Digital Compilation of Submerged Lands Sediment Textures, Sediment Geochemistry, and Washover Areas of the Texas Coast

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EXECUTIVE SUMMARY

This report summarizes the methods used by the Bureau of Economic Geology (BEG) to produce electronic files of sample locations, sediment textures, and geochemical analyses for about 6,700 sediment samples collected from the Submerged Lands of Texas including all coastal bays, estuaries, lagoons, and the inner continental shelf extending 10.3 mi into the Gulf of Mexico. Active washover areas and other potential sites of oil invasion along the Texas Gulf shore also were mapped and digitized for inclusion in the Texas Natural Resources Inventory (NRI) ARC/INFO geographic information system (GIS). The major categories of the NRI program addressed by this project include 1.2a2 (sediment metals), 1.2a9 (sediment grain size), 1.2a10 (sediment total organic carbon), 1.7e (sediment percent sand), and 2.6e(c) (morphology of washover areas).

The primary results of the project were electronic files containing the locations and attributes of surficial sediments and washover areas of the following seven coastal regions: Beaumont-Port Arthur (Sabine Lake), Houston Galveston (Galveston Bay), Bay City-Freeport, Port Lavaca (Matagorda Bay), Corpus Christi (Corpus Christi Bay), Kingsville (upper Laguna Madre), and Brownsville-Harlingen (lower Laguna Madre). These seven regions cover the entire Texas coast and include all of the NRI highest priority areas.

INTRODUCTION

During the course of this study, the Bureau of Economic Geology (BEG) accomplished three objectives for the Texas Natural Resources Inventory (NRI) Program. The first objective provided a comprehensive baseline inventory of sediment characteristics (sediment textures and geochemistry) of the Submerged Lands of Texas. The Submerged Lands include all the state-owned coastal bays, estuaries, and lagoons as well as the inner continental shelf extending 10.3 mi (three leagues) into the Gulf of

Mexico. The second objective culminated in maps of the locations of active washover areas and other sites of potential oil invasion along the Texas Gulf shoreline. The third objective involved presenting the sample locations, sediment textures, geochemical analyses, and washover data layers in an ARC/INFO format that is compatible with the NRI geographic information system (GIS).

PREVIOUS RELATED STUDIES

The BEG previously mapped sedimentological and geochemical attributes of sediments of the submerged lands and washover areas on the barrier islands of the Texas coast, but all of the prior mapping was done before GIS was available for digitization and electronic storage of data. Modern systematic mapping of the Texas coast began in the late 1960s when the Environmental Geologic Atlas Series was conceived and implemented (Fisher et al., 1973; Brown et al., 1976). This multi-year Bureau-initiated program set the standard for comprehensive synthesis of physical, chemical, and biological data that were specifically designed to address the need for regional baseline inventories suitable for environmental investigations. The Environmental Geologic Atlas Series organized diverse types of information and presented it in tables, charts, and multicolor maps that are intended for use by planners and resource managers as well as by scientists and engineers. The principal mapping techniques that supported this work involved interpretation of aerial photographs, extensive field investigations, and aerial over flights. To make the maps even more useful, other related data also were compiled such as ecological surveys, climatological and oceanographic records, engineering properties, locations of energy and mineral resources, and locations of transmission routes.

The Environmental Geologic Atlas Series included maps of active physical processes specifically showing locations of washover areas for the entire Texas Gulf shoreline. Maps derived from the coastal atlas and other supplementary data were used subsequently to construct the Atlas of Natural Hazards of the Texas Coastal Zone (Brown et al., 1974) that, among other features, identified the major washover areas and sites of hurricane landfall along the Gulf shore.

In the mid 1970s, the BEG initiated another comprehensive atlas series that focused on the state-owned subtidal regions of the Texas coast (White et al., 1983, 1985, 1986, 1987, 1988, 1989a, 1989b). The submerged lands were inventoried and significant physical, chemical, and biological properties were identified and measured. The resulting quantitative maps and reports, known as the Submerged Lands of Texas Atlases, cover the wetlands, bays, estuaries, lagoons, and inner continental shelf environments where navigation projects, industrial site development, and mineral resource extraction activities are being conducted or are planned for the near future.

The BEG baseline inventory serves as the only synoptic systematic sediment sampling of submerged state-owned property in Texas and clearly plays a unique role in the Natural Resources Inventory Program. Sediment textures, geochemical analyses, and sample locations are the primary data that were transformed into a digital format (ARC/INFO) for the NRI GIS.

The BEG operates both workstation and PC versions of ARC/INFO and has generated numerous map products to support our research projects. Recent examples of GIS products include a series of maps depicting wetland changes for the Galveston Bay National Estuary Program (GBNEP), and historical shoreline positions of the southeastern Texas coast for the U.S. Geological Survey. The maps of sequential shoreline positions were used to calculate recent erosion rates for the GLO Coastal Zone Management Program. Our GIS is operated by personnel with special training in applications emphasizing both computer programming and the interfacing of scientific and computer knowledge.

PROJECT DESCRIPTION

Current demand for sedimentological, geochemical, and washover data generated by the BEG are causing some environmental engineering firms and other users of coastal information to digitize the data from small-scale maps published by the BEG. This approach could introduce significant errors if the digitizer is unfamiliar with the original data formats and scales of mapping. Furthermore, the dates of sample collection and analysis differ from the dates of data publication by several years. Because the BEG was responsible for collecting the original samples, conducting most of the laboratory analyses, and generating the sedimentological data, it is best equipped to assure the quality of digitization, assignment of attributes, and the GIS formatting of the electronic databases.

Approximately 6,700 sediment samples were collected and analyzed for the Submerged Lands Project (White et al., 1983, 1985, 1986, 1987, 1988, 1989a, 1989b). About two-thirds of the samples are within the Sabine Lake, Galveston Bay, Corpus Christi Bay, and lower Laguna Madre areas, which are the areas of highest priority for assimilating the NRI layers.

