The Coastal and Marine Ecological Classification Standard (CMECS)

Revised Substrate Component

(Interim Version)

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CMECS Implementation Group

Contents

Substrate Component

Substrate is defined in the Coastal and Marine Ecological Classification Standard (CMECS) as the non-living materials that form an aquatic bottom or seafloor, or that provide a surface (e.g., floating objects, buoys) for growth of attached biota. Substrate may be composed of any substance, natural or man-made. Describing the composition of the substrate is a fundamental part of any ecological classification scheme. Substrate provides context and setting for many aquatic processes, and it provides living space for benthic and attached biota.

The Substrate Component (Section 7, p. 98, FGDC-STD-018-2012) is a characterization of the composition and particle size of the surface layers of the substrate; this component is designed to be compatible with a range of sampling tools. The Substrate Component provides guidance to characterize the layers of substrate that support the majority of multicellular life (the upper layer of hard substrate, or (typically) the upper 15 centimeters of soft substrate) in a way that is consistent with a variety of past practices. The Substrate Component and the Biotic Component (Section 8, p. 119, FGDC-STD-018-2012) describe the non-living (Substrate) and living (Biotic) aspects of a plan-view perspective of the seafloor at comparable scales.

Substrate Component observational unit scales range from sediment corers or grabs, to sediment profile or plan-view photographs of the seafloor, to defined quadrats or transects, to video clips, to high-resolution acoustic images. At larger scales, the structure, shape, and surface pattern of the substrate are described by the Geoform Component (Section 6, p. 60, FGDC-STD-018-2012).

Implementation Guidance for all Substrate Component Units

The Coastal and Marine Ecological Classification Standard (CMECS) does not prescribe metrics or methodologies for substrate analysis or interpretation at this time. Classifications throughout the Substrate Component may be based on visual percent cover for plan-view images or metrics such as percent weight, or percent composition for other approaches (e.g., retrieved samples).

CMECS components are intended to be scale-independent and method-independent; the reported scale of substrate "patchiness" is determined by the scale of observation, and so is somewhat method-dependent. To assist with comparability, practitioners should always report sampling gear, methods, units, scale of observation, and scale of reporting in project metadata. Data users should be aware of the methods that were used to collect and report data, and should make note of any data limitations that may exist.

Modifier terms (Section 7.6 and Section 10, FGDC-STD-018-2012) can be applied as needed to further describe substrate characteristics. Recommended modifiers for substrate units include: *Anthropogenic Impact, aRPD and RPD Depth, Benthic Depth Zones, Co-occurring Elements, Coral Reef Zone, Energy Intensity, Induration, Percent Cover (Fine), Mineral Precipitate, Percent Cover (Coarse), Seafloor Rugosity, Small-Scale Slope, Substrate Descriptor, Substrate Layering, Surface Pattern, Temporal Persistence.*

The Co-occurring Elements modifier (Section 10.6.2, p. 213, FGDC-STD-018-2012) may be used to describe the presence of secondary substrate units within the observational unit (i.e., image frame, sampling grid cell, etc.)

Substrate Origin: Geologic Substrate

Benthic substrates where sufficient evidence shows that Geologic Substrate exceeds (is dominant over) both Biogenic and Anthropogenic Substrates, considered separately. Geologic Substrates are composed of consolidated igneous, metamorphic, or sedimentary rock or finer unconsolidated particles, and are classified according to particle size and mixes of particle sizes. When Geologic Substrate is present, but does not constitute the dominant substrate origin, it may be included as a Co-occurring Element.

Substrate Origin describes the genesis of the substrate, not the process by which it is emplaced. If the Substrate Origin cannot be definitively determined, the analyst may opt to use "Indeterminate" in place of Origin type and use the Geologic Origin units for further classification.

Substrate Class: Consolidated Mineral Substrate

Igneous, metamorphic, or sedimentary rock with particle sizes greater than or equal to 4.0 meters (4,096 millimeters) in any dimension that cover 50% or greater of the Geologic Substrate surface.

Depending on the sampling method used and scale of the observational unit, classifying larger features may require extrapolating information from surrounding observations or additional studies. The Geoform Component may also be used to extend the substrate classification for such features (p. 227, FGDC-STD-018-2012).

Substrate Subclass: Bedrock

Substrate with mostly continuous formations of bedrock that cover 50% or more of the Geologic Substrate surface.

Substrate Subclass: Megaclast

Substrate where individual rocks with particle sizes greater than or equal to 4.0 meters (4,096 millimeters) in any dimension cover 50% or more of the Geologic Substrate surface.

Substrate Subclass: Tar

Substrate dominated by tar, asphalt, or other hydrocarbon material that has extruded onto the seafloor. This material has cooled from a semi-liquid state and now forms a potential attachment surface for biota. This substrate is usually associated with seeps, tar mounds, or tar lily geoforms.

Substrate Class: Coarse Unconsolidated Mineral Substrate

Geologic Substrate where Unconsolidated Mineral Substrate covers 50% or more of the surface area with ≥ 5% Gravel (2 millimeters to < 4,096 millimeters in diameter).

The CMECS Coarse and Fine Unconsolidated Mineral Substrate classes and subordinate units use Folk (1954) terminology to describe particle sizes of loose mineral substrates as shown in the ternary diagram in Figure 7.2 (revised version). Units with bracketed letters, e.g., [G], [(g)sM], correspond to the labeled polygons in Figure 7.2, using conventions from Folk (1954).

Substrate Subclass: Gravel Substrate [G]

Geologic Unconsolidated Mineral Substrate surface is ≥ 80% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter).

