TECHNICAL REPORT NO. 11

PHOTOGRAPHIC ANALYSIS OF NATURAL AND IMPOUNDED SALT MARSH IN THE VICINITY OF MERRITT ISLAND, FLORIDA

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Introduction

Qualitative analyses of available photographs and maps of Merritt Island, Florida provide a large-scale, historical perspective of ecological changes of the marshes in the vicinity. Sites that deserve closer scrutiny can be identified. Secondarily, such an analysis provides a geographical orientation essential for communication not only between newcomers and those familiar with the area, but also among those familiar with the area but who refer to sites by differing methods.

Photographs and maps from various sources were examined. Below are listed what we consider to be the most useful subset of these for ecological and geographical assessment of salt marsh impoundments on Merritt Island, Florida. The use of an image processing system is beyond the scope of this study. Image processing systems such as NASA's Image 100 system are very useful for vegetative analysis if image data of an appropriate scale are available. For Merritt Island salt marshes, LANDSAT data are available, but the scale is much too large to distinguish the different types and amounts of marsh vegetation within impoundments.

Sources of Photographs.

1. Jack Salmela, Brevard County Mosquito Control District: many ground-level and low-altitude aerial photographs, and two

16-mm films that show marshes in the vicinity of Merritt Island just before, during, and after impounding or ditch-and-fill.

2. Agricutural Stabilization and Conservation Service (ASCS), United States Department of Agriculture, Aerial Photographs of Brevard County, Florida: Index Sheets 1, 2 and 4 (1 inch = 1 mile) for 1943, 1951, 1958, 1969, and 1979, and corresponding individual contact sheets (1:20000 to 1:50000 depending on year). Except for 1979 contact sheets, all are available at the University of Florida Map Library, Gainesville.

3. State of Florida, Department of Transportation (DOT): annual-overflight color-infrared photos of Merritt Island, Florida of varying quality for use in vegetative analyses (M.J. Provancha, personal communication). Available at Bionetics Corporation, Kennedy Space Center, Florida.

Sources of Maps.

1. Merritt Island National Wildlife Refuge, Marsh and Water Management Plan (Leenhouts 1983): maps showing impoundments by reference number (e.g. T-10-K, see Table 1) within each MINWR Management Unit (1:60,000), and maps showing location of all water control structures (1:9,600).

2. National Aeronautics and Space Administration (NASA), Kennedy Space Center, Master Planning Maps: index (1:120,000), and individual maps (1:9,600) show dikes and some water control structures, but do not identify impoundments by reference number.

3. United States Geological Survey (USGS) Topographic Maps

(1:24,000): Oak Hill, Pardon Island, Mims, Wilson, Titusville, Orsino, and False Cape quadrangles. Obsolete maps of 1949 to 1952 and subsequent photorevisions and orthophotomaps are available in the University of Florida Map Library, Gainesville. These show the geographical names of various locations before impoundment and record geographical, but not vegetational, changes following impoundment.

4. Florida Regional Coastal Zone Management (FRCZM) Atlas, Region 6, East Central Florida (East Central Florida Regional Planning Council 1975a) and corresponding Environmental Quality Assessment (East Central Florida Regional Planning Council 1975b). These show major point sources of sewage in the vicinity of Merritt Island, Florida. They are available in the University of Florida Map Library, Gainesville.

Overflight, Site Visits, and Discussions with Knowledgeable Persons

Interpretation of maps and photographs is greatly enhanced by overflights of the area, site visits at ground-level, and discussions with those familiar with the history of the marshes as well as the photographs. On 7 September 1984, we visited with Mr. Mark J. Provancha of Bionetics Corporation to discuss his efforts to quantitatively analyze vegetation in marshes and uplands of Merritt Island using 1979 color-infrared aerial photographs made by the Florida Department of Transportation. On 3 December 1984, we flew over Merritt Island by helicopter with Mr. Willard P. Leenhouts of the Merritt Island National Wildlife

Refuge, made photographs, and recorded notes of our in-flight discussion on a portable tape recorder. On 4 December 1984, Mr. Jack Salmela of the Brevard County Mosquito Control District (BCMCD) reviewed and discussed with us some of the many low-altitude and ground-level photographs and two 16-mm films he made just before, during and after completion of the permanent mosquito control measures of NASA and BCMCD (impoundment construction, ditching and filling of salt marsh).

Results

Marshes in the vicinity of Merritt Island occur on the western edges of current or former barrier beaches, on the western side of Merritt Island, between old dune ridges, and adjacent to creeks such as Banana Creek, Moore Creek , Seven Pines Creek, Dummit Creek, and Max Hoeck Creek. Marshes that contained Saltwort, *Batis maritima*, were the primary target of mosquito control (J. Salmela, personal communication). Of secondary importance were the tall rushes and grasses of higher marsh elevation: Black Needle Rush (*Juncus roemerianus*), and *Spartina bakerii*, a cordgrass common to Merritt Island, but reported rarely from other areas of the United States. The objective of mosquito control was to keep such areas flooded sufficiently to prevent the completion of the life cycle of the salt marsh mosquitoes, *Aedes taeniorhynchus* and *A. solicitans*.

