Stock (g C ft^-3)	Plankton Loss (g C)	Equivalent Z. marina (ft ^2)
-2			0	114102	1	0.0042475	484.65087	107.34019
-3			0	114102	0.8512922	0.0036159	412.57949	91.377867
-4			0	114102	0.7246983	0.0030782	351.22568	77.789262
-5			0	114102	0.61693	0.0026204	298.99567	66.221389
-6			0	114102	0.5251877	0.0022307	254.53267	56.37375
-7			0	114102	0.4470882	0.001899	216.68167	47.990531
-8			0	114102	0.3806027	0.0016166	184.45941	40.853963
-9			0	114102	0.3240041	0.0013762	157.02885	34.778659
-10			0	114102	0.2758221	0.0011716	133.67743	29.6068
-11			0	114102	0.2348052	0.0009973	113.79855	25.204036
-12			0	114102	0.1998878	0.000849	96.875811	21.455999
-13			0	114102	0.1701629	0.0007228	82.469618	18.265324
-14			0	114102	0.1448584	0.0006153	70.20574	15.549127
-15	3		0	114102	0.1233168	0.0005238	59.765596	13.23685
-16	0		0	114102	0.1049786	0.0004459	50.877984	11.268426
-17	0		0	114102	0.0893675	0.0003796	43.312029	9.5927232
-18	5		0	114102	0.0760778	0.0003231	36.871191	8.1662101
-19	0		0	114102	0.0647645	0.0002751	31.388156	6.9518306
-20	3		0	114102	0.0551335	0.0002342	26.720491	5.9180389
-21	5		0	114102	0.0469347	0.0001994	22.746945	5.0379802
-22	0		0	114102	0.0399551	0.0001697	19.364296	4.288793
-23	3		0	114102	0.0340135	0.0001445	16.484673	3.6510159
-24	5		0	114102	0.0289554	0.000123	14.033273	3.1080812
-25	0		0	114102	0.0246495	0.0001047	11.946415	2.6458852
-26	0		0	114102	0.020984	8.913E-05	10.16989	2.2524213
-27	3		0	114102	0.0178635	7.588E-05	8.6575475	1.9174686
-28	3		0	114102	0.015207	6.459E-05	7.3701023	1.632326
-29	8		0	114102	0.0129456	5.499E-05	6.2741103	1.3895863
-30	5		0	114102	0.0110205	4.681E-05	5.341101	1.182944
-31	3		0	114102	0	0	0	0
-32	13		0	114102	0	0	0	0
-33	102		0	114102	0	0	0	0
-34	3328		0	114102	0	0	0	0
-35	11003		0	114102	0	0	0	0
-36	10703		0	114102	0	0	0	0
-37	21210		0	114102	0	0	0	0
-38	36180		0	114102	0	0	0	0
-39	14139		0	114102	0	0	0	0
-40	8133		0	114102	0	0	0	0
-41	4029		0	114102	0	0	0	0
-42	3116		0	114102	0	0	0	0
-43	3011		0	114102	0	0	0	0
-44	2803		0	114102	0	0	0	0
-45	2714		0	114102	0	0	0	0
-46	2698		0	114102	0	0	0	0
-47	2660		0	114102	0	0	0	0
-48	2988		0	114102	0	0	0	0
-49	3423	72	3456	114102	0	0	0	0
-50	4828	315	15435	114030	0	0	0	0
-51	8648	2295	114750	113715	0	0	0	0
-52	17098	5076	258876	111420	0	0	0	0
-53	40166	37647	1957644	106344	0	0	0	0
-54	50068	49059	2600127	68697	0	0	0	0
-55	19364	19485	1052190	19638	0	0	0	0
-56	59	153	8415	153	0	0	0	0
Totals	**272527**	**114102**	**6010893**	**6010893**	**NA**	**0**	**3229**	**715**
Totals (ac.)	**6.256**	**2.619**						**0.016**

As has been noted previously, the water column functional losses are reliant upon a number of underpinning assumptions some are stronger than others and, where decisions as to what assumptions should be applied have been required, these have favored a more liberal estimate of impact and a more conservative value of mitigation habitat. The supplemental mitigation needs associated with water column functional loss would be added to the previously quantified mitigation offset requirements as illustrated in Table 4.

Table 4. Eelgrass Habitat Equivalency to offset Functional Loss of within the Water Column

Project Element Impact Location	**MGBW Commercial Out Lease Floating Dry Dock Eelgrass Habitat Based Mitigation Requirements**	**NBSD Mole Pier Floating Dry Dock Eelgrass Habitat Based Mitigation Requirements**
Initial Calculated Mitigation Need	1.073 acre	0.068 acre
Water Column Supplemental Need	0.011 acre	0.016 acre
Total	**1.084 acre**	**0.084 acre**

The contribution of water column impact and thus mitigation for both the floating dry docks was determined to be minor compared to other sources of habitat functional loss. However, given the presence of the presently deeper water and large size of the proposed mole pier dry dock, there is a slightly greater assessed impact and mitigation need for the mole pier dry dock than the MGBW dry dock. It is also notable that the greatest driver of impact is not the depth of water, as functional loss degrades quickly with increasing water depth as the shading effect lessens with an ambient attenuation of light; rather the greatest driver of lost function is the scale of the surface coverage.

Please let us know if you need any additional information to support this effort. We appreciate the opportunity to assist you.

Sincerely,

Keith W. Merkel

Keith W. Merkel
Principal Consultant

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