As part of the NRI project, we formatted in ASCII text files the sediment textures (percent gravel, sand, silt, clay, and mud, and mean grain size), concentrations of selected geochemical elements (total organic carbon, boron, barium, calcium, chromium, copper, iron, manganese, nickel, lead, strontium, and zinc), and sample locations in the following coastal regions (fig. 1): Beaumont-Port Arthur (Sabine Lake), Houston Galveston (Galveston Bay), Bay City-Freeport, Port Lavaca (Matagorda Bay), Corpus Christi (Corpus Christi Bay), Kingsville (upper Laguna Madre), and Brownsville-Harlingen (lower Laguna Madre).

We also mapped the active washover areas and other potential sites of oil invasion along the Gulf shoreline. Knowing the locations and characteristics of washover areas is

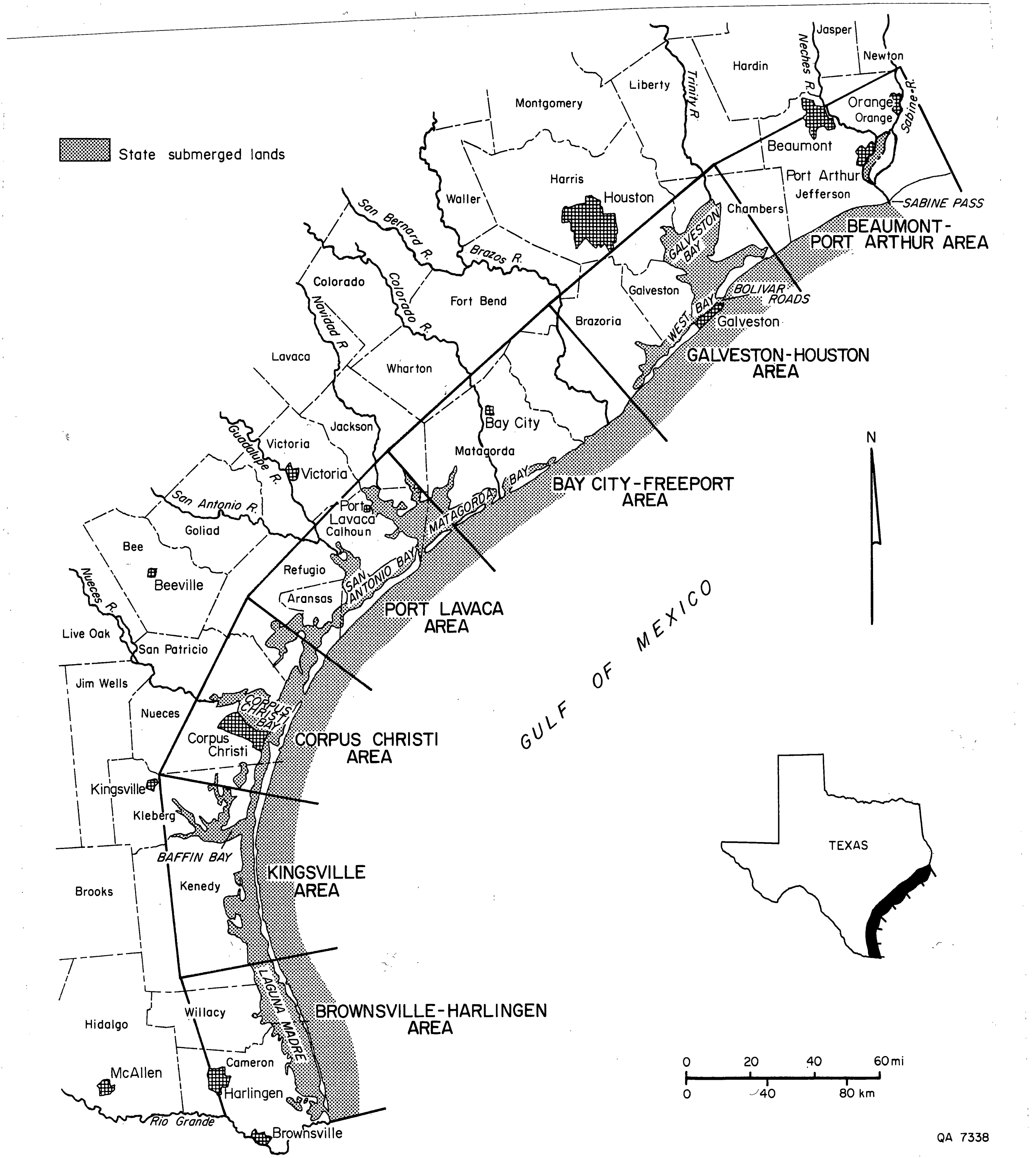

Figure 1. Index map showing seven area maps that cover the submerged lands of Texas. Modified from Brown (1972–1980).

vital to proper management of coastal resources. This is because washovers pose some of the greatest natural hazards in the coastal environment while at the same time serving important functions in terms of barrier island dynamics and sustenance of the backbarrier marshes and sand flats. Historically, washovers of the Texas coast are reoccupied repeatedly by high flood waters and powerful currents during major storms, and they are unsafe sites for coastal construction.

DATA COLLECTION AND ANALYTICAL PROCEDURES

The following sections on sample collection and analyses describe the procedures used during the Submerged Lands Project, which was conducted in the mid- to late-1970s. These sections are included to provide basic information about sample processing and accuracy of the analyses.

Collection of Sediment Samples

Surficial sediment samples were taken with grab samplers at sites spaced approximately 1 mi (1.6 km) apart in the bay-estuary-lagoon system and on the inner continental shelf to a distance of about 11.2 mi (18 km) seaward of the Gulf shoreline. Ponar clam-shell grab samplers (approximate capacity of 0.065 ft^3 [0.0018 m^3]) were used in the bay system, and Smith-McIntyre samplers capacity of 0.46 ft^3 [0.013 m^3]) were used on the shelf. Sediment penetration depths ranged between 1.5 and 4 inches (4 and 10 cm). Samples were described at the time of collection in terms of sediment type, color, and other visual characteristics (McGowen and Morton, 1979) and were then subsampled and stored in containers for quantitative sedimentological, geochemical, and biological analyses in the laboratory. Results of these analyses are presented in a seven-volume atlas series of Texas coastal submerged lands (White et al., 1983, 1985, 1986, 1987, 1988, 1989a, 1989b).

