UNIVERSITY OF CALIFORNIA
Santa Barbara

# Prototyping a Campus Sustainability Management System

A Group Project submitted in partial satisfaction of the requirements for the degree of

Master's in Environmental Science and Management for the Donald Bren School of Environmental Science and Management

by

Erin Claybaugh
Dawn Hock
Amy Jewel

Committee in charge:
James Frew
David Stoms

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Erin Claybaugh

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Amy Jewel

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Dawn Hock


The mission of the Donald Bren School of Environmental Science & Management is to produce professionals with unrivaled training in environmental science and management who will devote their unique skills to the diagnosis, assessment, mitigation, prevention, and remedy of the environmental problems of today and the future. A guiding principal of the School is that the analysis of environmental problems requires quantitative training in more than one discipline and an awareness of the physical, biological, social, political, and economic consequences that arise from scientific or technological decisions.

The Group Project is required of all students in the Master's of Environmental Science and Management (MESM) Program. It is a four-quarter activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Final Group Project Report is authored by MESM students and has been reviewed and approved by:

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James Frew

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Ernst von Weizsäcker

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David Stoms

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## Abstract

A growing number of cities and universities have created sustainability plans that include specific environmental, social, and economic performance goals. Sustainability metrics or indicators are often used to track progress towards these goals. However, compiling, monitoring, and reporting performance information for large organizations is highly complex. Therefore, sustainability reports often include aggregated data that is not specific enough to reveal spatial and temporal trends. In conjunction with the Sustainability Program at the University of California, Santa Barbara (UCSB), this project created a prototype of a campus-wide environmental sustainability management system (ESMS) to collect and store indicator data at designated spatial and temporal scales.

The ESMS includes a database that can be used with spreadsheet and Geographic Information System (GIS) software. To demonstrate the usefulness of the database, we populated the system with data relevant to three environmental indicators in the areas of energy, water, and solid waste/recycling. Our analysis of the indicator data helped identify buildings whose environmental performance could be improved.

The database is a straightforward, effective tool for storing and managing campus sustainability performance data, as well as generating sustainability reports. The system can also be used to better understand specific environmental performance of buildings on campus, which can help campus decision makers make educated decisions linked to sustainability goals.

# Executive Summary

***Introduction***

The concept of sustainability connects economic, social and environmental concerns to influence decisions that can improve the quality of life for all generations. In recent years, many cities and campuses (e.g., universities, corporate headquarters, research labs, military bases) have become proactive proponents of sustainability and have developed plans and goals to incorporate the concepts of sustainability into their operations, planning, and management practices. To track progress toward achieving sustainability goals, metrics and indicators are often employed.

The problem, however, lies in the complexity of compiling, monitoring, and reporting performance information for large organizations. Additionally, connecting individual behavior to overall campus performance provides another large challenge, especially considering few campus-wide actions, policies, or technological enhancements can improve sustainability performance. Therefore, indicators must be defined at spatial and temporal scales small enough to effectively reflect individual or department-level behavior, but general enough to apply to the entire campus.

The University of California, Santa Barbara (UCSB) recently created a Sustainability Program; the University is also developing a Campus Sustainability Plan (CSP) with 41 indicators tracking sustainability in nine sectors: Built Environment, Sustainable Energy and Water, Academic and Research, Communications, Grounds, Procurement, Food, Transportation, and Waste. The Sustainability Program will publish annual Sustainability Reports once the CSP is finalized.

Many of the indicators identified in the CSP are not currently monitored and tracked because they have only recently been identified by the authors of the CSP. Currently, only campus-wide, annual totals for sustainability performance indicators are posted on the UCSB Sustainability website. This reporting does not provide data for specific buildings or for smaller time intervals. The most sophisticated system currently used to track indicators is Itron, a centralized, web-based system that tracks energy and water usage for campus buildings. Although the Itron system has helped managers reduce campus energy use and associated costs through lowering peak demand and identifying problem spots, many buildings are not currently connected to the system. In addition, Itron is not used primarily for reporting purposes, but for managing energy usage.

### *Goals and Approach*

This paper presents the design, testing, and use of a prototype campus-based Environmental Sustainability Management System (ESMS): a data organization system that links the flow of energy and materials through campus using sustainability indicators at disaggregated spatial and temporal scales. The project's client and the ultimate user of the ESMS is the Sustainability Program at UCSB.

To design the ESMS, we:

- Investigated the campus monitoring needs and available data;
- Determined a relevant subset of indicators based on the Campus Sustainability Plan;
- Gathered and formatted relevant sustainability indicator data at disaggregated spatial and temporal scales;
- Organized the data in a Microsoft Access database and created Geographic Information System shapefiles to represent the UCSB campus;
- Tested the ESMS by analyzing 3 specific environmental indicators of the campus built environment.

### *Database Design*

The data gathering process revealed that sustainability performance information on campus is inconsistent, decentralized, and often incomplete. To begin the design of the database, campus data was gathered to create a GIS-based spatial representation of the campus. This data included both spatial and non-spatial campus information, with a focus on campus building information, such as building types, square footage, and space usage.

To demonstrate the usefulness of the ESMS, we chose a subset of indicators to be included in the ESMS prototype. The chosen indicators were:

- Electricity usage per square foot
- Potable water usage per square foot
- Solid Waste (trash and recycling) generated per square foot

With input from the Client, these indicators were chosen based on the current priorities of the Sustainability Program at UCSB. These indicators are limited to the "built environment" on campus and are also limited to environmental performance. However, additional sustainability indicators could be added to the ESMS prototype in the future.

### *Data Analysis*

We compared campus buildings' sustainability performance based on the three chosen indicators. Furthermore, we grouped buildings using a classification scheme developed by the Facilities Management department at UCSB. Each building is classified into one of the following three categories: Administrative, Light Research, and Heavy Research, based on the types of activities occurring in the buildings.

We found that Heavy Research buildings tend to use more electricity and potable water per square foot than Light Research and Administrative buildings. However, the Administrative buildings generate the most trash and recycling per square foot. Significant variation was found within each group of building types, indicating potential areas of improvement for those buildings using more resources than other buildings of the same type.

### ***Conclusions and Recommendations***

Collecting data, performing data analysis, and creating the ESMS prototype led us to identify several areas for improvement in the Campus Sustainability Program. Our recommendations fall into three broad areas of Tracking and Monitoring, Management, and Education Recommendations. In addition, more detailed recommendations for the continued implementation of the ESMS are provided in Chapter Six.

<u>Tracking and Monitoring Recommendations:</u>

1. ***Create a data tracking system for the campus that includes methods to consistently and reliably obtain data.***
   a. ***Install water and electricity meters that measure flow volumes, not flow rates, on all campus buildings.***
   b. ***Connect all major buildings' electricity meters to Itron.***
   c. ***Create an ongoing schedule for building waste audits, including auditing of nearby outdoor recycling bins***
   d. ***Develop similar protocols for collecting data on other indicators of high priority.***

2. ***Develop and implement a comprehensive and central method to store data, such as a shared server with limited permissions or a central person who inputs/records data.***

Management Recommendations:

1. ***Find the "low-hanging fruit" by identifying buildings that have the potential to achieve higher performance, based on normalized analysis by building type.***

2. ***Reconsider the building classification scheme, especially for Administrative buildings. Ensure that buildings are classified properly with respect to sustainability indicators.***

Education Recommendations:

1. ***Improve methods for sharing and disseminating information.***

The Campus Sustainability Program has identified bold goals in nine broad areas of sustainability, along with sustainability indicators to track progress towards these goals. The ESMS can help campus personnel store, organize, and analyze sustainability performance data, and can also provide reports with more spatial and temporal detail than previously available. We suggest that the continued use of the ESMS and the expansion of the prototype could ultimately improve sustainability performance and reporting, and help the campus reach its sustainability goals.

# Chapter One: Introduction

## 1.1 Sustainability as a Guiding Principle

The concept of sustainability has emerged as a potential framework to address the many environmental problems caused by depleted resources and increased pollution. Sustainable development was first defined in Our Common Future, a report published by the World Commission on Environment and Development in 1987. Also known as the Brundtland report, named after the report's commissioner, Gro Harlem Brundtland, this document defined sustainable development for the modern environmental movement:

> *"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."* (World Commission on Environment and Development, 1987)

Usually the concept of sustainable development includes a balance between environmental, economic, and social goals. According to the U.S. Environmental Protection Agency (EPA), the basic principles of sustainability include:

> *"Balancing a growing economy, protection for the environment, and social responsibility, so they together lead to an improved quality of life for ourselves and future generations."* (U.S. EPA, 2007)

Thus, the basic concept of sustainability is simple: a sustainable process can be repeated over and over without increasingly negative environmental, economic, or social impacts. However, the concept does not include a set of generally accepted, concrete, and easily measurable goals. Since the concept of sustainability first emerged, many authors have written about its "fuzziness" and vagueness (Jin and High, 2004). For example, determining how to incorporate sustainability into institutions depends on cultural values, which differ in space and time. How can we determine what resources are most valuable to future generations without knowing their values? Due to these ambiguities and definition difficulties, many experts find that sustainability is best applied as a philosophy or guiding principle, and not a definitive prescription for decision making.

## 1.2 The Use of Sustainability Indicators

Through the use of a monitoring program that uses measurable indicators, however, the concept of sustainability can be better defined and more easily quantified. An agreed-upon subset of indicators can represent a larger set of possible values and priorities amongst the three spheres of sustainability (environmental, economic, and social).

In regards to the utility of sustainability indicators, Jain (2005) wrote: “The ability to analyze different alternatives or to assess progress towards sustainability will then depend on establishing measurable entities or metrics used for sustainability” (p. 71). Similarly, Rapport and Singh (2005) argue that achieving sustainable development requires periodic monitoring of the state of the environment. Such monitoring provides early-warning signals of dysfunction, in addition to timely detection of likely sources of stress to the environment.

Choosing which indicators to include in a monitoring program is a difficult task. Levett (1998) writes that sustainability indicators should be relevant to policy, resonant, scientifically valid, and measurable. However, indicators with all these attributes are difficult to identify. Levett argues that indicators should instead be chosen based on their suitability for their purpose as defined in a project, such as an Environmental Management System (EMS). Furthermore, the goals of a project are likely to be driven by cultural, political, and economic factors, in addition to local issues.

Rapport and Singh (2005) argue that “what is required, first and foremost, is a framework for information gathering that reflects ecological, socio-economic, cultural, and human health aspects and takes into account the interrelationships among these components” (p. 410). Furthermore, Ramos et al (2004) write that indicators should be organized into a consistent framework.

Regardless of how sustainability indicators are chosen, they should reflect the goals of the organization that is monitoring sustainability performance.

## 1.3 Sustainability and University Campuses

Sustainable development can occur on local to global scales. Most sustainability programs apply to no smaller than a regional scale, simply because achieving sustainability requires a diversity of resources, most of which are not found at the local level. For example, local communities seldom produce all their own renewable supplies of food, water, and energy.

Colleges and universities provide smaller environments and scales for sustainability programs. The Talloires Declaration (TD) is a ten-point action plan for incorporating sustainability and environmental literacy in teaching, research, operations and outreach at colleges and universities (Talloires Declaration: University Presidents for a Sustainable Future, 1990). Composed in 1990 at an international conference in Talloires, France, TD has been subscribed to by over 300 universities in over 40 countries, including the University of California, Santa Barbara. In addition, over 100 universities in the United States currently have programs dedicated to sustainability.

Thus, at the local scale, universities worldwide are harnessing their energies to address the problem of sustainability, and many are using indicator programs to monitor their progress.  Universities are uniquely positioned to develop and implement sustainability programs at the local level because they have critical resources such as diverse groups of people, progressive attitudes, and intellectual leaders who are willing to experiment with new ideas. In addition, larger universities can be considered local communities, providing housing, dining, sports and recreation, medical care, and transportation. Thus, universities are excellent training grounds for the practice of sustainability.

In addition to reducing their environmental impact, many campus groups have found that sustainable programs can also create large cost savings while maintaining or improving the social goals of the institution, an important factor in the face of tight educational budgets.

## 1.4 Sustainability at the University of California, Santa Barbara

### *1.4.1 Campus Sustainability Plan*

Our client, the University of California, Santa Barbara (UCSB) has developed a Campus Sustainability Plan (CSP) (University of California, Santa Barbara, 2007). The CSP was developed by a group of students, staff, and faculty known as campus "Change Agents" during a collaborative process, which was partly facilitated by external consultants. Nine "Change Agent" groups were formed:

- Built Environment
- Sustainable Energy and Water
- Academic and Research
- Communications
- Grounds
- Procurement
- Food

- Transportation
- Waste

Each developed goals and indicators for their focus area. The plan includes a total of 41 sustainability indicators to be monitored. A draft CSP was completed and awaits approval. UCSB hopes to publish its first Sustainability Report in 2007 to document progress towards improving performance, according to the sustainability indicators.

Sustainability at the university level comes with many challenges, two of which are learning how sustainability principles can benefit the campus community and determining how to incorporate sustainability into the campus culture and business operations. A critical step in that process is to provide campus decision makers with information that identifies the use of resources and emissions of wastes at the spatial scales that management will consider to improve performance. Many of the current sustainability audit systems at UCSB only report annual campus aggregate values, hiding the impacts of individuals, departments, buildings, etc. For example, only campus-wide totals are reported for energy and water indicators (see the next section of this chapter for an example of currently reported data). These aggregate results also do not reveal variability at less-than-annual time scales.

In addition, current sustainability initiatives and research at UCSB are not centrally coordinated. Responsibility for sustainability practices is spread across several campus departments and individuals within those departments, which contributes to the incomplete portrait of sustainability on campus based on indicators. Furthermore, the Campus Sustainability Plan is a “work in progress”: some of the indicators included in the Plan have no data, as they have only recently been identified. Additionally, some indicators have no standard protocols for data collection or data storage.

To address some of these challenges, the draft Campus Sustainability Plan recommends a new Campus Sustainability Committee and a new Campus Sustainability Office. One of the responsibilities of the proposed Sustainability Office would be: "…coordination and effective communication between each committee, department or division involved in campus sustainability efforts…" (University of California, Santa Barbara, 2007). Another responsibility would be to collect and manage "data vital to continual implementation of the Campus Sustainability Plan." To conclude, the UCSB campus needs a more centralized, coordinated sustainability effort, including a data collection and management system.

