University of Redlands

**Web Maps for Environmental Learning at Highland Sam J. Racadio
Library & Environmental Learning Center**

A Major Individual Project submitted in partial satisfaction of the requirements
for the degree of Master of Science in Geographic Information Systems

by

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December 2012

Web Maps for Environmental Learning at Highland Sam J. Racadio Library &
Environmental Learning Center

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December 2012

Acknowledgements

First of all, I thank the Almighty God for giving me strength and grace to go through the project. I would like to thank Jack Dangermond, Esri President for his scholarship that enabled me to complete the program. Also the MS GIS program, University of Redlands for additional funding for my studies. I could have not accomplished this without their kindness.

I would like to thank my advisor Dr. Ruijin Ma for his guidance through the project. Without him, the project could have not been completed successfully. Special thanks to Ruben Ortiz, Assistant Systems Manager, University of Redlands; for troubleshooting and technical assistance. Thanks to Debra Riley, Program Coordinator, MS GIS Program, University of Redlands for all of her assistance; she was like a mother to me.

Very special gratitude to due to my wife Sarah for allowing me to come for my studies here in Redlands, California, leaving her alone in Kenya with all the family responsibilities. Thank you also for your continuous encouragement, prayers and best wishes.

I have also to thank Praveen Ponnusamy, Lead Developer in the JavaScript team at Esri; for his help in coding for my project; he helped me to understand the JavaScript API well.

Last but not least, I thank all the Cohort 21 students in the MS GIS program, University of Redlands for their assistance in one way or the other. In particular, I would like to thank Melodi King, Shreyas Shinde, and John Yembu.

Abstract

**Web Maps for Environmental Learning at Highland Sam J. Racadio Library &
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by

Clifford Otieno Okembo

There is an exponential increase in the environmental issues globally causing various destructive events to both people and resources. This has raised concern to the industry stakeholders and the governments at local, regional, and global levels. Highland Library located in the City of Highland in California was not left behind. With their mission to educate the public of the importance of sound environmental management through learning, they had a problem in identifying the best media to use in communicating this to a wider audience.

The project proposed the use of web maps for environmental learning. Using the ArcGIS API for JavaScript, ArcGIS Server, and ArcGIS Desktop, a web map application was developed that presented the identified environmental themes at different scale levels of the Library, City of Highland, County of San Bernardino, State of California, United States of America, and the World.

With the application running through a browser on desktop computer, the library visitors were able to easily visualize and understand the environmental themes presented.

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List of Acronyms and Definitions

API	Application Programming Interface
CSS	Cascading Style Sheet
ELC	Environmental Learning Center
GIS	Geographic Information Systems
HTML	Hyper Text Markup Language
HTTP	Hypertext Transfer Protocol
ICT	Information and communication technology
IDE	Integrated Development Environment
LEED	Leadership in Energy and Environmental Design
MS GIS	Master of Science in Geographic Information Systems
OGC	Open Geospatial Consortium
PPGIS	Public Participatory Geographic Information Systems
UGC	User-generated Content
W3C	World Wide Web Consortium
WGIS	Web-based Geographic Information Systems
WWW	World Wide Web

Chapter 1 – Introduction

Environmental management is a critical issue in the world today, more so with numerous cases of disasters such as floods, wild fires, soil erosion, and famine which have resulted from degradation of natural resources through poor agricultural practices, deforestation, mining, population increase, and urbanization. As a mitigation factor, many governments have resorted to environmental education and sustainable development. This campaign has not been limited to policy makers but has been extended to the upcoming professionals and ages as low as fifth grade students. A map is an effective way to present information to a diverse audience with varying analytical skills. Maps have been used in educating people in different disciplines. With the emergence of the Internet and web map technology, maps can now be effectively delivered to a wider audience via computer web browsers, mobile phones, and tablets. This report presents the development of a series of web maps for environmental learning. The project was completed for Raymond Carnes who is a volunteer at Highland Sam J. Racadio Library & Environmental Learning Center (ELC), located in the City of Highland, California. The web application uses maps to convey information about the environment and its conservation to library visitors at the library, city, county, state, continental, and global scale levels.

1.1 Client

The client for this project was Raymond Carnes, Implementation Engineer at Ursa Information Systems. The end users for the project are the library visitors represented by Lauren Bergh, Program Specialist at Highland Sam J. Racadio Library & Environmental Learning Center. The client was interested in teaching library visitors about the environment using digital maps over the internet, beginning from the library that is Leadership in Energy and Environmental Design (LEED) certified, to the whole world. The client also provided most of the data for the project.

1.2 Problem Statement

Communicating key environmental themes interactively is challenging, especially to an audience with basic or no analytical skills. The client identified web maps as the best way to go about this, but needed help to implement such web maps. The problem addressed in this project was how to use a geographic information system (GIS) over the Internet to present the environmental issues of interest to the general public, requiring little to no GIS skills or knowledge from the audience.

1.3 Proposed Solution

Web mapping has evolved to be the best way to deliver spatial information to a diverse audience. This project proposed to create a web map for each of the identified environmental themes at different geographical areas. Map documents would be created and published to a GIS server as map services. The map services would then be used to

create interactive web maps deployed to the client's computers through an internet browser.

1.3.1 Goals and Objectives

The primary goal of this project was to develop interactive web maps for environmental learning through the Internet on a computer. The following were specific objectives that assisted in meeting the stated goal:

- a) Design a GIS database that contains all the datasets for the project;
- b) Author map documents from the identified thematic data in the GIS database;
- c) Publish the map documents to a GIS server as map services;
- d) Develop interactive web maps using ArcGIS Application Programming Interface (API) for JavaScript to consume the published map services.

1.3.2 Scope

The project was based on the selected environmental themes at the library, city, county, state, continent, and global levels; not all environmental themes were incorporated. The maps had navigation, exploration, and interaction functionalities, but no analysis or geoprocessing functionalities. The web application was designed for personal computers with a screen resolution of 1280x1024 and above, running Microsoft Windows XP Operation System and Internet Explorer 7.0.

1.3.3 Methods

ArcCatalog, an ArcGIS Desktop 10.0 application, was used to scrub the datasets received from the client, project them to the Web Mercator coordinate system, and to modify fields in the attribute tables where necessary. It was also used to build a file geodatabase, which stored and organized the datasets in feature datasets based on the geography, including Library, City of Highland, County of San Bernardino, California, USA, and the World. The ArcMap application was then used to symbolize, label, and author map documents. ArcMap was also used to create Map Service Definition files that were published to ArcGIS Server 10.0.

ArcGIS Server 10.0 was used to host dynamic map services. A web application was built using the ArcGIS for JavaScript API 3.1 that consumed these map services along with basemaps hosted by Esri. The web application was tested on Internet Explorer 7.0 and deployed to the client's site for use by the library visitors. Figure 1-1 shows the workflow implemented in the project.

Figure 1-1: Workflow used in the project

1.4 Audience

This report is intended for professionals from different disciplines with basic GIS and information technology skills. These include ELC and City of Highland staff involved in the management of the ELC or interested in ELC programs.

1.5 Overview of the Rest of this Report

This report is organized in seven chapters. Chapter Two presents a literature review of previous work related to the use of GIS for learning, environmental education, and web mapping. Chapter Three discusses the system analysis and design of the project, including the overall project plan. Chapter Four outlines the database design, and database conceptual and logical models. Chapter Five focuses on the steps taken to implement and complete the project. Chapter Six provides the use case of the developed application. Finally, Chapter Seven provides summary drawn from this project and ideas for possible future work.

Chapter 2 – Background and Literature Review

Referring to past research done in the project domain is vital for any project. It provides insights and best practices for executing an operation. This chapter investigates the previous work done on web mapping and its use in learning and environmental education. The chapter is arranged into four sections: Section 2.1 reviews the work done in the web mapping domain; Section 2.2 investigates the use of World Wide Web for learning and education; Section 2.3 examines the web mapping as used for environmental management; and Section 2.4 summarizes the chapter.

