

Geographic Information Systems for Coral Reef Conservation, Capacity Building, and
Public Education in American Samoa

by
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Emily M. Larkin for the degree of Master of Science in Geography presented on October 27, 2004.

Title: Geographic Information Systems for Coral Reef Conservation, Capacity Building, and Public Education in American Samoa

Abstract approved:

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Coral reefs around the world face numerous threats, both natural and anthropogenic, including pollution, natural disasters, invasive species, habitat destruction, and destructive methods of fishing. Given enough time, coral can recover from natural disasters, but anthropogenic threats decrease corals' ability to recover from things such as hurricanes. It is difficult to protect coral reefs when they are not fully mapped or understood and without public support for their protection. This project is an attempt to both understand more about two small coral reefs around the island of Tutuila, American Samoa and to facilitate public outreach and education about coral reefs in American Samoa. New benthic zone and structure classifications have been produced for Fagaitua Bay and for National Park of American Samoa, which extend earlier satellite-based classifications into much deeper water. Although it is not possible, at this time, to tie benthic classifications to species or community types, it is hoped that further ground-truth data may establish some connection between the two.

Government officials and resource managers increasingly use GIS to determine the locations of critical habitats in need of protection. There is growing concern, however, that the general public is excluded from the decision-making process due to the lack of publicly-accessible data. The American Samoa Benthic Terrain Viewer (ASBTv) is a web-based geographic information system (GIS) that allows users to display data and conduct simple GIS analyses without the need to purchase stand-alone GIS software. All of the benthic classifications produced for American Samoa as part of this and other projects are available on the ASBTv. ASBTv also includes the world's first web-based GIS in the Samoan language. Educational modules developed for American Samoa Community College are also part of the effort to make the public more aware of current research on the coral reefs in American Samoa. It is also hoped that they will aid in GIS capacity building efforts by providing students with the opportunity to learn GIS using local data. The educational modules include a capstone final project where students must tie in the technical skills they have learned in the class to a real-world problem: a hypothetical marine protected area proposal. None of these efforts towards public education, GIS capacity building, and reef protection can stand alone. Without traditional outreach, Internet outreach is often unsuccessful. Without public support, reef protection and GIS education will not often be successful.

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1. Introduction

1.1 Overview

Coral reefs are among the Earth's most diverse and endangered ecosystems. One of the most serious challenges facing those involved in coral reef protection is that many of them are poorly understood and have not been mapped to a useful level of detail. For example, few detailed maps exist for depths below 30 m for coral reefs and only five percent of the world's reefs are mapped to a regional scale (Miller and Crosby 1998). This is a particular problem in remote areas in the western Pacific, where it may be difficult to deploy the necessary research vessels, mapping systems, and monitoring instruments. In recent years, mapping the coral reefs with US waters along with creating more opportunities for public education about coral reefs have been given a higher priority. The Coral Reef Ecosystem Division has made it a priority to map all coral reefs within U.S. waters to depths of at least 30 m (Evans et al. 2000).

The importance of geographic information systems (GIS) as a management tool for coral reefs was recognized at the 2000 Pacific Regional Symposium of the International Coral Reef Initiative. One of the goals established was that each Pacific Island Nation would create a coral reef GIS to help manage and protect its coral reefs by 2010 (Crosby 2002). However, there has been mounting concern that GIS provides access to information only for well-educated, privileged groups already part of traditional power structures (Obermeyer 1998; Weiner and Harris 1998). In the developing world, this problem is exacerbated by a lack of local technological infrastructure and capacity. Often, few people are trained in GIS in developing countries and many that obtain those skills leave for developed countries and better salaries. Expatriates, who tend to have a

high rate of turnover, may make up a large percentage of the GIS community (Britton 2000). Many expatriates work on short-term contracts, creating institutional memory and project longevity problems as well. Local users who do stay may not have much support or a well-organized GIS community on which to rely when problems and challenges arise (Britton 2000). Contributing to this problem are research projects done in developing countries that are often never “brought back” to the societies hosting the research. For example, researchers may conduct GIS projects in developing countries, but environmental GIS data and results generated by these projects remain inaccessible to local resource managers, GIS analysts, and the general public (Britton 2000).

GIS and geography education are keys to development of an active, local GIS community (Britton 2000). There are at least two things that challenge those in higher education when trying to encourage students in GIS. Making GIS lessons meaningful to students is one challenge in creating a set of modules for use in an introductory course. Using local data may help spark interest among students who otherwise would not relate to the material used in a GIS class (O’Dea 2002). Often students may be intimidated by the idea of working with GIS, thinking that it requires more specialized computer skills at a basic level than it actually does (Mueller and Wickham 2003). There are ways to make introductory GIS less intimidating, while still making sure students are getting a solid base of GIS concepts and increasing their interest in science (Hall-Wallace and McAuliffe 2002). Although many universities and community colleges have GIS courses and programs now, little has been written about curriculum development in higher education. Again, this problem is exacerbated in the developing world as stated by

Bishop et al. (2002): “Software, appropriate digital data, relevant educational materials and an existing skill base among educators may all be in short supply in developing countries making rapid assimilation and application of the technology difficult.”

1.2 Objectives

The overall purpose of this thesis is to expose the American Samoan public to GIS in a way that is intuitive and provides a better understanding of the marine resources around Tutuila. To accomplish this goal, the following three questions need to be answered: 1) What is the status of coral reefs in American Samoa? Prior to the 2001 and 2002 multibeam sonar surveys, no previous surveys had been done in Fagaitua Bay and NPSA below 30 m (Wright 2002b, Wright et al. 2002). 2) What is the best way to provide access to seafloor research and data in American Samoa? As noted earlier, standard GIS software packages are expensive and require training in order to use. 3) How best to promote GIS education in American Samoa and to get students thinking about marine conservation issues? There are GIS classes on-island, but they are currently using data from off-island.

The overriding goal of this thesis and answers to the questions above will be accomplished through four main objectives:

- 1) Creation of benthic terrain characterizations for Fagaitua Bay and the Tutuila unit of NPSA.
- 2) Design of a web-based GIS with Samoan- and English-language functionality.
- 3) Creation of a bibliographic database of marine resources in American Samoa.

4) Development of educational modules about benthic terrain classification and GIS concepts for use in introductory GIS classes at American Samoa Community College.

The materials developed as part of this thesis will be made available to the American Samoa GIS Users Group, agencies on-island, and the general public for public education about the local coral reefs.

1.3 Justification for Research

Prior to the 2001 and 2002 multibeam surveys, little was known about the American Samoan coral reefs below 30 m in depth. As stated earlier, they face numerous threats, but anthropogenic threats hamper coral's ability to recover from periodic natural disturbances such as hurricanes. Without knowing more about the deeper areas, both within MPAs and outside of MPAs in American Samoa, it is difficult for local resource managers to make management decisions about the reefs under their protection, since management decisions and threats to the reefs affect the entire reef, not just the shallow areas. This thesis will provide more information about two of the reefs in American Samoa, one protected and one outside any MPAs.

Another common problem in ocean science is deciding where to focus resources. Ideally, every part of the ocean floor would be mapped to sub-meter accuracy and visited by submersibles; however, money and time are limiting factors in any enterprise. As noted earlier, little of the ocean floor is mapped to a useful level of detail. The results of this part of the thesis will help future researchers pinpoint areas in need of further study on the reefs around American Samoa.

This thesis also addresses some of the need for public education about coral reefs in American Samoa. Gaining public support for measures to increase protections on coral reefs is critical to the success of such measures (Fiske 1992). The web-based GIS will allow the public access to current research being done on the reefs, hopefully providing the public with a greater understanding of the structure and fragility of the reefs. There is also a serious need for translations of scientific information into local languages (Britton 2000; Crosby, Brighthouse, and Pichon 2002). Local language translations reach far more people than would otherwise be reached by a public education project. This project will add to the currently limited Samoan-language Internet resources.

Educational modules using local data have the potential to spark students' interest in GIS and further technical capacity building efforts in American Samoa. Exposing local students to GIS early in their post-secondary educations may make them more likely to pursue further GIS training (West 2003). Lessons using GIS are inherently associated with a place. Lessons about somewhere halfway around the world can seem irrelevant, so the educational modules will allow students the opportunity to work with local data and problems. The modules will also provide exposure to ideas about coral reef conservation and MPA establishment, while teaching students about how the seafloor is mapped and studied. In addition to their use at American Samoa Community College, the modules, along with all of the necessary data, will be available to anyone with an interest in using them through the Internet.

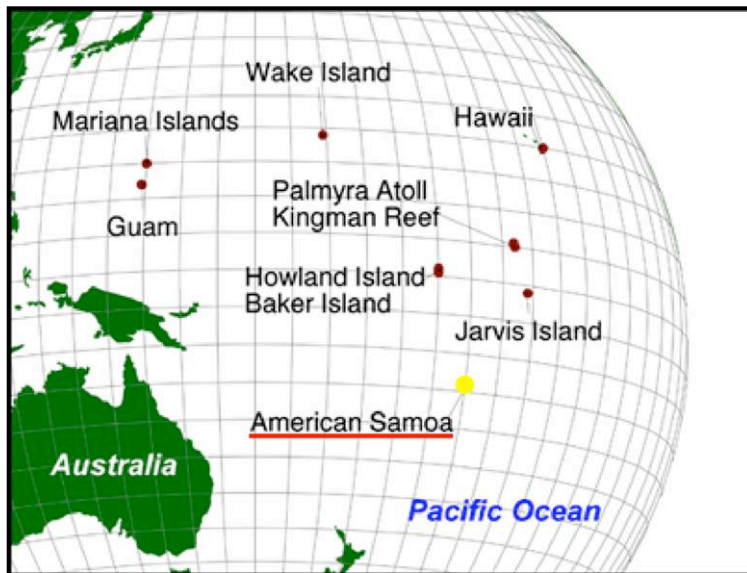


Figure 1.1—Location of American Samoa (after NOAA National Oceanographic Data Center).

1.4 Study Area

American Samoa, a chain of five volcanic islands (Tutuila, Aunu'u, Ofu, Olosega and Ta'u) and two coral atolls (Rose and Swains), became a territory of the United States in 1900.

The islands are located in the southern Pacific Ocean approximately 2300 miles southeast of Hawaii (Figure 1.1). The majority of the population and the territorial capital, Pago Pago, are located on the island of Tutuila, the largest island in American Samoa at 53 square miles (Central Intelligence Agency 2003).

Coral reefs comprise approximately 296 km² of the territorial waters of American Samoa (Richmond et al. 2002). They face threats in the form of bleaching events, hurricanes, sea level rise and from invasive species such as *Acanthaster planci* (crown-of-thorns starfish). Given enough time, coral can recover from most such events. However, the reefs face additional threats from pollution, over-fishing and destructive fishing methods (e.g. dynamite fishing, fishing with bleach) which can hamper the ability of coral to recover from natural disasters (Craig et al. 2001; Green et al. 1999; Miller and Crosby 1998; Richmond et al. 2002). A recent study repeating surveys that had been



Figure 1.2—Pufferfish in National Park of American Samoa (E. Larkin).

done 85 years earlier found serious decline among soft corals in Pago Pago Harbor, most likely due to past pollution and habitat destruction (Cornish and DiDonato 2004). Overfishing and habitat destruction are currently considered the most serious modern threats to the reefs and fisheries in American Samoa (Richmond et al. 2002).

Three federal marine protected areas (MPAs) have been established in American Samoa to help protect coral reefs: Fagatele Bay National Marine Sanctuary (FBNMS), National Park of American Samoa (NPSA), and Rose Atoll National Wildlife Sanctuary. FBNMS was established on the southeast end of Tutuila in 1986 with local support (Fiske 1992). National Park of American Samoa (NPSA) was established in 1993 on three islands: Tutuila, Ofu, and Ta'u (Figure 1.2). NPSA is unique within the U.S. National Park Service because the land and water rights contained within the park are leased by the National Park Service from villages that had traditional control over those resources. Local residents retain limited rights to practice traditional agriculture and fishing within certain areas of the park (National Park Service 1997). The only no-take MPA in American Samoa is Rose Atoll National Wildlife Sanctuary, located on the unpopulated, remote atoll of the same name, which is not included in this study (Richmond et al. 2002). The American Samoa Government's Department of Marine and Wildlife

Resources has a community-based MPA program that works at the village level to establish MPAs (Daschbach, pers. comm., 2004).

In addition to being the focus of marine studies, American Samoa, along with other Pacific U.S. territories, has been the focus of a number of recent GIS-related efforts. The National Oceanic and Atmospheric Administration's (NOAA) Pacific Services Center has obtained high-resolution satellite imagery for American Samoa. There is currently a partnership program that places an assistant on-island for two years to provide GIS support (Killpack 2004). NOAA Coastal Services Center also conducted GIS workshops in 2003 and 2004 for government employees to help build GIS capacity in American Samoa (J. Murphy, pers. comm. 2004). Oregon State University and the American Samoa GIS User Group created a memorandum of understanding for exchange of information, students, researchers and data (Wright 2002a).

2. Benthic Classifications of Fagaitua Bay and National Park of American Samoa

2.1 Benthic Mapping to Inform Resource Management

Resource management in marine settings presents special challenges to managers. Even in the best situations, seafloor data can be difficult to obtain given the expense of obtaining that data, the amount of the earth's surface covered by the ocean and the time involved in data acquisition. Increasingly, GIS is being applied to management problems in marine settings. There are a number of ways to map the seafloor, each having its own advantages and disadvantages. Diving surveys are time-consuming and expensive, especially if a large area needs to be surveyed, and there is a lower limit to how deep divers can go. Remotely operated vehicle (ROVs) and submersible surveys are also time-consuming and expensive. Also, given the limited number of such vehicles, deeper waters are often given priority over intermediate and shallower areas such as coral reefs. The advantage of these two methods is that they produce very detailed surveys. Satellite imagery is also a useful tool for shallow seafloor mapping. It can provide coverage for large areas with good detail relatively inexpensively and quickly. In good, clear conditions, satellite imagery such as that from Ikonos can penetrate seawater down to a depth of 30 m at a resolution up to 4 m (Coyne et al. 2000). Beyond the obvious limitation of depth, satellite image quality is affected by wind and wave action, turbidity, and sun angle.

Surveys done with sidescan and multibeam equipment have the advantage of being able to cover a larger area in a shorter amount of time than either dive or ROV surveys. They are also able to produce accurate maps even at great depths. Although,

they do not produce true images of the seafloor, they do produce the underwater equivalent of a digital elevation model, a bathymetry grid. This grid can then be processed further to reveal more about the texture and complexity of the area. Multibeam sonar surveys have the added advantage of being able to collect backscatter information as well as bathymetry.

Earlier surveys in American Samoa depended on diving transects to map the coral reefs around Tutuila and the Manu'a Island Group (Craig et al. 2001; Green et al. 1999; Richmond et al. 2002). These surveys are extremely valuable because they have been repeated approximately every three years for nearly 20 years, which is one of the longest time-series data sets for reefs in the Pacific (N. Daschbach, pers. comm. 2004). Although these surveys produced valuable information, particularly in terms of comprehensive species lists and rates of recovery after disasters, they were unable to cover large areas and only the most recent surveys in 2004 were geo-referenced (N. Daschbach, pers. comm. 2004). Ikonos imagery has been an important tool in classifying benthic terrain American Samoa. Most of the waters around American Samoa are relatively clear, allowing for detection of coral to depths of 30 m (Coyne et al. 2002).

Multibeam sonar surveys were completed around Tutuila in 2001 and 2002 (Wright 2002b; Wright et al. 2002). Described here are the creation of benthic zone and structure maps for Fagaitua Bay and National Park of American Samoa (NPSA) using the multibeam bathymetry grids produced in the surveys, and incorporating GIS algorithms for bathymetric position index (BPI), and slope. Fagaitua Bay is a small, shallow inlet on the southeast side of Tutuila with a fringing reef. The bay is approximately three km

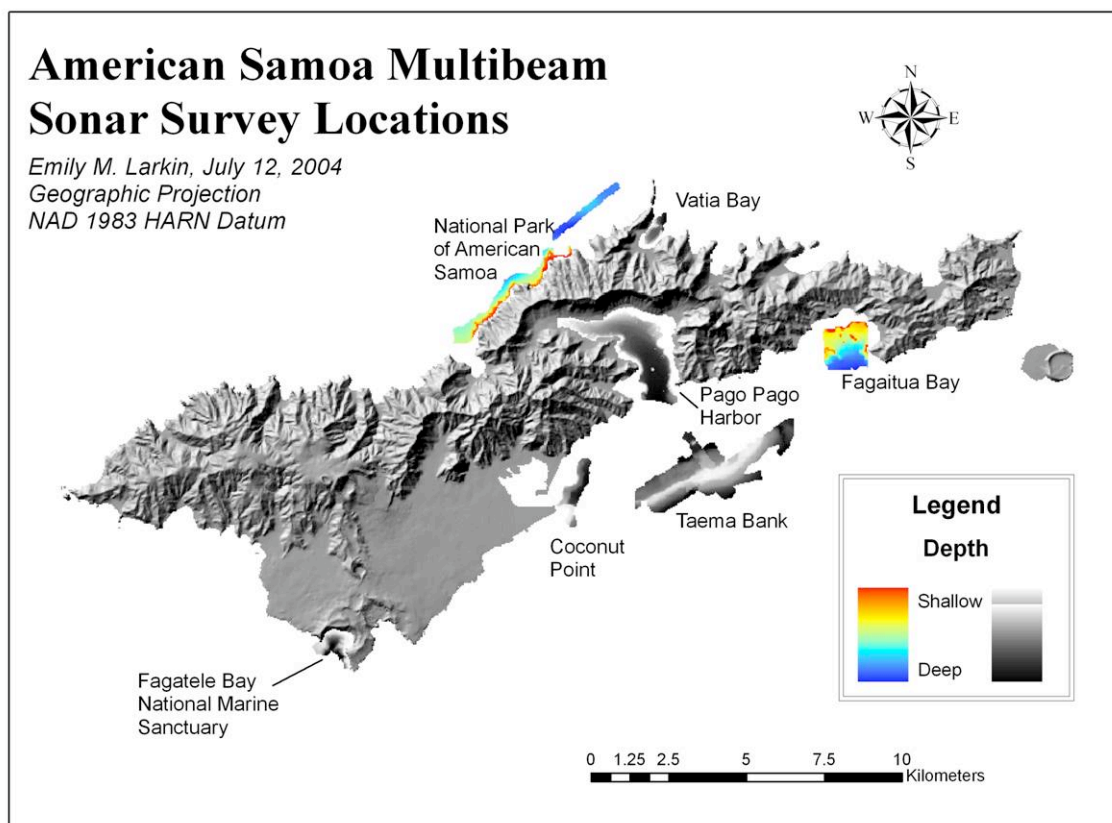


Figure 2.1—Multibeam sonar survey locations around the island of Tutuila, American Samoa. Areas shown in color are the focus of this study.

across in an east-west direction, although the surveyed area of the bay is approximately two-thirds that wide. The maximum depth in the surveyed area of the reef is 78 m.

NPSA is the only national park in the United States that is located south of the equator. The park has units on three of the five volcanic islands in American Samoa: Tutuila, Ofu, and Ta'u. It is also the only U.S. National Park that includes both terrestrial and marine resources within the park boundaries (National Park Service 2004). Unlike Fagaitua Bay, there is no large, wide fringing reef around the Tutuila unit of the park. This allowed the surveys to come much closer to shore than in Fagaitua Bay. A narrow swath of seafloor in the offshore portion of the Tutuila unit of NPSA was surveyed in

2001 at a resolution of 2 m (Wright et al. 2002). The maximum depth in the surveyed area of the park is 61 m.

In addition to these areas, five others were surveyed at the same time in 2001 and in later surveys in 2002 (Wright 2002b) and are being analyzed by other researchers (Figure 2.1).

2.2 Methodology

Several analysis steps are necessary to classify bathymetry into benthic zones and structures (Figure 2.2). The bathymetry data are in raster format, so analyses were done primarily either in the Spatial Analyst extension of ArcGIS or in ArcInfo Grid. The first

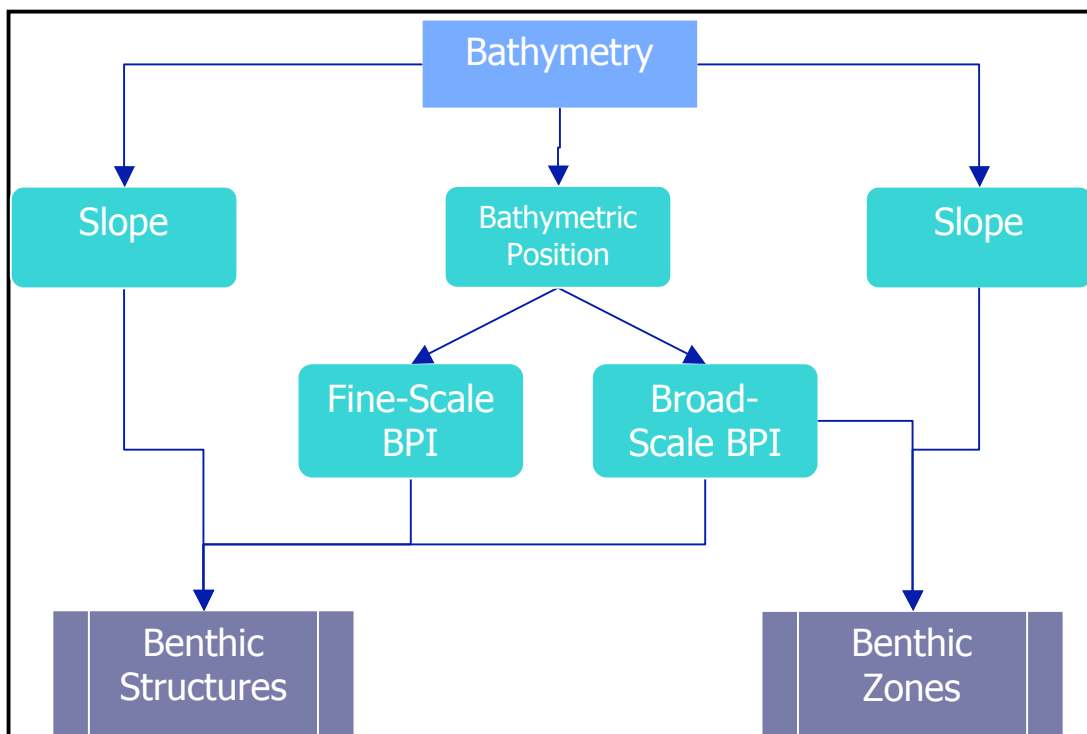


Figure 2.2—The basic steps required to produce benthic zone and structure classifications

step was a slope analysis. Slope compares the elevation, or depths in this case, of each grid cell to the elevations of surrounding cells to determine the steepness of an area (Longley et al. 2001). Slope is either calculated as a slope percentage or angle within Spatial Analyst. For this study, all slopes were calculated in degrees.

