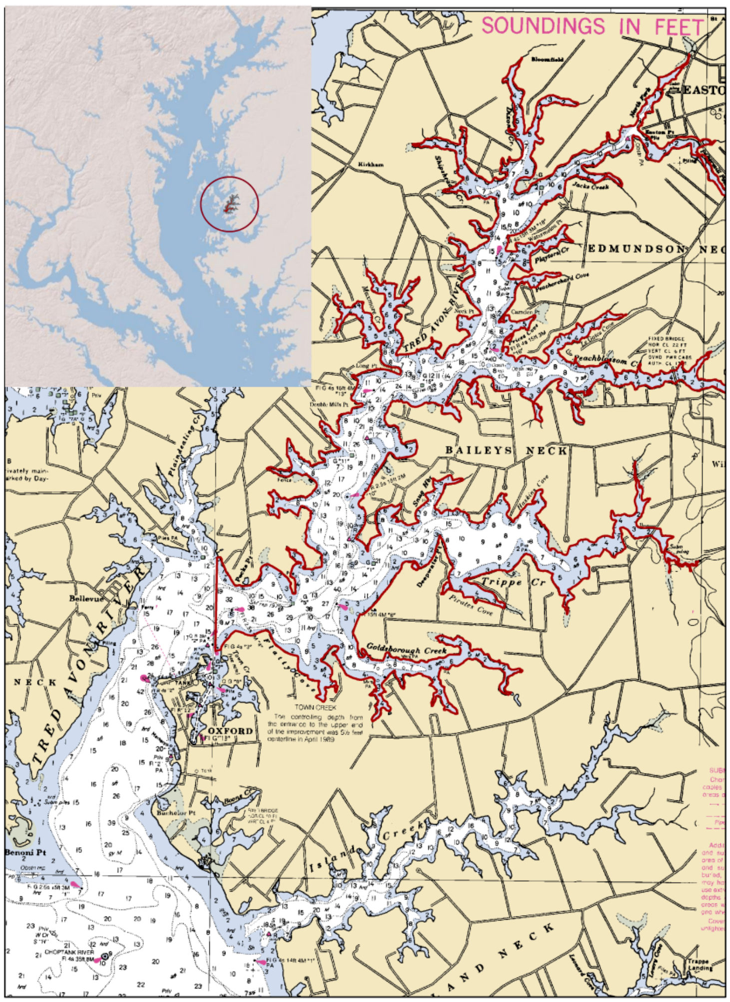
Tred Avon River Oyster Restoration Tributary Plan:

V1

A blueprint for sanctuary restoration

As drafted by the
Maryland Interagency Oyster Restoration Workgroup of the
Sustainable Fisheries Goal Implementation Team
April 2015



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The Tred Avon River Oyster Restoration Tributary Plan is meant to be an adaptive, living document. The expectation is that there will be many lessons learned, and that the plan will be adapted to reflect changing conditions and new information as restoration and monitoring progress. Continued dialogue with the consulting scientists, interested stakeholders, and the public is critical to this adaptive process.

Comments on this document are encouraged at any time, and can be directed to Stephanie Westby, Stephanie.westby@noaa.gov.

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The appendices are available on the Internet at:
ftp://ftp.chesapeakebay.net/noaa/Tred%20Avon%20appendices/

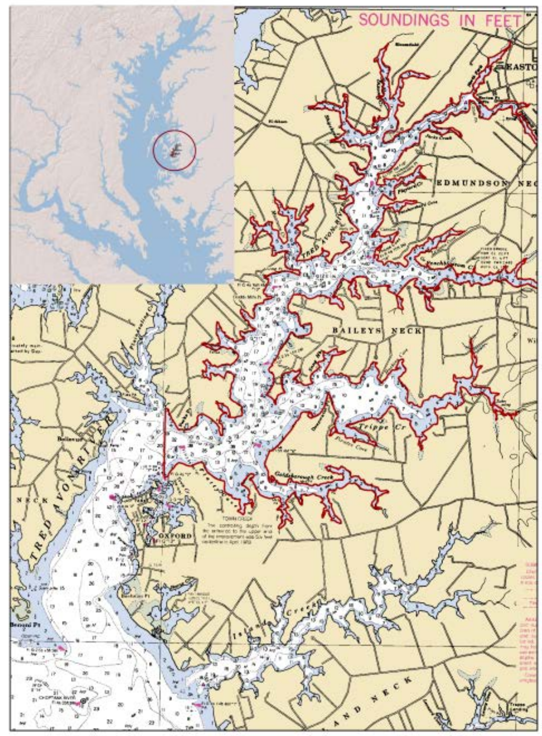
Executive Summary

In May 2009, President Obama issued Executive Order 13508, “Chesapeake Bay Protection and Restoration.” The oyster outcome associated with this executive order calls for large-scale, tributary-based oyster restoration. Similarly, the 2014 Chesapeake Bay Watershed Agreement calls for restoring oyster populations in 10 Chesapeake tributaries by 2025. The Chesapeake Bay Program’s Sustainable Fisheries Goal Implementation Team (GIT) is charged with advancing this goal. The GIT previously convened the Oyster Metrics Workgroup, which established a Bay-wide, science-based, consensus definition of a ”restored tributary” per the executive order goal. The GIT has now convened interagency workgroups in Maryland and Virginia to plan restoration work in each state, in consultation with appropriate partners.

DNR, NOAA, and USACE are charged with implementation of the Tred Avon River tributary plan. However, the productive collaboration of academic, non-governmental, and local groups involved in Chesapeake Bay restoration will greatly help achieve restoration success.

Based on consideration of salinity levels, available restorable bottom, protection from harvest, historical spat set, and other criteria, the Maryland Interagency Workgroup, in consultation with Maryland oyster restoration partners, selected Harris Creek as the first tributary for large-scale oyster restoration, Little Choptank river as the second, and Tred Avon River as the third.

Figure 1: Tred Avon River Oyster



What follows is the Tred Avon River Oyster Restoration Tributary Plan. It details the restoration site selection process, and the reef construction, seeding, and monitoring required to bring the Tred Avon River oyster sanctuary in line with the oyster metrics definition of a successfully-restored tributary. It calls for restoring 147 acres of oyster reefs in the Tred Avon River oyster sanctuary, and includes:

- a description of the process used to develop the tributary plan,
- a map showing which areas of the river are targeted to receive plantings of substrate (reef material) and oyster seed,
- a needs analysis for oyster seed and substrate,
- a cost analysis, and
- a discussion of monitoring, implementation, and progress tracking.

The implementation time frame will depend primarily on availability of funding. Existing hatchery oyster seed production capacity is sufficient to allow for implementation of this plan in one or two years from initial implementation. However, other tributaries are being restored simultaneously, and there are other competing demands for hatchery seed. These will likely extend the completion timeframe.

For planning purposes, this document assumes a worst-case scenario where the Tred Avon River does not receive any natural recruitment (spat set) over the course of plan implementation. Since 1985, the Tred Avon River has generally seen low levels of natural spat set. Within that timeframe, only two years (1985 and 1991) saw significant spat sets. From 2000 through 2013, the river saw very low spat sets (DNR, 2013; see Appendix A). It is possible that the river may receive natural spat sets during the implementation time frame, yielding additional oysters at no seeding cost. Thus, it is possible that the seed number and seed cost estimates herein are high.

Along with the Harris Creek and Little Choptank projects, this plan represents an unprecedented scale of oyster restoration in a single tributary in Maryland. Implementation of the Tred Avon River tributary plan is expected to begin in early 2015. Significant data collection and analysis went into the development of the Tred Avon River tributary plan, including benthic sonar mapping with video and ground truthing to identify suitable bottom for restoration, water quality analysis, examination of historic oyster bars, consideration of past and current oyster recruitment, and a survey to determine current oyster populations in the Tred Avon oyster sanctuary. Additionally, public participation was encouraged during an open house to hear input on the plan.

