U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
U.S. FISH AND WILDLIFE SERVICE

WATER-RESOURCES INVESTIGATIONS REPORT 00-4007

## INTRODUCTION

St. Vincent National Wildlife Refuge is managed by the U.S. Fish and Wildlife Service (USFWS). The refuge was acquired in 1968 from a private land owner and occupies all of St. Vincent Island, a barrier island located off the southern coast of the Florida Panhandle near Apalachicola (fig. 1). The island, which covers 12,358 acres, is about 9 miles long and 4 miles across at its widest point. Eighty miles of unpaved roads that grid the island are presently used for refuge management, law enforcement, and visitor hiking trails.

Prior to becoming a refuge, the natural flow of surface water on the island was altered by road and ditch construction that enabled timbering of pine. Restoring the natural flow of surface water on the island to its historical state is one of the USFWS's goals for ecosystem restoration.

During past road construction activities, fill was placed in the creeks to create raised roadbeds. This activity changed the natural flow of surface water by (1) acting as an earthen dam that impounded creeks; (2) restricting flow, thus increasing the depth of water in the channels of creeks; or (3) blocking the natural movement of saltwater in the creeks in coastal areas, thus altering water salinity. Along some sections of road, grading substantially lowered land-surface elevations. Along these sections of roads, adjacent creeks commonly flowed into one another during high-water conditions, thus allowing the transfer of water from one drainage basin to another. In some areas on the island, ditches were dug to manipulate the movement of surface water.

### Acknowledgments

The authors wish to express appreciation to Thom Lewis of the U.S. Fish and Wildlife Service for his help in setting up this project, for conducting extensive tours of the island, and for providing equipment that made the project run smoothly. The authors also wish to express appreciation to Donald Kosin and Gail Carmody of the USFWS for their valuable help and support.

### Purpose and Scope

The purpose of this report is to describe the effects that road construction and other modifications have had on the natural flow of surface water, to present restoration priorities with respect to various sites, and to discuss various suggested options for restoration.

### Physical Setting

The subsurface geology and hydrology of St. Vincent Island has not been investigated in the past. However, a 1,026-foot-deep well was drilled on St. George Island, which lies a few miles east of St. Vincent Island (Trapp, 1977), and the two islands are expected to have concomitant hydrology and geology because of their close proximity. Drilling results indicated that St. George Island is underlain by sand from land surface to a depth of 75 feet (ft), and by hard and soft limestone and dolomite from 75 to 1,026 ft below land surface. Freshwater was found in the upper 215 ft with brackish water (14,400 milligrams per liter chloride) found below 215 ft.

The natural topography of St. Vincent Island consists of a series of generally east-west trending sand ridges that reflect the historical deposition of the sand dunes (Campbell, 1984; photograph 1). The crests of the largest ridges rise from 6 to 12 ft above sea level. Creeks, present in the shallow valleys between the ridges, drain water from the interior of the island to several lakes and to the Gulf of Mexico. [illegible]

A conceptual ground-water-flow model is depicted in figure 3. Rainfall recharges the surficial aquifer as the result of high infiltration rates associated with sandy soils. Aquifer permeability for the conceptual model was assumed to be relatively homogenous with no large permeability contrasts to distort flow in the zone where freshwater is present. As the model in figure 3 indicates, ground water flows from the sandy upland recharge areas downgradient to creeks, lakes, or the Gulf of Mexico.

The east-west trending roads were constructed along the sand ridges and are parallel to the creeks, whereas the north-south trending roads that cut across the width of the island rise and fall over the ridges and across the creeks. In most places where a road crossed a creek, the roadbed was raised by fill to keep it dry and passable. These raised roadbeds range from a few feet in length and 1-2 ft high to hundreds of feet in length and several feet high. Consequently, the roads act as dams, which have resulted in impoundments being created, thus altering the wet/dry cycle on the island. Culverts were installed at some road crossings to allow for drainage, but this was done primarily to prevent the road from washing out rather than an attempt to restore natural-flow conditions.

### Methods of Investigation

During fieldwork, all sites on the island where roadwork and other modifications altered surface-water flow were identified. Site location was determined by using a Geographic Positioning System having a 30-ft accuracy. The sites investigated were (1) road crossings that block creeks; (2) road crossings or ditches that connect adjacent creeks; and (3) road crossings that potentially block saltwater movement in the creeks near the coast. All of the island's roads (80 miles) were driven, and an assessment was made of each creek crossing. Surface-water-flow measurements were made in some creeks as a guide for estimating surface-water flows at all creeks.