Substrate Group: Very Coarse Gravel

Geologic Unconsolidated Mineral Substrate surface is ≥ 80% Gravel particles 64 millimeters to < 4,096 millimeters in diameter.

Substrate Subgroup: Boulder

Geologic Unconsolidated Mineral Substrate surface is ≥ 80% Gravel particles 256 millimeters to < 4,096 millimeters in diameter.

Substrate Subgroup: Cobble

Geologic Unconsolidated Mineral Substrate surface is ≥ 80% Gravel particles 64 millimeters to < 256 millimeters in diameter.

Substrate Group: Moderately Coarse Gravel

Geologic Unconsolidated Mineral Substrate surface is ≥ 80% Gravel particles 2 millimeters to < 64 millimeters in diameter.

Substrate Subgroup: Pebble

Geologic Unconsolidated Mineral Substrate surface is ≥ 80% Gravel particles 4 millimeters to < 64 millimeters in diameter.

Substrate Subgroup: Granule

Geologic Unconsolidated Mineral Substrate surface is ≥ 80% Gravel particles 2 millimeters to < 4 millimeters in diameter.

Substrate Subclass: Mixed Gravels

Geologic Unconsolidated Mineral Substrate surface is 5% to < 80% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter) with the remaining mix composed of Sand (particles 0.0625 millimeters to < 2 millimeters in diameter) and/or Mud (particles < 0.0625 millimeters in diameter).

Substrate Group: Gravel Mixes

Geologic Unconsolidated Mineral Substrate surface is 30% to < 80% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter) with the remaining mix composed of Sand (particles 0.0625 millimeters to < 2 millimeters in diameter) and/or Mud (particles < 0.0625 millimeters in diameter).

Substrate Subgroup: Sandy Gravel [sG]

Geologic Unconsolidated Mineral Substrate surface is 30% to < 80% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter), with Sand (particles

Getting Started

If Gravel particles make up > 80% of the substrate, continue classifying using the Gravel Substrate subclass units.

If Gravel particles make up ≥ 5% but < 80%, continue classifying using the Mixed Gravel subclass units.

If Gravel particles make up 0.01% to < 5% continue classifying using the Trace Gravel subclass within the Fine Unconsolidated Mineral Substrate class.

0.0625 millimeters to < 2 millimeters in diameter) composing 90% or more of the remaining Sand-Mud mix.

Substrate Subgroup: Muddy Sandy Gravel [msG]

Geologic Unconsolidated Mineral Substrate surface is 30% to < 80% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter), with Sand (particles 0.0625 millimeters to < 2 millimeters in diameter) composing from 50% to < 90% of the remaining Sand-Mud mix.

Substrate Subgroup: Muddy Gravel [mG]

Geologic Unconsolidated Mineral Substrate surface is 30% to < 80% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter), with Mud (particles < 0.004 millimeters in diameter) composing 50% or more of the remaining Mud-Sand mix.

Implementation Guidance for Classification of Gravel in All Units

Due to the importance of different particle sizes of Gravel as habitat for many organisms, Gravel subgroup particle sizes (Boulder, Cobble, Pebble, Granule) **must be identified whenever particle sizes are known or can be estimated** within any mix and at any level of classification. *Examples:*

- *Gravel Mixes -> Pebble Mixes*
- *Muddy Sandy Gravel -> Muddy Sandy Cobble*
- *Gravelly Sand -> Bouldery Sand*

When classifying mixes of two different Gravel subgroup particle sizes, use combinations of the subgroup unit names with the overall dominant size first.
Examples: Boulder-Cobble, Cobble-Boulder, Cobble-Granule, Pebble-Granule, Granule-Boulder.

When classifying mixes, or when there is a need to identify specific particle sizes beyond the subgroup definitions, the subgroup terms for the Gravel group (Boulder, Cobble, Pebble, Granule), Sand group (Very Coarse Sand, Coarse Sand, Medium Sand, Fine, Sand, Very Fine Sand), and Mud group (Silt, Silt-Clay, Clay) may optionally be substituted for the group term. *Examples:*

- *Muddy Sandy Gravel -> Silty Sandy Gravel*
- *Slightly Gravelly Sandy Mud -> Slightly Gravelly Sandy Clay*
- *Gravelly Muddy Sand -> Gravelly Muddy Coarse Sand*
- *Slightly Gravelly Sand -> Slightly Gravelly Medium Sand*

Substrate Group: Gravelly Mixes

Geologic Unconsolidated Mineral Substrate surface is 5% to < 30% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter) with the remaining mix composed of Sand (particles 0.0625 millimeters to < 2 millimeters in diameter) and/or Mud (particles < 0.0625 millimeters in diameter).

Substrate Subgroup: Gravelly Sand [gS]

Geologic Unconsolidated Mineral Substrate surface is 5% to < 30% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter), and the remaining Sand-Mud mix is 90% or more Sand (particles 0.0625 millimeters to < 2 millimeters in diameter).

Substrate Subgroup: Gravelly Muddy Sand [gmS]

Geologic Unconsolidated Mineral Substrate surface is 5% to < 30% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter), and the remaining Sand-Mud mix is 50% to < 90% Sand (particles 0.0625 millimeters to < 2 millimeters in diameter).

Substrate Subgroup: Gravelly Mud [gM]

Geologic Unconsolidated Mineral Substrate surface is 5% to < 30% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter), and the remaining Sand-Mud mix is 50% or more Mud (particles < 0.004 millimeters in diameter).

Substrate Class: Fine Unconsolidated Mineral Substrate

Geologic Substrate where Unconsolidated Mineral Substrate covers 50% or more of the surface area with < 5% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter).

