Tampa Bay National Estuary Program
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TAMPA BAY
National Estuary Program

AN ASSESSMENT OF SEDIMENT CONTAMINATION IN TAMPA BAY, FLORIDA USING THE SEDIMENT QUALITY TRIAD APPROACH

FINAL REPORT

JULY 1996

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IN TAMPA BAY, FLORIDA
USING THE SEDIMENT QUALITY TRIAD APPROACH

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EXECUTIVE SUMMARY

The Tampa Bay National Estuary Program (TBNEP) has identified the contamination of Tampa Bay sediments and the potential for deleterious impacts to benthic organisms and other living resources as an issue of concern. The purpose of this report is to summarize and map the available information on the extent and severity of sediment contamination it Tampa Bay, utilizing existing information.

Sediment contamination is addressed in TBNEP's Comprehensive Conservation and Management Plan (CCMP), which seeks to help coordinate management activities for Tampa Bay and its watershed. In support of the CCMP's Toxic Action Plan (TAP), TBNEP sponsored a workshop of the Science Advisory Group (SAG) on Sediment Assessment in May of 1995, with the objective of providing TBNEP with guidance for establishing contaminant loading targets to Tampa Bay. One approach to achieving this objective was to evaluate the usefulness of sediment quality assessment guidelines (SQAGs) as indicators of potential impacts resulting from the release of toxic contaminants in the bay. Statewide SQAGs for several chemicals have been developed for Florida coastal and estuarine waters by MacDonald (1994). The complete SAG workshop proceedings, results, and list of attendees has been summarized by MacDonald (1995).

During the workshop, discussions focused on the usefulness of three different methods of assessing sediment contamination: 1) comparisons of sediment chemical concentrations and empirically-derived sediment effects levels (probable effects levels - PEL, and threshold effects levels - TEL); 2) results of sediment toxicity tests; and 3) assessments of benthic community structure. Although each of these measures may indicate the occurrence of contaminant impacts, no one method can definitively identify the absolute significance of the contamination levels. Therefore, a useful management assessment tool is to evaluate all three metrics for the same areas to obtain a series of data that will better identify contamination effects. This approach is referred to as the "weight of evidence" approach. The three measures of sediment contamination, when used together, are referred to as the "sediment quality triad," or "triad."

To bring the triad's weight of evidence to a particular site, all three types of sediment characterization (chemistry, toxicity, and benthos) must be collected at the same time from the same location, preferable from the same sample. Although this level of sampling is recommended for future field programs, only one data set for Tampa Bay contains all three types of information, as described below.

Tampa Bay is relatively well-studied with respect to sediment characteristics, although unstudied areas still exist. One outcome of the SAG workshop was the recognition that, although several large data sets describing Tampa Bay sediment characteristics do exist, these data have not been analyzed together. The simultaneous evaluation of these data sets would give the opportunity to obtain a more definitive assessment of sediment quality in the bay. To this end, overlay maps of the diverse data sets of sediment chemistry, toxicity testing, and benthic community structure were prepared to evaluate sediment contamination and to evaluate the sediment quality triad approach.

Coastal Environmental, Inc. (Coastal) was tasked by TBNEP to obtain and verify the usefulness of available data sets of sediment chemistry, toxicity testing, and benthic sampling in Tampa Bay; to use geographic information system (GIS) mapping techniques to develop a series of maps illustrating the spatial extent of chemical contamination in Tampa Bay; and to evaluate the triad approach for assessing Tampa Bay sediment contamination. The following report describes the data sets that were identified and obtained, the selection process that was used to determine which data sets were appropriate for use in this analysis, the methods used to create the map series, and the results of the various evaluations.

In general, the combined data sets showed much the same patterns of sediment contamination as did the individual data sets when observed alone. Sediment contamination in Tampa Bay is most prevalent in the parts of the bay that receive inputs from urban and industrial activities in the watershed. These areas include Hillsborough Bay, especially north Hillsborough Bay in the Port of Tampa area, and east Hillsborough Bay; Bayboro Harbor, adjacent to downtown St. Petersburg; and Boca Ciega Bay, which receives runoff from a highly urbanized watershed. The portions of the bay receiving inflows from less urban areas did not exhibit nearly as high or frequent levels of sediment contamination, although evidence of residual pesticides, such as DDT, were observed in some areas receiving urban runoff.

Of the three measures of potential sediment contamination, sediment chemistry and toxicity tests followed similar spatial trends. Results of both types of analyses showed the most frequent occurrence of contaminated sediments in nearshore areas adjacent to urban centers. The benthic analyses also showed spatial trends, although not as clearly defined as the other two analyses. Less diverse benthic communities were more often identified in Hillsborough Bay and other urban nearshore areas.

The assessment of the triad approach revealed that, although some data have been collected to meet the collection criteria of the triad, insufficient information exists to assess most of the bay using this approach. Only one field program -- the National Oceanic and Atmospheric Administration (NOAA) National Status and Trends (NST) study conducted by Long et al. (1994) -- have all three data types collected simultaneously in space and time. The sites with all three parameters are of insufficient density to allow an overall assessment of Tampa Bay using the triad approach. Recommendations for future investigations of Tampa Bay sediment contamination include the expanded use of the sediment quality triad, or using established correlations between sediment toxicity and chemistry to predict the occurrence of toxic sediments based on concentration alone. Other recommendations for future work include refining estimates of the extent of sediment contamination based on other existing estimates (Long et al. 1994; MacDonald et al. 1995), and the evaluation of the consequences of the bioavailability of certain contaminants of concern. Due to the differences in the mode of toxicity of high weight PAHs and low weight PAHs, the relative contributions of these two classes of contaminants, and individual PAHs, should be investigated in detail.

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ACKNOWLEDGMENTS

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This report was prepared by Coastal Environmental, Inc. and MacDonald Environmental Services, Ltd. staff. Text was written by Hans Zarbock, Dennis Logan, and Donald MacDonald, and reviewed by Anthony Janicki. GIS mapping was completed by Guo Cheng, and statistical analyses were completed by Susan Janicki and Harold Wilson.

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LIST OF ACRONYMS

AVS	acid-volatile sulfide
CCMP	Comprehensive Conservation and Management Plan
DO	dissolved oxygen
EMAP	Environmental Monitoring and Assessment Program
FDEP	Florida Department of Environmental Protection
GIS	geographic information system
PCB	polychlorinated biphenyl
PEL	probable effects level
MDL	minimum detection limit
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NTS	National Status and Trends
SAG	Science Advisory Committee
SQAG	sediment quality assessment guideline
SQT	sediment quality triad
TBNEP	Tampa Bay National Estuary Program
tDDT	total DDT
TEL	threshold effects level
tPAH	polycyclic aromatic hydrocarbons
TIE	toxicity identification evaluation
TOC	total organic carbon

SECTION 1.0 INTRODUCTION

The Tampa Bay National Estuary Program (TBNEP) has identified the contamination of Tampa Bay sediments and the potential for deleterious impacts to benthic organisms and other living resources as an issue of concern. In particular, TBNEP has identified several "contaminants of concern" as having the greatest potential for local impacts to the bay's living resources and to public health. Contaminants of concern include six metals (cadmium, chromium, copper, lead, mercury, and zinc), four organochlorine pesticides (chlordane, DDT, dieldrin, and endrin), and two classes of organic chemicals: polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs). The contaminants of concern include potentially harmful chemicals that have either been identified in Tampa Bay sediments or are typically found in urban estuaries. Estimates of sources and loading magnitudes of these compounds are summarized in the document "Chemical Contaminants in the Tampa Bay Estuary: A Summary of Distributions and Inputs" (Frithsen et al. 1995).

Sediment contamination is being addressed in TBNEP's Comprehensive Conservation and Management Plan (CCMP), which seeks to help coordinate management activities for Tampa Bay and its watershed. In support of the CCMP's Toxic Action Plan, TBNEP sponsored a workshop of the Science Advisory Committee (SAG) in May of 1995, with the objective of providing TBNEP with guidance for establishing contaminant loading targets to Tampa Bay. The seven major segments of Tampa Bay are illustrated in Figure 1-1.

One approach to achieving this objective was to evaluate the usefulness of sediment quality assessment guidelines (SQAGs) as indicators of potential impacts resulting from the release of toxic contaminants in the bay. Advisory statewide SQAGs for many chemicals, including most of the TBNEP contaminants of concern, were previously developed for Florida estuarine waters by MacDonald (1994). The complete SAG workshop proceedings, results, and list of attendees has been summarized by MacDonald (1995).

During the workshop, discussion eventually focused on the usefulness of three different measures of sediment contamination: 1) comparisons of sediment chemical concentrations and empirically-derived threshold effects levels (probable effects levels - PEL, and threshold effects levels - TEL); 2) results of sediment toxicity tests; and 3) observations of benthic community structure. Although each of these indicators may suggest the occurrence of contaminant impacts, no one method can definitively identify the absolute significance of the contamination levels.

A useful management assessment tool is the evaluation of all three metrics of sediment contamination for the same areas to obtain a series of data that will better identify the extent and severity of contamination. This approach is referred to as the "weight of evidence" approach. The three measures of sediment contamination (sediment chemistry, toxicity testing, and benthic community structure), when used together, are referred to as the "sediment quality triad" (SQT).

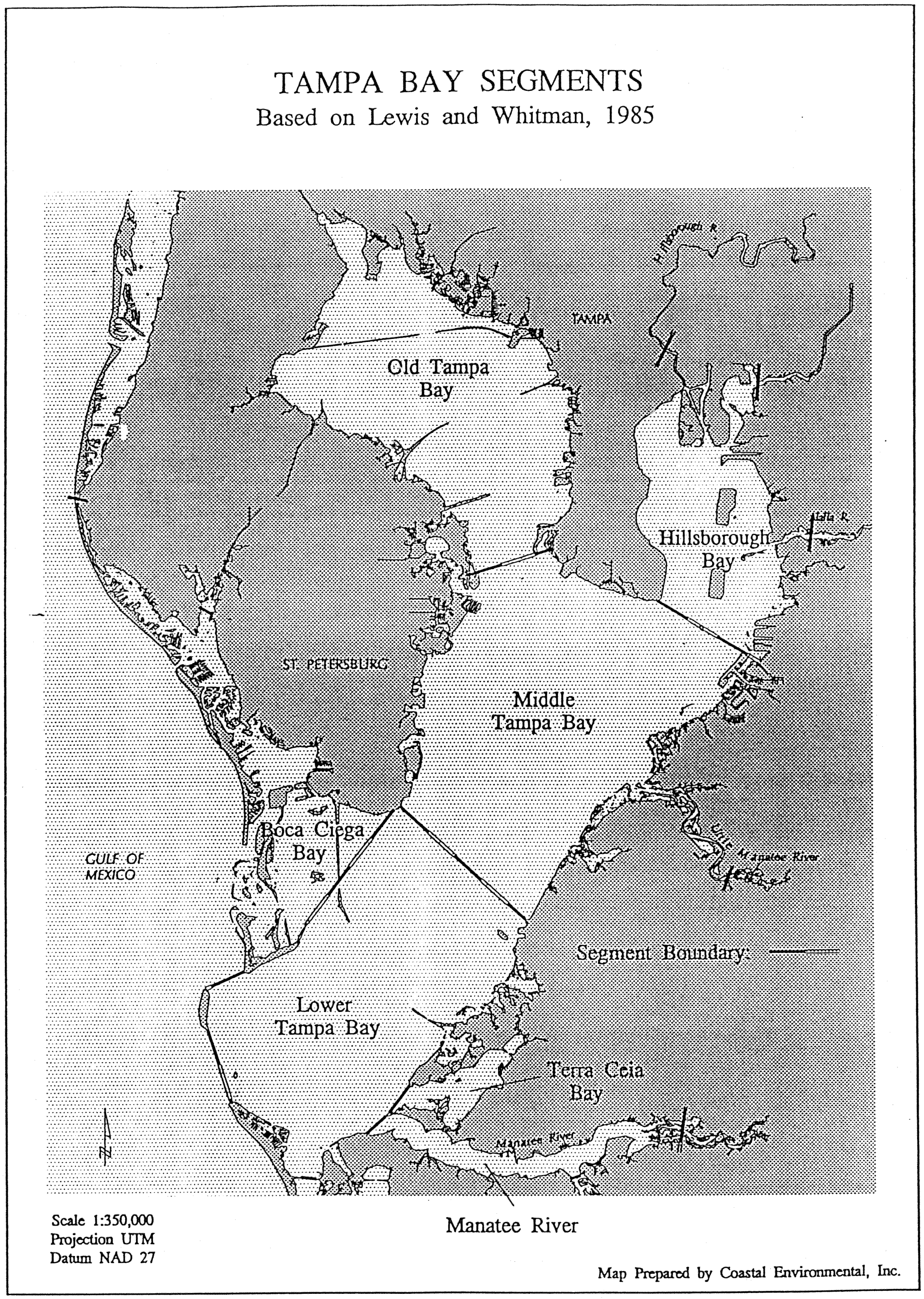

Figure 1-1. Tampa Bay segments.

The SQT method combines sediment contaminant analysis, sediment toxicity testing, and measures of biological conditions to quantitatively assess pollution-induced degradation. The SQT is an integrated approach that links sediment contaminant levels to 1) their potential toxic effects, as measured by toxicity testing; and 2) affects on ambient populations of benthic organisms, as measured by benthic community status indicators (Hyland and Costa 1995).

The SQT (triad), although a very useful measure of sediment contamination that was identified at the workshop, is also the most difficult to obtain. To bring the triad's weight of evidence to a particular site, all three types of sediment characterization (chemistry, toxicity, and benthos) should be collected at the same time from the same location, preferrable from the same sample. Although this level of sampling is to be recommended for future field programs, only one data set for Tampa Bay contains all three types of information, as described below. However, the triad approach has been successfully used in several estuarine monitoring programs (Chapman 1990; MacDonald 1995; Hyland and Costa 1995).

Tampa Bay is relatively well-studied with respect to sediment characteristics, although unstudied areas do exist. Much of the information characterizing Tampa Bay sediments is summarized in Frithsen et al. (1995). Relevant data sets, and others not addressed in Frithsen et al. (1995) are described herein. One outcome of the SAG workshop was the recognition that, although several large data sets describing Tampa Bay sediment characteristics do exist, these data have not been analyzed together. The simultaneous evaluation of these data sets would give the opportunity to obtain a more definitive assessment of sediment quality in the bay.

Therefore, final results of the SAG worshop included direction to produce overlay maps of the diverse data sets of sediment chemistry, toxicity testing, and benthic community structure to evaluate sediment contamination, and to evaluate the sediment quality triad approach to the same end. This report summarizes work that has occurred to accomplish these two recommendations as an initial activity to manage potential toxic contaminants in Tampa Bay.

Coastal Environmental, Inc. (Coastal) was tasked by TBNEP to obtain and verify the usefulness of available data sets of sediment chemistry, toxicity testing, and benthic sampling in Tampa Bay; to use geographic information system (GIS) mapping techniques to develop a series of maps illustrating the spatial extent of chemical contamination in Tampa Bay using an overlay mapping approach; and to evaluate the triad approach for assessing Tampa Bay sediment contamination. The following report describes the data sets that were identified and obtained, the selection process that was used to determine which data sets were appropriate for use in this analysis, the methods used to create the map series, and the results. This report summarizes Coastal Environmental, Inc.'s (Coastal) activities pursuant to the sediment contamination mapping recommendations of the TBNEP SAG workshop held during May of 1995.

1.1 Purpose and Objectives

The overall objective of this project was to assess the extent and severity of documented or likely sediment contamination in Tampa Bay by:

- obtaining and verifying the usefulness of available data sets of sediment chemistry, toxicity testing, and benthic sampling in Tampa Bay;
- developing a series of maps using geographic information system (GIS) mapping techniques to illustrating the spatial extent of chemical contamination in Tampa Bay; and
- evaluating the triad approach for assessing Tampa Bay sediment contamination.

The activities completed to achieve these objectives are summarized below. Section 1.2 details the scope of work for this report, Section 2 describes the data that were obtained and used for mapping purposes, Section 3 summarizes development of the map series and results of the mapping activities, and Section 4 presents the conclusions and recommendations of this study. Section 5 includes the cited literature.

1.2 Scope of Work

Project Approach

The purpose of the following tasks is to assess the extent and severity of documented or likely toxic contamination of sediments in Tampa Bay using sediment quality, toxicity, and benthic monitoring data in conjunction with Geographic Information System (GIS) mapping and analysis techniques. Of special interest are the "contaminants of concern", that include metals (cadmium, chromium, copper, lead, mercury, zinc), organochlorine pesticides (chlordane, dieldrin, DDT, endrin), and other organic compounds (polycyclic aromatic hydrocarbons, or PAHs and polychlorinated biphenyls, or PCBs). Three tools directly related to assessing contamination of sediments by potentially toxic materials were used to evaluate Tampa Bay sediments for affects from these chemicals. These tools are collectively referred to as the "sediment quality triad" (SQT, or triad) and are summarized below.

- Sediment contamination levels - Concentrations of several contaminants of concern have been measured at a variety of sites in Tampa Bay. Sediment effect levels of many of the contaminants of concern have been established and may collectively be referred to as "sediment quality assessment guidelines" (SQAG), as described by MacDonald (1994). The SQAGs are intended to define three ranges of contaminant concentrations that were rarely, occasionally, or frequently associated with adverse biological effects (MacDonald et al 1996), as follows:

PEL - probable effects level - the concentration above which biological effects are likely;

TEL - threshold effects level - the concentration below which biological effects are not expected.

Concentrations of contaminants of concern in bay sediments were compared to these threshold levels to identify sites that are most likely to be impacted by contamination.

- Sediment toxicity - To test sediment toxicity, sensitive life stages of organisms considered to be "indicator species" are placed in contact with sediment solid phase, solvent phase, or sediment pore water at various dilutions. The degree of survival of the biological indicators provides information on the level of toxicity of the sediments. Test species used for the analysis of Tampa Bay sediments have included the sea urchin *Arbacia punctulata* (eggs), the amphipod *Ampelisca abdita* (adult), the bivalve *Mulinia lateralis* (larvae), and bacteria including the Microtox™ bacteria *Photobacterium phosphorium* (bioluminescence), as described in Section 2.2. In whole sediment and pore water tests, specific constituents are not identified as toxic. Instead, the overall effect of all components of the sediment are evaluated together.

- Benthic assessment - Sampling benthic invertebrate communities for species composition and abundance gives an indication of the severity of impacts at a site. Organisms that are more tolerant of stressed conditions tend to occur at impacted sites, whereas intolerant organisms are less likely to be found. Also, the diversity (number of different species) of the benthic community is often greater in unstressed areas.

The triad approach combines these three types of data in one of two ways. The first method of using the triad is through the synoptic sampling of all three types of sediment characterization (chemistry, toxicity, and benthos). These samples should be collected at the same time from the same location, preferably from the same sample. The synoptic triad, although the most useful and rigorous measure of sediment contamination that was identified at the workshop, is also the most difficult to obtain. Only one data set for Tampa Bay contained all three types of information (Long et al. 1994 and MacDonald unpublished). However, this data set did not provide the wide spatial coverage required for a bay-wide assessment of potential sediment contamination effects. In addition, the data collected by Long et al. (1994) and MacDonald (unpublished) included many sites targeted to areas of the bay where sediment contamination was suspected. Therefore, it would not be possible to make statistically-unbiased, technically-defensible estimates of the areal extent of potentially contaminated areas based on these data. Of the benthic data available, only the EMAP design benthic sampling (Hochberg et al. 1992; Grabe et al. 1995) was based on randomly located sites that would allow such estimates to be make.

The second method (essentially an overlay mapping) incorporates the weight of evidence in a similar manner. For this second method, all available chemistry, toxicity, and benthic data for a given area are summarized, even if the data were collected at different times. Although this is a less rigorous approach, it does provide a broader spatial coverage. When using this method, the inherent limitations of using diverse data sets should be noted. Sampling during different seasons or weather conditions, different sampling or analytical techniques, testing for different analytes, different minimum detection limits, changing conditions over time, and other factors must be considered when analyzing such data aggregations. A particularly important limitation of pooling data sets is the potential for spatial heterogeneity between samples. For example, if a sediment chemistry sample is collected from a sandy bottom and a benthic sample is taken in a muddy environment, the comparability of these samples is significantly reduced.

Other tools that have proven useful in this type of investigation include the use of each measure of sediment contamination alone (e.g., sediment chemistry with SQAGs); using existing maps of sediment grain size and physical impacts (such as past dredge and fill activities); and the identification of land uses in tributary areas (suggesting potential sources for observed sediment contaminants). In addition, it is desirable to identify potentially confounding factors. To this end, existing sediment or water quality data on such parameters as bottom dissolved oxygen (DO), hydrogen sulfide, ammonia, and salinity can be used to help understand toxic impacts in relation to stresses caused from other environmental conditions.

The ultimate goal of this investigation was to estimate the spatial extent of Tampa Bay that is potentially impacted by toxic contaminants, and the severity of those impacts. Identifying the extent and severity of sediment contamination provides a useful tool for making management decisions regarding the control and limitation of contaminant releases into the environment. Subsequent to delineating areas with significant pollution-induced degradation, the examination and control of potential inputs and contributors to those areas may reduce further impacts. To delineate impacted areas, results from the three testing methods are pooled to identify areas of concern. The results allowed the identification of areas that may be mapped as one of the following four categories:

- "highly contaminated areas" - toxicant effects exceeding one or more indicator levels (e.g., threshold (PEL) concentration, multiple positive toxicity test result, or indications of degraded benthic community structure);

- "restorable areas" - toxicants present, but at moderate levels not exceeding upper (PEL or multiple toxicity) thresholds;

- "protectable areas" - relatively unstressed areas to be protected from any further impacts from contamination; and

- "unknown areas" - areas with insufficient data to make an assessment.

It should be noted that the classification of areas of the bay into any of these four groups is based on a relative comparison of an area to other areas that display less, or more, evidence of sediment contamination. Thus, it should not be assumed, for example, that an area classified as "highly contaminated" is not restorable. Conversely, because of the patchy nature of sediment contaminant accumulation and gaps in coverage of sampling, it should not be assumed that areas classified as "protectable" do not have any elevated levels of sediment contamination.

Scope of Work

The elements of this assessment of sediment quality conditions in Tampa Bay include the following tasks. The first three tasks identify and map areas of the bay corresponding to stressed or unstressed conditions as determined by several metrics discussed below. Tasks 4 through 7 were designed to assign a relative level of environmental quality to areas of the bay bottom based on the results of Tasks 1 through 3.

Task 1) Identify and map 1) areas within the bay that have been subject to physical habitat alterations such as dredge and fill activities; and 2) bay bottom sediment types (grain size and composition) of physically unaffected areas.

Task 2) Identify and map areas within the bay that have benthic communities classified as "degraded," based on an absolute scale if feasible, or on a relative basis using a comparative index.

Task 3) Examine existing ambient water quality data and identify sites or zones with water quality ("worst case" or seasonal characteristics) that may adversely impact benthic communities through effects other than those associated with the contaminants of concern (for example salinity, bottom DO, ammonia, and hydrogen sulfide).

Task 4) Identify and map areas within the bay that have sediments that are acutely toxic to aquatic organisms.

Task 5) Identify and map areas within the bay that have the potential for adverse biological effects due to the presence of elevated levels of sediment-associated contaminants (by comparison of sediment chemistry to the SQAGs).

Task 6) Identify and map areas within the bay that have a high, moderate, and low potential for adverse biological effects due to contaminated sediments (as indicated by the overlay mapping procedure using all sediment chemistry, toxicity test results, and benthic assessments).

Task 7) Identify and map areas within the bay that have a high, moderate, and low potential for adverse biological effects due to contaminated sediments (as indicated by the sediment quality triad).

It must be noted that, although the SQT does provide a relatively rigorous measure of sediment contamination compared to individual legs of the triad, the SQT does not give proof of causality. That is, a direct relationship between biotic effects and either sediment chemical levels above PELs or TELs, toxicity test results, or benthic community evaluations, is not provided by use of only the SQT. Additional investigations, including sediment spiking with suspected active agents, or a toxicity identification evaluation (TIE) must be completed prior to passing judgement on the direct link between sediment contamination and impacts to living resources. These two supplemental tests are designed to provide further evidence on individual chemicals that may be responsible for pollution-induced impacts. Sediment spiking includes the introduction of elevated concentrations of specific contaminants into clean sediment, with subsequent toxicity testing of solid phase, pore water, or solvent phase to determine if the introduced chemical causes the same effects as whole samples taken in the field. TIE testing includes whole sample testing, followed by subsequent tests after the sediment sample is subjected to chemical extractions that remove individual or classes of potential contaminants. The remaining contaminants are then evaluated for their specific impacts.

The individual tasks required to complete this assessment are detailed in the following sections. Subsequent sections discuss the degree of success that was achieved in completing these tasks due to data or other constraints.

SECTION 2.0 DATA AVAILABILITY AND ANALYSIS

As stated above, Tampa Bay has been studied more, with respect to sediment characteristics, than many estuaries (Long et al. 1991 and 1994). However, no collection and synthesis of the independent data sets has previously occurred. The first task for this mapping project was to identify and obtain as many existing data sets of Tampa Bay sediment chemistry, toxicity testing, and benthic sampling as feasible, and to evaluate these data sets and identify which ones were appropriate for mapping. These work efforts are discussed below.

2.1 Assessment of Data Sets

Candidate data sets of Tampa Bay sediment chemistry, toxicity testing, and benthic sampling were identified. These data covered a wide temporal range. The most relevant data were collected in recent years (1984-1994), but some data were collected as early as the 1960's. These data also addressed a wide range of spatial coverages. Some data sets addressed only small areas of the bay, for example the lower Hillsborough River and bay bottom adjacent to the river mouth (Trefry et al. 1989). Several data sets covered, or were intended to cover, large portions of the bay or major potentially-impacted areas (Long et al. 1991 and 1994; Brooks and Doyle 1992; Seal et al. 1994; Grabe et al. 1995).

Data sets were assessed, and determined to be suitable or not suitable for use in the sediment contaminant mapping. It should be noted that the rejection of a data set does not necessarily imply that it did not contain valid and accurate data, but only that it did not meet one or more of the assessment criteria. Data sets were examined using the following criteria:

1) The data set was complied from a variety of unknown or unverifiable sources. An example is Long et al. (1991), which discusses results of three small toxicity testing programs completed by others.

2) Sampling results were dated and potentially obsolete. Reasons for not using older data are that collection or analytical techniques may have changed, or that sediment conditions may have changed. In general, all data collected prior to 1980 were rejected.

3) Sampling and analytical methods were not verifiable. No data set was rejected for not meeting this criteria.

4) Data were not from an appropriate area, or were from an isolated area. An example of this is metals data collected by Trefry et al (1989), which sampled mainly in the lower Hillsborough River and into extreme upper Hillsborough Bay. Because this study was to investigate only the bay segments and upper Hillsborough Bay was well-sampled by other field programs, this data set was not used.

5) Paper or digital records were not available. Much work on benthic invertebrates has been completed by Simon and Mahadevan (1985). However, referenced citations revealed insufficient data (e.g., proceeding abstracts, etc.), and inquiries failed to locate data sets.

6) Analyses were not completed or results were not yet available. For example, some of the 1993 TBNEP/EMAP design data (Grabe et al. 1995) including PAH and other hydrocarbons had not been received from the analytical laboratory in time to include in the analysis, so the results of that work could not be used.

2.2 Data Sets Used to Assess Contamination in Tampa Bay Sediments

Following the initial identification of all data sets of Tampa Bay sediment chemistry, toxicity testing, and benthic sampling, each data set was assessed to determine its appropriateness for use in the mapping study. Based on the six criteria listed above, several data sets were determined to be useful in this analysis. The data sets that were used in the mapping analysis are summarized in Table 2-1, and are further described in Section 3.

- Physical Alteration of Sediments and Sediment Characteristics

Areas that are significantly impacted through physical alteration should be excluded from further consideration relative to the effects of toxic chemicals. These areas were identified using the existing maps of physical alterations in Tampa Bay (Coastal 1994), and are presented in Appendix A. Data for this coverage were obtained from aerial photographs, other studies, USGS quadrangle maps, environmental permit files, field investigations, anecdotal information, and other sources.

Information on bottom types is also required to identify areas that could support healthy benthic communities and areas that could be most affected by contaminant inputs (i.e., depositional areas). For this reason, available information on bottom types (i.e., hard vs. soft substrates, grain size, organic content, etc.) within Tampa Bay was collected and synthesized. Sources of this type of information included NOAA, FDEP, TBNEP, USGS, and EPCHC. In addition, sediment physical data were also frequently collected in conjunction with sediment chemistry sampling (Long et al. 1991; 1994; Brooks and Doyle 1992). These data were synthesized by Coastal (1994), and that summary coverage was used for this analysis, as presented in Appendix B.

- Sediment Chemistry

A great deal of information exists regarding Tampa Bay sediment chemistry. Data on the levels of total metals and selected organics were collected throughout the early 1980's (Seal et al. 1994). More recently, the results of several surveys have provided additional information on the concentrations of metals and PAHs (Brooks and Doyle 1992; Doyle et al. 1989; Long et al. 1991). Over the past four years, four additional surveys were completed which provide detailed data on many chemical constituents (Long et al. 1994; Grabe et al. 1995). The analytes included in these latter studies were total metals, PCBs, PAHs, organochlorine pesticides, and a series of conventional measurements.

- Toxicity Testing

In 1991 and 1992, NOAA and FDEP conducted a detailed investigation of the toxicity of Tampa Bay sediments. In the first phase of the study, samples were collected from 90 stations. Four toxicity tests were conducted on each sample, including a 10-day amphipod (*Ampelisca abdita*) survival test using solid-phase sediment, a 1-hour sea urchin (*Arbacia punctulata*) fertilization tests using porewater, a 5-minute Microtox (*Photobacterium phosphorium*) bioluminescence test using organic extracts, and a 48-hour bivalve (*Mulinea lateralis*) development test using elutriates. In the second phase of the study, 75 samples were collected and three of the four toxicity tests were conducted (the bivalve test was not used) (Long et al. 1994). Matching sediment chemistry testing was completed with the toxicity sample collection, making these data suitable for use in the synoptic triad analysis, when used with the benthic community data described below.

The National Marine Fisheries Service (NMFS) also conducted adult sea urchin and polychaete tests on 12 samples collected in McKay Bay (McCain et al. 1996). Detailed sediment chemistry data were collected on most of the samples, including total metals, PAHs, PCBs, pesticides, ammonia, and hydrogen sulfide. Total organic carbon (TOC), and acid-volatile sulfide (AVS), and grain size were also collected on most of these samples. Together, these surveys provide broad coverage of the depositional habitats in Tampa Bay. However, because of the limited spatial extent of the NMFS testing, those data were not used.

- Benthic Community Sampling

In Tampa Bay, a substantial quantity of benthic community data exists with which to evaluate the status of the benthic community. In 1992, roughly 75 samples were collected at sites located in Hillsborough Bay, Old Tampa Bay, Boca Ciega Bay, and nearby St. Petersburg, in conjunction with Long et al. (1994) toxicity and sediment chemistry sampling (MacDonald unpublished). In addition, more than 80 samples were collected in 1993 and again in 1994 using the TBNEP/EMAP design protocol for site selection and sample collection (Hochberg et al. 1992; Grabe et al. 1995).

2.3 Data Sets Not Used to Assess Contamination in Tampa Bay Sediments

Based on a review of all data sets with respect to the above criteria, some information was excluded from further analysis. Data sets not meeting all of the above criteria and excluded from the mapping analysis are presented in Table 2-2.

Table 2-1. Data sets used to assess contamination in Tampa Bay sediments.

Data Source	Data Type				Date Collected	No. Tampa Bay Sites
	Sediment Type	Sediment Chemistry	Toxicity Tests	Benthic Community		
Long et al. (1994)	X(1)	metals, PAH, PCB	X		1991-92	165
Coastal (1994)	X				varies	NA
Long et al. (1991)		metals, PCB, PAH, pest.	X(1)		1985-90	8
MacDonald (1992, unpublished) (2)				X	1991-92	50
Seal et al. (1994)	X(1)	metals, PAH, PCBs, HC			1983-92	101
Grabe et al. (1995)	X(1)	metals, PAH(3), HC(3)		X	1993	160
Brooks & Doyle (1992)	X(1)	metals			1989-90	75

(1) Data not used (sparse, from other studies, dated, or summarized by others).
(2) Benthic samples collected simultaneously with Long's sediment chemistry.
(3) PAH and HC data not available (results not received from USEPA laboratory).

Table 2-2. Data sets not used to assess contamination in Tampa Bay sediments.					
Data Source	Data Type				Reasons Not Used
	Sediment Type	Sediment Chemistry	Toxicity Tests	Benthic Comm.	
Long et al. (1991)			X		2,3
Delfino et al. (1991)		X			4
NMFS (Unpublished)			X		5
Grabe et al. (1995) (1993 data)		X (organics)			6
Grabe et al. (1995) (1994 data)	X	X		X	6
Trefry (1989)		X			4
Jones, Edmunds, & Assoc. (1979; 1980)			X		2
ESE, Inc. (1979)			X		2
Doyle et al. (1985)		X			5
Goodell & Gorsline (1961)				X	2
Simon & Mahadevan (1985)				X	1, 5
Dames & Moore (1975)				X	2, 4

Reasons Not Used:

1) Data set was complied from a variety of unknown sources.
2) Results are dated and potentially obsolete. Sediment conditions may have changed.
3) Sampling and analytical methods were not verifiable.
4) Data were not from appropriate areas, or from isolated areas.
5) Paper or digital records were not found.
6) Analyses not completed/results not available.

SECTION 3.0 MAPPING METHODOLOGY AND RESULTS

After the selection of data sets to be used for the mapping was completed, selected data sets were subjected to a final quality control. Electronic files were converted into the appropriate format. Hard copy data sets were entered into electronic format as necessary.

3.1 Mapping Methodology

The sediment chemistry, toxicity testing, and benthic sampling data were entered into a data set using the Statistical Analysis System (SAS). Because the purpose of the mapping was to evaluate the extent and severity of sediment contamination in Tampa Bay, an index system was developed to rank the sampling sites independently for each type of information, as described below.

- Sediment contamination levels - Concentrations of the TBNEP contaminants of concern have been measured at a variety of sites in Tampa Bay. Threshold levels of all of the contaminants of concern except the pesticide endrin have been established through empirical means, and, as stated above, are collectively referred to as SQAGs (MacDonald 1994). SQAG threshold limits for each chemical are classified PELs and TELs, as defined in Section 1.2.

  Table 3-1 presents the PEL and TEL concentrations that were used for the analysis. Concentrations of contaminants of concern in bay sediments were compared to these threshold levels to identify sites that are most impacted by contamination. Sampling sites were ranked with respect to sediment chemical concentrations.

  An index scoring method was used to rank the sampling sites as most impacted, somewhat impacted, or not impacted. The index scores of 0-3 were assigned to each sampling site as follows:

  Index Score = 0: No TEL or PEL exceedences.

  Index Score = 1: One or more TEL exceedences, but no PEL exceedences.

  Index Score = 2: One PEL exceedence, possibly one or more TEL exceedences.

  Index Score = 3: Two or more PEL exceedences.

  This scoring system was used because, from a management standpoint, it was assumed that differentiating between multiple TEL or PEL exceedences (for example, between 5 or 7 exceedences) was not as important as distinguishing those sites with 0, 1, or 2 PEL

Table 3-1. PEL/TEL values for TBNEP contaminants of concern.		
Substance (units)	TEL	PEL
Cadmium (mg/kg)	0.676	4.21
Chromium (mg/kg)	52.3	160
Copper (mg/kg)	18.7	108
Lead (mg/kg)	30.2	112
Mercury (mg/kg)	0.13	0.696
Zinc (mg/kg)	124	271
tPCB(ug/kg)	21.6	189
tPAH (ug/kg)	1684	16770
Chlordane (ug/kg)	2.26	4.79
tDDT (ug/kg)	3.89	51.7
Dieldrin (ug/kg)	0.715	4.3
Endrin	ID	ID

ID = Insufficient Data, PEL/TEL not established

exceedences (MacDonald 1994). The reasoning for this is that one PEL exceedence may well impact living resources just as much as several exceedences. That is, each contaminant in itself was considered to be potentially toxic if found in a high enough concentration. For this reason, the map index scores gave a higher precedence to PEL exceedences than to TEL exceedences. Additionally, in general, there is more certainty associated with the PEL concentrations as a defined threshold level for impacts to living resources, than with the TEL limits, depending on the individual test (MacDonald et al. 1995).

- Sediment toxicity - To test sediment toxicity, one or more aquatic organisms are placed in contact with sediment solid phase, organic extracts (solvents), or sediment pore water at various dilutions. Survival of these indicator species provides a measure of the toxicity of the sediments. In these sediment and pore water tests, specific constituents are not identified as toxic, but the overall affect of all components of the sediment and pore water are evaluated together. To develop an index score, the NOAA toxicity test results (Long et al. 1994) were used. The three tests that were used for both Phase 1 and Phase 2 testing (Long et al. 1994) were:

- 10-day amphipod (*Ampelisca abdita*) survival test using solid-phase sediment,

- 1-hour sea urchin (*Arbacia punctulata*) fertilization tests using 25% porewater, and

- 5-minute Microtox (*Photobacterium phosphorium*) bioluminescence test using organic extracts.

At each site, an index value of "1" was assigned for each toxicity test result that was identified as significantly toxic by Long et al. (1994). The results were summed for each site, and index scores of 0,1,2, or 3 were mapped.

- Benthic assessment - Sampling benthic invertebrate communities for species composition and abundance can give an indication of the severity of impacts at a site. Organisms that are more tolerant of stressed conditions are more likely to occur in impacted sites, whereas intolerant organisms are less likely to be found. Also, the diversity (number of different species) of the benthic community is often greater in unstressed areas. Sediment contaminants represent one stressor for benthic invertebrate communities. Other stressors may include water quality, water temperature, or physical disruption.

  It was desired to use an index to evaluate the absolute or relative degree of impacts that were exhibited by the sampled benthic sites. Previously, the EMAP Louisianian Province Benthic Index had been applied to the 1993 data obtained in Tampa Bay using the EMAP monitoring program design (Coastal 1995). The index scoring for the EMAP Louisianian Province Benthic Index had been developed for the western and central Gulf of Mexico region of the United States, an area that includes several estuary systems that are much more impacted than Tampa Bay. The EMAP Louisianian Province Benthic Index is scored on a scale of 0-10, with scores of 4.1 or lower indicating degraded conditions. No sites in Tampa Bay exhibited index scores that indicated impacted or degraded conditions. Potential reasons for this may be that the sites used to develop the EMAP Louisianian Province Benthic Index include several highly contaminated areas, or that there is a higher diversity of tropical and subtropical species assemblages in Tampa Bay than commonly found in the Louisianian Province.

  The EMAP Louisianian Province Benthic Index is a function of abundances of benthic classes and families, along with species diversity. Other measures of benthic community status may include (Burton 1992):

  - species composition - quantifies the number of species in a defined community,

  - evenness of individuals among species - estimates how individuals are distributed among species (relative abundance),

  - biomass and trophic levels - measures the distribution of biomass among species and the trophic complexity of a community,

- life history and functional characteristics - uses species environmental requirements and behavior to gage community status,

- indicator species - founded on the premise that an organism's presence or absence in a particular habitat is an indicator of the habitat quality and the health of the ecosystem, and

- resemblance indices - designed to be similar to diversity indices but only as a comparative measure between communities or between samples in a community,

- diversity indices - formulated to combine two independent components of community structure (the number of species, or richness; and the relative abundance of individuals, or evenness) into a single derived variable. Examples include Shannon, Shannon and Weaver, Margalef, and Simpson, among others (Burton 1992).

Several of these methods were evaluated to determine an appropriate measure of benthic impacts, including species richness, the presence or absence of benthic invertebrates, and the presence or absence of amphipods. In addition, the Shannon Index (Zar 1984) was applied to the benthic data, and the results were scored by quartile, with the least diverse 25% sites receiving the score of "3", and the most diverse sites receiving a score of "0."

3.2 Mapping

The locations of all sampling sites included in the data sets shown in Table 2-1 were identified using latitude-longitude coordinates provided with each data set. The sites were mapped, and are presented in Appendix A. Tables accompany the maps in Appendix A to summarize the total number of PEL/TEL exceedences for each parameter in each data set. Index scores (described above) for each site in the individual data sets from Table 2-1 were determined and mapped using an ARC-INFO 6.1 UNIX system. Results are presented in Appendix B. For ease of map interpretation, sediment chemistry metals and organic compounds have been mapped separately for some of the data sets. Appendix C includes tables listing all sampling sites, and the number of PEL/TEL exceedences for each parameter at each site.

The main objective of this project was to investigate the overall coverage of Tampa Bay for all data sets, and for synoptic SQT data. To this end, data sets of the same type, and all data sets, were mapped together and are shown below. Also, the triad data are presented below to illustrate the extent of bay coverage that this method provides using existing information, and to evaluate spatial trends in potential sediment contamination as indicated by the SQT.

In addition, areas of the bay bottom that have been physically altered, and areas with sediments with higher than average fines content (Coastal 1994) have been mapped. These maps provide valuable information for evaluating the significance of potential sediment contamination. Areas with physically altered conditions may not support healthy benthic communities, even in the absence of contaminants. Also, sediments with a high content of fine-grained particles often exhibit higher concentrations of metals and organic compounds than adjacent coarser-grained sediments. Finally, sediment characteristics may influence the diversity and abundance of benthic organisms, independent of contaminant levels. Appendix D presents maps showing physically altered areas of Tampa Bay. Appendix E shows areas of fine-grained sediments.

- Combined Data Sets

Benthic Organisms

An application of the Shannon Index to the combined TBNEP/EMAP design 1993 data (Grabe et al. 1995) and MacDonald (unpublished) benthic data is presented on Figure 3-1. Both data sets show similar spatial tendencies, with most sites in the lower diversity quartiles occurring in areas more likely to be impacted by sediment contaminants. As stated above, hypoxic conditions are periodically reported in shallow portions of the bay, especially Hillsborough Bay (Johansson and Squires 1989). Additionally, many of the areas with low diversity Shannon Index scores are in areas of the bay subject to impacts from the physical disturbance of sediments such as wind-driven or shipping activities. These factors could affect the results of the benthic analysis as much as contaminated sediments.