Fieldwork was conducted in two phases. Phase 1 occurred from February 23-27 and from March 16-18, 1998. This phase assessed the blockage of surface-water flow from the raised roadbeds, as well as the modifications that allowed naturally separated creeks to connect. Phase 2 was conducted from May 26-29, 1998. This phase assessed the disruption of saltwater movement in creeks near the coast.

At each site where a road crossed a creek, the elevation of the roadbed above the natural channel was measured, the average width of the roadbed was measured, and the road length across the creek was estimated. These distances were determined either by survey, by using a steel-tape measure, or by visual estimation. Results of the fieldwork are given in table 1 (site locations shown on fig. 4).

At each site where a road or ditch caused adjacent creeks to connect, the direction of flow was documented. To easily discern creek connections, some fieldwork was conducted after a heavy rainfall. Ditches that connected adjacent creeks were documented as they were found during regular field trips. Fieldwork results are presented in table 2 (site locations shown on fig. 4).

At coastal sites where road crossings were suspected of blocking the movement of saltwater in the creeks, specific conductance was measured in the creek water on both sides of the road and compared-the greater the difference, the more disruptive to flow the road was assumed to be.

At large crossings, especially near the lakes or large creeks, conductivity was measured at the water surface and at 1-ft intervals below the surface to determine if stratification was occurring. In some areas, conductivity was measured in [illegible]

[illegible] feet per second ($ft^3/s$) at sites 72 (0.24 $ft^3/s$), 116 (1.0 $ft^3/s$), 126 (0.35 $ft^3/s$), 136 (0.98 $ft^3/s$), 148 (2.75 $ft^3/s$), and 170 (0.09 $ft^3/s$). The remaining sites on this stretch of road were dry. Flow measurements were taken following several days of dry weather when the flow in the creeks represented base flow. However, this short dry period culminated several months of higher-than-average rainfall, so the flows probably represent higher-than-average base-flow conditions.

Major drainage basins defined by the larger sand ridges were delineated by using USGS 7.5-minute topographic maps, and are shown as dashed green contours on figure 4. Smaller ridges lying between the major ridges had very little surface expression and could not be discerned on the maps. Because the creeks exist in the relatively narrow valleys between the dune ridges, the surface- and ground-water drainage basins are assumed to be roughly coincidental.

## SURFACE-WATER-FLOW ALTERATIONS

The construction of roads and ditches have altered surface-water flow on the island. At sites where a road crosses a creek, the fill blocks the flow of water. At areas near the coast, the fill can block the natural movement of saltwater inland.

### Road Crossing Sites

Surface-water flow occurs in two different ways on the island—by channel flow or by sheetflow. Channel flow, where water flows in a defined creek channel, occurred at 250 of the 261 sites. Sheetflow, where water flows only inches deep over an area from tens to hundreds of feet across, occurred at 11 sites. Some sites had characteristics of both types of flow, and these were classified based on which flow seemed to predominate.

Roads that crossed a creek with channel-flow characteristics were subdivided into three categories as (1) sites where the road blocks flow (RBF, shown as black triangles on fig. 4); (2) sites where a culvert is present (shown as green triangles on fig. 4); and (3) sites where a low-water crossing (LWC) is present (shown as blue triangles on fig. 4). Additional information on the sites is given in table 1.

Of the 250 channel-flow sites, 147 were classified as RBF, 40 were culvert, and 63 were LWC. At RBF sites, the raised roadbed was sufficiently high to block the flow of water under most conditions (photograph 2, site 224). At culvert sites, the roadbed elevation also blocked the flow of water, but a culvert allowed water to flow under the road (photograph 3, site 241). The culvert site shown in photograph 3 is one of the largest culverts on the island. Most of the culverts are of smaller diameter and do not have a gate. At LWC sites, there is little, if any, rise in the roadbed, and water flows over the road under most conditions (photograph 4, site 141—there is no raised road and surface-water flow was unimpeded). In some places, though, a slight rise in the roadbed could block flow under low-water conditions.

Sites where sheetflow occurs were characterized by wide and very shallow creek bottoms. At some sites, a single culvert was installed, but these were insufficient to restore sheetflow. Sheetflow sites with culverts are depicted by green dots on figure 4, whereas sites with no culverts are depicted by red dots. Sheetflow sites include 4, 11, 23*, 50, 58, 74, 88, 114*, 119*, 134, and 187* (an asterisk indicates that a site includes a culvert). These sites are described in table 1. Site 88, representative of most sheetflow sites, is shown in photograph 5.