Pre-impoundment Salt Marshes of Merritt Island.

Prior to impoundment, Saltwort typically occurred in communities of mixed short vegetation consisting of Saltwort, Seashore Saltgrass (Distichlis spicata), Salt Jointgrass (Paspalum vaginatum), and both annual and perennial species of glasswort (Salicornia spp.). Marshes with this mix of vegetation are referred to as "grassy" marsh by Mr. Jack Salmela of BCMCD. The marshes of the west side of Merritt Island from Peacocks Pocket at the south to Dummit Cove at the north, and the marshes west of Shiloh from Duckroost Point to Turnbull Creek consisted of this mixed "grassy" marsh at lower elevations and the taller S. bakerii and J. roemerianus at higher elevations closer to hammocks, old dune ridges, major uplands, or causeways. The marshes west of Shiloh were well known for their extensive salt pannes (J. Salmela, personal communication). These sandy areas of very high soil salinity produced neither emergent vegetation nor mosquitoes. Although large salt pannes occurred, they accounted for probably less than 10% of the marsh area west of Shiloh.

The marshes of Moore Creek had few tall mangroves prior to impoundment. Stunted White Mangroves (Laguncularia racemosa) were present near the edge of the creek, but Paspalum and Distichlis dominated the interior of the marsh in BCMCD photographs.

Saltwort also occurred as an understory in sparsely populated forests of Black Mangrove (Avicennia germinans) or White Mangrove.

Dense forests of tall mangroves were rare in the vicinity of Merritt Island. Mangroves were typically more common in the more easterly and southerly marshes. Near the water's edge along the eastern side of Mosquito Lagoon and the Eastern half of Banana

Creek and north Banana River, small areas of dense mangrove occurred (e.g. Pardon Island, Eddy Creek, Jack Davis Island). Stunted White and Black Mangroves sparsely dotted the "grassy" marshes of the west side of Merritt Island and the Shiloh marshes. In these areas, mangroves also surrounded some of the many circular ponds in the marshes, but were generally not a dominant vegetation type. Freeze damage to mangroves, such as occurred in late December 1983 is also evident in BCMCD photographs made in the 1960's.

Nowhere in the Merritt Island National Wildlife Refuge did extensive forests of dense, tall mangroves exist such as those found in south Florida. Therefore, studies of south Florida mangroves are only of peripheral interest in determining salt marsh values in the vicinity of Merritt Island.

Even in marshes where mangroves were most dense, Mr. Jack Salmela of BCMCD estimates that mangroves historically covered no more than 30% of the marsh areas that were impounded. His photos and 1:20,000 scale ASCS photos of the area confirm this estimate. Saltwort was dominant in marsh with mangroves (e.g. Pardon Island, Eddy Creek, Jack Davis Island). This type of marsh and the mixed vegetation "grassy" marsh were the principal marsh types prior to impoundment.

The mixed "grassy" marshes at Turnbull Creek (north tip of Indian River) have never been impounded. These marshes and those of the broken impoundment T-10-K (between Black Point Creek and Marsh Bay Creek) are perhaps very similar to the marshes that occurred prior to impoundment on the west side of Merritt Island

and west of Shiloh. The Turnbull Creek marshes are devoid of mangrove; Saltmarsh Cordgrass (Spartina alterniflora) occurs at water's edge. Unimpounded Saltwort-and-mangrove islands of the east side of Mosquito Lagoon north of the Brevard County Line and the marshes of the broken impoundment west of Playalinda Beach are perhaps representative of the marshes of the east side of Mosquito Lagoon and north Banana River prior to impoundment.

Post-impoundment Changes.

The most obvious changes created by impoundment are 1) the loss of edge, 2) the loss of emergent saltmarsh vegetation in areas of "overflooding," 3) the appearance of vegetation more characteristic of fresher water, 4) the appearance of very low turbidity, tea-colored water more characteristic of freshwater swamps than of the Indian River or Mosquito Lagoon, 5) constant change in vegetation caused both by impoundment and by the changes in management of these impoundments, 6) an overall increase in diversity of vegetation type among impoundments, but not always within each impoundment.

It is not clear that impounded marsh has less net primary production than had the natural salt marsh, and in fact, by trapping nutrients in run-off, the production of both submerged and emergent vegetation may be higher in impoundments that are associated with an extensive watershed. Management activities in general create changes of a frequency that induce early successional stages, which are believed to have higher net production, but perhaps lower or similar gross production than later stages (Odum 1969). In addition, given the same nutrients and sunlight, slightly brackish marshes may be more productive than either fresh or saltier marshes because salinity is more optimal more of the time (less energy is needed to store or remove salts over the long run, even in an environment of variable, but on average low salinity). Loss of "tidal subsidy," (Odum et al. 1983)is more than replaced by gains in pumping and freshwater retention in these relatively nontidal salt marshes. This topic will be covered in detail in the final report.