The CMECS Coarse and Fine Unconsolidated Mineral Substrate classes and subordinate units use Folk (1954) terminology to describe particle sizes of loose mineral substrates as shown in the ternary diagram in Figure 7.2 (revised version). Units with bracketed letters, e.g., [G], [(g)sM], correspond to the labeled polygons in Figure 7.2, using conventions from Folk (1954).

Substrate Subclass: Trace Gravels

Unconsolidated Mineral Substrate surface is 0.01% (a trace) of Gravel to < 5% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter) with the remaining mix composed of Sand (particles 0.0625 millimeters to < 2 millimeters in diameter) and/or Mud (particles < 0.0625 millimeters in diameter).

Substrate Group: Sandy Mixes with Trace Gravel

Geologic Unconsolidated Mineral Substrate surface is 0.01% (a trace) of Gravel (particles 2 millimeters to < 4,096 millimeters in diameter) to < 5% Gravel, and the remaining Sand-Mud mix is 50% or more Sand (particles 0.0625 millimeters to < 2 millimeters in diameter).

Substrate Subgroup: Slightly Gravelly Sand [(g)S]

Geologic Unconsolidated Mineral Substrate surface is 0.01% (a trace) of Gravel (particles 2 millimeters to < 4,096 millimeters in diameter) to < 5% Gravel, and the remaining Sand-Mud mix is 90% or more Sand (particles 0.0625 millimeters to < 2 millimeters in diameter).

Substrate Subgroup: Slightly Gravelly Muddy Sand [(g)mS]

Geologic Unconsolidated Mineral Substrate surface is 0.01% (a trace) of Gravel (particles 2 millimeters to < 4,096 millimeters in diameter) to < 5% Gravel, and the remaining Sand-Mud mix is 50% to < 90% Sand (particles 0.0625 millimeters to < 2 millimeters in diameter).

Substrate Group: Muddy Mixes with Trace Gravel

Geologic Unconsolidated Mineral Substrate surface is 0.01% (a trace) of Gravel (particles 2 millimeters to < 4,096 millimeters in diameter) to <5% Gravel, and the remaining Sand-Mud mix is 50% or more Mud (particles < 0.0625 millimeters in diameter).

Substrate Subgroup: Slightly Gravelly Sandy Mud [(g)sM]

Geologic Unconsolidated Mineral Substrate surface is 0.01% (a trace) of Gravel (particles 2 millimeters to < 4,096 millimeters in diameter) to <5% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter), and the remaining Sand-Mud mix is 50% to <90% Mud (particles < 0.0625 millimeters in diameter).

Substrate Subgroup: Slightly Gravelly Mud [(g)M]

Geologic Unconsolidated Mineral Substrate surface is 0.01% (a trace) of Gravel (particles 2 millimeters to < 4,096 millimeters in diameter) to < 5% Gravel, and the remaining Sand-Mud mix is 90% or more Mud (particles < 0.0625 millimeters in diameter).

Substrate Subclass: Sandy Substrate

Geologic Unconsolidated Mineral Substrate surface contains no trace of Gravel and is >50% Sand (particles 0.0625 millimeters to < 2 millimeters in diameter) with the remainder composed of Mud (particles < 0.0625 millimeters in diameter).

Substrate Group: Sand [S]

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is ≥ 90% Sand (particles 0.0625 millimeters to < 2 millimeters in diameter).

Substrate Subgroup: Very Coarse Sand

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is ≥ 90% Sand particles 1 millimeter to < 2 millimeters in diameter.

Substrate Subgroup: Coarse Sand

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is ≥ 90% Sand particles 0.5 millimeters to < 1 millimeter in diameter.

Substrate Subgroup: Medium Sand

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is ≥ 90% Sand particles 0.25 millimeters to < 0.5 millimeters in diameter.

Substrate Subgroup: Fine Sand

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is ≥ 90% Sand particles 0.125 millimeters to < 0.25 millimeters in diameter.

Substrate Subgroup: Very Fine Sand

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is ≥ 90% Sand particles 0.0625 millimeters to < 0.125 millimeters in diameter.

Substrate Group: Muddy Sand [mS]

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is 50% to < 90% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the remainder is Mud (particles less than 0.0625 millimeters in diameter).

Substrate Subgroup: Silty Sand [zS]

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is 50% to < 90% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the remaining Silt-Clay mix is 67% or more Silt (particles 0.0040 millimeters to < 0.0625 millimeters in diameter).

Substrate Subgroup: Silty-Clayey Sand [zcS]

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is 50% to < 90% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the remaining Silt-Clay mix is 33% to < 67% Silt (particles 0.0040 millimeters to < 0.0625 millimeters in diameter).

Substrate Subgroup: Clayey Sand [cS]

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is 50% to < 90% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the remaining Clay-Silt mix is 67% or more Clay (particles < 0.0040 millimeters in diameter).

Substrate Subclass: Muddy Substrate

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is > 50% Mud (particles < 0.0625 millimeters in diameter) with the remainder composed of Sand (particles 0.0625 millimeters to 2 millimeters in diameter).

Substrate Group: Sandy Mud [sM]

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is 50% to 90% Mud (particles < 0.0625 millimeters in diameter); the remainder is Sand (particles 0.0625 millimeters to < 2 millimeters in diameter).

Substrate Subgroup: Sandy Silt [sZ]

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is 10% to < 50% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the remaining Silt-Clay mix is 67% or more Silt (particles 0.0040 millimeters to < 0.0625 millimeters in diameter).

Substrate Subgroup: Sandy Silt-Clay [sZC]

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is 10% to < 50% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the remaining Silt-Clay mix is 33% to < 67% Silt (particles 0.0040 millimeters to < 0.0625 millimeters in diameter).

