State of the Watershed

The Armand Bayou watershed has experienced substantial changes, both in a geologic time frame of 30,000 years, and in a historic time frame related to human habitation. This Phase I Plan presents what is currently known about the watershed and the results of these influences, in terms of habitat, water quality, flooding and stormwater management, and public outreach and education.

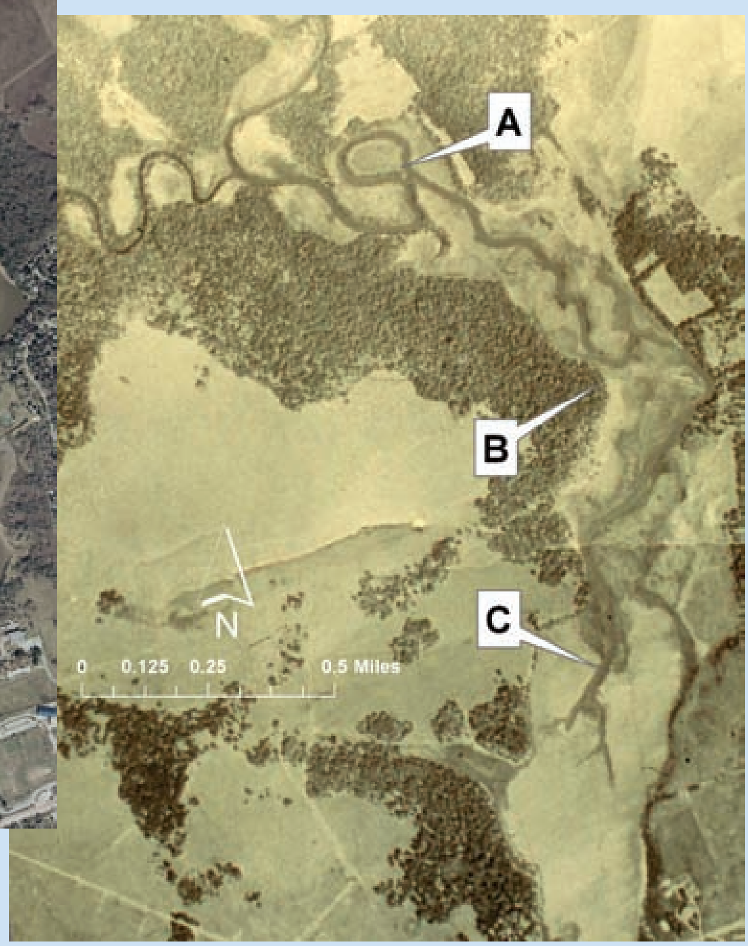
The Phase II Plan will build on the Phase I Plan to address implementation of the Armand Bayou Watershed Partnership's (Watershed Partnership) goals toward accomplishing its mission and realizing its vision of a protected and enhanced watershed. In developing the Phase II Plan, the Watershed Partnership will work to establish priorities, create a detailed plan of management options, and implement improvement projects. Thus, the Phase II Plan will include specific action items to achieve the Watershed Partnership's goals. Some examples of possible actions are included in the discussions below.

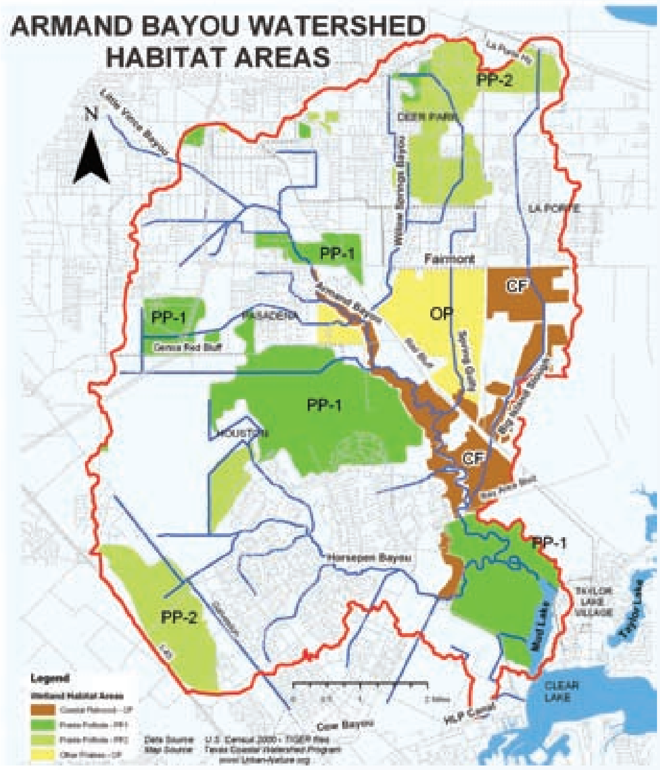
Historical Perspective on the Physical and Hydrologic Nature of Armand Bayou

The region where the Armand Bayou watershed lies is a flat plain lying 10 to 30 feet above sea level and occupying the west shore of Galveston Bay. This plain developed over the last 30,000 years by the buildup of sediments carried to the coast largely by the Brazos River. As the Brazos slowly shifted southwestward, it left behind a gently undulating plain made up broad low areas that lay between higher riverbank deposits.

A large proportion of the region's rainfall runoff flowed to the coast via sloughs and streams. Thousands of circular ponds were formed through the reworking of linear fragments of the ancient river channels, or through wind erosion "blow outs" within the silt and fine sand deposits of the ancient alluvial levees. Very near the coast, long winding intact fragments of the channels remain. Prior to drainage and development, approximately one-third of the region supported wetland vegetation.

Comparison of aerials taken in 2002 (above) and 1953 (right) show the changing topography in the Armand Bayou watershed.





Armand Bayou watershed habitat areas

In addition, many bayous and tidal embayments, which were formed when sea level was lower during the last ice age, pierce from the Bay into the coastal plain. The streams that originate in this region and meandered towards the Bay first began as shallow, marshy swales draining the marsh-dotted tall-grass plain. As they approached the Bay, they usually cut down relatively abruptly to sea level, forming ever-widening, winding tidal channels with steep banks, and would at some point join up with the larger tidal embayments or bayous. Armand Bayou is one of the largest of these and empties into Mud Lake, which flows to Clear Lake, and thence to Galveston Bay.

Habitat

In spite of heavy impacts by development over the years, the Armand Bayou watershed retains some very unique and valuable natural areas or habitat.[17] Lower Armand Bayou is one of very few unchannelized stream segments in the Houston metropolitan area. People throughout the region consider the habitat in this watershed to be one of the most important amenities in the Houston-Galveston area.

The natural areas of the Armand Bayou watershed are much more than just beautiful areas to enjoy. These areas provide a variety of services that come without cost, but which cost dearly when the natural areas are gone and the lost services must be replaced. Depressional wetlands, i.e. prairie pothole wetlands, in the watershed, for example, provide flood detention. In the Armand Bayou watershed, prairie pothole wetlands provide at least 3,000 acre-feet of detention,[18] over and above the natural storage of the native soils in the area.

Natural features in the watershed also act to clean runoff. Rainfall that falls on natural areas soaks into the ground or is slowed and filtered as it courses through vegetation. Without the natural prairie pothole wetlands, much of the rainfall now ends up as runoff. The fraction that soaks into the ground continues to help recharge underground aquifers and helps to maintain a constant flow of water into the bayous and bay.

The natural areas of the watershed are critical habitat for a variety of wildlife that still exists in this area. The Armand Bayou Nature Center, for example, …

> "is home to more than 370 species of birds, mammals, reptiles, and amphibians including white-tailed deer, armadillo, swamp rabbits, bobcats, coyotes, turtles, alligators, frogs, and venomous and non-venomous snakes. Over 220 species of birds reside or rely on the Nature Center as a safe resting place on their long migratory journeys. [The Nature Center] lies along the Central Flyway, which is the largest migratory bird route in North America. … The vegetation of Armand Bayou is characteristic of the East Texas coastal plain. The bayou lies in a biological transition zone between the southern mixed hardwood forest, the coastal prairie, and the coastal salt marshes. The site contains the remnants of one of the few remaining native prairies, small areas of shallow, brackish marshlands, and bottomland hardwood or riparian woodland areas. These areas are historically and ecologically important and require constant efforts in preservation and restoration."[19]

Species lists are provided in Appendix E. Many of these lists were developed from range maps of the species, and all of the species have not necessarily been observed and documented in the watershed. These distinctions between sources of data are noted in the lists.

