Differentiation of Ecological Zones in the Okavango Delta, Botswana by Classification and Contextural Analyses of Landsat MSS Data

Susan Ringrose

Department of Environmental Science, University of Botswana, Private Bag 0022, Gaborone, Botswana Wilma Matheson

Science Department, Gaborone Secondary School, Private Bag 0019, Gaborone, Botswana *Timothy Boyle*

Satellite Remote Sensing Centre, P.O. Box 3718, Johannesburg, Republic of South Africa

ABSTRACT: Visual and digital analysis of Landsat MSS data resulted in the Okavango delta being subdivided into ecological zones. This was achieved by computer classification techniques followed by contextural analysis. This latter technique provided a finer subdivision of spectrally similar features by comparison of classification results with collateral data. Whereas the inherent causes of spectral similarity in wetlands have been previously described, an additional complexity was found in savanna woodlands and described as the vegetative "darkening effect." Twelve ecological zones were developed for flood inception and maximum flood periods. The delta was shown to consist of 17,000 km² land-based ecological zones and 11,000 km² water-based zones. Seasonal changes were minimal, even after high inflow, because of the large storage capacity of the delta consequent upon prior low flow and drought conditions. The largest increases were in the area of open water which expanded submerging dark soil areas and aquatic vegetation and water. Areas of exposed soil increased resulting from phenological change and drought.

INTRODUCTION

HYDROLOGICAL AND VEGETATIVE CHARACTERISTICS of wetlands in Africa have received scant attention in the literature, particularly from the perspective of macro-hydrological dynamics and ecological change. These latter attributes can be assessed using remote sensing techniques which are proving particularly valuable in drier and remoter parts of the continent. In Africa about one percent of the 30 \times 10⁶ km² surface area is inland wetland. These areas are critical for such countries as Botswana which suffer periodic drought.

Previous work has demonstrated that Landsat MSS data are useful for spectral discrimination of large, vegetated wetlands, (Gilmer *et al.*, 1980; Butera, 1983; Jensen *et al.*, 1986). In Africa, Landsat imagery has been used to detect hydrological change on the Niger river (Brivio *et al.*, 1984). Marshland biomass in Tunisia has been assessed by comparing multi-band radiometer data to Landsat MSS (Chisnall and Stevenson, 1985).

The present work analyzed the capability of Landsat MSS data for differentiating ecological zones in an extensive and seasonally changeable inland wetland environment. As the Okavango delta comprised wetland within an overall savanna woodland environment, particular attention was placed on the spectral separability of land-based and water-based features within the entire environmental complex. This was undertaken by grouping a series of related features into ecological zones, defined as having a higher degree of internal homogenuity than features outside the zone (Rubec, 1983). Particular importance was attached to measuring the extent of flooding and assessing flooding effects on adjacent land- and water-based ecological zones. These data were needed in support of development and environmental programs in Botswana, and stemmed from a request from the Botswana Department of Water Affairs for quantitative data on the delta's hydrology and ecology.

OKAVANGO DELTA STUDY AREA

The Okavango delta is an area of inland swamp (28,000 km²) comprising aquatic vegetation, open water, and dry land (Fig-

PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING, Vol. 54, No. 5, May 1988, pp. 601–608 ure 1). The delta receives a mean annual rainfall of 500mm (range 170 to 1100mm) during the wet season which lasts from October to May. The annual flow is not synchronous with the wet season. The flood reaches distributory limits during the cool, dry season (July-August), resulting from rainfall on the Angolan Planalto Central which feeds into northern Botswana through the Cubango and Cuito channels (Smith, 1976). The mean annual inflow is 10×10^9 m³ and the outflow is 0.45 x 10^9 m³; hence, most water is stored or evaporated throughout the system (Porter, 1987).

