The Citizen's Guide to the Charleston Harbor Project

The Importance of Wetlands

Flood and Erosion Protection: Wetlands protect against flood damage by acting as natural tubs or sponges - storing water and then slowly releasing it. Wetlands act as buffers for the mainland by slowing and absorbing storm surges as well as the daily inrush of the tides, so they also prevent erosion of the coastline. The roots of wetland plants secure riverbanks against erosion.

Filtering Pollutants: Wetlands protect water bodies by removing significant amounts of sediments, nutrients, organic matter, and pollutants from runoff before these substances can enter the water. Many molecules easily adsorb, or attach, to individual sediment particles. As a result, sediments can act as chemical sinks by adsorbing pollutants. The salt-tolerant plants in the wetlands then filter out the sediments from surface runoff before it reaches the water body. In addition, filter feeders, such as oysters and clams, clean the water as they feed.

Serving as Habitat: The accumulation of nutrients from both fresh and salt water sources makes estuaries extremely productive areas, having tremendous food reserves that support vast numbers of organisms. The fluctuating temperature, salinity, and dissolved oxygen levels of small tidal creeks in wetlands make them difficult places for many organisms to survive, but these same conditions make the creeks excellent nursery grounds for the larval stages of creatures such as shrimp, oysters, and crabs. Since they have broader tolerances than the larger adult predators, the larval prey species can survive where the predators cannot. Without wetlands, these species would not survive long enough to reach adulthood.

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Preface

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COMMERCE, SCIENCE, AND
TRANSPORTATION: RANKING

APPROPRIATIONS
COMMERCE, JUSTICE, STATE AND
THE JUDICIARY: RANKING
DEFENSE
LABOR, HEALTH AND HUMAN SERVICES,
EDUCATION
ENERGY AND WATER DEVELOPMENT
INTERIOR

BUDGET

DEMOCRATIC POLICY COMMITTEE

This "Citizens Guide" summarizes six years of work that is of particular importance to those of us who make our homes along the South Carolina coast. Over twenty-five years ago, coastal populations were surging, and pristine coastal property and wetlands were being lost at an alarming rate. Concern for our nation's coastal resources prompted me to sponsor the Coastal Zone Management Act of 1972. That legislation did much to protect the natural resources that are one of the distinctive features of our quality of life in the Lowcountry. But by 1990, new problems called for new approaches.

The Charleston Harbor Project, conducted under the Coastal Zone Management Act, is such an approach. It is an example of local leadership, initiative, and concern translated into informed action. The Charleston Harbor Project began with people asking, "What does rapid growth mean to our community? How does it affect our economy, our environment , and our cultural and recreational resources?" Project scientists, local officials, and field research teams have worked for the last six years to identify policy issues and how best to address them. The Charleston Harbor Project examined pollution and stormwater runoff, subdivision design and industrial permits, tidal creeks and colonial wading birds, and much more. Using state-of-the-art methods and technology, a core group of local experts developed a series of carefully conducted investigations designed to assure that public policy is grounded in sound science and seasoned judgement.

The current population of Berkeley, Charleston, and Dorchester counties -- the region examined under the Charleston Harbor Project -- is more than twice as large as it was in 1950 and is expected to rise by another 120,000 by 2015. The cultural, recreational, and natural resources that attract both permanent residents and visitors to the area are at stake. Unless we plan now to manage our region's growth, we risk losing assets that we never can recover.

The Southeast lost 605,000 acres of wetlands between 1985 and 1995, and the effects of those losses can be seen in many large coastal communities to the north and south of Charleston such as Tampa Bay and the Chesapeake Bay. Charleston has a chance to avoid similar problems through far-sighted action. The Charleston Harbor Project lays out a timely and effective strategy for combining economic growth and sound environmental management.

Senator Ernest F. Hollings

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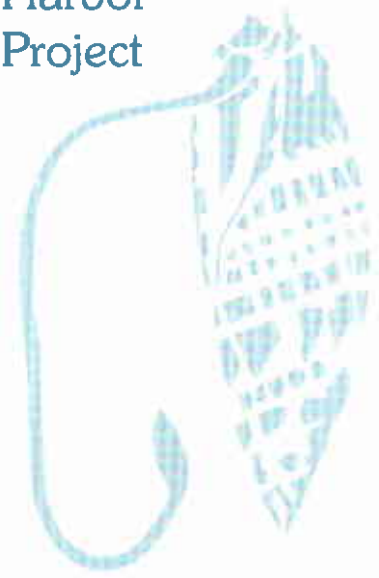
The Charleston Harbor Project



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Words and phrases that are italicized can be found in the glossary at the end of the booklet. Though, in many cases, familiar and a part of everyday usage, the words are defined with the technical meaning used by the professionals who conducted the studies and wrote about their research and findings.

The Charleston Harbor Project Study Area

The Charleston Harbor Project Study Area

The Charleston Harbor Project is a multi-year program of applied research leading to the preparation of a Special Area Management Plan (SAMP) for the Charleston, South Carolina, metropolitan area. A SAMP is a coastal management planning process that allows modifications to general coast-wide policies where local conditions or circumstances call for special measures. A Special Area Management Plan is needed in Charleston because of rapid population growth and associated land use changes. Growth increases the stress on sensitive natural systems—from egret nesting grounds to marsh vistas—that play so large a role in Lowcountry life.

Charleston, South Carolina, and its surrounding uplands and *estuary* represent a nationally significant cultural, natural, and economic resource. Charleston is a center of commerce, government, and education, and a place where historic buildings and natural beauty combine to create a favorite destination for travelers. The port is one of the largest container ship handlers in the nation, and the Harbor supports the largest commercial shrimp fishery in the state. New industries are coming to the area in record numbers. Striking a balance that will both sustain economic growth and protect the environment becomes an increasing concern.

covers more than 1,900 square miles
contains over 140 miles of rivers
is home to half a million people
and to millions of plants and animals

A Citizen Initiative

The Charleston Harbor Project came about as a result of growing citizen determination to protect the special character of the Charleston Harbor area. The experience of other places provides a glimpse of one future for Charleston, a future no one welcomes. In the aftermath of rapid growth, city after city has suffered widespread environmental damage, including pollution, blight, and problems with water supply or water quality. After-the-fact attempts at restoration are expensive and often disappointing:

It can happen here.

Boston Harbor:
An 11-year cleanup program is now underway. Cost estimates are $3.5-$4 billion.

Chesapeake Bay:
Over $2 billion has been spent on the Chesapeake Bay Restoration Project. Some S60 million is needed annually to sustain the cleanup.

Tampa Bay:
Cost to date is $2.5 billion. Continuing expenditures are over $200 million per year.

New York Harbor:
Enormous cleanup efforts are underway. A single project for correcting sewer overflows is estimated to cost as much as $5 billion for New York and $1.5 billion for New Jersey.

San Diego Bay:
Over the past five years, $16 million was spent to clean up the Bay, with a focus on commercial sites. The Navy provided over $4 million for radioactive waste cleanup work. The city is constructing a $134 million sewage outfall project to deal with sewage spill and increased discharges.

Years of growing environmental awareness, sometimes as the result of costly tragedies, have made us more conscious and conscientious about environmental issues.

Charleston citizens want to avoid a future where only strangers would think of swimming in the Harbor, or where sweetgrass and basket-makers are only memories. They seek an innovative, common-sense approach to management for the long-term protection of Charleston's water resources.

CHP Response

Background & Approach

From the outset, the Charleston Harbor Project has emphasized intergovernmental cooperation in planning and management and the continuing involvement of civic leaders and the business community. Coordinated management at the *watershed* level will enable the community to consider economic, cultural, and natural resource decisions in a common context. This approach accomplishes two purposes: it fosters new working relationships, and it supports every phase of the work by creating a broad network of knowledge. Policies that work are based on a sound understanding of conditions and processes; they evolve from rigorous research in the natural sciences, or professional review of engineering, economic or organizational issues. The Harbor Project was designed to develop responsible, well-conceived public policies and to direct attention to critical areas where too little is now known and more work is needed. For example, Harbor Project researchers were the first to identify previously unrecognized problems such as *toxic* pollution in some urbanized creeks, and to systematically investigate the *ecology* of *tidal creeks* and the key role of soils and *stormwater runoff* in overall water quality.

Primary Goals of the Harbor Project:

To maintain and enhance the quality of the environment in the Charleston Harbor estuary system,
To maintain the wide range of uses of waters and natural resources of the system,
To anticipate and address *potential* problems before adverse impacts occur.

The work involves reviewing and, where necessary, rethinking what is now being done in Charleston. What is the overall state of the Harbor as an economic resource and a natural asset? Are critical conditions improving or deteriorating? What are the measurable results of current management policies? What methods used elsewhere might be applied here? What trade-offs are involved in arriving at a recommended combination of goals and policies?

Funding & Program Support

In 1992, the National Oceanic and Atmospheric Administration provided federal funding for the six-year Charleston Harbor Project through the national Office of Ocean and Coastal Resource Management. Additional support has been provided through jointly-funded projects with state and federal agencies such as the U.S. Environmental Protection Agency, U.S. Geological Survey, U.S. Army Corps of Engineers, U.S. Department of Defense, the S.C. Department of Transportation, S.C. Department of Archives and History, Charleston County, and local utilities. The Project has been carried out by the S.C. Department of Health and Environmental Control through its Office of Ocean and Coastal Resource Management. Research projects have been conducted by specialists from public and private institutions including the S.C. Department of Health and Environmental Control, the S.C. Department of Natural Resources, the University of Charleston, The Citadel, the University of South Carolina, Clemson University, the Jones Ecological Research Center, and many others.

Twelve public *Task Forces* were established to focus on key topic areas. Participants have included representatives from federal, state, and local governments; private citizens; and community and civic organizations. Over 200 people attended workshops and briefings, evaluation sessions, and other meetings, some committing hundreds of hours.

Task Forces

Biological Resources	Marina
Cultural Resources	Point Source
Data & GIS	Public Involvement
Dredge/Spoil Disposal	Recreation
Economic	Stormwater
Land Use	Water Quality Modeling

The *Management Committee* consists of the Chairperson and Vice Chairperson from each Task Force as well as representatives of key agencies involved in the planning and management of the Harbor Project area. The findings and recommendations of each Task Force were considered by the Management Committee to add an inter-disciplinary and multi-issue perspective.

CHP Organization Structure & Community Participation

Better Management

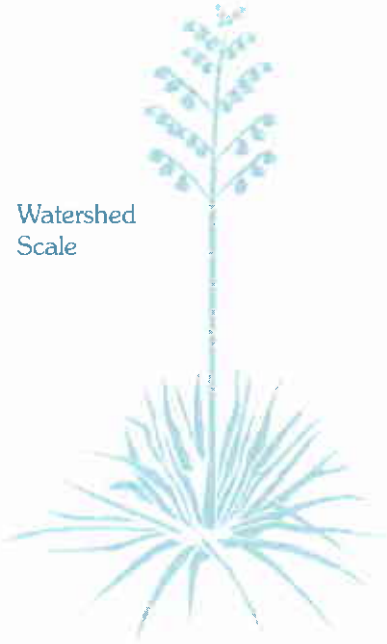
A recurring theme in the Harbor Project is matching the scale and timing of public policies to the problems they are meant to solve.

Current Best Practices

Too often, management strategies are short-sighted or based on perspectives and reasoning that have become outdated. For example, many environmental management reviews are triggered by permit requests from individual property-owners. Decisions on these permit requests are made on a parcel-by-parcel basis. Little attention is given to the combined effects of the same action on a series of nearby properties, or the cumulative effects over a span of five or ten years on an entire habitat. As another example, under the original *wetlands* regulations, small isolated wetlands often are unprotected as long as larger adjacent wetlands are buffered. These smaller wetlands have been routinely filled as properties are developed. With the passage of time there has been a noticeable decline in such species as the flatwoods salamander, for which the small wetlands are a critical habitat.

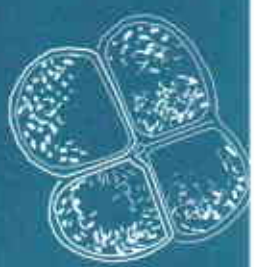
Watershed Scale

Management of the Charleston Harbor at the watershed level provides a logical alternative to the current parcel-level permit review. An area-wide watershed planning scale allows local, state, and federal managers more flexibility with permit decisions, better spatial definition of natural resources, and more predictability for economic development. Watershed-level planning can ensure that transportation corridors do not conflict with areas that should be protected as biological *habitats*. And the change in scale makes region-wide measures, such as *mitigation banks*, workable strategies for sensible solutions to localized problems. The Charleston Regional Watershed boundary adopted by the CHP is consistent with natural drainage boundaries for water quality management, the ecosystem boundary for natural resource management, and the regional community boundary for economic development.



CHP
Featured Project

Modeling the Dynamic Charleston Harbor System



Water quality management protects the living creatures of the Watershed and is essential to the commerce and enterprise that make a place prosperous. Understanding the complex interactions of river flows, tides, and rainfall is critical to effective management in the Watershed. They are dynamic processes, varying from place to place and season to season.

One of the first goals of the Harbor Project was the development of an improved *water quality model* of the Charleston Harbor system, a model which would represent the Cooper River as well as the Ashley and Wando rivers, and would directly account for the impact of stormwater runoff.

Many agencies and institutions took part in the data collection, analysis, model design, and calibration work. The CHP formed a multi-disciplinary team of experts and began to develop what was to become nationally recognized expertise in the field. The team consisted of Mr. Paul Conrads, United States Geological Survey; Dr. Earl Hayter and Dr. Steve McCutcheon, Clemson University; Dr. B.J. Kjerfve and Dr. Hank McKellar, University of South Carolina; Dr. Elizabeth Blood, Jones Ecological Research Center; and Ms. Terry Sicherman, Mr. Pauley Smith, Mr. Frank Dantzler, Mr. Jeff Wychowski, and Mr. Chester Sansbury of the S.C. Department of Health and Environmental Control.

The team delivered an operational water quality model representing the Cooper and Wando rivers. (A model representing the Ashley River has since been completed.) Computer models enable managers to develop measurable thresholds for maximum discharges and to undertake watershed scale management instead of only permit-by-permit rulings. The CHP model simulates water levels, streamflows, salinity, and concentrations of *nutrients*. It mathematically describes the natural system, and enables decision-makers to estimate the impact of change—to ask "what if?" It marks a significant improvement over earlier models.

Models developed by Dr. Blood predict the amount of pollutants that go into the Cooper and Wando rivers from different types of development. Two stormwater runoff models were created for applications in regional and local planning. A detailed spatial model was used to compare the impacts of typical *"Sprawl"* land use patterns and mixed use "Town" design in a large, unbuilt tract known as Belle Hall Plantation. A large scale model was used to develop the first *nitrogen* budget for air, land, and discharge pipe sources in Charleston Harbor. These models utilize *Geographic Information System (GIS)* technology for analysis and display, enabling planners and resource managers to visualize the relationships between patterns of urbanization and surface water quality.

CHP
Featured Project

Belle Hall Plantation Charrette

Designing for Development & Environment

Sprawl

Town

This project investigated the environmental impact of design options for developing a 583 acre tract of land in the Town of Mount Pleasant. The property, Belle Hall Plantation, is in a prime location. Design alternatives had to be feasible in terms of existing land planning regulations, standard practices, and business planning (financing and scheduling, market demand, etc.).

The urban design firm of Dover, Kohl & Partners led a three day exercise, or *charrette*, in which the participants designed two development scenarios. The Sprawl scenario was based on conventional site layout practices as currently followed in the area—large lots and wide streets, cul de sacs, and a "power center" commercial area. *Design principles* for the Town scenario were based on examples from Savannah, Downtown Charleston, and the Old Village in Mount Pleasant—conserving open space by using smaller lots with a grid street pattern and blending commercial and residential areas. Participants included planners from the Town of Mount Pleasant and Charleston County, private and public sector engineers, architects, developers, ecologists, and local officials.