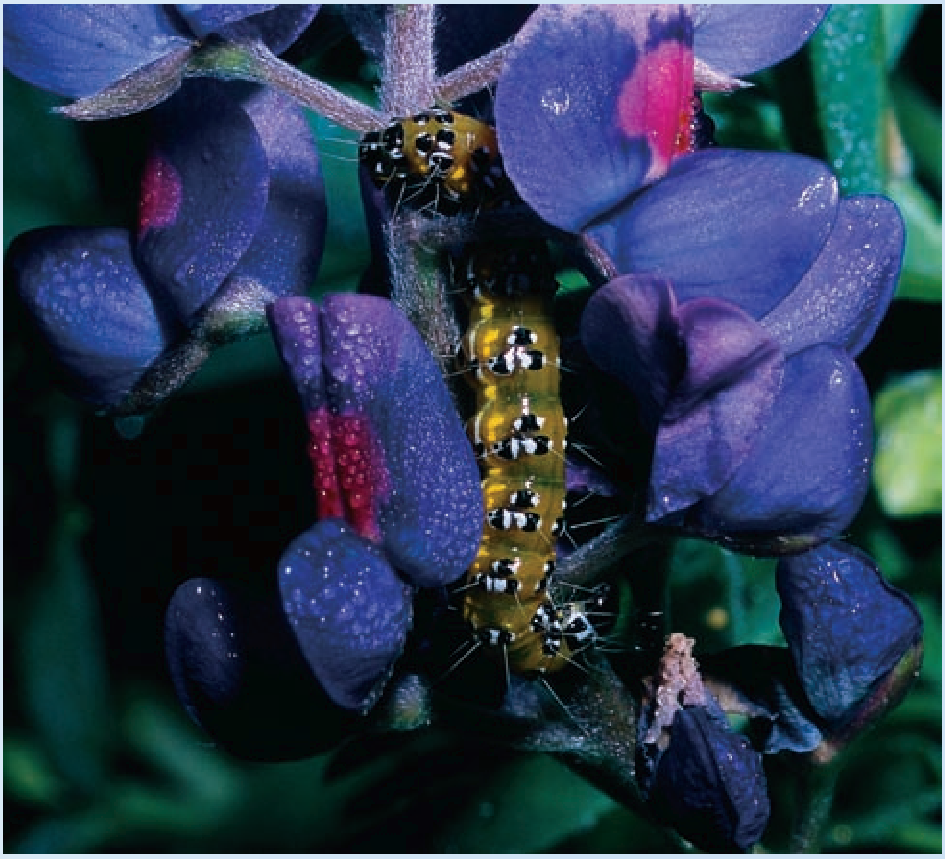
Because of the goods and services provided by natural areas, it is entirely appropriate to refer to them collectively as part of our "green infrastructure." It would be very difficult to live and do business without the "gray" infrastructure of roads, electric power grids, etc. Lack of green infrastructure in this watershed could likewise cause serious disruptions (vastly increased flooding, for example). Green infrastructure can save money by providing ecological services that would be expensive to replace by gray infrastructure. Green infrastructure also improves the quality of life for area residents.

Armand Bayou, like many of the larger bayous, is lined with forest along its lower reaches. Forestlands are usually associated

[17]Habitat refers to natural areas that are suitable for wildlife, and that retain at least some of their natural character. The terms "habitat" and "natural areas" are used interchangeably in this document. Open space refers to any undeveloped area and includes natural habitat as well as parks and pastures.
[18]9,000 acres of prairie pothole habitat in the watershed, which is about 30% depressional wetlands, with about 1 ft average depth.
[19]Armand Bayou Nature Center website (http://www.abnc.org)

with ancient and modern stream drainages. Today almost all, if not all, of the broad marshy valleys of the watershed have been drained. Almost all or all of the marshy sloughs and wide, shallow bayous have been converted into ditches above the tide, including Armand Bayou.

Many of the tidal portions of the bayous have also been channelized, though the lower portion of Armand Bayou has thus far escaped this flood control measure. It contains one of the longest unchannelized stretches of bayou in the region. In addition, it still hosts large areas of upland prairie, riparian forest, and bottomland and flatwood hardwood forests.



Terrestrial Habitats

The Armand Bayou Habitat Map (Figure 3) shows three habitat types for the watershed:

Coastal Flatwoods are woodlands or forests with a dominant overstory of willow oak. Understory plants include palmettos and wood oats. Included in this classification are narrow bands of riparian floodplain forests along the lower reaches of Armand Bayou and Big Island Slough. These riparian forests are characterized by elms and ashes.

Prairie Pothole Complexes are prairies characterized by depressions called potholes and small knolls called mima or pimple mounds. This category is further subdivided by relative preservation of potholes and pimple mounds: PP-1 for excellent preservation and PP-2 for moderate preservation. Undisturbed grassland vegetation of the coastal prairie pothole complexes consists of big bluestem, little bluestem, gamagrass, Indiangrass, switchgrass, etc. Few areas in the watershed have large expanses of this "tallgrass" prairie grasses left, but significant patches of these grasses can be found in the watershed.

Other Prairies are mainly clayey prairies without the pimple-mound complexes.

Just over half the watershed is in open space (about 21,000 land acres and about 1,000 acres of open water). Of that amount, about 14,000 acres could be considered as "significant" habitat (i.e. relatively undisturbed).

For natural areas to be functional, either as "green infrastructure" or as habitat for wildlife, size and continuity of individual areas becomes very important. In simple terms, the larger the area, and the more connected to other areas, the better it functions. Most wildlife has some very specific areal requirements for sustainable habitat. Wildlife habitat in the Armand Bayou watershed has long been depleted well below the minimum requirements for bears and other large species (which may need up to a few thousand acres per animal). Yet, enough contiguous wildlife habitat is still present to support deer, bobcats, hawks, and similar species.[20]

How much land would be required to sustain a fully functioning Gulf Coast Prairie ecosystem is not known, but given that larger mammals, such as bears, require well over 7,000 acres to thrive,[21] a good guess might be in the range of at least 10,000 acres in a single patch. No single, contiguous habitat fragment in this watershed approaches this figure, but a few fragments between 1,000 to 2,500 acres with important ecological functionality remain. A number of habitat fragments in the 300-600 acre range also may be found in the watershed.

The value of small habitat fragments increases greatly if they are interconnected by habitat "corridors." The functionality of these corridors increases as their widths increase, but even narrow corridors can be important. A fair amount of connectivity remains between the habitat fragments of the watershed. A little planning could insure this connectivity remains in place and is even increased.

Aquatic Habitats

The Armand Bayou watershed is home to several aquatic habitat types, including open water habitat of the freshwater to brackish bayou and the emergent marshes found within it. These marshes historically filled Mud Lake and virtually disappeared when

[20]Biederman, Robert. 2003. Body size and area-incidence relationships: Is there a general pattern? Global Ecology and Biogeography. 12:381-387.
[21]Ibid.

PHOTO © CLIFF MEINHARDT

subsidence resulted in the drowning of these habitats within the last 50 years. In recent years, the Nature Center and partners have restored approximately twelve of these habitats. The narrow strips of restored wetlands are too small to be shown on the map.

Salt marsh communities are found in the lower reaches of the bayou in high salinity areas. Prevalent species include smooth cordgrass and marsh elder. Brackish marsh inhabits the transitional zone between salt marsh and fresh marsh and is affected by variations in water levels and salinities. In general, the brackish marsh is dominated by marshhay cordgrass and saltgrass. Fresh marshes are primarily found in upper reaches of the bayou that are affected by saltwater flooding only during large tropical storms or hurricanes. The fresh water in these marshes is sufficient to maintain a low salinity suitable for such species as marsh millet (or giant cutgrass), coastal arrowhead, and squarestem spikesedge.

The emergent marshes present in Armand Bayou and its tributaries serve as nursery and forage areas for a number of aquatic organisms from different levels of the food chain. Several commercially and recreationally important species are found in the bayou as well. Species of finfish and shellfish found in Armand Bayou include brown shrimp, freshwater goby, mosquitofish, gulf killifish, sailfin molly, sheepshead minnow, tidewater silverside, striped mullet, pipefish, Atlantic croaker, catfish, and spotted seatrout.

Armand Bayou likely featured submerged aquatic vegetation in areas of shallow, sandy flats. Subsidence and turbidity associated with human activities have eliminated any naturally occurring beds. Nature Center planted Widgeongrass (Ruppia maritima), a species of freshwater tolerant submerged aquatic vegetation, in several apparently suitable areas recently, but these attempts have been largely unsuccessful. Whether physiological conditions, substrate quality, depredation from exotic herbivores, or other factors caused the failures of these restoration efforts is unknown.

Species lists are found in Appendix F.

Invasive Species

Several invasive species are currently found in Nature Center, several of which have caused ecologically significant problems, and others are expected to create future problems. Water hyacinth, hydrilla, and other invasive aquatic plants have created serious problems in freshwater reaches in the Bayou itself, while elephant ear and other emergent plants have displaced productive native wetland plants that serve as important sources of food, substrate, and shelter along the Bayou's edge. Giant salvinia, a devastating aquatic weed, has been found in local water bodies, and presents a potential threat to Armand Bayou. Deep-rooted sedge is an extremely aggressive emergent freshwater wetland plant. This sedge is likely to have already established local populations within the Armand Bayou watershed. These aquatic plants are difficult to control and can cover the water's surface, shading submerged vegetation.

Among invasive aquatic fauna found in the watershed, channeled applesnails are herbivorous gastropods native to South America. The applesnails are recent invaders that tolerate a variety of salinities and can decimate aquatic vegetation. They are also thought to serve as a vector of disease and parasites. They are suspected of destroying restored widgeongrass beds in the Bayou, and scientists are concerned that this prolific herbivore will cause substantial damage to freshwater vegetation in coming years.