<u>1. Loss of edge and limited access by estuarine fish.</u> Large expanses of estuarine edge formerly accessible to estuarine fish may now be of limited availability, or completely unavailable. Edge or ecotone is important to the survival of estuarine fish both for food and protection from predators. Loss of edge is a general consequence of impoundment that is perhaps most obvious adjacent to Moore Creek, Banana Creek, Max Hoeck Creek, and Pardon Island. Several creeks have been completely blocked by dikes without water control structures (e.g. Drainout Creek, Seven Pines Creek, south end of Jones Creek). Ditching activities may have partially mitigated some of the edge lost by impoundment. Perimeter ditches, if made accessible, and ditches from ditch-and-fill can be used by estuarine organisms. Concentrated ditching, such as on Big Island (north of VAB) may not be as effective as the same amount of edge dispersed throughout the estuary.

Impoundments lacking water exchange capabilities with the estuary are completely unavailable to estuarine organisms. However, it is unclear how detrimental limited access is to estuarine fish. The effect may vary with the degree of access and the volume of estuarine water that enters an impoundment. When impoundments are filled with estuarine water (via culverts or pumps), planktonic eggs and larvae passively enter also. Pump-passage mortality is unknown, however.

Use of impoundments by free-swimming organisms should vary with the subsurface cross-sectional area of open water-control structures. Design and operation of water-control structures may result in selective avoidance by certain species or sizes.

Decreased accessibility may not mean less production of estuarine fish because more resources may be available for each growing fish, and limited access at the culvert may restrict adult predators of juvenile fish.

Moore Creek is perhaps the single best example of estuarine edge reduction. Considerable loss of the edges of Moore Creek through diking to create impoundments C-15-C, D, E and C-20-A has occurred. In addition, the mouth of Moore Creek has been diked resulting in limited access to, and exchange with, the estuary. Less estuarine water has entered since impoundment, as evidenced by decreased salinity. The lower salinity of Moore Creek by itself should have little effect on estuarine fish, however, because they are euryhaline.

2. Overflooding. When water control is limited to capturing rainfall, runoff, or estuarine water during limited times of high water, adequate mosquito control requires holding water for much of the time as insurance against its absence when needed. When pumps are available, less water need be stored in impoundments to

achieve flooding when needed. The more powerful the pump, the less anticipation is necessary, and hence less pumping and water storage is needed to meet mosquito control objectives (J. Salmela, personal communication). Therefore, in the more remote impoundments, where pumps are not available, water levels have in the past been high enough to kill emergent vegetation, but this is not essential for good mosquito control. Black Mangroves will be killed when water covers their pneumatophores for two weeks, but except for the need to store water, mosquito control can be accomplished with water levels well below the tips of the mangroves (Provost 1973). According to W.P. Leenhouts (personal communication) Black Mangroves have been killed by overflooding in, for example, impoundment T-40 (east of Cucumber Island), in T-27-B, C, and D (Max Hoeck Creek and Max Hoeck Back Creek), and in C-28-A (Jack Davis Island).

Generally all emergent saltmarsh vegetation is killed by overflooding including the mixed "grassy" vegetation and the taller grasses and rushes. Standing water with or without submerged vascular plants results. On 1969 ASCS aerial photographs, former marsh areas apparently without emergent vegetation and with standing water included T-24-A, and B, T-10-A, B, C, D, E, F, G, H, and I, and the estuarine edges of T-24-D and Shiloh 5. Rotary ditching of marsh (e.g. T-24-C) can improve access by mosquito-eating fish and thereby eliminate the need for water storage for mosquito control.

Where management of waterfowl is an objective, however, the growth of submerged aquatic vegetation such as Chara or Ruppia in saltier water (to perhaps 15 o/oo) is desirable. However, some of the areas that contain standing saline water are not often utilized by waterfowl, for example T-21 at Duckroost Point (W.P. Leenhouts, personal communication).

3. Production of Freshwater Marsh Vegetation. Because impoundments trap and hold rainwater and land drainage, the water and soil salinity may drop to very near fresh during summer when control structures are closed to capture rain. Except in those impoundments managed for wintering waterfowl, dikes can be opened in November when the mosquito breeding season is waning. Estuarine water can exchange, though exchange may be restricted both by the stored head of freshwater and the small culverts in long expanses of dike.

In areas that collect freshwater from large watersheds (e.g. Shiloh 5 and T-24-D), or where estuarine exchange does not occur due to lack of any water inlets or outlets in the dikes (e.g. T-34, and some diked tributaries to Banana Creek), freshwater emergent vegetation is common. Cattail (*Typha latifolia*) has been a persistent invader in these marshes and impoundment T-34 is completely filled with willows (*Salix* sp.). Drought in summer 1984 caused lower water and presumably a corresponding increase in soil salinity. Drought also necessitated pumping of estuarine water into impoundments for mosquito control. Thus, Cattail died in many of the impoundments where it had been prevalent (e.g. Shiloh 3 and 5, T-24-D).