The two designs were then compared using computer simulation models to forecast environmental impacts. The results showed that water flowing from the project area to the nearby creeks and marshes and the Wando River would be far less polluted under the Town scenario because it provided more open space between the development and the receiving water body. Also, in the Town scenario, the placement and the overall reduction of *impervious surfaces* (roofs, streets, sidewalks) meant that rainwater would be more likely to be absorbed into grass and soil and less likely to move quickly across pavement, etc., carrying oil, chemicals, or other pollutants into the creeks and ponds. The amount of *surface runoff from the Sprawl scenario* was 43% higher than the Town scenario. *Sediment loads* were also three times higher in the Sprawl scenario than in the Town scenario.

It should also be noted that the preservation of open space in the Town scenario provided much greater opportunities for the preservation of biological habitat and such amenities as walkways and viewscapes. Projected *infrastructure* costs were almost 50% lower in the Town scenario because there were fewer roads to pave and water/sewer lines to install. The more compact Town design was also advantageous from the standpoint of planning for such public services as police and fire protection and garbage collection.

The project was the subject of featured articles in *News-Notes*, a periodical published nationally by the Environmental Protection Agency, and in the quarterly of the National Association of Home Builders. Innovative design concepts applied in the Belle Hall Charrette are currently incorporated in high profile local development projects.

CHP
Featured Project

Tidal Creek Project

The Creeks & Estuaries

The Tidal Creek Project is the capstone of two years of coordinated CHP water quality and fishery habitat projects that identified small tidal creeks as potentially critical management points within the Charleston Harbor estuary.

Rapid population increases are projected for the Charleston Harbor Project area. This growth requires significant land use changes as forests are converted for human uses. Land use changes degrade water quality by short-circuiting natural absorption and treatment of runoff through the soils. As land use intensity increases from forest to suburban, urban, or industrial uses, runoff quantity increases and water quality declines. The Tidal Creek Project demonstrated dramatic and potentially detrimental changes in small tidal creeks.

Earlier CHP projects document the critical importance of small tidal creeks as nursery areas for highly valued fishes and crustaceans. CHP research also shows water quality conditions in small creeks to be much more extreme and stressful than conditions in large rivers. Although water quality management is designed to protect fishery habitats, policies focused on main rivers may not adequately protect critical habitats. Since the productivity of these nursery areas is dependent on adequate water quality, the Tidal Creek Project was to develop recommendations for the proper management of these important habitats.

The Tidal Creek Project designed specific objectives to protect these habitats:

- Characterize and define the ecological values and services of tidal creek systems.
- Identify pollution threats to the tidal creeks resulting from human development.
- Develop environmental quality criteria for sustaining tidal creek nursery functions.

The Tidal Creek Project was conducted by the S.C. DNR Marine Resources Division Marine Resources Research Institute (Dr. A. Frederick Holland, George Riekirk, Scott B. Lerberg, Lynn E. Zimmerman, Denise M. Sanger). The National Marine Fisheries Service Southeast Fisheries Science Center also participated (Dr. Geoffrey Scott, Dr. Michael Fulton, Brian C. Thompson, James W. Daugomah, John C. DeVane, Kevin M. Beck, and Aaron R. Diaz).

The Tidal Creek Project selected twenty-four creeks in the CHP study area with typical land use patterns: pristine, suburban, urban, and industrial. The physical, chemical, and biological characteristics of these creeks were measured and compared. The findings include:

- Pristine small tidal creeks are naturally stressful environments where fish and shrimp survive near the limits of their tolerance during extreme summer conditions.
- As nearby land is converted to residential, commercial, or industrial uses, conditions in tidal creeks intensify markedly. The creeks become less suitable as nursery grounds. Salinity levels vary erratically. There is more toxic contamination in sediments, and the health and vigor of individual animals declines.
- Small tidal creeks act as conduits for pollutants associated with uplands development, carrying them into the estuary.

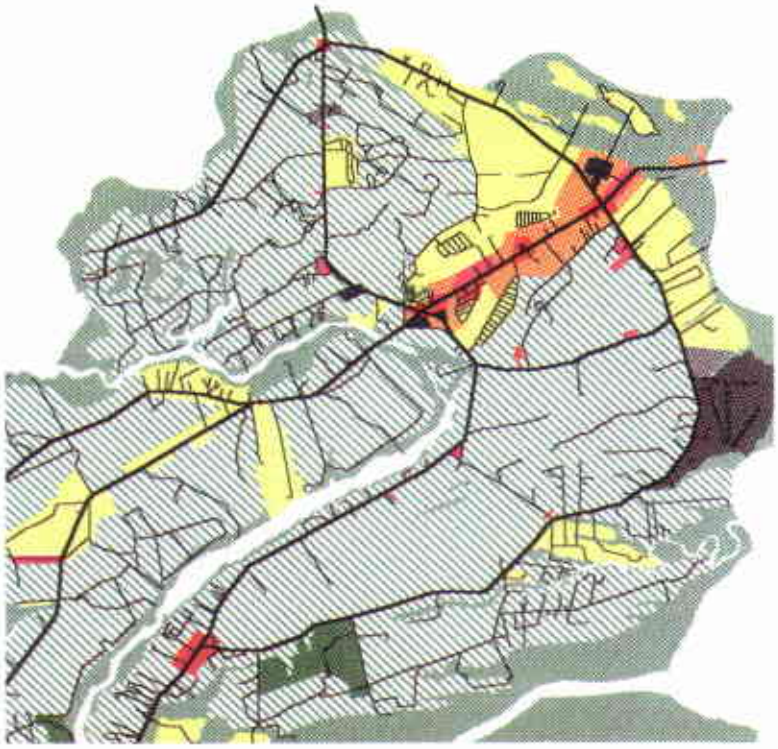
The Tidal Creek Project identified small tidal creeks as a critically important component of southeastern estuaries. The study deepens the understanding of the intimate relationship between land use and biological health in an estuarine environment. Plans are underway to continue tidal creek research, expand monitoring programs, and develop new techniques for the protection and preservation of these environments through the cooperative efforts of federal, state, and local managers.

Related work on the variability of estuarine creeks was carried out by Dr. Phillip Dustan of the University of Charleston, S.C., Dr. Hank McKellar from the University of South Carolina, and others. Their work was designed to derive a better understanding of the coupling between land and creek by monitoring fine scale changes in water quality. Creeks in developed areas were compared to creeks near pristine watersheds. They found that stormwater runoff enters the urbanized estuary quickly, causing sharp changes in water salinity and other parameters. Rainfall and runoff in the less developed watershed indicated an "ecological dampening" effect linked to the hydraulics of the two watersheds and the size of the storm. Threshold effects were observed and catalogued that were unknown prior to their research.

CHP
Featured Project

Metropolitan Charleston 1990 - 2015

Impact of Future Urban Growth



Johns Island Land Use

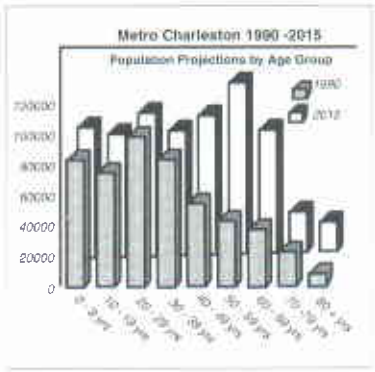
The Berkeley-Charleston-Dorchester Council of Governments was the lead agency in a study of development trends and projections in Metropolitan Charleston. The S.C. Department of Transportation and the S.C. Department of Commerce also participated. The work incorporated the collective experience and expectations of planners from three counties and eleven cities and towns, as well as officials from school systems, public utilities, and special service districts.

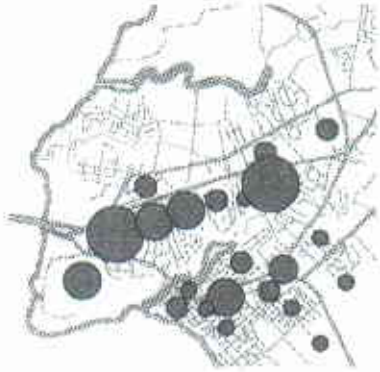
In 1990, there were more than half a million people living in the tri-county region. It was the fastest growing major metropolitan area in South Carolina between 1980 and 1990. The tri-county region accounted for one-fifth of the total population growth in the state during the eighties. *Demographers* and *economic developers* agreed that the region would continue to be a growth center into the twenty-first century. Local officials are asking, "How will all this change the Lowcountry and our communities?"

The Metro Charleston 1990-2015 project was designed to apply "fact-driven" planning approaches to the problem of understanding urban change. The work involved constructing complex computer files of subdivision plans, business locations, wetlands, vacant land, schools, demographic characteristics, and other factors. The tri-county area is vast and diverse, and regionwide planning must necessarily proceed with attention to how it will affect life in the

GIS MAPPING LAYERS

- *PLANNING ISSUES*
  - Existing or Planned Access
  - Essential Services(Utilities)
  - Zoning Districts & General Plans
  - Planned & Proposed Projects
- *DEVELOPMENT FACTORS*
  - Parcel/Tract & Ownership Patterns
  - Existing Development & Uses
  - Zoning & Permitted Uses
  - Approved Plans
- *LAND & LOCATION*
  - Flood Zones
  - Wetlands
  - Soil Types
  - Open space/Conservation Areas
  - Restricted Use Zones





neighborhoods and localities that, taken together, form the whole. Accordingly, more than 500 small areas were used as geographic "building blocks" to derive regional trends and projections. Planners used computer mapping programs to gain new understandings of the relationships between economic centers.

This was the first planning project to create a future land use model of the metro area using Geographic Information System technology. It was also the first to: develop a detailed spatial analysis of retail sales patterns; compile a full inventory of local, state, and federal employment by location; map the sites of some 13,000 business locations by type of business and number of employees; and create a regional map of more than 400 current or planned residential development and commercial/industrial sites.

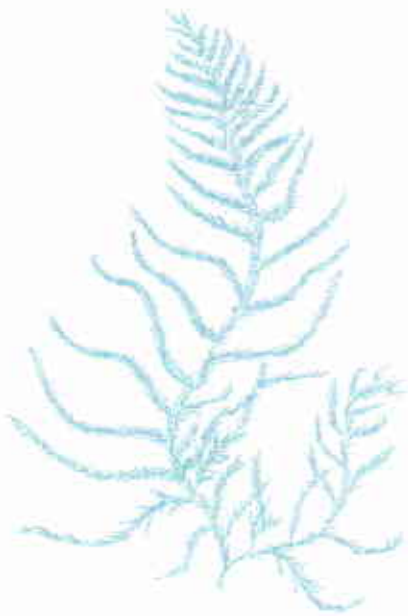
This work, combined with the detailed representation of vacant, developable parcels from aerial photography, forms the basis for location-specific watershed level planning—*mitigation* areas, *greenspaces*, *habitat* corridors, and conservation areas.

The findings of Metro Charleston 1990-2015 are used in the long-range capital improvement planning of the S.C. Department of Transportation, in the Section 208 Regional Water Quality Management Plan, and in agency planning processes carried out by local school districts and library systems.

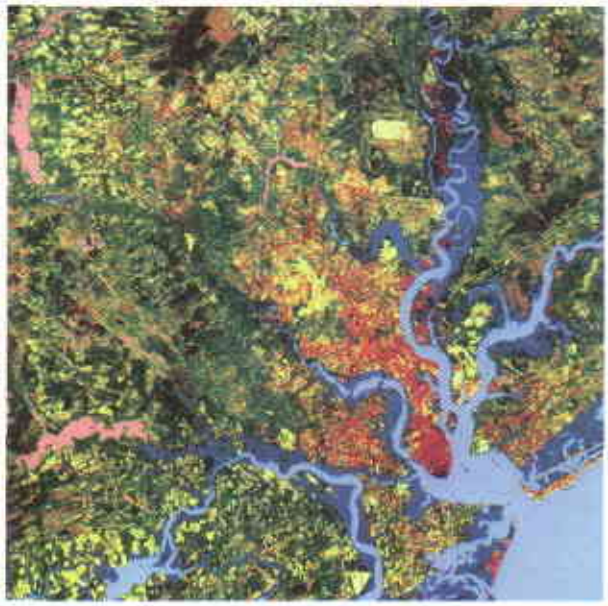
The Charleston Harbor Watershed

The Harbor Project was designed to contribute to the development of science-based resource management and planning, and to carry out this work at the area-wide, or watershed, level. A *watershed* is a single geographic unit defined by natural *topography*; its boundaries enclose the flow and absorption of surface waters and rainfall. Watersheds typically cover all or part of the jurisdictional boundaries of several towns, cities, or counties. The Charleston Harbor Project area forms the lower section of the Catawba-Santee Watershed. It extends from the outlet of Lake Moultrie to the coast, and includes the land areas that drain into the Stono, Ashley, Cooper, and Wando rivers. The Project area combines growing industrial, commercial, and residential developments with *marsh* vistas, vast wooded tracts, and *swamps*.

The boundaries of the Project area and the complex patterns of natural and man-made habitats are shown here in an image derived from a satellite image of coastal South Carolina. The Charleston Peninsula is seen at the convergence of the Cooper, Wando, and Ashley rivers. The Harbor opens into the dark blue bank of ocean waters. The color patterns reflect subtle differences in the landscape that are detectable from orbiting satellites—different colors in the satellite photographs indicate cultivated land, urban development, forested wetlands, bottomland hardwoods, etc. Computer enhanced images of this kind are used for change detection, *gap analysis*, habitat delineation, and other resource management functions.



The CHP watershed management program was designed to complement the existing environmental management framework and the information base that supports it. Special emphasis was placed on preserving the natural settings that were seen as most important to the quality of life in the Lowcountry, particularly those that were at risk from urban land transformations and water quality degradation. Over the last six years, the Charleston Harbor Project has set about to develop the information required to begin management at the watershed level through:



1991 LANDSAT TM Image
S.C. Department of Natural Resources, Southeastern Remote Sensing Center

Regional Watershed Management Requirements

- Identifying key natural resources and historic/cultural/recreational assets in the Watershed;
- Compiling inventories, assessments, and maps of these vital features and habitats;
- Conducting focused research and assembling the technical expertise to assist regulators and planners;
- Developing systems-oriented understandings of natural and social processes that drive management issues;
- Devising methods for evaluating the success of policies to improve management (i.e., monitoring and evaluating both natural resources and policy effectiveness);
- Establishing a comprehensive data storage, retrieval, and analysis system.

Baseline Information

At the outset of the Project, an assessment showed that little long-term planning information was available for the Watershed, and few record files were systematically updated or subjected to quality control review. The information base was characterized as uneven—data rich but information poor. Therefore, the CHP developed coordinated sampling protocols and created research teams composed of academic, government, and private experts from the state and region. These teams inventoried, mapped, and assessed the biological, cultural, economic, and recreational resources in the Project area. A central data repository for Geographic Information Systems products was created at the University of Charleston. Important natural and human processes associated with urbanization were examined to define "thresholds" or critical factors that would have a significant impact on the overall health of the estuary.

Natural Processes

Water chemistry, drainage, and tidal and seasonal changes affecting water quality were examined at spatial scales ranging from the 675 square mile Cooper-Wando river system down to tidal creeks less than 10 feet wide. New water quality computer models were designed and calibrated for use in permitting decisions, industrial and municipal waste load allocations, and for "what if?" simulations to estimate potential impacts on the Ashley, Cooper, and Wando rivers. Stormwater runoff models were also developed so planners could examine the likely water quality impact of projected land use changes at large and small scales.

Plant & Animal Communities

Biologists conducted a comprehensive survey of threatened and endangered species, rare plants, and their specialized habitats. Studies of tidal creeks produced new insights into how rainstorms, heat, tidal flux, and other factors make life precarious for plants and animals and how some of these same conditions provide refuge or protection when large predators will not enter the creeks to feed. Other work explored how wetlands, fish migrations, bird habitats, successional woodlands, and recreation sites were affected by the rediversion of flows from the Cooper into the Santee River.