#### *1.4.2 An Example of Current Sustainability Reporting at UCSB*

As mentioned above, the current reporting of sustainability information is mostly aggregated into campus-wide, annual totals. An example of current sustainability indicator reporting is provided in Table 1 below.

**Table 1: An Example of Current UCSB Sustainability Indicator Reporting**

| Indicators | 2003-04 | 2004-05 | 2005-06 |
|---|---|---|---|
| Energy:<br>**Electricity Use per Square Foot**<br>(kWh per Square Foot per Year) | 18.2 | 18.6 | 19.2 |
| Energy:<br>**Total Electricity Use** (State-funded buildings only) [1] (kWh per Year) | 61,078,289 | 63,729,176 | 65,238,854 |
| Energy:<br>**Electricity Use per Student/faculty/staff**<br>(kWh per Person per Year) | 2,452 | 2,542 | Unavailable |
| Water:<br>**Total Fresh Water Use** (Main Campus only)[2]<br>(Hundred Cubic Feet per Year) | 198,114 | 233,781 | Unavailable |
| Water:<br>**Total Reclaimed Water Use** (Main Campus only) (Hundred Cubic Feet per Year) | 74,526 | 61,796 | 58,597 |

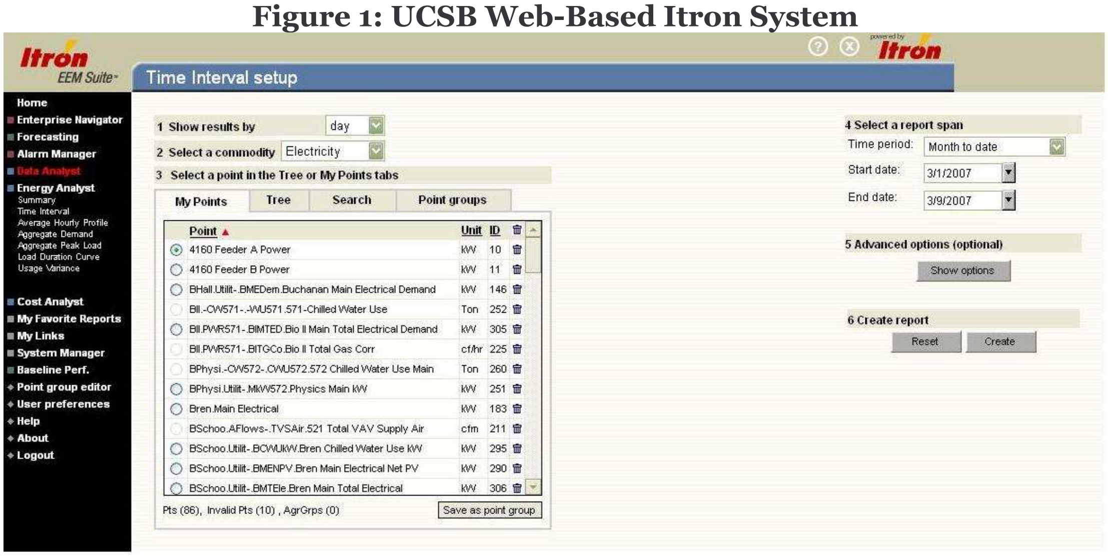
[1] In this table, "State-funded buildings" does not include buildings funded by student fees, such as the University Center.

[2] "Main Campus" includes state funded and non-state funded buildings, but does not include buildings operated by Housing and Residential Services.

The UCSB Energy and Water Manager prepared the indicator data above in addition to a comprehensive annual energy report that shows energy trends and describes new conservation projects. Energy and water data is collected from campus building meters and stored in a centralized web-based system known as Itron (personal communication with Jim Dewey, March 9, 2007). The Itron system was installed in 2001 to more efficiently monitor and analyze the University's energy usage. It has helped the campus lower peak demand, find problem spots, reduce energy use, and find related cost savings. The system has also improved campus energy planning and projections (Itron, 2005).

Most of the meters connected to Itron were formerly connected to a decentralized energy management system known as Johnson Controls Metasys (personal communication with Jim Dewey, March 9, 2007). The Metasys system still collects some meter data and then feeds it into the Itron system. In addition, new electric and gas meters have been installed and connected to Itron, bypassing Metasys. Figure 1 below shows a screenshot of the campus Itron system.

**Figure 1: UCSB Web-Based Itron System**



Although Itron has successfully been used to benchmark energy usage and identify buildings that are using more energy than expected, it has some limitations:

- The web-based interface is only accessible to users with a password.
- Itron is designed for energy managers, not for disseminating information about energy use to the campus community (although the UCSB Energy team does have a webpage with real-time electricity information for 23 buildings).
- Itron only collects and reports building electricity usage data for 32 buildings, out of 433 total campus buildings.
- Water usage information is only available for 3 buildings.
- Itron only allows users to retrieve data for 30 days at a time. Thus, Itron is not useful for determining monthly and annual trends for particular buildings' energy and water usage. (However, Metasys stores monthly water data in a SQL database, accessible by the Campus Energy Manager, which allows for time trend analyses.)

# Chapter Two: The Environmental Sustainability Management System (ESMS)

## 2.1 General Project Goals

Since UCSB sustainability indicator information is currently reported on a highly aggregated scale, the ultimate goal of this project is to disaggregate campus sustainability indicator information to a finer spatial and temporal scale so that campus decision-makers can make informed sustainability-based management decisions regarding resource use. Thus, this project involves the design, testing, and use of a spatial information system that links the flow of energy and materials through the campus using disaggregated sustainability indicator data. Our final product is a prototype Environmental Sustainability Management System (ESMS), which can be easily improved and expanded as additional data needs are identified. The project's clients, and ESMS end users, are the Campus Sustainability Manager and other staff members in the Facilities Management department. More specific objectives are provided in the third section of this chapter.

Technologies such as Database Management Systems (DBMS), Geographic Information Systems (GIS), and three-dimensional visualization have aided environmental decision making by greatly improving the quantity and quality of data available for analysis. Databases can facilitate data analysis through improved data storage and modeling of relationships between data sets. GIS-based indicators provide powerful visualizations of complex interconnections between systems (Shea, 1998). We hope that pairing GIS with disaggregated, quantitative indicator data will help campus decision makers to more clearly understand and visualize the potential costs and benefits of their decisions.

The prototype we developed can facilitate the reporting process, and can be an analytic platform for identifying buildings with lower-than-average sustainability performance. This can lead to the investigation of the underlying causes for the lower-than-average performance, as well as the evaluation of management options to improve performance. Additionally, the maps produced by the prototype could be easily used in campus-wide education efforts, and in the upcoming UCSB Sustainability Report, to increase awareness of environmental impacts on campus.

Finally, we hope that this project's prototype ESMS can be a template for academic, military, and corporate campuses around the world.

## 2.2 Project Scope and Sustainability Program Priorities

Our project combines the newly-developed sustainability indicator program defined in the Campus Sustainability Plan with a GIS-based framework to facilitate information gathering, storage, and analysis. However, this project's scope is limited to analyzing environmental sustainability indicators, which typically include measurements of natural resource use or environmental impacts. Due to limited time and resources, this project does not include economic and social sustainability indicators, although some of the indicator data and data analysis have social or economic implications.

Our purpose is to provide a prototype, or a proof-of-concept, for a campus-based Environmental Sustainability Management System; thus, including all of the campus sustainability indicators was unnecessary. With guidance from the project client, the Campus Sustainability Manager, we chose the following three indicators for our prototype system:

- **Energy Usage**: kilowatt-hours (KWh) per maintained gross square foot of built environment

- **Potable Water Usage**: gallons per maintained gross square foot of built environment
- **Recycling and Solid Waste**: pounds generated per assignable square foot of built environment

Although the contemporary scientific convention uses metric (SI) units, we have chosen to conform to the English units used in the CSP and by the client.

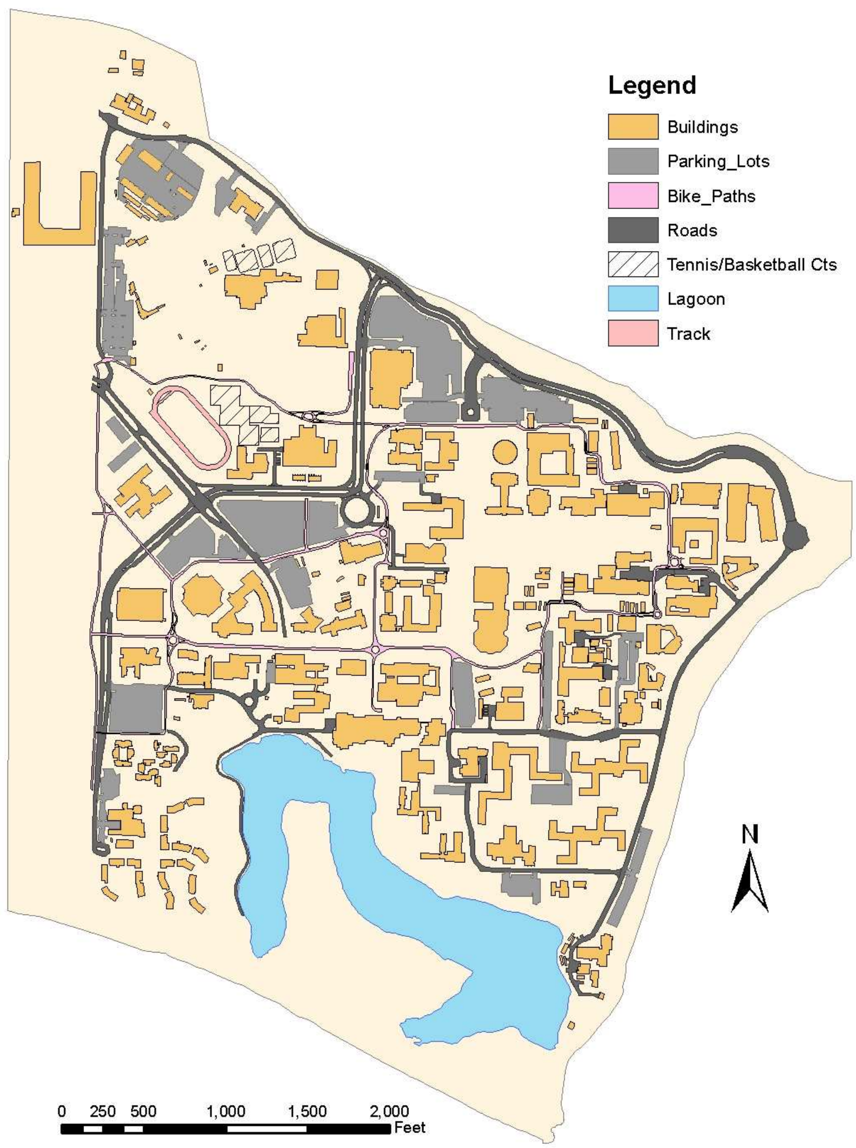
In coordination with the project client, we chose the above indicators because they cover a broad range of categories and are also popular across many campus sustainability programs. Additionally, improvements in these categories yield cost savings, an important motivation for creating the ESMS prototype.

Furthermore, the indicators in our prototype directly contribute to campus-wide goals. For example, UCSB joined the California Climate Action Registry to measure and reduce campus greenhouse gas (GHG) emissions and has committed to GHG emission reduction targets issued by Governor Schwarzenegger. The energy indicator highlighted in the ESMS prototype will clearly reveal the heaviest energy users on campus, which can help the Energy Manager in planning how to reduce GHG emissions. Ultimately, our prototype will inform decisions that increase energy efficiency, reduce energy consumption, and, consequently, enable UCSB to meet its emissions reduction goals.

Despite the comprehensive set of indicators highlighted in our prototype, our scope is limited to the sustainability performance of campus buildings (the "built environment"). This limitation reflects the difficulty of obtaining data for the outdoor environment, as well as the current priorities of the Campus Sustainability Program.

For the purposes of this project, the UCSB campus is defined by the boundaries drawn in Figure 2. UCSB does have buildings outside the boundaries we have drawn, and the university's students, staff, faculty, and others constantly commute to and from campus, impacting the environment. However, these buildings and impacts are outside the scope of this project.

**Figure 2: Main Campus Area Definition**



We chose to include the electricity usage indicator because energy is a top priority of the UCSB Sustainability Program. Specifically, the Energy and Water Manager wants to explore “Energy Budgets” for each department on campus, with the goal of eventually charging departments for energy usages that exceed their specific budgets. Conversely, departments with usage levels below their budget would receive credits or reimbursements for the unused energy. The concept of energy budgets has been successfully implemented at other campuses, such as Stanford University (Stanford Energy Conservation Incentive Program, 2007), and is an innovative incentive for energy conservation to the end user of energy. Two challenges in creating an energy budgets program between departments are ensuring fairness, given departments’ unique energy needs, and motivating performance improvements. The ESMS could be used to assist in the development of energy budgets.

Moreover, UCSB intends to gain Leadership in Energy and Environmental Design (LEED) certification from the U.S. Green Building Council for 25 campus buildings over the next 5 years. UCSB is pilot-testing a new program known as LEED Portfolio, intended for university, military, and corporate campuses, in which an entire portfolio of buildings become LEED certified. This program includes both new buildings and existing buildings. Because LEED certification has become a priority for the Campus Sustainability Manager, our prototype is also intended to assist the LEED certification process.

## 2.3 Objectives

Our project’s overall goal is to disaggregate campus sustainability indicator data to a finer spatial scale in order to make informed sustainability-based management decisions regarding resource use. Our specific objectives include:

- Select a subset of the campus sustainability indicators to be monitored and reported for specific disaggregated campus elements (such as buildings or departments).
- Determine the feasibility of collecting data at a finer spatial resolution.
- Gather and standardize data from relevant campus elements for the selected subset of indicators.
- Design a database to store, analyze, and report the selected indicators and related sustainability projects.
- Implement the database for the selected subset of indicators as an environmental sustainability management system (ESMS) prototype and generate reports at disaggregated temporal and spatial scales.
- Make recommendations to the Sustainability Program Committee regarding continuing usage of the ESMS to support decision-making and sustainability reporting.