Summary: Tred Avon River Oyster Restoration Tributary Plan

Total Acres Targeted for Restoration	**147**
Total Seed Required	**661.5 million**
Total Substrate Required (cubic yards)	**119,499**
Total Implementation Cost (restoration and monitoring)	**$11.4 million**

Tred Avon River Oyster Restoration Tributary Plan

Context and Scope:

President Obama's Executive Order 13508 called for federal agencies to establish specific measurable environmental goals for restoring the Chesapeake Bay. These environmental goals were laid out in the May 2010 *Strategy for Protecting and Restoring the Chesapeake Bay Watershed*. (Federal Leadership Committee for the Chesapeake Bay). This strategy specifically called for restored oyster populations in 20 Chesapeake Bay tributaries by 2025. The 2014 Chesapeake Bay Agreement later adapted this goal to 10 tributaries by 2025. In support of these policies, the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team (GIT) convened the Oyster Metrics Workgroup to develop a science-based, common definition of a successfully-restored tributary for the purpose of tracking progress toward the goal. The workgroup was composed of representatives from the state and federal agencies involved in Chesapeake Bay oyster restoration, as well as oyster scientists from academic institutions. The workgroup produced a report detailing these success metrics (Oyster Metrics Workgroup, 2011). These metrics serve as the basis for the Tred Avon River tributary plan. The following criteria were among those set forth in the metrics report:

- A successfully-restored reef should:
  - have a minimum mean density of 50 oysters and 50 grams dry weight/square meter (m^2) covering at least 30 percent of the target restoration area at 6 years post restoration;[1]
  - have two or more age classes present; and
  - exhibit stable or increasing spatial extent, reef height and shell budget.
- A successfully-restored tributary is one where 50 to 100 percent of the currently-restorable bottom has oyster reefs that meet the reef-level metrics above. Restorable bottom is defined as area that, at a minimum, has appropriate bottom quality and water quality for oyster survival).
- An suitable candidate tributary is one where 50 to 100 percent of the currently restorable bottom is equivalent to at least 8 percent, and preferably more, of its historic oyster bottom.

In 2012, U.S. Army Corps of Engineers (USACE) drafted a native oyster restoration master plan that evaluated tributaries of the Chesapeake Bay to determine those tributaries with the potential to support large-scale oyster restoration efforts. In 2012, the GIT established the Maryland Interagency Workgroup consisting of representatives from the National Oceanic and Atmospheric Administration (NOAA), USACE's Baltimore District, and the Maryland Department of Natural Resources (DNR). The purpose of this group is to facilitate oyster restoration by coordinating efforts among the state and federal agencies, in consultation with

[1] In addition, a minimum threshold for restoration success was set at a mean density of 15 oysters and 15 grams dry weight biomass/m^2 covering at least 30 percent of the target restoration area at 6 years post restoration activity. Minimum threshold is defined as the lowest levels that indicate some degree of success. However, this tributary plan is focused on the 50 oysters/m^2 target density for a successfully restored reef.

the scientific, academic and oyster restoration communities. The workgroup utilized the USACE Native Oyster Restoration Master Plan and the Maryland Oyster Restoration and Aquaculture Development Plan as the foundations of its work. In consultation with consulting scientists, the workgroup has selected the first three tributaries for large-scale restoration focus: the Harris Creek, the Little Choptank River, and the Tred Avon River oyster sanctuaries, all on Maryland's Eastern Shore.

This plan describes the actions necessary to bring the Tred Avon River sanctuary's oyster population and habitat to the oyster metrics definition of a successfully restored tributary. The plan includes specific areas targeted for restoration work, an analysis of the amount of seed and substrate required, and an estimated cost. Included too is a monitoring framework that will allow for the determination of whether or not the Tred Avon River oyster sanctuary can be considered "successfully restored", per the oyster metrics definition.

This plan estimates the funding required to restore and monitor the Tred Avon River oyster sanctuary, per the oyster metrics definition, at $11.4 million. Some funds have already been identified (see implementation section); identifying the balance will need to be an ongoing effort for the oyster restoration partners. This plan will clarify the needs, and allow government agencies, non-profit organizations, academics and other stakeholders to collectively identify the resources needed for implementation.

Tred Avon River Tributary Plan Process

The Tred Avon River Oyster Restoration Tributary Plan was developed using the following steps:

1. Identify tributary for restoration and set restoration acreage target:

   The Tred Avon River oyster sanctuary was selected as the third candidate for large-scale oyster restoration (nearby Harris Creek was the first, and the Little Choptank River was the second) by the Maryland Interagency Workgroup. The selection was based on the findings of the USACE master plan, DNR's fall survey data, the Maryland oyster sanctuary list, and bottom survey data from the Maryland Geological Survey and NOAA. Criteria used in the tributary selection included water quality (salinity and dissolved oxygen appropriate for survival and reproduction), availability of restorable bottom (hard bottom capable of supporting oysters and substrate), historic spat set data (Appendix A), potential for larval retention, oyster sanctuary status, and tributary size. The Tred Avon River oyster sanctuary scored favorably for all criteria (see Appendix B for GIS analysis). The selection process and results were discussed with the consulting scientists.

2. Define restoration goal (target acreage):

As noted earlier, the oyster metrics report defined a successfully-restored tributary as one where 50 to 100 percent of currently restorable bottom, constituting at least 8 percent of historic oyster habitat, consists of restored reefs. NOAA performed a restorable bottom analysis (Appendix B) for the Tred Avon River oyster sanctuary, based on data from the USACE master plan, the oyster sanctuary boundaries, water quality data, and bottom survey data from Maryland Geological Survey and NOAA. General planning guidance from the U.S. Coast Guard was also considered during this process including setbacks of 250 feet from marinas and navigational aids. This analysis showed 251 acres of currently-restorable bottom in Tred Avon River oyster sanctuary. In order to meet the 50 to 100 percent of currently-restorable bottom goal, 125 to 251 acres would need to be restored in the Tred Avon River. The second part of the oyster metrics goal is that this amount—125 to 251 acres—must constitute at least 8 percent of historic oyster habitat. The Yates survey of 1913 identified 851 acres of historic oyster habitat in the river; 8 percent of that is 68 acres. Therefore, restoring between 125 and 251 acres would meet both parts of the oyster metrics goal. Further analysis, described in the blueprint map section of this document, established the restoration goal at 147 acres. (See Table 3, and Figures 2 and 3).

3. Conduct pre-restoration oyster population surveys:

   DNR conducted a spatially-explicit population and oyster density survey of the reefs in the Tred Avon River oyster sanctuary in the summer of 2013.

4. Develop a draft map summarizing major datasets:

   The workgroup summarized the available spatially-referenced data in a map showing potential locations for different reef restoration treatments. From here, the workgroup selected areas suitable for two types of treatment: seed only, or substrate plus seed. The workgroup also looked for areas in the Tred Avon River sanctuary that currently meet the oyster density goal, as determined by the population survey. (No reefs currently meet the target oyster density goal in the Tred Avon River sanctuary.) Additionally, the Coast Guard gives general guidance of a 150-foot setback from federally-maintained channels. Within the Tred Avon River, there are two federally maintained channels – one at the lower end in Town Creek and one in the upper portion between Peachblossom Creek and Easton. The Town Creek channel is outside of the sanctuary limits; however, the sanctuary does coincide with the upper channel for a short distance. Within that area, potential restoration sites were reviewed for compliance with the 150-foot buffer. Sites falling within the buffer were eliminated from the blueprint map. Additionally, a 250-foot buffer was placed around residential docks. Sites falling within that buffer were eliminated. Navigational clearance of 6 feet mean lower low water will be maintained overtop of all reefs where substrate will be added.

5. Send draft blueprint map and tributary plan to consulting scientists for review:

In addition to input from the Coast Guard, the workgroup sought the input of a group of Chesapeake Bay scientists from the academic community, federal and state resource agencies, and non-profit organizations. It is expected that communication with the scientific community will be ongoing throughout restoration.

6. Conduct public open house:

   A public open house was conducted on November 7, 2013 at Oxford Research Lab on Maryland's Eastern Shore to hear input on the draft Tred Avon River Oyster Restoration Tributary Plan. Additionally, USACE solicited local input on waterway use, navigation, and navigational needs in October 2015. USACE sent flyers requesting input to 500 local residents as well as marinas and the Oxford Yacht Club.'

7. Finalize blueprint map and tributary plan:

   Using the input from consulting scientists and the public, the workgroup finalized the Tred Avon River Oyster Restoration Tributary Plan. The plan will be a living document, to be updated as appropriate based on adaptive management and the availability of new data.

8. Obtain Section 10 permit, as needed:

   At this time, no Section 10 permit is expected to be required for substrate placement in the Tred Avon River oyster sanctuary, since USACE will be implementing that portion of the project with federal funds.