2.1 Web Mapping

Web mapping is a relatively new concept which has been strengthened by the development of the Web 2.0. It is composed of a bi-directional communication between the server hosting services and the consumers using their diverse devices. Web 2.0 has been described by Fu and Sun (2011) as a read-write Web that features an abundance of user-generated content (UGC) and a reverse (i.e., bottom-up) information flow. People often use the Internet for most of their day-to-day work. According to Haklay, Singleton, & Parker (2008), the rapid developments in Web mapping and geographic information use have been facilitated by global trends in the way individuals and communities use the Internet and new technologies to create, share and use information, through innovative and collaborative applications.

Web mapping requires services that are hosted in servers. There are different definitions of Web mapping or Web GIS. Fu and Sun (2012) defined it as GIS that uses web technology to communicate between components. They explained that Web GIS is a type of distributed information system and further illustrated that a web GIS should have a server and a client; where the server is a web application server, and a client that can be a web browser, a desktop application, or a mobile application.

For a web map to be interactive, the user interface has to be designed with the audience in mind. Rattray (2006) called this Web-based Geographic Information System (WGIS) and pointed out that building effective partnership, emphasizing accessibility in the user interface, and developing flexible system architecture were the three most important aspects of community-based WGIS projects. He added that light-weight clients should be considered for those with limited access to broadband connectivity. The process of users interacting with a web map by querying, editing, and even making decisions is referred to by some scholars as a Public Participatory Geographic Information System (PPGIS). User experience has become an important consideration for Web application design, including Web GIS design. Therefore, the goal of PPGIS is to involve the general public in producing needed data and participating in decision making through the use of GIS (Fu & Sun, 2011).

Web design should be inclusive and factor in future changes in technology and environment. Fu & Sun (2011) pointed out that the most important component in a web GIS is the web GIS server. For the success of a web GIS application, the server's functionality, customizability, scalability, and performance are to be critically considered. This is because the capability and quality of a Web GIS application is

greatly determined by the Web GIS server. Zaslavsky (2000) pointed out that the system should be able to accommodate almost any client browser and provide access to significant GIS functionality and large databases residing on a server. Apart from the web server, there are other factors that may be considered, including bandwidth, price, graphic quality, interactivity, and the server and client side compatibility considerations as listed by Zaslavsky (2000).

Maps are very important in communicating GIS data and results. Kraak emphasized that maps are obviously playing important roles in GIS. He believed that “not only do they present the final results of the spatial analysis, but they are also critical during the whole iterative process of geospatial data handling. The popularity of GIS has had a great impact on maps” (Kraak, 2004, p. 83). Cartwright et al. (as cited in Kraak) pointed out that new media such as the Web not only allow for dynamic presentation but also for user interaction. Kraak (2004) argued that maps are not just a medium to display final results but are used anywhere in the geospatial data handling process. Developments in information and communication technology (ICT) have also brought mapping closer to other disciplines and influenced people’s approach to maps.

According to Kraak (2004), millions of maps are being made today and used by an audience that would not necessarily have thought of creating maps themselves in the past. He pointed out that web maps have some advantages that are shared with all digital maps. One can zoom in or out, and layers can be switched on or off. A map can also be queried; clicking a symbol can give access to the database behind the map. Simple operations such as measuring distance or areas can be executed. This makes web maps more interactive. He added that surfers expect interactivity because if they cannot interact with the Web page, the web page will be considered dull, and it is very likely they will move on to the next website.

In his campaign for web maps, Kraak (2004) said that the great advantage of web maps was that the Web allowed one to offer the data and maps platform independently and a virtually unlimited number of users can access the map anywhere at all times. But there are factors that have to be considered while using the web resources. Among these are Internet connection, traffic intensity, data efficiency, and capacity of the client and server machines. There are many vendors for web mapping infrastructures, both commercial and non-commercial. He explained that many maps used in a Web GIS environment were Internet mapping solutions based on products offered by organizations, for instance, Esri. There were also some academic non-commercial and open source software developments available for use, such as MapServer.

2.2 Use of the World Wide Web for Learning and Education

Since the birth of the internet, the World Wide Web (WWW), commonly referred to as the Web, has found numerous uses in various application fields. Education has also not been left behind. Much research is done through the web. Online studies and distance learning have emerged, as well as electronic learning or e-learning. Zaïane (2001) pointed out that the rapid development of the Web has made it the most important media for collecting, sharing, and distributing information. It has become a universally day-to-day tool for the common people, starting from a child sharing music files with friends to a senior receiving photographs and messages from grandchildren across the world.

The use of the Web in education has expanded tremendously from sharing course content and course development to curriculum development and delivery. The field of GIS education has also used the web for different applications. In his research about GIS education for K-12 education, Baker (2005) found that Internet-based mapping provides a powerful means for successfully establishing GIS technology in the K-12 education community. This is because it helped to avoid the barriers associated with desktop GIS. These technology-supported learning expanded both the data available for student use and the scale of their explorations, allowing for infinite variations in students' search for explanations. Tsou and Yanow concurred with Baker that, "students can learn spatial literacy and geographic knowledge in real-world scenarios via Web-based forums among others" (Tsou & Yanow, 2010, p. 46).

Baker realized that for many classrooms, particularly at the elementary and middle school level, Internet-based mapping provides enough spatial and database query tools to extend classroom learning to include greater emphasis on analysis. Though Internet-based mapping do not often have the analytical power of a desktop GIS, they have a variety of functionality that are better suited to the K-12 classroom. These analysis activities can allow students to identify distributions, create targeted searches, reclassify data, construct buffer zones, gauge proximities and bounding regions, and launch queries. Internet-based learning is possible because Internet access is almost ubiquitous in K-12 education in the USA. Research showed that Internet access was present in 99 percent of schools and 92 percent of instructional classrooms across the United States (Baker, 2005).

Tsou and Yanow (2010) affirmed that Web-mapping technology provides easy access to local, national, and global geospatial information. With the establishment of geospatial cyber infrastructure, such as the National Map and the National Atlas, National Aeronautics and Space Administration (NASA) Earth Science Gateway, and Geospatial One Stop, students are able to explore the world at both macro and micro scales, and to study various scientific and social subjects, such as volcano eruptions in Iceland and urban sprawl in Brazil. Web maps also facilitate scientific inquiries by integrating thematic maps, census data, and satellite images. Open-access 3D viewers, such as Google Earth, help students understand urban and rural environments, ocean currents, land uses, and spatial patterns in various subjects. Tsou and Yanow (2010) emphasized that the main goal of GIS professionals, especially educators, is to equip students with a spatial literacy foundation including spatial awareness and spatial and quantitative reasoning methodologies. These can help students to discover the value of geographic knowledge and develop their ability to explore and visualize real-world critical problems such as global climate change, natural disaster recovery and responses, and watershed conservation.

2.3 Web Mapping for Environmental Learning

Web maps have been used in environmental learning among many other applications in education. The main goal has been to equip students with the sense of environmental management and care for their surroundings. Blaut, J. M., George, McCleary, and Blaut, A. S. (1970) studied whether a test population of North American and Puerto Rican children of school-entering age, mainly six-year-olds, could interpret and utilize an environmental map without training or prior exposure to the representation. They

concluded that “if preliterate first graders have the ability to interpret vertical aerial photographs at first sight, and to derive and use an environmental map without instruction, then the teaching of macro-environmental concepts from geography, biology, and social science need not be postponed until literacy has been acquired. These concepts can be introduced at the age of five or six through the visual medium of maps and aerial photographs” (Blaut, George, McCleary, & Blaut, 1970, p. 348).

According to MacEachren (1992), a person’s environmental knowledge depends upon how knowledge is acquired and mentally processed. What people know about an environment depends on how knowledge is acquired and on the mental processes by which that knowledge is organized, stored in memory, and later retrieved. He also found that interactive computer systems have the potential to influence learning strategies by controlling the manner in which mapped information is presented. He suggested that a successful system for computer-assisted environmental learning requires an overview map to help people make the jump from disconnected fragments to a holistic representation.