Work is ongoing on the dynamics of water flow, including ancillary studies undertaken for the Department of Water Affairs by SMEC (Snowy Mountain Engineering Corporation, 1986– 1987). This has followed pioneer work by the United Nations on various aspects of the ecology (e.g., Jackson, 1976; Astle and Graham, 1976) and soils (e.g., Staring, 1987). Previous satellite remote sensing analyses have been mainly restricted to the peripheral woodlands (Vujakovic, 1985) or used visually to assist with hydrological modelling (Hutton and Dincer, 1979).

METHODS

VISUAL ANALYSIS OF LANDSAT DATA

Four Landsat MSS scenes were required to encompass the Okavango delta wetland along with the closest peripheral lakes and outflow rivers. Requested print data from SRSC (Satellite Remote Sensing Centre), Johannesburg, were precision corrected and edge enhanced. Two sets of color composite prints at 1:250,000 scale were acquired for 1984 for preliminary analysis and to assist with field data collection. Two sets of computer compatible tapes were also obtained for the same period (Table 1). These sets were focused on the flood inception stage (February-April) (Plate 1) and the maximum flood extent (July) (Plate 2) to provide data on environmental change and flow dynamics throughout the delta system. February-April had to be used because of the lack of cloud free coverage within a closer time period on parallel orbits. The data were considered adequate as relatively little water had passed through the system during March, 1984.

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FIG. 1. Location of Okavango delta and distribution of main physical features.

TABLE 1. SCENE IDENTIFICATION AND IMAGE DATES FOR COLOR COMPOSITE PRINTS AND COMPUTER COMPATIBLE TAPES

NW	SW	NE	SE
40590-07590	40590-07593	40631-07515	40631-07522
26 Feb 84	26 Feb 84	07 Apr 84	07 Apr 84
40734-07564	40734-07564	50141-07539	50141-07541
19 Jul 84	19 Jul 84	20 Jul 84	20 Jul 84

Both sets of color composite prints were mosaicked to provide an overview of aquatic and land environments. Eight tentative ecological zones were identified and mapped on the basis of their hue, texture, and relative spatial location. This latter criterion essentially separated out spectrally similar aquatic and land-based zones by comparison with existing maps. Some information on the composition of the zones was compiled from panchromatic aerial photographs at 1:50,000 scale from May, 1983. Although drier than April 1984, a consistant similarity of macro-swamp features was observed and translated on the print data as zones with a specific composition, such as areas of floating aquatic vegetation and floodplains.

FIELD WORK

Field work was undertaken during August 1986, a year in which the flood was less extensive than in August 1984. Because

two sets of mosaics were available for flood inception (dry) and maximum flood (wet) periods, ecological zones occurring during both periods could be checked out. Field work included extensive aerial reconnaissance, followed by a 900-km road traverse. Areas in the panhandle were checked by boat. Sample areas from each of the eight mapped ecological zones were assessed on the ground. Data collection included information on the major soil types, vegetation composition and structure, and nature of the aquatic environment. Within each zone, areal estimates were made on accompanying aerial photographs to determine the dominant reflective feature in a given ecological zone.

These features were then subject to *in situ* data collection using standard operating procedures for the Exotech 100AX radiometer, (Hardisky *et al.*, 1984). All measurements were taken on clear days within two hours of local solar noon. One hundred and one delta features were measured throughout the eight ecological zones. The Exotech data were converted to percent reflectance for further analysis.

COMPUTER ANALYSIS

Data processing was undertaken at SRSC using EASI-FACE software from Peceptron Computing Inc., Canada. The hardware was a Perkin-Elmer 3230 system with COMTAL 8000 display capability. The original tapes were precision corrected, edge enhanced, and geometrically corrected. Initial analysis took place



PLATE 1. Mosaicked image of the Okavango Delta, March-April 1984.



PLATE 2. Mosaicked image of the Okavango Delta, July-August 1984.

on the northwest Okavango tape for July, 1984. Once the methodology was established, it was applied to mosaicked July data and subsequently, using different classes, to mosaicked February-April data.