Urban Growth

A detailed analysis of current and future population characteristics, trends, and land uses was developed in cooperation with local planners. The two-year study reviewed many aspects of urbanization, including employment patterns, building permits, highway construction programs, capital improvement programs, zoning and development plans, and vacant properties. Future growth zones were identified. Constraints on growth such as wetlands, land configuration, or lack of infrastructure were incorporated into the twenty-year projections, and later became part of other local planning projects, such as gap analysis, *greenbelt* planning, and *urban growth boundary* proposals.

Research Synthesis

In the research synthesis phase, results of specific research projects were placed into the context of concurrent work done in related fields. For 18 months, CHP researchers met as study teams and focus groups to exchange findings and discuss management implications for the Watershed. Biologists and engineers, economic developers and archaeologists, urban planners and ecologists, and agency administrators met to better understand the dynamics of the Harbor system. They investigated current conditions and trends, identified problems, ranked options within a plan of action, and blocked out a strategy for on-going monitoring and further research. The synthesis process faced questions of space, scale, and time; direct and indirect causation; the suitability and reliability of change indicators; cost allocations and "opportunity costs"; and jurisdictional divisions between various levels of government. From this work developed a frame of reference for policy initiatives, firmly based in careful study and critical thinking.

Local, State & Federal Partnerships

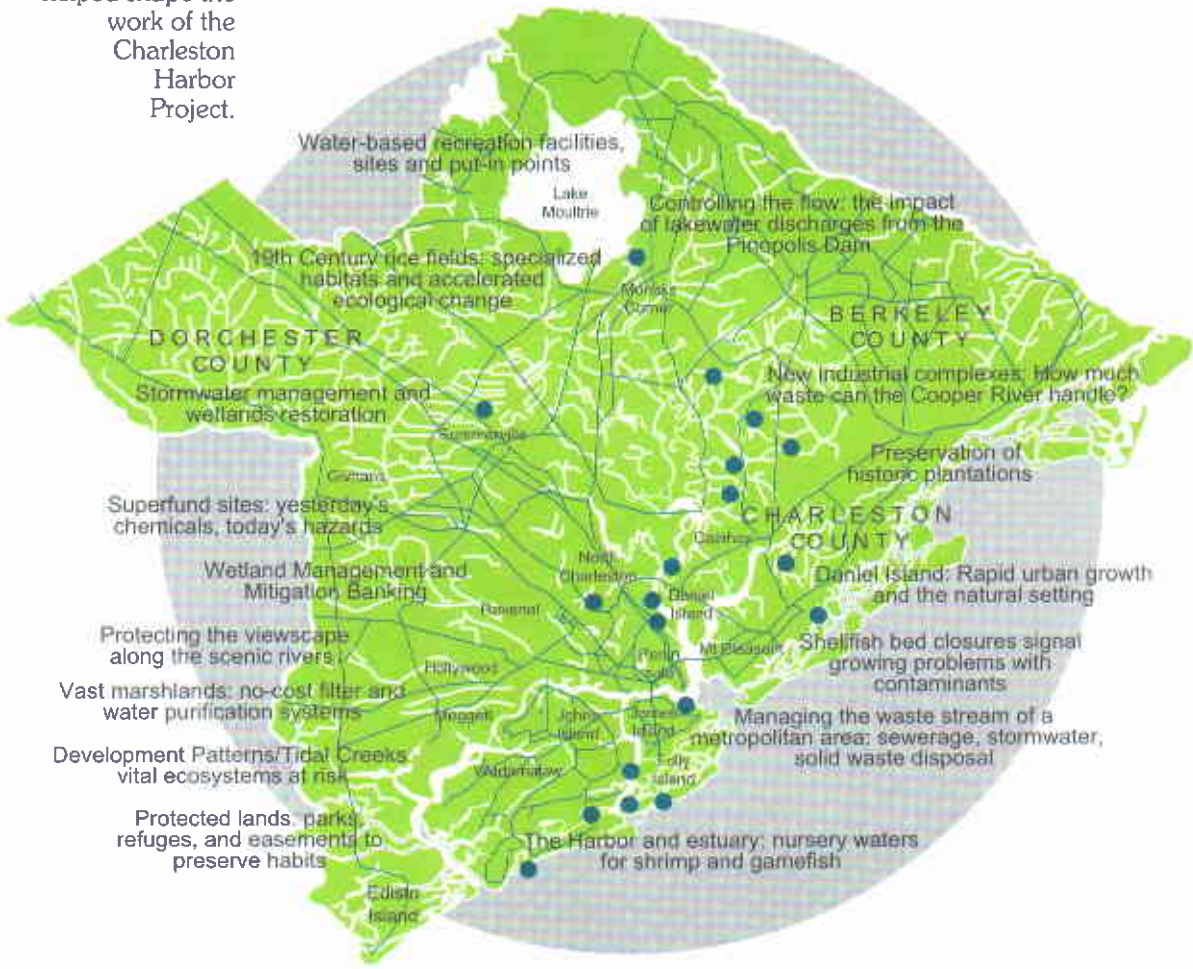
Federal and state agencies have played the leading role in environmental protection over the years. The South Carolina Departments of Health and Environmental Control, Natural Resources, and Agriculture combine their regulatory functions with policy-connected research. Still, changes on the uplands of the Watershed, often crucial to plant and animal communities, are most directly affected by decisions of local governments. County and city officials decide on standards for lot sizes, zoning designations, or the extension of water and sewer lines. These decisions may determine the location and density of docks, the amount and composition of stormwater runoff, or the alignment and size of roads. Historically, these local government decisions are made without a full awareness of their environmental consequences.

Policy Development

Natural resources and cultural resources are required elements in local government plans through the enactment of the S.C. 1994 Comprehensive Planning Act. This necessitates active partnerships at all levels of government. Successful watershed management requires coordinated local and state planning efforts and integrated responsibility and accountability. It also requires strong technical support. The Harbor Project itself is one example of how these links can be established; its work is carried out through a series of working partnerships with local communities, regional and state agencies, and academic centers.

The effects of urbanization on natural resources are not well understood. The processes are interrelated and dynamic. Unfortunately, the rapid pace of change will not allow managers to postpone action until they possess "perfect knowledge." The increasing pressures of population growth, coupled with severe budget constraints, demand more efficient cooperation among academic experts, state and federal regulators, and local governments.

These issues have helped shape the work of the Charleston Harbor Project.



Local Problems Local Solutions

The CHP Special Area Management Plan provides a regional framework for sustainable coastal development. Within the region-wide objectives, local communities can develop local plans with tailored approaches to the federal coastal management objectives. County and municipal government agencies have accepted CHP support in updating the Natural Resource elements and Cultural Resource elements of their local plans. This partnership provides a mechanism for ongoing community watershed management.

The 1998 CHP Special Area Management Plan will provide an overview of the current status of the Charleston *estuary* and surrounding uplands. In related work, both the S.C. Department of Health and Environmental Control and the S.C. Department of Natural Resources develop strategic plans for environmental protection every five years. The Berkeley-Charleston-Dorchester Council of Governments is also required by law to update tri-county transportation and wastewater facilities plans at five-year intervals. Many of the key factors for watershed management are contained in these planning programs: water quality, air quality, solid waste disposal, population projections and expected areas of growth, and endangered species and habitats. By synchronizing the CHP Watershed assessment and planning cycles with these on-going efforts, related public policies can be reviewed and renewed as parts of a connected whole.

State of the Harbor Reports

A *State of the Harbor* report to the community will serve to focus attention on a broad agenda of concerted action. Since local government officials play a crucial role in watershed management decisions, the *State of the Harbor* report will examine issues and developments from the standpoint of cities, counties, and districts, as well as the long-established purview of state and federal agencies. The CHP provides administrative support for long-term cooperative watershed planning, periodic special reports, and the publication of the full *State of the Harbor* report every five years.

The Changing Landscape

The Charleston Harbor Estuary is less than 5,000 years old and was formed during the final stages of the Wisconsin Glaciation. When the first Europeans arrived, the Watershed consisted of some 1,400 square miles of pristine forests, rivers and streams, maritime forests, and wetlands. The Cooper River lazily flowed from its headwaters to the Atlantic Ocean. Perhaps 1,000 Indians lived in the Watershed uplands and along the rivers and streams. Oyster beds were almost continuous from the mouth of Shem Creek extending up both sides of the Wando River. Oysters were also common in the lower stretches of the Cooper and Ashley rivers. Deer, beaver, river otter, mink, red and gray fox, eastern cougar, and bobcat were plentiful and provided the indigenous population with food, shelter, and clothing. Extensive oak and pine forests, plants, and salt and fresh water marshes provided building materials, foods, and medicines.

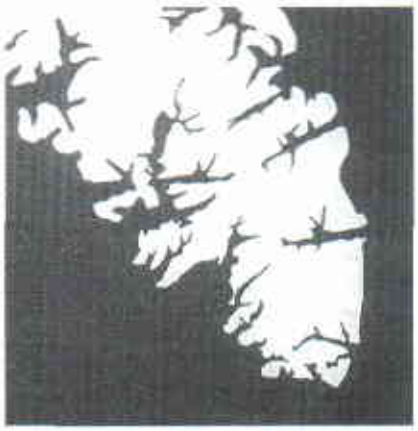
Early Settlement

To the first European settlers, their new home was a continent rich in natural resources, vast and wild. From the earliest days, living in settlements on the edge of wilderness helped to form a new European-American culture. As axes and plows cut into the wilderness, watershed by watershed, the natural environment gave way to colonization, agriculture, industrialization, and population growth.

Area Transformations

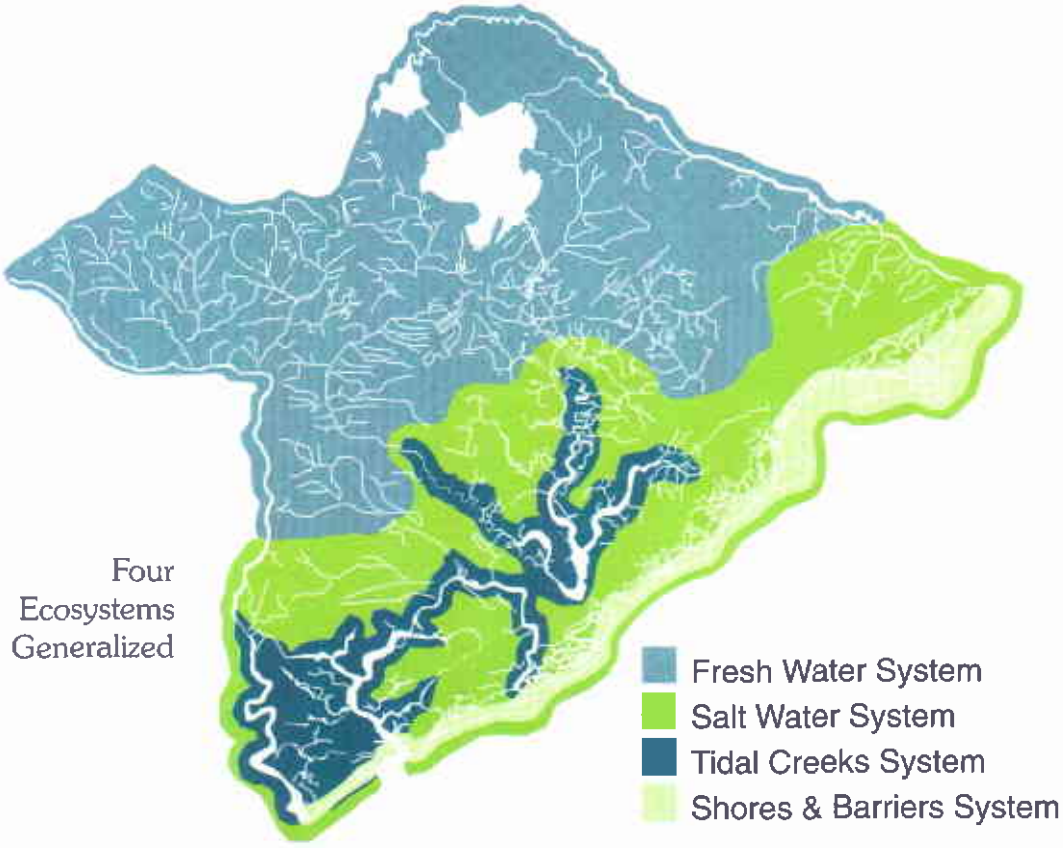
- Over time, the Charleston Peninsula was transformed as marsh and wetland areas were *filled*—about half of downtown Charleston is built on fill.
- The cultivation of rice, made possible by the extensive modification of wetlands and the availability of slave labor, initiated the first major human modification to the Watershed.
- Beginning in 1850, periodic *dredging* of the Cooper River was necessary to assure safe passage for vessels entering the busy port.
- In the 1940s, work on the intracoastal waterway through Charleston Harbor was completed, facilitating the north/south passage of commercial ships. The Santee-Cooper Hydroelectric Project—the greatest man-made change to the Watershed—was completed at nearly the same time. The Project included the construction of the Pinopolis Dam at the headwaters of the Cooper River and the formation of Lake Moultrie. A diversion canal, connecting Lake Marion on the Santee River to Lake Moultrie, effectively increased the drainage area of the Charleston Harbor Watershed from 1,400 to over 15,600 square miles. The Cooper River was thus transformed from a tidal slough to a major river.
- Since the 1950s, surging economic and population growth of the metropolitan area have led to rapid and far-reaching changes—for the Watershed and for every aspect of Lowcountry life. The tri-county population doubled between 1950 and 1990. Growth on a somewhat lesser scale is expected to continue into the next century. As development extends into the surrounding *countryside*, the impact of urbanization on the region's natural resources becomes more and more difficult to manage.

Pristine
marsh
environment



The original Charleston peninsular highland as shown on the 1839 Halsey Map.

Existing buildout from 1992 aerial photography.



Four
Ecosystems
Generalized

Advancing
Shoreline
over the
millennia

The Natural Environment

Shorelines & Barrier Islands

On any summer weekend, the population of our beaches and seashores swells by thousands. The large scale development of seaside properties accompanies the rapid growth of coastal cities. In Charleston, the sandy *barrier island* shoreline is a highly dynamic and ever-changing environment. The natural processes of *erosion* and *accretion* are affected by measures to retain or restore beach profiles. Golf courses, *septic* tanks, and auto *traffic become part of a redefined ocean's edge* and result in new concerns for water supply and water quality, disturbance or displacement of sustaining plant and animal populations, waste disposal, etc.

Long-submerged streets off Folly Beach, the abandoned Morris Island Lighthouse, and the devastation of Hurricane Hugo are all evidence of cycles we do not control. The map on the facing page shows successive bands of barrier islands across geologic time, advancing from Moncks Corner millennia ago to the familiar coastline of today. The prospect of global warming within the next 100 years could profoundly alter the land, the water, and the coastal *ecosystems* of the Watershed.

Protected coastal environments influence the urban development of *the Watershed*. The air quality zone for the Cape Romain National Wildlife Refuge extends across the entire Watershed and is used to limit emissions or discharges from any new industrial or commercial operation. The S.C. Beachfront Management Act, the Federal Flood Insurance program, the Federal Emergency Management Act, and others are all part of the public policy framework governing development on the barrier islands.

Cooper River Bridge over Charleston Harbor

The Natural Environment

Salt Water Domain

Charleston Harbor is an *estuary*, a place where inflowing salt water from the ocean mixes with fresh water from rivers and streams. It includes the deep water channels and docks for ocean-going passenger ships and cargo vessels, as well as the broad river courses where sailboats and pleasure craft mix. Looking inward from the mouth of the Harbor or down from a bridge span, one can see the magnitude of the system. In all, the waters of the estuary cover nearly 125 square miles. The Ashley, Cooper, and Wando rivers flow into it and merge with immense quantities of seawater in a constant tidal flux. Its waters have been crossed by bridges and deepened by dredging; they have formed the prized vista from verandahs and office windows.