Although the sediment data are considered comparable throughout the entire coastal region, different types of boats, navigation techniques, and sampling equipment were used in the bays and on the inner shelf. This was primarily because of differences in water depths and wave heights between the two regions. For example, a large ship and precision radio-navigation equipment were used to collect samples on the inner shelf. In contrast, small boats and less accurate triangulation and dead-reckoning navigation were used in the bays for the same purpose.

Sample Analyses

Sediment Textures - Textural analyses provide the primary sedimentologic data for the submerged lands. Analyses were performed by staff at the Bureau of Economic Geology's Sedimentology Laboratory, except for samples from the southern half of the inner shelf of the Brownsville-Harlingen area (fig. 1), which were analyzed by the U.S. Geological Survey (USGS). Textural analyses included quantitative determination of the gravel, sand, and mud fractions in each sample, followed by more detailed textural analyses of the sand and mud fractions. Size distribution in the sand fraction was determined with a rapid sediment analyzer (Schlee, 1966) and in the mud (silt and clay) fraction, with a Coulter Counter (Shideler, 1976).

Most aspects of the basic sample preparation and particle-size analyses were described by Krumbein and Pettijohn (1938), Ingram (1971), and Folk (1974), among others. Weight percents of the primary grain-size classes were used to determine gravel - sand - mud ratios for each textural sample. Grain-size distribution within the sand fraction (including sand-sized shell material), was determined using a Rapid Sediment Analyzer. Grain-size distribution within the mud fraction was determined with a Coulter II electronic suspended particle counter. Grain-size analysis of mud by Coulter Counter offers several advantages—including speed of analysis—over traditional methods (pipette and hydrometer).

Textural analyses of a given sample may vary depending on the method used to analyze the clay fraction. Within the clay size range of particles, traditional methods extrapolate data beyond the range of actual measurement (approximately 0.5 mm to 0.06 mm), whereas with Coulter Counter analysis, the extrapolation is not made beyond 0.5 mm. Accordingly, with sediments high in clay, the Coulter analysis generally indicates a coarser distribution than does the pipette analysis. Thus, the tendency for bay-center and shelf muds to be more silty than clayey may be partly a reflection of the method of the Coulter Counter analysis. General textural analyses procedures are outlined in the flow diagram (fig. 2); a more detailed discussion, of textural procedures used in the Submerged Lands project is given by Nance (1982).

Textural data are presented as percent gravel (shell), sand, silt, clay, and mud (silt and clay), and mean grain size in phi units of the sand, silt, and clay fractions. Phi units are logarithmic transformations of the Wentworth (1922) grade scale and are defined as the negative logarithm (base 2) of the particle diameter (Krumbein, 1934). In the phi scale, larger numbers represent finer grain sizes. Because gravel was excluded in the determinations of mean grain size, mean phi size reported will be less than the true value for sediment samples with a measurable gravel component.

Geochemical Analyses - Geochemical analyses for the Submerged Lands of Texas were performed on the whole sediment sample (rather than on a particular size fraction) to determine the concentration of total organic carbon (TOC) and a spectrum of major and trace elements. Such information helps to clarify the relation between sediment size and associated trace metal abundance. The data provide an inventory of the regional distribution of various detectable trace and major elements in the surface sediments of submerged lands. More than 6,500 samples were analyzed for TOC by staff at the Bureau's Mineral Studies Laboratory, using a wet-combustion technique (Jackson, 1958). Fewer samples were analyzed for trace and major element concentrations. The USGS Analytical Laboratories in Reston, Virginia, performed most of these latter analyses using

