AN ABSTRACT OF THE RESEARCH REPORT OF

Gregory M. Benoit for the degree of Master of Science in Marine Resource Management presented on September 27, 1996. Title: An Interactive Metadata Catalog for the Tillamook Bay National Estuary Project Geographic Information System.

The collection, evaluation, and organization of spatial information is instrumental to the successful development and execution of planning policies and management programs. Geographic Information Systems (GIS) provide the technology to integrate varying informational needs into a single relational database for ease in data retrieval and analysis. The use of a GIS by the Tillamook Bay National Estuary Project (TBNEP) has developed out of a need for more efficient utilization of large quantities of spatial information for watershed analysis, ecological modeling, educational and managerial purposes. An inventory of 161 GIS data layers has been completed. A metadata catalog that defines the available entities, attributes, and associated domain values of these geographic coverages was constructed. The catalog allows the user to identify mapped features and associated metadata information available for these features, in addition to the quality, definitions, and other characteristics of the data in an interactive environment. A potential user is able to peruse the metadata information and render an informed judgment about the fitness of the data for the projected use. This interactive metadata catalog is used to advise system users of the content, characteristics, quality and availability of GIS coverages, while providing information that can be used to assess potential problems or limitations inherent in the GIS database.
An Interactive Metadata Catalog for the Tillamook Bay National Estuary Project
Geographic Information System

by

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1. INTRODUCTION

1.1 The Tillamook Bay National Estuary Project

The Tillamook Bay National Estuary Project (TBNEP) is a four year, community-based effort to study and begin to resolve environmental problems of Tillamook Bay and its watershed. The program, established in 1992, is funded by the U. S. Environmental Protection Agency as part of the National Estuary Program. There are three primary environmental problems being addressed by the TBNEP: 1) declines in living resources of the bay and watershed, 2) watershed erosion and resulting sedimentation, and 3) bacterial contamination and its effects on shellfish harvesting and water contact uses of the bay.

In an effort to address these environmental problems the TBNEP has established five goals that are to be accomplished throughout the course of the project (TBNEP, 1995). Primary among these is to establish water quality standards that are designed to protect “beneficial uses” of the bay. These include swimming, fishing, shellfishing, and use by native fish and wildlife. A second priority is to restore the bay from damaging effects of sedimentation in order to improve habitat and navigation. The protection and enhancement of a spawning and rearing habitat for anadromous fish is a third priority. A comprehensive plan for the bay that will protect bay water quality and living resources while promoting compatibility among Tillamook County’s natural resource-related industries will also be developed. The establishment of the above mentioned goals that address the environmental problems of the Tillamook Bay was motivated by concern for
the region’s natural resources. Problems similar to those that occur in the Tillamook Bay also occur in other estuaries and coastal watersheds in Oregon. Thus, the final goal of the TBNEP is to apply the lessons learned in Tillamook Bay to other estuaries in Oregon.

1.2 Rationale

In an effort to provide the necessary tools for addressing the above mentioned priority tasks, an extensive geographic information system (GIS) has been developed by the TBNEP. Relating to this, the establishment of standard protocols for the appropriate handling of error and uncertainty in data layers and for the construction of a well developed metadata catalog are current priorities for the completion of a useful GIS.

The importance of using a GIS for resource management has been recognized by the TBNEP. However, users must have a means of determining the utility of information within a GIS layer. For example, digital cartographic files contain large quantities of descriptive information that can be used to define the usefulness of the digital coverage. This information must be made available to a GIS user in a format such that data utility easily can be assessed. Metadata, “data about data,” are used to organize and document the descriptive information that is necessary to assess the applicability of the digital cartographic file for a projected use. To insure a successful GIS, the TBNEP has developed an interactive metadata catalog that documents metadata information for the geographic coverages that compose their GIS database.
The objective of this paper is to function as an informational guidebook for users of the TBNEP GIS. It is intended not only to describe the Interactive Metadata Catalog but also to introduce information systems, metadata management and sources of error in GIS data layers. This document will provide an inexperienced user with the information necessary for making informed decisions while using the TBNEP GIS.

Pursuant to this objective, Chapter Two answers the question of what is an information system, with particular emphasis on geographic information systems. Additionally, the important role of GIS as a tool for resource study and management of the Tillamook Bay by TBNEP staff is discussed. Chapter Three defines the term “metadata management” and its role in a successful GIS database. The TBNEP metadata strategy and how metadata are directly linked to the TBNEP GIS database are described. Chapter Four is dedicated to the issue of data quality. To assess data quality, and additionally, to interpret how this information will influence the utility of a data layer, sources of error and error propagation in GIS data layers must be understood. Chapter Five describes the development and use of an interactive metadata catalog. This catalog has been developed as a vehicle for navigating through large quantities of descriptive metadata information. It is intended to serve as a stand alone document with complete remote access to the TBNEP GIS database. Lastly, applications of the Interactive Metadata Catalogue as well as recommendations to the TBNEP for future development of the metadata catalog and the GIS database are presented in Chapter Six. Limitations in the metadata database in addition to guidelines for improving the database are described.
2. INFORMATION SYSTEMS

2.1 Introduction

The collection, evaluation, and organization of information is instrumental to the successful development and execution of planning and management programs. However, there are many factors that influence the utilitarian value of information that is gathered. These include, for example, data accessibility, data compatibility, data quality, time constraints on data collection activities, decision maker/planner awareness, individual processing limits, source reliability, and budget constraints (Brooks, 1985). Increased demand for storage, analysis, and display of large quantities of data, in addition to increased attention to the above mentioned issue areas, has led to the development of sophisticated information systems. Such systems have developed largely in an effort to increase the functionality of information. Calkins (1972) argues that data become usable information only after they have been retrieved and processed for a certain defined purpose. Thus, the use of information systems has developed out of a need for more efficient utilization of large quantities of information for planning, management, and decision making purposes.

2.2 An Information System

An information system is defined as "a group of entities and activities meaningfully connected and satisfactorily bounded, which interact for a common purpose or purposes" (Thomas and Shofer, 1970 in Calkins, 1972). Calkins (1972) argues that the elements that comprise an information system can be described in terms of three subsystems: an
internal management subsystem, a data processing subsystem, and a data analysis subsystem (Figure 2.1).

The management subsystem consists of the organizational and staffing procedures and protocols for the correct usage of the other two subsystems. This includes a long-term staff plan, an educational plan for the users of the system, and a user feedback program.

The data processing subsystem consists of data acquisition, input, and storage functions.

The data analysis subsystem consists of data retrieval and analysis functions, such as statistical analysis, in addition to data preparation and presentation capabilities.
To insure maximum functionality of the data that are generated from an information system, a strategy needs to be developed to bridge the interface between the above mentioned subsystems and the information system user. Such a strategy, referred to as an information use system, is designed to address access issues to the desired information. For example, some users involved in the decision making and planning process may have the skills necessary to interpret data generated from an information system, while others must rely on technical assistance from those skilled in particular applications. To insure that data output is delivered in a readily understandable and valuable format to all data users, an information use system must be developed (Tomlinson, et al., 1976; Calkins, 1972). An information use system is used in concert with the above mentioned three information subsystems to provide functional data to a user.

2.3 Types of Information Systems

Several types of information systems have developed to address varying data needs and applications (Calkins, 1972). First, Operational Information Systems (OIS) are designed to provide information needed to meet the operational needs (i.e., technical operations) of organizations that utilize internally generated data. Second, Management Information Systems (MIS) contain information that is available to top level managers for the management of the organization. MIS are used for providing information that will aid in insuring the continuing success of any particular function of an organization. Third, Planning Information Systems (PIS) rely heavily on outside sources of data to provide information that is required to address varying planning related concerns. For example, a PIS is required to organize and process natural resource management information to
insure responsible decision making. Lastly, Spatial Information Systems (SIS) have developed out of the need for geo-referenced data that are useful in planning information systems. Spatial, often referred to as geographical, information systems differ from other information systems in that they are designed specifically for the retrieval of data by use of "location identifiers" that compose a data record (Calkins, 1972; Honeycutt, et al., 1980). Locational identifiers include: 1) external indices, 2) coordinate references, such as latitude and longitude, 3) arbitrary grids, such as locationally referenced data cells, and 4) explicit boundaries, as defined by the coordinates of the polygons by which they are bound (Tomlinson, 1970 in Calkins, 1972). Figure 2.2 illustrates these locational identifiers for geographical information systems.

![Locational Identifiers](image)

Figure 2.2: Locational identifiers for geographical information systems (Calkins, 1972).

### 2.4 Information System Design

The successful utilization of an information system is dependent upon its design. Although perhaps technically advanced, a poorly designed system has little utilitarian value if it does not meet the needs of its users. Perhaps the most important issue in
developing an information system is to identify the data types needed to address the users' queries.

