Title
Creation of a Comprehensive Managed Areas Spatial Database for the Conterminous United States (96-4)

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Abstract

In this report, the creation of a digital, spatially referenced database of managed areas in the conterminous United States is described. A Geographic Information System (GIS) was used for database compilation to provide a high degree of flexibility for updates, queries, and manipulations. As concern over the degradation of ecosystems increases, so does the need for information about the spatial location and aerial extent of managed and protected areas. Recently, focus on the ecological issues of environmental preservation has been shifting from protection of individual endangered or sensitive species to protection of entire interrelated ecosystems. To meet the demands of studies in this area, datasets for large areas of land must be created and/or compiled. Guidelines and methods for creating these types of large datasets must also be established; currently there is little information of this type available. These factors were the motivation for the creation of this Managed Areas Database (MAD).

This database contains all types of managed areas existing in the conterminous United States, including land held by federal, state, tribal, and private agencies and organizations. This large number of public agencies with land holdings and the numerous area designations makes the task of gathering and integrating managed areas data difficult and time consuming.

MAD was developed at an approximate map scale of 1:2,000,000, with a Minimum Mapping Unit (MMU) of about 100 hectares. A number of digital and hard copy map sources were employed in compilation of this database.

The database is divided into two separate GIS coverages. The first is a data layer containing polygons showing the boundaries of managed areas. The second is a layer containing data points which represent managed areas that are not large enough to meet the MMU requirements for the polygon coverage. Point coverage data may be less useful in some studies, however, it was felt that including all managed areas from the available map sources would produce a more complete database.

This technical summary document describes both the methodology employed and problems encountered in creating this managed areas database. In this document, we describe attributes available in the database, map sources used for compilation, classification of managed areas, integration of map sources, and possible sources of error. This managed areas GIS database can be combined with other information layers such as species and ecosystem distribution to allow comparison of administrative and ecological boundaries which may or may not coincide. Researchers will also be able to begin assessing the degree of protection given certain species or ecosystems at regional or national scales, and this database may someday be part of a much needed global coverage of managed areas.

Disclaimer

This product has been created for use in coarse scale, generalized mapping, planning and/or policy applications. If this product is used in any form, the Remote Sensing Research Unit at the University of California Santa Barbara must be credited as originator of this data set. Its use in fine scale studies should be considered carefully, and it is recommended that in these cases, more detailed data sources be reviewed. The product has been created to mapping and GIS database compilation standards as described in the body of the text, and any uses of the data should take this into account. The precise accuracy characteristics of this product have yet to be determined. We make no claim as to the accuracy of this product in this form. Neither the Remote Sensing Research Unit nor the University of California, Santa Barbara shall be held responsible for improper uses or inadequate findings as a result of the use of this database.

Acknowledgments

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-R. Gavin McGhie
May, 1996

1. Introduction

As the human population grows, ecosystems continue to be modified and degraded at steadily increasing rates. Scientists and conservationists have become greatly concerned at the loss of the world's biological diversity and natural resources (Leader-Williams, et. al., 1990; Scott, et. al., 1987; Hall, et. al., 1991). Human induced changes in land cover for agriculture and urbanization are among the most prevalent and visible impacts of human activities on the global environment. These changes have great implications for ecosystem health, biogeochemical fluxes, and climate (Townshend, et. al., 1991). With the destruction of these ecosystems, numerous individual species are driven to extinction while others are reduced to endangered or sensitive status. Human activity has been directly or indirectly responsible for the partial or wholesale destruction of many habitats, as well as the extinction of at least 63 mammal species and 88 bird species since AD 1600 along with more unrecorded species (Leader-Williams, et. al., 1990). In the United States, 253 endangered plant species face the risk of extinction in the next 5 years, and 427 more species may disappear by the end of the century (Blockstein, 1990). Presently, the U.S. Fish and Wildlife Service lists over 1000 species as endangered or threatened. Predictions have been made that extinctions may reach 5000 per year by the end of this century (Scott, 1990). In the immediate past, the environmental focus has been on attempting to protect these endangered or sensitive species. The principal aim has been toward recovery and reestablishment of species already on the verge of extinction instead of the prevention of future losses (Blockstein, 1990). A systems-level strategy seems to be the best way to preserve biological diversity, and saving groups of species in self-maintaining ecosystems can be a cost effective addition to endangered species recovery (Scott, et. al., 1989).

While some ecosystems and habitats are protected so they may remain pristine or recover from previous disturbance, many are being modified or degraded. Within these ecosystems, numerous species are nearing extinction or have become extinct. These ecosystem changes are occurring in both developed and developing countries. Most recently, attention to ecosystem changes has largely been focused on the depletion of species and habitats within tropical rainforests in developing nations. Legal designation of protected areas began later in developing countries, but the focused attention to the issue within developing countries during this century has caused the numbers of protected areas to increase, rapidly surpassing those in developed nations. The average size of all protected areas has decreased, but those in developing countries are on average larger than those in developed countries (Leader-Williams, et. al., 1990). For these and other reasons, developed nations cannot ignore the destruction of flora and fauna through poorly managed land practices such as improper logging or cattle grazing.

There is a great need to change the focus of conservation from the protection of individual endangered species to protection of entire ecosystems and preservation of biological diversity. There is also a need for improved coordination of the various species protection groups to avoid duplication of effort. To reach these goals, a comprehensive federal plan for conservation of biodiversity and entire habitats is needed. At this time, there is a lack of useful information about species diversity and a fragmented and uncoordinated patchwork of protection activities (Blockstein, 1990). If sensitive or endangered communities of flora and fauna are to be preserved, it is necessary to slow or reverse this ongoing process of degradation.

The best way to preserve organisms is through the creation and maintenance of protected areas in sufficient numbers and adequate size (Blockstein, 1990). Hall, et. al. (1991) have shown that protected wilderness either changes, or has disturbance rates, less than non-wilderness areas. Inventory of currently protected or managed areas is the first logical step in a plan for protecting ecosystems from further damage or destruction. Areas must be identified where floral and faunal associations are effectively managed. We must also identify areas where further action must be taken to improve ecosystem health. The first piece of data needed for this type of study is a map or database of the locations of managed areas in the region of interest. Such information could improve understanding of how to prevent further damage to ecosystems and how they can recover from previous disturbances.

1.1 Background

A Geographic Information Systems (GIS) allows for overlaying different thematic data sets and provides the analyst with an efficient method of determining relationships between various layers of information. The strength of a GIS is that it offers the most powerful tool currently available for integrating spatial databases (Dobson, 1993). Spatial relationships between areas and the fragmentation of these areas are examples of what can be determined utilizing a GIS. Size and shape of ecological units or habitat areas are also important for species viability and reserve planning (Beardsley and Stoms, 1993). For these reasons, it was felt that a GIS was the best option for creation of a managed areas database.

A number of other groups have compiled environmental GIS databases which have included managed areas as a data component. The World Conservation Monitoring Centre (WCMC) maintains a worldwide environmental spatial database. WCMC is currently digitizing boundaries of protected areas in their environmental database using a GIS to link the spatial data with selected tabular attribute information. The map scale of this project is about 1:1,000,000 with a 5000 hectare minimum mapping unit (MMU) (Beardsley and Stoms, 1993). However, this database seems to be outdated for the United States, as there are numerous areas missing.

The United States Geological Survey (USGS) has produced a digital line graph (DLG) data series which includes administrative boundaries of national parks, wilderness areas, and Native American reservations (USGS, 1990). This coverage is limited to federally owned lands, and the DLG source maps were relatively old (Beardsley and Stoms, 1993). However, the USGS has recently completed a revised federal lands GIS database which is registered to the Public Land Survey System (PLSS) (Wortman, 1996).

Crumpacker, et. al., (1988) used GIS with a managed areas data layer to assess the status of ecosystems on Federal and Indian Lands in this database. The Kuchler potential natural vegetation (PNV) map of the United States (1964) was used as a surrogate for the ecosystem layer and Federal and Indian Lands boundary data were extracted from the National

Geographic Society's Federal Lands map from 1982. The map scale of the analysis was approximately 1:5,000,000 and included only Federal and Indian Lands for examination. MAD contains more detailed information and a finer spatial resolution than the database used by Crumpacker. There are some important considerations in using PNV types to identify gaps in the protected areas network, since potential vegetation may be far removed from what actually occurs in an area that it may not provide much guidance for biodiversity and its protection (Scott, et. al., 1989).

Klubnikin (1979) performed similar work for the state of California at the scale of 1:1,000,000 using acetate overlays and a vegetation base map compiled by Kuchler for California. The purpose of this study was to identify, characterize, and map preserves and protected areas, and to identify types and amounts of natural vegetation communities and their distributions in relation to these preserves. Although this study was more detailed, it was limited to the state of California and did not address the need for an in depth, comprehensive plan for the entire country.

Another related study is being performed by the National Biological Service (NBS), along with cooperators in many states. The Gap Analysis Project (GAP) was initiated to analyze flora and fauna, and protected areas in order to identify and locate gaps in protection which are necessary for long term ecosystem preservation but have not yet been designated as preserves (Beardsley and Stoms, 1993). The map scale of this project is about 1:100,000; representing far greater spatial detail than MAD. GAP is a method of proactive conservation planning which compares species distributions to the location of protected areas using a GIS (Scott, et. al., 1993). The GAP program is currently implemented and operated at the state level (Beardsley and Stoms, 1993). It is limited in extent by the states which are involved in the project, although the state GAP programs operate in a coordinated manner. In summary, the majority of the prior work related to the research area described by this paper has been limited in spatial extent and/or management area and informational specifics.

1.2 Project Objective

The objective of this project was to create a functional and comprehensive spatial database for lands managed by federal, state, or private conservation agencies in the conterminous United States using a Geographic Information System (GIS). This project began as an outgrowth of work done by Drs. John E. Estes, J. Michael Scott, and Frank Davis on the GAP program of the then U.S. Fish and Wildlife Service. Early work on the compilation of MAD was done by Ms. Karen Beardsley (1993) at the Remote Sensing Research Unit at the University of California, Santa Barbara, and much of the format of the initial data compilation was adopted for the current project. It is intended that this database shall include all areas within the conterminous United States which are under some form of administrative management: including environmental protection, national security, or resource reasons. Areas are managed with different goals dependent on designation and/or state in which they are located. Although the original intent of this project was to compile a database for ecologically protected areas, it was decided that the database should include areas under any form of management status. Including all types of management areas will allow the extraction of any desired management profiles or area types for future use. Including level of environmental protection that each management regime provides will also be helpful. This will result in the best comprehensive plan for a flexible, multi-faceted GIS database. Since the definition of the term “protected area” is often in disagreement, referring to areas as “managed” will minimize the necessity of categorizing areas as protected or unprotected (Beardsley and Stoms, 1993). Many lands managed for resource production may play a role in maintaining regional biodiversity for species and ecosystems which are less sensitive to disturbance (Scott, et. al., 1993).