Ditches were dug to facilitate the drainage of water from the island. Ten [illegible] is shown in figure 5. [illegible] were converted to percent [illegible] and 100 percent indi[illegible] equation:

$$\text{Percent seawater} = \frac{\text{Specific conductance}}{50{,}000\ \mu S/cm} \times 100.$$

Background measurements taken in lakes and creeks in the interior part of the island indicated the presence of freshwater only in these areas. Near the coast, seawater in the creeks ranged up to 100 percent.

Inset A, figure 5, shows an enlargement of the area around site 119 (this site is also shown in photograph 6). At this site, the roadbed is about 700 ft long and rises 3-4 ft above the bottom of the natural channel. A 12-inch-diameter metal culvert was installed where the road crosses the open water. Specific-conductance measurements were taken across the road to determine the difference in saltwater content. As shown in the inset, the salinities were nearly the same in the open-water areas, indicating that the culvert was not restricting the movement of saltwater. However, large differences in saltwater content were observed south of the culvert, indicating that the road was restricting the movement of saltwater. The ditch aligned east of and parallel to road 6 probably allowed saltwater to intrude further than it would have naturally; however, even if the ditch were not present, some differences probably would have been measured, and almost certainly would have been observed during a very high tide.

Inset B, figure 5, shows an enlargement of the area around site 241 (this site is also shown in photograph 3). At this site, the roadbed is about 60 ft long and rises 3-4 ft above the bottom of the natural channel. A 48-inch-diameter metal culvert with a gate was installed to connect lakes 3 and 4. Measurements of specific conductance increased gradually, indicating a smooth transition in the saltwater content from lake 3 to the more inland lake 4. The specific-conductance values indicated that, when fully open, the culvert did not restrict the movement of saltwater.

At site 88 (figs. 4 and 5) in the northeastern part of the island, the north-east trending roadbed is about 900 ft long and rises 1-2 ft above the bottom of the natural channel; no culvert was installed. On the seaward side of the road, the saltwater content ranged from 26 to 41 percent, whereas on the inland side, the values were 8 and 9 percent, indicating that the road was restricting the movement of saltwater. Saltwater also may have been affecting the distribution of vegetation, as cattails were observed to be growing on the left side of the road, but were absent on the right (photograph 5).

### Surface-Water Flows

Base-flow rates for several creeks were measured and used to estimate the recharge rate on the island. The recharge rate was estimated by dividing the measured surface-water flows by the ground-water drainage area, which gave an average value of 40 in/yr. The estimated recharge rate was then multiplied by the drainage area upstream from each road crossing to calculate the amount of expected base flow. Expected base flow at each road crossing site is shown in blue on figure 4. Flow rates were calculated as a guide to determine the suggested size of a culvert that would be needed to handle the flow if a culvert were to be installed.

## RESTORATION OF NATURAL SURFACE-WATER FLOW

The overall plan of the USFWS to restore natural surface-water flow consists of two parts: (1) to systematically restore natural flow where roads currently block or impede flow; and (2) to block flow where roads or ditches connect adjacent creeks or wetland areas. Restoration of the natural flow of water is based on hydrologic considerations only.

### Restoration Priorities and Options at Road Crossing Sites

The effects of road construction on surface-water flow ranged from major to none. To quantify the effects of road construction on the natural flow of surface water, an arbitrary ranking system was devised to prioritize sites based on the degree of alteration to flow. Sites where roads may be blocking the natural movement of saltwater were not ranked separately, but rather included in the general ranking of sites. Each of the 261 sites was ranked on a scale from 1 to 5 with 1 indicating a major alteration of the surface-water flow and 5 indicating no alteration of the natural flow. Quantifying the effects of road construction also provided a better understanding of which road crossings had the greatest adverse effect on flow, thus enabling investigators to prioritize sites with respect to restoration needs.