Cattail is not prevalent in the impounded Mosquito Lagoon marshes except in the southern areas (Max Hoeck Creek and Max Hoeck

Back Creek) that have been impounded by the railroad causeway.

4. Low Turbidity, Tea-Colored Water. The water in impoundments is more typical of the blackwaters of Southern swamps. Estuarine water on 3 December 1984, however, was green and turbid, indicative of abundant phytoplankton. Utilization of plant nutrients in water by abundant emergent and submerged macrophytes and a lack of water movement may explain the relative color and clarity of impounded water.

5. Constant Changes in Impoundment Vegetation. Impounded salt marshes are very dynamic and are perturbed frequently. The response time of species is fast, however. Thus, these areas should not be considered unstable, but rather resilient (Webster et al. 1975). In Merritt Island salt marsh impoundments, water stands on the marsh for extended and variable periods, and is generally shallow, though levels fluctuate. Dissolved oxygen and salinity fluctuations probably exceed those of the estuary, which has sufficient volume to buffer such fluctuations.

The impoundment ecosystem constantly responds to this variability and manipulation. With the exception of mangroves, most of the species of vegetation both in the natural marsh and the impounded marsh respond quickly to changes. For example, rotary ditching of impoundment T-24-C was followed by an expansion of *Distichlis* within one year (W.P. Leenhouts, personal communication). Impoundment T-10-K was drained in 1969 and dikes were removed in 1977 (Leenhouts 1983). Vegetation in that impoundment is now very similar to that evident in Jack Salmela's pre-impoundment photos of the west side of Merritt Island.

Standing water apparently has favored the production of White Mangrove, which was found by J. Salmela to produce adventitious roots and grow well under such conditions. Periodic freezes in the vicinity of Merritt Island kill White Mangrove. Sufficient freezes can also kill Black Mangroves, though they are generally hardier than White Mangroves. Periodic freeze damage opens the understory for invasion by faster growing marsh plants such as the mixed "grassy" species or _Spartina alterniflora_. The open understory may also favor the germination of mangrove seedlings. Mangrove growth in the vicinity of Merritt Island is periodically reset by freezes, but other plants grow in their temporary absence. As mangroves seedlings mature, they shade the shorter plants and reoccupy the area, perhaps within 10 years if freezes do not recur.

6. Impoundments are Heterogeneous. Varying water sources, varying temperatures from west to east and north to south, and varying management of impoundments create a variety of conditions to which plants and presumably all species respond. Vegetation of the natural salt marsh primarily consists of the eight species listed in the first few paragraphs of Results. Impoundment vegetation includes these plus a variety of fresh and brackish water emergent, floating, and submerged vegetation. The diversity of vascular plants in some impoundments may be very low, or vascular plants may not be present. However, in others, diversity is no doubt greater than in pre-impoundment marsh. The overall diversity of the Merritt Island salt marsh is higher because of impoundment.

Conclusions

Areas of Greatest and Least Impact. Generally, impoundment changes the composition of marsh vegetation, eliminates edge habitat (ecotone), and results in a variable, inconsistently changing environment. Because of the variety of conditions and the frequent disturbance at appropriate frequencies and scales, species diversity, when the entire area of former salt marsh is considered, is most certainly higher. To date we can provide some rough indication of the areas we believe have been altered most radically by impoundment, and those that appear to have been altered least.

One of two areas of greatest alteration is between the railroad causeway and the Shuttle Crawlerway (impoundments T-27-C, D, T-33-A, B, C, and T-29-A, B). These areas were dune slacks that were once connected to either south Mosquito Lagoon or north Banana River. Now they are completely or nearly completely isolated from the estuary and are filled with freshwater vegetation.

The second area of greatest alteration is the west side of Merritt Island in the vicinity of Titusville Road from Gator Creek to Boggy Pond (impoundments T-24-A, B, T-10-A, B, C, D, E, F, G, and east end of Gator Creek). These impoundments have little or no salt marsh vegetation, and many are managed for waterfowl. In these, standing water without emergent vegetation is actively sought.

The area of least impact appears to be the Shiloh 1 impoundment south of Griffis Bay. Vegetation here consists of salt marsh species. No crude changes are visible on the ASCS aerial photographs, as they are on all other impoundments. This is the most saline of the Shiloh impoundments (Leenhouts and Salmela, personal communications).

Perhaps next-to-least affected is impoundment T-27-A where saltwater is pumped into the impoundment. Old dune ridges contain the mixed vegetation "grassy" marsh, while the swales between the dunes contain open water. Saltwater also enters T-21 (Duckroost Point) via a drilled saltwater-well. Waterfowl use of this area is low, perhaps because the standing water is too salty to support Ruppia (Leenhouts, personal communication).

