

Environmental monitoring systems in South Florida, USA

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Abstract Severe environmental problems caused by anthropogenic water quality and quantity changes have been recognized in South Florida and are being addressed through restoration programmes. Data collection networks are key to environmental problem recognition, diagnosis and solution development, as well as for monitoring success of restoration efforts. The South Florida Water Management District operates extensive monitoring networks for measuring hydrologic, hydrogeologic, meteorologic and water quality parameters using state-of-the-art techniques for data capture, transmission, processing, and archiving. These include ultrasonic velocity meters, acoustic Doppler profilers, automatic water samplers, electronic data loggers and radio frequency/telephone linkages. An Automatic Remote Data Acquisition Monitoring System (ARDAMS) and a Supervisory Control and Data Acquisition System (SCADA) allow for real-time data acquisition, remotely-controlled operation of water control structures and two-way communication with field instrumentation at remote sites. Data are stored on corporate Oracle-based environmental database systems with direct remote accessibility via modem and the Internet. The databases are linked internally to several computer applications, including the ARCInfo geographic information system, hydrologic and hydrogeologic models to facilitate rapid utilization of the data for trend detection and water resources systems evaluations.

Evaluación de sistemas ambientales en el Sur de la Florida, USA

Resumen Severos problemas ambientales, causados por el hombre en la hidrología y calidad del agua, han sido reconocidos en el Sur de la Florida y están siendo considerados a través de programas de restauración. Redes de colección de datos son fundamentales para el reconocimiento, diagnóstico, y solución de problemas ambientales, así como para evaluar el éxito de los esfuerzos de restauración. El Distrito de Administración de Agua del Sur de la Florida (SFWMD) opera extensas redes para coleccionar parámetros hidrológicos, hidrogeológicos, meteorológicos y de calidad de agua usando las técnicas más avanzadas para medir, transmitir, procesar y almacenar datos. Estas técnicas incluyen medidores de velocidad ultrasónicos, perfiles acústicos tipo Doppler, equipos de muestras de agua automáticos, registradores electrónicos de datos, conexiones de radio de frecuencia y telefónicas. Un sistema automático de adquisición de datos remotos (ARDAMS) y un sistema de supervisión de control y adquisición de datos (SCADA) permiten la adquisición de datos en tiempo real, operaciones a control remoto de estructuras de control de agua, e instrumentos para transmitir y recibir datos a lugares remotos. Los datos son almacenados en un sistema de base de datos ambiental (ORACLE) con acceso directo vía modem y por el internet. La base de datos está conectada internamente a varios programas de computadora, incluyendo el sistema de información geográfico ARCInfo, modelos hidrológicos e hidrogeológicos que facilitan la rápida utilización de los datos para detectar tendencias y evaluar los recursos hídricos.

INTRODUCTION

The South Florida Water Management District (SFWMD) and its predecessor agencies have been involved in the collection of hydrologic, hydrogeologic, water quality and biological data since the 1940s. The need for this data has increased greatly as population growth, economic development and the growing concern for anthropogenic environmental impacts have intensified. Urban wastes and stormwater runoff in heavily populated coastal areas and agricultural runoff and chemical use in interior areas threaten environmentally sensitive wetland areas and coastal estuaries, and the fauna and flora they support. In addition to the impacts on the quality of life and environmental values in the area, human health may also be affected. Currently there are over 2000 monitoring locations from which data are obtained regularly.

Hydrologic and environmental features

South Florida is characterized by a subtropical climate, low topography and relief, and a seasonally variable rainfall pattern. The hydrologic regime in south Florida is dominated by a highly managed system consisting of channelled streams, canals, levees, impoundments, water control structures and pumping stations which provide flood management, water storage and water supply for humans and the environment. The primary water management system, known as the Central and Southern Florida (C&SF) Project consists of over 990 miles of primary canals, 978 miles of levees, 212 primary water control structures, 30 pumping stations as well as many secondary and tertiary canals water control structures (Interagency Working Group Report, 1994). The area has several hundred natural lakes ranging in size from the 750 square mile centrally located Lake Okeechobee, the second largest natural lake in the United States, to lakes and ponds less than an acre in size. Major canals, which are used for flood control and water supply conveyance, radiate from the Lake in all directions. Inflow to the Lake is mainly from the north via a channelled Kissimmee River which drains heavily urbanized areas such as the city of Orlando and agricultural areas predominantly in cattle farming and citrus. The outflow towards the east, west and south supplies water to the vast Everglades Agricultural Area, which produces sugar cane and winter vegetables, and the urbanized southeast coast. Commercial and residential land development has also produced several thousand manmade lakes for detention and water quality treatment of runoff from developed property. Several low velocity streams are found at the low-relief coastal margins of the area.