Of the 261 ranked road sites, 180 sites were identified (ranked from 1 to 4) where the natural flow of surface water had been altered by road construction. Specifically, 21 sites were given a ranking of 1, which indicated that these sites experienced the greatest alteration of flow, and therefore, had the highest priority in terms of restoration. In descending order of priority, ranks of 2, 3, and 4 were assigned to 38 sites, 63 sites, and 58 sites, respectively (fig. 4, table 1). A total of 81 road sites was given a ranking of 5, which indicated no alteration of the natural flow of surface water. It should be noted, however, that nearly all of these 81 sites were places where the USFWS had previously removed the roadbed, thus creating a low-water crossing. As a result, these sites needed no further modification.

As previously described, surface-water flow at road crossing sites occurs either as channel flow or as sheetflow. Two possible options are available to restore the natural flow of surface water at the road crossing sites where channel flow occurs. The first option would be to install culverts at those sites where drivable roads are needed to maintain the refuge. The second option would be to remove roads completely, thereby creating low-water crossings.

Where natural flow would best be restored by installing a culvert, the proposed size of a culvert (table 1) was determined based on a scenario in which the expected high base flow would pass through the culvert with only about 0.25 ft of water-level rise from one side of the road to the other. Under these circumstances, substantial ponding would be deterred, although creeks may still overflow onto roads during periods immediately following intense rainfall.

Culvert sizes were calculated using the method described by Bodhaine (1969), and were based on round, steel culverts-culverts made of concrete or plastic would give slightly different flow rates. This method assumes that the ponded water completely covers the opening of the culverts, which is the most likely scenario during high-flow conditions. The equation used, and a sample calculation for the case where the head difference across the culvert is 0.25 ft, are shown below.

$$Flow = CA_o\sqrt{\frac{2g(h_1-h_2)}{1+\dfrac{29C^2n^2L}{R_o^{4/3}}}} =$$

$$(0.84)(0.79ft^2)\sqrt{\frac{2(32.2ft^2/s)(0.25ft)}{1+\dfrac{29(0.84)^2(0.024ft)^2(20ft)}{0.25ft^{4/3}}}} = 1.7ft^3/s$$

where:

- $Flow$ = flow through culvert, in cubic feet per second;
- $C$ = coefficient of discharge, no units;
- $A_o$ = area of culvert, in feet squared;
- $g$ = acceleration due to gravity, in cubic feet per second;
- $h_1$ = head on upstream side of culvert, in feet;
- $h_2$ = head on downstream side of culvert, in feet;
- $n$ = Manning's coefficient, in feet;
- $L$ = culvert length, in feet; and
- $R_o$ = hydraulic radius of culvert barrel (the hydraulic radius is equal to the diameter divided by 4), in feet.

Eleven road sites were classified as sheetflow crossings. Natural flow may best be restored by removing roads where sheetflow occurs. Where roads cannot be removed, the natural flow of water could be reestablished by using 12-inch-diameter culverts spaced 75 ft apart along the roadbed (table 1).

### Restoration Priorities and Options at Sites Where a Road or Ditch Connect Adjacent Creeks

Twenty-five sites were identified where a road or ditch connected adjacent creeks. The roads and ditches were combined and ranked together because they have a similar effect, which is to allow surface water to flow from one drainage basin to another. The sites were ranked from 1 through 3, with sites ranked as 1 having caused the greatest disturbance; these sites have the highest priority for restoration. Sites ranked as 3 indicate the least disturbance and have the lowest priority for restoration. Table 2 presents a list of options with respect to restoring natural flow at the sites. Some sites were not ranked because road restoration will eliminate the problem of creek connections.

## REFERENCES

Bodhaine, G.L.,1969, Measurement of peak discharge at culverts by indirect methods: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A3, 60 p.

Campbell, K.M., 1984, St. Vincent Island: Florida Geological Survey Open-File Report 8, 19 p.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 2254, 263 p.

National Oceanic and Atmospheric Administration, 1995-98, Climatological data for Florida: National Climatic Data Center, monthly reports, variously paginated.

Trapp, Henry, Jr., 1977, Exploratory water well, St. George Island, Florida: U.S. Geological Survey Open-File Report 77-652, 33 p.