2.4.1 Decision Analysis

Planning and management decisions are made based on the relevant information that is available. "Decision analysis" is defined as how a user analyzes this information and uses it for decision making. Gorry, et al. (1971) argue that decision making is a three phase process. The first phase they define to be the act of searching for an environment that requires a decision to be made. The second phase involves developing, and analyzing possible courses of action. In the last stage, it is necessary to develop a course of action based on the environment that requires decision making. Decisions are ultimately made based upon how individuals conduct their data analysis and what information they consider to be important.

In actuality, decisions are often made solely based on information that is readily available rather than that which is most appropriate for the objectives at hand. This is often problematic as goals and objectives that are broadly defined are too general for inclusion in information design and data collection methodologies. Therefore, it is important to have narrowly defined objectives and well developed questions when establishing a database. Tomlinson, et al. (1976) have designed a three stage schematic framework for the design and evaluation of information systems based upon well defined objectives (Figure 2.3): 1) determination of the system's objectives, assessment of resources, and development and evaluation of specifications; 2) description and evaluation of alternative
system designs that are capable of meeting the specifications set forth in stage one; and 3) overall evaluation of alternative system designs in terms of potential benefits and costs. If the results of any stage in this scheme are not satisfactory, then the system design will have to be altered.

Figure 2.3: Information system design and evaluation model. Stage 1: determination of the system's objectives, assessment of resources, and development of specifications. Stage 2: Description of alternative system designs capable of meeting the specifications outlined in stage 1. Stage 3: Potential benefit and cost analysis of alternative systems design (Tomlinson, 1976).
2.4.2 Determination of Data Needs Based on User Objectives

There are several approaches for the collection of data for inclusion in an information system. The “shotgun” approach, although very common in today’s information age, is perhaps the least cost effective. It is possible for decision makers to be overwhelmed by an abundance of irrelevant information. Therefore, it is important to prioritize data for collection, compilation, and incorporation into an information system based upon well defined user objectives. Calkins (1972) defines three strategies for designing an information system based upon well defined data needs and objectives. The first option is to conduct exhaustive studies to isolate user needs and data use objectives prior to system design activities. The second is to insure that the informational outputs of the system will be usable and will lead to better decision making. The final strategy is to use the information system itself as a vehicle for exploring possible data needs. Calkins (1972) argues that strategy one is not feasible due to limited financial resources available to conduct exhaustive studies. Option two tends to make an information system an end in itself rather than a tool for achieving stated goals and objectives. Thus, option three is generally the most effective as one can identify informational needs and potential data sources based upon the users objectives and goals. One must consider data currently being used, data that would be valuable if available, and data that are expected to be required in the future (Calkins, 1972). Thus, to design and implement a successful information system, it is important to establish a strategy that will help determine data requirements, examining both the short term and long range data needs of the user. A data definition table (Figure 2.4), often referred to as a metadata catalog, is a useful tool
for documenting this information and organizing data that are needed to satisfy the informational requirements of a particular application.

Figure 2.4: Data definition table: a useful tool in identifying informational use objectives and data coverages needed to satisfy information requirements (Calkins, 1972).

2.5 Geographic Information Systems

A geographic information system is a system of computer hardware, software, and procedures designed to support the capture, management, manipulation, analysis, and display of spatially referenced information. A GIS incorporates three distinct aspects of computer technology: database management functions, spatial analysis functions, and applications for the manipulation and display of spatial information (Figure 2.5).
Figure 2.5: Integration of different aspects of computer technology in a geographic information system (Antenucci, et al., 1991).

A modern GIS has the capability to integrate the above mentioned functions into a single relational database for greater ease in performing data retrieval and analysis functions. Additionally, a GIS has cartographic display ability for aiding in the visualization of geographic information needed in natural resource management. Overlay functions, which are used for complex analysis of spatial data, can be performed over varying spatial and temporal scales, aiding in the analysis and hypothesis testing of scientific data. An additional component of a GIS is that non-spatial attribute information is linked to spatially oriented identifiers by use of the GIS database management system. This feature allows display of non-spatial data in a spatial context. The above mentioned functions of a GIS provide for the storage, manipulation, and display of geographic data. Such a system is ideal for use in resource management in that data manipulation and query functions of the GIS can be used to evaluate spatial information.
2.6 Use of a GIS by the TBNEP

A paramount mission of the TBNEP is to designate the most significant, or 'priority,' environmental problems of the Tillamook Bay and to involve the local community in the management of these problems. The use of a GIS by the TBNEP is instrumental to accomplishing this goal. A well developed and documented GIS will facilitate successful management and study of natural resources in the Tillamook Bay by providing greatly improved tools for the organization and manipulation of spatial information. Additionally, analysis of spatial data can be performed by any staff member, and these analyses in turn are available to all staff members thus avoiding redundancy and insuring consistency of data operations. Lastly, a GIS is expandable to meet future needs of its users.

In addition to the organizational benefits of using a GIS, such systems can aid in natural resource planning and analysis. Information stored in a GIS can be easily and efficiently retrieved, a necessary feature for making educated, responsible planning decisions in a timely manner. This information can be presented in the form of a report or a visual presentation, such as a map, for ease in viewing and analyzing data. Additionally, use of a GIS by TBNEP staff can promote interagency compatibility and communication through data sharing so that a more holistic approach can be taken towards resource management. Lastly, a GIS can be used by TBNEP staff to perform sophisticated analyses and queries that will assist in the interpretation of spatial information.
2.7 Conclusion

Data accessibility, compatibility and quality, time constraints on data collection activities, decision maker/planner awareness, individual processing limits, source reliability, and budget constraints are all factors that influence information utility (Brooks, 1985). Resulting from the complex nature of information use, detailed planning and careful thought must be invested in the development of an information system used in planning and management decision making. Without clearly defined objectives and goals, and a means to achieve these goals, the development of a valuable information system is extremely difficult.

Due to advances in computer technology and remote sensing techniques, data are becoming easier, more efficient, and less costly to access, accumulate, and analyze. Thus, it is becoming less problematic for users to accumulate large quantities of information for incorporation into an information system. However, it is imperative that only the information needed for a particular objective be collected. As TBNEP planning and management interests develop, the information system itself will have to change to meet new objectives. Thus, it is important to have the functional ability to adapt the utility of the TBNEP GIS to well defined objectives and goals.
3. METADATA DOCUMENTATION AND MANAGEMENT

3.1 Introduction

Successful use of spatial data depends on the ability to locate the information and to understand the information’s characteristics and quality. The term metadata, “data about data,” has been developed to describe the content, quality, condition, and other characteristics of data. Metadata are used to help organize and maintain an agency’s or organization’s spatial data holdings. Additionally, metadata should ideally provide information necessary to process and interpret data obtained from an external source. In essence, metadata answer the “who, what, when, where, and how” about the data that are being documented (U.S. Geological Survey Global Change Research Program, 1996).

3.2 Metadata Documentation and Management

The necessity for metadata information has led not only to the development of metadata directories and dictionaries, but also to standards governing their creation. At the federal level, the Spatial Data Transfer Standards (SDTS) were created in 1992 to address a number of issues critical to successful spatial data transfer. These include: 1) conceptual modeling, 2) logical structuring, 3) details of physical encoding, 4) definitions of feature and attribute terms, and 5) inclusion of metadata and quality reporting. The SDTS focus primarily on data transfer and exchange. They were, however, later supplemented by data quality standards that emerged from the Federal Geographic Data Committee (FGDC), a working group of the National Committee for Digital Cartographic Data Standards (NCDCDS) (Chrisman, 1994; NCDCDS, 1988; National Institute of Standards and
In June 1994, the FGDC approved the “Content Standards for Digital Geospatial Metadata” which demanded that a data quality report be included with all digital cartographic data created by federal agencies (FGDC, 1994). A data quality report must document information relating to lineage, positional accuracy, attribute accuracy, logical consistency, completeness, and temporal accuracy of the spatial information. The purpose of the standard is to provide a common set of definitions and terminology for documentation of metadata information.

A metadata directory defines a layer’s entities and attributes while conveying this information to database administrators and GIS users in a clear and concise manner. The directory allows the user to identify the map features and attribute data available for specific applications, in addition to the quality, definitions, completeness and other characteristics of those data. Due to the nature of electronic information, GIS data can be shared among multiple organizations that update, maintain, and use specific sets of information. This requires effective documentation of data characteristics and sources to insure data integrity. Furthermore, organizations that do not document spatial information often find that, over time or as a result of personnel changes, the content or quality of the information is no longer known. At this point, organizations unfortunately cannot trust the results generated from the data. Additionally, lack of information about other organizations’ and agencies’ data can lead to a duplication of effort.

