

**GIS-BASED
SCREENING FOR
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SECONDARY
IMPACTS FROM
DEVELOPMENT
PROJECTS IN
NORTHERN GUAM**

By

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WERI

**WATER AND ENVIRONMENTAL RESEARCH INSTITUTE
OF THE WESTERN PACIFIC
UNIVERSITY OF GUAM**

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ABSTRACT

Over the next few years it is anticipated that Guam will experience significant growth due to military relocations and increasing tourism, which comes at a price to environmental resources. Because of the anticipated rapid growth, pressure will be placed on regulatory agencies to review projects without carefully considering the cumulative and secondary impact (CSI) effects they may have on the environment. CSIs due to developments are “impacts that may be insignificant by themselves but when combined with other development impacts in an area over time become a significant problem” (National Oceanic and Atmospheric Administration [NOAA], 2012). A policy is needed to protect the environment from CSIs due to developments; however, tools are needed to assist in the formation of this policy.

The objective of this study is to use Geographic Information System (GIS) technology to create a tool to screen for potential CSIs. This objective was met by achieving the goals of this study, which are to (1) develop the Northern Guam Geodatabase, (2) create an Affected Areas Tool, and (3) quantify effects from different development scenarios for Northern Guam.

The Northern Guam Geodatabase developed in this project contains 29 feature datasets and 5 raster datasets portraying geographic information about Northern Guam. The Affect Areas Tool is a GIS-based tool that utilizes inputs from the Northern Guam Geodatabase to screen the resources that may be affected by future developments. For determination of CSIs, a benefit of GIS datasets is that they can be used to inventory, evaluate, and predict future environmental changes. The outcome of the land development scenarios considered here indicates that for Northern Guam, undeveloped lands will be converted to urban/built-up areas with forested areas being affected the most. Furthermore, the potential uses of this tool to manage water and environmental resources of Northern Guam are discussed.

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Chapter 1. Introduction

1.1 Statement of Environmental Concern

In 2010 the United States Census reported that the residential population on Guam was 159,358. This is an increase from the 1960 population of 67,000 with an average annual growth rate of 2.8% (U.S. Census Bureau, 2011). In addition, in 2010 a total of 1,187,831 tourists visited Guam (Guam Visitors Bureau, 2011). Furthermore, the population is expected to increase with the military relocation from Okinawa, Japan, to Guam, which will include approximately 5000 Marines and 1300 dependents (U.S. Navy, Naval Facilities Engineering Command, Pacific (NAVFAC Pacific), 2013). In addition to these numbers, 600 Army personnel with 900 dependents, and 9000 transient military personnel are expected to arrive on Guam (U.S. Navy, Naval Facilities Engineering Command, Pacific (NAVFAC Pacific), 2010a).

With this population growth, Guam's economy is also projected to grow from the emergence or expansion of businesses, services, and housing. Because of increased population pressure and economic growth there is an urgent concern to protect Guam's natural resources. Laws and regulations have been implemented in addressing direct environmental impacts from developments; however, not much emphasis has been placed on cumulative and secondary impact (CSI) effects. CSIs from developments are "impacts that may be insignificant by themselves but when combined with other development impacts in an area over time become a significant problem" (National Oceanic and Atmospheric Administration [NOAA], 2012).

According to the Guam Coastal Management Program (GCMP, 2011), even without the military buildup, development on the island has reached a stage where CSIs should be considered. On Guam, though, local planners are not required to include the effects of CSIs in environmental reviews or in the permitting process. Thus, the GCMP is planning to develop a policy that creates a mechanism to assess CSIs due to proposed developments.

1.2 Study Area

Guam (13°28' N, 144°45'E) is the largest and southernmost island in the Marianas. The island is 30 miles (48 km) long and 4 to 11.5 miles (6 to 19 km) wide. Guam's total land area excluding its reefs is 212 square miles (550 km²). Guam is about 1200 nautical miles (2200 km) east of the Philippines and is halfway between Japan and Papua New Guinea.

Guam has a warm humid climate with annual temperatures of about 81°F (27°C). Two distinct seasons occur on the island, a dry season from January to June and a wet season from July to December. Annual rainfall ranges from 85 to

115 inches (2160 to 1920 mm) with 70% of the rainfall occurring during the wet seasons (Lander & Guard, 2003).

Guam is divided into a northern limestone province and a southern volcanic province (Tracey et al., 1964). The two geographic provinces are divided by a major fault at the waist of the island stretching from Adelup Point and Pago Bay. The surface of the island is divided into four physiographic categories consisting of a limestone plateau, volcanic uplands, interior basins, and coastal lowlands (Tracey et al., 1964).

In this study, Northern Guam is the portion of the island that ranges north of the fault line stretching from Adelup Point to Pago Bay (Figure 1). Northern Guam consists of a karst limestone plateau that slopes southwestward from an elevation of 600 ft. (180 m) in the north to less than 200 ft. (60 m) near the southern boundary. The northern plateau includes volcanic rock that protrudes the limestone surface at Mount Santa Rosa and Mataguac Hill. The limestone is very permeable and allows for rapid water seepage. Only a few marshes and ephemeral streams exist near Mount Santa Rosa. Habitat types in Northern Guam include limestone forests, scrub forests, and freshwater emergent wetlands.

Northern Guam is more populated than Southern Guam, with 60% of the entire population residing in the northern municipalities of Barrigada, Dededo, Mangilao, Tamuning and Yigo. The Northern Guam Lens (NGL) Aquifer supplies drinking water for more than 80% of the residents and virtually all of the tourists on the island. Based on the 1982 NGL study (Camp, Dresser, and McKee), the Guam Environmental Protection Agency (GEPA) determined the sustainable yield for groundwater withdrawal to be 227 mld (60 mgd). In addition, the GEPA (2007) reported that the total groundwater withdrawal was 188 mld (49.7 mgd), which is 81% of the sustainable yield for the NGL Aquifer.

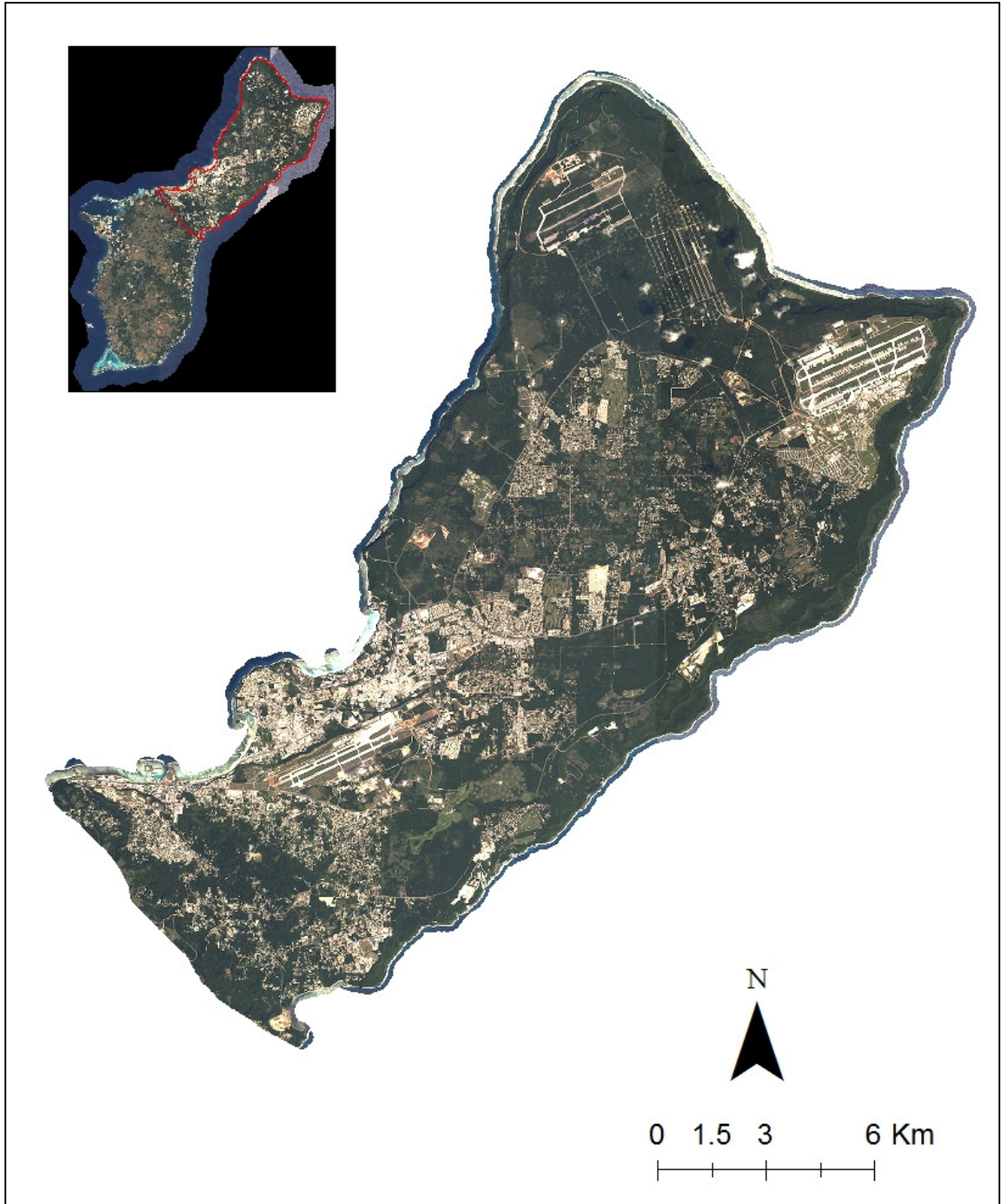


Figure 1. WorldView-2 satellite imagery by Digital Globe for Northern Guam.

Through Section 309 of the Coastal Zone Management Act, states and territories are encouraged to make changes in one or more of the 9 coastal enhancement areas through a coastal zone enhancement program. The 9 coastal enhancement areas include coastal hazards, energy and government facility siting, CSIs, ocean resources, wetlands, marine debris, special area management plans, public access, and aquaculture. These enhancement areas are rated from high priority to low priority based on urgency of needs with respect to the other enhancement areas.

The 2010 update to Section 309 of Guam's Coastal Management Program lists CSIs as one of Guam's high priority items. For Northern Guam, CSIs of concern include storm-water runoff, loss of habitat, water quality degradation, potential contamination and pollution problems (GCMP, 2011). The CSIs of concern are induced by development-related activities such as increased development, loss of large vegetation tracts, and increased impermeable surfaces. The GCMP is planning to develop a CSI policy to manage impacts; however, gaps exist in the tools needed to accomplish this.

1.3 Objective and Goals of the Study

The objective of this study is to develop a Geographic Information Systems (GIS)-based tool that will screen potential CSIs in Northern Guam. This objective was met by accomplishing the following goals:

- 1) Development of the Northern Guam Geodatabase, a qualitative tool that provides baseline spatial data for assessing CSIs in Northern Guam. The goal is to create a comprehensive geodatabase with aspects of natural and built environments in the study area that government agencies can utilize for assessment of future projects.
- 2) Development of the Affected Areas Tool, which is a GIS-based tool that makes use of the Northern Guam Geodatabase to screen and quantify affected resources of proposed developments.
- 3) Quantification of land use change scenarios from proposed developments in Northern Guam.

Chapter 2. Literature Review

2.1 Cumulative and Secondary Impacts (CSIs)

2.1.1 Definitions

There is increasing evidence that the most detrimental environmental effects do not necessarily come from the direct effects of a particular action but rather from the combination of multiple actions over time (Council on Environmental Quality [CEQ], 1997). Following procedural provisions of the National Environmental Policy Act of 1969, the CEQ defines a cumulative impact as: "...the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (40 CFR 1508.7)".

Cumulative impacts are evaluated with the direct and indirect impacts of a proposed project. The CEQ defines direct and indirect impacts as follows:

- The terms "effect" and "impact" are used synonymously in CEQ regulations (40 CFR §1508.8).
- "Direct effects are caused by the action and occur at the same time and place." (40 CFR § 1508.8).
- "Indirect effects are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable. Indirect effects may include growth-inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems." (40 CFR § 1508.8). Indirect impacts are usually interchangeable with secondary impacts.

2.1.2 Examples of Cumulative Impacts

Analyzing the type of cumulative impact is up to the agency or person studying the proposed project. Presently there has not been a standard typology to classify cumulative impacts. Table 1 shows examples of cumulative impacts as described by the CEQ (1997).

Table 1. Examples of cumulative impacts.

Types	Main Characteristics	Description
1. Time crowding	Frequent and repetitive effects on an environmental system	Forest harvesting rate exceeds regrowth
2. Time lags	Delayed effects	Exposure to carcinogens
3. Space crowding	High spatial density of effects on environmental systems	Pollution discharges into streams from nonpoint sources
4. Cross-boundary	Effects occur away from the source	Acidic precipitation
5. Fragmentation	Change in landscape pattern	Fragmentation of historic district
6. Compounding effects	Effects arising from multiple sources or pathways	Synergism among pesticides
7. Indirect effects	Secondary effects	Commercial development following highway construction
8. Triggers and thresholds	Fundamental change in system behavior or structure	Global climate change

Source: Council on Environmental Quality, 1997.

2.1.3 Analyzing Cumulative Impacts

CEQ regulations require federal agencies to consider the cumulative impacts of proposed projects. The level of an environmental study usually dictates if a cumulative impact study is required. Assessments of cumulative impacts are absolutely required in an Environmental Impact Statement (EIS). For an Environmental Assessment (EA), cumulative impact analysis is generally required, however because EAs generally focus on significant impacts, the cumulative impacts of proposed projects are sometimes underestimated or not discussed (CEQ, 1997).

Applicable to cumulative impact studies, screening is the step used to identify the project proposals that require an EA. There are two approaches for environmental screening, prescriptive and discretionary. The prescriptive approach determines whether or not a proposal is exempt from environmental review based on legislations and regulations. The discretionary approach analyzes proposals on a case-by-case basis, and is used when potential environmental impacts are unclear.

After screening, the process of an environmental review includes (1) scoping, (2) describing the affected environment, and (3) determining environmental consequences. There is no strict guideline as to what method should be used in assessing cumulative impacts; however, it is suggested that cumulative impact practitioners choose a method or a combination of methods that are appropriate for a project. Methods prescribed by the CEQ (1997) for analyzing cumulative impacts are shown in Table 2.

Table 2. Methods for analyzing cumulative impacts.

Methods	Brief Description
Questionnaires, interviews, and panels	Gathering information about the wide range of actions and effects needed for the cumulative impact analysis
Checklists	Identifying potential cumulative impacts by reviewing important human activities and potentially affected resources
Matrices	Determining the cumulative impact on resources, ecosystems, and human communities by combining individual effects from different actions
Network and system diagrams	tracing the multiple, subsidiary effects of actions that accumulate on resources, ecosystems, and human communities
Modeling	Quantifying the cause and effect relationship leading to cumulative effects
Trend analysis	Assessing the status of a resources, ecosystems, and human communities over time and identifying cumulative impact problems, and establishing appropriate baselines or predicting future cumulative impacts
Overlay mapping GIS	Incorporating locational information into cumulative impact analyses and help setting the boundaries of the analysis, analyzing landscape parameters, and identifying areas where affects will be the greatest.

Source: Council on Environmental Quality, 1997.

2.2 CSI-related Studies on Guam

2.2.1 CSI Study on Recreational Activities in Piti and Cocos Lagoon Guam (Tsuda & Donaldson, 2004)

Tsuda and Donaldson (2004) evaluated the CSIs of three marine recreational activities: Fish Eye Underwater Observatory in Piti, Seawalkers in Piti and Cocos Lagoon, and Scuba BOB (Breathing Observation Bubble) in Cocos Lagoon. The study utilized two control sites to compare with impact sites at the recreational areas, where each area was surveyed for benthic cover, fish percentage, and water quality. Results from the study showed no significant differences between physical and chemical characteristics at the marine recreational sites. However, there was a significant impact to seagrass beds in the control sites (no diver/snorkeler) due to temporary physical disturbances that increased turbidity and suspended solids. The study presented a sampling plan with emphasis on multivariate analyses at the community level, rather than a simple analysis comparing abundance and percentage of seagrass to potential CSIs that will most likely occur at the community level over time.

2.2.2 Land Suitability Analysis (GCMP, 2011)

Duenas, Camacho, and Associates prepared a GIS-based conservation/development suitability analysis using green infrastructure concepts for the Guam Bureau of Statistics and Plans (GCMP, 2011). The GIS tool highlights areas where conservation or development should likely occur. The model has four scenarios and utilizes weighted overlays and other tools to provide an output of high-to-low land development suitability. According to the GCMP (2011), this GIS tool will aid in the creation of a CSI policy to determine areas of concerns.

2.3 GIS and CSI

GIS is defined as a computer-based system to aid in the collection, maintenance, storage, analysis, output, and distribution of spatial data (Bolstad, 2008). GIS spatial-data models can be either displayed as vector-based models or raster-based models. Vector-based models incorporate the use of discrete elements such as points, lines, and polygons as representations of geometric objects on the earth. Vector objects include roads, wells, and buildings. Raster-based models involve dividing the areas of interest into rectangular grid cells (also called pixels), that represent continuous features such as elevation and slope.

GIS has been commonly used for the presentation of environmental information. GIS layers can be created to display past, present, and future environmental changes. For cumulative impacts, GIS layers can be combined through the assignment of different importance or vulnerability weights (Atkinson & Canter, 2011).

Assessing CSIs requires the analysis of large amounts of complex data involving multiple actions, environmental resources, and impact-causing agents, taking into account the spatial and temporal distribution factors. Atkinson et al. (2011) argued that the strength of using GIS to assess cumulative impacts includes: (1) information assemblages pertaining to spatial patterns and proximity of effects, resource fragmentation, and protected areas, (2) effective visuals for environmental assessment and environmental impact statements, and (3) demonstration of resource vulnerability. These strengths may prove important to the land use planner or resource manager. However, using the GIS approach for cumulative impacts, like other models, may have some limitations and can be very costly. Limitations include the absence of specific indirect effects and the potential difficulties in addressing the magnitude of cumulative effects of past, present, and future actions (Atkinson et al., 2011).

2.4 Related GIS and CSI studies

2.4.1 Methods for Cumulative Hydrological Impact Assessment Modeling (Hamerlinck & Oakleaf, 1997)

Hamerlinck and Oakleaf (1997) discussed the methods of using GIS technology in the Wyoming Cumulative Impact Assessment modeling process. Aside from providing insight on the integration of GISs with other hydrologic models, it provides valuable insight on the acquisition, handling, and manipulation of GIS data layers for the development of a GIS database. For this paper, the development of the Northern Guam Geodatabase will follow some of the prescribed methods by Hamerlinck and Oakleaf (1997).

2.4.2 Area-wide Cumulative Effects Analyses (ACEA) Using GIS (Muller et al., 2007)

In 2006, Muller et al. conducted a study to evaluate cumulative environmental effects resulting from transportation and other transportation induced projects. The ACEA was conducted for the Denver Regional Council of Governments. The areas of cumulative effects that were evaluated were land use, biological resources, and water technology. Remote sensing and GIS tools were used to develop tools for the cumulative effects analyses.

For land use, the cumulative effects model employed utilized a five-step method of data collection followed by GIS mapping. Steps are summarized below:

- Step 1. Build an inventory of past and present land use patterns and developable lands relying on high resolution spatial data.
- Step 2. Review historical and current local plans and regulations.

- Step 3. Review regional plans and regulations on transportation, including land use plans, and inter-jurisdictional agreements.
- Step 4. Evaluate other land market information. A logit regression was used to analyze past and present residential growth changes to project future changes. The regression predicted land use change as a function of variables such as distance to local roads and housing density.
- Step 5. Numbers of developed acres at primary density ranges were tabulated for project, local, and regional scales. The tabulations were classified into past and present categories using the assessor's "year built" data attributes.