The Harbor

This highly dynamic zone provides habitat for marine, fresh water, and estuarine organisms. It is a vital breeding and nursery ground for fish, shrimp, crabs, oysters, and clams. Without the shelter provided by estuarine plants, the larval stages of these species would not survive long enough to reach adulthood.

Lower River Reaches

The rivers and creeks of an estuary system serve as arteries, bringing nutrient-enriched materials. The presence of salt water causes dissolved particles to combine with one another and sink to the bottom. This process concentrates the nutrients and makes an estuary one of the most productive ecosystems on earth. Shrimp, crabs, fish, and porpoises all thrive in the food-rich waters of the estuary. Many species that spawn in the tidal creeks or inland waters grow from juveniles to full-sized adults in the estuary. The settling that occurs in the estuary concentrates contaminants as well as nutrients. Estuaries receive large quantities of organic and inorganic chemicals from industrial waste disposal, sewer discharge systems, stormwater runoff, and atmospheric deposits. The Clean Water Act and other public policy initiatives have long focused on measures to assure that impacted waters in estuaries are "drinkable, swimmable and fishable."

The Natural Environment

Tidal Creeks

Shallow marshes and *tidal creeks* provide critical seasonal habitat for numerous adult and *juvenile finfish, crustaceans,* and shellfish, as well as year-round habitat for resident shellfish and waterbirds. They also serve as refuges and nurseries for juvenile fishes. Many tidal creek animals have a common life history. They spawn in the ocean or inlets, the larvae ride tidal currents to the marsh creeks, and, after rapid growth, the animals move seaward as they approach adult-size. This environment is critical to the survival of blue crabs and local shrimp varieties, as well as spotted sea trout, red drum, southern flounder and other highly-prized coastal gamefish.

Due to the gently sloping coastal plain and large tidal range, an estimated 8,500 acres of marsh exist in the Charleston Harbor area. More than 4000 acres are *brackish* and salt water marsh, another 3,000 acres are fresh water marshes, and 800 are impounded waters, mainly former rice fields.

Stress Factors

Recent Harbor Project studies and other research efforts are focusing anew on the ecology of tidal creeks. Tidal creeks are a highly variable environment—affected by the complex interaction of tidal cycles, seasonal shifts in daylight hours and temperature, and high volume stormwater *runoff*. To survive in this environment, animals and plants must be highly adaptive. Even so, the continually changing conditions subject them to constant and often increasing stress.

Natural Filter

Tidal creeks and their associated vegetation are both a flow-way for upland waters and a natural filter preserving water quality. Salt marsh grass has been found to attract and capture toxic metals which enter creeks as pollutants, and the expanses of marsh in the Watershed perform an "ecological service" that is comparable to that of a regional wastewater treatment plant.

Protecting the Watershed tidal creeks from degradation is an area of growing concern. Public policies governing adjacent land use, *stormwater* runoff, and waste disposal are being re-examined to determine their effects on these specialized, critical environments.

Salt marsh view from city water treatment plant

Rice
Impoundments

Wood stork

The Natural Environment

Fresh Water

Above the reach of the salt water tidal surge is the fresh water environment of rivers, streams, and wetlands. The Cooper River and its *tributaries* provide an abundant supply of fresh water and a controlled flow source from the Lake Moultrie dam outlet. The Ashley and Wando rivers are slow-current waterways that originate in fresh water swamps and drain comparatively small sections. Fresh water *wetlands* cover more than one - eighth of the Charleston Harbor Watershed.

The fresh water environment is home to smallmouth black bass and American shad, day lilies, rare plant colonies, eagles, ospreys, and countless other birds. The rivers and lakes are also the spawning waters for such salt water fish as shad, sturgeon, and striped bass–the attraction for tens of thousands of recreational fishermen who visit the Watershed each year. Wood storks are now found here; they are an endangered species that began to appear in Charleston after irrigation canals in the Florida Everglades left them without protection from predators.

Rivers

The Frances Marion National Forest forms a vast highland reserve for many fresh water animals and plants. Along these rivers lie important archaeological and historic sites, such as Medway Plantation. Here, too, are the singular environmental conditions found in old rice impoundments and large conservation easements, but, unfortunately sharing the water edge with major industrial plants developing on riverside sites.

Wetlands

As for the Watershed as a whole, public policies affecting fresh water environment involve federal, state, and local agencies and apply to a wide array of issues: wetlands, endangered species, flood control, economic development, and waste management. Moreover, these policies shape decisions at scales ranging from individual parcels of land to sub-state regions. Each has its primary purpose, but unintended secondary effects may significantly change natural conditions. For example, wetland areas of less than one acre do not fall within the scope of the wetlands management program; they are routinely filled as land is made ready for construction. Small isolated wetlands, however, are critical habitats for some animals.

James Island
1939 Aerial

The Manmade Environment

Charleston is a 300 year old enterprise, growing from a peninsula settlement to a mix of suburbs, industrial parks, historic neighborhoods, and shopping complexes. It has progressively expanded from the original port city, following waterways and high land corridors. Plantation dikes, the Mark Clark Expressway, phosphate mines, tilled land, burial grounds, and buildings and streets –these are all works of man with an enduring effect on their natural surroundings.

Urban Growth

As a city evolves, "fringe" areas become "close in" and new land uses replace old ones. The map on the facing page shows how the now bustling suburb of James Island was once all rural farmland. The aerial photo was taken in 1939. Even only sixteen years ago, development had not yet laid claim to the forested river views.

Between 1970 and 1990, the tri-county population grew by half, but the developed land area increased fivefold. Population growth on this scale is expected to continue, driven by the arrival of newcomers from other parts of the country and ongoing commercial/industrial development. By 2015, according to the most recent forecasts, an additional 120,000 people may be living in the region.

Overall, changes in the rivers and the Harbor occur over much longer timespans. The broad waterways that divide the cityscape seem hardly affected by the comings and goings on land. But often overlooked urban impacts–land disturbance from sprawl development, stormwater runoff, contaminants and pollution–can so alter the natural balance that lush green settings become sparse and blighted. The effects of urbanization become a more and more important issue in the Watershed, as evidenced by plans for greenbelts, primary growth zones, alternative subdivision design, recycling, and community-level natural resource assessments.

Edges of James Island, 1982

The Manmade Environment

Economic Development

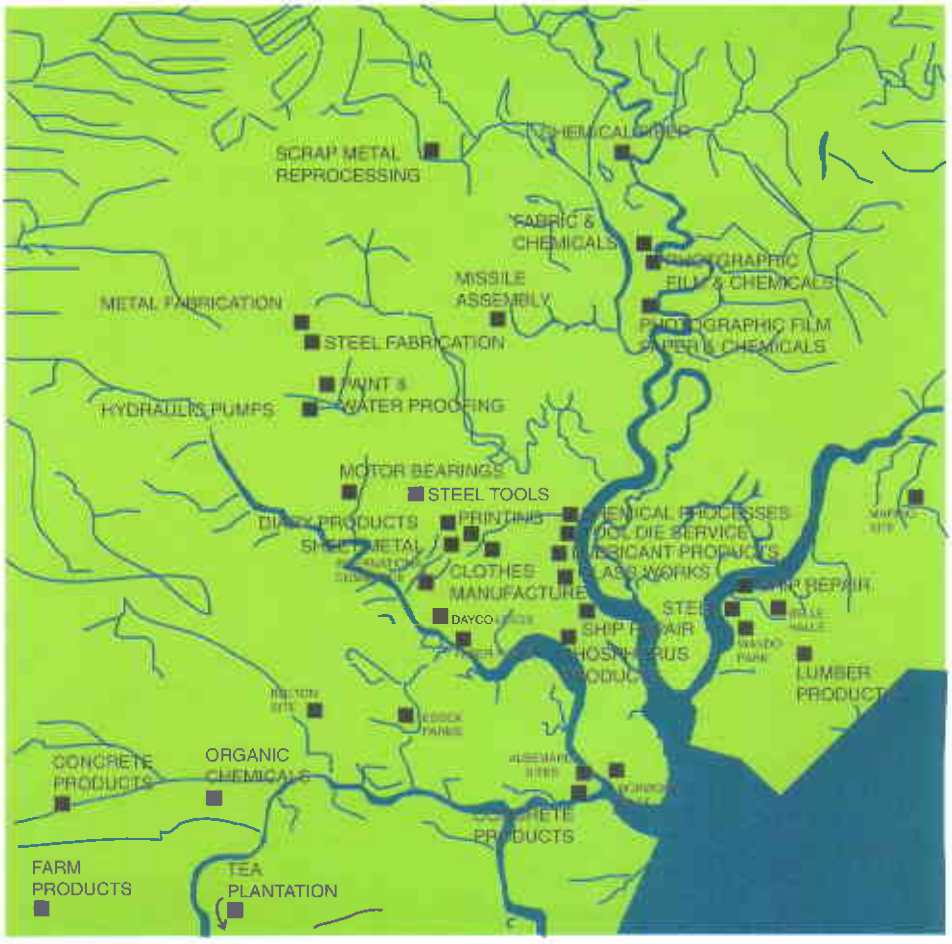
In recent years, Charleston has enjoyed an economic boom that was slowed only temporarily from such setbacks as Hurricane Hugo and the closing of the Charleston Naval Base. The Charleston metropolitan region is a leading area in the state in virtually every key economic indicator, including tourism, retail sales, capital investment, and total personal income. More than half a million tourists visit the area annually, injecting nearly a billion dollars into the local economy. The Medical University of South Carolina is a center of research and physician training; other hospitals and health-related enterprises are key economic assets. In 1997, the Port of Charleston handled over ten million tons of cargo. It is the fifth largest container port in the United States, and is second only to the combined ports of New York and New Jersey on the East Coast. Successful economic development initiatives to recruit new manufacturing firms are contributing to record investments in facilities and equipment—between 1995 and 1997, industries invested more than 1.6 billion dollars in new plant construction.

The Cooper River has the greatest number and density of industrial and port facilities among the three river systems that form the Charleston Harbor Estuary. The modern shore-side terminals and installations of the State Ports Authority, the developing industrial/institutional center on the former U. S. Naval Base, petroleum complexes, the WestVaco plant, and other commercial facilities are located on the western shore. The Bushy Park industrial area borders the Cooper upriver. Amoco, Nucor, and other industrial complexes are being built along the upper Cooper.

The Ashley River has the second largest number of industrial and commercial facilities; most are located along the eastern shoreline. The upper Wando River presently has the least upland development. The only major industrial facility on the upper Wando is Detyens Shipyard at Cainhoy. In the lower reaches of the Wando, the State Ports Authority maintains the Wando Terminal Facility in Mount Pleasant, and plans to expand across the river on Daniel Island.

An economic environment must be viewed as a set of linked systems, similar to a natural environment. Sustaining a local economic base involves continuing attention to the supply of materials and power, access to facilities and markets, water supplies, waste disposal, and control of byproducts, balance, and diversity among enterprises, security, and working capital. Economic developers learn from the example of places that failed to maintain this "whole system" view of a community and its economic base—left-behind company towns in New England, weedy railroad tracks in what were once the coal mining centers of West Virginia, and "No Trespassing" signs around empty chemical plants waiting for Superfund cleanup.

The "built" environment of the Watershed is the structural context of a way of life. The mix of resources, energy, initiative, and imagination determines the quality of life in a community, its prosperity, and its long-term potential.



The Cultural/Historic Environment

Charleston's rich, dramatic history is an important part of everyday life in the city today. Peninsula streets are lined with examples of architectural styles reaching back into the 17th century–the result of long-time efforts to preserve and restore early buildings. Archaeological sites, plantations, and Revolutionary War and Civil War battle sites are found throughout the Watershed.

Recover Restore Conserve & Value

The inventory of historic structures and sites extends across eras that were shaped by the cultivation of rice, indigo, and cotton; trade; phosphate mining; ship building; and manufacturing. These periods were marked by hurricanes, fires, wars, economic decline and growth, slavery, segregation, and civil rights. The legacy of these times is continually enriched in a place that values its history. For example, recent years have seen the discovery of the Confederate submarine Hunley, the preservation of the art deco Riviera Theater, and the restoration of the Bennett's Rice Mill after Hurricane Hugo.

This is a place where:

- In February 1780, Charlestonians saw the encirclement of the city by the British under General Clinton and the beginnings of the Siege of Charles Town.
- The opening salvo of the Civil War was fired in the early morning hours of April 12, 1861. After thirty-four hours of continuous bombardment, Union forces surrendered Fort Sumter to the newly created Confederate States of America.
- The Blockade and Siege of Charleston began in May 1861 with the arrival of the Union ship USS Niagara.
- On August 22,1863, General Pierre G.T. Beauregard refused to surrender the city, and Union forces began the bombardment of Charleston that would last for 587 days.

In the aftermath of the Civil War, the city entered a time of economic hardship that lasted for generations. Shipbuilding and port activity in the First World War only preceded the nation-wide depression of the 1930s. The Charleston Naval Base grew to a major installation during the Second World War. Tourism has grown dramatically in the last twenty years; historic buildings, gardens and plantations have become the trademark scenes of the city.

Residents of Charleston were among the first to recognize the importance of historic preservation. Efforts to protect and restore older buildings through historic districts and site acquisition have expanded to include such measures as land trusts and conservation easements to retain a landscape or viewscape.

The Cultural/ Recreational Environment

History, culture, and recreation are intertwined in events as elaborate as the Spoleto Festival, as casual as Concerts in the Park, and as high-spirited as sand sculpture contests or the annual Float Frenzy on the Folly River. Today, Charleston is known for exhibits and performances, bridge runs, sweet-grass baskets, seaside golf courses, and round-the-world sailing races.

Nearly everywhere, water is an integral part of Lowcountry culture, pastimes and play. Stadiums and parks feature riverviews. Weekend shrimpers cast their nets into marsh-lined creeks; fishermen drop their lines from boats and bridges. Charleston families gather for reunions and laugh at old stories around fish fries and oyster roasts.

Questions of supply, demand, and access shape the future of water-related cultural and recreational activities. Waterfront properties are sought-after locations for development. Land values rise accordingly, making it more and more difficult to acquire sites for public parks or boat landings. Recently, successful bond campaigns raised local funds for park lands, while state and federal funding was curtailed. In parts of the Watershed, patterns of development have severely restricted public access to the waterways.

With a rapidly increasing population and more visitors every year, facilities are becoming crowded and waterspace and traffic control are major concerns. Today, there are more than 45,000 small boats and pleasure craft in the Watershed—50% more than a decade ago. Natural communities are damaged or destroyed from overuse. Cape Romaine is protected as a wildlife preserve with no auto access, while Medway Plantation is protected under a conservation easement. But Crab Bank provides an example of the harmful impact of too many careless boaters, and the end result of urban pollutants and contamination are clear when shrimps and fishes from Charleston Harbor are compared to those from Bulls Bay.

The Harbor Project produced a baseline for systematic management; an inventory of water-related recreation facilities; area-by-area projections of residential and commercial development; and coordinated research into the requirements, conditions, trends, and dynamics of aquatic animals and plants.

Research Findings, Planning Applications & Suggested Actions

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Introduction

The multi-year research program of the Charleston Harbor Project was designed to assist federal, state, and local governments in framing action plans. There are immediate and long-term issues. There are issues of public policy and private initiatives. There are issues that involve the entire Watershed as well as highly localized issues.