Discussing environmental management by use of web mapping, Gordin, Gomez, Pea, and Fishman (1996) suggested that evaluating the data obtained over the Internet often requires flexible tools that allow the iterative selection of data and analytical operations on it. They indicated that tools like this were becoming increasingly common on the web through the use of forms. A server can facilitate the interactive exploration of digital maps through the operations of selecting a part of the globe, zooming in on the globe, and specifying what aspects to portray, e.g., rivers or political boundaries. In this manner, not only is information provided, but an environment for querying and investigating that information is specified. In talking about applications of web maps in the environment, they gave a fascinating example of an application called the World-Wide Earthquake Locator that combines the information on recent earthquakes with the map server to provide customized maps of where recent earthquakes occurred (Gordin, Gomez, Pea, & Fishman, 1996).

2.4 Summary

In this chapter, previous work in the domain of the project was examined. The chapter discussed the concept of web mapping, its development, and current applications. The use of the web was investigated, especially its use for learning and education. Finally, web mapping and its application in environmental learning was discussed. The chapter affirms that it is possible to use the Web to sensitize students to the concepts of environmental management by showing them different environmental themes through maps. It is also believed that from what students see and interact with, they are able to change their behavior and perception of the world they live in. This will ultimately be incorporated in their choices and decisions as they grow and later on help them to make good policies for their areas of concern.

Chapter 3 – Systems Analysis and Design

This chapter elaborates the system design that was used in the project. System analysis and design are key concepts and milestones in project management: they give the overall picture of the project, and their successes lead a successful project. The chapter is arranged in five sections. Section 3.1 states the problem to be solved, Section 3.2 elaborates the requirements for the project, Section 3.3 discusses the system design, Section 3.4 presents the project plan, and finally, and Section 3.5 summarizes the chapter.

3.1 Problem Statement

The environment is deteriorating at a faster rate than the efforts put to restore it. Different methods and media have been used to sensitize people about the benefits of environmental management. Internet technology is also developing at a faster rate and many people use it every day. The client identified a web map as the best way to communicate to an audience about environmental management, but he needed help to implement this. The problem addressed in this project was how to use a geographic information system (GIS) over the Internet to interactively present the environmental issues of interest to the general public.

3.2 Requirements Analysis

The requirements for this project were classified into functional and non-functional requirements. Functional requirements are those that satisfy the user's needs and are parts of the system that users directly interact with. These were derived after deliberations with the client to learn what specific issues needed to be addressed in the final output. Some of the features identified included the user interface and thematic maps.

Non-functional requirements were also identified. These are features in the final output that the users do not necessarily have to interact with directly, but support the functional requirements. These non-functional requirements can be viewed as technical, operational, and transitional requirements, such as the development language and the required web browser. All the requirements identified were listed and described in Table 1.

Table 1. System Requirements.

Requirement	Description	Type
Thematic maps	At least two maps for every geographical area	Functional
Map navigation	Mouse only used to explore the maps; no keyboard input	Functional

Requirement	Description	Type
Text and picture information	Provide background information about every theme presented	Functional
Detailed Information about features	To give more information on any clicked point on the map via a pop-up window	Functional
Desktop Computer	System to run on a specific computer; no laptop, mobile or tablet	Non-Functional
Internet Explorer	The only browser allowed in the library	Non-Functional
ArcGIS JavaScript API	Client side development language	Non-Functional
ArcGIS for Desktop	For data management and map making	Non-Functional
ArcGIS for Server	For serving the maps to the internet	Non-Functional
Hosting Server	University of Redland's server was used as the client plans to procure their own	Non-Functional
User manual	Brief and simple step-by-step instruction to help new users familiarize themselves with the system operation	Non-Functional

3.3 System Design

Based on the client's needs and requirements, a system was designed to facilitate the successful execution of the project. The system was designed with three main components: a geodatabase, map services, and a web application. The use of the web application is highlighted and the communication between the components illustrated. Figure 3-1 presents a diagram of system design.

Figure 3-1: System design

There is a cycle of operation between the publishing of map services and the consuming the web application stages. Whenever a user opens the application or clicks on anything in the application, a request is sent based on Hypertext Transfer Protocol (HTTP) to Internet Information Services (IIS) web server through the Internet. On receiving the information, the web server sends the request to the GIS Server which hosts the map services. The map services are made of the data kept in the database server, so the database server is then requested to provide the information needed. A response is then initiated from the database server, through the GIS Server, IIS, the Internet, and finally to the computer from which the user sent the request. Figure 3-2 demonstrates how the communication takes place between the system components.

Figure 3-2: Cycle for consuming a service

3.3.1 Geodatabase

Data received from the client was made suitable for the project using ArcGIS Desktop 10.0. ArcCatalog application, which is a data management application in ArcGIS Desktop, was used to scrub the datasets by adding required but missing information, deleting unrequired content, standardizing information, and projecting the data to a common coordinate system. The datasets were then organized in feature datasets inside a file geodatabase. The vector data types were put in the feature datasets as feature classes, while the raster data type were arranged in the file geodatabase root as raster datasets. A file geodatabase, as opposed to personal geodatabase, was used because it is an improved version of personal geodatabase as it is scalable, does not restrict the file size, and is recommended for use in both small to large implementations by the software company.

3.3.2 Map Services

ArcMap, a mapping application for ArcGIS Desktop, was used to arrange the relevant datasets as layers, to symbolize them appropriately, and to label them accordingly. The layers were then saved as map documents (.mxd). The .mxd files were then analyzed and saved as map service definition files (.msd) which are optimized format for web maps using a Map Publishing Toolbar. ArcGIS Server 10.0 was used to create map

services. The .msd files created above were published to ArcGIS Server with mapping and enabled keyhole markup language (kml) capabilities. Mapping capabilities allowed the service to be consumed as a map service using ArcGIS related technologies, while enabling kml allowed the service to be consumed by other technologies that comply with the Open Geospatial Consortium (OGC) mapping standards.

3.3.3 Web Application

ArcGIS API for JavaScript 3.1 was used to create a web application by mashing-up the Esri basemaps, available free on the Internet, with the map services published. Hyper Text Markup Language (HTML 4.01), a web development language, and Cascading Style Sheet (CSS3), a language that defines how to display HTML elements, were used to design the web interface. The web application allowed users to view different thematic maps, navigate through the themes, see picture and text information, and query for detailed information about features presented.

3.3.4 Consuming the Web Application

The web applications developed were then ready for use on personal computers; the client restricted the use of the application to a specified stationary computer. Internet Explorer 7.0 running on the Windows XP operating system was used to consume the application because the client did not have a budget for system upgrade or for an up-to-date computer.

3.4 Project Plan

Planning is very crucial for a successful project. The project plan was divided into five main phases: initiation, planning, implementing, quality control, and closing. Table 2 provides an overview of the project plan and Table 3 lists the activities in each phase of the project plan.

Table 2. Phases of the project plan

	Months							
Phase	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Initiation
Planning
Implementing
Quality Control
Closing

Table 3. Activities in the phases of project plan

Name	Duration (days)	Start Date	Finish Date
Initiation			
Identify goals and objectives	5	5/7/2012	5/11/2012
Document project cost and benefits	5	5/14/2012	5/18/2012
Planning			
Define scope	1	5/21/2012	5/21/2012
Develop project schedule	4	5/22/2012	5/25/2012
Plan for quality	5	5/28/2012	6/1/2012
Develop system requirements	5	6/4/2012	6/8/2012
Develop risk plans	5	6/11/2012	6/15/2012
Implementing			
Develop GIS database	15	6/18/2012	7/6/2012
Create map services	15	7/9/2012	7/27/2012
Develop web applications	40	7/30/2012	10/12/2012
Test web applications	5	10/15/2012	10/19/2012
Quality Control			
Manage scope and requirements	115	5/21/2012	10/26/2012
control schedule	148	5/28/2012	12/12/2012
Manage risks	95	6/18/2012	10/26/2012
Control quality	138	6/4/2012	12/12/2012
Document processes	163	5/7/2012	12/12/2012
Closing			
Deploy to the client	5	10/22/2012	10/26/2012
First draft report	5	10/29/2012	11/2/2012
Review of first draft by the Editor and Advisor	10	11/5/2012	11/16/2012

Name	Duration (days)	Start Date	Finish Date
Incorporate suggested edits from the Editor and Advisor	5	11/19/2012	11/23/2012
MIP Defenses	12	11/26/2012	12/11/2012
Incorporate suggested edits from the MIP Committee	5	12/5/2012	12/11/2012
MIP final copy submission	1	12/12/2012	12/12/2012

The implementation of the plan was on schedule because the project could not be extended beyond December 12, 2012. Research into the best technology to use in executing the project was done concurrently with the project execution so as to save time. Though planning and executing are different aspects in project management, the planned schedule aided in timely delivery of the results and successful completion of the project.