From visual analysis it appeared that much of the scene variability occurred in MSS 7. Simple density slicing of this band into clear water, three vegetation/water classes, and two bare soil classes proved unsuccessful. An attempt at two-dimensional (MSS 5 and 7) density slicing and supervised classification in three bands (MSS 4, 5, and 7) also proved unsuccessful.

An interactive procedure called UNTRAIN was then applied to explore the MSS 5 and 7 two-dimensional feature space. A graphic two-dimensional scatterplot was overplayed on the image data on the screen. Areas verified in the field were identified by means of the cursor and seen to correspond to specific areas in feature space. These areas were manually encircled using graphic trace. The reverse process indicated the areal extent of the ellipses on the image. When all feature space was covered, interpretations could be ascribed to each ellipse where the area was known in the field. More ellipse areas were required to accommodate additional radiometric information (from the tapes relative to the prints) and to provide maximum potential separability of the clustered data.

Signatures were developed by using the ellipse areas to develop starting means. The unsupervised training procedure was then run for two iterations to preserve the integrity of the original class means. The areas were classified using a parallelpiped classifier with maximum-liklihood resolution of ties (Estes *et al.*, 1983).

This procedure resulted in eight computer derived classes for the July, 1984 data and 13 classes for the February-April data. These were developed separately to compensate for seasonal differences in reflectance between the two data sets. This meant that, despite increased shadow in July, comparable ecological zones were identified. The increased shadow accounted for a general shift in radiometric range of 15 to 20 digital values.

The four quadrants were later mosaicked for both time periods to produce composite sets for analysis (Plates 1 and 2). The mosaics were true north corrected using ground control points and were output in the Universal Transverse Mercator projection at 250-m pixel size using nearest neighbor resampling. The February-April image was registered to the July image using the same ground control points. Two control images of 152 grid squares, each measuring 20 km, were then generated. The classification routines used the control images to output separate class areas for each grid square. The areas of the squares were plotted separately onto 1:350,000-scale map sheets for future reference.

RESULTS

INITIAL COMPUTER ANALYSIS

A total of 13 classes were identified from the February-April data set and eight classes from the July set. No pixels were classified in the null category and there were no recorded cases of overlapping pixels. Only minor errors from atmospheric effects and sensor noise were anticipated (Landgrebe and Malaret, 1986). A high degree of discrepancy was, however, noted during an examination of the aerial extent of water- and landbased classes on the screen. Areas known to contain water were allocated to dryland vegetation classes and vice versa. A closer examination of near infrared (NIR) to red feature space revealed a Y-shaped distribution (Figure 2). The spectral reflectance of exposed highly reflective soil areas occupied location I, dominantly actively growing aquatic vegetation occupied location II, and open water occupied location III. In the center, classes were found comprising a mixture of features, including land-based vegetated areas and water-based vegetation classes.



FIG. 2. Results of computer classification showing distribution in feature space of class centers of thirteen classes for the February-April data set (A) and eight classes for the July data set (B).

RADIOMETER ANALYSIS

Radiometer results from 101 features were grouped on the basis of similarity of features measured, i.e., plant groups, soil groups, etc., and on the basis of geographic location relative to the eight field-checked ecological zones. Two-way analysis of variance statistical tests were run on each bandwidth to determine the spectral separability of the groups. Standard F-tests were applied to determine whether the groups of features were significantly similar (Best *et al.*, 1981). Means and variances of the groups are shown on Table 2, with mean values plotted as Figure 3. The eight groups comprised the following feature areas:

- (1) Open water, submerged aquatic vegetation, and black soil
- (2) Grass, green vegetation on dry land and water, and aquatic vegetation.
- (3) Dense, actively growing vegetation on dry land and in channels.
- (4) Sparse actively growing vegetation on dry land and floodplains.
- (5) Dead or knocked down vegetation (terrestial and aquatic).
- (6) Exposed dry channel soil (grey).
- (7) Exposed light colored soil on islands and pans.
- (8) Dead grass and litter.