All Studies (Sediment Chemistry - Metals and Organics)

Figures 3-2 and 3-3 present the combined mapping of all sediment chemistry data sets. Results of metals and organics analysis are included. The index score ("0", "1", "2", or "3") indicates the total number of metals and organic PEL and TEL exceedences at each sampling site, in the same manner as the individual data set maps.

This map shows a clear spatial trend in elevated sediment concentrations of contaminants of concern. Many of the sites near known or potential sources of contaminant inputs (Port of Tampa, upper and lower Hillsborough Bay, coastal Pinellas County -- especially near Bayboro Harbor and Boca Ciega Bay, Port Manatee, and the Manatee River), show multiple PEL and TEL exceedences.

It is likely that two factors contribute significantly to observed high concentrations of contaminants of concern. First, many of the areas with multiple PEL and TEL exceedences are near sources of contaminants. Although potentially toxic materials can enter the bay through atmospheric deposition and groundwater seepage, surface water inflow is a likely pathway for large amounts of contaminants (Frithsen et al. 1995). Many areas identified as having high contaminant concentrations are adjacent to or near surface water discharge points that may convey significant amounts of contaminants into the bay. These discharges may

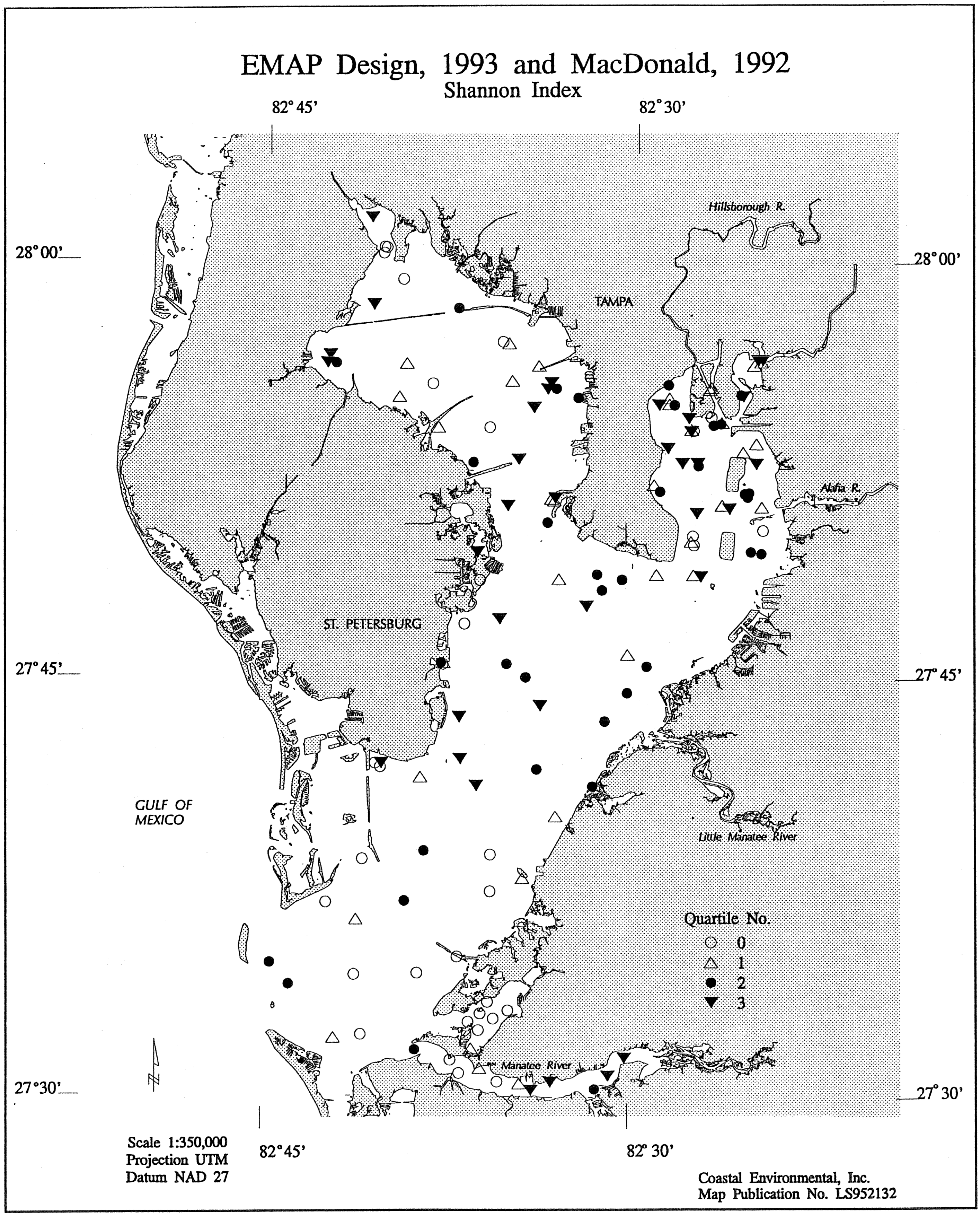

Figure 3-1. TBNEP/EMAP design (1993) and MacDonald (unpublished) Shannon Index scores.

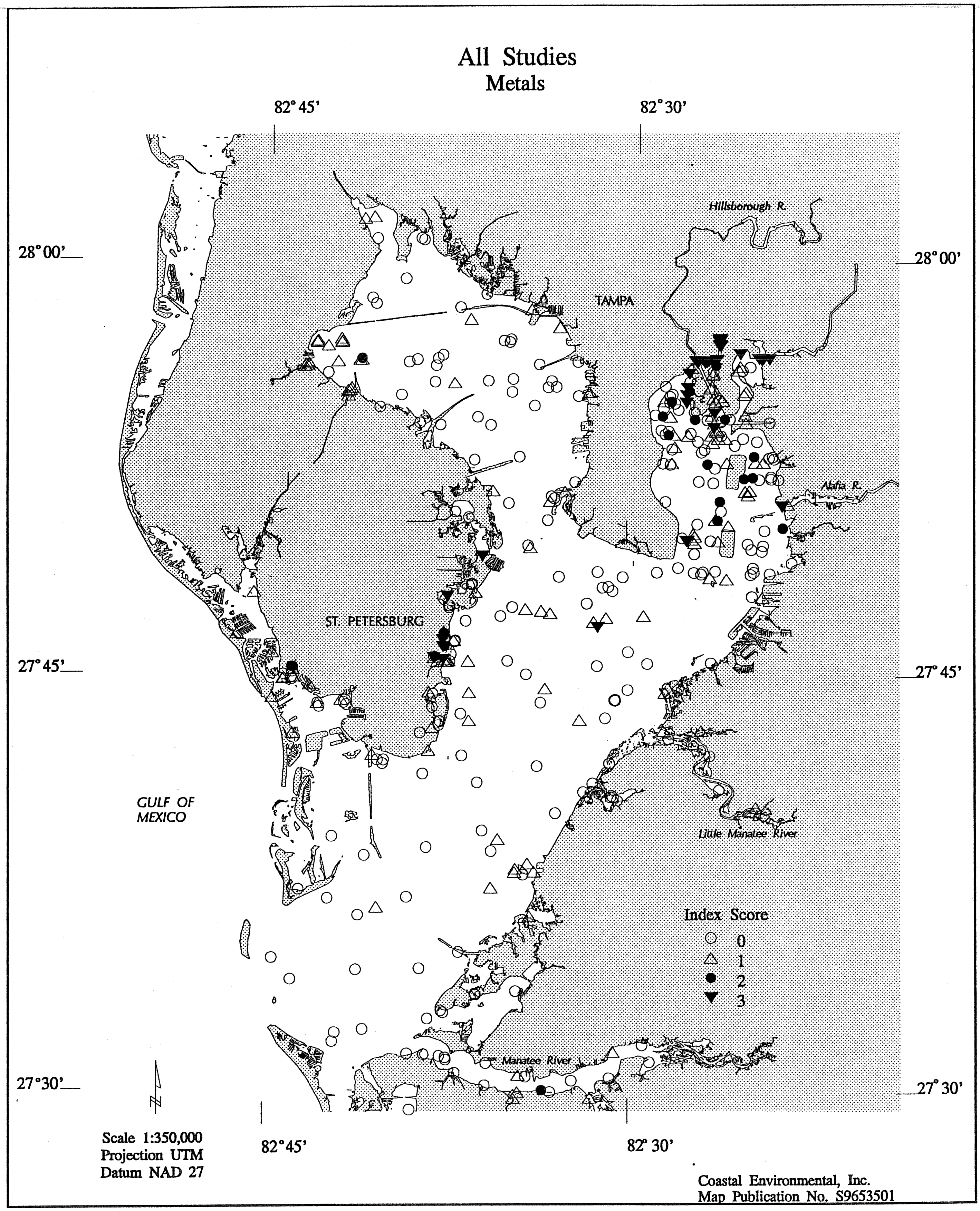

Figure 3-2. All studies (sediment chemistry - metals).

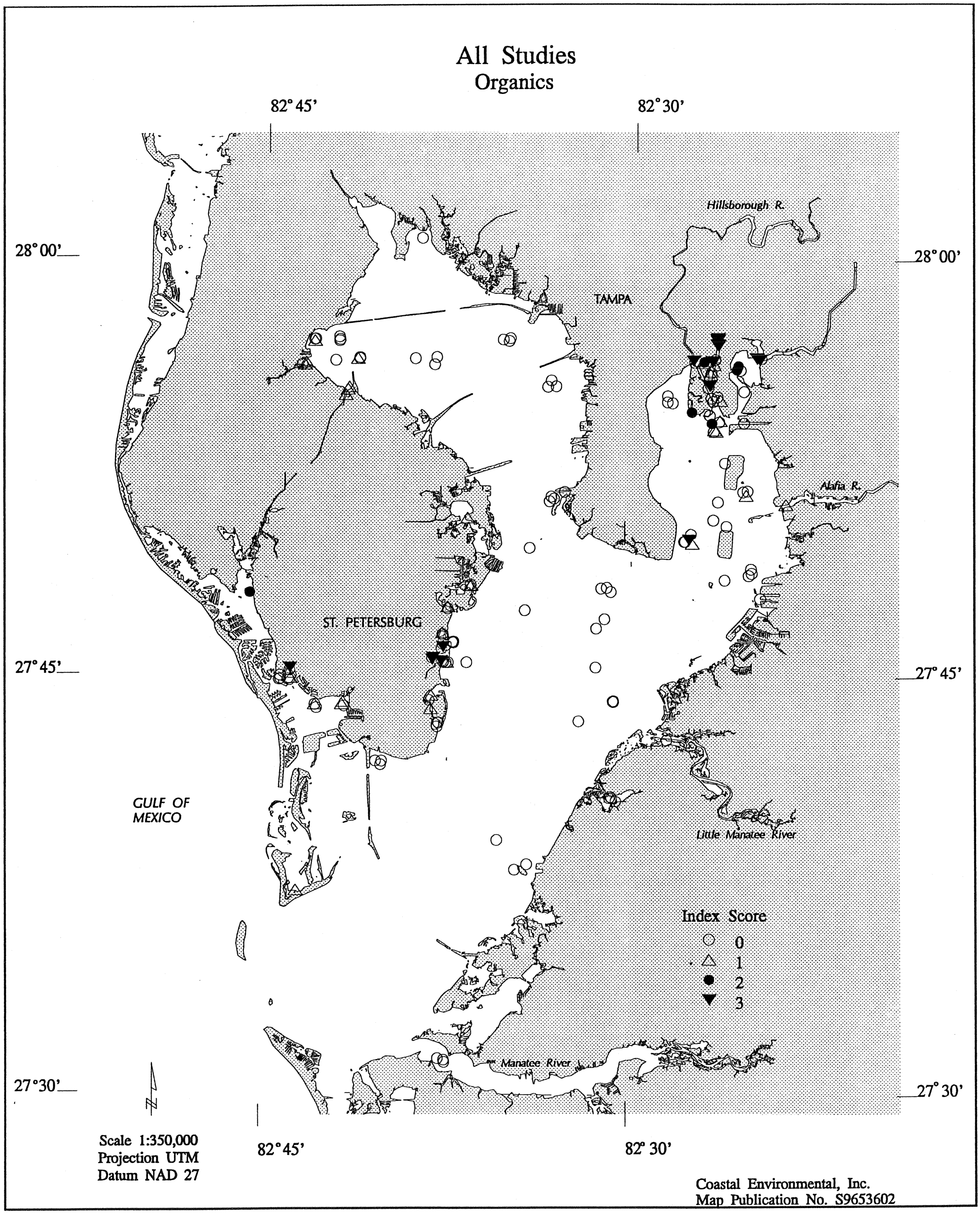

Figure 3-3. All studies (sediment chemistry - organics).

include recent or historical inputs of by-products and wastes of industrial, urban, or agricultural activities.

The second factor that may significantly contribute to the observed high concentrations of contaminants of concern in bay sediments are the sediment characteristics and depositional environment. Stormwater runoff carries with it fine-grained particulate material (suspended solids), which may in turn carry metal or organic contaminants. The fine-grained materials are deposited along the shore near outfalls, where they may accumulate because of the frequency of inputs, the low-energy environment in the protected nearshore areas, or their transport and accretion due to currents. Thus, the occurrence of high sediment contaminant concentrations may be the result of both sources and the depositional environment.

All Studies (Sediment Chemistry, Toxicity, and Benthic)

Figures 3-4, 3-5, 3-6, and 3-7 present the combined results of all three types of testing -- sediment chemistry, toxicity tests, and benthic community assessment. All data sets shown in Table 2-1 were summarized and used for these figures. The index scoring for these sites ("0", "1", "2", or "3") indicates the highest index score for any of the three types of testing. Different individual index scores were not added, and only the highest individual index score is shown at a site. For example, if both sediment toxicity and chemistry testing occurred at a site, and one PEL exceedence and one positive toxicity test result were observed, then the overall index score was counted as "2" (for the PEL exceedence), not "3". For this analysis, it was assumed that a score for any test result was equivalent and as reliable as the same numeric score for a different test result (e.g., a score of "2" for sediment chemistry held the same weight as a score of "2" for toxicity testing).

For ease of interpretation, four maps are presented, each showing all sites that received a single index score value. Low scores may indicate either a partial set of tests or a relatively low potential for impacts, but high scores may be interpreted to indicate a high potential for impact. The maps provide insight into the overall conditions of Tampa Bay sediments. Figure 3-4 shows sites with an index score of 0, which represent the least impacted of the sampling sites or incomplete data. It should be noted that many "clean" sites are found throughout the bay, including many areas of contaminant input and accumulation.

Figure 3-5 shows sites with an index score of 1, which may represent sampling sites with relatively little potential impact or incomplete data. Again, many of these less impacted sites are found throughout the bay, including areas of contaminant input and accumulation. Figure 3-6 shows sites with an index score of 2, which represent sampling sites with moderate impact. These moderately impacted sites begin to show a more discernible spatial trend, and are observed more frequently in areas of contaminant input and accumulation. It is interesting to note that, while the higher scoring (2) benthic sites are spread throughout the bay, the sites

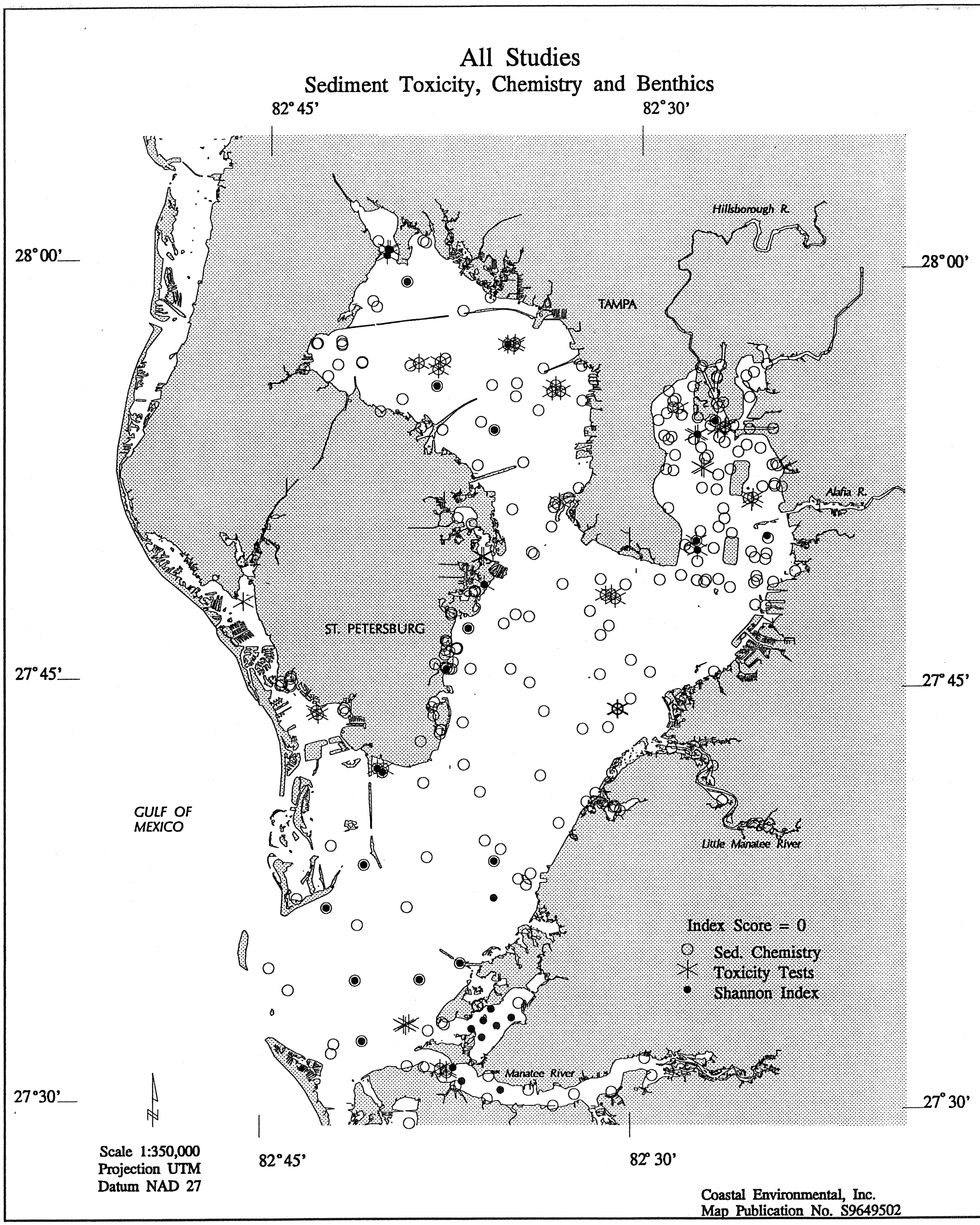

Figure 3-4. All studies (sediment chemistry, toxicity, and benthics) with an overall index score of 0.

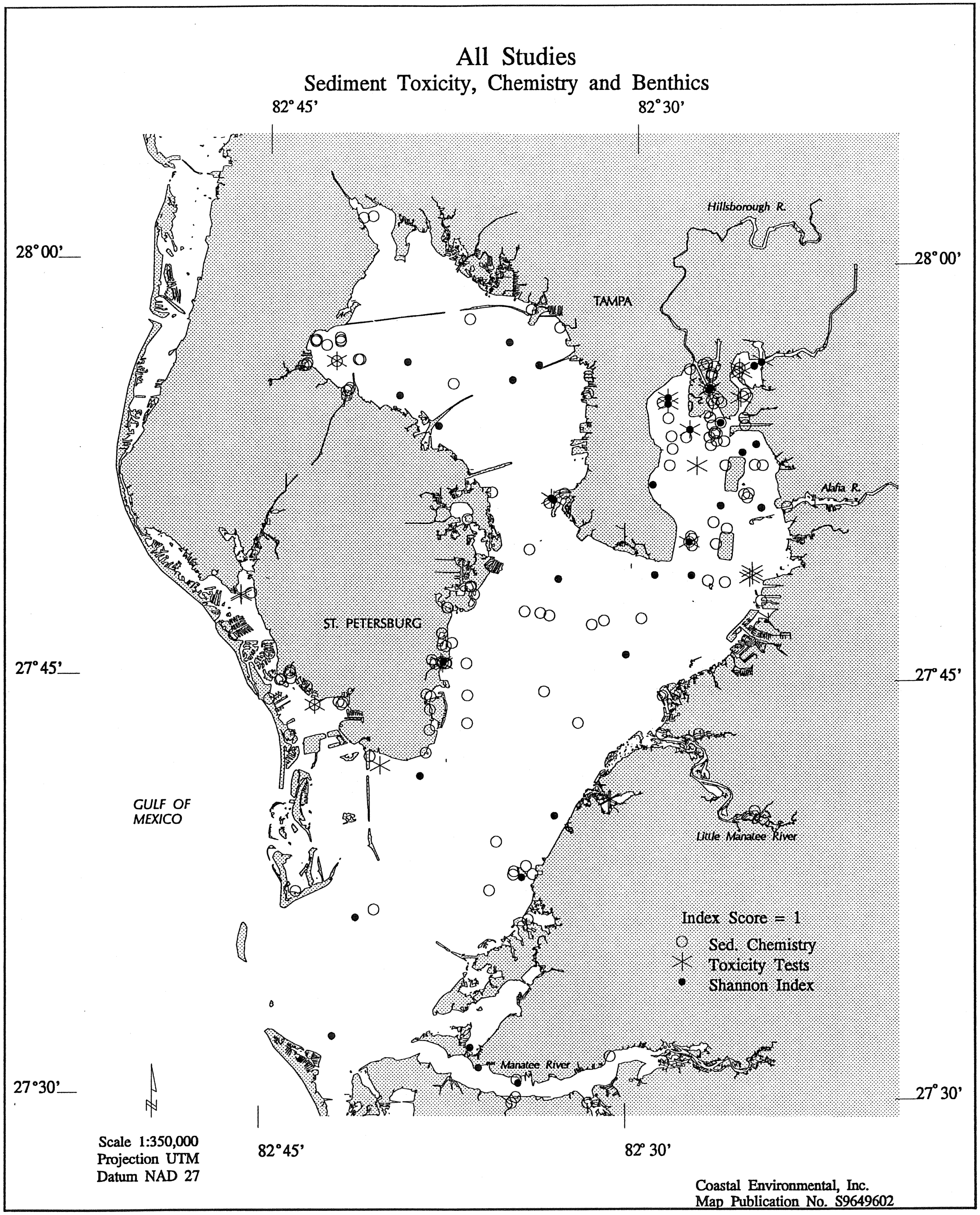

Figure 3-5. All studies (sediment chemistry, toxicity, and benthics) with an overall index score of 1.

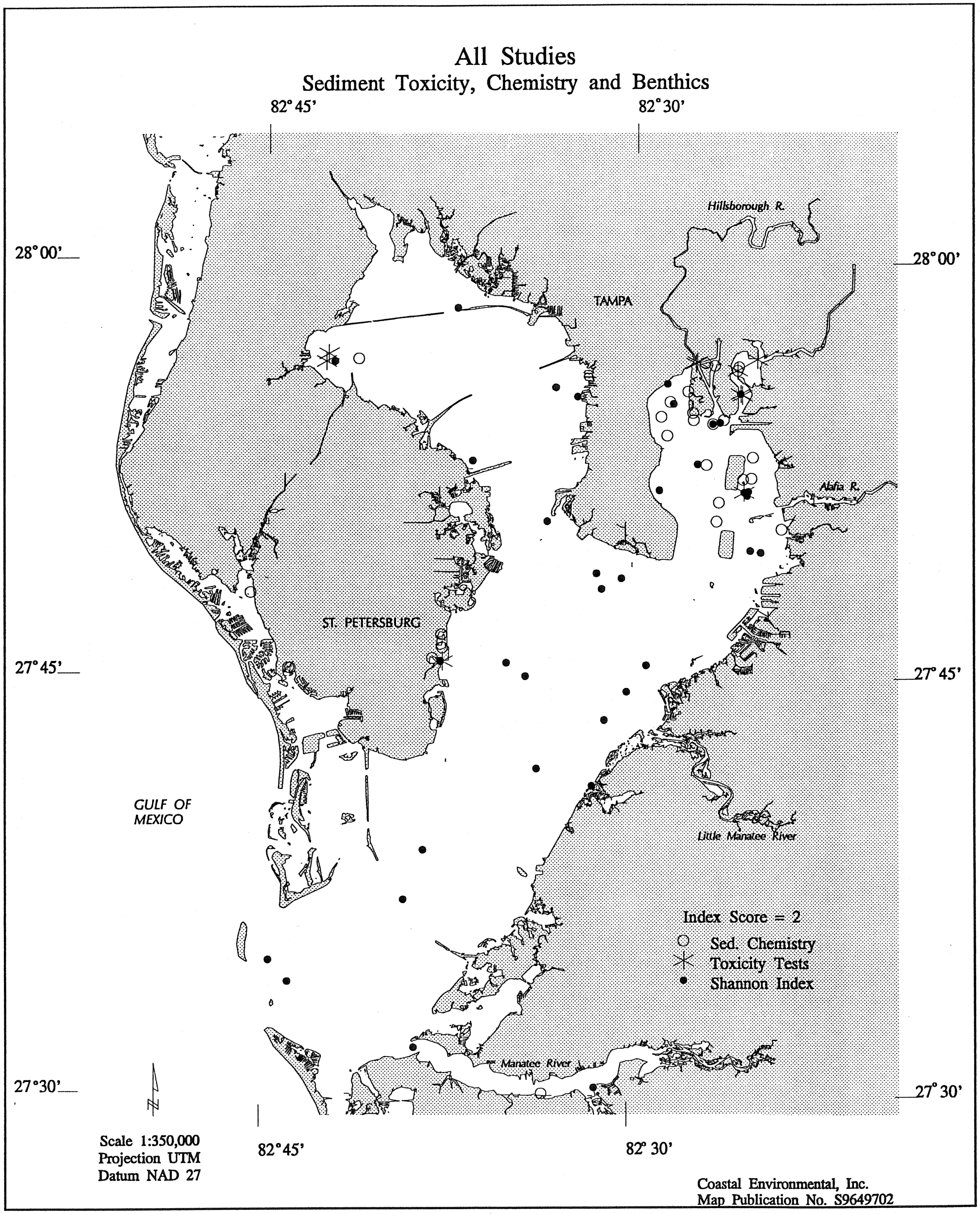

Figure 3-6. All studies (sediment chemistry, toxicity, and benthics) with an overall index score of 2.

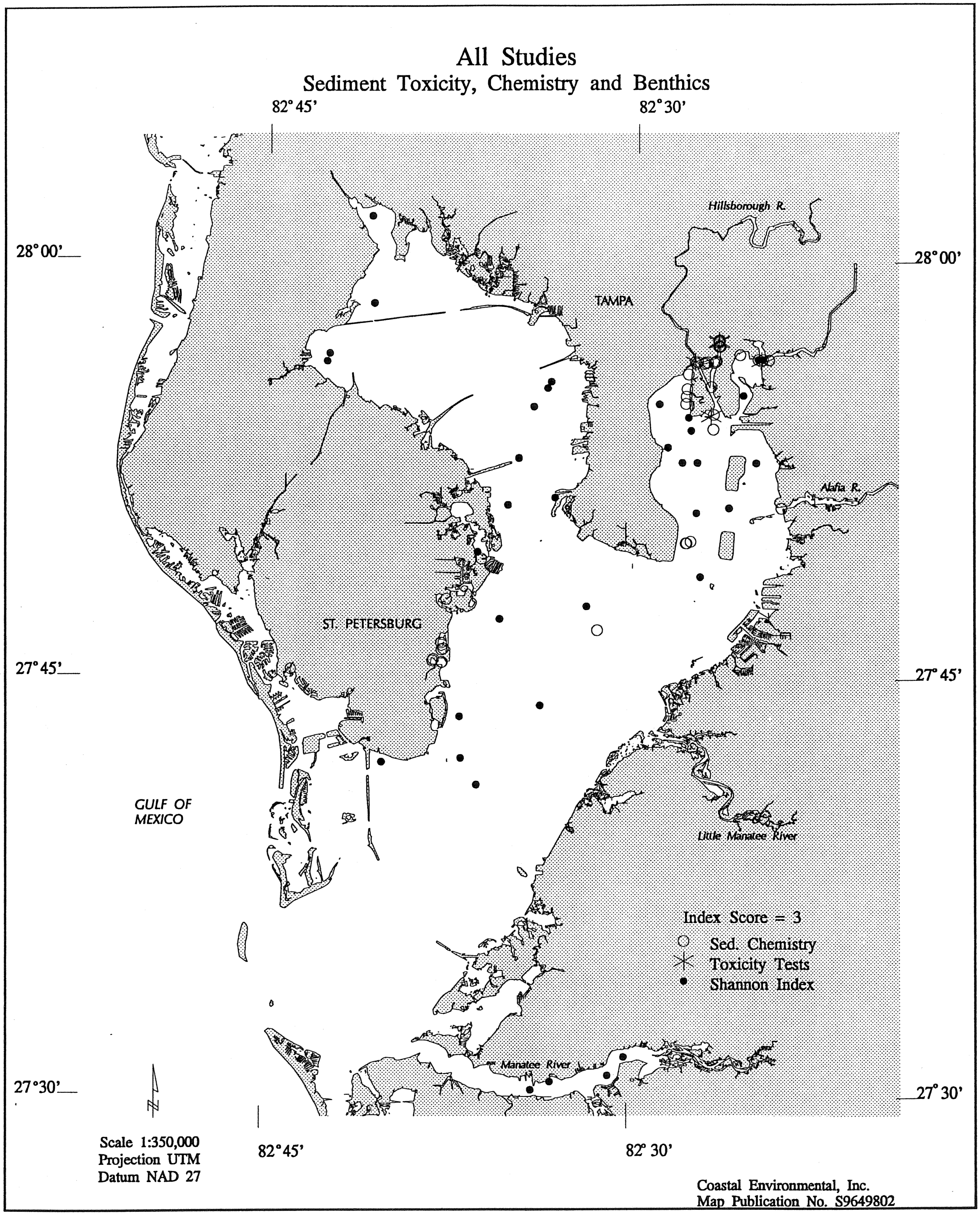

Figure 3-7. All studies (sediment chemistry, toxicity, and benthics) with an overall index score of 3.

with a score of 2 by virtue of toxicity or sediment chemistry testing are totally confined to areas subject to urban runoff or point source inputs, or to Hillsborough Bay.

Figure 3-7 shows sites with an index score of 3, which represent sampling sites with the highest potential impact. These most impacted sites show a notable spatial trend, and are clearly observed more frequently in areas of known or suspected contaminant input and accumulation. Sites with an index score of 3 are observed in Hillsborough Bay, coastal Pinellas County (especially Bayboro Harbor and Boca Ciega Bay) and the Manatee River. Again, the high scoring benthic sites are spread throughout the bay, but (with one exception) sites with a score of 3 resulting from toxicity or sediment chemistry testing are totally confined to coastal regions and Hillsborough Bay.

This suggests that existing testing methods are not unambiguous in terms of identifying contaminated areas, and, more importantly, that the entire series of maps should be considered as a whole, not individually. Also, the frequency of sampling in the bay segments needs to be considered when interpreting these figures. It would be erroneous to make conclusions regarding the relative level of sediment contamination in areas of the bay based solely on the number of sites with index scores of 2 or more found in a bay segment.

Triad Synoptic Sites

The more rigorous synoptic triad sampling sites, which yielded simultaneously sampled data for sediment chemistry, toxicity testing, and benthic analysis, from Long et al. (1994) and MacDonald (unpublished) are shown in Figures 3-8 through 3-11. Two factors are evident from a review of these figures. First, although the combination of these data within tight spatial and temporal limits provides a good degree of certainty with the results, there is not a full coverage of the bay using only these sites. Second, the spatial trends from the triad sites are very similar to the pooled data, with lower index score sites spread over the entire bay, including areas of suspected of observed contamination, and the higher index score sites focusing on the coastal and urban areas.

Section 4 summarizes and discusses these findings, and recommends future work to better characterize the potential for toxic effects on, and provide management guidance to protect, Tampa Bay's living resources.

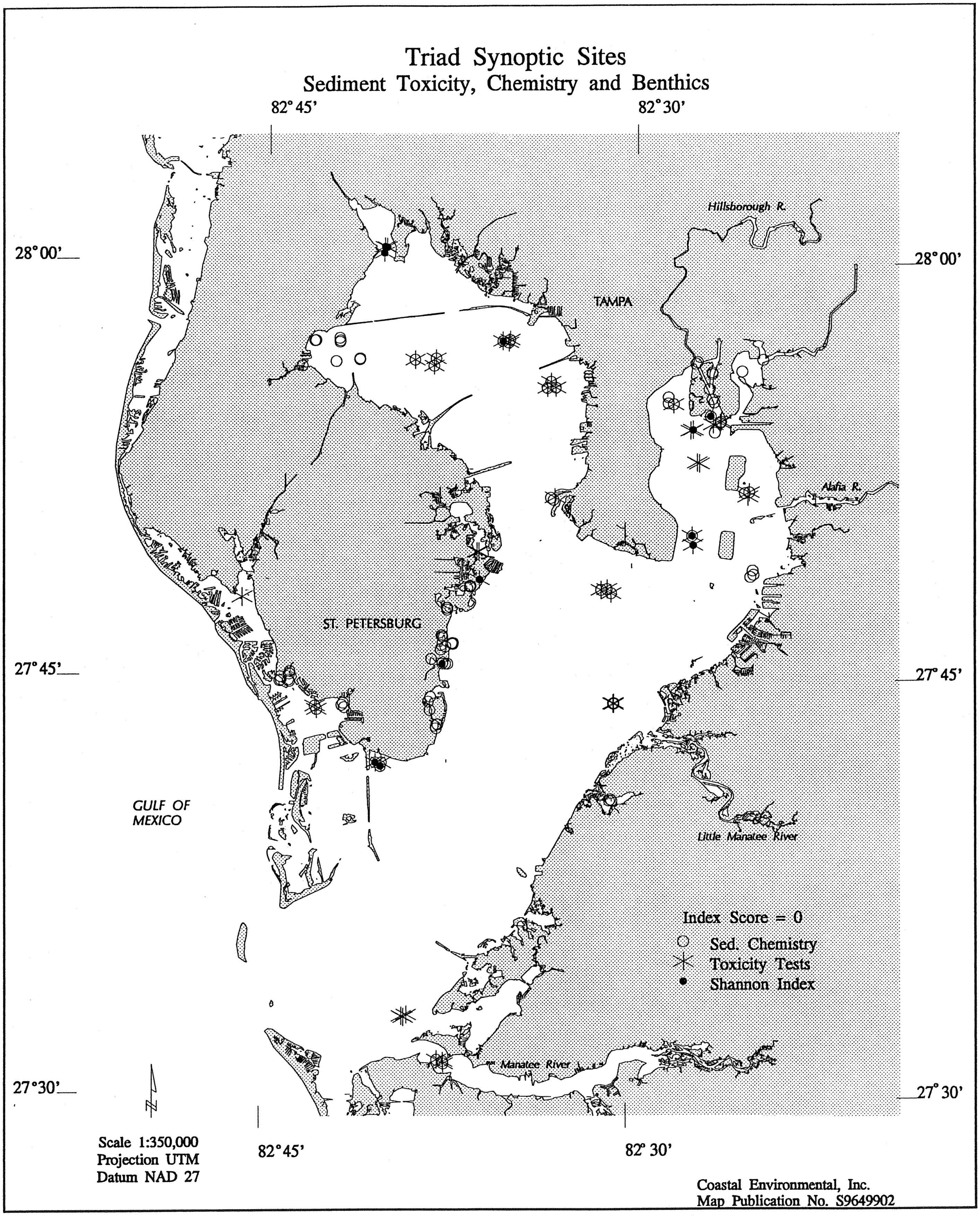

Figure 3-8. Synoptic triad sites with an overall index score of 0.

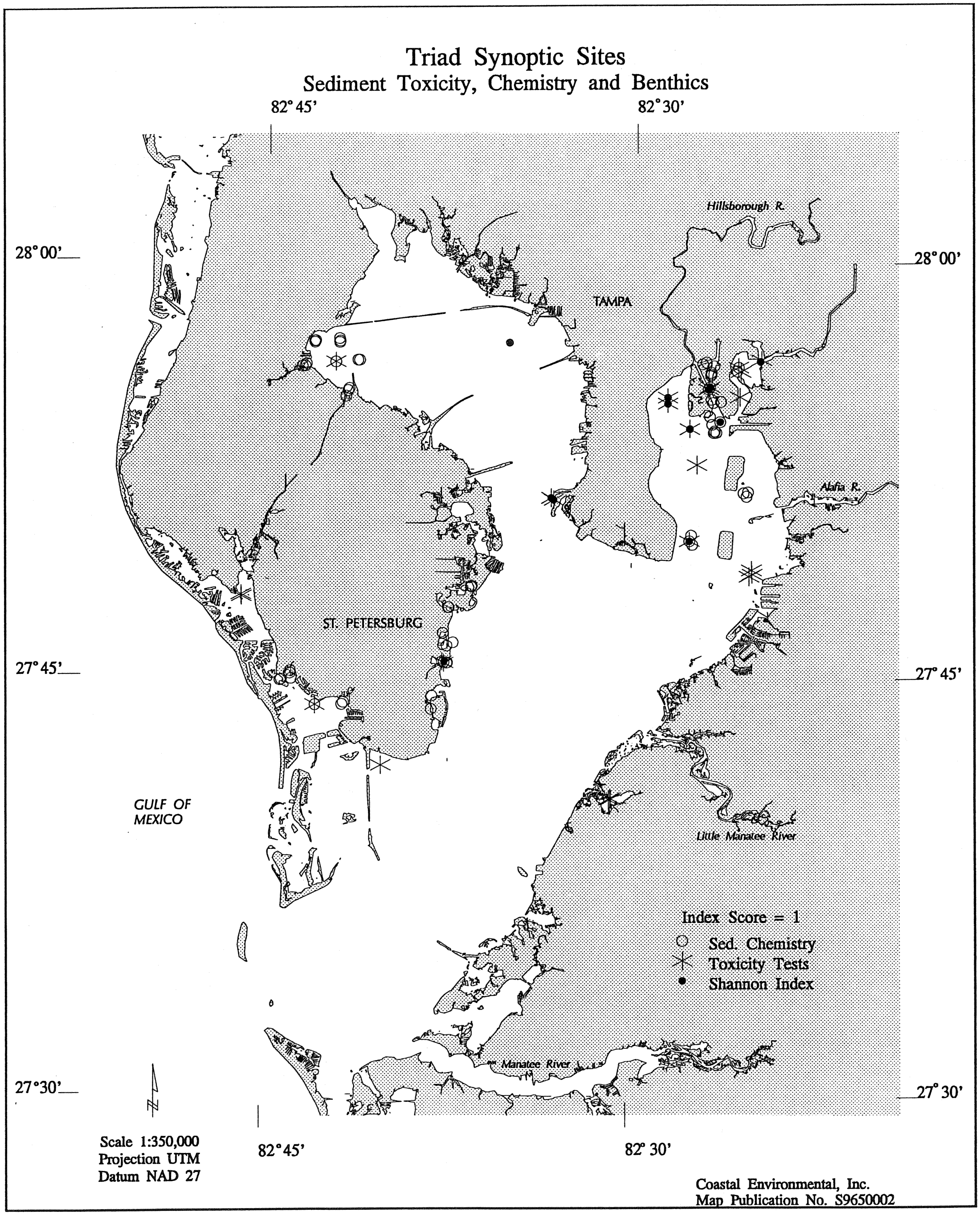

Figure 3-9. Synoptic triad sites with an overall index score of 1.

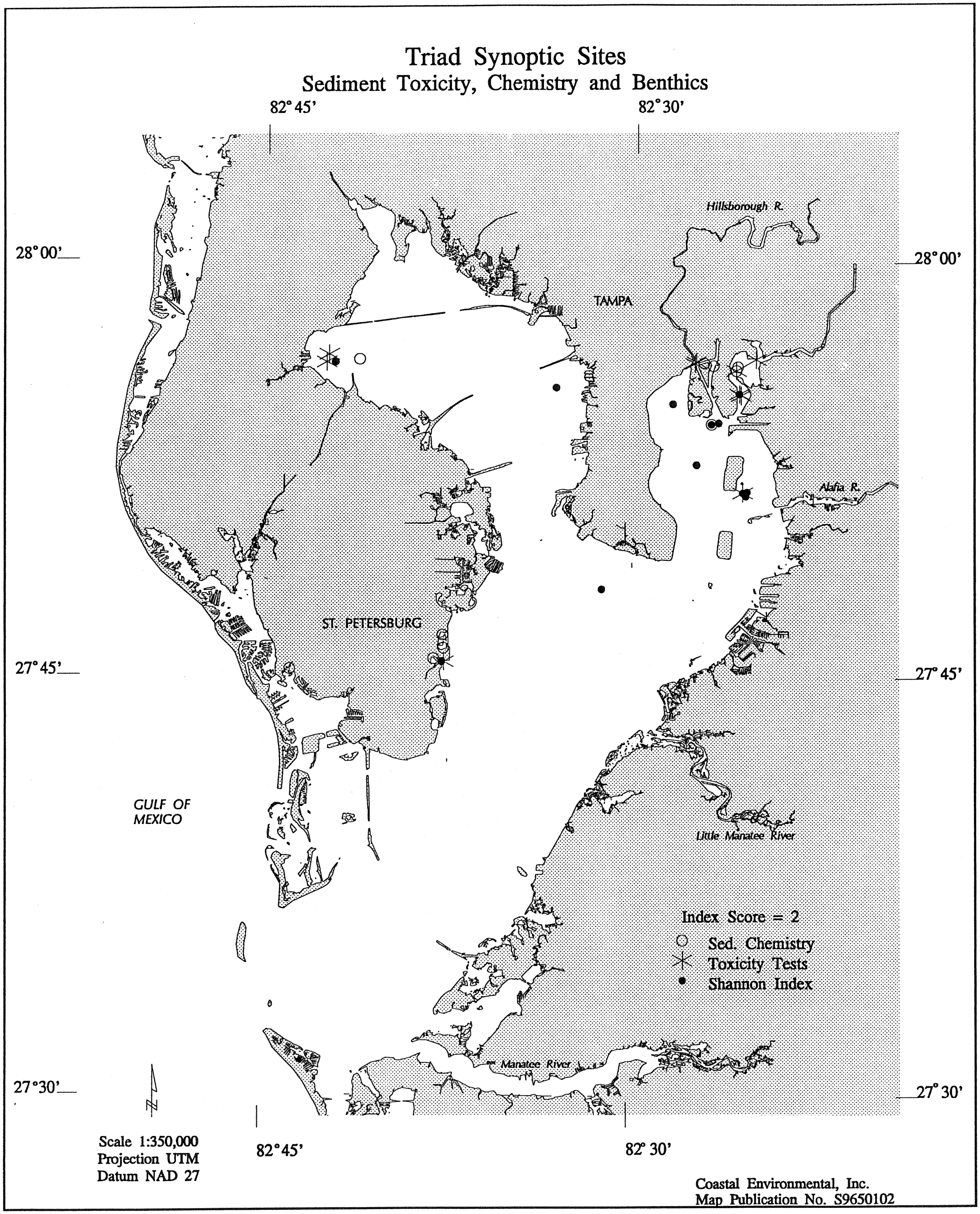

Figure 3-10. Synoptic triad sites with an overall index score of 2.