The land-use findings were that at project scale, all land that is not protected will be developed. At the local scale, the authors projected continued growth in the valleys and other accessible areas. The ACEA project showed that GIS can be applied to assessing cumulative impacts. For the most part, data needed for the ACEA project was readily available. However this might not be the case for all projects, such as the lack of historical data. The authors suggested that the importance of stakeholder involvement is important for the collecting and sharing of data.

2.4.3 Quantification of Land Transformation (Amin & Fazal, 2012)

In the journal article titled "Quantification of Land Transformation Using Remote Sensing and GIS Techniques", the authors showed that there had been a large-scale urban transformation in Srinagar City, India. The GIS analysis revealed that the built-up area in Srinagar City had increased by 3835 hectares, while agricultural land suffered the most loss of 2549 hectares. According to Amin and Fazal (2012) it is important to understand the relationship between human activities and the environment, especially in rapidly growing areas, as the cumulative impacts from development may be realized too late to involve mitigation measures.

2.4.4 Cumulative Impacts Model (Digital Coast, 2008)

The Cumulative Impacts Model is an interactive model that provides global estimates on human impacts on coastal systems. The tool can be launched from the NOAA Digital Coast Website. The tool provides 17 different maps of activities such as fishing, commercial shipping, organic pollution, and climate change. The tool provides cumulative impact scores ranging from 0 to 90 and has an output table showing a breakdown of the score.

Chapter 3. Methods and Development

GIS data are important when screening for CSIs, as it can be used to inventory and evaluate the existing environment. Utilizing GIS technology, a goal for the study is to create a comprehensive Northern Guam Geodatabase with aspects of natural and built environments for resource managers to use. Accompanying the geodatabase is an Affected Areas Tool. Using inputs from the Northern Guam Geodatabase, the output of the tool will show how much of an area's resources will be affected. This section shows the methods employed in creating the Northern Guam Geodatabase and the Affected Areas Tool.

3.1. Northern Guam Geodatabase

The GIS software utilized in this study is ARC/INFO 10.1. GIS data sets for Northern Guam were derived using geoprocessing and spatial analyst tools in Arc Map 10.1 and managed in Arc Catalog 10.1. Five steps were identified in creating the Northern Guam Geodatabase. These steps adapted from Hamerlinck and Oakleaf (1997) include: 1) data collection, 2) data automation, 3) database design, 4) quality control, and 5) metadata completion.

Collection of Data

Efforts were set on collecting the most recent and available GIS datasets of Northern Guam. The datasets were collected, catalogued, and reviewed. Interviews and email correspondence were set up with local government agencies to inventory existing data. GIS data were collected from:

- Guam Bureau of Statistics and Plans
- Guam Coastal Atlas
- Guam Waterworks Authority
- United States Fish and Wildlife, Pacific Islands Fish and Wildlife Office
- Water and Environmental Research Institute of the Western Pacific at the University of Guam

Data Automation

Automation of GIS data for Northern Guam layers was performed in ArcMap 10.1. Most of the pre-existing GIS layers displayed geographic information about the entire island, thus it was necessary to convert the data from their original format to create GIS layers for Northern Guam. A polygon of Northern Guam was created based on the boundary of the Pago-Adelup fault on the geology shapefile for Guam using Trace and Draw tools on ArcMap (Figure 2). Vector type layers were clipped and the raster layers were extracted by mask to the Northern Guam polygon. For consistency, all GIS layers derived for Northern Guam were projected into a common coordinate system, WGS 1984 UTM Zone 55N.

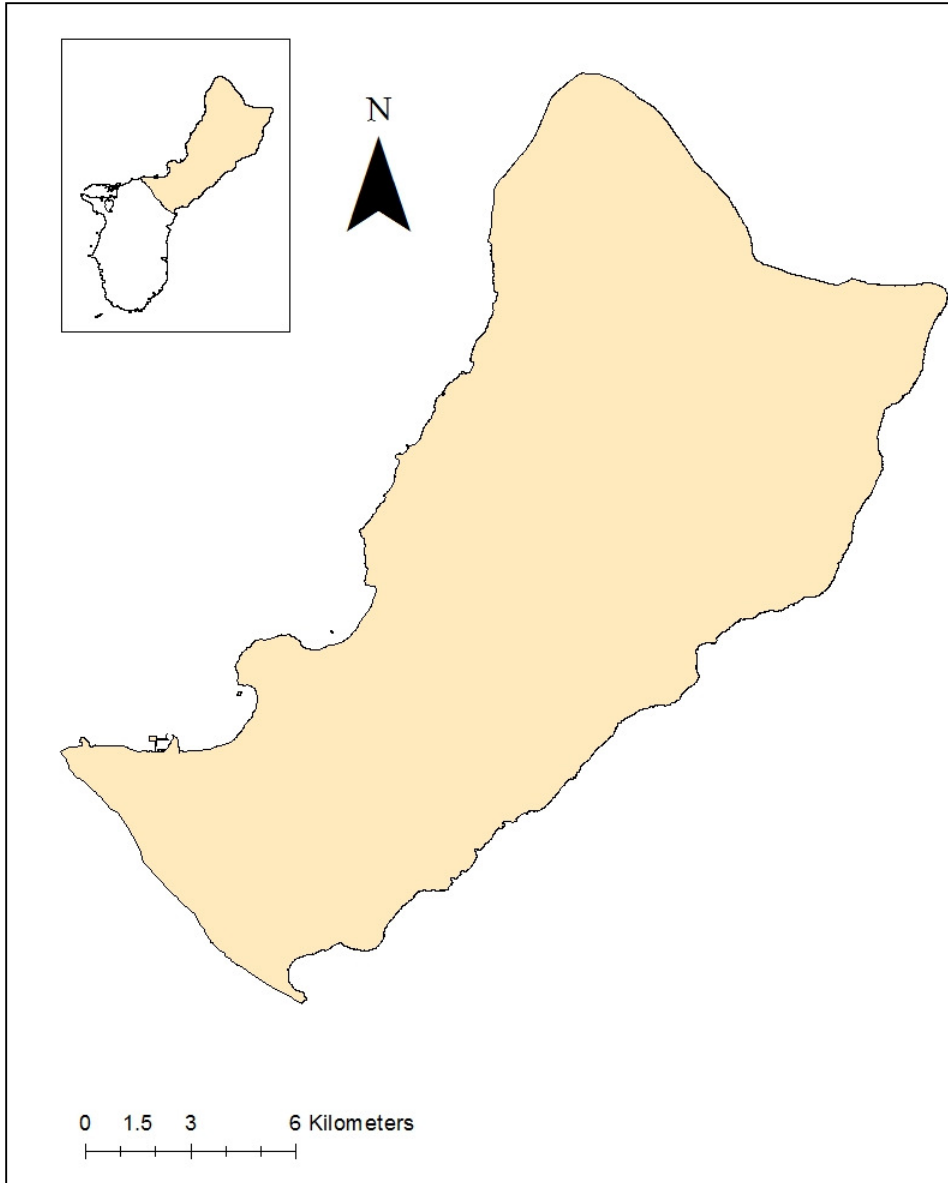


Figure 2. Outline of Northern Guam used in this study for automation of data.

File Geodatabase Design

GIS files derived for Northern Guam were managed through Arc Catalog 10.1 and stored in a file geodatabase. A file geodatabase is a collection of various types of GIS datasets held in a file system folder (Environmental Systems Research Institute, Inc. [ESRI], 2013). Although geodatabases have a wide range of uses, the purpose for the geodatabase in this study is to provide a central location where the GIS data are stored. Components of the Northern Guam Geodatabase include feature classes, feature datasets, and raster datasets. In bullet points below are the ESRI definitions of each of the components of the geodatabase:

- Feature class (type of vector data) is a set of geographic features with the same geometry type, the same attributes, and the same spatial reference. Common feature class types are points, polygons, and lines.
- Feature dataset is a set of feature classes stored together with a common spatial reference.
- Raster dataset are raster data stored in a geodatabase.

GIS datasets derived for Northern Guam involved categorization into different themes. A GIS theme is a collection of common geographic elements such as roads, soil types, vegetation, etc. (ESRI, 2013). In the geodatabase, feature datasets were added based on the categorized themes. The vector data derived for Northern Guam were imported as feature class to their respective feature datasets in the geodatabase (Table 3). The raster data extracted for Northern Guam were imported to the geodatabase as individual raster datasets. Appendix A provides a brief description of all the GIS files in the geodatabase.

Quality Control

Quality control measures for the datasets were done by producing the desired layer for Northern Guam and comparing it to the features of the original layer. This allowed for the identification of missing or duplicate information contained within the datasets.

Table 3. Organization of the feature datasets in the Northern Guam Geodatabase.

Feature Dataset	Feature Class	Feature Type
Businesses	N_Guam_Business	Point
	N_Guam_GolfCourses_07	Polygon
	N_Guam_Hotels_07	Point
	N_Guam_MajorBuildings	Point
	N_Guam_ShoppingCenters_07	Point
Coastal Features	N_Guam_CoastalFeatures	Point
Conservation Areas	N_Guam_ConservationAreas	Polygon
	N_Guam_EcologicalReserverAreas	Polygon
	N_Guam_MPA_Boundaries	
Development	N_Guam_FEDCON_Project	Point
	N_Guam_GLUC_public	Polygon
	N_Guam_GLUCdevelopments	Polygon
Federal	N_Guam_MilitaryAreas	Polgyon
Flood	N_Guam_Fema_Flood_Area	Polygon
Geology	N_Guam_Geology	Polygon
Groundwater	N_Guam_GrounwaterSubbasins_VolcanicBase mentUpdate	Polygon
	N_GuamAquiferSystem_EPA	Polgyon
Guam Septic Tank Survey	N_Guam_Buildings062706	Point
	N_Guam_NonSeweredBuildings	Point
	N_Guam_NonSeweredBldgsWin200ftOfSwrMai ns	Point
	N_Guam_SeweredBuildings	Point

Table 3-Continued

Feature Dataset	Feature Class Name	Feature Type
GWA-Sewer	N_Guam_GravityLine	Line
	N_Guam_Manhole	Point
	N_Guam_PumpStation	Point
	N_Guam_Sewer_Service	Point
	N_Guam_SewerLateral	Line
	N_Guam_SewerMain	Line
	N_Guam_WWTP	Point
GWA-Water	N_Guam_Waterstructure	Point
	N_Guam_wClearWell	Point
	N_Guam_wEnclosedStorageFacility	Point
	N_Guam_wmeter	Point
	N_Guam_wPressurizedMain	Line
	N_Guam_wProductionWells	Point
	N_Guam_wPump	Point
N_Guam_wSamplingStation	Point	
Historical Sites	N_Guam_Historical_sites	Point
Hydrography	central_north_streams	Line
	N_Guam_wetlands	Polygon
Land Cover	N_Guam_landcover	Polygon
	N_Guam_landcover2011	Polygon
Land Parcels	N_Guam_landparcels	Polgyon
Parks	N_Guam_FederalParks	Polygon
	N_Guam_SmallParks	Polygon
Ponding Basin	N_Guam_PondingBasins	Point
Population	N_Guam_2000_census_blk_housing_data	Polygon
	N_Guam_2000_2010_Pop_by_Municipality	Polygon

Table 3-Continued

Feature Dataset	Feature Class Name	Feature Type
Precipitation	N_Guam_ppt_1971_2000	Polygon
Proposed	N_Guam_FEDCON_Project	Point
	N_Guam_GLUC_public	Polygon
	N_Guam_GLUCdevelopments	
Public Sector	N_Guam_Public_Sector	Point
Reservoirs	N_Guam_Reservoirs	Point
Roads	N_Guam_Routes	Line
	N_Guam_Streets_updated_bsp_2012	Line
Shoreline	N_Guam_Shoreline	Polygon
Sinkholes	N_Guam_Sinkholes	Line
Soils	N_Guam_SoilHydroGroups	Polygon
	N_Guam_SoilMapUnits	Polygon
	N_Guam_SoilSurfaceTexture	Polygon
Species	N_Guam_HeritageLayer07_GuamSPP	Polygon
Vegetation	N_Guam_Veg	Polygon
Villages	N_Guam_Municipality	Polygon
	N_Guam_Villages	Polygon
Zones	N_Guam_North_Zones	Polygon

Metadata

Metadata, which is information about the data, is an essential part of GIS as it tells users about the content, quality, type, and information regarding the use of the data. Since the Northern Guam layers were derived from existing layers, the original metadata was kept, however the method in which the Northern Guam layers were derived was updated to the existing metadata. Metadata was completed for some layer files in which the metadata was not previously developed. Because the original layers had different metadata style, for the Northern Guam Geodatabase, the default Item Description metadata style was used.

3.2 Affected Areas Tool

The Affected Areas Tool was developed in Arc GIS 10.1 by using ModelBuilder. ModelBuilder is an application that is used to create, edit, and manage models; it also allows for the creating and sharing of models as tools ESRI (ESRI, 2013). The Affected Areas Tool was adapted from a previously developed tool made by ESRI to look at the impacts of new roads on vegetation (ESRI, 2013). This tool was modified in this work to investigate the effects of proposed development(s) in Northern Guam using GIS data contained in the Northern Guam Geodatabase.

Utilizing ModelBuilder, the Affected Areas Tool contained two variable inputs and three processing tools. The inputs of the tool include a Proposed Development Input, which is a polygon outlining the area of a proposed development, and an Input Feature which is a resource to be evaluated, which can be selected from the Northern Guam Geodatabase. The processing tools include Buffer, Clip, and Summary Statistics. In screening for CSIs, the tool executes a buffer around the proposed development sites and clips it to the resource being studied. Additionally, the user can apply certain statistics – such as *Sum* and *Count* – on the resource being studied.

The tools, inputs, and output variables were treated as model parameters (Letter P on figure 3) so that the model can run with different inputs. By applying model parameters, the tool could be executed with its own dialog box.

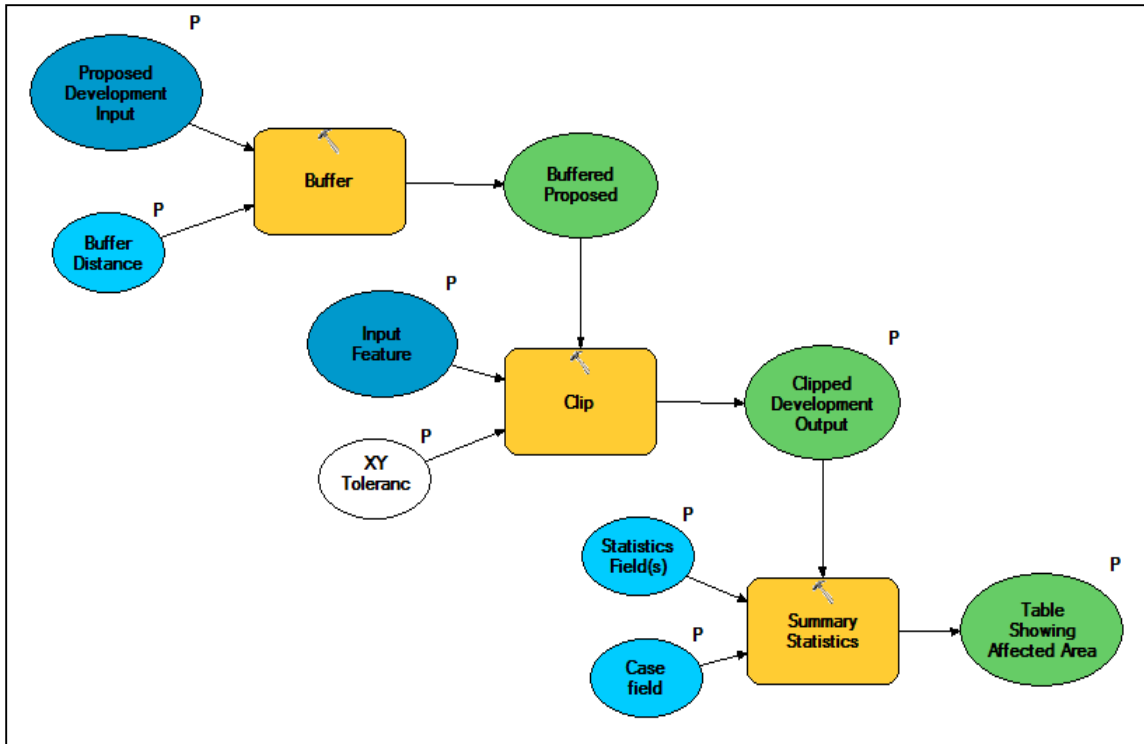


Figure 3. Workflow of Affected Areas Tool on ModelBuilder. Letter “P” indicates model parameters.

3.3 CSI – Changes in Land Cover due to Proposed Developments

3.3.1 Datasets and Sources

Satellite Imagery

Satellite images consisted of the 2006 QuickBird (QB06) and the 2011 WorldView-2 (WV2) (Figure 4). The QB06 is a 4-band, 0.6-m by 0.6-m resolution, digital orthoimage taken between May 21 2005 and May 31 2006 (over one year). The WV2 is an 8-band, 0.5-m by 0.5-m resolution, digital orthoimage taken on February 5, 2011. Both satellite images were taken by DigitalGlobe and post-processed by the U.S. Department of Agriculture, Natural Resources Conservation Service, and National Geospatial Management Center. No adjustments were needed for either of the images.

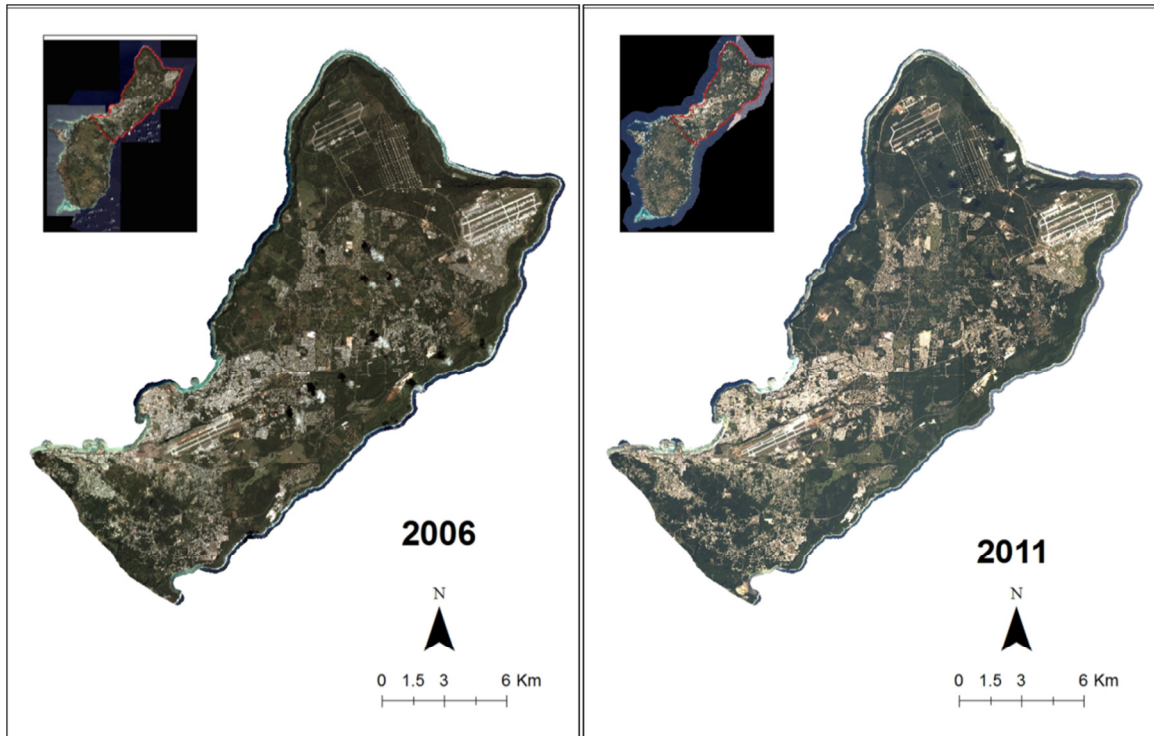


Figure 4. Satellite imagery of Guam: QuickBird 2006 (left) and WorldView-2 2011 (right).

