

## **Using GIS as a Bridge**

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### **Abstract**

The University of St. Thomas and the Buffalo Bayou Partnership (an intergovernmental organization with funding from Harris County and the City of Houston, TX) have formed a strategic alliance to promote “wise-use” development of the areas surrounding the Buffalo Bayou. The Buffalo Bayou flows through the heart of Houston, TX, and is impacted by many surrounding activities. To facilitate the relationship between the University and the Partnership, GIS has served as a bridge between the organizations. Using GIS and GPS, the two organizations have been able to exchange information, discuss research and development projects, perform analyses, and plan for future research programs. The creation of new map and data files and the ability to quickly transfer these using the Internet has served a synergistic function, greatly enhancing what both organizations would have been able to accomplish alone. Although GIS does not define the relationship, it is greatly enhanced by it.

### **Introduction**

#### UST-BBP Interaction

In the spring of 2003, the Office of Volunteer Opportunities at the University of St. Thomas in Houston, Texas made a phone call to the department of environmental studies. They had made contact with the Buffalo Bayou Partnership, a quasi-governmental/non-profit organization whose mission is wise use and development along the Buffalo Bayou (Figure 1). The Buffalo Bayou Partnership was looking for volunteers to help in clean up activities along the Bayou and, perhaps student research projects involving the department's students.

Dr. Ravi Srinivas, then chair of the department, met with Aaron Tuley, then director of planning for the Partnership. The two of them began a dialogue along the lines of how the department and Partnership could benefit from an arrangement that would link the two entities together. The result of this discussion was a Memorandum of Understanding, which established the department of environmental studies, and the University of St. Thomas, as a primary partner with the Buffalo Bayou Partnership involving projects along the entire extent of their area of influence along the Bayou.

In the fall semester of 2003, the first students began working in an area known as the Tapley Tributary. This area had been landscaped by Charles Tapley in 1975, and had since become overgrown and covered with overbank deposits from frequent flooding. Students from the department and introductory courses attended monthly clean up activities to remove invasive species, plant native species, and clean up trash. A natural seep in the area provided a constant, slow flow of water through the tributary into the Buffalo Bayou. The Partnership wished to improve the seep and “wet” areas by constructing a small set of wetland ponds in the upper regions of the tributary.

Students from the department’s GIS class conducted a study of the elevations and substrate conditions at the location. Using the results of this study, the Partnership enlisted the aid of several education, scouting and volunteer groups to convert a moist swale into a self-sustaining wetland.

In the spring of 2004, Brian Fredieu, an environmental science student began a study of water quality in the West Sector (Figure 2) of the Bayou. The Clean Water Act mandates that cities consider the quality of their stormwater inputs into the natural waterways as part of the National Pollutant Discharge Elimination System as they affect water quality in their waterways.

Part of the mandate for the Buffalo Bayou Partnership from the City of Houston and Harris County (both governmental sponsors of the Partnership) is to improve water quality along the Bayou. Towards that goal, the Partnership has purchased the “Mighty Tidy,” a skimmer boat that removes floatable trash from the Bayou (Figure 3). Brian and Dr. Maury Harris, current chair and professor of environmental studies at UST, used aerial photographs and stormwater system files from the City of Houston Planning Department and the software program ArcView to determine the significant inputs into the Bayou. From this information, Brian found six locations, four stormwater outfalls and two tributaries of the Bayou that might provide significant input (Figure 4). His study took place over a year, and included water sampling and GIS analysis of the stormsheds. Using the ESRI Census files, Brian also conducted a demographic survey of the six areas.

In the fall of 2004, Dr. Bill Fenner, adjunct professor of environmental studies at UST, began an erosion study along the Downtown and West Sectors of the Bayou. In several places, erosion by the Bayou’s waters is threatening infrastructure of the hiking/biking trail. This study is being conducted to determine the relationship between stream morphology and erosion profiles along the Bayou. Using this information, the Bayou Partnership, working with the City of Houston Parks Department will move the trails further away from the banks of the Bayou.

Also in the fall of 2004, Dr. Harris was engaged by the Partnership, Trust for Public Land, and the City of Houston Parks Department to prepare the master plan for the Buffalo Bend Nature Park using ArcView, on the east side of Houston (Figure 5, 6). Senator Kay Bailey Hutchison and Congressman Gene Green helped to obtain NOAA funding for the location to turn it into a nature park. The park is 10.5 acres and will contain two wetlands, hiking trails, a

neighborhood art park, Bayou access points for hikers and canoe/kayak access (Figure 7). This project is currently out for bid and should begin construction in the fall of 2005.

Beginning in the summer of 2005, the department of environmental studies at UST was awarded funding for a field, research project at the Greentree Reservoir area along the north bank of the Buffalo Bayou in the East Sector (Figure 8). The study has been funded by George Mitchell, owner of Mitchell Energy and developer of the Woodlands, master-planned community north of Houston. This study will provide a baseline study of the area so that the Partnership can begin a conversion project to turn an overgrown swale of the Bayou into a three pond, reservoir area for waterfowl. The students will collect chemical, biological, ecological, and environmental data, which will be prepared, analyzed, and presented using GIS.