# Chapter Three: Data Collection and Data Limitations

## 3.1 Campus Data Collection

Creating a database that would be useful in making sustainability-based decisions at a disaggregated level required creating an accurate depiction of the campus within a GIS framework. To do this, both spatial and non-spatial information was collected for common features of the main campus.

### *3.1.1 Spatial Campus Features*

Collections of spatial campus features, or "shapefiles"[3], were created based on Computer Assisted Design (CAD) files provided by UCSB's Physical Facilities Office. The original CAD files were created from aerial photos and architectural schematics. See Table 2 for more details on the creation of the CAD files from the files' metadata.

**Table 2: Metadata Details for the Campus CAD Files:**

| Metadata Item | Details |
|---|---|
| Unit of Measurement | Feet |
| Coordinate System | NAD 1983 State Plane Coordinate System |
| Survey Date | June 13, 2006 |
| Aerial Photo Resolution | 0.25 feet per pixel |
| Survey Horizontal Positional Accuracy | Continuous Operating Reference Stations: COPR and UCSB |

Various limitations were found when converting the CAD data to shapefiles. For example, tree canopies obstructed the view of certain outdoor features in the aerial photos (i.e. walkways and bike paths), which caused many sections of these features to be missing. Polyline features in the campus base layer CAD file had to be converted to polygons in order to assign attribute information to each object. Many of these polylines were incomplete, making

[3] For a definition of shapefiles, see ESRI, *ESRI Shapefile Technical Description*. 1998.

a direct conversion to polygons using the available ESRI tools difficult. Therefore, we digitized the CAD base map data into polygon shapefiles by hand using ESRI's ArcMap application. Campus object types were classified as buildings, roads, bike paths, parking lots, and other surfaces.

As the GIS shapefiles were digitized from the CAD files, they were assumed to be of comparable accuracy. However, spatial features were only used for visualization. Spatial attributes such as square footage were provided from authoritative sources and not from the internal GIS calculations. Thus, the accuracy of the digitization of the building footprints is not a concern in the prototype.

#### *3.1.2 Building Types*

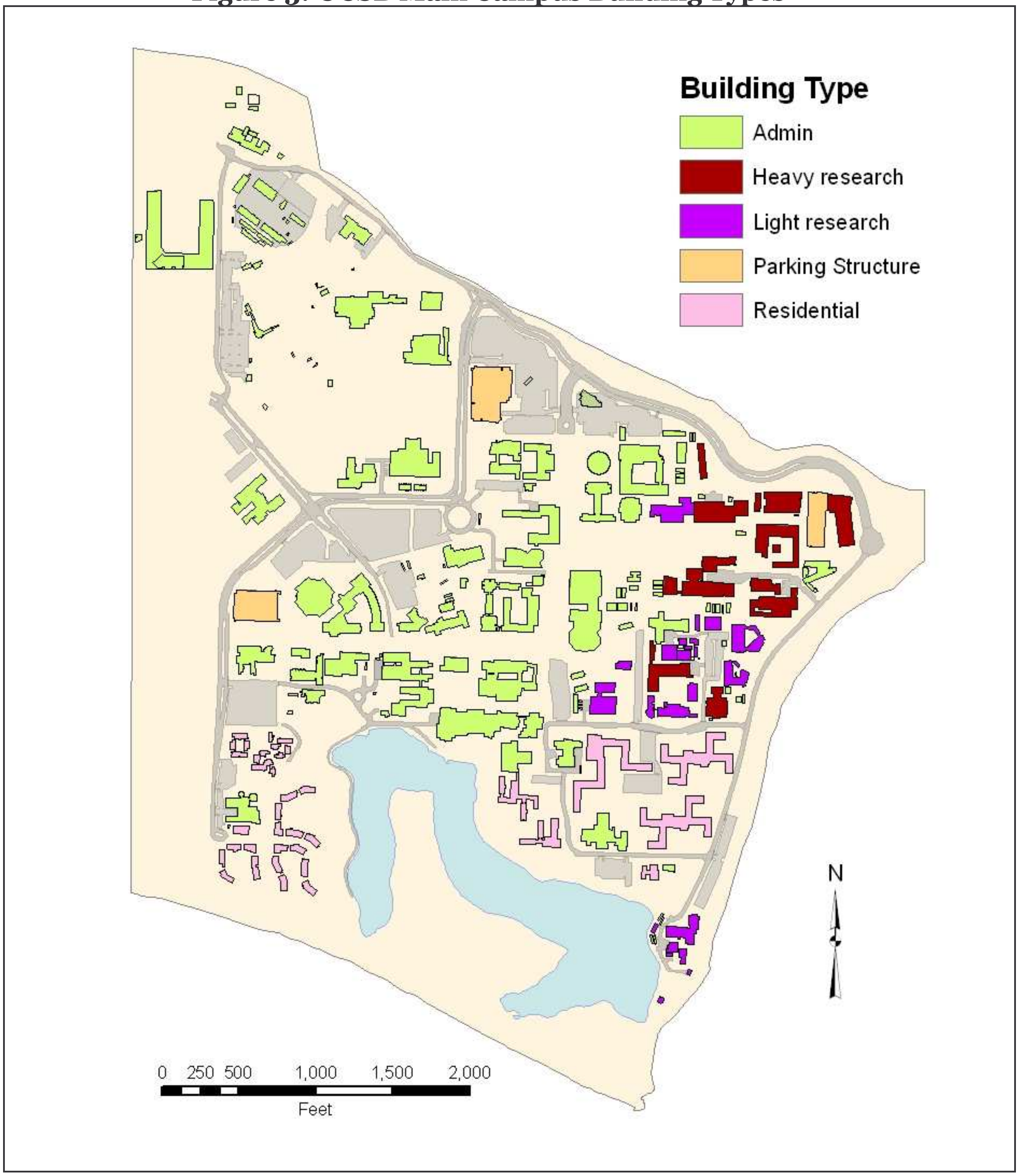
Each building on campus is assigned one of three building types by the Physical Facilities department (personal communication with Jim Dewey, March 9, 2007):

- **Administrative (Admin):** Buildings that are primarily offices, classrooms, and/or teaching labs
- **Light Research:** Buildings containing some research labs, teaching labs and/or fume hoods in addition to classrooms and offices
- **Heavy Research:** Buildings mostly comprised of research labs, teaching labs and/or fume hoods

We added two types to the classification scheme: Parking Structure and Residential, as these are expected to use different amounts of resources than other buildings on campus. The Sustainability Manager at UCSB provided us with each building's classification.

Figure 3 shows the locations of various building types on campus.

**Figure 3: UCSB Main Campus Building Types**



### *3.1.3 Building Attributes*

UCSB's Senior Facilities Requirements Analyst of the Office of Budget and Planning provided building square footage and building usage information for 2006.

UCSB uses several different square footage definitions for campus buildings:

- *Basic square footage*: most indoor areas.
- *Covered square footage*: outdoor patios and walkways under a form of cover that is connected to a building.
- *Overall gross square footage*: sum of basic square footage and covered square footage.
- *Overall maintained square footage*: maintained areas within each building.
- *Assignable square footage*: areas assigned to a campus department for a specific purpose, which does not include storage closets, bathrooms, and the building's mechanical rooms.

The maintenance budget for each building is based on overall maintained square footage; this is the square footage value used for most of our analyses, unless otherwise noted.

Building usage was determined by space audits provided to the Office of Budget and Planning by each department on campus. The space audit information, provided in Microsoft Excel spreadsheets, includes the number of rooms dedicated to a specific use and their total assignable square footage. The UCSB energy manager provided maintained gross square footage values for each building.

### *3.1.4 Outdoor Waste Receptacles*

UCSB's Campus Recycling Coordinator provided a map of outdoor waste receptacles in PDF format, showing the positions of trash cans, recycling bins, cardboard dumpsters, trash dumpsters, and magazine/catalog dumpsters. This information was transferred to a shapefile by first converting the PDF document to a TIFF image, then georeferencing the image to the building shapefile already created. Each waste receptacle was then digitized by hand into the recycling/trash container shapefile and its type entered as an attribute value in the shapefile table.

## 3.2 ESMS Indicators

As noted in Chapter Two, the ESMS prototype highlights three indicators, which were chosen with guidance from the UCSB Sustainability Manager:

- Energy Usage: kWh/square foot of built environment
- Potable Water Usage: gallons/square foot of built environment
- Recycling/Solid Waste: pounds generated/square foot of built environment

The data-gathering process revealed technical and political barriers and severe data deficiencies. Data was spread throughout various departments across campus, including Facilities Management, Geography, Environmental Sciences, and Campus Planning. This reflects the decentralized nature of sustainability programs at UCSB; traditionally, many different departments and individuals at UCSB have been responsible for various sustainability initiatives.

We found that annual campus-wide consumption of electricity and potable water and generation of solid waste are known with high accuracy because these amounts are tracked by their respective utility organization in order to bill the campus. Data at the building level, however, are much less accurate, because these amounts are tracked using different methods.

Daily electricity and water use data for individual buildings were collected using UCSB's Itron system, a web interface to a SQL database which holds automatically recorded meter information. The SQL database is accessible to the Physical Facilities Department through their own Microsoft Access database, but for this project, we downloaded the data through the web interface.

Daily data was downloaded for the years 2004 through 2006. Before 2004, few buildings were monitored by Itron, so data from these years was excluded. In total, electricity data was downloaded for 35 buildings, and potable water data was downloaded for 3 buildings (See Table 3). The Itron system allows the user to query data for one building at a time in 30 day increments, which can then be exported to a Microsoft Excel spreadsheet. Additionally, limitations of the Itron system prevented us from downloading hourly electricity and water usage data for the same time period for every building available.

**Table 3: UCSB Buildings Automatically Metered for Electricity and Water and Available Through Itron**

| **Data Type** | **Buildings with metering information available in Itron** | | |
|---|---|---|---|
| Total electricity | Biology 2<br>Bren Hall<br>Broida Hall<br>Buchanan Hall<br>Campbell Hall<br>Cheadle Hall<br>Chemistry<br>Coral Tree Café<br>Davidson Library<br>Ellison Hall<br>Engineering Sciences<br>Engineering 2<br>Girvetz Hall | Harold Frank Hall<br>Humanities and Social Sciences Building (HSSB)<br>Kerr Hall<br>Kohn Hall<br>Marine Biology Lab Marine Sciences Building<br>Mesa Parking Structure<br>Materials Research Lab<br>Music<br>North Hall<br>Ortega | Phelps Hall<br>Physical Sciences Building<br>North Psychology<br>Recreation Center<br>Rec Center Expansion<br>Student Affairs and Administration Building<br>Snidecor Hall<br>South Hall<br>Student Health<br>University Center<br>Webb Hall |
| Potable water | Girvetz Hall<br>Bren Hall<br>Engineering Sciences | | |

In addition to data from Itron, we obtained monthly electricity and water usage values for December 2006 for “recharge” buildings on campus. Recharge buildings are funded by non-state sources such as student fees or special grants; these buildings are managed separately from state-funded buildings and most are not connected to the Itron system. Instead, recharge buildings’ meters are manually read each month, and electricity usage is billed back to the building by UCSB Facilities Management. We only received one month of data because data for other months was known to be inaccurate, according to University accountants. The combination of recharge data with the billing information from the electric utility company provided an accurate measure of total campus usage.

The Energy Manager in UCSB’s Physical Facilities Department provided billing information, in Microsoft Excel spreadsheets, for both potable and recycled water usage for the main campus. The data are organized by month, and grouped by the water mains leading to campus: two for potable water and one for recycled water. This provided an actual measurement of campus-wide use.

Waste data were provided by the campus Recycling Coordinator in UCSB’s Physical Facilities Department, as well as from sustainability coordinators in the Geography Department and the Donald Bren School of Environmental Science and Management. Waste data were available for 7 buildings from audits conducted from 2003-2007: Bren Hall, Ellison Hall, Embarcadero Hall, Engineering 2, Girvetz Hall, Recreation Center, and Webb Hall. Waste audits are conducted on chosen buildings each year, based on measured municipal solid waste exiting the building for one day. All the waste (including both non-recyclable and recyclable items) are sorted, according to type, and weighed; the original placement of all waste into trash or recycling bins is also noted. All waste is then divided into four basic categories, depending on the item type and placement bin:

| Placed into Trash Bins | Placed into Recycling Bins |
|---|---|
| Correctly Sorted Trash | Incorrectly Sorted Trash |
| Incorrectly Sorted Recyclables | Correctly Sorted Recyclables |

This data were provided to us on paper, which we then entered into tables. In addition, we obtained the annual campus-wide totals for the following two categories, as reported by the campus waste hauler to the Recycling Coordinator:

- Total Annual Trash Weights (Correctly Sorted Trash and Incorrectly Sorted Recyclables)
- Correctly Sorted Recyclables

## 3.3 Sustainability Projects

For the purposes of connecting management decisions to resource use, we collected information about past sustainability projects. These were energy-related projects, completed between 2003 and 2005, that took place on a building-by-building basis. This information was provided by UCSB's Sustainability Manager in a Microsoft Excel spreadsheet. The project information can be compared to resource use data to document the effectiveness of these projects, particularly in relation to sustainability indicators.

## 3.4 Data Limitations

### *3.4.1 Data Scale and Availability*

There was limited information available for resource usage for individual buildings on campus. Though all buildings are metered for water and electricity, these meters are not all connected to the Itron system or regularly read by a meter reader. As a result, the number of buildings we were able to track and analyze for electricity and water usage was limited. In terms of waste data, only 2 to 4 buildings on the main campus are audited each year. These waste audits are done for one day only, which is likely not representative of the entire year. Thus, our waste analysis was limited by the number of buildings with available data and small amount of data for those few buildings.

### *3.4.2 Data Quality*

The methods used by the electricity and water meters to measure usage have inherent limitations. Both the water and electricity meters on campus are analog meters that measure rates, as opposed to volumes. These meters capture usage rates every 5 minutes, which are then averaged into 15-minute intervals (personal communication with Jim Dewey, March 9, 2007). The averaged 15-minute time intervals are then averaged according to the time frame being queried, which reduces the accuracy of the presentations of the actual building resource usage. In addition, the occasional measuring of usage rates (i.e. every 5 minutes) will miss short-term spikes in usage, leading to further inaccuracies.