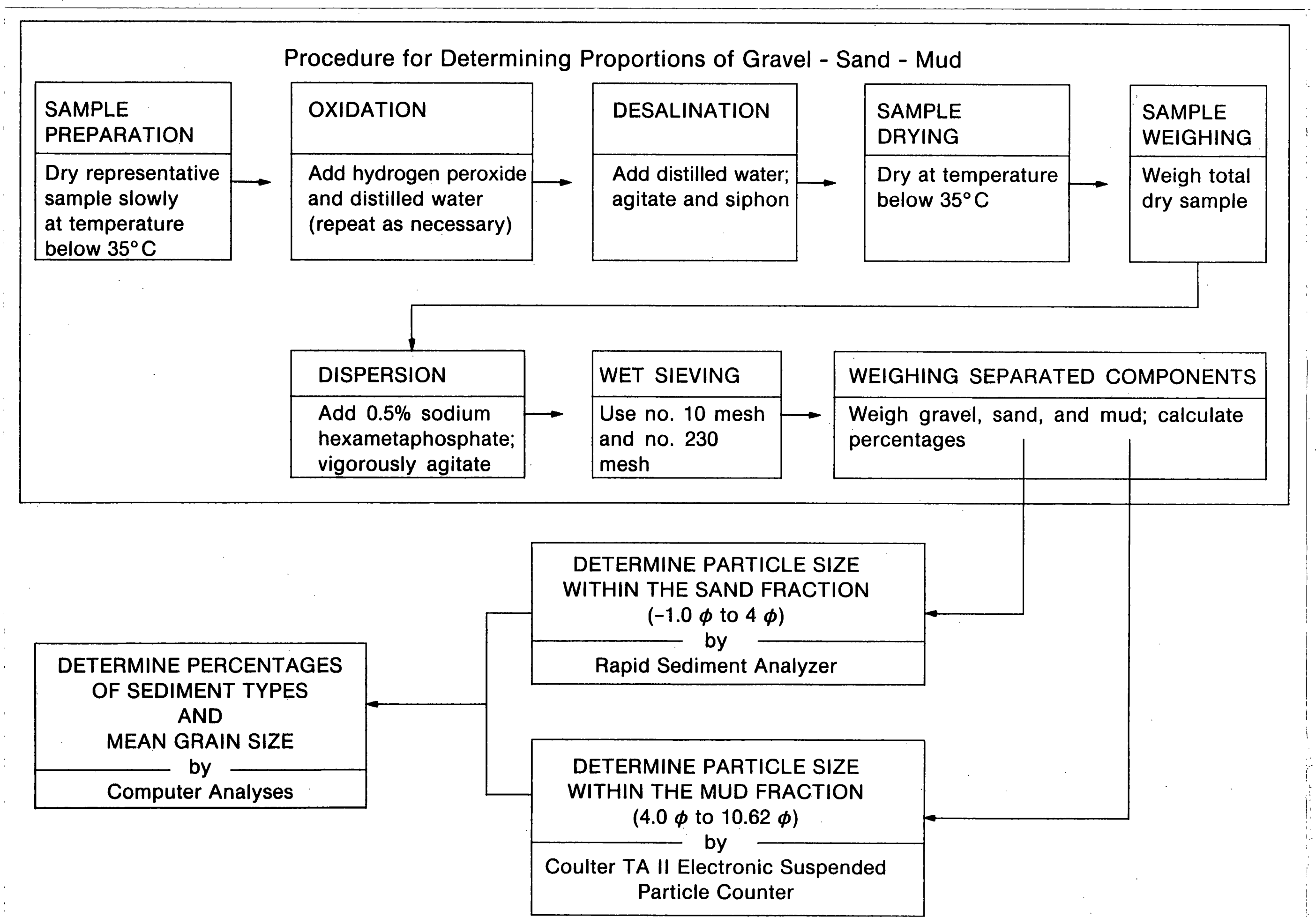

Figure 2. Flow diagram of general textural-analysis procedures.

an emission spectrograph and a computerized system of spectral analysis (Dorrzapf, 1973), which provides semiquantitative results (relative standard deviation for each reported concentration being + 50 percent and - 33 percent*). Supplementary quantitative analyses of chemical elements in selected samples were conducted by the Bureau of Economic Geology's Mineral Studies Laboratory staff, using an inductively coupled plasma-atomic emission spectrometer (ICP-AES). Samples were fused at high temperature with lithium (tetra:meta) borate and dissolved in dilute hydrochloric acid. The ICP-AES provides highly reproducible data because the variability of duplicate analyses for most elements is less than 2 percent. The accuracy of analyses for most common major and minor elements usually ranges from 100 ± 1 percent to 100 ± 5 percent (depending on the element) if the concentration levels fall within the optimal range for quantitative measurement. The optimal range is 5 to 10^4 times the detection limit for each element (C. L. Ho and S. W. Tweedy, personal communication, 1982). The accuracy of analyses of trace elements is not as high as for major and minor elements, particularly when the concentration is near the minimum level of detection**. Because two different methods of chemical element analysis were used—the computerized emission spectrographic methods by the USGS and the ICP-AES method by the BEG—both sets of data are identified separately. Samples were scanned for as many as 65 elements. The number of elements varied depending on method of analysis used. Twelve elements, including TOC, were selected for mapping. They are barium (Ba), boron (B),

* On the basis of initial calibration conditions, the minumum concentrations (in parts per million) for elements determined by computerized spectrographic analysis of silicate rocks are barium, 2.2; boron, 4.6; chromium, 1.0; copper, 1.5; lead, 6.8; manganese, 1.0; nickel, 1.5; strontium, 1.0; and zinc, 15.

** The minimum level of detection for each element analyzed by ICP-AES varies depending on the dilution factor resulting from dissolution of the solid sample. The abundance of interfering elements also can affect detection limits. In general, given a dilution factor of 100 (most commonly used in this study), the minimum levels of detection in parts per million are barium, 1; calcium, 7; chromium, 3; copper, 3-5; iron, 2; lead, 40; manganese, 0.5; nickel, 7; strontium, 0.5; and zinc, 1. Minimum level of detection given for lead is for a solid sample.

calcium (Ca), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), nickel (Ni), strontium (Sr), and zinc (Zn). Variations in this suite of elements occurred in some bays such as Sabine Lake, where concentrations of cobalt (Co) were mapped primarily because of a lack of mappable data for boron and lead. In Sabine Lake, Matagorda, Espiritu Santo, and San Antonio Bays, sediments were not analyzed for boron, and the ICP-AES minimum detection level for lead is too high to provide a mappable range in concentrations.

Mapping Washover Features

Washovers were mapped by research staff at the BEG primarily using low altitude aerial videotape surveys of coastal Texas produced by the Louisiana Geological Survey (LGS) (Westphal et al., 1992) and recorded during a cooperative helicopter flight in July of 1992 by staff of LGS and BEG. Videotapes were high quality and were accompanied by audio commentaries of shorelines made by experienced coastal geologists. In addition, oblique 35 mm color slides were taken at low altitude of most shorelines during the flight.

Washover areas were mapped while viewing the videotapes on a 27-inch high-resolution color monitor and using a video cassette recorder with slow and fast advance and reverse features. Washovers were also located on CIR aerial photographs, scale 1:24,000, to verify their position and accurately map them on base maps. Mapping procedures consisted of identifying washovers, marking their boundaries on topographic base maps, and labeling them with the appropriate classification. Washovers were delineated on the most recent USGS topographic maps (scale 1:24,000) (Table 1). In areas where shorelines on topographic maps were very much out of date and did not match the more recent videography and aerial photographs, the shoreline positions were updated (with a Bausch and Lomb Zoom Transfer Scope) using high altitude vertical stereographic aerial photographs taken during the year 1989. These local shoreline

Table 1. List of 7.5 minute topographic maps covering the Texas Gulf shoreline, which were examined for washover features. Maps are listed in order from north to south (Sabine Pass to the Rio Grande).

Texas Point	South of Palacios Point
Sabine Pass	Decros Point
Clam Lake	Pass Cavallo SW
Star Lake	Long Island
South of Star Lake	Panther Point NE
Mud Lake	Panther Point
High Island	Mesquite Bay
Frozen Point	St. Charles Bay SE
Caplen	St. Charles Bay SW
Flake	Allyns Bight
The Jetties	Estes
Galveston	Port Aransas
Lake Como	Crane Islands, SW
Sea Isle	Pita Island
San Luis Pass	South Bird Island
Christmas Point	South Bird Island SE
Freeport	Yarborough Pass
Jones Creek	Portrero Cortado
Cedar Lakes East	Portrero Lopeno NW
Cedar Lakes West	Portrero Lopeno SE
Sargent	Green Island
Brown Cedar Cut	North of Port Isabel NW
Dressing Point	North of Port Isabel SW
Matagorda	Port Isabel NW
Matagorda SW	Port Isabel
Palacios SE	Mouth of Rio Grande
Palacios Point	

updates allowed a more precise and accurate depiction of washover channels on the base maps.