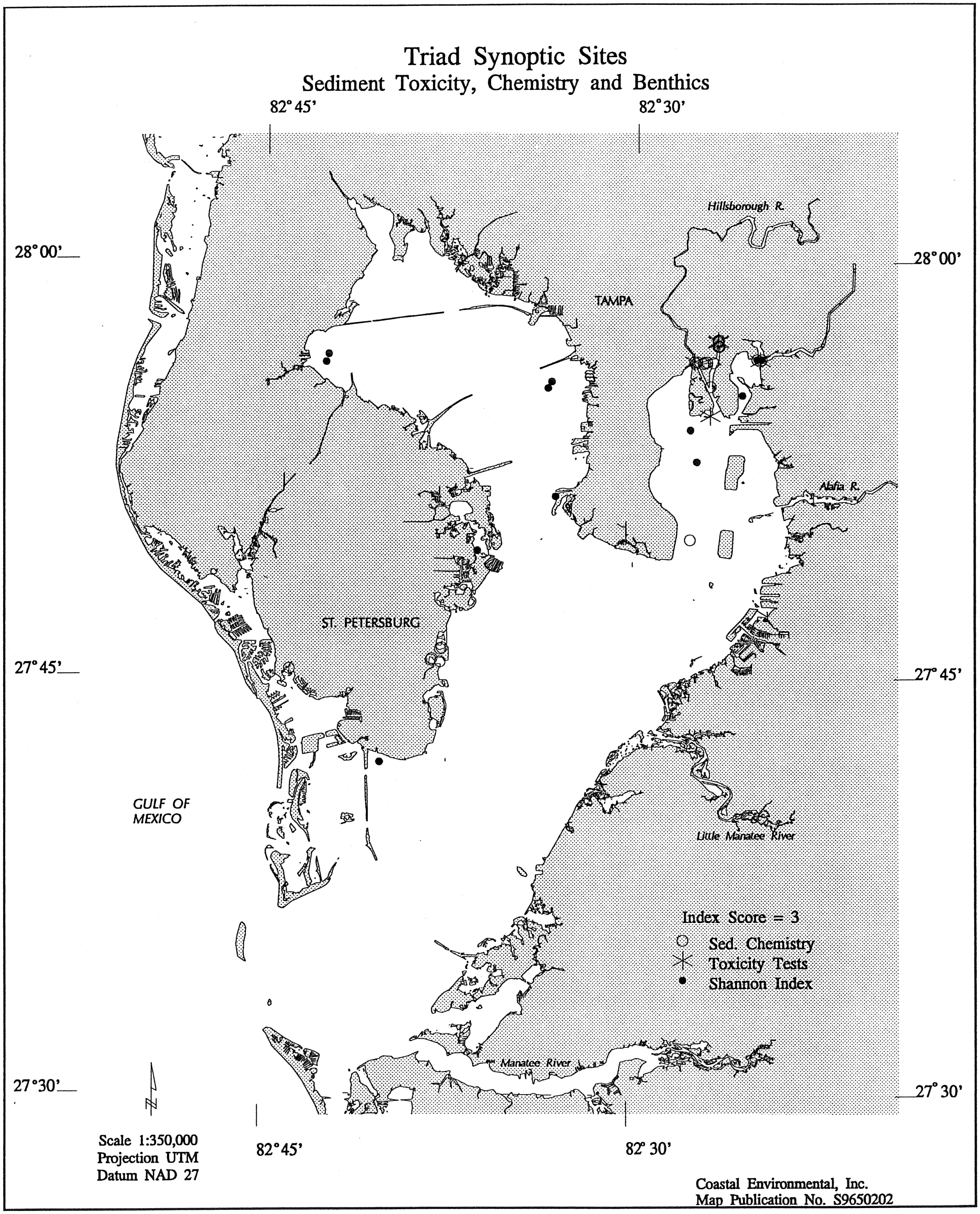

Figure 3-11. Synoptic triad sites with an overall index score of 3.

SECTION 4.0 DISCUSSION AND RECOMMENDATIONS

Sediment contamination is being addressed in TBNEP's Comprehensive Conservation and Management Plan (CCMP), which seeks to help coordinate management activities for Tampa Bay and its watershed. In support of the CCMP's Toxic Action Plan (TAP), a workshop of the Science Advisory Group (SAG) on Sediment Assessment was held, with the objective of providing TBNEP with guidance for establishing contaminant loading targets to Tampa Bay. During the workshop, discussions focused on the usefulness of the following three methods of sediment contamination:

1) comparison of sediment chemical concentrations and empirically derived threshold effects levels (probable effects levels - PEL, and threshold effects levels - TEL);

2) sediment and pore water toxicity tests; and

3) assessments of benthic community structure.

Although each of these methods may suggest the occurrence of contaminant impacts, no one method to date can definitively identify the absolute significance of the contamination levels. Therefore, a useful management assessment tool is to evaluate all three methods for the same areas to obtain a series of data that will better quantify potential contamination effects. As stated above, this approach is referred to as the "weight of evidence" approach, and the assessment methods of sediment contamination, when used together, are referred to as the sediment quality triad.

4.1 Discussion

The triad approach may be used in one of two ways. The first method of using the triad is through the synoptic sampling of all three types of sediment characterization (chemistry, toxicity, and benthos). These samples must be collected at the same time from the same location, preferable from the same sample. The synoptic triad, although the most useful and rigorous measure of sediment contamination that was identified at the workshop, is also the most difficult to obtain. Although this level of sampling is to be recommended for future field programs, only one data set for Tampa Bay contains all three types of information (Long et al. 1994 and MacDonald unpublished), and does not provide the wide spatial coverage required for a bay-wide assessment of potential sediment contamination effects, as can be seen from observing Figures 3-8 through 3-11.

The second method is to simply summarize all available chemistry, toxicity, and benthic data for a given area. Although this is a less rigorous approach, it provides a broader spatial coverage of the bay. The results of this second method are shown in Figures 3-4 through 3-7. When using this second method, essentially a mapping overlay, the inherent limitations of using diverse data sets such as seasonal sampling, weather conditions, sampling for different analytes, different sampling or analytical techniques, different minimum detection limits, and other factors must be considered.

The analysis of the pooled data (Figures 3-4 through 3-7) shows that the most impacted sites follow a notable spatial pattern, and are clearly observed more frequently in areas of known or suspected contaminant input and accumulation. Sites with an overall index score or 3 are observed in upper and lower Hillsborough Bay, coastal Pinellas County (especially Bayboro Harbor, near the Allen's Creek outfall, and Boca Ciega Bay), Port Manatee, and the Manatee River. These areas all receive surface water runoff and groundwater seepage from urban areas with intensive commercial, industrial, residential, and other activities.

Results from the synoptic triad sites are presented in Figures 3-8 through 3-11. As can be seen, the number and distribution of these sites is too limited to make any conclusions regarding the extent and severity of sediment contamination using those data alone. In addition, those sites that were sampled were often purposefully located in areas of suspected contamination, so the results of this sampling effort, as well as being limited in spatial extent, are biased in terms of providing an estimate of the overall extent of sediment contamination in Tampa Bay. However, as stated above, these factors are not shortcoming of the data collection effort, but merely reflect the objectives of that particular monitoring program.

The overall index scores for all sites are illustrated in Section 3. Sampling site identification figures are presented in Appendix C. The specific parameters that had elevated concentrations at any site are indicated in Appendix D. The tables in Appendix D provide a valuable tool for identifying and managing potential sources of contaminants. However, when reviewing the results presented in Section 3, several factors should be considered in the interpretation.

For example, it should be noted that hypoxic conditions are periodically reported in shallow portions of the bay, especially Hillsborough Bay (Johansson and Squires 1989). This factor has been positively correlated with low diversity in benthic communities (Coastal 1995). Salinity is also a factor that can affect benthic diversity. Additionally, many of the areas with low index scores are in areas of the bay subject to impacts from disturbance of the sediments, either by wind-driven or shipping activities. Either of these factors could affect the results of the benthic analysis as much as contaminated sediments (Grabe et al. 1995).

It is likely that two other factors contribute significantly to observed high concentrations of contaminants of concern. First, many of the areas with multiple PEL and TEL exceedences are near sources of contaminant inputs. Although potentially toxic materials can enter the bay through atmospheric deposition and groundwater seepage, surface water and point source inflows are likely pathways for large amounts of contaminants (Frithsen et al. 1995). Most of the areas identified as having high concentrations of toxicants are adjacent to or near surface water discharge points that may convey significant amounts of contaminants into the bay. These discharges may currently include, or historically have included by-products and wastes of industrial, urban, or agricultural activities.

Other factors that may significantly contribute to the observed high concentrations of contaminants of concern in nearshore bay sediments are sediment characteristics and depositional environment.

Stormwater runoff carries with it fine-grained particulate material (suspended solids), which may in turn carry metallic or organic contaminants. The fine-grained materials are deposited along the shore near outfalls, where they may accumulate because of the frequency of inputs and the low-energy estuarine environment in the protected nearshore areas. Thus, the occurrence of high sediment contaminant concentrations may be the result of both sources and inputs, and the depositional environment.

Fine-grained sediments with high organic content may scavenge many pollutants for several reasons. Many of the fine-grained particles have been ingested and excreted by filter feeders and have a reactive organic coating. Also, clay minerals have highly attractive charges within their molecular structure. Finally, fine-grained sediments have a high surface area to volume ratio, which presents more attractive surfaces for binding chemicals (Brooks and Doyle 1992).

The accumulation of potential contaminants to sediments raises the issue of bioavailability. As contaminants settle towards the bottom, they may be ingested by filter feeders and excreted into the sediments. This reduces the bioavailability of many compounds for most organisms except deposit feeders, which may ingest the material once on the bottom. This biological cycling makes contaminants biologically unavailable for most organisms, thus sediment toxicity would be effectively lower than predicted using a PEL/TEL approach.

It should also be noted that the percent fines in sediments can influence the type and number of benthic organisms found at a site, regardless of the sediment chemistry. This factor will also influence benthic community analysis.

The frequency of sampling in the bay segments should also be considered when interpreting the above figures. It would be erroneous to interpret the figures and make conclusions regarding the relative level of sediment contamination in areas of the bay based solely on the number of sites with index scores of 2 or more found in a bay segment. For example, it would be incorrect to state that Hillsborough Bay is the most contaminated bay segment because it has more sampling sites with index scores of 2 or more than any other bay segment. Although Hillsborough Bay does exhibit the most extensive sediment contamination of any bay segment, the large numbers of sampling sites in Hillsborough Bay relative to other segments skews an analysis of this type.

A better method of interpretation is to examine the percentage of sites sampled to those sites with high index scores. Table 4-1 shows, for each bay segment, the total number of sampling sites reported, and the number of sites with each index score. In Table 4-1, the number of sampling sites with each index score are shown, and the percentage of total sites sampled within a bay segment with each index score are also shown (in italics). As can be seen, the segments with the highest percentage of high index scores are Boca Ciega Bay (32%), Hillsborough Bay (31%), and Old Tampa Bay (24%). The lowest number of high index scores were observed in Terra Ceia Bay (0%).

One of the objectives of this project was to identify data deficiencies, and indicate areas with insufficient data to assess sediment characteristics. Based on the mapping of individual and pooled data sets, there appears to be a relatively good coverage on a bay-wide basis for all data types. Areas with relatively few sampling sites include northeast Old Tampa Bay and northeast Middle Tampa Bay.

There are also many nearshore sites near large urban or agricultural outfalls that may well exhibit sediment contamination also, but the level of effort required to identify contaminated sites on a small scale is so large as to be infeasible, except on a selected basis. One of the aspects of determining the extent and severity of sediment contamination is the site-specific and localized nature of the effects of contaminant inputs. Because of this, it is infeasible to expect to collect sufficient data to discretely delineate all contaminated areas. Therefore, screening tools such as the use of indicator sediment chemistry parameters or screening-level toxicity tests are very important in the management of potentially toxic contaminants. Other means of maximizing the information gained with respect to the level of effort for data collection is to identify potential sources and areas most at risk (most sensitive) prior to initiating sampling.

Table 4-1. Summary of overall index scores by bay segment (all studies).

Bay Segment	Total Sampling Sites	Index Score = 0 (no.)/(%)	Index Score = 1 (no.)/(%)	Index Score = 2 (no.)/(%)	Index Score = >3 (no.)/(%)
Old Tampa Bay	104	50 *48*	16 *15*	13 *12*	25 *24*
Hillsborough Bay	211	85 *40*	32 *15*	29 *14*	65 *31*
Middle Tampa Bay	134	69 *52*	20 *15*	19 *14*	26 *19*
Lower Tampa Bay	39	24 *62*	7 *18*	7 *18*	1 *3*
Boca Ciega Bay	40	17 *42*	7 *18*	3 *8*	13 *32*
Terra Ceia Bay	11	10 *91*	1 *9*	0 *0*	0 *0*
Manatee River	31	17 *55*	3 *10*	5 *16*	6 *19*

One other interesting result of the mapping is the large number of "clean" sites found in Hillsborough Bay and other areas that have the most contaminated sites as well. This demonstrates the site specific and variable nature of sediment contamination, and suggests that existing testing methods are not unambiguous in terms of identifying contaminated areas.

The scope of work for this project, discussed in detail in Section 1, presented ambitious goals for assessing Tampa Bay's sediment quality and potential effects on living resources. Many data sets were identified, analyzed, and used to produce maps of individual data sources, and of pooled sources. It was desired to identify regions of the bay as "highly contaminated", "restorable", "protectable areas", or "unknown areas" with insufficient data to make an assessment. Based on the individual and pooled data, general assignments can be made for most areas of Tampa Bay:

- **Highly contaminated areas -** Based on the pooled data set mapping of sites with index scores of 2 or 3, the most highly contaminated areas in Tampa Bay include upper Hillsborough Bay, Bayboro Harbor, Boca Ciega Bay and northeast coastal Pinellas County. Appendix D presents a list of which parameters exceeded PEL and TEL levels for each sampling site. Those data are valuable for identifying potential sources of contaminant inputs.

- **Restorable areas -** Restorable (slightly impacted) areas include much of the bay bottom. Many areas of the bay exhibit low overall index scores (score of 1), which indicates some impact but not necessarily totally degraded conditions. The pooled data figure (Figure 3-24) shows sites with index score of 1 spread throughout the bay. This suggests that the impacts of contaminant loading are fairly widespread, but that the level of degradation is not advanced to date, however, incomplete data sets also contribute to sites not indicating high impairment potential.

- **Protectable areas -** Relatively unstressed areas that can be protected from any further degradation include sites with an overall index score of 0. These sites include much of the lower bay, including much of Lower Tampa Bay and Terra Ceia Bay. The major factors that allow these areas to remain relatively unstressed include a lack of contaminant sources and a dynamic physical environment that does not favor the accumulation of fine-grained sediments or the retention of contaminating substances.

- **Unknown areas, with insufficient data to make an assessment -** As stated above, the areas of the with the least data available include northeast Old Tampa Bay and northeast Middle Tampa Bay. It should be noted that these two areas are relatively near potential sources of contaminant inputs, and represent areas that are of interest for other environmental concerns, such as seagrass recolonization. Because of this, these two sites should be subjected to further sampling.

Finally, one of the objectives of this study was to quantify the areal extent of the above-classified areas. This task proved difficult because of the nature of the data that were available for analysis. If it is desired to estimate an areal coverage as represented by individual data points, it is necessary to design the sampling program to meet this objective. One of the major assumptions of using a data set for this purpose is that the sampling locations were selected at random. Because many different data sets were used for this analysis and because several of those data sets resulted from sampling programs that were intended to target contaminated areas, the assumption of random site location does not hold. In fact, only the TBNEP/EMAP design 1993 data were obtained from randomly-located sites. Therefore, it is not possible to develop a technically-defensible estimate of the areal extent of sediment contamination based on the data available to date.

In addition, the localized and site-specific nature of sediment contamination effects makes such an extrapolation even more difficult. However, based on the relative density of sampling sites and the overall index scores of the pooled data (not just the synoptic triad data), an attempt has been made to qualitatively delineate contaminated, restorable, protectable, and unknowable areas in Tampa Bay. Figure 4-1 illustrates this delineation, which is not dissimilar to the findings of past sampling analyses. It should be noted that the delineations are generalized, and do not reflect all small-scale potentially contaminated areas.

Contaminated areas generally reflect parts of the bay that are in the vicinity of one or more sampling sites with overall index scores of 2 or 3. Because of the uncertainty of the interpretation of the benthic index scores, more (subjective) weight was given to sediment chemistry and toxicity test results. Areas of the bay that are classified as contaminated include much of Hillsborough Bay, and smaller areas including west-central Old Tampa Bay, Bayboro Harbor, and sections of Boca Ciega Bay. It must be noted that the terms "highly contaminated" and "restorable" are defined for this study on a relative basis, in comparison to other areas of Tampa Bay displaying less, or more, evidence of sediment contamination. Thus, it should not be assumed that portions of the bay delineated as contaminated are not restorable.

Restorable areas include southwest Hillsborough Bay, much of north Old Tampa Bay, west Middle Tampa Bay, much of Boca Ciega Bay, and small areas off Rocky Point, Port Tampa, Port Manatee and in the Manatee River.

Protectable areas include south Old Tampa Bay, east and central Middle Tampa Bay, much of Lower Tampa Bay, Terra Ceia Bay, and much of the Manatee River. Unknown areas, with very sparse or no data, include only a relatively modest part of the bay, including northeast Middle Tampa Bay, upper Lower Tampa Bay, and south Boca Ciea Bay. It must be remembered that these delineations are qualitative in nature, and reflect a visual inspection of the results of the overall index scoring. Long et al. (1994) estimated, in a quantitative sense, the spatial extent of sediment toxic to amphipods in Tampa Bay, but no attempt to provide a technically-defensible spatial trend analysis is made herein.

4.2 Recommendations

The synoptic sampling triad approach provides a relatively rigorous weight of evidence for assessing the extent and severity of sediment contamination. Although abundant sediment chemistry data exist to characterize Tampa Bay, only one data set includes all three legs of the synoptically-sampled triad, as discussed above. In future studies, it would be very advantageous to collect all three types of sediment samples simultaneously to obtain the synoptic triad. This approach would provide the most rigorous data set feasible to assess the extent and degree of sediment contamination in Tampa Bay.

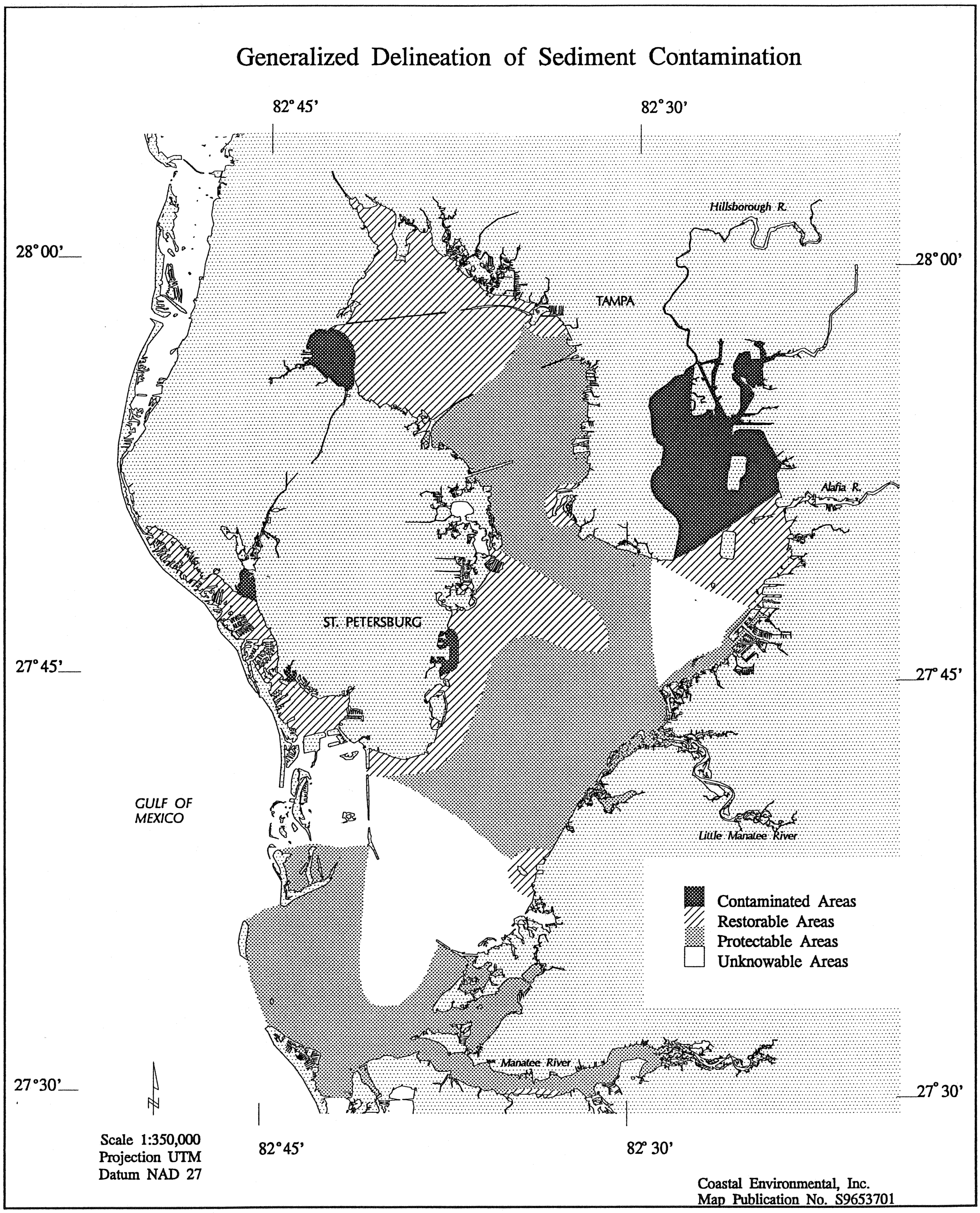

Figure 4-1. General areas of contaminated sediments in Tampa Bay.

The collection and analysis of all three data types can be difficult, time-consuming, and expensive. However, the collection of sediment quality triad data at a selected subset of current monitoring stations would provide a considerable data base with which to measure the association between sediment chemistry and toxicity, assuming a causal relationship between the two.

An alternate approach is to evaluate the applicability of using sediment chemistry or a screening-level toxicity test as an indicator of potential sediment toxicity. Studies to evaluate the correlation between sediment chemistry exceedences of SQAGs and sediment toxicity effects have been completed (Long et al. 1994), and it may be appropriate to predict sediment contamination using chemical analysis alone. This may well provide a more cost and time-efficient means of protecting Tampa Bay's living resources from sediment contaminant effects. For the latter approach, a screening level test must be either selected from current test protocols or developed.

One of the aspects of determining the extent and severity of sediment contamination is the site-specific and localized nature of the effects of contaminant inputs. Therefore, screening tools such as the use of these indicator sediment chemistry parameters or toxicity tests, are very important in the management of potentially toxic contaminants. Other means of maximizing the information gained with respect to the level of effort for data collection is to identify potential sources and areas most sensitive to risk prior to initiating sampling.

Other recommendations for future work include refining estimates of the extent of sediment contamination based on other existing estimates (Long et al. 1994; MacDonald et al. 1995). By synthesizing the results of these works, a more technically-defensible assessment of the estimates of the areal extent of contaminants and their potential impacts may be achieved.

In addition, the consequences of the bioavailability of certain contaminants of concern should be further evaluated. Due to the differences in the mode of toxicity of high molecular weight (HMW) PAHs and low molecular weight (LMW) PAHs, the relative contributions of these two classes of contaminants, and individual PAHs, should be investigated in detail. PAH compounds may vary in origin, method of transport to sediments, release rate from sediments, and affinity for organic tissue (Helmstetter and Alden 1994), as well as degree of toxicity to biota.

Distiguishing between HMW and LMW PAHs is important because of variations in individual compounds', and compound classes', potencies. This variation is reflected it the TELs for HMW PAHs (665 ug/kg) and LMW PAHs (312 ug/kg) (MacDonald et al 1995). However, Long et al. (1994) found that HMW compounds were very highly correlated with both diminished sea urchin egg fertilization and Microtox™ test results.

An initial examination of PAH data suggest that spatial patterns of PAH concentrations in Tampa Bay sediments do vary between HMW and LMW PAHs. Many LMW PAH concentrations (Long et al. 1994) exceeding individual constituent TELs (MacDonald et al. 1995) are confined to sites located in upper Hillsborough Bay, Ybor Channel, and McKay Bay (sites 1, 2, and 3). Compounds included in this suite of LMW PAHs include naphthalene, acenaphthylene, acenaphthene, and flourene. LMW

PAHs phenathral and anthracene were slightly more widely distributed. Several HMW PAHs, in contrast, were found in concentrations exceeding individual TELs at sites 13 (near Big Bend), 15 (western Old Tampa Bay), 16 and 18 (central Old Tampa Bay), 19 (Port Tampa), 23 (near the Little Manatee River), and 24 (southeast Boca Ciega Bay), as well as at sites 1, 2, and 3. The occurrence of elevated concentrations of both LMW and HMW PAHs in Tampa Bay sediments, and the documented carcinogenic properties of many of these compounds (Eisler 1987), should make the further study of the origin, transport, and deposition of PAHs in Tampa Bay a high priority .

Some of these recommendations are being accomplished through an on-going TBNEP project that is attempting to identify potential sources of specific contaminants and perform a risk assessment of the potential for impacts to Tampa Bay's biota. Further work in the field, in the laboratory, and using existing data will further our knowledge of Tampa Bay's sediments and their effect on living resources.

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ERRATUM:

The following citation should be added to Section 5.0, Literature Cited:

MacDonald, D.D. Unpublished data. MacDonald Environmental Services, Ltd. Ladysmith, British Columbia, Canada.

APPENDICES

APPENDIX A - Sediment Sampling Site Locations

APPENDIX B - Results of Individual Data Set Mapping

APPENDIX C - Summary of PEL and TEL Exceedences by Sampling Site

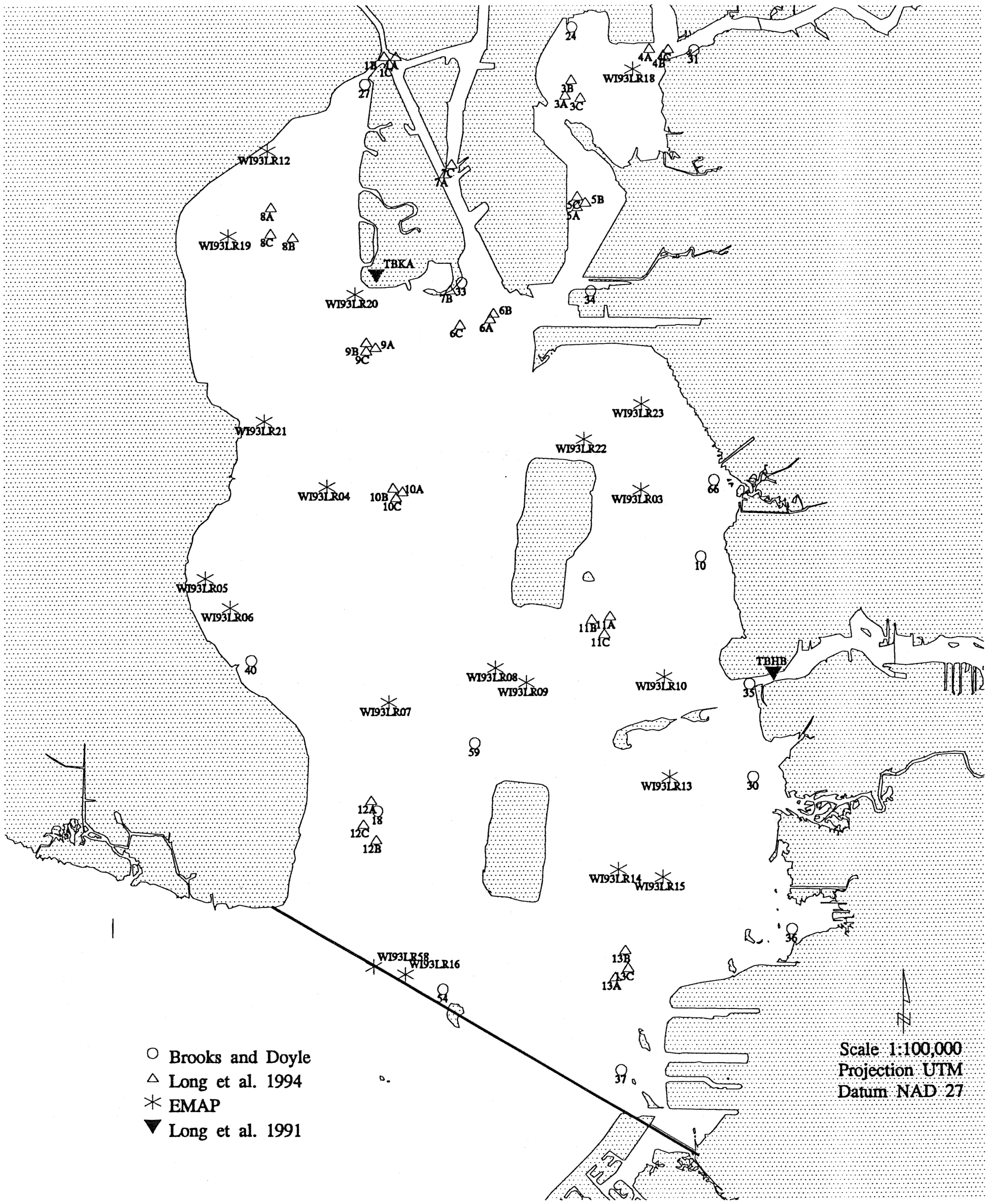
APPENDIX D - Areas of Physical Alteration to Tampa Bay Bottom

APPENDIX E - Tampa Bay Sediment Characteristics

APPENDIX A

Sediment Sampling Site Locations

SAMPLING SITE LOCATION
Hillsborough Bay



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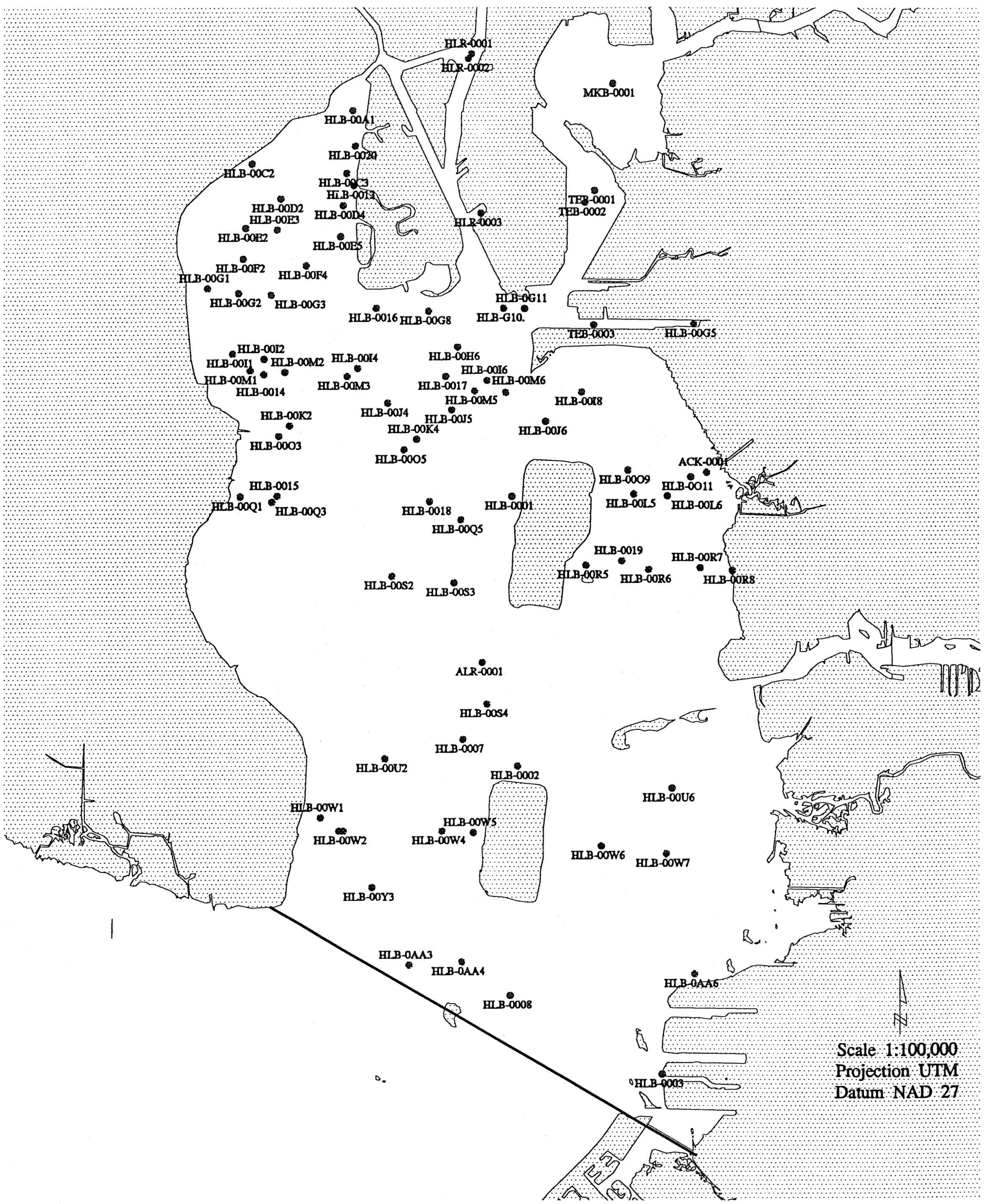
Map Publication No: S9651701

FDEP
Hillsborough Bay



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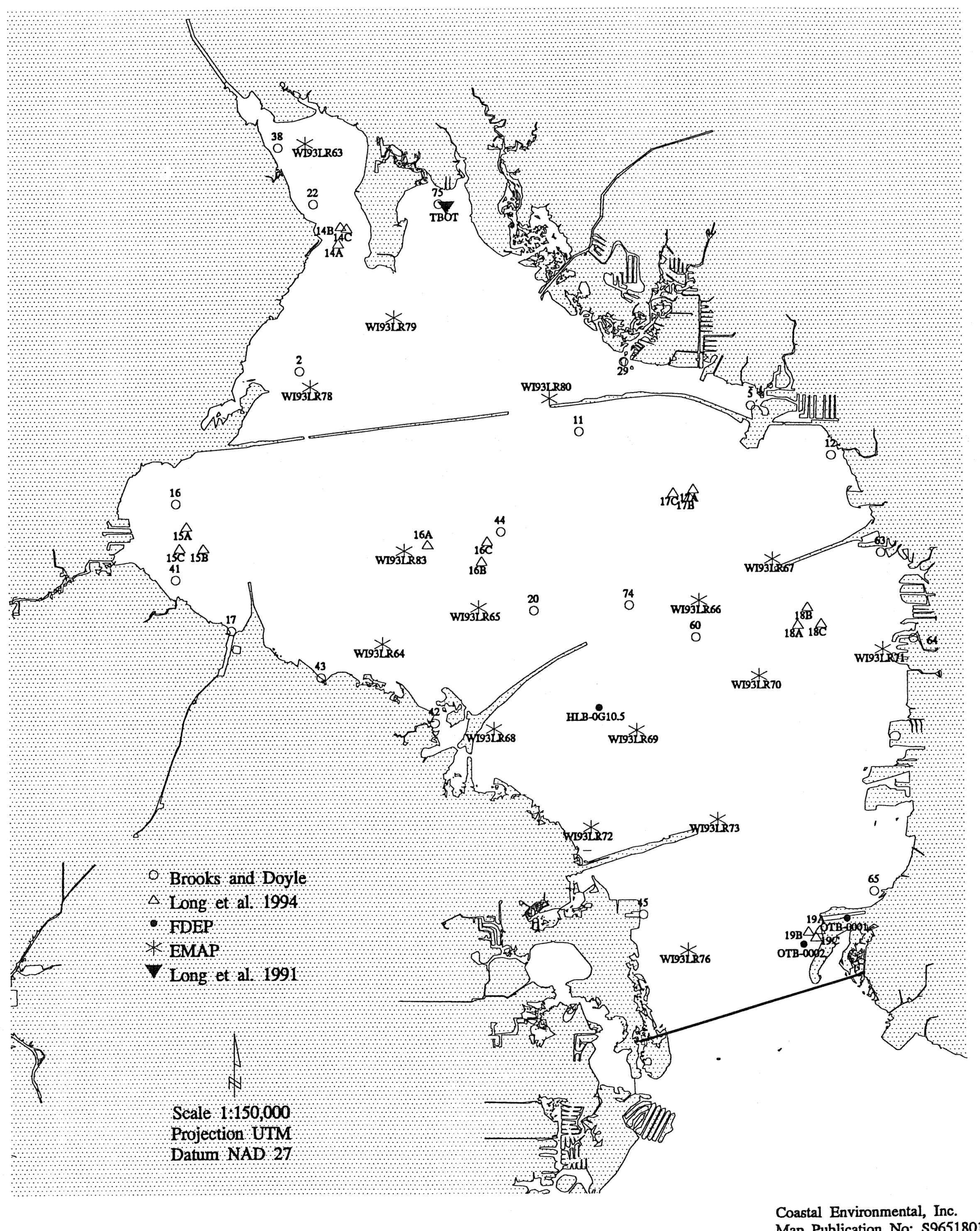
SAMPLING SITE LOCATION
Old Tampa Bay



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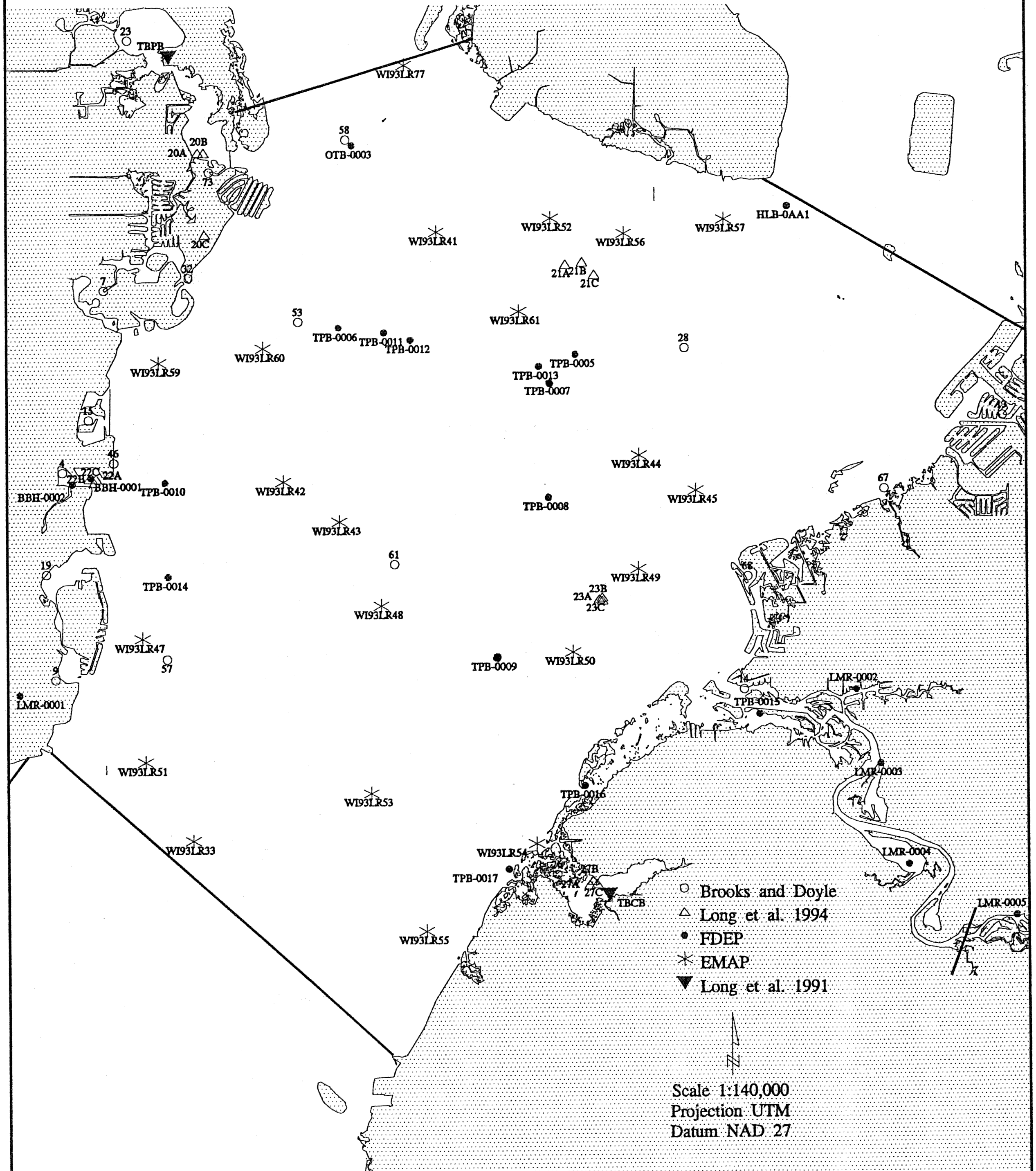
Middle Tampa Bay