A two-dimensional feature space plot provided some comparison between field spectral measurements and those obtained from computer analysis. The different feature groups are shown separated out on Figure 4. The plot was Y-shaped, similar to the computer-derived two-dimensional plots, with similar

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		Me	ean		Variance			ce size		
Group*	4	5	6	7	4	5	6	7	N	
1	2.94	3.38	3.81	4.64	0.93	1.99	8.18	14.07	12	
2	7.71	9.55	15.87	20.08	4.73	4.5	15.43	15.39	24	
3	5.80	5.82	23.51	31.13	2.97	4.15	23.75	27.38	23	
4	4.39	5.52	13.07	17.34	1.26	2.04	13.67	13.24	18	
5	10.78	13.93	20.88	27.01	1.14	4.12	1.41	5.18	6	
6	14.64	18.28	22.56	28.08	2.65	3.1	0.04	11.13	6	
7	34.43	39.76	43.87	51.14	40.10	40.05	40.52	41.35	6	
8	17.04	22.46	28.52	38.45	21.59	16.08	23.47	23.09	6	

*For explanation, see text.

TABLE 2



Fig. 3. Plot of means for each MSS bandwidth of field derived EX-OTECH data. The feature groups (1-8) are explained in the accompanying text.



FIG. 4. Two-dimensional feature space plot of field-derived EX-OTECH data, illustrating convergence and overlapping of clusters. The clusters (1–8) are explained in the accompanying text.

features found at locations I, II, and III. In the center, overlapping occurred especially between groups 2 and 4, which were compound groups in their own right. This underscored the difficulty of attaining spectral separability of such diverse features as grass, green land-based vegetation (trees and shrubs), water and aquatic vegetation, and sparse, actively growing vegetation.

REASSESSMENT OF COMPUTER RESULTS AND APPLICATION OF CONTEXTURAL ANALYSIS

The results of the computer classification showed that, while statistically the February-April data set could be classified into 15 classes and July into 8 classes, these did not provide an entirely recognizable distribution of features. The twodimensional feature space plots from both digitally derived and field radiometer data showed a lack of feature separability where the line II - III converges with the line I - III. Here a higher or lower degree of misclassification was inevitable, depending on the class means chosen. The critical zone in the February-April imagery was between DN 15-50 in MSS 5 and DN 45-80 in MSS 7. In July, the critical zone was between DN 12-36 in MSS 5 and DN 34-65 in MSS 7. Separation of the resulting classes was required by the use of additional information to extricate meaningful ecological zones from the classification. This was also required to remove the untimely water flow resulting from the mismatching of February and April data.

Contextural analysis was a manual form of correction involving the comparison of class area results from each of the 152 grid squares (for the two data sets) directly with aerial photograph data, topographic map information, and field work data. In each case, assumptions were made for each class re-interpretation depending on the evidence from ancillary data. For instance, if an obvious land area had been classified as water and aquatic vegetation, then the re-interpretation for that square was

Area \times hectares = land-based vegetation.

In squares containing 30 percent water and aquatic vegetation and 70 percent dead grass and trees, the class areas ascribed were proportionately represented. Every class area was checked against the available data and the necessary subdivisions or reinterpretations were made, particularly for features within the convergence area on Figures 2 and 4.

After regrouping, subdividing, and merging classes, evidence from the two data sets was combined to form twelve ecologically distinct zones, as shown on Table 3. Zones 10, 11, and 12 were separated out directly by supervised classification. The remainder were, to a greater or lesser extent, separated from their spectral equivalents during contextural analysis.

