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Project Summary

Aerial Photography and Ground Verification at Power Plant Sites: Wisconsin Power Plant Impact Study

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This study demonstrated and evaluated nine methods for monitoring the deterioration of a large wetland on the site of a newly-constructed coal-fired power plant in Columbia County, Wisconsin. Four of the nine methods used data from ground sampling; two were remote sensing methods without ground verification; and three were remote sensing methods which either used ground verification or relied on the analyst's "on-the-ground" knowledge of the area.

These methods were evaluated on the basis of whether they monitor change at a species or a community level, whether they monitor community change in terms of area or location or both, and whether they provide information about trends in plant communities. They were also evaluated in terms of time, cost, sensitivity, and reliability. Changes in the wetland over a three-year period are presented, as determined by each of the methods. Eight appendices provide information and raw data for several of the methods, color/texture keys for interpreting air photos, and an annotated bibliography on remote sensing methods.

This Project Summary was developed by EPA's Environmental Research Laboratory, Duluth, MN, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Background

The full report describes part of a large study documenting the environmental impact of construction and operation of a 1050 MW coal-fired power plant in south central Wisconsin. A major goal of the study was to develop new, less expensive and more effective methods for predicting and measuring environmental change.

This subproject had a dual purpose:

1. To document the nature and extent of changes in vegetation by a variety of ground-based and remote sensing methods, and
2. To compare and evaluate the methods on the basis of their efficiency, sensitivity, and reliability.

Before construction, the site was an extensive marsh/sedge meadow with areas of floodplain forest and a few low, semi-wooded knolls. The marsh included small expanses of open water with emergent vegetation, and pockets of shrub carr and alder thicket. The soil was a peat mat overlying sand. Construction and operation of the power plant in this setting resulted in the elimination of seasonal fluctuations in water level, an increased flow of ground water, and year-round thermal loading of the ground water. All plant communities responded to these changed conditions.

Methods

Changes were monitored by nine different methods representing both traditional and new approaches. Four were ground based; five involved remote sensing with or without ground verification. Together, they provided information at many levels. The evaluation of the results and methods considered which methods can best:

1. Detect changes at the species level with time.
2. Detect changes at the community level in the area and location of each type of plant community.
3. Document trends in changes in vegetation.

Ground Sampling Methods

The study site was an area of 33.5 ha, marked off into transects at 50 m intervals with sampling stations every 50 m along these transects. Data were collected each summer and fall, from 1974 through 1977.

Diversity Index

The diversity index gives information about changes in the total number of species. The number of species present at each sampling station was counted, and these values were summed for each year of the study. The index was calculated as the annual percentage gain or loss in species or as a change in relation to some base year.

Subjective Classification

This method classifies vegetation by type of community. Twelve classes of vegetation were defined empirically, according to the most prominent species in each one. (Classes identified in this way and by the seven other ground-based and remote sensing methods are shown in Table 1.) Stem counts were then made of each species found at a sampling station, and on this basis the station was assigned to the appropriate class. For maximum reliability, the subjective classification method requires that the analyst adhere strictly to the criteria established for each class.

Table 1. *Classes of Vegetation Identified by Eight Ground-Based and Remote Sensing Methods*

Vegetation class	*Subjective classification*	*Association analysis*	*Vegetation structure analysis*	*Airphoto monitoring*	*Disturbance mapping*	*Airphoto grid analysis*	*Airphoto interpreted vegetation mapping*	*Computer-assisted mapping*
Carex stricta	X	X				(X)*	(X)	X
Degraded C. stricta	X	X				(X)	(X)	X
C. lacustris	X	X				(X)	(X)	X
Degraded C. lacustris	X					(X)	(X)	
Transition	X	X				(X)	(X)	X
Degraded transition	X	X				(X)	(X)	
Emergents	X	X				(X)	(X)	X
Degraded emergents	X					(X)	(X)	
Spiraea alba	X	X				X	X	X
Shrubs	X	X	X	X		X	X	
Open water	X	X	X	X	X	X	X	X
Open-emergents		X						
Weedy annuals	X	X		X		(X)	(X)	X
Transition-emergents				X		X	X	
Sedges and grasses						X	X	
Grasslike				X				
Tall-coarse				X				
Grasslike-tall				X				
Disturbed vegetation					X			
Undisturbed vegetation					X			
Degraded sedges				X		X	X	X
Shrubs and trees				X				
Typha latifolia						(X)	(X)	
Scirpus fluviatilis						(X)	(X)	
Floating mat						(X)	(X)	
Lemna minor				X		(X)	(X)	X
Trees				X		(X)	(X)	
Spiraea/sedges								X
Spiraea/shrubs								X