3.5 Summary

This chapter discussed the system analysis and design. The system requirements were analyzed, grouped into functional and non-functional requirements, and documented. It was important to design a system based on the needs specified by the client. The chapter illustrated how the design was done, the main components of the system, and how they work together. Planning is a very important activity in project management, the project planning was done and the chapter detailed how the schedule was for the whole project.

Chapter 4 – Database Design

Database design is an essential milestone in project management. In order to reflect the reality of the geography represented and to assure the success of the project, a sound database was designed. This chapter discusses how conceptual and logical data models were developed. Section 4.1 explains the conceptual data model; Section 4.2 illustrates the logical data model, giving clarification on the sources of data, the data collection methods, and the data scrubbing and loading methods; and Section 4.3 gives a summary of the whole chapter.

4.1 Conceptual Data Model

Designing a conceptual model is necessary in understanding the client's problem and for developing a working solution. A conceptual model describes the client's entities of interest and their relationships. It is independent of any particular implementation approach and does not apply any database model.

Based on the client's need, a map viewer was designed. At least one map is displayed inside the map viewer. Each map must have a legend and one or more description information. At least one map is organized in a scale level and a scale level is contained within another scale level. Figure 4-1 shows the conceptual data model designed for the project.

Figure 4-1: Conceptual data model

4.2 Logical Data Model

A logical data model was derived from the conceptual data model. Great care was taken in its design since it was the model used in the implementation of the project. It detailed all the feature classes and raster datasets that were organized in a file geodatabase (.gdb) using ArcGIS Desktop 10.0. Inside the file geodatabase, six feature datasets were created based on the six scale levels of maps. All the datasets used were projected to the WGS 1984 Web Mercator projection system, which is the ideal projection for any dataset intended for display over the web. Six diagrams were developed to illustrate the feature datasets and the scale levels described in the conceptual model. In each, sources of data, data collection methods, and data scrubbing and loading methods were explained.

4.2.1 Scale 1: Library and Environmental Learning Center (ELC)

This level demonstrates how both the interior and exterior of the Library were represented. Four feature classes were used to represent the library within two maps. Figure 4-2 lists the four feature classes within the S1_Library feature dataset.

Figure 4-2: Logical data model for Library & ELC scale

Map data were provided for this level in hard copy of a drawing of the building to be used for the inside map. These data were scanned into an image in JPEG format. It was then georeferenced and digitized to produce three feature classes, namely perimeter, wall, and interior library layout. No data were provided for the exterior map, so they were digitized from an Esri imagery basemap available over the Internet into the external feature class. Three attributes were added to all the feature classes created: the names of a building section, a description of its function, and a photograph of the section. All the feature classes were then imported into the S1_Library feature dataset.

4.2.2 Scale 2: City of Highland

At this scale, two feature classes were used to represent the public transportation within the City of Highland. Omnitrans is the only means of public transportation in the city. Its route was mapped and represented as a feature class. A boundary feature class showing

the extent of the city was also created. Both were stored in S2_HighlandCity feature dataset. Figure 4-3 provides a list of the feature classes in the feature dataset and a thumbnail of the city boundary.

Figure 4-3: Logical data model for the City of Highland scale

The client provided data for this scale in a shapefile format at the extent of the County of San Bernardino. The datasets were clipped to the extent of the city and then exported to the S2_HighlandCity feature dataset created. There were many attribute fields in the original data that were not needed and hence, deleted. New attributes were created to represent the information needed. The OmnitransRoute feature class finally had three fields: the name of the service authority, the route number, and a link to a photograph representing the bus route.

4.2.3 Scale 3: County of San Bernardino

Four feature classes and a raster dataset were used to represent four themes at the County of San Bernardino scale level. The feature classes were stored in the S3_SanBernardino feature dataset, while the raster dataset was stored in the Highlandlibrary.gdb. Figure 4-4 shows the feature classes, the raster dataset, and a thumbnail of the county boundary.

Figure 4-4: Logical data model for the County of San Bernardino scale

All datasets used in this scale level were received from the client in shapefile or TIFF image format. The shapefiles were exported to the feature dataset as feature classes and the image was exported to the geodatabase as a raster dataset. Some attribute fields were deleted from the datasets as they were not needed. These additional attributes were added to the City and PublicTransportation feature classes: the name, a description, and a link to a picture showing both the route and route number for PublicTransportation feature class.

4.2.4 Scale 4: State of California

Two themes — protected areas and human impacts — were represented at this level by three datasets: two feature classes and one raster dataset. The feature classes were stored in the S4_CaliforniaState feature dataset while the raster dataset was stored in the Highlandlibrary.gdb. Figure 4-5 lists the feature classes, the raster dataset and a thumbnail of the state boundary.

Figure 4-5: Logical data model for the State of California scale

The client provided the State Boundary and ProtectedArea datasets in shapefile format, which were imported into the S4_CaliforniaState feature dataset. The Human Impacts raster dataset was downloaded from ArcGIS.com website as a map package (.mpk) covering the whole western United States region. The raster was then extracted and clipped using the State Boundary feature class to the extent of California.

4.2.5 Scale 5: United States of America

Four feature classes were used at this level to represent three themes of top and bottom ten green states, parks, and protected areas in the United States of America. They were all stored in the S5_USA feature dataset. Figure 4-6 shows the feature dataset with the feature classes it contains and a thumbnail of the States Boundary.

Figure 4-6: Logical data model for the United States of America scale

The States Boundary and ProtectedAreas datasets were provided by the client as shapefiles. They were converted and stored in the feature dataset as feature classes. Parks data were downloaded from the ArcGIS.com website as a layer package (.lpx), which was extracted and imported into the feature dataset. The top and bottom ten green states data were extracted using the States Boundary feature class. Existing attribute were all deleted, and new ones were added based on the information obtained from the <http://247wallst.com> website. The website contained information about ranking of all states based on their green indicators and provided a list of the top ten green states and bottom ten green states. It also provided information about the criteria used in ranking, the elements considered, and photographs representing the green factors in those states.

4.2.6 Scale 6: World

Six themes were represented at this level by seven datasets: five feature classes and two raster datasets. The feature classes were stored in the S6_World feature dataset, while the raster datasets were store in the Highlandlibrary.gdb. Figure 4-7 provides a list of all the feature classes, the raster datasets, and a thumbnail of the Countries Boundary.

Figure 4-7: Logical data model for the World scale

Apart from the Top Ten Green Countries and Human Impacts, the client supplied all other datasets in shapefile or TIFF image format. All were exported to the S6_World feature dataset except for the Earth by Night and Land Cover datasets, which were exported as raster datasets into the Highlandlibrary.gdb. The Human Impacts data was downloaded from the ArcGIS.com website as map package (.mpk). They were in point data type and were converted to a polygon feature class for better viewing and stored in the feature dataset. The top ten green countries list was retrieved from the <http://green-buzz.net> website in HTML format. This was used to extract the top ten green countries listed from the Countries Boundary feature class. The existing attribute fields were replaced by the new ones from the web document, which showed the name of the county, its rank, a description of what makes it green, and a link to a photograph.

4.3 Summary

This chapter detailed the conceptual and logical data models. The conceptual data model depicted the reflection of the entities of interest. The logical data model represented the model developed to meet the client's need, the GIS database used, how it was organized, and the datasets that went into it.

Chapter 5 – Implementation

A web application was developed for this project. Using the application, the client was able to view maps of different environmental themes at various scales of the Library, City of Highland, County of San Bernardino, State of California, United States of America, and the World. This chapter illustrates how the project was implemented and is organized in four sections: Section 5.1 explains how the map documents were prepared; Section 5.2 demonstrates how the map services were published; Section 5.3 details how the web application was developed; and Section 5.4 gives a summary for the whole chapter.

