

Report as of FY2008 for 2006VI67B: "Impervious Surface Analysis of Terrestrial Watersheds of the U.S. Virgin Islands with Application to the East End Marine Park, St. Croix "

Publications

- Water Resources Research Institute Reports:
 - ◆ Rennis, Denise, Colin Finney, Henry Smith, 2008, Impervious Surface Analysis of Terrestrial Watersheds of the U. S. Virgin Islands, Virgin Islands Water Resources Research Institute, University of the Virgin Islands, St. Thomas, U. S. Virgin Islands, 55 pages.

Report Follows

PROBLEM AND RESEARCH OBJECTIVES

One of the principal effects of development and urbanization is the conversion of pervious surfaces into impervious surfaces—anthropogenic surfaces that inhibit the infiltration of water into the soil. In the US Virgin Islands (USVI), housing, roads, and commercial and industrial development are increasingly replacing natural terrestrial environments, such as grasslands and forests. Research over the past two decades has indicated that increased quantities of impervious surfaces are closely associated with environmental degradation (Schueler, 1994; Arnold and Gibbons, 1996), specifically that the quantity of impervious surfaces in a watershed is inversely correlated with the health of that watershed and the health of waterbodies, such as coastal environments, that receive discharges from that watershed (Center for Watershed Protection, 2003).

Land-use regulations have placed some controls over development activities and these help to limit the impacts from impervious surfaces; however, the effectiveness of these controls can only be evaluated by long-term monitoring of the environmental impacts, both site-specific and cumulative, of land-use decisions, and this rarely occurs. Field monitoring sites are often difficult to reach, the weather may be too inclement, and field sampling is expensive both in terms of budget and staff resources. Using imperviousness as an environmental indicator for watershed health has been gaining popularity over the last decade. Imperviousness is measurable and the data can easily be presented in geographical information systems (GIS).

The goal of this study was to develop a remote sensing/geographical information system-based methodology that classifies impervious cover to a much finer level than currently exists so that impervious surfaces can be monitored as an index of watershed health. The Coral Bay watershed on St. John, USVI, where nonpoint source pollution from incompatible upland development has been identified as a major threat, was used as a case study. The major thrust of this study was focused on the GIS-based methodology for discriminating, mapping, and quantifying terrestrial impervious surfaces at a watershed and subwatershed scale, using remote sensing imagery.

METHODOLOGY

The methodology involved the following steps:

- 1) Selection and analysis of the remote sensing component;
- 2) Establishing classification categories;
- 3) Image analysis and processing;
- 4) Impervious surface class cover validation;
- 5) Calculation of impervious surface cover;
- 6) Application of infiltration coefficients and threshold values;
- 7) Evaluation of change over an 11-year period;

- 8) Assessment of the application of the methodology to other watersheds.

PRINCIPAL ACCOMPLISHMENTS AND SIGNIFICANCE

We developed a remote sensing/GIS-based methodology that enables land managers and regulators in the USVI to monitor and quantify impervious surface cover on a subwatershed, watershed, or island basis. Our use of multispectral IKONOS imagery [courtesy of the National Oceanic and Atmospheric Administration (NOAA)] allows large land areas to be covered by one or two high-resolution scenes; this is not possible with aerial photographs. Another advantage of using satellite imagery is the increased frequency that images become available and obtainable, allowing assessments over a shorter time period than the 5- or 10-year periods that have been typical for monitoring changes in vegetation cover. As growth (i.e. impervious surface cover) tends to come in spurts, the ability to monitor more frequently is a necessity.

The land-cover classes identified in this study are consistent with the land-cover classes of NOAA's Coastal Change Analysis Program (C-CAP) initiative (NOAA, 1995). Using our methodology land managers in the USVI would be able to compare changes in impervious surface cover with land-cover changes reported by NOAA for other regions over the nation where such information exists. To date, no C-CAP investigation has been undertaken for the USVI.