9. Implement seeding and substrate activities:

   The tributary plan is expected to be implemented by NOAA, USACE, and DNR. NOAA is planning to contribute funds for seeding activities, as well as mapping and survey actions. USACE is planning to contribute to substrate placement efforts. DNR is expecting to contribute to the reef seeding, as well as mapping and survey activities. All three partners plan to contribute to project planning and monitoring efforts.

10. Monitor project performance and adaptively manage:

    Using the protocols discussed in the oyster metrics report, the workgroup will monitor the performance of the restoration sites in Tred Avon River oyster sanctuary. Key parameters to be monitored include reef structure, population density, total reef population, and the number of age classes. Additionally, the workgroup will monitor water quality and other parameters that affect project success. Monitoring is planned to occur several times within six years following implementation. Depending on the results of the monitoring, additional seeding or other adaptive management actions will be undertaken. Details of the monitoring plan are found in the monitoring section of this document. NOAA, USACE-Baltimore District and DNR will produce annual reports describing progress that has been made on restoring the oyster population in Tred Avon River oyster sanctuary.

Data Used in the Tred Avon Tributary Plan

This section details the parameters considered in the selection of Tred Avon River oyster sanctuary for intensive oyster restoration, the selection of restoration sites within the sanctuary, and the determination of location and type of reef treatment. Some of these parameters were considered in greater depth in the USACE master plan process and/or the Maryland Oyster Restoration and Aquaculture Development Plan process. They warrant mention here, though, since the Tred Avon River tributary plan largely builds on these plans. Further description of each parameter is discussed below.

Table 1: Criteria Considered During the Tred Avon River Tributary Plan Process

Physiochemical	Water quality (dissolved oxygen (DO), salinity, temperature)
Physical	Bottom quality, sedimentation, depth
Biological	Location and quantity of existing oyster population, historical spat set
Other	Sanctuary boundaries; land use; location relative to other estuarine habitats (SAV); input from public, Coast Guard, and consulting scientists

Physiochemical Criteria

Tred Avon River is classified as a mesohaline tributary. Salinity and dissolved oxygen (DO) data were compiled and screened through USACE's master plan efforts by Versar, Inc. Point data were gathered by DNR, the Maryland Department of the Environment, the Alliance for Chesapeake Bay, and the Chesapeake Bay Program. The same salinity dataset was also used to evaluate Tred Avon River for the potential risk from freshets. Temperature is not a limiting factor in Tred Avon River and needed no further consideration. Details of the physiochemical selection criteria are provided in the USACE master plan.

Physical Criteria

Only areas between 4 and 20 feet in water depth were considered suitable for restoration. Deeper waters typically experience low DO conditions and higher sedimentation that are not suitable for oysters or the reef community. Shallower waters conflict with other uses of the waterway. Water depth between 4 and 6.5 feet deep was considered unsuitable for substrate additions due to concerns about navigational interference. Thus, only water depths between 6.5 and 20 feet were considered suitable for substrate additions.

Adequate bottom must be available for oyster restoration. Hard bottom, capable of supporting shell or other material likely to catch spat, as well as areas that currently hold oyster shell were identified by bottom surveys using sonar in conjunction with various ground-truthing methods.

Side-scan sonar surveys conducted by the Maryland Geological Survey (MGS) in 2009 and multi-beam sonar surveys conducted by the NOAA Chesapeake Bay Office (NCBO) in 2013 provided the necessary background data to identify general bottom type;. A more detailed investigation of the seabed conducted by NCBO determined the quality of the seabed and its ability to support restoration actions. Seabed-type polygons were classified by NOAA using the Coastal and Marine Ecological Classification Standard (CMECS) [2] Substrate Component. Boundaries for proposed substrate reefs were created from the CMECS polygons, NCBO fine-scale acoustic survey data (bathymetry, sub-bottom profiling, and seabed classification), ponar sediment grabs, and seabed and oyster abundance data derived from patent-tong surveys conducted by the Maryland Department of Natural Resources in 2013. (Appendices B, C).

Biological Criteria

DNR conducted oyster population assessments for size and density in the summer of 2013 (see Appendix C). Patent tongs were used to sample areas in the Tred Avon River with habitat suitable for oysters as determined by sonar surveys conducted by Maryland Geological Survey and NOAA. A total of 222 samples were taken. The number sizes of the oysters in each sample were recorded.

Spat set data compiled by DNR's fall survey from 1985 to 2012 were considered in an effort to understand larval settlement patterns in Tred Avon River (Appendix A). Fall survey

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[2] Chesapeake Bay-CMECS is the integration of several digital maps that identify the boundaries and distribution of seabed materials and bottom habitats in the Chesapeake Bay. It is a hierarchical ecological classification system that is universally applicable for coastal and marine ecosystems. It was developed by the NOAA Coastal Services Center, in partnership with NatureServe and others, to create a standard classification system that integrates different types of data from multiple sources to fully characterize a specific area. Raw survey data were acquired by the NOAA Chesapeake Bay Office and the Maryland Geological Survey with acoustic seafloor survey systems and validated with video and sediment grab samples. Final seabed habitat polygons were classified using a variant of the CMECS. CB-CMECS places an emphasis on describing the American oyster reef community, and the sediments that encompass it. The oyster reef units described in CB-CMECS are those that can be acoustically derived and differentiated, and are classed based upon their morphological characteristics. CMECS reef attributes in addition to other spatial data sources inform the restoration potential of targeted sites. An example is the "aggregate patch reef" which describes oyster bottom that comprises shell mounds surrounded by soft sediments. Healthy oyster communities exist on this type of habitat, but in most cases restoration potential would be low. More CMECS information, including a description of the classifications, is at http://ftp.ncbo.cgclientx.com/ecoscience/Chesapeake_Bay_Benthic_Habitat_Polygons_CMECS/.

spat set data are available for one location in Tred Avon River, Double Mills reef. This dataset was used to make the conservative assumption that there will be no natural spat set over the next 6 years (see seed needs analysis section below). This dataset is the most recent available, thus it was assumed to be most relevant to current conditions in the river. Historical spat set was also considered and used in selecting Tred Avon River as a target tributary (Krantz and Meritt from 1939-1975, see Appendix A).

The oyster diseases Dermo (*Perkinsus marinus*) and MSX (*Haplosporidium nelsoni*) are more virulent in higher salinity waters, leading to higher mortality in these areas. Reproduction is also more successful in higher salinity areas. To balance disease-related mortality and reproduction, mesohaline areas were considered to be high priority for restoration.

Harmful algal blooms (HAB) resulting from *Prorocentrum minimum* and *Karlodinium veneficum* blooms have been documented in the Choptank River (Brownlee et al. 2005; Glibert et al. 2001), but Tred Avon River has not been identified to have significant HAB problems or susceptibilities. Blooms of *Prorocentrum minimum* and *Ulva lactuca* have been documented in the past.

Other Criteria

The State of Maryland has designated 3,937 acres within Tred Avon River as oyster sanctuary, where no commercial harvest of wild oysters is permitted.

The watershed of the Tred Avon River spans 31,242 acres. Land use in the watershed draining to Tred Avon River is largely agricultural (cultivated crops and pasture/hay) with some forested, wetlands, and developed areas. Easton, situated at the head of the Tred Avon River, is the densest and largest urban/suburban development in the watershed. There are 5,358 acres of forests and wetlands in the Tred Avon watershed. This information was used by USACE in its oyster restoration master plan, which in turn informed the selection of Tred Avon River as a site for large-scale oyster restoration.

Four federally listed rare, threatened, or endangered species have been identified in Talbot County which contains the Tred Avon River watershed: Delaware fox squirrel, Eastern fox squirrel, dwarf wedgemussel (Alasmidonta heterodon), and seth forest water scavenger beetle (as listed by Landscope 2012 for Talbot County). Additionally, there are 9 animals and 15 plant species found in Talbot County on Maryland's rare, threatened, or endangered species list.

Submerged aquatic vegetation (SAV) habitat, as designated by the Chesapeake Bay Program, exists in the Tred Avon River. There has been no SAV identified in the main portion of the Tred Avon River since 2005. On average, there have been 140 acres of SAV beds in the Tred Avon River segment (LCHMH) in the past 10 years (2003-2012). SAV beds were more expansive in the decade prior to that, averaging 500 acres annually (1993-2002). In 2011, a number of the small creeks within the Tred Avon system (Hudson Creek, Back Creek, Phillips Creek, Beckwith

Creek, and Smith Creek) supported SAV beds. Target restoration sites were cross-checked with SAV maps (dataset here) to ensure that no reef construction or oyster planting would occur on SAV beds.