Development Projects

To identify development projects, the “Guam_GLUC_public.shp” was obtained from Guam-BSP. The layer contained polygons delineating zoning applications from 1995 through 2011 presented to the Guam Land Use Commission. To specify the projects applicable to Northern Guam, the layer was clipped to the Northern Guam polygon and renamed “N_Guam_GLUC_development.shp”.

Information in the attribute table of the original layer and the clipped layer did not contain information on the status of the projects. A new field titled “status” was added to the attribute table of “N_Guam_GLUC_public.shp”. Under the “status” field, added information was categorized as “Completed”, “Ongoing”, or “Proposed”.

In the attribute table, keywords such as “build”, “construct”, “develop”, and “Tentative Development Plan (TDP)” present in the “PROJ_DESCR” had been used to identify development projects. When a keyword was present, the record was selected. The selected record’s polygon was then overlaid for comparison on top of the QB06 and the WV2 satellite imageries. If the area of a selected

polygon showed signs of completed construction activities based on the satellite images then the “status” field of the polygon would be updated to “Completed”. If the area showed partial and uncompleted construction activities in WV2 then the “status” field would be labeled “Ongoing”. If the area showed no signs of obstruction or construction activities in both satellite images then the “status” field would be labeled “Proposed”. This step was repeated for all of the records in the “N_Guam_GLUC_development.shp”. If more than one record contained the same information or area, the most recent zoning application was selected for those records. After all 222 records were viewed, there were 54 completed developments, 17 ongoing developments, and 61 proposed developments.

From the updated “N_Guam_GLUC_development.shp”, the Select By Attributes Tool was used to select the status of the records that were “Completed”. The selected records were then exported as a separate shapefile and titled “N_Guam_CompletedDevelopments.shp”. The step was repeated for the other status categories with their output as “N_Guam_OngoingDevelopments.shp”, and “N_Guam_ProposedDevelopments.shp”. Figure 5 shows the identified development projects for analysis in this study.

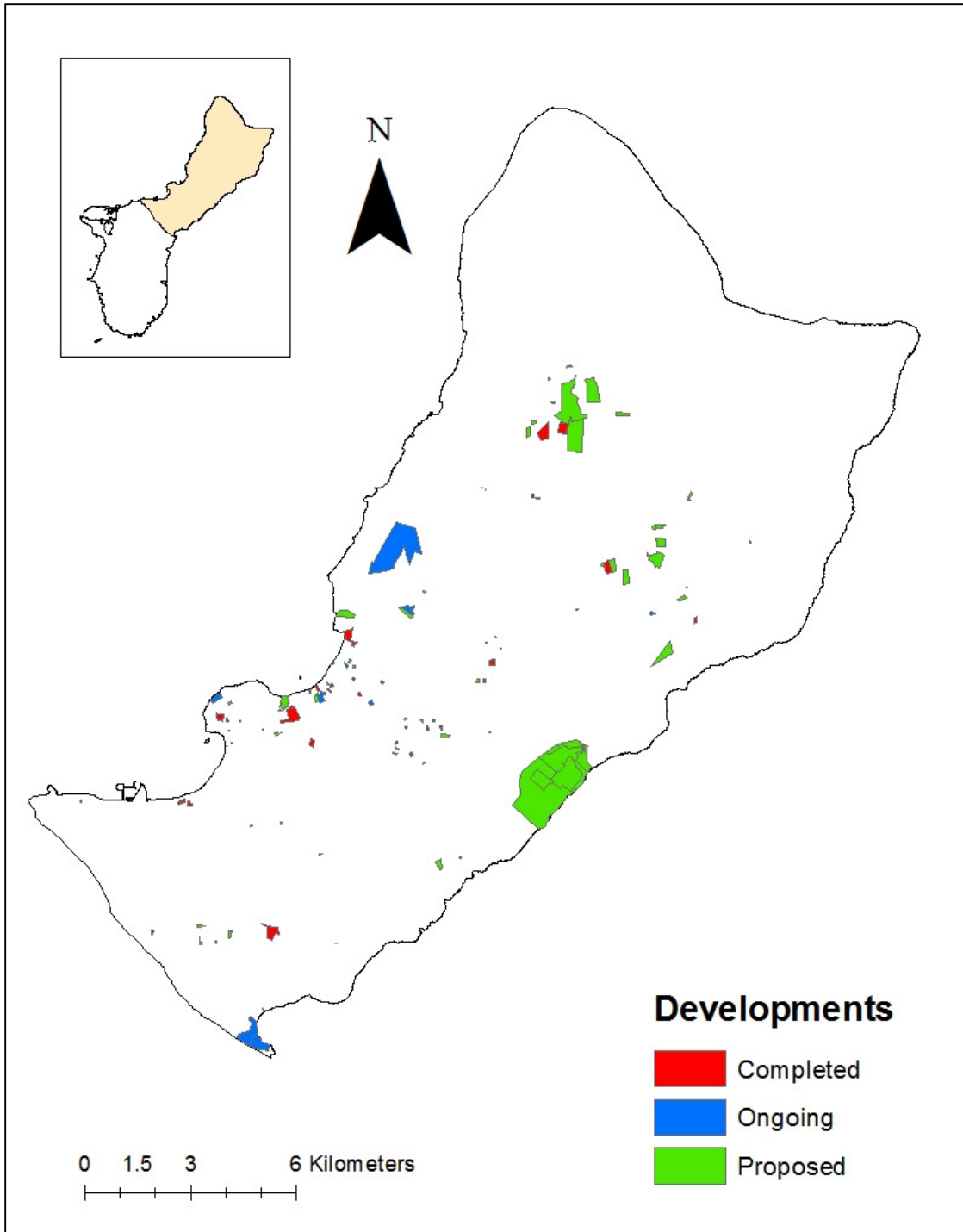


Figure 5. *Completed, Ongoing, and Proposed Developments* used in the land cover change from development analyses.

Land Cover Datasets

The 2006 and 2011 Land Cover datasets used in this analysis were downloaded from NOAA's Coastal Change Analysis Program (C-CAP) website (<http://csc.noaa.gov/ccapftp/>). Both the 2006 and 2011 land cover datasets have a resolution of 2.4 m by 2.4 m. The land cover datasets showed the entire island and each dataset was extracted by polygon to the extent of Northern Guam.

Because only area is known for the developments and not the actual building plans (e.g. impervious surface, green spaces, building heights), potential impacts to land cover from development in this study are limited to investigating the areas converted to urban or built up area. Because of this reasoning the land cover datasets were reclassified into simplified categories (Table 4). Reclassification categories were based on the classification scheme presented in Liu and Fischer (2006) methods for vegetation mapping in Guam. The reclassified land cover maps are shown in Appendix B.

Table 4. Summary of assigned values to reclassified land cover datasets.

Value	Class	Re-Classify Value	Class
2	Impervious Surface	1	Urban/ Built-Up
5	Developed Open Space	1	Urban/ Built-Up
6	Cultivated	2	Agriculture
7	Pasture/Hay	3	Grassland
8	Grassland	3	Grassland
10	Evergreen Forest	4	Forest
12	Scrub/Shrub	3	Grassland
13	Palustrine Forested Wetland	5	Wetland
14	Palustrine Scrub/Shrub Wetland	5	Wetland
15	Palustrine Emergent Wetland	5	Wetland
19	Unconsolidated Shore	5	Wetland
20	Bare Land	6	Bare Land

3.3.2 CSI Land Cover Change Scenarios

Direct Impacts

Using 2005 land cover, the scenarios evaluated were (1) *Completed Developments*; (2) *Completed and Ongoing Developments*; and (3) *Completed, Ongoing, and Proposed Developments*. The appropriate shapefiles derived in the development identification section were converted to 2-m rasters based on the resolution of the land cover datasets. For each of the scenarios, the direct impacts to land cover from the development rasters were evaluated using the *Con IsNull* function in the raster calculator. The *Con IsNull* function assigned the no-data values in the development rasters to 1, the value of urban/built-up land in the reclassified land cover datasets.

Secondary Impacts

CSIs of developments consist of direct and secondary impacts. Direct impacts are usually limited to the boundaries of a proposed project, while secondary impacts are not necessarily limited to the boundaries. To investigate the secondary impacts from the developments to land cover, 50-m and 100-m buffers were added to the development rasters. The changes in land cover scenarios were also evaluated with each of the buffered raster using the *Con IsNull* function in the raster calculator.

3.3.3 Comparison of Land Cover Scenarios

To compare the land cover changes from the developments, tables were developed showing the area in hectares and percentage for Northern Guam for each of the land cover scenarios. For each scenario the percent change was calculated by dividing the observed change of a land cover class by the sum of all the land cover changes.

It was inferred that the *Completed and Ongoing Developments* scenario would closely resemble the existing land cover today. This scenario was further analyzed by performing a land transformation analysis using Zonal Histogram in ArcMap to indicate the land cover classes that have been converted to urban/built-up areas.

To investigate if the changes from a development match existing land cover conditions, each of the scenarios was compared with the 2011 land cover. A table was developed showing the land cover scenario that resembled values of the 2011 land cover.

Chapter 4. Results

4.1. Northern Guam Geodatabase

The Northern Guam Geodatabase (Figure 6) contains 29 feature datasets and 5 raster datasets. Feature datasets contain one or more feature class, namely polygon, point, and line feature classes.

The Northern Guam Geodatabase provides environmental planners and managers a central location to access quick and easy GIS data for Northern Guam. The geodatabase can be used as a qualitative tool where multiple developments at different locations can be screened in relation to groundwater basins, production wells, sewer lines, septic systems, or any other input found in the geodatabase. Appendix C provides steps for viewing the Northern Guam Geodatabase in ArcCatalog, and for viewing the Northern Guam Geodatabase with proposed developments in ArcMap.

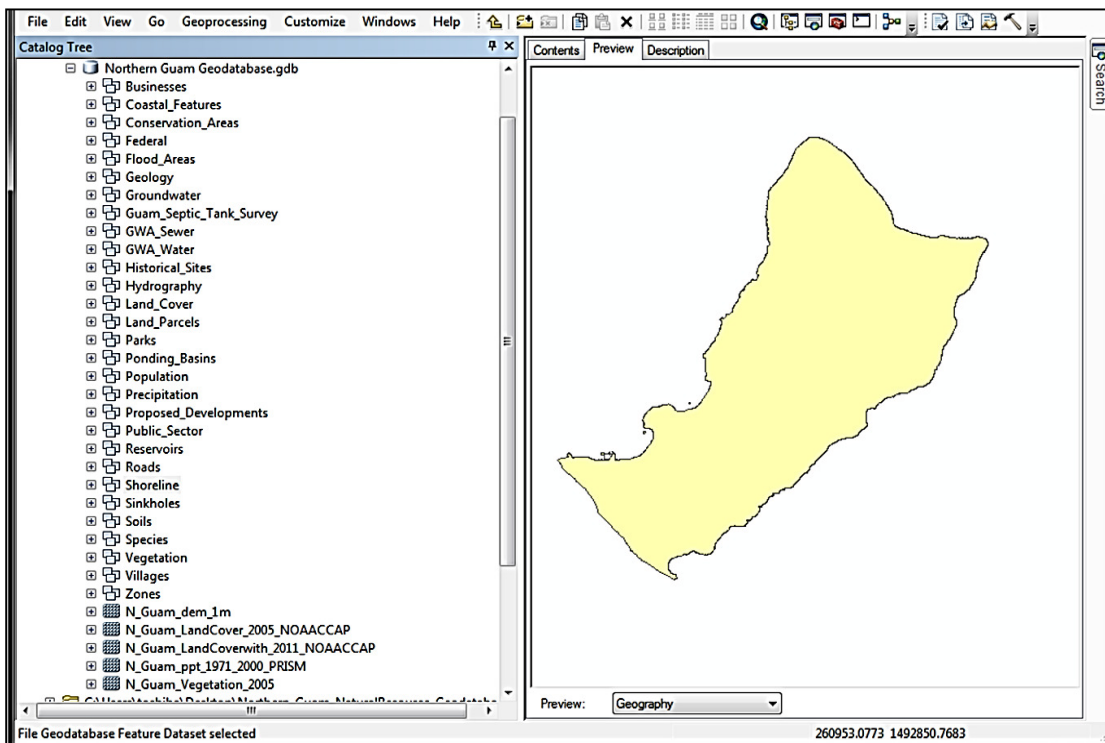


Figure 6. Screenshot of the Northern Guam Geodatabase in ArcCatalog.

4.2 Affected Areas Tool

Figure 7 shows a screenshot of the Affected Areas Tool dialog box. The tool utilizes inputs from the Northern Guam Geodatabase to show how much of a resource would be potentially affected by a proposed development. Appendix D provides steps for using the Affected Areas Tool in ArcMap.

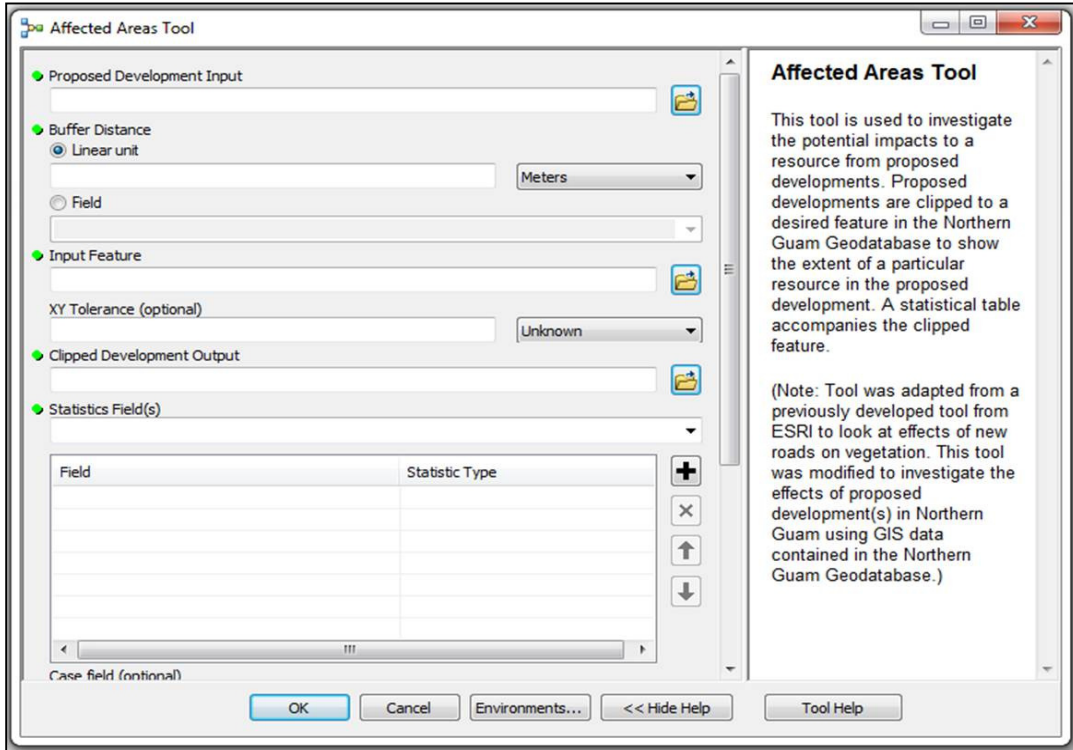


Figure 7. Screenshot of the Affected Areas Tool dialog box.

4.3 CSI – Land Cover Changes from Developments on Northern Guam

4.3.1 Direct Impacts

Land Cover Changes

Analyses from the development scenarios indicate changes to land cover areas for Northern Guam (Table 5). The *Completed Developments* scenario (Figure 8) shows a 0.30% decrease in forest area, 0.68% increase in urban/built-up area, 0.22% decrease in grassland area, no change for cultivated area, no decrease in wetland area, and a 1.73% decrease in bare land area. The *Completed and Ongoing Developments* scenario (Figure 9) shows a 0.97% decrease in forest area, 2.55% increase in urban/built-up area, 4.45% decrease in grassland area, no change for cultivated area, 0.32% decrease in wetland area, and 3.19% decrease in bare land area. The *Completed, Ongoing, and Proposed Developments* scenario (Figure 10) shows a 3.17% decrease in forest area, 7.82% increase in urban/built-up area, 4.45% decrease in grassland area, 2.17% decrease in cultivated area, 0.35% decrease in wetland area, and 7.38% decrease in bare land area.

Table 5. Land cover classes from the development scenarios and their corresponding areas (ha and %) for Northern Guam. Reclassified 2005 Land Cover Map values provided for comparison.

Class	Northern Guam Reclassified 2005 Land Cover		Land Cover with <i>Completed</i> <i>Developments</i>		Land Cover with <i>Completed and</i> <i>Ongoing</i> <i>Developments</i>		Land Cover <i>Completed,</i> <i>Ongoing, and</i> <i>Proposed</i> <i>Developments</i>	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest	14233.86	54.26	14191.80	54.10	14096.35	53.74	13782.72	52.54
Urban/Built-Up	7997.20	30.49	8051.85	30.69	8200.97	31.26	8622.19	32.87
Grassland	3293.02	12.55	3285.77	12.53	3237.28	12.34	3146.42	11.99
Bare Land	307.28	1.17	301.96	1.15	297.49	1.13	284.60	1.08
Wetland	227.08	0.87	227.06	0.87	226.34	0.86	226.29	0.86
Cultivated	174.49	0.67	174.49	0.67	174.49	0.67	170.69	0.65

Note: Total land area for Northern Guam is 26,232.93 ha (100.0%).

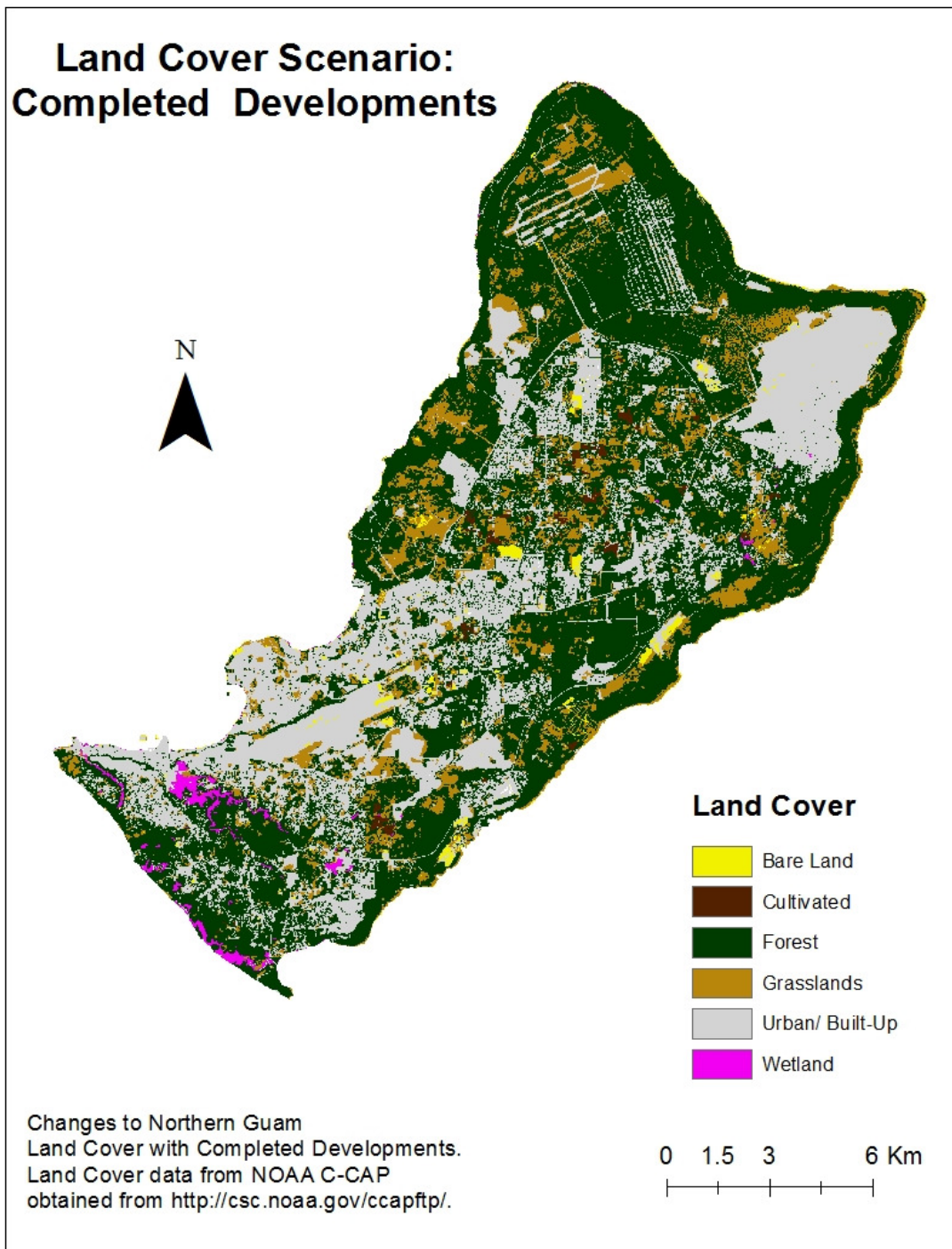


Figure 8. Map of *Completed Developments* scenario.