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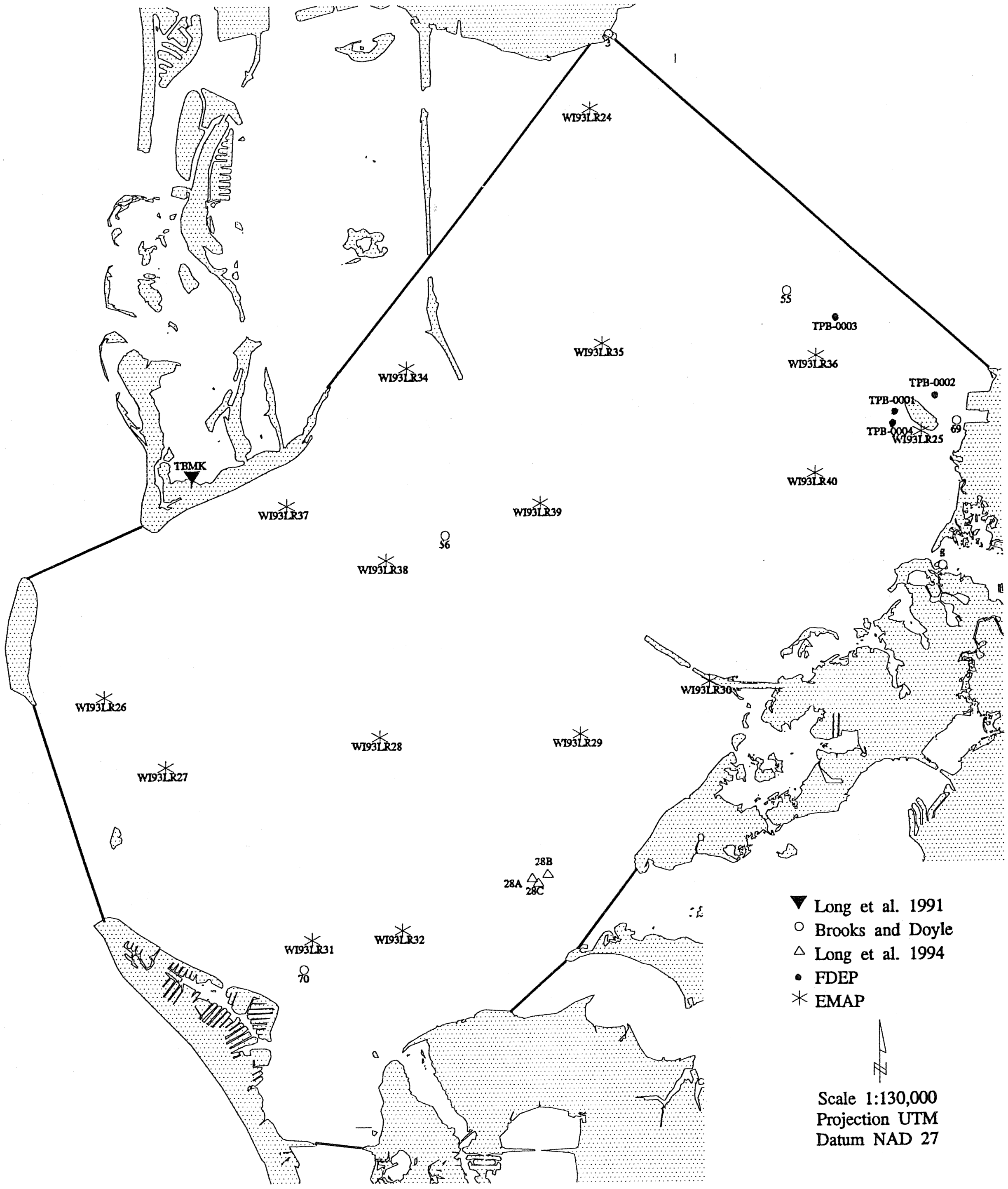
SAMPLING SITE LOCATION
Lower Tampa Bay



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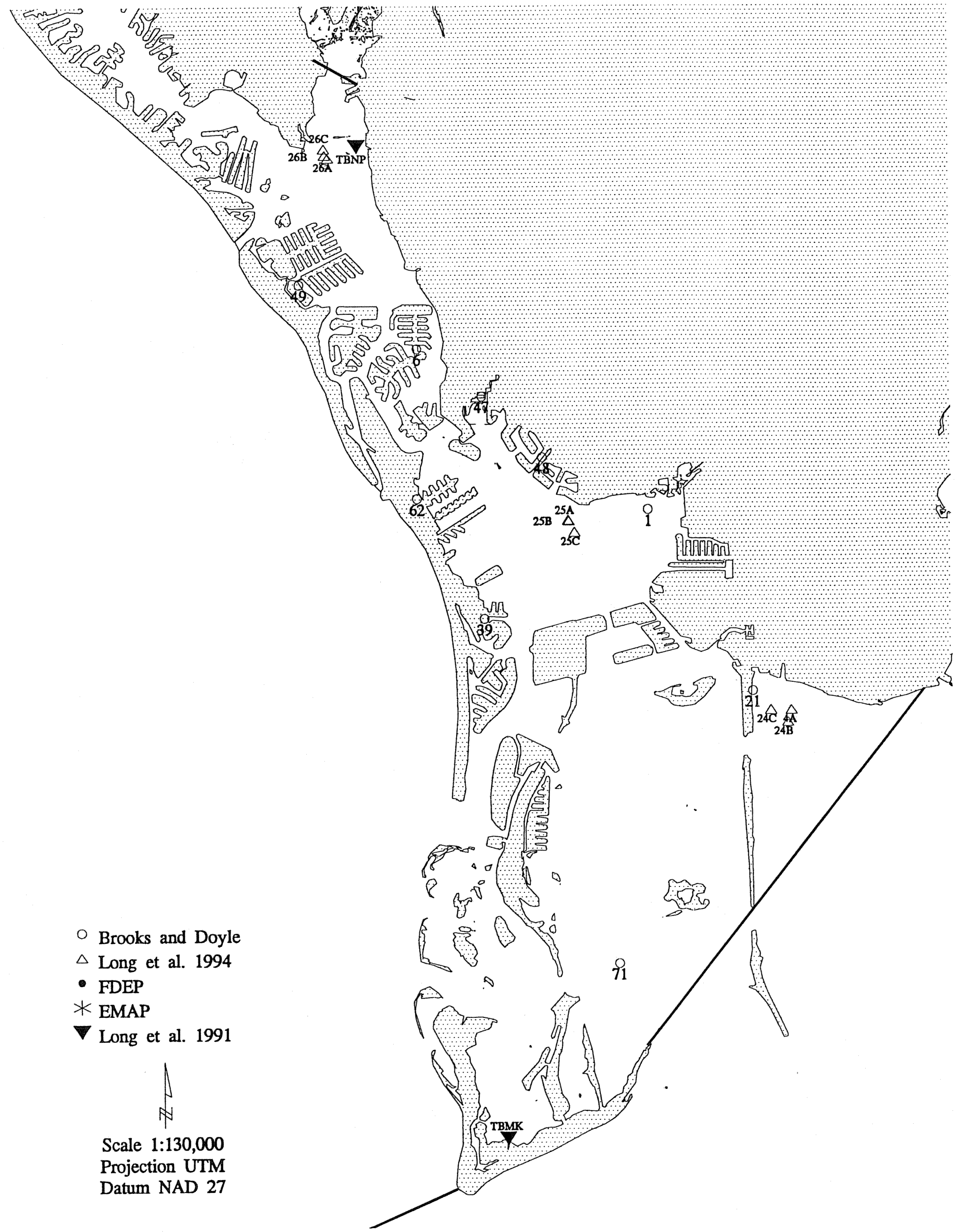
SAMPLING SITE LOCATION

Boca Ciega Bay



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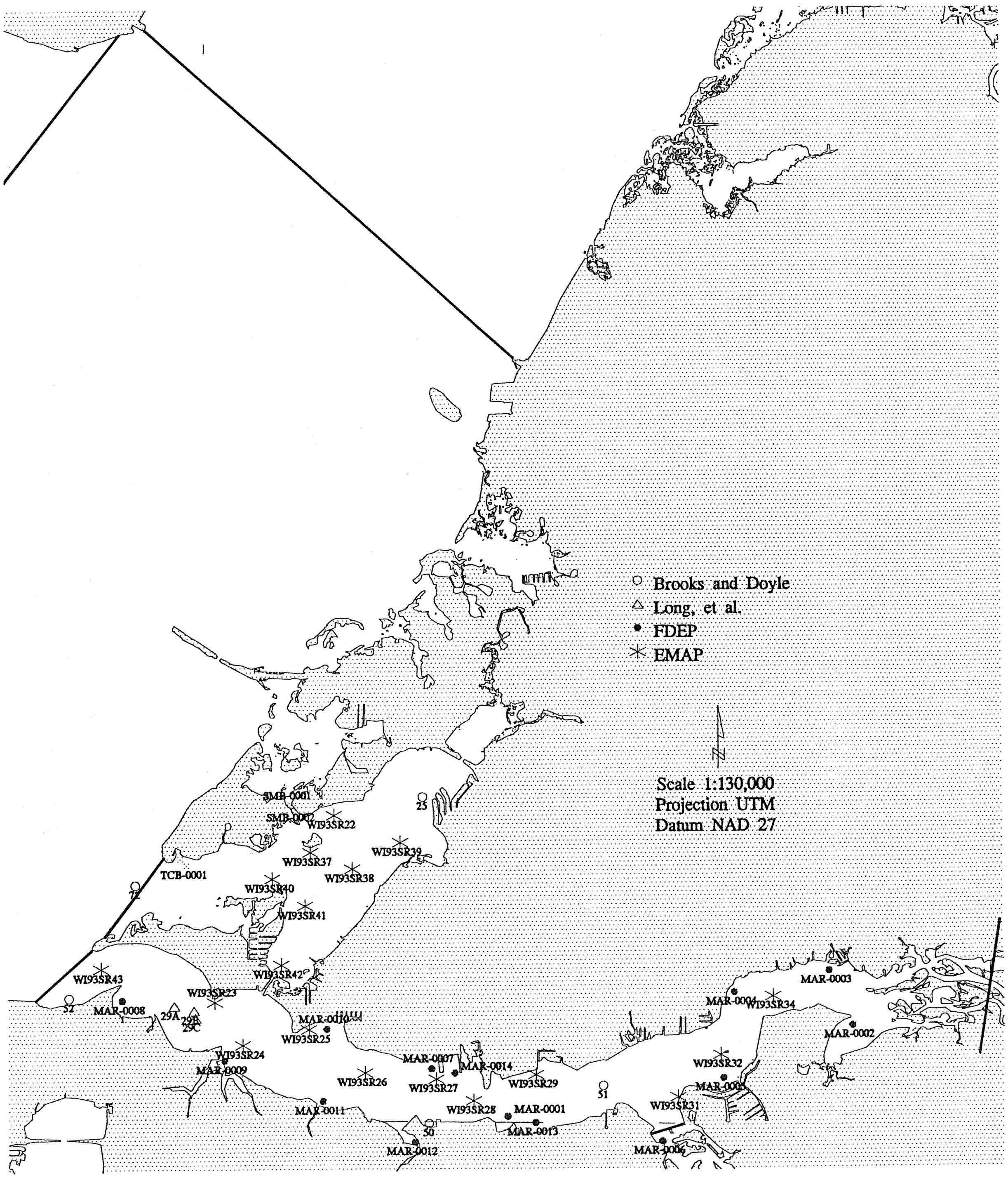
Map Publication No: S9652101

SAMPLING SITE LOCATION
Terra Ceia Bay and Manatee River



Coastal Environmental, Inc.
Map Publication No: S9652201

APPENDIX B

Results of Individual Data Set Mapping

LIST OF TABLES

LIST OF FIGURES

RESULTS OF INDIVIDUAL DATA SET MAPPING

The locations of all sampling sites included in the data sets shown in Table 2-1 were identified using latitude-longitude coordinates provided with each data set. The sites were mapped, and are presented in Appendix A. Index scores (described above) for each site in the individual data sets from Table 2-1 were determined and mapped using an ARC-INFO 6.1 UNIX system. Results are presented below, accompanied by tables summarizing the total number of PEL/TEL exceedences for each parameter in each data set. For ease of map interpretation, sediment chemistry metals and organic compounds have been mapped separately for some of the data sets. Appendix C includes tables listing the number of PEL/TEL exceedences for each parameter at each site for all data sets.

- Sediment Chemistry

FDEP 1994

Figure B-1 presents the index scores for the FDEP (Seal et al. 1994) metals data. As can be seen, Hillsborough Bay was by far the most frequently sampled area of Tampa Bay. Middle Tampa Bay and the Manatee River also had several samples each, with only three sites in Old Tampa Bay and four in Lower Tampa Bay. It should be noted that the Lower Tampa Bay sites were all offshore of Port Manatee, so these are most likely not representative of that bay segment.

As can be seen, sites with index scores of two or more occur frequently in upper Hillsborough Bay, but are also observed in all other sampled bay segments. Many of the sites near known or suspected sources of contaminants, including Port of Tampa, Port Tampa, Bayboro Harbor, Port Manatee, and urban areas along the Manatee River, show two or more PEL/TEL exceedences per site. Interestingly, several of the upper Hillsborough Bay sites, and most of the lower Hillsborough Bay sites, show no exceedences.

Table B-1 shows general information about the data set and results, including the number of PEL/TEL exceedences. All metals exceeded threshold levels at numerous sites. Cadmium exceeded PELs and TELs most often, followed by chromium and mercury.

Figure B-2 presents results of FDEP (Seal et al. 1994) sediment organic chemical concentrations. Fewer samples were taken, and no PEL/TEL exceedences were noted. However, it shown be noted (Table B-1) that the minimum detection limits (MDL) for many, but not all, of the organic chemicals that were analyzed were higher than the SQAGs. This fact severely limits the usefulness of the FDEP data set in determining harmful levels of organic chemicals.

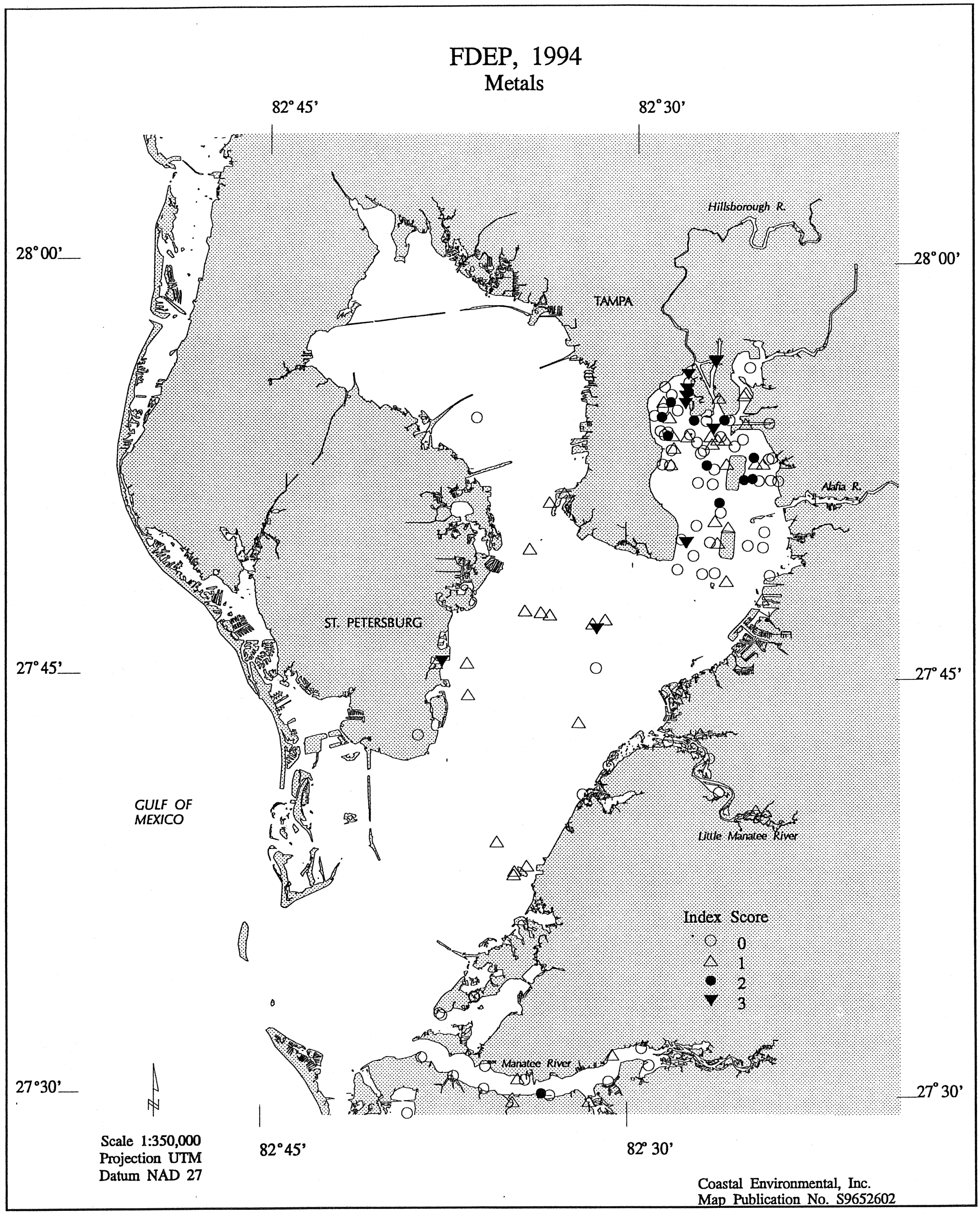


Figure B-1. FDEP (Seal et al. 1994) metals data index scores.

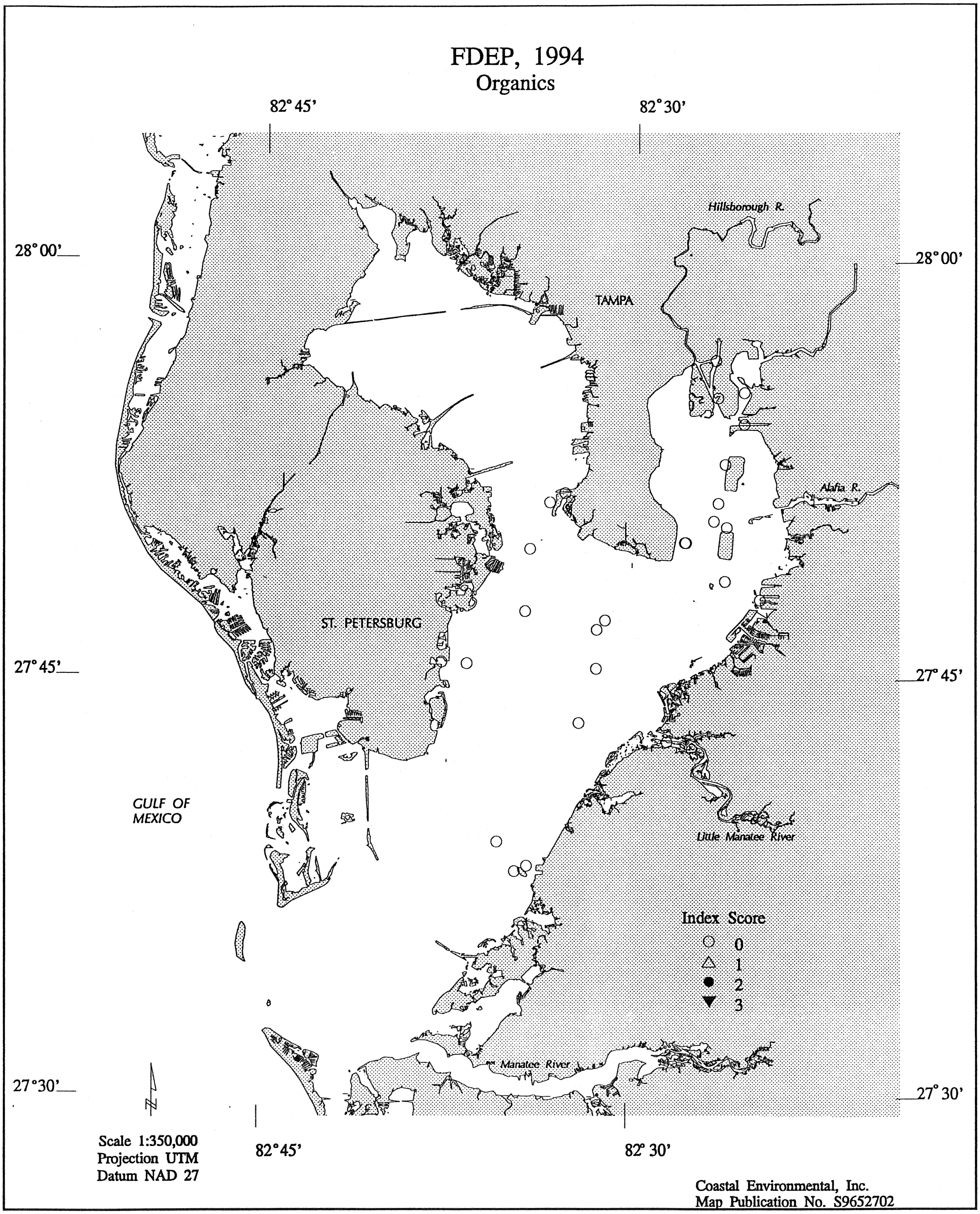


Figure B-2. FDEP (Seal et al. 1994) organics index scores.

Table B-1. Summary of data contained in FDEP (Seal et al. 1994) sediment chemistry data set.

Parameter	No. Sites Sampled/Used	No. Reps per Sample	Min. Detection Limit (mg/kg)	No. TEL Exceedences	No. PEL Exceedences
METALS					
cadmium	101	3	0.02	46	3
chromium	101	3	0.99	34	10
copper	101	3	0.13	31	4
lead	101	3	0.04	21	8
mercury	101	3	0.007	38	6
zinc	101	3	0.38	18	3
ORGANIC COMPOUNDS					
tPCB	26	3	0.1	0	0
tPAH	26	3	0.1	0	0
chlordane	26	3	0.001-0.1	0	0
tDDT	26	3	0.001-0.1	0	0
dieldrin	26	3	0.001-0.1	0	0
endrin	26	3	0.001-0.1	No TEL established.	No PEL established.

NOTES: Blank lines indicate parameters not sampled.
PEL = Probable Effects Level; TEL = Threshold Effects Level

Long et al. 1994

Figures B-3 and B-4 show Long et al. (1994) Phase 1 and Phase 2 metals data index scores, respectively. In Phase 1, Hillsborough Bay is most sampled, with scattered sites in Old Tampa Bay, Middle Tampa Bay, Lower Tampa Bay, Boca Ciega Bay, and the Manatee River. Several of the sites near known or probable contaminant sources, including Port of Tampa, Bayboro Harbor, western Old Tampa Bay, and Boca Ciega Bay, show two or more PEL/TEL exceedences.

It should be noted that Long et al. (1994) designed both Phase 1 and Phase 2 programs to sample sites that were likely to exhibit contaminant-related impacts. Phase 2 in particular was very focused on areas of the bay that were most likely to have high concentrations or positive toxicity test results. Tables B-2 and B-3 show that numerous samples had metals concentrations above PEL or TEL levels. All six metal contaminants of concern showed frequent PEL/TEL exceedences. Figures B-5 and B-6 show the results of Phase 1 and Phase 2 testing for organic compounds. The results show a spatial trend similar to the metals analysis, with the sites near likely or known contaminant sources (Port of Tampa, coastal Pinellas County and Boca Ciega Bay) having multiple PEL/TEL exceedences. Chlordane, tPCB, and tDDT were most often observed in high levels at these sites (Tables B-2 and B-3).

Long et al. 1991

Long et al. (1991) sampled eight sites as an initial screening for Tampa Bay sediment contamination. From those sites, a total of six PEL/TEL exceedences for metals were observed, as shown in Figure B-7 and Table B-4. These sites, and others, were sampled during the following Phase 1 and Phase 2 sampling described above. Figure B-8 presents the results of organic chemical analysis for these sites. All organic contaminants of concern for which TEL and PEL threshold concentration data were available were exceeded, with tPCB and tDDT exceeding most frequently. Both PEL and TEL levels were exceeded.

TBNEP/EMAP

Figure B-9 shows the metals index scores for the TBNEP/EMAP design 1993 monitoring data (Hochberg et al. 1992; Grabe et al. 1995). In contrast to other data sets, only one site, in Safety Harbor in extreme north Old Tampa Bay, has a chromium exceedence for any PEL or TEL (Table B-5). Several factors likely contributed to these findings. First, no metals data were obtained from samples taken in the Manatee River, and no samples were taken in Boca Ciega Bay. These areas are all likely sites to show sediment contamination, if sampled. Hillsborough Bay had four samples analyzed for metals, but were not mapped.

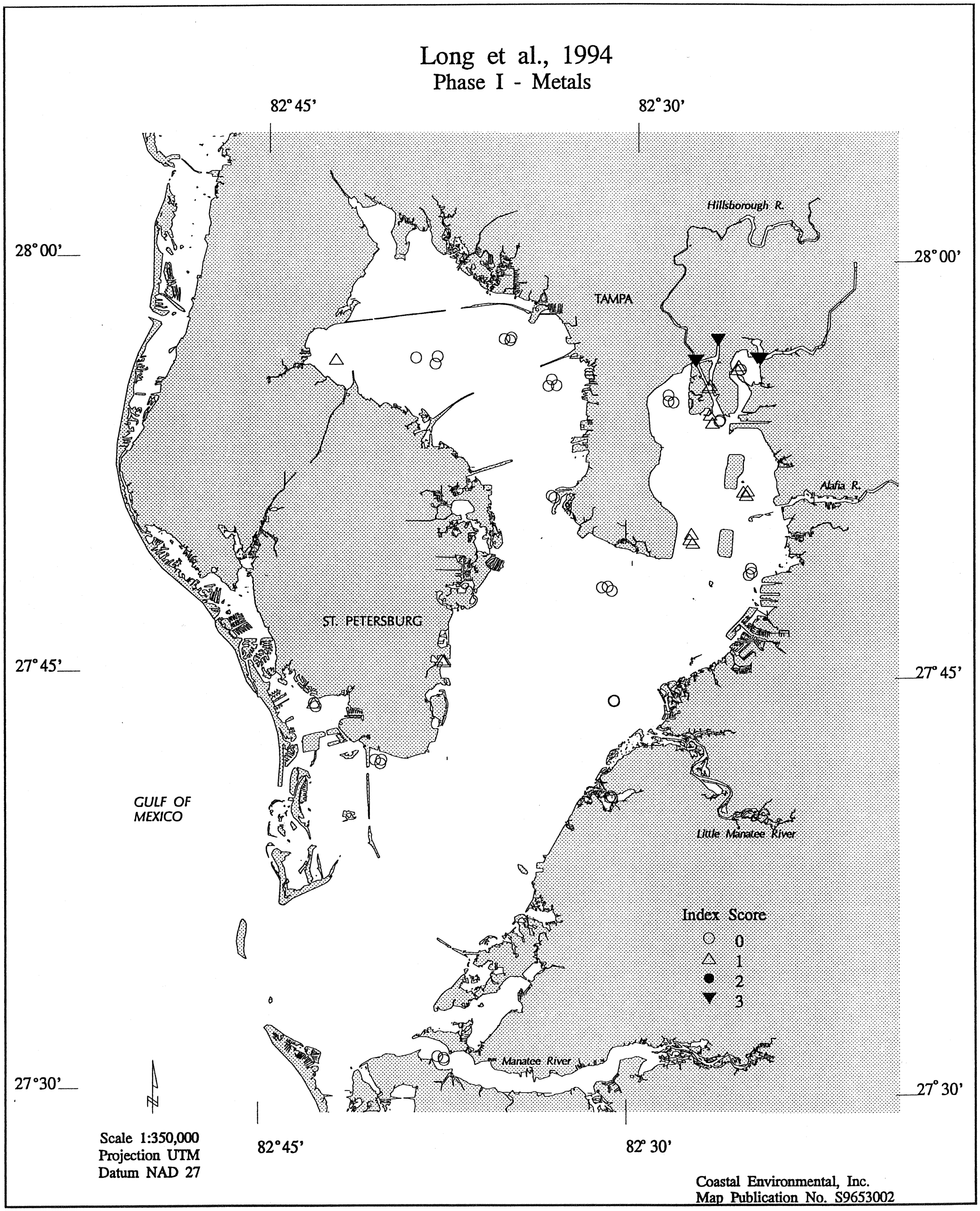


Figure B-3. Long et al. (1994) Phase 1 metals data index scores.

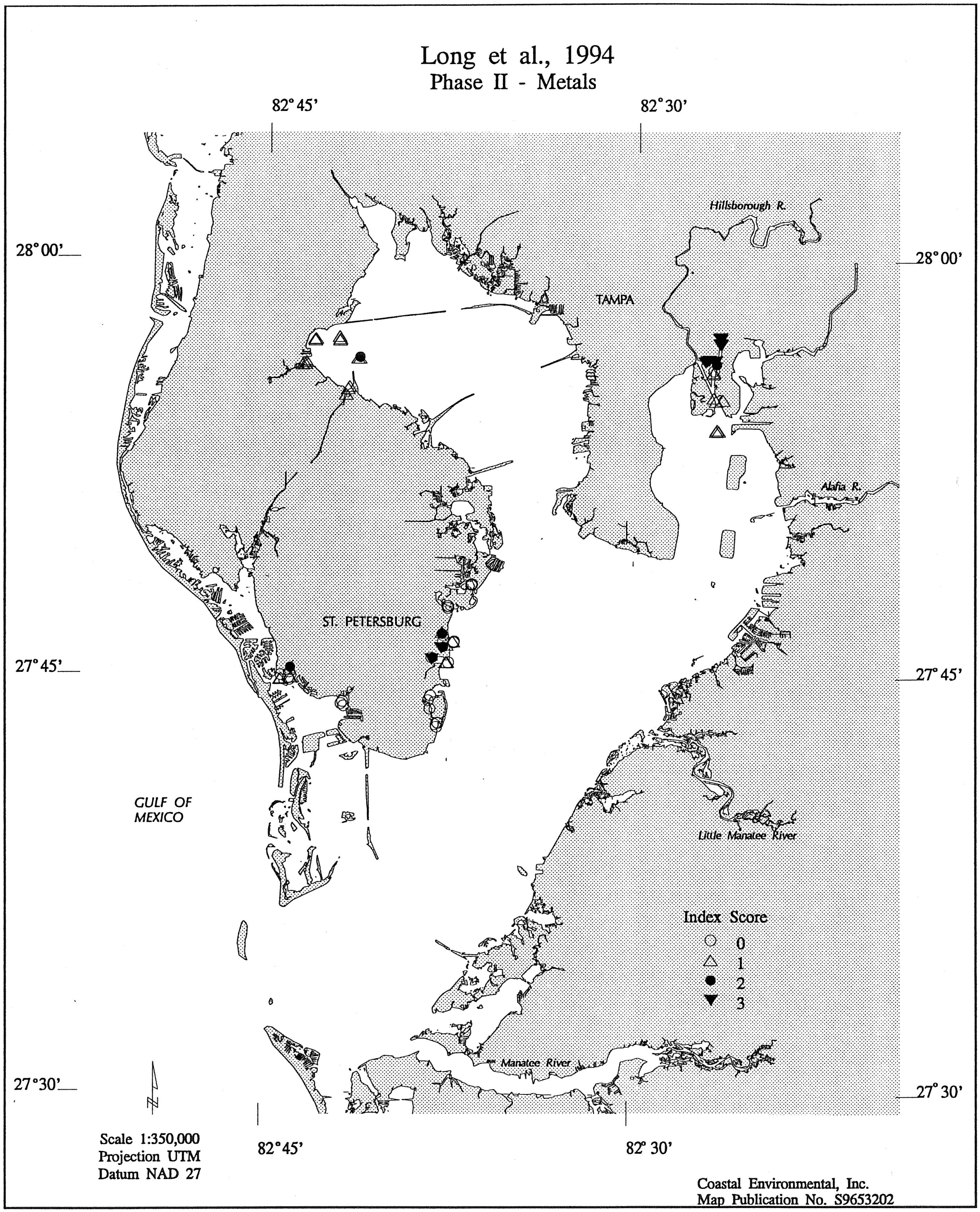


Figure B-4. Long et al. (1994) Phase 2 metals data index scores.

Table B-2. Summary of data contained in Long et al. (1994) Phase 1 sediment chemistry data set.

Parameter	No. Sites Sampled/Used	No. Reps per Sample	Min. Detection Limit (ppm)	No. TEL Exceedences	No. PEL Exceedences
METALS					
cadmium	63	1	0.04	15	4
chromium	63	1	1.4	20	0
copper	63	1	0.2	10	8
lead	63	1	0.4	10	9
mercury	63	1	7	18	0
zinc	63	1	0.5	3	9
ORGANIC COMPOUNDS					
tPCB	63	1	0.3 (ng/g)	4	12
tPAH	63	1	0.5 (ng/g)	0	0
chlordane	63	1	0.5 (ng/g)	3	9
tDDT	63	1	0.1(ng/g)	9	6
dieldrin	63	1	0.1 (ng/g)	0	0
endrin	63	1	1.0 (ng/g)	No TEL established.	No PEL established.

NOTES: Blank lines indicate parameters not sampled.
PEL = Probable Effects Level; TEL = Threshold Effects Level

Table B-3. Summary of data contained in Long et al. (1994) Phase 2 sediment chemistry data set.

Parameter	No. Sites Sampled/Used	No. Reps per Sample	Min. Detection Limit (ppm)	No. TEL Exceedences	No. PEL Exceedences
METALS					
cadmium	165	1	0.04	43	0
chromium	165	1	1.4	39	1
copper	165	1	0.2	22	14
lead	165	1	0.4	29	15
mercury	165	1	7	39	0
zinc	165	1	0.5	11	14
ORGANIC COMPOUNDS					
tPCB	165	1	0.3 (ng/g)	19	10
tPAH	165	1	0.5 (ng/g)	0	0
chlordane	165	1	0.5 (ng/g)	13	9
tDDT	165	1	0.1(ng/g)	23	10
dieldrin	165	1	0.1 (ng/g)	28	7
endrin	165	1	1.0 (ng/g)	No TEL established.	No PEL established.

NOTES: Blank lines indicate parameters not sampled.
PEL = Probable Effects Level; TEL = Threshold Effects Level

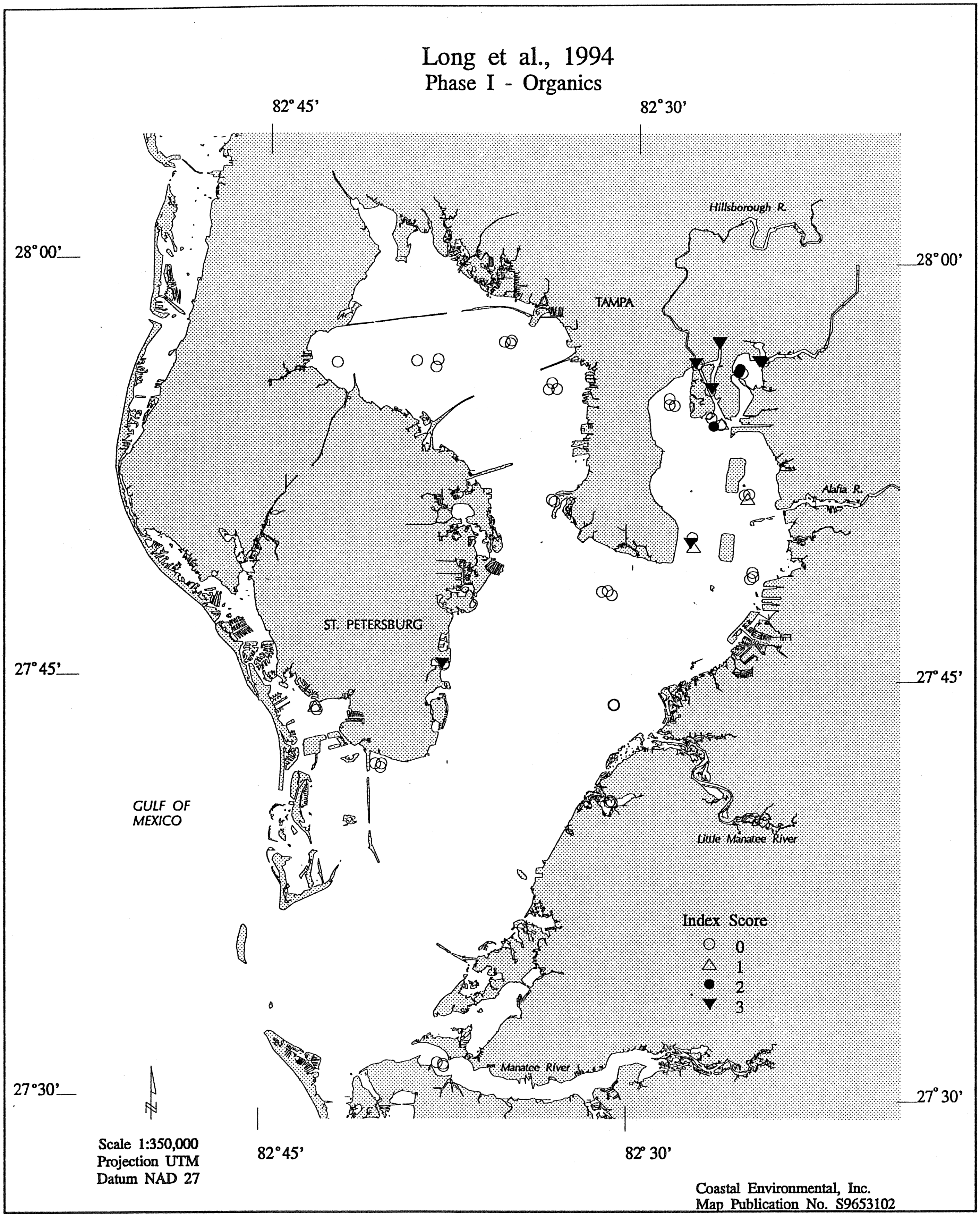


Figure B-5. Long et al. (1994) Phase 1 organics data index scores.

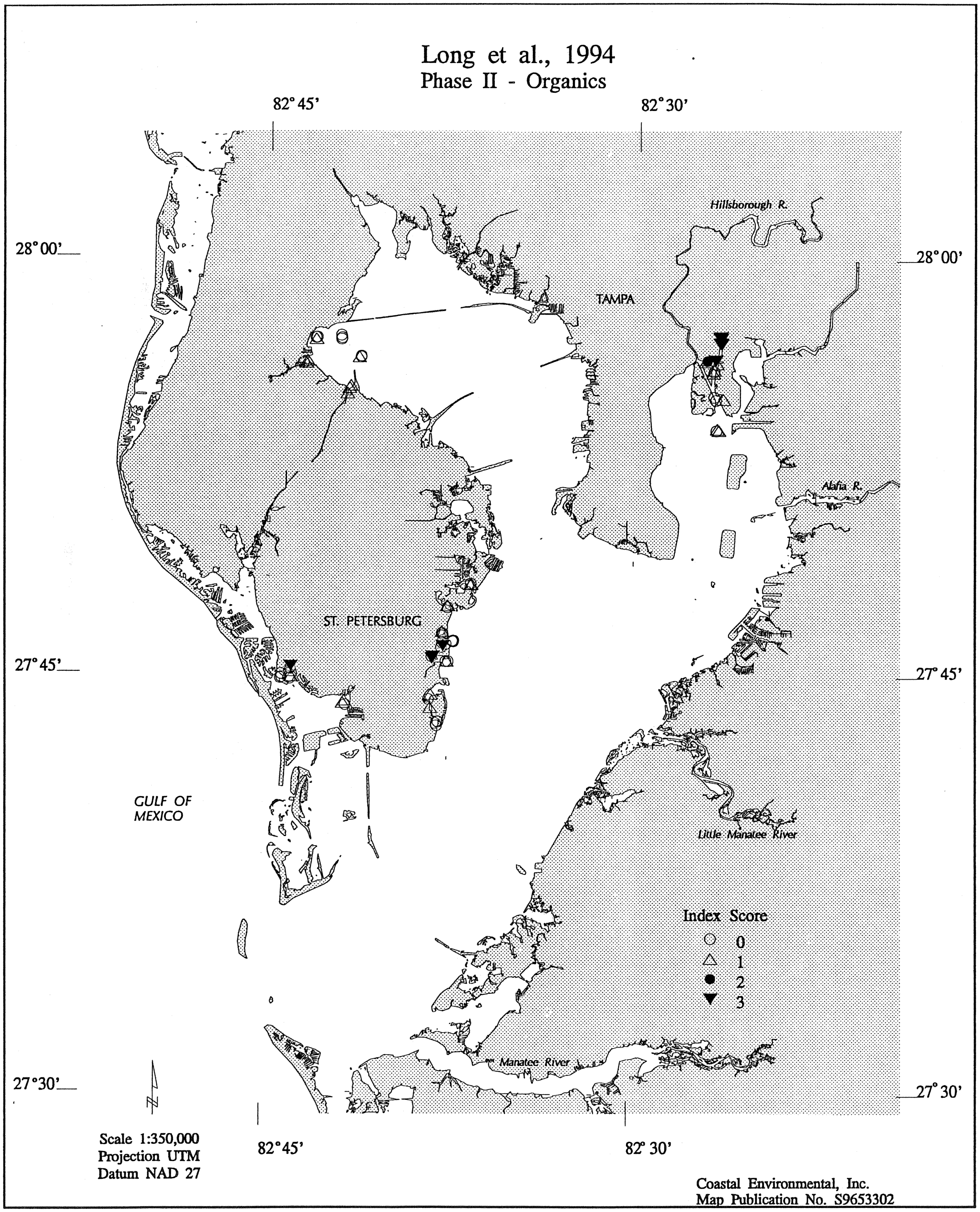


Figure B-6. Long et al. (1994) Phase 2 organics data index scores.