This portion of the ***Citizen's Guide to the Charleston Harbor Project*** summarizes the research findings, planning applications, and suggested actions that should appear in the larger publication later this year. This is the point-by-point assessment of what can be done to accommodate urban growth and economic development while preserving the beauty and environmental health of the region. The assessment is part of the planning process for a CHP Special Area Management Plan. All of the suggested actions in this abstract are derived from meetings with advisory panels, research teams, and agency managers. They represent an initial agenda for the upcoming meetings of the CHP Management Committee, the S.C. DHEC Board, and local governments, who will work together to formulate final recommendations. The Special Area Management Plan will translate those recommendations into an action program detailing operational responsibilities, requirements, and schedules.

Certain key concepts emerged as the work developed:

Local Problems/Local Solutions - *The CHP Special Area Management Plan will provide a regional framework for sustainable coastal development, supported by the coordinated actions of state agencies. Within the region-wide objectives, local communities are developing their own approaches to natural resources issues, especially through the comprehensive planning process. Local government decisions - land use, zoning, development standards, infrastructure - are often the decisive factor in protecting and preserving natural resources.*

Whole Systems - *A resilient and resourceful people were months recovering from Hurricane Hugo, a storm which dramatically demonstrated how complex the systems are that make cities comfortable and productive. Similarly inter-connected are the day-by-day effects of urban communities on the surrounding countryside—only partly understood, but subtly and inexorably changing the natural setting of the Lowcountry.*

The importance of ***Tipping Points*** - *Natural adaptations can compensate for worsening conditions up to a point, and it is not always clear in advance when that point will be reached. The tipping point may cause minor difficulties to compound until what was just a stressful environment becomes lethal for certain creatures.*

Water Quality

Research Initiatives

RESEARCH INITIATIVES

The drainage pattern and other natural processes of a watershed concentrate nutrients and contaminants in the estuary. In their natural state, estuaries are among the richest environments on earth. In urbanizing areas, the waste stream of cities often makes its way into the source-water rivers of an estuary. The *assimilative capacity* (ability to handle nutrients and pollutants) of its rivers changes accordingly, and *eutrophication* or contamination may result—signs of a system less and less able to support plant and animal communities.

Second Generation Environmental Problems: Conditions and Trends

Environmental laws passed in the 1970s, such as the Clean Water Act, have been successful in addressing the specific issues they were intended to solve. They have not, however, been able to address the more complex *second generation* environmental problems, such as *nonpoint source pollution (NPS)* from urban runoff. The sources of such pollution cross political jurisdictions and regulatory boundaries. The quality of the environment is now the net result of many small, often uncoordinated decisions, and a more holistic regulatory approach is required.

- The main channels of our rivers (main stems) have long been used as the indicators of overall water quality. Harbor Project researchers determined that the three river system components—the main stems, primary creeks, and small tidal creeks, each behave differently. Water quality conditions in small creeks often differ significantly from main stem measurements. It is important to understand the dynamics of the three components, because each serves a crucial function for the Harbor as a whole. Harbor Project researchers examined the populations of fish, shrimp, crabs and other organisms in small tidal creeks and the role of these creeks as critically important nursery habitats.

- Increasingly, the Lowcountry tradition of shellfish harvesting is threatened by land development practices because shellfish grounds require good water quality. Oysters and clams, as *filter feeders*, can concentrate contaminants in their tissues and people commonly eat shellfish raw. The bacterial contamination that forces the closing of shellfish grounds is directly related to the amount of runoff from surrounding developed areas. When two inches of

rain falls in a storm, the runoff frequently contaminates the waters between the Isle of Palms and Mount Pleasant to the extent that they must be closed to shellfish harvesting. Occasionally after such storms, even swimming can become a health risk.

- Development can bring increased bacterial contamination from many possible sources, such as septic tanks, sewage discharges, and animal waste. This contamination is a difficult problem to manage when the main source of the bacteria is not known. Harbor Project research resulted in improved methods for identifying the sources of bacterial contamination through the use of DNA fingerprinting.

Current Policy and Standards: Reports from the Field

Since the 1970s, DHEC has based its water quality classifications on the desired ecological, commercial, or recreational uses of each water body. Existing water quality does not necessarily determine a water body's classification. If a community wants a river to be designated as Class SFH (protected for shellfish harvesting) and the river does not meet the established standards, appropriate regulations and procedures are imposed to improve water quality to the desired use.

- The two principal criteria in DHEC's water quality designations are: 1) *dissolved oxygen (DO)*, based on minimal levels required for animals to survive, and 2) levels of bacterial contamination, which are important for protecting public health. CHP research examined DO dynamics in detail and found concentrations of dissolved oxygen in many parts of the estuary were below state and federal standards.

Measuring Dynamic Conditions and Variability

Oxygen dissolved in water is essential for life, and several cyclical factors affect dissolved oxygen levels and water quality. Daily, seasonal, and tidal cycles all drive the levels of dissolved oxygen in estuaries. One more very important cycle involves rainstorms: DO levels decrease after a rainstorm as *organic* (e.g., bacteria) and *inorganic* (e.g., ammonium) oxygen-demanding substances are washed into water bodies. In addition to the fluctuating DO levels after a rainstorm, organisms in an estuary must also be capable of adapting to the associated rapid drop in water temperature and salinity. A storm

can cause a tidal creek to change from hypersaline (high salt content) to fresh water in a matter of minutes. These difficult conditions actually protect larval stages of many species because they have broader tolerances than larger fish and other animals that feed on them. In other words, tidal creeks provide a comparatively sheltered, nutrient-rich environment for fishes, shrimps, and other animals at vulnerable stages in their life cycles.

- Urbanization and land development can cause critical changes to water quality. When ammonium, a common end product of sewage treatment, is discharged into a river, it rapidly depletes oxygen as it turns into nitrate. Nitrate (commonly used as fertilizer) can travel into a water body such as Goose Creek and cause the destructive process of *eutrophication*. Stormwater runoff deposits most of the pollutant load that collects in the air and on impervious surfaces into receiving water bodies, creating additional stresses in creeks located near developed areas. CHP research demonstrated that the variability in DO, temperature, and salinity and the resulting stress on creek-dwelling creatures were greater than previously believed, especially in those creeks near developed areas.

Chemical Contamination

Chemical contaminants released into the water can be toxic, impairing reproduction and survival rates in plants and animals. Past research did not identify chemical contamination as a serious problem in the Charleston Harbor estuary, but sampling had been taken only in the main rivers. Harbor Project researchers shifted the focus to small tidal creeks and found much higher concentrations of contaminants in the small creeks than in the rivers they drain into.

- Researchers discovered that chemical contamination found in small tidal creeks can be directly related to the type and intensity of adjacent land use. Long-banned agricultural and industrial chemicals, such as DDT (banned 25 years ago), still persist in various creeks.
- Although many of the most serious contaminants have been traced to past agricultural and industrial processes, current industrial by-products are also found in parts of the watershed. Chromium contamination in Shipyard Creek in North Charleston exceeded the highest level reported for any comparable research site in the world.

Nutrient Loads and Limits

Harbor Project researchers developed estimates of the amount of nitrogen now deposited into the waters of the Charleston Harbor from human activities and land uses. These estimates include the contribution of *point source*, *nonpoint source*, and airborne pollutants to the total inorganic nitrogen load in the estuary.

- Marsh grasses act as filters, improving water quality by capturing pollutants. One researcher found that the marsh grasses of Goose Creek remove as much nitrogen from area waters as the Hanahan Sewage Treatment Plant discharges. In spite of the enormous tidal flushing and the vast expanse of marshes, area waters can only assimilate a finite amount of nutrients, especially nitrogen, without detrimental effects. Researchers reported signs that some local water bodies are approaching their nitrogen limit.

Point Source Discharges

More than three-fourths of all inorganic nitrogen entering area waters comes from regulated point source discharge sites - municipal and industrial waste treatment facilities (easily identifiable 'points').

- In recent years, an average of 5.5 million pounds of ammonium was discharged into the Harbor. Permit records show that the North Charleston Sewer District accounts for more than 90% of the total annual point source load in the Cooper and Ashley rivers, 5.1 *million* pounds of ammonium. The next largest facility, the City of Charleston's Plum Island plant, discharges 68 *thousand* pounds of ammonium in a typical year.

- Researchers found that river waters and the discharges they carry do not travel directly to the ocean after reaching the Harbor. Because of tidal flows, they linger in the Harbor and can even move back up other rivers. Even after fifteen days, water released from the Pinopolis Dam near Moncks Corner may be found (in diluted amounts) up the Wando River near Cainhoy, which demonstrates the interconnected nature of the Charleston Harbor Watershed.

Nonpoint Source/Stormwater Runoff

Sediments, nutrients, and organic and toxic substances generated by land uses and human activities are regularly carried into nearby water bodies by stormwater runoff and *percolation*. If present in amounts

beyond the absorption capacities of creeks or rivers, these substances become pollutants that disrupt the established ecological balance. This is referred to as nonpoint source pollution.

- CHP analysis of stormwater entering the Ashley River from Summerville determined that in the period after heavy rains, nonpoint source loads there (from stormwater runoff) are comparable to point source loads from sewage treatment plants over the same span of time.

Air Quality/PAH

Since Charleston Harbor is in the same airshed as Cape Romain National Wildlife Refuge, air pollution standards within the CHP study area are controlled by air quality conditions in the refuge. All national wildlife refuges have a 'Class One' designation in the National Air Quality Standards monitoring network. Any new point source air emissions (smokestacks) within 100 kilometers of a Class One zone must be treated to a level that ensures that the air quality in the nearby zone does not decline.

- Airborne contaminants from car exhaust, plant emissions, and other sources contain various nitrogen and toxic compounds, including polycyclic aromatic hydrocarbons (PAHs). These contaminants are brought back down to earth in dust and rain. Scientists working for the Harbor Project determined that, in a storm, rain directly deposits more inorganic nitrogen into Harbor waters than is washed off the land. They found that 13% of the inorganic nitrogen load that enters the waters of the Harbor Project study area comes from directly deposited airborne contaminants. In larger urban areas, such as those surrounding the Chesapeake Bay and Tampa Bay, air pollution can represent 30% of the total nitrogen load.

- PAHs are a good indicator of urbanization and suburban development because they are produced by automobile exhaust. These contaminants disrupt the reproduction and survival of grass shrimp, a principal forage food for fish. Researchers found much higher concentrations of PAHs in urban and suburban tidal creeks than in the major rivers and the Harbor. The impact of PAH contaminants is particularly great in small tidal creeks near traffic arteries, such as Shem Creek in Mount Pleasant and several creeks that feed into the Ashley River.

Manage Water Quality in the Harbor as a System

The Charleston Watershed is a vast, continually changing mix: established cities, urbanizing areas, country towns and their surroundings, and still-remote natural settings. The parts form a whole system, where informed public policy should combine monitoring, place-based planning, and a focus on carrying capacities.

Monitoring: Recognize area-by-area differences and monitor water quality in the primary creeks and small tidal creeks as well as in the rivers.

Place-based Planning: Public policies governing development within a drainage basin impact natural functions and ultimately determine how a water body "performs" and what human uses it can support. Consider drainage basins and subbasins as integral parts of community planning.

Carrying Capacities: Efficient management of water quality requires systematic consideration of the three prime sources of nutrients: point source, nonpoint source, and airborne pollutants that fall directly into the water. National experience has shown that estuaries can receive only a finite amount of nutrients before detrimental effects to the ecosystem impair natural functions.

SUGGESTED ACTIONS

- Continue to refine and improve the computer simulation and modeling work that represents the Harbor as a whole system.
- Expand current monitoring programs to place greater emphasis on locations in smaller streams and creeks. Observe the natural variability of water quality indicators such as dissolved oxygen over daily, seasonal, and annual cycles. Continue to improve monitoring through the introduction of new methodologies and equipment.
- Designate areas for uses compatible with their existing natural functions and their potential for recreational and economic activities. Create Special Area Management Plans (SAMPs) as joint undertakings with local governments and state agencies so that public policies are coordinated to achieve long-term water quality objectives for each drainage subbasin.

- Make the Harbor Project's watershed nitrogen budget operational through refining Harbor Project estimates and incorporating them into the ongoing regulatory actions of the various agencies concerned with air and water pollution.

- Recognize and protect wetlands for their capacity to filter pollutants and control flooding and erosion. Employ wetland *buffers*, *riparian* buffers, and stormwater *best management practices (BMPs)* in developed and developing areas to reduce bacterial contamination and nutrient loading (pollution) into area marshes.

- Widen the use of the DNA fingerprinting technique developed by Harbor Project researchers to determine sources of bacterial contamination in area waters. The procedure can be used to help local governments develop management policies to combat bacterial contamination.

Use Administrative Records and Local Planning Processes to Assess the Cumulative Effects of Urbanization

All key actions that affect the watershed are parts of a larger pattern of change. From septic tank design to parking lot drainage or channel dredging, regulatory agencies use permitting powers to safeguard the public interest by protecting the Harbor and its tributaries. Site-level permitting and regulatory actions must be seen in a broader context; the cumulative impacts of individual decisions affect the entire drainage basin. Taken together, public records provide an overview of urban development that can be systematically linked to related water quality conditions and observable changes in plant and animal communities.

SUGGESTED ACTIONS

- Provide technical support to municipal, county, and regional government agencies with research findings and expert advice to apply science-based management techniques in the development of policies affecting water quality.

- Develop an applied research program, supported by computer mapping, archiving, and database management, to determine the impacts of urbanization on water quality.

- Establish a State of the Harbor program with a five-year planning and management cycle and annual operational goals and objectives. Work in cooperation with other agencies and local communities and within the context of the parallel planning cycles of the S.C. Department of Natural Resources (DNR); the S. C. Department of Health and Environmental Control (DHEC); Office of Environmental Quality Control (EQC); the Office of Ocean and Coastal Resource Management (OCRM); the Berkeley-Charleston-Dorchester Council of Government's (COG) 208 wastewater program; and the Charleston Area Transportation Study (CHATS) program. Continue to refine management policies to ensure that biological, economic, and water quality standards are maintained.

Biology

Habitats & Species

The Charleston Harbor Project area is a complex landscape of biological habitats, including uplands, fresh water wetlands, estuarine wetlands, and open waters. These habitats combine to form a regional *ecosystem*. Wetland plants and animals were the subject of a series of CHP research projects; and fish, shrimp, and crab species were studied in open water habitats. Particular attention was paid to wetlands because of their strategic role in the ecology of the Charleston Harbor Watershed.

Wetlands are important to many environmental processes, depending, in part, on the size and conformation (position in the landscape) of the wetland. Wetland ecosystems provide a variety of plant and animal habitats and enhance water quality. Wetland plants and the broader flow pathways provided by ponds or wetlands slow stormwater runoff. Wetland soils and plants gradually assimilate nutrients and detoxify or bury contaminants. This process takes weeks and requires large contiguous wetland systems because of their long retention times.

Status of Colonial Wading Birds in CHP Study Area

Colonial wading birds, such as egrets, herons, and wood storks, are key indicators of the overall health of the biological communities in the watershed. The birds are warm-blooded and require a high food intake to survive. They are highly mobile and need a variety of habitats across the watershed for feeding, nesting, and *roosting*. Therefore, the populations and reproductive success of adults are good in

dicators of the productivity of fisheries and availability of wetland habitats. Additionally, colonial wading birds are highly valued species that are sensitive to human encroachment into their feeding and nesting habitats.

- Nesting populations of colonial wading birds have declined in the lower Charleston Harbor over the last two decades. In 1975 the Drum Island rookery supported 15,000 nesting pairs. The birds abandoned the island by 1988 when it became overrun with *predators*. Except for the Daniel Island area, there were few alternative sites in the watershed because of expanding urbanization.

- Researchers discovered that eagles, ospreys, and colonial wading birds are abundant in certain areas along the Cooper River. The birds have become particularly dependent on former rice impoundments there, using them as habitat. Rice impoundments are diked reservoirs that were used in the past for rice cultivation.

Rare Species and Habitats

In addition to the wading bird studies, the CHP performed a series of more specific studies to assess the effectiveness of current wetland management policies in protecting rare species and habitats. These projects were also designed to provide a sufficient data base to allow resource managers to move from parcel-level management to more appropriate ecosystem-level management.