Perhaps one of the most important types of information describing a GIS layer is data quality. The SDTS requirements were developed to assess total amounts of error in
digital cartographic data sets; yet, they provide little assistance in determining the sources of error (Chrisman, 1994). To address this, a well maintained data dictionary can be used to advise system users of the content, characteristics, quality and availability of GIS information, while additionally providing information that can be used to assess potential problems or limitations inherent in the database. Lanter (1991) expresses this view: "The meta-data level contains abstract information describing the quality of data stored in the geographic level; therefore, implementing the meta-data level creates an information system about the GIS data base." Metadata form the basis for making informed decisions regarding the fitness of a particular data source (Chrisman, 1994). The FGDC outlines four categories of metadata information that help to define the fitness of spatial data:

- Availability information necessary for determining what data sets exist for a geographic location.
- Fitness of use information necessary for determining if a data set meets a specified need.
- Access information necessary for acquiring an identified data set.
- Transfer information necessary for processing and using a data set.

A potential user should be able to peruse the metadata information and render an informed judgment as to what data exist, the fitness of the data for the projected use, and the requirements for accessing these data. The way in which data elements are evaluated, and the relative importance of the data elements, will not be the same for all users or for all potential uses of the metadata. With a complete metadata directory for a data set, the
user should be able to answer the question of whether the information source serves the intended purpose sufficiently to be worthy of analysis (Chrisman, 1994).

3.3 **Metadata Documentation and Management for TBNEP**

The use of a GIS for the TBNEP has developed out of a need for more efficient utilization of large quantities of information for planning, management, educational, and decision making purposes. A well organized and comprehensive metadata database is essential for effective management of this GIS. Additionally, metadata management will help the TBNEP to publicize its GIS and help to document descriptive information for the layers it contains. The primary concerns about data utility by the TBNEP are the degree of data accessibility, data compatibility, source reliability and functionality of the TBNEP GIS data layers. To address the above concerns, the TBNEP has planned to develop a metadata catalog that defines the entities and attributes associated with their geographic coverages.

3.4 **Conclusion**

Metadata documentation has been shown to be an effective method of advising system users of the content, characteristics, quality and availability of GIS coverages, while providing information that can be used to assess potential problems or limitations inherent in GIS data layers. This information is essential for GIS users to make an accurate assessment of data utility. The importance of a metadata catalog that identifies data characteristics has been recognized by the TBNEP as a major component of a complete and successful GIS database. A potential user must be able to peruse the
metadata information and render an informed judgment about the fitness of the GIS data for their projected use.

However, as the TBNEP GIS database itself, as well as the number of users of the database, continues to grow, issues of data quality are becoming increasingly more important. As mentioned above, documenting sources of error and error propagation is instrumental to assessing the overall accuracy of a GIS coverage. To assess data accuracy, TBNEP staff and TBNEP GIS users must be aware of the many sources of error that may exist in a GIS data layer.
4. ERROR SOURCES AND ERROR PROPAGATION IN GEOGRAPHIC INFORMATION SYSTEMS

4.1 Introduction

TBNEP has employed a GIS for the analysis of spatial information necessary for ecological study and management. However, to insure accurate interpretation of this spatial information the TBNEP has made it a priority for its staff to be aware of possible errors and limitations in GIS data, as this information may influence the usefulness of a data layer in ecological study and management.

The power of GIS is its ability to integrate data from a variety of sources, such as aerial photographs, satellite imagery, and digitized maps, for data management and analysis. However, data sources are subject to varying levels of error associated with acquisition, processing, analysis, conversion, and final product presentation. These sources of error have a direct impact on the confidence of management decisions made based upon the data (Lunetta, et al., 1991). Computers as a spatial data handling tool have introduced a false sense of security when considering data accuracy. The use of GIS in resource management is increasing; yet, a comprehensive understanding of spatial data error sources lags far behind. Lanter and Veregin (1992) argue that GIS "provide a means of deriving new information without simultaneously providing a mechanism for establishing its reliability." It is debatable whether GIS actually derive, or create, new information; however, GIS do serve as a useful tool for deriving insight and developing knowledge.
Historically, GIS users have treated their data as perfect models of the world. However, the inevitable deviations between the representation and actual characteristics of these data constitute error (Chrisman, 1991). Additionally, GIS software is largely deficient in tools for statistical recognition of and analysis of attribute error sources and spatial data relationships (Scott, 1994). For this reason, the neglect of error sources in GIS layer creation requires immediate attention as it is considered to be a major problem within data accuracy.

### 4.2 Error Propagation

The utility of GIS derived products can be assessed by understanding how error sources have propagated through data collection, transcription, translation, and analysis. However, error assessments typically occur at the conclusion of data analysis and rarely during each stage of the analysis process. For a better understanding of the accuracy of GIS data layers, it is imperative to develop the ability to quantify error associated with the data as well as to monitor error as it propagates through GIS applications. Bedard (1987) emphasizes this point by saying:

"Uncertainty results from indeterminacy in the spatial distribution of this characteristic, because no accurate real world standard exists against which the mapped characteristics can be compared.... According to this view, a map or other spatial data product is a model of the real world, necessarily incomplete and generalized. Uncertainty is therefore propagated and transformed each time a conceptual or physical model is constructed in the course of GIS applications processing" (Bedard, 1987 in Lanter and Veregin, 1992).
Error can be an attribute of a specific data layer (resulting from data collection and translation) or the result of an analysis that combines different data layers. Errors in source information are often modified by data transformation functions that are then passed on to resulting layers. This is somewhat problematic in that cumulative error may result when analyzing composite images of data layers as each individual layer is subject to error. Additionally, data transformation procedures themselves can often create error where none existed previously (Lanter and Veregin, 1992).

A significant amount of research has focused on the development of error propagation models (Lanter and Veregin, 1992; Openshaw, 1989). However, Hunter and Goodchild (1995) argue that the growing diversity of spatial data applications and the number of spatial processes now available suggest that there can be neither a single all-embracing error model for spatial data, nor any one optimum method for presenting error. Thus, it is essential that GIS data users be aware of potential sources of error and realize that they may influence the quality of final data products.

4.3 Sources of Error

Like all measurements, spatial data have levels of accuracy that are limited by methods of data collection and transmission as well as human error. Errors in data sources that comprise a GIS layer are numerous and varied. D. A. Mead (1982) concludes that the quality of data within a GIS is affected by “the age of data, aerial coverage, source map scale, source map resolution, format, accessibility of the data, costs of data acquisition, degree of modification from the source data, and data accuracy” (Mead, 1982 in Walsh, et
al., 1987). Such factors dictating data error can be generalized into two types of error sources that contribute to the reduction in accuracy of products generated by a GIS: inherent and operational (Walsh, et al., 1987). Inherent error refers to error present in data source information, while operation error refers to errors that occur during data transformation and processing as data are incorporated into a GIS.

4.3.1 Inherent Error

Inherent error is described as the error present in source documents such as base maps and aerial photographs. Potential data sources may contain inherent error as a result of field data acquisition and delineation activities, interpretation of data characteristics, and systematic errors within a data source (Walsh, et al., 1987).

4.3.1.1 Data Acquisition

Various errors occur during data acquisition activities, such as field data collection, and are incorporated into source documents later used to create a GIS layer. Data acquisition errors result from both primary and secondary methods used to collect data (Thapa and Bossler, 1992). Primary data collection methods refer to data that are collected in the field, as opposed to secondary methods which refer to data collected from existing documents. There are numerous sources of error associated with both data collection methodologies, as discussed below.
Primary collection methods:

Field data are often used to produce documents that may serve as base layers for the creation of a GIS layer. Errors that result from these activities are often passed on to source documents and later incorporated into GIS layers. Error associated with primary data acquisition can be due to personal errors such as delineation and measurement of data features, instrument related errors, atmospheric variations, or remote sensing errors.

- Delineation: Accurate delineation of geographic features to be included in spatial analysis is essential for minimizing quality problems associated with the data. An excellent example of this concept is found in the study of shoreline recession. An accurate delineation of the coastal bluff is necessary for determining shoreline change in some areas; however, seasonal variations in vegetative cover can affect one’s ability to accurately delineate the edge of the bluff. Additionally, delineation of other coastal features, such as the high water line, from remotely sensed data sources such as aerial photographs and satellite imagery is also subject to inaccuracy. Such features appear on the beach face only as tonal changes due to differences of water content of the sand (Dolan, 1978; Shoshany, 1992, Smith; 1990). The determination of this interface is subject to much interpretive error.
- Measurement: Often, data features and atmospheric conditions are difficult to measure and thus may hinder accurate determination of feature characteristics and representation. The errors that occur during feature measurement may then be transferred to a GIS layer. As a result, the GIS layer will incorporate the errors that occurred during data collection, and thus, measurements and inferences from this GIS layer may not reflect the "real world" situation.

- Instrumentation: Instrument errors are primarily the result of adjustment and calibration errors as well as faulty construction. Errors related to instrumentation will influence the accuracy and quality of collected data.

- Atmospheric variations: Error also results from the fluctuation in atmospheric conditions due to seasonal and storm induced variations in temperature, moisture levels, pressure, humidity, wind, and sun illumination.