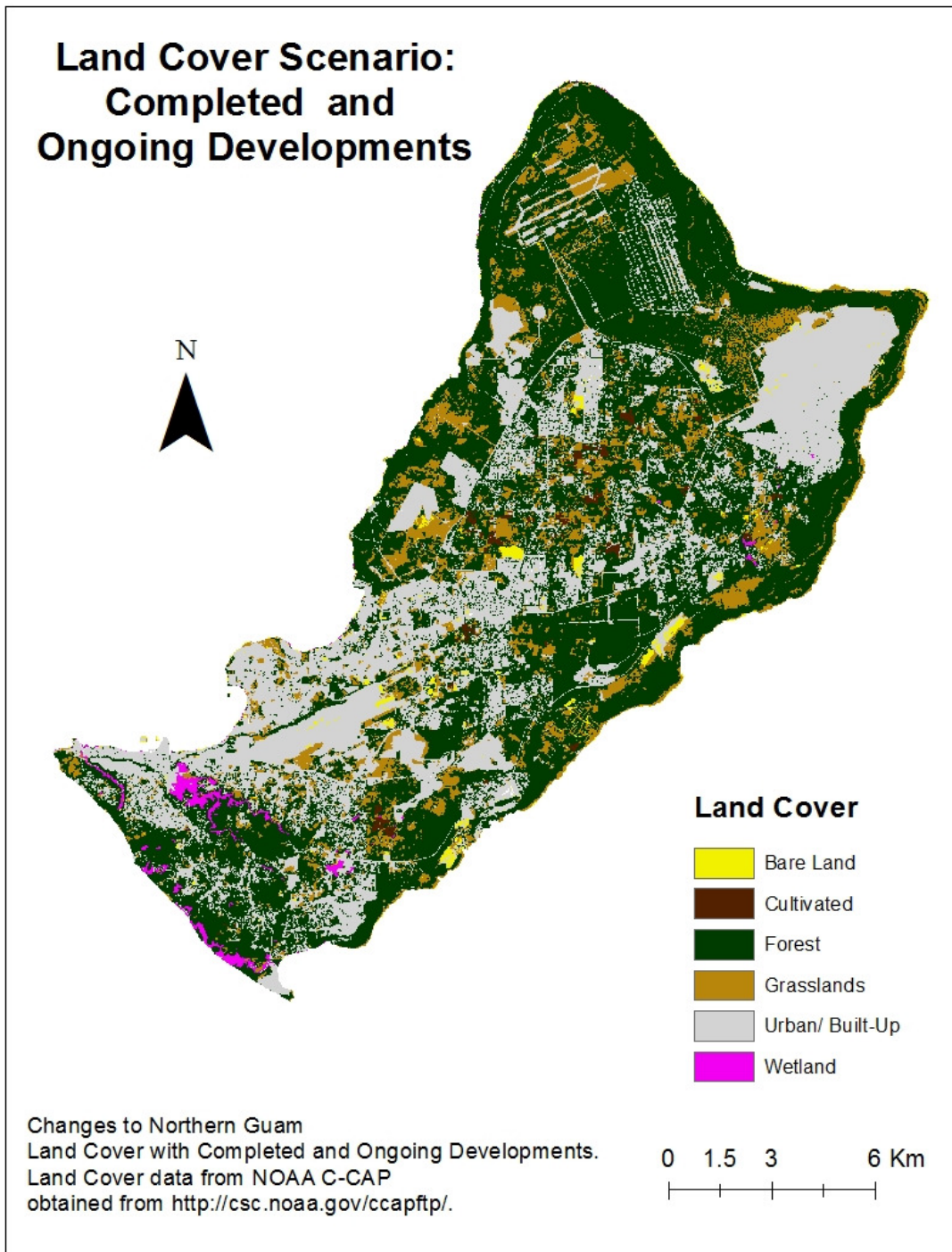


Figure 9. Map of *Completed and Ongoing Developments* scenario.

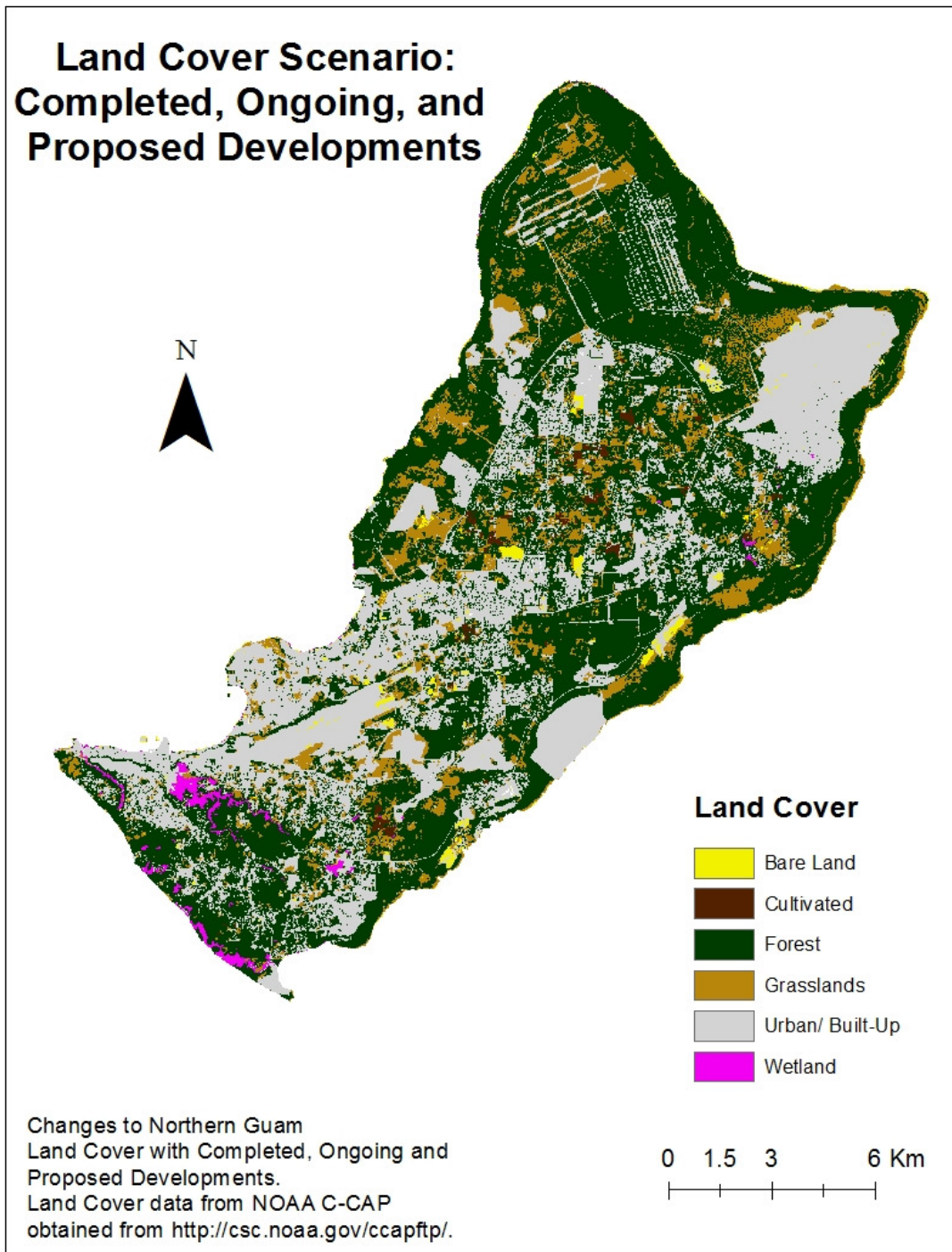


Figure 10. Map of *Completed, Ongoing, and Proposed Developments* scenario.

Trends from the development scenarios indicate the combined lost area of forest, grassland, and bare land is equal to the gained urban/built up area (Figure 11). Throughout the development scenarios grassland area lost up to 146 ha and bare land area lost up to 23 ha. The development impacts to wetland area and cultivated area are less than 1% area changed. The *Completed, Ongoing, and Proposed Developments* scenario suggests that if all the developments were approved and implemented Northern Guam would lose about 450 ha of forest area (Figure 11). However, with this scenario, forest area in Northern Guam would only decrease from 54% to 52%.

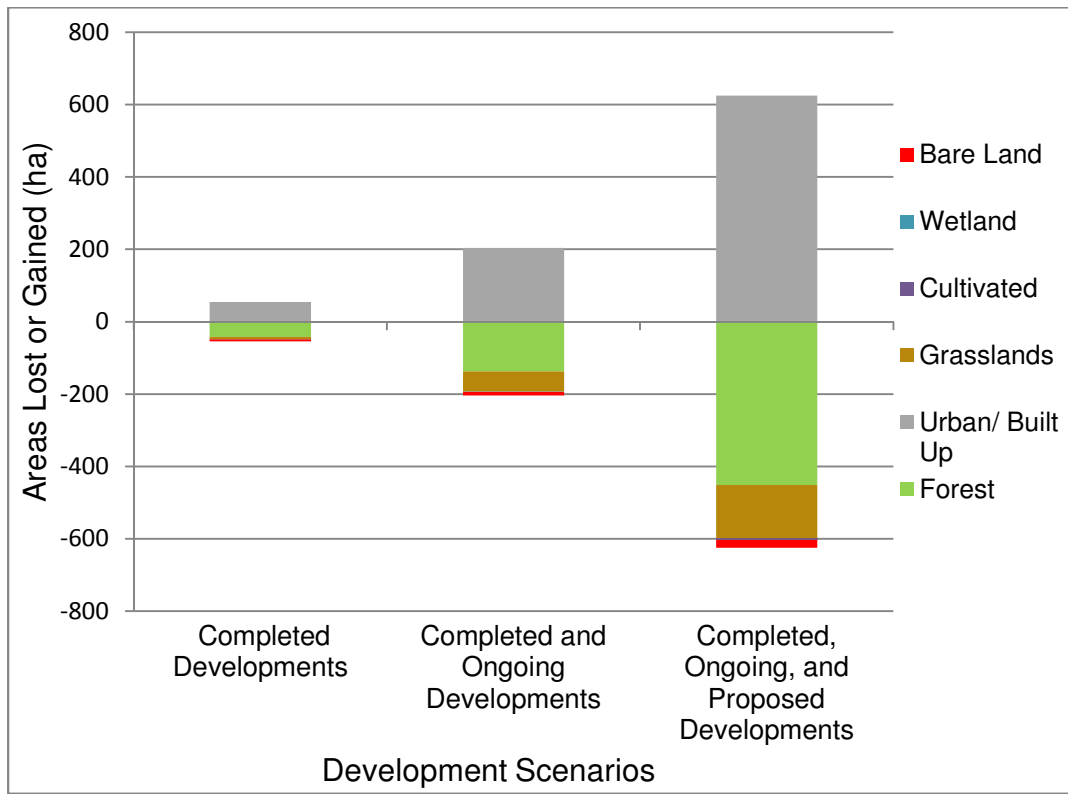


Figure 11. Land cover areas lost or gained from the development scenarios. Changes to cultivated and wetland areas were less than 1% and thus do not show on the graph.

Land Transformation – Completed and Ongoing Developments Scenario

The *Completed and Ongoing Developments* scenario most closely matches the present-day existing land cover conditions. Land transformation analyses of the *Completed and Ongoing Developments* scenario indicate that urban/built-up area occupies up 8200.97 ha of Northern Guam (Table 5).

Increases in urban/built-up area since 2005 were accompanied with decreases of 137.51 ha in forest area, 55.74 ha in grassland area, 0.74 ha in wetland area, and 9.79 ha in bare land area. No loss of cultivated area occurred with the *Completed and Ongoing Developments* scenario (Table 5).

4.3.2 Secondary Impacts

Land Cover Change – 50-m Buffer

The 50-m buffered development scenarios exhibited the same trends as the un-buffered development scenarios, above, with respect to decreases in forest and other areas and an increase in urban/built-up area (Table 6). The 50-m buffered *Completed Developments* scenario exhibited a decrease in forest area of 0.63%, increase in urban/ built-up area of 1.43%, decrease in grassland area of 0.49%, decrease in bare land area of 2.63%, decrease in wetland area of 0.27%, and decrease in cultivated area of 0.01%. The 50-m buffered *Completed and Ongoing Developments* scenario exhibited a decrease in forest area of 1.52%, increase in urban/built-up area of 3.92%, decrease in grassland area of 2.39%, decrease in bare land area of 5.24%, decrease in wetland area of 0.73%, and decrease in cultivated area of 0.08%. The 50-m buffered *Completed, Ongoing, and Proposed Developments* scenario exhibited a decrease in forest area of 4.46%, increase in urban/built-up area of 10.74%, decrease in grassland area of 5.65%, decrease in bare land area of 10.38%, decrease in wetland area of 0.85%, and decrease in cultivated area of 2.25%.

Table 6. Land cover classes from the development scenarios with a 50-m buffer and their corresponding areas (ha and %) for Northern Guam. Reclassified 2005 Land Cover Map values provided for comparison.

Class	Northern Guam Reclassified 2005 Land Cover (No Buffer)		Land Cover with <i>Completed Developments</i>		Land Cover with <i>Completed and Ongoing Developments</i>		Land Cover <i>Completed, Ongoing, and Proposed Developments</i>	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest	14233.86	54.26	14144.09	53.92	14016.89	53.43	13598.39	51.84
Urban/Built-Up	7997.20	30.49	8111.62	30.92	8310.70	31.68	8856.35	33.76
Grasslands	3293.02	12.55	3277.00	12.49	3214.39	12.25	3107.08	11.84
Bare Land	307.28	1.17	299.19	1.14	291.18	1.11	275.40	1.05
Wetland	227.08	0.87	226.56	0.86	225.42	0.86	225.16	0.86
Cultivated	174.49	0.67	174.47	0.67	174.35	0.66	170.56	0.65

Note: Total land area for Northern Guam is 26,232.93 ha (100.0%).

Land Cover Change – 100-m Buffer

The 100-m buffer development scenarios exhibited the same trends as the un-buffered and 50-m buffered scenarios, above, with respect to conversion of forest and other areas to urban/built-up area; however, the areas of converted land are more pronounced (Table 7). The 100-m buffered *Completed Developments* scenario exhibited a decrease in forest area of 1.11%, increase in urban/built-up area of 2.50%, decrease in grassland area of 0.87%, decrease in bare land area of 3.66%, decrease in wetland area of 0.65%, and decrease in cultivated area of 0.23%. The 100-m buffered *Completed and Ongoing Developments* scenario exhibited a decrease in forest area of 2.26%, increase in urban/built-up area of 5.71%, decrease in grassland area of 3.31%, decrease in bare land area of 7.14%, decrease in wetland area of 1.49%, and decrease in cultivated area of 0.30%. The 100-m buffered *Completed, Ongoing, and Proposed Developments* scenario exhibited a decrease in forest area of 6.08%, increase in urban/built-up area of 14.36%, decrease in grassland area of 7.12%, decrease in bare land area of 13.14%, decrease in wetland area of 1.68%, and decrease in cultivated area of 2.75%.

Table 7. Land cover classes from the development scenarios with a 100-m buffer and their corresponding areas (ha and %) for Northern Guam. Reclassified 2005 Land Cover Map values provided for comparison.

Class	Reclassified 2005 Land Cover (No Buffer)		Land Cover with <i>Completed Developments</i>		Land Cover with <i>Completed and Ongoing Developments</i>		Land Cover <i>Completed, Ongoing, and Proposed Developments</i>	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest	14233.86	54.26	14075.97	53.66	13912.02	53.03	13368.85	50.96
Urban/Built-Up	7997.20	30.49	8196.82	31.25	8453.78	32.23	9145.52	34.86
Grasslands	3293.02	12.55	3264.40	12.44	3184.15	12.14	3058.71	11.66
Bare Land	307.28	1.17	296.04	1.13	285.32	1.09	266.89	1.02
Wetland	227.08	0.87	225.61	0.86	223.69	0.85	223.26	0.85
Cultivated	174.49	0.67	174.09	0.66	173.97	0.66	169.69	0.65

Note: Total land area for Northern Guam is 26,232.93 ha (100.0%).

4.3.3 Comparison with 2011 Reclassified Land Cover

Comparisons of the land cover scenarios to the buffered scenarios reveals that the 50-m buffered *Completed and Ongoing Developments* scenario has the closest match to the 2011 land cover (Table 8). Urban/built-up area for the development scenario and the 2011 Reclassified Land Cover Map for Northern Guam had close values with only a 0.03% difference.

The areas (in hectares) for cultivated, wetland, and bare land areas did not closely match; however, forest area from the scenario and the reclassified map differed by only 0.01%. A possible explanation is that comparison of the scenarios only considered the transformation of areas to urban and built-up area; other activities that might contribute to changes in the land cover, such as the conversion of grassland to cultivated land, rather than to urban/ built-up land, were not determined.

Table 8. Comparison of 50-m buffered *Completed and Ongoing Developments* scenario with 2011 Reclassified Land Cover Map values for Northern Guam.

Class	<i>Completed and Ongoing Developments</i>		2011 Reclassified Land Cover	
	Area (ha)	%	Area (ha)	%
Forest	14016.89	53.43	13878.82	52.90
Urban/Built Up	8310.70	31.68	8319.85	31.71
Grasslands	3214.39	12.25	3279.28	12.50
Cultivated	174.35	0.66	140.30	0.53
Wetland	225.42	0.86	232.20	0.89
Bare Land	291.18	1.11	387.06	1.48

Note: Total land area for Northern Guam is 26,232.93 ha (100.0%).

Chapter 5. Discussion

5.1 Northern Guam Geodatabase and Affected Areas Tool

The nature of cumulative impacts is usually project specific. The Northern Guam Geodatabase coupled with the Affected Areas Tool can be used as a screening method to simultaneously assess potential CSIs from multiple projects. Future studies may yield new or updated GIS layers. The Northern Guam Geodatabase should be updated if new layers or updates are made available, which would allow users to work with the most updated information.