* *Not all of these classes can be identified on every airphoto. Parentheses indicate classes merged with others and not included as distinct classes in the final analysis.*

Association Analysis

Association analysis is a type of cluster analysis which groups stations according to their similarities in species composition. Thirty-four common, visually dominant species were selected as attributes in identifying clusters. Each station was rated + or – for the presence or absence of each attribute. A computer program then divided the stations into two clusters of maximum dissimilarity. Division was based on presence or absence of the single species which created the greatest dissimilarity in species composition of the resulting clusters, using sum chi square as a dissimiliarity coefficient. Subdivision into further clusters continued on this basis until the desired number of clusters had been created. The result is a hierarchial structure that can be displayed as a dendrogram. The clusters created by association analysis were named to correspond as well as possible with other classifications of vegetation used in this study (Table 1).

Vegetation Structure Analysis

Another way to monitor changes in the study area with time is on the basis of changes in gross vegetation structure. Five categories of structure were defined (Table 1). Each station was assigned to one of these according to the results of ground sampling, year by year.

Remote Sensing Methods

For the five remote sensing methods, airphotos were interpreted or analyzed in a variety of ways. The photos were taken with both color and color infrared film, at scales of from 1:11,500 to 1:120,000. Color infrared film gave the best, most discriminating results; the scales that permitted the most satisfactory interpretations were 1:19,000 and 1:38,000. Airphoto data were collected monthly during the growing season and several times during the rest of the year.

Airphoto Monitoring

Airphotos can be used without ground verification to monitor sites which are inaccessible from the ground. This method may provide a high degree of detail, but alone it does not map or quantify information. It gives a simple photographic record of change, accompanied by any interpretations the analyst is able to make. Six types of features could readily be interpreted from airphotos, and with some ground verification, two additional classes of vegetation could be identified (Table 1).

Airphoto Interpreted Disturbance Maps

Disturbance mapping identifies only three types of area: undisturbed vegetation, disturbed vegetation, and open water. Disturbed areas represent degraded vegetation resulting from erosion of the peat mat. They are easy to recognize on airphotos as changes in appearance from earlier photos.

Maps were made by tracing the boundaries of the three types of area on mylar overlying enlarged airphotos. No ground verification is needed for this method. The extent of change is easy to quantify, for example, by use of a planimeter.

Methods Combining Airphotos and Ground Sampling Data

Airphoto Interpreted Vegetation Maps

Vegetation classification maps were drawn in the same way as the disturbance maps, with mylar overlays showing the locations of transects and sampling stations. Patterns seen on the photos were traced and labeled by referring to the ground-based data and classification for each station. Classes recognizable on the airphotos did not always correspond exactly to ground-based classifications, and some classes identified on the ground or in individual airphotos had to be merged so that comparisons could be made among the airphoto interpreted vegetation maps (Table 1).

A color and texture key was assembled for each airphoto to facilitate consistent mapping of the various communities. The total area of each community was determined as for the disturbance maps, and expressed as a percentage of the study area. One problem with this kind of mapping is that communities sometimes grade into one another, and the boundaries between them do not appear distinct. This detracts from the precision of the method.

Airphoto Grid Analysis

In airphoto grid analysis, airphotos were overlaid with grids to scale (a cell representing 50 m^2 on the ground), with the locations of ground stations and transects also shown. Classes of vegetation were identified (Table 1) and a color/texture key was assembled as in airphoto interpreted vegetation mapping. The differences between the two methods is that, in grid analysis, assigning vegetation classes and determining the percentage of cover of each class are done simultaneously on a cell by cell basis. Results are presented as percentage cover or change in percentage cover for each class of vegetation, when the method is used to monitor change over time.

Computer Assisted Vegetation Mapping

Color and color infrared photos were scanned with a densitometer using three different filters to obtain analyses of color bands in the red, green, and blue spectral regions. The size of the scanning unit (pixel) corresponded to a spot size of 1.9 m (3.6 m^2) on the ground. Continuous output from the photomultiplier tube of the densitometer was converted to integer values, pixel by pixel. Through a series of computer programs, these data underwent various transformations and corrections. Sets of data were then selected for "training" the computer to distinguish among different classes of vegetation. This part of the analysis requires a high degree of interaction between the analyst and the computer.

After the limits of each class had been defined and the probability distribution of data values within each class had been determined, the spectral response signature of each pixel was compared to the spectral response signatures of the final training sets and classified for the best fit. Three models for classification were used in this study. They involved different amounts of time and expense and gave somewhat different results.