Undergoing more obvious changes, but still retaining significant salt marsh vegetation, are the impoundments from Boggy Pond around Black Point to Dummitt Cove (T-10-H, I, J, L, M, and T-9). Although some overflooding is evident in lower areas, these impoundments contain salt marsh species typical prior to impoundment. These impoundments may have the highest diversity of vegetation.

Moore Creek is of special interest; of all the impoundments constructed, we believe the greatest amount of edge habitat was removed or isolated here.

Also highly altered are the marshes of east Banana Creek (C-21 & 36, T-34, T-35, T-37-A, B). T-34 west of Happy Creek has no culverts and is entirely filled with willows. Overflooding is apparent in Ross Creek (C-21 & 36).

Overflooding of mangroves is evident in the impoundments in north Banana River near Jack Davis Island (C-28-A, B) and in those on the east side of Mosquito Lagoon east of Cucumber Island (T-40) and in Volusia County (V-1 and V-2).

On ASCS aerial photographs from 1969, a great deal of standing water is evident at the edges of Shiloh 3 and 5, and T-24-D between Peacocks Pocket and Catfish Creek. Freshwater vegetation, especially Cattail, has grown fairly well in these impoundments. Some Cattail has survived last summer's drought, especially in Shiloh 3 and 5.

The marshes adjacent to Banana Creek west of the VAB have also been considerably altered (impoundments T-16, T-17, T-18-A, B, C-15-D, C-20-A, B, C). Several creeks in this area have been completely blocked (Drainout Creek, Seven Pines Creek, and the south end of Jones Creek). Freshwater marsh vegetation, especially Cattail, is encroaching on this area. Higher ground, however, contains S. bakerii in abundance, as perhaps existed prior to impoundment.

Controllability of Marsh Vegetation. As is evident from the restoration of natural marsh in T-10-K (dikes broken), in T-24-C (rotary-ditched), and in the breached coastal strand impoundments (west of Playalinda Beach), impoundment is reversible with respect to marsh vegetation. Recovery occurs very quickly because the plants of the natural salt marsh are effective colonizers and grow rapidly. Vegetation and access by estuarine fish are controllable with adequate water-control structures. Manipulative experiments with whole impoundments have been done for many years on Merritt Island, and the knowlegdeable people are still in the area (e.g. Jack Salmela and W. P. Leenhouts). Unfortunately, the results of most of these whole system experiments are not formally recorded. Managers use a great deal of trial-and-error to refine their techniques, but details are not readily available.

Vegetation Mapping and Annual Overflights. With sufficient training and ground-level or low-altitude overflights, analyses of existing photos of Merritt Island can uncover and quantify many details of the ecological history of its salt marshes. Important details include the response of vegetation to specific changes in management, and the loss of edge and partial mitigation by ditching. Mr. Mark J. Provancha of the Bionetics Corporation at Kennedy Space Center is mapping marsh vegetation in impoundments from 1979 DOT color-infrared aerial photographs. Freeze, drought, and changes in management have altered vegetation since 1979, but DOT color-infrared photographs from 1984 are available.

Vegetation in impoundments and marshes can be adequately monitored (perhaps with less effort and expense) with annual overflights by helicopter. The purpose of these would be to record major shifts in vegetation and compare these to weather conditions and changes in management that occurred during the previous year. Such records would be invaluable for the future management of separate impoundments for ducks, wading birds, estuarine fish, freshwater fish, wildlife observation, natural marsh preservation, and sewage disposal, all within the constraint of adequate mosquito control. A suggested pattern for annual overflights is shown in Figure 1.

Jack Salmela's Photographs. Mr. Jack Salmela's prints, slides, and motion pictures are a resource of immeasurable value for documenting the vegetation of pre-impoundment salt marsh and the history of mosquito control on Merritt Island. Some of the slide emulsions have deteriorated, and the motion pictures are brittle, though can still be projected. Mr. Salmela recalls considerable detail about these photos which has not been recorded. In our opinion, the collection should be annotated and protected.

Sewage Input to Estuary. Nine major point sources of domestic sewage enter estuaries in the immediate vicinity of Merritt Island, Florida (East Central Florida Regional Planning Council 1975a, 1975b). In 1975, 8.67 million gallons per day (MGD) of secondarily-treated effluent were discharged: 1.5 MGD into Indian River between Titusville Road and the railroad causeway, 0.9 MGD into Indian River between Titusville Road and the NASA causeway, and the remainder into Banana River, south of highway A1A either directly or via Sykes Creek. During the Adaptive Environmental Assessment, we were shown water quality data collected by Brevard County that shows a general decline in nitrogen and phosphorus in Banana River along a transect from A1A north towards Banana Creek. Loss of nutrient or organic input by impounding saltmarsh is not a problem for estuarine fish. Any loss of nutrients has been more than mitigated by sewage and non-point-source nutrients associated with development and agriculture. The filtering capacity of these marshes may now be very useful. Land or marsh application of sewage may help to abate eutrophication of Indian River and Mosquito Lagoon. Increased turbidity in Indian River may decrease seagrass production and abundance.