The compilation of this database was undertaken to begin to meet the need for comprehensive data representing large spatial areas. Previous to MAD’s inception, there was no known coordinated source which could provide maps of all managed areas within a large region (Beardsley and Stoms, 1993). As the need for studies of the environment shifts focus from intensely studying small areas and individual species to the study of whole ecosystems and the connectivity of these systems and species, larger, more comprehensive datasets are needed. This database will serve both as a model for development of future datasets of this type as well as a useful addition to the holdings of data available for environmental studies covering large areas.

There are many types of data holdings managed by numerous agencies for a number of different reasons. This factor was important in deciding to compile a comprehensive database including all types of managed areas in the United States. This is the first database which contains spatially accurate information for all protected or managed areas in the United States.

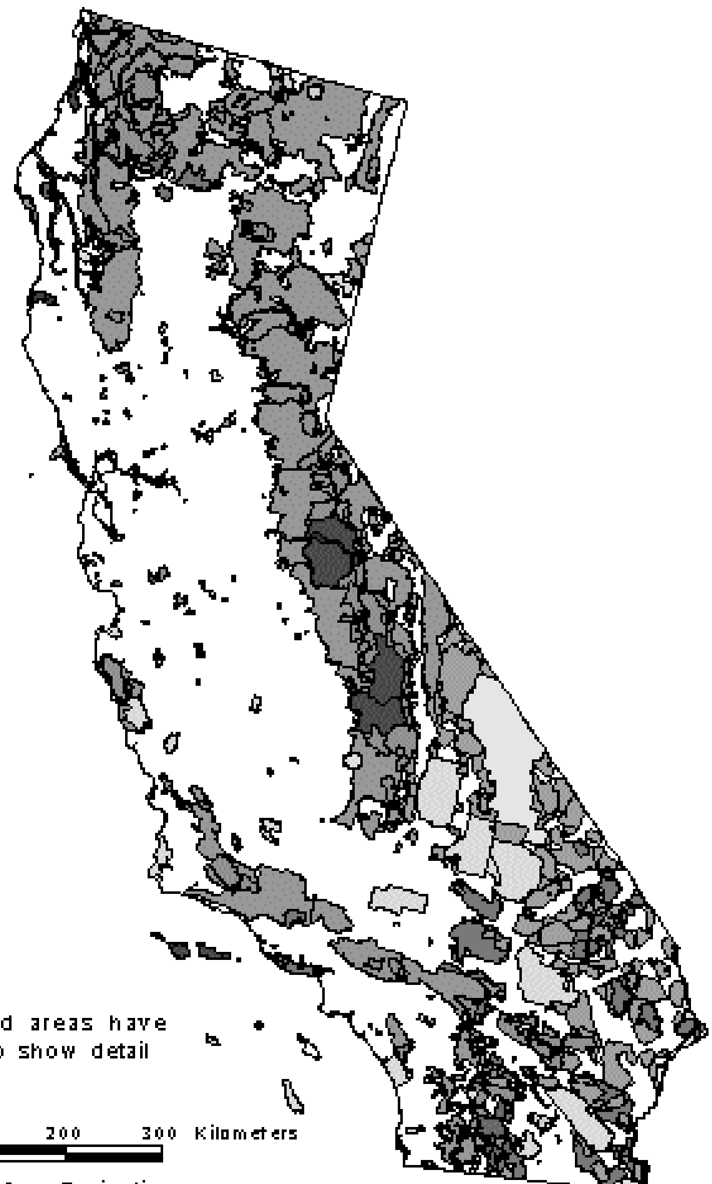
1.2.1 Study Area

The area included within this database is the conterminous United States. Alaska and Hawaii are not included at this time, as the intention of this project is to focus on procedures to assess the adequacy of ecosystem preservation over large spatial areas. Also, the intent is to examine techniques for combining spatial data from many unique sources across large regions occasionally spanning political boundaries.

1.2.2 Database Scale and Accuracy

The precise spatial accuracy of this digital database has not yet been determined. The digital base layer used for database compilation is at the scale of 1:2,000,000, and attempts were made to duplicate the level of detail existing in this base layer. The scale of MAD will be approximated at 1:2,000,000 until an accuracy assessment is completed and results of this assessment compared to National Map Accuracy Standards. Since any digital or hard copy map has limitations, the spatial scale of this dataset must be considered and should not be used in local scale analyses or detailed planning issues. Although much of the data are of greater detail than the nominal 1:2,000,000 scale, (and the database appears more accurate while digitally magnified and displayed- see Figures 1 and 2), it should be treated as a coarse scale dataset with proportional accuracy. All boundaries must be considered approximate to

California's Managed Areas

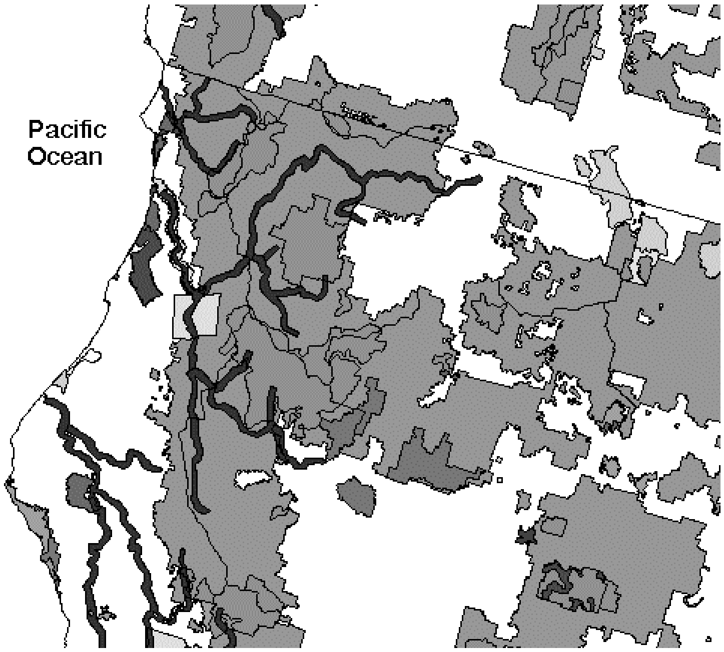


California's managed areas have been isolated here to show detail at the state level

100 0 100 200 300 Kilometers

Albers Equal-Area Map Projection

North-Western California



This region in north-western California along the Oregon border was chosen to show the detail of this database at a more local scale.

The location was chosen because of the high density of management units in the area, including wild and scenic rivers and wilderness areas.

REMOTE SENSING RESEARCH UNIT

RSRU

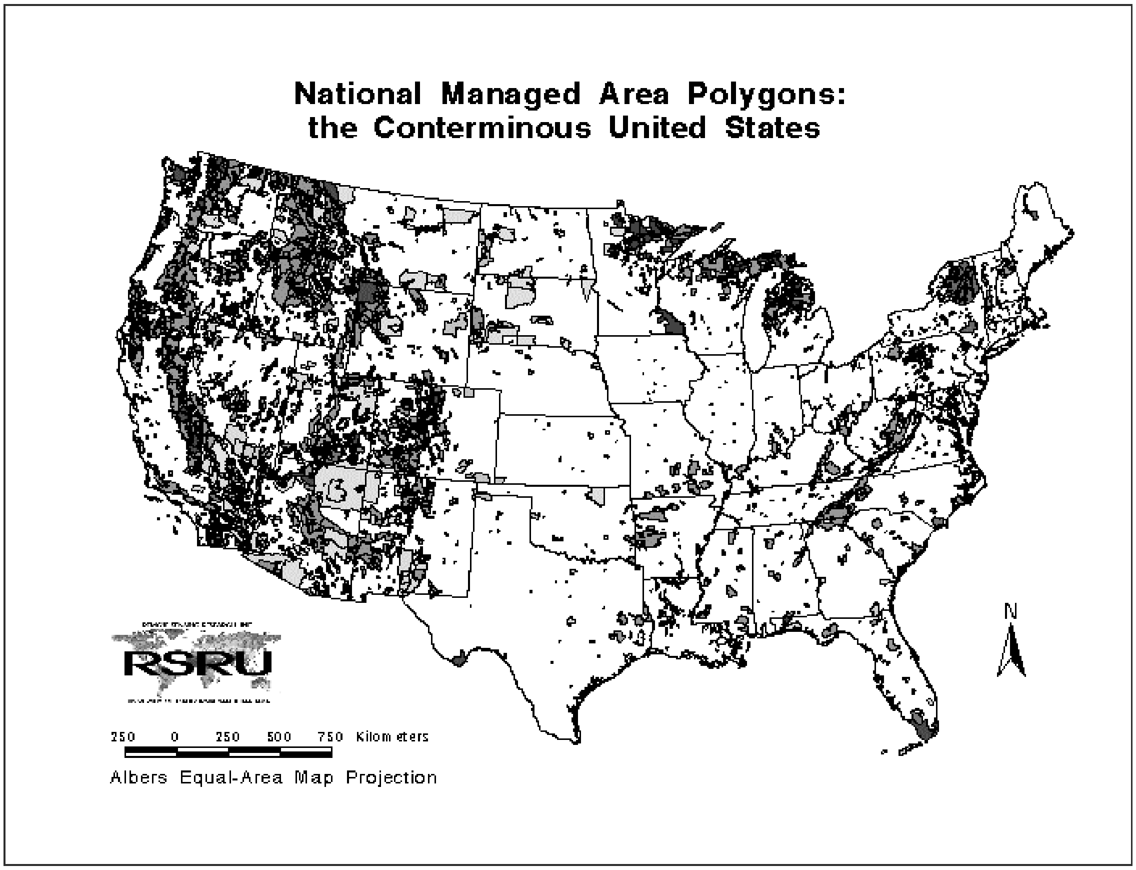
16 0 16 32 48 Kilometers

Albers Equal-Area Map Projection

scale, and finer scale data should be consulted when decisions are being made regarding the exact location of political boundaries. Maps complying with National Map Accuracy Standards at the scale of 1:2,000,000 will have features accurate to within about 1.70 km (1.05 miles) of their true location (Thompson, 1979).