- Remote sensing: Remote sensing data acquisition techniques are becoming increasingly important in providing spatial data for incorporation into a GIS. However, numerous sources of error may exist in remotely sensed imagery. Lunetta, et al., (1991) outlines four types of error present in remotely sensed imagery; those that result from scale, spatial registration, illumination geometry, and sensor systems themselves.
Scale variations result from platform errors such as the stability of the moving platform used to acquire imagery, variations due to camera tilt, radial scale variations away from the nadir, and distortions due to relief variations of the surface photographed (Dolan, 1978, 1980; Stafford, 1971; Anders, 1991). The resulting distortions must be corrected or minimized to reduce the measurement errors to an acceptable level for accurately assessing data utility. Secondly, in order to geometrically rectify remotely sensed imagery, stable control points are required on both the images themselves and the base map being used to rectify the image. However, due to the scale of the aerial photograph, natural processes, or land use changes, ground control points of comparable sources may have been destroyed, moved, or altered in some way; thus, less reliable control points often must be used at the expense of accuracy (Anders, 1991; Lunetta, et al., 1991). Third, scene correction errors such as relief displacements and atmospheric effects, such as absorption and scatter, can drastically alter the accuracy of spatial data. Lastly, remote sensor systems can produce error themselves due to design accuracy of sensor detectors. Thus, inferences based on data collected from remotely sensed imagery are subject to error.

- Secondary collection methods:

As opposed to primary data collection methods in which data are generated from field studies, secondary methods of data collection refer to data gathered from
existing documents. Errors that may occur in these original documents will be incorporated into the GIS layers that have been created from these flawed data. This method of data collection incurs errors associated with compilation, plotting, drawing, generalization, map reproduction, scale, feature definition uncertainty, feature exaggeration, and scanning and digitizing errors (Thapa and Bossler, 1992).

- Compilation: Compilation errors are commonly found in maps that are generated from varying sources of information. For example, the construction of topographic maps usually requires compilation of various data sources to a common scale. Users should be aware that this process is subject to error and, thus, so are the resulting topographic maps.

- Plotting controls: Accurate rectification to valid control points is essential for preserving the accuracy of spatial data. If a base map with faulty control points is being used for creation of data layers, the resulting GIS data products will be subject to a large degree of inaccuracy.

- Drawing: The use of computerized methods of map production has helped to minimize drawing errors associated with final map products. However, maps being used as a data source for GIS layer creation may still have drawing errors associated with them.
- Generalization: Generalization techniques are often used when constructing maps. These techniques typically result in a reduction or enhancement of the spatial, spectral, and thematic resolution of the original data. When using a generalized base map for GIS data analysis, a user must be made aware of the degree to which the original data were altered in order to accurately detect errors that may have resulted from changes in the resolutions of the original data.

- Map reproduction: There are often errors in map reproductions as a result of color registration errors and material deformation. Studies have found that error, although often small, is present in maps due to color printing techniques (Maling, 1989 in Thapa and Bossler, 1992). Additionally, the dimensions of paper maps are subject to deformation due to changes in temperature and moisture. Studies have demonstrated that the net change in dimension after heating and cooling of paper maps can be as high as 1.5% in length and 2.5% in width (Maling, 1989 in Thapa and Bossler, 1992). Such alterations of the original map can influence symbol accuracy.

- Scale: When using several maps for the production of a GIS product, it is essential that the maps be of the same scale and rectified to the same map projection. Scale is a measure of map dimensions versus those of reality.
Thus, scale sets the limit on the information that can be derived from a map. For example, if two maps have different scale, then the resolution and thus the amount of information that can be derived from the maps is limited by the smallest map scale. Additionally, spatial resolution is an increasing problem in GIS as a user can alter the scale of spatial data without a corresponding change in its spatial resolution. This often results in misleading conclusions based on the data scale.

- Feature definition: The methodology used in the definition of a mapped feature or attribute may differ among individuals. Variations in the definition of a feature may introduce some uncertainty in the positional and orientational accuracy of that feature.

- Feature exaggeration: Features on a map are often exaggerated and enhanced to increase the communicative value and legibility of the map. This can result in a significant amount of scale and positional error if an exaggerated map is used for purposes for which it was not intended.

- Digitizing: Digitizing errors are often due to the width of the feature, skill of the operator, feature complexity, digitizer resolution, and feature density.
4.3.1.2 Interpretation

In addition to errors associated with primary and secondary methods of data acquisition, errors may also occur through the visual interpretation of spatial information to be used in GIS layer creation. Haining and Arbia (1993) believe that there are important differences between spatial error and the visual plausibility of that error. However, the interpretation of mapped features is often the basis upon which conclusions drawn from maps are made. The credibility of data sources is directly linked to the ability to accurately and clearly distinguish feature characteristics.

4.3.1.3 Systematic

Accurate assessment of feature characteristics requires that original data sources be consistent in depicting the conditions in which the data were acquired. However, if errors occur due to inconsistent data acquisition methods, and this information is then used in layer generation, errors in the original data will be systematically propagated throughout all future data operations. Thapa and Bossier (1992) conclude that if systematic errors are present, although consistent in occurrence, the data may not be accurate. Errors that are systematic in nature may occur as a result of environmental processes, instrument miscalibration, or human limitations (Thapa and Bossier, 1992). Extreme care should be exercised to insure consistency among data sets with respect to seasonality, atmospheric conditions, data collection methodologies, and human interactions.
4.3.2 Operational Error

In addition to inherent error, or error present within data source information, operational error may be introduced through the manipulation and processing of data as they are entered into a GIS. Not only are inherent error sources input into a GIS at this stage of analysis, but also entirely new forms of error occur as a result of data comparison, data extraction, and data entry within the GIS (Walsh, et al., 1987). Operational errors often result from human bias, data placement, attribute identification, data processing, data analysis, data conversion, and final product presentation (Walsh, et al., 1987).

4.3.2.1 Human

Errors are often caused by the carelessness of an individual in using recording equipment, using digitizing equipment, reading scales or data outputs, or in documenting observations. Errors that do occur as a result of this carelessness are eventually incorporated into GIS data and can drastically alter data quality.

4.3.2.2 Positional

Operational error often results from positional error such as inaccurate placement of horizontal and vertical boundaries. Inaccurate positional information may influence the correlation of mapped data to real world coordinates.
4.3.2.3 Attribute Identification

Attribute identification error can often result from errors in categorizing and delineating data and human bias that exists when interpreting data (Walsh, et al., 1987). Methods in which data are categorized must be consistent.

4.3.2.4 Data Processing

Significant errors can result if the data have not been geometrically rectified to a map projection. Additionally, data conversion can produce inaccuracies since it is possible to resample data to the extent where they have a poor relationship with the original information (Lunetta, et al., 1991).

4.3.2.5 Data Analysis

There are several sources of error that occur throughout the course of data analysis. For example, a general lack of well documented methods and adequate statistical tools for quantitatively assessing data error exists. GIS software packages do not present adequate statistical options. As Lunetta, et al., (1991) note, "... inexperienced analysts may blindly follow the software hierarchy using default options without thinking about what is happening to the data." As a result, quantitative statistical analysis of spatial data may be incorrect, leading to faulty conclusions based on the data. Secondly, data registration, temporal, and classification system errors may be present. Registration errors influence the positional accuracy of the data. The temporal resolution of GIS data must be considered as a possible source or error. And lastly, error may be present due to the inaccuracy of the classification systems when integrating remotely sensed data into a GIS.
The above mentioned sources of error must be understood and accounted for prior to data analysis. Error that is present will eventually be incorporated into the data layer, resulting in inaccurate representation of original source data.

4.3.2.6 Data Conversion

Slight alterations of spatial data occur when data are transferred from one file format to another. For example, spatial data are typically recorded in either raster or vector format; however most GIS software specifically requires either one or the other data format. Thus, it is often necessary to perform raster to vector and vector to raster conversion procedures depending on the software being used. This can lead to slight alteration of the original data source.

4.3.2.7 Final Product Presentation

Interpretive error, a lesser known source of error, surfaces through the presentation of the final GIS project. Interpretive error can be avoided in a final product if a detailed report of geometric and thematic error sources, processing procedures, and operations is provided to assist users in data analysis (Lunetta, et al., 1991).

Error in GIS data layers can be categorized by inherent and operational error sources. As mentioned above, inherent error results from inaccurate data source documents while operational error results from data manipulations. The various sources of error associated with these categories can easily affect data accuracy as they are incorporated into a GIS
layer. An understanding of these error sources will help a user evaluate the accuracy of a data layer and decide if a layer is adequate to use.

4.4 Decision Making

Map users tend to accept map products as truth simply because adequate information regarding the lineage of data layers and the accuracy of associated thematic and geometric features has not been provided (Lunetta, et al., 1991). This creates a tremendous potential for map users to overestimate the accuracy of the data products. There are numerous methods to isolate error in data products, yet they do not define what level of error is acceptable for a particular application. Inferences based on inaccurate GIS data may prove incorrect, resulting in serious consequences. Data users need to know of the limitations in a GIS data product to estimate acceptable amounts of error for a particular decision making context.