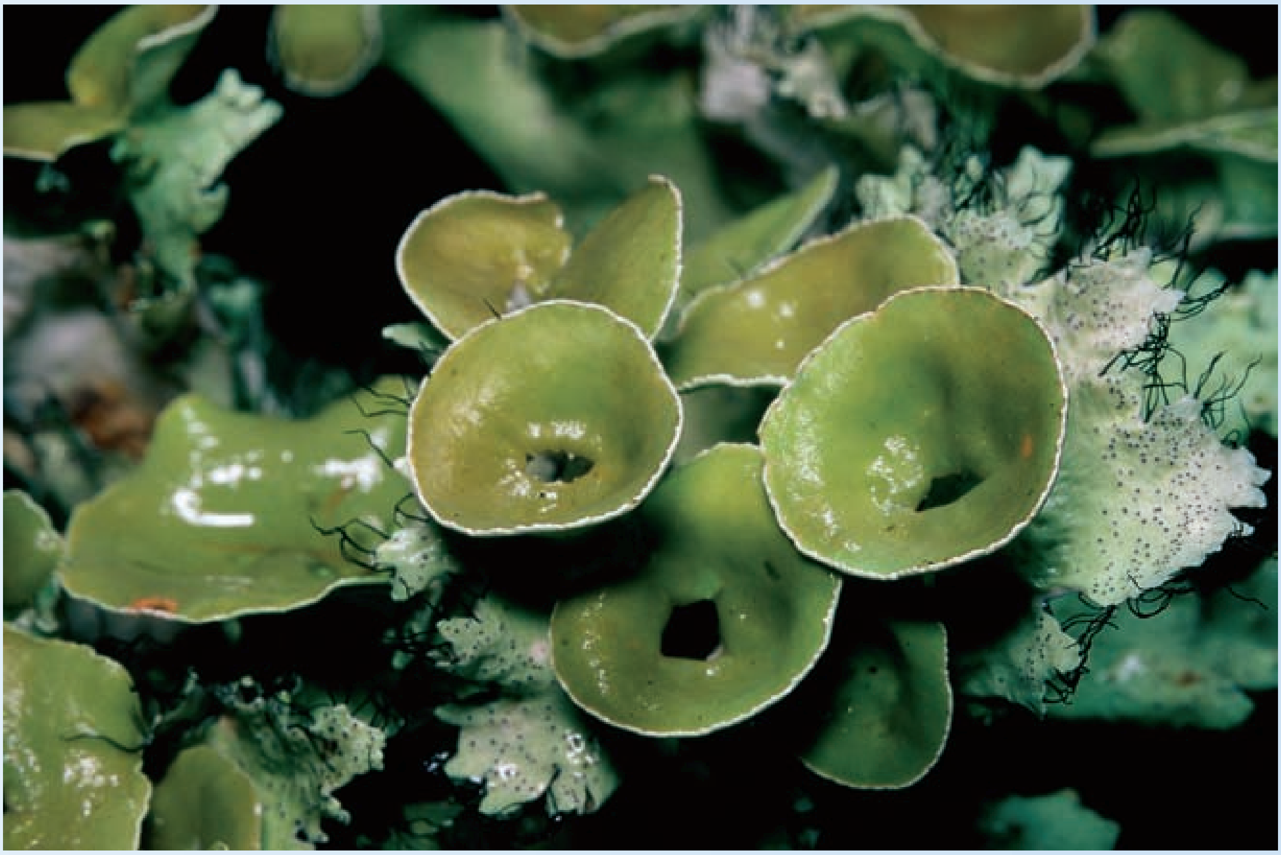
Terrestrial invasives in the watershed negatively impact coastal prairie and flatwood habitats by displacing native vegetation and radically altering the overall habitat, oftentimes faster than the native fauna can keep up with. The Chinese tallow tree is a prominent example of an invasive tree that can completely overtake and change native habitat. Introduced in the area in the 1920's, this tree has completely taken over thousands of acres of native coastal prairie, displacing native flora and disrupting native fauna. In addition to impacts on wildlife, invasive Chinese tallow woods likely alter the hydrologic balance in the area. The tallow trees transpire much more soil moisture than the native grasslands and thus may decrease underground freshwater inflows into Armand Bayou and its tributaries. Other species of invasive plants, such as vasey grass, elephant ear, and Chinese privet, also out-compete native vegetation.

Species of terrestrial invasive animals include the fire ant and feral hog. Fire ants impact ground nesting bird populations, while feral hogs, through their rooting behavior, can leave areas devoid of vegetation, robbing terrestrial natives (e.g. white tailed deer) of their food supply. Nutria is a species of herbivorous rodent native to South America, which has caused extensive damage to wetlands in Louisiana, and is found in the Armand Bayou watershed.

All of these species impact native plants and animals directly or indirectly. Control of invasives is costly in terms of necessary human and monetary resources. The losses to habitat that result can be irrevocable if the species are allowed to spread unchecked. Resource managers and concerned citizens are waging a prolonged battle against invasive species in the watershed. Nature Center staff and volunteers implement range management techniques such as the bush-hog and controlled burns to contain the spread of Chinese tallow in its prairies. The Galveston Bay Estuary Program and the U.S. Fish and Wildlife Service have partnered with the Nature Center to reclaim dozens of acres of historic prairie areas converted to tallow forests, and to control hydrilla in the bayou. Serious resource constraints hamper the ability of managers to protect the biological integrity of the Nature Center against the effects of invasive species. This is compounded by the fact that few state- and nationally-funded programs geared specifically toward the control and prevention of invasive species exist. However, given the ecologic and economic impacts of invasive species, control and prevention will likely continue to rise as a priority. To balance these impacts, resources dedicated to these ends will need to rise as well.

Protected Lands

While most of the natural areas in the watershed are subject to loss through development, a few significant areas have been protected. Only a few private landowners with extensive open



space landholdings in the watershed remain. Kinder-Morgan, which currently owns a gas complex in the center of the watershed, is one of the largest. Exxon Pipeline and Exxon Production also own significant holdings in the watershed.

Armand Bayou Nature Center

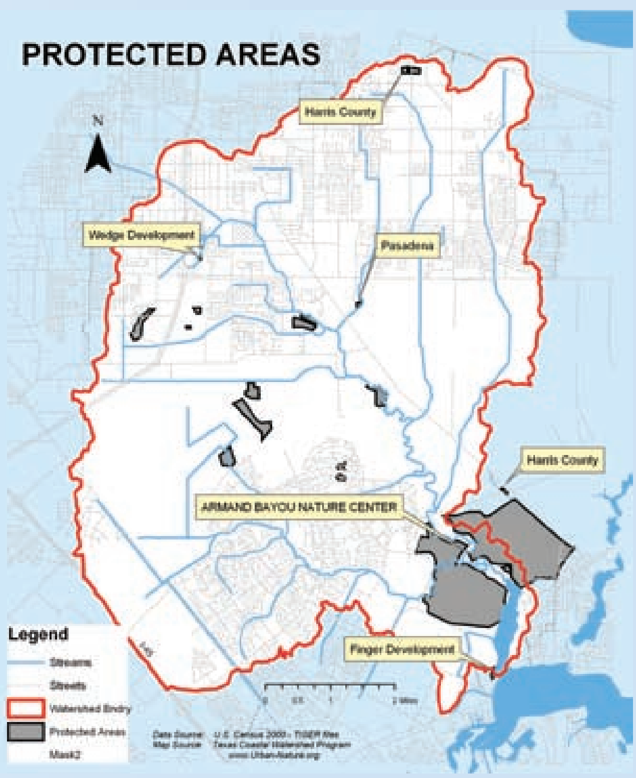
Armand Bayou Nature Center (Nature Center) is one of the largest urban nature preserves in the country, and protects 2,500 acres. The preserve was established in 1974. The land is owned by Harris County, but is leased to the Nature Center through a 99-year lease. Although no conservation easement or other mechanism for permanent preservation is in place, the lease contract contains clauses to allow the lease to rollover indefinitely, and ABNC would keep the land open.

Armand Bayou Coastal Preserve

The Armand Bayou Coastal Preserve is one of just four Coastal Preserves along the Texas Gulf Coast. This preserve consists of about 300 acres mainly confined to the main channel of Armand Bayou. The Armand Bayou Coastal Preserve is leased from the General Land Office by the Texas Parks and Wildlife Department. This arrangement limits construction adjacent to this preserve. The boundary of the preserve is the mean high water mark and the upper tidal limit of the Bayou, which is roughly 0.5 mile downstream of Genoa-Red Bluff Road.

FEMA Buyout

As a result of the 1998 Tropical Storm Francis, the City of Pasadena removed approximately 9 acres from the floodplain via a



Armand Bayou watershed protected lands

FEMA buyout of 16 homes in the year 2000. Approximately another 14 acres was removed from the floodplain in 2002 through a joint buyout of 44 homes by Harris County and the City of Pasadena after the 2001 Tropical Storm Allison. These properties are required by FEMA to remain permanent open space and contain perpetual restrictions in each deed prohibiting them from being developed with any structure.

Detention Basins

Detention basins in the watershed range from small commercial systems owned by business owners to large systems serving hundreds of homes owned by community associations, as well as some very large regional systems that are owned by the City of Pasadena or Harris County Flood Control District. While some jurisdictions in the watershed have for many years required stormwater detention to mitigate development impacts, others have only more recently begun to do so. These basins can be designed for wet-bottom or dry-bottom detention. As wet-bottom basins, they may provide habitat for aquatic species. They may also be planted with native prairie vegetation. While detention basins are not protected land, the water storage volume they were designed to hold must be maintained. A detention basin could possibly be redeveloped if the water storage volume was mitigated to a nearby site.

Other

In addition, some other large parcels of land in the watershed are in public ownership, but not necessarily with legal/institutional protections. For instance, several hundred acres of undeveloped coastal prairie and flatwood forest areas lie within the Johnson Space Center, near Horsepen Bayou and Mud Lake. NASA currently leases the land from Rice University. No easement or formal conservation designation appears to be in place, but no plans to terminate the lease in the near future, or to further develop existing natural areas, are known.

Also, the University of Houston-Clear Lake (UHCL) campus straddles Horsepen Bayou, a tributary of Armand Bayou. The four-hundred-acre campus includes approximately 150 acres of riparian forest areas that are planned to remain wild in perpetuity. However, no easement protects this area. Additionally, a 37-acre tract at the intersection of Middlebrook Road and Space Center Boulevard has been donated to UHCL from NASA, and is to be used for environmental studies.

PHOTO BY ANN BRINLY

Possible Action Items Toward Plan Implementation for Habitat

To accomplish the Watershed Partnership's goal to "protect and restore valuable habitat areas through the watershed," Phase II action items may range from planning to restoration to acquisition. Some examples for the Phase II planning process could be:

1. Prioritize remaining open space for preservation.
2. Develop funding sources for placing critical habitats in the public domain.
3. Expand the riparian vegetation buffer along Armand Bayou and incorporate management of the buffer into flood control plans.