MAD includes two distinct data layers. A polygon coverage (see Figure 3) includes areas large enough to meet the Minimum Mapping Unit (MMU) size requirements, and a coverage of point data was created for those smaller areas that do not (Figure 4). The MMU of the polygon layer in this database is approximately 100 hectares. There are, however, some units of smaller size included in the polygon coverage. These represent private or non-managed holdings, fragmented or disjunct portions of larger areas, and sliver areas from overlapping units. These were left in the database to help maintain area and shape relationships of the management borders. There are also a limited number of areas slightly greater than or equal to the MMU in size which are not included in MAD due to map scale or source content issues, because, in compiling this database, we did not to seek to identify small areas by examining finer scale maps, but instead included them when they existed on sources already being used.

We make no claim that all managed areas greater than the MMU size are included in MAD. The MAD dataset of point locations was created to make MAD as comprehensive as possible by including all managed areas existing on the data sources used in compilation. This will allow reference to areas which are known to exist, yet were not large enough to be included on the polygon portion of the database. The polygon coverage contains approximately 7500 areas when overlapping management types are included, and the point coverage contains 1580 unique areas. The projection of both coverages in this database is Albers Equal-Area in meter units (see Table 1). The Albers projection was chosen, because it includes two standard parallels and is ideally suited for the United States. Equal-area (or equivalent) map projections also maintain all area relationships (Dent, 1990), and equivalency is an important database characteristic for the study of areal parameters of ecosystems and managed areas.


National Managed Area Polygons:
the Conterminous United States
RSRU
N
250 0 250 500 750 Kilometers
Albers Equal-Area Map Projection

National Managed Areas Points:
the Conterminous United States

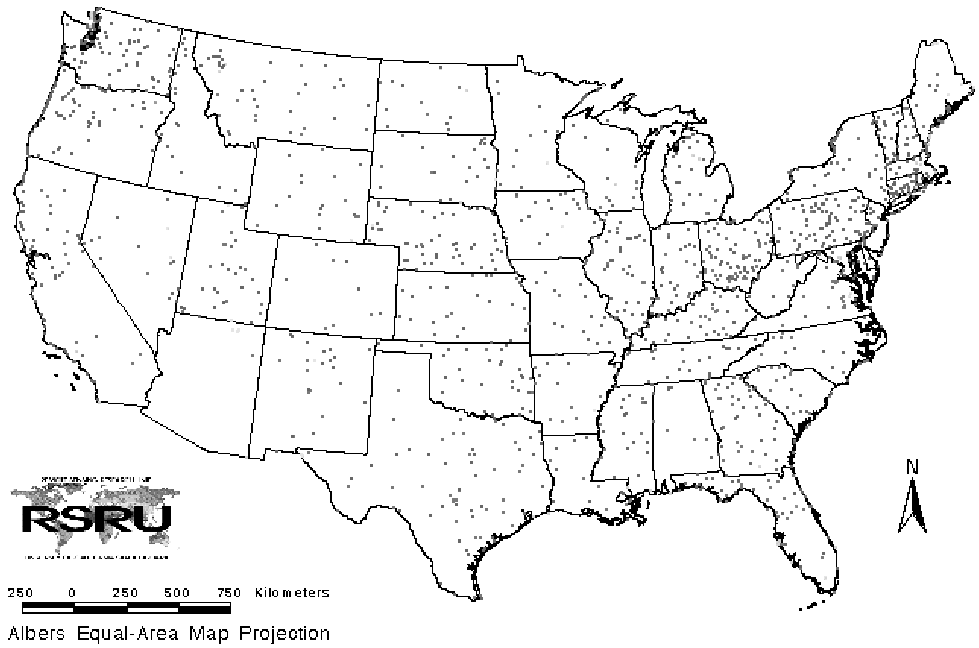


TABLE 1
Geographic Database Description

Output of the DESCRIBE ARC/INFO® software command

FEATURE CLASSES

Feature Class	Subclass	Number of Attributes Features	Topology?
ARCS		15762	
POLYGONS		7506	Yes
NODES		12356	

SECONDARY FEATURES

Tics	251
Arc Segments	268878
Polygon Labels	7505

TOLERANCES

Fuzzy =	0.920 V	Dangle =	0.000 V

COVERAGE BOUNDARY

Xmin =	-2355203.500	Xmax =	2254720.500
Ymin =	261294.000	Ymax =	3150660.250

COORDINATE SYSTEM DESCRIPTION

Projection	ALBERS		
Units	METERS	Spheroid	CLARKE1866
Parameters:			
1st standard parallel	29 30 0.000		
2nd standard parallel	45 30 0.000		
central meridian	-96 0 0.000		
latitude of projection's origin	23 0 0.000		
false easting (meters)	0.00000		
false northing (meters)	0.00000		

2. Database Features and Capabilities

In this section, an overview of the important features and capabilities of MAD is presented. This includes the types of information, or attributes, entered for each area record in the database, and a description of ways to employ this information to create subsets of the database and to extract information from it. Formats and order of data are clearly outlined. As the work of WCMC provides a foundation for this effort, the section begins with a review of their related database activities.

2.1 The World Conservation Monitoring Centre (WCMC) Database

Much of the format of the attribute table for this managed areas database was based on tabular data held by WCMC's Protected Areas Data Unit (PADU). Currently, their database contains over 30,000 protected areas worldwide (Beardsley and Stoms, 1993). WCMC is in the process of transforming this global tabular database for protected areas into spatial form using a GIS. For incorporation into MAD, only minor alterations have been made, including the addition of attributes for the data source and additional designations used for overlapping areas with multiple managing agencies.

Some of the managed areas included in MAD were present in WCMC's records, but the majority were not. Due to the adherence to WCMC’s database attribute model, there are items in many records which are presently blank. These residual items were left in the attribute table for possible future additions and are not complete for all managed areas in the database. Some records do, however, have values for these fields as MAD and WCMC data were merged. Examples of these residual items are the “longitude”, “latitude”, and “size” items. These are included in WCMC's tabular data, but most are automatically recorded in a GIS database, and it is unnecessary to include them twice. Others were not emphasized because they are relative only to WCMC or information was lacking.

An important item taken from the WCMC data set is the site code for each area. WCMC assigns a unique 5-digit number to each area held in their database. These were included in MAD so that information from the two data sets could be easily merged. For those records already existing at WCMC, the site code and all other relevant information was entered into MAD. For the areas which were absent from the WCMC database, a set of unused numbers from 75,000 to 81,000 was set aside by WCMC. These numbers were allotted to new areas as they were added and will be available for future relation to their database. A potential inconsistency may occur with these additional managed areas where WCMC held a record for an area which was very similar in name to that found on one of the MAD data sources but could not be verified as a match. For instance, WCMC may have held a record as a State Park while it was found as a State Historic Park or a National Monument on the source used for compilation. In these cases, a new site code was assigned and the area name and designation were entered as found on the source the boundaries were taken from. As well, it must be noted that not all WCMC records could be geographically located, and, thus, not all are included in MAD.

2.2 Feature Attributes

This database includes all types of managed areas existing in the conterminous United States. These include National and State Forests, National, State, and County Parks, National Wildlife Refuges, Wilderness Areas, Indian and Military Reservations, etc. (see Appendix A). The database includes attributes for each area. These attributes include items such as data sources, area designations, and levels of protection status (see Table 2) that allow the database to be manipulated or queried in numerous ways. A GIS can also include area and perimeter attributes when the coverage is georegistered and the topology is built. This allows for the extraction of new layers or themes in the GIS which are suited to user specific tasks.

2.2.1 Multiple Management Designations

Many areas in the United States are managed in more than one manner by more than one agency. An example of this is a Wild and Scenic River running through a Wilderness Area which is also part of a National Forest. These occur where different managed areas partially or completely overlap. To handle areas like these, the database includes three fields for several attributes. The attributes with multiple fields are area name, designation, site code, and both protection level categories (see Table 2). For the attributes with multiple fields, there is a correspondence between the field numbers of each. For example, area name 2 corresponds only to designation 2, site code 2, and so on. When querying the database, some areas may require that all three of these fields be searched for desired characteristics. We have attempted to be consistent as to order of designations within each category, but there were cases where this was not possible. *Queries should be made on all three fields.*

2.2.2 Attribute Descriptions

Site code - A unique 5-digit number (called a “site code”) is allocated to each area in the coverage. This allows outside data to be related to this database automatically. As described earlier, tabular data from WCMC was incorporated into this database, thus MAD site codes are modeled after WCMC database codes. However, as outlined in section 2.1, there is not a complete one-to-one correspondence between WCMC’s data for the United States and those areas included in MAD.

Area name - The proper name of each managed area is included as a primary attribute. By including each area’s place name, users seeking specific managed areas may more easily locate the management unit(s) they are interested in. Including place names also provides users more direct access to information on specific area(s) which they have queried by allowing them to search literature and other databases by each area’s proper name.

When querying the field containing proper names for the areas, it must be remembered that all abbreviations are not consistent. For example, a query for "Mount Baker" should be performed searching for the abbreviated name "Mt. Baker" if not returned immediately under the full name "Mount Baker". If the entity is found as "Mount", it will not be entered

TABLE 2
Database Attributes and Their Descriptions

Attribute	Field Name	Description
site code *	site_code site_code2 site_code3	-a unique number for each area for database relations
area name *	areaname areaname2 areaname3	-the proper name of each managed area represented
designation *	designation designation2 designation3	-describes the designation type for each managed area (this is the complete list of designations included)
IUCN category *	iucncat iucncat2 iucncat3	-a code used by World Conservation Monitoring Center (WCMC) to represent the level of protection status for each designation type
GAP category *	gapcat gapcat2 gapcat3	-a level of management based on the National Biological Service's Gap Analysis Program (GAP)
state	state	-the state in which the area is located
source	source	-the digital or hard copy map source from which the arc(s) making up the border of the polygon were taken (includes combinations of sources)
condensed designations	avsort	-a condensed list of management designations
	area	-an area for each management unit (calculated by ARC/INFO)
	perimeter	-a perimeter measure for each management unit (calculated by ARC/INFO)
	mad_poly#	-an internal ID number used by ARC/INFO
	mad_poly-id	-an ARC/INFO user ID number to help keep track of records
**	cmccode	-unused WCMC variable
**	lat	-each area's latitudinal location
**	lon	- each area's longitudinal location
**	islatlon	-unused WCMC variable
**	size	-area size as published by WCMC
**	year	-year of area establishment as published by WCMC
**	realm	-unused WCMC variable
**	province	-unused WCMC variable
**	biome	-unused WCMC variable

* These attributes have up to 3 information categories for polygons with multiple or overlapping management profiles.
** These attributes were modeled from WCMC's database but were not emphasized in MAD's creation.

elsewhere as "Mt." This inconsistency in MAD arises from differences and inconsistency in nomenclature in the source data.