4.5 Conclusion

Error in GIS data layers has been shown to be a result of inherent error relating to data acquisition and operational error associated with the manipulation of data for input into a GIS. Both of these sources of error may influence final GIS data products from which faulty conclusions may be drawn. Although GIS data layers often contain both inherent and operational error, accurate inferences of data utility can be maximized by developing a thorough understanding of these sources of error.
Openshaw (1989) gives several reasons as to why there is a lack of attention to error by GIS users. Primarily, he believes that much of the current use of spatial data is the same as historical uses, although we are using more precise tools than before. He argues that if error was not perceived a problem in the past, then why is it now? Secondly, there is a lack of techniques for measuring uncertainty of spatial data and GIS outputs. Third, the seriousness of the problem is unknown. Fourth, a lack of a consensus on established rules for dealing with errors in GIS data exists, often due to varying user requirements. Lastly, a lack of standard methods for modeling error in GIS functions contributes to the neglect of error in GIS data. Since a general lack of attention to error in GIS data has occurred, it is imperative that original data as well as data analysis operations be extremely accurate. This will help to insure the highest level of data accuracy possible. Documents that attempt to quantify spatial phenomena should include a statement of data accuracy that addresses the sources of error present in the spatial information.
5. AN INTERACTIVE METADATA CATALOG FOR THE TILLAMOOK BAY NATIONAL ESTUARY PROJECT GEOGRAPHIC INFORMATION SYSTEM

5.1 Introduction

It has been shown that a well organized and comprehensive metadata database is essential for effective management of the TBNEP GIS. Primary concerns about data utility include the degree of data accessibility, data compatibility, and reliability and functionality of source information. In addition to addressing these concerns, a metadata catalog should provide a statement on information accuracy as well as error sources present in their GIS data layers. In an effort to address these issues, a TBNEP metadata catalog has been developed.

5.2 Limitations of Standard Metadata Catalog

Although metadata catalogs are valuable, there are some limitations with the standard metadata file. Typically, metadata catalogs are large and cumbersome, making it problematic to access desired information quickly and easily. Furthermore, these files do not “stand alone,” in that the metadata information is often removed from the GIS layer which is being described. An interactive metadata file would alleviate many of these problems by allowing for quick, easy access to the desired information.

5.3 The TBNEP Interactive Metadata Catalog

The TBNEP metadata catalog allows the user to identify the quality, definitions, and other characteristics of mapped features and their associated attribute data in an
interactive environment. The ultimate goal of the project is to create a metadata catalog that will serve as a stand alone document with the geographic image being described actually nested within the metadata documentation. This will allow the GIS user access to an image of the geographic theme of interest while simultaneously gaining access to metadata information describing the coverage. An interactive design for the TBNEP metadata catalog facilitates maximum functionality of the metadata catalog.

In order to make the information more accessible, the Interactive Metadata Catalog will be distributed on a compact disk that will not only contain the metadata catalog, but also information describing the TBNEP GIS, how GIS will be used to study priority problems, the TBNEP GIS layers themselves, and images and information relating the mission of the TBNEP. The final product will also contain ESRI's ArcView 1.0 software, complete with a "patch" that will allow compatibility with ArcInfo V.7 coverages. This software package is necessary in order to view and peruse the geographic themes contained in the TBNEP GIS.

5.3.1 Methods
An inventory of 161 GIS data layers in the possession of TBNEP has been completed (Appendix A). Thirty four fields of metadata information are used to describe each of the 161 geographic coverages contained within the TBNEP GIS database. The metadata fields listed below have been designed to capture descriptive information that will aid in decision making as well as the ability to assess functionality of the data layer. A standard set of data elements has been established, designed to consistently identify the same
descriptive information for all layers in the TBNEP GIS database. The directory also has sections that specify contact information for individuals or organizations that have developed or distributed the data, temporal information for time periods covered by the data, and citation information for the data set and for information sources from which the data set was derived. The metadata catalog is designed to document data set identification information, data set descriptive information, source data information, and metadata administration information.

- **Data Set Identification**: This section is designed to provide basic identification information about the geographic coverage. Included in this section is the title of the layer, the geographic area covered, and the date when the coverage was created.

  - **Data Set Name**: The name of the data set in which the coverage is contained.
  - **Data File Name**: The file name of the actual coverage.
  - **Feature Type**: Line, polygon, point.
  - **Projection**: Description of the spatial reference information for the map projection of the coverage.
  - **Resolution/Scale**: The scale or maximum resolution of the coverage to ground coordinates.
  - **Extent of Coverage**: Description of the spatial reference information for the geographic extent of the coverage.
  - **Size, export dir.**: Size, in Megabytes, of the .E00 export files.
  - **Size, directory**: Size, in Megabytes, of the actual directory coverage within ArcView.
  - **Provider**: Organization or agency who provided the geographic information, coverage, or theme.
  - **Attributes**: Information about the non-graphic data that describes the content of the data set including the entities represented by graphic elements. Examples include the names and definitions of features, attributes, and attribute values.
  - **Date**: Date when the geographic coverage was generated.

- **Data Set Description**: This section is designed to provide descriptive information about the geographic coverage in addition to data quality. Included is positional and attribute accuracy, consistency information, and methods used to produce the data.

  - **Description**: A description of the geographic coverage, including its full name.
  - **Purpose**: The purpose for which the coverage was generated.
- Sampling Methods: Methods used to collect the data that are contained within and represented by the geographic coverage.
- Estimate of Positional Accuracy: Quantitative estimate of positional accuracy.
- Quality/Limitations: Qualitative estimate of data quality and accuracy and limitations of use of the coverage. Information contained in this field is useful for determining the fitness of a data set for projected uses.
- Data Dictionary/Documentation: Additional documentation that may be of future value.
- Keywords: Key word identifiers that describe the data set and the geographic coverage.
- Projection: Map projection of source document.
- Name of Source Map: Name of the source from which the geographic coverage was generated.
- Accuracy Assessment: Qualitative or quantitative assessment of how closely the locational data represent true location.

- Source Information: This section is designed to provide descriptive documentation of the source from which the geographic coverage was generated.

- Form: The form of the source data that were used to generate the geographic coverage (map, aerial photography, ground study, etc.).
- Scale: Scale of the source used to generate the coverage.
- Resolution/Minimum Mapping Units: Measure of the accuracy or detail of the geographic display.
- Date: Date of the source information.
- Update Frequency: Frequency of revisions or updates of the source that was used to generate theme.
- Organization: Agency or organization responsible for the development of the coverage.
- Contact: Contact information about the individual, agency or organization familiar with the generation of the coverage.
- Distribution Limitations/Restrictions: Information about obtaining the data set, including restrictions or limitations on public distribution of the coverage or data used to generate the coverage.

- Metadata Administration: This section is designed to record information on the status of the metadata information.

- Entry Date: Date that metadata information was entered into the database dictionary.
- Data Entry by Whom: Individual, with contact information, who entered the metadata information.
- Updates: Frequency of updates and revisions to the metadata information.
- Data Entry by Whom: Individual, with contact information, who entered the updated metadata information.
An example of the metadata information that has been collected for each data layer contained in the TBNEP GIS database is represented by the geology coverage (Appendix B). The geology metadata example will be used throughout this chapter to help illustrate the Interactive Metadata Catalog's layout and functions. The geology metadata information is designed much like a standard text document, with main subject headings (i.e., Data Set Identification) highlighted by bold text.

Available metadata information describing each of the TBNEP data layers has been assembled and placed into a digital text document. Approximately two to three pages of metadata documentation is dedicated to each of the 161 data layers contained in the TBNEP GIS database. Since this text file is quite large and cumbersome, the VivaTexte Authoring software was used to “build” hypertext necessary to convert the existing metadata file into an interactive catalog. Layouts of the individual GIS layers in the TBNEP GIS database were produced in ESRI’s ArcView 2.1a GIS software (Figure 5.1). These layout images were then "linked" to the existing metadata text information of the coverage which is being described through a series of commands available in the VivaTexte software. The format of an image layout linked to the documentation allows a user to peruse metadata information with the option of simultaneously viewing an image of the coverage. A complete “stand alone” GIS metadata database is available to a user completely separate from the actual GIS layers themselves. This format is intended to provide the user with access to all the information necessary to make an informed decision as to the functionality of the data layer without access to the GIS coverages being necessary.
5.3.2 Catalog Layout

The TBNEP Interactive Metadata Catalog is a computer based application that is compatible with IBM Personal Computers (PC), or PC compatible systems, running the Microsoft Windows operating system. A program group titled “TBNEP Metadata Catalog” appears in the Windows Program Manager once the metadata catalog has been installed (Appendix C). A user can select this application to access the metadata catalog. The catalog opens to an introductory page containing TBNEP project contact information.
as well as a menu of other options. These options compose the three main categories of information contained in the interactive catalog: “What is the TBNEP?,” “What is Metadata Management and GIS?,” and “Metadata Documentation” (Figure 5.2).