Large areas of natural wetlands are still a feature of the area although much of the wetlands have been drained for agriculture and urban development. Approximately one half of the original four million acres of Everglades wetlands remain in preserve areas such as the Water Conservation Areas, Everglades National Park, and the Big Cypress National Preserve (see Fig. 1).

South Florida contains a variety of ecosystems ranging from uplands, riverine systems, marshes and sloughs to estuarine systems. The uplands consist mainly of pine/palmetto flatlands with little relief. The major rivers in the area (Kissimmee, Caloosahatchee, St Lucie) have all been altered by dredging and channelization. The

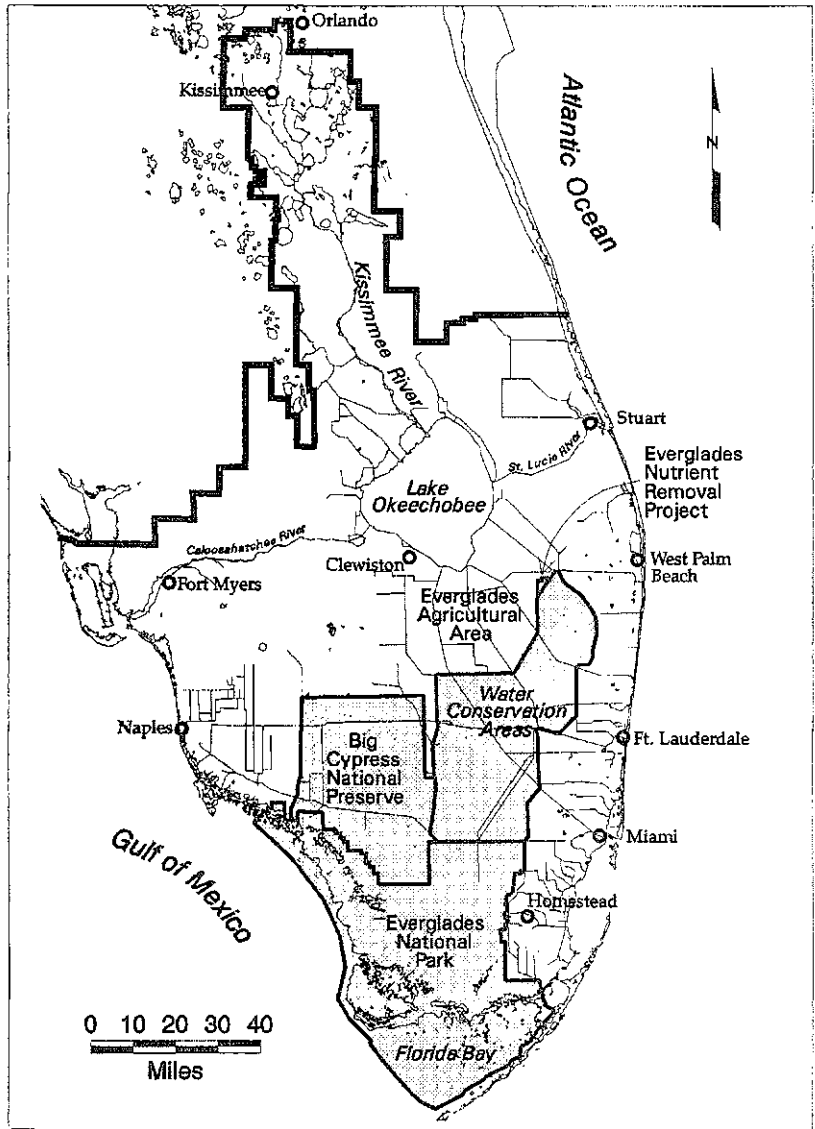


Fig. 1 South Florida Water Management District.