In the area name field, an abbreviation was used at the end of the proper name for each area so that two or more areas with the same name, but different designations, can be distinguished (see Appendix A). An example of this is "NP" for National Park. Therefore, in the state of Washington, Olympic NP is used for the area name, not just Olympic. This will avoid confusing the National Park with Olympic National Forest (Olympic NF).

Many managed areas on the compilation sources had no identifying area name and none could be found on ancillary data. These data were titled "Name Unknown" and will be edited as new information is acquired.

Designation - Designation, such as National Park, is another attribute included which will enable the user to isolate unique management types. For instance, a user may require data based strictly on Wilderness Areas. The inclusion of the “designation” attribute allows MAD to be queried so that a subset of MAD can be extracted and only information relevant to Wilderness Areas needs to be processed. The “designation” attribute is also beneficial to ecosystem and species studies. This allows the calculation of the degree of protection provided by specific management profiles. This information can help to determine the best management strategy for each particular use. Appendix A includes the complete list of designations used.

For each managed area type, two different attributes are included for establishing a level of protection, or management status. These are the IUCN and GAP categories. This allows query of the database by desired protection profile(s). Defining levels of protection for land parcels is one of the most difficult steps in producing a managed areas map, and classification is often based more on the title of the managed area than its management goals or ownership status. Management status refers to the degree to which an area is managed to maintain biodiversity (Scott, et. al., 1993).

IUCN category - One of the management classification systems is taken directly from the World Conservation Union’s (IUCN) categories for conservation management (*note* - this agency was formerly known as the International Union for the Conservation of Nature). IUCN (1990) has developed a system of categories for conservation management of protected areas. The IUCN categories are based on ten levels of protection (see Table 3). Areas were individually classified for this system. The IUCN scheme is presently being modified to an improved six level system to overcome shortcomings of the original system (Paine, 1996). A complete discussion of the new IUCN category system is included in (IUCN, 1994), or can be obtained by contacting either IUCN or WCMC.

The IUCN category protection system is included in MAD for most of the areas for which WCMC previously held records. Areas for which there was no record at WCMC and those areas for which the degree of protection was not known to WCMC are given a classification of “?” indicating unknown for this field in MAD. Because of these characteristics, all records are also categorized into the GAP system of protection levels.

TABLE 3
IUCN Categories for Conservation Management

I	Scientific Reserve/ Strict Nature Reserve
II	National Park
III	Natural Monument/ Natural Landmark
IV	Nature Conservation Reserve/ Managed Nature Reserve/ Wildlife Sanctuary
V	Protected Landscape or Seascape
VI	Resource Reserve
VII	Anthropological Reserve/ Natural Biotic Area
VIII	Multiple Use Management Area/ Managed Resource Area
IX	Biosphere Reserves
X	World Heritage Sites (Natural)

(IUCN, 1990)

GAP category - The other system of protection classification is based on management levels established by the Gap Analysis Project (GAP) being conducted in the United States (see Table 4). Based on the GAP classification system, all areas are categorized into one of four levels of protection ranging from undisturbed to urban development. In the beta release of this database, these GAP categories are tentative; they are generalized and likely to receive further modification.

It is intended that all management categories be nationally consistent throughout the database, but variations of management strategies and practices between states is to be expected. By assigning an area to a management level based on its designation alone, some areas are likely to be classified incorrectly. The designation "Wilderness" provides an example. Wilderness Areas are under management by numerous agencies in the U.S., but, for this dataset, we assign all Wilderness Areas to a single GAP management level. This neglects the fact that some Wilderness Areas may allow different uses than others.

State- Portions of the database covering individual states may be easily extracted for state planning issues and reference. The state attribute allows users to easily and quickly isolate the data for any state(s) in which they are interested. This will add to the utility of the database for state planning issues. Information regarding which state an area lies within will serve numerous purposes.

Source - Data input from the different map sources used in creation may be separated and studied. This will be very important for issues such as assessing the accuracy of MAD. Keeping track of sources from which data was extracted will be beneficial for reference and may help to identify patterns of accuracy in the database. Appendix B lists the codes used to indicate data sources. Source issues are discussed further in section 3.

TABLE 4
GAP Protection Level Descriptions

Management Status 1	-an area with an active management plan in operation that is maintained in its natural state and within which natural disturbance events are either allowed to proceed without interference or are mimicked through management.
Management Status 2	-an area that is generally managed for its natural values, but which may receive use that degrades the quality of natural communities that are present.
Management Status 3	-most non-designated public lands, including USFS, BLM, and state park lands. Legal mandates prevent permanent conversion to anthropogenic habitat types (with some exceptions, such as tree plantations) and confer protection to populations of Federally listed endangered, threatened, and/or candidate species
Management Status 4	-private or public land without an existing easement or irrevocable management agreement that maintains native species and natural communities and which is managed primarily or exclusively for intensive human activity.

(Scott, et. al., 1993)

Condensed designation (avsort) - The original database contains too many management designation types for practical use in sorting the managed areas and would produce a map legend with far too much detail. For this reason, major management designations have been retained for this attribute, and many of the less frequently occurring designations have been collapsed into a single category called "other areas". Both the collapsed and the complete versions of management designations exist as database attributes (see Table 2).

We plan to distribute the beta version of MAD to agencies and groups throughout the U.S. Review and feedback information on database accuracy of all thematic and positional attributes (especially the management levels) will be solicited. Through this process, corrections to the database will be made and an updated operational version will be released.

2.3 Additional Details for Attribute Query

Much of the formatting of this database was chosen for compatibility with the WCMC global protected areas data set. In compiling any large spatial database, there are numerous approaches to developing the data structure, and a number of decisions must be made regarding this structure. Specific aspects of MAD's attributes include:

- Small holdings of private or other non-managed lands within the boundaries of larger managed areas were named "Not a managed area" and designated "EMPTY" for description in the database attribute table. These non-managed areas were also given the site code "99999".

- Large managed areas extending over state borders were broken into separate areas by state for logical query purposes.

- It must be remembered that several of the attributes in MAD have 3 fields to account for overlapping management areas. Therefore, when querying the database, all three of these fields must be searched for desired characteristics. We have attempted to be consistent as to the order of designations within each category, but there were cases where this was not possible. All queries should be made on each of the three fields.

3. Sources Used for Compilation

A number of sources were used for compilation of MAD. Digital sources in both tabular and GIS spatial database format were used as well as data from hard copy or paper maps which were digitized into the GIS. Each source was assigned a numeric code in the database (see Appendix B). Attempts were made to gather source data, representative of the desired managed area theme, at a map scale similar to the chosen base layer (see sections 1.2.2 and 3.1).

MAD includes an attribute indicating the source(s) of the boundary locations (arcs) for each polygon. This allows determination of the source(s) from which the boundary was derived and can be used to help determine the accuracy or reliability of each area's spatial extent. Those boundary arcs determined to be positionally inaccurate may require modification through incorporation of better source data for an updated version of MAD.

MAD source attribute information refers to the source of the polygon boundaries, not necessarily where other attribute information was obtained. Attributes may be verified more easily on a number of sources. The attribute information was normally taken from one of the sources used for database compilation (see Appendix B- Data Sources), but additional sources were occasionally consulted, either for necessary information absent from the primary sources or for verification purposes (these sources are listed at the end of Appendix B).

Where possible, each record was verified on several map sources. In some cases, sources did not agree on attributes and/or boundaries. In these cases, the information used was that verified on the largest number of sources or that of the source which was determined most accurate. For accuracy determination, a hierarchy of sources was established based on recommended standards from private and public mapping agencies (see section 3.4).

Boundaries added to the base layer from supplemental sources were digitized, projected into the Albers Equal-Area map projection (if necessary), then integrated into MAD. Supplemental source data were added by comparing each to the working copy of the database; we examined small regions from the west coast of the U.S. to the east coast, and added those boundaries (arcs) not yet present. Layers of data were added to the georegistered base map, by projecting them to the same coordinate system using the GIS technique of a distribution of tic marks, or tie points, across the data set domain (see Appendix C).

3.1 Digital and Hard Copy Sources

A number of digital and paper map sources were used in compiling this database (see Appendix B). Initially, a comprehensive digital database was needed for use as a base map. The Federal Lands GIS layer from the ArcUSA™ Database (ESRI, 1992) was used for this base data set. These data were compiled at a map scale of 1:2,000,000, and they already contained a large number of the managed areas in the United States. This database did, however, lack some Federal Lands' boundaries (such as divisions of National Forests) as well as the state and private land holdings; these major additions or modifications have now been incorporated into the data set. The ArcUSA™ data set was compiled from 1970's data, and is somewhat out-dated, but was the best available source data set for our use.

We also employed the ArcUSA™ state boundary layer at a map scale of 1:2,000,000 as a background coverage. This state boundary data is being released with the MAD polygon and point managed areas coverages to help locate map features in relation to the state boundaries and to physical features such as water bodies. Portions of this database covering the coastline and state boundaries contain intellectual property of Environmental Systems Research Institute, Inc. (ESRI) and are used herein with permission. End users are permitted to use these data for their own internal use including any derivative work, but are prohibited from using and redistributing these data individually or in any derivative work to third parties (see Appendix D).

We next incorporated the administrative boundary digital GIS database created by John Findley at the United States Geological Survey, National Mapping Division (USGS/NMD). This database was obtained during the early stages of the project and included many of the boundaries dividing larger National Forest holdings into the individual National Forest units as well as other managed areas not included on the ArcUSA™ Federal Lands layer.