Next, BPI was calculated at two different scales to highlight both large and small features. BPI is based on topographic position index, developed by Andrew Weiss (2001) for use in classifying terrestrial features. BPI compares the elevation of each pixel to the elevations of those pixels within a user-defined radius around the pixels to show peaks and valleys in the data. The shape of the analysis area is user-defined and can include circle and annulus (a donut shape). The end result is a grid showing the location of each pixel in relationship to the pixels around it. Positive BPI values indicate crests or

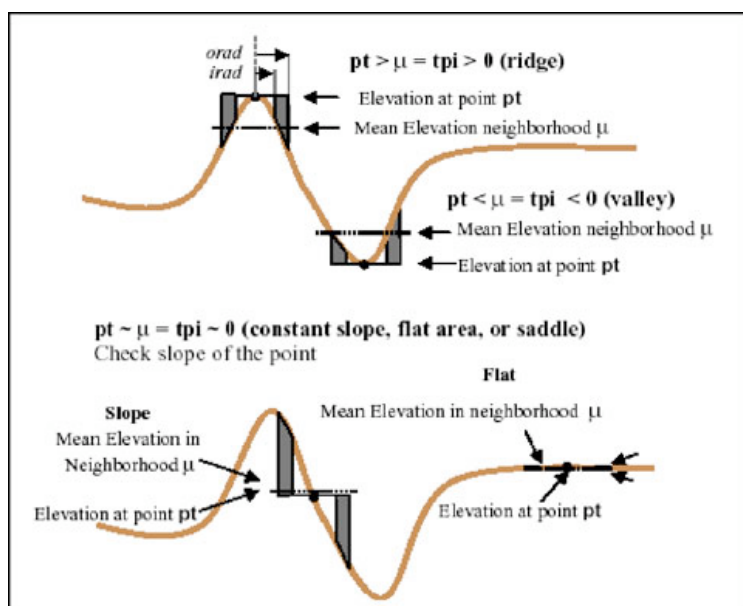


Figure 2.3—Bathymetric Position Index (BPI). Areas with strongly negative BPI values are depressions. Areas with strongly positive BPI values are ridges or crests. Areas with values approaching zero are either flats or slopes (after Weiss

ridges, negative BPI values indicate valleys or depressions and BPI values of zero indicate either slopes or flat areas (Figure 2.3).

Slope values are needed to distinguish between flats and slopes (Lundblad 2004; Weiss 2001). Topographic position index can be an indicator for terrestrial

biodiversity (Weiss 2001). BPI is integral to delineating benthic zones and structures which have preliminarily been linked to biodiversity (Karlson et al. 2004; Kvitek et al. 2003; Weiss 2001).

By using different scales to look at the data, features of different sizes can be emphasized. Broad-scale BPI was used to look for large features, such as large valleys or ridges. In this case, broad-scale BPI focused on features of approximately 250 m in at least one dimension, after the classification scheme developed for American Samoa by Lundblad (2004). Fine-scale BPI was used to look for smaller features, such as a ridge along a larger slope or a valley within a larger flat area (Lundblad 2004). Broad- and fine-BPI can be combined with slope and bathymetry to delineate general benthic zones and more specific benthic structures (Lundblad 2004; Whitmire 2003).

Broad-scale BPI was calculated with the following general algorithm in ArcInfo Grid:

$$\text{int}((\text{bathy-focalmean}(\text{bathy}, \text{annulus}, \text{irad}, \text{orad})) + 0.5)$$

bathy = the input bathymetry grid

irad = the inner radius of the analysis area

orad = the outer radius of the analysis area

Inner radius and outer radius values were chosen based on features of interest in the study areas (Lundblad 2004).

Fine-scale BPI was calculated using a slightly different formula. Rather than using an annulus, or donut-shaped, analysis area, a circle was used because the features of interest were smaller. The inner radius is automatically 1 when a circle is used, so

there was no need to input an inner radius. As with broad-scale BPI, the outer radius value was determined by local features of interest, again following the classification scheme of Lundblad (2004).

Fine-scale BPI was calculated with the following algorithm in ArcInfo Grid:

$\text{int}((\text{bathy-focalmean}(\text{bathy}, \text{circle}, \text{orad})) + 0.5)$

In order to produce consistent classifications that could be compared between sites, the same scales were used for all BPI calculations in both areas of study. Some areas analyzed by Lundblad (2004) were calculated using the same methodology, but different BPI values. This resulted in slightly different classifications using the same terminology. Fine-scale BPI was determined using a scalefactor of 20. Broad-scale BPI was produced using a scale factor of 250. Scale factor is determined by multiplying the resolution of the grid by the outer radius used in the BPI equation. Since the bathymetry grid for Fagaitua Bay has a resolution of 1 m, this means that, for broad-scale BPI, the inner radius and outer radius for were 50 and 250, respectively (Figure 2.4). For fine-scale BPI in Fagaitua Bay, an outer radius of 20 was used (Figure 2.5). Since the bathymetry grid for NPSA has a resolution of 2 m, the inner and outer radii for broad-scale BPI were 25 and 125, respectively (Figure 2.6). The fine-scale BPI outer radius chosen for NPSA was 10 (Figure 2.7). The regular pattern of lines that can be seen in all of the BPI grids is an artifact from collection of the original bathymetry, likely resulting from effects of survey boat motion in heavier weather that were not removed completely in the post-processing. Future work with the bathymetry grids could include application of a filter to the data (e.g., boxcar, gaussian or median) either to the original multibeam

data with an analysis package such as Generic Mapping Tools or MBSystem, or to the GIS version of the data using grid functions in ArcInfo Workstation. These methods were not applied in this study, as the region has recently been resurveyed by the NOAA Coral Reef Ecosystem Division, and their grids may also be used for subsequent terrain classifications.

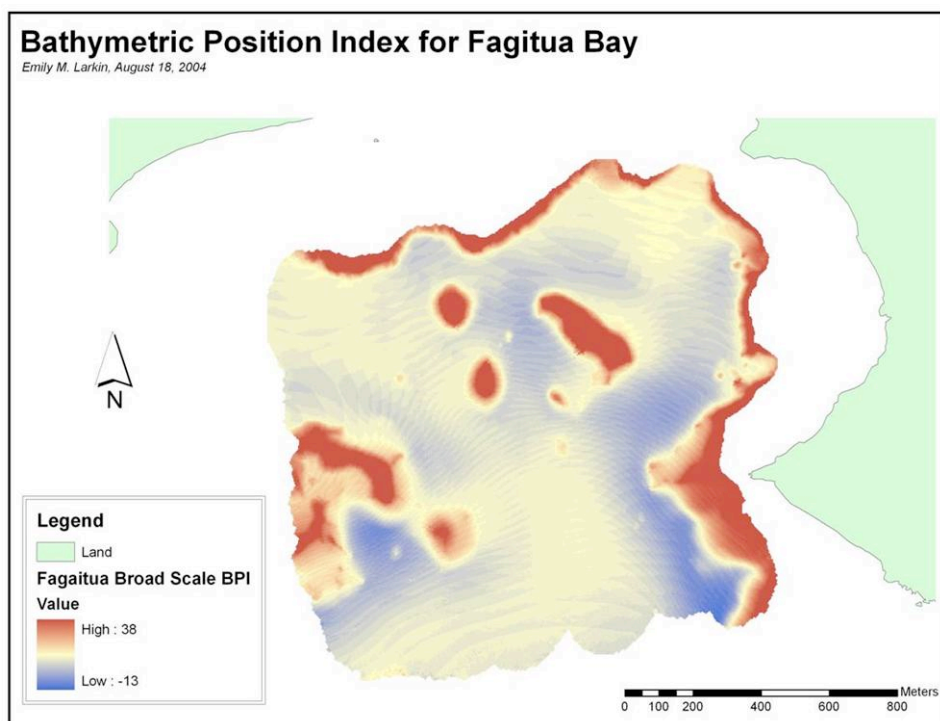


Figure 2.4—Broad-scale BPI for Fagaitua Bay. Red areas are crests, blue areas are depressions, and yellow areas are either flats or slopes. The scale factor is 250.

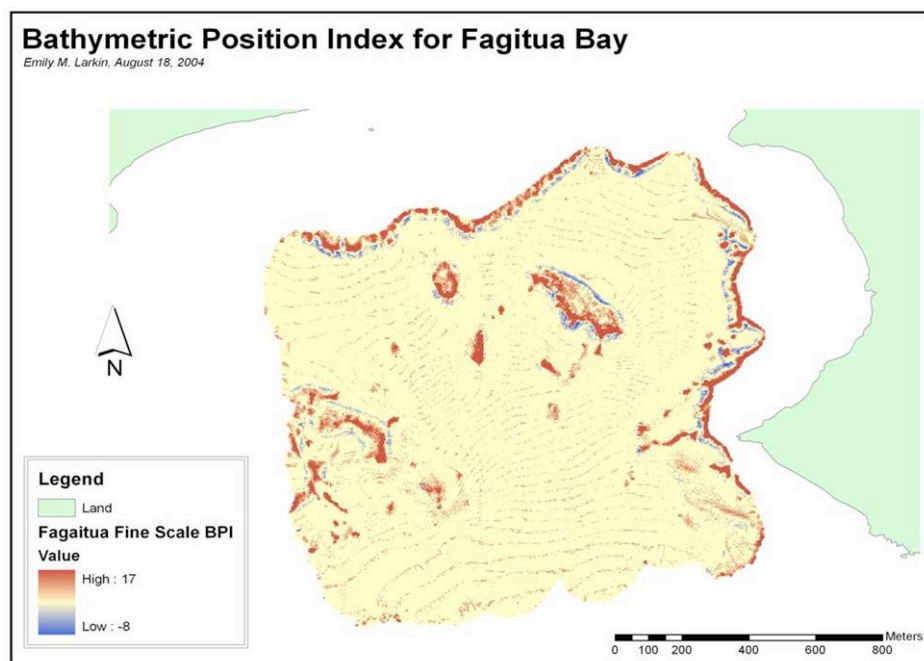


Figure 2.5—Fine-scale BPI for Fagaitua Bay. Red areas are crests, blue areas are depressions, and yellow areas are either flats or slopes. The scale factor is

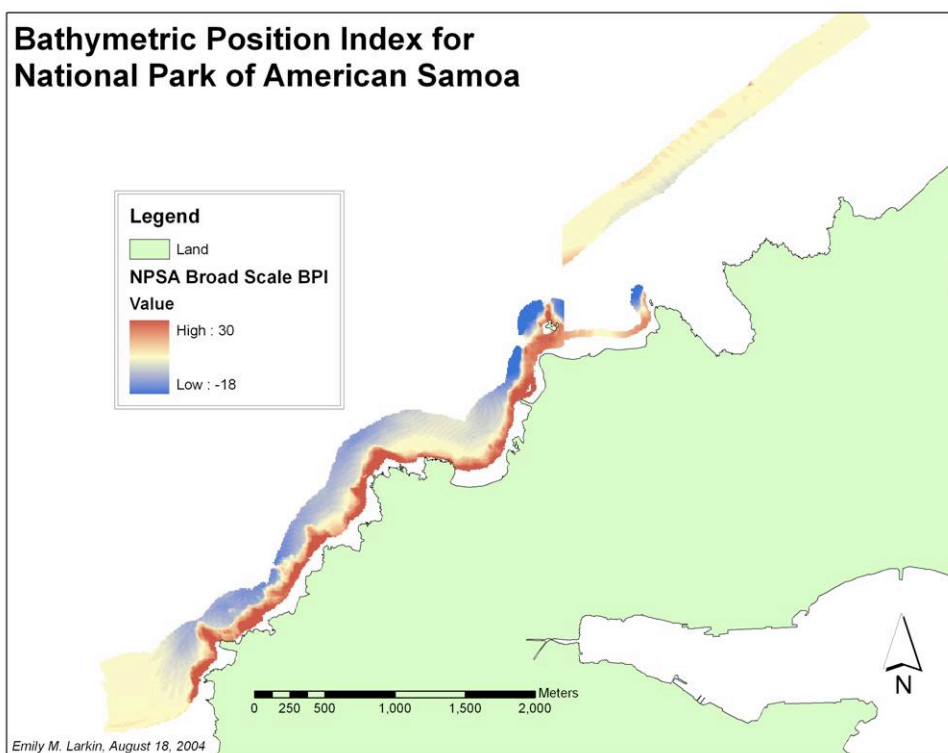


Figure 2.6—Broad-scale BPI for NPSA. Red areas are crests, blue areas are depressions, and yellow areas are either flats or slopes. The scale factor is 250.

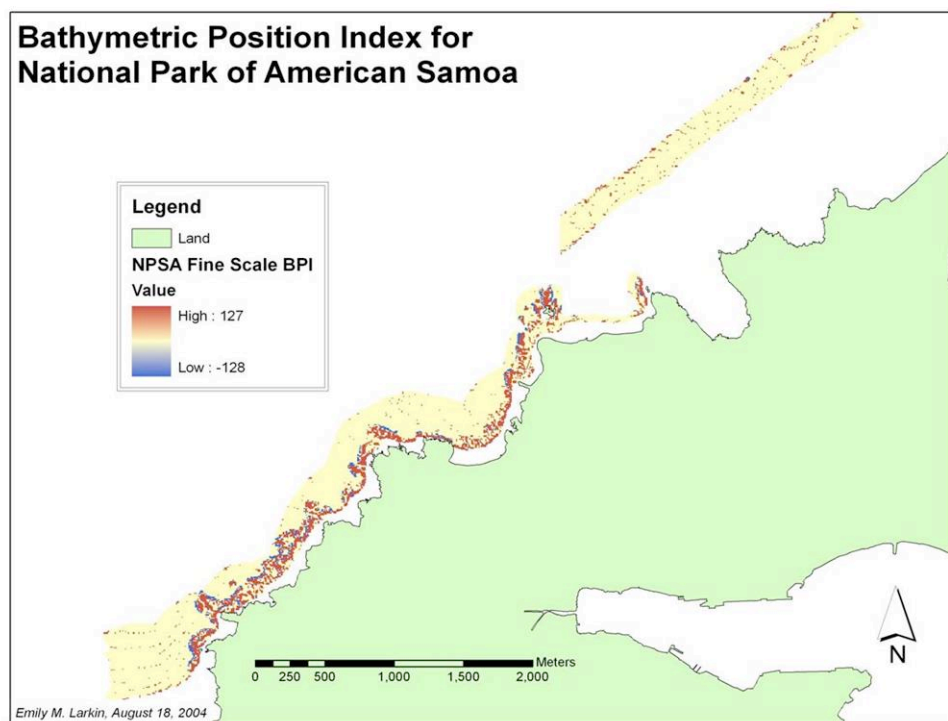


Figure 2.7—Fine-scale BPI for NPSA. Red areas are crests, blue areas are depressions, and yellow areas are either flats or slopes. The scale factor is 20.

BPI grids were then standardized according to the following algorithm so they could be compared and used in benthic zone and structure calculations:

$$\text{int}((((\text{BPI} - \text{mean})/\text{stdv}) * 100) + .5)$$

2.2.1 Benthic Zones

The bathymetry for both areas was classified into four general zones based on broad-scale BPI and slope values. These classifications and the algorithm are based on those developed by Lundblad (2004), which was based, in part, on the landform classification method developed by Weiss (2001). The following algorithm was used in ArcInfo Grid:

```
if (B-BPI >= 100) out_zones = 1
else if (B-BPI <= -100) out_zones = 2
else if (B-BPI > -100 and B-BPI < 100 and slope <= gentle) out_zones = 3
else if (B-BPI > -100 and B-BPI < 100 and slope > gentle) out_zones = 4
endif
```

B-BPI = the standardized broad-scale BPI grid

out_zones = the output file

slope = the name of the slope grid

gentle = the slope value used to distinguish between flats and slopes.

Five degrees was used for the slope input value. Grid uses the values of 100 and -100 to indicate one standard deviation above the mean and below the mean, respectively.

The resulting classifications are indicated by the four numbers:

- (1) Crests
- (2) Depressions
- (3) Flats
- (4) Slopes

2.2.2 Benthic Structures

The bathymetry grids were further classified into benthic structures. Benthic structures are finer classifications than benthic zones. There are thirteen of them, again based on Lundblad (2004). Again, 5 degrees was used for the gentle slope value, while 70 degrees was used for the extreme slope value. A depth of -15 m was used where the algorithm calls for a depth value. This value was chosen because there appeared to be a break in slope values at that point in both study areas. In Fagaitua Bay, for example, the terrain slopes steeply off of the reef platform down to about 15 m before leveling off.

The following algorithm was used in Grid to create the classifications:

```

if ( $F-BPI \leq -100$  and  $B-BPI \leq -100$ )  $out\_structures = 1$ 

else if ( $F-BPI \leq -100$  and  $B-BPI > -100$  and  $B-BPI < 100$  and  $slope \leq gentle$  )
 $out\_structures = 2$ 

else if ( $F-BPI \leq -100$  and  $B-BPI > -100$  and  $B-BPI < 100$  and  $slope > gentle$ )
 $out\_structures = 3$ 

else if ( $F-BPI \leq -100$  and  $B-BPI \geq 100$ )  $out\_structures = 4$ 

else if ( $F-BPI > -100$  and  $F-BPI < 100$  and  $B-BPI \leq -100$ )  $out\_structures = 5$ 

else if ( $F-BPI > -100$  and  $F-BPI < 100$  and  $B-BPI > -100$  and  $slope \leq gentle$  and
 $bathy \leq shallow$ )  $out\_structures = 6$ 

else if ( $F-BPI > -100$  and  $F-BPI < 100$  and  $B-BPI > -100$  and  $slope \leq gentle$  and
 $bathy > shallow$ )  $out\_structures = 7$ 

else if ( $F-BPI > -100$  and  $F-BPI < 100$  and  $B-BPI > -100$  and  $slope > gentle$  and
 $slope \leq extreme$ )  $out\_structures = 8$ 

else if ( $F-BPI \geq 100$  and  $B-BPI \leq -100$ )  $out\_structures = 9$ 

else if ( $F-BPI \geq 100$  and  $B-BPI > -100$  and  $B-BPI < 100$  and  $slope \leq gentle$ )
 $out\_structures = 10$ 

```

```
else if ( $F-BPI \geq 100$  and  $B-BPI > -100$  and  $B-BPI < 100$  and  $slope > gentle$ )
   $out\_structures = 11$ 
```

```
else if ( $F-BPI \geq 100$  and  $B-BPI \geq 100$ )  $out\_structures = 12$ 
```

```
else if ( $F-BPI > -100$  and  $F-BPI < 100$  and  $B-BPI > -100$  and  $slope > extreme$ )
   $out\_structures = 13$ 
```

```
endif
```

$B-BPI$ = broad scale BPI grid

$F-BPI$ = fine scale BPI grid

out_zones = name of the output grid

$slope$ = the slope grid derived from bathymetry

$gentle$ = the user defined slope value indicating a gentle slope

$bathy$ = the high-resolution bathymetry grid

$shallow$ = user defined depth that separates the shelf from other broad flats

$extreme$ = the user defined slope value indicative of an extreme slope

The final classification was as follows, again according to Lundblad (2004) to ensure consistency of classification terminology throughout American Samoa:

- (1) Narrow depression
- (2) Local depression on flat
- (3) Lateral midslope depression
- (4) Depression on crest
- (5) Broad depression with an open bottom
- (6) Broad flat
- (7) Shelf
- (8) Open slopes
- (9) Local crest in depression
- (10) Local crest on flat
- (11) Lateral midslope crest
- (12) Narrow crest
- (13) Steep slope.