#### Buffalo Bayou Partnership

In 1984, Houston Mayor Kathy Whitmire appointed a task force to study the Buffalo Bayou and develop a realistic strategy for its redevelopment. In 1986, the City of Houston and Harris County created the Buffalo Bayou Partnership, a coalition of civic, environmental, governmental and business representatives. The director nominees are confirmed by the Mayor of Houston and the Harris County Judge. The 501 (c) (3) non-profit corporation is responsible for developing and facilitating improvements to the Buffalo Bayou Greenway system.

The Partnership board and staff continue to work on projects and initiatives associated with the *Buffalo Bayou and Beyond* (Master Plan) to redevelop the city's historic waterway into a pedestrian-oriented waterfront district (Figure 9, 10). The Partnership is involved in land and right-of-way acquisition along the Bayou for the development of parks and hiking/biking trails and habitat restoration projects throughout the Bayou corridor.

To achieve these and other goals, the Partnership has cultivated relationships with various local organizations and groups. At least once each month, a volunteer day is set to allow the local community to engage in activities that both promote the Bayou, as well as help to clean up the Bayou area. Tree plantings, trash pick-ups, wetland construction and plantings, trail maintenance, removal of invasive species and tangling/choking vines, and water clean ups are examples of these activities.

One of the Buffalo Bayou Partnership's goals is to integrate the Buffalo Bayou into a county-wide, area-wide regional eco-park (Figure 11). The bayou systems of Harris County are extensive and were originally redesigned to convey stormwater and prevent or lessen flooding in the region. A regional environmental awakening, lead by the Buffalo Bayou Partnership and the Bayou Preservation Association, has lead to development efforts throughout the region to turn the bayou systems into a system of public parks and recreation areas.

#### Environmental Studies at the University of St. Thomas

The department of environmental studies at UST was formed in 1992. Dr. Maury Harris, the first and current chair of the department, was hired to develop an environmental curriculum in the liberal arts tradition, emphasizing the Catholic Church's teachings on environmental stewardship and ethical practices. The department was founded with a heavy field orientation, with almost all of the classes having some experiential learning component.

While preparing the proposal for the department, the University decided to construct a new science building to house chemistry, physics, and the new department of environmental studies. A departmental computer laboratory was part of the request prepared by the environmental program. Until that time, all students were forced to use a central laboratory. The University, at first, balked at supporting a separate, departmental computer lab. At a meeting of

the Geological Society of America, Dr. Harris saw a presentation on the use of GIS for geological investigation. The decision was made that GIS would become an important component of the curriculum of the department, and that GIS would be used in all of the courses where appropriate. With a new understanding the curricular importance of the computer lab, the University agreed to its inclusion in the building's design. At the time the building was finished, the environmental studies department was the first to have an internal intranet system, internal e-mail, a file server, and with 4.5 gigabytes of memory, the department had over twice the storage capacity of the University's mainframe.

Because of the field orientation of the original program degree plans, and the geology background of Dr. Harris, students needed to be able to display the data that they collected within a geographic framework. GIS was the perfect solution to what would have been boring, static statistical charts and graphs for data display (Figure 12).

Dr. Ravi Srinivas was hired soon after the establishment of the degree programs. With the addition of Dr. Srinivas, and a number of adjunct and part-time faculty members, the department has evolved. Based upon an internal program study, and the report of an external reviewer, in 2005 the department has adopted an urban focus, with field work in the urban environment as an important part of this focus. To support this urban focus, the department has also begun requiring, of all of its majors, a second course in GIS.

### **Buffalo Bayou Partnership and GIS**

In the year 2000, the Buffalo Bayou Partnership began requesting proposals from landscape architect and engineering firms from across the county to develop a master plan for the Buffalo Bayou, the primary water transport system through Houston, TX. Because most of the natural conditions of the bayou were lost over time to industrialization and urbanization, a key component needing to be incorporated into the master plan was the reestablishment of natural features such as oxbows, meanders and wetlands and re-structured riparian zones to recreate

historical conditions and a more ecologically significant system that integrates flood management, species habitat and access throughout the corridor. In 2002, the final document, the *Buffalo Bayou and Beyond Master Plan* was released. At the time of its creation, the Buffalo Bayou Partnership had no in house GIS capabilities so the consultants were used to create maps in ArcView. Primarily these maps consisted of existing land use information and overlays to that land use to present the vision for the future of the Buffalo Bayou.