Kissimmee River and its flood plain are currently undergoing restoration to protect and enhance habitat values. Lake Okeechobee, which provides recreational as well as water supply and flood control benefits, is impacted by excessive nutrient runoff from its contributing drainage basins and is currently the focus of intensive environmental protection and restoration efforts.

South of Lake Okeechobee, the Everglades ecosystem consisting of extensive shallow sawgrass marshes, wet prairies, tree islands and aquatic sloughs provides habitat for large numbers of wading birds as well as storks, snail kites, bald eagles, panthers and crocodiles. Nutrients from agricultural runoff and changes in the timing

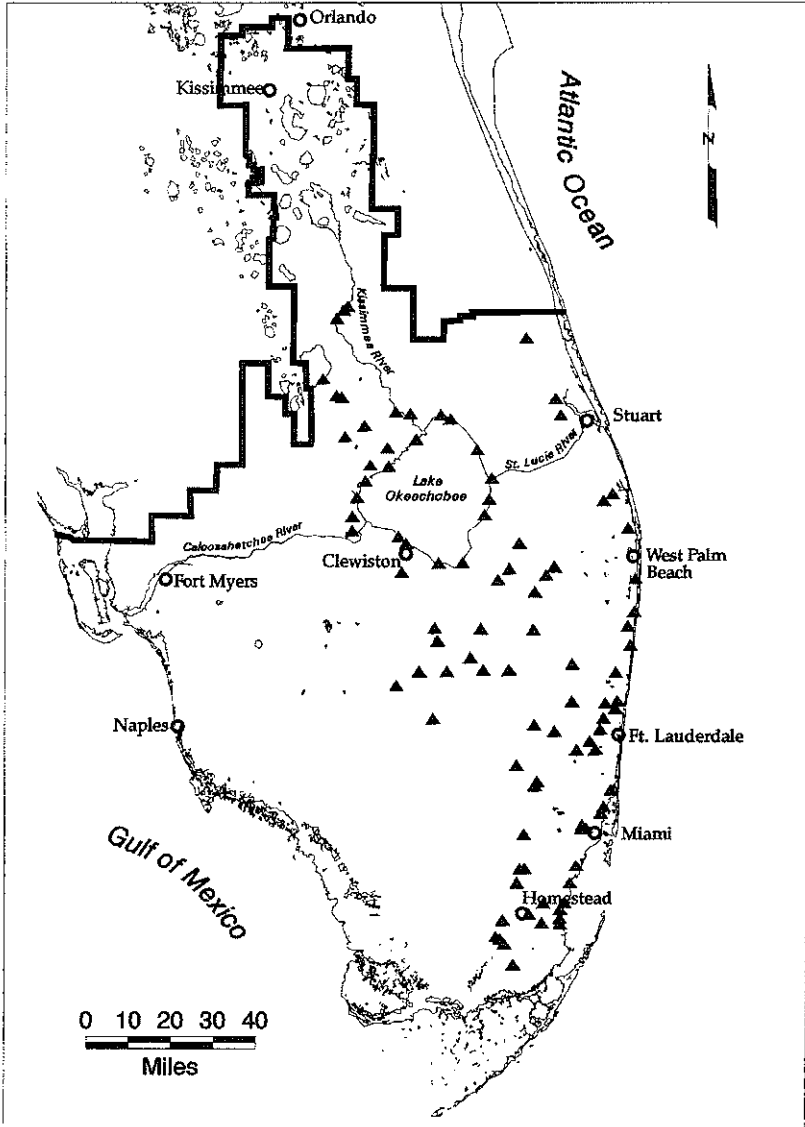


Fig. 2 Microwave telemetry sites.

and distribution of water flow have caused undesirable alterations in these ecosystems. Agricultural best management practices and an ambitious stormwater treatment system consisting of filtration marshes are being implemented to address the problem (SFWMD, 1992). A prototype of the marsh treatment systems known as the Everglades Nutrient Removal (ENR) project has been in operation since 1994. The Everglades Nutrient Removal project is a 40 000 acre manmade marsh water treatment system which uses biological uptake and settlement of sediment to remove nutrients from runoff originating in farming areas, prior to discharge of this water to environmentally sensitive areas (SFWMD, 1995).

Florida Bay, which lies at the southern extremity of the Kissimmee River–Everglades–Lake Okeechobee ecosystems, is a shallow extensive embayment with enormous recreational and fisheries values. Upstream drainage and diversion of water has upset the delicate balance in this estuary resulting in seagrass die-off, increases in salinity and turbidity, extensive and persistent algal blooms and declines in sponge, fish and shellfish populations.