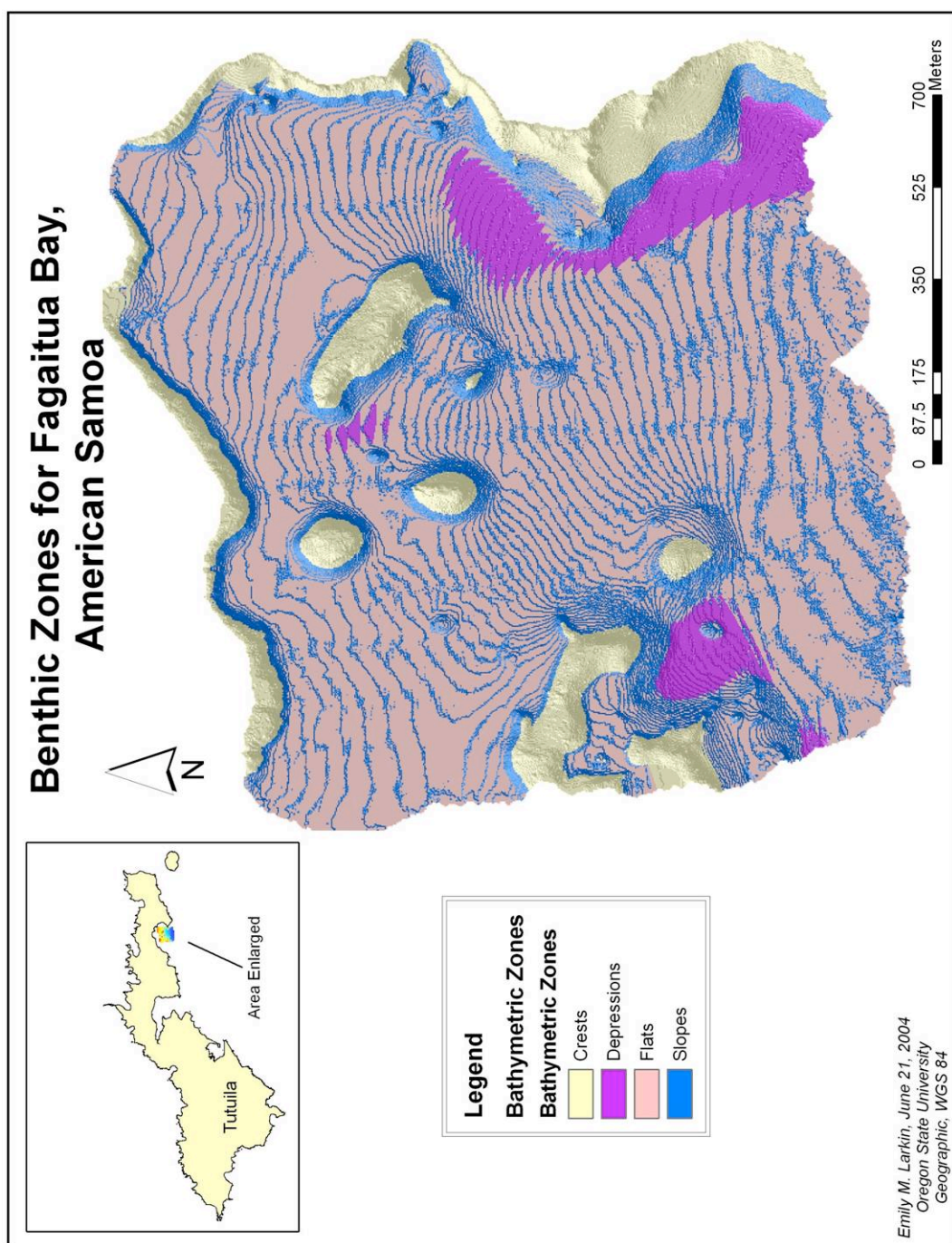
2.3 Results

2.3.1 Fagaitua Bay

Figure 2.8 shows the benthic zone classification for Fagaitua Bay. Figure 2.9 shows benthic structures for Fagaitua Bay. The colors in the figures are a standard color scheme for benthic zones and structures in American Samoa. Again, the regular pattern of lines that can be seen in all of the BPI grids is due to a problem with the initial data collection having to do with correcting for swell. This resulted in the zone and structure algorithms erroneously classifying the lines as a separate feature.

The area covered by the 2001 multibeam sonar survey overlaps areas classified by the National Oceanic and Atmospheric Administration (NOAA) Center for Coastal Monitoring and Assessment using Ikonos imagery (Coyne et al. 2002). With the exception of a few small areas on the edge of the bathymetry grid, the entire bathymetry grid lies within an area classified as *shelf* under the Ikonos-based classifications, which is a more general classification than used in this project. Additionally, the Ikonos-based classifications only extend to 30 m in depth.

The results of the benthic zone classification were compared to ground truth points collected around Tutuila by a group including staff of NPSA (A. Graves, pers. comm. 2001, as cited in Lundblad 2004). Although a large number of points were collected within Fagaitua Bay, only twenty-four points were collected within the surveyed parts of the bay and three of those points did not include any benthic zone information. No ground-truth points were collected from the deeper portions of the bay (Figure 2.10). Furthermore, of the twenty-four collected points, fifteen were collected



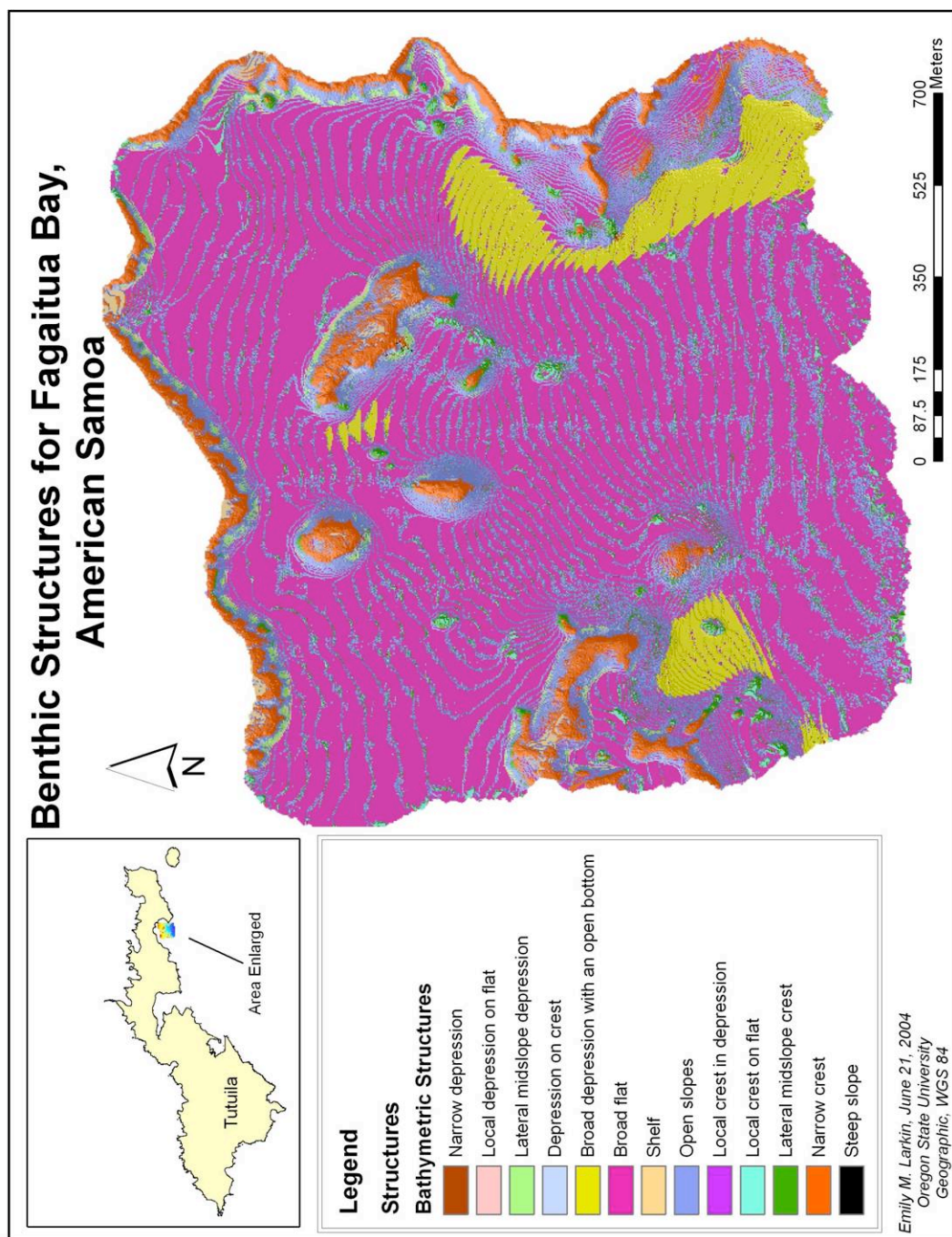


Figure 2.9—Benthic Structures for Fagaitua Bay, Tutuila, American Samoa

within the same benthic zone: *Bank/Shelf*. The naming system used for the ground truth points is not the same as the naming system used in this thesis, so comparison between the two is difficult and somewhat subjective. More ground-truth points using a consistent naming system are required to truly evaluate the accuracy of the classifications; however, no more have been collected. That being said, there was some agreement between the

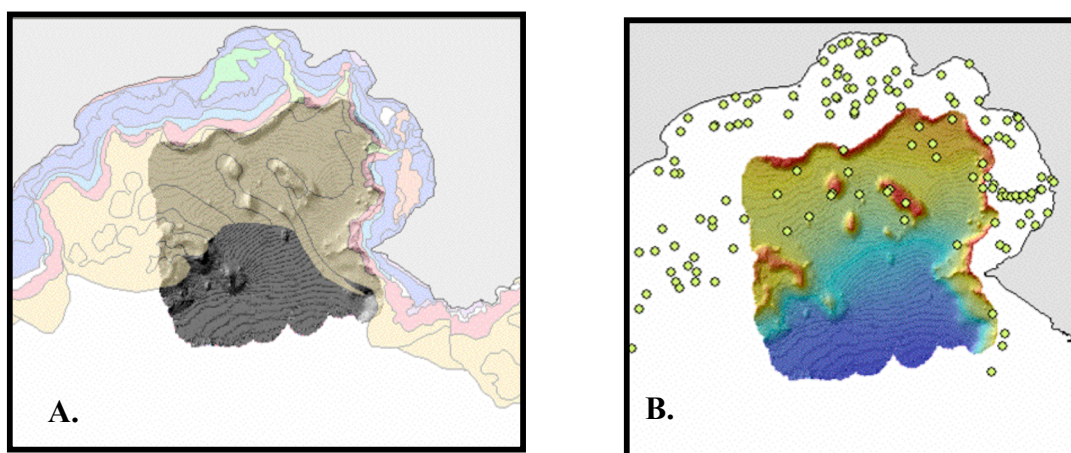


Figure 2.10—Overlap between Ikonos-based classification, ground-truth points, and bathymetry for Fagaitua Bay. A) About two-thirds of the bathymetry (dark gray) is overlapped by Ikonos-based classifications. Ikonos-based classifications go down to 30 m in depth. B) Twenty-four ground-truth points collected by NPSA fall within the bathymetry.

results shown above and the points collected by NPSA. Almost all of the points classified as *Bank/Shelf* fall within the area classified as *flats* in this thesis.

2.3.2 National Park of American Samoa

The same methodology and parameters were used to classify NPSA bathymetry as for Fagaitua Bay bathymetry. Figure 2.11 shows the benthic zone classifications for NPSA. Benthic structures are shown in Figure 2.12. There are some areas where the

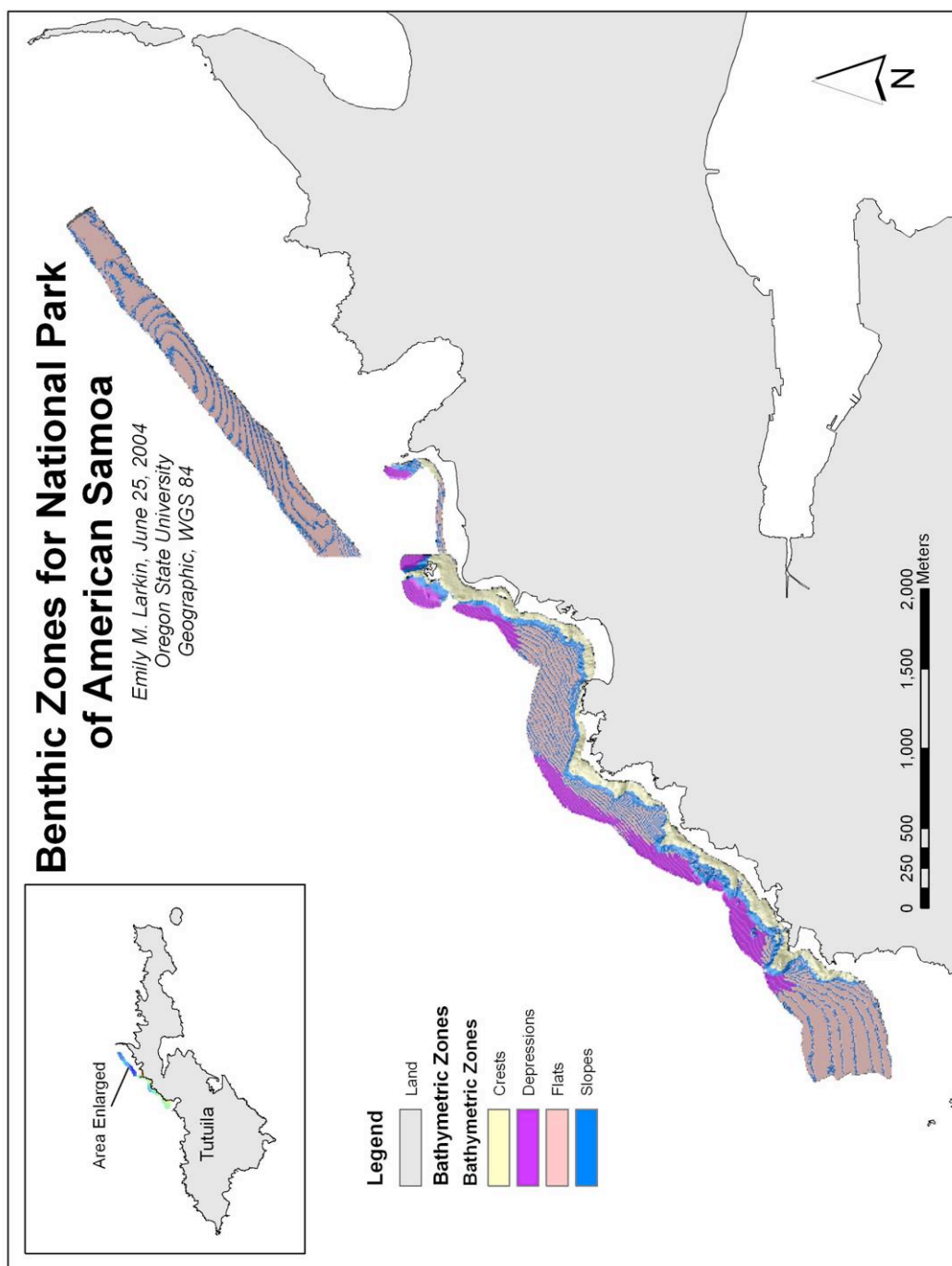


Figure 2.11—Benthic zones of National Park of American Samoa.

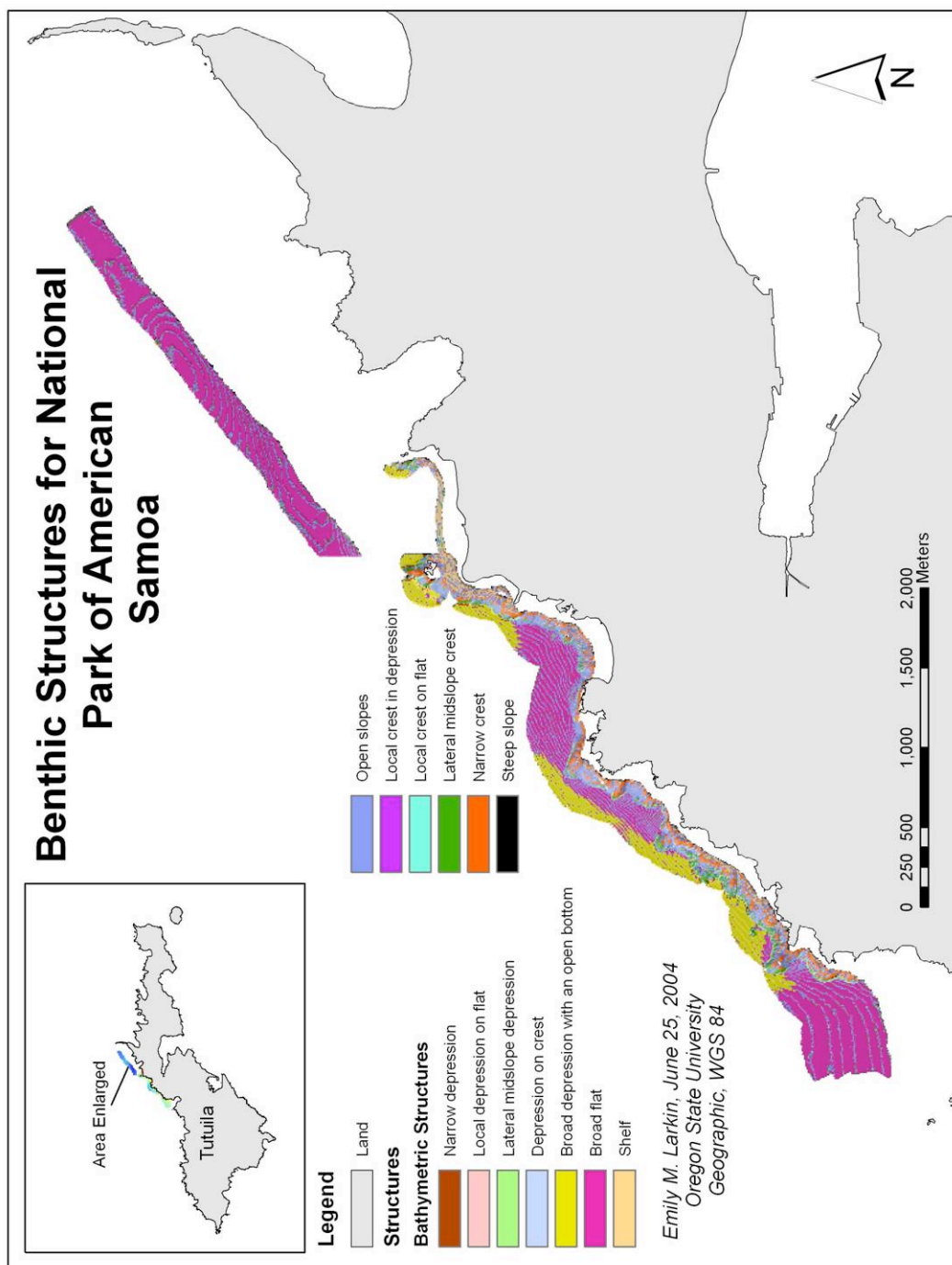


Figure 2.12—Benthic Structures for National Park of American Samoa.

surveys appear to overlap the shoreline. Since the post-processing of the data included tidal corrections based on information from Pago Pago Harbor, most likely the overlap is due to tides being slightly different on the north side of the island which could have skewed the post-processing slightly. The same problem with regularly spaced lines appears in the NPSA grids as well.

No NPSA ground-truth points overlap benthic zones in NPSA, so no error analysis against these points was possible. Comparison was also not possible between these classifications and the Ikonos-based classifications because only a small portion of the former overlap the latter (Figure 2.13).

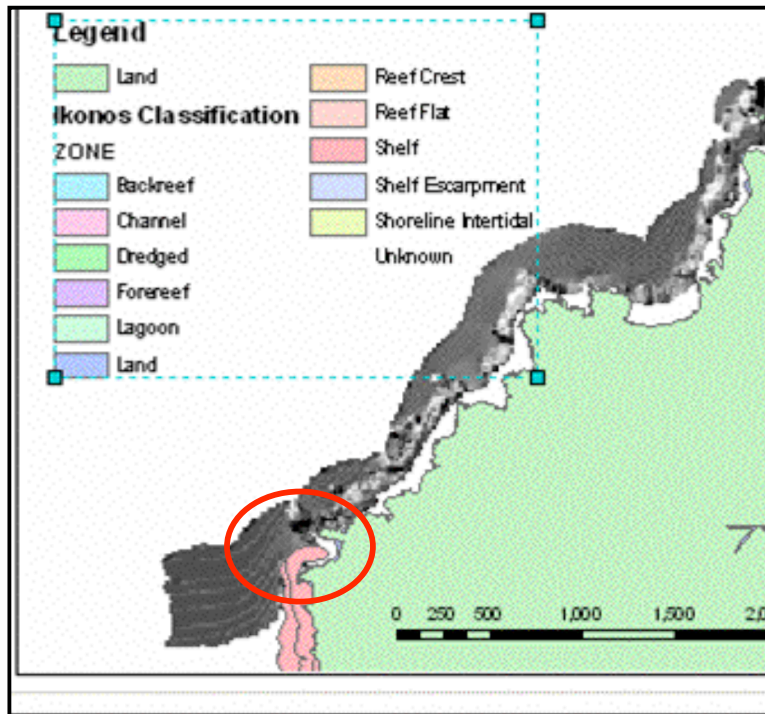


Figure 2.13—The overlap between Ikonos-based classifications and NPSA bathymetry. It was not sufficient to make any comparisons between the two.

2.4 Discussion

Many studies using sonar data use backscatter information to aid in classification of benthic terrain. Backscatter can give a better idea of the texture of the seafloor based on the intensity of the return of the signal. In good conditions, backscatter can even be used to determine the type of substrate (Diaz 2000), which would help distinguish between the dominant substrate in American Samoa, basalt, and coral. Therefore, more detailed analyses can be done with backscatter information including several techniques originally developed for satellite imagery (Hurst and Karson 2004). Unfortunately, no backscatter was collected in either Fagaitua Bay or NPSA.

Ground-truthing is also needed before any benthic terrain classifications can be tied to species or fish community types around American Samoa. More ground-truth points are also needed to extend or refine the Ikonos-based classifications to deeper water. To date, no ground-truth points below 30 m have been collected around Tutuila. Karlson et al. (2004), in a study that included American Samoa, indicated that general benthic terrain type may be correlated with biodiversity. Sloped areas were found to have a greater number of fish species present than flat areas; however, the study indicated that more work was needed to refine the results of that study. This is a trend seen not only in American Samoa, but across the Indo-Pacific region (Karlson et al. 2004). It is not possible at this time to make any definite conclusions about benthic habitats from benthic zones or structures. Far more ground-truth work needs to be done to determine if there is a link between them.

Benthic classifications such as those produced in this thesis may help researchers better focus their efforts to study coral reefs by identifying areas in need of more detailed survey. Although it is not possible to tie benthic zones and structures to specific habitats or species at this time, there is also evidence that the form of the substrate can influence species richness. Videography surveys and submersible dives are planned in 2005, with the hope that a stronger link will be found between benthic terrain and species assemblages. Since this study identifies areas that may eventually prove to have higher biodiversity, resource managers may be able to use this information to make better management decisions with regard to additional MPA designation.