A priority of the plan was to utilize the existing greenspace as efficiently as possible to incorporate features of each need. To oversee this effort, the BBP developed a conservation division in 2003. The initial project within the division was to operate and administer a skimmer boat that removes floatable litter and debris from the surface of the waterway. The skimmer boat traverses over 40 miles of the Buffalo Bayou, the Port of Houston Ship Channel, and 8 major tributaries that feed into the waterway. After the first few months, it was quickly realized that the only way to monitor and track the vessel was to incorporate GIS. Working in Arc 8.x, and an online tracking device the operation has gathered spatial information on the boat's movements and collection within twelve different zones of the patrolled waters (Figure 13). By doing this we are able to determine the most efficient methods to predict the movement of floatables, and collect floatables from the waterway and its banks. GIS has also enabled us to locate natural collection areas, monitor which bayous, tributaries and stormwater outfalls that are most likely releasing large quantities of material, times of release related to weather conditions and Army Corps of Engineer dam releases.

With success of the use of GIS and GPS with the skimmer boat, we mapped the existing trail system, park infrastructure such as benches, trash receptacles, parking, watering systems, public art, as well as types of maintenance within parks along the bayou. Importing the data collected from the field has enabled us to understand the percentage of space for conservation and park and trail maps throughout the city that are on the bayou.

Our next effort with GIS came when we began the Buffalo Bayou Park Vegetation Management Plan. In the plan we mapped out all the ecologically significant conditions, types of management and maintenance needed in these areas, plant lists for bottomland hardwood, wetland, wildflower, prairie and riparian zones of the park. GIS was essential to the development and efficient approach to this work (Figures 14, 15, 16). We also use GIS to design new trails along the bayou where we incorporate plantings of native material, groupings for

specific ecotypes etc. An example of this is on the east end trail, located on the Houston's east side, a culturally diverse network of neighborhoods and industry. BBP UST and the Houston Audubon Society have just entered into a partnership to survey birds along the system and how they utilize (or avoid) natural, urban and industrial conditions along the bayou.

## **Environmental Studies and GIS**

### **Coursework**

The original degree plan for the department listed a single GIS course called "Introduction to Environmental GIS." This title was a compromise made between the departments of environmental studies and computer science because the computer science department was concerned that someone else would be allowed to teach computer science classes. Under the original agreement, only environmental studies and environmental science students would be able to take the GIS class.

In 1994, the first GIS course was offered by the department. Unfortunately, in 1994 the data sets that were available were usually large-scale resolution files and the most readily available source of data was the CD-ROM included with ArcView (Figure 17). The 1:1,000,000 USA file size was a problem for early computers (in terms of memory and hard drive space), so we were only able to store a copy of the file on the file server, located across the hall from the computer lab. Transferring the file, or even opening the file over the intranet, took almost 12 hours. Students would begin the process at the end of the day, and would return the next morning to use the file within ArcView.

The University has purchased computers, on average, every two years for the environmental studies departmental computer laboratory so that the department can keep up with



the computing requirements for the current versions of GIS software. The introduction to environmental GIS laboratory has been offered once a year for the last 11 years.

In 2000, the department added an additional, advanced GIS course to the curriculum. Students in this course must take three courses online from the ESRI campus ([campus.esri.com](http://campus.esri.com)), including 3-D Analyst and Spatial Analyst. The third course is a specialty course focusing upon the student's area of interest. The specialty courses that have been by taken by students, to this point, includes Conservation GIS, Spatial Hydrology and Urban Planning. The three online courses account for 60% of the course grade (the quizzes taken online may be retaken to make a higher grade as often as desired). After they online courses are completed, students must prepare a project portfolio using the procedures learned from their specialty course. This project is worth 40% of the course grade. Failure to complete the project, along with a prefect 100% on all of the quizzes in each of the courses would result in a grade of "D" for the course. The final project is the "quality check" for the University on the students' capabilities and learning.

Students have also taken a special topics course using GIS within the program. Some employers want to see 9 hours of GIS-related course work and students have asked for an additional course. Although the requests have been limited, students have conducted demographic studies related to businesses and environmental hazards using ArcView.

Students in other classes have used ArcView and GIS. Students in the ecology for environmental management course have been using GIS and ArcView for the preparation of maps for their course projects. In this class, students must prepare a distribution map for selected ecosystems using ArcView. When the class goes on field trips, we prepare maps for the study area using GIS and students display their results of field studies on ArcView maps. One of our most important preprofessional courses, environmental investigations, uses GIS and ArcView for

the display of statistical analyses. Students must prepare a proposal for the study of an environmental problem and make a presentation of their results to the class. Students use GIS to prepare their proposals and to prepare maps for their PowerPoint presentations.

### Thesis and Research

Students graduating with the Bachelor of Science degree from the environmental studies program must complete a research project for graduation. For the last seven years, all of these students have used GIS for some portion of their research work. Austin Taylor prepared an investigation of erosion and subsidence at Galveston Island State Park (Figure 18). Austin's work involved taking core samples, as well as the analysis of aerial photographs. Austin used Image Analysis to compare aerial photographs from 1964 through 2000. Based upon his study and the use of Image Analysis, Austin was able to determine the erosion and subsidence rates in the park and complete his work (Figure 19).