Substrate Subgroup: Sandy Clay [sC]

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is 10% to < 50% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the remaining Clay-Silt mix is 67% or more Clay (particles < 0.004 millimeters in diameter).

Substrate Group: Mud [M]

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is 90% or more Mud (particles < 0.0625 millimeters in diameter); the remainder (< 10%) is Sand (particles 0.0625 millimeters to < 2 millimeters in diameter).

Substrate Subgroup: Silt [Z]

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is < 10% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the remaining Silt-Clay mix is 67% or more Silt (particles 0.0040 millimeters to < 0.0625 millimeters in diameter).

Substrate Subgroup: Silt-Clay [ZC]

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is < 10% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the remaining Silt-Clay mix is < 33% to 67% Silt (particles 0.0040 millimeters to < 0.0625 millimeters in diameter).

Substrate Subgroup: Clay [C]

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is < 10% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the remaining Clay-Silt mix is 67% or more Clay (particles < 0.004 millimeters in diameter).

Substrate Origin: Biogenic Substrate

Benthic substrates where sufficient evidence shows that Biogenic Substrate exceeds (is dominant over) that of both Geologic and Anthropogenic Substrates, when all are considered separately. Biogenic substrates are the non-living material that supports, intersperses, or overlays the living biota described in the Biotic Component (see Section 7.2), and are either generated by living biota, such as shells and tests, or are non-living remnants of living biota, such as skeletons, dead wood, and detritus.

Biogenic substrates are classified at the class level by the level of consolidation, and at the subclass and group levels by particle size and biological source of the material. Subgroup units

provide further descriptive detail where possible. Particle size bins at the Biogenic Substrate class, subclass, and group levels correspond to the Geologic Substrate units as follows:

- Class: Consolidated Biogenic Substrate is equivalent to the Geologic Origin class: Consolidated Mineral Substrate (≥ 4,096 millimeters in any dimension)
- Subclass: Biogenic Rubble is equivalent to the Geologic Origin group: Very Coarse Gravel (64 millimeters to < 4,096 millimeters in diameter)
- Subclass: Biogenic Hash is equivalent to the Geologic Origin group: Moderately Coarse Gravel (2 millimeters to < 64 millimeters in diameter)
- Subclass: Biogenic Sand is equivalent to the Geologic Origin group: Sand (0.0625 millimeters to < 2 millimeters in diameter)
- Group: Organic Mud is equivalent to the Geologic Origin group: Mud (< 0.0625 millimeters in diameter)

These units are derived from Wentworth (1922), and they can be broken down into Wentworth grain size classes for greater precision, if desired.

Substrate Origin describes the genesis of the substrate, not the process by which it is emplaced. If the Substrate Origin cannot be definitively determined, the analyst may opt to use "Indeterminate" in place of origin type and use the Geologic Origin units for further classification.

Implementation Guidance for all Biogenic Origin Units

CMECS does not prescribe metrics or methodologies for substrate analysis or interpretation at this time. The terms "dominant" and "primarily" in the Biogenic Substrate Origin describe the substrate type that is present in the greatest visual percent cover for plan-view images or metrics such as percent weight, or percent composition for other approaches (e.g., retrieved samples).

When two Biogenic Substrate types are present, "dominant" and "primarily" are equivalent to > 50%. When three or more types exist, the dominant type may occur at a lower percent-of-total value. Biogenic Substrate types that are present, but do not constitute the dominant feature, may be included as a Co-occurring Element modifier (see Section 10).

Substrate Class: Consolidated Biogenic Substrate

Non-living, consolidated material formed by living biota that are greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension and cover 50% or greater of the Biogenic Substrate surface. Examples include mounds, ridges, or pavements composed of calcium carbonate reef material generated by corals, cemented aggregations of shells and worm tubes, and very large woody particles.

Substrate Subclass: Reef Substrate

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is formed by living, reef-building biota such as scleratinian corals, molluscs, and worms.

Substrate Group: Coral Reef

Consolidated substrate that is formed and dominated by living or non-living hard coral reefs (bioherms). The material may be intact coral skeletons in relatively intact condition or may be formed from the agglomeration of coral rubble/hash or other particles into a fixed non-mobile surface.

Substrate Group: Rhodolith Reef

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is dominated by rhodoliths.

Substrate Group: Shell Reef

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is dominated by non-living cemented, conglomerated, or otherwise self-adhered shell reefs.

Substrate Subgroup: Coquina Reef

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is dominated by Shell Reef primarily composed of cemented or conglomerated Coquina shells.

Substrate Subgroup: Crepidula Reef

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is dominated by Shell Reef primarily composed of conglomerated Crepidula shells. While Crepidula are slowly mobile and do not cement their shells, the gregarious settlement of their larvae on conspecifics (Zhao and Qian 2002) can lead to very dense accumulations with a flat, reef-like texture as live shells build over dead shells.

Substrate Subgroup: Mussel Reef

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic

Substrate surface, and is dominated by Shell Reef primarily composed of self-adhered or conglomerated mussel shells.

Substrate Subgroup: Oyster Reef

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is dominated by Shell Reef primarily composed of cemented or conglomerated oyster shells that form a stable substrate surface.

Substrate Group: Worm Reef

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is dominated by cemented or conglomerated calcareous or sandy tubes of polychaetes or other worm-like fauna.

Substrate Subgroup: Sabellariid Reef

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is dominated by Worm Reef primarily composed of cemented mineral-based or shell-based sabellariid worm tubes.