5.1 Preparing Map Documents

After all data were loaded to the geodatabase, map documents were prepared for all the themes identified at each scale level. The feature classes were added into the ArcMap as layers with appropriate symbolization and labeling.

A total of eighteen maps were prepared for the project. At the scale level of the Library, two maps were made to represent the floor footprint and view from above of the library. The Public Transportation map was done at the scale level of the City of Highland. Four maps — Protected Areas, Cities, Public Transportation, and Land Cover — were compiled at the County of San Bernardino scale level. For the State of California scale level, two maps — Protected Areas and Human Footprint — were created. Three maps — Top and Bottom Ten Green States, Parks, and Protected Areas — were generated for the United States of America scale level. Finally, for the scale level of the world, six maps were created: Land Cover, Ecoregions, Top Ten Green Countries, Earth by Night, Human Footprint, and Population Density. The map of most and least green states in the United States of America is illustrated in Figure 5-1 as an example of the maps generated; Appendix A provides all the other maps.

Figure 5-1: Map document for most and least green States in the USA

5.2 Publishing Map Services

The map documents prepared were ready for publishing using ArcGIS Server 10.0. Using the Map Service Publishing toolbar in ArcMap, they were first analyzed using the Analyze Map tool to check for any errors, warnings, or general messages that could compromise the performance of the services created, such as the coordinate system conflict, presence of online basemaps, and labeling at all scale levels. Figure 5-2 shows Map Service Publishing toolbar used to analyze and map service definition files.

Figure 5-2: Map Service Publishing toolbar

Map services could not be published if any errors existed. Warnings are issues that need to be looked into, but are not required to be corrected for map services to be published. All the warnings were worked on and necessary adjustments were made for the warnings. Messages are general information that need to be worked on, but do not affect the service. All the messages were also looked into and worked on accordingly.

The analyzed maps, free from errors, warnings, and messages, were then saved as map service definition (.msd) files using the Save Map Service Definition tool. The .msd is an optimized format for map services, and is the format highly recommended for web maps.

There are two ways of publishing a map service. The first is through the ArcGIS Server Manager, a user interface for ArcGIS Server. The second one is through the Catalog window within ArcGIS for Desktop. The second method uses the power of ArcGIS Server in the background; a connection has to be established for the ArcGIS Server to run within ArcGIS Desktop. The project used the second method so as to take advantage of viewing the map in ArcGIS Desktop, as well as previewing the map service created in the same application.

5.2.1 Connecting the ArcGIS Server to ArcGIS Desktop

Using the second method of publishing the map service, ArcGIS Server was added to the Catalog window in ArcGIS Desktop. This was accomplished in two steps. The first step was to check the GIS Servers option through ArcCatalog options window as shown in Figure 5-3.

Figure 5-3: Check GIS Servers in ArcCatalog application

This made the GIS Servers to be accessible through Catalog window in ArcMap application as shown is Figure 5-4.

Figure 5-4: GIS Servers folder in Catalog windows

ArcGIS Server was added to the GIS Servers using the Add ArcGIS Server command within the GIS Server folder which connects the ArcGIS Server to the ArcGIS Desktop, as in Figure 5-5.

Figure 5-5: Add ArcGIS Server command

Upon double clicking the command, a dialog box popped up and prompted for the type of connection to be established, either using or managing GIS services. Manage GIS services was chosen to enable administrative privileges. The next dialog box presented a second window where the Universal Resource Locator (URL) and the host name of the ArcGIS server instance were specified. The connection process was completed when the finish button was clicked, as illustrated in Figure 5-6.

Figure 5-6: Connecting to ArcGIS Server

The name of the ArcGIS Server instance could then be found in the server's list within ArcGIS Desktop. It was connected as an Administrator, and was then used to publish map services. Figure 5-7 shows the ArcGIS Server instance added with administrative privileges.

Figure 5-7: ArcGIS for Server instance in the Catalog window

5.2.2 Publishing Map Services

After establishing ArcGIS Server connection to the ArcGIS Desktop, the map service definition (.msd) files created were published to ArcGIS Server from the Catalog window in ArcMap as map services. To do this, the specific .msd file was right clicked and Publish to ArcGIS Server was chosen from the context menus that appeared, as demonstrated in Figure 5-8.

Figure 5-8: Publish to ArcGIS Server

This opened a Publish to ArcGIS Server wizard. In the first window, the server name, service name, and the folder to store the service were entered, as shown in Figure 5-9.

Figure 5-9: Defining a map service

In the next window, the capabilities of the service were specified. The first was the Mapping capability which is a default and mandatory capability for map service. The second was the KML capability, which granted the map service capability to be used by other non-ArcGIS platforms that comply with the OGC standards. Figure 5-10 shows the capabilities that were chosen for the map service published.

Figure 5-10: Capabilities for the map service

The same process was followed for all the eighteen .msd files that were prepared. They were then accessible from the ArcGIS Server Directory, a component of ArcGIS Server that maintains a catalogue of all the services published as shown in Figure 5-11.

Figure 5-11: ArcGIS Server Directory

5.3 Developing Web Application

Two Integrated Development Environments (IDE) were used in the development: Aptana Studio3 and Notepad++. The former was used in the initial development because it is intuitive and autocompletes the codes; the latter was used for code modification or minor changes because it is fast due to its few functionalities.

Three development languages were used: HTML, CSS and JavaScript. HTML 4.01 was used to design the interface and acted as a container for the other languages. The project used HTML version 4.01 because it was the latest version and also in strict compliance to the World Wide Web Consortium (W3C) standards for HTML. Cascading Style Sheet Version 3 (CSS3) was used for styling purpose in the application. JavaScript was the main development language. Specifically, the project used the ArcGIS Application Programming Interface (API) for JavaScript, which is used for consuming map services on the web. The API runs on the dojo framework, which helps in writing robust and efficient JavaScript code. Figure 5-12 presents the languages used and their dependencies: ArcGIS API for JavaScript built on dojo toolkit within JavaScript; JavaScript codes run within the HTML elements; and CSS is used for styling the HTML elements.

Figure 5-12: Programming languages used

5.3.1 Required Modules

Several modules were imported for use in the application from the ArcGIS API for JavaScript library. These included the widgets that were instrumental in enabling several functionalities in the application. All the modules used in the ArcGIS API for JavaScript were built using the digit module which is the user interface framework built on top of Dojo toolkit. They were imported using the `dojo.require()` class. Table 3 lists the modules that were imported and their functions.

Table 4. Required modules and their functions

Module	Function
dijit.dijit	Added prepackaged user interface components from dojo to application
esri.map	Facilitated mapping capability
esri.dijit.FeatureLayer	Facilitated working with feature layers
dijit.layout.BoarderContainer	Design boarder containers for the interface
dijit.layout.ContentPane	Design content panes for the interface
dijit.layout.AccordionContainer	Designed the application's layout
dijit.layout.TabContainer	Designed the tabs
esri.dijit.Legend	Imported map legend
esri.dijit.PopupTemplate	Configured the pop-up parameters
esri.dijit.Popup	Configured the pop-up window
esri.dijit.Gauge	Created a dashboard

5.3.2 Layout Design

The layout of the application was built using both HTML <div> tags and imported modules. The <div> tags are one of the recommended ways of designing a webpage layout. For better layout design, the digit modules were used together with the <div> tags. These included the Accordion Container for designing the user interface and being a repository for the other layout digits, the Boarder Container for dividing the interface into different regions, the Content pane for managing the information put within a specific region of the interface, and the Tab container for specifying the title on the left region.

The application had five regions designed as shown in Figure 5-13. The top region contained six menus representing the six scale levels of the maps. Within each menu, unique sub-menus representing each theme at that scale level. Both the menus and sub-menus were used to navigate from one scale level to others and to navigate from one theme to others. The left region contained brief instructions on how to explore the map, a legend for the specific theme, and charts. The center theme contained the map with interaction capabilities, such as zooming, panning, hovering, and clicking. The right region had the background information for the theme presented. For some themes, this region displayed the results of user interactions. The bottom region was for footer information.