After all needed boundaries were extracted from this digital layer, paper map sources were sought out. The process of incorporating boundary data from paper map sources included manual digitization, re-projection, and re-scaling of the data. The first hard copy map source reviewed was the USGS 1:500,000 scale topographical map series. This series includes more detail and is spatially more accurate than our digital source data sets, but was felt to be a useful source of relevant data. Individual states were viewed in small sections, and boundaries not included in the digital data sets were digitized into a separate GIS coverage. This coverage was then re-projected and integrated with the working coverage. The same process was repeated with the rest of the paper map sources.

We next used the Wilderness Status Map Series produced by the Bureau of Land Management (BLM) at a map scale of 1:1,000,000. This recently updated map source contains federal boundaries and the majority of Wilderness Areas in the United States and is also very accurate. This series, however, only covers the western states. Several managed areas were also extracted from state maps in other series' published by BLM (see Appendix B). Finally, we employed the National Geographic Society's "Close-Up USA" 1988 map series. This series is produced at a variable map scale from about 1:1,000,000 to 1:2,000,000. As these maps seem to have been designed more for visual purposes than precise boundary information, many of the managed areas boundaries were in disagreement with the other sources (see section 4.1). This series was employed as a last resort to add areas not found on any other sources.

3.2 Combination Sources

The compilation of this database required collection and integration of data from a number of sources as detailed above. Due to the overlap of numerous management areas boundaries, it was necessary to create source codes for areas created from more than one source. Often boundaries would already be in place for one area, such as a National Forest, and missing for another area located directly adjacent to the National Forest boundary. For these areas, only missing boundary section(s), or arcs, were digitized; these were then merged with the boundaries already in place. This created managed area polygons with multiple sources shown as polygon attributes.

Another feature of the data set are islands, or areas completely enclosed by larger areas. These occur in areas where there are private or non-managed holdings inside the boundaries of larger managed area holdings, and/or where designations of one management type were within larger areas of different designation to be managed separately or jointly. Where islands exist inside larger areas, the source identification number was assigned only to the outermost perimeter of the larger area. The source for the interior holding can be found by examining its source attribute.

3.3 Ancillary Sources Used for Attribute Verification

Ancillary data was employed along with the map sources used for MAD compilation (see Appendix B). There were instances when an area on one source map was not present elsewhere, and none of the sources used for compilation held a name for the area. For this situation, other sources had to be consulted. Ancillary data were also employed when sources were in either spatial or informational disagreement. The base digital data sets used for MAD did not include any place or area names as attributes and also required ancillary references. Areas for which no name was found on any source of ancillary data were labeled "Name Unknown".

3.4 Methods for Integrating Sources

In order to promote consistent procedures for MAD compilation, a hierarchical scheme was developed to integrate data from the variety of sources. In most cases, the ArcUSA™ Federal Lands digital database was used as the standard accurate base data layer for MAD. The NMD coverage was also considered relatively accurate at the map scale of 1:2,000,000 and used to add missing boundary segments to the ArcUSA™ database. The USGS 1:500,000 topographic map series and the BLM 1:1,000,000 Wilderness Status map series were ordered next in the accuracy hierarchy. For integration purposes, the USGS maps were merged first, because although the BLM maps were more recently revised, the USGS series was at a finer scale and more spatially comprehensive. BLM data were, however, used to replace some areas already integrated but believed to be less accurate on the USGS sources. This was especially true for managed lands administered by the BLM, such as Wilderness Areas. Finally, areas from the Close-Up USA map series were added to the database to include areas not found on any of the other sources.

The data were integrated one source at a time, examining small sections of each state and moving from the west coast of the U.S. to the east coast. This allowed a visual assessment of the database to identify missing areas. Digital source data are originally compiled in Albers Equal-Area map projection and were simply copied to the working MAD spatial database where needed. Data from paper source maps were manually digitized into their respective projections, re-projected into Albers Equal-Area, and copied to the working database. Since data from multiple sources with different map scales and projections were not exactly alike in digital form, some of the data had to be visually inspected and manually corrected. Some of the data sources conflicted in the size, shape, and name of managed areas, and there were occasional disagreements among USGS maps of different scales. For instance, two adjacent polygons, digitized from different map sources, did not always perfectly agree on the shared boundary segment. In these cases, the segment from the source with the best hierarchical standing was retained.

4. Sources of Error and Accuracy Issues in MAD

A GIS approach to database compilation may provide better solutions than paper maps for some issues, but they introduce a number of technical issues and problems that are inherent to these systems. This is particularly true when compiling large digital spatial databases with multiple data sources of different map scale and projections. As an example, error may be introduced when registering all the maps to a consistent coordinate system and changing the map projection. Database error can be both spatial, such as boundary location, and informational, such as the accuracy of the attribute data. Any digital database, whose lineage is unknown or uncertain, may have inherited error which remains undetected.

In this section, we discuss probable and possible sources of error in MAD. The discussion of these errors is merely hypothetical and such errors may not necessarily exist in MAD. The nature and degree of error and inaccuracy in MAD has, to date, not been analyzed. It must, however, be considered that in terms of locational accuracy this database has been designated as a 1:2,000,000 scale product, and therefore, precise locational or spatial accuracy is unlikely. Additionally, this database is currently released as a beta version for distribution to knowledgeable scientists who are expected to provide feedback for future modification and update. It is, however, intended that precision and accuracy of MAD will be in accord with the designated database scale.

4.1 Error Introduced by Source Data

It is probable that some amount of error has been introduced into this database due to error in the source data. In a few instances, different source data from the same agency did not agree. As an example, Wilderness Status maps from BLM occasionally showed areas in adjacent states on both state’s maps, and the location, shape, and size of the same areas on each were in disagreement. For these cases, BLM recommended the use of the information from the map of the state in which the area was located (Green, 1995). There are indications that cases exist where there is disagreement within the agency. It should be noted that further subdivisions of some small managed areas from the Wilderness Status maps were not included, because they could not be adequately interpreted.

Another example of this type of error was found in USGS source maps. There was disagreement in location of areas between different scale maps. For instance, some 1:500,000 scale maps represented different boundary shapes or locations than found on 1:100,000 maps. This is believed to be more than just the issue of map scale. It is likely a byproduct of a different lineage for each map series rather than simply an artifact of different map scales. It was unclear which of these series were more accurate. It seems that the 1:100,000 scale series should be more accurate, but this series was too detailed for MAD compilation purposes at this time. The USGS 1:500,000 scale map series made available for MAD were also in poor condition. Many of the older maps were wrinkled and torn. This is another source of potential error introduced by the digitizing process.

Inherited error may also have been introduced into MAD by using the National Geographic Society's Close-Up USA 1988 map series. It appears that these maps were created with some degree of artistic license. It is believed that a number of areas digitized from this map series are inaccurate, because they often disagreed with other source maps or seemed generalized. This is especially the case for Wilderness Areas, which are the most accurate on the recently updated BLM Wilderness Status map series (which most were taken from). This National Geographic map source was used for extraction of many areas on MAD, because they were not located on any other sources of similar scale. The scale of individual Close-Up USA maps varies from approximately 1:1,000,000 to 1:2,000,000. Many areas which would not ordinarily be depicted on maps of this scale were included in the Close-Up USA series. Wild and Scenic Rivers appeared to be simply highlighted lines where the protected sections of the rivers occurred, and not carefully drawn political boundaries. For this reason, the true width of these protected rivers, the true shape of the boundaries, and the total area of each management zone taken from the Close-Up USA 1988 series and depicted in MAD may be less accurate. Most of these rivers would not show up on Close-Up USA if their width was drawn to scale, so their inclusion in MAD merits only approximate locational information. Many State Forests, State Parks, and other management types were found only on this Close-Up USA map series, especially in the eastern United States.

A number of informational errors may also be present in some areas in MAD. Information may be missing or inaccurate in a specified context. Inappropriate information is often related to problems in coding and transcription (Star and Estes, 1990). Occasionally, typographical errors on map sources may be introduced into the database and remain unnoticed for some time. Many of the areas included in the database had no political or place name to accompany their designation, so they were labeled as "Name Unknown". In several cases, different source maps had different names for the same area. Where this occurred, a decision was made about the correct name (based on the previously mentioned hierarchy); these decisions may not be correct in all cases.

Another informational source of error may occur in the GAP level of protection assigned to the management areas. Although these levels of protection are tentative at this time, we are aware of problems with this classification scheme based on designation alone. For instance, all Military Reservations are assigned to a single protection category. However, some of these areas are in their pristine state while others are developed or used as weapon test sites. The level of protection assigned in MAD is usually that of the least protected holdings for each designation, and for Military Reservations this means that they are all assigned to a very low protection status. Some areas under military control may actually serve as valuable protected natural areas because of their limited public access, and many relatively undisturbed buffer-zones for these areas have been described as important refuges for at least locally endangered habitats or wildlife (Westing, 1992). It must be emphasized that areas are not always protected or managed uniformly across their entire holdings, yet management levels in MAD are classified uniformly.

4.1.1 Age of Data

Political boundaries are continuously being altered and there is likely to be some error introduced into this database due to the age of the source data. Often there are no high quality, recently updated data available for many of the managed areas. In fact, one of the reasons for the creation of this Managed Areas Database (MAD) is to compile accurate, recently reviewed data so that there is much better knowledge of what areas exist at this time. However, it will take some time to verify all of the areas present on this database. Some of the data used in creation of MAD were outdated, but several of the sources used were more recent (such as the BLM Wilderness Status maps and the National Geographic Society's series). Some of the available USGS source maps were revised only as recently as 1966, but some states were updated as recently as 1990. The older source data will probably introduce temporal error.

The digital source data were also relatively dated. The base map from ESRI was digitized from maps compiled in the 1970's; some boundaries may be inaccurate. Unknown or unclear lineage of digital sources may also introduce inaccuracy related to the age of data, since it may not be known where boundaries were obtained. Since the completion of MAD, an updated version of the Federal Lands digital spatial database has been released by USGS (Wortman, 1996). This database will serve as a good reference in verification and assessing the accuracy of MAD data.

4.1.2 Non-Verifiable Data

Some data included in MAD is of unknown accuracy, because it could not be reliably verified. There are managed areas present on some sources which were not included in MAD, because they were believed to be inaccurate or outdated. For example, several areas existing on ESRI's ArcUSA™ Federal Lands database were modified or excluded, because they could not be found on any ancillary sources, and name information was not included with the Federal boundary data. Most of these areas were of the designation "Military Reservation" or "Park or Monument".