The methods used to measure the types of waste exiting the buildings are highly accurate and therefore are assumed to be of high quality. As noted above, however, the waste audit data may not be representative of the average amount of waste generated by building, since they are only conducted on one day per year.

### *3.4.3 Variability in Data*

There was high variability within the indicator data gathered. The most variable data was from the water meters connected to the Itron system, which included both negative and abnormally high values. The same problems were observed in the electricity usage data, although the variability was not as high. Due to the limited amount of waste data, its variability is difficult to analyze.

# Chapter Four: ESMS Database Design and Implementation

## 4.1 Creating the Sustainability Database

### *4.1.1 Evolution of the Database Design*

Initially, the project planned to use ESRI's geodatabase structure, where all campus data, geometry, rules, and relationships are stored within one database. As the project evolved, we found that that it may be necessary for users without GIS experience to be able to use the sustainability database. We also wanted to design a database that is simple to use so that a person with little database experience would be able to extract basic information.

To meet the usability goals of the sustainability database, we decided to keep spatial information as shapefiles organized within a folder and use Microsoft Access to organize non-spatial data. In this way, spatial data files could be easily updated and used in other programs, such as CAD programs. In a GIS program, shapefiles can be "joined" to non-spatial data tables contained within Access to examine indicator data within a geographical framework. In addition, Access is a commonly used database program accessible to users not familiar with GIS programs. Access also allows for the creation of forms and reports for ease of use by people unfamiliar with database programs. Our design allows for the simple importation of data and the ability to examine data non-spatially, either directly within Access or through other programs, such as Microsoft Excel, which accept exported tables of information.

### *4.1.2 Database Design*

To ensure that the database would be usable to campus organizations that currently collect resource use data, we designed the database to contain tables or "entities" in the same format as the information we acquired during the data collection process (for example, with the same attribute names).

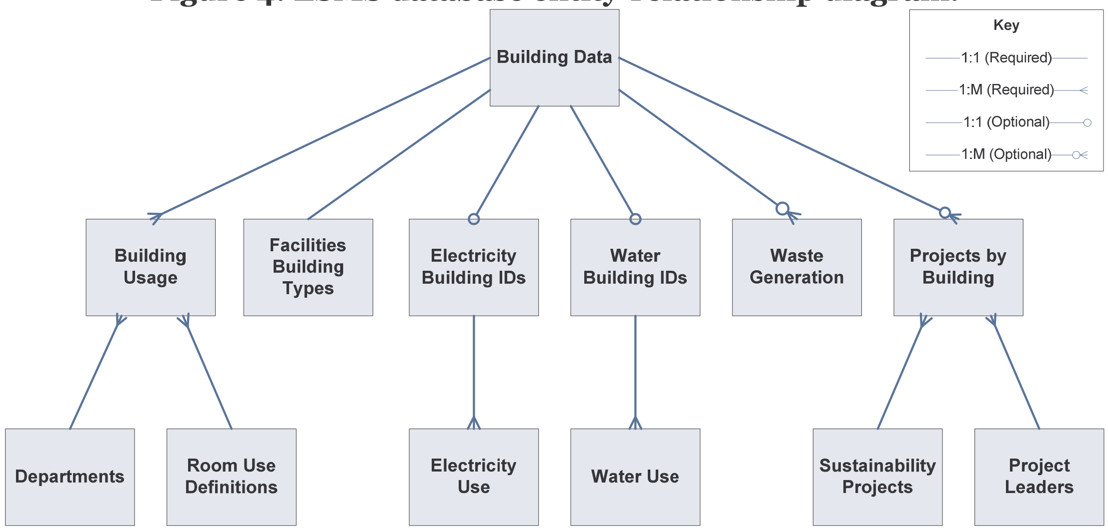
A benefit of using Access is that we can create relationships between entities, allowing us to break down large tables into smaller tables connected by relationships. This prevents data redundancy that could lead to updating, insertion, and deletion anomalies, in addition to multiple-value problems (Roman 2002).

The first step in creating the database was to import the non-spatial information gathered during the data collection process, most of which was provided as Excel spreadsheets. Importing data into the database required differing levels of modification to the Excel tables, where attributes had to be in columns in the first row of the table and records (generally by building) in rows below. Some tables, such as the water, electricity, and building usage data were already in this format. Other tables, such as the recycling data, were organized in multiple Excel spreadsheets and required modification to be imported into the database. To import each Excel table, Access's "import table" option was used with default attribute types and no primary key. Once the tables were imported, any error files generated were examined to ensure that no data was lost.

The second step included evaluating each table and assigning data types, domain, requirements to each attribute, and primary keys, when applicable (see Appendix II). Generally, the primary keys were "Building Code" as this is consistently used across campus to identify all buildings, even those without a common name. Cases in which a primary key was not applicable were tables where no single attribute had non-repeating records. To ensure that tables would properly join to the building shapefile, all "Building Code" attributes were required to have type "long integer."

Lastly, relationships between entities were assigned (see Figure 4.) Access automatically classifies each relationship as one to one, one to many, or many to many. The “enforce referential integrity” option was selected for each relationship to ensure that changes within each entity would not compromise the rest of the database.

**Figure 4: ESMS database entity-relationship diagram.**




## 4.2 Turning Sustainability Program Priorities into Queries

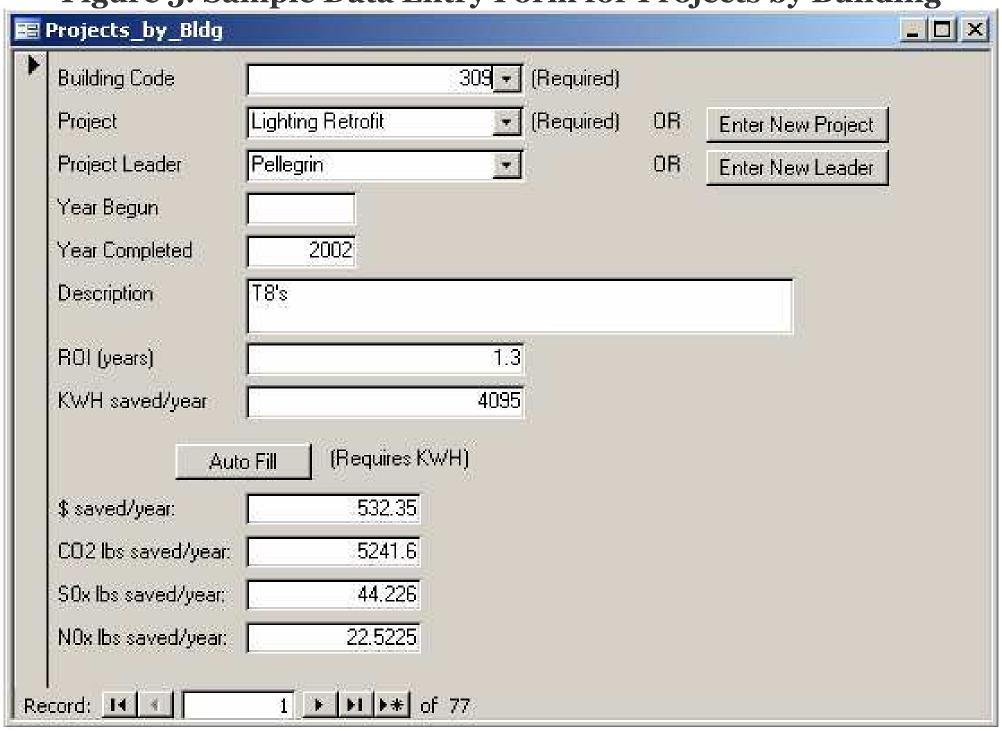
Once the shapefiles and the non-spatial database were completed, they were tested with queries in Access and table joins in ArcMap. We successfully generated various tables useful to UCSB’s Sustainability Program. These included building types combined with detailed usage, average resource usage for a given time period, resource use normalized by square footage of built environment, and sustainability projects by building. These tables were then joined to the buildings shapefile within ArcMap by “Building Code”.

Though these are only a subset of what is possible with the database, the results of these queries show that data from multiple entities on the UCSB campus can be successfully merged together to generate information useful for sustainability-based decision making.

## 4.3 User Interface

To ensure usability of the database by users of differing skill levels, we created Microsoft Access forms for data entry, we well as reports for ease of exporting data. Forms to edit and create new records were designed for most entities, including recycling audit data, building types, project names, project leader information, and projects by building (see Figure 5.)

**Figure 5: Sample Data Entry Form for Projects by Building**




Data entry forms were not created for those entities that are already accessible to Physical Facilities through their SQL server, such as water, electricity, and maintained gross square footage. Forms were also not created for data that is collected by other departments other than Physical Facilities, such as departmental room usage. This data is collected on a yearly basis and can be easily imported into the Access database without an entry form.

Additional reports that may be useful to the Sustainability Program were also generated. These were based primarily on the queries discussed above, and were found to be easily generated in Microsoft Access (see Figure 6.)

**Figure 6: Sample Report for ESMS Database Based on Query of Projects by Building**

# Project_List

**ProjectName** HVAC-Chilled Water Loop

| Building_Name | Description | Year Completed |
|---|---|---|
| HAROLD FRANK HALL | Replace old A/C with chilled | 2006 |
| DAVIDSON LIB | Upgrade from constant air volu | 2006 |
| CHEMISTRY | Optimization controls for highe | 2004 |

**ProjectName** Lab Vent-Pump

| Building_Name | Description | Year Completed |
|---|---|---|
| PSB NORTH | VFD and motor upgrade on all | 2005 |
| ENGR 2 | VFD and motor upgrade on all | 2005 |
| CHEMISTRY | VFD and motor upgrade on all | 2004 |

# Chapter Five: Data Analysis and Results

Mindful of the data limitations discussed in Chapter Three, we analyzed the indicator data to seek trends among buildings classified as the same type and to further examine variability within the electricity use, water use, and waste generation data. Large variability between buildings of the same type might indicate either 1) opportunities for improved sustainability performance in buildings with extremely high values, 2) a need to extend monitoring to more buildings because average values for the type are not representative of the individual buildings, or 3) a need to revise the building type classification scheme.

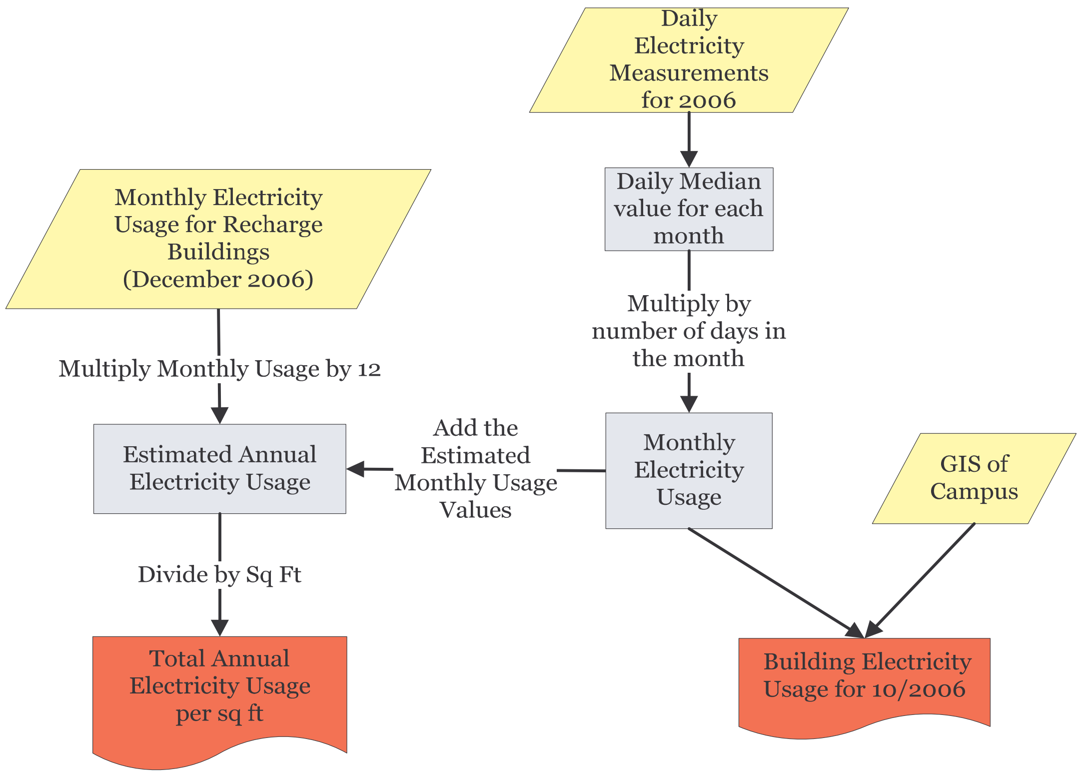
## 5.1 Electricity Indicator Data Analysis and Results

*5.1.1. Process of Electricity Data Analysis*

To analyze electricity usage by building, we began with the daily electricity usage data collected for 2006 (See Figure 7). We first found the daily median for each building for each month in 2006; we chose to use the median value to mitigate the effect of erroneously high or low values. We then conducted two extrapolations:

1) Each month's daily median was multiplied by the number of days in that month to estimate total monthly electricity usage for each building. (Buildings with no data were not included in this analysis.)
2) Each extrapolated monthly value was added up to obtain an estimated annual electricity usage for each building, then divided by the square footage of building space to obtain annual electricity usage per square foot ($kWh/ft^2/year$) for each building. We used the maintained gross square footage value for this analysis. We also obtained monthly electricity usage for recharge buildings and multiplied this value by 12 to estimate an annual electricity usage for these buildings.