Two types of washover areas are present along the Texas coast, individual restricted channels that breach higher dune elevations, and broad low-lying areas that have elevations lower than those associated with typical storm surges. The restricted washover channels are found on South and Central Padre Island, Mustang Island, and on East and West Matagorda Peninsula. The coast-parallel zones of inundation and washover are located on the upper coast between Sabine Pass and High Island and in the Sargent Beach-Cedar Lakes area. A third mapping category includes narrow intradune channels that primarily act as drains for barrier runoff. These same features could also serve as conduits for spilled oil penetrating back into the dunes.

Washover Zones - Along much of the upper and central Texas coast, fore-island dunes are not well developed and are not high enough to block storm surge. These areas, which are susceptible to extensive flooding and overwash during hurricanes, were mapped as washover zones (fig. 3). Most of Matagorda Peninsula was mapped as a washover zone, for example.

Washover Channels - Washover channels are discrete, typically shore-normal, topographical low features that have been formed by elevated storm waters flowing through breaches in the fore-dune ridge. The channels are typically reoccupied during each hurricane and tropical storm. Washover channels generally consist of a single channel, up to 2,000 m in width (although most are much more narrow), that extend through the dune ridge and split into two or more smaller channels or merge with broad wind-tidal flats and lagoon environments (fig. 3). In mapping washover channels, the landward ends were generally terminated at the point where the channels were no longer confined by flanking dune ridges. Washover fans and aprons are common depositional

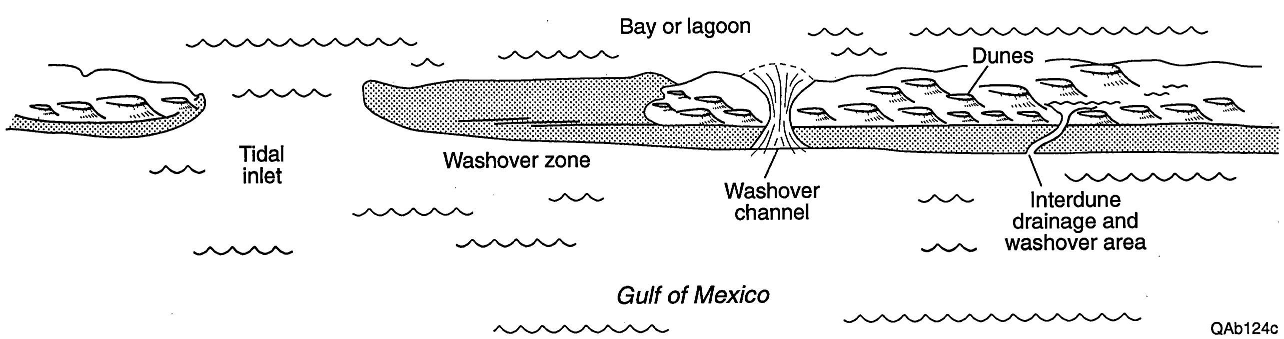

Figure 3. Generalized illustration of potential oil invasion sites from an open-ocean spill. Sites include tidal inlet, washover zone, washover channel and interdune drainage and washover area.

features at the downstream end of the channels where storm surge waters spread out over the broader flats (fig. 3).

Interdune/Marsh Drainage and Washover Areas: - Interdune/marsh drainage and washover areas are relatively narrow, typically sinuous low channels that cut across the backbeach between fore-island dunes and higher marshes, and connect to interdune swales or channels. Some of these features cross non-washover zones such as on Matagorda Island and Bolivar Peninsula, whereas others cross washover zones such as between High Island and Sabine Pass. The channels drain ponded water from interdune and marsh swales and can serve as conduits for the transport of Gulf waters and oil into the swales during higher than normal tides.

GEOGRAPHIC INFORMATION SYSTEM PROCEDURES

Electronic Formatting of Published Data

Text Data Entry Procedures - The textural and geochemical data entered into the GIS originated as two separate media: tables from published Submerged Lands reports (White et al., 1983, 1985, 1986, 1987, 1988, 1989a, 1989b) and computer printouts of latitude/longitude pairs for offshore sample locations. The published tables were in the form of clean pasteups suitable for printing, and consisted of 161 pages of tabular data, approximately 20 columns wide and 40 to 50 rows long, in 6 to 7 point text, with titles, annotations, and "group break" subtitles. There were a total of about 7,100 rows of data. The computer printouts, roughly 10 years old and generated on a line printer, consisted of about 3,500 lines of unevenly faded and misaligned numeric text.

After some preliminary testing with a scanner and Optical Character Recognition (OCR) software (see below), we concluded that these two media needed different input methods. The paste-up text was crisp and clean, and although the letters were small, the OCR software could recognize the text at an accuracy of 95 percent or higher and at a speed of about one page per minute. The software had problems with non-alphanumeric text, but this was not a significant problem because special symbols occurred only infrequently in the text.

The computer printouts could not be read optically because of the variable quality of the printing and the misalignment of the text. A recognition accuracy of 20 percent was about average for the three sample pages we scanned. It was determined that standard keypad entry of the latitude/longitude pairs into Excel 4.0 was appropriate for this material.

Optical Character Recognition (OCR) Software - We used OmniPage 5.0 for the Macintosh for the OCR portion of the data entry. After a trial with a demonstration copy of the software and representative pages from one of the Submerged Lands reports, the recognition rate and scanning speed was determined to be more than adequate. An Apple black-and-white scanner was used to load the text images; while OmniPage has its own scanner driver, about halfway through the scanning process, the data entry operator switched to AppleScan driver software to scan the text, because the first-time recognition rate improved when AppleScan was used. OmniPage accepts scanned input from either its own driver or from any of a number of commercial scanner drivers, including AppleScan. After a page of data was scanned, the operator saved the text into Excel format.