Olga DeBakey, daughter of Dr. Michael DeBakey, studied the potential eutrophication of Lake Raven, south of Huntsville, Texas (Figure 20). Olga used ArcView to locate sample locations on the lake and display her data in the finished thesis. Brian Fredieu, as already stated, completed his Bachelor of Science thesis work on a study of potential impacts on water quality along the Bayou (Figure 21). Brian used the shape files from a variety of sources to select the sample locations, display research results, and conduct a demographic study of the area (Figure 22).

In the summer of 2005, Anthony Nocella will be working with Dr. Harris on a demographic project to completely characterize the Buffalo Bayou Impact Area within the city's inner loop (Figure 23). This study will be the most complete, to date, on the areas within the

loop, including downtown Houston. This work will be used by the Buffalo Bayou Partnership for future planning in the region.

### **Cooperative Work Between BBP and UST Using GIS**

The agreement between the Buffalo Bayou Partnership and the University of St. Thomas has grown beyond what was envisioned in the Memorandum of Understanding. With the new urban focus, the importance of the arrangement has afforded many opportunities for the students and faculty at the University that would have been impossible before. Alternately, the Buffalo Bayou Partnership has received help to an extent not possible before the agreement. By working with UST, the Partnership has developed ways to interact with other universities.

Joint projects conducted at the Tapley Tributary, the stormwater water quality study, the development of a master plan for the Buffalo Bayou Nature Park, the erosion pin study, and the Greentree Reservoir study, have all been made easier with the use of GIS by both organizations. Many times in the past, when the department of environmental studies has worked with another group, all of the GIS work has been done at the University. Other organizations either lack the funding for the equipment, or lack the personnel to work with GIS programs. The Buffalo Bayou Partnership's conservation division uses GIS in their work and GIS files have become more commonly traded between the two organizations than business cards.

#### **Tapley Tributary**

The Partnership also uses the faculty at UST as a resource for working with GIS. When data files do not project into the correct coordinates, or when an analytical method does not work, help is only a phone call (usually cell phone call) away. In this way, UST has worked as a "help center" for the Partnership in the preparation of maps and analyses conducted using

ArcView. In return, the Partnership has provided UST with access to shape and data files that were previously unavailable to them (or at least unknown). One set of files that has proved to have been of the greatest benefit, has been the availability of the 1-meter, aerial photographs of the Houston region. Using these files, students can now zoom in and determine the exact nature (residential, commercial, industrial) of any region in the city for analysis.

The West Sector (Figure 24) has been altered between Sabine and Shepherd and between Memorial Drive and Allen Parkway into a linear, urban parkway. Extensive landscaping of the area removed some of the riparian ecosystems, vital for the support of natural communities. Part of the work of the Conservation Division of the Partnership is to restore, where possible, original ecosystems in the area. The Master Plan for the Buffalo Bayou Partnership includes ecosystem restoration for the development of wildlife in the region, as well as wise-use development for human activities.

On the Tapley Tributary project, students collected soil samples and elevation data to determine the feasibility of turning the headwaters area into a wetland. This was one of the first major ecosystem restoration projects on the Buffalo Bayou by the Partnership. The locations for the soils samples, as well as delineation of the moist areas of the headwaters for Tapley Tributary, were gathered in the field using GPS devices. The GPS data was then used to construct maps, for planning by the Partnership. The data files made several trips back-and-forth between the organizations.

### Stormwater Quality Study

The City of Houston, as many major cities in the United States, is somewhat behind in the preparation of their NPDES studies for compliance with the Clean Water Act. One of the goals of the Buffalo Bayou Partnership is to improve the water quality in the Bayou. Scott

Barnes, director of conservation with the Partnership contacted UST about conducting a water quality study, looking at the influence of major sources of water as they enter into the Bayou. Brian Fredieu, a student of Dr. Harris', took on the study of four stormwater outfalls and two tributaries at they enter into the Bayou (Figure 25). The project was started using GIS files from the City of Houston Public Works Department representing the stormwater systems that empty in the Bayou. Four of these were selected, based upon the size of the stormsheds and the nature of the areas drained. Two tributaries, the Glenwood Tributary and White Oak Bayou, were also sampled for their influence on water quality (Figure 26).

The original files were first observed on the City of Houston's GIMS web site. Unfortunately these files were not available for viewing at a scale that was useful for the study. One unfortunate drawback of the wide use of the IMS systems is that governmental (and other) entities have made their files available for viewing (at a scale determined by them), but not for download. While IMS gives the producer of data more control over its display, it also takes away a degree of flexibility of others who might want to use the data.

Using ArcView, Dr. Harris used the files to determine the stormsheds for each outfall (Figure 27). Working with Scott Barnes, Dr. Harris selected four stormwater outfalls for sampling and Brian began work. Aerial photographs of the stormsheds and watersheds were used to determine the nature of each area. When the study was over, the data was analyzed and displayed using ArcView. Additionally, Brian used the available ESRI Census data files to characterize the populations of the regions. By now, copies of the resultant files reside on at least four computers, including machines at the Partnership office as well as those at UST.