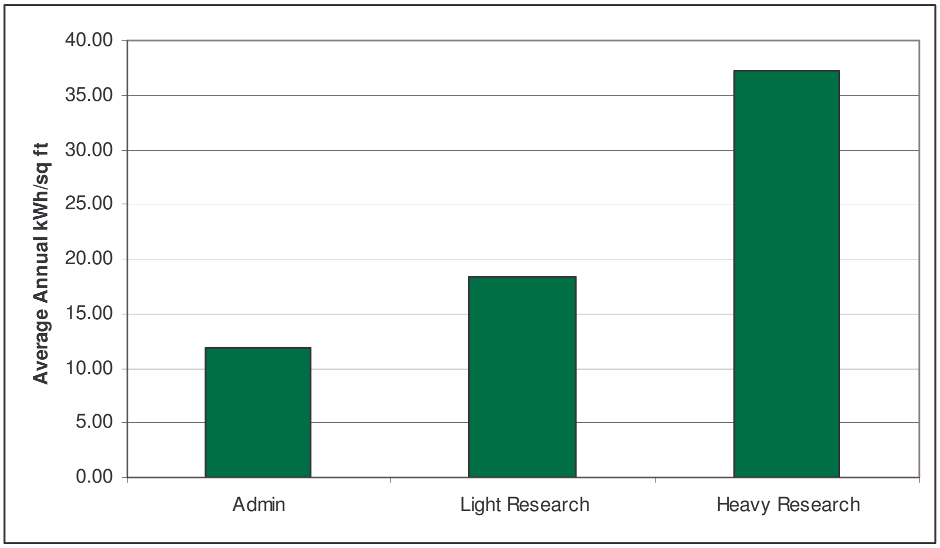
**Figure 7: Electricity Analysis Flow Chart**




### *5.1.2 Results and Discussion*

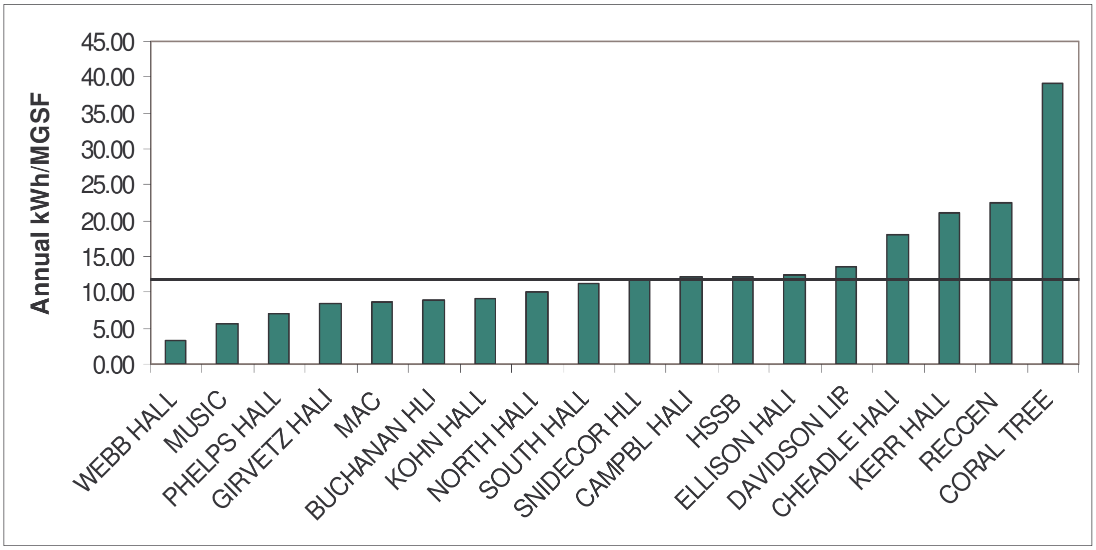
As Figure 7 shows, the second stage of analysis included comparing the annual electricity usage by building type in kWh/ft$^2$/year. Our results are displayed in Figure 8. Not surprisingly, Administrative buildings use the least electricity per square foot while Heavy Research uses three times as much.

**Figure 8: Average Annual Electricity Usage by Building Type**




Furthermore, we found high variability in electricity usage within each building type. Figure 9 shows the average annual electricity usage per square foot for Admin buildings - the line drawn on the graph represents the median value. Clearly, many buildings fall both below and above the median. For example, Coral Tree has the highest electricity usage per square foot (about 39 kWh/ft$^2$/year); this building is a dining facility, containing refrigerators and other appliances that use large amounts of electricity. In contrast, Webb Hall, which is mostly offices and classrooms, has the lowest electricity usage per square foot (3.26 kWh/ft$^2$/year). This large range of electrical consumption within the Admin class suggests that this classification is not particularly useful. Building type classification is especially important if energy budgets will be assigned by building type.

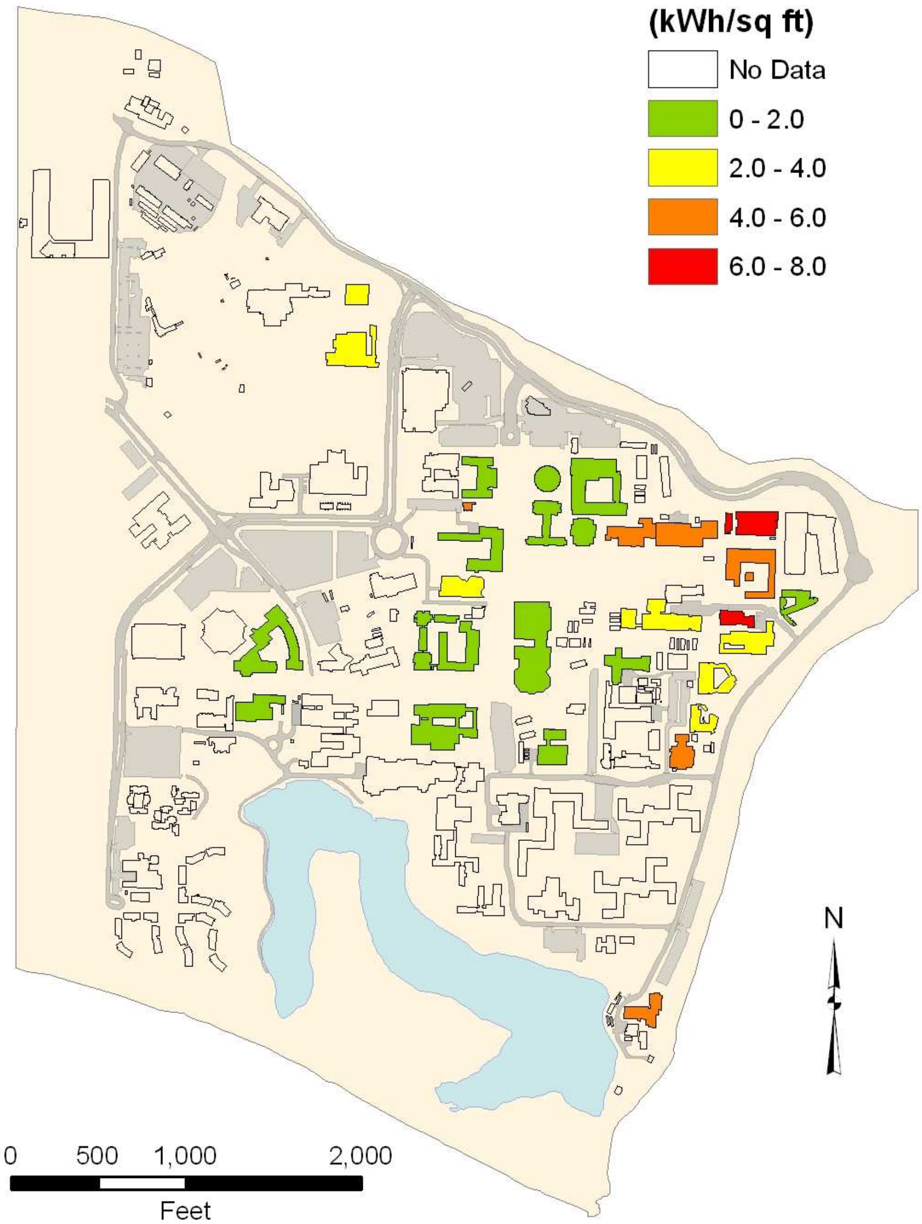
**Figure 9: Admin Buildings - Estimated Annual Electricity Usage per Square Foot**




Note: The black line represents the median value.

We also analyzed the potential spatial relationship of campus electricity usage. Figure 10 shows a GIS map of campus electricity usage per square foot per month (kWh/ft$^2$-month) for October 2006. Most of the buildings with highest usage per square foot (shown in red) are classified as Heavy Research buildings, which are expected to have higher electricity usage per square foot due to the special equipment in laboratory spaces. This map does not show the electricity usage for all buildings due to data limitations; however, the map does illustrate the concentration of scientific research buildings on campus, which tend to use more energy than Administrative buildings. The map also shows a regional lack of electricity data from the southern and western portions of campus (largely residence halls that are not on the system).

**Figure 10: Monthly Electricity Usage per Square Foot**




### *5.1.3 Limitations of Analysis*

As noted in Chapter Three, we collected electricity data from the Itron system, which employs metering based on instantaneous rate measurements. In the current metering system, meters measure electricity use (in kW) every 5 minutes; every 3 measurements are averaged and stored as a 15-minute average. To get a total amount of electricity used for a specified time interval, the 15-minute averages are averaged as a kilowatt-hour (kWh) of usage. These are added up according to the specified time period. For example, if one would like to know the amount of electricity used in a given day, the 15-minute measurements are averaged over 24 hours to obtain a mean 15-minute kWh of usage. This number is then multiplied by 96 (24*4 because each hour has four 15-minute spans) to get the total kWh's used that day. This method generates potentially inaccurate data because the instantaneous measurements may miss large consumption events that occur between the instances of measurement. Furthermore, this method quickly accumulates and exaggerates potential error due to the numerous averages calculated. An alternative and more accurate measurement method would be to continuously measure cumulative usage.

Only 35 of UCSB's state-funded buildings have meters that are currently connected to Itron. In addition, most of the recharge buildings are not, and may never be, connected to Itron because most of these buildings are managed separately from the state-funded buildings. However, our extrapolated annual electricity usage included recharge building calculations, which were based on a recharge electricity bill for December 2006. The December electricity use total was extrapolated to reflect the electricity usage for an entire year and added to the Itron-based extrapolations to generate an estimated annual electricity usage for the entire campus. The recharge building calculations do not reflect seasonal influences on electricity usage.

## 5.2 Water Indicator Data Analysis and Results

### *5.2.1 Water Data Analysis*

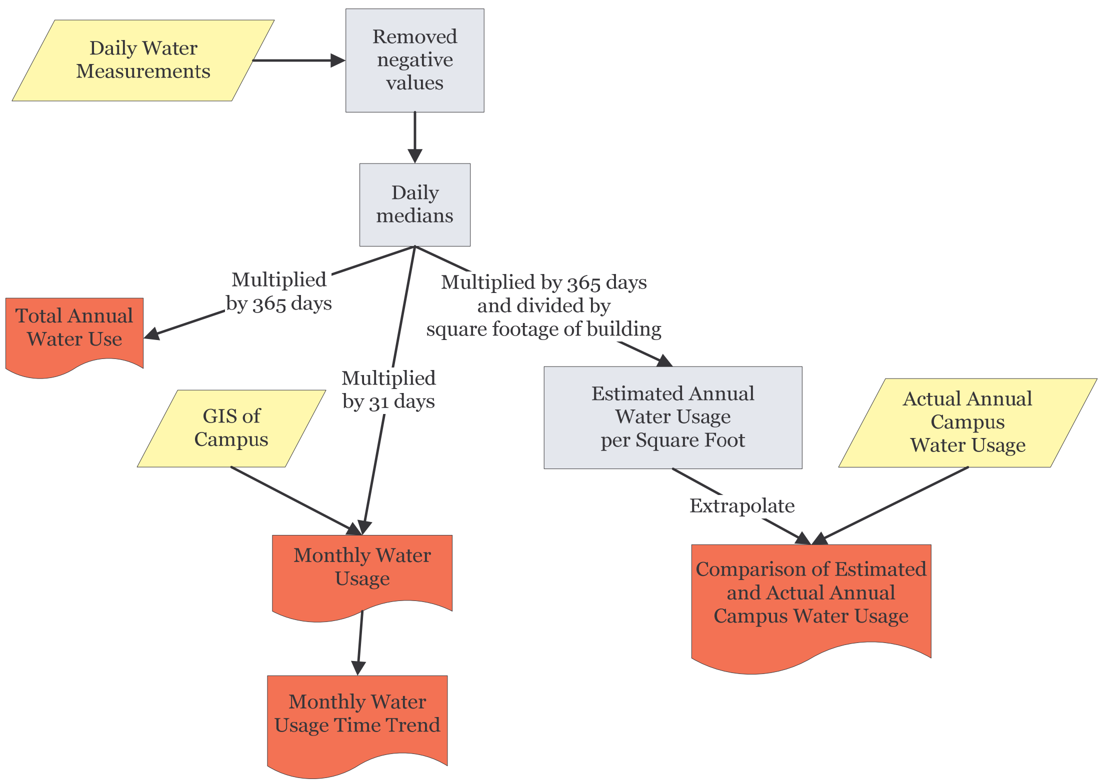
The water analysis used daily water measurements collected for the three buildings available on the Itron system: Girvetz Hall, Bren Hall, and Engineering Sciences. These buildings fall under each of the three physical facilities building types of Admin, Light Research, and Heavy Research, respectively, so we interpreted the analysis by building type instead of by building. Three different analyses were completed to estimate overall campus water usage and view time and spatial trends (See Figure 11).

The first step was to remove any negative daily values within the data, as these were clearly erroneous. We next found the median daily value for 2006 for each building; as with the electricity data, we decided to use the median daily value due to the high variability within the data (i.e. erroneously high values would cause the total usage to appear falsely high). The daily median values were then extrapolated out in three ways:

1) Each daily usage value was multiplied by 365 and then divided by the building's square footage to obtain estimated annual water usage per square foot by building. For this analysis, we used Maintained Gross Square Footage.
2) To estimate annual campus water usage, we multiplied annual water usages per square foot for each building type by the square footage of each campus building, matching the building types.
3) The estimated annual water usages were added together and compared to actual main campus water usage values.

A median daily water usage value was found for each month of 2006 for each of the three buildings available. These daily water usage values were then multiplied by the number of days in each month to obtain estimated monthly water usage by building. One month of data (October 2006) was also joined to the campus shapefile to visualize spatial water usage.