Figure 5-13: Application graphic user interface design

5.3.3 Cascading Style Sheet

Cascading Style Sheet (CSS) is a language used to define how HTML elements are displayed or generally, essentially for styling the HTML elements. A CSS file was created separately to reduce the amount of codes in the HTML files. The styles specified using CSS included, among others, the font type, font color, background color, and borders' styles. CSS was also used in the layout design by specifying the size of all the regions, the background color, and the borders. CSS uses the elements id or class to specify property. Each <div> tag was assigned a unique id that was used by CSS to specify their properties. A link to the CSS file created was defined within the HTML

files. Another link was also created to the hosted CSS in ArcGIS.com website. This is a default CSS developed to work with the ArcGIS API for JavaScript and is required for any application. Figure 5-14 shows an example of the CSS file created for the application. All the styles specified in the CSS file are provided in Appendix B.

```
37  html, body {  
38      height: 100%; width: 100%; margin: 0; padding: 0;  
39  }  
40  body {  
41      background-color: #777; overflow: hidden; font-family: "Trebuchet MS"; color: white;  
42  }  
43  #map {  
44      overflow: hidden; padding: 0;  
45  }  
46  .rightPaneTitle {  
47      font-weight: bold;  
48  }  
49  .esriLegendServiceLabel {  
50      display: none;  
51  }
```

Figure 5-14: A sample of CSS styles

5.3.4 Application Functionality

Instead of deploying ArcGIS API for JavaScript 3.1 library locally, a link was created so as to consume the one hosted at the ArcGIS.com website for free. The 3.1 version was chosen because it was the latest release by then.

JavaScript code was written to add map layers and to configure the required functionalities to the application. A function was used to specify the map details and was called any time the page was loaded using `dojo.addOnLoad()` class. Within this function, the map extent was specified using `esri.geometry.Extent()` class to ensure that every time the application is launched, the required area is displayed by default. A basemap layer from the ArcGIS online website was added to the application using `esri.layers.ArcGISTiledMapServiceLayer()` class to provide background information and to orientate the map user. Map services published in this project were added as operational layers using `esri.layers.ArcGISDynamicMapServiceLayer()` class. Operational layers were also used to configure the legend widget, which only works with map service layers. A layer from the map service was also added using the `esri.layers.FeatureLayer()` class and was used to configure popup and gauge widgets.

Various functionalities were added to the application created; these included the legend which was displayed on the left pane using the legend widget. The legend was configured to consume the legend information from the map service and set to draw at any time the application is launched using the `legend.startup()` class. Figure 5-15 shows a sample legend from the world population density theme.

Figure 5-15: Sample legend

Popup window was configured for all the map services with vector layers, but not for map services with raster layers because raster layers do not support pop-up. Map services for larger geographical areas and less information were displayed using the pop-up window. Figure 5-16 shows a pop-up window displayed from the California Protected Areas theme.

Figure 5-16: Pop-up window displayed

Feature information from map services for small to medium geographical areas with great detail was displayed on the right pane because there was enough space to accommodate them. Figure 5-17 shows information displayed on the right pane.

Figure 5-17: Feature information on the right pane

Statistical charts were used to convey the information from the maps. Static pie charts were used in Protected Areas maps for both State of California and the USA. Dynamic pie charts were used to show the various factors contributing to the total ecological footprints in the Human Footprints map at the World scale level. A MediaInfos component within the pop-up template class was used to configure the dynamic pie chart. Figure 5-18 shows the static pie chart for the California Protected Areas on the left and dynamic pie chart for the World Human Footprints on the right.

Figure 5-18: Static and dynamic pie charts

A dashboard was created for the Top and Bottom Green States in the United States of America using the gauge widget. This helped to visualize the relationship between the green state ranking and Gross Domestic Product (GDP) ranks for the states. This functioned as a simple comparison viewer for different variables and change when a specific state is queried. Figure 5-19 shows the ranks on the dashboard for State of Idaho.

Figure 5-19: Dashboard

A complete code for the Top and Bottom Ten Green States in the USA is provided in Appendix C as an example.

5.4 Summary

This chapter described how the project was implemented. It detailed how the map documents were prepared, analyzed, and saved as .msd files using the Map Service

Publishing toolbar. The chapter also illustrated how the map services were published to the server using ArcGIS Server. Finally, it demonstrated how the web application was developed using the ArcGIS API for JavaScript.

Chapter 6 – Use Case

The main purpose for this project was to provide an interactive map application for visualizing environmental themes through the Web. After the successful implementation, the library visitors were able to use the web application. This chapter presents the use case for the web application. It is arranged in three sections: Section 6.1 describes the application's user interface; Section 6.2 demonstrates the special media used; and Section 6.3 gives a summary of the chapter.

6.1 User Interface

The user interface for the application was developed in a standard design, for all the environmental themes presented at all scale levels. This was to ease the use of the application and to make it intuitive. Figure 6-1 shows an example of the user interface that was developed.

Figure 6-1: User interface for the application

The interface had five main panels at the top, left, center, right, and bottom with specific functions across the application. The top panel was used to navigate from one scale level to the other and from one environmental theme to the other within a scale level. Scale levels were represented as menus, while the environmental themes represented as sub-menus. Figure 6-2 shows the top region of the application.

Figure 6-2: Top panel of the application

The left panel displays the instructions on map interaction, the map legend, and the statistical information on certain environmental themes. A user can expect a pie chart or a dashboard for some maps. Figure 6-3 shows an example of the left panel.

Figure 6-3: Left panel of the application

The center panel was designed for map visualization. As the main interaction area in the application, a user can zoom in or out, pan, hover over, and click on any feature based on the instruction given at the left panel. Pop-up windows were also displayed in this panel for some themes to show detailed information about a feature. Figure 6-4 shows a center panel with pop-up window displayed.

Figure 6-4: Center panel with pop-up window

The right panel was designed for three purposes. When a user navigates to the map theme, the right panel displays the background information of the environmental theme and the overview map showing the location of the library as illustrated in Figure 6-5a. When a user inquires about a feature, the detailed information about the feature is displayed on the right panel as illustrated in Figure 6-5b.

Figure 6-5: Right panel of the application

The bottom region was designed for footer information, specifically the name of the application developer and affiliation.

6.2 Special Media

In order to effectively communicate the information presented in some of the environmental themes, special media forms were used, in particular, the pie charts and dashboard. Two kinds of pie charts were used, namely static and dynamic pie charts. Static pie charts were generated for the Protected Areas theme for both the State of California and the United States of America. Figure 6-6 shows the static pie chart for the State of California.

Figure 6-6: Static pie chart

For the World Human Footprints theme, a dynamic pie chart was created. It was developed in a pop-up window and the detailed information in each pie was displayed when one hovers over it, giving the name of the footprint and the percentage it contributes to the total ecological footprints. Figure 6-7 shows the dynamic pie chart in the pop-up window for the United States of America.

Figure 6-7: Dynamic pie chart

A dashboard was developed for the Top and Bottom Ten Green States theme. It was used to show the contrast in the green states ranking and the Gross Domestic Product (GDP) for an inquired state. Figure 6-8 demonstrates the dashboard showing the variation for the state of South Dakota.

Figure 6-8: Dashboard

6.3 Summary

The chapter presented a use case for the web map application developed. It presented the application's user interface and explained the role of all the regions in the application. It also highlighted the special media used in some of the environmental themes to enhance communication of the information presented.

Chapter 7 – Summary and Future Work

This chapter presents the summary of the project and suggestion for future work. The chapter is organized in two sections: Section 7.1 gives a summary of the project, and Section 7.2 provides recommendations for future work.

7.1 Project Summary

This project demonstrated how web maps could be used to facilitate learning about the environment at various scale levels of interest. The project client, Raymond Carnes, and the Highland Library in the City of Highland, California, needed to use a geographic information system (GIS) over the Internet to present environmental themes at different scale levels of the Library, City of Highland, County of San Bernardino, State of California, United States of America, and the World. They needed to equip the library visitors with environmental knowledge that could help them make better decisions on how to better manage their surroundings based on what they learned. The main goal for the project was to help the client develop interactive maps for environmental education through the Internet. Through appropriate methods, the project created a web map application for each of the identified environmental themes at different geographical areas.