Substrate Subgroup: Serpulid Reef

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is dominated by Worm Reef that is primarily composed of cemented or conglomerated calcareous serpulid worm tubes.

Substrate Subclass: Very Large Wood

Consolidated Biogenic Substrate that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, and is composed of non-living, very large wood fragments that cover 50% or greater of the Biogenic Substrate surface. These include rooted, partially buried, and sunken intact non-living woody plant structures, such as remnant trunks, branches, roots, and root networks.

Substrate Group: Very Large Trunk or Root Substrate

Consolidated Biogenic Substrate that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is composed of non-living trees, trunks, branches, roots, or root structures.

Substrate Subgroup: Tree

Consolidated Biogenic Substrate that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated

Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is composed of non-living trees.

Substrate Subgroup: Very Large Trunk or Branch

Consolidated Biogenic Substrate that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is composed of non-living, very large branches.

Substrate Subgroup: Very Large Wood Fragment

Consolidated Biogenic Substrate that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is composed of non-living, very large wood fragments.

Substrate Subgroup: Very Large Root or Root Network

Consolidated Biogenic Substrate that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is composed of non-living, very large roots, root balls, or root networks.

Substrate Subclass: Biogenic Pavement

Consolidated Biogenic Substrate that is a relatively flat, continuous area of solid substrate greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is composed of low-relief carbonate deposits formed by the cemented, remnant skeletons and tests of living biota.

Substrate Group: Coralline Pavement

Consolidated Biogenic Substrate that is a relatively flat, continuous area of solid substrate greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is composed of carbonate deposits formed by the cemented, remnant skeletons of corals.

Substrate Class: Coarse Unconsolidated Biogenic Substrate

Biogenic Unconsolidated Substrate that is dominated by Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface. Particles may be either loose whole or broken non-living biogenic fragments or, particularly in the larger Rubble sizes, particles may be cemented, conglomerated, or otherwise attached so as to form consolidated material. The Coarse Unconsolidated Biogenic Substrate subclass includes rubble of various origins, as well as woody debris.

Substrate Subclass: Biogenic Rubble

Unconsolidated Biogenic Substrate dominated by Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface. Particles may be either loose whole or broken non-living biogenic fragments or, particularly in the larger Rubble sizes, fragments may be cemented, conglomerated, or otherwise attached so as to form Boulders of consolidated material.

Substrate Group: Algal Rubble

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living calcareous algae.

Substrate Subgroup: Rhodolith Rubble

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living Rhodolith fragments.

Substrate Group: Coral Rubble

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living coral fragments.

Substrate Group: Shell Rubble

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living shells. Most (but not all) shell-builders are mollusks.

Substrate Subgroup: Coquina Rubble

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of cemented or conglomerated Coquina shells. Note that Coquina shells are described in a separate substrate subgroup due to their distinctive features and special significance in many areas.

Substrate Subgroup: Crepidula Rubble

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of conglomerated *Crepidula* shells. While *Crepidula* are slowly mobile and do not cement their shells, the gregarious settlement of their larvae on conspecifics (Zhao and Qian 2002) can lead to very dense accumulations as live shells build over dead shells, and sediments fill in to bind these areas into flat shelly masses.

Substrate Subgroup: Mussel Rubble

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of self-adhered or conglomerated mussel shells.

Substrate Subgroup: Oyster Rubble

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of cemented or conglomerated oyster shells.

Substrate Group: Wood Rubble

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living woody material.

Substrate Subgroup: Very Coarse Woody Debris

Biogenic Rubble particles (256 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroup Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living, very coarse woody debris.

Substrate Subgroup: Coarse Woody Debris

Biogenic Rubble particles (64 millimeters to < 256 millimeters, equivalent to Geologic Origin subgroup Cobble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living, coarse woody debris.

Substrate Group: Worm Rubble

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of the cemented or conglomerated calcareous or sandy tubes of polychaetes or other worm-like fauna.

Substrate Subgroup: Sabellariid Rubble

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of sand and shell bits cemented with adhesive proteins into cohesive, clustered tubes by sabellariid worms (e.g., *Sabellaria* or *Phragmatopoma*).

Substrate Subgroup: Serpulid Rubble

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of cemented calcareous worm tubes produced by serpulid worms, e.g., *Serpula*.

Substrate Class: Fine Unconsolidated Biogenic Substrate

Biogenic Unconsolidated Substrate that is dominated by fine biogenic substrate particles (0.004 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble, and groups Sand and Mud) that cover 50% or greater of the Biogenic Substrate surface, including hash of various origins, as well as organic material and oozes.

Substrate Subclass: Biogenic Hash

Biogenic Unconsolidated Substrate dominated by Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface. Particles may be either loose whole or broken non-living biogenic fragments.

Substrate Group: Algal Hash

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living calcareous algae fragments.

Substrate Subgroup: Rhodolith Hash

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living Rhodolith fragments.

Substrate Group: Coral Hash

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living coral fragments.

Substrate Subgroup: Acropora Hash

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living *Acropora* fragments.

Substrate Group: Shell Hash

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are of primarily composed of non-living shells and shell bits. Most (but not all) shell-builders are mollusks.

Substrate Subgroup: Coquina Hash

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of cemented or conglomerated Coquina shells and shell bits.

Substrate Subgroup: Crepidula Hash

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of loose *Crepidula* shells and shell bits.

Substrate Subgroup: Mussel Hash

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of loose mussel shells and shell bits.

Substrate Subgroup: Oyster Hash

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of loose oyster shells and shell bits.

Substrate Group: Fine Woody Debris

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed non-living fine woody debris.

Substrate Group: Worm Hash

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of fragments of the cemented or conglomerated calcareous or sandy tubes of polychaetes or other worm-like fauna.