Blueprint Map

Initial analyses performed for the USACE master plan determined that salinity and dissolved oxygen were suitable throughout the Tred Avon River (USACE 2012). Spatial data were then overlaid in ArcGIS to locate proposed restoration sites. This GIS analysis included the bottom classification (Appendix B), and DNR population survey results (Appendix C).

The foundation of this tributary plan is the blueprint map, based on the spatial analysis, which shows the locations of proposed restoration activities. Sites that met all the following criteria were considered suitable for restoration in the Tred Avon River oyster sanctuary:

1. Hard benthic habitat (Seabed areas suitable for substrate placement, based on CMECS bottom characterization of muddy sand, unclassified hard bottom, sand, and sandy mud- Appendix B).
2. In areas with depths of 4 to 20 feet;
3. Suitable water quality to support oyster populations;
4. Not on leased bottom;
5. Within a legal natural oyster bar;
6. Outside of a 250-foot radius around aids to navigation;
7. More than 150 feet from the federally-maintained navigation channels (upper Tred Avon from Peachblossom Creek to Easton Point);
8. More than 250 feet from a marina;
9. Have an existing population of fewer than 50 oysters per square meter (Interpolated oyster population density data from DNR's 2013 survey- Appendix C. The interpolation method used was the Nearest Neighbor/Inverse Distance Weighted method.)
10. Outside of a 250-foot radius around residential docks;
11. Not identified by the general public or the Coast Guard as a navigational concern;
12. Not slated as a future planting site for DNR's Marylander's Grow Oysters program;
13. Not on a control site as selected in this plan.

Hard benthic habitat was defined as areas that, per acoustic surveys, were found to have the CMECS classifications of artificial reef, aggregate patch reef, fringe reef, patch reef, sand and scattered oyster shell, sandy mud, sand, and muddy sand. Buffers were left around navigational aids, federally-maintained navigational channels (upper Tred Avon River channel), residential docks, and marinas.

The 20-foot maximum depth cutoff was used due to concerns about potential hypoxia and anoxia at greater depths. The shallow depth limit (4 feet) was based on the practical limit of the vessels used for restoration activities, as well as the limits of the acoustic surveys used to create the restorable bottom analysis. However, for substrate placement, a depth limit of 6 feet was used to allow for safe navigation over the substrate. To maintain 6 feet of navigable water, reef material and seed could be placed up to depths of 6.5 ft to restore a 6 inch reef and 7 ft to restore a 12 inch reef.

Areas with more than 50 oysters per square meter would meet the minimum density goal per the oyster metrics report, so these would not be targeted for initial seeding. Note that in the Tred Avon oyster sanctuary, no areas were found to have more than 50 oysters per square meter in 2013).

Using the above criteria one through eight above, 251 acres were identified as suitable for restoration action (Appendix B, and Figure 2 and Table 3). (Criteria 10 through 13 were considered after a draft plan had been developed for public input; see Tred Avon River Tributary Plan Process section above and p. 17). The next step was to determine what restoration treatment was most suitable for each target area. Two treatments were identified: planting oyster seed only, and planting substrate with oyster seed on top. Adding seed only is less costly than adding both substrate and seed, and so it is the first-choice treatment. However, the seed-only option is only suitable where sufficient shell base currently exists. In the absence of existing suitable shell base, substrate must be added to create a hard reef structure. Seed oysters can then be planted on top of the new substrate base. Substrate may be any combination of oyster shell, clam shell, or alternative substrate such as crushed concrete or rock. Reef balls can be added for additional three-dimensional structure, either with or without seed oysters set onto them.

The existing density of oysters was a key consideration in determining whether an area would be targeted for seed only, or substrate and seed. The assumption was that an area that supported existing oysters in quantity (by consensus of the workgroup, that amount was 5 oysters per square meter) should not be overplanted with substrate. This would risk smothering existing oysters. Also, the presence of oysters in such quantity served as an indication that existing substrate was suitable, thus the area would likely do well with the addition of seed only. Areas with hard benthic habitat and fewer than 5 oysters per square meter were further examined to determine if they could be restored using seed only, or if they required the addition of reef-building substrate, followed by oyster seed, to restore. Data sets including sonar maps, oyster density, ponar grabs, and shell quality characterization were considered on each site individually. Areas with substantial quantities of high-quality surface shell and with closer to 5 oysters per square meter were targeted for seed only. Areas that had little shell or predominately low-quality brown or black (anoxic) shell, and few oysters were targeted for substrate, followed by seed. The treatment type will be adapted as needed based on the additional pre-planting diver ground-truthing information. (See description below of ground-truthing protocol to be employed).

Additionally, areas shallower than 6.5 feet deep were considered unsuitable for substrate placement, due to navigational concerns. This plan allows for a minimum navigational clearance of 6 feet (mean lower low water) overtop of reefs requiring substrate. In water 6.5 feet deep, 6-inch-high reefs will be constructed, allowing for 6 feet of navigational clearance. In water 7 or more feet deep, reefs up to one foot high will be constructed, again allowing for the minimum 6-foot navigational clearance.

As of fall 2014, DNR's permit in the Tred Avon River, and USACE's NEPA clearance, both limit placement of substrate to areas where 8 feet of navigational clearance can remain over a completed reef. Placing substrate in so as to leave only 6 feet of navigational clearance will require completion of supplemental NEPA documentation by USACE, or a permit modification for DNR work.

Restoration using the seed-only treatment is targeted in waters 4-20 feet deep. Table 2 is a summary of the criteria used to determine restoration treatment for each area .

Table 2: Criteria used to determine treatment type for each targeted restoration area

Criteria	**Restoration Treatment Type**
Water depth less than 4 feet or greater than 20 feet	No action; unsuitable for restoration
Soft benthic habitat	No action; unsuitable for restoration
Areas with hard benthic habitat, water depths between 4 and 20 feet, and with between 5 and 50 oysters/m^2	Add seed only (no substrate)
Areas with hard benthic habitat, water depths between 4 and 20 feet, and fewer than 5 oysters/m^2	Review sonar maps, and oyster density, ground truth, and shell quality data to determine if these sites can be restored using seed only, or if they require substrate. *(See decision criteria in next two rows)*
Areas with hard benthic habitat, fewer than 5 oysters/m^2, AND with predominately white (oxic) shell, high quality shell, substantial surface shell, more oysters	Add seed only (no substrate)
Areas with hard benthic habitat, fewer than 5 oysters/m^2, AND with predominately brown or black (anoxic) shell, low quality shell, very little surface shell, few oysters, and in waters 6.5 to 20 feet deep	Add substrate, followed by seed

Next, GIS was used to create maps showing the appropriate treatment type in each area. From here, workgroup members blocked off areas into somewhat-regular polygons to facilitate planting and tracking. Some areas were eliminated or changed in this process. For example, very small, odd-shaped appendages to the larger polygons, and long, thin slices bordering unsuitable bottom, were eliminated as they would likely be difficult to plant accurately. Also, areas less than one contiguous acre were eliminated.

From here, the workgroup sent the draft blueprint map and plan to consulting scientists, and hosted an open house and virtual open house to collect public input. USACE also sent letters to all waterfront homeowners within the sanctuary, and posted signs at marinas and other public facilities asking for input. [Among the input received was that of citizen volunteers from DNR's Marylanders Grow Oysters (MGO) program. Working with DNR, this group identified sites for future MGO plantings, and requested that this successful program proceed apace, undisturbed by the work proposed in this plan. These sites, totaling six acres, will be tracked separately from this plan by the MGO program, and are not included in the target restoration goal in this plan].

The combined professional and public input, and eliminating reefs less than one acre and creating somewhat-regular polygons, reduced the target to 182 acres. An additional 28 acres were removed from the restoration target to serve as project controls (see controls section). The result was a target of 154 acres. Diver ground truthing has shown that sonar surveys may overestimate the area of hard bottom suitable for planting seed oysters. Based on field experience, it was assumed that the area suitable for planting seed only, as determined by sonar, will be reduced by 10 percent upon examination by divers. A 10-percent reduction *of the area targeted for seed-only* reduces the 154 acres identified to 147 acres. This amount, 147 acres, is the actual oyster restoration goal for the Tred Avon oyster sanctuary. (See Figure 2 and Table 3).