4. Work with private landowners of undeveloped land to develop land management plans that restore and enhance native prairies and riparian ecologies.

Water Quality

"Water quality" is a complex concept, comprised of physical, chemical, and biological components. Taken individually or collectively, these components are indicators of the environmental condition of a water body. The environmental condition of water bodies of the Armand Bayou Watershed can be described in different ways. For instance, some studies indicate that Armand Bayou has a diverse fish population indicative of "good" water quality. Conversely, Armand Bayou and its tributaries have experienced low concentrations of dissolved oxygen and fish kills, indicative of impaired water quality.

Since water quality data have only been collected for about thirty years, we cannot be certain if low dissolved oxygen levels occurred in the bayou prior to settlement, when the watershed was in its original condition. But as noted in the Introduction, major changes to the natural landscape have taken place resulting in impervious surfaces. These changes alter the natural hydrology and lessen the pollutant-filtering abilities of the soils and vegetation. The resulting increased storm water runoff, carrying pollutants such as fertilizers, pesticides and oil from our urban and suburban landscapes, can be detrimental to water quality.

In order to protect water quality, the Texas Commission on Environmental Quality (TCEQ) establishes water quality standards. The Texas Surface Water Quality Standards are designed to establish numerical and narrative goals for water quality and provide a basis for which TCEQ regulatory programs can implement and attain those goals. In Armand Bayou, standards are set to be protective of three categories of water use:

Sampling locations for Armand Bayou

1. Aquatic life use – designed to protect plant and animal species that live in and around the water, such as standards for dissolved oxygen concentration;
2. Contact recreation - designed to lower the probability of human illness from swimming and other water sports involving direct contact with the water, such as standards for fecal coliform bacteria concentration; and
3. Fish consumption - designed

to protect consumers from consuming fish or shellfish that may be contaminated by pollutants in the water, such as standards for mercury concentrations in fish tissue.

Various entities monitor water quality on a regular basis in the Armand Bayou Watershed, including the TCEQ, City of Houston Health and Human Services Department, and local Texas Watch citizen monitors. Each entity has its own set of monitoring stations, which are coordinated by the local Texas Clean Rivers Program partner agency, the Houston-Galveston Area Council. In addition to water quality monitoring, TCEQ assesses the data to compare actual water quality conditions to the established standards. The TCEQ assessment determines which water bodies are meeting the standards set for their use and which are not. Water bodies are considered impaired by the TCEQ if they do not meet applicable water quality standards or are threatened for one or more designated uses by one or more pollutants.

In fact, the tidal and above tidal portions of Armand Bayou are currently listed on the state's list of impaired water bodies, or the State of Texas Clean Water Act Section 303(d) List) because they did not meet TCEQ dissolved oxygen standards. Water quality samples evaluated in 1998 indicated that dissolved oxygen levels were periodically low, which could stress the fish community and other aquatic life.

In response to these data findings, the Texas Commission on Environmental Quality initiated a study in 1999 to determine the extent and severity of the low dissolved oxygen levels and the appropriateness of the water quality standard for aquatic life use. The initial analyses of the new data revealed that, while the dissolved oxygen concentrations were often low during hot weather, no indication was found that the aquatic life community was impaired. Nor did the study find oxygen-reducing pollutant(s) that would need to be controlled.

Because the 1999 study was inconclusive, a Total Maximum Daily Load, a detailed water quality restoration assessment, was not deemed appropriate to protect aquatic life in Armand Bayou. The TCEQ collects dissolved oxygen, nutrient, and chlorophyll data on a quarterly basis in Armand Bayou. These data will be used to help determine the causes of the low oxygen levels. Also, TCEQ has collected additional data on fish communities to help evaluate the effects of the Armand Bayou water quality regime.

Armand Bayou Water Quality Assessment

For the purposes of this watershed plan, data from the time period of 1998-2003 for eight key parameters – salinity, dissolved oxygen, chlorophyll-a, nutrients, bacteria, water clarity, sediment contaminants, and biological data – were chosen to assess the current state of water quality in Armand Bayou. Some of these parameters were compared to TCEQ water quality standards, although water quality can be less than optimal even when the water quality standards are attained. The standards were designed to cover a large range of water bodies, and represent a minimum for regulatory purposes. These standards may not be as protective of the watershed as desired by the Armand Bayou Watershed Partnership

To facilitate review, Armand Bayou and its tributaries were partitioned into seven distinct reaches. Four are on the mainstem: Mud Lake (the lower tidal reach downstream of the confluence with Horsepen Bayou), Middle Tidal (from the confluence with Horsepen Bayou to the confluence with Big Island Slough), Upper Tidal (near Oil Field Road), and Above Tidal (near Genoa-Red Bluff Road). The other three reaches represent major tributaries: Spring Gully, Big Island Slough, and Horsepen Bayou.

Descriptions and a summary of findings for each of the selected parameters are summarized below. A detailed discussion of the water quality assessment is located in Appendix F.

Salinity

Salinity, a measure of the concentration of dissolved salts in the water, is important because living organisms, both plant and animal, are each adapted to live within a certain salinity range. As Armand Bayou is a tidally influenced water body, it will have generally decreasing concentrations of salt as one moves from the mouth of the bayou to the headwaters.

Salinity, which is usually reported in parts per thousand (ppt), ranges from less than 1 ppt in fresh water to 35 ppt in the salt water of the Gulf of Mexico. Since Armand Bayou is located in the Galveston Bay Estuary, a mixing zone for fresh and salt water, salinity naturally fluctuates with rainfall and runoff. Salinity is low during wet periods and higher during dry periods at the same location. The salinity of Armand Bayou and its tributaries ranged from 0.2 ppt to 20 ppt, typical of a low salinity estuarine system

PHOTO BY JACK LEWIS, TEXAS DEPARTMENT OF TRANSPORTATION

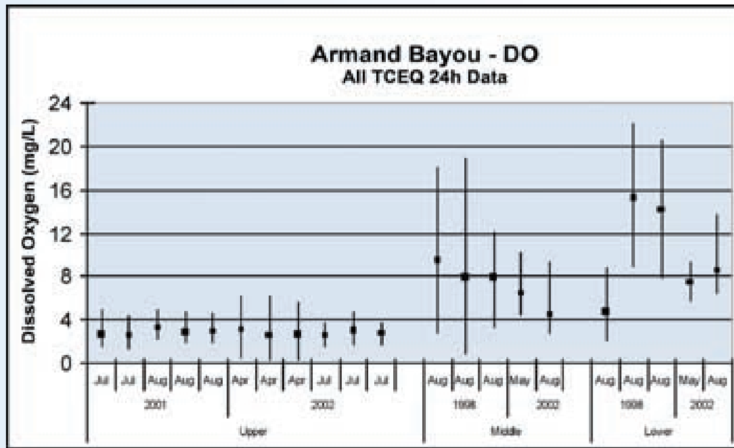
(Appendix F, Table 1). In addition to the three tidal segments of the mainstem, much of Horsepen Bayou and Big Island Slough are also affected by tides, so periodic higher salinity values are to be expected there.

Dissolved Oxygen

Dissolved oxygen is the concentration of oxygen in the water body as reported in milligrams per liter (mg/L). Dissolved oxygen is the traditional measure of aquatic health because aquatic organisms depend upon it; they will suffer if concentrations become too low. In the worst-case scenario, fish kills can result from very low concentrations (less than 2 mg/L). On the other hand, high concentrations of dissolved oxygen (greater than 10 mg/L) result from excess photosynthesis, which can also be detrimental to the water body (see Chlorophyll-a on page 28).

Dissolved oxygen concentration is dependent upon the temperature of the water, salinity, aeration from wind and water turbulence, the presence of oxygen-demanding substances and living organisms. Dissolved oxygen levels typically fluctuate in a daily cycle, with higher levels in the afternoon due to photosynthesis, and lowest levels in the early morning due to respiration (the use of oxygen by living organisms).

Dissolved oxygen levels in Armand Bayou may have been affected by accelerated subsidence (see Subsidence section). As the bayou deepened and widened, much of the fringing riparian forest was destroyed. Instead of being covered by a tree canopy, the bayou now has open water areas devoid of shade, which could result in higher temperatures and lower dissolved oxygen levels.



Dissolved oxygen data from Armand Bayou at Oil Field Road (Upper), Bay Area Boulevard (Middle) and Mud Lake (Lower). (Source: Previously unpublished TCEQ data)

The state water quality standard for dissolved oxygen in the tidal portion of Armand Bayou (from the confluence with Clear Lake to a point 0.5 miles downstream of Genoa-Red Bluff Road in Pasadena) is a minimum daily average of 4 mg/L. The above tidal portion (from a point 0.5 miles downstream of Genoa-Red Bluff Road in Pasadena to a point 2.5 miles upstream of Genoa-Red Bluff Road) requires a minimum daily average of 5 mg/L.

Dissolved oxygen can be measured either by instantaneous ("grab") samples or by continuous instrument monitoring over a 24-hour period. Overall, the grab samples indicated that dissolved oxygen was lowest in the Upper Tidal reach of Armand Bayou, averaging 4.4 mg/L at the surface and 3.5 mg/L below the surface. Dissolved oxygen levels in Mud Lake, Horsepen Bayou and the Middle Tidal reaches were generally high, with only a few surface readings that fell below 4 mg/L (Appendix F, Table 2). It is important to note that some of the grab samples utilized in this assessment were taken in the afternoon, after a day of photosynthesis, and, therefore, may not reveal the actual minimum dissolved oxygen in the water body.