Maps documents (.mxd) were made using layers from the GIS database using ArcGIS for Desktop 10.0. The Maps Service Publishing toolbox was used to analyze and save the maps as Map Service Definition (.msd) files. These were then used to publish map services using the ArcGIS for Server 10.0. Aptana Studio3 and NotePad++ were used as an Integrated Development Environment (IDE) for the project. HTML 4.01, CSS3, and ArcGIS Application Programming Interface (API) for JavaScript 3.1 languages were used to develop the web application. The application developed was delivered to the client and installed on their desktop computer dedicated for using the application. The library visitors have been using the application to explore the environmental themes.

7.2 Future Work

The project met the client's need and solved its problem. There are, however, four suggestions for future work on the project. First and foremost, the environmental themes identified need to be consistent across the scale levels for better education. This will enable visitors to learn more about a particular theme from the local to global level, expanding their understanding of the theme presented at all the scale levels.

Secondly, a mobile application for this project could be incorporated. The application created for this project only runs on a desktop computer, restricting those using smart phones and tablets. Since the use of smart phones is growing globally, a mobile application could reach a wider audience.

Thirdly, basic analysis could be added. These may include functions such as finding bike routes to school or home, locating school or home from the library, and identifying

the nearest park from home or school. This will help the users to appreciate the application more.

Finally, there is a need to add more environmental themes than the ones represented in the project. Examples include deforestation, soil erosion, and weather dynamics that are as a result of environmental degradation. This could create demand for the development of more applications focusing either on one scale level or on one environmental theme.

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Appendix A. Map Documents

There were eighteen maps that were prepared. The screenshot of each map as they appear in ArcMap is shown below.

Map 1: Floor footprint of the library

Map 2: Library view from above

Map 3: Public Transportation for the City of Highland

Map 4: Protected Areas in the County of San Bernardino

Map 5: Cities in the County of San Bernardino

Map 6: Public Transportation for the County of San Bernardino

Map 7: Land Cover in the County of San Bernardino

Map 8: Protected Areas in the State of California

Map 9: Human Footprints in the State of California

Map 10: Top and Bottom Ten Green States in the USA

Map 11: Parks in the USA

Map 12: Protected Areas in the USA

Map 13: World Land Cover

Map 14: World Ecoregions

Map 15: Top Ten Green Countries in the World

Map 16: World Light at Night

Map 17: Human Footprints of the World

Map 18: Population Density of the World

Appendix B. CSS File Code for the Application

This is the CSS code for the application from the highlandlibrary.css file.

```
/* Styling for the web map application */
a {
    text-decoration:none;
}
a:link{
    color:orange;
}
a:visited{
    color:orange;
}
a:hover{
    background: orange; color:#fff;
}
body#index a#inside, a#libnav,
body#outsidelibrary a#outside, a#libnav,
body#highland a#hglpbltns, a#citynav,
body#sanbernardino a#xx, a#countynav,
body#sancities a#sancts, a#countynav,
body#sanlandcover a#sanlndcvr, a#countynav,
body#sanpublictransportation a#sanpbctrns, a#countynav,
body#california a#calprtars, a#statenav,
body#calhumanfootprints a#calhmnftpnt, a#statenav,
body#usa a#usgrnstt, a#usnav,
body#usparks a#uspks, a#usnav,
body#usprotectedareas a#usprtars, a#usnav,
body#world a#wlndcvr, a#worldnav,
body#worldearthbynight a#wethbnght, a#worldnav,
body#worldcoregions a#wecrgn, a#worldnav,
body#worldgreencountries a#wgrncntry, a#worldnav,
body#worldhumanfootprints a#whmnftpnt, a#worldnav,
body#worldpopulationdensity a#wpopden, a#worldnav{
    border-style:solid;
    border-width:0.5px;
    color: #fff;
    background: orange;
}
html, body {
    height: 100%; width: 100%; margin: 0; padding: 0;
}
body{
    background-color:#777; overflow:hidden; font-family: "Trebuchet MS";
    color:white;
}
#map{
    overflow:hidden; padding:0;
}
.rightPaneTitle {
    font-weight: bold;
}
.esriLegendServiceLabel {
```

```

        display: none;
    }
    #mainwindow{
        width: 100%; height: 100%; margin: 0;
    }
    .claro{
        background-color: steelblue; overflow: hidden;
    }
    #mainWindow{
        width: 100%; height: 100%; margin: 0; position: absolute;
    }
    #header{
        border: solid thin silver; overflow: hidden; text-align: center; font-
        size: 20px;
    }
    #menu{
        background-color: #778899; font-size: 25px; font-style: bold; text-
        align: center;
    }
    #content{
        background-color: #2E8B57; font-size: 20px; text-align: center;
    }
    #leftpane{
        border: solid thin silver; overflow: hidden; width: 15%;
    }
    #legend, #graph{
        background-color: steelblue;
    }
    #intro{
        color: #000000; font-size: 20px;
    }
    #mapDiv{
        border: solid thin silver; overflow: hidden; width: 100%; height: 100%;
        background-color: white; position: relative;
    }
    #dashboard {
        background: #1A8080; color: #000; font-family: arial; height: auto;
        overflow: hidden; padding: 5px; position: absolute; left: 10px;
        text-align: center; bottom: 10px; width: 300px; z-index: 1000; -moz-
        box-shadow: 0 0 5px #888;
        -webkit-box-shadow: 0 0 5px #888; box-shadow: 0 0 5px #888; -webkit-
        border-radius: 4px; -moz-border-radius: 4px;
        border-radius: 4px; border: 1px solid #fff;
    }
    #dashboardWidgets {
        background: #fff; color: #000; margin: 0 auto; text-align: left;
    }
    #rightpane{
        border: solid thin silver; overflow: hidden; width: 15%;
    }
    #footer{
        border: solid thin silver; overflow: hidden; text-align: center;
    }
}