Some areas might have been excluded or assigned a name or designation which proves to be inaccurate. This might occur for a number of reasons. In some cases, verification was not possible, or decisions about which source was most reliable for data occurring on more than one source may be in error. It is likely that some areas are included in the database which no longer exist as managed areas. Again, for these reasons, MAD is currently being distributed in beta form for assessment and feedback so that modifications can be made and an updated and accurate database compiled.

4.2 Digitizing Error

The most common source of vector GIS data comes from existing maps. Features of interest are extracted by digitization or electromechanical scanning. Each of these extraction processes has different kinds of error in accuracy and precision. The output depends on the skill of the operator and the quality of the systems being used (Ehlers, et. al., 1991).

Digitization usually involves an operator manually tracing the desired features through the use of a flat surface called a digitizing tablet and a pen-like stylus or flat cursor. Digitizing tablets, which were extensively employed for this database, are the most common means of converting maps and other graphic data to digital format, but inherently have finite resolution (Star and Estes, 1990). Digitizing also includes additional inexact human interpretation.

There is also a limit to the size of individual features that can be distinguished on a map. This limit is related to the thickness of the ink representing the various features and the ability of the human eye to interpret these features. It is often necessary to make political boundaries much wider or larger in area than is actually the case. Boundaries are sometimes represented as several miles wide when in reality they represent a line having no true width. Often these boundaries are made thicker to represent the type of boundary they represent. Interpretation of these boundaries by the operator are unlikely to be exact and consistent throughout the data compilation process. It is highly probable that two person's interpretations will vary as well.

Another source of error arising from interpretation of features is the number of vertices used to represent a non-linear feature. In a GIS, curved linear features are conventionally represented by polylines (vectors) made up of an ordered set of points (vertices) connected by multiple straight line segments. Increasing the density of points can improve accuracy (Goodchild, 1994). Areas are represented by polygons constructed by linking appropriate vectors (Star and Estes, 1990). Each operator is likely to interpret a different number of vertices needed to construct a curved feature, and this will create an inability for exact duplication of areas. Many times, paper maps have text associated with features that may obstruct the location of area boundaries. In these cases, the operator will be forced to make judgments about where to locate the boundary.

Another source of error introduced during digitization results from the medium on which the source map is drawn. Photographic films are considered very stable while paper maps may stretch or warp under varying amounts of temperature and humidity. Paper shrinkage or expansion can range up to 3 percent depending on paper type, thickness, and processing methods (Star and Estes, 1990). Paper maps are often torn or wrinkled, especially when aged, and are occasionally distributed in a folded format. All of these characteristics may create error in the digitization process.

4.3 Error from Integrating Sources

Errors will be introduced by the data integration process, as MAD required integrating data from a number of sources of different quality, accuracy, publication date, map scales and cartographic projections. To minimize error and allow efficient, systematic data compilation, a consistent data integration methodology must be developed. Decisions regarding source data accuracy must be made. Procedures to combine digital sources, and to select boundary segments for use when there is more than one for a certain boundary segment, can be problematic. For MAD, when a managed area and an original base map polygon adjoined, the original arc was retained unless identified as incorrect. Error is introduced when boundaries do not match exactly where different digital source data are integrated, and operator interpolation is necessary.

Due to the integration of multiple data sources, portions of the database will have varying accuracy related to the accuracy of the source data. For this reason, a code has been assigned to each record in the database to help keep track of the boundaries and error which they may have inherited. This code is related to one of the map sources used in creation of MAD (see Appendix B). A large number of areas may be made up from the integrated multiple sources, in which case, codes for combinations of sources were used. These areas will be more difficult to assess for accuracy, but this information will be useful for future reference. With the inclusion of this coding scheme, an assessment of the error present in the database may be examined separately for each data source.

5. Summary, Conclusions, and Recommendations

5.1 Summary

The compilation of managed areas in digital form for the 48 conterminous United States has been completed at an estimated map scale of 1:2,000,000. Previously, a lack of standardization has hindered studies related to managed land over large spatial areas. Since MAD has been compiled as a consistent and comprehensive GIS of all managed areas in the conterminous United States, it will facilitate the study of ecosystem and species types in relation to the management zones over a large area, and may bring forth ideas for important future studies. Errors which currently exist in the database will be revised and corrected as the database is updated. The extensive number of agencies owning and managing numerous designations of land for different purposes has added difficulty in integrating source data to create a truly comprehensive resource.

The intent of this document is to describe, in some useful detail, the creation and completion of MAD. Also discussed are database comprehensiveness, methods required for proper use of this database, and capabilities and limitations of the database. Problems encountered during the compilation process, which may have introduced error to MAD, as well as the accuracy issues are discussed. In its present form, it is believed that this database will be found to be extremely useful as it is released. A large database such as this may contain some degree of spatial and attribute error, but feedback from initial users will be documented and revisions made so that this database is as accurate and useful as possible.

MAD will contribute significantly to the present base of managed and protected areas data for the world and will provide stimulus and direction for similar projects to be undertaken in other regions. Without a strong commitment by the United States government at conserving their own biological diversity, it will be difficult to convince developing nations to put off short-term economic gains for long-term survival of biological resources (Blockstein, 1990). Lessons learned from this project will help simplify future projects such as products at finer scales with more detailed attribute information.

5.1.1 Problems Encountered

A number of difficulties were encountered while designing and compiling this national scale Managed Areas Database (MAD). Most of these issues have been resolved. Others still must be addressed. Attention must be given to areas which had unknown or unclear place names, as well as those areas where the map sources were in disagreement. Omission of a few areas may have occurred; these will need to be included in the future by using additional sources. There were instances when a lack of cooperation, and inconsistencies, among managing agencies caused difficulty in the compilation process. We discovered disagreement within map sources as well as data fragmented throughout a large number of different sources. Many areas which were present on the BLM maps were in disagreement with or absent from the USGS maps. This is often the case with sources from the other agencies as well, and is one of the primary reasons for constructing a comprehensive database such as MAD. For example, from the source data, the State Forests of New York were located only on the Close-Up USA map series and were unnamed. Attempts were made to contact state officials for the verification of these names, yet each county seemed to have their own records and there was no comprehensive map for the state. For this release of MAD, it was decided to leave these and similar areas unnamed so that modifications may be made as more information is obtained.

Aside from source data collection, the most difficult aspect of MAD's creation was integration of these widely varying sources. The integration of various unique map sources may have caused errors requiring further analysis. Every attempt was made to insure accuracy during the data integration process by assessing the accuracy of source data and through consistent compilation techniques. Qualitative decisions were made about source data accuracy using criteria such as publishing agency's reliability, age of data, and map scale. An attempt has been made to document difficulty in this process by adding a source attribute for each area that enables each boundary to be traced to its source map origin.

5.2 Scientific Contribution

Much time and effort has gone into the construction of this comprehensive Managed Areas Database (MAD). Much of the data had to be manually digitized. This process is the most resource intensive phase of constructing a digital cartographic data base using a GIS (Star and Estes, 1990). This data base will provide much needed spatial information to the planning community, and will contribute to creating future databases of this type. MAD may be of use in many types of studies including land cover protection and management, sensitive or endangered species status, and general planning issues.

5.3 Further Recommendations

It is highly recommended that this database be revised, updated, and corrected as errors and inconsistencies are identified. To accomplish this, it will be necessary for a group or an agency to commit to maintaining this database. At present, it is unclear where MAD will be supported and who will be responsible for updates and maintenance. At this time, it is intended that this beta version of MAD will be released to knowledgeable individuals and groups throughout the United States for assessment and commentary. From their feedback, corrections to the database will be made, and an updated version released. Using GIS, maintenance and periodic updates of dynamic land management data is made less difficult. This first update and release will be carried out at the Remote Sensing Research Unit (RSRU) by the author and associates. Ideally, the database will retain old boundary segments which are accurate but have been legally altered so that temporal studies may be conducted.

Another necessary step in the creation of data of this type will be to repeat the process with finer scale data so that more detailed studies can be performed. This process is currently being conducted at an approximate map scale of 1:100,000 for all of the conterminous United States through the Gap Analysis Project (GAP) (Biggs, et. al., 1994), but completed data for all of the conterminous United States is currently unavailable (US GAP Data Sets, 1996). It is hoped that these data will soon be available for each state in the nation. Once each state is complete, all of these databases can be integrated into a single national scale coverage. The larger scale MAD database, though more coarse in scale, will be implemented more quickly. Another advantage of MAD is that integrating local studies into regional then global studies may introduce significant temporal inconsistencies (Townshend, et. al., 1991).

It is also recommended that the managed areas in MAD be divided according to the actual management practices within each area. Often an area of high interest has a special management designation within larger managed areas, so it would be ideal to assess each area on an individual basis (Scott, et. al., 1993). Although this more detailed data may be necessary for local scale planning issues, we feel that a coarse scale national database can be of great value for national level policy decisions.

There are many countries throughout the world which have not even begun to inventory their land cover or preserves. To date, there are no reliable, large-scale, global data concerning numerous areas such as landcover (Estes, et. al., 1994). For conservation purposes, it is recommended that 10 percent of each of the world's major habitat types be included within protected areas (Leader-Williams, et. al., 1990). At this time, accurate percentages of major habitat types cannot be determined because of inadequate data. Very little consistent and accurate data is presently available, and more work should be done in this area. Creating this large scale database will contribute to future efforts by providing guidance in the compilation of other managed areas databases similar to how GAP has been a model for similar studies in other countries such as Australia and Africa (Lombard, et. al., 1992, and Pressey, et. al., 1995). Datasets covering Canada and Mexico are two important datasets which, when compiled, may be joined with MAD for a comprehensive coverage of nearly all of the North American continent.

The compilation of large scale datasets such as MAD is a necessary first step in the inventory of protected areas across the globe. The earth must begin to be viewed as one large series of interconnected systems instead of many unique yet disjunct systems separated by political boundaries.

We further recommend that this database be incorporated into the WCMC global protected areas database so that they may help to provide feedback and updates as their records are modified. As mentioned previously, MAD was developed with a unique 5-digit site code for each area in the database so that it may be easily joined with WCMC's additional records. It is hoped that more countries or agencies will follow this example and begin efforts in the inventory of their own species and conservation of these species through proper management techniques.