- The status of certain rare bird species was determined by compiling inventories and conducting mapping studies for eagle, osprey, and certain migratory songbird populations. Eagle and osprey populations are periodically assessed by DNR. The CHP provided funding in 1993-94 for a census in the Charleston Harbor Watershed. Many species of migratory songbirds, including warblers, buntings, and yellowthroats, migrate down the Atlantic coast to South America using shrub/scrub habitats along the way for resting and feeding. These habitats typically fall just outside the jurisdiction of wetlands regulations and are being rapidly developed. Shrub/scrub habitats are critical to the survival of these migratory birds and were examined in the Harbor Project study area to determine rarity.

- Since wetland regulations are limited to the wetland boundary, parking lots and other development can completely encircle small

wetlands, severely impacting their habitat and *hydrologic* functions. Current administrative policies base the value of wetlands primarily on size and, therefore, favor large wetlands. Isolated wetlands (less than one acre in size) are frequently filled for development in exchange for buffers of larger wetlands. CHP researchers found that wetlands less than one acre in size comprise up to 15% of the total wetland area of the Charleston Harbor Watershed. These small wetlands are not adequately protected under current policies. Researchers determined that many of the rare plants, birds, amphibians, and reptiles studied in the CHP study area depend upon the unique conditions of these small, isolated wetland habitats. As their habitats are lost, rare species become endangered species, and federal law requires protective measures. Unfortunately, these measures are considered a serious obstacle to economic development in a community.

The Effect of Growth and Land Use on Biological Habitat

The growth of towns and cities affects biological resources by converting open or forested land to urban, suburban, and agricultural uses and by discharging wastewater into the rivers and the Harbor. CHP researchers examined current biological resource management policies and their implications for the future of the Charleston Harbor Watershed. The CHP Biological Resources Task Force determined current federal and state wetlands policies to be generally effective, having provided an adequate level of protection over the past ten years. However, the task force identified future urban growth as a serious challenge to the Harbor's health.

- CHP researchers projected that over 45 square miles of undeveloped land would be converted to commercial, industrial, and residential use by the time the metropolitan area population grows to 600,000 people. Land transformation at this scale, including direct losses due to fills and indirect impacts from habitat segmentation and hydrologic changes, can be expected to dramatically alter current levels of wetland function and value in the Charleston Harbor Watershed.

- During the research phase of the Charleston Harbor Project, the estuarine research team systematically examined all of the habitat components of the Charleston Harbor Estuary and documented that estuarine fisheries are dependent on small tidal creeks and adjacent shallows for nursery habitat. These creeks provide rich food sources for large numbers of many species of recreationally important fishes (flounder, trout, red drum) and invertebrates (shrimp, crabs).

- CHP research found that natural conditions in small tidal creeks fluctuate widely and challenge the physiological tolerances of all species. However, the small size and physiology of larvae and juveniles of many *prey* species allow them to survive in areas where larger predators cannot. The intensity of land use, reflected by the amount of impervious surfaces (paved roads, roofs, etc.), increases stormwater runoff into small tidal creeks, changing the water chemistry of the creeks and increasing contamination. Researchers discovered that this process introduces additional environmental variability and can increase stresses to the point that even the juvenile creatures in the small tidal creeks cannot survive. Researchers found that there are more species of creek-dwelling creatures in forested creeks than in those near urban/suburban areas. This correlated with the amount of impervious surface surrounding the creeks, with the most marked changes occurring when impervious surfaces cover over 30% of the drainage area.

- Researchers found former rice impoundments along the Cooper River - now important habitats for colonial wading birds - to be undergoing the process of succession at a rapid rate. Succession is the natural transition of a wetland from a marsh to a forest. It is a very slow process, but the degree of change measured in the former rice impoundments over the ten-year period of 1985-1994 would normally take centuries to occur. Reduced flows from the Pinopolis Dam, beginning in 1985, caused the rapid rate of succession. The Santee-Cooper Hydroelectric Project, creating Lake Moultrie and Lake Marion in the 1940s, greatly increased water flows on the Cooper River and kept the former rice impoundments flooded. In 1985 water was rediverted back to the Santee River, reducing the amount of water flowing into the Cooper River. Much less water was left in the impoundments, which allowed terrestrial plant life to take hold and greatly speed up the transition of wetland to dry terrain. The process makes the former impoundments much less useful as habitat for the colonial wading birds.

Managing at the Level of the Ecosystem

Successful management in the future will require an area-wide approach to protect ecosystem function and value instead of the present emphasis on individual sites. Existing management programs need to be coordinated with a regional wetlands plan linking issues of future land use, development, and *mitigation banking*.

SUGGESTED ACTIONS

- Integrate ecosystem-level planning into the wetland management policy structure. The current wetland regulatory programs managed by the Army Corps of Engineers (COE), the Department of Natural Resources and the Office of Ocean and Coastal Resource Management form the main authorities under which most fresh water wetlands are managed. Existing regulations are designed to protect wetland habitats and associated wildlife and water quality functions. However, the current practice of parcel-level review does not provide managers with the opportunity for large-scale and long-term ecosystem management.

- Provide technical assistance to city and county planning departments regarding the most effective policies for protecting area habitats, waterways, and wetlands. As urban areas expand, wetland systems, if not filled directly, are frequently fragmented from adjacent habitats. Managers must develop compatible plans for urban growth and natural resource protection, with attention to maintaining the size and overall configuration of wetland systems. *Best management practices* to protect area waterways include buffers, development set-backs from creeks, *greenways*, and *neotraditional* land planning.

- Develop a monitoring strategy specific to small tidal creeks to ensure that these creeks and the plants and animals found there are adequately protected.

- Coordinate the efforts of federal, state, and local agencies to protect shellfish grounds from the effects of future growth and urbanization.

- Support the work of the U. S. Fish and Wildlife Service and other agencies to maintain an inventory of natural sites in the area under some form of legal protection, including public nature preserves and private conservation easements.

- Support research to analyze options for protecting former rice impoundments now used as habitat by colonial wading birds.

- Establish local mitigation banks to maintain large contiguous wetlands within developing areas.

Economic Development

RESEARCH INITIATIVES

The Charleston Harbor Watershed is a center of economic activity: exchange, production, and distribution. As an economic resource, water provides a means of access (sea lanes, harbor terminals, inland rivers and waterways) and an essential component for commercial and industrial processes.

Regional economic development efforts have earned national recognition in recent years, with successful programs to target and recruit new businesses and support the retention and expansion of existing firms. From the standpoint of watershed management, key economic development issues include:

– Assuring that environmental policies effectively preserve water quality and natural habitat so that the Lowcountry remains an unspoiled and attractive area for new businesses, visitors, and newcomers;
–Improving the competitive position of the watershed by arranging to permit prime industrial sites in advance and streamline regulatory processes;
– Fostering working relationships between economic developers and environmental management agencies that integrate the objectives of economic growth and conservation of natural systems.

Assimilative Capacity of Rivers

Water availability and good water quality are critical for economic development. Large quantities of water are needed by industries for processing, for discharging, and for shipping; but the recreation and tourism industries require good water quality. Harbor Project researchers examined the impacts of industrial discharges and the effects of land use patterns on water quality.

The assimilative capacity of a river is the amount of discharge it can receive at a given level of waste treatment without degrading the water quality and, consequently, the biological health of the river. The assimilative capacity of local rivers has become a growing concern in the Harbor Project area. Assimilative capacity can be expanded by increasing treatment levels. However, a higher level of treatment raises costs significantly for a discharger.

- Public policies regulate discharges into the rivers by controlling discharge amounts through permitting. Permits are issued for five-year cycles, and at the end of each cycle water quality conditions are reviewed to determine whether levels of discharge should be adjusted. At present, actual discharges fall far below permitted levels. Sewage and industrial dischargers are authorized to add an amount of effluent which is more than three times greater than they now put into the rivers. Field observations have shown that in some locations, area waters are already showing signs of decline linked to wastewater discharge.

Simulating the Impact of Development

A reliable gauge of water quality conditions in the watershed is necessary for sound economic planning and effective urban planning. Because water quality depends on many changing conditions, computer modeling has become a standard tool for management. Use of models is an evolving process; as technology improves, predictions improve.

- Harbor Project researchers developed a *water quality model* that represents an important advance in the development of science-based and decision-oriented modeling. Municipal and industrial treatment plant managers, economic development planners, and research specialists took part in creating the model. This collaboration demonstrated the importance of broad-based input in the design and development of policy-related tools affecting local communities. The CHP Model is serving as the basis for continuing efforts to improve and refine water quality modeling.

The Long View: Contamination as a Legacy

Today's economic development plans must combine measures that foster growth with measures that safeguard the environment. In parts of the Watershed, unwise economic activities of the past have left a legacy of contamination.

- Traces of DDT, banned twenty-five years ago, can still be found in area waters. In Shipyard Creek, CHP researchers found levels of chromium contamination that were as high as any reported in the world.

Dredge Maintenance and Disposal: a 40-Year Plan.

Harbor Project researchers performed a 40-year dredge and spoil assessment to determine the best sites for future dredge disposal, sites that would be economically feasible and least damaging to the environment. Working with the Army Corps of Engineers, the CHP undertook ecological and cultural assessments of planned or potential dredge disposal sites. The work led to the designation of preferred (least impact) locations for long-term spoil disposal.

Area-wide Planning to Protect Economic Assets

Managing the watershed as a whole depends on monitoring environmental conditions and trends, estimating the impact of potential development-related changes, and determining ways to minimize or offset unavoidable effects of urbanization. This process involves a shift from site-level management to a management approach that places site decisions in the context of changes to the entire Charleston Harbor Watershed. In this sense, individual property decisions are integrated into the management of the Harbor as a whole.

SUGGESTED ACTIONS

- Mitigation Banks: Establish county and/or municipal mitigation banks in the Harbor Project area to simplify and expedite the wetland permitting process. At present, there are no local mitigation sites; local development mitigation fees are used to enlarge sites in Horry County and elsewhere. Plan replacement wetlands in the Charleston area as both environmental and economic assets by assuring that the resultant reserves are designed to accommodate multiple uses (e.g., protecting important habitats and providing nature trails).
- Place modeling documentation on the CHP Water Quality Model in the public domain, making it available for use by planners and researchers.
- Develop a technical advisory committee for future planning for point source dischargers.

Competitive Position

As more businesses seek the location advantages of the tri-county area, environmental managers look to protect natural resources while accommodating sustainable growth. In turn, the protected natural resources will become a heavy advantage in drawing businesses to this area.

SUGGESTED ACTIONS

- Encourage economic development agencies to target industries compatible with sound environmental management. Place a premium on industries without wastes or by-products that could present long-term problems of storage or disposal. Add this environmental consideration to the current criteria guiding industrial recruitment efforts.

- Seek to minimize uncertainty and speed the permitting process by initiating an advanced permitting program for Class A industrial parks (light industrial). Work with local economic development offices to determine the suitability of their prime sites for future development and establish advanced permits for the sites that, when developed, would have the least impact on the environment. By giving companies the incentive to purchase a site that has already been permitted, local governments can promote economic development *and* minimize possible damage to the environment. This process would save industrial companies the time and inconvenience of looking for a site and then waiting to find out if an environmental regulation will prevent them from getting a permit. These preliminary permit assessments would be periodically reviewed to assure that they are consistent with current regulatory policies.

Urban Growth

RESEARCH INITIATIVES

Urbanization can be viewed as a process by which a natural landscape is transformed into a "built" environment. Within the spreading city, the pattern of existing land uses changes continually as a result of changes in commerce, technology, resource base, and regional/national competitive position - the many forces that shape urban form. The long-term success of a city depends on sound uses of the land in the city's core and at its edges. Compact development with orderly and compatible relationships between urban uses contributes to cost-effective services in all parts of the city. Through the provision of open space, preservation of natural habitats, and close monitoring of environmental processes and conditions, communities can protect the livability and prosperity of their cities.

Charleston Harbor Project research projects on urban growth include: The Tidal Creek Study - lead agency, Marine Resources Research Institute; The Belle Hall Study - lead agency, Dover, Kohl, & Partners; Nonpoint Source Modeling and Analysis - lead agency, Jones Ecological Research Center; and The Metro Charleston 1990-2015 Study - lead agency, Berkeley-Charleston-Dorchester Council of Governments (COG).

Civic leaders and public officials share the vision of a well-designed, prosperous city in an unspoiled natural environment. Decisions are constantly made that affect the whole Watershed. CHP researchers focused on critical issues at the watershed level, the community level, the site level, and on the infrastructure systems which support development at all levels.

Watershed Level

- *Population:* The population of the tri-county area has more than doubled since 1950. It was the fastest-growing region in the state from 1980 to 1990. Between 1990 and the year 2015 the population is projected to increase by 113,000. Approximately 44,500 additional housing units, 55,600 jobs, and 61,400 motor vehicles are also projected.
- *Land Transformation:* Regional planners and state officials have established that although the region's population increased by about 40% between 1973 and 1994, its urban land area grew by more

than 250%, six times faster than the population. Under current land development practices, CHP researchers projected that more than 45 square miles of additional land would be needed to provide for anticipated urban growth over the next three decades. For comparison, the Charleston Peninsula from the Neck to the Battery covers about 8 square miles.

Community Level

- *Jurisdictional Differences:* The Charleston Harbor Project Study Area consists of all or parts of 18 municipalities and three counties. Differences in planning and zoning regulations and in standards for development complicate resource management; jurisdictional boundaries follow property lines and not natural features of the landscape, such as creeks, marshes, and other biological habitats.
- *Comprehensive Plans:* In 1994 South Carolina enacted legislation requiring all municipal and county governments with zoning regulations to develop comprehensive plans by 1999. These plans must include a Natural Resources element. Harbor Project planners developed an approach for applying local environmental research to aid counties and municipalities in preparing and/or revising this element of their comprehensive plans.

Site Level

- *Impervious Surfaces:* Design of the "built" environment is critical to the long-term health of surrounding ecosystems. Development plans determine how much of a site will be covered by roads, sidewalks, driveways, and roofs. These impervious surfaces can impair habitats and water quality by funneling stormwater runoff and pollutants directly into receiving water bodies, without benefit of filtration into the ground. Researchers determined that water quality begins to deteriorate when 10% of the land area surrounding a water body is covered by impervious surfaces. When coverage reaches 30%, water quality and biological habitats can degrade significantly.
- *Urbanization and Tidal Creeks:* CHP researchers studied the natural variability of water quality in two estuarine creeks - one in a highly urbanized watershed and the other in a pristine, forested watershed to measure the effects of different land use practices on

creeks and rivers. The urban creek received much more runoff and contaminants due to the surrounding land uses and amount of impervious surfaces. The urban creek was subject to more rapid and extreme changes in salinity, temperature, and dissolved oxygen than the forested creek - mainly after rainstorms, which generate high amounts of runoff. These fluctuations make survival much more difficult for organisms living in the urban creek environment.

- *Best management practices: retention ponds* (constructed in developments to receive runoff) and vegetative buffers are the primary BMPs used to lessen the impact of stormwater runoff.

- *Buffers:* CHP researchers evaluated the trapping efficiencies of planted and natural vegetative buffers - strips of land between water bodies and developments that capture and filter stormwater runoff. Analysis showed that a 50-foot buffer is necessary to protect vital tidal creeks and wetlands from sedimentation and pollutant loading.

Infrastructure: Support Systems for Towns and Cities

- *Roads:* Roads are the most damaging impervious surface because they funnel runoff and pollutants directly into drains and receiving water bodies. Under present standards, 12-22% of the land area planned for residential development is set aside for infrastructure, mostly roads. Over $200 million of federal grant money will be spent in the tri-county area over the next five years for the construction and improvement of bridges, highways, and roads. This money does not include funding for replacement of the Cooper River Bridge, which may be arranged through the State Infrastructure Bank. In recent years, more and more road construction and maintenance costs have been shifted to state and local governments as a result of changes in federal budget allocations.