<u>Blueprint Map Summary</u>

In summary, the oyster metrics report defined a successfully restored tributary as one where 50 to 100 percent of the currently restorable bottom, constituting at least 8 percent of historic bottom, meets the reef-level goals. In the Tred Avon River, the restorable bottom analysis (Appendix B) showed 251 acres of restorable bottom, so the absolute minimum threshold to consider this tributary restored is half that, or 125 acres, of restored reefs. This tributary plan targets 147 acres, allowing for the possibility that some of that acreage may not respond sufficiently to the restoration activity. (See Figure 2 and Table 3).

Table 3: Acreage by Reef Treatment (with anticipated reduction)

Reef Treatment	Acres Identified in Blueprint Map	Suitable Acreage (with 'seed only' treatment areas reduced by 10%)
Currently meets target density of 50+ oysters/m^2	0	0
Reef treatment: Add seed only	71	63
Reef treatment: Add substrate and seed*	84	84
Total Acreage Requiring Reef Treatment	**154**	**147**

* 59.7 acres in waters 6.5 to 9 ft. deep; 24 acres in waters 9 to 20 ft. deep

Figure 2: Tred Avon Goal Development
This graphic describes how the Tred Avon River goal of restoring 147 acres of oyster reef was developed.

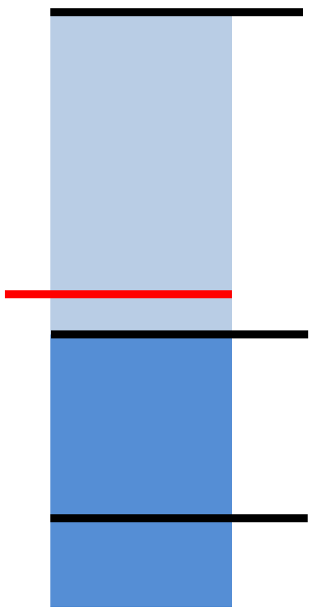
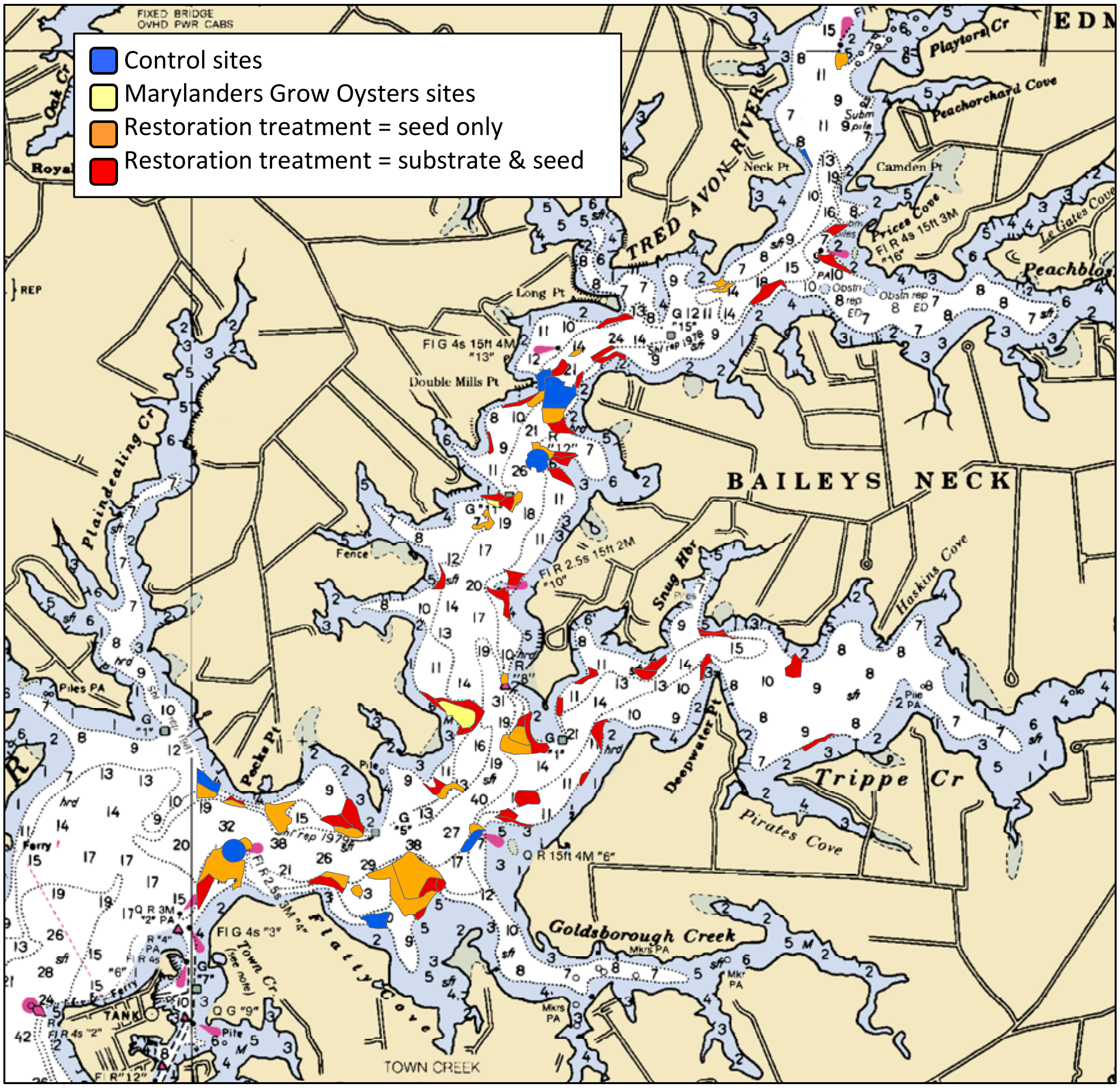


Figure 3: Blueprint Map



See Appendix D at ftp://ftp.chesapeakebay.net/noaa/Tred%20Avon%20appendices/ for downloadable maps for detailed viewing.

Note that the Blueprint Map above identifies 154 acres for restoration. The goal is 147 acres, assuming that 10 percent of the *seed-only areas* identified above will, upon further ground truthing, actually be unsuitable (too soft). See page 17 and Table 3 for further explanation of the 10 percent reduction.

Ground Truthing

Prior to seeding, diver ground truthing will be performed on all sites targeted for seed-only treatment. The purpose of the ground truthing is to validate the acoustic surveys, and to modify the boundaries of target sites if needed to ensure oysters are placed on hard substrate. Ground truthing of any given site is expected to occur within a few months prior to restoration work.

Diver ground-truthing protocol: Seed-only sites will undergo diver ground truthing. Diver ground truthing will be accomplished by running several transects within each target area. The number of transects depends on the size of the area. Typically, each transect will be 200 meters long, marked every 2 meters for reference. Transect lines will be laid out haphazardly within the target polygon; divers will then swim along the line and report the condition of the bottom every 2 meters. Parameters to characterize bottom condition will be recorded at each 2-meter interval. The parameters include: amount of exposed shell, substrate type, substrate penetration and oyster density. Divers will determine a score for each parameter. Table 4 outlines the score for each category, with increasing metric values indicating bottom-type improvement.

Table 4: Summary of Ground-Truthing Protocols

Exposed Shell	Value	Substrate Type	Value *	Penetration (cm)	Value *
Zero	0	Silt	0	70	0
Very Little / Patch	1	Mud	1	40	1
Some	2	Sandy Mud	2	20	2
Exposed	3	Sand	3	10	3
Oyster Bar	4	Rock / Bar Fill / Debris	4	5	4
		Shell Hash	5	0	5
		Loose Shell	6		
		Oyster	7		

* Increasing metric values show bottom-type improvement

The data for each transect will be recorded directly into a Microsoft Access database created specifically for the Paynter Labs. The mode value of each category will be used to determine whether each transect can be categorized as preferred, acceptable, or unacceptable bottom. The bottom-type category will be determined as the category within which two of the three data types (exposed shell, substrate type and penetration) fall. This information will be then relayed to ORP staff and the workgroup to help make decisions about which target areas, or portions of target areas, may not be suitable for planting spat.