Sediment Sample Locations

Gulf Samples - Geographic coordinates of samples collected on the inner shelf in the Gulf of Mexico represent positions (decimal degrees latitude and longitude) recorded by the range-range navigation system. These coordinates were entered into an electronic spreadsheet and stored as ASCII files. The ASCII file coordinates were then loaded into an ARC/INFO GIS program (GENERATE), which creates a point feature coverage (GIS layer) of sediment sample locations. The sediment sample point feature is assigned a unique identification code that corresponds to the sample number in the Submerged Lands textural and geochemical data table.

Bay/lagoon Samples - Bay and lagoon sediment sample location data were captured using conventional digitizing methods. Sediment sample locations plotted in the field were digitized directly from BEG work maps, primarily National Oceanic and Atmospheric Administration (NOAA) nautical charts. Other work maps exhibiting sample locations include USGS 7.5' quadrangle maps and an original Mylar draft map of sample locations in Matagorda Bay. For a few samples, the only source of sample location is the published Submerged Lands sediment sample map. The sediment sample point feature is assigned a unique identification code that corresponds to the sample number in the Submerged Lands textural and geochemical data table.

Washover Features

Washover features were digitized directly from USGS 7.5' quadrangle work maps. Washover channels and interdune drainages were digitized as polygon features, whereas straight lines parallel to the shoreline represent coastal areas mapped as washover zones. Closed polygons were created by adding straight lines that represent the landward and seaward limits of the washover feature. In the GIS files, attribute codes were assigned to distinguish washover channels from interdune drainages.

QUALITY ASSURANCE PROCEDURES

Most of the tasks conducted for this NRI project did not involve the collection of new data but rather the electronic formatting of previously generated data. Therefore a BEG Quality Assurance Plan Specific Work Instruction (SWI 3.17) served as the procedure that ensured that the data quality standards set for the project were met. SWI 3.17, entitled "Review of Geographic Information System Maps and Data Tabulations," is presented in Appendix B. It describes the technical review of maps and historical data after the data were digitized but prior to their transmittal to the NRI geographic information system.

Point locations and codes were examined by the GIS analyst through comparison with the published sediment sample station numbers and locations map. The computer printouts represented spatial data, and thus could be plotted and checked against original maps of the offshore locations. The data were examined again in the same manner by a project scientist. Discrepancies between digital data and the sediment sample numbers and locations were noted and checked against original field notes or plots. As a final step, the corrected data were plotted and compared to the original sample numbers and locations. High accuracy was achieved through these procedures. For example, of approximately 3,500 shelf sample locations, less than 10 had to be corrected because of errors in data entry.

The scanned tables represented textural and geochemical data and thus could not be checked against a map. After scanning and converting the image to Excel, the data entry operator proofed the resultant spreadsheet against the paste-up originals. Needed changes were marked on the spreadsheet copy, and corrected in Excel.

All materials were eventually saved in comma-delimited format (CSV) in Excel, transferred to a DEC workstation and then to the Texas General Land Office for inclusion in the NRI geographic information system.

PROJECT RESULTS

The primary project deliverables were electronic files containing the locations and attributes of surficial sediments and washover areas of the Submerged Lands of Texas. Other project deliverables included a work plan and Quality Assurance Project Plan (QAPP), quarterly progress reports, and this summary report that describes the data compilation, washover mapping techniques, and digitization procedures. The electronic files are in an ARC/INFO format that is compatible with the NRI ARC/INFO geographic information system. The detailed information in the data bases will satisfy the need for accurate geographic locations of the various sedimentological parameters within each of the priority coastal areas.

The digital version of the sediment sample numbers and locations is more precise than the published paper maps. Digitization of original work maps at scales of 1:24,000 to 1:50,000 produce more precise washover and sample locations than can be derived from the published 1:125,000 scale paper maps. Rigorous quality assurance procedures followed at all phases of data conversion ensure accuracy of the electronic files.

Results of the project will provide a historical basis for detecting and monitoring changes in the coastal barriers, bays, estuaries, and lagoons, and on the inner continental shelf. The completed work also provides educational benefits regarding the diversity and locations of washover areas and sediment types in Texas coastal waters and will offer a variety of derivatives with broad applications for coastal management and planning. An example of a derivative product would be maps depicting surficial sand distribution in areas considered to be candidates for beach replenishment.

REFERENCES

Brown, L. F., Jr., project coordinator, 1972–1980, Environmental geologic atlas of the Texas Coastal Zone: The University of Texas at Austin, Bureau of Economic Geology, 7 atlases.

Brown, L. F., Morton, R. A., McGowen, J. H., Kreitler, C. W., and Fisher, W. L., 1974, Natural Hazards of the Texas Coastal Zone: The University of Texas at Austin, Bureau of Economic Geology, 13 p.

Brown, L. F., Brewton, J. L., McGowen, J. H., Evans, T. J., Fisher, W. L., and Groat, C. G., 1976, Environmental geologic atlas of the Texas coastal zone, Corpus Christi area: The University of Texas at Austin, Bureau of Economic Geology, 123 p.

Dorrzapf, A. F., Jr., 1973, Spectrochemical computer analysis—argon-oxygen D-C arc method for silicate rocks: U.S. Geological Survey Journal of Research, v. 1, no. 5, p. 559–562.

Fisher, W. L., Brown L. F., McGowen J. H., and Groat, C. G., 1973, Environmental geologic atlas of the Texas coastal zone, Beaumont-Port Arthur area: The University of Texas at Austin, Bureau of Economic Geology, 93 p.

Folk, R. L., 1974, Petrology of sedimentary rocks: Austin, Texas, Hemphill Publishing, p. 16–24.

Ingram, R. L., 1971, Sieve analysis, *in* Carver, R. E., ed., Procedures in sedimentary petrology: New York, Wiley-Interscience, p. 49–67.

Jackson, M. L., 1958, Soil chemical analysis: New York, Prentice-Hall, 498 p.

Krumbein, W. C., 1934, Size frequency distributions of sediments: Journal of Sedimentary Petrology, v. 4, p. 65–77.