Our methodology was applied to the Coral Bay watershed, St. John, where we categorized impervious surfaces into five classes based on false-color processing and selected five subsets (one on the east coast, one on the south coast, one in the northern uplands, and two around the town of Coral Bay) for more detailed analysis (Fig. 1). We showed that impervious surface cover across the watershed appears to be below a threshold that warrants concern, but specific areas of the watershed, particularly around the town of Coral Bay and in at least one area of the south coast, are experiencing growth that should be more closely examined (Table 1). Early detection of environmental problems will help to limit or prevent environmental degradation and help protect biological diversity.

Figure 1. Processing of the IKONOS image resulted in five false-color classes of impervious surfaces in the Coral Bay, St. John, watershed. Also shown are enlargements of the five selected areas for detailed analysis (includes material © Space Imaging LLC, all rights reserved).

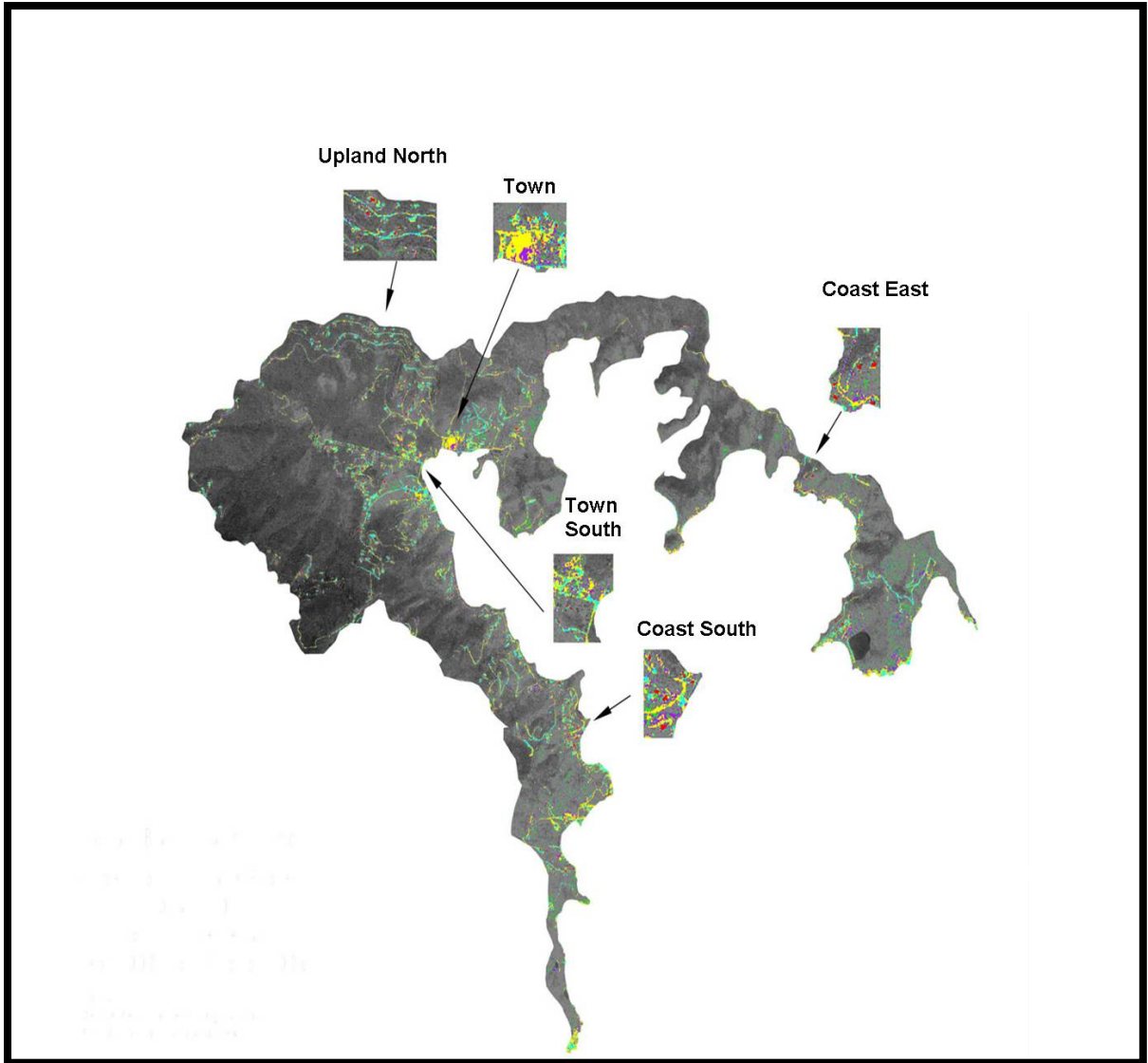


Table 1. Percentage of impervious surface cover in each of the five classes for the Coral Bay watershed and subsets, incorporating an infiltration coefficient.

Class	Watershed	Coast E	Coast S	Upland N	Town	Town S
Total Area (ha)	18,851.50	89.59	65.27	203.12	111.66	138.33
Class 1	0.21	1.29	1.68	0.69	0.67	0.29
Class 2	2.23	5.2	10.88	2.93	18.43	8.86
Class 3	1.42	2.3	4.25	3.78	5.13	4.42
Class 4	1.25	3.16	6.12	1.18	5.56	2.95
Class 5	0.5	1.06	1.66	0.41	0.98	0.87
Total (%)	5.61	13.01	24.59	8.99	30.77	17.39

Despite considerable effort, discrimination between different types of impervious surfaces (e.g., older versus newer concrete roads, concrete versus asphalt, man-made surfaces versus natural rock outcrops) based on their spectral signatures was not accomplished. To some extent this was due to topographic slope and angle of the sun during image capture, both of which affect surface reflectivity. Greater resolution should be possible with a satellite system that uses a larger number of bands than the IKONOS system (which uses five). Impervious