Substrate Subgroup: Sabellariid Hash

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of fragments of the sand-shell-protein matrix and tubes constructed by sabellariid worms.

Substrate Subgroup: Serpulid Hash

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of fragments of the calcareous tubes of serpulid worms.

Substrate Subclass: Biogenic Sand

Biogenic Unconsolidated Substrate dominated by Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken down, non-living biogenic material. Shells or other remains are generally broken and difficult to identify. For this reason,

only substrate-forming taxa that produce distinctive Sand types are listed as substrate subgroups.

When the composition and origin of Sand is unclear, it is assumed to be mineral Sand, and is classified as a Geologic Origin substrate.

Substrate Group: Algal Sand

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down calcareous algae. This Sand may have a characteristic white color as it becomes bleached by the sun.

Substrate Subgroup: Halimeda Sand

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of recognizable, broken segment-like fronds of *Halimeda*, a green coralline alga.

Substrate Subgroup: Rhodolith Sand

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down Rhodolith material.

Substrate Group: Coral Sand

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down coral material.

Substrate Subgroup: Diploria Sand

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down *Diploria* coral.

Substrate Group: Shell Sand

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down shell material.

Substrate Subgroup: Coquina Sand

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down coquina shell.

Substrate Subgroup: Mussel Sand

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down mussel shell.

Substrate Subgroup: Oyster Sand

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down mussel shell.

Substrate Group: Worm Sand

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down mussel shell.

Substrate Subgroup: Sabellariid Sand

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down sand-shell-protein matrix and tubes constructed by sabellariid worms.

Substrate Subgroup: Serpulid Sand

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down calcareous tubes of serpulid worms.

Substrate Subclass: Fine Organic Substrate

Biogenic Unconsolidated Substrate dominated by Fine Organic Substrate particles (0.004 to < 0.625 millimeters, equivalent to Geologic Origin group Mud) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living organic material.

Substrate Group: Peat

Fine Organic Substrate particles that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living peat deposits, from modern or prehistoric times.

Substrate Group: Organic Detritus

Fine Organic Substrate particles (0.004 to < 4 millimeters, equivalent to Geologic Origin group Mud) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of decomposing plant and animal tissues, often in an advanced state of utilization and decay. Organic Detritus may be produced *in situ*, deposited from above or transported horizontally, or may be remnant material.

Substrate Group: Organic Mud

Fine Organic Substrate particles (0.004 to < 0.625 millimeters, equivalent to Geologic Origin group Mud) that cover 50% or greater of the Biogenic Substrate surface with an organic carbon content of greater than 5%.

Substrate Subclass: Ooze Substrate

Deep sea substrates that are composed of > 30% tests, shells, or frustules of small plankton, including diatoms, radiolarians, pteropods, foraminifera, and other marine plankters. Oozes are

common in deeper waters far from shore, where terrestrial inputs to the bottom sediments are very low, and where surface productivity is reasonably high.

Based on common practice in the field, definition of a substrate as "ooze" requires a 30% or greater (but not necessarily "dominant") ooze composition within the sediments. Once defined as an "ooze," the type of ooze is determined by dominant percent composition.

Substrate Group: Carbonate Ooze

Ooze Substrate that cover 50% or greater of the Biogenic Substrate surface and are dominated by calcium carbonate-based shells of foraminifera, coccolithophores, pteropods, or other calcareous plankton. These oozes are limited to seafloors shallower than the carbonate compensation depth (4-5 kilometers); calcium carbonate dissolves in the cold acidic waters deeper than this.

Substrate Subgroup: Coccolithophore Ooze

Ooze Substrate that covers 50% or greater of the Biogenic Substrate surface and is formed primarily from carbonate tests of phytoplanktonic coccolithophores.

Substrate Subgroup: Foramniferan Ooze

Ooze Substrate that covers 50% or greater of the Biogenic Substrate surface and is formed primarily from carbonate tests of foraminiferans.

Substrate Subgroup: Pteropod Ooze

Ooze Substrate that covers 50% or greater of the Biogenic Substrate surface and is formed primarily from the shells of pteropods (a group of planktonic mollusks).

Substrate Group: Siliceous Ooze

Ooze Substrate that covers 50% or greater of the Biogenic Substrate surface and is dominated by silicate-based shells of diatoms, radiolarians, and other organisms. These oozes are limited to seafloors shallower than the carbonate compensation depth (4-5 kilometers); calcium carbonate dissolves in the cold acidic waters deeper than this.

Substrate Subgroup: Diatomaceous Ooze

Ooze Substrate that covers 50% or greater of the Biogenic Substrate surface and is formed primarily from the silica-based frustules or tests of phytoplanktonic diatoms.

Substrate Subgroup: Radiolarian Ooze

Ooze Substrate that covers 50% or greater of the Biogenic Substrate surface and is formed primarily from the silica-based tests of amoeba-like radiolarians.

Substrate Origin: Anthropogenic Substrate

Benthic substrates where sufficient evidence shows that Anthropogenic Substrate exceeds (is dominant over) that of both Geologic and Biogenic Substrates, when all are considered separately. Anthropogenic substrates are composed of material created by human physical, chemical, or other processes. Examples include metals, plastics, ceramics, cement, and construction aggregates. Wood, although it is biogenic in origin, is included here to describe

instances where it has been shaped, textured, treated, or otherwise altered from its natural condition and thus has different habitat suitability and/or function.