5.2 Changes to Land Cover Resulting from CSI Development Scenarios

The trends in the development scenarios indicate forest area and other undeveloped lands will be converted to urban/built-up area. Furthermore, the analyses suggest that undeveloped lands most likely will be developed in the future. Based on the 2011 Reclassified Land Cover Map, forest area covers about 53% of Northern Guam. CSIs resulting from land cover changes such as urban sprawl and fragmentation in Northern Guam due to future developments, will impact forest resources the most.

The buffers applied to the land cover scenarios indicated that conversion to urban/built-up area also occurs outside the boundaries of development projects. In forming a CSI policy it is important to take into account that development projects may consequently span outside their defined area and secondary impacts should face the same evaluation as potential direct impacts.

5.3 Land Cover Changes and Implications to Water Quality

The conversion of undeveloped lands to urban/built-up area involves the removal of vegetation and exposure of soils. Native vegetation absorbs rainfall and slows runoff velocities, enhancing the infiltration of water into the subsurface (Horsley Witten Group, 2012). In addition, when construction clearing occurs, soils are exposed, leading to erosion. Without following proper erosion control methods, land-clearing activities may result in sediment runoff that can wash into roads, clog drainage systems, and result in flooding. Ultimately sediment-laden runoff can reach coastal waters carrying contaminants that reduce water quality and promote sedimentation over seagrass beds and coral reefs. Likewise, polluted runoff from new developments or seepage from septic tanks, if not properly treated, may infiltrate and overload the remedial capacity of natural soils and contaminate the Northern Guam Aquifer, which is a valuable source of drinking water. An example of using the Affected Areas Tool to establish protection zones free of contaminant sources (e.g., septic tanks) around drinking water wells is shown in Appendix D.

Chapter 6. CONCLUSIONS

In studying CSIs induced by developments, the scope of this study was to provide the baseline GIS data and tools for managers to screen for resources that may be affected by proposed developments. The Northern Guam Geodatabase developed in this project contains 29 feature datasets and 5 raster datasets portraying geographic information about Northern Guam. The Affect Areas Tool is a GIS-based tool that utilizes inputs from the Northern Guam Geodatabase to screen and quantify the resources that may be affected from future developments. The outcome of the land development scenarios considered here indicates that for Northern Guam, undeveloped lands will be converted to urban/built-up areas with forested areas being affected the most.

Further research will be needed to model the routes that contaminants originating from developments take to reach the aquifer or coastal areas. In addition, future studies may also model the accumulation of certain pollutants in water resources related to developments or land uses. A specific concern worthy of study would involve the transformations that aqueous forms of nitrogen undergo over time under various environmental conditions, as occurs when infiltrate makes it vertical descent through the vadose zone toward the groundwater table. In addition, future studies may choose to couple GIS techniques with other methods to model CSIs.

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U.S. Navy, Naval Facilities Engineering Command, Pacific (NAVFAC Pacific). (2013). *Final Scoping Summary Report, Guam and CNMI Relocation (2012 Roadmap Adjustments) Supplemental Environmental Impact Statement*. Pearl Harbor, Hawaii: NAFVC Joint Guam Program Office

Appendix A

Descriptions of GIS files in the Northern Guam Geodatabase

Brief descriptions of the GIS files contained in the Northern Guam Geodatabase.

Feature Datasets and Feature Classes

Businesses

N_Guam_Business: Polygon feature class delineating business coverage. Projection is WGS 1984. Clipped from original shapefile "business". Credits: Permission of Bureau of Plans, Government of Guam.

N_Guam_GolfCourses_07: Point feature class showing golf course locations in Northern Guam. Projection is WGS 1984. Original shapefile "07_golf_courses". Original Dataset developed for the Guam Map Book Project 2006/2007. Credits: Maria Kottermair, Bureau of Statistics and Planning.

N_Guam_Hotels_07: Point feature class that represents hotels in the North. Projection is WGS 1984. Original layer "07_hotels" created in 2007. Original Dataset developed for the Guam Map Book Project 2006/2007. Credits: Maria Kottermair, Bureau of Statistics and Planning.

N_Guam_MajorBuildings: Point feature class showing major office buildings: DNA Building, GCIC Building, and ITC Building. Projection is WGS 1984. Original shapefile "07_major_buildings". Original Dataset developed for the Guam Map Book Project 2006/2007. Credits: Maria Kottermair, Bureau of Statistics and Planning.

N_Guam_ShoppingCenters_07: Point feature class that shows shopping centers in Northern Guam. Projection is WGS 1984. From original shapefile "07_shoppingcenters". Credits: Maria Kottermair, Bureau of Statistics and Planning

Coastal Features

N_Guam_CoastalFeatures: Point feature class to provide labels of the coastal features for Northern Guam. Projection is WGS 1984. Original shapefile from "coastal_features". Credits: Permission of the Bureau of Planning, Gov. of Guam.

Conservation Areas

N_Guam_ConservationAreas: Polygon feature class delineating conservation areas in Northern Guam. Projection is WGS 1984. Original shapefile from "Guam_Conservation_Areas".

N_Guam_EcologicalReserverAreas: Polygon feature class delineating ecological reserve areas in Northern Guam. Projection is WGS 1984. Original shapefile from "Ecological_Reserve_Areas".

N_Guam_MPA_Boundaries: Polygon feature class delineating marine preserve boundaries in Northern Guam. Original shapefile "Guam_MPA_Boundaries" obtained from Guam Coastal Atlas. According to metadata the display boundaries are not exact and should be used for display purposes only.

Developments

N_Guam_FEDCON_Project: shapefile showing Federal consistency projects (FEDERALCON_PROJECTS) for years 1999 to 2011. Obtained from Guam Bureau of Statistics and Plans. Permission to use by the staff of GIS/LUP Section, Bureau of Statistics and Plans, Government of Guam.

N_Guam_GLUC_public: coverage of Guam Land Use Commission (GLUC) Projects for Fiscal Years 2005 to 2008 (FY05 to FY08). Original shapefile "Guam_GLUC_public". Obtained from Guam Bureau of Statistics and Plans.

N_Guam_GLUCdevelopments: Layer modified with an extra field "status" to show status of development projects as completed, ongoing, or proposed. Development project polygon status was obtained by comparing land area from 2005 and 2011 satellite imagery for Northern Guam. Shapefile obtained from the bureau of statistics and plans; Leena Muller WERI Research Assistant.

Federal

N_Guam_MilitaryAreas: Polygon feature representing military areas in Northern Guam. Projections is WGS 1984. Original shapefile "Military_Areas". Acknowledgment to the U.S. Geological Survey.

Flood Areas

N_Guam_Fema_Flood_Area: The Digital Flood Insurance Rate Map for Northern Guam. Clipped from original shapefile "Fema_Flood_Area". Acknowledgements to FEMA.

Geology

N_Guam_Geology: Polygon feature class represents geology coverage for Northern Guam. Clipped from original shapefile "Map_Geology_Detail_Adjusted" which purpose was to represent known geologic units in southern Guam. Projection is WGS 1984. Credits: William Lettis and Associates.

Groundwater

N_Guam_GrounwaterSubbasins_VolcanicBasementUpdate: Updated groundwater subbasins based on updated volcanic basement map (In Press WERI Tech Report #142).

N_GuamAquiferSystem_EPA: Northern Guam sole source aquifer designation area obtained from EPA Region 9 website <http://www.epa.gov/region9/water/groundwater/ssa.html>. Data converted from .kmz to shapefile. Map metadata has disclaimer as layer to be used for general representation only.

Guam Septic Tank Survey

N_Guam_Buildings062706: Point feature class representing sewerred and non sewerred buildings in Northern Guam. Projection WGS 1984. Clipped from original shapefile "Buildings062706". Based on Water and Environmental Research Insitutute (WERI) Septic Tank Study.

N_Guam_NonSeweredBuildings: Point feature class representing non sewerred buildings in Northern Guam. Projection WGS 1984. Data extracted from original shapefile "Buildings062706". Based on Water and Environmental Research Insitutute (WERI) 2001 Septic Tank Study.

N_Guam_NonSwerdBldgsWin200ftOfSwrMains: Point feature class representing non sewerred buildings within 200 ft of sewer mains. Shapefile derived from applying a 200 ft buffer around sewer main and clipping non sewerred buildings to the sewer main buffer.

N_Guam_SeweredBuildings: Point feature class representing sewerred buildings in Northern Guam. Projection WGS 1984. Clipped from original shapefile "Buildings062706". Based on Water and Environmental Research Insitutute (WERI) 2001 Septic Tank Study.

GWA-Sewer (With Permission)

N_Guam_GravityLine: Line feature class representing sewer gravity lines for Northern Guam. Projection WGS 1984. Clipped from original shapefile "GravityLine". Permission of use by Guam Waterworks Authority (GWA).

N_Guam_Manhole: Point feature class representing locations of sewer manholes. Projection is WGS 1984. Clipped from original shapefile "Manhole". Permission of use by Guam Waterworks Authority (GWA).

N_Guam_PumpStation: Point feature class representing sewer pump stations. Projection is WGS 1984. Clipped from original shapefile "PumpStation". Permission of use by Guam Waterworks Authority (GWA).

N_Guam_Sewer_Service: Point feature class for sewer service. Projection WGS 1984. Clipped from original shapefile "Service". Permission of use by Guam Waterworks Authority (GWA).

N_Guam_SewerLateral: Line feature class representing sewer lateral lines . Projection is WGS 1984. Clipped from original shapefile "SewerLateral". Permission of use by Guam Waterworks Authority (GWA).

N_Guam_SewerMain: Line feature class to represent sewer mains in Northern Guam. Projection is WGS 1984. Clipped from original shapefile "SewerMain". Permission of use by Guam Waterworks Authority (GWA).

N_Guam_WWTP: Point feature class representing waste water treatment plants in Central and Northern Guam. Projection is WGS 1984. Clipped from original shapefile "Plants". Permission of use by Guam Waterworks Authority (GWA).

GWA-Water (With Permission)

N_Guam_Waterstructure: point feature class presenting GWA water structure in Northern Guam. Water structure include pump, production wells, and enclosed storage facility. Projection WGS 1984. Clipped from original shapefile "wNetworkStructure". Permission of use by Guam Waterworks Authority (GWA).

N_Guam_wClearWell: Point feature class representing clear wells in Northern Guam. Projection WGS 1984. Clipped from original shapefile "wClearWell ". Permission of use by Guam Waterworks Authority (GWA).

N_Guam_wEnclosedStorageFacility: Point feature class representing enclosed storage facilities for water in Northern Guam. Projection WGS 1984. Data points for shapefile selected from "North_wnetworkstructure". Permission of use by Guam Waterworks Authority (GWA).

N_Guam_wmeter: Point feature class representing water meters in Northern Guam. Projection WGS 1984. Clipped from original shapefile "wMeter ". Permission of use by Guam Waterworks Authority (GWA).

N_Guam_wPressurizedMain: Line feature class representing pressurized water main in Northern Guam. Projection WGS 1984. Clipped from original shapefile "wPressurizedMain ". Permission of use by Guam Waterworks Authority (GWA).

N_Guam_wProductionWells: Point feature representing GWA production wells in Northern Guam. Projection WGS 1984. Data points for shapefile selected from "North_wnetworkstructure". Permission of use by Guam Waterworks Authority (GWA).

N_Guam_wPump: Point feature class representing water pumps in Northern Guam. Projection WGS 1984. Data points for shapefile selected from "North_wnetworkstructure". Permission of use by Guam Waterworks Authority (GWA).

N_Guam_wSamplingStation: Point feature class representing water sampling stations in Northern Guam. Projection WGS 1984. Clipped from original shapefile "wSamplingStation". Permission of use by Guam Waterworks Authority (GWA).

Historical Sites

N_Guam_Historical_sites: Point feature class representing historical sites in Northern Guam. Projection is WGS 1984. Clipped from original shapefile "historical_sites". Credits: Permission of Bureau of Planning, Government of Guam.

Hydrography

central_north_streams: line feature class showing streams in Central Guam. Projection is WGS 1984. Clipped from original shapefile "stream". Credit: US Census Bureau.

N_Guam_wetlands: Polygon feature class shapefile delineating wetland in Northern Guam. Shapefile derived from extracting wetland areas in 2005 land cover map. Credits: NOAA (C-CAP) 2005 Land Cover Map; Leena Muller WERI Research Assistant.

Land Cover

N_Guam_landcover 2005: Polygon feature class representing different land cover classes for Northern Guam. Extracted by mask to Northern Guam from 2005 NOAA C-CAP Land Cover Map and converted to polygon. Projection is WGS 1984. Credits: NOAA Coastal Services Center.

N_Guam_landcover 2011: Polygon feature class representing different land cover classes for Northern Guam. Extracted from 2011 NOAA C-CAP Land Cover Map and converted to shapefile. Projection is WGS 1984. Credits: NOAA Coastal Services Center.

Land Parcels

N_Guam_landparcels: Coverage for land parcels in Northern Guam. Clipped to Northern Guam from original shapefile "LandParcels_Mege". Projection is WGS 1984. Credits: Data from Department of Land Management; Conversion to GIS Layer funded by the Bureau of Statistics and Plans Coastal Management Program.

Parks

N_Guam_FederalParks: Polygon feature class for Northern Guam federal parks. Original shapefile "Federal_Parks". Projection is WGS 1984. Acknowledgment to the U.S. Geological Survey.

N_Guam_SmallParks: Polygon feature class for Northern Guam small parks. Original shapefile "Small_Parks". Projection is WGS 1984. Acknowledgment to the U.S. Geological Survey.

Ponding Basin

N_Guam_PondingBasins: Point feature class representing ponding basin locations for Northern Guam. Projection is WGS 1984.

Population

N_Guam_2000_census_blk_housing_data: Polygon representing total population count in the year 2000. US Census Bureau.

N_Guam_2000_2010_Pop_by_Municipality: polygon feature class representing population count in 2000 and 2010 for each municipality in Northern Guam. Clipped from original shapefile "Guam_2000_2010_Pop_by_Municipality". Source: U.S. Census Bureau, Census 2000 for Guam and the 2010 Census for Guam. Credits: Leena Muller

Precipitation

N_Guam_ppt_1971_2000: Polygon feature class representing average precipitation for Northern Guam period 1971-2000. Converted to polygon from raster N_Guam_ppt_1971_2000_1. Grid data obtained from PRISM Climate Group
(http://www.prism.oregonstate.edu/products/viewer.phtml?vartype=ppt&file=/pub/prism/pacisl/grids/ppt/Normals/guam_ppt_1971_2000.14.asc.gz)

Public Sector

N_Guam_Public_Sector: Provide a coverage of the location of governments facilities in Northern Guam. Shapefile include features for government-public sector facilities, local, federal, and foreign that exist on Guam. Projection WGS 1984. Original layer clipped from PUBLIC_SECTOR. Obtained from Guam Bureau of Statistics and Plans. Permission of the staff of GIS/LUP Section, Bureau of Statistics and Plans, Government of Guam

Reservoirs

N_Guam_Reservoirs: Point feature class of Northern Guam reservoirs. Projection is WGS 1984. File was clipped from reservoir shapefile. Original reservoir shapefile was created to aid the U.S. Army Corps of Engineers Water/Wastewater Technical Assistance Team locate and examine all GWA reservoirs after Super typhoon Pongsona hit Guam in December 2002.

Roads

N_Guam_Routes: Line feature class representing street routes. Projection is WGS 1984. Layer was derived from original layer streets_updated_bsp_2012 created by the Bureau of Statistics and; Plans (BSP) Land Use Planning/Coastal Management Program. The department of Public Works Office of Highway Planning assisted. The Mayors Council provided assistance by providing feedback of streets names in their village.

N_Guam_Streets_updated_bsp_2012: Street layer for Northern Guam. Projection is WGS 1984. Layer was derived from original layer streets_updated_bsp_2012 created by the Bureau of Statistics and; Plans (BSP) Land Use Planning/Coastal Management Program. The department of Public Works Office of Highway Planning assisted. The Mayors Council provided assistance by providing feedback of streets names in their village.

Shoreline

N_Guam_Shoreline: Shoreline boundary for Northern Guam. Clipped from original shapefile "shoreline". Projection is WGS 1984. Guam Coastal Atlas (<http://www.guammarinelab.com/coastal.atlas/htm/Data.htm>)

Sinkholes

N_Guam_Sinkholes: Line coverage for sinkholes in Northern Guam. Projection is WGS_1984_UTM_Zone_55N. Credits: Danko Taborosi, 2000.

Soils

N_Guam_SoilHydroGroups: The purpose of this data set is to show groups of soils having similar runoff potential under similar storm and cover conditions for Northern Guam. Projection is WGS 1984. Original shapefile from Soil_HydroGroups. Credits William Lettis and Associates; NRCS.

N_Guam_SoilMapUnits: This data set represents the soil map units for Northern Guam. Clipped from original shapefile "Soil_MapUnits" for the entire Territory of Guam, as defined by the Natural Resources Conservation Service (NRCS). Credits William Lettis and Associates; NRCS.

N_Guam_SoilSurfaceTexture: This data set represents the soil for Northern Guam classified based on texture, as defined by the Natural Resources Conservation Service (NRCS). Original shapefile Soil_SurfaceTexture. Projections is WGS 1984. Credits William Lettis and Associates; NRCS.

Species

N_Guam_Benthic_Habitat_Data: This data set was developed for the Guam Coastal Atlas Project and is intended to serve as the primary source of benthic habitat information for the island of Guam. Shapefile clipped to outline of Northern Guam. Original shapefile "Guam_Coastal_Atlas_Benthic_Habitat_Data". Credits: David R. Burdick, 2004-2007 NOAA Pacific Islands Assistant for Guam.

N_Guam_HeritageLayer07_GuamSPP: Polygon shapefile made in 2007 to identify locations of federally and locally listed species and species of concern in Northern Guam. Does not include Pteropus information. Projection is WGS 1984. Clipped from original shapefile "MarianalIslands_HeritageLayer07_GuamSPP_minusPteropus". Credits U.S. Fish and Wildlife Service's Pacific Islands Fish and Wildlife Office.

Vegetation

N_Guam_Veg: Polygon feature representing vegetation coverage for Northern Guam. Clipped from original shapefile "guamveg0622". Projection is WGS 1984. Credit USDA Forest Service Region 5 State and Private Forestry, Forest Health Protection.

Villages

N_Guam_Municipality_Area: Polygon feature representing the extent of municipal areas for Northern Guam. Clipped from original shapefile municipal_boundary_gcs84_Pr_utm. Projection is WGS 1984. Credit Bureau of Statistics and Plans (BSP).

N_Guam_Villages: Polygon feature representing the villages in Northern Guam. Projections is WGS 1984. Credit Bureau of Statistics and Plans (BSP).

Zones

N_Guam_Zones: Shapefile of Land Use zones for Northern Guam. Clipped from original shapefile from "ZoneMap_Update". Projection is WGS 1984. Created by the Bureau of Statistics and Plans (BSP) Land Use Planning/Coastal Management Program. Land Parcel Data was from the Department of Land Management. The Survey Division provided the data. NEXGEN Integrators, Inc. was contracted for this project. Note: Zone Map may be not up to date but it is currently the best available.

Raster Datasets

N_Guam_dem_1m_LIDAR: raster dataset depicting elevation information for Northern Guam. Cell resolution is 1 m by 1 m. Extracted by mask to Northern Guam from "dem_1m". Credits: Maria Kottermair, Research Assistant, Water and Environmental Research Institute, University of Guam, U.S.A. Original TIN by Benton Ching, P.E., U.S. Army Corps of Engineers, Honolulu District, Technical Integration Group.

N_Guam_LandCover_2005_NOAACCAP: raster dataset providing different land cover information for Northern Guam. Land cover data for 2005. Cell resolution is 2.4 m by 2.4 m. Extracted by mask to Northern Guam from "c-cap_noaa_guam_landcover_contractorfinal_24june09Copy.img". Credits: NOAA's Ocean Service, Coastal Services Center (CSC).