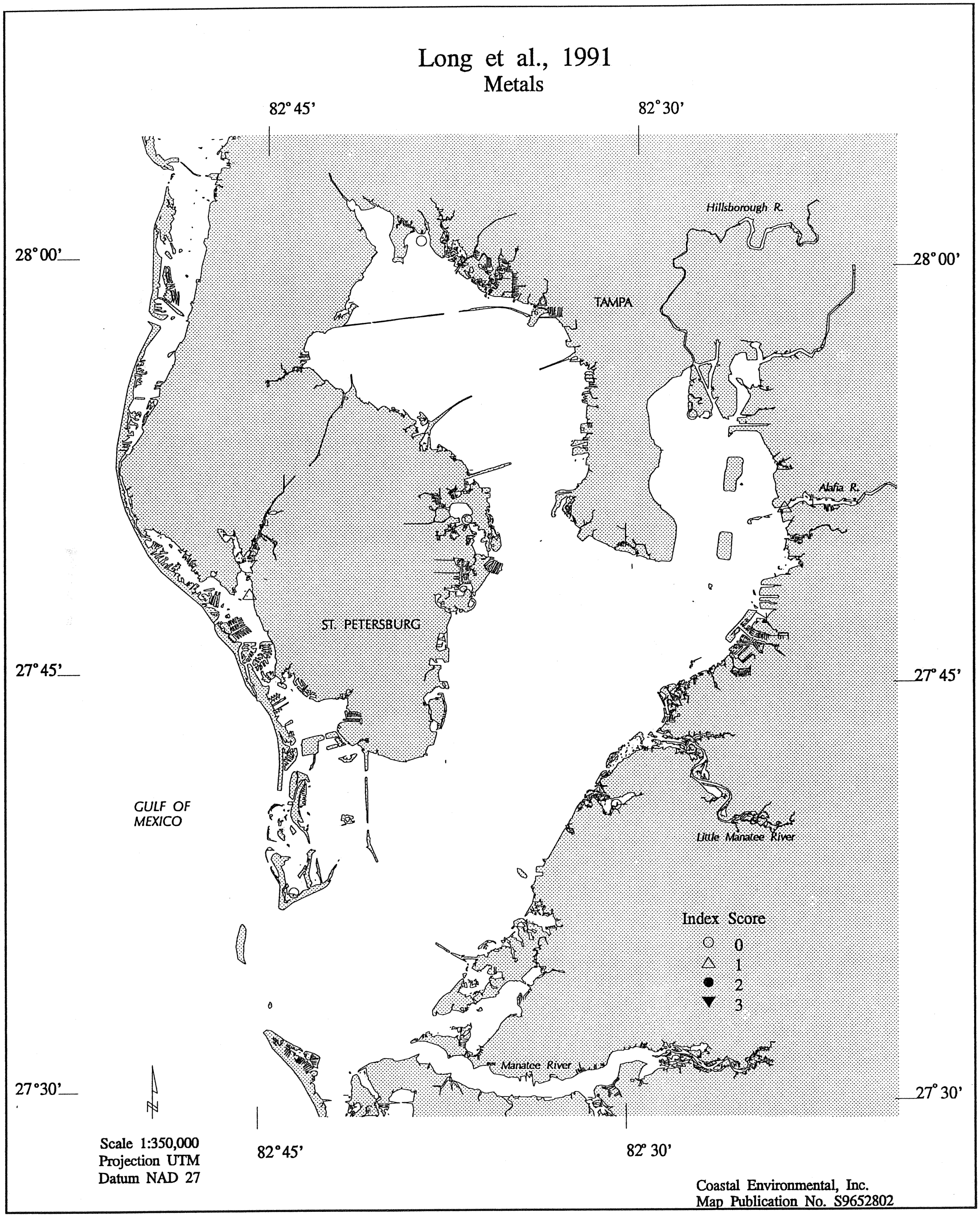


Figure B-7. Long et al. (1991) metals data index scores.

Table B-4. Summary of data contained in Long et al. (1991) sediment chemistry data set

Parameter	No. Sites Sampled/Used	No. Reps per Sample	Min. Detection Limit (ppm)	No. TEL Exceedences	No. PEL Exceedences
METALS					
cadmium	8	1	0.04	2	0
chromium	8	1	1.4	1	0
copper	8	1	0.2	1	0
lead	8	1	0.4	0	0
mercury	8	1	7	2	0
zinc	8	1	0.5	0	0
ORGANIC COMPOUNDS					
tPCB	8	1	0.3 (ng/g)	4	0
tPAH	8	1	0.5 (ng/g)	2	0
chlordane	8	1	0.5 (ng/g)	2	1
tDDT	8	1	0.1 (ng/g)	4	0
dieldrin	8	1	0.1 (ng/g)	1	1
endrin	8	1	1.0 (ng/g)	No TEL established.	No PEL established.

NOTES: Blank lines indicate parameters not sampled.
PEL = Probable Effects Level; TEL = Threshold Effects Level

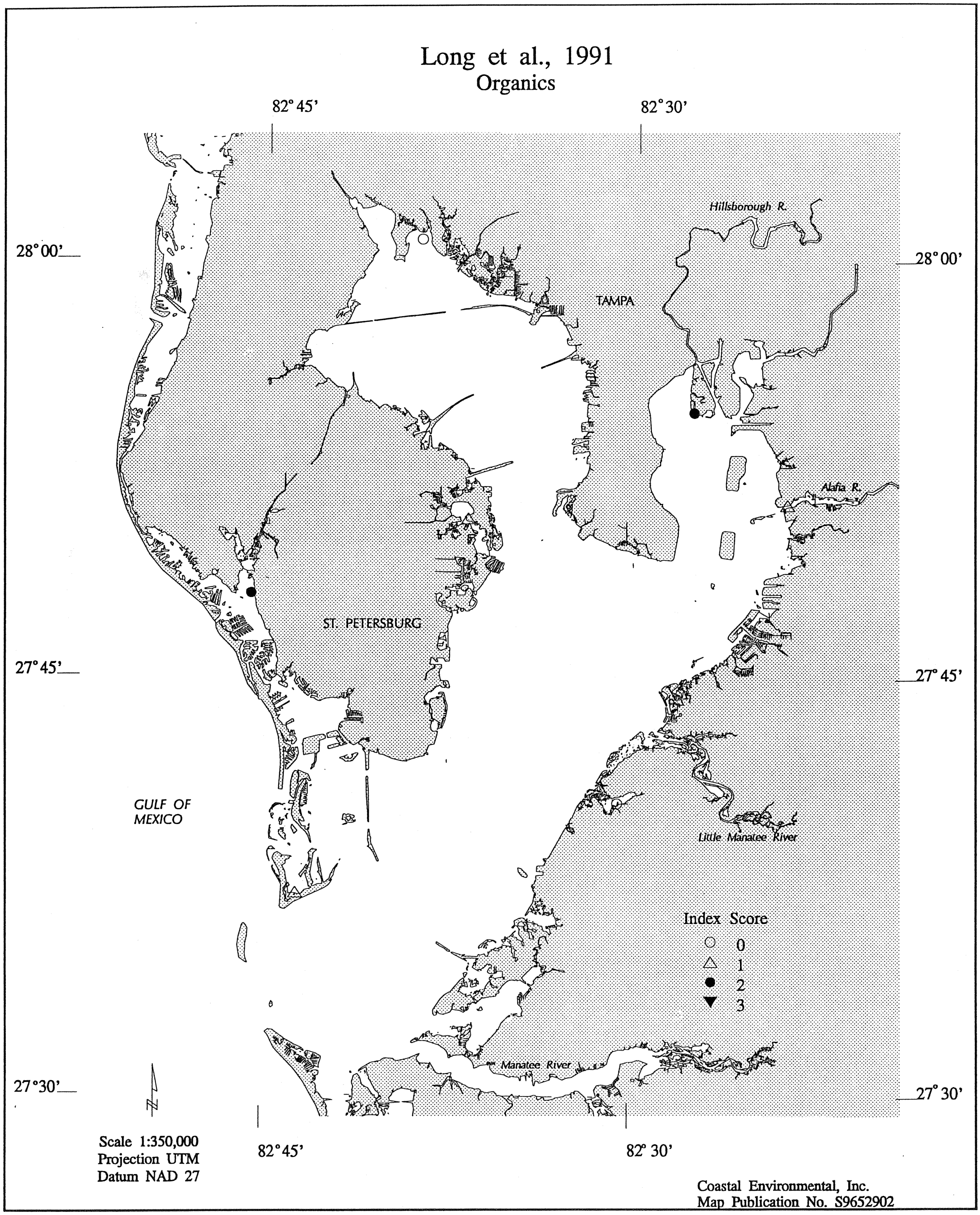


Figure B-8. Long et al. (1991) organics data index scores.

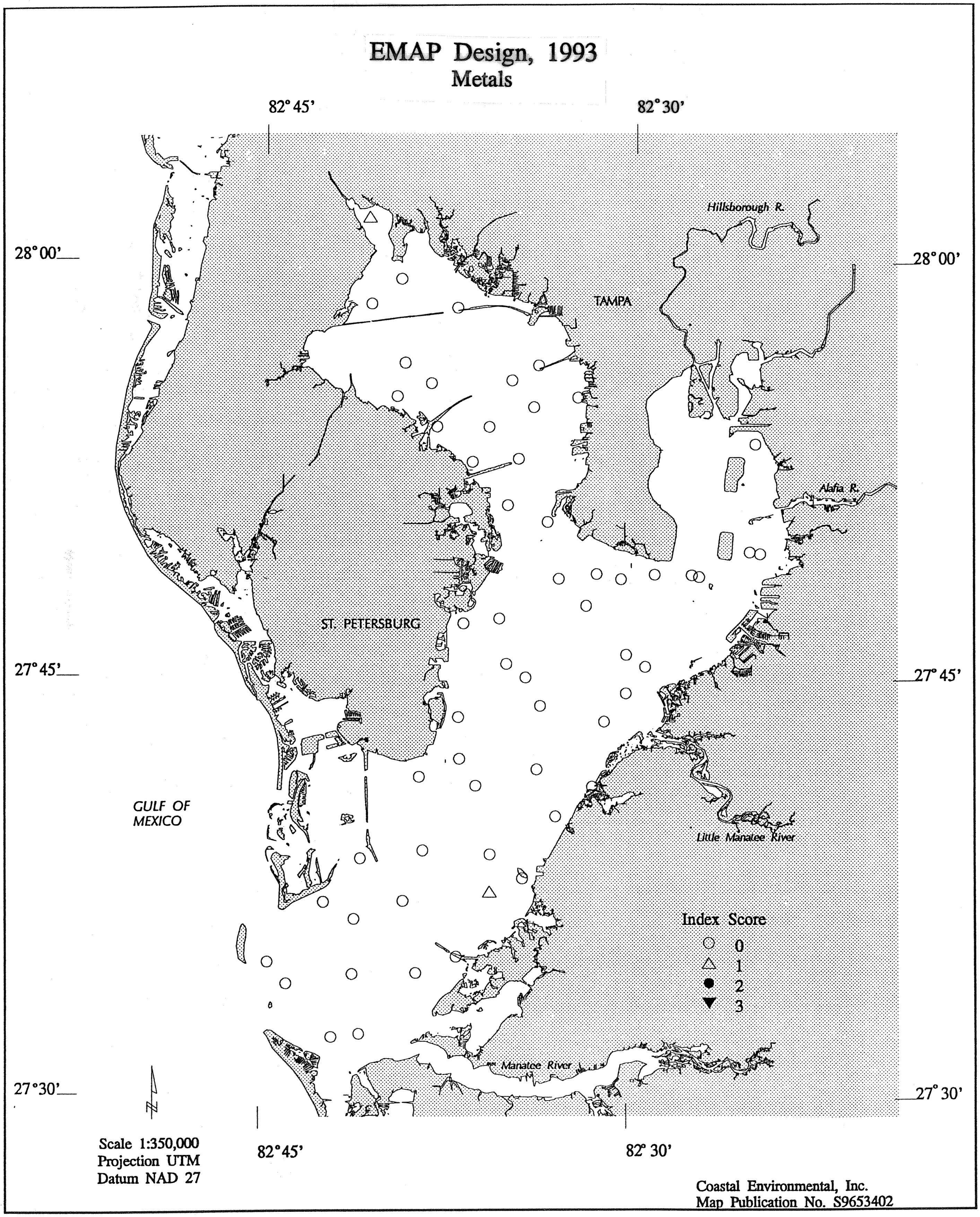


Figure B-9. TBNEP/EMAP design (1993) metals data index scores.

Table B-5. Summary of data contained in TBNEP/EMAP design 1993 sediment chemistry data set

Parameter	No. Sites Sampled/Used	No. Reps per Sample	Min. Detection Limit (ug/gm)	No. TEL Exceedences	No. PEL Exceedences	Index Score
METALS						
cadmium	82	1	0.03	0	0	0
chromium	82	1	4	1	0	1
copper	82	1	1.1	0	0	0
lead	83	1	0.9	0	0	0
mercury	82	1	0.007	0	0	0
zinc	82	1	1.1	0	0	0

NOTES: Blank lines indicate parameters not sampled.
PEL = Probable Effects Level; TEL = Threshold Effects Level

Also, the sample sites are well distributed throughout the bay. The sites were selected using the EMAP random sampling methodology, so that the site locations theoretically are unbiased and do not target areas likely to show contamination. Finally, many of the sites most likely to show contamination are in nearshore depositional areas. Using the EMAP sampling methods, if a site within a sampling grid was located on land, it was thrown out and not relocated, so several of the nearshore grids have no samples.

Therefore, the lack of PEL/TEL exceedences from the TBNEP/EMAP design 1993 data should not be construed to suggest that no sediment contamination exists in Tampa Bay. The TBNEP/EMAP design 1994 data will include samples from Hillsborough Bay, Manatee River, and Boca Ciega Bay, and may well show contamination in those areas. No organic chemicals were analyzed from the TBNEP/EMAP design 1993 samples.

Brooks and Doyle (1992)

Brooks and Doyle (1992) sampled a wide range of sites within the bay, including both nearshore areas targeting likely sites with contamination, as well as ship channels and open water sites. Figure B-10 and Table B-6 present the results, which show multiple PEL/TEL exceedences at many of the nearshore sites. Sites at upper and lower Hillsborough Bay, coastal Pinellas County, and Boca Ciega Bay, ship channel sites, Port Manatee, and the Manatee River all showed impacted conditions. Lead was most often found in high concentrations. No organic compounds were analyzed in these samples.

- Sediment Toxicity

Long et al. (1994)

Figure B-11 presents the results for the Long et al. (1994) Phase 1 and Phase 2 toxicity testing. Testing was completed at sites in Hillsborough Bay, Old Tampa Bay, Middle Tampa Bay, Boca Ciega Bay, Cockroach Bay, and the Manatee River. Several sites near potential contamination sources (Port of Tampa, Hillsborough Bay, Bayboro Harbor, coastal Pinellas County, and Boca Ciega Bay) showed positive toxicity test results. Sites in the middle of major bay segments did not exhibit toxicity.

The sea urchin egg fertility tests had the highest positive (toxic) results at sites in northern Hillsborough Bay (Ybor Channel, McKay Bay, eastern Hillsborough Bay, western Old Tampa Bay, and Bayboro Harbor. Cockroach Bay also had positive test results. Amphipod toxicity testing showed positive results at sites in northern and eastern Hillsborough Bay, and at a site in central Boca Ciega Bay. Microtox™ testing resulted in positive results only in ship channels in northern Hillsborough Bay.

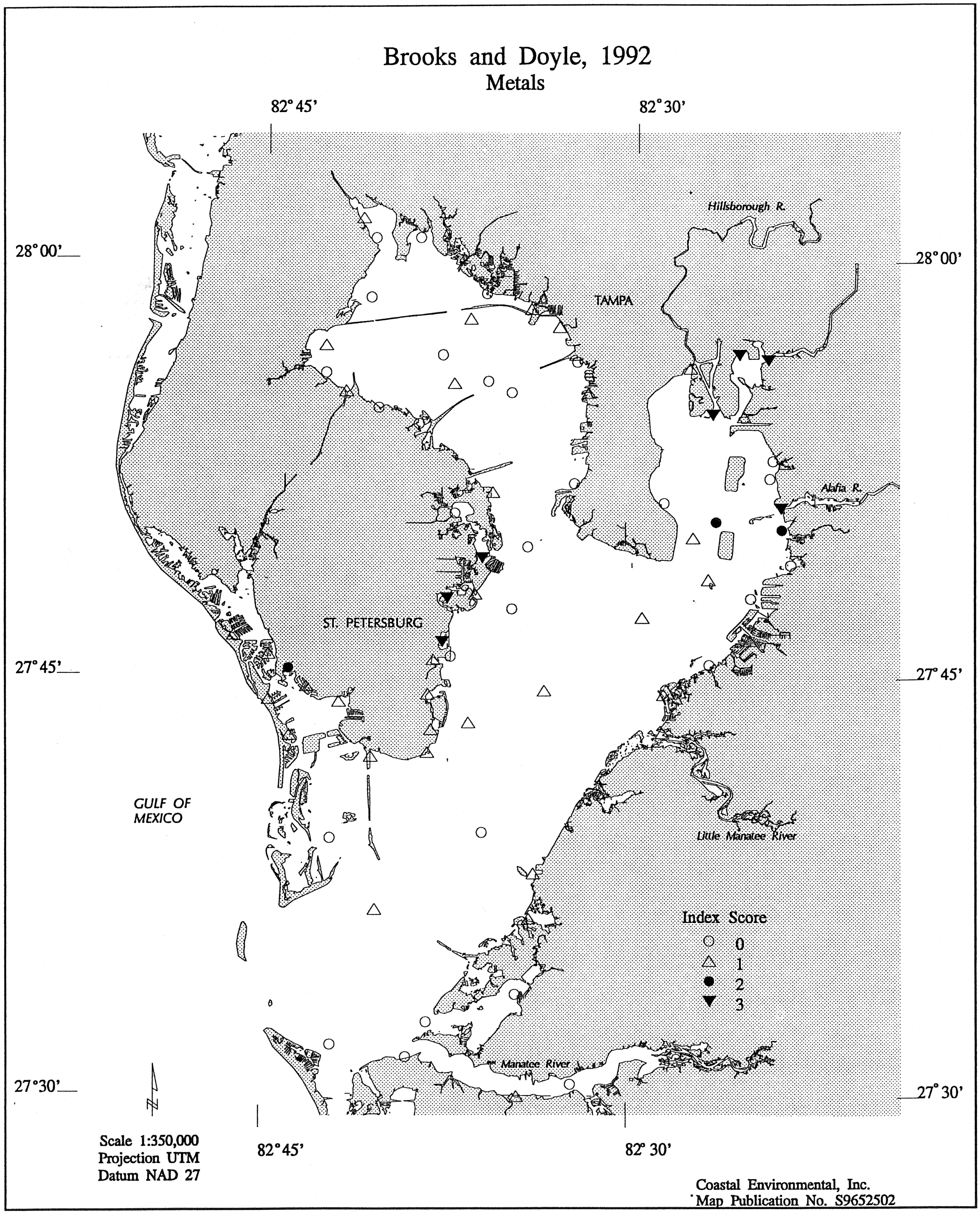


Figure B-10. Brooks and Doyle (1992) metals data index scores.

Table B-6. Summary of data contained in Brooks & Doyle (1992) sediment chemistry data set.

Parameter	No. Sites Sampled/Used	No. Reps per Sample	Min. Detection Limit (mg/kg)	No. TEL Exceedences	No. PEL Exceedences	Index Score
METALS						
cadmium	75	2	0.1	10	3	13
chromium	75	2	1.0	22	2	24
copper	75	2	2.5	26	3	29
lead	75	2	0.5	34	8	42
mercury	75	2	0.03	11	4	15
zinc	75	2	2.0	4	6	10

NOTES: Blank lines indicate parameters not sampled.
PEL = Probable Effects Level; TEL = Threshold Effects Level

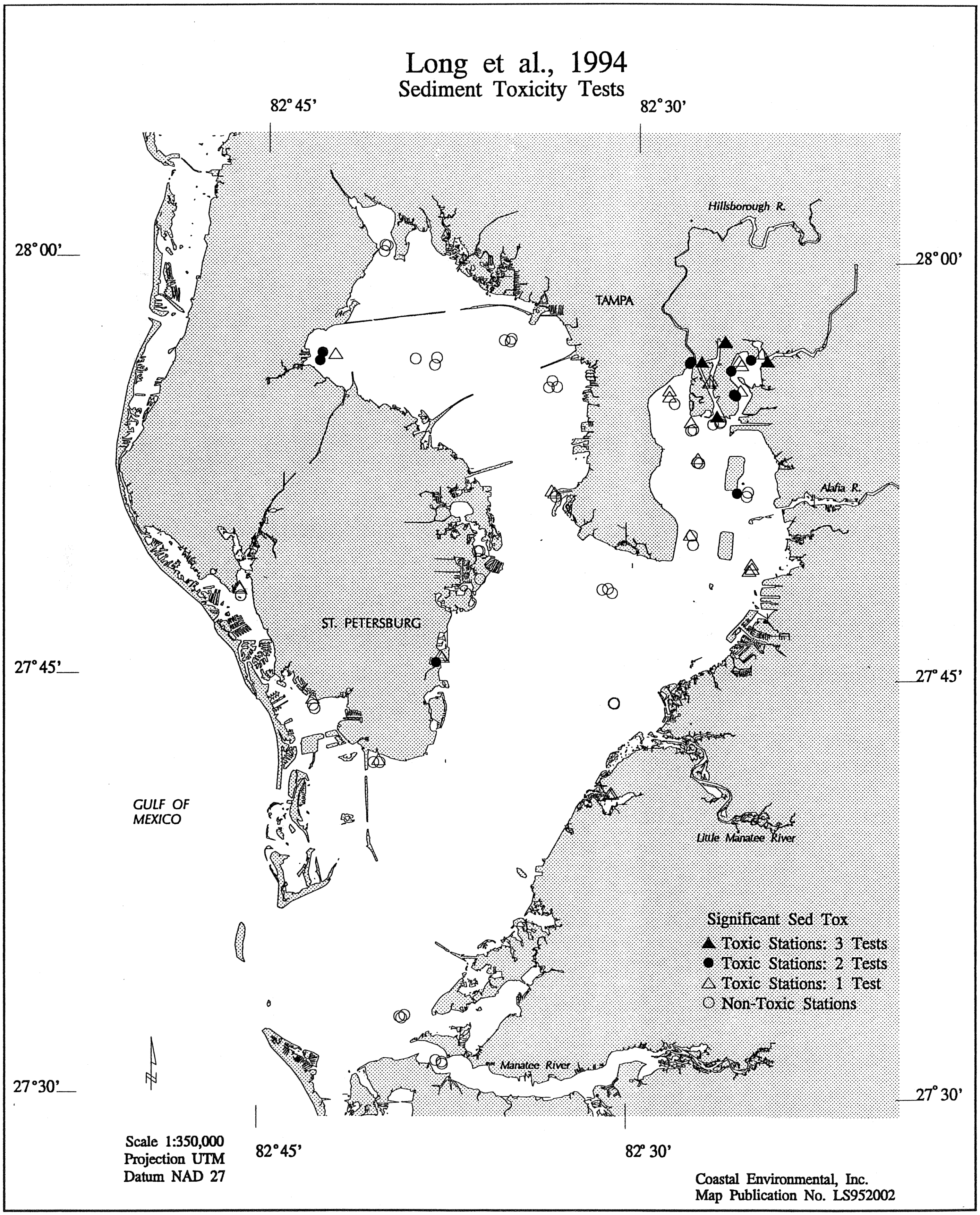


Figure B-11. Long et al. (1994) toxicity testing index scores.

- Benthic Community

<u>TBNEP/EMAP Design (1993)</u>

The TBNEP/EMAP design 1993 benthic data were evaluated using several methods. As discussed above, the use of the EMAP Louisianian Province Benthic Index proved unsatisfactory because no sites were impacted enough to meet the EMAP index criteria for "degraded," as discussed in Section 3.1. In an attempt to relate the relative degree of impacts of the sampling sites, the EMAP index was used and the results were divided into qualitative quartiles (0-25%, 26-50%, 51-75%, and 76-100%) labeled "0", "1", "2", or "3", with "3" being the most impaired. This allowed a subjective comparison of the sites, but with no determination as to how degraded any benthic group was on an absolute scale. Results are shown in Figure 3-12. Sites within Hillsborough Bay showed the most degradation, although many sites throughout the bay also exhibited similar characteristics.

It should be noted that hypoxic (low oxygen) conditions are periodically reported in shallow portions of the bay, especially Hillsborough Bay (Johansson and Squires 1989). Additionally, many of the areas with low index scores are in areas of the bay subject to impacts from disturbance of the sediments, either by wind-driven or shipping activities. These, or other, factors could affect the results of the benthic analysis as much as contaminated sediments.

The TBNEP/EMAP design 1993 data were also evaluated using the Shannon Index, which incorporates the number of all individuals, the number of species, and the distribution of individuals among species to yield a relative measure of diversity. Lower values are often associated with higher levels of environmental stress. Once again the quantile system was employed, and in this case the lowest Shannon index values were given the highest quantile score (3). Results are shown in Figure B-13. The Shannon Index shows similar spatial trends to the EMAP Index, but fewer sites in Hillsborough Bay are in the lower diversity quartiles, and more sites in other bay segments are in lower diversity quartiles.

Other measures of benthic community structure were used to evaluate the TBNEP/EMAP 1993 design data. Figure B-14 shows the results of a simple tally of number of species at each site (species richness). For this analysis, the number of species were counted and the sites were divided into quartiles. The quartiles were labeled "0", "1", "2", or "3" based on the number of species at that site, with "0" being the least diverse.

Many of the sites with highest species richness were observed in lower Tampa Bay, Terra Ceia Bay, and the Manatee River. The lowest species richness occurred in Middle Tampa Bay and Hillsborough Bay. As discussed above, sediment contamination or other factors could be a cause of this pattern.

Two other metrics of benthic community health were evaluated. Figure B-15 shows the results of testing for presence or absence of benthic organisms at each site. No sites that were

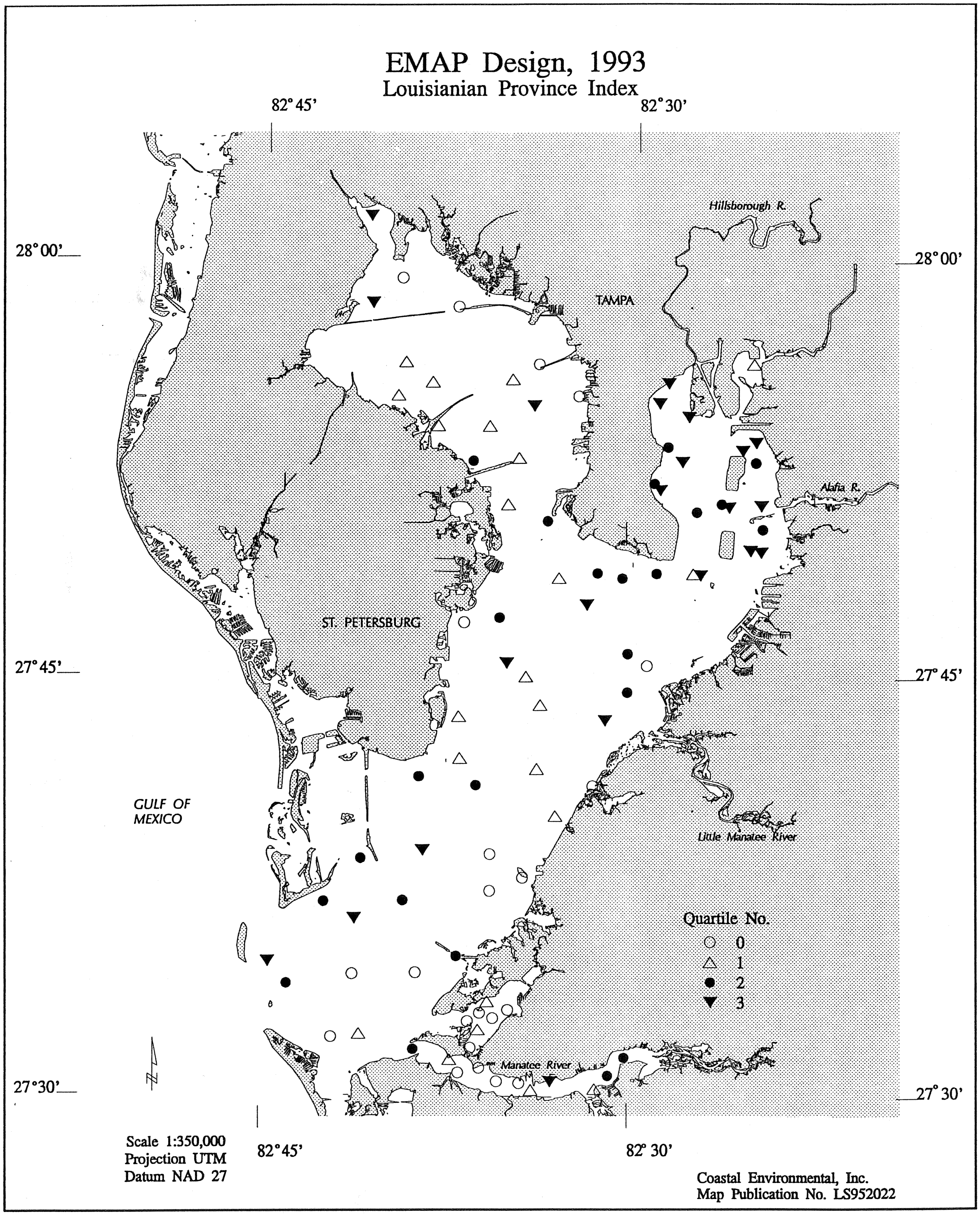


Figure B-12. TBNEP/EMAP design 1993 Louisianian Province Benthic Index scores.

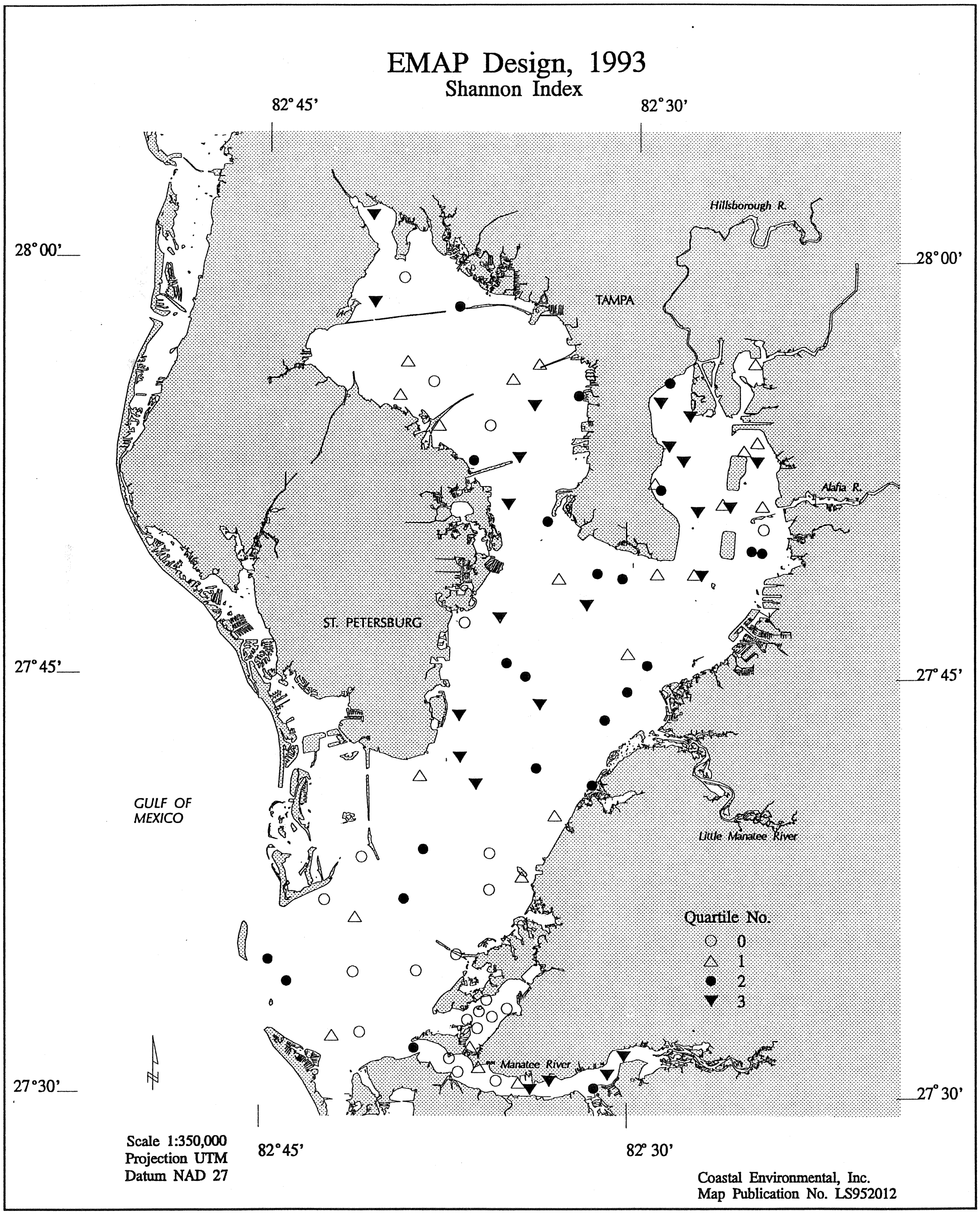


Figure B-13. TBNEP/EMAP design 1993 Shannon Index scores.

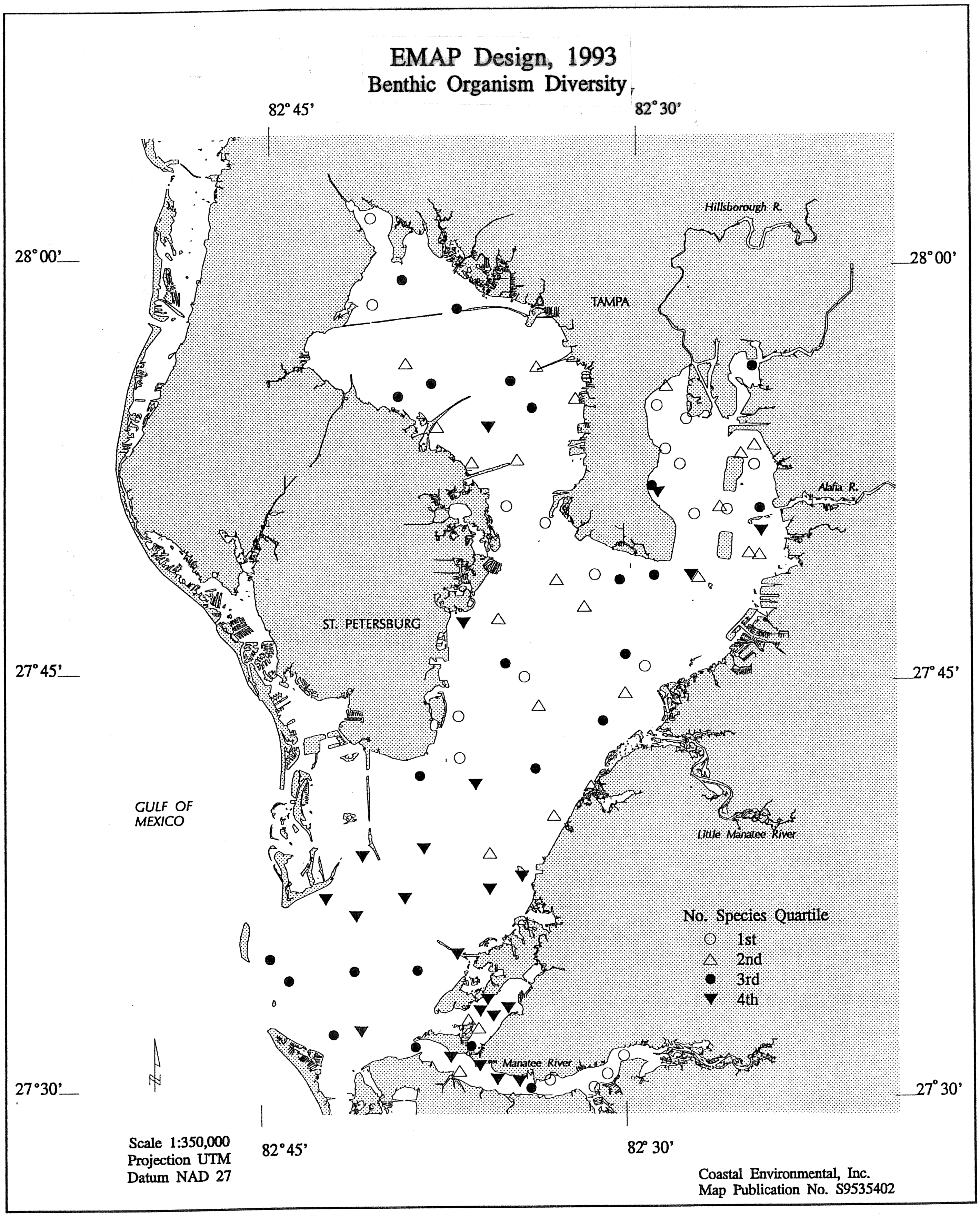


Figure B-14. TBNEP/EMAP design 1993 benthic organism diversity index scores.

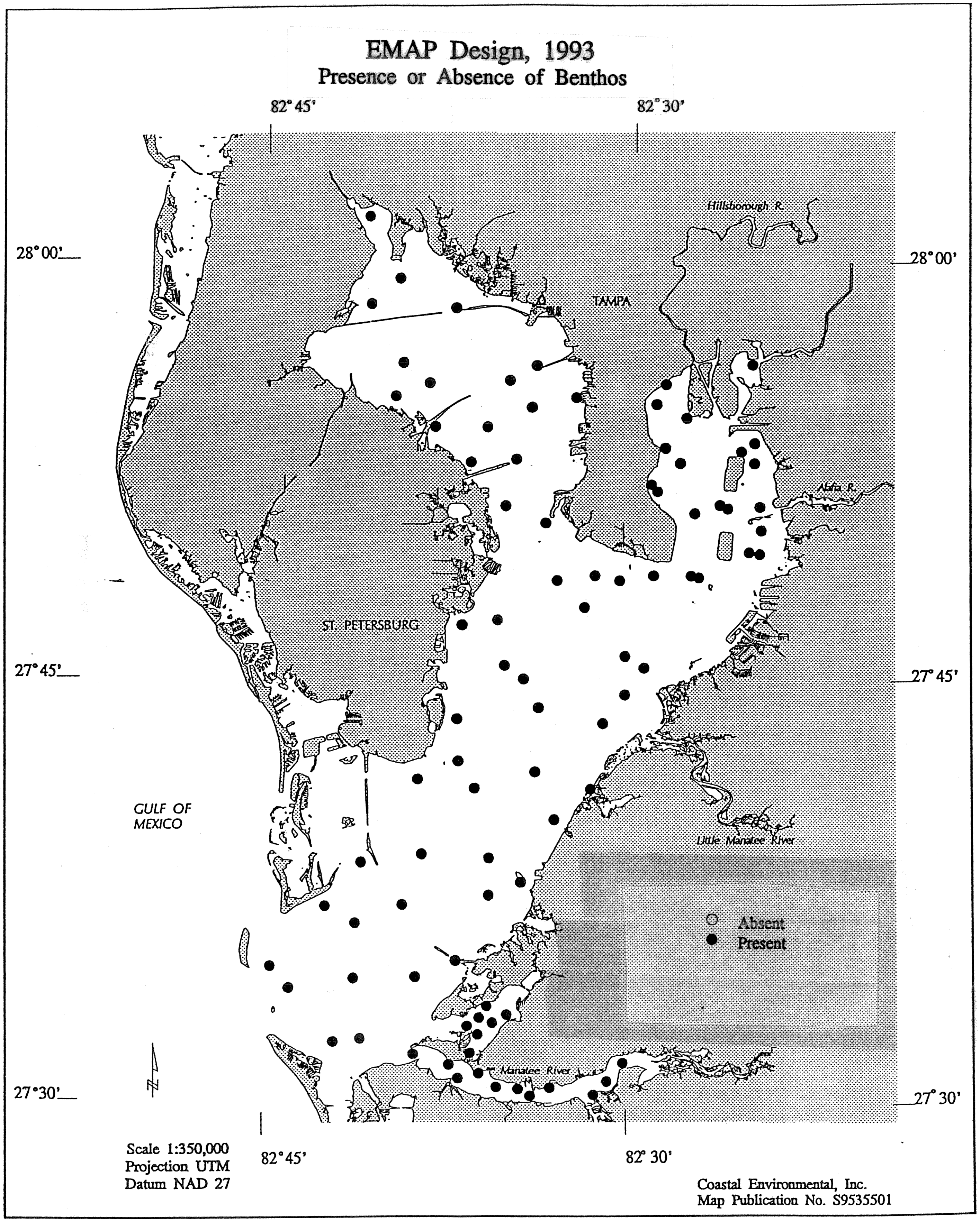


Figure B-15. TBNEP/EMAP design (1993) presence or absence of benthic organisms index scores.

sampled exhibited a total lack of benthos. Figure B-16 illustrates the testing for presence or absence of amphipods, a relatively ubiquitous benthic taxon. Most sites had amphipods present, and there was no apparent spatial pattern for those sites without amphipods.