ECOLOGICAL ZONES

A brief summary of the classification plus contextural analysis results was as follows. The zones separated out by contextural analysis are shown on Table 3. Zone 1 was open-water and included not only lagoons and channels but also areas of relatively sparse aquatic vegetation including *Pycreus*, *Nymphaea*, and

TABLE 3.	ECOLOGICAL ZONES RESULTING FROM CLASSIFICATION AND
	CONTEXTURAL ANALYSIS

	ECOLOGICAL ZONE	MAIN VEGETATION TYPES
*	1 Open Water	Pycreas, Nymphaea, Caerula, Miscanthidium, Typha spp.
*	2 Wet Dark Soil	None
+	3 Water and Aquatic Vegetation	Typha latifolia, Cyperus artic- ulatus
		scripus inclinatus: Phrag- mites, Nymphae and Miscanthi- dium spp.
×	4 Aquatic Vegetation and Water	Phragmites australis, Cyperus papyrus and Miscanth- idium spp.
Δ	5 Wet Knocked- Down Vegetation	Dominantly Sedgeland
×	6 Mixed Vegetation in Floodplain Zone	Acacia nigrescens, Imperata cylindrica, Phoenix reclinata Hyphaene ventricosa, Juncus, Vossia, Pannicum and
		Echinochloa spp.
×	7 Actively Growing Vegetation in Riparian Zone with Multi-Storey Characteristics	Trees: Ficus verruculosa, Kigelia pinnata Shrubs: Rhus, Combretum, Maytenus spp. Herbs: Amaranthacea, Acanthacae
+	8 Land-Based Green Vegetation	Acacia, Boscia, Colophos- pernum, Combretum, Lonchocarpus, Terminalia, Ziziphus, spp.
Δ	9 Dry Burned Areas or Knocked-Down (Dead) Vegetation	No particular species
	10 Vegetation Dry Channels and/or Floodplains	Acacia, Boscia, Combretum Ziziphus spp.
	11 Unvegetated Dry Channels and Floodplains	Very sparse Vegetation, Dominant Acacia spp.
	12 Exposed Sand and Pan Soil	none

* \times + \triangle - Separated by contextural analysis.

Caerula species. This was separated from the exposed dark, wet soil of the Ngami basin by contextural analysis.

Zone 3, water and aquatic vegetation (water dominant), has a very dark blue signature. It contains monocotyledon or grasslike vegetation with typically Typha latifolia and Miscanthidium spp. A similar dark blue signature was found for Zone 3, a terrestial vegetation zone dominated by Acacia spp. and broadleaved shrubs and trees, including Colophospernum mopane. This kind of Kalahari bush with 30 to 40 percent green (drought adapted) vegetation cover typically exhibits the "darkening effect." Increases in vegetation cover are commensurate with decreases in both red and NIR bands (Otterman, 1980, 1983; Otterman and Robinove, 1982; Ringrose and Matheson, 1987). The exact causes behind the "darkening effect" vary throughout the world, but include the influence of internal and external shadow, various combinations of dead material, relatively high soil reflectance, inherent leaf adaptation properties, and stress (Everitt and Nixon, 1986).

Zone 4, aquatic vegetation and water, had a red signature characteristic of dense, actively growing vegetation. This zone was dominated by the giant reeds *Phragmites australis* and *Cyperus papyrus*. These perpetually undergo cycles of death and regeneration throughout the year. This was separated by contextural analysis from a zone with a similar red signature (Zone 6) found on the floodplain of the panhandle in July after the flood had passed. High soil moisture promoted the growth of dense grasses and reeds flanked by green vegetation consisting of palms (*Phoenix and Hyphaena spp.*) and *Acacia spp*. A third red signature zone was Zone 7 which consisted of multi-storey landbased vegetation in the immediate riparian areas. Here tall trees (e.g., *Kigelia pinnata*) dominated with well developed shrub and herbaceous layers.

Zone 5, wet vegetation knocked down by trampling, had a blue-green signature. This area contained dominant sedgeland communities. These, and other sedgeland areas, are significant in providing the best overall habitat for the delta's abundant wildlife, (D. Perry, SMEC, personal communication). A similar spectral signature was found for Zone 9, which consisted of dry areas which were either burned over or contained standing dead or knocked down land-based vegetation.