To better determine the minimum dissolved oxygen levels experienced by a water body, instruments were deployed that measured the oxygen levels every 15 minutes throughout the day and night. The graph illustrates the dissolved oxygen range measured in different parts of Armand Bayou (the Upper, Middle, and Lower Tidal reaches) over several distinct 24-hour periods. Each month, the measurement was taken at the same location for each reach of the bayou. Each vertical line represents the dissolved oxygen range from one 24-hour period and the square indicates the average dissolved oxygen for that 24-hour period. This graph shows that the Upper Tidal reach experienced very low dissolved levels frequently, while the Middle and Lower Tidal reaches experienced both very high and very low dissolved oxygen values in a single day. Values above 10 mg/L indicate the presence of an algal bloom, while values below 4 mg/L do not meet the minimum water quality standard. While the grab samples have the disadvantage that unrepresentative concentrations may result if samples are not taken in the morning, the pattern of lowest dissolved oxygen in the Upper Tidal reach was consistent in both types of samples.

Dissolved oxygen studies are currently being undertaken by the Texas Commission on Environmental Quality in order to address the need for a Total Maximum Daily Load.

Chlorophyll-a

Chlorophyll-a is a measure of a photosynthetic pigment in green plants in micrograms/liter (μg/L), and is an indicator of the algal population (phytoplankton). Phytoplankton are microscopic algae that drift in the water, harnessing the energy of the sun and making it available to living organisms. Through this mechanism, they form the base of one of two types of food webs in the Galveston Bay system. Additionally, dissolved oxygen is produced as a byproduct of algal photosynthesis. While phytoplankton are beneficial through this energy capture and oxygen production, excessive concentrations of phytoplankton, or algal blooms, can become detrimental to a water body. These blooms, which require high amounts of dissolved oxygen when they respire at night or when decomposing following death, are usually caused by excess nutrients in the water. Thus, chlorophyll-a is an important measure of bayou health.

In Armand Bayou, average chlorophyll-a values were highest in the Mud Lake, Middle Tidal, and Horsepen Bayou reaches, where the dissolved oxygen levels were also very high (Appendix F, Table 3). Chlorophyll values above 20 μg/L are generally considered detrimental; the average values in these three segments exceed that threshold, sometimes by a large margin.

Nutrients

Nutrients are necessary for the growth of plants, including phytoplankton. Low concentrations of nutrients can reduce plant growth and therefore impede the production of food for dependent living organisms, while excess concentrations can cause algal blooms. Nutrient concentrations are sometimes measured to determine water quality as it relates to non-point source (storm water runoff) pollution and wastewater treatment. Nutrient parameters measured in Armand Bayou and its tributaries included ammonia and total phosphorus, reported in mg/L. Another important parameter, nitrate-nitrite, was not included in this assessment because a complete data set for Armand Bayou was not available.

Both ammonia and total phosphorus values were high in Horsepen Bayou while only phosphorus was elevated in Mud Lake and Middle Tidal reaches (Appendix F, Table 4). These are the same areas that exhibit high chlorophyll-a concentrations and high dissolved oxygen.

Fecal Coliform Bacteria

Fecal coliform bacteria are present in the intestines of animals. They are an indicator of the presence of human or animal waste in the water and thus are an important public safety measurement. Fecal coliforms themselves do not typically cause illness in humans, but their presence indicates that other disease-causing microbes could be present. A screening level for individual samples has been set at a maximum 400 colonies (cfu)/100ml to be protective of swimmers. After a heavy rain event, most water bodies will have high fecal coliform levels. If the screening level is exceeded by more than 25% of the individual samples, the water body will be listed as impaired by the TCEQ.

Based upon the screening level, fecal coliform bacteria counts were high in about 20% of the samples collected in Armand Bayou and its tributaries (Appendix F, Table 5). No obvious differences among the reaches were found.

Water Clarity (Turbidity)

Water clarity is a measure of the amount of sunlight that can penetrate the water column. Clarity is decreased by the presence of suspended and dissolved materials, which may be from living matter such as phytoplankton or from non-living matter such as sediment. Since submerged plants need sunlight for growth, this is an important parameter. Waters that have low clarity are said to be turbid. The degree of turbidity can be measured by the use of a Secchi disk, a black and white disk that is lowered into the water to the point just above where the disk is no longer visible. That point, measured in meters, is referred to as the Secchi depth.

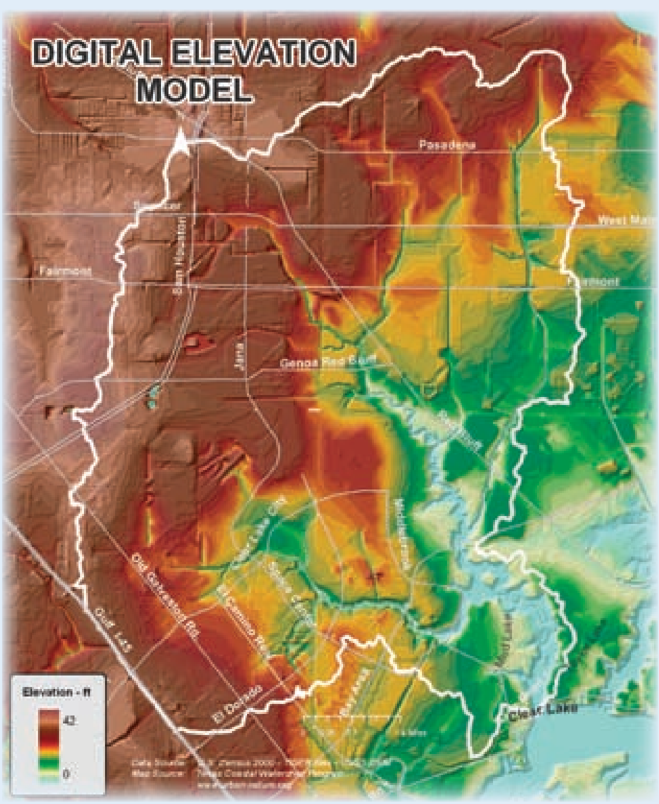
The data indicate that water clarity averaged the lowest in the Mud Lake and Middle Tidal reaches (Appendix F, Table 6). Local waters are noted for their relatively high turbidity. However, it is important to track turbidity, since man-made inputs from construction sites, urban development, and other land use changes may artificially decrease water clarity.

Sediment Contaminants

Contaminants in sediments may cause adverse effects to living organisms. Many pollutants are transported into the waters of the Galveston Bay area attached to sediment particles. These compounds may remain in the sediments for many years and can be passed up the food chain to humans. Contaminants in the sediments may include metals or organic compounds that originate from natural or man-made sources. Some metals of concern and their potential sources include:

- arsenic (from fossil fuel combustion and industrial discharges);
- barium (from oil and gas drilling muds, bricks, tiles, and rubber);
- cadmium (from corrosion of alloys and plated surfaces, electroplating wastes and industrial charges);
- chromium (from corrosion of metal plated surfaces, electroplating wastes, and industrial discharges);
- copper (from corrosion of copper plumbing, anti-fouling paints, and electroplating wastes);
- lead (from leaded gasoline, batteries, and exterior paints and stains);
- mercury (from natural erosion and industrial discharges);
- nickel (from nickel plating and batteries); and

PHOTO BY STEPHAN MYERS



- zinc (from tires, galvanized metal, and exterior paints and stains).

Sediment was sampled for metals twice in 2002 by the TCEQ. In those samples, no metal concentrations exceeded screening levels that are associated with adverse effects in living organisms. See Appendix F for further discussion.

Biological Data

The study of water quality in the Armand Bayou watershed would be incomplete without an assessment of its dependent living organisms. The Texas Commission on Environmental Quality collected data on biological parameters from three sites in 2002. The data are currently being evaluated by the agency, along with data collected by Parsons, Inc. for its "Report for Water Quality and Biological Characterization of Armand Bayou, Houston, Texas, (May, 2000)."

Fish kills are sudden die-offs of significant numbers of fish and they indicate that an aquatic environment has become unsuitable. Fish kills may be caused by low dissolved oxygen, spills of toxic materials, or extreme temperatures. Records show seven major fish kills in the Armand Bayou watershed since 1971; most located in the tributaries (Appendix F, Table 7). Four were attributed to low dissolved oxygen. The fish kills were short in duration.

Flooding and the Water Quality Connection

In addition to damage to the built environment, flooding brings a large volume of pollutants from the Armand Bayou Watershed to its water bodies. In the built environment, contaminants such as excess sediment from construction areas and eroding land, fertilizers, pesticides, oil and grease and floatable trash are transported to Armand Bayou and its tributaries. While the concentration of these contaminants may be low due to the large volume of water transporting them, the actual loading (the concentration multiplied by the runoff volume) of these contaminants can be detrimental. In addition, the biological component of water quality can be harmed as abnormal high stream flows, resulting from increased impervious surfaces and storm sewer infrastructure, scour the bayous and streams of natural habitat.

Possible Action Items Toward Plan Implementation for Water Quality

To accomplish the Watershed Partnership's goal to "enhance water quality to minimize fish kills, maintain aquatic diversity, and provide safe contract recreation opportunities," Phase II action items may range from increased monitoring to improved management of runoff pollution. Some examples for the Phase II planning process could be:

1. Utilize automated dissolve oxygen sampling to better capture potential impacts to the aquatic life community.
2. Incorporate water quality features in detention basins.
3. Plant trees along streams to provide stream cover, which would reduce water temperatures and improve dissolved oxygen values.