<u>MacDonald (unpublished)</u>

MacDonald sampled benthic organisms coincident with Long et al. (1994) sediment sampling. Results of applying the Shannon Index to MacDonald's data are shown in Figure B-17. Most of the sites in Hillsborough Bay and in nearshore sites are within the lower diversity quartiles. The site with an index score of 2 in Middle Tampa Bay was located in a ship channel. MacDonald's level of identification of benthic organisms was not appropriate for use of the EMAP Louisianian Province Index, so that test of impacts was not completed for this data set. However, other measures of benthic community structure were used. Figure B-18 shows community diversity. Figure B-19 shows the results of testing for presence or absence of benthic organisms at each site. No sites that were sampled exhibited a total lack of benthos. However, MacDonald (unpublished) did not sample sites in north Ybor Channel because initial observations did not reveal benthos. A thorough sampling of this area may have identified sites with an absence of benthic organisms Figure B-20 illustrates the testing for presence or absence of amphipods. All sites had amphipods present.

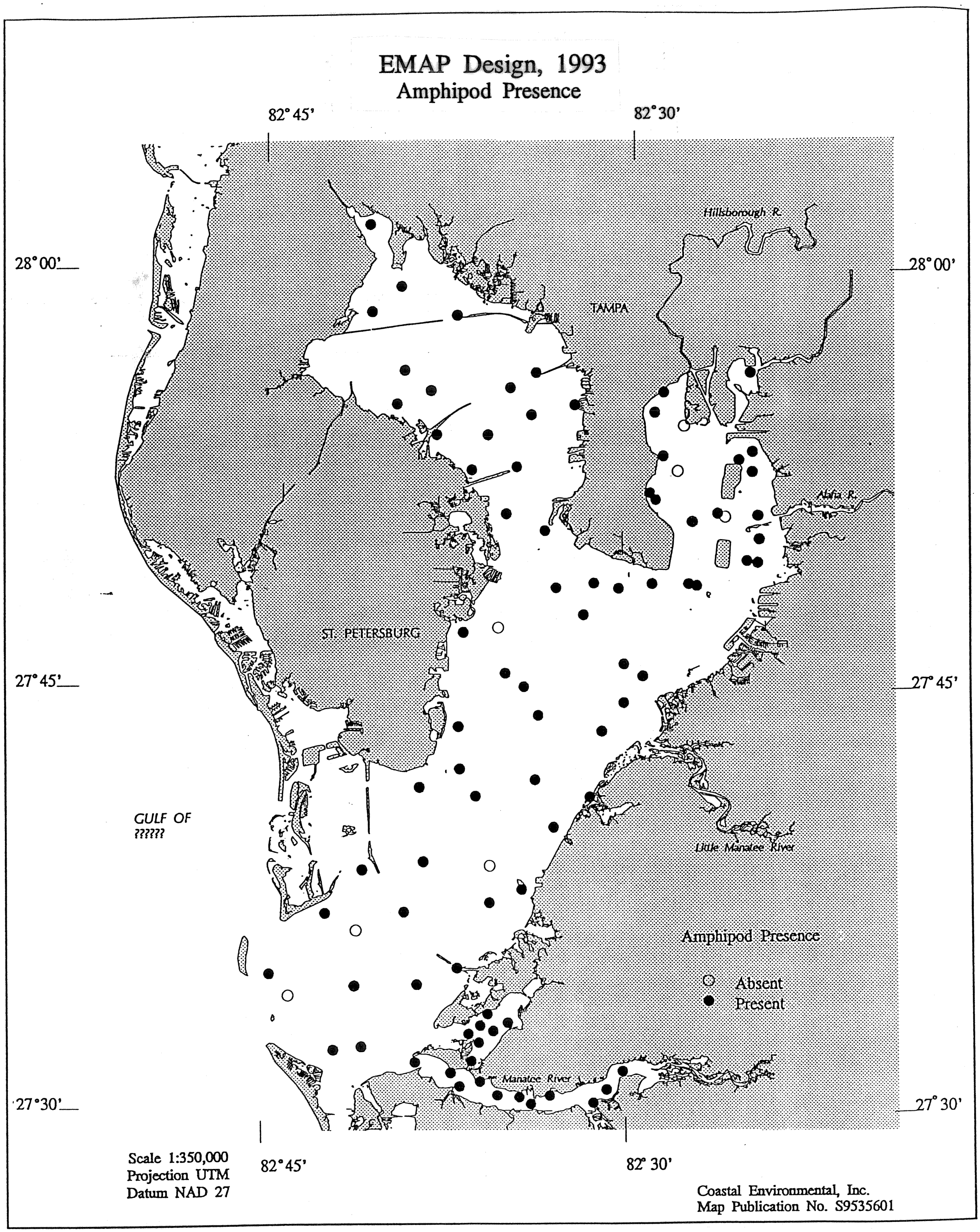


Figure B-16. TBNEP/EMAP design (1993) presence or absence of amphipods index scores.

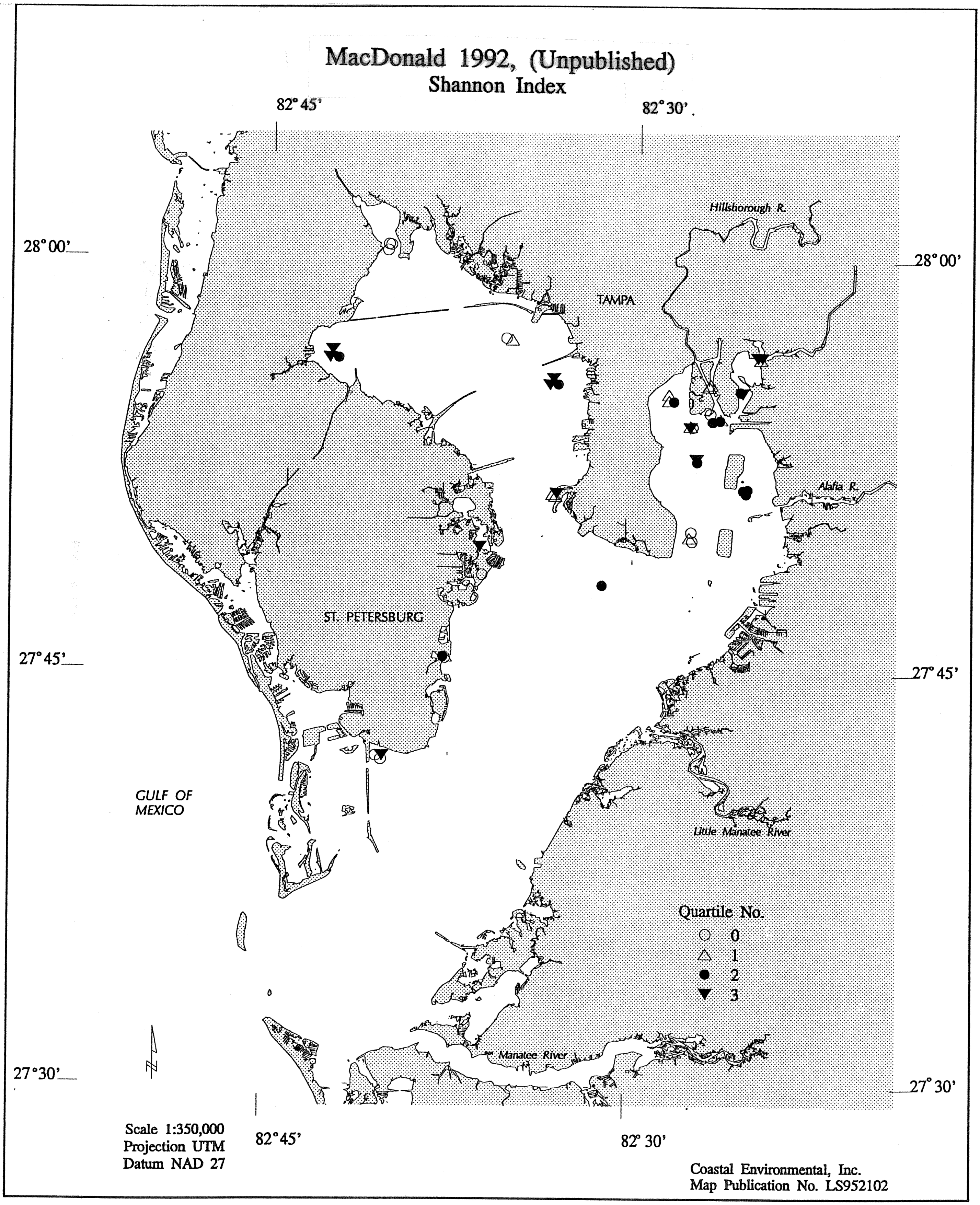


Figure B-17. MacDonald (unpublished) Shannon Index scores.

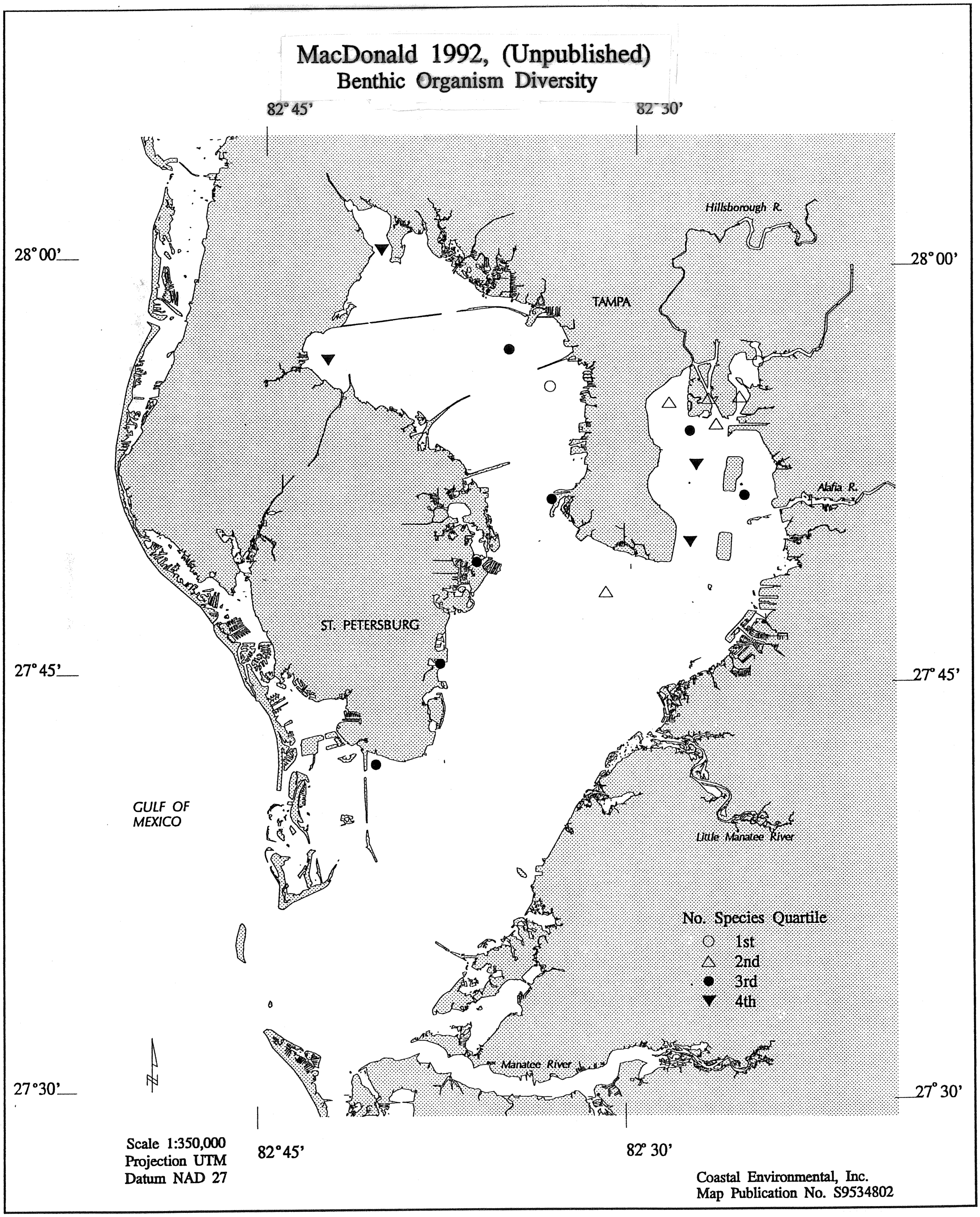


Figure B-18. MacDonald (unpublished) benthic organism diversity index scores.

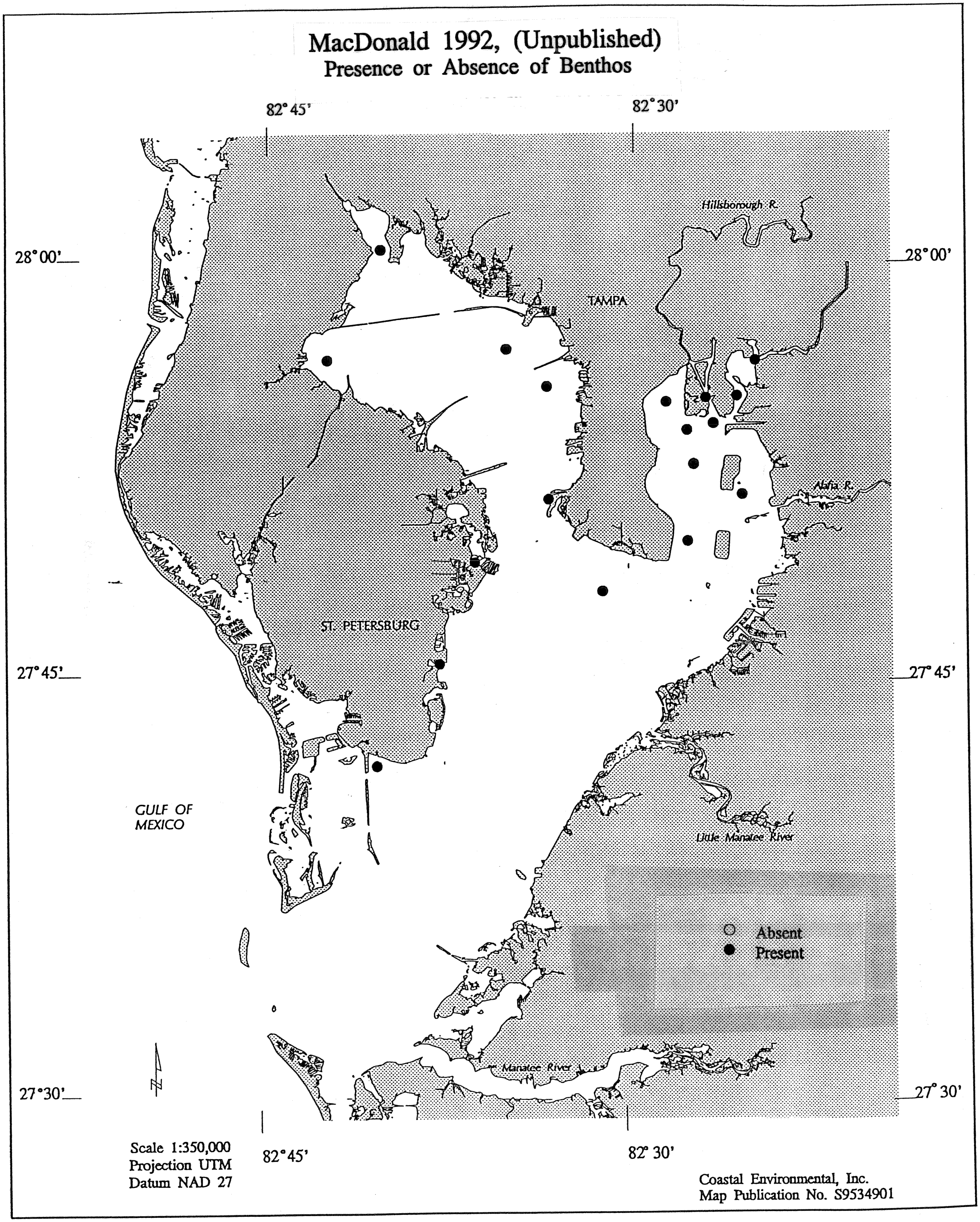


Figure B-19. MacDonald (unpublished) presence of absence of benthic organisms index scores.

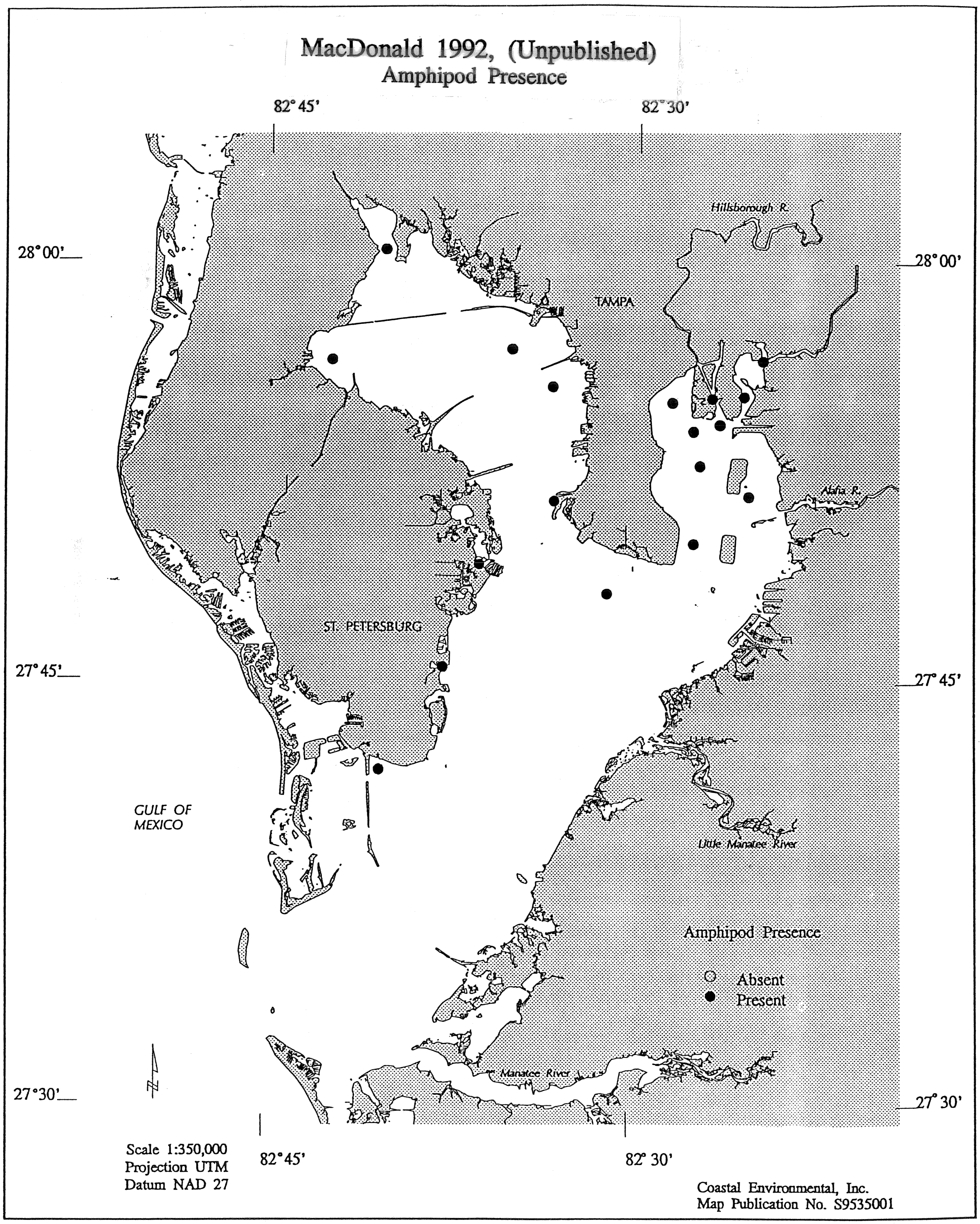


Figure B-20. MacDonald (unpublished) presence of absence of amphipods index scores.

APPENDIX C

Summary of PEL and TEL Exceedences by Sampling Site

FDEP, 1994 SEDIMENT CHEMISTRY - METALS TEL and PEL Exceedences								
STATION	AG_TEL	AS_TEL	CD_TEL	CR_TEL	CU_TEL	HG_TEL	PB_TEL	ZN_TEL
ACK-0001								
ALR-0001			X		X		X	X
BBH-0001	X	X	X		X		X	X
BBH-0002	X		X		X			
HLB-0001			X			X		
HLB-0002						X		
HLB-0003			X			X		
HLB-0007			X	X	X	X		X
HLB-0008			X	X		X		
HLB-0013	X	X	X		X	X	X	X
HLB-0014	X		X			X	X	
HLB-0015			X	X				
HLB-0016	X		X		X	X	X	X
HLB-0017				X		X		
HLB-0018	X		X		X	X	X	
HLB-0019	X	X	X		X		X	X
HLB-0020								
HLB-00A1			X	X	X			X
HLB-00C2								
HLB-00C3					X			X
HLB-00D2								
HLB-00D4			X		X			X
HLB-00E2		X						
HLB-00E3								
HLB-00E5			X	X	X			X
HLB-00F2								
HLB-00F4								
HLB-00G1								
HLB-00G2		X	X	X	X	X	X	X
HLB-00G3		X	X	X	X	X	X	
HLB-00G5								
HLB-00G8								
HLB-00H6			X		X		X	X
HLB-00I1								
HLB-00I2								
HLB-00I4								
HLB-00I6								
HLB-00I8								
HLB-00J4								
HLB-00J5		X	X					
HLB-00J6								
HLB-00K2			X	X	X	X	X	

FDEP, 1994 SEDIMENT CHEMISTRY - METALS
TEL and PEL Exceedences (cont.)

STATION	AG TEL	AS TEL	CD TEL	CR TEL	CU TEL	HG TEL	PB TEL	ZN TEL
HLB-00K4								
HLB-00L5			X		X			
HLB-00L6			X	X		X		
HLB-00M1								
HLB-00M2			X	X	X	X	X	
HLB-00M3			X					
HLB-00M5		X	X	X		X		
HLB-00M6			X	X				
HLB-00O3								
HLB-00O5								
HLB-00O9			X	X	X			
HLB-00Q1								
HLB-00Q3								
HLB-00Q5								
HLB-00R5		X	X	X			X	
HLB-00R6								
HLB-00R7								
HLB-00R8								
HLB-00S2								
HLB-00S3								
HLB-00S4								
HLB-00U2								
HLB-00U6								
HLB-00W1								
HLB-00W2		X		X		X		X
HLB-00W2		X		X		X		X
HLB-00W4								
HLB-00W5		X						
HLB-00W6								
HLB-00W7								
HLB-00Y3								
HLB-0AA1								
HLB-0AA3								
HLB-0AA4								
HLB-0AA6								
HLB-0G10.5								
HLB-0G11								
HLB-0O11								
HLB-G10.			X	X	X	X	X	X
HLR-0001	X	X	X	X				
HLR-0002	X		X	X		X		
HLR-0003	X		X	X	X	X	X	X

FDEP, 1994 SEDIMENT CHEMISTRY - METALS TEL and PEL Exceedences (cont.)								
STATION	AG_TEL	AS_TEL	CD_TEL	CR_TEL	CU_TEL	HG_TEL	PB_TEL	ZN_TEL
LMR-0001								
LMR-0002			X	X	X			
LMR-0003								
LMR-0004								
LMR-0005			X	X	X			
MAR-0001								
MAR-0002								
MAR-0003								
MAR-0004							X	
MAR-0005								
MAR-0006				X	X			
MAR-0007				X	X	X	X	
MAR-0008								
MAR-0009								
MAR-0010								
MAR-0011								
MAR-0012			X	X	X	X	X	
MAR-0013								
MAR-0014								
MKB-0001								
OTB-0001						X		
OTB-0002			X	X		X		
OTB-0003						X		
PSB-0001								
SMB-0001								
SMB-0001								
SMB-0002								
SMB-0002								
TCB-0001								
TCB-0001								
TCB-0001								
TEB-0001			X			X	X	X
TEB-0002	X		X	X		X	X	
TEB-0003	X		X	X	X	X		X
TPB-0001				X		X		
TPB-0002						X		
TPB-0003						X		
TPB-0004			X		X	X		
TPB-0005			X	X				
TPB-0006						X		
TPB-0007			X		X			
TPB-0008								

FDEP, 1994 SEDIMENT CHEMISTRY - METALS
TEL and PEL Exceedences (cont.)

STATION	AG TEL	AS TEL	CD TEL	CR TEL	CU TEL	HG TEL	PB TEL	ZN TEL
TPB-0009						X		
TPB-0010						X		
TPB-0011						X		
TPB-0012		X	X	X	X			
TPB-0013		X	X	X		X		
TPB-0014	X		X	X	X		X	
TPB-0015								
TPB-0016								
TPB-0017								
STATION	AG PEL	AS PEL	CD PEL	CR PEL	CU PEL	HG PEL	PB PEL	ZN PEL
ACK-0001								
ALR-0001						X		
BBH-0001				X		X		
BBH-0002								
HLB-0001								
HLB-0002								
HLB-0003								
HLB-0007								
HLB-0008								
HLB-0013				X				
HLB-0014				X				
HLB-0015								
HLB-0016				X				
HLB-0017								
HLB-0018				X				
HLB-0019				X				
HLB-0020								
HLB-00A1		X				X	X	
HLB-00C2								
HLB-00C3		X	X	X			X	
HLB-00D2								
HLB-00D4		X		X			X	
HLB-00E2								
HLB-00E3		X						
HLB-00E5		X					X	
HLB-00F2								
HLB-00F4								
HLB-00G1								
HLB-00G2								
HLB-00G3								
HLB-00G5								
HLB-00G8								

FDEP, 1994 SEDIMENT CHEMISTRY - METALS
TEL and PEL Exceedences (cont.)

STATION	AG PEL	AS PEL	CD PEL	CR PEL	CU PEL	HG PEL	PB PEL	ZN PEL
HLB-00H6		X		X				
HLB-00I1								
HLB-00I2								
HLB-00I4								
HLB-00I6								
HLB-00I8								
HLB-00J4								
HLB-00J5								
HLB-00J6								
HLB-00K2								
HLB-00K4								
HLB-00L5								
HLB-00L6								
HLB-00M1								
HLB-00M2								
HLB-00M3								
HLB-00M5								
HLB-00M6								
HLB-00O3								
HLB-00O5								
HLB-00O9		X						
HLB-00Q1								
HLB-00Q3								
HLB-00Q5								
HLB-00R5						X		
HLB-00R6								
HLB-00R7								
HLB-00R8								
HLB-00S2								
HLB-00S3								
HLB-00S4								
HLB-00U2								
HLB-00U6								
HLB-00W1								
HLB-00W2			X		X		X	
HLB-00W2			X		X		X	
HLB-00W4								
HLB-00W5								
HLB-00W6								
HLB-00W7								
HLB-00Y3								
HLB-0AA1								

FDEP, 1994 SEDIMENT CHEMISTRY - METALS
TEL and PEL Exceedences (cont.)

STATION	AG PEL	AS PEL	CD PEL	CR PEL	CU PEL	HG PEL	PB PEL	ZN PEL
HLB-0AA3								
HLB-0AA4								
HLB-0AA6								
HLB-0G10.5								
HLB-0G11								
HLB-0O11								
HLB-G10.		X						
HLR-0001					X	X	X	X
HLR-0002					X		X	X
HLR-0003								
LMR-0001								
LMR-0002								
LMR-0003								
LMR-0004								
LMR-0005								
MAR-0001								X
MAR-0002								
MAR-0003								
MAR-0004								
MAR-0005								
MAR-0006								
MAR-0007								
MAR-0008								
MAR-0009								
MAR-0010								
MAR-0011								
MAR-0012								
MAR-0013								
MAR-0014								
MKB-0001								
OTB-0001								
OTB-0002								
OTB-0003								
PSB-0001								
SMB-0001								
SMB-0001								
SMB-0002								
SMB-0002								
TCB-0001								
TCB-0001								
TCB-0001								
TEB-0001								

FDEP, 1994 SEDIMENT CHEMISTRY - METALS
TEL and PEL Exceedences (cont.)

STATION	AG PEL	AS PEL	CD PEL	CR PEL	CU PEL	HG PEL	PB PEL	ZN PEL
TEB-0002								
TEB-0003								
TPB-0001								
TPB-0002								
TPB-0003								
TPB-0004								
TPB-0005								
TPB-0006								
TPB-0007				X		X		
TPB-0008								
TPB-0009								
TPB-0010								
TPB-0011								
TPB-0012								
TPB-0013								
TPB-0014								
TPB-0015								
TPB-0016								
TPB-0017								
TPB-0017								

FDEP, 1994 Sediment Chemistry - Organics
TEL and PEL Exceedences

STATION	PCB TEL	PAH TEL	CLD TEL	DDD TEL	DDE TEL	DDT TEL	DEL TEL	LND TEL
ACK-0001								
ALR-0001								
BBH-0001								
BBH-0002								
HLB-0001								
HLB-0002								
HLB-0003								
HLB-0007								
HLB-0008								
HLB-0013								
HLB-0014								
HLB-0015								
HLB-0016								
HLB-0017								
HLB-0018								
HLB-0019								
HLB-0020								
HLB-00A1								
HLB-00C2								
HLB-00C3								
HLB-00D2								
HLB-00D4								
HLB-00E2								
HLB-00E3								
HLB-00E5								
HLB-00F2								
HLB-00F4								
HLB-00G1								
HLB-00G2								
HLB-00G3								
HLB-00G5								
HLB-00G8								
HLB-00H6								
HLB-00I1								
HLB-00I2								
HLB-00I4								
HLB-00I6								
HLB-00I8								
HLB-00J4								
HLB-00J5								
HLB-00J6								
HLB-00K2								

FDEP, 1994 Sediment Chemistry - Organics
TEL and PEL Exceedences (cont.)

STATION	PCB TEL	PAH TEL	CLD TEL	DDD TEL	DDE TEL	DDT TEL	DEL TEL	LND TEL
HLB-00K4								
HLB-00L5								
HLB-00L6								
HLB-00M1								
HLB-00M2								
HLB-00M3								
HLB-00M5								
HLB-00M6								
HLB-00O3								
HLB-00O5								
HLB-00O9								
HLB-00Q1								
HLB-00Q3								
HLB-00Q5								
HLB-00R5								
HLB-00R6								
HLB-00R7								
HLB-00R8								
HLB-00S2								
HLB-00S3								
HLB-00S4								
HLB-00U2								
HLB-00U6								
HLB-00W1								
HLB-00W2								
HLB-00W2								
HLB-00W4								
HLB-00W5								
HLB-00W6								
HLB-00W7								
HLB-00Y3								
HLB-0AA1								
HLB-0AA3								
HLB-0AA4								
HLB-0AA6								
HLB-0G10.5								
HLB-0G11								
HLB-0O11								
HLB-G10.								
HLR-0001								
HLR-0002								
HLR-0003								

FDEP, 1994 Sediment Chemistry - Organics
TEL and PEL Exceedences (cont.)

STATION	PCB TEL	PAH TEL	CLD TEL	DDD TEL	DDE TEL	DDT TEL	DEL TEL	LND TEL
LMR-0001								
LMR-0002								
LMR-0003								
LMR-0004								
LMR-0005								
MAR-0001								
MAR-0002								
MAR-0003								
MAR-0004								
MAR-0005								
MAR-0006								
MAR-0007								
MAR-0008								
MAR-0009								
MAR-0010								
MAR-0011								
MAR-0012								
MAR-0013								
MAR-0014								
MKB-0001								
OTB-0001								
OTB-0002								
OTB-0003								
PSB-0001								
SMB-0001								
SMB-0001								
SMB-0002								
SMB-0002								
TCB-0001								
TCB-0001								
TCB-0001								
TEB-0001								
TEB-0002								
TEB-0003								
TPB-0001								
TPB-0002								
TPB-0003								
TPB-0004								
TPB-0005								
TPB-0006								
TPB-0007								
TPB-0008								

FDEP, 1994 Sediment Chemistry - Organics
TEL and PEL Exceedences (cont.)

STATION	PCB TEL	PAH TEL	CLD TEL	DDD TEL	DDE TEL	DDT TEL	DEL TEL	LND TEL
TPB-0009								
TPB-0010								
TPB-0011								
TPB-0012								
TPB-0013								
TPB-0014								
TPB-0015								
TPB-0016								
TPB-0017								

STATION	PCB PEL	PAH PEL	CLD PEL	DDD PEL	DDE PEL	DDT PEL	DEL PELL	LND PEL
ACK-0001								
ALR-0001								
BBH-0001								
BBH-0002								
HLB-0001								
HLB-0002								
HLB-0003								
HLB-0007								
HLB-0008								
HLB-0013								
HLB-0014								
HLB-0015								
HLB-0016								
HLB-0017								
HLB-0018								
HLB-0019								
HLB-0020								
HLB-00A1								
HLB-00C2								
HLB-00C3								
HLB-00D2								
HLB-00D4								
HLB-00E2								
HLB-00E3								
HLB-00E5								
HLB-00F2								
HLB-00F4								
HLB-00G1								
HLB-00G2								
HLB-00G3								
HLB-00G5								
HLB-00G8								

FDEP, 1994 Sediment Chemistry - Organics
TEL and PEL Exceedences (cont.)

STATION	PCB PEL	PAH PEL	CLD PEL	DDD PEL	DDE PEL	DDT PEL	DEL PELL	LND PEL
HLB-00H6								
HLB-00I1								
HLB-00I2								
HLB-00I4								
HLB-00I6								
HLB-00I8								
HLB-00J4								
HLB-00J5								
HLB-00J6								
HLB-00K2								
HLB-00K4								
HLB-00L5								
HLB-00L6								
HLB-00M1								
HLB-00M2								
HLB-00M3								
HLB-00M5								
HLB-00M6								
HLB-00O3								
HLB-00O5								
HLB-00O9								
HLB-00Q1								
HLB-00Q3								
HLB-00Q5								
HLB-00R5								
HLB-00R6								
HLB-00R7								
HLB-00R8								
HLB-00S2								
HLB-00S3								
HLB-00S4								
HLB-00U2								
HLB-00U6								
HLB-00W1								
HLB-00W2								
HLB-00W2								
HLB-00W4								
HLB-00W5								
HLB-00W6								
HLB-00W7								
HLB-00Y3								
HLB-0AA1								

FDEP, 1994 Sediment Chemistry - Organics
TEL and PEL Exceedences (cont.)

STATION	PCB PEL	PAH PEL	CLD PEL	DDD PEL	DDE PEL	DDT PEL	DEL PELL	LND PEL
HLB-0AA3								
HLB-0AA4								
HLB-0AA6								
HLB-0G10.5								
HLB-0G11								
HLB-0O11								
HLB-G10.								
HLR-0001								
HLR-0002								
HLR-0003								
LMR-0001								
LMR-0002								
LMR-0003								
LMR-0004								
LMR-0005								
MAR-0001								
MAR-0002								
MAR-0003								
MAR-0004								
MAR-0005								
MAR-0006								
MAR-0007								
MAR-0008								
MAR-0009								
MAR-0010								
MAR-0011								
MAR-0012								
MAR-0013								
MAR-0014								
MKB-0001								
OTB-0001								
OTB-0002								
OTB-0003								
PSB-0001								
SMB-0001								
SMB-0001								
SMB-0002								
SMB-0002								
TCB-0001								
TCB-0001								
TCB-0001								
TEB-0001								

FDEP, 1994 Sediment Chemistry - Organics
TEL and PEL Exceedences (cont.)

STATION	PCB PEL	PAH PEL	CLD PEL	DDD PEL	DDE PEL	DDT PEL	DEL PELL	LND PEL
TEB-0002								
TEB-0003								
TPB-0001								
TPB-0002								
TPB-0003								
TPB-0004								
TPB-0005								
TPB-0006								
TPB-0007								
TPB-0008								
TPB-0009								
TPB-0010								
TPB-0011								
TPB-0012								
TPB-0013								
TPB-0014								
TPB-0015								
TPB-0016								
TPB-0017								

EMAP Design, 1993 Sediment Chemistry TEL and PEL Exceedences								
STATION	AG TEL	AS TEL	CD TEL	CR TEL	CU TEL	HG TEL	PB TEL	ZN TEL
WI93LR03								
WI93LR04								
WI93LR05								
WI93LR06								
WI93LR07								
WI93LR08								
WI93LR09								
WI93LR10								
WI93LR12								
WI93LR13								
WI93LR14								
WI93LR15								
WI93LR16								
WI93LR18								
WI93LR19								
WI93LR20								
WI93LR21								
WI93LR22								
WI93LR23								
WI93LR24								
WI93LR25								
WI93LR26								
WI93LR27								
WI93LR28								
WI93LR29								
WI93LR30								
WI93LR31								
WI93LR32								
WI93LR33								
WI93LR34								
WI93LR35								
WI93LR36								
WI93LR37								
WI93LR38								
WI93LR39								
WI93LR40		X						
WI93LR41								
WI93LR42								
WI93LR43								
WI93LR44								
WI93LR45								
WI93LR47								

EMAP Design, 1993 Sediment Chemistry
TEL and PEL Exceedences (cont.)

STATION	AG_TEL	AS_TEL	CD_TEL	CR_TEL	CU_TEL	HG_TEL	PB_TEL	ZN_TEL
WI93LR48								
WI93LR49								
WI93LR50								
WI93LR51								
WI93LR52								
WI93LR53								
WI93LR54								
WI93LR55								
WI93LR56								
WI93LR57								
WI93LR58								
WI93LR59								
WI93LR60								
WI93LR61								
WI93LR63				X				
WI93LR64								
WI93LR65								
WI93LR66								
WI93LR67								
WI93LR68								
WI93LR69								
WI93LR70								
WI93LR71								
WI93LR72								
WI93LR73								
WI93LR76								
WI93LR77								
WI93LR78								
WI93LR79								
WI93LR80								
WI93LR83								
WI93SR22								
WI93SR23								
WI93SR24								
WI93SR25								
WI93SR26								
WI93SR27								
WI93SR28								
WI93SR29								
WI93SR31								
WI93SR32								
WI93SR34								

EMAP Design, 1993 Sediment Chemistry
TEL and PEL Exceedences (cont.)

STATION	AG_TEL	AS_TEL	CD_TEL	CR_TEL	CU_TEL	HG_TEL	PB_TEL	ZN_TEL
WI93SR37								
WI93SR38								
WI93SR39								
WI93SR40								
WI93SR41								
WI93SR42								
WI93SR43								
STATION	AG_PEL	AS_PEL	CD_PEL	CR_PEL	CU_PEL	HG_PEL	PB_PEL	ZN_PEL
WI93LR03								
WI93LR04								
WI93LR05								
WI93LR06								
WI93LR07								
WI93LR08								
WI93LR09								
WI93LR10								
WI93LR12								
WI93LR13								
WI93LR14								
WI93LR15								
WI93LR16								
WI93LR18								
WI93LR19								
WI93LR20								
WI93LR21								
WI93LR22								
WI93LR23								
WI93LR24								
WI93LR25								
WI93LR26								
WI93LR27								
WI93LR28								
WI93LR29								
WI93LR30								
WI93LR31								
WI93LR32								
WI93LR33								
WI93LR34								
WI93LR35								
WI93LR36								
WI93LR37								
WI93LR38								

EMAP Design, 1993 Sediment Chemistry
TEL and PEL Exceedences (cont.)

STATION	AG_PEL	AS_PEL	CD_PEL	CR_PEL	CU_PEL	HG_PEL	PB_PEL	ZN_PEL
WI93LR39								
WI93LR40								
WI93LR41								
WI93LR42								
WI93LR43								
WI93LR44								
WI93LR45								
WI93LR47								
WI93LR48								
WI93LR49								
WI93LR50								
WI93LR51								
WI93LR52								
WI93LR53								
WI93LR54								
WI93LR55								
WI93LR56								
WI93LR57								
WI93LR58								
WI93LR59								
WI93LR60								
WI93LR61								
WI93LR63								
WI93LR64								
WI93LR65								
WI93LR66								
WI93LR67								
WI93LR68								
WI93LR69								
WI93LR70								
WI93LR71								
WI93LR72								
WI93LR73								
WI93LR76								
WI93LR77								
WI93LR78								
WI93LR79								
WI93LR80								
WI93LR83								
WI93SR22								
WI93SR23								
WI93SR24								

EMAP Design, 1993 Sediment Chemistry TEL and PEL Exceedences (cont.)								
STATION	AG_PEL	AS_PEL	CD_PEL	CR_PEL	CU_PEL	HG_PEL	PB_PEL	ZN_PEL
WI93SR25								
WI93SR26								
WI93SR27								
WI93SR28								
WI93SR29								
WI93SR31								
WI93SR32								
WI93SR34								
WI93SR37								
WI93SR38								
WI93SR39								
WI93SR40								
WI93SR41								
WI93SR42								
WI93SR43								
WI93SR43								

Long et al., 1994 Sediment Chemistry - Phase 1 Metals TEL and PEL Exceedences						
STATION	CD_TEL	CR_TEL	CU_TEL	HG_TEL	PB_TEL	ZN_TEL
11A	X	X				
11B		X				
11C		X				
12A	X	X	X	X	X	
12B	X	X		X	X	
12C	X	X	X	X	X	
13A						
13B						
13C						
15B		X				
16A						
16B						
16C						
17A						
17B						
17C						
18A						
18B						
18C			X			
19B						
19C						
1A	X	X		X		
1B	X	X		X		
1C	X	X		X		
21A						
21B						
21C						
22A			X	X	X	
22B			X	X	X	
22C				X		
23A						
23B						
23C						
24A						
24B						
24C						
25A						
25B		X	X			
25C						
27A						
27B						
27C						

Long et al., 1994 Sediment Chemistry - Phase 1 Metals
TEL and PEL Exceedences

STATION	CD TEL	CR TEL	CU TEL	HG TEL	PB TEL	ZN TEL
29A						
29B						
29C						
2A	X	X		X		
2B		X		X		
2C	X	X		X		
3A	X				X	
3B	X				X	
3C						
4A		X	X	X		
4B		X	X	X		
4C		X	X	X		
6A						
6B						
6C	X					
7A	X	X	X	X	X	X
7B	X	X		X	X	X
7C	X	X		X	X	X
8A						
8B						
8C						
STATION	CD PEL	CR PEL	CU PEL	HG PEL	PB PEL	ZN PEL
11A						
11B						
11C						
12A						
12B						
12C						
13A						
13B						
13C						
15B						
16A						
16B						
16C						
17A						
17B						
17C						
18A						
18B						
18C						
19B						

Long et al., 1994 Sediment Chemistry - Phase 1 Metals
TEL and PEL Exceedences

STATION	CD_PEL	CR_PEL	CU_PEL	HG_PEL	PB_PEL	ZN_PEL
19C						
1A			X		X	X
1B			X		X	X
1C			X		X	X
21A						
21B						
21C						
22A						
22B						
22C						
23A						
23B						
23C						
24A						
24B						
24C						
25A						
25B						
25C						
27A						
27B						
27C						
29A						
29B						
29C						
2A			X		X	X
2B	X		X		X	X
2C			X		X	X
3A						
3B						
3C						
4A	X				X	X
4B	X				X	X
4C	X				X	X
6A						
6B						
6C						
7A						
7B			X			
7C			X			
8A						
8B						

Long et al., 1994 Sediment Chemistry - Phase 1 Metals TEL and PEL Exceedences						
STATION	CD_PEL	CR_PEL	CU_PEL	HG_PEL	PB_PEL	ZN_PEL
8C						

Long et al., 1994 Sediment Chemistry - Phase 1 Organics TEL and PEL Exceedences					
STATION	PCB TEL	PAH TEL	CLD TEL	DDT TEL	DEL TEL
11A					
11B					
11C	X			X	
12A					
12B	X				
12C				X	
13A					
13B					
13C					
15B					
16A					
16B					
16C					
17A					
17B					
17C					
18A					
18B					
18C					
19B					
19C					
1A					
1B					
1C					
21A					
21B					
21C					
22A				X	
22B					
22C					
23A					
23B					
23C					
24A					
24B					
24C					
25A					
25B	X		X	X	
25C					
27A					
27B					
27C					

Long et al., 1994 Sediment Chemistry - Phase 1 Organics
TEL and PEL Exceedences (cont.)