3. Web-based GIS in American Samoa

3.1 Introduction to web-based GIS

As mentioned earlier, a great deal of mapping and research has been done on the coral reefs around American Samoa in recent years. This information may eventually be used to designate new marine protected areas in the territory. Making this information accessible to the public is an important step in gaining public support for MPAs. The importance of GIS as a management and public outreach tool for coral reefs was recognized at the 2000 Pacific Regional Symposium of the International Coral Reef Initiative (Crosby 2002). One of the goals established was that each Pacific island nation would create a publicly accessible GIS for management and protection of its coral reefs by 2010 (Crosby 2002). The advantages of using a GIS are well-known: A GIS can provide a relatively simple way to manage large, complex data sets. A well-designed GIS has the capability to display complex information graphically, making it more easily understood (Al-Kodmany 2001).

There has been mounting concern, however, that GIS provides information and data access only for well-educated, privileged groups already part of traditional power structures (Obermeyer 1998; Harris and Weiner 1998). Mainstream GIS software packages potentially exclude most of the general public from utilizing GIS technology and spatial data due to cost and inaccessibility to novice users (Peng 2001). One of the greatest barriers to greater public participation in planning processes is the lack of public access to spatial information (Barndt 1998). A GIS used in the public realm may also disproportionately benefit those who already have the technical skills to understand and

work with it, further disenfranchising those without the necessary technical skills (Al-Kodmany 2001). In many areas, while spatial data may exist and be used in making resource management planning decisions, data are not necessarily available to the public or may be costly and difficult to obtain, and according to Killpack (2004), may be the most expensive component of any GIS, especially if the data are high resolution satellite data such as Ikonos and QuickBird. Additionally, data are often scattered among a myriad of different agencies and organizations, rather than being available from one central location or clearinghouse (Harris and Weiner 1998). Software and data compatibility issues and incomplete or non-existent metadata can present further barriers to distribution of spatial data (Wright et al. 2000). Often, even when data are freely available and well-documented, users need extensive training and access to expensive software in order to effectively access the data (Obermeyer 1998). When data are not readily available, the general public may never get the opportunity to use data in a way that allows people to draw their own conclusions about natural resources, preventing them from participating in the decision making process in a meaningful way. Instead, the public must rely on information presented by government organizations or resource managers, which can lead to credibility problems, especially if the community sees the decision-makers as outsiders.

All of the problems with data compatibility and acquisition that are present in developed areas are exacerbated by the remote locations and lack of technological infrastructure and capacity of Pacific island nations. Often, few people are trained in GIS and many who obtain those skills leave for better salaries in areas with higher standards

of living. Along with intellectual flight, data access is an equally challenging problem in developing areas. The acquisition of a even single set of imagery may be impossible due to the cost of the imagery (Killpack 2004). Internet access necessary for download of data, when they exist, may be slow and unreliable. The benefits of research may never be made practically available in the areas in which the research was done, preventing local resource managers and the general public from using information generated by such projects, and research results may not be translated into the local language (Britton 2000).

A web-based GIS can potentially solve some of the problems of spatial data distribution. It has the practical advantage of allowing users to work with the data on their own terms and pace. The Internet can be a very powerful tool for making data available to far more people than would normally have access to them (Wong and Chua 2001). The only software necessary to use a web-based GIS to view data and conduct basic analyses is an Internet browser such as Microsoft's Internet Explorer or The Mozilla Organization's Firefox browser. A web-based GIS has several advantages over a traditional text-and-picture web site: (1) more information can be conveyed in a web-based GIS than in a traditional web site because several layers may be displayed at once and in any combination (Green 2001a) and (2) a web-based GIS can serve multiple levels of users including beginners with little or no GIS experience and more advanced users needing to download data and metadata for more detailed custom analyses (Peng 2001). Peng (2001) describes five levels of increasing web-based GIS functionality: (1) a static map and text displayed on a web page containing little opportunity for user interaction or input; (2) similar to the first, but various parts of the map may be linked to other pages

with more information; (3) the map is still static, but some method for user feedback is provided (e.g. email); (4) a dynamic map allowing the user to customize the display of the map and control which layers of data are displayed; and (5) a dynamic map that allows users to edit data layers (although original data sources are protected) for input into the community planning process. This last level of functionality is most often used in the planning process where stakeholders may propose alternatives to land or resource planning decisions (Peng 2001).

Web-based GIS sites are increasingly being used for marine data distribution by other organizations. Examples include ReefBase (Oliver et al. 2004) and the Moorea Community Geographic Information System (Edlund and Knupp 2004). Both sites distribute current research to the general public. Although ReefBase presents information about coral reefs, it is global in scope, so it cannot readily provide detailed information about reefs in a specific area. The Moorea Community GIS, a site providing information about the coastal resources on the island of Moorea, French Polynesia, presents detailed information about marine protected areas around the island. Users can customize the display of the map or access GIS data and the site is bilingual: available in both English and French, further improving accessibility to the residents of Moorea.

3.2 American Samoa and Technology

It is important to have an idea of what Internet infrastructure exists in American Samoa, since this thesis attempts to solve the problem of data distribution through use of the Internet. There are approximately 13,000 phone lines in American Samoa (CIA

2003). There is one Internet service provider in American Samoa, Samoateleco.com, which provides both dial-up access and expensive digital subscriber line (DSL) access. Blue Sky Cellular provides wireless Internet access, although it is also fairly expensive. American Samoa Community College has Internet access in the GIS lab, although it is, at times, unreliable at the time of writing. Free Internet access is available at the Feleti Barstow Public Library in PagoPago. Although, there are no data available on the level of computer ownership or home Internet access, sufficient Internet users exist in American Samoa that Google, the popular search engine, has a mirror site in American Samoa (<http://www.google.as>).

3.3 American Samoa Benthic Terrain Viewer

This study addresses the problem of public outreach and accessibility of scientific research and data in American Samoa through a web-based GIS called the American Samoa Benthic Terrain Viewer (ASBTv) and a Samoan-language mirror site, *O le 'Alititai o Amerika Samoa* (The Seafloor of American Samoa). Although the problem of disseminating scientific information is not unique to the Pacific, the remote location of the territory makes dissemination of current research that directly concerns American Samoa problematic. While there has been a proliferation of research on the coral reefs around the territory in the past few years, little of this information is available to the public in a form that is readily understandable or useable. This information may potentially be used in the establishment of marine protected areas (MPAs), which, in a society still partially dependent on subsistence fishing, directly affects the general public (Gilman 1997). It is vital that the information used in resource management decisions be

made available to those affected by these decisions. In addition to the general public in American Samoa, the target audience of the ASBTv includes teachers, community college and high school students, and local resource managers, as research on coral reefs can be included in science curriculum.

The ASBTv allows users to access spatial data from the coral reefs in American Samoa with either an English-language or a Samoan-language interface. The Internet addresses (URLs) for the websites are:

ASBTv:

<http://scallywag.science.oregonstate.edu/website/AmSamoa/viewer.htm>

O le 'Alititai o Amerika Samoa:

<http://scallywag.science.oregonstate.edu/website/Faasamoa/viewer.htm>

The data on which the websites are based are multibeam sonar surveys of seven areas around the island of Tutuila (Figure 2.1). FBNMS, the Tutuila Unit of NPSA, Taema Bank, Pago Pago Harbor, and Fagaitua Bay were surveyed in 2001 (Wright et al. 2002). In 2002, surveys were conducted in FBNMS, Taema Bank, Vatia Bay and Coconut Point (Wright 2002b). Benthic zone and structure maps have been created for the seven study areas from the bathymetry data produced by the surveys. Benthic zones and structures, in combination with rugosity and visual survey data, may be useful for identifying particularly sensitive areas in need of protection (Lundblad 2004). The ASBTv allows users to access bathymetry data along with the benthic zone classifications created from the bathymetry data. These data may be used in future

resource management decisions as part of a larger project involving mapping potential areas of high biodiversity or particularly sensitive areas.

The ASBTv provides links to the data used to create the site, which are available for free download. These data and a number of other GIS data sets related to American Samoa, both terrestrial and marine, are available at the Fagatele Bay National Marine Sanctuary GIS Data Archive, maintained at Oregon State University (Wright 2001). However, these data necessitate that the user have GIS software installed locally on his or her machine and knowledge of how to use it. The ASBTv will allow interested local residents to keep up with research being done on resources on which they depend as well as providing an access point for information about the deeper areas of the reef where little was known previously (Lundblad 2004; Wright et al. 2002).

Also included on the ASBTv is a link to the American Samoa Coastal and Marine Bibliographic Database. The database, developed by the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center (CSC) and Oregon State University (OSU), contains a record of published resources related to marine issues in American Samoa. The CSC did the programming necessary to make it available for inclusion in the ASBTv, while the database was populated at OSU as part of this thesis.

Various library article databases, the Internet, and hard-copy bibliographies were searched in compiling the database, which includes journal articles, government reports, conference proceedings, web pages, and books. The earliest reference to marine resources in American Samoa was a book published in 1842. Sixteen books and articles were published between 1917 and 1929. There was a large gap in publications between

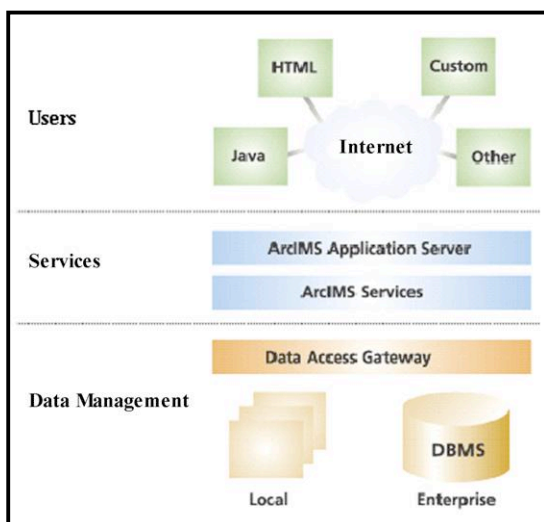


Figure 3.1—Schematic of how users interact with data in a web-based GIS. Data are housed and managed in a secure location. Users connect via the Internet to a web server that interacts with the data through ArcIMS connectors (after ESRI 2002b).

1932 and 1952, which is not surprising given world events at the time. Nearly three-quarters of the entries have been published since 1980.

3.4 Site Architecture

The ASBTV and the Samoan version, *O le 'Alititai o Amerika Samoa*, were created using Arc Internet Map Server (ArcIMS) version 4.01 (later upgraded to ArcIMS 9.0), an Internet map server or web-based GIS application. In a web-based

GIS, the data necessary to create a map and conduct analyses are housed in one location and are accessed remotely though the Internet (Figure 3.1). This differs from a traditional GIS in that the user does not need to install GIS software on his or her computer and does not need to be able to store large data sets locally on his or her machine. The level of functionality, accessibility, and complexity in a web-based GIS depends on how it is designed (Peng and Tsou 2003, O'Dea 2002).

Several different kinds of map services, including image, feature, and metadata services, can be created in ArcIMS. An image service creates a map image (such as a .jpg file) from the data layers included in the service and has the capability to display both vector and raster data. A feature server can display only vector data and requires the user to download a Java plug-in (a small piece of software) in order to function (ESRI

2002b). Operations are completed server-side rather than on the user end, reducing the user's need for a high-speed computer (ESRI 2002a). The ASBTv was designed as an image service because of the need to display raster data and to avoid making users download additional software to use the site. Within an image service, there are two ways to construct the site: as a hypertext markup language (HTML) image service or as a Java image service. The Java image service has the same limitation as the feature service in that it requires the user to download a plug-in (ESRI 2002b). Some users may be wary of downloading files from the Internet and installing them on their computers, which precludes using a Java service. Also, users with slow Internet connections, such as 28.8 kbps dial-up connections, may not wish to cause further delay by downloading a plug-in before using the map service. An HTML image service in ArcIMS is controlled by the .axl file (ArcIMS extensible markup language (XML)—a derivative of XML) (ESRI 2002b). The .axl file tells the map service in which directories to look for data and how to display various layers available on the map service including geographic extent and color schemes. The file is supported by a number of HTML files making up the frames and their display properties on the site and Java script files that determine how each tool and button functions on the site (ESRI 2002a, ESRI 2002b).

A certain level of computer literacy is required to use the ASBTv. This is an inherent problem with GIS and public outreach (Al-Kodmany 2001). Several steps have been taken to minimize the level of skills necessary to use the ASBTv. The initial display on the ASBTv is a hillshaded digital elevation model of the island of Tutuila

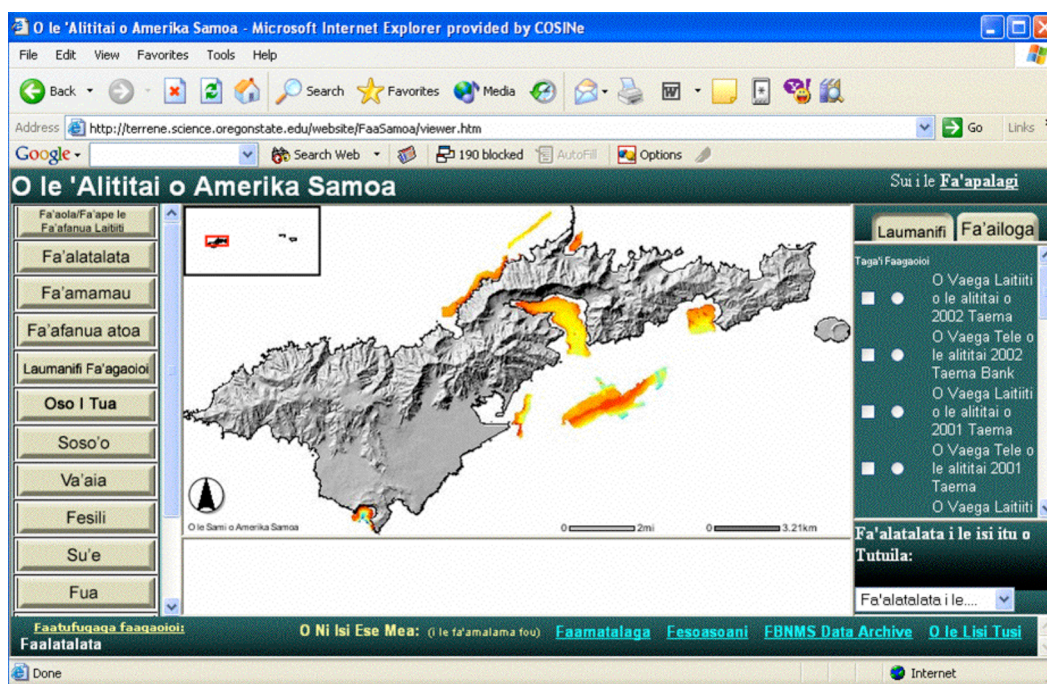
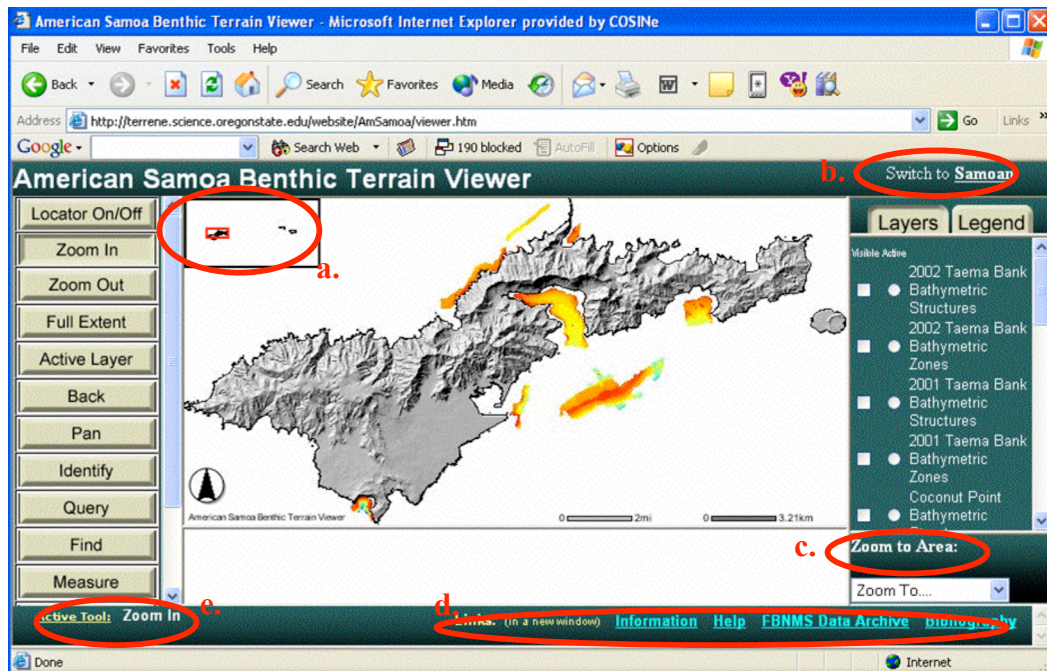


Figure 3.2—The American Samoa Benthic Terrain Viewer. Above: Screenshot of the American Samoa Benthic Terrain Viewer using Microsoft's Internet Explorer v. 6.0. Features of the ASBTv include: a) the overview map, b) a link to the Samoan-language version of the ASBTv, c) a menu allowing users to zoom in to an area of interest, d) links to more coral reef resources, and e) the active tool box. Below: Screenshot of *O le 'Alititai o Amerika Samoa* (The Seafloor of American Samoa) using Microsoft's Internet Explorer.

along with the bathymetry for the seven study areas around Tutuila: FBNMS, NPSA, Taema Bank, Fagaitua Bay, Coconut Point, Pago Pago Harbor and Vatia Bay (Figure 3.2). The user is then able to add or remove layers as he or she wishes by checking or unchecking the boxes next to the layer names. The featured layers are the benthic zone and rugosity classifications developed as part of a larger project in the territory (Lundblad 2004). Terrestrial layers such as villages and roads are included to help users orient themselves on the map. A list of layers on the ASBTv is included in Appendix B. A dropdown menu allows users to zoom to one of the areas that have been studied extensively. A number of tools, explained in detail on the help screen, add functionality to the site. To help users unfamiliar with typical GIS tool images, the default toolbar images in ArcIMS were replaced with images containing words. For example, rather than using the default button with a picture of a globe to indicate the function that will show the full geographic extent of the map, the words Full Extent appear on a button (Figure 3.3). Included among the tools are those that allow the user to conduct operations

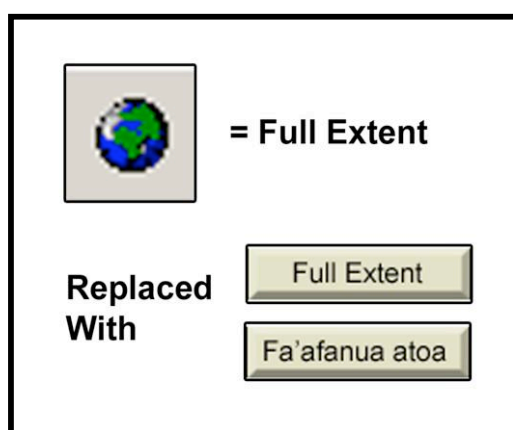


Figure 3.3—Making GIS accessible. Toolbar images were replaced with word buttons to enhance usability.

and basic analyses such as measuring distances, creating buffers, zooming in and out, and identifying features. Users can create maps with a legend, scale bar, title and north arrow through the print map utility. The site has links to other important resources such as the American Samoa Coastal and Marine Bibliographic Database



Figure 3.4-- A portion of the help screen for the ASBTv using Netscape Navigator 7.1. Each tool is explained in detail next a picture of the tool. The use of words rather than symbols, such as a magnifying glass to indicate the zoom function, will aid users unfamiliar with common GIS tool symbology.

and the Fagatele Bay National Marine Sanctuary GIS Data Archive. An extensive help screen has been written to aid users unfamiliar with either the Internet or GIS use the site more effectively (Figure 3.4). To further the aim of public education and outreach, an additional screen has been created with information

about the coral reefs in American Samoa and how they were mapped. The coral reef page contains links to sites with more detailed information about coral reefs, should the user be interested in learning more than the ASBTv offers.

The ASBTv and the Samoan version of the site, along with all data, are currently being hosted at Oregon State University using an Apache 2.0 and Apache Tomcat 4.0 Web Server. The ASBTv and its Samoan counterpart are two separate map services with separate .axl files and separate sets of HTML and Java files that reference the same data directories and data. This allows for simpler updates and ensures both sites contain the same content. If data for existing map service layers need to be updated, they only need to be done once, but if new layers are to be added, each .axl file must be updated.

Changing the display language of an ArcIMS map service is accomplished by changing each display parameter in the Java script file `aimsResource.js`, changing the titles in the `.axl` file, changing several parameters in the `aimsParam.js` file, and changing the title in the `viewer.htm` file.

3.5 Discussion

3.5.1 Technical Challenges

Although the communications infrastructure in American Samoa is at a level to allow use of the Internet as a public education tool, it appears the ASBTV may be a few years ahead of its utility in terms of loading times. Preliminary testing indicated that the ASBTV would run fairly slow on-island, but on further evaluation it became apparent that it runs so slowly that its use is likely to be limited to off-island people at the present time. Internet connections are known to be somewhat unstable and fairly slow in American Samoa. Static web pages load fairly quickly on most connections; however the ASBTV requires a lot of data transfer, slowing things down considerably. Although Bannan (2002) reported in *Pacific Magazine* that the public schools in American Samoa received a grant in 2002 to upgrade Internet access to T-1 connections, not all science or geography classrooms have computers and teachers still reported that their connections were slow and loading the site was not possible. The ASBTV works very slowly when viewed over a 50 kbps dial-up internet connection, but higher speed connections are recommended. One less than perfect solution involves the FBNMS GIS Data Archive. This website allows users to download marine GIS data and to see static images of most

of the data. While users cannot customize the display or show features in which they are interested, they can at least view the data.

Although it is not practical to use the ASBTv on-island currently, that does not mean that it has no purpose. A significant number of Samoans live outside American Samoa and the independent nation of Samoa, particularly in Australia, New Zealand, and the United States (US State Department 2004). Many of them still speak Samoan and maintain close ties to the islands, some of them even returning to live at some point. This is an audience that may be interested in conservation issues concerning American Samoa. The ASBTv may also be useful for increasing the awareness of GIS in American Samoa in the rest of the United States.