surfaces in the Coral Bay watershed include both anthropogenic surfaces as well as natural ones, and we consider the ability to quantify the natural imperviousness of land as essential in order to better evaluate the effects of anthropogenic changes. Further work on refining the spectral signatures will be necessary to achieve this.

By performing an analysis of change in impervious surface cover over the last 11 years (Table 2), we demonstrated that at least one different technique for calculating change can be compatible with our described methodology.

Table 2. Percent change in impervious surface cover in the Coral Bay watershed over an 11-year period.

Subset	Percent Impervious Surfaces		
	1994	2005	% Change
Coast East	10.35	13.01	2.66
Coast South	7.17	24.59	17.41
Upland North	8.61	8.99	0.38
Town	15.43	30.77	15.33
Town South	4.20	17.39	13.20

Ideally similar techniques should be used in comparison studies to limit design differences that might affect results; however, until the use of spectral signatures from satellite imagery is more widely used, existing baseline data are likely to be in a form that is not satellite based.

The methodology we describe in this study can easily be applied to other watersheds and other islands. The watershed of the St. Croix East End Marine Park (SXEEMP), in particular, would benefit from extensive monitoring of impervious surfaces to ensure economic growth in the watershed does not lead to water quality degradation and loss of biodiversity in the marine park.

References Mentioned in this Summary

Arnold, Jr. C.L. and C.J. Gibbons, 1996, Impervious surface coverage. The emergence of a key environmental indicator, *Journal of the American Planning Association*, 62(2), 243-258.

Center for Watershed Protection, 2003, *Impacts of Impervious Cover on Aquatic Systems*, 150 pp., Ellicott City, MD.

National Oceanic and Atmospheric Administration (NOAA), 1995, NOAA Coastal Change Analysis Program (C-CAP): Guidance for Regional Implementation, NOAA Technical Report NMFS, 123, 92 pp.

Schueler, R.R., 1994, The importance of imperviousness, *Watershed Protection Techniques*, 1, 3, 100-111.