Anthropogenic substrates are classified at the class level by particle size and degree of stability in relation to the surrounding substrate, i.e., fixed (immobile and generally large structures or fragments) or unconsolidated (potentially mobile, of varying particle sizes); Subclass and group level units are further refined by particle size and composition. The Anthropogenic Origin does not include any subgroup units but users may provide further descriptive detail if desired. Particle size bins at the Anthropogenic Substrate class and subclass levels correspond to the Geologic Substrate units as follows:

- Class: Fixed Anthropogenic Substrate is equivalent to the Geologic Origin class Consolidated Mineral Substrate (≥ 4,096 millimeters in any dimension)
- Class: Coarse Unconsolidated Anthropogenic Substrate is equivalent to the Geologic Origin group Very Coarse Gravel (64 millimeters to < 4,096 millimeters in diameter)
- Class: Fine Unconsolidated Anthropogenic Substrate Hash is equivalent to the Geologic Origin groups Moderately Coarse Gravel (2 millimeters to < 64 millimeters in diameter), Sand (0.0625 millimeters to < 2 millimeters in diameter), and Mud (< 0.0625 millimeters in diameter).

These units are derived from Wentworth (1922), and they can be broken down into Wentworth grain size classes for greater precision, if desired.

Substrate Origin describes the genesis of the substrate, not the process by which it is emplaced. If the Substrate Origin cannot be definitively determined, the analyst may opt to use "Indeterminate" in place of origin type and use the Geologic Origin units for further classification.

Substrate Class: Fixed Anthropogenic Substrate

Anthropogenic Substrates that are greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension

Implementation Guidance for all Anthropogenic Origin Units

CMECS does not prescribe metrics or methodologies for substrate analysis or interpretation at this time. The terms "dominant" and "primarily" in the Anthropogenic Substrate Origin describe the substrate type that is present in the greatest visual percent cover for plan-view images or metrics such as percent weight, or percent composition for other approaches (e.g., retrieved samples).

When two Anthropogenic Substrate types are present, "dominant" and "primarily" are equivalent to > 50%. When three or more types exist, the dominant type may occur at a lower percent-of-total value. Anthropogenic Substrate types that are present, but do not constitute the dominant feature, may be included as a Co-occurring Element modifier (see Section 10).

and cover 50% or greater of the Anthropogenic Substrate surface. Examples include man-made materials such as metal pipelines, concrete bulkheads, and treated-wood pilings that are either fixed (adhered to, embedded in, or otherwise attached to) the environment.

Substrate Subclass: Fixed Aggregate Substrate

Anthropogenic Substrates that are greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension and cover 50% or greater of the Anthropogenic Substrate surface are consolidated or fixed in the surrounding environment and are dominated by aggregate, primarily construction, materials. This includes concrete, asphalt, brick, porcelain, or similar materials. Examples of features that form anthropogenic substrates include boat ramps, piers, and seawalls.

Substrate Subclass: Fixed Metal Substrate

Anthropogenic Substrates that are greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension and cover 50% or greater of the Anthropogenic Substrate surface are consolidated or fixed in the surrounding environment and are composed of metal. Examples include sheet metal, ship hulls/parts, metallic walls/bulkheads, pipes, valves, mooring chains, or other infrastructural objects.

Substrate Subclass: Fixed Trash/Plastic Substrate

Anthropogenic Substrates that are greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension and cover 50% or greater of the Anthropogenic Substrate surface are consolidated or fixed in the surrounding environment and composed of plastic, trash, or other disposed materials. Examples include PVC piping, valves, or other infrastructural objects.

Substrate Subclass: Fixed Anthropogenic Wood Substrate

Anthropogenic Substrates that are greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension and cover 50% or greater of the Anthropogenic Substrate surface are consolidated or fixed in the surrounding environment and are composed of wood that has been shaped, textured, treated, or otherwise altered, and forms a stable surface in the environment. Examples include pilings, posts, daymarks, docks or other infrastructural objects.

Substrate Group: Pilings

Anthropogenic Substrates that are greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension and cover 50% or greater of the Anthropogenic Substrate surface, are consolidated or fixed in the surrounding environment and are composed of wood, such as pilings or other support structures.

Substrate Class: Coarse Unconsolidated Anthropogenic Substrate

Unconsolidated Anthropogenic Substrate that is dominated by Coarse Anthropogenic particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Anthropogenic Substrate surface. Particles may be

either loose whole or broken fragments of man-made material or in the case of wood, biogenic but significantly altered.

Substrate Subclass: Coarse Unconsolidated Aggregate Substrate

Unconsolidated Anthropogenic Substrate that is dominated by Coarse Anthropogenic particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Anthropogenic Substrate surface and are composed of aggregate pieces, or fragments.

Substrate Group: Aggregate Rubble

Unconsolidated Anthropogenic Substrate that is dominated by Coarse Anthropogenic particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Anthropogenic Substrate surface and are composed of rubble-sized aggregate particles/fragments.

Substrate Subclass: Coarse Unconsolidated Metal Substrate

Unconsolidated Anthropogenic Substrate that is dominated by Coarse Anthropogenic particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Anthropogenic Substrate surface and are composed of metal pieces or fragments.

Substrate Group: Metal Rubble

Unconsolidated Anthropogenic Substrate that is dominated by Coarse Anthropogenic particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Anthropogenic Substrate surface and are composed of metal particles.

Substrate Subclass: Coarse Unconsolidated Trash/Plastic Substrate

Unconsolidated Anthropogenic Substrate that is dominated by Coarse Anthropogenic particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Anthropogenic Substrate surface and are composed of plastic or trash pieces or fragments.

Substrate Group: Trash/Plastic Rubble

Unconsolidated Anthropogenic Substrate that is dominated by Coarse Anthropogenic particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Anthropogenic Substrate surface trash or plastic pieces or fragments.