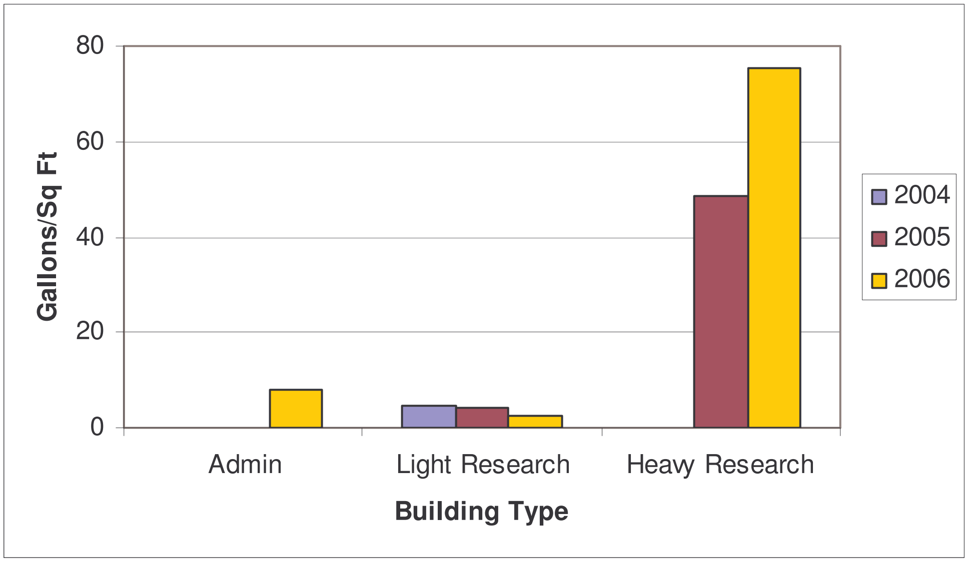
**Figure 11: Water Data Analysis Flow Chart**




### *5.2.2 Results and Discussion*

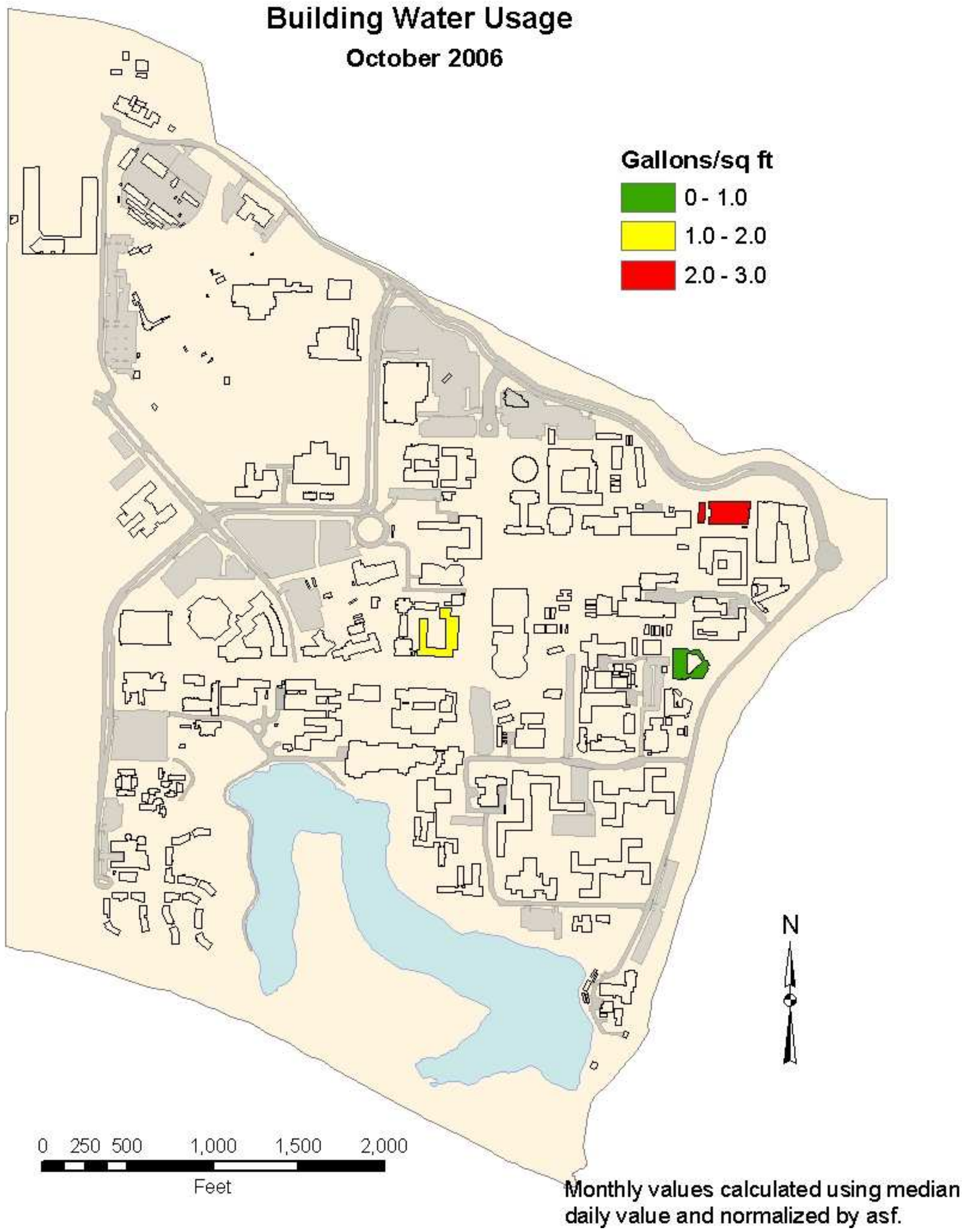
The first phase of water analysis was performed to determine which building type used the most water per square foot in 2004, 2005, and 2006. Figure 12 shows that the Light Research building consumed the least amount of water per square foot, and the annual amount decreased each year from 2004 to 2006. The Heavy Research building used the most amount of water per square foot, and the amount increased from 2005 to 2006. Data was only available for the Admin building for 2006; this building used more water per square foot than the Light Research building.

**Figure 12: Average Estimated Annual Water Usage by Building Type**



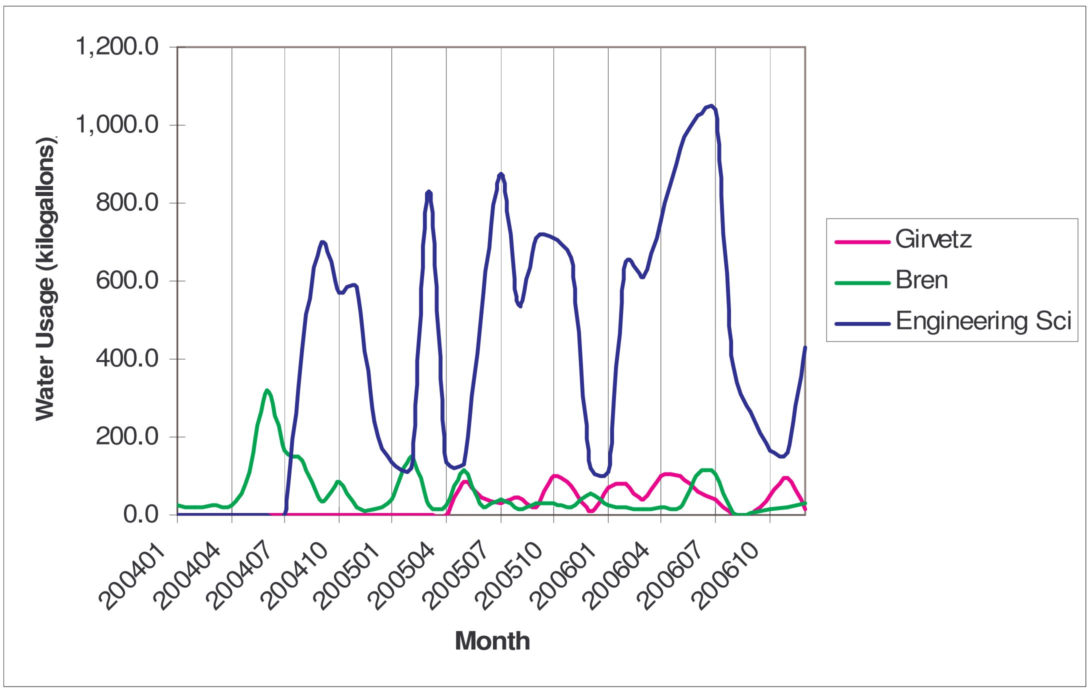

The next path of water analysis was to assess any spatial relationships of campus water usage for October 2006 (See Figure 13). This figure emphasizes the lack of water data — it is difficult to make conclusions about the spatial layout of campus water usage.

**Figure 13: Monthly Water Usage per Square Foot by Building Type**




The third phase of the water analysis evaluated a water usage time trend for 2004-2006. Figure 14 shows the fluctuating water usage by building type. Some of these fluctuations may be due to the imprecise water metering methods, which may randomly catch large water consumption events. Some of the dips in water usage may correspond to seasonal changes in the number of building occupants. For example, dips in the Engineering Science building's water usage occur roughly during academic breaks in January, April, and June of 2005. Large peaks in usage, such as those for the Engineering Sciences building, could possibly be due to different experiments that require large amounts of water. The ESMS identifies these potential anomalies so that managers can isolate the causes and if appropriate make changes to improve sustainability performance.

**Figure 14: Extrapolated Monthly Water Usage by Building**




Finally, we compared estimated annual campus water usage to actual annual campus water usage for 2006 (see Table 4.) The estimated campus potable water usage, including usage from the Housing and Residential Services buildings, is 93 million gallons. Comparing this estimation to the actual campus potable water usage of 171.8 million gallons leaves a difference of 78.9 million gallons. This is a significant difference that has at least two explanations. First, the extrapolated water usage for all the Light Research buildings on campus is based on Bren Hall water usage, which may be anomalously low – Bren Hall is a LEED-NC Platinum certified building and is outfitted with more water conservation fixtures than most of the other Light Research buildings on campus. Thus, there is probably substantial variability around the value for this building type, with most buildings exceeding Bren's water usage. Second, the estimated campus water usage does not consider the amount of potable water used for landscaping irrigation. At this point, we do not know how much water these two factors would add to the estimated campus water usage. This finding underscores our point that reporting campus-wide resource use does not explain where and how water is being consumed, which also masks the opportunities for improvement. Even trying to extrapolate campus-wide water use from a few buildings' data leaves 46% of the water consumption unaccounted for.

**Table 4: Comparison of Estimated and Actual Campus Water Usage**

| | |
|---|---|
| **Estimated Total Admin, Light Research, and Heavy Research (mil gal)** | **87.2** |
| **Actual Total HR&S Water Use (mil gal)** | **5.8** |
| **Estimated Total Campus Water Use (mil gal)** | **93.0** |
| **Actual Main Campus Potable Water Use (mil gal)** | **171.8** |
| **Difference (mil gal)** | **78.9** |

*5.2.3 Limitations of Analysis*

Our water analyses were limited by several factors. Figure 13 illustrates the limited and inconsistent data available for water usage on campus; only three buildings' meters are connected to the Itron system, and only one building type has data for each of the 3 years. Despite the unreliable and variable data, however, the results are plausible. For example, Heavy Research buildings probably use the most water per square foot due to equipment, labs, and/or aquarium facilities that require a significant amount of water. Furthermore, the Light Research building in our analysis is the Bren building, which is LEED-NC Platinum certified, meaning Bren is outfitted with waterconserving fixtures and toilets, unlike most other Light Research buildings. The occupants of the Bren building could also be more aware of water scarcity and water conservation methods, which may influence Bren's total water usage.

Similar to the electricity data limitations, Itron measures water as instantaneous flow, generating inaccurate and perhaps incomplete water data. These measurements also require correctly functioning meters, which was not the case for the Bren water meter in 2004 and part of 2005 as illustrated by negative water use values measured during those years. Although the negative values were removed and not used during our analysis, the presence of negative values reveals problems with the current water metering system.

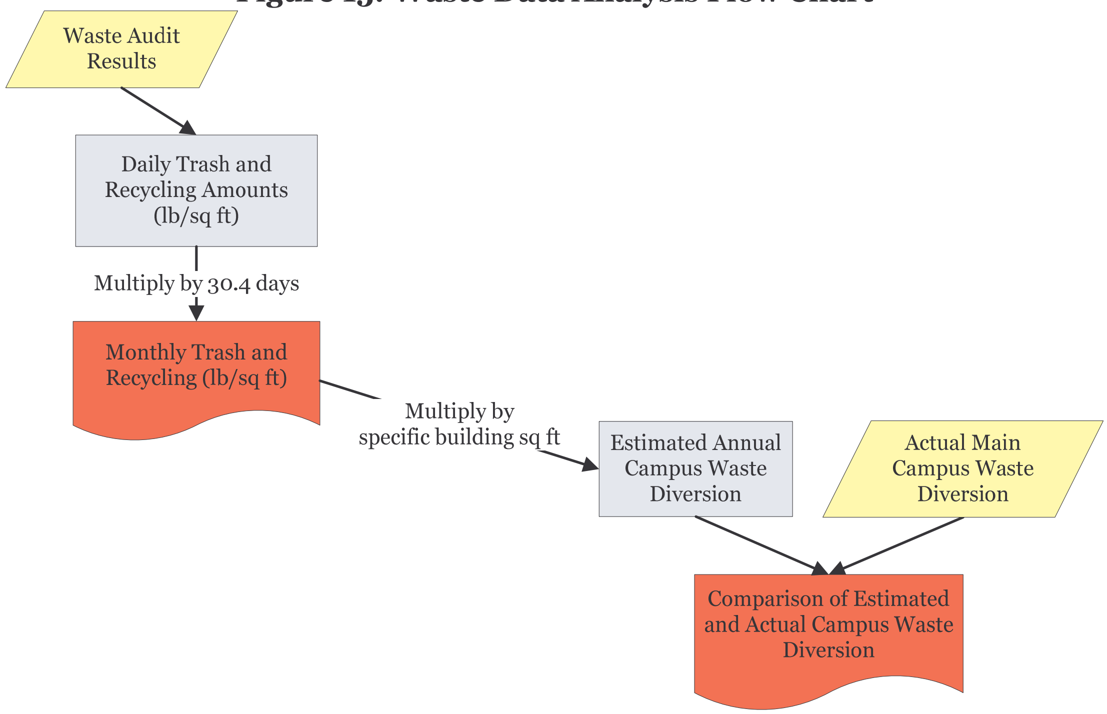
The limited data prevents a robust analysis of campus water usage. We lack data for potable water used outside of campus buildings, such as potable water used for landscape irrigation. Our analysis also does not include reclaimed water usage. Data regarding these two water uses would help to better understand campus water use and behavior changes necessary to reduce potable water consumption.