Flooding and Stormwater Management

Flooding is a natural occurrence for any river or bayou. The Armand Bayou watershed is even more prone to flooding because of several conditions that make stormwater management a challenge. The Texas Gulf Coast is a semi-tropical environment capable of receiving substantial amounts of rain in a given event. The average annual amount of rainfall for the Armand Bayou watershed is approximately 48 inches. Occasional tropical storms and hurricanes cause heavy accumulations (several inches per hour) in a very short time. The topography of the area is extremely flat with a slope of less than one foot per mile. This, coupled with heavy rainfall, results in slow-moving runoff. Additionally, hurricane force winds are often accompanied by storm surges that cause the bayou to flow backwards as the storm comes ashore. The proximity of the watershed to the Gulf of Mexico and Galveston Bay, and its low overall elevation, means that ocean tides also affect the area. Furthermore, the generally clayey soils have relatively slow infiltration rates, further exacerbating the flooding potential.

Pre-settlement runoff was significantly different than it is today. With the large amount of flat lands in the watershed, the wetland depressions, and the stream associated vegetation, seasonal and peak rainfall patterns of Armand Bayou would have been very different. Less water ran off, and ran off over a longer period of time, after each storm event.

In an effort to drain large flat areas of the watershed, early settlers constructed ditches. The more modern human influences of development in the watershed have resulted in the creation of more hard surfaces. As rain falls on these developed sites, the volume that runs off is increased. Rain also flows across these smooth surfaces faster, creating expedited rates of runoff. In the development process, these two effects must be mitigated in order to maintain upstream and downstream flow conditions.

The region as a whole has also experienced significant land subsidence due to ground water withdrawal. The upper portion of the watershed has subsided more than the lower portion, which has resulted in a flattening of the stream gradient and, therefore, slower runoff.

Stream Infrastructure

Stream Facts

Basic stream facts – including such information as stream segment length, sub-basin area, approximate number of outfalls into each segment, and size and capacity of detention basins – are shown on the spreadsheet provided as part of Appendix H to this report.

Flows

The point of discharge of the Armand Bayou Watershed into Clear Lake is at NASA Parkway, approximately 3.4 miles upstream from Galveston Bay. According to the Clear Creek Regional Flood Control Study Report, the maximum allowable discharge rate of Armand Bayou, to prevent downstream flooding in Clear Lake, is 24,827 cubic feet per second for the one-percent event.[22] The City of Houston Wastewater Treatment Plant located adjacent to Horsepen Bayou contributes a maximum allowable discharge of 47.9 cubic feet per second, with an average discharge of 15.5 cubic feet per second.

Pre-settlement water flows would have been substantially different than those seen today. Because many natural surfaces have been paved over, much of the rainfall runs directly into the bayous, without infiltrating into the soil as much of it would have done prior to development. The water that was stored in the natural wetlands and that seeped into the soil would have provided a more constant "base" flow in Armand Bayou and its tributaries than seen today.

A common misconception is that the very clayey soils that are so common in this watershed differ very little from hard surfaces such as asphalt or concrete. While clayey soils do take on much less water than sandy soils (particularly in the winter), the clayey prairie soils in this watershed in their native state were able to absorb much more water than an impervious surface such as concrete, which absorbs no water at all. The naturally high amount of organic matter in the native prairie maintained good structure in the soil, which allowed a relatively high amount of water to seep into the soil.

The paving over of natural surfaces greatly aggravated flooding in the watershed. Increasing the runoff rapidly exceeded the receiving capacity of the bayou channels. It is important to remember, however, that flooding was a natural and frequent occurrence in this watershed. Prior to settlement, very few natural streams were present in the watershed, so that once the capacity of the vegetated wetlands and the infiltration capacity of the soil were exceeded (a not infrequent occurrence in the winter months when the soils swell shut), water would collect and stand until it could slowly run off. Paving has affected mainly the smaller storms. A large storm, such as Allison, would have caused flooding regardless of development in the watershed.

Types of Flooding

Three types of flooding occur in the Armand Bayou watershed: stream flooding (overbank), outside the floodplain flooding, and coastal flooding (storm surge).

Stream Flooding

Shallow floodplains exist throughout much of the county and incorporate thousands of residences and businesses. Flooding begins when the channel capacity is exceeded and usually lasts for hours rather than days.

Outside the Floodplain Flooding

Another flooding scenario is caused by ponding and overland flow, and can occur almost anywhere. When intense local rainfall exceeds storm sewer or roadside ditch capacity, the water can pond in the streets enough to flood residences that are not necessarily near a creek or bayou.

The water will seek a path to the channel by flowing overland

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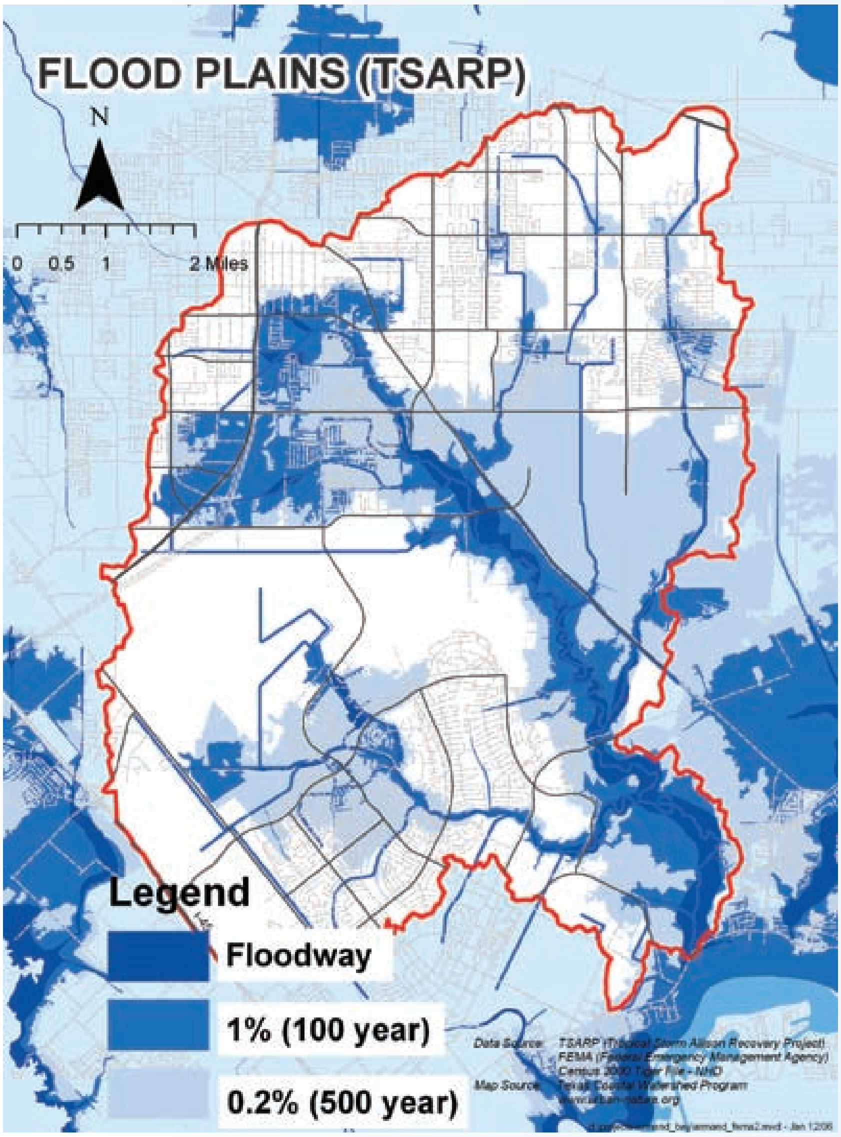
[22] The "one-percent" event is the rainfall amount that has a one-in-100 chance of occurring in any given year. This has also been termed the "100-year" event in the past, but that term implies that the rainfall event should only occur once in 100 years, which is a less accurate way of conveying the chances.



(sheet flow). When residences and other structures are in that path, additional flooding can occur. This type of flooding is not identified on the Flood Insurance Rate Maps.

Coastal Flooding

Coastal flooding occurs when unusually high tides or hurricane surges inundate low-lying structures. Ground subsidence can result in more frequent and severe coastal flooding.

Subsidence and Flooding

When subsidence causes an increase in the stream gradient (the slope), flooding generally decreases. When the stream gradient decreases, flooding generally increases. The subsidence from 1906 to 1978 caused the stream gradient to decrease along Armand Bayou and most of its tributaries, and, therefore, created more flooding.

Tide and storm surge heights are not affected by subsidence. However, in tidal areas in the watershed, an increase in the amount of terrain inundated by tidal and storm surges is directly correlated to subsidence: The land is lower, but the tide and storm surge heights are unchanged; hence, these natural occurrences inundate more land.

Subsidence is not reversible, but can be controlled, as illustrated by the actions of the Harris-Galveston Coastal Subsidence District, created in 1975. Since then, implementation of the Subsidence District's plan has halted the accelerated subsidence in the watershed.

Changing Floodplains

Flooding is a natural occurrence, but flooding problems are exacerbated by urbanization. Urbanization has resulted in increased runoff, which has overwhelmed natural channel capacities. The first large-scale development began about forty-five years ago, and development has proceeded rapidly since that time. With the creation of the regulatory floodplain around 1970, development approvals within the floodplain have generally ceased. Certain developments built outside the floodplain prior to 1970 exist in what is now the current floodplain. Many of those structures experience repetitive flooding.

New and better analytical tools have been developed, which have improved the mapping of floodplains. New floodplain maps, based on land elevations determined using LIDAR (LIght Detection And Ranging), are becoming available from the Harris County Flood Control District (See www.tsarp.org).

Areas Experiencing Repetitive Flood Losses

In response to the skyrocketing cost of these insurance claims for the National Flood Insurance Program, FEMA began offering funds through the Hazard Mitigation Grant Program to remove those homes that have the greatest likelihood of flooding multiple times. From 1998 to 2003, more than 60 homes in Pasadena were removed from the floodplain in the upper watershed, and that land has been protected from future development.