5.3.1 Future Plans for Studies Using MAD

Several studies are currently planned for MAD. First, we plan to conduct a spatial accuracy assessment of the managed area boundaries using USGS 1:24,000 topographic maps as the geodetic framework. Digital sources will not be used for this reference data as they may also have inherent error. This analysis will be performed as follows:

1) Reference points will be drawn in a random sample stratified by source, possibly weighted by management area density, at definite corners or other distinct features of the political boundaries, and their coordinates recorded in latitude/longitude.
2) These units will then be converted to a measurement unit (such as meters) for analysis.
3) These sample points will next be located on the 1:24,000 USGS maps, and recorded in the same manner and a statistical analysis will be completed.
4) Comparison of the points on MAD with these same points on the geodetic framework will be made. Statistical accuracy will increase as the distance between these points decreases.
5) A frequency distribution of the distance between paired points and accompanying descriptive statistics will be presented for each data source used in compiling MAD.
6) From these results, positional accuracy of the managed area boundaries will be established and an approximate map scale calculated.

We believe this is the best method of assessing the accuracy of a digital spatial database when there is an unclear lineage of map projections and transformations, and the map boundaries cannot be field checked (Goodchild, 1996).

An analysis of accuracy will also be stated for the individual sources used in compiling the database. This will be accomplished by examining the results of the accuracy analysis in groups based on the map sources included in the database attributes for each area. Accuracy measures of each of these map sources in its original form will also be presented.

After accuracy is established, MAD will be overlaid with the Ecoregions GIS database developed by Bailey (1995) to determine which ecosystems are being adequately protected by which managing agencies and policies. According to the Department of the Interior, reserves of 23,000 acres or more, managed by the four largest federal land management agencies, failed to include 22 percent of the recognized ecosystem types in the United States and underrepresented another 29 percent (Blockstein, 1990). This is an example of the type of comprehensive analysis that can be carried out using MAD. A measure of the relative percentages of each ecosystem type in each managed or protected area will be calculated. This will provide information about the lack of protection of ecosystems in the conterminous United States by each designation of managed area, and will help determine where future protected areas should be located for maximum impact. In the past, many protected areas were established for economic reasons with limited scientific input in their design. Protected areas established in this way rarely provide adequate protection for the nation’s biological diversity (Leader-Williams, et. al., 1990).

5.3.2 Other Potential Uses of MAD

Aside from the examples provided above, MAD has many possible uses in the study of the environment. Aspects of climatic research requires knowledge of where park and preserve boundaries are located and to what degree they provide biodiversity protection along environmental gradients (Beardsley and Stoms, 1993). The MAD database may be used with remotely sensed vegetation data to determine if the vegetation communities are disturbed to a different degree between distinct managed area designations and whether there appears to be a difference in disturbance patterns within and outside of managed areas. This can be accomplished by employing satellite data to identify disturbed and undisturbed vegetation classes, and overlaying these data with MAD to determine the percentages of disturbed landcover in managed areas relative to non-managed areas. Assessments can also be made about the average degree of disturbance present in each designation of managed area.

MAD could also be combined with data on unique vegetation classes. This can be of more value than assessment of ecosystem protection using PNV types as described in section 1.1, because it is more representative of actual vegetation present across the country. An example of this type of data would be the database created from Advanced Very High Resolution Radiometer (AVHRR) satellite data by Loveland, et. al. (1991). This could provide information on the vegetation communities which are least and best protected by management practices in the conterminous United States. It will show which management designations are best at protecting the different vegetation types and which ones provide little in the way of protection. This type of study could provide information about sensitive vegetation types which are under-represented in managed or protected areas, and where new areas can be located in the future to best protect these vegetation classes. This study would be similar to GAP Analysis but at a more coarse and less detailed map scale.

Based on the theory of island biogeography, the size and shape of protected areas is believed to affect biological diversity and species richness. Protected areas have primarily been established with their location, size, and shape determined largely by social and political factors (Leader-Williams, et. al., 1990). Using MAD with vegetation or other species data may help determine the influence of size and shape of protected areas on species richness and which parameters are best suited for protection guidelines. A procedure must be developed to identify key parameters necessary in the siting of new nature reserves and how these parameters relate to one another. Factors such as the degree of fragmentation of the reserves, isolation of habitat patches, and the existence of corridors for migrations or dispersal events must be considered (Lombard, et. al., 1992).

Along with the studies mentioned above, analysis could be conducted using Digital Elevation Models (DEM) in combination with MAD to determine changes in protection effectiveness with management alterations such as protecting areas containing selected slope characteristics or adding all areas over a certain elevation to some designation of protected area. This might also yield information on the average slope and elevation of each managed area designation in the database. This type of study could help to identify problems with the protected area system such as the primary establishment of protected areas on upland regions which neglects the lower elevation regions. The finding that the majority of wilderness areas are located at higher elevations implies that lower-elevation ecosystem types are underrepresented in wilderness areas and other biodiversity management areas. This can have negative effects, since these lower-elevation ecosystems are usually the most productive and diverse in species (Scott, et. al., 1993).

One more example of a type of study using MAD would be to buffer each managed area inwards from its boundary to see how much and which types of ecosystems are lost from protection. This might provide insight about species inhabiting the perimeter of these managed areas being affected by boundary activities such as roads or urbanization. Some wilderness areas even share boundaries with urban subdivisions such as the Twin Peaks Wilderness adjacent to Salt Lake City, Utah and the Sandia Wilderness in Albuquerque, New Mexico (Fege and Corrigall, 1990). If a disturbance is discovered, a solution can be found such as buffer strips allowing limited use between the protected area and the source of the incursion, or around the entire reserve (Lombard, et. al., 1992). It must be remembered that natural systems do not recognize political boundaries, and, therefore, are not shielded from activities occurring on the opposite side of an imaginary line. This disturbance may either cause the loss of certain species in those areas or the increase in species density as they are driven toward the core of these managed areas.

6. Accessing the Database and Contact Information

Accessing the Database via World Wide Web:

This database is available on the WWW at:
http://www.ncgia.ucsb.edu/sb/mad/mad.html

Accessing the database via ftp:

For those without access to the WWW, the database can be accessed by anonymous ftp at the following site:
ear.geog.ucsb.edu

-where username will be "anonymous" and the password will be your login name.

From this site, go into the pub/ directory and here you will find the files listed below:

mad_poly.e00	-this is the managed areas coverage exported from ARC/INFO in polyon form.
mad_poly.e00.gz	-same file as above except compressed with gzip
mad_point.e00	-this is the point coverage for small areas in ARC/INFO export format

SUPPLEMENTARY COVERAGES:

latlon.e00	-an algorithm generated latitude/longitude grid at 1 degree intervals
st2m.e00	-a state boundary coverage for use as a background (released with permission from ESRI- see copyright in Appendix D)

If you have no access to either of these methods or for more information, you can contact:

Mr. R. Gavin McGhie
Remote Sensing Research Unit (RSRU)
University of California Santa Barbara
Department of Geography
Santa Barbara, CA 93106-4060
Phone: (805) 893-3845
Fax: (805) 893-3703
e-mail: gavin@geog.ucsb.edu

or

NCGIA Publications
NCGIA
University of California Santa Barbara
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Fax: (805) 893-8617
e-mail: ncgiapub@geog.ucsb.edu

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APPENDIX A
Managed Areas Designations

Designation	Abbreviations Used in Area Name
Aquatic Park	(AqP)
Biosphere Reserve	(BR)
Bird Sanctuary	(BS)
Conservation Area	(CA)
County Park	(CP)
County Regional Park	(CRP)
Ecological Reserve	(ER)
Forest Park	(FoP)
Forest Preserve	(FP)
Further Planning Area	(FPA)
Government Reservation	(GRes)
Indian Reservation *	(IndRv)
International Peace Garden	(IPG)
Management Area	(MA)
Marine Sanctuary	(MS)
Military Reservation *	(MilRes)
National Battlefield	(NBat)
National Battlefield Park	(NBatP)
National Conservation Area	(NCA)
National Estuarine Research Reserve	(NERR)
National Forest *	(NF)
National Game Reserve	(NGR)
National Grassland *	(NG)
National Historic Park	(NHP)
National Historic Site	(NHS)
National Lakeshore	(NL)
National Marine Sanctuary	(NMS)
National Memorial	(NMem)
National Military Park	(NMilP)
National Monument *	(NaM)
National Natural Landmark	(NNL)
National Park *	(NP)
National Preserve	(NaPr)
National Recreation Area *	(NRA)
National Reserve and Recreation Area	(NRRA)
National River	(NaRiv)
National Seashore *	(NS)
National Scenic River	(NScRv)
National Scientific Reserve	(NSR)
National Wildlife Refuge *	(NWR)

Natural Area	(NA)
Other Area *	(OA)
Outstanding Natural Area	(ONA)
Park	(P)
Parkway	(PWY)
Primitive Area	(PA)
Private Reserve	(PR)
Rancheria	(RNCHR)
Recommended Wilderness	(RW)
Recreation Area	(RA)
Recreation Lands	(RL)
Refuge	(R)
Regional Park	(RP)
State Beach	(SB)
State Bird Refuge	(SBR)
State Forest *	(SF)
State Historic Park	(SHP)
State Historic Site	(SHS)
State Historical Monument	(SHM)
State Lake	(SL)
State Memorial Park	(SMP)
State Natural Area	(SNA)
State Natural Area Reserve	(SNAR)
State Nature Reserve	(StNR)
State Park *	(SP)
State Park and Forest	(SP & F)
State Recreation Area *	(SRA)
State Reserve	(SR)
State Vehicular Recreation Area	(SVRA)
State Wildlife Recreation Area	(SWRA)
Waterfowl Management Area	(WfMA)
Waterfowl Reserve	(WR)
Wayside	(WS)
Wild and Scenic River *	(WScRv)
Wilderness (BLM, USFS, NPS) *	No Abbreviation
Wilderness (FWS) *	No Abbreviation
Wilderness NFW (Forest Service) *	No Abbreviation
Wilderness (State) *	No Abbreviation
Wilderness Area	(WA)
Wilderness Study Area *	(WSA)
Wilderness Unit	(WU)
Wildlife Management Area	(WMA)
Wildlife Research Area	(WRA)

* These areas were retained in the condensed designation category. All others were condensed into "other areas".