The ASBTv definitely works much better on high-speed Internet connections, such as DSL and T-1 connections. However, the reality in American Samoa is that many people will be limited to using the site over a dial-up connection, even at many of the government agencies. Several things were done to make the site load as quickly as possible, but most likely it simply will not work fast enough. The raster files included on the site were resampled from resolutions of 1 m and 2 m to 5 m and 10 m, respectively, allowing faster loading times. Displaying 5 m grids, rather than 1 m grids, on an ArcIMS site does not perceptibly diminish the quality of the site or of the display. It does result in generalization of some features, but the actual, high-resolution data are freely available to those who have a need for such data.

A second solution involves constructing a geodatabase from the raster layers and using ArcSDE, a middleware between ArcIMS and a database, to communicate between

the geodatabase and ArcIMS. This is a particularly useful solution for projects with very large grids, since geodatabases more efficiently store and index the data. In this case, the grids are very small—less than 30 Mb each—so the improved loading time would be offset by the necessity of going through another network connection. Additionally, this may not be a feasible alternative for all projects of this type due to the expense of the database program and the skills necessary to administer a database. In addition to a GIS analyst, the project would need someone adept at database administration.

There are plans to serve and support the sites locally on Tutuila; however, as of 2004, the technological infrastructure is not at a level where this is possible. The American Samoa GIS User Group has plans to create and host a local ArcIMS site in the near future, so it may be possible soon. Finding a local host for the ASBTv may greatly improve loading times, but there are no definite plans to move the site yet.

One possible alternative that should be explored is making data available on compact discs along with the free data viewer ArcExplorer for a nominal charge to cover the cost of the CD. This is similar to the approach taken by the City of Corvallis, Oregon, where data are available for download, but may also be obtained on CD from the city for ten dollars or may be borrowed from the public library. Taking this approach in American Samoa would allow those without Internet connections and those with very slow Internet connections access to data as well. This would also help address the problem of unstable Internet connections.

There are other challenges associated with using ArcIMS to display raster data such as benthic zone, structure, and bathymetry grids. Although raster data formats are

supported in ArcIMS, it is neither easy nor intuitive to display them on an ArcIMS map service, much less do anything with them. While there is a graphic user interface utility, ArcIMS Author, to add vector data to an ArcIMS map service, it does not allow the addition of raster layers. Additionally, if an .axl file containing both raster and vector layers is opened with Author, it will delete all of the raster layers, even if the .axl file is not changed or saved. Raster layers must be written into the .axl file by hand. It is also difficult to make identification of raster pixel values possible. The default programming in the ArcIMS JavaScript files only allows the identify tool to recognize vector layers. Converting the raster layers to a vector format such as polygon shapefiles is a possible partial solution to these problems; however, while this may be appropriate for discrete data such as benthic zones, it is not appropriate for data made up of continuous variables such as bathymetry grids. Additionally, error is introduced and some data are lost in the conversion.

The solution to being able to use the identify tool on raster data in ArcIMS requires JavaScript and HTML code editing. The table of contents file (toc.htm) file must be edited so ArcIMS will allow a raster layer to be made an active layer (a layer must be “active” to do any analyses on it or to use any tools on it). Without this edit, no radio button appears next to raster layers allowing users to make a raster layer active. The following JavaScript files must be edited to allow the identify tool to work on raster data: aimsCustom.js, aimsIdentify.js, aimsXML.js, and aimsLayers.js (T. Valentine, pers. comm. 2004; Valentine and Dodgett 2003). If any of them are omitted, the identify tool will only work on vector layers or may not work at all. The specific changes can be

found in Appendix A. Whether using ArcSDE or not, making ArcIMS allow queries on raster data requires at least some knowledge of JavaScript programming, something that may also be problematic for some projects, particularly in remote areas.

While the bibliographic database provides a useful list of what has been published about marine resources in American Samoa, it does not solve the problem of availability of references on-island. Libraries in American Samoa do not have the budget to maintain subscriptions to a large number of academic journals, where much of the research has been published. While these may be available through inter-library loan (not necessarily free-of-charge) or online, government reports and conference proceedings can be even more difficult to obtain. While the Internet can solve some of the problems of knowing whether things exist, it cannot always solve the problem of access (Britton 2000).

3.5.2 Social Challenges

In addition to making the ASBTV accessible to as many people as possible, translating the ASBTV into Samoan adds to the limited Samoan-language resources available on the Internet. The ASBTV is the only Samoan-language web-based GIS in existence and it is one of only a handful of Samoan-language sites dealing with scientific information. Although English is the official language in American Samoa, Samoan is still widely spoken. Most people converse informally in Samoan and, although almost everyone knows English, village outreach meetings are conducted in Samoan. Britton (2002) and Crosby et al. (2001) recognized that scientific information translated into the local language greatly improves accessibility and can generate more interest in the

subject area by people who would normally be left out of the information distribution process. Currently, few official government web pages are translated into Samoan in either American or the independent nation of Samoa. Brigham Young University-Hawaii (Fautimau 1998) and an organization in New Zealand, *Fagasa*, maintain pages dedicated to learning and preserving the Samoan language and a number of personal web pages with Samoan content also exist. There are even fewer Internet resources concerned with scientific research in American Samoa or in the independent nation of Samoa and most of these contain little if any Samoan language content. A notable exception is the National Park of American Samoa preliminary online fish inventory, which includes Samoan, English and scientific names for most fish found in American Samoa (National Park Service 2003). Rosia Tavita of FBNMS assisted with translations.

An interesting observation during the 2004 workshops in American Samoa was that, of people asked, only one elderly woman in an outreach meeting in the village of Fagasa, knew what the word '*alititai* (seafloor) meant. Most everyone else asked had never heard the word before, although it is found in the Samoan Dictionary (Milner 1993). Most people asked in the independent nation of Samoa, not just elderly persons, did know the definition of '*alititai*. Although not a scientific survey in any way, it does point to the need for more availability of information in Samoan from a language-preservation standpoint and to the changing use of words in American Samoa. Towards this end, rather than assuming people know what it means, '*alititai* is now defined on the website.

Although it is not clear at the present time how the ASBTV will be used, due to the current speed of Internet connections in American Samoa, most use for the time being will probably be off-island. Eventually, the ASBTV, combined with educational modules about marine GIS and coral reef conservation developed for American Samoa Community College and work being done by the American Samoa Government Department of Commerce, may lead to greater public awareness of the conservation issues surrounding the reefs in American Samoa. It may also be a useful tool for agencies and organizations, such as the American Samoa GIS Users' Group, wishing to conduct public outreach and facilitate more public participation in the process for designation of marine protected areas. By providing a visual sense of what is actually out in the deeper reefs around American Samoa, the site could be a starting point for discussions about marine protected area designation held with the public.

4. GIS Education and Local Data—Making GIS Interesting for Capacity Building

4.1 GIS Education for Capacity Building

Many jobs requiring GIS skills are not specifically GIS Analyst positions. Resource management, public works, emergency management, land use planning and public health are all fields in which someone may have a job where, for example, land use planning is his or her primary responsibility, but the position may still require some level of GIS skills (Britton 2000). The number of jobs requiring GIS skills outnumbers the number of workers with GIS skills, even in developed countries, although developing countries face far more serious shortages (Bishop et al. 2002). An important part of meeting the needs of a GIS community is the training of students who will eventually enter a GIS-related profession. Exposing students to positive experiences with GIS early in their post-secondary education makes it more likely that they will be comfortable taking advanced GIS classes and that they will go on to use GIS in their careers (Mueller and Wickham 2003; West 2003).

An important key to local capacity building is local education and integration of local GIS users into the GIS community. Introductory GIS classes in higher education are where many GIS professionals began and this exposure to GIS can help provide a knowledge base for a growing GIS community (Britton 2000, Deadman et al. 2000). GIS can be a very powerful tool for science and geography education, providing a means to develop critical thinking and analysis skills crucial to the scientific capacity-building necessary for long-term local management of resources (Crosby et al. 2002, Green 2001; West 2003). GIS can also help students become more comfortable with spatial

representations of information (Biilmann 2001). Students who take a course including basic GIS skills often become more comfortable, not only with GIS concepts and skills, but using and working with computers in general, a skill that may also be in short supply in a developing country. Although a student who takes an introductory course in GIS may not continue on to a career in GIS, even the computer skills gained from the experience can be of great value (West 2003).

Although a large body of literature exists describing how to design a GIS curriculum for elementary and secondary schools, less has been written about introducing GIS to students in higher education. Much of the existing literature on GIS in higher education primarily deals with the design of an entire GIS program or the technological challenges of starting a GIS program, rather than the design of the curriculum itself. Another set of literature on GIS in higher education focuses more on how GIS education fits in with traditional geography education (Kemp, et al. 1992). That being said, the National Center for Geographic Information and Analysis (NCGIA) is an excellent resource for GIS curriculum and course design in higher education. The website details concepts that should be covered in a GIS curriculum and provides strategies for covering them (NCGIA 2004).

4.2 Educational Modules for ASCC

4.2.1 General Strategies

One of the greatest challenges to GIS education is the availability of data and a curriculum that makes use of local data. This is particularly true in remote areas, where

data may not be accessible or, even exist at all. The use of data and lessons built around areas with which students are familiar has been found to contribute to the success of a GIS curriculum (O'Dea 2002). American Samoa is unique among the Pacific island states in that it has been the focus of a number of marine surveys producing data that are available free of charge. It also has an active GIS community, the American Samoa GIS Users' Group. The challenge has been to integrate that data into the local GIS curriculum. Four educational modules were designed to introduce students to a variety of GIS principles and skills using local data. The lessons, incorporating Ikonos satellite imagery, multibeam sonar data, and ground-truth point data, are each designed to be completed over a number of class periods. It was assumed, when writing the modules, that students in the class would be at a beginner level with GIS software and concepts, particularly with regard to raster data and operations.

The modules are designed around ArcGIS 8.x, the version of ESRI's GIS software installed at American Samoa Community College. They make heavy use of the Spatial Analyst Extension, included with ArcGIS 8.x. The lessons focus on raster data, the skills associated with working on raster data, and are designed to increase progressively in complexity, giving students experience with a range of operations in ArcGIS. Most introductory classes focus on vector data, so this set of modules focusing on raster data will be a good supplement to a beginning GIS curriculum.

All lessons include several of the features described by Bishop et al (2002) as being necessary in GIS educational modules. Each lesson specifically states the objectives of the lesson and what skills and concepts with which students should be

familiar on completion of the lesson. This gives students a sense of what to expect from the lesson. Questions that require thought and feedback are included at the end of each lesson as well. Students are also asked to do simple research on the Internet on their own to find answers to certain questions, hopefully impressing on them the tie between GIS and subjects that do not appear to be, at first glance, GIS related subjects. Some of the modules point students to specific sites, while others require students to search for information using a search engine such as Google. As noted earlier, although a dynamic site such as the ASBTv does work very well in American Samoa, static web pages load in a reasonable length of time, making Internet research feasible. This will also force students to draw their own conclusions about what they have learned.

There are a number of concepts outlined by NCGIA (2004) as being necessary for a core GIS curriculum that are covered by the educational modules. Per NCGIA standards for community college and technical programs, the educational modules focus on the application of GIS skills, the concepts behind those applications, and teaching GIS concepts with real-world problems. The initial lesson introduces students to very basic operations. These include many of the spatial analysis operations used in the second and third lessons. The lessons also include application of GIS to a real-world problem which is included in the NCGIA standards (2004).

The modules were designed to help students navigate through the complex ArcGIS software. File names have been simplified so they are as intuitive as possible. They follow a consistent format when introducing new tools, functions, and commands, which will hopefully minimize confusions on the students' part. When new tools and



Figure 4.1—Making GIS easier to learn, part 1. Pictures of buttons and tools are included in the text of the modules to help students find their way around the software.

buttons are introduced, an image of the tool is included in the text to help students find the appropriate button (Figure

4.1). Hall-Wallace and McAuliffe (2002) noted that including pictures directly in the instructions helped students navigate GIS software. Another solution to make software

navigation easier concerns pull-down menus. When

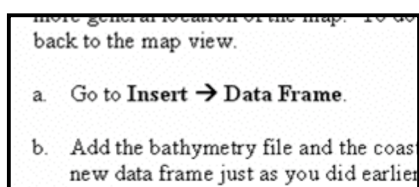


Figure 4.2—Making GIS easier to learn, part 2. Pull-down menu commands are explained with a by using the arrow indicating the next menu or command.

a command is buried in a pull-down menu, the instructions show all of the steps involved in finding that command (Figure 4.2). Screenshots are included in all of the modules, particularly of dialog boxes and wizards. The pictures of where things are make

elaborate explanations in the instructions less necessary and make the instructions less confusing. In some cases, the expected results are also shown so students do not get lost and discover the next step will not work with their erroneous result.

4.2.2 Specific Lesson Descriptions

The entire educational modules are included in Appendix C. The first lesson introduces students to working with data in ArcMap and reading metadata in ArcCatalog. This lesson relies heavily on Ikonos imagery because the representation of geographic space is more intuitive in high-resolution Satellite imagery than in a bathymetry grid, introduced later in the lesson, or in a digital elevation model (DEM). Students are asked to look at various terrestrial and marine features around the island of Tutuila and to use

simple GIS tools such as measure and identify. Students will compare the water quality, which is evident from the image, in various bays around the island. Students are also asked to draw conclusions about why water quality differences exist between bays. The second part of the lesson introduces students to a bathymetry grid of Pago Pago Harbor. Students will have the opportunity to supplement their work in ArcGIS by using the Internet to investigate the wreck of the *Chehalis* that can be seen on bathymetry grids of Pago Pago Harbor. The final part of the lesson has students use the NPSA Fish Inventory and the Internet to answer questions about some of the fish in American Samoa. On completion of this lesson, students will be able to: add data to an ArcMap project, measure objects in ArcMap, use the identify tool in ArcMap, make a simple layout, explain what factors affect the quality of a remotely-sensed image, and briefly explain the history of the *Chehalis* wreck and why it still poses a threat to Pago Pago Harbor.

The second lesson introduces students to the Spatial Analyst extension of ArcGIS, to the Benthic Terrain Modeler, and to benthic classifications. The Benthic Terrain Modeler (BTM), an ArcGIS 8.x-based tool, was developed by the NOAA Coastal Services Center using the methods of Lundblad (2004), to simplify the process of benthic terrain classification (Rinehart et al. 2004). The tool includes a wizard interface, removing the need for command-line input, making it far more accessible to the beginning GIS user, especially those with little experience working in a command-line input. One has the option of allowing the BTM to create all of the grids necessary for benthic classifications. Most people using the BTM will probably use this option. The other option allows the user to use preexisting grids to create benthic zone and structure

classifications. This feature is particularly useful for the second educational module. Students will create all of the necessary grids, such as standardized BPI, individually. This will allow the students to learn how the BTM really works and understand the processes behind it. Since the BTM has a wizard interface, students will not have to grapple with command-line input and will be able to run classifications for both benthic zones and structures (running benthic structures using command-line input is too difficult for an introductory level class). Using the BTM also avoids the need for a full installation of ArcInfo workstation, which is considerably more expensive than ArcGIS Desktop and currently unavailable at ASCC.

The lesson uses bathymetry grids from Pago Pago Harbor from 2001. Students are asked to create benthic zone and structure grids by going through a series of steps including creation of slope, BPI grids, and standardized BPI grids. BPI and standardized BPI grids are created through the raster calculator within Spatial Analyst. The final part of the lesson is done using the BTM. Students will use pre-defined classification dictionaries designed for the lesson—one for zones and one for structures. At the end of this lesson, students should be able to add extensions to ArcMap, do a slope analysis, define a slope analysis, use the raster calculator, define bathymetric position index, create BPI grids, use the BTM to create benthic zone and structure classifications, and define benthic zones and structures.

In the third lesson, students continue to work in Spatial Analyst, but they are also introduced to 3D Analyst and ArcScene. Students create three-dimensional representations of FBNMS. Several analyses are introduced in the lesson, including

hillshade and viewshed analyses. This is the first lesson that students actually work with vector data and use some of the functionality of ArcCatalog. Students are asked to create a new shapefile and add points to it to complete the viewshed analysis. Students typically enjoy working with three-dimensional visualizations and this proved to be no exception at the workshops held in September, 2004 at ASCC. Questions were included in the lesson to ensure that students realized that three-dimensional visualization does have a purpose beyond simply creating pretty pictures. By the end of the third lesson, students will be able to define hillshade and viewshed analyses, create a three-dimensional view of a bathymetry grid, create a new shapefile and add data to it.

The final component, part of the third lesson, asks students to use ground-truth points, do a buffer analysis, and use various web resources to delineate a new, imaginary MPA in Fagaitua Bay. This section is meant as the capstone assignment for the modules. Students are asked to think about all of the issues surrounding the creation of MPAs, including how they affect local populations dependent on subsistence fishing, how to approach local villages about an MPA, what types of regulations an MPA should have, and the need to include diverse habitats within the MPA. These are complicated issues in any natural resource management strategy and students will probably find this part of the project to be fairly challenging. At the end of this part of module, students will have developed a strategy for creating an imaginary MPA and produced a short written proposal for their MPA. Students will be required to include any maps they feel are necessary to illustrate their proposal, so it will be a good demonstration of the technical

GIS skills they have learned in the modules as well as a demonstration of their ability to think through a complex problem.

4.3 Discussion

The educational modules attempt to address the idea of tying technical skills to real-world concepts and problems that require more than technical skills alone to solve. There are concerns that many GIS curricula teach excellent technical skills but do not address how they should be applied to complex real-world problems, particularly in areas where geographic information management is still fairly new (Dunn et al. 1999). The project in the third lesson requiring students to design an MPA and develop strategies to gain public support will help students understand that GIS underlies many planning decisions, even when it is not patently obvious to an outside observer. Since decisions made using a GIS have real world effects, hopefully, the students will gain an understanding of how GIS can help make management and planning decisions, but also how working with the public in the real world (i.e. not on a computer screen) can make seemingly easy decisions much more complicated. This is certainly not just true in American Samoa, but throughout the world.

The educational modules were presented as a short two-day workshop at American Samoa Community College (ASCC) in September, 2004. The workshop was attended by instructors at ASCC, government employees, and several students at ASCC. The workshop was very successful and participants' response to the workshop was overwhelmingly positive. Both the GIS instructor and the marine science instructor at ASCC expressed interest in using them in their classes, so forty student copies were left

with them for use in their classes. Feedback was gathered and the modules were updated to reflect some of the participants' suggestions.

One unanticipated problem was that the computers at ASCC did not have ArcInfo Workstation, which is necessary for the processing required to find benthic zones in the second educational module. Workshop attendees completed all of the steps up to that point and then the final step, the actual creation of benthic zones, was demonstrated on a laptop with the necessary software. Participants felt that going through each of the steps behind the creation of benthic zones was valuable enough that they would not want to see the entire lesson done in the BTM. It has a wizard interface that allows creation of benthic zone and structure grids without actually knowing how they are being calculated. Given the way the BTM was designed, it was possible to re-design the lesson so students still work through all of the steps up to classification and use the BTM to actually create the benthic zone and structure classifications.

In addition to being used by the American Samoa Community College, the modules could potentially be used by high school science or geography classes if they have access to the appropriate software. Students at that level would be more than capable of completing the modules as written. The ASBTM could also be used to help introduce students to GIS concepts with some additional instruction. The modules have already generated interest outside of American Samoa by instructors who want to incorporate marine GIS into their lesson plans. The lessons are well-suited for use in any introductory GIS class, as they present concepts that are important in any GIS curriculum. While the other educational modules will have wider applicability outside

American Samoa, the last part of the third module is specifically designed for American Samoan students since students will address how to create an MPA in American Samoan waters considering local conditions and problems. It might be easily adapted, however, to other Pacific island nations with similar local concerns and challenges to creating parks and reserves.

Many GIS users, particularly in developing countries, are self-taught and are not able or willing to take a term or more away from their jobs to pursue a degree or even a class in GIS (Gould 2001). Gould (2001) argues that short training courses offered by academic institutions or self-directed lessons are potential solutions to this problem. It may be easier for GIS users to spend a week or two away from their jobs or even to persuade their employers to pay for a short course than it would be for them to take a class that lasts an entire term. The educational modules developed as part of this project were easily adapted to a short-course format with few changes. The only part of the educational modules that did not work as well in a short format was the marine protected area project, but with more planning, this could be adapted to a workshop format as well. Working in groups on different aspects of a proposal, workshop participants could develop a proposal in a much shorter amount of time than a student in a typical semester-long introductory GIS class. Alternatively, the educational modules produced as part of this project could stand alone as self-paced tutorials. Often people self-taught in GIS have significant gaps in their knowledge (Gould 2001) that these modules might address, particularly if the gaps happen to be in working with raster data.

A common problem when writing any kind of documentation or lessons for a particular version of software is that, inevitably, it is out of date before or soon after it is completed. This has turned out to be the case with the educational modules. Although currently, ASCC is using ArcGIS 8.x in their computer labs, ArcGIS 9 was released in June, 2004. Much of the way the software handles raster data has not changed with the new version and only a small portion of the modules focus on vector analyses, so few changes are needed. The BTM is currently designed for Arc 8.x, but updates are in progress to facilitate smooth operation in Arc 9.

To reach the widest audience, the modules will be distributed in several ways. First, a number of traditional bound paper copies were distributed in American Samoa in September, 2004. Each person attending the workshops received a teachers' edition of the educational modules which included a data CD with all of the data for the modules, electronic copies of the modules themselves, supplemental PowerPoint presentations, and answer sheets. The modules will also be available electronically on the Internet, from an information page on the ASBTV. The module files will be converted to PDF files and compressed together with the answer sheets and the necessary data layers in .zip files. Environmental Systems Research Institute (ESRI) also maintains an archive of GIS educational modules as part of their web pages. The archive is searchable by software and by subject, making it both a good source for lesson plans and a good distribution point for educational modules. The modules may be archived there as well. This will allow more educators to access the modules than those who originally receive the paper copies.