STATION	CD PEL	CR PEL	CU PEL	HG PEL	PB PEL
29A					
29B					
29C					
2A					
2B					
2C					
3A			X	X	
3B			X	X	
3C					
4A				X	
4B					
4C					
6A					
6B	X			X	
6C				X	
7A					
7B					
7C					
8A					
8B					
8C					

STATION	PCB TEL	PAH TEL	CLD TEL	DDT TEL	DEL TEL
11A					
11B					
11C	X			X	
12A					
12B	X				
12C				X	
13A					
13B					
13C					
15B					
16A					
16B					
16C					
17A					
17B					
17C					
18A					
18B					
18C					
19B					

Long et al., 1994 Sediment Chemistry - Phase 1 Organics
TEL and PEL Exceedences (cont.)

STATION	PCB TEL	PAH TEL	CLD TEL	DDT TEL	DEL TEL
19C					
1A					
1B					
1C					
21A					
21B					
21C					
22A				X	
22B					
22C					
23A					
23B					
23C					
24A					
24B					
24C					
25A					
25B	X		X	X	
25C					
27A					
27B					
27C					
29A					
29B					
29C					
2A					
2B					
2C					
3A			X	X	
3B			X	X	
3C					
4A				X	
4B					
4C					
6A					
6B	X			X	
6C				X	
7A					
7B					
7C					
8A					
8B					
8C					

Long et al., 1994 Sediment Chemistry - Phase 2 Metals TEL and PEL Exceedences (cont.)						
STATION	CD_TEL	CR_TEL	CU_TEL	HG_TEL	PB_TEL	ZN_TEL
10A	X	X	X	X	X	
10B	X	X	X	X	X	
10C	X	X	X	X	X	
11A	X	X	X	X	X	
11B	X	X	X	X	X	
11C	X	X			X	
12A						
12B						
12C						
13A	X	X		X		
13B	X	X		X		
13C	X	X		X		
14A						
14B			X			
14C						
15A	X			X	X	
15B						
15C	X	X	X	X		X
16A	X	X		X		X
16B	X	X		X		
16C	X	X	X	X	X	X
17A						
17B				X		
17C						
18A	X		X	X		X
18B						
18C	X		X	X		
19A	X	X	X	X	X	
19B						
19C				X	X	
1A	X	X		X		
1B	X	X		X		
1C	X	X		X		
20A						
20B						
20C						
21A						
21B						
21C						
22A						
22B						
22C						

Long et al., 1994 Sediment Chemistry - Phase 2 Metals
TEL and PEL Exceedences (cont.)

STATION	CD_TEL	CR_TEL	CU_TEL	HG_TEL	PB_TEL	ZN_TEL
23A	X	X	X	X		X
23B	X		X	X	X	X
23C						
24A	X	X	X		X	
24B						
24C						
25A	X	X	X	X	X	
25B						
25C	X		X			
2A	X	X		X		
2B	X	X		X		
2C	X	X		X		
3A	X	X		X	X	
3B	X	X		X	X	
3C	X	X		X	X	
4A	X	X	X	X	X	X
4B			X			
4C	X	X	X	X	X	X
5A	X	X	X	X	X	X
5B	X	X	X		X	X
5C	X	X	X	X	X	X
6A	X			X		
6B	X			X		
6C	X					
7A	X	X			X	
7B		X			X	
7C		X				
8A		X		X	X	
8B	X	X			X	
8C		X			X	
9A	X			X	X	
9B		X			X	
9C	X	X		X	X	
STATION	CD_PEL	CR_PEL	CU_PEL	HG_PEL	PB_PEL	ZN_PEL
10A						
10B						
10C						
11A						
11B						
11C						
12A						
12B						

Long et al., 1994 Sediment Chemistry - Phase 2 Metals
TEL and PEL Exceedences (cont.)

STATION	CD_PEL	CR_PEL	CU_PEL	HG_PEL	PB_PEL	ZN_PEL
12C						
13A			X		X	X
13B			X		X	X
13C			X		X	X
14A						
14B						
14C						
15A						
15B						
15C					X	
16A			X		X	
16B			X		X	X
16C						
17A						
17B						
17C						
18A					X	
18B						
18C					X	X
19A						
19B						
19C						
1A			X		X	X
1B			X		X	X
1C			X		X	X
20A						
20B						
20C						
21A						
21B						
21C						
22A						
22B						
22C						
23A					X	
23B						
23C						
24A						
24B						
24C						
25A						
25B						

Long et al., 1994 Sediment Chemistry - Phase 2 Metals TEL and PEL Exceedences (cont.)						
STATION	CD_PEL	CR_PEL	CU_PEL	HG_PEL	PB_PEL	ZN_PEL
25C						
2A			X		X	X
2B			X		X	X
2C			X		X	X
3A			X			X
3B			X			X
3C			X			X
4A						
4B						
4C						
5A						
5B						
5C						
6A						
6B						
6C						
7A						
7B						
7C						
8A						
8B						
8C						
9A		X				
9B						
9C						
9C						

Long et al., 1994 Sediment Chemistry - Phase 2 Organics TEL and PEL Exceedences					
STATION	PCB_TEL	PAH_TEL	CLD_TEL	DDT_TEL	DEL_TEL
10A					
10B	X		X	X	X
10C	X		X	X	X
11A	X			X	X
11B	X			X	X
11C					X
12A					X
12B					
12C				X	X
13A	X		X	X	X
13B	X			X	X
13C	X		X	X	X
14A	X		X	X	X
14B	X			X	
14C					
15A	X		X	X	X
15B					
15C					
16A	X			X	
16B					
16C					
17A					
17B					
17C					
18A					
18B					
18C	X				
19A	X			X	X
19B					
19C					
1A					
1B					
1C					
20A				X	
20B					
20C					X
21A					
21B					
21C					
22A					
22B				X	X
22C					X

Long et al., 1994 Sediment Chemistry - Phase 2 Organics
TEL and PEL Exceedences (cont.)

STATION	PCB TEL	PAH TEL	CLD TEL	DDT TEL	DEL TEL
23A					
23B					
23C	X		X	X	X
24A			X	X	X
24B					
24C					
25A					
25B					
25C					
2A			X		X
2B					X
2C			X		
3A			X		X
3B			X		X
3C	X		X	X	X
4A					
4B	X				X
4C	X			X	X
5A					
5B					
5C	X			X	
6A	X			X	X
6B					
6C					X
7A					
7B					
7C				X	
8A					
8B					
8C					
9A					
9B				X	X
9C					
STATION	PCB TEL	PAH TEL	CLD TEL	DDT TEL	DEL TEL
10A					
10B	X		X	X	X
10C	X		X	X	X
11A	X			X	X
11B	X			X	X
11C					X
12A					X
12B					

Long et al., 1994 Sediment Chemistry - Phase 2 Organics TEL and PEL Exceedences (cont.)					
STATION	PCB_TEL	PAH_TEL	CLD_TEL	DDT_TEL	DEL_TEL
12C				X	X
13A	X		X	X	X
13B	X			X	X
13C	X		X	X	X
14A	X		X	X	X
14B	X			X	
14C					
15A	X		X	X	X
15B					
15C					
16A	X			X	
16B					
16C					
17A					
17B					
17C					
18A					
18B					
18C	X				
19A	X			X	X
19B					
19C					
1A					
1B					
1C					
20A				X	
20B					
20C					X
21A					
21B					
21C					
22A					
22B				X	X
22C					X
23A					
23B					
23C	X		X	X	X
24A			X	X	X
24B					
24C					
25A					
25B					

Long et al., 1994 Sediment Chemistry - Phase 2 Organics TEL and PEL Exceedences (cont.)					
STATION	PCB TEL	PAH TEL	CLD TEL	DDT TEL	DEL TEL
25C					
2A			X		X
2B					X
2C			X		
3A			X		X
3B			X		X
3C	X		X	X	X
4A					
4B	X				X
4C	X			X	X
5A					
5B					
5C	X			X	
6A	X			X	X
6B					
6C					X
7A					
7B					
7C				X	
8A					
8B					
8C					
9A					
9B				X	X
9C					

Brooks and Doyle, 1992 - Sediment Chemistry TEL and PEL Exceedences						
STATION	CD_TEL	CR_TEL	CU_TEL	HG_TEL	PB_TEL	ZN_TEL
1					X	
2						
3				X	X	
4					X	
5		X	X		X	
6		X	X		X	
7	X	X	X			
8					X	
9			X		X	
10						
11					X	
12		X	X		X	
13			X			
14			X	X	X	
15	X	X				
16		X		X	X	
17		X	X		X	
18	X	X	X	X	X	
19			X		X	
20					X	
21		X	X		X	
22						
23						
24	X	X	X	X		
25						
26						
27	X				X	
28	X			X	X	
29						
30		X	X	X	X	X
31						
32		X	X		X	
33	X	X	X	X		
34	X		X		X	X
35			X	X	X	X
36						
37						
38		X				
39		X	X		X	
40						
41						

Brooks and Doyle, 1992 - Sediment Chemistry
TEL and PEL Exceedences (cont.)

STATION	CD_TEL	CR_TEL	CU_TEL	HG_TEL	PB_TEL	ZN_TEL
42						
43						
44						
45		X	X		X	
46						
47			X	X		X
48		X	X		X	
49					X	
50			X		X	
51						
52						
53						
54					X	
55						
56					X	
57					X	
58						
59	X	X	X	X		
60						
61					X	
62		X	X		X	
63						
64	X	X	X		X	
65						
66						
67						
68					X	
69		X	X			
70						
71						
72						
73		X				X
74						
75						
STATION	CD_PEL	CR_PEL	CU_PEL	HG_PEL	PB_PEL	ZN_PEL
1						
2						
3						
4						
5						
6						
7				X	X	X

Brooks and Doyle, 1992 - Sediment Chemistry TEL and PEL Exceedences (cont.)						
STATION	CD_PEL	CR_PEL	CU_PEL	HG_PEL	PB_PEL	ZN_PEL
8						
9						
10						
11						
12						
13						
14						
15			X	X	X	X
16						
17						
18						
19						
20						
21						
22						
23						
24					X	X
25						
26						
27						
28						
29						
30	X					
31	X	X	X	X	X	X
32						
33					X	X
34						
35	X	X				
36						
37						
38						
39						
40						
41						
42						
43						
44						
45						
46						
47					X	
48						
49						

Brooks and Doyle, 1992 - Sediment Chemistry TEL and PEL Exceedences (cont.)						
STATION	CD PEL	CR PEL	CU PEL	HG PEL	PB PEL	ZN PEL
50						
51						
52						
53						
54						
55						
56						
57						
58						
59					X	
60						
61						
62						
63						
64						
65						
66						
67						
68						
69						
70						
71						
72						
73			X	X	X	
74						
75						

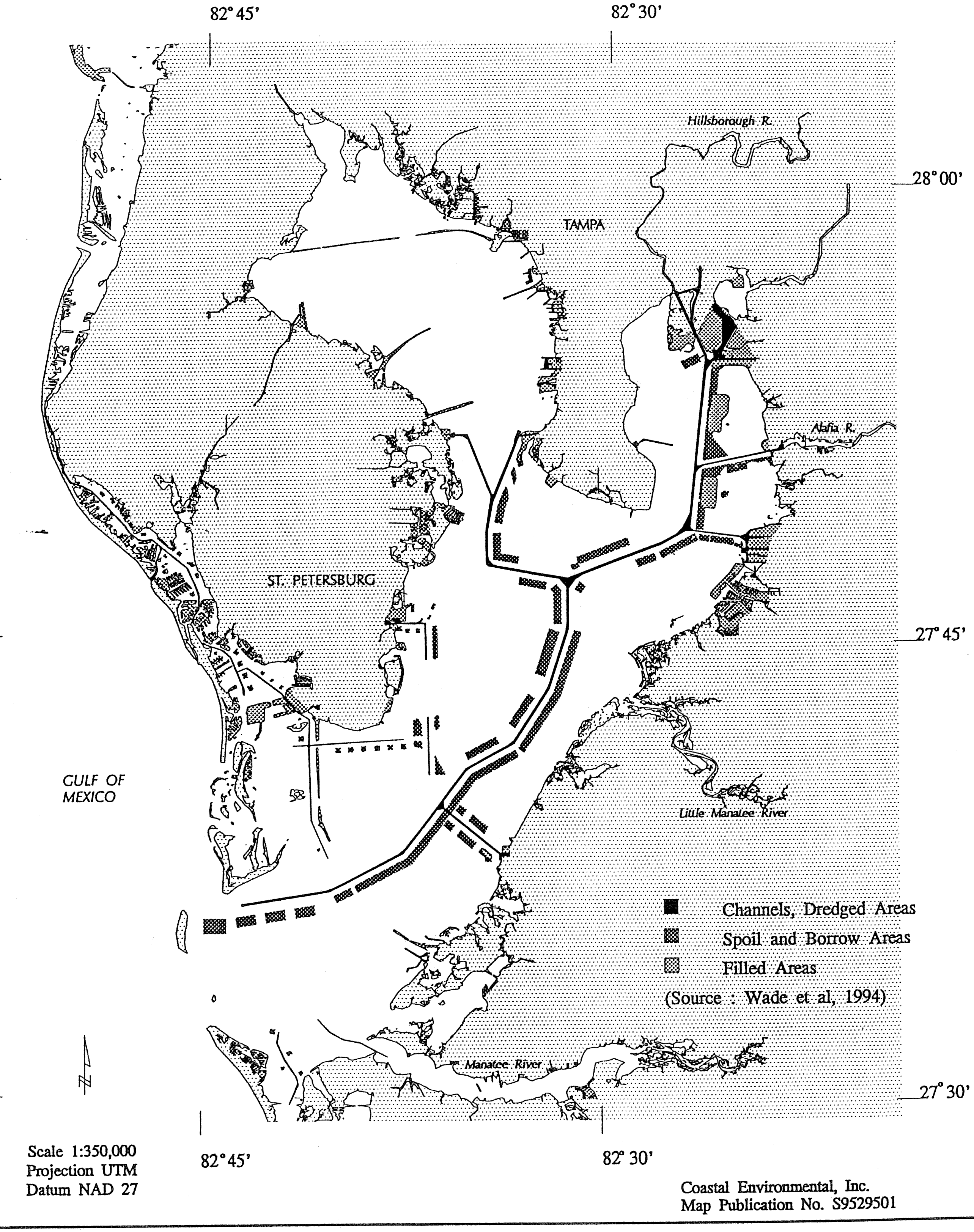
Long et al., 1991 Sediment Chemstry
TEL and PEL Exceedences

STATION	CD TEL	CR TEL	CU TEL	HG TEL	PB TEL	ZN TEL
TBHB	X	X			X	
TBNP	X		X		X	
TBPB						
TBKA						
TBMK						
TAM						
TBOT						
TBCB						
STATION	CD PEL	CR PEL	CU PEL	HG PEL	PB PEL	ZN PEL
TBHB						
TBNP						
TBPB						
TBKA						
TBMK						
TAM						
TBOT						
TBCB						
STATION	PCB TEL	PAH TEL	CLD TEL	DDT TEL	DEL TEL	
TBHB	X			X		
TBNP	X	X		X	X	
TBPB	X		X	X		
TBKA	X	X		X		
TBMK			X			
TAM						
TBOT						
TBCB						
STATION	PCB PEL	PAH PEL	CLD PEL	DDT PEL	DEL PEL	
TBHB						
TBNP			X			
TBPB						
TBKA					X	
TBMK						
TAM						
TBOT						
TBCB						

APPENDIX D

Areas of Physical Alteration to Tampa Bay Bottom

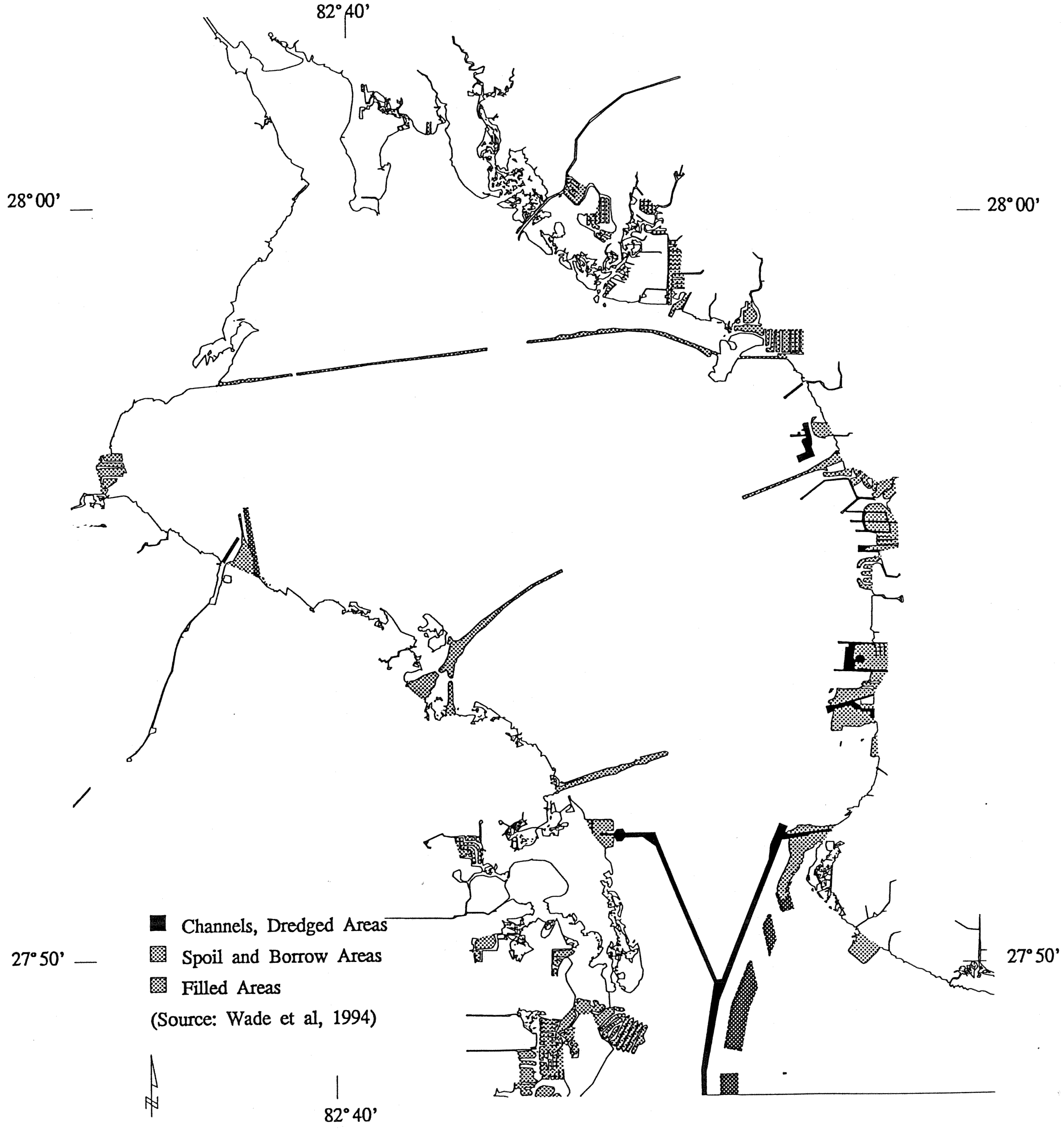
PHYSICALLY ALTERED AREAS



Scale 1:350,000
Projection UTM
Datum NAD 27

Coastal Environmental, Inc.
Map Publication No. S9529501

PHYSICALLY ALTERED AREAS
Old Tampa Bay



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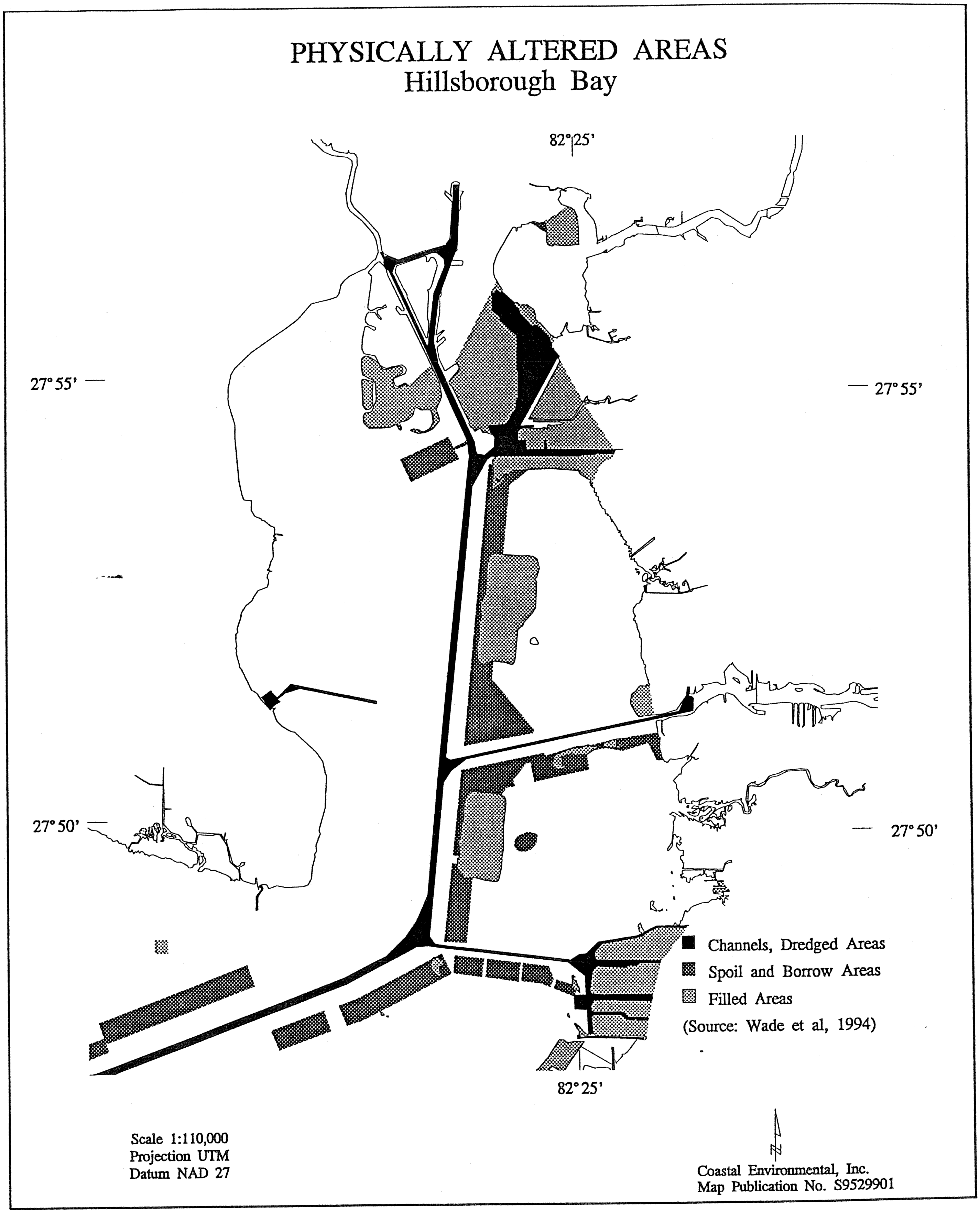
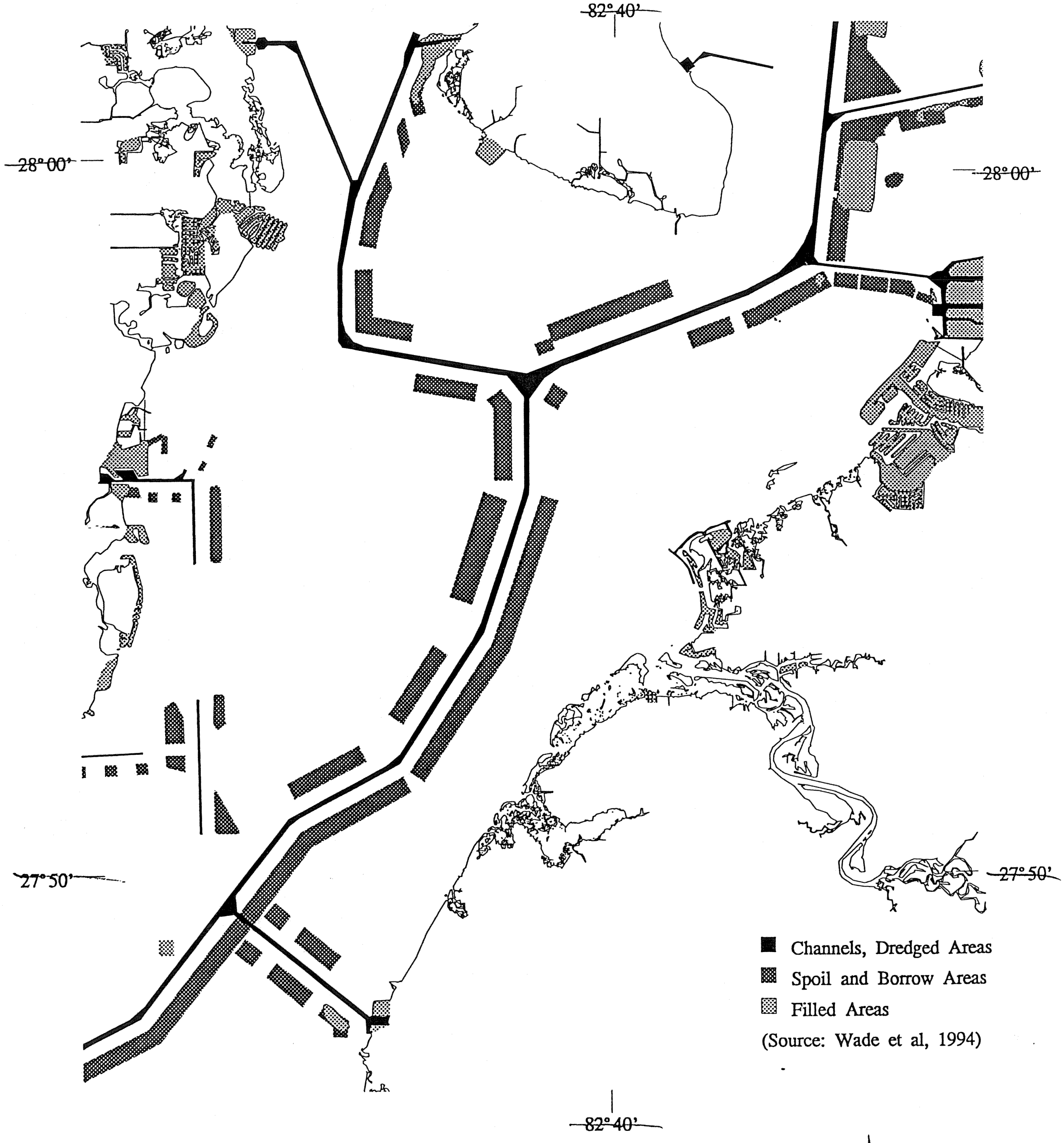
Coastal Environmental, Inc.
Map Publication No. S9529701


PHYSICALLY ALTERED AREAS
Hillsborough Bay
82°25'
27°55'
27°55'
27°50'
27°50'
Channels, Dredged Areas
Spoil and Borrow Areas
Filled Areas
(Source: Wade et al, 1994)
82°25'
Scale 1:110,000
Projection UTM
Datum NAD 27
N
Coastal Environmental, Inc.
Map Publication No. S9529901

PHYSICALLY ALTERED AREAS
Middle Tampa Bay



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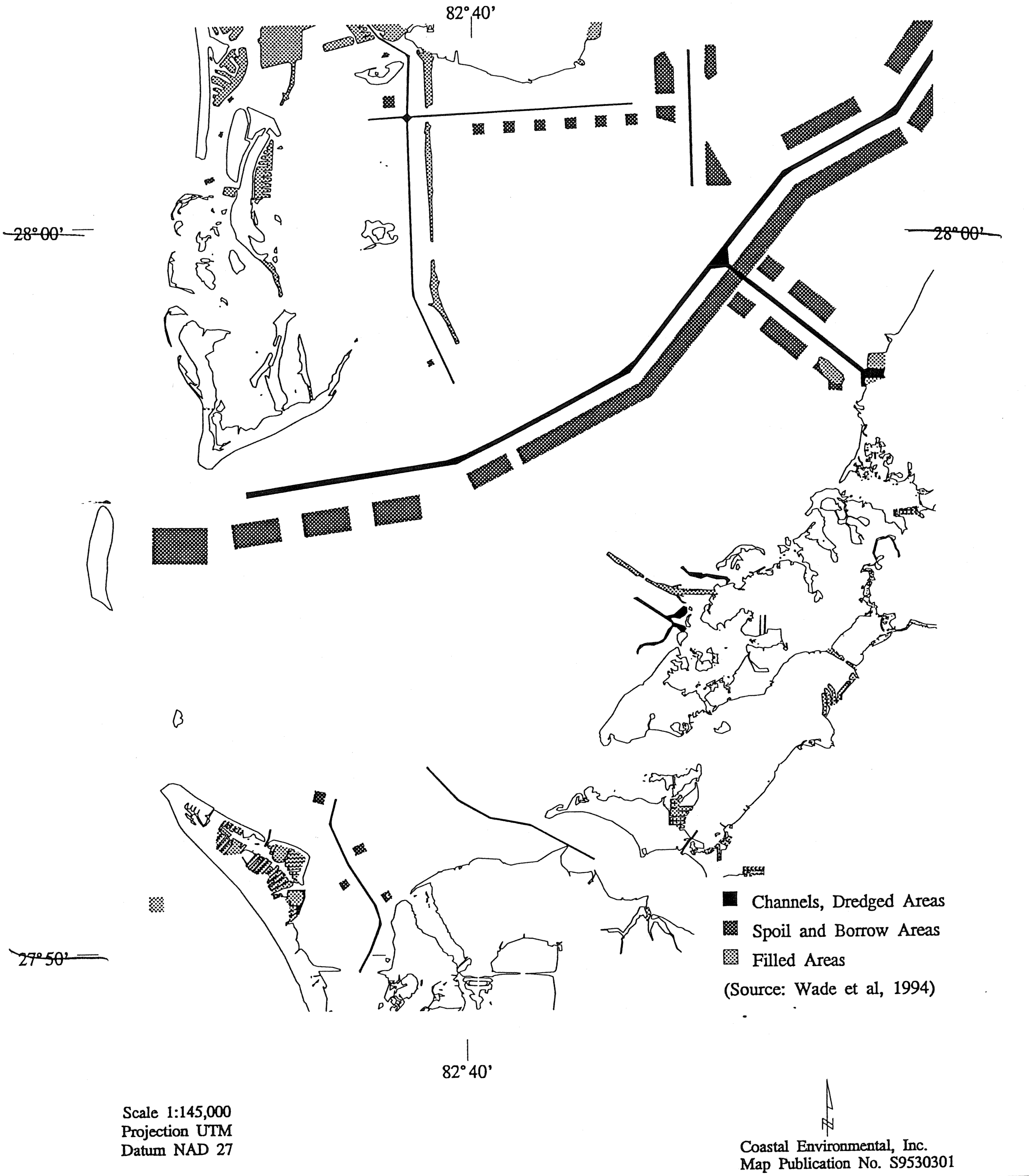
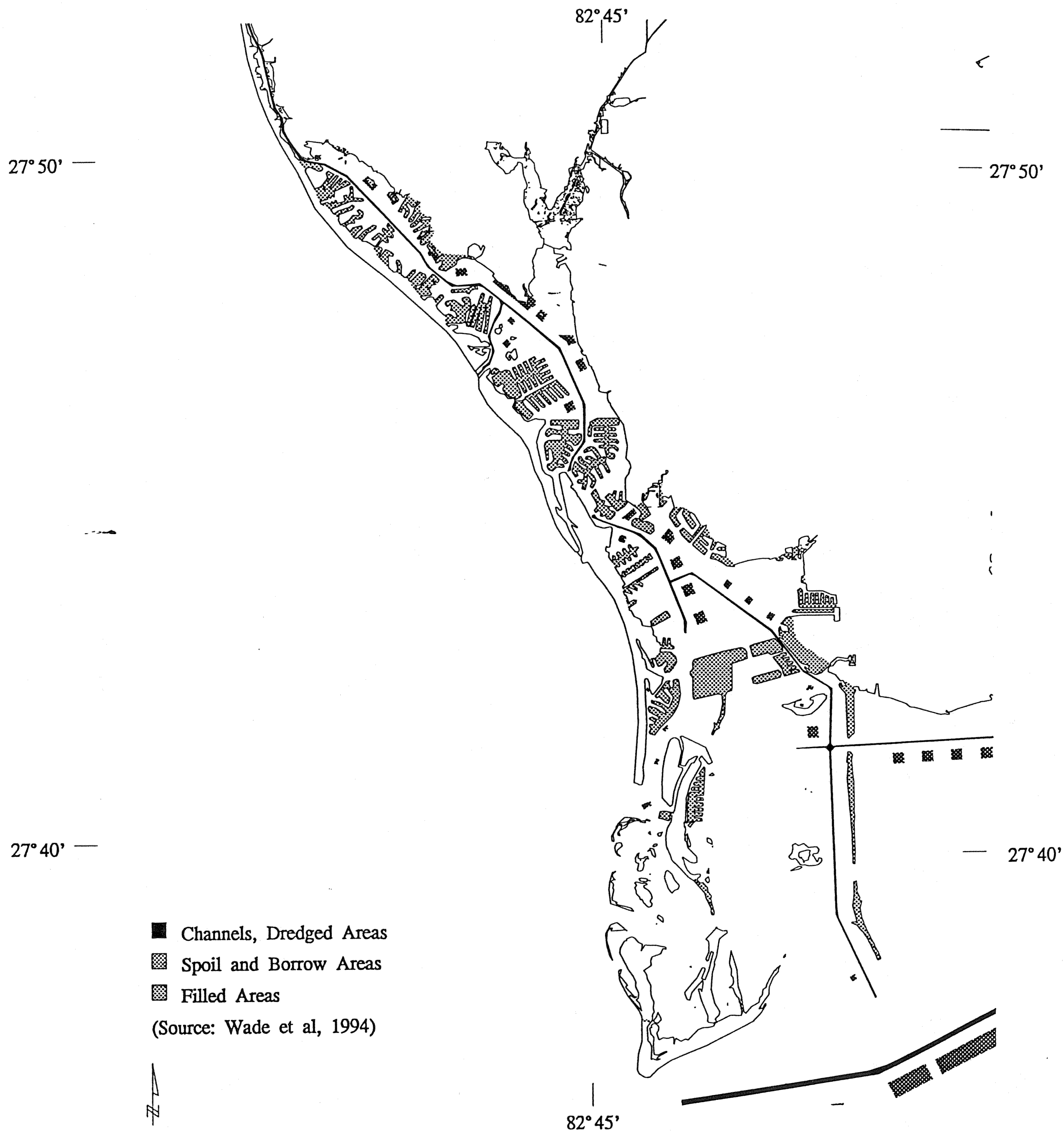
Projection UTM
Datum NAD 27

Coastal Environmental, Inc.
Map Publication No. S9530101

PHYSICALLY ALTERED AREAS
Lower Tampa Bay



PHYSICALLY ALTERED AREAS
Boca Ciega Bay



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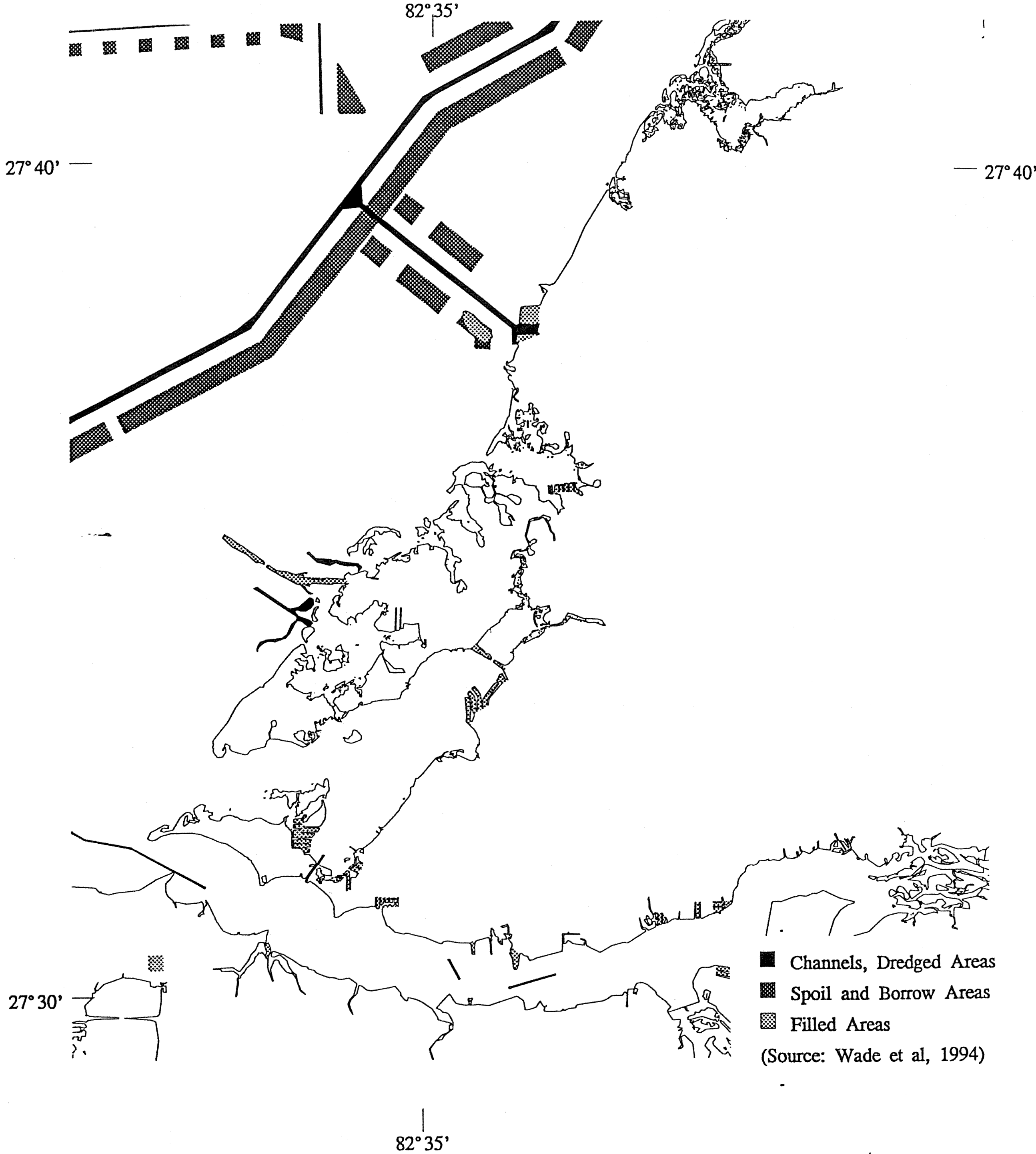
Datum NAD 27