- *Water:* Water quality ranges from fair to good in the Charleston Harbor Watershed and compares favorably to other large urban areas. However, there is growing concern over the waste *assimilative capacity* of the lower Cooper River. As permitted discharges and stormwater runoff increase, further loading is expected to cause lower *dissolved oxygen* concentrations than are allowed by state standards (as of 1997).

- *Sewer/Treated Waste:* In recent years, an average of 5.5 million pounds of ammonium (composed of nitrogen and hydrogen) has been discharged into the Harbor. In spite of the enormous tidal flushing and the vast expanse of marshes, area waters can only

assimilate a finite amount of nutrients, especially nitrogen, without detrimental effects to their biological health. CHP researchers reported signs that some local water bodies are approaching their nitrogen limit. Although assimilative capacity can be enlarged by increasing the amount of waste treatment, a higher level of treatment raises costs significantly.

- *Onsite Wastewater Disposal Systems (OSDS)*: OSDS, also known as septic tank systems, are commonly used in the CHP study area. Recent data indicate that approximately 35% of the homes in Charleston County use OSDS for wastewater disposal. To protect *groundwater*, state regulations require, among other setback distances, a minimum separation distance between the bottom of the OSDS effluent distribution trenches and the estimated level of the seasonal high *water table*.

- *Solid Waste:* During Fiscal Year 1996, over 1.07 million metric tons of solid waste were disposed of in landfills in the tri-county region, including four active municipal landfills; eight industrial landfills; four construction, demolition, and land-clearing debris sites; and one ash monofill site (incinerator). Permitted capacities for the four municipal landfills will be reached between 1998 and 2010.

The Belle Hall Study

Researchers designed development plans for a 583 acre section of the Belle Hall Plantation Tract in Mount Pleasant using two scenarios: a "Sprawl" design and a *neotraditional* or "Town" design. The design team incorporated the findings of recent studies which suggest the only effective way to manage nutrient loading in a watershed is to combine Best Management Practices with land use policies that minimize the effects of stormwater runoff.

- CHP researchers evaluated the effects of combining neotraditional planning with BMPs for managing stormwater runoff on the Belle Hall tract. A nonpoint source pollution model demonstrated that the Sprawl design for Belle Hall would generate 43% more runoff and three times greater sediment loads than the Town design.

- Placement of appropriate vegetative buffers between a receiving water body and the areas of heaviest land use (highest percentage of impervious surface) was found to be critical in the design to prevent runoff.

- Infrastructure costs for the Town design were found to be half that of the Sprawl design.

Assist Local Governments in Development of Comprehensive Plans

In 1994 the South Carolina Legislature enacted the South Carolina Local Government Comprehensive Planning Enabling Act, requiring counties and municipalities to develop comprehensive plans. This law consolidates existing planning legislation and updates current practices with new methods, tools, and procedures. Plans must be completed in 1999 and include the following elements: Population, Economy, Natural Resources, Cultural Resources, Community Facilities, Housing, and Land Use.

SUGGESTED ACTIONS

- Provide local governments with Harbor Project research results to assist them in producing their comprehensive plans and develop a framework for other public agencies to provide expertise and technical advice.

- Analyze environmental implications of differences in planning and zoning regulations across the region, particularly where jurisdictional boundaries are crossed by streams, rivers, and other habitat corridors.

Expand Watershed-Level Planning Initiatives with Ongoing Monitoring, Research, and Policy Refinement

An ongoing system of monitoring, research, and policy refinement is needed for effective resource management. Monitoring is needed to see if present policies are working; research is needed to determine what to do if policies are not working; and policy refinement is needed to improve the policies that are not working. Every five years DHEC must either develop or revise regional watershed plans. The five-year planning cycle permits DHEC to focus its resources on targeted geographical areas. The Berkeley-Charleston-Dorchester Council of Governments is the designated agency for developing and maintaining the region's water quality planning programs. Similar five-year planning cycles exist for transportation, natural resources, wastewater, and local urban planning.

SUGGESTED ACTIONS

- Implement the Special Area Management Plan process when conflicts arise over resources. With a SAMP, officials can develop strategies, including refinement of existing policies, to manage resources and address conflicts in certain locations. A SAMP is designed to coordinate efforts by all involved local, state, and federal entities.

- Develop an applied research agenda to measure the effectiveness of current natural resource management policies. Obtain the information needed to support science-based decision making using research programs already in place in the state, such as the Marine Resources Research Institute, the National Estuarine Research Reserve program, and research initiatives by state colleges and universities.

Develop Local Mitigation Banks

Under the Clean Water Act, if a wetland is to be filled, the landowner must replace it with a similar wetland. A mitigation bank is a site where wetlands are restored, created, or preserved expressly for the purpose of maintaining the total amount of wetlands in the landscape. A landowner can either restore or create new wetlands at the impacted site or purchase "wetland mitigation credits" from an established area mitigation bank.

SUGGESTED ACTIONS

- Establish local mitigation banks to consolidate isolated mitigation projects into larger tracts, which could provide greater ecological benefit. Connect mitigation banks to general permits in order to streamline and quicken permit review for landowners.

- Expand the federal policy of "no net loss" of wetlands to prevent losses in wetland value, not just losses of wetland acreage. The value of a wetland is determined by its importance to the surrounding ecosystem. The region's most valuable wetlands must first be identified to achieve the best results from a mitigation banking system.

- Develop policies for the management of wetlands smaller than one acre. These small wetlands are not adequately protected under current state and federal policies. Many rare species use only these small wetlands as habitat, so such wetlands should receive consideration in any mitigation banking system.

- Combine BMPs with innovative land use designs to minimize the volume of stormwater runoff. Environmentally sound design concepts, such as those demonstrated in the Belle Hall Study, can cut infrastructure costs significantly for local and state governments but will require revisions to zoning ordinances in many localities.

- Establish greenways— areas of undeveloped land in and around urban areas that are set aside to remain in their natural state. In addition to alleviating stormwater runoff, greenways can serve multiple purposes, including preserving habitat, existing as passive parks for human recreation, and protecting valuable cultural sites from encroaching development.

- Establish fifty-foot vegetative buffers between salt marshes and new developments. The capacity of these wetlands to protect against pollution, flooding, and erosion makes establishment of such buffers economically, as well as environmentally, sensible. Wherever possible, construct similar buffers in existing developments to restore wetland and tidal creek habitats.

- Design roadways to reduce stormwater runoff by minimizing the total amount of impervious surface, particularly in sensitive areas near wetlands and tidal creeks. Design stormwater drainage systems to better mimic the path of runoff in natural systems. Existing roads and bridges should be examined for possible retrofitting to reduce impacts on natural resources.

- Design additional wetland and water body restoration programs with local governments in the CHP area, using the Summerville project as the model for interagency cooperation.

- Construct basin-wide drainage systems that make use of large retention ponds, shared by several developments, as a cost-effective stormwater management solution. Regular inspections and maintenance of these ponds would ensure that they are functioning as designed.

Increase Use of Best Management Practices and Efficient Land Use Planning

Engineers and planners incorporated Best Management Practices and efficient land use planning measures into CHP site planning and restoration projects. Because these projects protect the environment and save money for local governments and developers, they can be expected to play an increasingly important role in future development of the Watershed.

The Summerville Example

- *In 1994, the Harbor Project initiated a wetlands restoration project at the Sawmill Branch Canal in Summerville with funding from the Environmental Protection Agency (EPA). The canal was formed in the 1960s by the Army Corps of Engineers to control flooding by deepening the existing creek and placing the dredge spoil between the creek and adjacent wetlands.*

  However, drainage pipes from the wetlands to the canal were placed too low and did not allow the wetlands to retain and filter stormwater. Other stormwater drain pipes from nearby developments bypassed the wetlands altogether and drained directly into the canal. The result was sedimentation and polluted water in the canal, inadequate water supply to the wetlands, and eroded streambanks.

  The restoration project, an effort by CHP, the Town of Summerville, Dorchester County, and other government agencies, solved the problem of the drainage pipes that led directly into the canal by redirecting them into the wetlands. The pipes that led from the wetlands to the canal were raised to allow the wetlands to retain more water. The water in the creek is now cleaner because the wetlands can filter it, and the wetlands are much healthier because they again have an adequate supply of water.

Address Waste Management Needs

State and federal environmental legislation of the past 25 years, such as the Clean Water Act and the Solid Waste Management Act, has concentrated on cleaning up the environment and setting standards to keep it clean. Waste management, including solid waste, wastewater, and OSDS (septic systems), has improved in South Carolina, but new technologies and more efficient practices are needed to further protect the environment and guard against the problems associated with extensive population growth and urbanization.

Wetland protection is especially vital along the lower Cooper River. Researchers found that wetlands there import ammonia and organic material during the critical summer low-flow period, the time of year when groundwater levels are typically at their lowest. Water in the lower Cooper does not drain directly into the ocean but lingers in the Harbor and can even move back up into the same or other river systems. Therefore, there is a premium on proper industrial site design and monitoring on the lower Cooper to protect its water quality. Bushy Park presents an example of how to construct a successful industrial complex while minimizing the impact to the Cooper River and surrounding biological habitats.

SUGGESTED ACTIONS – Wastewater

- Where feasible, consolidate wastewater treatment and/or discharge facilities into area-wide facilities. Small-scale treatment plants, often referred to as "package plants," are subject to a disproportionate number of problems with operations, maintenance and long term financing. Also, with numerous small-scale plants, it is difficult to determine which facility is responsible when an insufficiently treated discharge is released into one of the area's rivers.

- Determine if there is sufficient assimilative capacity in the major waterways of the CHP to accommodate additional waste loads. The total maximum daily load (TMDL) anticipated for the year 2000 should include estimation of the nonpoint source pollution load. A TMDL is the maximum allowed pollutant loading to a water body.

- Run the CHP dynamic water quality model during typical spring and summer seasons. Study the impact of industrial and sewage discharges from the lower Cooper River on dissolved oxygen levels in the Wando River. If a significant amount of Cooper River

water with low dissolved oxygen levels enters the Wando during each tidal cycle, then the point source allocations for sources on the lower Cooper must account for this impact.

- Map areas currently served by natural wetlands and continue studies to determine the assimilative capacity of wetlands. Map projected growth areas of the basin to guide planners and civic leaders in locating new wastewater treatment plants, industrial dischargers, and residential developments.

- Monitor the long-term behavior of retention ponds and vegetative filter strips in the Harbor Project area. Develop appropriate standards for such specific land uses as marinas and golf courses to ensure that adjacent wetlands and tidal creeks are not unnecessarily impacted.

SUGGESTED ACTIONS - Solid Waste

- Evaluate the feasibility of constructing a regional landfill. Construct any new landfill at least five kilometers from waterbird nesting sites to reduce the possibility of concentrating predators near the sites. DNR recommends that landfills be located at least three kilometers away, but since the present lack of suitable nesting sites within the estuary appears to be the major factor limiting waterbird populations, the distance should be increased to five kilometers to ensure that the remaining sites are protected.

SUGGESTED ACTIONS - Septic Systems (OSDS)

- Implement a voluntary homeowner inspection, operation, and maintenance program. OSDS must be inspected to ascertain whether they are regularly performing as designed or impairing surface waters or groundwater. Include a recommended pump-out schedule with all OSDS permits issued in the coastal zone. Most OSDS tanks need to be pumped out every 3 to 5 years to remove the accumulated layers of sludge.

- Inspect systems in those areas where failed systems are believed to cause groundwater contamination. If connection to centralized sewer is available, require property owners with failing systems to connect to the centralized treatment system.

- Conduct research to determine if shallow septic system designs and other alternative OSDS systems (typically used in areas marginally suited for conventional systems) adequately protect groundwater and surface waters.

Culture & Recreation

RESEARCH INITIATIVES

The CHP program initiatives related to cultural and recreational resources have focused on the preservation of historic and culturally important places, access to recreational opportunities in the Harbor and river systems, and measures to avoid harming or depleting the natural and cultural resources that define Charleston. In the Charleston Harbor Watershed, history and geography have combined to bring about a rich cultural heritage and a unique quality of life. Cultural resources are important assets to the region's economy as well; over 200,000 people visit Fort Sumter annually, with an average local expenditure of $150 each. Recent estimates indicate that the major historic parks and museums in the region attract about 1.5 million visits per year.

Cultural Resources

Civil War Sites

The Charleston Harbor Project area contains some of the most significant historic and archaeological sites in the United States. Through archival research and land surveys, the boundaries of many Union and Confederate Civil War sites in the region were recorded by a *Global Positioning System* unit.

- Researchers determined the current (as of 1994) condition of each site as well as the short- and long-term threats to each site. Some sites have been destroyed through erosion or development. This information is being developed into Geographic Information System data layers that can be used by local governments and state resource management agencies to prevent the inadvertent loss of historic Civil War sites.

Submerged Archaeological Sites

The submerged cultural resources of the Charleston Harbor area preserve an important physical record of the Charleston area's development. Properly preserved and recorded, the remains of sunken ships, inundation sites, and maritime related structures can provide insight into the past that is otherwise unavailable in the historical record. Initial literature and archive investigations focused on the documenta-

tion of activities such as exploration, colonization, agriculture, and trade, that contributed to the region's submerged archaeological record.

- Researchers studied manuscript sources of shipwreck data (libraries, archives, historical societies) to obtain site-specific information. Cartographic research identified a variety of maps and charts illustrating human activity in the Charleston Harbor area. Researchers identified historic activity areas, such as shipyards, plantations, and ferry crossings, to define potential development sites that have a high probability of containing submerged cultural resources. These areas were assigned one of three "sensitivity zone" designations, corresponding to the likelihood that they might contain underwater remains of significance to archeological research.

Archaeological Model and Database

CHP researchers developed a prototype for a predictive model that would enable government agencies and planners to predict where archaeological sites would most likely occur within the Charleston Harbor area, assigning probability ratings for particular tracts of land under development consideration. This approach assigns a probability rating for a particular tract of land under development consideration (the probability an archaeological site will be located on the tract). The archaeological database upon which the prototype was constructed consisted of 1,208 known sites from Beaufort, Berkeley, Charleston, and Colleton counties. The sites were evaluated by archeologists from 1985 to 1994 as part of compliance surveys required for planned developments. This database assured a consistent methodology of site discovery and definition. The database for the model includes both archaeological characteristics (functional use, age, and site size) and environmental characteristics (soils, streams, and topography).

Consolidated Planning for the Watershed

A Cultural Resources Management Plan (CRMP) for the CHP area could protect against the inadvertent loss of important sites and at the same time streamline the permitting process for development. Similar plans are in place for military bases and other federal lands. They serve to identify high sensitivity areas — unprotected areas with a high potential of containing hidden cultural resources — in advance of specific development proposals.

SUGGESTED ACTIONS

- Designate sensitive areas based on the S.C. Department of Archives and History's knowledge of historic sites and with the assistance of the S.C. Institute of Archaeology and Anthropology.
- Maintain an inventory of historic properties, including submerged sites, buildings, districts, landscapes, vistas, and archaeological sites, for interpretation and education programs.
- Integrate existing cultural resources management plans, including those for the Naval Weapons Station and Francis Marion National Forest, in the development of the Cultural Resources Management Plan. The S.C. Department of Archives and History should remain the lead agency in cultural resources planning because of its staff's expertise and ability to ensure the application of consistent assessment methods across the CHP area.
- Support and promote the development of local academic and scientific research programs focused on the region's cultural heritage.

Recreational Resources

Dominant Natural Resource

Many of the recreational opportunities in the CHP area are based on its abundant cultural and natural resources and are centered around water, the region's dominant natural resource. Although access to these recreational resources is presently adequate, increased tourism and economic and residential development may soon cause problems of overcrowding and overuse.