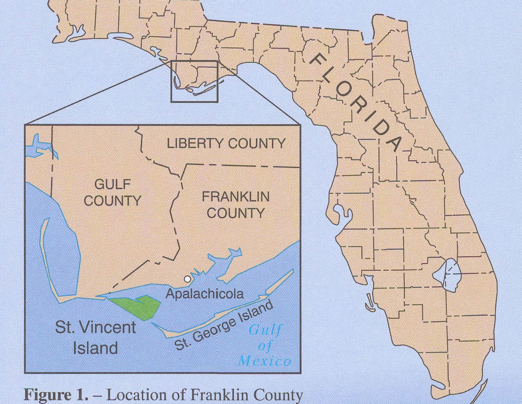


**Figure 1.** – Location of Franklin County and St. Vincent Island.

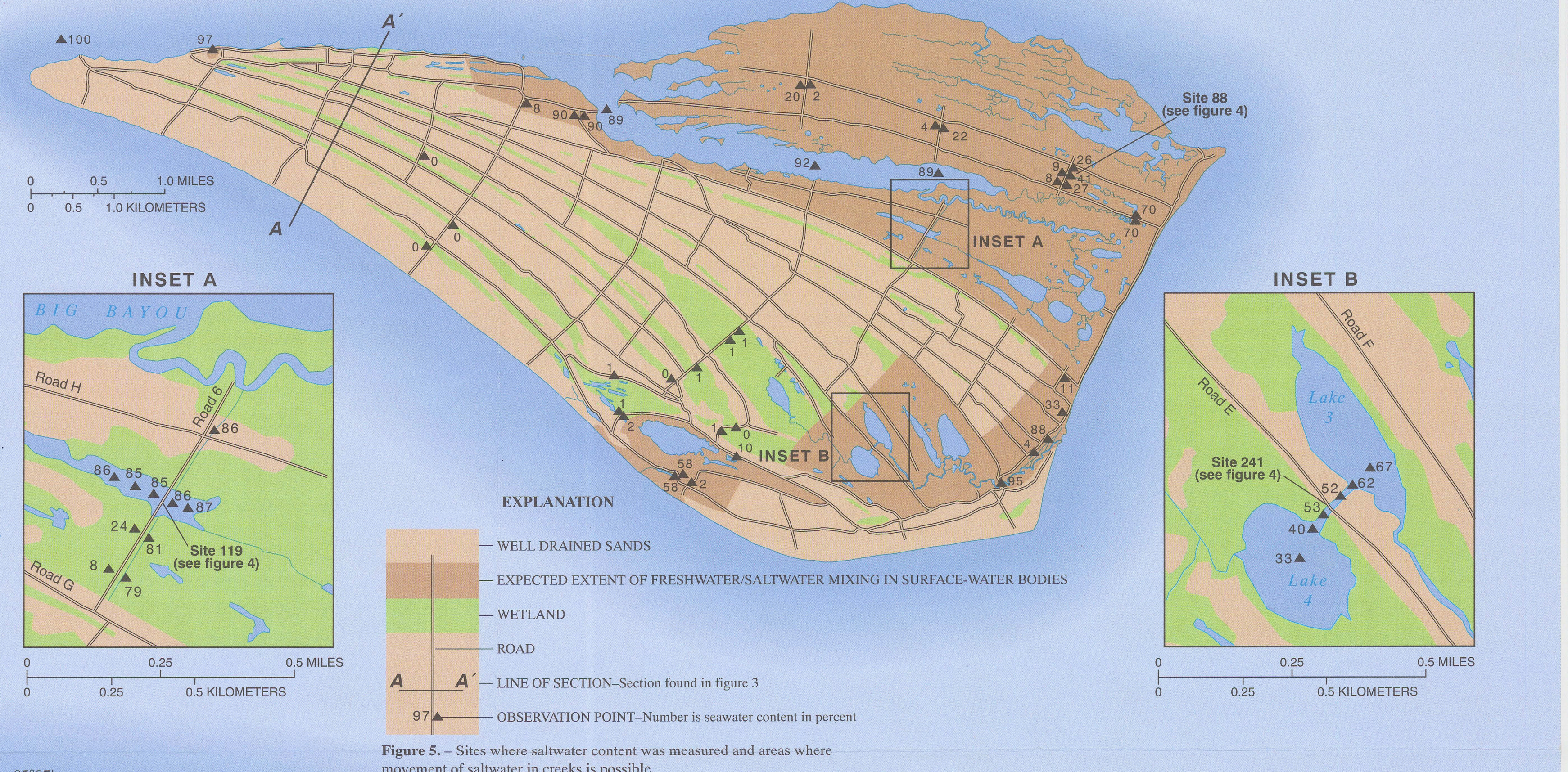


**Figure 5.** – Sites where saltwater content was measured and areas where movement of saltwater in creeks is possible.

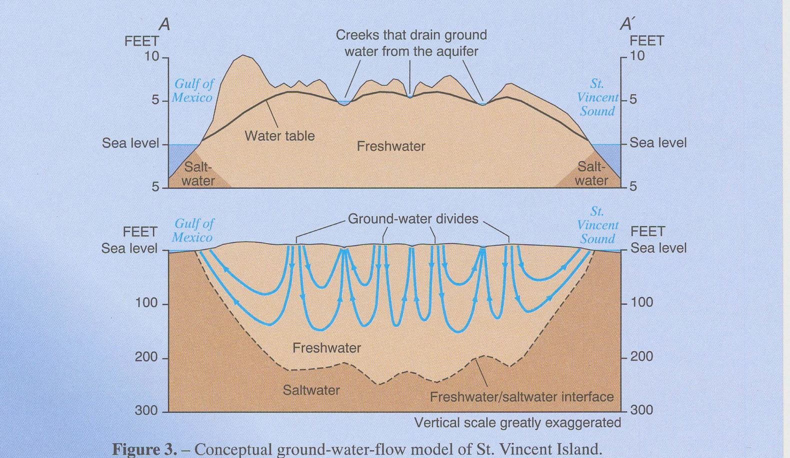


**Figure 3.** – Conceptual ground-water-flow model of St. Vincent Island.


**Figure 4.** – St. Vincent Island, showing sites where roads cross creeks and where roads or ditches connect adjacent creeks.

**Photograph 2.** – Road crossing site 224. This is an example of a site where a raised roadbed blocks surface-water flow. The photograph was taken facing northeast.

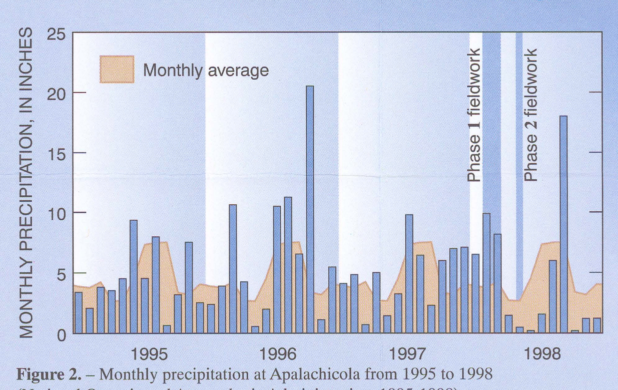


**Figure 2.** – Monthly precipitation at Apalachicola from 1995 to 1998 (National Oceanic and Atmospheric Administration, 1995-1998).

**Table 2.** Locations where ditches or excessive road grading has resulted in allowing water to merge into adjacent creeks
[Locations are shown as red arrows on figure 4; na, not applicable]

| Flow arrow number | Rank | Type | Culvert size, in inches | Restoration options |
|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

**Photograph 3.** – Road crossing at site 241 (see figure 5, inset B). This is an example of a site where a culvert has been installed to allow flow under the road. The photograph was taken facing north.

**Photograph 4.