5. Conclusions

This project has taken a multi-pronged approach to increasing public knowledge about the coral reefs and benthic terrain in American Samoa. The creation of benthic zone and structure maps for two nearshore areas around Tutuila will provide managers with a better understanding of the areas they regulate and protect. The ASBTv and O le 'Alititai o Amerika Samoa, in combination with the American Samoa Coastal and Marine Bibliographic Database, provide the public with access to marine GIS data, maps, and marine-related literature.

Web-based GIS cannot solve all of the data access issues in American Samoa simply because the technological infrastructure is not at a point where high-speed Internet access is ubiquitous. Although every effort has been made to make the ASBTv load as quickly as possible, even Internet-savvy users on particularly slow connections may become frustrated and give up on the ASBTv. It is likely that it will be a few years before Internet connections are fast enough to make the site usable by a wider audience. For the time being, most of the use of the ASBTv will probably be off-island. The American Samoa Coastal & Marine Bibliographic Database is an independent site, however and works quite well in American Samoa.

Another limitation to web-based GIS is that a person must have a certain level of computer literacy in order to effectively use it and some form of Internet access, even at the most basic level. Traditional outreach and some instruction are necessary to make more people feel comfortable with a web-based GIS. Even in areas where a large percentage of the population has access to the Internet, it is unlikely a website will gain a

wide audience without some significant form of advertising and traditional forms of outreach. Without more traditional forms of outreach, many people would never be reached by a web-based GIS, particularly those with less access to computer technology. These are often the people most likely to still dependent on more traditional resources and would be most affected by decisions to restrict fishing or create MPAs (Wong and Chua 2001). If participatory structures are not already in place, data access alone will not spark participation in decision processes (Tulloch and Shapiro 2003). In spite of these challenges, the creation of the ASBTv is an important step toward making data available to as many people as possible. Local-language translations of scientific information are also extremely important to reaching as many people as possible. Although the majority of American Samoans speak English, community outreach programs in villages are often conducted in Samoan.

Educational modules designed for the upper secondary and community college levels will help ensure that students are exposed to GIS being done locally. Educational modules will contribute to the technical capacity building effort in American Samoa. By tying GIS skills to real-world, local problems, it is hoped that students will be more interested in the subject matter and may go on to take more advanced GIS classes, possibly even leading to a career in GIS. The educational modules provide educators with another resource through which they can reach students. As Internet speeds increase in American Samoa, it may be useful to produce educational modules using the American Samoa Benthic Terrain Viewer for the high schools.

The combination of these three aspects of this project will increase the public's exposure to GIS in American Samoa and, ideally, increase the public's knowledge of the coral reefs in American Samoa. Web-based GIS, in combination with traditional outreach and educational outreach can provide a well-rounded way to educate and inform the public about research activities, providing a better connection between the public and the scientific community. It also presents the opportunity to increase public awareness of GIS use in a remote location. It is hoped that the use of the ASBTV may eventually lead to some form of public participation GIS, but time will be required to determine if this is the case and for local Internet connection speeds to catch up enough to make the site more reliable and user-friendly. There should also be some effort to incorporate local knowledge into the ASBTV, since this is important to the development of a participatory process (Wong and Chua 2001).

Future work planned for American Samoa includes two submersible or ROV dives, funded by the Hawaii Undersea Research Lab of the NOAA National Undersea Research Program, to ground truth the classifications produced as part of this and Lundblad's (2004) project. It is hoped that a stronger link will be found between benthic terrain and species or biological community types, particularly with regard to fish species. Additionally, the American Samoa GIS User Group is in the process of starting an ArcIMS website, which may mean that the ASBTV could be moved to Tutuila in the near future.

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APPENDICES

Appendix A—List of layers on the American Samoa Benthic Terrain Viewer

TABLE OF LAYERS ON THE ASBTv

Digital Elevation Model (DEM) of Tutuila
 DEM of the Manu'a Islands
 Fagaitua Bay Bathymetry
 Fagaitua Bay Benthic Zones
 Fagaitua Bay Benthic Structures
 Fagatele Bay National Marine Sanctuary (FBNMS) Bathymetry
 FBNMS Benthic Zones
 FBNMS Benthic Structures
 National Park of American Samoa (NPSA) Bathymetry
 NPSA Benthic Zones
 NPSA Benthic Structures
 Vatia Bay Bathymetry
 Vatia Bay Benthic Zones
 Vatia Bay Benthic Structures
 Pago Pago Harbor Bathymetry
 Pago Pago Harbor Benthic Zones
 Pago Pago Harbor Benthic Structures
 Coconut Point Bathymetry
 Coconut Point Benthic Zones
 Coconut Point Benthic Structures
 Taema Bank Bathymetry
 Taema Bank Benthic Zones
 Taema Bank Benthic Structures
 Revelle Bathymetry Data
 Roads for eastern Tutuila, Anunu'u and the Manu'a Islands
 Villages
 Counties

Appendix B—Identifying Raster Values in ArcIMS HTML Viewer

Raster files can be displayed by an ArcIMS map service fairly easily. However, the ability to do an identify query on a raster layer requires editing several javascript files and one HTML file.

1. In the *toc.htm* file, some changes need to be made to make a radio button show next to the layer name in the layer list. This allows users to make the raster layer active.
 - a. First, do a search for *LayerIsFeature*. This will go to the appropriate place in the *toc.htm* file.

- b. Delete the following code:

```
if (t.LayerIsFeature[i]) {  
  
and  
  
} else {  
    document.write('&nbsp;');  
}
```

2. In the *aimsIdentify.js* file, the existing identify needs to be edited and a new function added to allow the identify function to work on raster files.
 - a. Change the **//identify feature function** to the following:

```
function identify(e) {  
    if (checkIfActiveLayerAvailable()) {  
        highlightedOne="";  
        var theX = mouseX;  
        var theY = mouseY;  
        getMapXY(theX,theY);  
  
        if (LayerIsFeature[ActiveLayerIndex]) {  
            searchTolerance = (xDistance/iWidth) * pixelTolerance;  
            var tempWest = mapX - searchTolerance;  
            var tempNorth = mapY + searchTolerance;  
            var tempEast = mapX + searchTolerance;  
            var tempSouth = mapY - searchTolerance;  
            var theString =  
writeGetFeatures(tempWest,tempSouth,tempEast,tempNorth);  
            showRetrieveData();  
            sendToServer(imsQueryURL,theString,identifyXMLMode);  
        }  
    }  
}
```



```

    } else {
        var theString = writeGetPixelXML(ActiveLayer,mapX,mapY);
        //alert("Identify:" +theString);
        showRetrieveData();
        sendToServer(imsURL,theString,identifyPixelXMLMode);
    }

    //if (useTextFrame) parent.TextFrame.document.location =
    "text.htm";
    }
}

```

- b. Add the following function directly before **//function writeIdentifyXML**:

```

// New function to get pixel value
// mkd 10/22/02
function writeGetPixelXML(theLayer,xClick,yClick) {
    var theString = '<ARXML version="1.1"><REQUEST>\n';
    theString += '<GET_RASTER_INFO x="' +xClick+' " y="' +yClick+' " \n';
    theString += 'layerid="' +theLayer+' " >';
    theString += '</GET_RASTER_INFO>';
    theString += '</REQUEST>';
    theString += '</ARXML>';

    return theString;
}

```

3. In the *aimsCustom.js* file, a new variable has to be added and defined.

- a. Add the following line under global variables, near the top of the file:

```
identifyPixelXMLMode = 1001;
```

- b. Add the following function under **function useCustomFunction(the Reply)**,

where it says *insert code here*

```

if (XMLMode==1001) {
    // Response from pixel query
    //alert ("aimsCustom:" +theReply);
    var Win1 = parent.TextFrame;
    var theFrame = "parent.MapFrame";
    Win1.document.open();
    Win1.document.writeln('<html><meta http-equiv="Content-
Type" content="text/html; charset=' + charSet + '"><head><title>' +
titleList[7] + '</title></head>');
    Win1.document.writeln('<body bgcolor="' +
textFrameBackColor + '" text="Black" link="Blue" vlink="Gray"
LEFTMARGIN=0 onload="window.focus()">');
    Win1.document.writeln('<center>');
    Win1.document.writeln('<FONT FACE="Arial" SIZE="-1"><b>' +
LayerName[ActiveLayerIndex] + '</b></FONT>');
}

```

```

        Win1.document.writeln('<table border="1" cellspacing="0"
cellpadding="0" nowrap bgcolor="' + tableBackColor + '">');
        var pixelValue = justGetFieldValue(theReply,"value",1);

Win1.document.writeln('<tr><td>Value=</td><td>'+pixelValue+'</td></t
r>');
        Win1.document.writeln('</table>');
//        displayAttributeData(theReply);

```

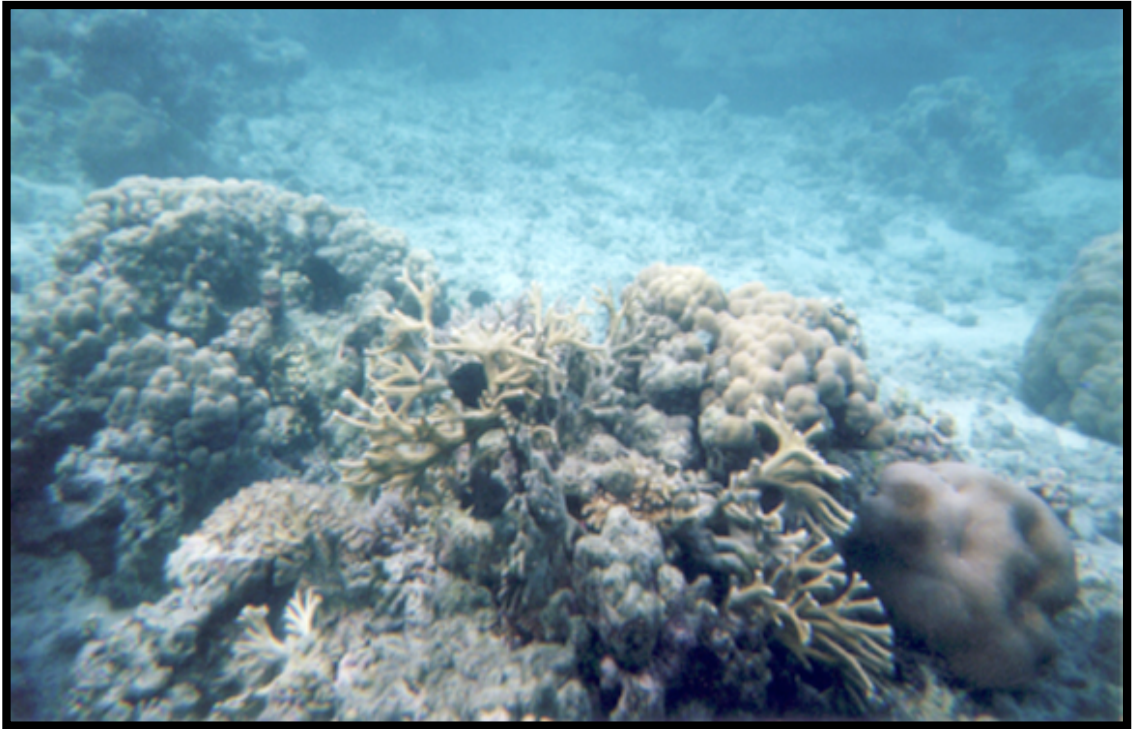
c. In the *aimsXML.js* file, add the following to the global variables:

```
var identifyPixelXMLMode = 1001;
```

d. In the *aimsLayers.js* file, change line 57 to look like this:

```
if (LayerIsFeature[i]) {          setLayerFields(i);    }
```

Appendix C—American Samoa Marine Data GIS Education Modules



American Samoa Marine Data GIS Education Modules

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September, 2004

Exploring the reefs

Introduction

Coral reefs surround many of the islands in the Samoan Archipelago. Many people depend on the reefs for fish, shellfish, etc. Coral reefs depend on clear, unpolluted water for survival. They face a number of threats from various problems such as pollution, sedimentation, destructive fishing methods and global climate change.

Until recently, little was known about the coral reefs in American Samoa below the point to which humans can dive. In 2001 and 2002, seven areas around Tutuila were surveyed between 2 m and 150 m in depth).

In this lesson, you will explore portions of the reefs around Tutuila using two types of remotely sensed imagery. One type is obtained from space with a satellite (electromagnetic energy) and the other is obtained at sea with a multibeam bathymetric mapping system (acoustic energy). Satellite imagery, in clear water, can penetrate the ocean down to 30 m. The images you will be working with were obtained using the Ikonos satellite.

Objectives

On completion of this lesson, you should be able to:

- Add data to an ArcMap project.
- Define *metadata* and explain its use.
- Change the *symbolology* for a *layer*.
- Measure objects in an ArcMap project.
- Identify features in an ArcMap project.
- Make a layout.
- Explain what factors affect the quality of a satellite image.


Symbolology—how ArcMap draws a *layer* in a project.


Layer—the reference, in ArcMap, to a data set.

Working with the Data

Ikonos imagery is obtained from the Ikonos satellite. The colors of the imagery are separated into *bands* (the imagery you will be looking at has 3 bands that appear in ArcGIS: red, blue and green). The red band does not penetrate water very well, but the blue and green bands can penetrate ocean water up to 30 meters in good conditions. Water clarity, pollution and waves can all affect how deep the imagery can detect. Color Ikonos images have a resolution of 4 meters.

Loading the data

1. Open ArcMap. Click the  add data button (or go to File -> Add Data).

2. Navigate to the directory where the data are stored. To do this you will likely have to click on the connect-to-folder  button. Choose the correct folder and click **Ok**.
3. Choose the file named **tut_color16.img** and click ok. It may take it a few minutes to load...be patient.

Exploring the data—Ikonos

1. **Metadata:** To find more information about the Ikonos image of Tutuila, you need to look at the metadata. Metadata is basically a file that tells more information about a GIS data file. Some information that may be contained in a metadata file includes date the information was obtained, resolution, projection, geographic coordinates and where the data originated. Without metadata, many files would not be useful.

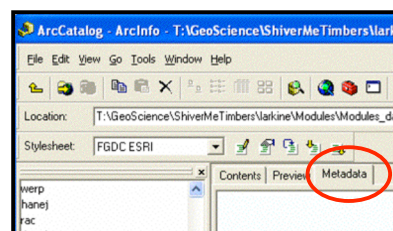




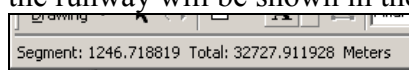
Figure 1—The metadata tab in ArcCatalog

Open ArcCatalog and navigate to where the image is stored. Click once on the file **tut_color16.img** on left hand side of the window. Now click on the *Metadata* tab above the right side (Figure 1). There are three tabs shown in the metadata: *Description*, *Spatial* and *Attributes*. Be sure to click on each one or you will miss some information.

- a. What is the resolution of the image (hint: it is a multi-spectral image)?
- b. How many original images were tiled (pieced together) to produce the image of Tutuila?
- c. Who created the image?
- d. When was it created?




Note: ArcCatalog is a program that allows you to manage your GIS data files. Since each shapefile and raster grid is actually a group of files, it is *never* a good idea to move or rename files in Windows Explorer. These types of things can be done in the same way in ArcCatalog and should always be done in ArcCatalog.

2. Go back to ArcMap. Zoom in to Pago Pago International Airport using the  zoom in tool. Click on the zoom in tool. Now, while holding the mouse button down on the map, draw a box around the area you want to see in more detail. Using the measure tool, find the length of the longer runway at the airport. Click on the measure tool , then click on one end of the runway and double-click on the other end. The length of the runway will be shown in the lower left corner of the ArcMap window:




- a. What is the length of the long runway at Pago Pago International Airport?
- b. What is the length of the long runway at Pago Pago International Airport in feet?

- 1) Right Click on **Layers**→**Properties**.
- 2) Click on the **General** tab and change the **Display** pulldown menu to show feet.
- 3) Change the display back to meters once you have the answer.

Note on Buttons and Tools: There is a difference between a button and a tool in ArcMap. When you click on a button, something happens without any other action on your part. For example, when you clicked on the  add data button, a file window appeared. There is also a zoom in button: . The button zooms in on the map when it is clicked. When you click a tool, however, nothing happens until you do something on the map. The zoom in *tool*  requires you to click on the map and draw a box before it will zoom in closer on the map.

3. Ikonos imagery can penetrate the ocean down to 30 m in clear, smooth water. Zoom in to Fagaitua Bay on the southeast side of Tutuila (Figure 2).

(The Full Extent  button can be used to zoom out to the entire island). The water in this image appears dark. Notice the dark triangle-shaped area in the shallow part of the reef. This area was dredged at one time and has since been re-colonized by coral.

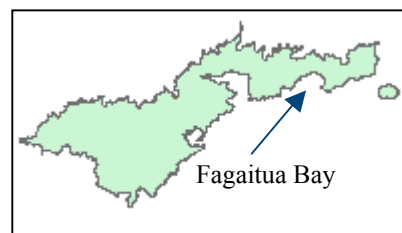


Figure 2—Fagaitua Bay.

- a. What are the white blotches around the shallow parts of the reef?
- b. How many channels (*ava*) leading from the shallow part of the reef out to sea can be seen in Fagaitua Bay?

4. Zoom in to Fagatele Bay (Figure 3) on the southwest end of Tutuila.

- c. Why isn't this part of the image as useful for looking at the seafloor as the image of Fagaitua Bay?

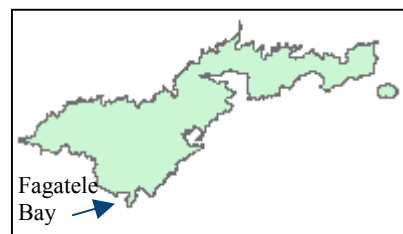


Figure 3—Fagatele Bay.

- d. What is causing the water to be less transparent than the water in Fagaitua Bay?

Zoom in to Pala Lagoon (just north of Pago Pago Airport).

- e. Why is the water in the lagoon red?
- f. Would you expect to find coral here? Why or why not?

Turn off the Ikonos image of Tutuila by clicking in the check box next to the layer name.

Exploring multibeam bathymetry

Bathymetry is the underwater version of topography. A bathymetry grid is made up of cells, each with a value equivalent to the depth of the ocean at that point (Figure 4). The real-world distance covered by one side of a pixel is the resolution of the grid. For example, the grid you will be working with today has a resolution of 5 m. That means that each side of a square pixel in the grid is equivalent to 5 m on the ground. Multibeam bathymetry can be used for depths of a just a few meters to over 1000 m.

1	8	3
2	9	7
4	7	6

Figure 4—A sample grid showing depth values.

Multibeam surveys works similar to a fish finder. A pulse of sound is bounced off of the ocean floor and the time it takes to return to the ship is measured. In general, the longer it takes for the sound pulse to return, the deeper the ocean is at that point. The resolution of the multibeam bathymetry grid used in this lesson is 5 meters, but in later lessons, bathymetry grids with resolutions of 1 meter will be used. Unlike satellite imagery, multibeam sonar is not a picture of the seafloor. It starts out as simply a collection of return times for the sound pulses. It is then processed to produce a bathymetry grid, a collection of depth values for the ocean floor.

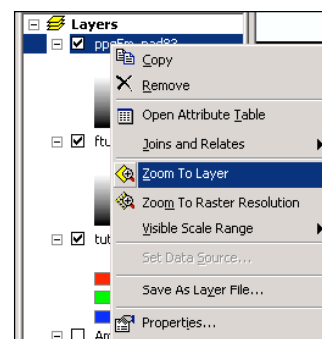


Figure 5—Zoom to Layer.

1. Add **pago_bathy** and **AmSam_cst** to your project (see p. 1 to remember how to do this). Right click on **ppg5m84_neg** in the Table of Contents (Figure 5). Choose **Zoom to Layer** from the options.

2. *Changing layer display:* Right click on **pago_bathy** in the layer list again. This time choose **Properties** (Figure 6). Click on the **Symbolology** tab (Figure 7). For this layer, the most appropriate way to display the information is **Stretched**, which should already be chosen. The color of the display can be changed in the **Color Ramp** box. Choose the color bar that goes from red to blue. Bathymetry is often shown using one that starts with red for shallow areas and ends with blue for deep areas. If the color bar is reversed (red for deep values), check the **Invert** box.

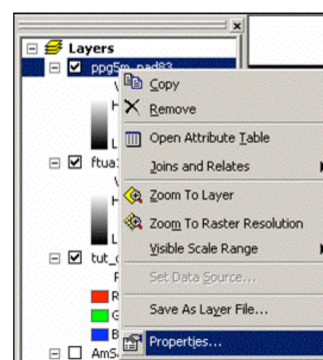


Figure 6—Accessing the Properties window.

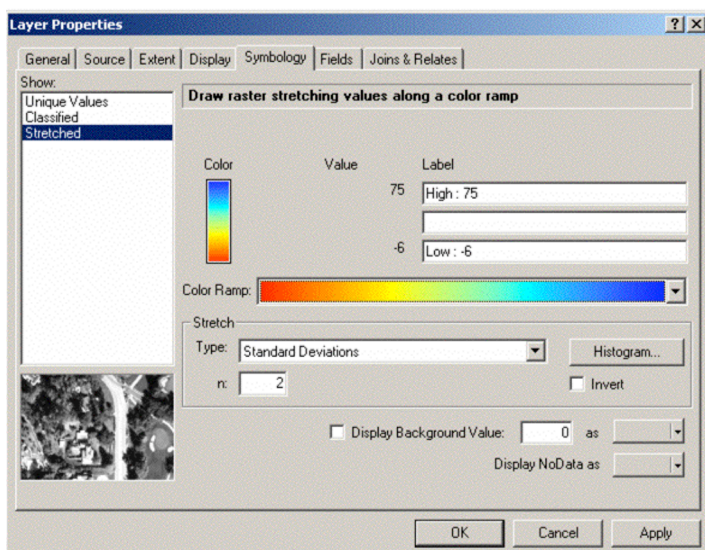
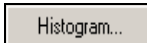


Figure 7—The Symbology tab.

where you clicked is, in meters. Click on different areas to compare depth values in different parts of the harbor.