**Figure 5.2:** The introductory page of the TBNEP Interactive Metadata Catalog.

“What is the TBNEP?”

The first option a user has when perusing the data catalog is to select the above “wave” icon which will then provide the user with a short introduction to the history and
structure of the TBNEP. The “wave” button accesses a pop-up window that contains introductory information describing the TBNEP, the primary environmental problems being addressed, and the long term missions and goals of the TBNEP (Figure 5.3).

Figure 5.3: “What is the TBNEP?” pop-up window.

“What is Metadata Management and GIS?”

A second option a user has is to select the above “computer” icon. This button is linked to descriptive information describing the interactive metadata catalog’s importance, as
well as further "links" on introductions to metadata documentation and geographic information systems (Figure 5.4). The "Introduction to Metadata Documentation and Management" option is linked to information that defines what metadata documentation is, while additionally describing the federal Spatial Data Transfer Standards and the general importance of metadata information. The "Introduction to Geographic Information Systems," option is linked to introductory information on what a GIS is, the use of a GIS by TBNEP, and the research priorities of TBNEP that are aided by the use of a GIS.

Figure 5.4: "What is Metadata Management and GIS?" window.
“Metadata Documentation”

The last option a user has is to select the “notepad” icon which accesses metadata information about the layers that comprise the TBNEP GIS. When the “Metadata Documentation” button is selected, the user has four additional options (Figure 5.5).

![Figure 5.5: “Metadata Documentation” window.](image)

First, the user can access a description of the metadata fields of information. This page is linked to an index of all the fields of information that have been collected for each
coverage and includes a short description of what the metadata information is conveying to the user. The user can also select the option “Metadata Management Dictionary: GIS layers created by TBNEP” which allows the user to search for metadata information on only those layers created by TBNEP. The third option, “Metadata Management Dictionary: GIS layers other than those created by TBNEP,” allows the user to search the database for descriptive metadata information on layers that were created by organizations and agencies other than the TBNEP. A fourth option is to search the database for imagery contained within the TBNEP GIS database.

The GIS layers in the TBNEP metadata catalog have also been organized around common topical themes or categories. These categories include: Bathymetry (bathymet), Demographics (demograp), Estuarine (estuary), Geology (geology), Hydrology (hydro), Imagery (imagery), Landcover (landcov), Landuse (landuse), Owner (owner), Political Boundaries (polbound), Regulatory (regulate), Soils (soils), and Water Quality (waterq) (Figure 5.5). An index of the layers’ relative similarity to the main category has been placed within these topical categories (Appendix D). Furthermore, the topical categories in the metadata catalog are organized exactly as the raw data for each layer is organized on the TBNEP GIS distribution CD to facilitate locating the desired layers on both the Interactive Metadata Catalog as well as on the distribution CD.
From within the above mentioned menu options, a user can select an individual data layer of interest which then accesses the metadata available for describing that layer.

When a theme is selected, the textual metadata information is displayed on the computer monitor (Figure 5.6). By selecting the “globe” icon the user has the option of accessing a “thumb-nail” image of the GIS layer being described, allowing for simultaneous viewing of both the metadata and the image itself (Figure 5.7). This format is intended to provide
the user with access to all the information necessary to make an informed decision as to
the functionality of the data layer.

Figure 5.7: "Globe" window: window accessed when "Globe" icon is selected from within the
metadata documentation.

5.4 Conclusion

A complete "stand alone" interactive metadata catalog that documents descriptive
information about TBNEP data layers has been developed. This catalog is intended to be
used as a tool to easily access metadata information used to determine the data quality
and functionality. An interactive format has been employed to facilitate easy data
of the large quantities of metadata information contained in the TBNEP GIS database. Additionally, a CD that contains the Interactive Metadata Catalog, the raw data of the geographic coverages themselves, in addition to the necessary software to access the geographic coverages, has been constructed. The final product is available on the compact disk which can be distributed to public agencies, organizations, and other interested members of the public, thus encouraging community partnership and the integration of community involvement with the Tillamook Bay National Estuary Project.
6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Issues and Recommendations

Metadata information has been used to construct a metadata catalog for the TBNEP GIS. When perusing the TBNEP GIS metadata documentation, several issues have been identified which affect the overall utility of the metadata catalog. Through the course of this project, several recommendations have been formulated to address limitations identified within the catalog.

6.1.1 Issue One: Accuracy and Data Quality

Very little accuracy and data quality information exists for the TBNEP GIS data layers even though this information is perhaps the most important descriptive data characteristic of a coverage. The importance of this data quality information has been argued by members of the cartographic community for quite some time, but only recently have standards for the generation of accuracy information been established. Adequate accuracy information exists for approximately 25% of the data contained in the TBNEP GIS. Prior to the construction of the metadata catalog, an assessment as to metadata completeness was not possible. The identification of gaps and holes in the metadata catalog will help to determine what additional quality information needs to be obtained. An assessment of metadata completeness is necessary in order to accurately gauge the overall utility of the GIS data base.
Recommendation: Inclusion of Data Quality Information. As digital cartographic coverages are generated by TBNEP staff and contracted consultants, accuracy assessment data as well as quality information must be included with all other documentation for that coverage in order to insure the functionality and integrity of the data. For example, sources of error such as assumptions made during data collection, methods of data collection and field measurements, and digitization quality should be thoroughly documented for all layers.

6.1.2 Issue Two: Lack of Available Metadata

Available metadata information has been collected for the layers in the TBNEP GIS by a student intern. Time and funding constraints limited the search for metadata to information that was easily available from those who created the data layer or had some role in the alteration of the data. However, much of the required metadata information has not been created, or is simply not available.

- Recommendation: Augment Missing or Incomplete Metadata. Incomplete data documentation is a major limitation of the data catalog as coverages are only as useful as the metadata information that describes them. It is imperative that TBNEP attempt to augment missing or incomplete metadata information by contracting with an individual who has the ability to gather the missing information.

- Recommendation: Formation of Partnerships for Data Collection. The TBNEP must establish partnerships with local, state, and federal agencies and other organizations
for transferring and/or developing common GIS data layers. Partnerships among these different organizations would facilitate data sharing while minimizing duplications of effort. Additionally, involvement in the creation of data layers by TBNEP staff would allow the staff to insure that proper data documentation efforts are taken.

- **Recommendation:** Use of TBNEP Metadata Template for Future Documentation. TBNEP must establish an agreement with contractors, agencies, and organizations involved in the creation of a TBNEP data layer to use the TBNEP metadata catalog format as a template for future data documentation. This would provide a common foundation to which an organization may add detailed metadata documentation such as attribute information. Furthermore, it would provide a base on which an agency or organization can accurately register and compile other themes of data. Such an agreement will aid in the incorporation of future data layers and their associated metadata documentation into the TBNEP GIS Interactive Metadata Catalog.

### 6.2 Applications of the Interactive Metadata Catalog

There are numerous applications of the Interactive Metadata Catalog related to the priority goals and tasks set forth by the TBNEP. The following two uses of the Interactive Metadata Catalog are examples of how metadata contained in the catalog can be used for scientific inquiry and database management.
6.2.1 Scientific Inquiry and Study

One of the primary goals of the TBNEP is for the continued protection and management of the Tillamook Bay and its natural resources. Increased human development impacts have led to the environmental degradation of the area. The TBNEP has constructed a GIS in an effort to provide the necessary tools for the analysis of spatial information used for scientific study and developing management strategies.

Several “priority” goals have been established to preserve and protect the natural resources of the Tillamook Bay. For example, one priority is to restore the bay from habitat degradation due to sedimentation. In an effort to address this concern, the use of the TBNEP GIS may be employed. Potential data layers that may be useful to study sedimentation processes in the bay are roads, rivers, streams, slope, ownership, historical burn areas, and confined feeding operations, for example. It may also be helpful to understand vegetative cover, soils types and geologic features of the area.

In this sediment study, several data layers of varying scale, spatial and temporal resolution, and map projection may be used. However, to develop an accurate model of sediment processes, the data used for analysis must be consistent with regards to scale, resolution, and projection. To assess data compatibility of these layers for use in a spatial analysis, documentation of data characteristics is needed. The Interactive Metadata Catalog documents such information that will aid in determining data utility. A user can peruse the metadata documentation and render an informed decision as to the fitness of that particular data layer in the sedimentation study.
6.2.2 Public Outreach and Data Longevity

The TBNEP has a strong public outreach component as part of its long term goals and objectives. Information that is developed or collected by the TBNEP is designed to be distributed to interested members of the community. However, the TBNEP is a temporary, four year project, and thus data that are generated by the TBNEP must be well documented to insure future use after the completion of the estuary project. This is especially true of the data layers contained in the TBNEP GIS database.