Inventory of Recreational Sites

An inventory of sites and facilities providing outdoor, water-based recreation was completed by the CHP in June 1994. The project documented the public's present level of recreational use of area water resources and established an agenda for the enhancement of the cultural and recreational uses of the Charleston Harbor Estuary.

- The inventory identified over 140 rivers and creeks in the CHP area, with more than two-thirds located in Charleston County. The inventory includes: 50 boat ramps, 18 marinas, 14 fishing camps, 6 state parks, 5 county parks, 2 forest preserves, and 2 boat tours. Of all the listings, 125 are located in Charleston County, 53 in Berkeley County, and 15 in Dorchester County.

Public Access

Charleston's coastal beaches and the Santee-Cooper lakes form a regional complex with many recreational opportunities. Most of the public access to water-related recreational opportunities is provided by twelve municipal and county governments in the CHP area. However, there are no county-sponsored recreational programs in either Berkeley or Dorchester counties, which has hampered the development of outdoor recreation in areas outside of city-owned or state-held lands.

- Large sections of coastline are restricted and inaccessible to public use. There are more than seventy-five miles of waterfront along Lake Moultrie and Lake Marion, but there are no supervised public swimming areas on either lake. There are several commercial beaches near Moncks Corner.

- There are numerous boat landings in the region, primarily in Charleston and Berkeley counties. Amenities, such as picnicking facilities with shade trees, are not available at most sites.

Consolidated Planning for the Watershed

An area-wide Coastal Recreational Council was proposed in the recent *Needs Assessment Study for Water-Based Recreation Programs and Facilities* (Charleston County Parks and Recreation Commission, 1997). Such an approach for the entire Watershed, with state and local government input, could provide a means for improving existing sites, and further expanding water-based recreational opportunities.

SUGGESTED ACTIONS

- Monitor public access, crowding, resource deterioration, and recreation facility maintenance. Provide new amenities, such as publicly accessible docks and fishing piers, picnicking areas, open spaces, and nature trails, to meet the demands of the region's increasing population.

- Promote land use policies and comprehensive planning that encourage the acquisition of waterfront properties and the establishment of public, water-based recreation areas. "Put in" sites (undeveloped waterfront land used by citizens to launch their canoes, kayaks, etc.) are scarce and the existing sites are highly used. With increased population and urban growth come two pressures: more people will use the existing sites, and some sites will be lost to development because they were not protected, creating an even higher demand on the remaining sites.

- Encourage the use of impact fees on future development to fund the acquisition of areas for public recreation.

- Encourage public-private partnerships to help generate the revenues needed to acquire, develop, and operate needed recreation-oriented facilities and programs.

- Use recreational and educational programs to direct the public from overused facilities to under-used sites. Encourage activities in particular areas (fishing, water skiing, etc.) based on the best uses of a water body. Use recreation facilities and programs to help educate the public on the benefits and values of natural ecological systems.

- Analyze existing regulations (land use, marinas, golf courses, etc.) to ensure that specific recreational uses do not add to pollution and habitat degradation. Revise regulations as necessary to better control recreational uses that exacerbate pollution.

Accretion: The depositing of land surface by water or wind. When land erodes in one area, it accumulates naturally in other areas.

Assimilative Capacity: The maximum pollutant discharge that a waterbody can receive (at a given rate of waste treatment) and still sustain the health of biological resources living in the water body.

Barrier Island: Narrow islands of sand that run parallel to the shoreline. They are separated from the mainland by a river, marsh, or lagoon, and inlets separate adjacent barrier islands. Barrier islands buffer the mainland from storms and heavy surf. In geologic terms, barrier islands are constantly on the move, with the contours of the islands always changing as wind and wave action cause erosion and accretion.

Best Management Practices (BMPs): Practices determined to be the most effective and feasible means of preventing or reducing pollution from point and nonpoint sources in order to protect water quality. Examples include buffer strips and detention/retention ponds.

Brackish: Somewhat salty water that is a combination of seawater and fresh water

Buffer Strip or Zone: Strips of land between a waterway and a developed area that are left undeveloped to protect the waterway from pollution and erosion by filtering runoff.

Charrette: An intensive public workshop that is usually run by professional planners or consultants but is sponsored by public officials. The purpose of a charrette is to solve a design-related problem facing a community or to offer alternatives to current design practices. The public is invited to attend and participate. A charrette usually lasts between three days and a week and culminates with the presentation of a final plan, a compilation of the best ideas offered during the charrette.

Demography: Study of the size, structure, dispersal, and development of human populations to establish reliable statistics on those populations. Governments use the information to guide policies on land planning, zoning, and permitting.

Detention/Retention Basins: Manmade ponds built in or near developments to receive stormwater runoff from those developments.

Dissolved Oxygen (DO): The amount of free oxygen dissolved in water. DO is required by higher organisms for respiration in water. DO levels in estuaries fluctuate widely from both natural and manmade influences.

Cycles Affecting DO: Daily, seasonal, and tidal cycles all drive the levels of dissolved oxygen in water bodies. Plants produce oxygen as a by-product of photosynthesis during daylight and consume oxygen for cellular respiration during darkness, so DO levels are lowest at dawn. During the tidal cycle, DO levels increase during high tide as the more oxygenated ocean waters flow in. Seasonally, DO levels are highest during winter, because colder water can hold more dissolved gas. Rainstorms also affect DO levels. Runoff from storms washes both organic (e.g., bacteria) and inorganic (ammonium) oxygen-demanding substances into the water, causing DO levels to decrease after a storm. Water bodies near developed areas suffer more severe drops in DO because the increased amount of impervious surfaces in developed areas generates more runoff than pristine areas, and the runoff picks up additional oxygen-demanding substances, such as lawn clippings and pesticides, that are the result of human activities.

Dredging: Deepening rivers or coastal waters by removing material from the bottom of the water body.

Ecology: The science of the relationships between organisms and their environment.

Ecosystem: All of the living organisms and the encompassing nonliving, physical environment in a region functioning as an integrated unit, such as a rain forest, coral reef, or grassland.

Erosion: The wearing away of land surface by water or wind. Erosion occurs naturally from weather, runoff, and ocean waves but is often intensified by human activities. When land erodes in one area, it accumulates naturally in other areas. This buildup of land is called accretion.

Estuary: A body of water, such as Charleston Harbor, where inflowing salt water from the ocean mixes with fresh water from rivers and streams. Examples include bays, lagoons, and tidal rivers. Estuaries play a vital role as breeding and/or nursery grounds for commercially important species, such as shrimp, crabs, oysters, clams, and numerous kinds of fish. Estuaries are among the most productive of habitats but are also among the most harsh; resident organisms must adapt to continual changes that accompany the mixture of fresh and seawater, including fluctuations in salinity, water temperature, dissolved oxygen levels, and nutrient concentrations.

Eutrophication: Excessive nutrient enrichment of water bodies, frequently the result of human activities, that causes an explosive growth or "bloom" of algae and other aquatic plants. The respiration of the

additional plant life depletes the water of dissolved oxygen (DO), leading to the death of most of these plants. As bacteria decompose the plants, most or all of the remaining DO is consumed. Such areas of low or no dissolved oxygen cannot support other creatures.

Filling: Depositing of material into marshy areas to create more land, frequently for purposes of real estate development. Filling can disturb the ecological cycle by destroying breeding and feeding grounds for many species of fish, shellfish, and other invertebrates.

Filter Feeders: Animals, such as oysters and clams, that pump large volumes of water through their bodies and extract food from it. As they filter water for food, they also remove sediments, chemicals, and organic matter, which cleans the water.

GAP Analysis: A procedure recently developed using GIS technology (see next entry). Scientists develop digital models on the distribution of biodiversity in a region in relation to land ownership and land use. "Species distribution" data layers are created and then overlaid onto a "protected land status" layer. Analysis of the combined layers highlights those areas of significant biodiversity which are not legally protected. Identification of these "gaps" in a state's existing environmental protection measures provides a basis for decision-making related to land acquisition, protection, and environmental impact assessment.

Geographic Information System (GIS): A computerized data management system developed by geographers for the capture, storage, analysis, and graphic display of data, most often spatially on maps. Different data "layers" can be placed on top of one another on maps (e.g., the layer of crime rate distribution for different neighborhoods placed over the layer showing population growth rates) to help recognize spatial trends or relationships, create greater understanding on an issue or scientific problem, and then used to set policy. GIS is especially useful in dealing with issues related to the environment and urban planning.

Global Positioning System (GPS): Instruments that are used to determine the exact position of a site on the earth. A portable unit at a site produces a signal. That signal is coordinated with two satellites producing similar signals. The position of the satellites and the unit can then be used for triangulation - determining the location on the earth of the unknown point by creating a triangle with the unknown point and the known position of the two satellites. This technology is very useful for several scientific and professional disciplines.

Greenbelt/Greenspace/Greenway: Land in a city or county that is designated to not allow residential/commercial/industrial development, but instead be preserved for habitat, recreation, or its traditional use, such as agriculture. Designating greenways is a means to counter urban sprawl and preserve nature and farmland, as well as other traditional uses. Greenways are frequently designed for multiple uses, such as preserving habitat and providing passive parks. A greenbelt is a greenway that surrounds a city.

Groundwater: Water collected underground in porous rock layers and soils that emerges at the surface as springs and streams. The groundwater upper level is called the water table. Groundwater has been estimated to account for more than 90% of all the fresh water on Earth.

Habitat: The total environment in which an organism lives. A habitat is able to provide for all of the needs of an organism, such as an adequate food supply.

Hydrology: The study of the properties, location, and movement of inland waters both above and below ground. The hydrologic cycle is the cycle of water movement from the atmosphere to the earth and back to the atmosphere through various processes, including precipitation, runoff, infiltration, evaporation, and transpiration.

Impervious Surface: Ground cover, such as roofs, paved surfaces, and impacted soils, that does not allow for infiltration of water into the ground. Impervious surfaces increase the volume and speed of runoff after a rainfall.

Infiltration: The penetration of water through the ground surface into the soil. Once in the soil, water may pass into the bedrock to become groundwater.

Infrastructure: The basic facilities, services, and structures needed for a community to function, such as a transportation network and sewer system.

Inorganic: Composed of no organic matter.

Load/Loading: The quantity (i.e. mass) of a material that enters a water body over a given time interval.

Marsh: A low-lying tract of soft wetland that is usually seasonally or tidally flooded or wet and is often dominated by one or a few plant species, especially grasses.

Mitigation Bank: A site where wetlands are restored, created, or preserved to serve as compensation for wetlands that are going to be filled for development elsewhere in a region. The bank is the site itself, and the currency is parcels of wetlands within the site.

Neotraditional Design: See **Traditional Town Design**.
Nitrogen: One of the major nutrients required for the growth of aquatic plants, usually present in water as organic nitrogen or as inorganic ammonia and nitrate. High concentrations of nitrogen can cause over-abundant aquatic plant and algal growth.
Nonpoint Source Pollution (NPS): Pollution from many diffuse sources that cannot be attributed to one identifiable "point," such as a discharge pipe. NPS pollution is caused by precipitation, atmospheric deposition, percolation, and runoff containing sediments, nutrients, and organic and toxic substances generated by various land uses and human activities. Rainfall can cause soil erosion and create runoff which carries sediments and pollutants to receiving water bodies.
Nutrients: Elements and chemicals, such as nitrogen and phosphorus, that are essential to plant growth. Too many nutrients in a water body can lead to eutrophication and result in a fish kill.
Organic: Derived from living organisms.
Percolation: The downward movement of water through the subsurface soil layers.
Point Source Pollution: Pollution from discharges from easily identifiable "points," such as sewage treatment discharge pipes.
Predator: An animal that hunts other animals.
Prey: An animal that is hunted by other animals.
Riparian: Related to or located on the bank of a natural watercourse, such as a river.
Roost: A place with perches where birds go to rest at night.
Runoff: Water from rain or irrigation that flows across, rather than into, the land. Runoff increases as the amount of impervious surfaces increases. Runoff often carries pollutants, such as pesticides, excess nutrients, and sediments. It is a major vehicle for nonpoint source pollution. In undeveloped forest land, little rain runs off as plant cover and roots allow rainwater to seep slowly into the soil. In developed suburban and urban land, the increased amount of impervious surfaces decreases the absorption of rainfall and increases runoff. Runoff flushes pollutants contained on the impervious surfaces and in the rainwater itself into nearby streams. High amounts of runoff can erode stream banks and cause flooding. After reaching the receiving water body, pollutants from runoff degrade water quality.
Special Area Management Plan (SAMP): A coastal management planning process used to develop recommendations on how to modify policies and regulations in areas where local conditions or circumstances call for special measures.

Sediment: Soil, sand, and minerals washed into water, usually after rain. Excess sediment can damage habitats by clouding waters and accumulating on the bottoms of water bodies.

Septic Tanks: Underground storage tanks for wastewater from homes having no sewer line to a treatment plant. Wastewater goes directly from the home to the tank, where organic waste is decomposed by bacteria, and the solids (sludge) settle to the bottom. The liquid waste then flows into a drainfield via perforated pipes, where it undergoes some purification by the surrounding soil. The sludge needs to be periodically pumped out or it will cause the system to fail and subsequently pollute the surrounding area.

Sprawl (or Urban Sprawl): Outward spread of cities as their populations increase that is marked by much less efficient use of land than in the older sections of the cities. With sprawl, a city's land area grows at a much faster rate than its population.

Stormwater: The runoff from rainstorms. Stormwater contains the highest amount of pollutants early in a storm; the first one inch of runoff, or "first flush," contains over eighty percent of the total pollutant load.

Swamp: A wetland dominated by woodsy vegetation.

Tidal Creek: A creek close to the ocean that is inundated by salt water at high tide.

Topography: Graphic representation on a map of the surface features of an area, showing their relative positions and elevations.

Toxic: Capable of causing injury or death, especially by chemical means.

Traditional Town Design: Developments designed similar to towns and neighborhoods built prior to World War II, with smaller lots, parks, a grid street pattern, and a mixture of commercial and residential uses within the neighborhoods. This design protects more open space and is more pedestrian-friendly than sprawl, placing residents within walking distance of parks and stores.

Tributary: A stream or river that flows into a larger stream or river.

Urban Growth Boundary (UGB): An officially adopted and mapped line that separates an urban area from its surrounding greenbelt of open lands, including agricultural land, parks, and nature preserves. UGBs are regulatory tools that serve to protect natural and rural land from development. They are designated to last for a significant period of time - usually over twenty years - to discourage speculation at the urban or suburban fringe.

Water Quality Modeling: Using computers and advanced mathematics to take available water quality data and simulate actual conditions in water bodies and predict future conditions.

Watershed: A drainage area or basin - a region where all the water, sediments, and dissolved materials flow into a common estuary (or other large body of water) by way of its creeks, rivers, and groundwater. A watershed covers much more area than the estuary it drains into. The Chesapeake Bay Watershed is fifteen times larger than the Bay itself.

Water Table: The level below which the ground is saturated with water

Wetlands: Areas, such as swamps and marshes, that are covered with water for periods of time long enough to support plants that thrive in wet soils. Not all wetlands have standing water year-round, however, as some wetlands may be dry during certain seasons. Wetlands are defined by their vegetation and soil types, in addition to their hydrology. They can receive water by rain, groundwater seepage, runoff, adjacent streams, and tides.

Sources: Nonpoint Source Pollution Glossary, Chesapeake Bay Program Glossary (off of the internet), and selected terms and phrases from the CHP working glossary for study related documents.

NOTES

Photographs courtesy of:

Cover - Great blue heron	Thomas M. Murphy, SCDNR
Page 5 - Wood stork nest	Thomas M. Murphy, SCDNR
Page 26 - Snowy egret	Thomas M. Murphy, SCDNR
Page 31 - Shipping containers	SC State Ports Authority
Page 33 - Sweetgrass basket weaver	Charleston Area Convention & Visitors Bureau

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