4. Another way to learn more about a grid is to look at the statistics for it. Right-click on the name of the Pago Pago Harbor grid and go to **Properties**. Click on the **Symbology** tab if it is not showing. Click on the **Histogram** button . This will bring up the *Histogram* window.

- a. What is the maximum depth in Pago Pago Harbor?
- b. What is the mean depth in Pago Pago Harbor?

5. Zoom in to the northern half of Pago Pago Harbor. The World War II tanker, Chehalis, sunk in Pago Pago Harbor in 1949. This wreck is visible from the multibeam bathymetry. Zoom in to the area circled along the south side of Pago Pago Harbor (Figure 8). Zoom in close enough that you can see all three features. The long straight feature is the wreck of the Chehalis.

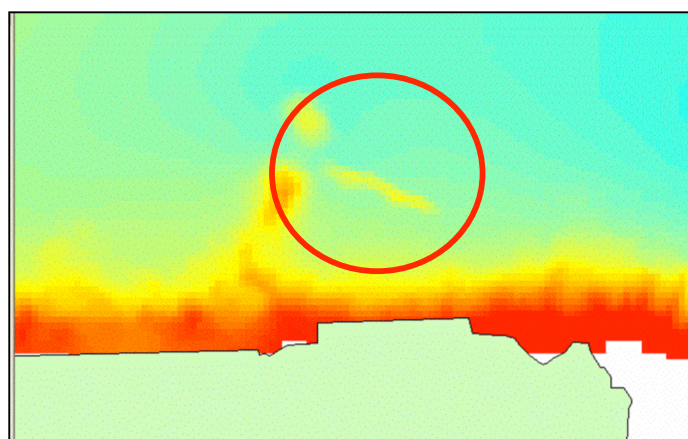



Figure 8—The wreck of the Chehalis.

3. Exploring the multibeam data. The **Identify** tool  can be used to learn more information about an area. First, make sure the **pago_bathy** layer is *active*. Do this by clicking on the name of the layer once, so that it is highlighted. Now click on the **Identify** tool and click somewhere on the **pago_bathy** grid. The *Identify Results* window will appear with information about where you clicked in it. The **pixel value** in the Identify Results window shows how deep the place

Visit the following web pages to answer questions c-e:

<http://www.history.navy.mil/danfs/c7/chehalis.htm> and <http://dusk.geo.orst.edu/esri02/>.

- How long is the wreck, in meters?
- How deep is the wreck?
- How did the Chehalis sink?
- What was she carrying?
- Is the Chehalis still a concern for pollution in the harbor? Why? (hint: think about what the ship was carrying).

Making a Layout

Printing maps from ArcMap requires making a layout.

- Zoom out so the map shows all of Pago Pago Harbor. Add the **AmSam_cst** layer. This is a *polygon* shapefile showing the coast of American Samoa. You can change the fill color by clicking on the color under the layer name in the layer list (Figure 9).
- Go to **File → Page Setup** and change the page orientation to *Landscape*. Make sure the page size is 11 x 8.5. Click on the layout button in the lower left hand corner of the map frame (Figure 10). The map frame will change to show a piece of paper and the part of your map that was visible in the map frame. **Note:** A new toolbar will

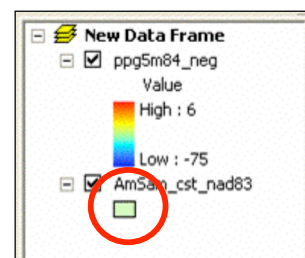
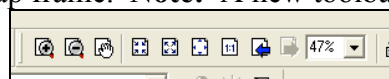


Figure 9—Changing the color of a layer.

appear in the layout view: the layout toolbar.



If you want to zoom in or move around on the *layout*, it is important to use this toolbar, rather than the map toolbar. If you use the map toolbar, your layout will change in unexpected ways.

- It is common to include an inset map to show a more general location of the map. To do this, go back to the map view.
 - Go to **Insert → Data Frame**.
 - Add the bathymetry file and the coast file to the new data frame just as you did earlier. Zoom in to the Tutuila. You may want to change the colors of both files, which is also done just as you did earlier.

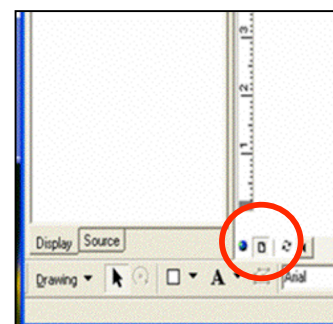


Figure 10—The Layout button.

- c. After you are happy with the colors, go back to the *Layout View*. There will be two maps there now, although they may be on top of each other. Click on the map of Tutuila and move it to the upper right or left corner of the page.

Note: The faint line around the edge of the page shows where the printable area is. Do not put anything outside of this line or it will be cut off by the printer.
 - d. Place the map of Pago Pago Harbor where you would like it. You can change the size of the image by clicking on a corner and dragging it larger or smaller.
 - e. Place the map of Pago Pago Harbor where you would like it. You can change the size of the image by clicking on a corner and dragging it larger or smaller.
 - f. Place the map of Pago Pago Harbor where you would like it. You can change the size of the image by clicking on a corner and dragging it larger or smaller.
4. There are a number of important things that should be included on a map:
- a. Title
 - b. Your Name
 - c. Date
 - d. North Arrow
 - e. Scale Bar
 - f. Neatline
 - g. Legend
- Note on Text Size:** The title should be the largest text in your layout. Your name and date should be smaller and less prominent. The north arrow and scale bars should be large enough to be easily read.
5. The processes to add a title, name and date are all similar.
- a. Go to **Insert → Title**. A text box will appear on the map. Type your title in the box. It probably is not a font and size that looks good, so click off of the text box. To edit the style of the text, *double-click on the text* or *right-click* and choose *Properties*. A window will appear with various options. You can edit the text itself in the box under the **Text** tab.
 - i. Click on the **Change Symbol** button to change the style of the text. This will bring up the *Symbol Selector* window with various font options. On the right side of the window is a box labeled *Options*. You can change the font, font size and appearance here. When you are done, click **Ok**.
 - ii. One other thing you may want to change is the *justification* of the text. This is how the text is aligned: left, right or center. This is done in the **Properties** window just under the text box.
 - iii. To move the Title, click once on the text. Arrows will appear; click and drag the text to where you want it.

- b. To add your name and the date, go to **Insert → Text**. A text box will appear and can be edited and moved in the same way that you made changes to the title.
6. To add a North Arrow, go to **Insert → North Arrow**. The *North Arrow Selector* window will appear. Pick one that suits you and click **Ok**. The North Arrow can be moved in the same way that you moved text. To change the size of the North Arrow, click on one of the corners and drag it to make it bigger or smaller.
7. To add a Scale Bar, go to **Insert → Scale Bar**. The *Scale Bar Selector* window will appear. Choose a scale bar style and click the **Properties** button, making the *Scale Bar* window appear. Make sure the units are in something that makes sense, such as meters, kilometers or miles and click **Ok** (Figure 11). Click **Ok** again. The scale bar can be moved in the same way text is moved. To resize it, click on one of the handles and drag it to a new size.
8. Adding a neatline: Go to **Insert → Neatline**. The *Neatline* window will appear. Choose the *Place Inside Margins* option. In the *Borders* pulldown menu, choose a neatline that you like. In the *Background* pulldown menu, choose **Hollow** (meaning “No Fill”). Click **Ok**.
9. The last thing you need to add is a legend. Make sure your map data frame is activated, NOT the inset map (To activate a data frame, right-click on it and choose **Activate**). Go to **Insert → Legend**. The Legend Wizard will appear. Click **Next** twice. Click **Ok** again. The scale bar can be moved in the same way text is moved. To resize it, click on one of the handles and drag it to a new size.
10. Adding a neatline: Go to **Insert → Neatline**. The *Neatline* window will appear. Choose the *Place Inside Margins* option. In the *Borders* pulldown menu, choose a neatline that you like. In the *Background* pulldown menu, choose **Hollow** (meaning “No Fill”). Click **Ok**.
11. The last thing you need to add is a legend. Make sure your map data frame is activated, NOT the inset map (To activate a data frame, right-click on it and choose

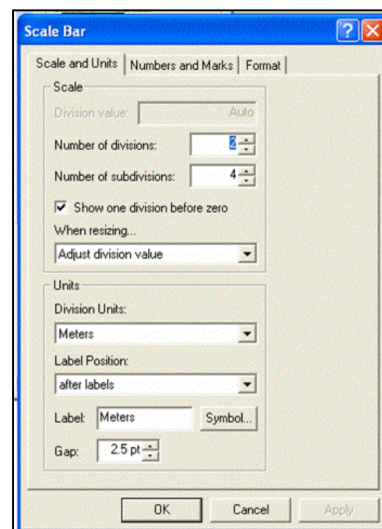


Figure 11—Changing the scale bar units.

Note: You can edit your legend after it appears by right-clicking on it and choosing **Properties**.

Activate.) Go to **Insert→Legend**. The Legend Wizard will appear. Click **Next** twice.

- a. On the *Border Options* screen, choose a border you like from the pulldown menu.
 - b. Click **Next** twice and then click **Finish**.
 - c. The legend will probably appear in an odd place such as directly over your map. It can be moved around and resized in the same manner as text or the north arrow.
12. Make sure everything on the map lies within the neatline (i.e. nothing touches or falls outside the neatline.). When you are happy with the map, print a copy to turn in.

National Park of American Samoa Fish Inventory

Go to the National Park of American Samoa Fish Inventory (<http://www.nps.gov/npsa/NPSAfish/>). Choose to different species of fish and answer the following questions about them. You may need to search for their scientific, English or Samoan names on Google and look at a several sites to find out more about them.

1. What are the scientific, English and Samoan names for the fish you chose?
2. Where do they live? (on the reef? deep ocean?)
3. What type of habitat do they prefer? (under rocks? open water?)
4. What do they eat?
5. Are they fish that you have seen, either in the water, at the market, or a fish you have eaten?
6. Are they threatened species? If so, why are they threatened and what is being done about it?

Additional Questions

1. If a satellite image has a resolution of 5 m, would it be possible to tell apart two cars parked next to each other (about 1.5 m apart)? Why or why not?
2. What is the coarsest resolution imagery that could be used to distinguish features that are 20 m apart?

What to turn in:

1. Answers to the questions.
2. Your layout from the second part of the lab.



Figure 12—A fish in National Park of American Samoa. (Photo by E. Larkin).

Benthic Classifications

Introduction

In this lesson, you will learn how to work with bathymetry to get a better understanding of what the ocean floor looks like. You will learn how to work with the raster calculator and how to work with ArcInfo GRID. Please keep in mind, in this lesson, typing accurately is very important.

Objectives

At the end of this lesson, you will be able to:

- Do a slope analysis.
- Use Raster Calculator to do simple analyses.
- Use the Benthic Terrain Modeler to create benthic zone and structure grids.
- Define: Slope, Bathymetric Position Index, benthic, standard deviation, classification dictionary and benthic zones.

The first analysis you will do is a *slope analysis* for Pago Pago Harbor. Slope is a measure of the steepness of the landscape. Areas with a greater degree of slope are steeper. Slope is calculated based on elevation (on land) or depth (under water) values. Slope is calculated in one of two ways: degree of slope or percent slope (Figure 13).

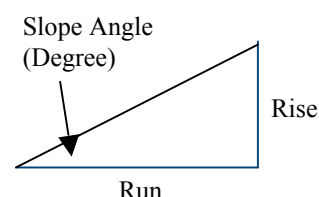


Figure 13—Percent slope = $\text{Rise} \div \text{Run} * 100$. Degree slope equals the Slope Angle. (after ESRI 2004).

1. Start ArcMap with a *New Empty Map* and add the **pago_bathy** grid to your project.
3. Make sure *Spatial Analyst* is turned on by going to **Tools→Extensions** and checking the box next to Spatial Analyst. If the Spatial Analyst toolbar does not show up, go to **View→Toolbars→Spatial Analyst**.

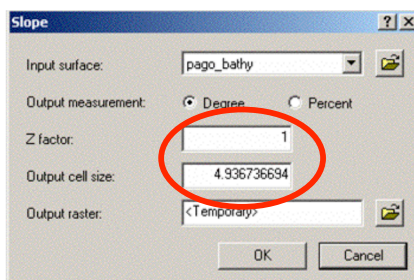


Figure 14—The slope window.

2. Add the Benthic Terrain Modeler toolbar by going to **Spatial Analyst →Surface Analysis→Slope**. This will bring up the Slope dialog box (Figure 14).
 - a. Make sure the **pago_bathy** grid is showing in the *Input Surface* field.
 - b. Leave the *Output Measurement* as **Degree**.

- c. Change the *Z factor* value to match the value in the *Output cell size* field. Click on the folder next to the *Output Raster* field and give a name to the file that will be created.

Note: Remember, filenames must be less than 13 characters.

The second part of the process will be to calculate Bathymetric Position Index. BPI determines where each pixel is in relationship to the pixels around it (Figure 15). The results of the BPI will give a better picture of what type of features are on the seafloor.

You will be working with a 5 meter grid of Pago Pago Harbor. BPI isolates features of a certain size, chosen by the user. In this case, you will look at small features and large features, so BPI will be calculated twice. Broad-scale BPI refers to large features and fine-scale BPI refers to small features.

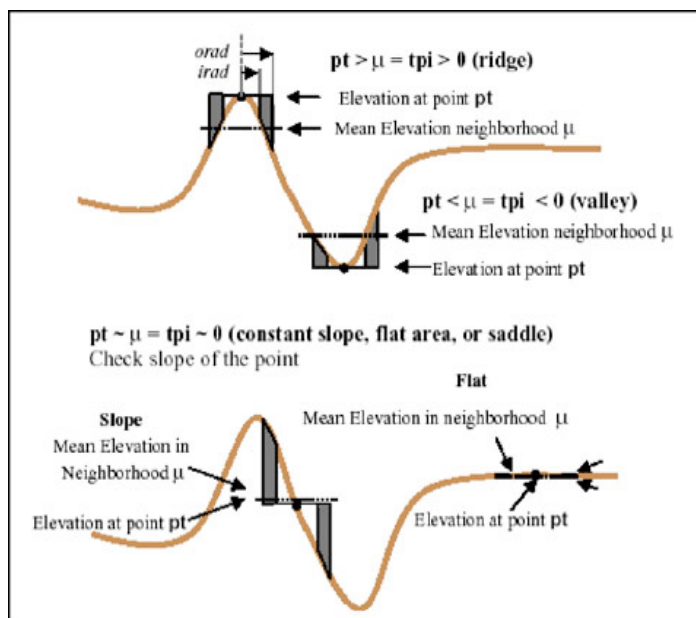


Figure 15--Bathymetric Position Index (after Weiss 2001)

The general form of the equation you will use is:

$$\text{BPI}_{\text{scalefactor}} = \text{int}((\text{bathymetry} - \text{focalmean}(\text{bathymetry}, \text{annulus}, \text{irad}, \text{orad})) + .5)$$

Scalefactor = is the map units of the outer radius multiplied by the resolution of the grid.

In this case, if we wanted a scalefactor of 100, meaning we are interested in features around 100 meters in size, we would use an outer radius of 20 (5 m resolution * 20 = 100).

Bathymetry = this is the name of the bathymetry grid, *pago_bathy*, in this case.

Annulus = this is the shape of the area that Spatial Analyst will use to calculate BPI. Spatial Analyst can use a number of shapes, including a circle and an annulus, which is shaped like a donut.

irad = this is the inner radius of the annulus.

orad = this is the outer radius of the annulus.

1. Go to **Spatial Analyst** → **Raster Calculator**.
2. The name of the bathymetry grid should be listed in the upper left in the raster calculator (Figure 16).
 - a. Double-clicking on the name of the bathymetry grid will make it appear in the bottom box. To do anything with it, you will have to type in commands to tell spatial analyst what to do. For now, make sure the bottom box is empty.

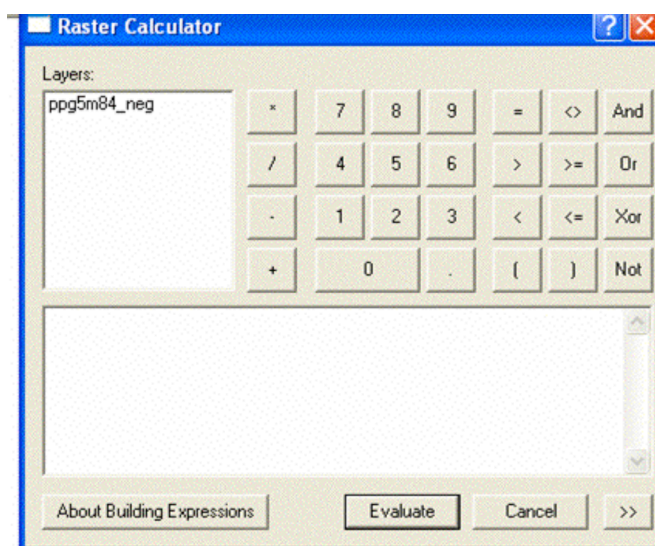


Figure 16—The Raster Calculator.

- b. First, we will calculate broad-scale BPI: Type the following commands into the bottom box of the raster calculator. **NOTE:** It is extremely important to type things into the raster calculator exactly as shown. *Spaces matter!!!*

int(([pago_bathy] – focalmean ([pago_bathy], annulus, 5, 40)) + .5)

- i. Be patient! This may take a few minutes.
 - ii. When it is finished, right click on the new layer and choose **Make Permanent**. **Important: Save your grid in the same folder that contains the bathymetry and slope grids.**
 - iii. Rename the title of the layer by right-clicking on the name of the layer and choosing **Properties**. Click on the **General** tab and rename the file **pago_200**.
 - iv. Create a layout showing broad-scale BPI. Be sure to include an inset map, title, name, date, north arrow, and scale bar.
- c. Now, calculate fine-scale BPI. A slightly different equation is used for this because you will use a circle instead of an annulus to calculate BPI. When using a circle, spatial analyst automatically assumes an inner radius of 1, so you do not have to define the inner radius. Open the **Raster Calculator** again. Type the following equation into the raster calculator as you did before:

int(([pago_bathy] – focalmean ([pago_bathy], circle, 2)) + .5)

- i. Make the new grid permanent and rename it **pago_10** (10 for the scale factor). **Important: Save your grid in the same folder that contains the bathymetry and slope grids.**

- ii. Create a layout showing fine-scale BPI.
3. Now the BPI grids must be standardized to the same scale.
 - a. The first thing you will need to do is find out the mean and standard deviation for each of the BPI grids.

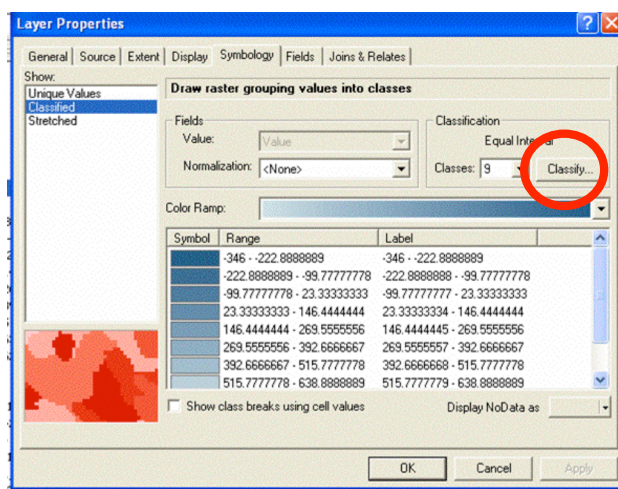


Figure 17—The classify button in the symbology window.

- i. Right click on the fine-scale BPI grid and choose **Properties**
- ii. In the **Symbology** tab, click of the **Classify** button (Figure 17).
- iii. A new window will appear. In the upper right corner, you will find the *mean* and *standard deviation* values. Write these down, all of the digits, for use a little later (Figure 18).
- iv. Close the Classification Window and the Properties window.
- v. Do the same for the broad-scale BPI.

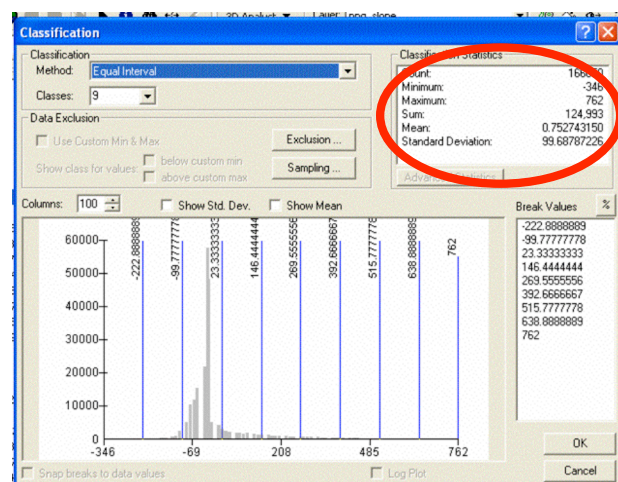


Figure 18—The statistics necessary to standardize BPI grids.

- b. The general equation you will use to standardize the BPI grids is:

$$\text{int}(\frac{([BPI] - \text{mean})}{\text{standard_deviation}} * 100) + .5)$$

So, if an example grid, named bpi_test, has a mean of 3.25 and a standard deviation of 2.25, the equation would look like:

$\text{int}(((([\text{bpi_test}] - 3.25) / 2.25) * 100) + .5)$

- i. In Raster Calculator, type the above equation using the mean and standard deviations from your fine-scale BPI grid.
 - ii. Replace *[BPI]* with the name of your fine-scale BPI grid.
 - iii. Click the calculate button.
 - iv. When ArcMap is finished making the new grid, make it permanent and name it **ppgfine_std**. *Important: Save your grid in the same folder that contains the bathymetry and slope grids.*
 - v. Repeat these steps for the broad-scale BPI.
- c. Save your project and exit ArcMap.