GIS database layers will be used for numerous application by members of the Tillamook Bay community long after the TBNEP has disbanded. Thus, a complete and accurate metadata catalog that describes the data layers must be developed to preserve the data’s descriptive information. After completion of the project, no staff members from the TBNEP will be available to answer questions of data accuracy and completeness. Therefore, the information on data integrity and completeness must be well documented so future users can easily assess the data’s characteristics.

For example, a user may have a reservation about using a particular data layer due to file size considerations. Metadata documentation of the layer file size contained in the Interactive Metadata Catalogue can be used to determine if a specific layer is compatible with their computer hardware and software specifications.

The TBNEP metadata catalog was made a priority by the TBNEP to insure that documentation information for the TBNEP GIS data layers will be available to users of
the TBNEP GIS long after the TBNEP dissolves. An Interactive Metadata Catalog is now available to data users to insure the long term success of this GIS.

6.3 Summary

Metadata documentation and management is an integral part of the overall success of the Tillamook Bay National Estuary Project’s Geographic Information System database. The use of a GIS at TBNEP has developed out of a need for more efficient utilization of spatial information for management and decision making purposes. It has been recognized that proper management of the information contained in the TBNEP GIS will insure high data quality and increased functionality of the data, benefiting all users of Tillamook Bay and its watershed. Metadata management has been shown to be an effective management tool of spatial data, helping to define the entities and attributes, quality and integrity, completeness, compatibility and availability of data layers. The Interactive Metadata Catalog has provided the TBNEP with an efficient and user friendly way to access the TBNEP GIS metadata information.
REFERENCES CITED


Cromp, R. F., 1991. Automated extraction of metadata from remotely sensed satellite imagery. ACSM- ASPRS Annual Convention, Baltimore. ACSM/ASPRS.


APPENDICES
APPENDIX A

Inventory of Coverages and Imagery within the TBNEP GIS
APPENDIX A. Inventory of Coverages and Imagery within the TBNEP GIS

- Inventory of Layers in the TBNEP GIS that were Created by TBNEP

<table>
<thead>
<tr>
<th>Coverage</th>
<th>Description</th>
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<td>Bathymetry points from NOS data from the 1950s</td>
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<td>b95pts</td>
<td>Bathymetry points from 1995 Army Corps of Engineers Survey</td>
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<td>Bathymetry grid</td>
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<td>bathpts</td>
<td>Bathymetry points</td>
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<td>bridgdos</td>
<td>ODF bridges locations with photographs</td>
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<td>code</td>
<td>Tax codes</td>
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<td>culvpts</td>
<td>Culvert location for major highways</td>
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<td>Easements</td>
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<td>Estuarine habitats</td>
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<td>Water flow stations</td>
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<td>Government lines</td>
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<td>histlns</td>
<td>Historical Parcel Lines</td>
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<td>ODFW aquatic/riparian habitat classification for the Kilchis River</td>
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<td>ODFW stream reach information for the Kilchis River habitat surveys</td>
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---|---
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uriver | Tillamook Watershed (TBW)- rivers
uroad | Tillamook Watershed (TBW)- roads
ustream | Tillamook Watershed (TBW)- streams
wqsta | ODEQ, USEPA remap, TBNEP sampling locations

- **Inventory of Layers in the TBNEP GIS that were Not Created by TBNEP**

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rdsmaj
rdsmin
riv100K
riv250K
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rsprod
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seclines
senate
slope
statsgo
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taxlot
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tilcohor
tilcohos
tillhab
tills
 tillv
tilown
tilsoils
timb1914
tractpop
uwshed

interp State Soil Geographic Data Base:
nonpoint sources of water pollution
option 9 land allocations for FEMAT
Oregon state boundary
Outline of all Tillamook County Assessors Maps
Ownership
State Soil Geographic Data Base:
Public land survey
Census population
Census population over 65 years of age
Oregon poverty rates
Precipitation contours
Precipitation polygons
Tillamook County Assessors Maps: Railroads
Motorcycle and OHV trails on ODF Tillamook lands
Roads major
Roads minor
River reach coverage
EPA rivers
Tillamook County Assessors Maps: Roads
State Soil Geographic Data Base:
Salmon stock status
Tillamook County Assessor Maps: Section Lines
Senate
Slope
State Soil Geographic Data Base
Tillamook County Assessor Maps: Subdivision Lines
State Soil Geographic Data Base:
Tillamook County Assessor Maps: Parcels
Tillamook Bay Soils Units
Oregon Natural Heritage T&E species locations
DSL essential habitat for Chum spawning
DSL essential habitat for Coho salmon rearing
DSL essential habitat for Coho salmon spawning
ODFW aquatic/riparian habitat classification for regions of the Tillamook Bay Watershed
Five major tributaries of Tillamook Bay
Vegetation
Ownership
State Soil Geographic Data Base:
1914 timber map
Population by tract
Tillamook Watershed (TBW)- subasins
GAP analysis vegetation
Inventory of Imagery in the TBNEP GIS that were Created by TBNEP

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<td>M8692LAM</td>
<td>Change matrix between 1986 and 1992 MSS for Tillamook Bay Watershed</td>
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<td>Classified composite 1974/1975 MSS for Tillamook Bay Watershed</td>
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<td>Classified image 1986 MSS for Tillamook Bay Watershed</td>
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<td>MYWSLAM</td>
<td>Estimated age of vegetation for Tillamook Bay Watershed</td>
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APPENDIX B

Example of Metadata Documentation for the Geologic Coverage of the Tillamook Bay Watershed
APPENDIX B. Example of Metadata Documentation for the Geologic Coverage of the Tillamook Bay Watershed (see Figure 5.1).

*Data Set Identification

Data Set Name: Geology
Data File Name: geology
Feature Type: Polygons and arcs
Projection: Lambert
Resolution/Scale: 1:250,000
Extent of Coverage: Tillamook Bay Watershed
Size: export dir. (bytes): 328,985
Size, directory (bytes): 122,517
Provider: Interrain Pacific
Attributes:
  Area
  Perimeter
  Geology
  Geology_id
  Ptype: name
Width: 10
Output: 10
Type: Character

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<td>Qls</td>
<td>Landslide and debris flow deposits (Holocene and Pleistocene)</td>
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<td>Qt</td>
<td>Terrace, pediment, and lag gravels (Holocene and Pleistocene)</td>
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<td>Tc</td>
<td>Columbia River basalt group and related flows (Miocene)</td>
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<tr>
<td>Ti</td>
<td>Mafic intrusions (Oligocene)</td>
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<td>Tim</td>
<td>Mafic and intermediate intrusive rocks (Miocene)</td>
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<td>Tms</td>
<td>Marine sedimentary rocks (middle and lower Miocene)</td>
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<td>Sedimentary rocks (Oligocene and upper Eocene)</td>
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<td>Siletz River volcanics and related rocks (middle and lower Eocene and Paleocene)</td>
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<td>Tss</td>
<td>Tuffaceous siltstone and sandstone (upper and middle Eocene)</td>
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<td>Tillamook volcanics (upper and middle Eocene)</td>
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<td>Marine facies</td>
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<td>Yamhill Formation and related rocks (upper and middle Eocene)</td>
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Date: August 26, 1993
*Data Set Description*

Description: Tillamook Bay Watershed Lithology
Purpose: Accurate geologic coverage of Oregon
Sampling Methods: Field observations and references of geologic studies
Estimate of Positional Accuracy:
Quality/Limitations:
Data Dictionary/Documentation: Yes- SSCGIS
Keywords: Geology, USGS
Projection: Lambert
Name of Source Map: Geologic Map of Oregon
NAVD or NAD: National Geodetic Vertical Datum of 1929
Accuracy Assessment: Single precision

*Source Information*

Form: Mylar. Walker, G. W., and Mac Leod, N. S., 1991, Geologic Map of Oregon (two sheets)
Scale: 1:500,000, 1 inch = 8 miles
Resolution/mmu: Contour interval 500 feet
Date: 1991
Update Frequency: Last updated, August 26, 1993: Gary Raines, USGS (702) 784-5591
Organization: United States Geologic Survey via Oregon State Service Center for GIS
Contact: Tillamook Bay NEP: (503) 322-2222; Fred Weigman (SSCGIS), (503) 378-4583
Distribution Limitations/Restrictions: None

*Metadata Administration*

Entry Date: November 28, 1995
Data Entry by Whom: Greg Benoit (OSU); (541) 737-3504
Updates: January 25, 1996
Data Entry by Whom: Greg Benoit (OSU); (541) 737-3504
APPENDIX C

Instructions for Viewing the TBNEP Interactive Metadata Catalog
APPENDIX C. Instructions for Viewing the TBNEP Interactive Metadata Catalog

Instruction for Installing the TBNEP Interactive Metadata Catalog

Attached to this research report is two 3.5 inch floppy disks that contain the Interactive Metadata Catalog for the TBNEP GIS. Please follow these simple instructions in order to view the catalog.