Monitoring networks

The South Florida Water Management operates an extensive network to collect hydrologic (water stage and flow) data (800 stations), water quality data (400 stations), rainfall (100 stations), and weather data (20 stations). A variety of instrumentation is utilized for data storage and retrieval. Instrumentation utilized by the SFWMD includes float/counterweight surface followers, pressure transducers and ultrasonic sensors. Data are recorded as graphical pen traces or converted to electronic signals by potentiometers and encoders for recording on punched tape or digital recorders (Kinsman *et al.*, 1994). Remote data access is possible through a microwave telemetry system, radio frequency data links, cellular telephone links or landlines.

The data are processed, quality assured and archived in an Oracle relational database. Processing consists of a number of steps including conversion to digital format where necessary, time and calibration adjustments and elimination of spurious data. Missing data may be filled in using standard approaches so that a complete data set is available for use.

The monitoring stations in the SFWMD may be operated primarily for real time, trend detection, compliance or research purposes. However each monitoring station may serve a variety of purposes. Real time networks are designed to provide immediate or near-immediate information to the end user, mainly for operational purposes during floods or drought. The major real-time system operated by the district is a microwave telemetry Supervisory Control and Data Acquisition (SCADA) system which has been functional since the mid 1980s (Fig. 2). The system consists of an operations centre and approximately 70 remote installations which provide data through dual direction microwave loops to the operations centre. The system allows for status checks, data collection and remote operation of various water control structures, and is highly reliable in providing extremely valuable information for operational decision making during extreme weather events. Data collected by the system are archived and become part of the long-term data set. The main drawback of the system as installed is the absence of on-site data storage which results in loss of data if data transmission is interrupted. Data may also be lost due to computer malfunction or scheduled downtime. The data types on this network include stage, rainfall, water conductivity and water control structure gate operations.

A second system capable of providing real-time data is the Automatic Remote Data Acquisition Monitoring System (ARDAMS) (Fig. 3). This system transmits data from remote locations through a radio frequency network. Although real time polling of the stations is possible, the system is primarily designed to provide once-per-day data