References

East Central Florida Regional Planning Council. 1975a. Florida Regional Coastal Zone Management Atlas, Region 6, East Central Florida. Bureau of Coastal Zone Planning, Division of Resource Management, Florida Department of Natural Resources.

East Central Florida Regional Planning Council. 1975b. Florida Regional Coastal Zone Environmental Quality Assessment, Region 6, East Central Florida. Bureau of Coastal Zone Planning, Division of Resource Management, Florida Department of Natural Resources.

Leenhouts, W.P. 1983. Marsh and water management plan, Merritt Island National Wildlife Refuge, Titusville, Florida.

Odum, E.P. 1969. The strategy of ecosystem development. Science 164: 262-270.

Odum, E.P., J.B. Birch, and J.L. Cooley. 1983. Comparison of giant cutgrass productivity in tidal and impounded marshes with special reference to tidal subsidy and waste assimilation. Estuaries 6: 88-94.

Provost, M.W. 1973. Salt marsh management in Florida. Proc. Tall Timbers Conf. on Ecology of Animal Control by Habitat Management 5: 5-17.

Webster, J.R., J.B. Waide, and B.C. Patten. 1975. Nutrient recycling and the stability of ecosystems. In Howell, F.G., J.B. Gentry, and M.H. Smith (eds.), Mineral Cycling in Southeastern Ecosystems. Technical Information Center, Office of Public Affairs, U.S. Energy Research and Development Administration. pp. 1-27.

Table 1. Cross-referenced list of impoundments and their location by several methods in common use at Kennedy Space Center and the Merritt Island National Wildlife Refuge. Impoundments are listed in order of their appearance on proposed overflight plan (Figure 1).

Impoundment	MINWR Mgmt Unit	KSC Master Plan*	Topo Map**	Geographic Name
T-10-A	2	F6, F7	M	Puckett Cr.
T-10-B	2	F6	M	402 to RR track
T-10-C	2	F6, F7	M	402 to RR track
T-10-D	2	F6, F7	M	Roach Hole
T-10-F	2	F6, F7	M	402 to RR track
T-10-E	2	F6	M	Boggy Pond
T-10-G	2	F6	M	N of RR track and 406
T-10-H	2	F6, G5, G6	M	Cow Pen Cr.
T-10-I	2	F6, G5	M	Cow Pen Cr.
T-10-J	2	G5, G6	M	Black Point
T-10-K	2	G5	M	"Dusky Impoundment"
T-10-L	2	G4, G5	W	Dummit Cr.
T-10-M	2	G4	W	Dummit Cr.
T-9	2	H3	W	Dummit Cove
T-21	1	H4	M	Duckroost Pt.
SHILOH 1	1	J3, J4	OH	Georges Flats, Giffis Bay
SHILOH 3	1	J4, J5	OH	Onion Farm Is.
SHILOH 5	1	J5, K4, K5	OH	Boathouse Pt., Turnbull Cr.
V-1	1	K2, L1	OH	Georges Slough to Glory Hole
V-2	1	K1, K2	OH	Glory Hole to Cat Hammock
T-44	1	J2, K1	PI	Cat Hammock to Pardon Is.
T-43	1	J2, J1	PI	Pardon Is.
T-42	1	J1	PI & W	Pardon Is., Klondike Bch.
T-41	3	H2, J1	W	Klondike Bch.
T-40	3	H1, H2	W	Cucumber Is.
T-39	3	G2, H1	W	Klondike Bch.
T-39-SOUTH	3	G1, G2	W	Klondike Bch., Eddy Cr
T-38	3	G1, G2	W	Eddy Cr., Max Hoeck Cr
T-27-A	3	G2, G3, H2, H3	W	Clark Slough
T-27-B	3	F2, F3, G1, G2	W	Max Hoeck Back Cr.
T-27-C	3	F1, F2, F3	W	Max Hoeck Cr., Max Hoeck Back Creek
T-27-D	5	F1, F2	W	Bald Pate Cr.
T-33-A	5	F1	W & FC	East of Pad 39B
T-33-B	5	F1	FC	SE of Pad 39B
T-33-C	5	E2, F1	FC	Gator Hole
T-29-A	5	E2, F1	FC	West of Pad 39A

Table 1. -- continued.