Three zones in Table 3 corresponded to classes 10, 11, and 12 and were spectrally distinct. Zone 10 was medium blue, Zone 11 was light blue, and Zone 12 had a light grey to white signature. Zones 10 and 11 represent different parts of old floodplains in the southwest portion of the delta. This was an area overgrazed by cattle, sheep, and goats, and is presently sparsely vegetated by *Acacia spp*. Zone 12 was also sparsely to moderately vegetated, but high reflectance of underlying Kalahari sand dominated the light spectral signature.

No formal attempts were made to develope "classification accuracy" because each grid square had, in effect, been checked during contextural analysis. A frequency-of-occurrence check was made by comparing the occurrence of ecological zones in 50 of the grid squares, relative to their occurrence on collateral aerial photograph data. This resulted in an accuracy of 80 percent for the February-April data set and 85 percent for the July data set.

The total area in each ecological zone was quantified to provide a data base for management in the delta (Table 4).

DISCUSSION

Comparison of results for both time periods showed that the Okavango delta environment was composed of about 17,000

TABLE 4. AREA AND AREA CHANGE OF ECOLOGICAL ZONES OBTAINED FROM 1984 LANDSAT MSS DATA

Aquatic-			
based February-March		July	Percent
zones*	(km²)	(km²)	change
1	708	2573	+6
2	1462	275	-4
3	4710	5085	+1
4	3646	2490	-4
5	Not present	1027	+4
6	Not present	210	+1
Land-based			
7	3050	4565	+2
8	2105	1588	-2
9	4517	2053	-9
10	1960	552	-5
11	2162	4152	+6
12	2246	4201	+7
Total swamp	10526	11660	
Total dryland	16949	17084	

*For explanation of zones, see Table 3.

km² land-based ecological zones, some of which were swamp related, and 11,000 km² water-based ecological zones kept permanently wet by recurrent floods. Most of the seasonal changes which took place in the delta during 1984 affected mainly the land-based zones (Table 4). During 1984 the delta experienced a particularly high inflow, 13.6 \times 10⁹ m³ and a low outflow, 0.26 \times 10⁹ m³. During 1983 and 1985 both inflow and outflow values were much below average (Porter, 1987). In 1984 more storage (than average) was anticipated because of intense evaporation in the previous year. The areal extent of inundation was not commensurate with high inflow in 1984 because of increased storage capacity in the delta. While seasonal change was less pronounced than usual, the direction of change, in terms of expansion and contraction of various ecological zones, remained the same.

In terms of aquatic zones, the most pronounced change was apparent in the area of open water, which showed a positive expansion of 1865 km² or 6.0 percent, mostly due to inundation of aquatic vegetation and water areas, which decreased by 1156 km² or 5 percent of the total area. A relatively large area of wet, knocked-down vegetation appeared in July (+4 percent). This area had previously been recognized as dry, knocked-down vegetation in February-April (-9 percent), about half of which was subsequently flooded. A large area of vegetated dry channels and/or floodplains identified in February-April was flooded by July. Relatively large increases occurred in unvegetated dry channel areas and pan and sandy soil areas from February-April to July. A partial explanation may be found in phenological changes which affect land areas irrespective of the flood cycle. The apparent decrease in vegetation cover in July may result from natural defoliation such that large areas appeared unvegetated or sparsely vegetated. Also, 1984 occurred in the middle of an intense drought cycle and vegetation suffered from water shortages, particularly in ecological zones which were independent of flooded areas.

CONCLUSIONS

Landsat visual and digital data can be used as a basis to monitor hydrological and ecological conditions in a savanna woodland swamp environment. The data can also be used to determine spatial components, such as ecological zones. To be accomplished successfully, a combination of computer classification techniques was required with individual classes checked against field work and ancillary aerial photograph data. In these respects, the subdivision of ecological zones achieved in this analysis resembled that achieved for inland wetlands throughout the world, (e.g., Jensen et al., 1986, 1987; Rose and Rosendahl, 1983). Problems in the subdivision of savanna wetlands were, however, intensified by the similarity in reflectance of a number of diverse features towards the lower end of the radiance scale. This results from the "darkening effect," a feature noted by other authors dealing with semi-arid or drought afflicted terrain, (e.g., Otterman, 1980, 1983). In the present case, the low radiance values in MSS 5 and MSS 7 resulting from relatively dense (up to 40 percent cover), land-based green vegetation proved sufficiently dark to cause problems when attempting normal classification routines, designed to separate land-based vegetation from water and aquatic vegetation.