Benthic Zones and Structures

Now you will actually calculate benthic zones and structures. Benthic zones are broad classifications of the landforms on the ocean floor. Benthic structures are finer, more detailed classifications of the landforms on the ocean floor. Benthic zones and structures are calculated using an extension called the Benthic Terrain Modeler. This tool will use the slope and BPI grids you created to classify the seafloor into zones and structures.

1. Add the **Benthic Terrain Modeler Toolbar** the same way you added the Spatial Analyst *toolbar* earlier in this lesson.
2. Click on the **Benthic Terrain Modeler Menu** and choose **Benthic Terrain Modeler Wizard**. Read the first screen and click next.
3. First, set your *working directory*. Setting the working directory tells the Benthic Terrain Modeler where to look for files and where to save files. Set your workspace by:
 - a. Clicking on the folder next to the *First, select working directory* field and browsing to where your slope and BPI grids are stored **OR**
 - b. Typing in the full path of that folder in that field.
4. Click the circle next to *Use previously created...*(Figure 19). Input the names of the **standardized** BPI grids into the correct fields. Input the name of the bathymetric grid (**pago_bathy**) into the correct field.
5. Click **Next**.

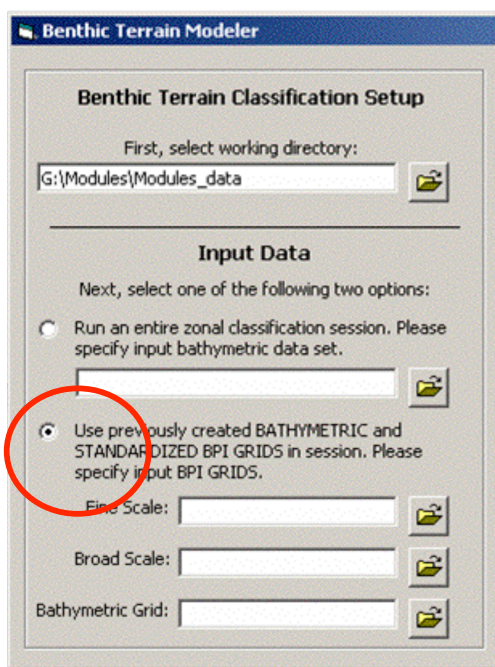


Figure 19—The first screen of the Benthic Terrain Classifier.

6. The next screen is the Classification Dictionary screen. You want to use an existing dictionary. Browse to the file **AmSamoa_zones.xml**. This dictionary tells the Benthic Terrain Classifier how to classify the grids into benthic zones. Click **Next**.
7. Make sure all the file names for BPI and bathymetric grids are correct. Also make sure it is using the correct classification dictionary.
8. Change the *output data set name* to **pago_zones**. Click **Finish**.
9. To create a benthic structure grid, repeat steps 3-5.
10. In the Classification Dictionary screen, set the classification dictionary to **AmSamoa_structures.xml**. Click **Next**.

11. Make sure all the file names for BPI and bathymetric grids are correct. Also make sure it is using the correct classification dictionary.
12. Change the *output data set name* to **pago_struct**. Click **Finish**.

Questions:

1. What is the scalefactor of the broad-scale BPI you calculated (refer to page 1 for how to calculate scalefactor)? Show your work.
2. Calculate the following for BPI. Show your work:
 - a. If you want a scalefactor of 400 and your grid resolution is 10 m, what outer radius should you use?
 - b. If you are using an outer radius of 16 and the grid resolution is 5 m, what is the scalefactor of the BPI?
3. What is the definition of standard deviation (look this up in a dictionary or on the internet)? What percentage of values lies within one standard deviation of a mean?

4. If you had the opportunity to take a submersible down in the bay, what areas would you like to see? Remember, some of the more complex areas may be areas that have more diverse fish and coral communities. Mark the areas on your benthic structures map with a pen and explain why you chose the areas you did.

What to turn in

1. Answers to the questions above.
2. Layouts showing fine-scale BPI, broad-scale BPI and benthic zones.

Spatial and 3D Analysts

Introduction

Spatial Analyst is the tool ArcGIS uses to conduct analyses with raster data. 3D Analyst and ArcScene allow users to display and work with three-dimensional data. Although they are not truly 3D, in that no three-dimensional calculations, such as volume, can be done on data, they are important tools for displaying data.

Objectives--By the end of this lesson, you should be able to:

- Create a new shapefile.
- Add data to a shapefile.
- Convert a bathymetry grid to a 3D display.
- Complete viewshed and hillshade analyses
- Select features with the attribute table
- Buffer a shapefile.
- Define: Viewshed and hillshade

Note: A Buffer Analysis defines an area around a feature of interest, in this case, coral. In this case, the buffered area around the coral can help identify an area that would provide protection for coral and reef fish.


1. Add the **FBNMS_bathy** grid to the project.
2. Make sure the Spatial Analyst and the 3D Analyst Extensions are turned on.
 - a. Go to **Tools**→ **Extensions**.
 - b. Check the boxes next to **Spatial Analyst** and **3D Analyst**.
 - c. To add the Spatial Analyst toolbar, go to **View** →**Toolbar**→**Spatial Analyst**.
 - d. Add the 3D Analyst Toolbar in the same manner.

1. Create a slope grid like you did in the previous lesson.
2. Right click on the new grid and choose **make permanent**. **Important: Save your grid in the same folder that contains the bathymetry grid.**

Note: Make sure you are saving where you intend! Check the folder in the top of the *Save As* dialog box. When naming raster files, the name can only be 13 characters long and it is *never* a good idea to have spaces in a filename.

Hillshade: Hillshade analysis is a way to see where light would fall on a landscape. The resulting grid will appear as a grayscale (black & white) image. Hillshade often shows the landscape quite dramatically. Compare the hillshade grid to the original bathymetry grid.

1. On the Spatial Analyst Toolbar, go to **Spatial Analysis**→**Surface Analysis**→**Hillshade**. This will bring up the Hillshade dialog box (Figure 20).
2. Make sure the bathymetry grid is showing in the *Input Surface* field.

3. For now, leave *Azimuth* and *Altitude*.
4. Change the *Output Cell Size* to 1 and choose a filename the same way you did above for slope. Click **Ok**.
5. Compare the Hillshade grid to the slope grid you made earlier.
 - a. What type of slope values appear in the areas that appear the steepest in the hillshade grid?
 - b. Try experimenting with several different Azimuth and Altitude values to see what happens when they are changed. What azimuth value makes the grid look inverted (i.e. ridges look like valleys)?
6. When you have a hillshade that you like, click on the title of the bathymetry grid and drag it above the hillshade grid.
7. Add the *Effects* toolbar in the same way you added the Spatial Analyst toolbar.
8. In the **Layer** box on the *Effects* toolbar, make sure the bathymetry grid is showing. Click on the **Transparency**  button. This will bring up a slider bar: Set the transparency to something around 50%. The greater the percentage, the more transparent the layer.
9. Create a layout showing your hillshade with bathymetry over it. Remember to include a title, your name, a north arrow, a scale bar, and the date.

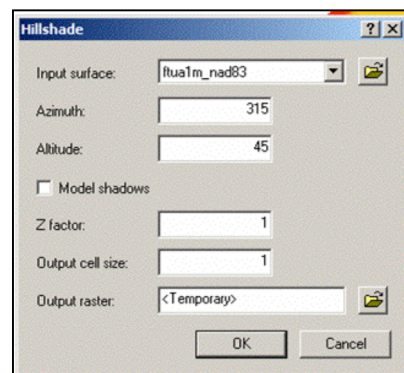


Figure 20—The Hillshade Dialog Box.


Azimuth is the direction from which the light is coming. North is 0° and, moving in a clockwise direction, the degrees increase. The most commonly used azimuth for mapping is 315, which would be northwest.

Altitude is the angle of the light source (sun) above the horizon. Forty-five degrees is the most commonly used altitude.

Creating and Editing a Theme

We need to create a new point shapefile.

1. Open ArcCatalog.
2. Go to **File→New→Shapefile**. In the *Create New Shapefile* dialog box, change the name of the file to something meaningful. Make sure that *Feature Type* is **Point** and click **Ok**.
3. Go back to ArcMap and add the shapefile you just created to your project. Make sure the *Editor* toolbar is visible. If not, add it.

4. On the Editor Toolbar, go to **Editor→Start Editing**.
5. Click on the Digitize Tool . On the map, add points to the shapefile by clicking on the map. A colored point will appear. Add five or six points.
6. Save your edits by going to **Editor→Save Edits**.
7. Stop editing by going to **Editor →Stop Editing**
8. You will use this shapefile later in the lab. Save your project and exit ArcMap.

3D Analyst

1. Open ArcScene. Add the bathymetry layer the same way you would add a layer in ArcMap. Make sure 3D Analyst is turned on (see the instructions on page 1 for how to do this).
2. In the 3D Analyst toolbar (if the toolbar is not showing, add it the same way you added the spatial analyst toolbar earlier), choose **Convert-->Raster to TIN**. The input file should be the bathymetry file. Choose a filename for the output file and make sure it is being saved in the correct location. Click **Ok**. Be patient, this will take a while.
3. When the TIN appears, right-click on the bathymetry file and go to **Properties**. Click on the **Base Heights** tab. Click the *Obtain heights for layer from surface* option (Figure 21). Choose the TIN file you just created from the pulldown menu. Click **Ok**.

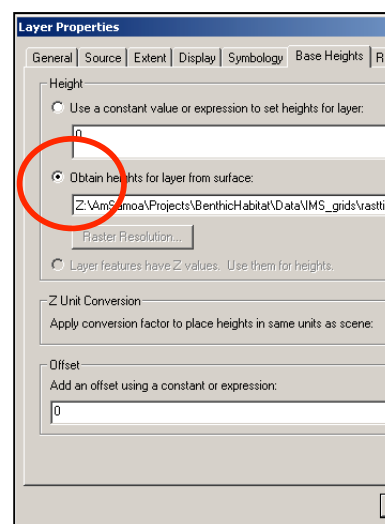



Figure 21—Choose “obtain heights from surface.”

4. Turn off the TIN layer. The bathymetry later should now be 3D.

Viewshed Analysis

A viewshed analysis shows you what can be seen from a point on a raster file. This analysis is commonly used to determine what can be seen from a given point in an area.

1. Go to **3D Analyst→Surface Analysis→Viewshed**. This will bring up the *Viewshed* dialog box.

Note: You may have to rotate the image using  to make it appear correctly. ArcScene does not always draw things perfectly.

- a. For *Input Surface* choose the bathymetry grid.
 - b. For *Observer Points* choose the point shapefile you created on page 3.
 - c. Change the *Output Cell Size* to 1.
 - d. Choose a filename. Since the output viewshed file will be a raster file, remember, the name must be 13 characters or less.
 - e. Click **Ok**.
2. The viewshed file will appear in the layer list. It will be composed of two colors, one for visible areas and one for areas that would not be visible from the observer points. In other words, if you were diving at one of the points, the visible areas are the areas you could see from that point.
 - a. What types of applications can you see for a viewshed analysis, either land or sea-based?
 - b. What industries use viewshed analysis? You may have to search the internet to find this out. Be sure to say where you got your information.
3. Add the hillshade file you created earlier in this lab. Make sure the viewshed file is first in the layer list and the hillshade file is second in the layer list.
4. Turn off all other layers.
5. Set the **Base Heights** for the viewshed to the TIN you created as described above.
6. Set the **Base Heights** for the hillshade in the same manner. Before you click Ok, set an offset for the Hillshade of -10 in the **Offset** box of the Base Heights tab (Figure 22). Click **Ok**.
7. Set the transparency of the viewshed file to somewhere around 50%. You may need to rotate the display to get it to display correctly.
8. Do a screenshot of your viewshed file on top of the hillshade. To do this, press the **Print Screen (PrtScrn)** button on the keyboard. Open Microsoft Word with a new document. Either do a **Ctrl-->V** or go to **Edit-->Paste** and your image will appear. Save your project.

MPA Designation

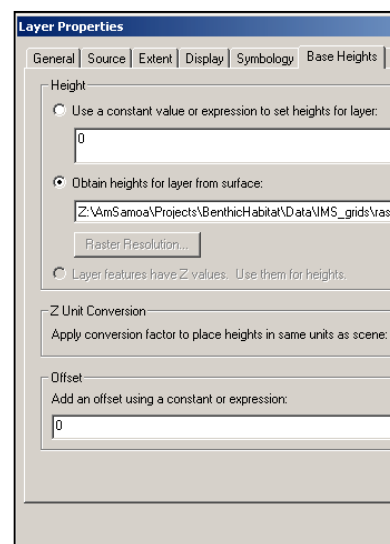


Figure 22—An offset is needed to make the layers display correctly.

Designating Marine Protected Areas (MPAs) can be difficult. It is important that the place chosen to be an MPA protect as many species as possible, often in the smallest possible area. Not only must you determine where the best location is for an MPA, you have to work with the people who would be affected by a marine reserve to make sure they, at the very least, do not oppose the MPA. There are two kinds of MPAs in American Samoa: no-take MPAs and MPAs where limited fishing is still allowed. The only no-take MPA in American Samoa is Rose Atoll National Wildlife Sanctuary.

1. How many federal MPAs are in American Samoa?
2. What types of fishing are allowed in Fagatele Bay National Marine Sanctuary and National Park of American Samoa (<http://www.fbnms.nos.noaa.gov/> and <http://www.nps.gov/npsa/home.htm/>)?
3. Add **ftua_bathy** and **Fagaitua_groundtruth**, to your project. Make sure they are all visible.
 - a. **Zoom to** Fagaitua Bay (see map at left).
 - b. Go to **Properties** and click on the **Symbology** tab. Change how the layer is displayed by clicking on **Categories** and then **Unique Values** (Figure 23).
 - i. In the **Value Field** pulldown menu, choose **AREA_1_MOD**.
 - ii. Click the **Add All Values** button. If the color scheme is something you like, click **Ok**. Otherwise, choose a different color scheme and click **ok**.
 - c. Use the **Identify** tool and click on several points.
4. Open the *Attribute Table* for **Fagaitua_groundtruth**. Right-click on the name of the file and choose **Open Attribute Table**.
 - a. Click on the **Options**→ **Select By Attribute** (Figure 24). This will bring up the *Select By Attributes* Window (Figure 25).
 - b. Under *Fields*, double-click on “**AREA_1_MOD**”

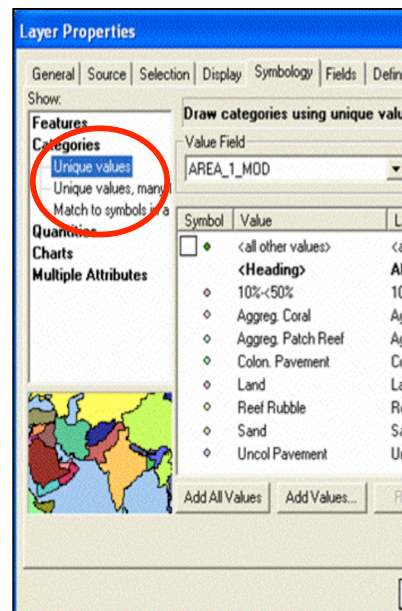


Figure 23—Classify the points based on unique values.

FLESHY_MAC	COLON_HAR	UNCOL_HAR
0	Colon. Pavement	
0	Colon. Pavement	
0	Colon. Pavement	
0		Reef Rubble
0		Reef Rubble
0		Reef Rubble
0	Aggreg. Coral	
0 10%-<50%		
0	Colon. Pavement	
0	Aggreg. Coral	
0	Colon. Pavement	
0	Colon. Pavement	
0		
0		
0		
0		

Records: (0 out of 144 Selected.) Options

Figure 24—The attribute table.
The options button allows you to select records

Select by Attributes

Enter a WHERE clause to select records in the table window.

Method: Create a new selection

Fields:

- "FID"
- "UNCONSOLID"
- "SEAGRASS"
- "FLESHY_MAC"
- "COLON_HAR"
- "UNCOL_HAR"
- "ENCRUST_CO"
- "OTHER"
- "ZONE"
- "DATE"

Unique Values:

Go To:

Get Unique Values

SELECT * FROM tut_ptsfinal_ftuacip WHERE:

Clear Verify Help Load... Save... Apply Close

Figure 25—The Select by Attributes window

- c. Click the = button
 - d. Click the **Get Unique Values** button.
 - e. Under *Unique Values*, double-click on 'Aggreg. Coral'
 - f. In the *Select From...* box, it should look like this:
"AREA_1_MOD" = 'Aggreg. Coral'
 - g. Click **Apply**.
 - h. Close the *Select By Attributes* window.
 - i. Look at the Attribute Table.
 - j. Look at the map, the points that are highlighted are those that you selected in the attribute table.
 - k. Go to **Options**→**Clear Selection**.
5. Now you will find out where most of the coral in Fagaitua Bay is located. To do that, you will have to select points based on more than one Unique Value using the **OR** connector.
- a. Follow steps 5 a-f above.
 - b. Click the **OR** button.
 - c. Repeat step 6a, but this time, instead of choosing 'Aggreg. Coral' for the *Unique Value*, choose '**Colon. Pavement**'.
 - d. Click the **OR** button.
 - e. Repeat steps 6c and 6d for the following *Unique Values*: Indivd. Patch Reef, Aggreg. Patch Reef, Colon. Pavement, and Scat. Coral/Rock.
 - f. Click **Apply**.
 - g. Close the *Select by Attributes* window.

- h. In the *Attribute Table*, some records will be highlighted. If you just want to see the selected records, click the **Selected** button. If you want to see all of the records again, click the **All** button.
- i. On the map, all of the selected points will be highlighted.
- j. Make a layout showing the selected points.

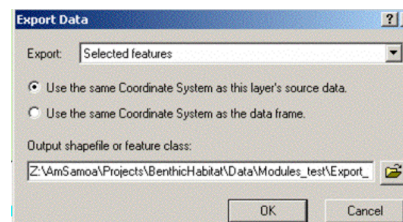


Figure 26—Exporting points as a new shapefile.

- 6. Now we are going to buffer around the coral points to determine the best place for an imaginary marine protected area.

- a. Right-click on the *ftua_ptsfinal* in the layer list. Choose **Data→Export Data**. Make sure *Selected Features* is showing in the *Export* pull-down menu. In the *Output* box, name your file **ftua_coral** (Figure 26).
- b. Turn off the **Fagaitua_groundtruth** layer.
- c. Go to **Tools→Buffer Wizard**.
- d. Choose *The Features of a Layer* and make sure **ftua_coral** is showing in the pull-down menu. Click **Next**.
- e. Change the *Buffer Units* to **Meters**.
- f. We want to create a 100 meter buffer around the coral, so type **100** in the box after *At a Specified Distance* (Figure 27). Click **Next**.
- g. Make sure that **Yes** is checked under *Dissolve Barriers*. Click **Finish**.

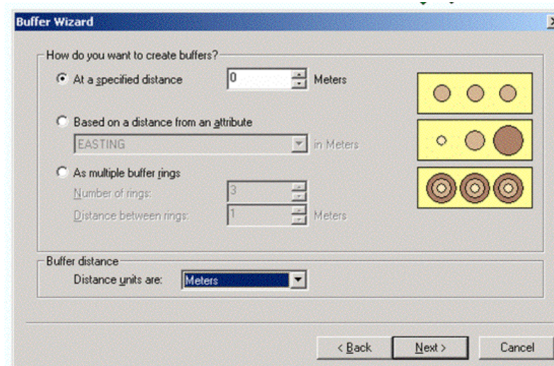


Figure 27—Buffer Wizard.

- 7. Now you need to decide where to designate an MPA.
 - a. Some things to keep in mind:
 - i. An MPA should be efficient: It should protect as much as possible while placing restrictions on as little area as possible.
 - ii. Many MPAs prohibit all fishing and collection, while others allow some types of fishing and collection.
 - iii. You will have to get people affected by the MPA rules to agree to them.
 - iv. An MPA that only protects shallow areas may not protect fish that spend part of their time in deep water.
 - b. Make a layout showing the buffered areas and draw where you will create an MPA. Keep in mind this is an imaginary MPA, but you will have to come up with a strategy to sell it to people who fish there.

8. Questions:

- a. How many points are classified as *Aggregate Coral*?
- b. How many total points have coral (step 6)?
- c. What areas of the bay have the densest clustering of coral?

9. Write a brief proposal (3-5 pages) with maps about your MPA. You will need to include maps of where the coral is located, where you propose to locate an MPA and what villages are affected (you may want to use **tut_villages**). Be sure to answer the following questions in the proposal:

- a. List four species of reef fish people eat in American Samoa. If you know the English name, find out the Samoan name. If you know the Samoan name, find out the English name. Use the National Park of American Samoa Fish Inventory for help with names (<http://www.nps.gov/npsa/NPSAfish/>).
- b. What kinds of fish might be protected by protecting coral? Use the *Natural History Guide to American Samoa* (<http://www.nps.gov/npsa/book/index.htm>) for more information. Be sure to cite your sources.
- c. Why did you choose to protect the area you did?
- d. Who would be affected by prohibiting all fishing in Fagaitua Bay?
- e. Which villages would you have to work with to create an MPA in Fagaitua Bay?
- f. How would you convince these villages to agree to a fishing ban? Outline a strategy for talking to villages, including who you would ask for help.
- g. What kinds of maps and information would you use to convince village leaders that an MPA is necessary in their area? Be sure to include these in the proposal.
- h. If you were going to allow some kinds of fishing, what kinds would you allow?
- i. What regulations will your MPA have?
- j. How will you enforce the regulations?
- k. If it was impossible to establish an MPA in Fagaitua Bay, where would be a good alternative?

What to Turn In

1. Answers to questions.
2. A layout showing the hillshade overlain by bathymetry.
3. An image showing the viewshed file on top of the hillshade from ArcScene.
5. A layout showing the points with coral.
6. Your MPA proposal.



Figure 28—A giant clam (*faisua*) from National Park of American Samoa. (Photo by E. Larkin).