Impound-ment	MINWR Mgmt Unit	KSC Master Plan*	Topo Map**	Geographic Name
T-29-B	5	E2	FC	Broadaxe Cr.
T-25-A	5	E1, E2	FC	Gulbrandson Cr. Pad 41
T-25-B	5	E1	FC	Pad 41
C-28-A	7	E2	FC	Jack Davis Is.
C-28-B	7	E1, E2	FC	West Conrad Cr.
T-30	7	D3, E2	FC	Is. East of Tea Hmck.
C-21-D	9	C3, C4	O	Buck Cr.
C-21-C	7	C3, D3	FC	Tea Cr., Futch Pt.
C-21-B	7	E2, D3	FC	Pepper Cr, Pepper Hmck
C-21 & 36	5	E3, E4	O	Billy Joe Pt, Ross Cr, Picnic Is.
T-35	5	E3, F2	O	East of Happy Cr.
T-34	5	E4, F3	O	West of Happy Cr.
T-37-B	5	E4	O	NE of VAB
T-37-A	5	E4	O	NE of VAB
C-20-C	6	E4	O	Drainout Cr.
T-18-B	4	E4	O	SE of Shuttle Runway
7 Pines Cr.	6	E4	O	Seven Pines Cr.
C-20-B	6	E4	O	W of Seven Pines Cr.
T-18-A	4	E4, E5	O	Hubs Landing
C-20-A	6	D5, D6, E4, E5	O	E of Moore Cr.
Moore Cr.	6	D6, D7, E5	O	Moore Cr.
C-15-E	6	D6	O	E of Oyster Prong
C-15-C	6	D6, D7	O	Middle and W Prongs
C-15-D	6	E5, E6	O	W of Moore Cr.
C-15-CB	6	C6, C7	O	Pine Is. Basin, Oyster Prong S of NASA Pkwy.
T-17	4	E5	O	E of Cedar Hammock Cr
T-16	4	E5, E6, F5	O	Cedar Hammock Cr. to Peacocks Pocket
T-24-D	4	E6, E7, F5, F6	O & T	Peacocks Pocket to Catfish Cr.
T-24-C	4	F6, F7	T	Gator Cr to Catfish Cr
T-24-A	4	F6, F7	M	W Gator Cr near 402
T-24-B	4	F6	M	E Gator Cr near 402
E. Gator Cr.	4	F5, F6	M	S of Beach Rd.

* Index to KSC Master Planning Maps is shown in Figure 2.

** M = Mims, Fla.
W = Wilson, Fla.
OH = Oak Hill, Fla.
PI = Pardon Island, Fla.
FC = False Cape, Fla.
O = Orsino, Fla.
T= Titusville, Fla.