Coastal Environmental, Inc.
Map Publication No. S9530501

PHYSICALLY ALTERED AREAS
Terra Ceia Bay/Manatee River



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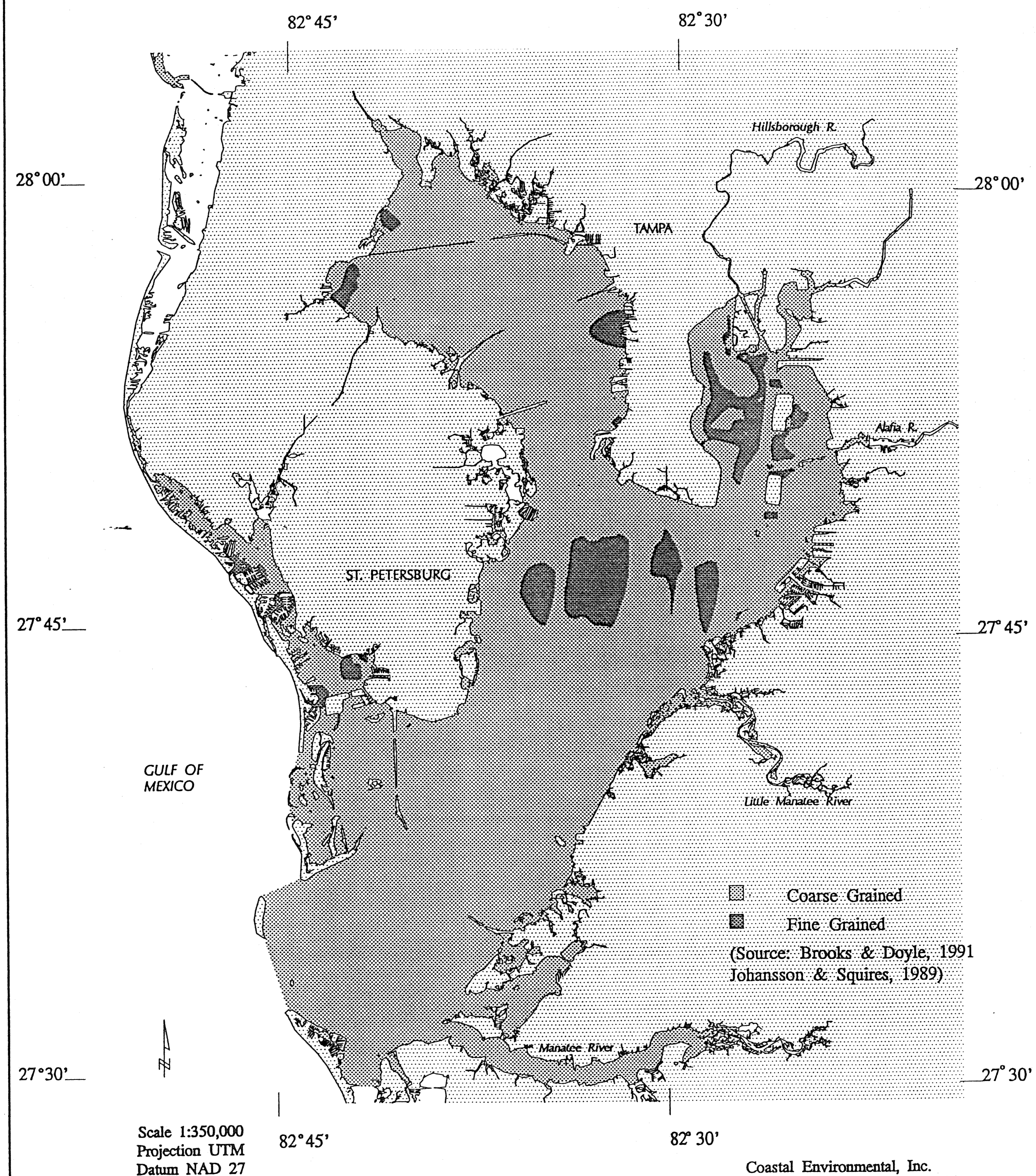
Coastal Environmental, Inc.
Map Publication No. S9530601

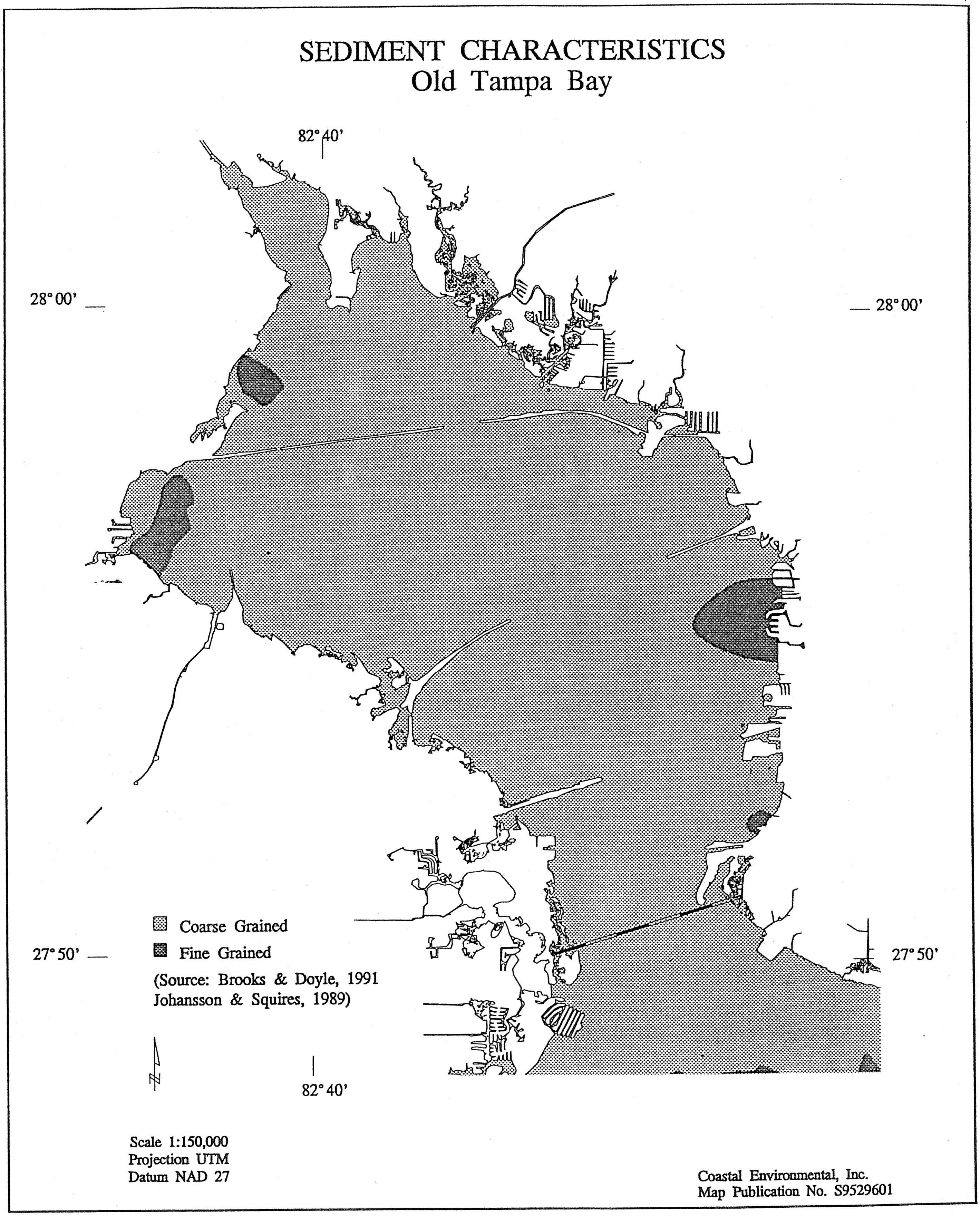
APPENDIX E

Tampa Bay Sediment Characteristics

SEDIMENT CHARACTERISTICS

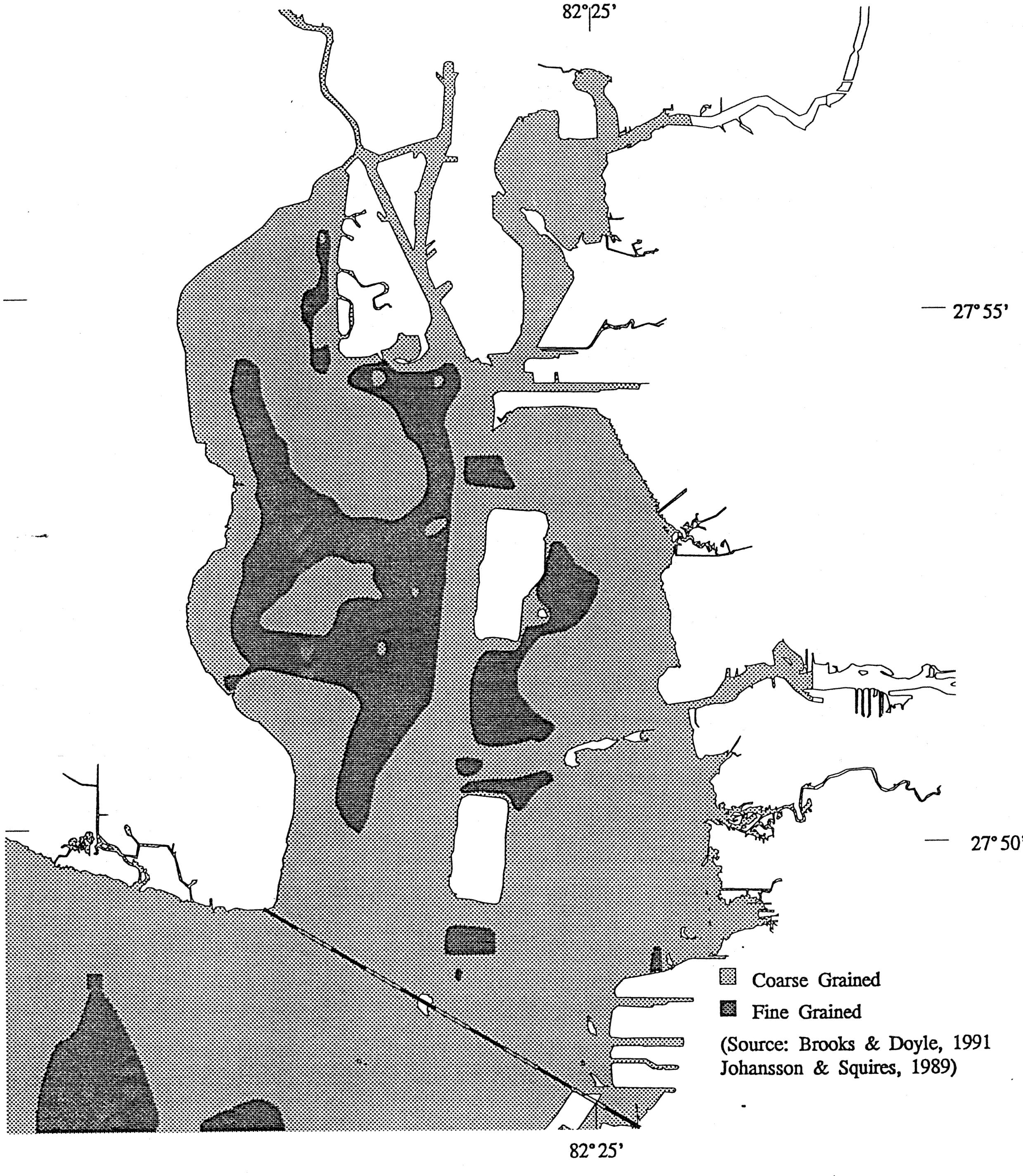


Coastal Environmental, Inc.
Map Publication No. S9529401



SEDIMENT CHARACTERISTICS
Old Tampa Bay
82° 40'
28° 00'
28° 00'
Coarse Grained
Fine Grained
(Source: Brooks & Doyle, 1991
Johansson & Squires, 1989)
27° 50'
27° 50'
82° 40'
Scale 1:150,000
Projection UTM
Datum NAD 27
Coastal Environmental, Inc.
Map Publication No. S9529601

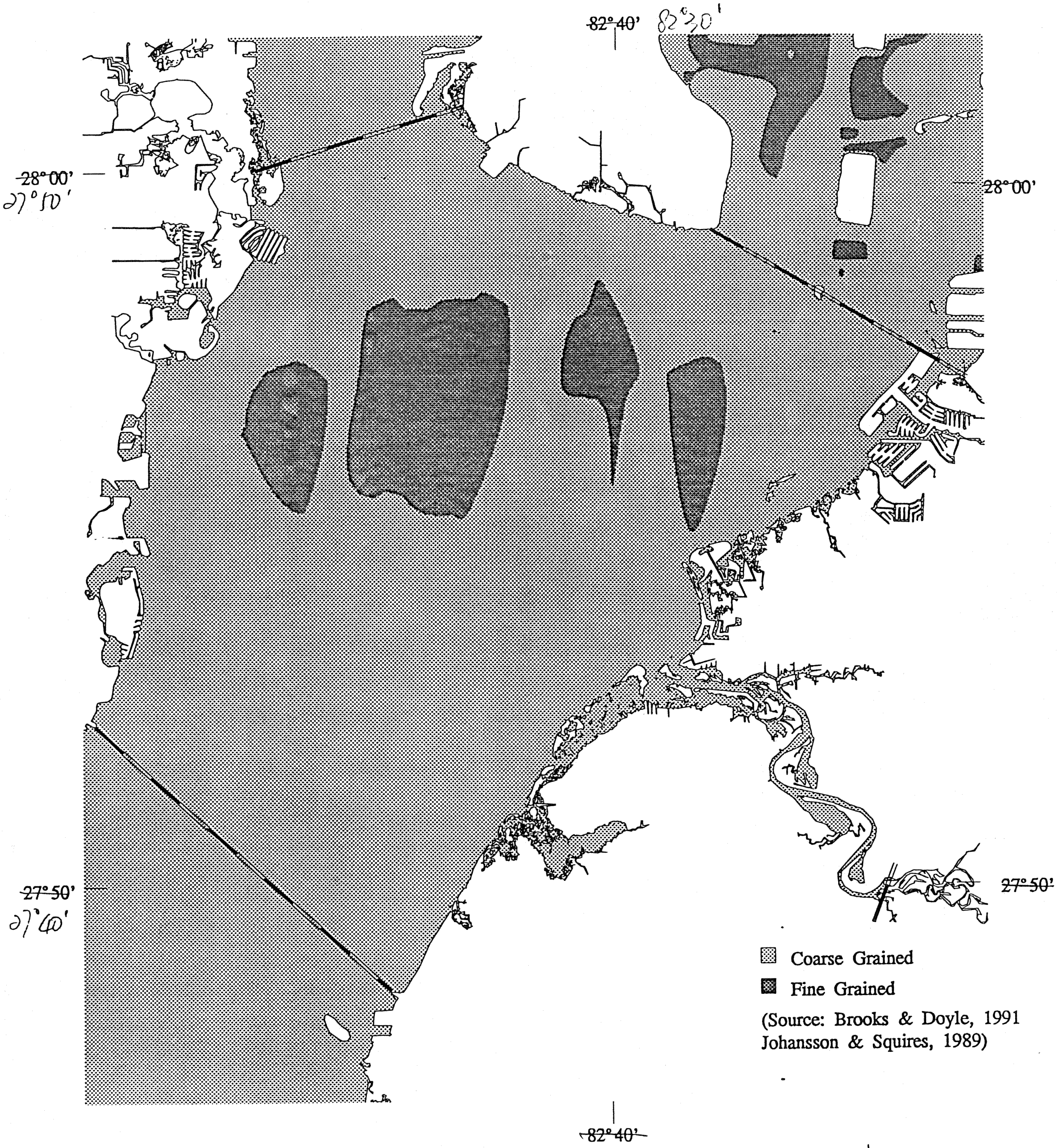
SEDIMENT CHARACTERISTICS
Hillsborough Bay



Scale 1:110,000
Projection UTM
Datum NAD 27

Coastal Environmental, Inc.
Map Publication No. S9529801

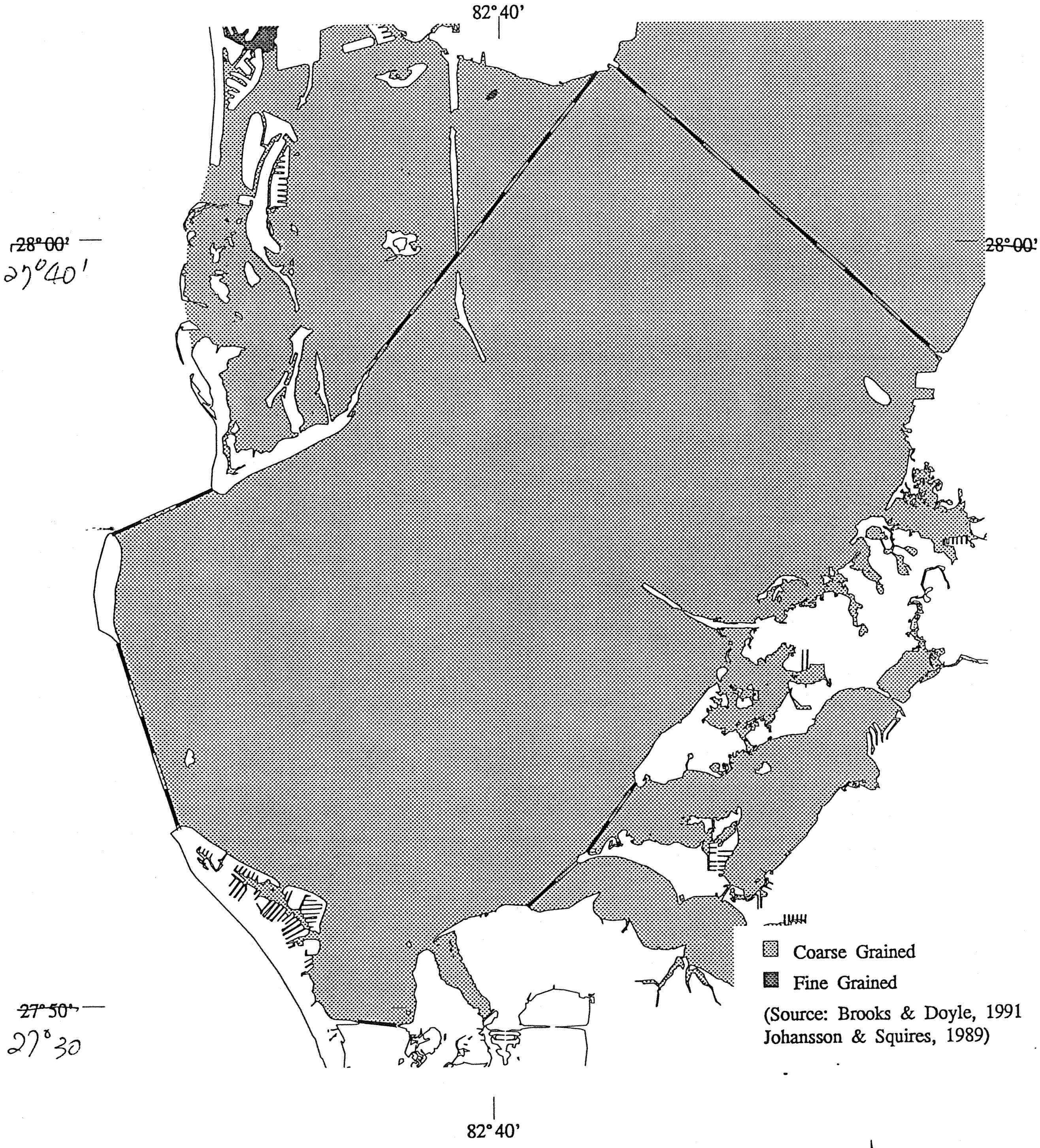
SEDIMENT CHARACTERISTICS
Middle Tampa Bay



Scale 1:155,000
Projection UTM
Datum NAD 27

Coastal Environmental, Inc.
Map Publication No. S9530001

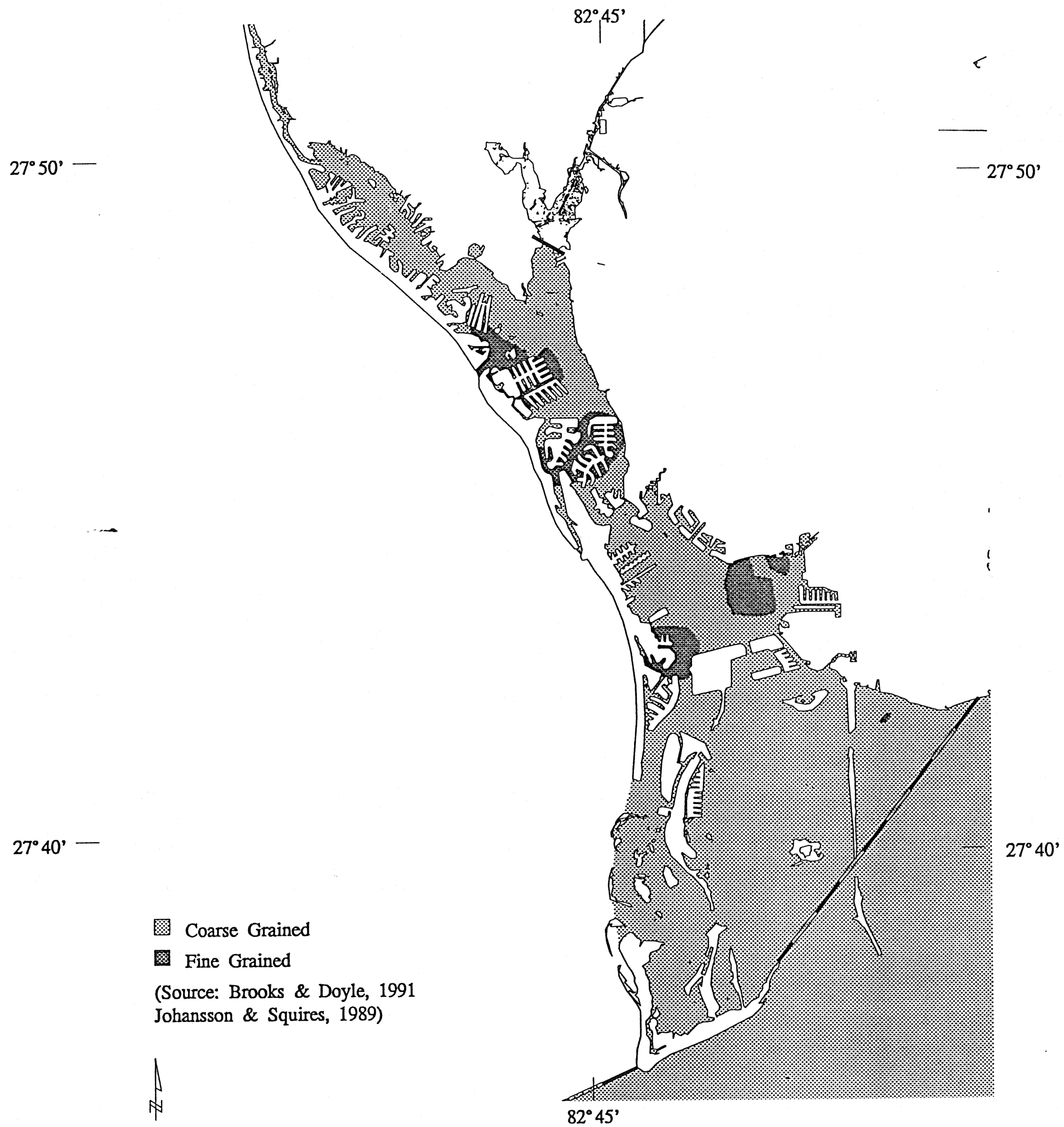
SEDIMENT CHARACTERISTICS
Lower Tampa Bay



Scale 1:145,000
Projection UTM
Datum NAD 27

Coastal Environmental, Inc.
Map Publication No. S9530201

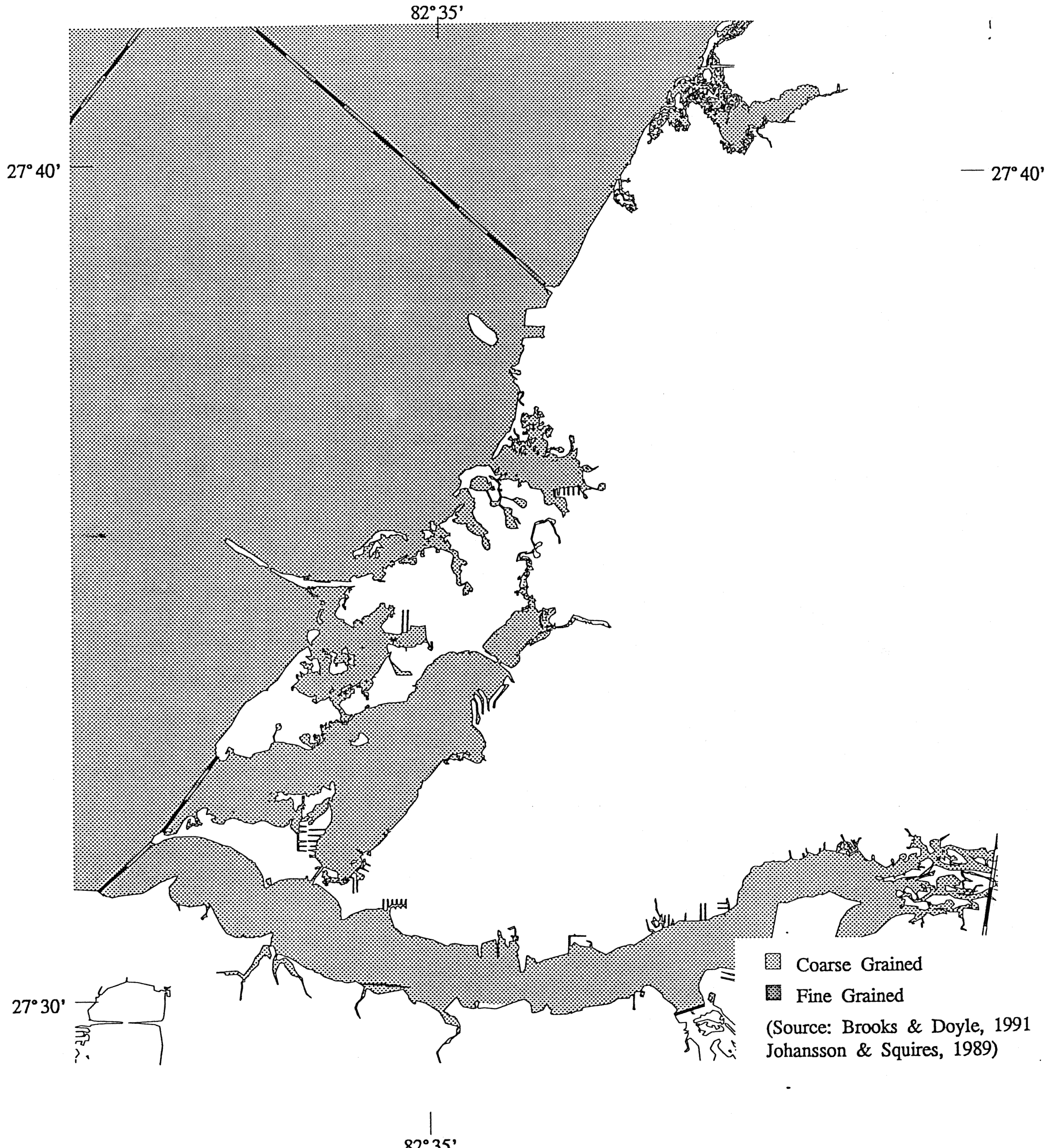
SEDIMENT CHARACTERISTICS
Boca Ciega Bay



Scale 1:165,000
Projection UTM
Datum NAD 27

Coastal Environmental, Inc.
Map Publication No. S9530401

SEDIMENT CHARACTERISTICS
Terra Ceia Bay/Manatee River



Scale 1:135,000
Projection UTM
Datum NAD 27

Coastal Environmental, Inc.
Map Publication No. S9530601

APPENDIX F

Living Resource Targets Phase II Workshop

- TECHNICAL SUMMARY -

LIVING RESOURCE TARGETS
PHASE II WORKSHOP

Prepared for:

Tampa Bay National Estuary Program
111 7th Avenue South
St. Petersburg, FL 33701

Prepared by:

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June 1996

LIVING RESOURCE TARGETS
PHASE II WORKSHOP

The Phase II Workshop for Living Resource Targets was held to address the need for, and feasibility of, establishing living resource targets using higher trophic level organisms. A previous attempt in 1992 by the Tampa Bay National Estuary Program (TBNEP) Technical Advisory Committee (TAC) to identify specific organisms as indicative of ecological health was unsuccessful. Alternatively, a consensus was reached to develop habitat targets for Tampa Bay, with the stipulation that the issue of identifying "target organisms" to gauge ecosystem health would be revisited after habitat targets were established. Since habitat targets have now been developed for Tampa Bay, the issue of using "target organisms" to assess ecosystem health was revisited. The report herein provides a summary of the Phase II Workshop, which was sponsored by the TBNEP and held at the Tampa Bay Regional Planning Council on May 2, 1996.

Background Information

As elements of the Comprehensive Conservation and Management Plan (CCMP), the TBNEP has established restoration targets for the major components of the primary producer level of the estuarine food web, including:

- phytoplankton (chlorophyll-a concentration target);
- seagrasses (areal target);
- emergent marshes (areal target); and
- mangrove forests (areal target).

Early in the tenure of the TBNEP, an attempt was made by the TAC to define "target organisms" whose populations could be used as a barometer of general ecological health. Due to the complexity of the estuarine food web, the logistical problems associated with assessing populations of motile organisms, and the lack of professional consensus as to which target organisms would be most appropriate, this effort was aborted. Instead, the TAC agreed to establish only habitat (e.g., seagrass, marsh and mangrove coverage) and water quality (e.g., chlorophyll-a) targets. These targets were established under the assumption that if benchmark habitat and water quality conditions were restored, the higher level components of the estuarine food wed (e.g., zooplankton, benthic invertebrates, fish, birds, reptiles, and mammals) would also reach a desirable equilibrium representative of benchmark conditions.

In recent years, decreases have been observed in the local populations of several "higher level" organisms, specifically bait fish and brown pelicans. It has been hypothesized by some that these changes are related to improved water quality conditions in Tampa Bay (e.g., lower chlorophyll-a concentrations). It is clear that management actions aimed at reducing the trophic state of, and restoring the proportions of habitats in, Tampa Bay, will have ripple effects throughout the higher levels of the estuarine food web. Therefore, the TBNEP has sought professional guidance, in the form of a workshop, as to the efficacy of monitoring and managing the higher trophic levels of the Tampa Bay ecosystem. In an attempt to bring together a variety of resource managers and scientists with vested interests proper management of Tampa Bay, the individuals listed in Appendix A were invited to attend the Living Resource Targets - Phase II Workshop.

Workshop Objectives

The Living Resource Targets - Phase II Workshop was intended as a long-range planning meeting called to address various issues related to the multi-level ecosystem management of Tampa Bay. The purpose of the workshop was to address the feasibility of, and need for, establishing living resource targets for higher level components of the Tampa Bay estuarine food web. The specific questions discussed at the workshop included:

1. What "higher level" organisms are most likely to be affected by the attainment of TBNEP habitat and water quality targets?

2. Is it possible to reach professional consensus on representative taxa for the higher trophic levels of the Tampa Bay estuarine food web? If so, which taxa are most appropriate?

3. Are these taxa likely to be positively or negatively impacted by the attainment of TBNEP habitat and water quality targets?

4. Are current monitoring programs sufficient to detect population trends in these taxa? If not, what changes to these programs would need to be made?

5. Is it desirable and/or feasible to establish population targets for these taxa, either now or in the future?

6. Could the combined attainment of TBNEP habitat, water quality, and higher level living resource targets enable the relaxation of regulatory water quality standards in Tampa Bay? For example, could the documented presence of a diverse assemblage of higher level taxa allow for a lower dissolved oxygen or BOD standard in a particular bay segment?

The objectives of the workshop were to: 1) develop consensus answers to the above questions; and 2) provide recommendations regarding the means by which higher level living resource targets could be established and monitored.

Workshop Discussion

The Phase II Workshop was facilitated by the staff of TBNEP and Coastal Environmental Inc. The following individuals participated in the Phase II Workshop.

Name	Organization
Gerold Morrison	Southwest Florida Water Management District
Thomas Ries	Southwest Florida Water Management District
Peggy Morgan	Florida Department of Environmental Protection
Steve Grabe	Environmental Protection Commission of Hillsborough County
Lisa Carter	Florida Department of Environmental Protection
Brent Johnson	Florida Department of Environmental Protection
Roger Johansson	City of Tampa, Bay Study Group
Don Moores	Pinellas County Department of Environmental Management
Rob Brown	Manatee County Environmental Management Division
Brad Weigle	Florida Department of Environmental Protection, FMRI
Tom Cuba	Delta Seven
Andy Squires	Coastal Environmental Inc.
Doug Robison	Coastal Environmental Inc.
Holly Greening	Tampa Bay National Estuary Program

Workshop facilitators opened by summarizing previous efforts by the TBNEP Living Resource Subcommittee to develop a list of species for the target setting process. Next, the objectives of the workshop were clearly stated including an explanation of each question listed above. The remainder of the workshop was structured such that each of the six questions was discussed and resolved before proceeding to the next question. A summary of the workshop follows.

Facilitators began by reviewing the conclusions drawn from a previous TBNEP workshop held during September of 1992, whereby the Living Resource Subcommittee met to develop a list of target species for critical Tampa Bay habitats. Critical habitats identified included:

- seagrass and other SAV;
- mangroves;
- tidal marshes;
- salt barren/high marsh;
- pelagic (> 10 ppt and < 10 ppt salinity);
- non-vegetated subtidal (> 10 ppt and < 10 ppt salinity); and
- non-vegetated intertidal (> 10 ppt and < 10 ppt salinity).

The identification of target species was needed to assess the viability of habitats to support desirable organisms. As a result, a list of potential target species was developed through consultation with local experts and relevant literature. At a subsequent meeting held on December 8, 1992, the TBNEP Living Resource Subcommittee concluded that adequate information was not available to identify "target species" for use in determining the viability of the critical habitats. More specifically, the subcommittee found that the:

- presence or absence of a limited number of "target" species was not appropriate to define the "viability" of a habitat; and

- there is a lack of a well defined environmental requirements for Tampa Bay species.

The subcommittee further recommended to:

- develop quantifiable habitat restoration/protection targets; and

- monitor a comprehensive group of organisms that use a specific habitat type in evaluating the effectiveness of habitat restoration/protection. If all or part of the identified viable community exists, then the effort is considered "successful."

Finally, in January of 1993, the TBNEP Management Committee decided that the "target species" concept should be revisited as more information on species specific environmental requirements becomes known and after quantifiable habitats are defined.

Upon completing the review of background information, workshop objectives were described and each of the following questions was clearly stated and explained to the workshop participants. Discussion associated with each question is summarized below.

Question 1: What "higher level" organisms are most likely to be affected by the attainment of TBNEP habitat and water quality targets?

Participants discussed a variety of "higher level" organisms that are likely to be affected by attaining habitat and water quality targets. Organisms mentioned included fish, seabirds, marine mammals as well as benthic tunicates, and zooplankton. Participants agreed that essentially all "higher level" organisms would be affected in some way as habitat and water quality targets are reached.

Question 2: Is it possible to reach professional consensus on representative taxa for the higher trophic levels of the Tampa Bay estuarine food web? If so, which taxa are most appropriate?

It was generally agreed that higher level organisms should ultimately be used to determine if habitat restoration is successful; however, a consensus could not be reached with regard to which specific taxa would be most representative of higher trophic levels. Most participants felt that fish and seabirds best represent the higher level organisms that are representative and desirable given the habitat restoration goals. Some participants suggested that one or two species may be indicative of a viable habitat in a specific area and time. Conversely, other participants felt that the same one or two species would not necessarily be indicative of viable habitat in another area of Tampa Bay or in the same area at a different time. It was suggested that the success of many higher level species is, only in part, related to viable habitat, and that several other factors (e.g., climate, predators, disease, etc.) may significantly affect the number of species present at any given time and place. Other participants suggested that the abundance of many different species (e.g., 30) or species guilds would be necessary to adequately represent higher trophic levels, and thus choosing one or two species would not be appropriate.

Question 3: Are these taxa likely to be positively or negatively impacted by the attainment of TBNEP habitat and water quality targets?

Participants agreed that the attainment of habitat and water quality targets would affect some higher level taxa negatively and other higher level taxa positively. Apparently, the nutrient enrichment of Tampa Bay by anthropogenic activities during the last 40 to 50 years or more has resulted in a shift from a predominantly macrophyte and detritus based trophic pathway to a predominantly phytoplankton based pathway. Assuming this shift has occurred, ecological ramifications manifested in the changing abundances of higher level taxa may result during the restoration process to return to the "natural" macrophyte-detritus based trophic pathway.

For example, the reduction in chlorophyll-a values (i.e., phytoplankton biomass) has apparently increased water clarity resulting in the expansion of seagrass beds in Tampa Bay since the mid 1980s. Increased seagrass habitat should also provide more habitat for spotted seatrout, and thus seatrout populations would be expected to increase. On the other hand, reductions in phytoplankton may result in lower numbers of herbivorous bait fish (e.g., menhaden *Brevoortia* spp.), which in turn, may reduce available food and relative abundances of pelicans or other seabirds which depend on bait fish.

Question 4: Are current monitoring programs sufficient to detect population trends in these taxa? If not, what changes to these programs would need to be made?

Participants agreed that most higher taxa species and/or groups are adequately sampled by existing monitoring programs such that population trends are sufficiently detected. Possible exceptions include the assessment of fish utilization of oligohaline environments and zooplankton baywide.

The existing fish monitoring program conducted by the Florida Marine Research Institute of FDEP has an excellent program for assessing juvenile fish populations in critical habitats of Tampa Bay. Their program, however, does not adequately sample oligohaline reaches of Tampa Bay's tributaries.

It was also suggested that data on zooplankton populations would provide a short-term indication of how changes in phytoplankton biomass (chlorophyll-a) and phytoplanktkon species composition affect higher trophic groups. Only one comprehensive study, conducted in the early 1970s, measured zooplankton abundance and species composition in Tampa Bay. Very little additional data exists on zooplankton community composition in Tampa Bay, yet zooplankton represent a major secondary consumer critical in the transfer of energy from primary producers to higher taxa such as fish and seabirds. It was also recognized that the establishment of a zooplankton monitoring program would necessitate simultaneous monitoring of phytoplankton communities to interpret phytoplankton-zooplankton relationships.

Question 5: Is it desirable and/or feasible to establish population targets for these taxa, either now or in the future?

The responses to Question 5 were similar to the responses described above for Question 2. Some participants felt that it may be desirable/feasible to use one or two species as targets while the majority of participants expressed the need to look at many species or measures of community health (e.g., diversity of benthic macroinvertebrates) to establish appropriate targets representative of specific habitats. Although higher level taxa are generally expected to increase as their associated habitats are restored, the natural variability in the abundance of individual taxa may often be too great to determine how much of that variability can be attributed to improved available habitat. Furthermore, information with regard to what population levels are desirable is not available nor expected to be available in the near future.

Question 6: Could the combined attainment of TBNEP habitat, water quality, and higher level living resource <u>targets</u> enable the relaxation of regulatory water quality <u>standards</u> in Tampa Bay? For example, could the documented presence of a diverse assemblage of higher level taxa allow for a lower dissolved oxygen or BOD standard in a particular bay segment?

Following considerable discussion, most participants expressed that at the present time regulatory water quality targets could not be relaxed given the attainment of habitat, water quality, and higher level living resource targets. Most participants, however, also indicated that the concept of using habitat, water quality, and higher level taxa targets instead of water quality standards is generally an appropriate direction to pursue in the future.

It was pointed out that many water quality standards (e.g., dissolved oxygen) are not appropriate to assess overall ecosystem health, but instead, are more appropriate for "end-of-pipe" regulatory issues. For example, to assess submerged unvegetated bottom habitat in Tampa Bay, it may be more appropriate to use benthic community composition to assess the quality of that habitat instead of bottom dissolved oxygen.

Other participants expressed that management goals should continue to be linked to attaining habitat targets, with provisions to continue monitoring programs aimed to monitor the relative abundance of desirable organisms expected to inhabit those critical environments. The monitoring of populations would serve as a check on habitat restoration/creation success. An alternative scenario presented was the setting of targets for an upper level organism accompanied by system management for that species rather than for the habitat. Workshop participants expressed conflicting viewpoints on this alternative scenario, consequently, the issue was not resolved.

Concluding Remarks

The conclusions presented more than three years ago at the December 8, 1992 workshop are essentially unchanged based on discussions during this Phase II Workshop. Final workshop conclusions are summarized below.

- Consensus on which target species are appropriate to assess the "viability" of Tampa Bay's critical habitats could not be reached.

- The ultimate goal of setting habitat targets is to restore desirable populations of higher level species; however, quantifiable targets should only be defined on the habitat level; existing information is lacking to assign population targets to specific organisms.

- The existing management strategy to focus on the attainment of quantifiable living resource habitat targets is appropriate and the strategy should include checks on the status of populations of higher level organisms using identified critical habitats through continuation of the existing Tampa Bay monitoring programs.

- Finally, the use of a habitat, water quality, or higher level living resource target, or some combination of those targets, to assess ecosystem health rather than using existing state water quality standards is conceptually appropriate and deserves further consideration as management strategies and the attainment of habitat targets are assessed in the future.

Appendix A

List of Invited Attendees

Ken Haddad - FMRI
Bob McMichael - FMRI
Tim MacDonald - FMRI
Stu Kennedy - FMRI
Joe O'Hop - FMRI
Penny Hall - FMRI
Brad Weigle - FMRI
Allen Huff - FMRI
Jim Beever - FGFWFC
Rick Garrity - FDEP
Ken Huntington - FDEP
Mike Perry - SWFWMD
Gerrold Morrison - SWFWMD
John Emery - SWFWMD
Tom Reis - SWFWMD
David Dale - NMFS
Jeff Brown - NMFS
Debra Mang - USFWS
Eric Summa - USACOE
John Stevely - Florida Sea Grant
Roger Johansson - City of Tampa
Terry Finch - City of Clearwater
Jake Stowers - Pinellas Co.
Don Moores - Pinellas Co.
Rob Brown - Manatee Co.
Roger Stewart - Hills. Co. EPC
Steve Grabe - Hills. Co. EPC
Rich Paul - National Audubon
Peter Clark - Tampa Baywatch
Ernie Estevez - Mote Marine Lab
Jim Culter - Mote Marine Lab
Jay Leverone - Mote Marine Lab
Robin Lewis - Lewis Environmental
Tom Cuba - Delta Seven
Dan Savercool - Dames & Moore
Norm Blake - USF Marine Science
Gabe Vargo - USF Marine Science
Susan Bell - USF Biology
Glenn Wolfenden - USF Biology
John Reynolds - Eckerd College