Table 5 outlines the requirements for each bottom-type categorization.

Table 5: Summary of Bottom-Type Categorization

Category	Exposed Shell Range	Substrate Type Range	Penetration Range
Preferred	3-4	4-7	5
Acceptable	2	3-4	3-4
Unacceptable	1-0	0-2	0-2

Seed Needs Analysis

A projected 661.5 million oyster seed will be required to implement this plan. This number assumes that 4 million spat-on-shell per acre will be added to all restoration areas targeted in this plan. The oyster metrics report calls for the target density of 50 oysters per square meter to be achieved within 6 years of restoration activity. This plan therefore lays out oyster survival projections over 6 years. To do this, assumptions were made regarding survival rates of both planted seed and existing oysters. It is recognized that oyster survival rates are highly variable, and that the actual survival rate is unknown. However, for planning purposes it was necessary to make reasonable assumptions as to survival rates. These assumptions may be revised in future iterations of this plan if more accurate rates are determined through the recommended monitoring (see monitoring section below).

First-year planted spat-on-shell survival rate: Based on Volstad et al (2008) and Oyster Recovery Partnership's field experience with hatchery-produced spat-on-shell in Maryland, the workgroup set assumed survival rates for first-year planted spat-on-shell at 15 percent.

Out- year planted spat-on-shell survival, and annual survival rate of existing oysters: To deduce the out-year annual survival rate, the workgroup considered historic annual mortality from DNR's fall surveys. This data set varies widely on the Tred Avon River, ranging from 0 to 85 percent since 1985 (see Table 6).

Table 6: Tred Avon River Annual Mortality Rates

Median 1985-2012	Median 2003-2012	Minimum	Maximum
11.5%	7.5%	0%	85%

As a conservative estimate, the workgroup used the 1985- 2012 median mortality rate of 11.5 percent as the projected annual mortality (rounded to 12 percent) for out-year mortality of planted spat-on-shell, and for existing oysters on the reef prior to restoration.

Summary of oyster survival assumptions for the Tred Avon River:

Planted spat-on-shell: First year survival rate = 15 percent;
Out-year annual survival rate = 88 percent;

Existing oysters (on the reef in summer 2013): Annual survival rate = 88 percent.

A key unknown is the level of natural spat sets that might occur in Tred Avon River over the implementation time frame, and what density of oysters might result from these spat sets. The workgroup dealt with this unknown by making a conservative assumption that there would be no natural spat set over the course of implementation. This assumption was based on the fact that there has not been a significant spat set in the Tred Avon River since 1991, and historically spat sets have been low in the river (Krantz and Meritt, 1977; MD DNR annual fall survey), See Appendix A). By making this assumption, the tributary plan calls for planting enough seed to reach the density goals in 6 years, even with no natural spat set in the river. Thus, the intent is to plan for a conservative scenario, and adapt the tributary plan as needed. The tributary plan calls for an initial large planting on most reefs, followed by monitoring in year 3, and an additional smaller planting in year 4 to ensure a multi-age-class population and target density after year 6. Population monitoring will be critical to determining the need for the additional seeding. This will occur, at a minimum, on each reef three and six years post-restoration (see monitoring section for details). Annual monitoring is also called for on three sentinel sites in the river. If diver ground truthing, DNR fall surveys or other data indicate a natural spat set, additional population surveys may be required on areas that have not yet been restored.

A summary of the 661.5-million seed calculation is provided in Table 7; the seed cost estimate is provided in Table 8.

Table 7: Seed Needs and Oyster Survival Assumptions

Reef Treat-ment	First Planting *(seed per m², assuming 4 million seed per acre)*	First Planting, year 1 annual survival rate	First Planting, year 2-6 annual survival Rate	Second Planting (in year 4) *seed per m², assuming 500,000 seed per acre*	Second Planting (in year 4) first year survival	Second Planting, years 5 and 6 annual survival Rate	Oyster Density After 6 Years *(surviving oysters from first and second plantings)* oysters per m²	Area Targeted for Restoration (acres)	Total Amount of Seed Needed for Treatment Type *(4.5 million seed per acre, over two plantings, multiplied by number of acres)*
Seed only	989	0.15	0.88	123	0.15	0.88	96	63.3	284,850,000
Substrate and seed	989	0.15	0.88	123	0.15	0.88	94	83.7	376,650,000
Total for Tributary Plan								**147**	**661,500,000**

Table 8: Seed Cost Analysis

Reef Treatment	Area to be Treated (acres)	Seed Required per Acre	Seed Required for Treatment Type	Seed Cost for Treatment Type (at $5,000 per 1 million seed)*
Seed only	63.3	4,500,000	284,850,000	$1,424,250
Substrate and seed	83.7	4,500,000	376,650,000	$1,883,250
Total for Tributary Plan	**147**		661,500,000	**$3,307,500**

* $5,000 per million spat-on-shell, including planting costs, based on ORP estimates (Stephan Abel, personal communication, July 2013). Note that this is an average cost, but actual cost depends on the number of oysters the University of Maryland hatchery produces each year. For example, as of mid-2013, hatchery production was relatively high, bringing average costs down to $4,200 per million spat, including planting costs.

Substrate Needs Analysis

A projected 119,400 cubic yards of substrate will be needed to implement the tributary plan. Substrate may be any combination of oyster shell, clam shell, or alternative substrates such as crushed concrete, rock, or reef balls.

The projection of substrate needs assumes reefs will be constructed to either 6-inch or 1-foot height. One-foot reefs will be constructed in areas with water depths of at least 7 feet, so as to allow a minimum of 6 feet of clearance overtop of the completed reef (64 acres). Six-inch reefs will be constructed in areas with water depth of 6.5 feet, also to allow a minimum of 6 feet of clearance overtop of the completed reef (20 acres). One-foot-high reefs require 1,613 cubic yards of substrate per acre; 6-inch-high reefs require 807 cubic yards of substrate per acre.

Reefs in nearby Harris Creek have been built to several different heights. If higher reefs or lower reefs perform better in Harris Creek, this plan will be adapted to favor oyster survivorship while efficaciously using substrate material. The computation of the substrate need is shown in Table 9, with the substrate cost estimated in Table 10.

Table 9: Substrate Needs Analysis

Reef Treatment	Area to be Treated (acres)	Amount Substrate Needed per Acre (cubic yards)	Amount of Substrate Needed for Treatment Type (cubic yards)
Substrate and seed (6-inch-high reefs)	20	807	16,140
Substrate and seed (One-foot-high reefs)	64	1,613	103,232
Seed only	63	0	0
Total for Tributary Plan (rounded)			**119,400**

The estimated cost to purchase and place substrate for reef construction in the Tred Avon River oyster sanctuary is $62 per cubic yard. This amounts to $100,000 per acre for a one-foot-high reef, and $50,000 per acre for a 6-inch-high reef.

This cost estimate was derived from the USACE 2014 reef construction contract in the Tred Avon River. Rock and mixed shell substrate used in that contract cost approximately $56 per cubic yard. In addition to the unit costs, there were other contract-wide costs (e.g., mobilization, demobilization, bonding, design, construction/project management, cost estimate, and solicitation), which amount to an additional 10 percent. The unit and contract costs together yield a rounded price of $62 per cubic yard for substrate. Other reef substrate materials may have different costs.

Table 10: Substrate Cost Analysis

Reef Treatment	Area to be Treated (acres)	Substrate Required per Treatment (6" reefs @ 807 cy/ acre; 1' reefs @ 1,613 cy/ acre)	Substrate Cost per Acre ($62 per cy)	Substrate Cost per Treatment (6" reefs @ 807 cy/ acre; 1' reefs @ 1,613 cy/ acre)
Substrate and seed (6-inch-high reefs)	20	807	$50,000	$1,000,000
Substrate and seed (1-foot-high reefs)	64	1,613	$100,000	$6,400,000
Seed only	70.7	0	$0	$0
Total for Plan				$7,400,000

Monitoring

The primary objective of the monitoring described here is to determine whether or not the restoration work meets the definition of a restored tributaryper the oyster metrics report. In addition, diagnostic parameters are recommended. These are basic water quality and biological parameters which can help determine the cause of success or failure of the restoration work. The extent of the monitoring is consistent with the scope of this document and the oyster metrics report. Cost estimates are approximate; they will likely evolve as monitoring progresses.