## Buffalo Bend Nature Park

The Trust for Public Land, represented in Houston by Linda Shead, identified a piece of property on the city's east side for development as a nature center. They worked with Harris County Flood Control, Harris County Precinct 2 (Sylvia Garcia, Commissioner), and the Buffalo Bayou Partnership to acquire the funding for the property (Figure 28). Because of the arrangement between the Partnership and UST, Dr. Harris was asked to participate in discussions regarding the property. The majority source of funding for the project was the National Oceanic and Atmospheric Administration, with the understanding that the land would be turned into a nature park with connections to the Bayou.

Aerial photographs (available from the Texas Natural Resource Information Service), topographic files (from Harris County Flood Control, Tropical Allison Research Project), and pavement files (from the City of Houston) were used to prepare the initial study of the property (Figure 29). This property had been used to dispose of construction debris from the relocation of stormwater drains and service pipes below the streets. The topography of the property has been altered by subsequent activity on the property. In order to prepare the master plan documents for the location, students at UST were used to conduct a study of the property under the direction of Dr. Harris, Scott Barnes and Chariss York.

Elevation data, collected using survey instruments and GPS units by the UST students, was used to correct the topographic files available from Harris County Flood Control (Figure 30). The original files were based upon LIDAR imagery collected in the fall of 2002. Subsequent activities on the property had altered the original surface. Several working sessions between interested parties were conducted to determine the nature of the development of this

property into a nature center. Requirements, lists of wants and needs, as well as input from the local community, were used to construct an original plan for the property.

The first maps were constructed on printouts of aerial photographs. These were then transferred to GIS maps with the construction of new shapefiles. The topographic map files were altered to the new surface configuration, and then the files were again altered to indicate the new surface for the park. The alteration of files, many times, was facilitated by the use of GIS. At one meeting, Dr. Harris was asked if he could change several features of the map. The response was, “before GIS, the answer was no, but because we now use GIS, I will have it ready tomorrow.” Using the Internet, Dr. Harris and Scott Barnes were able to trade files and make several changes to the park plans over a period of months.

After the master plan for the park was established, a set of detailed plans with measurements of all park features was prepared. These measurements were facilitated by the use of ArcView and the measurement function. When the Trust for Public Land conducted a ceremonial event commemorating the transfer of the property to Harris County Precinct 2 Commissioner Sylvia Garcia, posters were prepared by UST using ArcView to show attendees the plans for the park.

### Erosion Pin Study

One way to bring the people of Houston to the Bayou is to give them something to do in the Bayou region. The Partnership has worked to provide a trail system along the entire range of the three sectors (West Sector, Downtown, East Sector). Eventually, these trails will extend from Shepherd Drive in the west to the Turning Basin in the east. A threat to the trail system is erosion along the banks of the Bayou, flooding when the Bayou is in flood stage, and sediment deposits after the flooding has receded. Dr. Bill Fenner, an adjunct professor at UST, is currently

conducting a study of the types and nature of erosion and deposition along the Bayou. The project involves the use of eighteen erosion pins (2' long pieces of rebar that are pounded into the bank at points of interest).

Locations for these pins were first established using aerial photographs and GIS files from the City of Houston. The data, as it is being collected, is being entered into the database files for use at the end of the study. Already, there have been some significant results in this study. One area involves the study of erosion problems that threaten to undermine the trail and wash out a bridge.

#### Greentree Reservoir

Scott Barnes and Charis s York asked the University of St. Thomas for help on a project that involved the construction of a reservoir from an area of old-growth trees which has been overgrown with weeds and invasive species. The University, and the environmental studies program, approached the George Mitchell family for funding to allow the department to purchase equipment and conduct research. Six students from the science departments at UST are currently working on a baseline study of the area. Their work will involve a study of the chemical, biological, ecological, and environmental parameters of the proposed location. The entire project will be conducted using GIS and GPS technology to augment the field studies. The plans for the summer research project were developed using aerial photographs, existing elevation maps, and City of Houston shapefiles. Students will take paper maps, which are somewhat more current than the electronic versions, to determine the external drainage system (primarily stormwater) that will feed the reservoir system.

All samples locations will be verified using GPS, data will be collected using GPS locations for entry into ArcView, and the results of the study will be displayed using ArcView.



Additionally, the GIS maps will be used to prepare the final report and oral presentation using PowerPoint. The students will be presenting the results to the Partnership at the Buffalo Bayou Partnership office and a public presentation of their results will be presented on the UST campus.

## **Conclusions**

In this century, the “coin of the realm” is data. The ability to quickly transfer information, in a common format, often determines the success or failure of a project or plan. The Buffalo Bayou Partnership and the department of environmental studies at the University of St. Thomas have been able to use ArcView, and their shapefiles and datasets, to facilitate their work together. Individually, each of the organizations was limited by restrictions of manpower, time and resources. Together, with GIS serving as the bridge between the organizations, both organizations have been able to do more than they could have ever done alone.