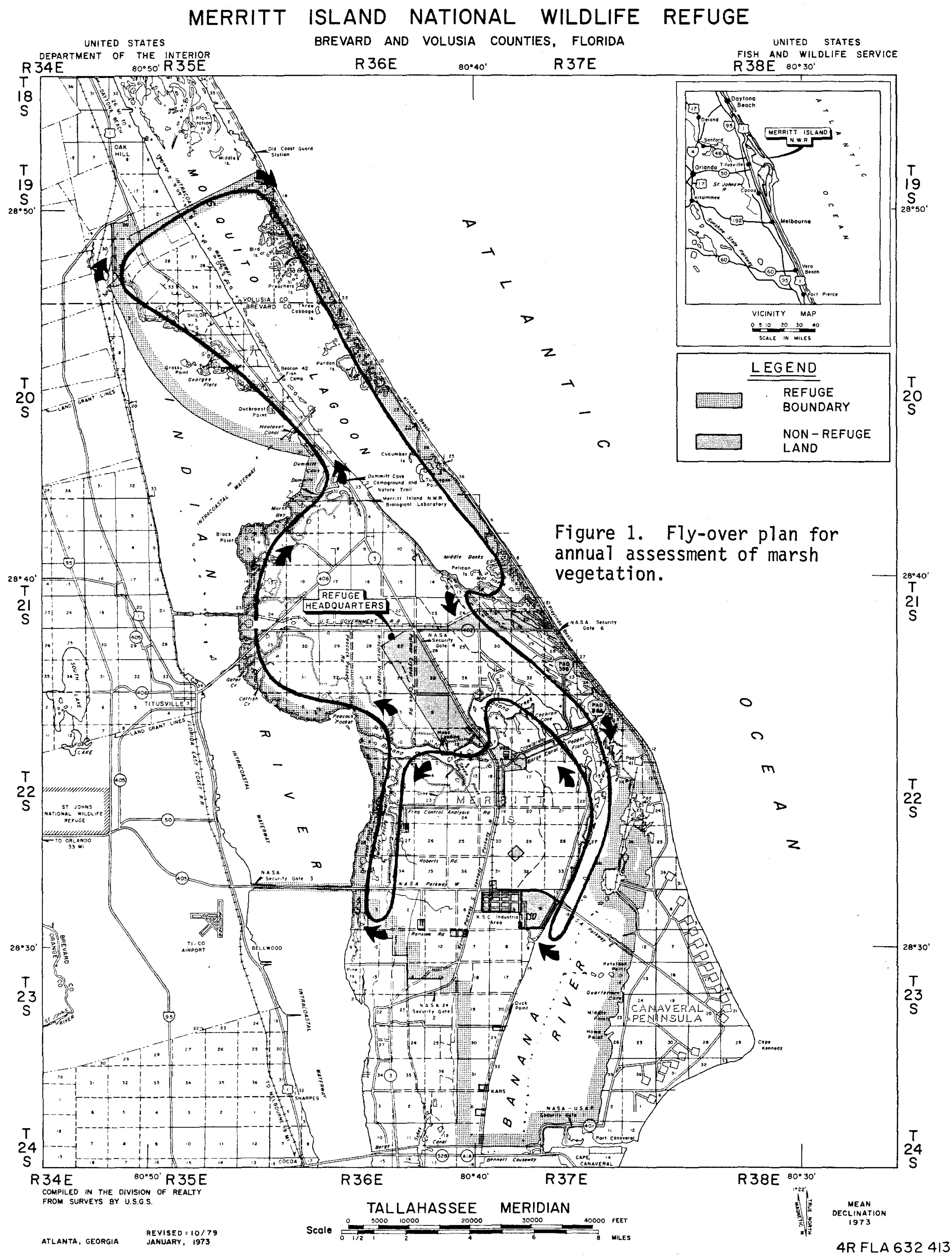

Figure 1. Fly-over plan for annual assessment of marsh vegetation.

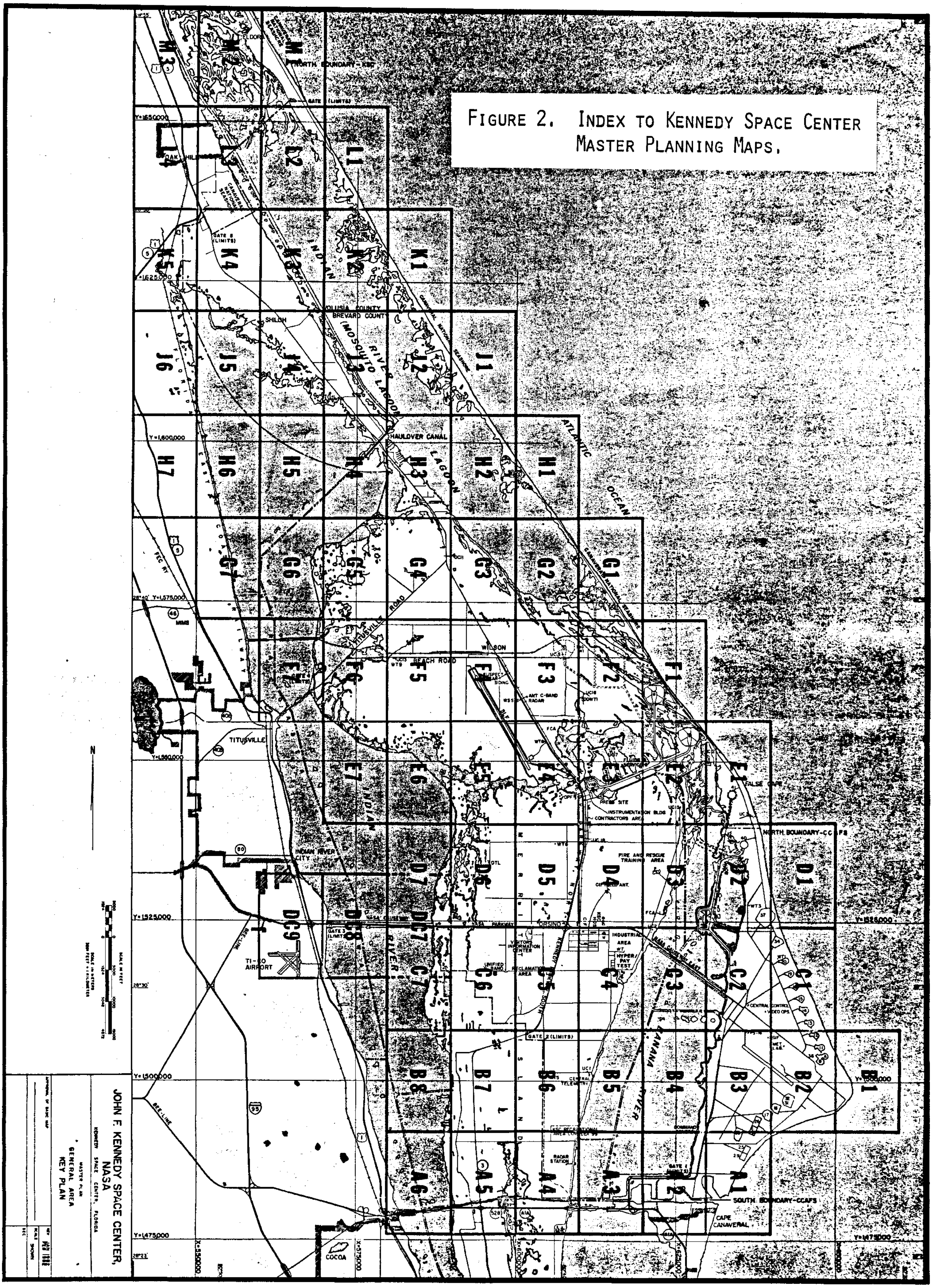

FIGURE 2. INDEX TO KENNEDY SPACE CENTER MASTER PLANNING MAPS.