As of 2003, the areas eligible for buyout using FEMA hazard mitigation funds have been Cresthaven Estates, and Bliss Meadows, south of Spencer Highway. The portion of Armand Bayou near Spencer Highway at Denkman and Trebor Streets has also experienced repetitive flooding losses. Approximately 80 homes in the Spencer Village subdivision, the Brandywood apartments and the about 6 nearby businesses have suffered repeated flooding. Homes in the Country Briar subdivision (located along B115-00-00 [see Appendix I]) have also suffered repetitive flooding.

Voluntary Buyout Status

Voluntary buyout of flood-damaged homes has been a major focus in the Armand Bayou watershed. With money available from the Federal Emergency Management Agency (FEMA), about 60 homes in the upper portion of the watershed have already been purchased (and demolished—and removed from future development) as part of recovery efforts after significant flooding events that occurred in 1998 and during Tropical Storm Allison in 2001. More buyouts may be possible if additional funds become available. Buyouts using FEMA funding are totally voluntary on the part of the seller. HCFCD may also consider voluntary buyout of other homes that are deep in the floodplain and cannot be removed from harm's way as part of the Flood Damage Reduction Plan. This Plan aims to lessen damages caused by flooding and may include a combination of structural and nonstructural elements.

Flood Insurance Study

FEMA Flood Insurance Rate Maps (FIRMs) are maps that show areas subject to flooding from a primary flooding source – typically streams – and show floodplains based on a 1% chance of flooding (sometimes 2% as well) in any given year. The FIRMs for Harris County, including Armand Bayou, were first produced by FEMA in May 1970. Subsequent revisions occurred as more reliable data became available. Most of the maps have been updated to November 6, 1996, and remain valid to date. Revisions are underway.

The FIRMs and the associated profiles reveal that the base flood elevation (BFE) downstream of Bay Area Boulevard is less than 12 feet msl for a storm surge type of event. Ground elevations in this area average 15 feet, but range from 5 to 20 feet msl. Upstream of Bay Area Boulevard, storm surge effects dissipate. The BFE downstream of Genoa-Red Bluff Road is 20 feet msl. Near Beltway 8, where ground elevations are generally 35-40 feet, the BFE reaches 30 feet msl.

The watershed's 1% riverine floodplain covers roughly 4,300 acres, or just less than seven square miles (as mapped as of December 1991). Hurricane surges in the lower reaches increase the amount of land in the 1% floodplain. During the 1% and more frequent events, the main stem and its tributaries are out of their banks. The main stem floodplain delineated on the FIRMs average more than 2,000 feet wide for the 1% storm. Segments of Armand Bayou tributaries contain the 1% event.

Detention

The concept of stormwater detention as an urban stormwater management tool is widely used throughout the Texas Gulf Coast. Detention is designed to alleviate expedited and increased runoff by collecting the rain that falls on a given site, directing it into an oversized storm sewer or basin, and detaining it from discharging into the stream or public storm sewer system until the peak flow of the stream or system has subsided. It then releases the stormwater through a small outflow pipe that is placed at an elevation below peak flow. Although detention facilities in upper reaches of a watershed have been found to reduce flood levels, detention in the lower reaches of a watershed is generally unnecessary because the objective is to flush the water out before the headwaters flow downstream.

Detention has been used to varying degrees by communities in the watershed. Detention gained popularity as a regulatory mechanism around 1980, but not all communities chose to require detention at that time. Most communities now require detention for large residential developments, and many require detention in some form for even small commercial development. Numerous private, onsite detention facilities ranging in size from less than one acre to more than 25 acres are scattered throughout the watershed.

In addition to requiring detention to offset impacts of a particular development, some communities have begun to provide large regional facilities on their own and/or in partnership with HCFCD to offset past development impacts. These facilities range in size from 35 acres to over 135 acres on upper Horsepen Bayou, Ellington Air Field, upper Armand Bayou, and near the actively developing Beltway 8 / Fairmont Parkway area.

Possible Action Items Toward Plan Implementation for Flooding and Stormwater Management

To accomplish the Watershed Partnership's goal to "reduce the impact of flooding on homes and business, using the watershed's natural ability to absorb floodwaters wherever possible," Phase II action items may range from continued use of voluntary buyouts to changing the amount of impervious cover in the watershed. Some examples for the Phase II planning process could be:

1. Explore all avenues for voluntary buyouts of repetitive flood loss properties.
2. Develop pilot projects on effective best management practices to reduce surface runoff from residential properties.
3. Develop ordinances to reward strategies that reduce runoff from residential and/or commercial properties.

Demographics

Who lives in the watershed? People are just as much a part of the watershed as the land, plants, and animals we have described in previous sections, and are part of what makes each watershed unique.

Examination of information available from the 2000 census reveals some interesting patterns. As shown in the first illustration, most of the development in the watershed did not begin until the 1960's, with most of the building occurring in the 1980s and 90s. The newest development is occurring in the central part of the watershed—northern Clear Lake and southeast Pasadena. Income is not evenly disturbed throughout the watershed—the wealthiest citizens live in Clear Lake and southeast Pasadena but a pocket of relative affluence is also found in Deer Park (Appendix C). The home ownership or tenure map (Appendix C) mirrors somewhat the income map but shows where the most stable populations occur—again: Deer Park, Clear Lake, and southeastern Pasadena.

The Travel Time to Work map (Appendix C) reveals how many people work in or near the watershed –time to work is smaller the closer your work is. The southern fringe of the watershed has a lot of people who work at NASA, and the Deer Park area has a significant number that work near the Houston Ship Channel. By and large, though, most people work at some distance to the watershed.

Demographics have been changing in the watershed. One demographic map in Appendix C shows the relative proportion of foreign-born residents in the watershed. Others show that Latinos and Asians are the dominant immigrant groups, with Asian populations concentrating in the Clear Lake area and Latinos in the upper part of the watershed. The highest concentrations of African Americans are found in the southwest corner of the watershed (Webster) and in the southernmost sector of the watershed.

Public Education and Outreach

Improved stewardship and involvement by the general populace is crucial to the successful restoration and preservation of Armand Bayou. Stewardship and involvement build ownership within the community and ultimately reduce management costs. Increased involvement and better stewardship may be developed through a greater awareness and understanding of the economic and environmental value the bayou possesses.

A coordinated outreach and public education campaign is necessary to enhance understanding, change attitudes, and stimulate action of people within the watershed. With knowledge, people can make informed decisions at home in regards to conservation landscaping, vehicle maintenance, disposal of household hazardous materials, and others. They are equipped to carry out individual and community-wide projects, such as conservation landscapes, trash pick-ups, recycling, water gardens, community vegetable gardens, and use of multi-purpose open space parks. As people learn more, they are more likely to engage in the decision making process, affecting policy and management decisions.

Awareness and Stewardship

Almost every visitor to the Armand Bayou Nature Center (Nature Center) understands the beauty and value of Armand Bayou. The water and its riparian corridor seem an intact, undamaged area; visitors are often unaware of the signs of subsidence and other human disturbance. They support the protection of this and similar natural areas. But the same patrons may not understand that they live in the Armand Bayou watershed, and that what they put on their lawns or throw on ditches or streets ends up in the Bayou itself.

In the Houston area, watersheds as a system are poorly understood. This is one of the main challenges facing the Armand Bayou watershed: how to create a sense of identity and community amongst the residents of the watershed, and an understanding of how watersheds work, so that they value the Bayou and its watershed and become effective stewards.

Current Outreach Efforts

The greater Houston region has benefited from years of water quality outreach, by various organizations ranging from the Texas Commission of Environmental Quality to the regional Houston-Galveston Area Council to more localized efforts, such as by the Nature Center. (See Appendices I and J.) While not always coordinated, the message does in fact seem to be catching on. Citizens are aware that water quality affects them as well as the environment, and have for the most part eliminated obviously detrimental actions like dumping used car oil into the storm drain. However, as mentioned above, they do not always make the connection between the storm drain in their street and the bayou ecosystem.

Generally speaking these outreach efforts can be categorized as one (or more) of the following:

Promotional Materials. These publications have been printed or are online and are often readily available; videos that can be borrowed or otherwise obtained for viewing. These are valuable to supplement presentations and to hand out at fairs and other outreach events with mass attendance. The material

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is standardized, and therefore the message is presented equally to all audiences. Printed materials help reinforce a message that may be lost, as they can be read and re-read at leisure. Because they have already been produced, these promotional items can usually be obtained free of charge, even in large quantities.

Workshop and Classroom Activities. Many organizations offer workshops to provide a hands-on experience. These range from creating a wildlife-friendly habitat on school grounds to wading knee-deep into the bayou to collect and examine "bugs" (macroinvertebrates) to locally based ecology courses like Master Naturalists. In some cases, the participants enroll and attend at a specific organization's facility (as in the case of the Nature Center's EcoDays); but in other cases, educators go to schools and teach students in their classrooms as part of their school curriculum. In addition, the activities can be varied depending on the educator and the audience, for a more individualized lesson.

Public Participation Opportunities. For those seeking a greater level of involvement, numerous opportunities for direct public participation exist. Storm drain marking, regular water quality monitoring, local recycling programs, clean-up days, and other activities are organized by the municipalities and organizations in the area. These are often highly staff- or volunteer-intensive, yet regularly are reported to have the greatest impact upon participants. Such opportunities also have the ability to provide immediate, direct, and quantifiable impact upon the environment.

Much of the outreach available in the Armand Bayou area is listed in the Appendices I and J.