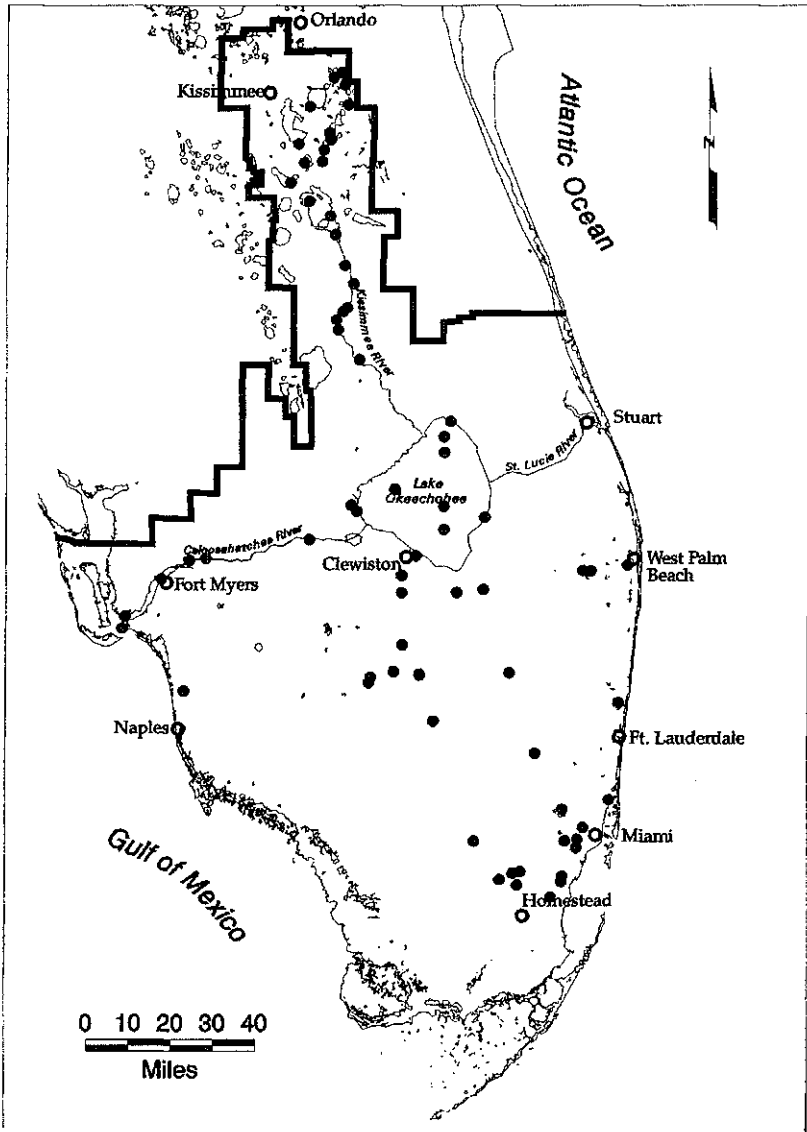


Fig. 3 Automatic Remote Data Acquisition System sites.

transmission from all the stations in the network. The transmission is activated late at night to avoid airwaves congestion. The system integrates data collection, processing and storage, and features automatic communication error detection and data checking. The reliability of this system is considered to be better than the microwave telemetry system since it features on-site backup data storage. The advantages of the system are improved access to the data and cost savings over manual collection. The data types on this network include stage, rainfall, water conductivity and water control structure gate operations.

Trend detection stations primarily provide a long-term record of key parameters required for the water management activities of the SFWMD. This network covers

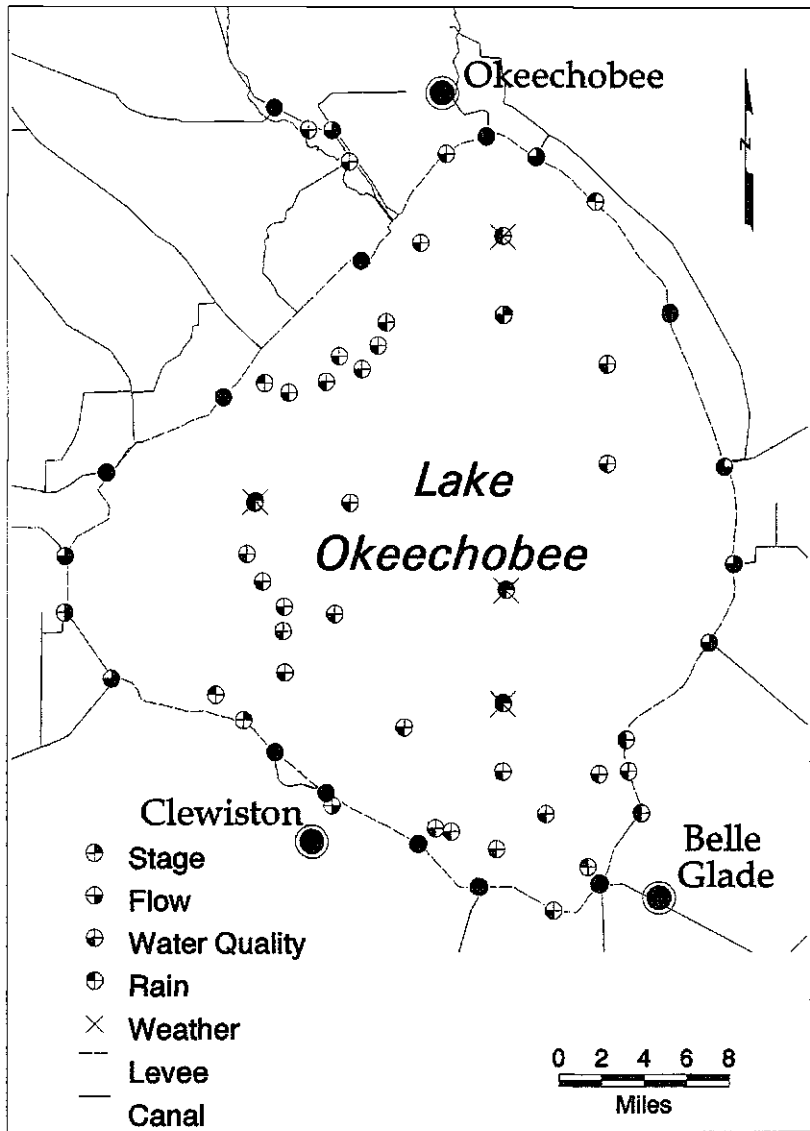


Fig. 4 Lake Okeechobee monitoring sites.