Krumbein, W. C., and Pettijohn, F. J., 1938, Manual of sedimentary petrography: New York, D. Appleton-Century, p. 43–75.

McGowen, J. H., and Morton, R. A., 1979, Sediment distribution, bathymetry, faults, and salt diapirs on the submerged lands of Texas: The University of Texas at Austin, Bureau of Economic Geology, 31 p.

Nance, H. S., 1982, Textural analyses of marine benthic sediments, Texas Coastal Zone: The University of Texas at Austin, Bureau of Economic Geology Open-File Report No. OF-BR-1982-1, 16 p.

Schlee, John, 1966, A modified Woods Hole rapid sediment analyzer: Journal of Sedimentary Petrology, v. 36, p. 403–413.

Shideler, G. L., 1976, A comparison of electronic particle counting and pipette techniques in routine mud analysis: Journal of Sedimentary Petrology. v. 46, p. 1017–1025.

Wentworth, C. K., 1922, A scale of grade and class terms for clastic sediments: Journal of Geology, v. 30, p. 377–392.

Westphal, K. A., Penland, S., Seal, R. W., and Morton, R. A., 1992, Aerial videotape survey of coastal Texas and Louisiana: Center for Coastal, Energy, and Environmental Resources, Louisiana State University, Coastal Geology Map Series No. 13, 210 p.

White, W. A., Calnan, T. R., Morton, R. A., Kimble, R. S., Littleton, T. G., McGowen, J. H., Nance, H. S., and Schmedes, K. E., 1983, Submerged lands of Texas, Corpus Christi area: sediments, geochemistry, benthic macroinvertebrates, and associated wetlands: The University of Texas at Austin, Bureau of Economic Geology, 154 p.

White, W. A., Calnan, T. R., Morton, R. A., Kimble, T. G., Littleton, T. G., McGowen, J. H., Nance, H. S., and Schmedes, K. E., 1985, Submerged lands of Texas, Galveston–Houston area: sediments, geochemistry, benthic macroinvertebrates, and associated wetlands: The University of Texas at Austin, Bureau of Economic Geology, 145 p.

White, W. A., Calnan, T. R., Morton, R. A., Kimble, R. S., Littleton, T. G., McGowen, J. H., Nance, H. S., and Schmedes, K. E., 1986, Submerged lands of Texas, Brownsville-Harlingen area: sediments, geochemistry, benthic macroinvertebrates, and associated wetlands: The University of Texas at Austin, Bureau of Economic Geology, 138 p.

White, W. A., Calnan, T. R., Morton, R. A., Kimble, R. S., Littleton, T. G., McGowen, J. H., Nance, H. S., and Schmedes, K. E., 1987, Submerged lands of Texas, Beaumont-Port Arthur area: sediments, geochemistry, benthic macroinvertebrates, and associated wetlands: The University of Texas at Austin, Bureau of Economic Geology, 110 p.

White, W. A., Calnan, T. R., Morton, R. A., Kimble, R. S., and Littleton, T. G., 1988, State submerged lands of Texas, Bay City-Freeport area: sediments, geochemistry, benthic macroinvertebrates, and associated wetlands: The University of Texas at Austin, Bureau of Economic Geology, 130 p.

White, W. A., Calnan, T. R., Morton, R. A., Kimble, R. S., and Littleton, T. G., 1989a, State submerged lands of Texas, Port Lavaca area: sediments, geochemistry, benthic macroinvertebrates, and associated wetlands: The University of Texas at Austin, Bureau of Economic Geology, 165 p.

White, W. A., Calnan, T. R., Morton, R. A., Kimble, R. S., and Littleton, T. G., 1989b, State submerged lands of Texas, Kingsville area: sediments, geochemistry, benthic macroinvertebrates, and associated wetlands: The University of Texas at Austin, Bureau of Economic Geology, 137 p.

BUREAU OF ECONOMIC GEOLOGY
THE UNIVERSITY OF TEXAS AT AUSTIN

QUALITY ASSURANCE PLAN

Revision 08, 4/1/94 **Supersedes: Quality Assurance Plan, Rev. 07**

POLICY STATEMENT

As a research institution of The University of Texas of Austin, and serving as the Geological Survey of Texas, the Bureau of Economic Geology is committed to excellence in research and public service. Our Quality Assurance program is an integral part of this commitment.

Quality Assurance provides a systematic means of achieving and verifying the quality of work performed in conjunction with geologic investigations. The program is consistent with the Bureau's interpretation of applicable federal and state laws, rules, regulations, and guidelines as well as industry standards and contractual requirements. Bureau employees involved in projects to which this Plan applies are responsible for achieving quality and adhering to applicable codes and standards in accordance with Specific Work Instructions and Quality Assurance Procedures.

The Quality Assurance Manager is responsible for coordinating the development and monitoring the effective implementation of the Quality Assurance program. The Quality Assurance Manager has authority to initiate, recommend, and provide solutions to quality-related problems. I will direct that work be stopped as necessary to safeguard the achievement of quality.

William L. Fisher, Director

APPENDIX A

Description of Spatial Components and Attribute Components Included in Geographic Information System

	Spatial Component				Attribute Component	
Data Category Name	Original Source(s)	Coverage Type(s) (point/arc/poly)	Scale	Input Format (data file format/ media type)	Original Source(s)	Input Format (data file format and media type)
Sediment sample locations	Navigation charts Topographic maps	point point	1:40,000 1:24,000	ARCINFO		
Washover areas	Topographic maps Videography	arc and polygons	1:24,000	ARCINFO		
Sediment textures				ASCII	BEG Submerged Lands Reports	
Sediment geochemistry				ASCII	BEG Submerged Lands Reports	

APPENDIX B

Bureau of Economic Geology Quality Assurance Plan

Specific Work Instruction 3.17

SPECIFIC WORK INSTRUCTION

BUREAU OF ECONOMIC GEOLOGY
THE UNIVERSITY OF TEXAS AT AUSTIN

SWI 3.17

Date: December 1, 1993
Supersedes: Not applicable

Revision: 0

TITLE:
REVIEW OF GEOGRAPHIC INFORMATION SYSTEM MAPS AND DATA TABULATIONS

APPROVAL:		CONCURRENCE:	
		[signature]	12/15/93
		DEPUTY ASSOCIATE DIRECTOR	DATE
[signature]	12/16/93	Stephen Stubb	12.15.93
DIRECTOR	DATE	QUALITY ASSURANCE MANAGER	DATE

1.0 PURPOSE AND SCOPE

The purpose of this SWI is to describe internal peer review of preliminary drafts of maps and data tabulations produced using a Geographic Information System (GIS). The peer review is to verify that the maps and data entered into the GIS accurately portray the original data sets (source data or source map). These activities precede submission of maps and data tabulations to Cartography for final preparation or direct use of data tabulations by authors in reports and publications.