The Partnership has been able to conduct more studies, undertake more projects, and work with data at a greater level of detail than possible before. The University of St. Thomas students have been able to work in “real world” conditions, working on studies and projects that are not only valuable as teaching tools, but they can see their work benefiting the entire Houston community. The department of environmental studies has been able to leverage the cooperative work between the school and Partnership into more funding, quality educational experiences, and has been able to make inroads into the local government.

Individually, each organization was already strong, and effective in their conduct of their respective work. Together, using GIS as a bridge, the combination of the two organizations has developed a level of synergy that will only increase through time.



Figure 1. The Buffalo Bayou flows through Houston, Texas. Houston, Texas is located in Harris County.



Figure 4. Buffalo Bayou stormwater quality study sample locations.



Figure 2. West sector, Buffalo Bayou.



Figure 5. The Buffalo Bend Nature Park is located on the south bank of the Bayou immediately west of Mercario Garcia Drive.



Figure 3. The Mighty Tidy is a skimmer boat purchased to help clean the floatable debris from the waters of the Bayou.



Figure 6. The site has been built up from its original surface configuration by the deposition of construction debris and excavated clay from the burying of pipes under the streets.



Figure 7. Master plan for the development of Buffalo Bayou Nature Park.

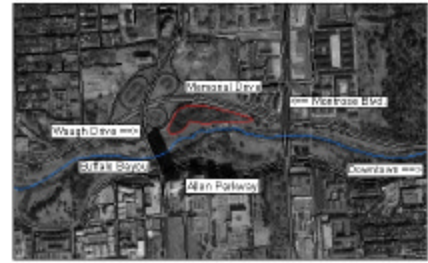


Figure 8. The Greentree Reservoir is located in the West Sector due east of Waugh Drive and south of Memorial Drive. This area is immediately west of downtown.



Figure 9. Current land use for the region.



Figure 10. Master Plan for the redevelopment of the Buffalo Bayou.

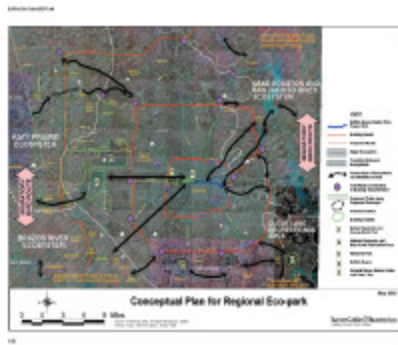


Figure 11. Conceptual plan for a regional eco-park prepared by Turner, Collie & Braden, Inc. for the Buffalo Bayou Partnership.

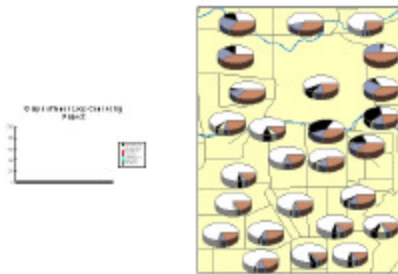


Figure 12. On the left, a traditional chart showing population statistics. On the right, a map showing the population statistics for each of the census blocks of the same area.

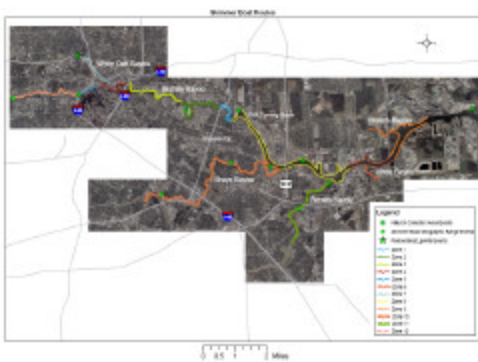


Figure 13. Map of the area serviced by the skimmer boat, the Mighty Tidy, during its operations.