Substrate Subclass: Coarse Unconsolidated Anthropogenic Wood Substrate

Unconsolidated Anthropogenic Substrate that is dominated by Coarse Anthropogenic particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Anthropogenic Substrate surface and are composed of wood pieces or fragments. Examples include pallets, boards, framing, or other human constructed/processed wooden objects. Smaller pieces of anthropogenic wood may be interspersed with the dominant larger fragments.

Substrate Group: Wood Rubble

Unconsolidated Anthropogenic Substrate that is dominated by Coarse Anthropogenic particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Anthropogenic Substrate surface composed of wood pieces or fragments.

Substrate Class: Fine Unconsolidated Anthropogenic Substrate

Unconsolidated Anthropogenic Substrate that is dominated by fine Anthropogenic Substrate particles (0.004 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble, and groups Sand and Mud) that cover 50% or greater of the Anthropogenic Substrate surface.

Substrate Subclass: Fine Unconsolidated Aggregate Substrate

Unconsolidated Anthropogenic Substrate that is dominated by Fine Anthropogenic particles (0.004 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble, and groups Sand and Mud) that cover 50% or greater of the Anthropogenic Substrate surface and that is composed of aggregate material.

Substrate Group: Aggregate Hash

Unconsolidated Anthropogenic Substrate that is dominated by Fine Anthropogenic particles (2 millimeters to < 64 millimeters, equivalent to Geologic Origin subgroups Granule) that cover 50% or greater of the Anthropogenic Substrate surface and that is composed of aggregate particles or fragments.

Substrate Group: Aggregate Fines

Unconsolidated Anthropogenic Substrate that is dominated by Fine Anthropogenic particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin subgroup Sand) that cover 50% or greater of the Anthropogenic Substrate surface and that is composed of aggregate particles or fragments.

Substrate Subclass: Fine Unconsolidated Metal Substrate

Anthropogenic unconsolidated substrate that is dominated by metal material with particle sizes ranging from 0.0625 millimeters to < 64 millimeters (size of sand to hash) and is composed of metal.

Substrate Group: Metal Hash

Unconsolidated Anthropogenic Substrate that is dominated by Fine Anthropogenic particles (2 millimeters to < 64 millimeters, equivalent to Geologic Origin subgroup Granule) that cover 50% or greater of the Anthropogenic Substrate surface and that is composed of metal.

Substrate Group: Metal Fines

Unconsolidated Anthropogenic Substrate that is dominated by Fine Anthropogenic particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin subgroup Sand) that cover 50% or greater of the Anthropogenic Substrate surface and that is composed of metal.

Substrate Subclass: Fine Unconsolidated Trash/Plastic Substrate

Anthropogenic unconsolidated substrate that is dominated by metal material with particle sizes ranging from 0.0625 millimeters to < 64 millimeters (size of sand to hash) and is composed of trash/plastic.

Substrate Group: Trash/Plastic Hash

Unconsolidated Anthropogenic Substrate that is dominated by Fine Anthropogenic particles (2 millimeters to < 64 millimeters, equivalent to Geologic Origin subgroups Granule) that cover 50% or greater of the Anthropogenic Substrate surface and that is composed of trash/plastic.

Substrate Group: Trash/Plastic Fines

Unconsolidated Anthropogenic Substrate that is dominated by Fine Anthropogenic particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin subgroup Sand) that cover 50% or greater of the Anthropogenic Substrate surface and that is composed of trash/plastic.

Substrate Subclass: Fine Unconsolidated Anthropogenic Wood Substrate

Anthropogenic unconsolidated substrate that is dominated by metal material with particle sizes ranging from 0.0625 millimeters to < 64 millimeters (size of sand to hash) and is composed of wood.

Substrate Group: Wood Hash

Unconsolidated Anthropogenic Substrate that is dominated by Fine Anthropogenic particles (2 millimeters to < 64 millimeters, equivalent to Geologic Origin subgroups Granule) that cover 50% or greater of the Anthropogenic Substrate surface and that is composed of wood.

Substrate Group: Wood Fines

Unconsolidated Anthropogenic Substrate that is dominated by Fine Anthropogenic particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin subgroup Sand) that cover 50% or greater of the Anthropogenic Substrate surface and that is composed of wood.

Proposed Additions to Substrate-Related Modifiers

Modifier Type: Anthropogenic

Modifier: Anthropogenic Impact

Unit: Constructed

Artificially built-up material that is either natural or man-made.

Modifier Type: Physical

Modifier: Mineral Precipitate

A substrate or deposit formed by the oxidation and precipitation of minerals from a body of water. Mineral precipitate substrates may form nodules, crusts, and geoforms.

Implementation Guidance: Specify the mineral composition if known.
Use in combination with Substrate or Geoform Component units as needed.

Unit: Crust

A layer of consolidated substrate overlying other consolidated or unconsolidated material. Crusts may be composed of chemical precipitates (e.g., ferromanganese, salt) or calcareous or crustose algae, or may form via sediment diagenesis, resulting in surficial lithification.

Unit: Nodules

Round or spherical concretions that form by accreting in concentric layers around a fragment of some other mineral or biological material, called a nucleus.

Unit: Patina

A thin or patchy layer of consolidated substrate overlying other consolidated or unconsolidated material. Patina may be composed of chemical precipitates (e.g., ferromanganese, salt) or calcareous or crustose algae, or may form via sediment diagenesis, resulting in surficial lithification.

Modifier: Substrate Descriptor

Unit: Porous

Containing voids, pores, or interstices, which may or may not connect.

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