Monitoring of Oyster Metrics Success Goals

The principle goal of monitoring efforts in Tred Avon River is to determine if the restored reefs can be considered "successful" per the oyster metrics standards. According to the oyster metrics report, evaluation of reef-level restoration success requires the determination of four parameters:

(1) structure of the restored reef (reef spatial extent, reef height, and shell budget),
(2) population density (as individual abundance and biomass),
(3) an estimate of total reef population (including biomass and number of individuals, and
(4) the number of age classes present on the reef.

In keeping with the oyster metrics report, these parameters will be measured as the basic monitoring protocol for the Tred Avon River oyster sanctuary under this plan, likely in partnership with academics, researchers, non-governmental organizations, private contractors, and other agencies. Table 11 describes in detail the recommended parameters to be monitored to evaluate progress towards the restoration goals.

Pre-restoration data on reef extent were collected by Maryland Geological Survey and NOAA using sonar, video, and grab samples. Baseline data on oyster population density were collected by DNR. These data were used to estimate baseline oyster population size and densities in the Tred Avon River oyster sanctuary. Future monitoring results will be compared to these baseline data, and to control sites, to determine the success of restoration efforts, and whether or not adaptive management actions are necessary. Table 11 lists estimated costs for monitoring per the oyster metrics success goals.

Diagnostic Monitoring

In addition to monitoring to evaluate the success or failure of restoration projects per the oyster metrics standards, it is wise to include further monitoring that will help determine the causes of the success or failure. These are deemed diagnostic monitoring parameters. These include basic water quality, disease, and physiologic factors that affect oyster health and reef structure persistence. Understanding these parameters alongside metrics of restoration success will allow practitioners to understand not only whether or not the project succeeded, but why. Table 12 lists the recommended diagnostic parameters.

Due to the large scope of monitoring, some of these factors will be measured only at designatedsentinel sites within the Tred Avon River oyster sanctuary. Sentinel sites are fixed sites that are monitored annually. Collecting data on these recommended diagnostic monitoring parameters will likely require partnering with academic institutions, non-governmental organizations (NGOs), and other state and federal agencies. Table 12 shows suggested diagnostic monitoring activities and estimated costs of these activities.

Table 11: Suggested Restoration Success Monitoring Activities

Parameter	Sentinel Site Monitoring*	All Site Monitoring**	Method of Measurement	Units/Performance Metric	Estimated Cost (assumes a 6-year monitoring timeline)
Population- Density	x	x	quadrat sampling or patent tong	number of oysters/m^2	These three parameters are collected simultaneously; cost to monitor sentinel sites annually for 6 years = \$33,000 (\$11,000 per year). The cost to monitor each of 440 acres in years 3 and 6 = \$512,720 (\$580 per acre per monitoring event).
Population-Biomass	x	x	regression	g wet or dry weight/m^2	
Size-Frequency Distribution (multiple age classes)	x	x	quadrat sampling or patent tong	(length, number)	
Spatset			quadrat sampling or patent tong	(spat/m^2) Evidence of successful recruitment during at least two recruitment periods	No additional cost (this data is collected as part of DNR's existing annual fall oyster survey)
Reef Height		x	sidescan or multibeam sonar/seismic profiling	(cm) Positive or neutral change in reef height from original structure	No additional cost (These three parameters are monitored as part of NOAA's existing program; the value of NOAA's data collection is \$80,000 over 6 years).
Reef Area		x	sidescan or multibeam sonar/seismic profiling	(m^2)	
Reef Patchiness		x	sidescan or multibeam sonar/seismic profiling	Percent of reef with hard substrate and/or 15 oysters m^2; target is >30%	
Shell Volume -- black/brown (shell budget)		x	patent tong or quadrat sampling (if possible)	increase in brown shell/black shell ratio	No additional cost
Total Additional Cost over 6 Years (rounded)					**\$546,000**

Table 12: Suggested Diagnostic Monitoring Activities

Parameter	Priority	Frequency	Number of Sites	Method of Measurement	Units/ Performance Metric	Estimated Cost
Dissolved Oxygen	High	Every 30 minutes	3 sentinel sites	Data logger	mg/L	$147,000 over 6 years, including equipment and labor
Temperature	High	Every 30 minutes	3 sentinel sites	Data logger	°C	
Salinity (Conductivity)	High	Every 30 minutes	3 sentinel sites	Data logger	PSU	
pH	Medium	Every 30 minutes	3 sentinel sites	Data logger	$-\log[H^+]$	
Total Algae (Chlorophyll a)	Medium	Every 30 minutes	3 sentinel sites	Data logger	µg/l	
Turbidity	Medium	Every 30 minutes	3 sentinel sites	Data logger	NTU	
Alkalinity	Medium	Monthly	3 sentinel sites	Titration	mg/L of $CaCO_3$	$100 for test kits; data can be collected when sensors are changed
Disease (Dermo, MSX)	High	Annually in fall	2	Histology	Prevalence, intensity	No additional cost (included with DNR's fall survey unless additional sites are added)
Predation	Low	Annually in fall	Signs of predation will be assessed during population surveys.	Shell examination	N/A	No additional cost
Poaching	High	Constant	All	MLEIN	N/A	No additional cost (part of DNR's existing MLEIN program)
Sedimentation Rate	High	Pre- and post-construction, years 3 and 6	3 sentinel sites	Sonar	cm/year	No additional cost (sedimentation rates can be estimated as part of NOAA's existing program)
Total Additional Cost over 6 Years (rounded)						**$147,000**

Table 13 summarizes the costs of the suggested restoration success and diagnostic monitoring activities for the Tred Avon oyster sanctuary.

Table 13: Summary of Monitoring Costs

Monitoring per Oyster Metrics Success Standards*	**$546,000**
Diagnostic Monitoring*	**$147,000**
Total Cost	**$693,000**

* This reflects the cost to monitor beyond what is already funded as part of ongoing federal, state and NGO programs.

<u>Monitoring Protocols</u>

More information is provided below for some of the monitoring identified in the restoration success monitoring table. Note that these are parameters already collected by agencies and/or partners.

Post-Planting Monitoring – Spat Growth and Mortality

Growth and mortality of seed plantings are monitored 4 to 8 weeks after planting by collecting spat on shell. The 4- to- 8- week window has been found to be the most effective in assessing these parameters. Focusing on a narrower window in time has proven difficult with weather and other variables affecting the opportunities to sample. Using the planting vessel's track lines as a target, divers collect hatchery shells from each survey location. Divers place a 0.3-meter x 0.3-meter quadrat on the bottom and collect all shells contained within the quadrat. Divers attempt to collect at least six quadrat samples at each site. When shell densities are too low for quadrat sampling, such that the diver could not find shell in areas with few track lines, the diver will instead haphazardly collect 50 to 100 shells from throughout the bar.

Each shell is examined for live spat, boxes, scars, and gapers. Additionally, the first 50 live spat observed in each sample are measured for shell height and, each shell is inspected for the presence of *Stylochus*. Shells are counted in the field, without magnification. The assumption is that live spat are visible at 4-8 weeks old. All shells are returned to the bar when sampling is complete. The number of spat per shell is multiplied by the total amount of shell planted on each bar to calculate the amount of spat detected on the bar by the post-planting monitoring survey. Spat survival is then calculated as the percentage of spat planted that was detected by the survey.

Oyster Population Surveys

Patent tong surveys are conducted on target reefs to assess restored oyster population dynamics including reef-level population estimates, oyster size frequency and disease dynamics, as well as spatial patterns of oyster and shell densities across a given reef.

A grid of 25-meter x 25-meter cells is overlaid onto the planted area using spatial tools in ArcGIS and each grid cell is sampled with hydraulic patent tongs. Number and size (mm) of live and dead (box) oysters are recorded at each grab. In addition, shell score (the amount of shell substrate collected in each tong grab) is quantified on a scale of 0 to 5[3]. The density of oysters at each point is calculated based on the grab area of the tongs (between 1 and 2 square meters depending on the vessel used) and a population estimate is generated using this density data. The total biomass of oysters at each reef is estimated according to Liddell (2007). The density of oysters and shell score at each patent tong survey point is spatially referenced using GIS. These spatial data allow for shell score and density plots to be generated to illustrate the spatial distribution of shell and oysters at each site. All oysters and shells, except those collected for disease sampling, are returned to the reef.