all data types, including hydrologic, hydrogeologic, meteorologic, water quality, and biological data. A variety of instrumentation is used to collect the data, ranging from graphic to digital data capture. Since 1985, the SFWMD has embarked on a programme to replace more than 300 graphic and punch tape recording devices with electronic sensors and electronic solid state data loggers. At present the district uses a variety of sensors but relies mainly on the Campbell Scientific CR-10 data logger for data storage. The digital system allows for capture of a wider array of parameters at each site at less cost. The data are captured in electronic form and can be easily transmitted from remote sites to the user. Direct computer processing and storage of

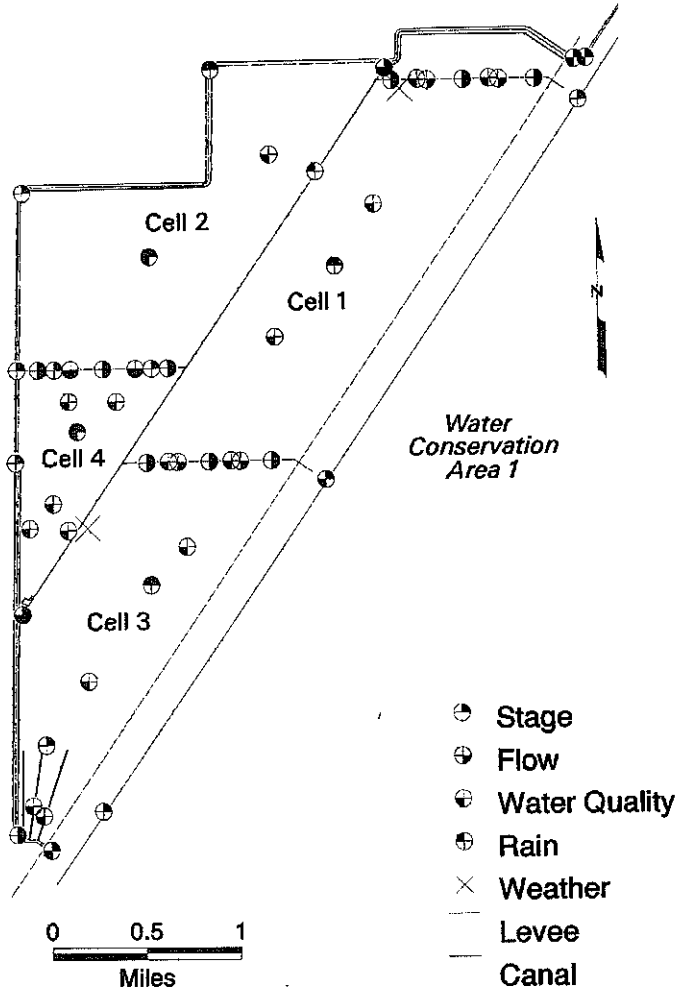


Fig. 5 Everglades Nutrient Removal project monitoring sites.

the data further reduces costs. Disadvantages are that electronic capture generally does not produce a continuous record of data, as produced by a graphic recorder, and the data cannot be directly viewed in the field.

Monitoring stations which serve mainly to determine compliance with established standards, permit requirements or environmental restoration goals focus on quantifying nutrient runoff from developed areas to environmentally sensitive areas. Accurate measurements of surface water flows, rainfall and nutrient concentrations are required to determine nutrient loads. To meet the required accuracy levels, acoustic velocity meters (AVM) are used for flow measurements. These meters use sound pulses transmitted through the water between two opposing transducers, and measure the travel time of the sound pulse along the path of known length and diagonal orientation to the flow, to calculate flow velocity. The calculated velocities are combined with stage information to produce flow data. The advantages of the AVM over current meters are: they allow for more rapid flow measurements, so that