** – Road crossing at site 141. This is an example of a low-water crossing site. There is no rise in the roadbed and natural water flow is not altered. The photograph was taken facing south.

**Photograph 1.** – Infrared photograph showing relic dune structure and wetlands (photograph is a composite of images taken between January 15 and March 3, 1994).

**Table 1.** Sites where roads cross a creek
[na, not applicable; LWC, low water crossing]

| Site number | Rank | Length, in feet | Width, in feet | Rise, in feet | Existing culvert size, in inches | Existing culvert material | Proposed culvert size, in inches | Suggested number of culverts | Restoration options | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

**Photograph 5.** – Road crossing at site 88. This is an example of a site where a road blocks sheetflow. The bed of the creek is inches deep and the crossing is 900 feet long. Note the bank of cattails in the distance to the left of the road. The photograph was taken facing north.

**Photograph 6.** – Road crossing at site 119 (see figure 5, inset A). A culvert is present at this site to allow water to flow under the road. The photograph was taken facing south.

Design and layout by Jim Tomberlin

Bases modified from U.S. Geological Survey State base maps, 1:500,000

# ASSESSMENT OF THE EFFECT OF ROAD CONSTRUCTION AND OTHER MODIFICATIONS ON SURFACE-WATER FLOW AT ST. VINCENT NATIONAL WILDLIFE REFUGE, FRANKLIN COUNTY, FLORIDA

By
J. Hal Davis and Michael F. Mokray
2000