```


Appendix C. Sample Application Code

This is the complete code for the Top and Bottom Ten States in the USA from the usa.html. It serves as an example of the eighteen different HTML files that were created.

```
<!DOCTYPE html PUBLIC "-//W3C//DTD HTML 4.01 strict//EN"
    "http://www.w3.org/TR/html4/strict.dtd">
<html>
    <head>
        <link rel="stylesheet" type="text/css"
href="http://serverapi.arcgisonline.com/jsapi/arcgis/3.1/js/dojo/dijit/themes/
claro/claro.css">
        <link rel="stylesheet" type='text/css'
href='http://serverapi.arcgisonline.com/jsapi/arcgis/3.1/js/esri/dijit/css/Pop
up.css' />
        <link rel="stylesheet" type='text/css'
href='http://gis.spatial.redlands.edu/cohort17/clifford_okembo/elchighland/hig
hlandlibrary.css' />
        <meta http-equiv="Content-Type" content="text/html; charset=utf-
8" />
        <title> Web Map for Environmental Learning</title>

        <script type="text/javascript">
var djConfig = {
    parseOnLoad: true
};
</script>
<script type="text/javascript"
src="http://serverapi.arcgisonline.com/jsapi/arcgis/?v=3.1">
</script>

        <script type="text/javascript">
//import the required modules
        dojo.require("dijit.dijit");
        dojo.require("dijit.layout.BorderContainer");
        dojo.require("dijit.layout.ContentPane");
        dojo.require("esri.map");
        dojo.require("esri.dijit.Legend");
        dojo.require("dijit.layout.AccordionContainer");
        dojo.require("dijit.layout.TabContainer");
        dojo.require("esri.layers.FeatureLayer");
        dojo.require("esri.dijit.Popup");
        dojo.require("esri.dijit.Gauge");

        var map;
        function init() {
            var popup= new esri.dijit.Popup(null,dojo.create("div"));

            var initialExtent = new esri.geometry.Extent({"xmin":-
14032175.221,"ymin":2800000.046,"xmax":-
7165694.822,"ymax":6500000.463,"spatialReference":{"wkid":102113}});

            map = new esri.Map("mapDiv", {
                extent: initialExtent,
```

```

        infoWindow: popup
    });
    //add basemap layer to the map
    var basemapURL=
"http://server.arcgisonline.com/ArcGIS/rest/services/World_Street_Map/MapServe
r"

    var basemap = new
esri.layers.ArcGISTiledMapServiceLayer(basemapURL,{opacity:0.5});
    map.addLayer(basemap);
    //add operational layer to the map
    var operationURL=
"http://gis.spatial.redlands.edu/ArcGIS/rest/services/clifford_okembo/USGrnStt
s/MapServer"
    var operation = new
esri.layers.ArcGISDynamicMapServiceLayer(operationURL);

    //add feature layer to the map
    var featureLayer = new
esri.layers.FeatureLayer("http://gis.spatial.redlands.edu/ArcGIS/rest/services
/clifford_okembo/USGrnStts/MapServer/0", {
    mode: esri.layers.FeatureLayer.MODE_ONDEMAND,
    "opacity":0,
    outFields: ["*"]
});
    //Gauge 1
    dojo.connect(featureLayer, "onLoad", createGauge);

    function createGauge(featureLayer) {
    // create JSON and pass it to the Gauge actor
    var gaugeParams = {
        "color": "#33CC33",
        "dataField": "greenstate", // name of the
attribute used for the gauge value
        "dataFormat": "value",
        "dataLabelField": "STATE_NAME",
        "layer": featureLayer,
        "maxDataValue": 51, // gauge max value, not used
when dataFormat is "percentage"
        "noFeatureLabel": "No name",
        "title": "Green State Rank",
        "unitLabel": " out of 51"
    },
    gauge = new esri.dijit.Gauge(gaugeParams, "gaugeDiv");
    gauge.startup();
    }
    // Gauge 2
    dojo.connect(featureLayer, "onLoad", createGauge1);

    function createGauge1(featureLayer) {
    // create JSON and pass it to the Gauge actor
    var gaugeParams1 = {
        "color": "#CC4C00",
        "dataField": "GDP_Rank", // name of the attribute
used for the gauge value
        "dataFormat": "value",

```

```

        "dataLabelField": "STATE_NAME",
        "layer": featureLayer,
        "maxDataValue": 51, // gauge max value, not used
when dataFormat is "percentage"
        "noFeatureLabel": "No name",
        "title": "GDP Rank",
        "unitLabel": " out of 51"
    },
    gauge = new esri.dijit.Gauge(gaugeParams1, "gaugeDiv1");
    gauge.startup();
}

dojo.connect(featureLayer, "onClick", function(evt){
    var attributes = evt.graphic.attributes;
    var rightPane = dojo.byId("rightpane");
    // the popup specifics
    var html = "<div
class='rightPaneTitle'>${STATE_NAME}</div>" +
        "<hr/>" +
        "<div>Green state number:
${greenstate}</div>" +
        "<hr/>" +
        "<div>- Population and Rank:
${poprank}</div>" +
        "<div>- GDP: ${gdprank}</div>" +
        "<div>- Carbon Footprint:
${cbnfootrank}</div>" +
        "<div>- Toxic waste and Rank:
${toxicwasterank}</div>" +
        "<div>- Alternative energy and
Rank: ${altengyrank}</div>" +
        "<hr/>" +
        "<img style='width: 100%; height:
50%;' src='${photolink}' />";

    var content = esri.substitute(attributes, html);
    dojo.attr(rightPane, "innerHTML", content);
});

map.addLayer(featureLayer);

dojo.connect(map, 'onLoad', function(map) {
    //resize the map when the browser resizes
    dojo.connect(dijit.byId('map'), 'resize', map, map.resize);
});

map.addLayers([ operation ]);

dojo.connect(map, "onLayersAddResult", function(response)
{
    var layerInfos = [];

```

```

dojo.forEach(response, function(result) {
    if (result.success) {
        layerInfos.push({ layer: result.layer });
    }
    else {
        console.error(result.error);
    }
});

//add the legend
var legend = new esri.dijit.Legend({
    map:map,
    layerInfos: layerInfos
},"legendDiv");

legend.startup();
});
}

dojo.addOnLoad(init);

</script>
</head>
<body class="claro" id="usa" >
<div id="mainWindow" dojotype="dijit.layout.BorderContainer"
design="headline" gutters="false" >
    <div id="header" dojotype="dijit.layout.ContentPane" region="top"
>
        <div id= "menu" dojoType="dijit.layout.ContentPane"
selected="true"; >
            <a
href="http://gis.spatial.redlands.edu/Cohort17/clifford_okembo/elchighland/index.html" >LIBRARY & ELC</a> |
            <a
href="http://gis.spatial.redlands.edu/Cohort17/clifford_okembo/elchighland/highland.html" >CITY OF HIGHLAND</a> |
            <a
href="http://gis.spatial.redlands.edu/Cohort17/clifford_okembo/elchighland/sanbernardino.html" >SAN BERNARDINO COUNTY</a> |
            <a
href="http://gis.spatial.redlands.edu/Cohort17/clifford_okembo/elchighland/california.html" >CALIFORNIA</a> |
            <a
href="http://gis.spatial.redlands.edu/Cohort17/clifford_okembo/elchighland/usa.html" id="usnav">USA</a> |
            <a
href="http://gis.spatial.redlands.edu/Cohort17/clifford_okembo/elchighland/world.html" >WORLD</a>
        </div>
        <div id="content"
dojoType="dijit.layout.ContentPane" selected="true"; >
            <a
href="http://gis.spatial.redlands.edu/Cohort17/clifford_okembo/elchighland/usa.html" id="usgrnstt">TOP AND BOTTOM GREEN STATES</a> |

```

```

        <a
href="http://gis.spatial.redlands.edu/Cohort17/clifford_okembo/elchighland/usp
arks.html" id="uspks">PARKS</a> |
        <a
href="http://gis.spatial.redlands.edu/Cohort17/clifford_okembo/elchighland/usp
rotectedareas.html" id="usprtars">PROTECTED AREAS</a>
        </div>
    </div>
    <div id="leftpane" dojotype="dijit.layout.ContentPane"
region="left" style="width:18%">
        <div dojoType="dijit.layout.AccordionContainer">
            <div id="legend" dojoType="dijit.layout.ContentPane"
title="Legend"; >
                <div id="intro" ><b>Click on</b> any of the
green and red states to view their on the <b>left pane</b>. Can you identify
all the twenty States? </div>
                <hr/>
                <div id="legendDiv"></div>
                <div id="dashboard">Dashboard
                    <div id="dashboardWidgets">
                        <div id="gaugeDiv"></div>
                        <div id="gaugeDiv1"></div>
                    </div>
                </div>
            </div>
        </div>
    </div>
    <div id="mapDiv" dojotype="dijit.layout.ContentPane"
region="center"></div>

    <div id="rightpane" dojotype="dijit.layout.ContentPane"
region="right" >
        <h3>Background Information</h3>
        <p>This Web Map shows the top ten AND bottom ten
'green' states in the United States of America as of July 2011. The research,
analysis and ranking was done by 24/7 Wall st. company.</p>
        <p>Earth Day is the perfect time to celebrate the positive steps
that some states are taking to preserve the environment. In 2011, the theme
for Earth
            Day was <b>"A Billion Acts of Green."</b> The idea highlights the
fact that many small acts can make a significant difference to the
environment.

            24/7 Wall St. analyzed the environmental issues
facing each state. In observance of Earth Day, they updated rankings to
reflect the most recent data.

            24/7 Wall St. examined energy consumption, pollution
problems and state energy policies. The most recent information, issued in
2009 and 2010, was used for all states.

            Thousands of data points were collected to determine
the most and least GREEN states.</p>
        <p></p>
    </div>

```

```
region="bottom" >  
    <div dojotype="dijit.layout.ContentPane" id="footer"  
        Developed by Clifford Okembo, University of Redlands</div>  
    </div>  
</body>  
</html>
```