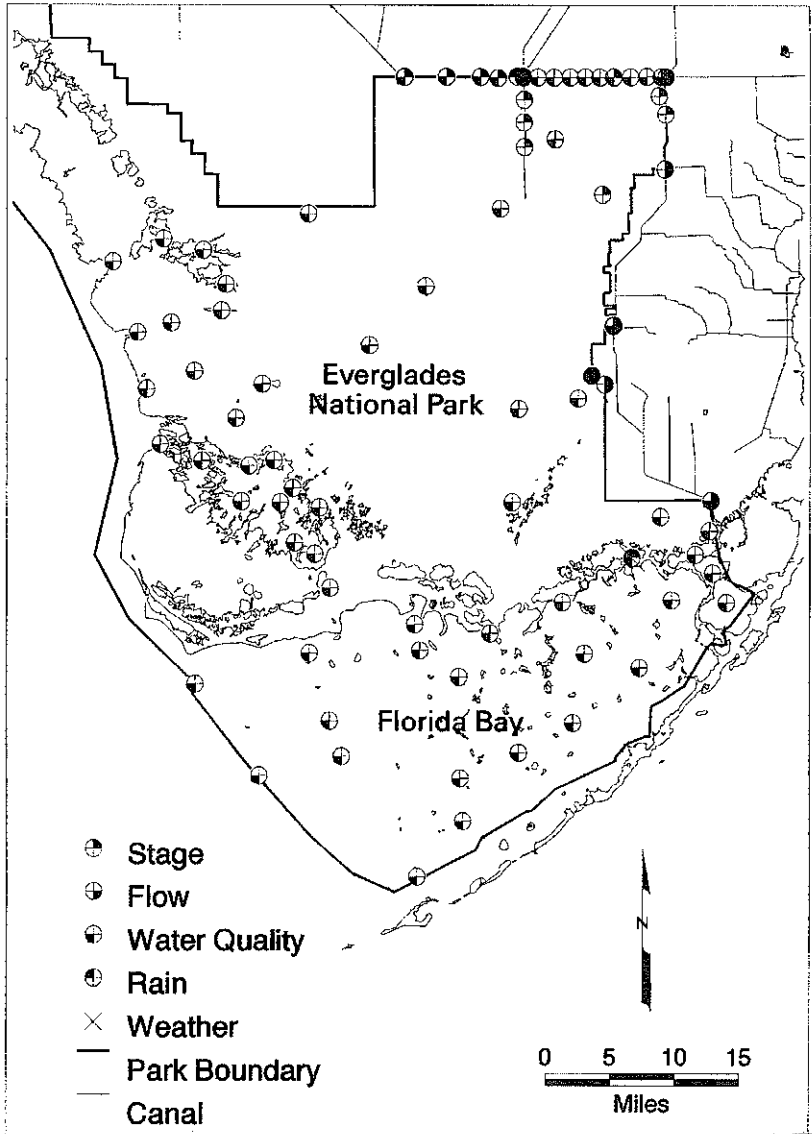


Fig. 6 Florida Bay monitoring sites.

readings can be completed without changes in flow conditions; measurement of lower velocities at greater accuracy; and on-site calculation of flow data. Water samples are collected using programmable automatic samplers to collect samples at specified time intervals or at intervals determined by flow volumes (flow proportional samples). To obtain flow proportional samples, flow calculations are performed by an on-site computer based on stage and gate geometry data, or based on data collected by acoustic velocity meters.

Examples of networks established for Lake Okeechobee, the Everglades Nutrient Removal project and Florida Bay estuary are shown in Figs 4, 5, and 6.

The objectives of these networks are to determine water quality impacts from agricultural runoff, and to track compliance with water quality standards. The data are also used to develop strategies for improving water quality (SFWMD, 1992). To achieve these objectives, routine flow, water level, meteorologic, water quality and biological monitoring was established at strategic points in the drainage basins, tributaries, inflows, open water and outflow points. The data are used to calculate water and material balances, and contaminant loads, and to determine environmental impacts. The focus of the monitoring is on the nutrient species phosphorus and nitrogen. Water quality parameters are measured *in situ* or samples are collected manually or by means of flow proportional automatic sampling techniques. The collected samples are analysed for routine anions and cations, metals and organic parameters. Biological impacts are gauged through analysis of samples for Chlorophyll *a*, a green pigment present in many species of algae which provides a useful indicator of the presence and density of algae in the water body. Dense concentrations of algae, called algal blooms are an indicator of nutrient enrichment which could lead to hypereutrophication and collapse of the aquatic ecosystems.

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