## 5.3 Waste Data Analysis and Results

### *5.3.1 Waste Data Analysis*

The waste data analysis (see Figure 15) used the waste audit results discussed in section 3.2. In our analysis, we refer to "trash" as all non-recyclable items, "recyclables" as items that can be recycled in the current campus system, and "solid waste" as the combination of trash and recyclables. Some trash and recyclables are sorted properly into trash and recycling bins, respectively. However, both trash and recyclables are also sorted incorrectly; trash can be placed in recycling bins, and recyclables can be placed in trash bins. In analyzing the waste audit results, we assume that improperly placed items are ultimately sent to a landfill, and not recycled; thus, all incorrectly sorted items are labeled as trash. Figure 15 shows the 2 phases of waste analysis.

**Figure 15: Waste Data Analysis Flow Chart**




The first step of the analysis was to divide each building's daily generation of trash and recycling by its square footage to obtain pounds of waste per square foot (lbs waste/$ft^2$) and pounds of recycling per square foot (lbs recycling/$ft^2$) on the day of the audit. These daily amounts were multiplied by 30.4 (the average number of days in a month) to create an estimated monthly value of waste generation per square foot. The monthly estimates were then divided into building types, where Girvetz Hall, Embarcadero Hall, and RecCen I and II are the Admin buildings, Bren Hall, Webb Hall, and Ellison Hall are the Light Research buildings, and Engineering 2 is the sole Heavy Research building. As there were three Admin buildings and three Light Research buildings with waste audit data available, each group's data values were averaged to obtain waste generation values for the building types.

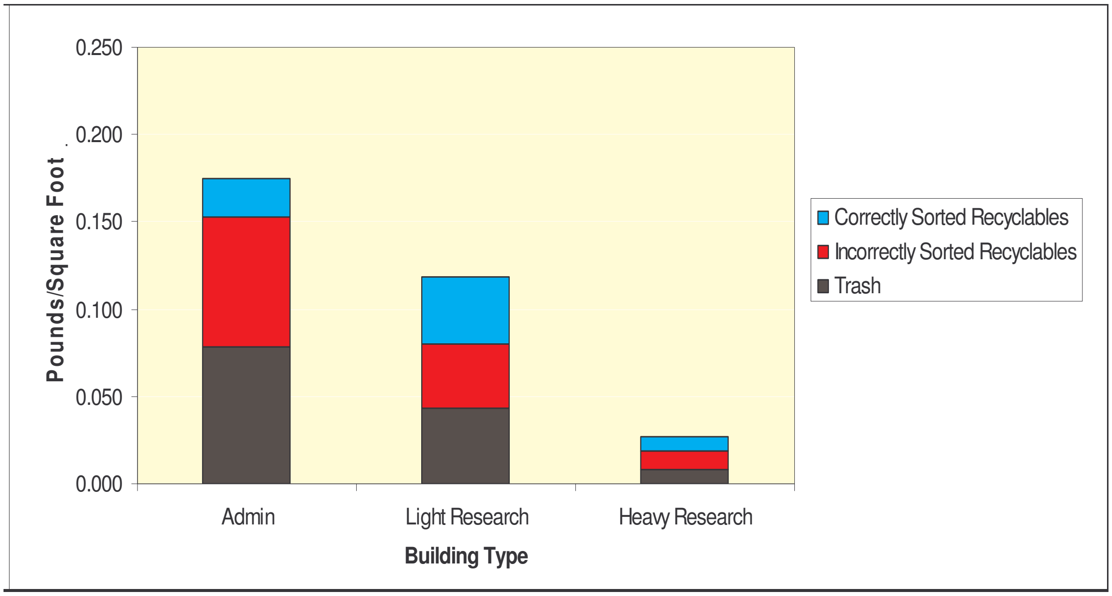
The second step of the waste analysis was to multiply the estimated monthly values for waste generation per square foot for each building type by each campus building's square footage, respective of building type. This estimated the total estimated amounts of waste (trash and recycling) for campus, which were compared to the total campus waste generation provided to us from annual billing statements.

### *5.3.2 Results and Discussion*

The first phase of the waste analysis compared the monthly recycling and trash amounts by building type. Figure 16 shows that Admin buildings created the most trash per square foot, as well as the most improperly placed recyclables and the most total solid waste per square foot. Heavy Research produces the least amount of solid waste per square foot, but the distribution of trash, incorrectly sorted recyclables and correctly sorted recyclables are almost equal. Ideally, the amount of correctly sorted recyclables would be larger than the amount of trash and incorrectly sorted recyclables, though some types of buildings may inevitably generate more non-recyclable waste. Light Research shows the highest amount of correctly sorted recyclables, but also a relatively significant amount of incorrectly sorted recyclables. As stated above, the Admin and Light Research buildings' data is also the most comprehensive because it was taken from 3 different buildings per category; the Heavy Research building's waste data were taken from only one building.

In the next phase, we compared estimated and actual annual campus recycling, trash, and solid waste totals to actual annual campus recycling, trash, and solid waste totals. These totals were significantly different (See Table 5).

**Figure 16: Breakdown of Trash and Recycling Disposal per Square Foot**




The actual recycling amount is about 8 times larger than the estimated recycling amount. One reason for the large difference could be that the building waste audits do not include construction recycling. Because waste amounts are based on weights (as opposed to volume), construction recycling, which includes large, heavy items, has significant potential influence over the campus totals.

**Table 5: Comparison of Estimated and Actual Campus Recycling, Trash, and Solid Waste Totals**

| | Recycling | Trash | Solid Waste |
|---|---|---|---|
| **Estimated Annual Total (tons)** | 412.1 | 1,396.2 | 1,808.3 |
| **Actual Annual Total (tons)** | 3,235.2 | 2,731.2 | 5,966.4 |
| **Difference** | 2,823.1 | 1,335.0 | 4,158.1 |

Another reason for the large difference between estimated and actual waste/recycling totals is that much of the campus waste and recycling is disposed of in outdoor bins, but waste audit data is specific to bins inside buildings. For example, waste disposed in the Associated Students (AS) solid waste clusters are not included in the estimated annual recycling total, but these amounts greatly affect both the total weights of trash and recycling and the recycling diversion rate. For our purposes, diversion rate is defined as the percentage of solid waste diverted from landfills to go to recycling centers.

In addition, the actual annual trash amount is larger than the estimated annual trash amount. This difference could be due to trash from construction projects and trash from housing and residential facilities, which may differ due to the behavior of the building occupants.

Also, the actual annual solid waste amount is simply the total of the actual trash and recycling amounts. Thus, the difference between estimated and actual solid waste is simply the combination of the differences between estimated and actual recycling and trash.

### *5.3.2 Limitations of Waste Data Analysis*

The waste analysis is limited by the amount of data; waste audit data was only available for seven campus buildings. In addition, waste audits only cover one day of solid waste generation. Furthermore, waste audit data only comes from the "built environment" of campus, and does not include data from construction areas or outdoor open space on campus, such as walkways and outdoor eating areas.

## 5.4 Discussion of Results

In spite of their limitations, the results from the analyses can be used in various ways. First of all, campus managers can use the analysis of normalized electricity and water usage and solid waste generation by building type to identify buildings that are poor performers in relation to other buildings of the same type. (In this case, poor performance is high electricity or water usage or high levels of solid waste generation.) These buildings may be appropriate for future retrofit projects, education programs to modify occupant behavior, or reassignment of the building to another building type.

For example, the Associated Students Recycling Program has a line item in their program budget for outreach and education. Based on the results of our analysis, the outreach and education efforts could be directed towards the Admin buildings, since these structures generate more solid waste per square foot than the Light Research and Heavy Research Buildings.

The next chapter provides a more concrete list of recommendations, based on the results of the analysis and our experience creating and implementing the ESMS. Future uses of the ESMS and new research directions are also explored.

# Chapter Six: Recommendations and Discussion

## 6.1 Tracking and Monitoring Recommendations

1. *Create a data tracking system for the campus that includes methods to consistently and reliably obtain data.*

    a. *Install water and electricity meters that measure flow volumes, not flow rates, on all campus buildings.*
    b. *Connect all major buildings' electricity meters to Itron.*
    c. *Create an ongoing schedule for building waste audits, including auditing of nearby outdoor recycling bins.*
    d. *Develop similar protocols for collecting data on other indicators of high priority.*

Lacking a baseline by building, or even good estimates for building types, we recommend that the University improve the current tracking and monitoring of environmental sustainability data. The current tracking systems are inadequate for helping the University monitor progress towards sustainability goals. For example, the water meters that are connected to the Itron system have a wide range of variability. Because these meters track flow rates intermittently (as opposed to the actual, constant flow volume), they are not sufficiently accurate. At least one meter is unreliable, as it records negative water use values for one building. We recommend that all new water and electricity meters record flow volumes, as these types of meters are more accurate and consistent.

Although electricity data is available for many of the buildings on campus, many buildings' meters are not connected to Itron. Adding connections will assist the campus energy team to better understand energy use in campus buildings. Also, most campus buildings have not been audited for trash and recycling generation amounts. We recommend that all major buildings be audited at least once in the next year, with student volunteers and interns working with campus academic programs in sustainability. These audits will create a useful baseline for performance. Furthermore, auditing of outdoor recycling and trash receptacles will allow the campus managers to better understand waste disposal practices and recycling diversion rates. Finally, other protocols for indicator tracking should be developed as necessary. For example, outdoor campus potable water usage is not being measured, but it could represent a significant amount of the potable water used on campus.

We recognize that these recommendations have a cost to the University. Facilities Management has considered adding meters and connecting the meters to Itron; meanwhile, the cost of connecting all the existing water and electricity meters to Itron has been estimated at $200,000. However, we recommend that a portion of buildings be connected to the Itron system each year, as funds become available. Priorities would be in building types with the greatest uncertainty or variability and therefore the greatest opportunities for improvement.

2. *Develop and implement a comprehensive and central method to store data, such as a shared folder with limited permissions or a central person who inputs/records data.*

The second recommendation addresses the current decentralized and uncoordinated nature of the sustainability programs and initiatives on campus. By creating a central storehouse for the data, campus sustainability experts and other interested parties might more easily be able to collaborate on new projects. In addition, a central database will also assist the Sustainability Manager in developing annual sustainability reports. The ESMS prototype is a starting point for developing a central data collection and storage protocol.

## 6.2 Management Recommendations

1. *Find the "low-hanging fruit" by identifying buildings that have the potential to achieve higher performance, based on normalized analysis by building type.*

The building type classification scheme provides a useful framework for analyzing the sustainability performance of campus buildings. Using the data we have collected, the University can identify buildings that are performing more poorly, on a normalized basis, than other buildings of the same type. These are potential buildings for conservation projects, in which the University may be able to find "low hanging fruit," or easily implemented low cost projects that could increase sustainability performance.

An example is the solid waste analysis facilitated by the ESMS. We found in our analysis that Admin buildings generate more solid waste (trash and recycling) per square foot than the Light and Heavy Research buildings. Focusing recycling education efforts on the Admin buildings that generate the most solid waste per square foot, based on waste audit results (as recommended in Section 6.1), could potentially lead to improved performance and even cost savings.

2. *Reconsider the building classification scheme, especially for Administrative buildings. Ensure that buildings are classified properly with respect to sustainability indicators.*

Although the building classification scheme provides a useful framework for analysis, there were several inconsistencies in how buildings are classified. In particular, the category of "Administrative" contains a variety of buildings, including some with laboratories, the Recreation Center (fitness center), the University Center (student center), and many buildings with other varying uses. We recommend that the “Administrative” building type be divided further, based on space usage within each building. See Appendix 3 for more detailed options.

Finally, some of the buildings appear to be classified incorrectly. We recommend that Facilities Management rework the building classification scheme so that it is relevant to sustainability indicators and reclassify all buildings accordingly. This will become more critical if Facilities Management begins charging departments for services based on building type, such as with energy budgets.

## 6.3 Education Recommendations

*1. Improve methods for sharing and disseminating information.*

Disseminating information to campus constituents about sustainability performance could increase overall awareness and ultimately improve campus sustainability performance. In addition, innovative opportunities for reducing environmental impacts could be found through new collaboration efforts or best practices sharing across campus. Many buildings now have separate sustainability efforts; improved communication between different groups’ efforts and campus-wide sustainability performance could prove useful to the many sustainability “change agents.”

One possibility for increasing the dissemination of information is installing centrally-located interactive kiosks for campus users and visitors. The UCSB Sustainability Manager has explored the option of installing three touch-screen kiosks on campus at highly-trafficked areas to improve sustainability awareness.

A less costly option is to publish maps and other sustainability data on the Campus Sustainability website and in the annual Sustainability Report. The ESMS prototype could easily create maps, charts and graphs, and other visual aids to better link campus users to their environmental impacts.

## 6.4 Specific Recommendations for ESMS Database Implementation

We also recommend several additional near-term uses for the prototype ESMS Database:

- Continue to create baseline measurements for energy, water, and trash/recycling, which are necessary to obtain LEED certification.
- Identify buildings with large opportunities to reduce electricity and water consumption and solid waste production.
- Analyze sustainability performance of campus built environment in relation to specific factors, such as the number of people regularly using each building.
- Track sustainability projects and the resulting improvements in campus sustainability indicator performance.
- Create energy budgets by building or department to help enforce energy conservation.
- Add documentation of policy changes or building-specific technological upgrades to investigate sustainability performance improvements in response to each change.
- Expand the ESMS to compare future sustainability projects, including each project's expected cost savings and potential improvements in sustainability indicator performance. An example is a comparison of the costs and benefits of adding solar panels vs. adding rooftop gardens on a building's roof.