This method offers consistent classification of vegetation and quantification of the area of each class, once the criteria for classification have been established. Classes are named by reference to ground-based data (Table 1). Results can be displayed with computer-printed maps or color photo maps.

Results

The combined results from all methods give information at several levels. The method of choice for any study depends on what kind of information is desired.

Changes at the Species Level

Of the methods employed in this study, only the diversity index provides direct information on changes occurring in the number of species in the area. However, the diversity index gives no information at the community level and cannot be used to locate or quantify areas of change. Furthermore, the method is useful only if there is a definite trend toward net gain or loss of species. If some species disappear from parts of the study area while others invade or increase, the diversity index may show no change. This particular study revealed a sharp decrease in diversity, as summarized in Table 2.

Changes at the Community Level

All methods other than the diversity index give some information on changes in the area or the location of plant communities or both. Ground sampling methods show point locations of communities and quantify changes in the relative percentage of stations in each class. Airphoto methods, whether quantitative or purely descriptive, are better able to show the area and location of plant communities than ground sampling methods.

Ground Sampling Methods

Both subjective classification and association analysis demonstrated changes with time in the number of stations assigned to each vegetation class (Table 3). These changes could be correlated with changes in water temperature, volume of flow, and erosion of the peat mat. The results show a successional trend toward deeper water species. Both methods indicate that *Carex lacustris*, transition, and emergent communities are more fragile than *C. stricta* and shrubby communities.

Vegetation structure analysis revealed that the grasslike and grasslike tall classes were most sensitive to impact. Of the 29 stations classified as grasslike in 1974, 21 were reclassified in 1977, and only one of twelve stations that were grasslike tall in 1974 retained this classi-

Table 2. *Diversity Index, 1974-1977*

Year	*Number of species (sum of numbers at 62 stations)*	*Change (number of species/year)*	*Diversity index* (% change/year)*
1974	*379*	-	-
1975	*357*	*-22*	*-5.8*
1976	*296*	*-61*	*-17.1*
1977	*266*	*-30*	*-10.1*

**A positive index number represents an overall gain in number of species; a negative number indicates a loss.*

fication three years later. The shift toward a tall coarse and open water vegetation structure occurred throughout the study area.

Remote Sensing Methods

The four remote sensing methods corroborate results of the ground sampling methods, that is, a trend from healthy, predominantly marsh/sedge meadow communities to eroded and disturbed wetland vegetation. Airphoto monitoring provides a photographic record of the change. The increasing and enlarging areas of open water and disturbed vegetation between September 1975 and October 1977 are shown in the airphoto interpreted disturbance maps (Figure 1). Table 4 shows results for the same period, for airphoto grid analysis and airphoto interpreted mapping, in terms of changes in percentage of cover of each vegetation class.

The discrepancies between airphoto interpretated vegetation mapping and airphoto grid analysis result from the difference in scale at which the analyses are done. Grid analysis, in which the percentage of each vegetation class is determined on a cell by cell basis, gives the more accurate information on changes in total area of each type of vegetation, but it cannot reveal changes in the location of the various communities. Vegetation mapping shows the predominant type of vegetation on a broader scale, and changes in the location of a plant community can be seen at a glance on maps similar to the disturbance maps of Figure 1.

Computer assisted mapping offers some advantages of each of the other remote sensing methods. Because the analyst can choose the size of the unit area to be classified (the pixel), the analyses can be made on as large or small a scale as desired. Results can be presented as the overall area of each vegetation class (Table 5) or as a map on which each pixel is shown in the color designated for the corresponding class of vegetation. Comparison of Tables 4 and 5 shows general agreement among the three methods. Of the three, computer assisted mapping offers the most consistent classification of vegetation and quantification of results and the most readable visual product in the form of maps.

Evaluation of Methods

The nine methods applied in this study were evaluated according to the kind of information provided, the expertise required, efficiency (requirements in time, capital equipment, materials), and sensitivity and reliability.

The diversity index is the only method which provides information on changes in numbers of species, but it provides no information at the community level. Ground sampling methods show point locations of communities and quantify changes in the numbers of stations classified as to type of community, but they cannot show changes in the area or location of communities as well as remote sensing methods can.

All methods require expertise in botany and ecology. Computer facilities and expertise are necessary for association analysis and computer assisted mapping. The five remote sensing methods demand skills in the visual interpretation of airphotos, and, in addition, computer assisted mapping involves interpretation of computer generated images. Drafting skills are necessary for disturbance mapping and vegetation mapping.