Possible Action Items Toward Plan Implementation for Public Outreach and Education

To accomplish the Watershed Partnership's goal to "improve awareness and understanding" and to "increase stewardship of Armand Bayou and its tributaries," Phase II action items may range from continued developing a coordinated outreach plan to promoting Armand outreach through new venues. Some examples for the Phase II planning process could be:

1. Develop and widely disseminate the results of the Phase I and Phase II plans.
2. Review regional, state, and national polls, and conduct local polling to determine the most effective messages to accomplish the Watershed Partnership's mission.
3. Develop key themes to serve as core messages to be incorporated in promotional materials and classroom/workshop activities by jurisdictions and organizations in the watershed.

Parks

A portion of the Armand Bayou Watershed Partnership Mission Statement is to improve the quality of life of the residents in the community. Parks and their availability play a role in the quality of life for a community. The municipalities in the Armand Bayou watershed are the City of Houston, the City of Pasadena, the City of La Porte, the City of Deer Park, and the City of Taylor Lake Village, all within Harris County Precinct Two. The City of Houston and the City of Pasadena comprise the greatest amount of land in the watershed, with 14,079 acres and 12,129 acres, respectively. Harris County, the City of Houston, the City of Pasadena, and the City of La Porte have adopted park master plans, which provide park system inventories and evaluation of the status of the park systems in relation to identified needs, goals, and objectives for parks in their respective areas.

The Greater Houston metropolitan area, like much of the nation, is growing. All municipalities in the watershed have acknowledged this growth in their master plans, as well as recognized the importance of expanding parks and open space

to meet the needs of a growing population. For many years, to find the suitable amount of parkland per population, municipalities relied on standards of the National Recreation and Park Association (NRPA). While those standards are no longer in place, it is important to estimate the amount of park acreage needed for a population. Local governments have used NRPA guidelines, as they relate to the size of parks, to evaluate the adequacy of their park systems and develop target goals, in the ranges listed in Table 1. However, each municipality's definition varies in acreage size, so classification of a park type is dependent upon the classification system of the municipality within which the park lies.

Table 1. Traditional Park Guidelines

Park Type	Service Distance	Desired Size	Desired Acreage per 1,000 people
Neighborhood	1/2 -1 mile	1 to 10 acres	1.25 - 2.5
Community and Linear	1 -3 mile	5 to 50 acres	5.0 - 8.0
Regional	Up to 5 miles	50 to 200+ acres	15 - 20

Table 2. Harris County Precinct Two Amenity Priorities

Rank	Priority
1	Land acquisition/ park expansion
2	Trails (natural and hard surface)
3	Nature/ Conservation areas
4	Soccer Fields
5	Football Fields
6	Skate park
7	Trees/ landscaping
8	Art, monuments, sculpture, etc.
9	Playgrounds

Harris County

The Armand Bayou watershed is found inside Precinct Two, which is in the eastern section of Harris County. *The Harris County Master Plan for Parks, Recreation, and Open Space* (Harris County Park Master Plan) was adopted in May 2001. Harris County has eight parks within the watershed, which include one neighborhood park, three community parks, one regional park, one linear park, one special use park, and one undeveloped park. Five of the parks can be found inside city limits, with three in unincorporated sections of the county.

General Goal and Objectives

The general goal of the Harris County Park Master Plan is to serve all recreational needs by promoting and developing parks in Harris County, while remaining fiscally responsible and mindful of parks in incorporated municipalities. The general objectives are to follow park standards – those can be found in the Harris County Park Master Plan - and improve park safety and accessibility. The County's goal towards the natural environment is to " continually identify, protect, and preserve quality natural open spaces for unstructured recreational activities, inherent aesthetic value and protection of valuable ecosystems," by working with surrounding governments and organizations, limiting development in sensitive areas, and returning parkland to their natural habitat.

Needs

In order for Harris County to meet its acreage goals for parks, it would need to acquire large tracts of land and develop them as parks or open spaces. Along with meeting the parkland acreage goal for the existing population, the acquisition of land in the county is important in order to keep up with the population growth, especially in areas that are not within incorporated cities. Precinct Two, as well as the other three precincts of Harris County, has identified desired recreational amenities. Table 2 gives an abbreviated ranking of park amenities for Precinct Two, as identified by Precinct Two park staff.

Houston

The City of Houston Parks and Recreation Master Plan (Houston Parks Master Plan) was adopted in October 2001. Houston has 3 parks inside the watershed, 1 neighborhood park, 1 regional park, and 1 linear park, with a total of 307 parks throughout the city. Many of the city goals, objectives, and needs may not apply or affect the portion of the city inside the Armand Bayou watershed.

General Goals and Objectives

Houston's parks goals and objectives can be found in full in the Houston Parks Master Plan, October 2001. The master plan has identified goals to provide all park types, recreational facilities, and activities to all citizens, while managing to encourage proper use. One goal speaks to a related goal of the Armand Bayou Watershed Partnership, that is, to use the park system to protect environmentally significant areas within the city for the public and for education. The objectives for all of these goals includes such things as: utilizing alternative sources of land, providing facilities to underserved areas, designing new durable parks, redeveloping existing parks, making use of partnerships, and expanding linear park system along bayous, rivers, and streams.

Needs

Park needs in Houston were identified for seven sectors of the city. The Southeast sector encompasses the area around I-45 between 610 Loop and the City of Webster, and a portion of the Armand Bayou watershed lies within this section. Sections of the Needs Assessment for the Houston Parks Master Plan have been left out of this discussion if they did not apply to the Armand Bayou watershed.

Three methodologies, or criteria, were used to identify the needs for parks: standard-based, demand-based, and resource-based. Defining needs through standard-based criteria involves analyzing state and national standards and a comparison across cities. A demand-based criterion takes into account public input. Resource-based criteria recognize unique resources, historical and natural, that should be protected in the park system.

To meet the goals set, the city would need to acquire eight new sites to abide by park standards and to match the community's demand, and this would also provide an opportunity for joint ventures. An expansion of two existing parks would improve park access and visibility, which would also relieve overuse. To improve park development, the city needs to rehabilitate and restore all existing parks, based on the current condition of existing parks, the popularity of the Parks to Standard Program (PTS), and community demand. Improvement and/or development of two vacant or undeveloped park sites is needed because of existing urbanized areas with inadequate parkland. To resolve conflicts with other sport activities the city needs to build two more soccer fields at existing and new parks and relocate tournament fields out of neighborhood parks. Also, constructing a new recreation center would serve communities and regions currently without centers. Acquiring and constructing seven new facilities would eliminate substandard facilities and reduce travel time by personnel.

Pasadena

The current *City of Pasadena Parks, Recreation, and Open Space Master Plan* (Pasadena Park Master Plan) was adopted in 1998. There are 7 parks in the Armand Bayou watershed that are owned and managed by the City of Pasadena, 4 pocket parks, 2 neighborhood parks, and 1 undeveloped park.

General Goals and Objectives

The general goal of the Pasadena Park Master Plan is to develop and enhance a balanced network of facilities that will serve the recreational needs of all the citizens. The general objectives are to adopt the standards and guidelines that are set in the park classification section of the Pasadena Park Master Plan and improve all parks by ensuring their access, safety, and maintenance standards. Environmentally, a goal of the Pasadena Park Master Plan is to protect and acquire open spaces for "unstructured" recreation, "aesthetic value, and protection of valuable ecosystems."

Needs

The identification of needs for the parks in the City of Pasadena was based on three methodologies. The standard-based methodology placed all parks into categories similar to those used by NRPA for assessment. The second method was demand-based and involved input, in various forms, from the public. The third method, resource-based, concerned analyzing unique resources in the city that would enrich the experience of users.

From these three approaches, the City has found that no more pocket, or mini, parks are needed; instead there is a need for neighborhood, community, and regional parks. A greenway, or trail, system is also needed to link the city park system together. Both of these needs require land acquisition or re-development of existing parks to more adequately meet the needs of the citizens. The city also needs to acquire more facilities, such as aquatic centers, playgrounds, recreation centers, RV parks, and picnic areas. Additionally, the citizens of Pasadena expressed a need for citywide beautification and an increase in natural areas.

La Porte

The La Porte Park Master Plan was adopted in 2001. The City of La Porte has 8 parks inside the watershed, which include 2 neighborhood parks, 1 community park, 3 regional parks, and 2 undeveloped parks. Like the City of Houston, many of the goals, objectives, and needs were written after assessing the entire city, so some of them may not apply or affect the portion of La Porte inside the Armand Bayou watershed.

General Goals and Objectives

The La Porte Park Master Plan identified seven goals, all followed by ensuing objectives for achieving the goals. One goal, however, stands out because of its compatibility with the goals of the Armand Bayou Watershed Partnership. The goal is to "preserve and protect unique natural open spaces and important habitat areas for threatened and endangered species of plants and wildlife." The objectives for this goal include such things as: improving the environmental quality of Galveston Bay, acquiring new land and maintaining existing lands, practicing sound flood management, and promoting environmental education.

Needs

The La Porte Park Master Plan has broken the park needs into two categories; facility needs, based on usage and standards, and citizen-expressed desires. The highest priorities based on facility standards are the addition of trails in the city, more nature viewing areas, more pavilions, more soccer fields, more baseball complexes, and more practice areas. The citizens of La Porte recognized some of the same needs as set by facility standards, but also acknowledged additional needs. High priority needs based on citizen feedback are more playground equipment, more picnic facilities, more trails, more natural habitats, more pavilions, and more senior centers. The Park and Recreation Department has also recognized a need to improve existing parks, playground safety, update over-used parks, and acquire more parklands.

Possible Action Items Toward Plan Implementation for Parks in the Watershed

To accomplish the Watershed Partnership's mission of "improving the quality of life in our community," Phase II action items may range from increasing water access to expanding park acreage. Some examples for the Phase II planning process could be:

1. Identify points of possible water access to the Armand Bayou and its tributaries.
2. Acquire new lands for new and existing parks in the watershed.
3. Identify areas of possible connectivity between parks and between the Armand Bayou and parks.