System requirements: A PC or PC compatible computer running the Microsoft Windows operating system.

Instructions:

* Insert disk into 3.5 inch floppy drive.

* From within File Manager, access the drive that contains the disk.

* From within the directory TBNEP, double click on the setup.exe file. This will begin the TBNEP Installation Utility setup process necessary for viewing the Interactive Metadata Catalog (The files are stored in the directory C:\VTXHTX that is created when running the TBNEP Installation Utility setup. This directory can easily be deleted after viewing the metadata catalog).

* The setup file then creates a group for the VivaTexte Installation Utility in the Program Manager called “TBNEP Metadata Catalog.”

* From within the “TBNEP Metadata Catalog” applications group, select the Metadata1 icon to view the Interactive Metadata Catalog for the TBNEP GIS.

* From within the metadata catalog, you will see several options for accessing information. For example, one will see the following “notepad” icon:

![Metadata Documentation](image)

Click on the notepad icon with the mouse button. This accesses an inventory of coverages and imagery in the TBNEP GIS.

An Interactive Metadata Catalog for the Tillamook Bay National Estuary Project Geographic Information System
APPENDIX D

Inventory of TBNEP GIS Coverages by Topical Category
APPENDIX D. Inventory of TBNEP GIS Coverages by Topical Category

- Bathymetry layers

b867pts  1867 Bathymetry points from US Coast Survey Office
b50pts   Bathymetry points from NOS data from the 1950s
b95pts   Bathymetry points from 1995 Army Corps of Engineers Survey
bathgrid Bathymetry grid
bathpts  Bathymetry points

- Demographic layers

bgpop    Block Group Population
blockcov Population by block
employ   Oregon employment
pop      Census population
pop_ge65 Census population over 65 years of age
pov_clip Oregon poverty rates
tractpop Population by tract

- Estuarine layers

afshuc   American Fisheries Society's Aquatic Diversity Areas
aquathab ODFW habitat classification
estuhabs Estuarine habitats
hthy_sal Healthy salmonids
kilfish  ODFW fish survey for the Kilchis River
kilhab   ODFW aquatic/riparian habitat classification for the Kilchis River
kilrch   ODFW stream reach information for the Kilchis River habitat surveys
salstock Salmon stock status
tepts    Oregon Natural Heritage T&E species locations
tilchum  DSL essential habitat for Chum spawning
tilcohor DSL essential habitat for Coho salmon rearing
tilcohos DSL essential habitat for Coho salmon spawning
tillafs  Aquatic Diversity Areas
tillhab  ODFW aquatic/riparian habitat classification for regions of the Tillamook Bay Watershed

- Geologic layers

geology  Geology
gnis     Geographic names
• Hydraulic layers

culy_lam_   Forest road culverts
culypts    Culvert location for major highways
dams       River dams
flowsta     Water flow stations
hyd_poly    Water body polygons
hydro      Rivers, creeks and bay
lbound     Tillamook Watershed (TBW)- shores
llake      Tillamook Watershed (TBW)- lakes
lriver     Tillamook Watershed (TBW)- rivers
lstream    Tillamook Watershed (TBW)- streams
lwshed     Tillamook Watershed (TBW)- subasins
prec_cnt    Precipitation contours
prec_pol    Precipitation polygons
riv100K     River reach coverage
riv250K     EPA rivers
subasins    5th field basins for ODWRD projects
tillsub    Five major tributaries of Tillamook Bay
ubound     Tillamook Watershed (TBW)- shores
ulake      Tillamook Watershed (TBW)- lakes
uriver     Tillamook Watershed (TBW)- rivers
ustream    Tillamook Watershed (TBW)- streams
wshed      Tillamook Watershed

• Imagery

M7X86LAM  Change matrix between 197x and 1986 MSS for Tillamook Bay Watershed
M8692LAM  Change matrix between 1986 and 1992 MSS for Tillamook Bay Watershed
MS7XCLAM  Classified composite 1974/1975 MSS for Tillamook Bay Watershed
MS86CLAM  Classified image 1986 MSS for Tillamook Bay Watershed
MS92CLAM  Classified image 1992 MSS for Tillamook Bay Watershed
MYWSLAM  Estimated age of vegetation for Tillamook Bay Watershed
TM85CLAM  Classified image 1985 TM for Tillamook Bay Watershed
TM93CLAM  Classified image 1993 TM for Tillamook Bay Watershed
W7X86LAM  Change matrix between 197x and 1986 MSS organized by subwatershed
W8692LAM  Change matrix between 1986 and 1992 MSS organized by subwatershed
WSLAM    Subwatersheds for Tillamook Bay Watershed

MS74HLAM   Histogram equalization of MSS data for Tillamook Bay Watershed
MS75HLAM   Histogram equalization of MSS data for Tillamook Bay Watershed
MS86HLAM   Histogram equalization of MSS data for Tillamook Bay Watershed
MS92HLAM  Histogram equalization of MSS data for Tillamook Bay Watershed
TM85HLAM  Histogram equalization of TM data for Tillamook Bay Watershed
TM93HLAM  Histogram equalization of TM data for Tillamook Bay Watershed

- Landcover layers

  aspect  Aspect
  elev    Elevation
  elev250c 100' elevation contours
  fematveg Vegetation by FEMAT serial stage classes
  slope   Slope
  tillveg Vegetation
  veg     GAP analysis vegetation

- Landuse layers

  acad    AutoCad Inventory Information
  BLMfoi  Forest operations inventory
  BLMhyd  Streams
  BLMown  BLM managed lands
  BLMpls  Public lands survey
  BLMpc   Timber class production capability class
  BLMrb   BLM roads
  bridgdos ODF bridges locations with photographs
  fgrove  ODF
  histfire History: timber age and fire
  lroad   Tillamook Watershed (TBW)- roads
  rd_ohv  Motorcycle and OHV trails on ODF Tillamook lands
  rdsmaj  Roads major
  rdsmin  Roads minor
  timb1914 1914 timber map
  uroad   Tillamook Watershed (TBW)- roads

- Owner layers

  brngdist Bearing and distance
  code    Tax codes
  easemt  Easements
  govlines Government lines
  histlns Historical Parcel Lines
  outline Outline of all Tillamook County Assessors Maps
  owner   Ownership
  railrd  Tillamook County Assessors Maps: Railroads
  roads   Tillamook County Assessors Maps: Roads
  S1012dd Tillamook County Assessor Maps: T1S R10W S12 QD QD
S11011  Tillamook County Assessor Maps: T1S R10W S11
S11011a Tillamook County Assessor Maps: T1S R10W S11 QA
S11012 Tillamook County Assessor Maps: T1S R10W S12
S196  Tillamook County Assessor Maps: T1S R9W S6
S196ac Tillamook County Assessor Maps: T1S R9W S6 QAQC
S197  Tillamook County Assessor Maps: T1S R9W S7
S197a Tillamook County Assessor Maps: T1S R9W S7
seclines Tillamook County Assessor Maps: Section Lines
subl Tillamook County Assessor Maps: Subdivision Lines
taxlot Tillamook County Assessor Maps: Parcels
tilown Ownership

- Political Boundary layers

cong90 Congressional districts
counties Counties
house90 House districts
oregon Oregon state boundary
pls Public land survey
senate Senate

- Regulatory layers

caf0 Confined animal feeding operations
cerc Superfund sites
northc2 Nonpoint sources of water pollution
npdes NPDES permit locations
opt9 Option 9 land allocations for FEMAT
outfall NPDES permit locations
oyster Tillamook Bay oyster plots
shellfis TBNEP Challenge Grant benthic survey
shellmgt ODA shellfish management areas
tillkws USDA FS Region 6 Key watersheds

- Soils layers

comp State Soil Geographic Data Base: Component
compyld State Soil Geographic Data Base: Component yield
forest State Soils Geographic Data Base: Forests
interp State Soil Geographic Data Base: Interpretation
layer State Soil Geographic Data Base: Layer
plantcom State Soil Geographic Data Base: Plant community
rsprod State Soil Geographic Data Base: Range site productivity
statsgo State Soil Geographic Data Base
taxclass State Soil Geographic Data Base: Taxonomic class
tbaysoil  Tillamook Bay Soils Units
tilsoils  State Soil Geographic Data Base: Tillamook Bay soils
windbrk  State Soil Geographic Data Base: Windbreak
wihabit  State Soil Geographic Data Base: Wildlife habitat
woodland State Soil Geographic Data Base: Woodland
woodmgt  State Soil Geographic Data Base: Woodland management
yldunits State Soil Geographic Data Base: Yield units

- Water Quality layers

wqsta    ODEQ, USEPA remap, TBNEP sampling locations
POSTER

An Interactive Metadata Catalog for the TBNEP GIS
An Interactive Metadata Catalog for the TBNEP GIS (poster)
DISKS

An Interactive Metadata Catalog for the TBNEP GIS
An Interactive Metadata Catalog for the TBNEP GIS (disks)