Detailed analyses compared the efficiency, sensitivity, and reliability of the nine methods. Table 6 summarizes the results. There is a fourfold difference in cost between the least expensive and the most expensive methods, and a twelvefold difference in the requirement for time between the fastest and the most time-consuming methods.

The greatest amount of information is obtained by combining ground based sampling methods with airphoto mapping methods. Ground sampling data give information on the nature of the occurring change, whereas mapping methods show where the change is occurring and how extensive it is. For

Table 3. *Changes in Classification of 62 Stations from 1974 TO 1977, by Methods of Subjective Classification and Association Analysis*

Classification in 1974, community	*Classification in 1977*			
	Subjective classification		*Association analysis*	
	Community	*No. of stations*	*Community*	*No. of stations*
Carex lacustris	C. lacustris	1		0
	Weedy annuals	2	*Weedy annuals*	2
	Degraded C. stricta	1	*Degraded* C. stricta	8
	Degraded C. lacustris	3	*Transition*	2
	C. stricta	3	*Degraded transition*	4
	Open water	4	*Emergents*	1
	Emergents	1	*Emergents-open*	3
C. stricta	C. stricta	5		4
	Degraded C. stricta	9	*Degraded* C. stricta	10
	Transition	1	Spiraea	1
			Weedy annuals	1
			Shrubs	1
Transition	*Transition*	1	*Transition*	1
	Degraded transition	4	*Degraded transition*	1
	Emergents	5	*Emergents*	4
	Open water	2	*Emergents-open*	1
Emergents	*Emergents*	2	*Emergents*	2
	Degraded emergents	6	*Emergents-open*	3
	Open water	3		
Shrubs	*Shrubs*	5	*Shrubs*	2
	C. stricta	1	*Emergents-open*	2
Spiraea	Spiraea	3		1
			C. stricta	2