N_Guam_LandCoverwith_2011_NOAACCAP: raster dataset providing different land cover information for Northern Guam. Land cover data for 2011. Cell resolution is 2.4 m 2.4 m. Extracted by mask to Northern Guam Polygon from "guam_2011_ccap_hr_land_cover.img". Credits: NOAA's Ocean Service, Coastal Services Center (CSC)

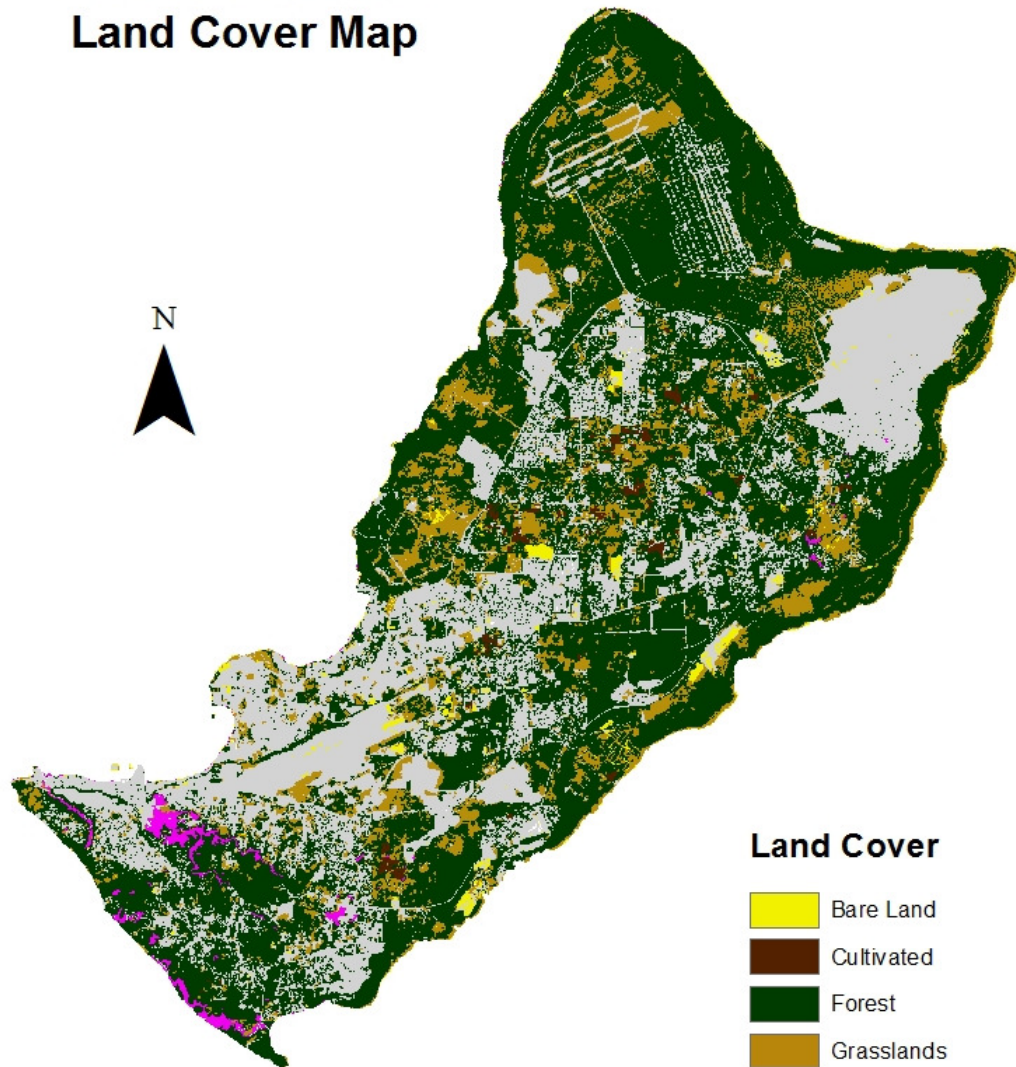
N_Guam_ppt_1971_2000_PRISM: raster dataset contains spatially gridded average monthly and annual precipitation for the climatological period 1971-2000 for Northern Guam. Cell resolution is 92.06 m by 92.06 m. Extracted by mask to Northern Guam from"". Credits: Chris Daly and Mike Halbleib of the PRISM Group at Oregon State University.

N_Guam_Vegetation_2005: raster dataset providing a detailed vegetation map for Northern Guam. Cell resolution is 4 m by 4 m. Extracted by mask to Northern Guam from "guamveg0622.img". Credits: USDA Forest Service Region 5 State and Private Forestry, Forest Health Protection

Appendix B

Reclassified Land Cover Maps for Northern Guam

2005 Reclassified Land Cover Map



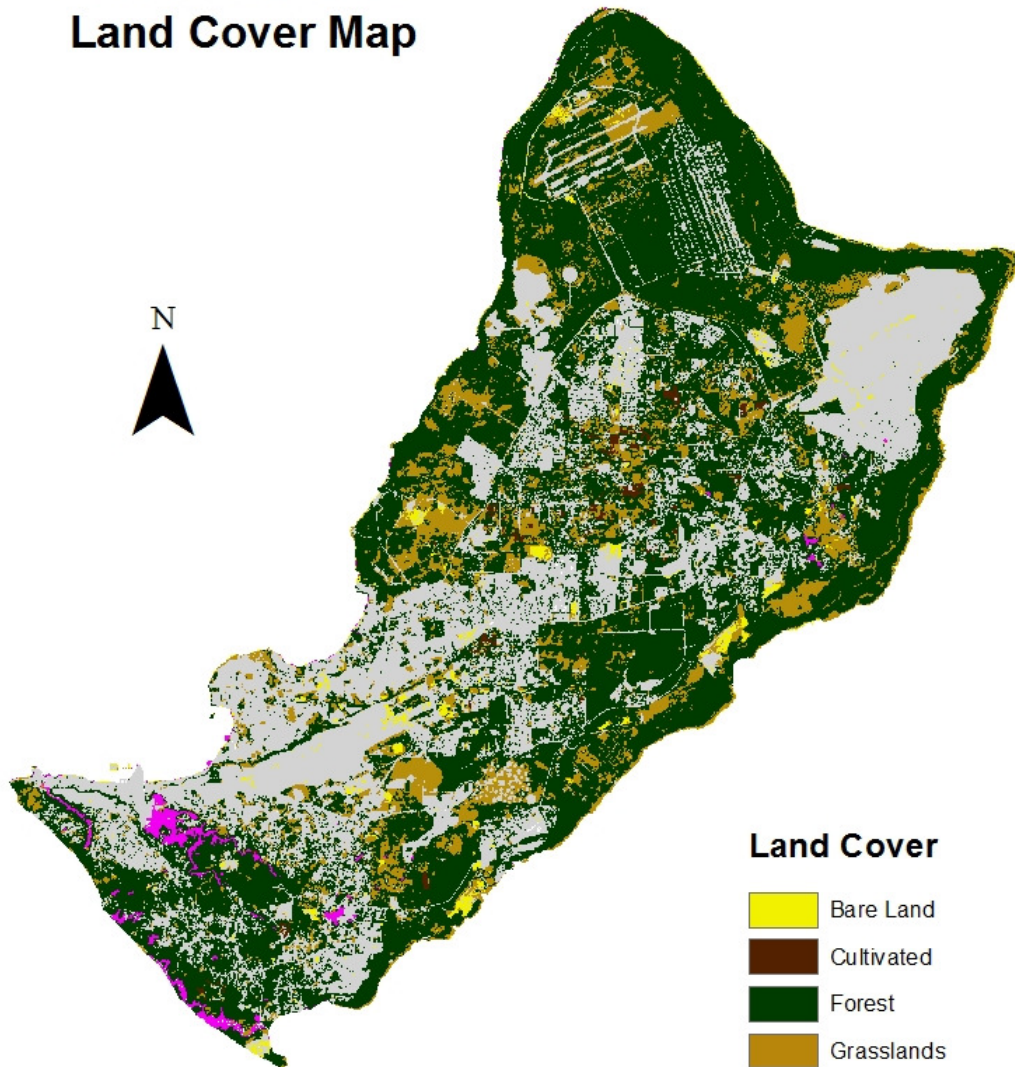
Land Cover

- Bare Land
- Cultivated
- Forest
- Grasslands
- Urban/ Built-Up
- Wetland

Land Cover data from NOAA C-CAP
obtained from <http://csc.noaa.gov/ccapftp/>.

0 1.5 3 6 Km

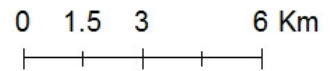
2011 Reclassified Land Cover Map



Land Cover

- Bare Land
- Cultivated
- Forest
- Grasslands
- Urban/ Built-Up
- Wetland

Land Cover data from NOAA C-CAP
obtained from <http://csc.noaa.gov/ccapftp/>.



Appendix C

Viewing the Northern Guam Geodatabase in ArcCatalog

Viewing the Northern Guam Geodatabase in ArcMap with Proposed
Development

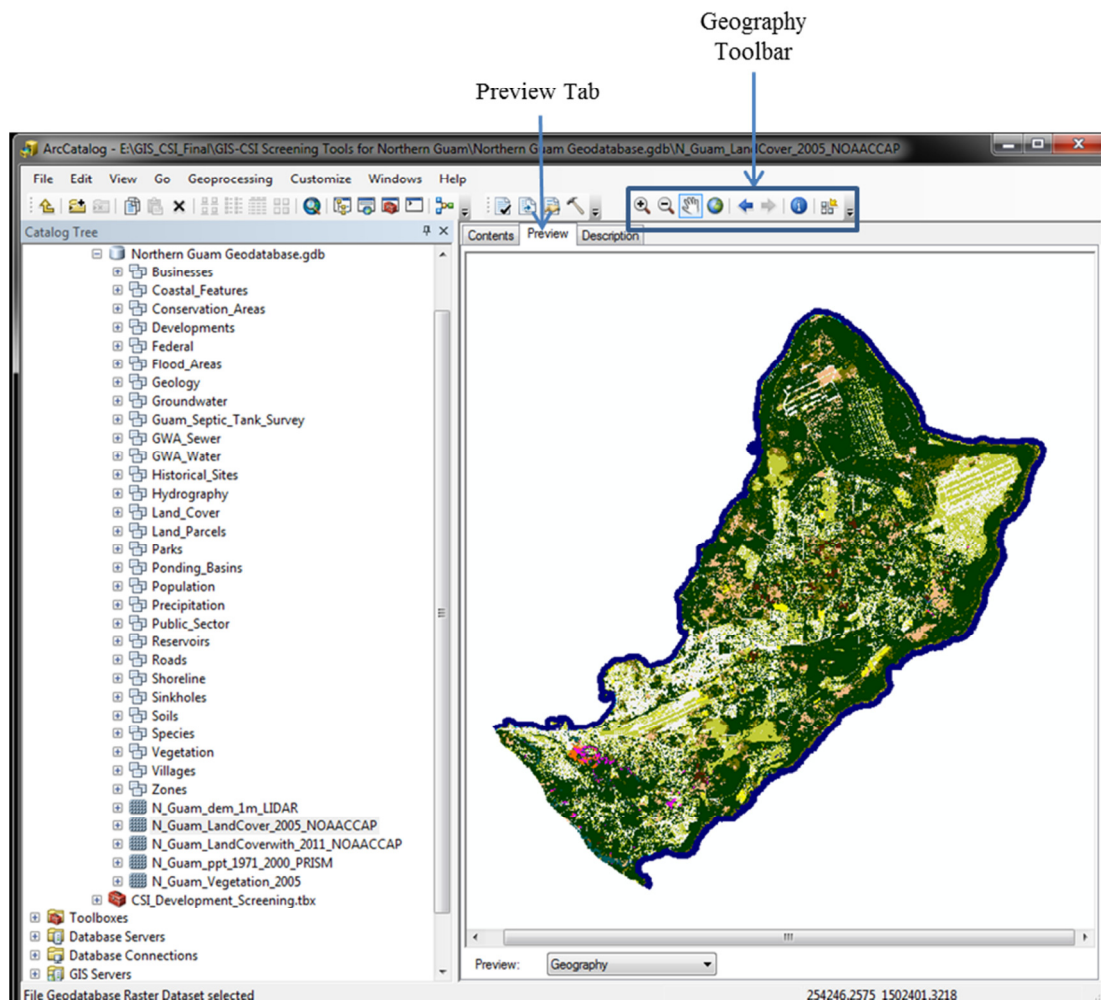
Viewing the Northern Guam Geodatabase in ArcCatalog

ArcCatalog is an application that provides a catalog window to view and manage geographical data that is stored on folders or related geodatabases. This document provides steps in viewing the contents of the Northern Guam Geodatabase. It is assumed that the user has knowledge about working with ArcGIS.

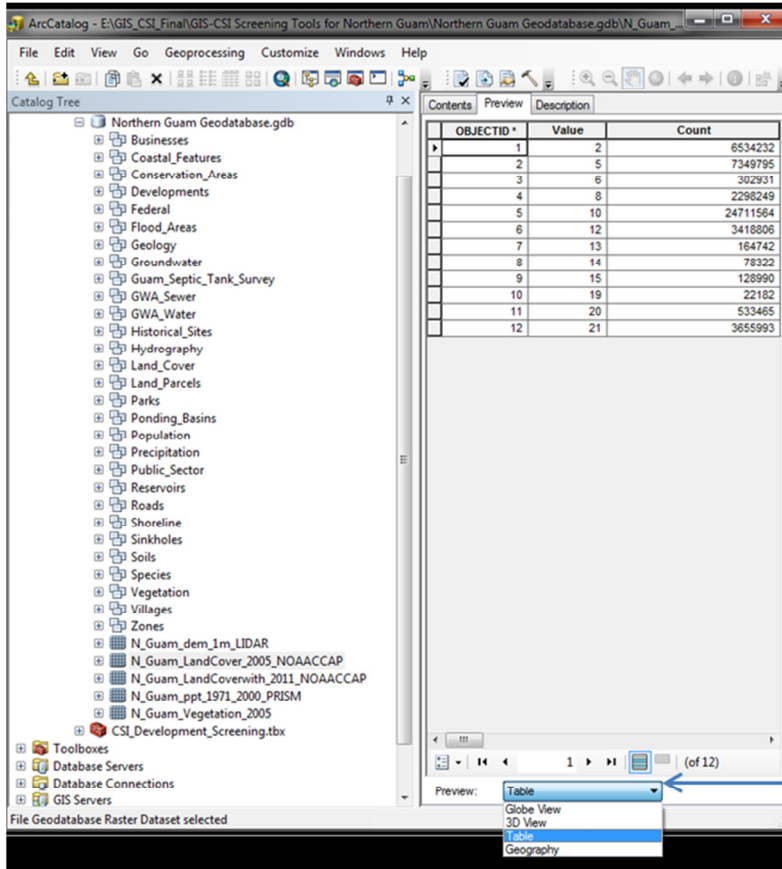
1. Open ArcCatalog
2. Connect to folder GIS_CSI_Final
3. When the folder is listed in the catalog tree, navigate to the Northern Guam Geodatabase and click the plus sign (“+”). Contents of the geodatabase are now displayed.



4. You can choose a feature class in a feature dataset or a raster dataset to preview its content. Select a feature class or a raster dataset by clicking the preview tab on top of the catalog display. The geography toolbar can be added to zoom in, zoom out, pan the image, view full extent of the image, identify features of the layers, or create a thumbnail image for the selected item.

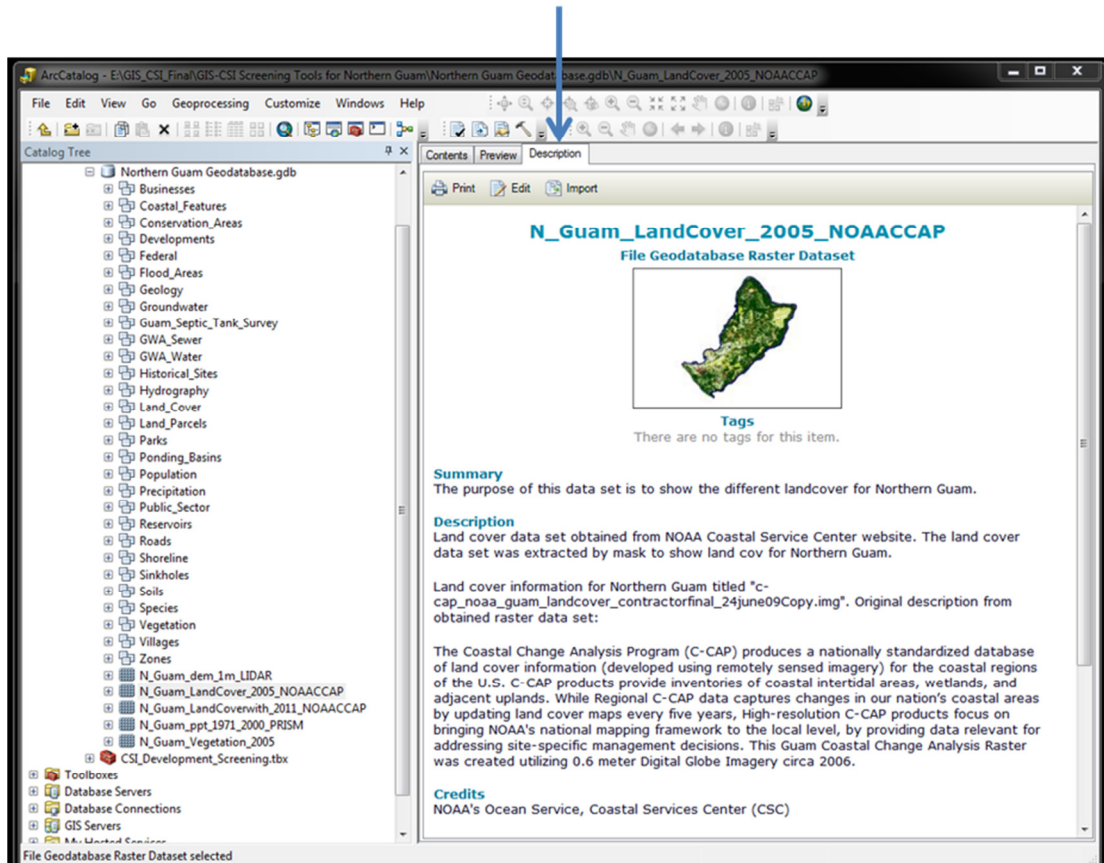


5. Aside from previewing the geography of the layer, the user can also view its associated attribute table by clicking the preview drop-down list on the bottom of the catalog display (figure).



6. Metadata is information about the GIS layer. General information about the GIS layer can be viewed or edited on the Description Tab.


Description Tab

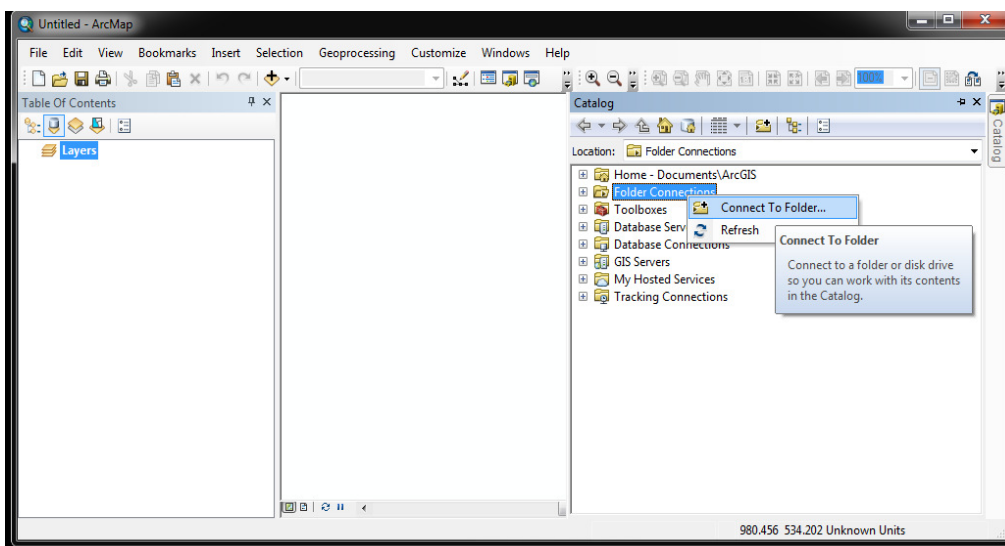


Viewing Northern Guam Geodatabase with Proposed Developments on ArcMap

ArcMap is an application that allows the users to display, query, create and edit GIS datasets for a study area. It also allows users to create map layouts.