2.0 DEFINITIONS

Data dictionary: A historical record detailing methods and information used in the preparation of GIS products. The data dictionary is comprised of information identified on data dictionary input forms. (Attachment 1)

GIS product: A map or data tabulation produced using a GIS.

GIS reviewer: A professional geoscientist.

Source data or information: The original data or information supplied to the GIS staff for entry into the GIS. The precision and accuracy of any GIS product is limited by the source data or information on which it is based.

3.0 RESPONSIBILITIES

Research staff are responsible for submitting source data and maps to the GIS staff and for ensuring source documents and information are precise and accurate.

GIS reviewers are responsible for determining if a GIS map or data tabulation adequately portrays the source data and if the GIS presentation has introduced any inaccuracies not present in the source data.

Attachment 1
GIS Data Dictionary Input Form

Layer Name: ______________ Layer Description: ______________

Layer Location: ______________ Geo. Area: ______________

Input Date: ______________

Original Data Description

Source: ______________

Scale: ______________ Date: ______________

Automation Scale: ______________ Multiple scales: ❑

Projection/ Parameters: ❑ Albers ❑ UTM ❑ State Plane ❑ Other (specify): ______________
❑ Lambert ❑ Polyconic

Units: ❑ Meters ❑ Feet ❑ Inches ❑ Other (specify): ______________
❑ DMS, DD

Comments (Datum, Parameters): ______________

Current Data Description

Projection/ Parameters: ❑ Albers ❑ UTM ❑ State Plane ❑ Other (specify): ______________
❑ Lambert ❑ Polyconic

Units: ❑ Meters ❑ Feet ❑ Other (specify): ______________
❑ DMS, DD

Coverage: ❑ Region ❑ Polygon ❑ Line ❑ Other (specify): ______________
❑ Point ❑ Annotation ❑ TIC

Comments (Datum, Parameters): ______________

Edit History

Date Edited	Edited/Changed By	Changes

Attachment 1
Bureau of Economic Geology
GIS Data Dictionary Input Form
(continued)

FILES		
Name*	Item	Description

* PAT - Polygon/Point attribute files; AAT - Arc attribute files; RDB - Relational data base

GIS staff are responsible for converting digital or hard copy data or information into a GIS product and for maintaining and filing GIS records.

The Quality Assurance Manager is responsible for verifying that work is being conducted in accordance with this procedure.

4.0 PROCEDURES

Research staff submit source data and maps to the GIS staff.

The GIS staff satisfy themselves that the draft GIS product is nearly in final form before submitting it for peer review. GIS staff may determine this with or without the involvement of the person who submitted the source data or map.

If the GIS product is a map, the GIS staff will print or produce a preliminary hard copy of the GIS map at the same scale as the source map and complete data dictionary input form (attachment 1). Copies of the GIS map and relevant source map and a copy of the data dictionary input form should be submitted to the GIS reviewer. If the GIS product is a data tabulation, a copy of the GIS version and the source data should be submitted to the GIS reviewer. All preliminary copies of GIS products will be clearly marked as "PRELIMINARY DRAFT - NOT FOR DISTRIBUTION."

GIS maps should be compared directly with the source map, preferably by overlaying the source map with the GIS map on a light table if the source data and the GIS product are at the same scale. Areas needing correction should be marked on the GIS map. GIS data tabulations should be compared with the source data. Corrections to data tabulations should be marked on the data tabulation or described in a memorandum or other document, or both. The GIS reviewer should date and initial the GIS map, data tabulation, memoranda and any other documents produced in the course of the review and return all materials to the GIS staff.

The GIS reviewer should discuss needed corrections with the GIS staff or, if corrections are significant, with the GIS staff and the person who provided the original source data. Once corrections have been completed, the GIS staff should print or produce a second draft of the GIS product and forward the product and review documentation to the GIS reviewer. The second draft should also be clearly marked as "PRELIMINARY DRAFT - NOT FOR DISTRIBUTION."

The GIS reviewer should review the corrected map or data tabulation to ensure all corrections have been made, sign and date the draft, and return all materials to the GIS staff. The GIS staff should forward a copy of the approved draft to the person who provided the original source data.

Copies of the original source data, signed originals of preliminary drafts, review documentation, and data documentation should be maintained and filed by the GIS staff.

No additional peer review is required unless significant changes are made to the approved final draft.

3.0 TRAINING

Professional geoscientists are, by virtue of their academic training and professional experience, capable of serving as GIS reviewers, and no additional training is required. GIS staff shall receive appropriate training in the operation of GIS equipment. The training shall be documented in accordance with Quality Assurance Procedure QAP 2.1, "Quality Assurance Training."

4.0 RECORDS

Copies of all documents generated by this SWI are Quality Assurance records and shall be submitted to the Records Center. Prior to submittal, the sender shall ensure that each document is complete, legible, and adequately identified. Control of these records shall be in accordance with QAP 17.1, "Quality Assurance Records Management."

Records generated by this Specific Work Instruction include:

- A copy of the original source data or map (NOTE: If the original source data exists only in a digital format (e.g., digital elevation model or Global Positioning System [GPS] data), then a printout is prepared, a scientist familiar with the data reviews it for adequacy, signs and dates the approved printout, and submits it to the Records Center.)
- Originals of signed drafts of GIS products
- Review documentation
- Data dictionary
- Data dicitonary input form
- Training documentation