Following standard classification procedures, the areas of misclassified pixels were reassigned and re-interpretated on a proportional basis. This involved comparing the classification results in 152 grid squares with aerial photograph data obtained during the flood inception stage of the delta. This resulted in the development of a series of acceptable ecological zones for the time periods February-April 1984 and July 1984. Temporal comparison of area results showed the delta environment was composed of about 17,000 km² dryland, which was infrequently

flooded, and 11,000 km² swamp, which was kept permanently wet by recurrent floods. Most of the swamp area was composed of water and aquatic vegetation (Zone 3) and most of the dryland was composed of burned or knocked down vegetation (Zone 9) or multi-story riparian vegetation (Zone 7). The increase in inundated area for an above average flood year in an extremely dry period amounted to an increase of 6.0 percent open water at the expense of aquatic vegetation and water and dark soil zones. Relatively large areas of dry knocked-down vegetation and vegetated dry channels and/or floodplains were flooded. Increases in exposed soil areas were probably due to seasonal defoliation and drought related factors.

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Dennis Klein & Associates 38 Miller Avenue, Suite 11, Mill Valley, CA 94941 Telephone 415-381-1750

D^{ENNIS} KLEIN & ASSOCIATES, Mill Valley, California, is the developer of FMS/AC[®] (Facility Mapping System for AutoCAD[®]). FMS/AC is application software which turns an AutoCAD into a full function AM/FM/GIS workstation.

This software provides users with little or no AutoCAD training, an error-free interface template for easy encoding of *Intelligent* Automated Mapping/Facility Management/Geographic Information System (AM/FM/GIS). Until FMS/AC, this functionality had not been seen in an AM/FM/GIS package inside AutoCAD.

FMS/ACs database management templates (FMAP¹⁰) system supports the following graphic database overlays:

LAND USE PLANNING	SANITARY SEWER SYSTEM
PARCELRECORDS	WATER SUPPLY SYSTEM
STORM DRAINAGE	STREET LIGHTING
STREET MAINTENANCE	BUILDING/LEASINGRECORDS
ELECTRICAL UT	TILITY DISTRIBUTION

FMS/AC capabilities make it possible for users to "find" and highlight map features that meet the conditions of a search query even if they are on inactive (frozen) layers. Manipulations of "found" features include attribute updating, color and layer changes, network tracing, and other graphic operations. As a result, FMS/AC is now able to perform all of its GIS operations without a single (time consuming) screen regeneration.

Each menu square in the pull-down bar menus displays a full statement explaining what it does. In addition, supporting picture icons further define functions including graphic illustrations of specific steps involved to encode map features. Such sophisticated tasks as adding connected linear elements to an intelligent utility network can now be accomplished by new users, without training or reference to the operator manual. Help screens are likewise fully illustrated.

Additional FMS/AC components include:

- A pull-down, icon-driven menu system, making FMS/AC truly self-teaching.
- Graphic-nongraphic interface that makes FMS/AC's database able to "scan" the graphic database for objects meeting search criteria conditions.
- Extensive library of intelligent symbols and supporting report templates for automatic data posting to any database management system (DBM) or to FMAP, the internal DBM system (dBaseIII+) capable of supporting queries of up to 30 variables (variable count can be expanded according to individual).
- Comprehensive User Manual which addresses all operational aspects of the software as well as definitive instructions for planning and implementing your AM/FM/GIS system. Includes detailed instructions for interfacing FMS/ AC with any DBM of choice other than FMAP.

Dennis Klein & Associates in addition to complete design of the FMS/AC Software, provide training for FMS/AC and service consultation for AM/FM/GIS Systems.

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608