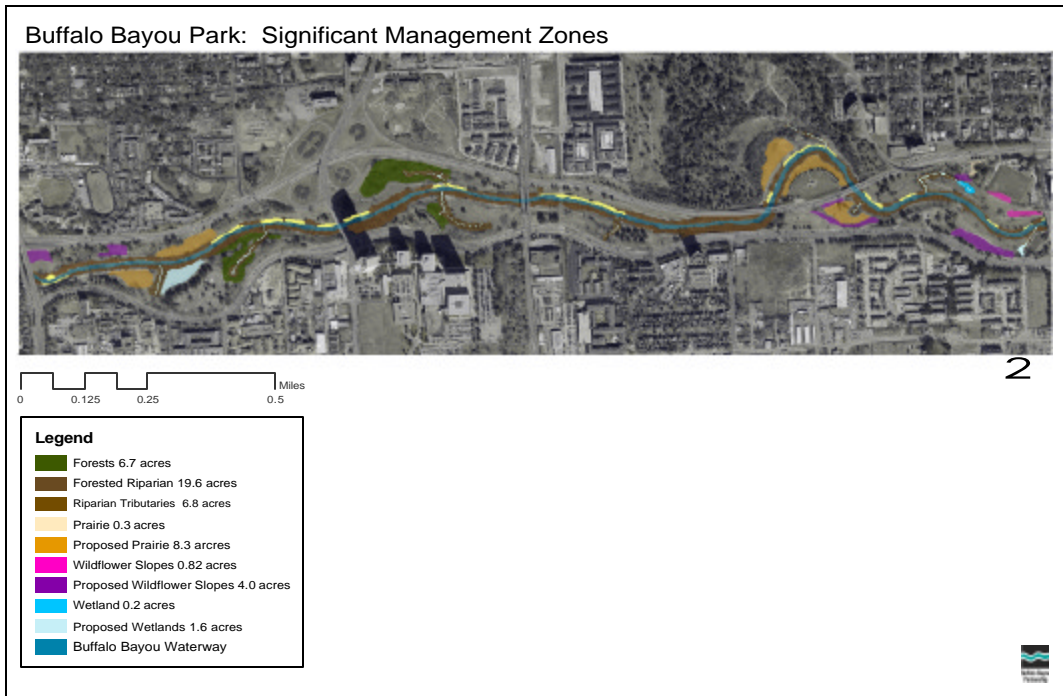


Figure 14. Buffalo Bayou Park existing zone map, prepared onsite using Arc View.

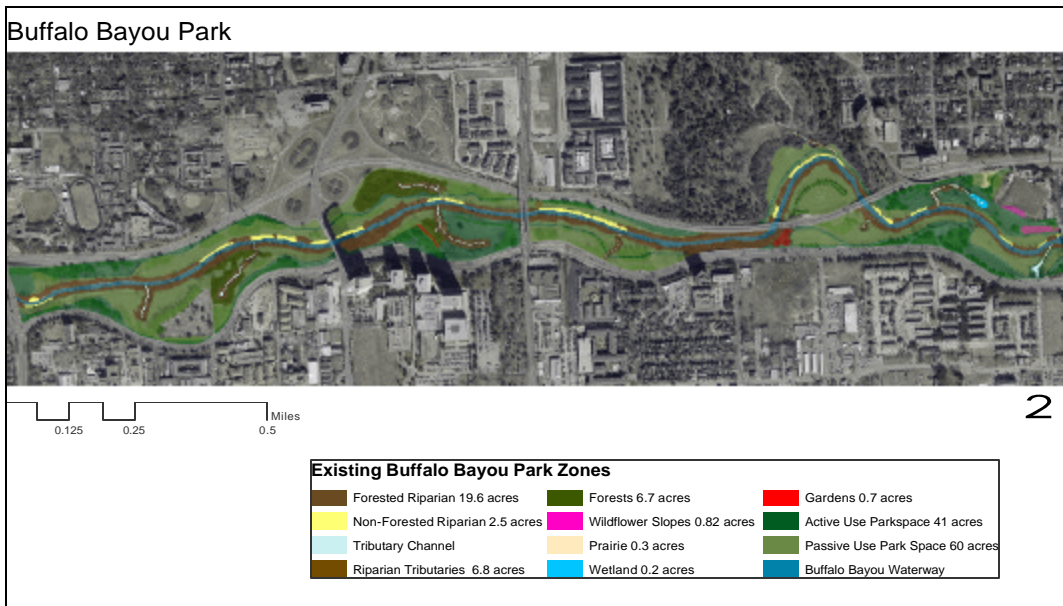


Figure 15. Significant management zones identified for the West Sector and prepared using ArcView.