APPENDIX B
Data Source Information

Source Codes	Data Sources
1	Federal Lands Layer (Fed2M layer of ArcUSA (ESRI, 1992)) [1:2,000,000]
2	Wilderness Status Maps from Bureau of Land Management (BLM) 1986-present [1:1,000,000]
3	Close-Up USA Map Series (National Geographic): ed. 1988 [map scale varies]
4	USAADM (digital data from John Findley, National Mapping Division: USGS)
5	United States Geological Survey (USGS) 1:250,000 Map Sheets (unknown dates- compiled by Karen Beardlsey)
6	BLM faxed documents (from Gary Yeager)
7	USGS 1:500,000 topographic Map Sheets (1966-1990)
8	Combination of USAADM (4) and Fed2M (1)
9	BLM 1:500,000 Public Lands Edition (1980) (Colorado only)
10	Combination of USAADM (4) and Wilderness Status Maps (2)
11	Combination of Fed2M (1), Wilderness Status Maps(2), and USAADM (4)
12	Combination of Fed2M (1) and Wilderness Status Maps (2)
13	Combination of Fed2M (1), Close-Up USA (3), and USAADM (4)
14	Combination of Fed2M (1) and Close-Up USA (3)
15	Combination of Close-Up USA (3) and USAADM (4)
16	Combination of USAADM (4) and USGS 1:500,000 (7)
17	Combination of Fed2M (1) and USGS 1:500,000 (7)
18	Combination of Fed2M (1), Close-Up USA (3), and USGS 1:500,000 (7)
19	Combination of Close-Up USA (3) and USGS 1:500,000 (7)
20	Combination of Fed2M (1) BLM (2) Close-Up (3) and USGS 1:500K (7)
21	Combination of Fed2M (1), USGS 1:500,000 (7), and USAADM (4)
22	BLM 1:500,000 "Surface Managment (Status) Responsibility" (1991) (Idaho only)
23	BLM 1:500,000 "Areas of Responsibility and Land Status" (1977) (Utah only)
24	BLM 1:1,000,000 (1990) (Nevada only)
25	Combination of Fed2M (1) and BLM 1:500,000 "Areas of Responsibility and Land Status" (23)
26	Combination of BLM (2) and USGS 1:500K (7)
27	Combination of Fed2M (1) BLM (2) and USGS 1:500K (7)
28	Combination of BLM (2) and Close-Up (3)
29	Combination of Fed2M (1) BLM (2) and Close-Up (3)
30	Combination of BLM (2) Close-Up (3) and USGS 1:500K (7)
31	Combination of BLM FAX (6) and USGS 1:500K (7)
32	Combination of BLM (2) and BLM 1:500K (23)
33	Combination of Fed2M (1) BLM (2) and BLM 1:500K (23)
34	Combination of BLM (2) Close-Up (3) and USAADM (4)
35	Combination of Fed2M (1) BLM (2) Close-Up (3) and USAADM (4)

Maps Used in Verification of Area Names and Boundaries

- American Automobile Association (AAA) state road map series [1989-1992].
- Additional United States Geological Survey (USGS) topographic maps from the scale of 1:24,000; 1:100,000; 1:250,000; and 1:500,000.
- USGS 1:500,000 Base Map (not the topographic map) for the New York rivers.
- Digital ARC/INFO spatial database from Bureau of Indian Affairs (BIA) at the scale of 1:2,000,000

Appendix C
Distribution of Tie Points

State	**I.D.**	**Point (Lat/Lon)**	**State**	**I.D.**	**Point (Lat/Lon)**	**State**	**I.D.**	**Point (Lat/Lon)**
WA	1	47N/ 123W	CA	38	41N/ 124W		75	34N/ 108W
	2	48N/ 122W	<N>	39	41N/ 121W		76	34N/ 104W
	3	46N/ 121W		40	40N/ 122W		77	33N/ 108W
	4	47N/ 118W		41	40N/ 124W		78	33N/ 104W
	5	48N/ 118W		42	38N/ 122W		79	32N/ 108W
OR	6	42N/124W		43	38N/ 120W	CO	80	40N/ 108W
	7	44N/ 124W		44	39N/ 122W		81	40N/ 104W
	8	44N/ 122W	<S>	45	36N/ 120W		82	39N/ 106W
	9	45N/ 123W		46	36N/ 118W		83	38N/ 108W
	10	45N/ 122W		47	36N/ 116W		84	38N/ 104W
	11	43N/ 119W		48	34N/ 120W	ND	85	48N/ 104W
	12	44N/ 120W		49	34N/ 118W		86	46N/ 104W
	13	45N/ 118W		50	34N/ 116W		87	48N/ 98W
	14	45N/ 120W	NV	51	41N/ 119W		88	46N/ 98W
ID	15	45N/ 116W		52	41N/ 116W		89	47N/ 100W
	16	45N/ 115W		53	40N/ 116W	SD	90	44N/ 102W
	17	47N/ 115W		54	40N/ 118W		91	45N/ 102W
	18	47N/ 117W		55	38N/ 118W		92	44N/ 100W
	19	48N/ 117W		56	38N/ 116W		93	44N/ 98W
	20	43N/ 115W		57	37N/ 117W		94	45N/ 98W
	21	43N/ 113W		58	37N/ 115W	NE	95	42N/ 102W
	22	44N/ 112W		59	36N/ 116W		96	40N/ 100W
WY	23	42N/ 110W	AZ	60	36N/ 114W		97	41N/ 100W
	24	42N/ 106W		61	36N/ 110W		98	42N/ 100W
	25	44N/ 106W		62	34N/ 114W		99	42N/ 98W
	26	44N/ 110W		63	34N/ 110W	KS	100	38N/ 100W
	27	43N/ 108W		64	34N/ 112W		101	39N/ 100W
MT	28	48N/ 115W		65	32N/ 112W		102	38N/ 98W
<W>	29	46N/ 114W		66	32N/ 110W		103	38N/ 96W
	30	47N/ 113W	UT	67	41N/ 113W		104	39N/ 96W
	31	46N/ 112W		68	41N/ 110W	MN	105	48N/ 96W
	32	48N/ 112W		69	40N/ 112W		106	46N/ 96W
<E>	33	46N/ 108W		70	38N/ 113W		107	48N/ 92W
	34	46N/ 106W		71	38N/ 110W		108	46N/ 94W
	35	47N/ 107W	NM	72	36N/ 108W		109	44N/ 96W
	36	48N/ 108W		73	36N/ 104W		110	44N/ 92W
	37	48N/ 106W		74	35N/ 106W	IA	111	43N/ 96W

State	**I.D.**	**Point (Lat/Lon)**	**State**	**I.D.**	**Point (Lat/Lon)**	**State**	**I.D.**	**Point (Lat/Lon)**
IA	112	42N/ 96W		153	30N/ 96W	AL	194	32N/ 88W
	113	42N/ 94W		154	30N/ 94W	NC	195	34N/ 82W
	114	42N/ 92W	WI	155	46N/ 92W		196	36N/ 82W
	115	43N/ 93W		156	46N/ 90W		197	34N/ 78W
MO	116	40N/ 92W		157	44N/ 90W		198	36N/ 78W
	117	40N/ 94W		158	44N/ 88W	MS	199	34N/ 90W
	118	38N/ 92W	MI	159	48N/ 88W		200	34N/ 89W
	119	37N/ 94W	<N>	160	46N/ 88W		201	32N/ 91W
	120	37N/ 90W		161	46N/ 86W		202	32N/ 90W
OK	121	36N/ 99W		162	46N/ 84W	GA	203	32N/ 84W
	122	35N/ 99W	<S>	163	44N/ 86W		204	32N/ 82W
	123	36N/ 97W		164	42N/ 86W		205	34N/ 85W
	124	36N/ 96W		165	44N/ 84W		206	34N/ 84W
	125	34N/ 96W		166	42N/ 84W	FL	207	30N/ 86W
LA	126	32N/ 94W	OH	167	41N/ 84W	<N>	208	30N/ 84W
	127	30N/ 94W		168	40N/ 84W		209	30N/ 82W
	128	31N/ 92W		169	41N/ 82W		210	28N/ 82W
	129	30N/ 91W		170	40N/ 82W	<S>	211	25N/ 81W
	130	30N/ 90W	IN	171	38N/ 88W		212	26N/ 81W
AR	131	36N/ 94W		172	38N/ 86W		213	26N/ 82W
	132	34N/ 94W		173	40N/ 87W		214	27N/ 81W
	133	35N/ 92W		174	40N/ 86W	WV	215	38N/ 82W
	134	35N/ 91W	KY	175	38N/ 88W		216	40N/ 82W
	135	36N/ 90W		176	37N/ 88W		217	38N/ 80W
TX	136	32N/ 98W		177	38N/ 84W		218	39N/ 80W
<Ne	137	34N/ 98W		178	37N/ 84W	VA	219	37N/ 81W
	138	32N/ 95W	IL	179	42N/ 90W		220	37N/ 80W
	139	33N/ 95W		180	42N/ 88W		221	-removed
<Sw	140	31N/ 105W		181	38N/ 90W		222	38N/ 78W
	141	30N/ 104W		182	38N/ 88W	MD/	223	39N/ 79W
	142	30N/ 102W	TN	183	36N/ 88W	DE	224	39N/ 78W
	143	31N/ 102W		184	35N/ 88W		225	39N/ 77W
<Nw	144	31N/ 105W		185	36N/ 84W		226	38N/ 76W
	145	31N/ 104W		186	35N/ 84W	NJ	227	39N/ 75W
	146	32N/ 102W	SC	187	35N/ 82W		228	40N/ 75W
	147	34N/ 102W		188	34N/ 82W		229	40N/ 74W
	148	34N/ 101W		189	33N/ 80W		230	41N/ 75W
	149	36N/ 101W		190	34N/ 80W	PA	231	40N/ 80W
	150	36N/ 102W	AL	191	34N/ 86W		232	42N/ 80W
<Se	151	30N/ 99W		192	34N/ 88W		233	40N/ 76W
	152	28N/ 99W		193	32N/ 86W		234	42N/ 76W

State	**I.D.**	**Point (Lat/Lon)**	**State**	**I.D.**	**Point (Lat/Lon)**	**State**	**I.D.**	**Point (Lat/Lon)**
NY	235	43N/ 79W	CT	241	42N/ 71W	ME	247	46N/ 70W
	236	43N/ 78W		242	42N/ 70W		248	46N/ 68W
	237	42N/ 76W	VT/	243	44N/ 73W		249	44N/ 70W
	238	42N/ 74W	NH	244	43N/ 73W		250	44N/ 68W
MA/	239	42N/ 73W		245	44N/ 72W		251	47N/ 68W
RI/	240	42N/ 72W		246	43N/ 72W			

APPENDIX D
ESRI Database Copyright and License Agreement

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