Reefs targeted for patent tong surveys are all reefs planted 3 and 6 years prior, in order to facilitate the consistent sampling of each reef. Sentinel reefs are targeted to act as long-term monitoring sites. These reefs are sampled every year (rather than every 3 years). This allows for the analysis of temporal trends in oyster population and disease levels, as well as how the spatial distribution of oyster density and shell base changes with time.

The dynamic nature of the conditions in the Chesapeake Bay and the ever-changing body of information on oysters and restoration in general require a flexible monitoring plan paired with controlled experiments to maximize restoration success and efficiency. Additionally, the productive collaboration of all agencies involved in Chesapeake Bay restoration has greatly helped with the success of restoration. The coordination of the efforts of the Maryland Geological Survey, DNR, NOAA Chesapeake Bay Office, ORP, and the Paynter Labs has allowed for the implementation of the most up-to-date data on the suitability of areas for planting. This coordination is critical to the success of oyster restoration.

Control Sites

Control sites (untreated areas) have been designated to allow comparison between restored reefs and untreated reefs within the Tred Avon River oyster sanctuary. These are areas that are otherwise suitable for restoration, but will receive neither substrate nor seed. (See Blueprint Map for control site locations). Of these, four sites were otherwise suitable for seed-only treatment, and four were otherwise suitable for substrate treatment. One of the sites suitable for seed-only is also a DNR fall survey site. Four other sites (two seed only and two substrate and seed site) were already serving as control sites for NOAA Oyster Reef Ecosystem

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[3] Oyster Recovery Partnership's tong fullness scale: 0=no shell in the tongs; 1= 1/5 full; 2= 2/5 full; 3= 3/5 full; 4= 4/5 full, 5= totally full. These values are for total volume of shell within the patent tongs.

Services research project, so were designated to receive no restoration treatment. The remaining three sites were selected so as to geographically cover the upstream/ downstream extent of the sanctuary.

<u>Research</u>

The workgroup also recognizes that the large-scale oyster restoration described in this plan provides unique opportunities for critical research.

The workgroup also recognizes that the large-scale oyster restoration described in this plan provides unique opportunities for critical research. Research topics that may be addressed utilizing the restoration framework described in this plan include, but are not limited to, assessment of the efficacy of different oyster restoration techniques, quantification of ecosystem services provided by restored oyster reefs, investigation of oyster larval transport and population dynamics, and analysis of disease dynamics.

The hope is that having this tributary plan will allow researchers, agencies and funders to understand the intended restoration work slated for Tred Avon oyster sanctuary, and to determine if it may constitute a suitable study site for research. In fact, it may be possible to actually design reefs to facilitate certain studies by having agencies and researchers work collaboratively. The ideal approach to large-scale, tributary-based restoration is to maximize the gain in both restored reefs as well as knowledge about successful restoration strategies. The interest in optimizing learning from the effort may need to be tempered, though, with the realities of limited resources.

<u>**Cost Analysis for Tred Avon River Tributary Plan**</u>

The total estimated cost for implementing this plan, including monitoring, is estimated at $11.4 million. Of that, $3.3 million is for hatchery-produced seed (including planting), and $7.4 million is for substrate (including material purchase and substrate placement). The remaining $693,000 is for monitoring. Table 14 summarizes the plan implementation cost (details of the seed costs are in Table 8; details of substrate costs are in Table 10; and details of monitoring costs are in Table 13).

This estimate assumes a cost of $5,000 per million planted oyster seed (ORP, July 2013), and $62per cubic yard for substrate (USACE, Baltimore District, 2014). This cost is for rock and mixed shell; costs could be different for other materials, such as fossilized oyster shell, reclaimed oyster shell or other substrates, should they become available in the large volumes necessary for this restoration project.

Table 14: Summary of Total Costs

661.5 Million Seed (rounded)	**$3.3 million**
119,400 Cubic Yards Substrate	**$7.4 million**
Monitoring	**$693,000**
Total Cost (rounded)	**$11.4 million**

<u>Implementation of the Tred Avon River Tributary Plan</u>

The time frame for implementing the Tred Avon River oyster restoration tributary plan depends primarily on funding. The cost for implementation and monitoring is estimated at $11.4 million. USACE has $2 million to begin reef construction in the Tred Avon River as early as 2015, with the expectation that future funding could be directed toward completing the Tred Avon tributary. DNR and NOAA anticipate being able to provide funding in future years toward implementation of the seeding activities in the Tred Avon tributary plan. Timeline for completing work is dependent upon available funding.

Project completion is also dependent upon oyster seed production, and performance of the restoration actions. The Horn Point hatchery has the capacity to produce over one billion spat-on-shell annually, to be planted by ORP. At current capacity, the 661.5-million seed demand for restoring the Tred Avon oyster sanctuary could be met in as little as one year. However, substrate placement would need to come before seed planting on 83.7 of the targeted acres. Also, other restoration projects (notably Harris Creek and the Little Choptank River, which have similar tributary restoration plans), oyster gardening programs, aquaculture, and public wild fishery grounds may also require seed from this partnership, so not all of Horn Point hatchery's annual production would go to the Tred Avon initiative. A natural spat set on the river could significantly reduce anticipated costs, seed needs, and the time frame in which restoration can be achieved.

Substrate for new reef construction may be a limiting factor. The amount of substrate needed to restore the Tred Avon oyster sanctuary is estimated at 119,400 cubic yards. This could be any combination of oyster shell, clam shell, or alternative substrates such as crushed concrete or rock. Reef balls can also be used for additional three-dimensionality. Oyster shell is a natural material, and relatively inexpensive if it can be found locally. However, it is currently in extremely short supply, and demand is high from both the restoration and aquaculture sectors. Also, shell from seafood processors can break apart into very small fragments ('fines') with multiple handlings resulting in reduced interstitial spaces. Further, oyster shell provides no protection from illegal harvesting/poaching. It may be possible to reclaim old shell from past unsuccessful restoration efforts, but it remains unclear how much of this shell is potentially recoverable and at what expense. Rock and concrete are readily available, and may help deter poaching. However, these materials are costly, and concerns exist about possible interference with other fisheries (e.g., trotlines for crab harvest). Reef balls are a good citizen outreach activity, and may help deter poaching. However, reef balls are costly as well, and concerns also exist about possible interference with trotlines.

Permits are another key component for implementation. Currently, DNR's permits limit placement of substrate to areas where a clearance of 8 feet of water depth will remain overtop of the reef post construction. Assuming 1 foot of substrate is placed, 9 feet of water depth or greater is needed to maintain the 8-foot clearance. The analyses performed for the tributary plan show that in order to meet the restoration target, shallower areas need to be restored. Should DNR proceed with any substrate construction, they would require a permit modification to construct reefs with less than 8 feet of navigational clearance. However, at this time, the substrate construction for the Tred Avon River tributary plan is planned to be undertaken 100 percent by USACE-Baltimore District under its Civil Works program. As a Federal construction project, USACE must comply with the National Environmental Policy Act (NEPA). Since prior NEPA documents did not address shallower depths, in October 2013 USACE initiated an effort to revise the existing NEPA documentation to work in areas with less than 8 feet of clearance so that the necessary acreage can be restored.

Adaptive Management and Project Tracking

The Tred Avon River Oyster Restoration Tributary Plan is meant to be an adaptive, living document. The expectation is that there will be many lessons learned, and that the plan will be adapted to reflect changing conditions and new information. The original document will be posted on the websites of the NOAA Chesapeake Bay Office and DNR. As the document is adapted, newer versions will be posted to ensure transparency. Continued dialogue with the consulting scientists, interested stakeholders, and the public is critical to this adaptive process. Comments on this document are encouraged at any time, and can be directed to Stephanie Westby, Stephanie.westby@noaa.gov.

NOAA, USACE-Baltimore District and DNR will produce annual updates describing progress that has been made on restoring the oyster population in the Tred Avon oyster sanctuary. These reports will be produced annually by spring for the previous calendar year. The reports will include: an accounting of the seed and substrate planted, a map showing the location of the seed and substrate plantings for the year, a summary of any major issues encountered by the project, a discussion of any adaptations made to the original plan, and planned work for the next year. These annual updates will be posted on the websites of the NOAA Chesapeake Bay Office and DNR.

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