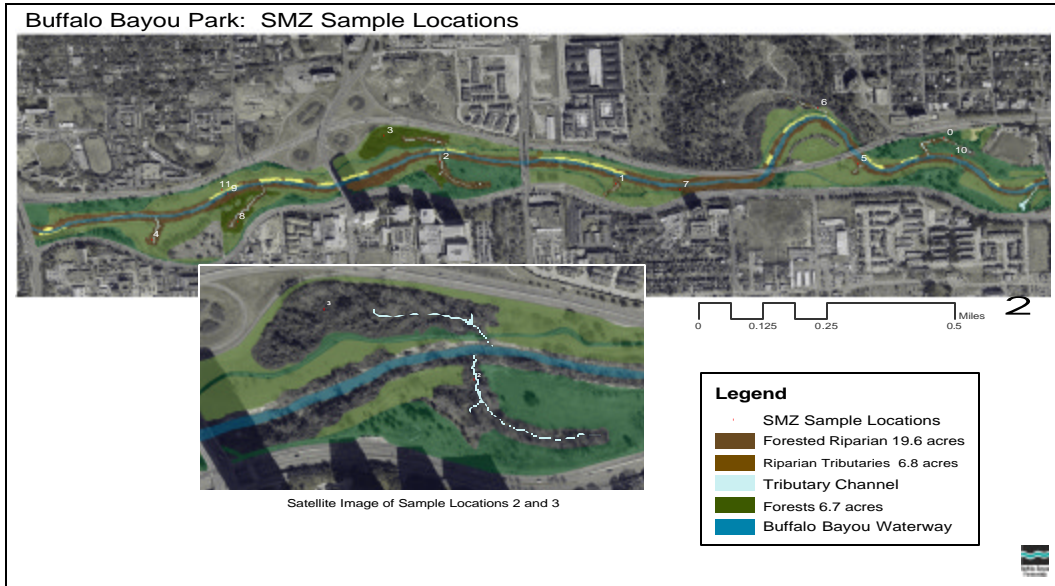


Figure 16. SMZ sample locations.



Figure 17. North America, represented by a data file provided with the ESRI program disk. Enlarged portion shows the lack of detail provided in the data set.

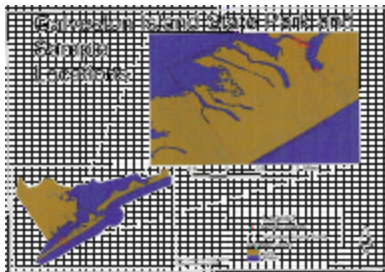


Figure 18. Galveston Island State Park. Location map prepared by Austin Taylor, as part of his senior thesis.

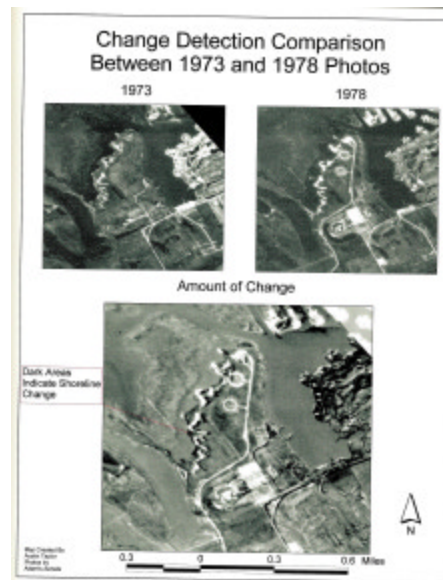


Figure 19. Aerial photographs compared to determine the loss of shoreline. This figure was originally one of Austin's maps used in the preparation of his senior thesis.



Figure 20. Lake Raven, Huntsville State Park, due south of Huntsville, Texas. Study location for Olga DeBakey's senior thesis.



Figure 23. Buffalo Bayou influence area.



Figure 21. Buffalo Bayou sample locations for the stormwater quality study.



Figure 24. The West Sector of the Buffalo Bayou lies west of Sabine Street, east of Shepherd Drive, south of Memorial Drive (primarily), and north of the Allen Parkway.

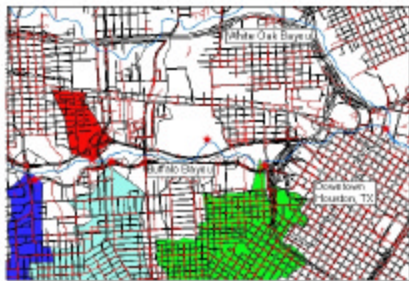


Figure 22. Stormsheds for the West Sector, determined using the City of Houston Planning Department's GIS files.



Figure 25. UL. Shepherd stormwater outfall. UR. North Waugh stormwater outfall. LL. South Waugh stormwater outfall. LR. Sabine stormwater outfall.





Figure 26. Samples were taken from the Glenwood Tributary and the confluence of White Oak Bayou and Buffalo Bayou to determine their relative influences on Bayou water quality as compared to the stormwater outfalls.



Figure 27. Stormwater pipe and drain locations, West Sector area.



Figure 28. Buffalo Bend Nature Park local infrastructure map, data sets were provided by the City of Houston Planning Department.

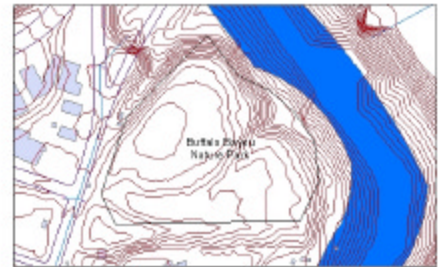


Figure 29. Original topographic map file, Buffalo Bend Nature Park. Provided by the Tropical Storm Allison Recovery Project.

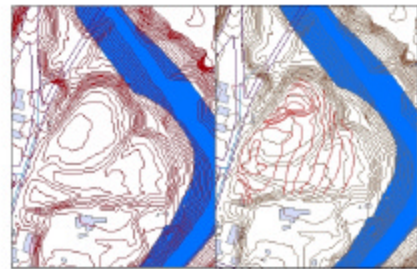


Figure 30. On the left, the original topographic map files for BBNP. On the right, the corrected file based upon onsite elevation surveying.



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