This document describes steps in viewing the Northern Guam Geodatabase with proposed developments on Arc Map and assumes that the user has knowledge of working with ArcGIS.

1. Open a blank ArcMap document.
2. To view the full extent of the Northern Guam geodatabase dock the catalog window on ArcMap and connect to GIS_CSI_Final folder . If the catalog window is not displayed you can open it by **Catalog** button  on the **Standard** toolbar or by clicking **Windows > Catalog** on the main menu.



3. View the outline of Northern Guam, by clicking the N_Guam_Shoreline feature class from the catalog tree and drag it anywhere in the ArcMap display.

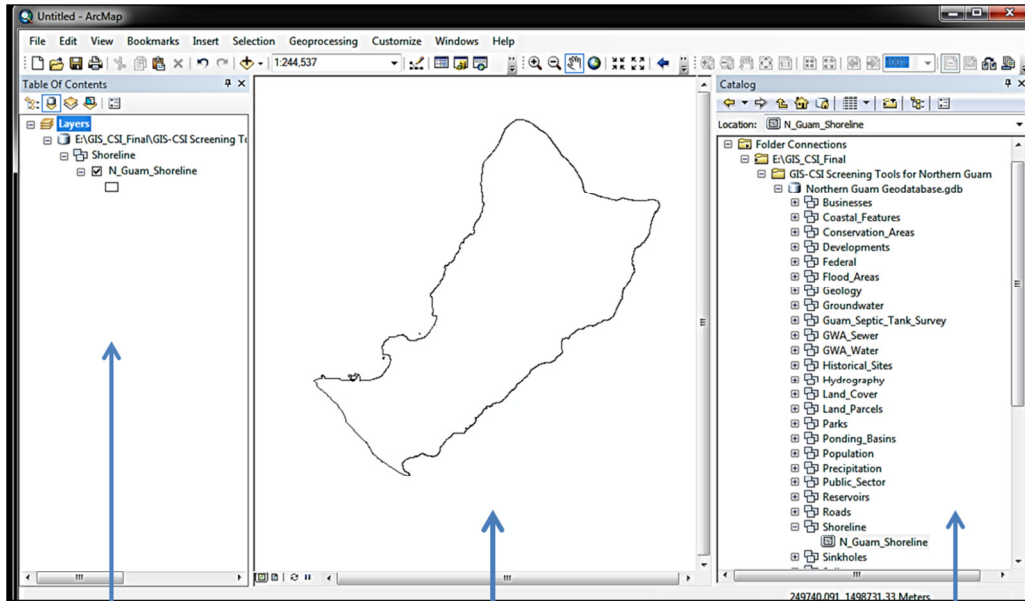
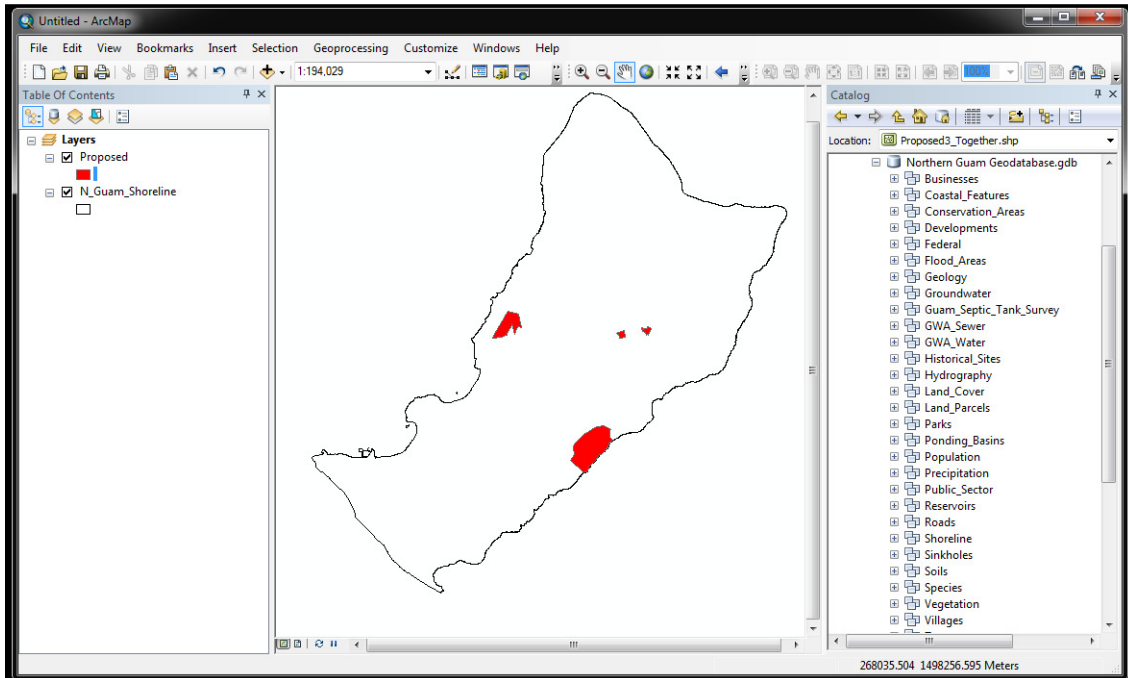


Table of Contents
Window

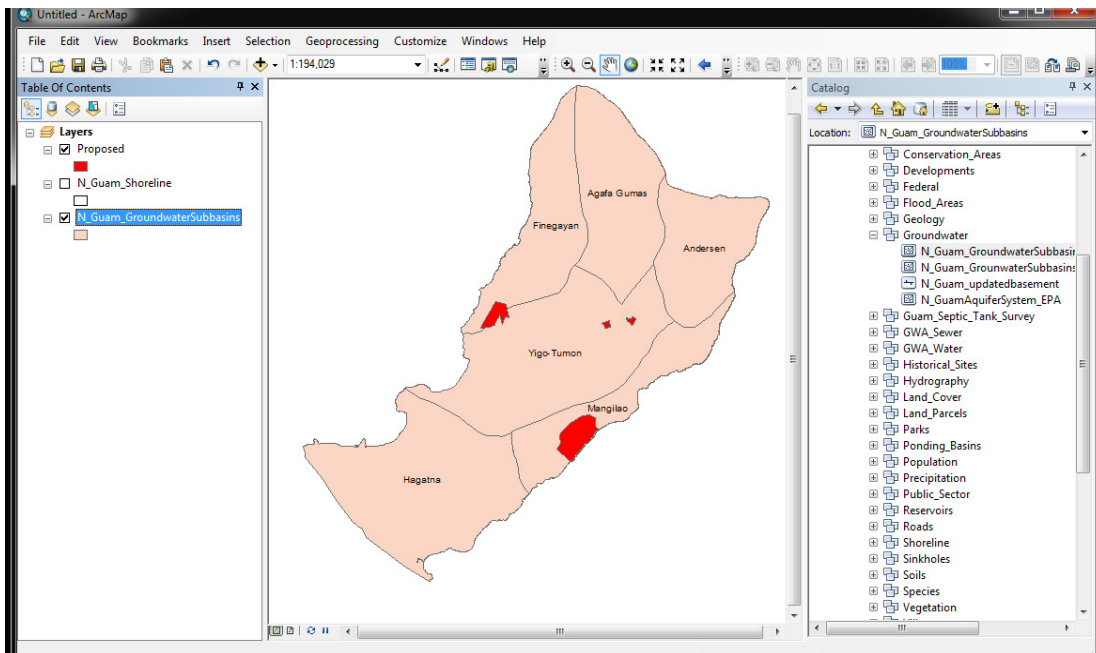
Arc Map Display

Catalog Window

4. Add the desired proposed development (s) layer to Arc Map. (Proposed development layer has been added for example)



5. The geodatabase viewed in ArcMap can be used as a qualitative tool as multiple developments can be screened by its location in relation to groundwater basins, production wells, sewer lines, septic systems, or any other input found in the geodatabase. Inputs from the geodatabase can be viewed by simply clicking and dragging any layer from the geodatabase to the ArcMap Display. (Location of the developments in relation to where they are located in the groundwater basin zones shown below).



Notes:

- Layers can be turned on or off by clicking on the check box located next to each layer name in the ArcMap table of contents.
- Layers can be arranged in the table of contents.
- The attribute table can be viewed by right-clicking the layer name, and then selecting "attribute table" from context menu list.
- Users can conduct spatial analysis using inputs from the geodatabase
- Users can export a map of layers viewed.

Appendix D

Affected Areas Tool:


(i) Vegetation (p. 62)

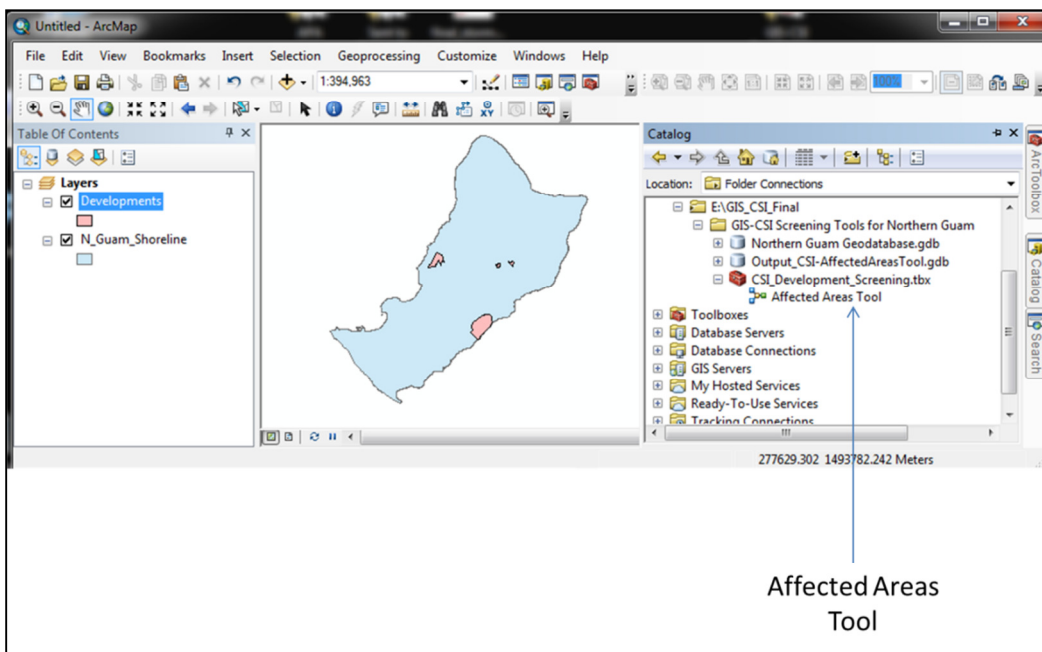
(ii) Wells within 1000 feet (p. 68)

The Affected Areas Tool - (i) Vegetation

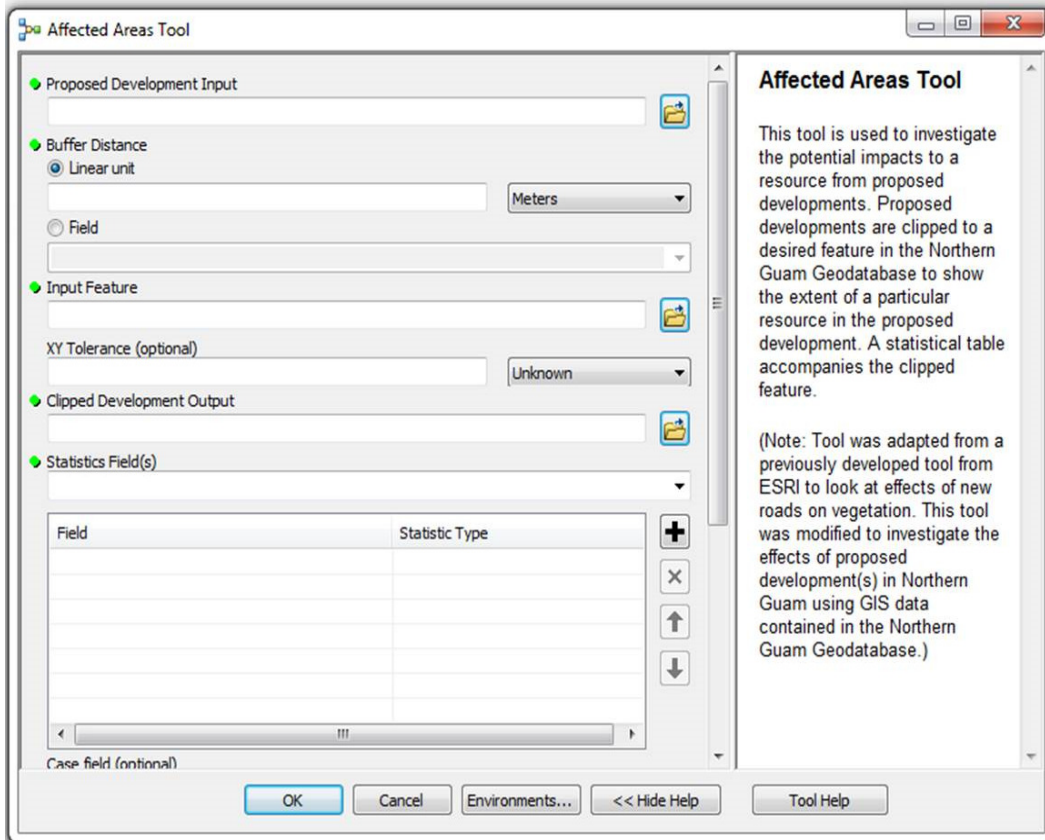
This document describes running the Affected Areas Tool to identify potentially affected vegetation types. A proposed development layer has been added for example purposes. Affected Areas Tool dialog box has a tool help which can guide the user with each of the tool parameters. It is assumed that the user has knowledge on working with ArcGIS.

Running Affected Areas Tool:

1. Open Arc Map
2. Add a proposed development layer (Add N_Guam_Shoreline from Northern Guam Geodatabase>Shoreline) if desired.
3. If not displayed, dock the catalog window on ArcMap and connect to GIS_CSI_Final folder. The  Affected Areas Tool is located in the CSI_Developments_Screening.tbx.



4. Double click the  Affected Areas Tool to open its dialog box.

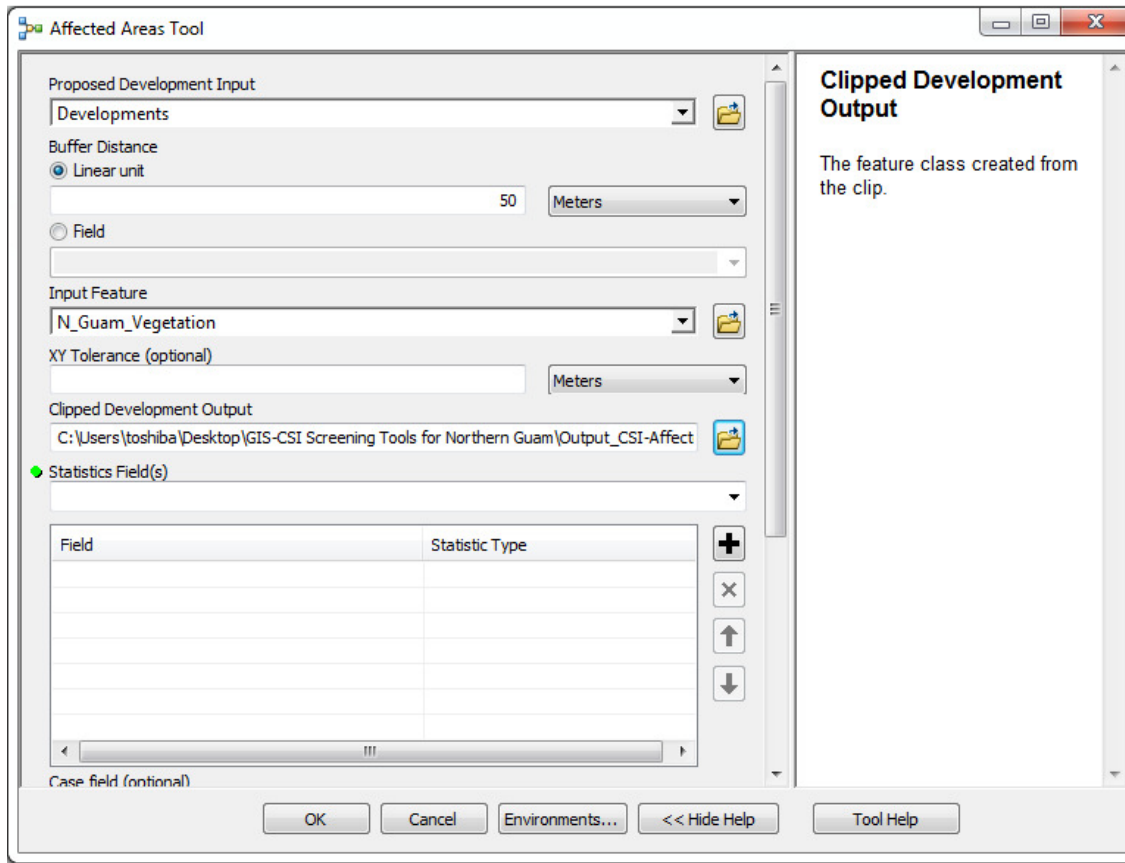


5. Click the drop-down arrow in the Proposed Development Input and select Developments.

6. Under Linear Unit in the Buffer Distance assign a buffer value (50-m added in this example).

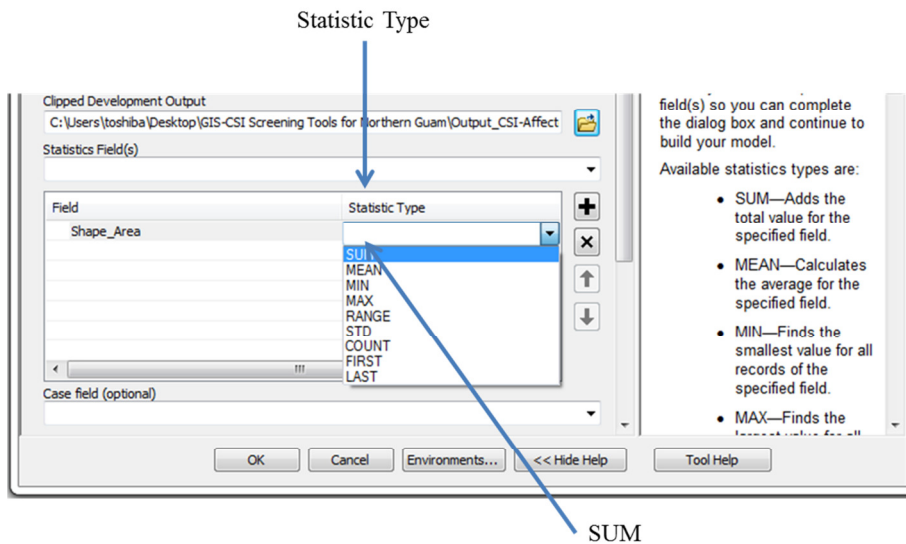
7. The input feature is the feature class used to clip the proposed development input. This is the resource potentially affected by the development. Input feature can be found in the Northern Guam Geodatabase. Navigate to the Northern Guam Geodatabase > Vegetation > N_Guam_Vegetation

8. For Clipped Development Output navigate to *GIS_CSI_Final\GIS-CSI Screening Tools for Northern Guam\Output_CSI-AffectedAreasTool.gdb* folder and give the output of the clip a proper name.