- Perform new analyses related to spatial aspects of the campus, which are more practical to analyze with spatial GIS tools.

## 6.5 Areas for Future Research

Collecting sustainability-related data and building the ESMS led us to consider one main research question: What frequency of data collection and reporting of sustainability indicators at a building level will motivate individuals, groups, or departments to modify their behavior or technologies?

Whereas our study has begun to provide the level of spatial data needed to potentially understand the link between information and improved sustainability performance, we have not attempted to conduct experiments to verify that performance changes could be related to increased knowledge. (See Peterson et al, 2007, for an example of this type of research.)

For example, we do not know how often departments within a building might want to know the overall electricity usage of the building if that department is attempting to reduce its individual electricity consumption. If the department were to reduce electricity consumption, then appropriate, timely feedback would be important for the occupants to realize that their conservation efforts were fruitful. However, the necessary frequency of monitoring and reporting indicators is unknown and probably not the same for all indicators.

## 6.6 Summary

In summary, the prototype ESMS offers basic organization and visualization of information at a level that is more likely to resonate with members of the UCSB campus. We believe this tool will help UCSB in its endeavor to move to the forefront of universities embracing sustainability.

# References


*ESRI Shapefile Technical Description* (1998, July). Retrieved December 12, 2006 from: http://www.esri.com/library/whitepapers/pdfs/shapefile.pdf

Itron Customer Success Story: University of California, Santa Barbara. (2005, April). Retrieved February 9, 2007 from: http://energy.ucsb.edu/_client/pdf/news/ItronArticle.pdf

Jain, R. (2005). Sustainability: metrics, specific indicators, and preference index. *Clean Technology Environmental Policy*, 7, 71-72.

Jin, X. & High, K. (2004). A new conceptual hierarchy for identifying environmental sustainability metrics. *Environmental Progress*, 23, 291-301.

Judd, D. (1996). GIS capabilities for strategic environmental management. *Earth Observation Magazine*. Retrieved May 1, 2006 from: http://www.eomonline.com/Common/Archives/Aug96/judd.htm

Levett, R. (1998). Sustainability indicators – integrating quality of life and environmental protection. *Journal of the Royal Statistical Society Series A – Statistics in Society*, 161, 291-302.

Petersen, J. E., Shunturov, V., Janda, K, Platt, G. and K. Weinberger. (2007.) Dormitory residents reduce electricity consumption when exposed to real-time visual feedback and incentives. *International Journal of Sustainability in Higher Education* 8: 16 - 33.

Rapport, D. J., & Singh, A. (2006). An EcoHealth-based framework for state of environment reporting. *Ecological Indicators*, 6, 409-428.

Roman, S. (2002). *Access database design & programming, 3rd Edition*. Sebastopol: O'Reilly & Associates, Inc.

Shea, C.P. (1998). GIS-Based sustainability indicators: helping people to see linkages. *Florida Sustainable Communities Newsletter*. Retrieved May 22, 2006 from: http://www.myflorida.com/fdi/fscc/news/state/gis.htm

*Talloires Declaration: University Presidents for a Sustainable Future.* Retrieved January 8, 2007 from: http://www.iisd.org/educate/declarat/talloire.htm

*Stanford Energy Conservation Incentive Program.* Retrieved March 12, 2007 from: http://facilities.stanford.edu/conservation/ECIP/SU_Utilities_Energy_Conserv_Incentive_Prgrm.htm

*Sustainability Indicators for UCSB.* Retrieved May 25, 2006 from: http://sustainability.ucsb.edu/plan/, "Indicators Spreadsheet."

*United States Environmental Protection Agency. How do land use and development practices affect the environment?* Retrieved May 8, 2007 from: *http://www.epa.gov/greenacres/landuse.html*

*University of California, Santa Barbara. Draft Campus Sustainability Plan.* (2007, May). Retrieved May 28, 2007 from: *http://sustainability.ucsb.edu/_client/pdf/plan/new_05_22_07/Sustainability%20Plan%2005-16-07.pdf*

World Commission on Environment and Development. (1987). *Our common future.* Oxford: Oxford University Press.

# Appendix One: Sustainability Indicators at UCSB

| Change Agent Group | Indicator or Metric |
|---|---|
| Academics and Research | Percentage of faculty population capable of finding resources on bringing sustainability into curriculum |
| Academics and Research | Percentage of students capable of finding courses on sustainability |
| Academics and Research | Percentage of students capable of finding resources on jobs and internships in sustainability |
| Built Environment | Square footage of LEED certified buildings |
| Built Environment | Square footage of LEED buildings as a percentage of total square footage of buildings on campus |
| Energy | Total electricity use (in kWh) |
| Energy | kWh per square foot of building space |
| Energy | Total natural gas use in therms |
| Energy | Gas use per square foot of building space |
| Energy | Total $CO_2$ emissions per calendar year (in metric tons) |
| Food/University Center | Total weight of food composted (in pounds) |
| Food/University Center | Percentage of food waste composted |
| Food/University Center | Total weight of bio-based plasticware |
| Food/University Center | Percentage of total plasticware that is bio-based (by weight) |
| Food/University Center | Percentage of organic produce |
| Food/University Center | Percentage of organic dairy products |
| Food/University Center | Percentage of organic meat, fish, and poultry |

| Change Agent Group | Indicator or Metric |
|---|---|
| Food/Housing and Residential Services | Total weight of composted material (in pounds) |
| Food/Housing and Residential Services | Percentage of total waste composted |
| Food/Housing and Residential Services | Total weight of bio-based plasticware |
| Food/Housing and Residential Services | Percentage of total plasticware that is bio-based (by weight) |
| Food/Housing and Residential Services | Percentage of organic produce |
| Food/Housing and Residential Services | Percentage of organic dairy products |
| Food/Housing and Residential Services | Percentage of organic meat, fish, and poultry |
| Landscape | Percentage of landscape irrigated with reclaimed water |
| Landscape | Amount of pesticides used (in gallons) |
| Landscape | Percentage of pesticide used that is non-toxic |
| Landscape | Percentage of campus grounds with native or xeriphytic plantings |
| Procurement | Percentage of recycled paper products used |
| Procurement | Percentage of appliances purchased that are Energy Star certified |
| Transportation | Total number of alternative fuel cars |
| Transportation | Percentage of entire fleet that is alternatively fueled |
| Transportation | Percentage of faculty/staff commuting by alternative transportation |
| Transportation | Percentage of students commuting by alternative transportation |

| Change Agent Group | Indicator or Metric |
|---|---|
| Waste | Total waste production (in tons) |
| Waste | Recycled solid waste (in tons) |
| Waste | Total percentage of material recycled |
| Water | Total potable water use (in hundreds of cubic feet) |
| Water | Total reclaimed water use (in hundreds of cubic feet) |
| Water | Reclaimed water use as a percentage of total water use |
| Water | Area of non-permeable surfaces (in square feet) |

# Appendix Two: Database Entities and Attributes

| Building Data | | | |
|---|---|---|---|
| **Attribute** | **Type** | **Domain** | **Required?** |
| Building Code | Integer | Three digit number | Required |
| Building Name | Text | Free text | Required |
| Number Floors | Integer | None | Required |
| Address | Text | Free Text | Required |
| OGSF | Integer | None | Required |
| Basic Area | Integer | None | Required |
| Covered Area | Integer | None | Required |

| Building Usage | | | |
|---|---|---|---|
| **Attribute** | **Type** | **Domain** | **Required?** |
| Building Code | Integer | Limited to building codes in Building Data table | Required |
| Department Code | Integer | Limited to department codes in Department table | Required |
| Use Code | Integer | Limited to Use Codes in Room Use Definitions Table | Required |
| Number of Rooms | Integer | None | Required |
| Assignable Area | Integer | None | Required |

| Departments | | | |
|---|---|---|---|
| **Attribute** | **Type** | **Domain** | **Required?** |
| Department Code | Autonumber | None | Required |
| Department Name | Text | Free Text | Required |
| Main Office Location | Text | Free Text | Required |

| Room Use Definitions | | | |
|---|---|---|---|
| **Attribute** | **Type** | **Domain** | **Required?** |
| Use Code | Integer | Between 0 and 999 | Required |
| Use Name | Text | Free text | Required |

| Facilities Building Types | | | |
|---|---|---|---|
| **Attribute** | **Type** | **Domain** | **Required?** |
| Building Code | Integer | Limited to building codes in Building Data table | Required |
| Building Type | Text | Free text | Required |

| Electricity Building IDs | | | |
|---|---|---|---|
| **Attribute** | **Type** | **Domain** | **Required?** |
| Building Code | Integer | Limited to building codes in Building Data table | Required |
| Electricity Meter ID | Integer | none | Required |
| Meter Type | Text | Free text | Required |
| Measurement Interval | Integer | None | Optional |

| Water Building IDs | | | |
|---|---|---|---|
| **Attribute** | **Type** | **Domain** | **Required?** |
| Building Code | Integer | Limited to building codes in Building Data table | Required |
| Water Meter ID | Integer | none | Required |
| Meter Type | Text | Free text | Required |
| Measurement Interval | Integer | None | Optional |

| Electricity Use | | | |
|---|---|---|---|
| **Attribute** | **Type** | **Domain** | **Required?** |
| Electricity Meter ID | Integer | List of Electricity IDs in Electricity Building IDs table | required |
| Date | Date | mm/dd/yyyy | required |
| Daily Electricity Use | Integer | none | optional |

| Water Use | | | |
|---|---|---|---|
| **Attribute** | **Type** | **Domain** | **Required?** |
| Water Meter ID | Integer | List of Water IDs in Water Building IDs table | required |
| Date | Date | mm/dd/yyyy | required |
| Daily Water Use | Integer | none | optional |

| Recycling | | | |
|---|---|---|---|
| **Attribute** | **Type** | **Domain** | **Required?** |
| Building Number | Integer | Limited to building codes in Building Data table | required |
| Date | Date | mm/dd/yyyy | required |
| Daily Trash Generation | Integer | none | optional |
| Daily Recycling Generation | Integer | none | optional |
| Daily Recycling Found in Trash | Integer | none | optional |
| Daily Trash Found in Recycling | Integer | none | optional |

| Projects by Building | | | |
|---|---|---|---|
| **Attribute** | **Type** | **Domain** | **Required?** |
| Building Number | Integer | Limited to building codes in Building Data table | required |
| Project Code | Integer | Limited to project codes in Sustainability Project Table | Required |
| Project Leader | Text | Limited to PLid's in Project Leader table | Required |
| Year Begun | Integer | Four digit number (yyyy) | Optional |
| Year Completed | Integer | Four digit number (yyyy) | Optional |
| Description | Memo | None | Optional |
| Cost | Integer | Dollar Amount | Optional |
| ROI | Integer | None | Optional |
| kWh Saved/Year | Integer | None | Optional |
| $ Saved/Year | Integer | None | Optional |
| CO2 lbs Saved/Year | Integer | None | Optional |
| SOx Saved/Year | Integer | None | Optional |
| NOx/Saved/Year | Integer | None | Optional |

| Sustainability Projects | | | |
|---|---|---|---|
| **Attribute** | **Type** | **Domain** | **Required?** |
| Project Code | Autonumber | none | required |
| Project Name | Text | Free text | required |

| Project Leaders | | | |
|---|---|---|---|
| **Attribute** | **Type** | **Domain** | **Required?** |
| PLid | Autonumber | none | Required |
| Leader Last Name | Text | Free text | Required |
| Leader First Name | Text | Free text | Required |
| Title | Text | Free text | Optional |
| Department | Text | Free Text | Required |
| Phone Number | Text | 10 digit phone number | Optional |
| Extension | Integer | None | Optional |
| Email Address | Text | Free text | Optional |

# Appendix Three:
# Suggested Building Classification Scheme

The current building type classification scheme includes three broad categories: Heavy Research, Light Research, and Administrative. The two research categories are straight forward, but adhere to vague definitions based on the annual kWh/sq foot of electricity usage and UCSB personnel's knowledge about the buildings and their space usages. The Administrative category, on the other hand, is neither straightforward nor concrete in definition and includes many buildings with special uses that do not fall into either research category.

Such a broad classification scheme loses accuracy and validity when analyzing indicator data. For example, the Recreation Center is the main exercise facility on campus that includes several exercise rooms housing electric and manual machines, as well as two pools, exercise fields, locker rooms, etc. This facility requires a significant amount of energy and water to maintain the building use. Currently it is classified as Administrative.

Furthermore, defining specific building type categories based on a transparent and accountable approach will add value and robustness to indicator data and analysis. To address the flaws in the current system, we suggest the following improvements.

**Increase the number of building type categories**
Accommodating over 20,000 faculty, staff, and students, the extensive campus has a large variety of building uses, including exercise and dining facilities, residences, labs, classrooms, theatres, and offices. Therefore, 3 building categories are not enough to accurately and dependably categorize campus buildings.

We recommend breaking the Administrative category into Basic Administrative and Special Use Administrative. Another option is to add specific categories based on space usage and size, such as Housing, Dining, Large Lecture Halls/Theaters, etc.

**Base building type categories on substantial, detailed definitions**

The current classification scheme is based on vague definitions involving system knowledge about the campus infrastructure among many experienced UCSB personnel. To better define the categories, we suggest the following classification scheme:

| **Building Type Category** | **Definition/Criteria** | **Examples of Buildings** |
|---|---|---|
| Basic Administrative | Mostly classrooms and offices | Webb Hall, Girvetz, Buchanan |
| Special Use Administrative | Theatre or lecture hall that holds 300+ people, library, recreation areas, medical center | Davidson Library, Campbell Hall, RecCen I and II |
| Light Research | Low fume hood density | Bren, Marine Biology, Psychology |
| Heavy Research | High fume hood density | Biology 2, Chemistry, Engineering Sciences, |
| Housing and Residential | Dorms, etc. | Anacapa, Santa Cruz |
| Parking Structures | Enclosed, multi-level parking area | Lot 10, Mesa Parking Structure |