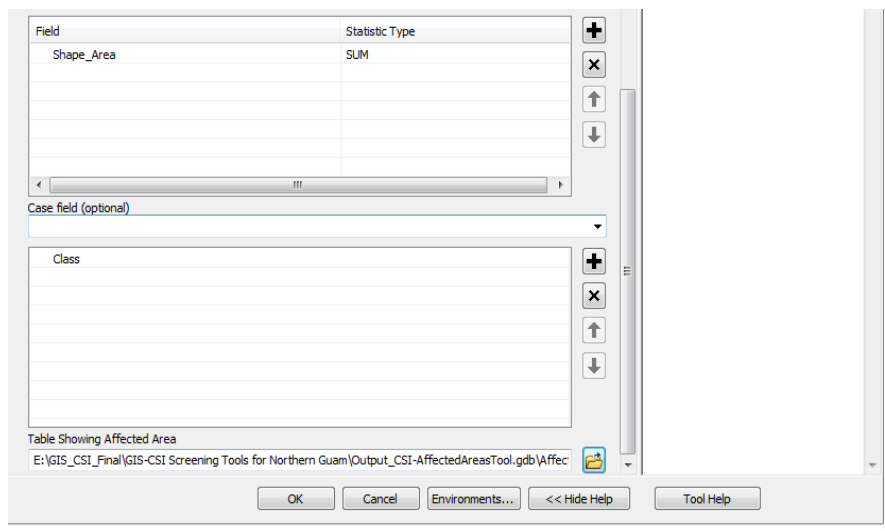
9. For the Statistics Field(s), this is the numeric field containing attribute values used to calculate the specified statistic. To look at the possible affected vegetation in Northern Guam choose Shape_Area in the Drop-Down list.

10. You will see an Error sign after selecting Shape_Area. Under Statistic Type choose the column after Shape_Area and select SUM from the drop-down list.



11. In the Case Field parameter select Class in the Drop-Down list.

12. For the Table Showing Affected Area parameter browse to the GIS_CSI_Final\GIS-CSI Screening Tools for Northern Guam\Output_CSI-AffectedAreasTool.gdb\ folder and save the table. (Note: output of the table has to be saved to a geodatabase).

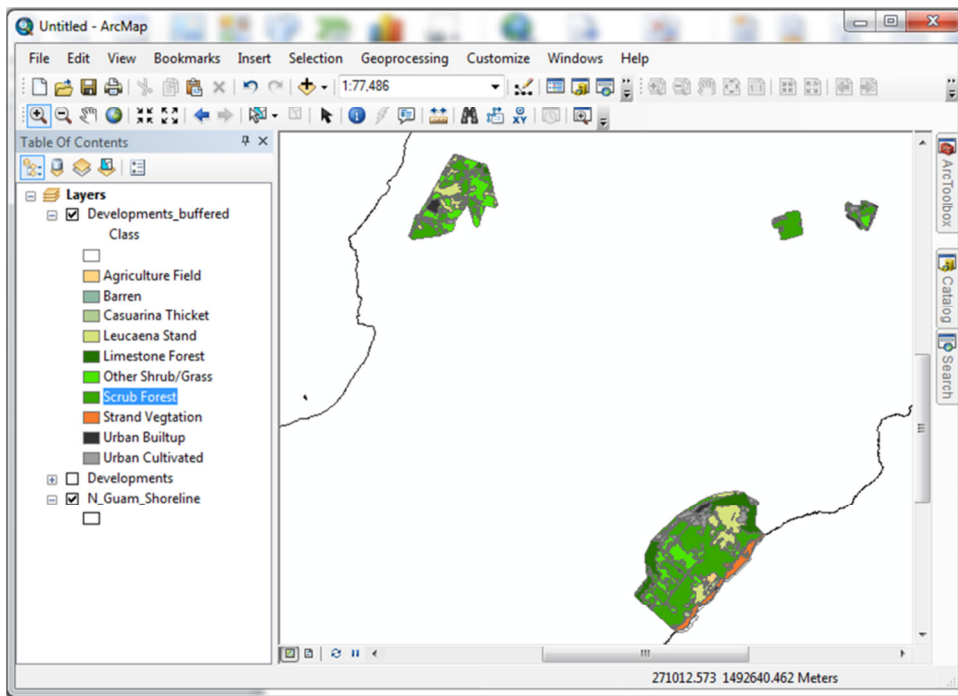



13. Press OK to run the tool.

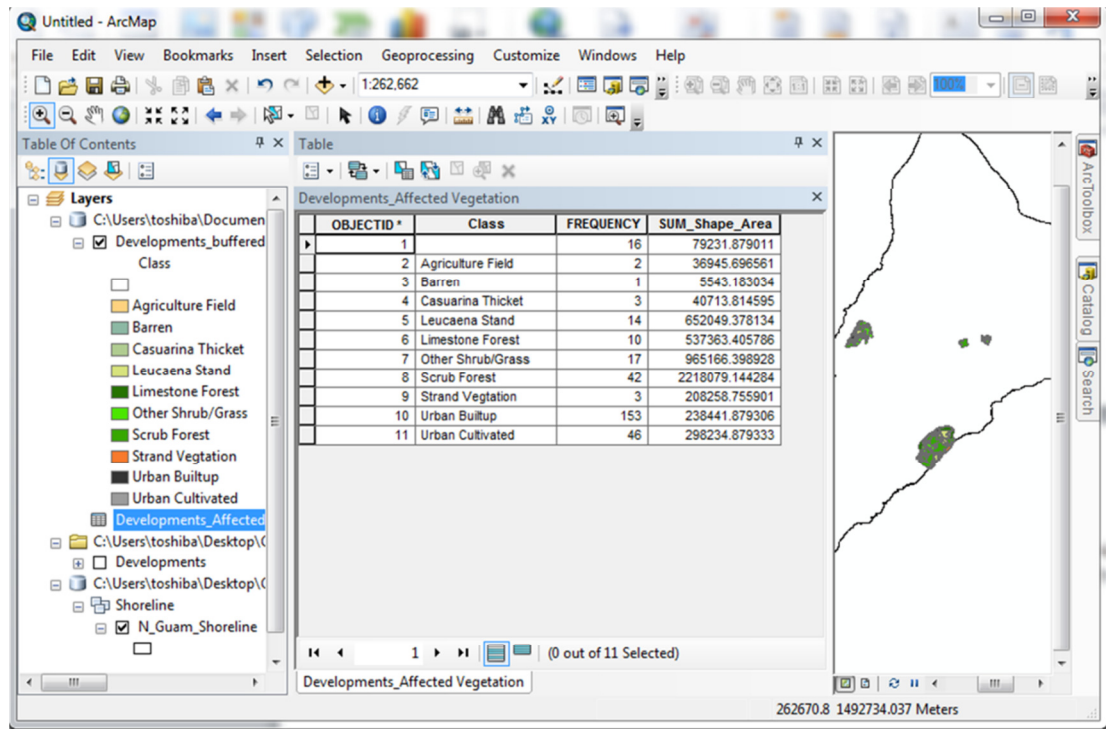
Outputs of Affected Areas Tool

After running the model, the outputs of the Affected Areas Tool is a polygon showing the buffer of the proposed developments, and a table outlining the sum of the vegetation potentially affected.

14. To symbolize the “Development_Buffered” right click Properties>Layer Properties>Symbology. Choose Unique Values in Categories and Value Field > Class.



15. To view the summary table, click List By Source  in the table of contents, and right click Development_AffectedVegetation > open (Your table may be named differently depending on what you named it in #10).





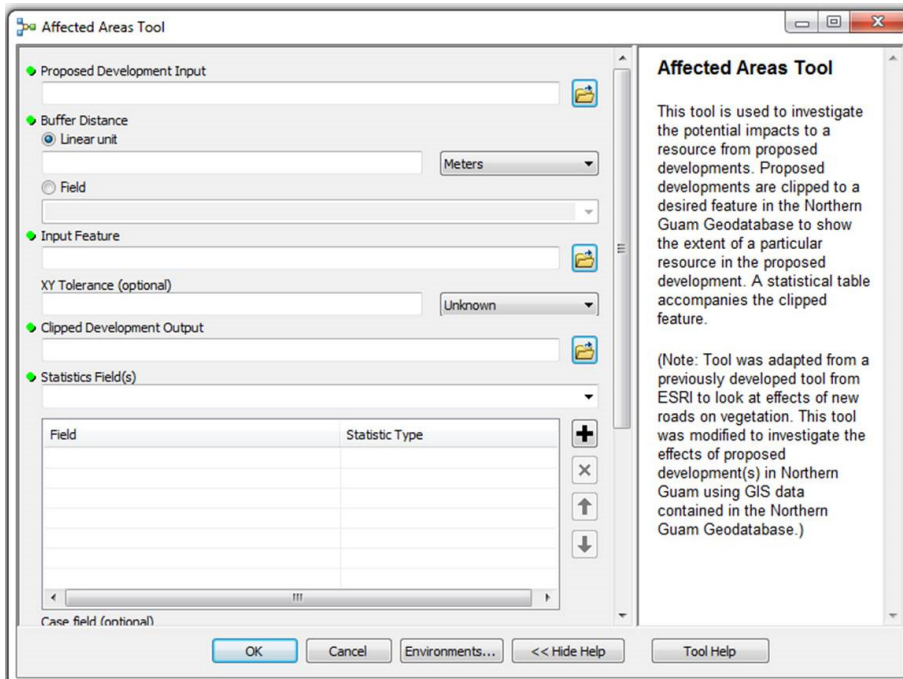
The Affected Areas Tool - (ii) Wells within 1000 feet

In 2003, GEPA adopted the Guam Wellhead Protection (WHP) Program Under the WHP, a protection zone was established for public drinking water wells. The protection zone is a radius of 1000 feet where no septic systems/leaching fields should be established. (Caution: Permission required from GWA to use files.)

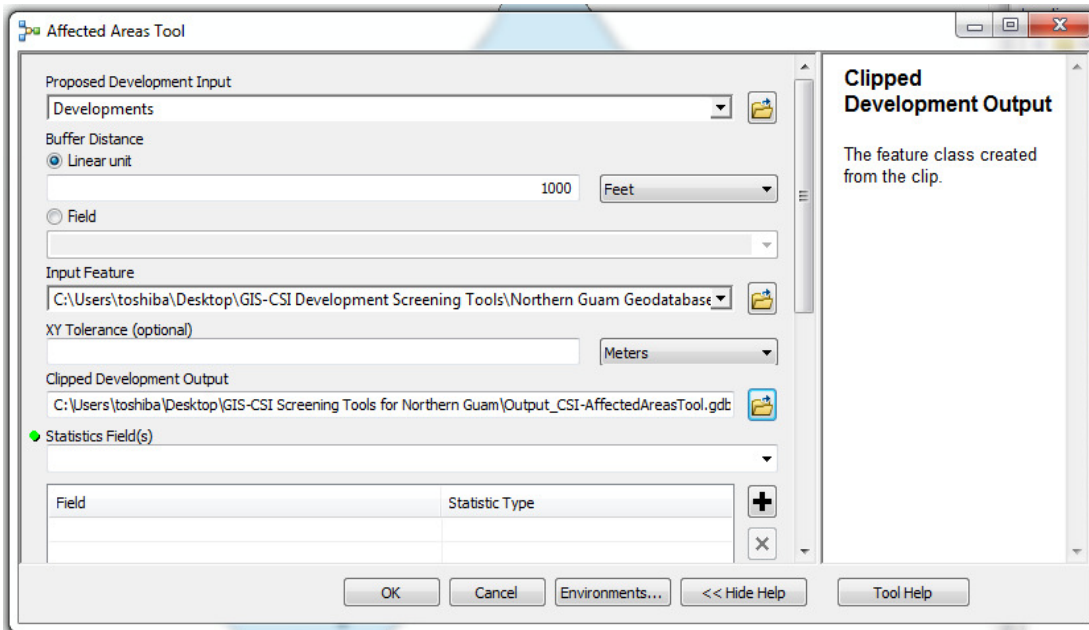
This document describes running the Affected Areas Tool with respect to developments within 1000 feet of drinking water wells, a proposed developments layer has been added for example purposes. The Affected Areas Tool dialog box has a help tool which can guide the user with each of the tool parameters. It is assumed that the user has knowledge of working with ArcGIS.

Running Affected Areas Tool:

1. Open Arc Map
2. Add a proposed development layer (Add N_Guam_Shoreline from Northern Guam Geodatabase>Shoreline) if desired.
3. If not displayed, dock the catalog window on ArcMap and connect to GIS_CSI_Final folder. The  Affected Areas Tool is located in the CSI_Developments_Screening.tbx.
4. Double-click the  Affected Areas Tool to open its dialog box



5. Click the drop-down arrow in the Proposed Development Input and select Developments.
6. Under Linear Unit in the Buffer Distance assign a buffer value. For this example a buffer of 1000 feet is specified.
7. The input feature is the feature class used to clip the proposed development input. This is the resource potentially affected by the development. The input feature can be found in the Northern Guam Geodatabase. Navigate to the Northern Guam Geodatabase > GWA_Water > N_Guam_ProductionWells.
8. For Clipped Development Output navigate to *GIS_CSI_Final\GIS-CSI Screening Tools for Northern Guam\Output_CSI-AffectedAreasTool.gdb* folder and give the output of the clip a proper name.

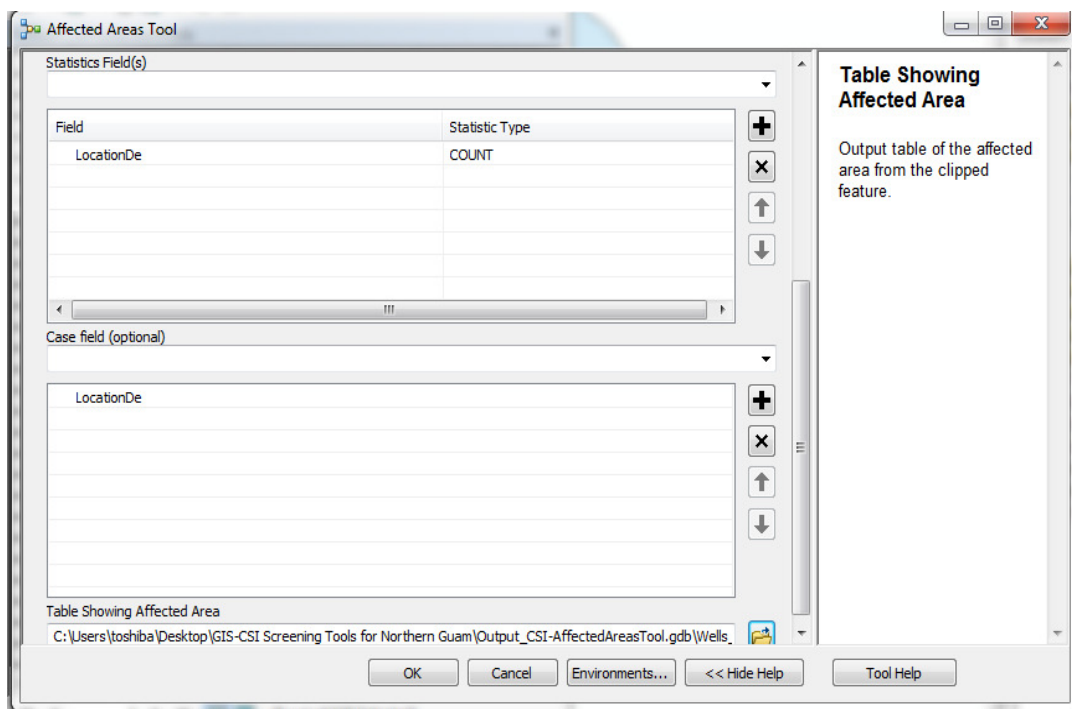


9. The Statistics Field (s), is the numeric field containing attribute values used to calculate the specified statistic. To look at wells within 1000 feet of the developments choose "Location_De". "Location_De", describes the location of the well however it **does not** show coordinates.

10. You will see an Error sign after selecting "Location_De". Point feature class statistics are limited to statistic types MIN, MAX, COUNT, FIRST, and LAST. Under Statistic Type choose the column after "Location_De" and select Count from the drop-down list.

11. In the case Field Parameter select "Location_De" in the Drop-Down list.

12. For the Table Showing Affected Area parameter browse to the to the: GIS_CSI_Final\GIS-CSI Screening Tools for Northern Guam\Output_CSI-AffectedAreasTool.gdb\ folder and save the table. (Note: output of the table has to be saved to a geodatabase).

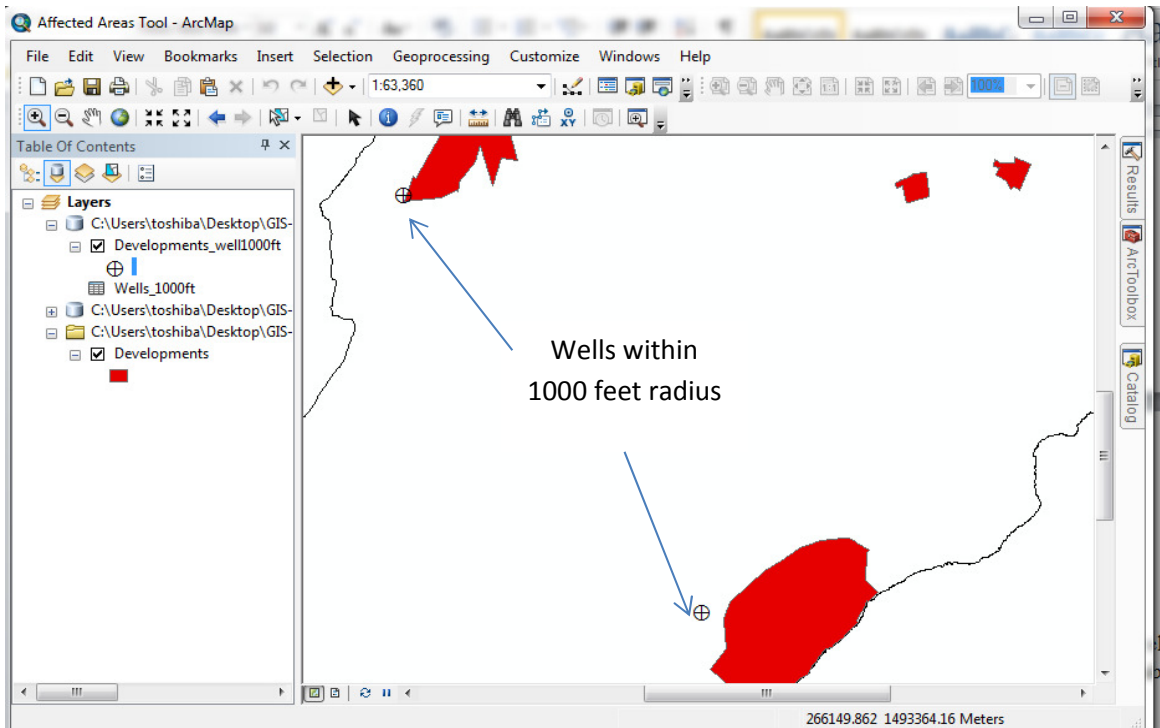



13. Press OK to run the tool.

Outputs of Affected Areas Tool

After running the tool the outputs of the Affected Areas Tool is a point feature class showing the wells within a 1000-foot radius of the developments, with an output table showing the count of the wells found.

14. Outputs of the tool indicate that only two wells are present within 1000 feet of the developments.



15. To view the summary table, click List By Source  in the table of contents, and right click Wells_1000ft > open (your table may be named differently depending on what you named it in #10).