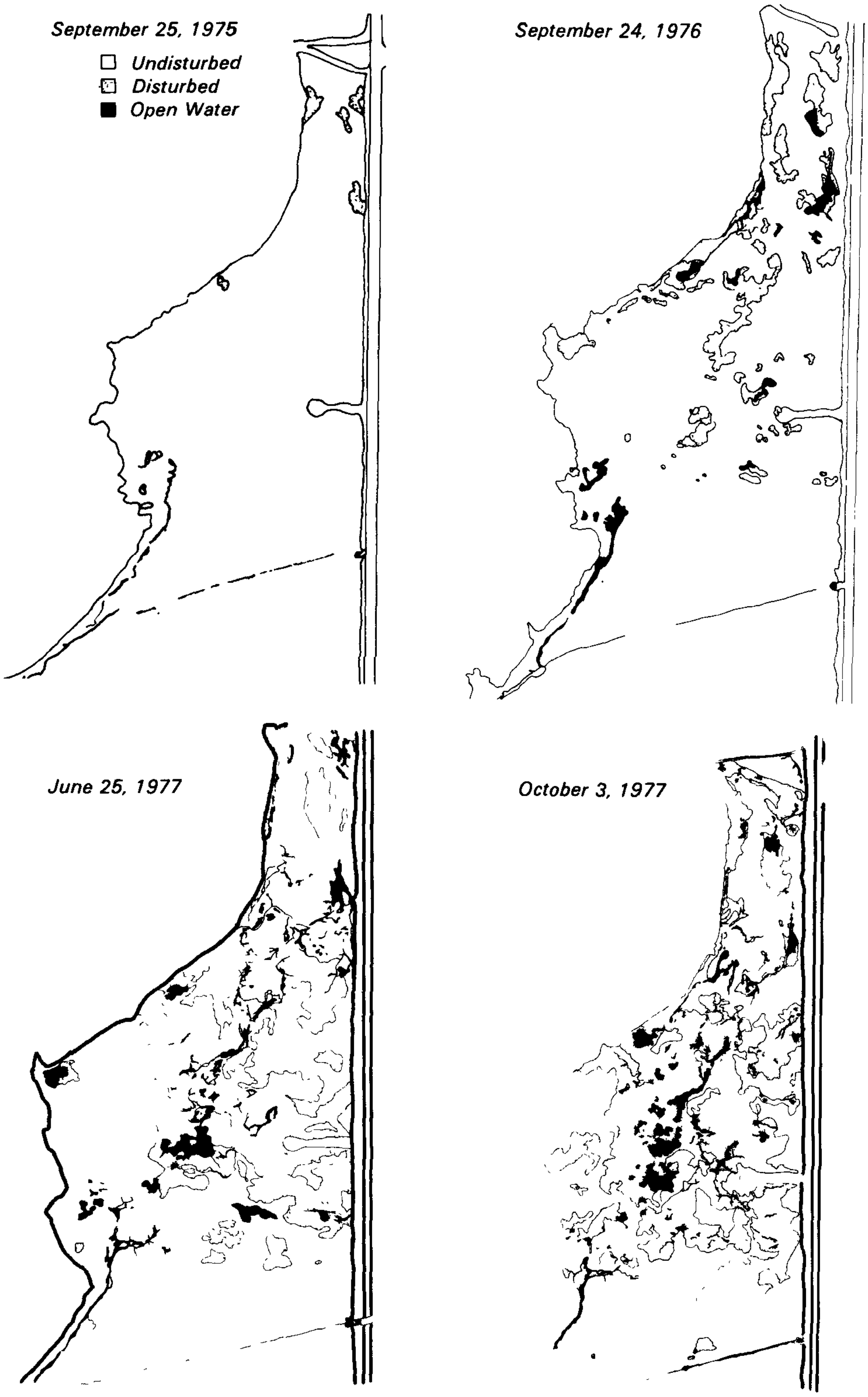

Figure 1. *Changes in vegetation at site of Columbia Generating Station, 1975-1977, as shown by airphoto disturbance mapping.*

small data sets, subjective classification is effective in demonstrating trends in plant communities and can be combined effectively with airphoto-interpreted vegetation mapping. Both of these methods are costly and time consuming, however, and would not be the methods of choice for large data sets. For large amounts of data, association analysis can be used effectively in conjunction with grid analysis or computer assisted mapping. The choice of remote sensing method would depend on the nature of the results desired - whether highly quantitative in terms of community area, or both quantifiable and visual, such as a map.

Grid analysis is also compatible with disturbance mapping, for use in large areas. Grid analysis measures the percent change in cover of each vegetation class, and disturbance mapping shows the extent and location of gross change. Similarly, association analysis and disturbance mapping provide complementary information for large data sets. If facilities are available, the ideal combination of methods for extensive monitoring would be association analysis, to identify community change, and computer assisted mapping, for visual displays and quantitative presentation of results.

Table 4. *Percentage Cover of Each Vegetation Class, as Determined by Airphoto Grid Analysis and Airphoto Interpreted Mapping*

	% of each class			
	Grid analysis		Airphoto interpreted mapping	
Vegetation class	Sept. 1975	Oct. 1977	Sept. 1975	Oct. 1977
Shrub	7.4	7.8	11	5.7
Spiraea	9.5	9.2	11	7.5
Open water	5.2	10	1.5	10
Transition-Emergents	25	25	22	15
Sedges	50	11	45	22
Degraded sedges	–	12	–	20
Other disturbance	2.2	24	7.5	17
Unclassified	–	–	1.9	1.3

Table 5. *Summary of Results of Computer Assisted Vegetation Mapping*

	% of total area	
Class of vegetation	September 1975	June 1977
Shrubs	9.7	6.7
Spiraea/Sedges	18	9.6
Open water	0.5	8.1
Transition-Emergents	22	17
Sedges	39	13
Degraded Sedges	–	21
Other Disturbance	1.8	18
Other, and unclassified	9	5.8

Table 6. *Comparison of Methods Based on Efficiency, Sensitivity, and Reliability*

			Sensitivity[2]		
	Efficiency[1]		No. classes	Type	
Method	Time	Cost	defined	of data	Reliability[3]
Diversity Index	2	1	–	2	1
Subjective Classification	3	2	1	1	3
Association Analysis	2	1	2	2	1
Vegetation Structure Analysis	2	1	3	2	3
Airphoto Monitoring	1	1	2	3	3
Disturbance Mapping	1	1	3	3	3
Airphoto Grid Analysis	3	3	1	3	2
Airphoto Vegetation Mapping	3	3	1	3	2
Computer Assisted Mapping	2	3	2	3	2

[1]A rating of 1 represents high efficiency, i.e., low time or cost requirements. A rating of 3 represents relatively low efficiency.

[2]A rating of 1 represents a high degree of sensitivity to subtle changes. It requires that a large number of vegetation classes be defined, or that data be based on stem counts. A rating of 3 represents few classes distinguished or airphoto data. Presence-absence data receive a rating of 2.

[3]The reliability rating is based on the repeatability of data collection, the level of subjectivity (the degree to which the analyst must interpret the data), and whether results are quantitative or qualitative. A rating of 1 represents a high level of repeatability, a high degree of objectivity, or computer quantitative results. In this table, the methods were rated most reliable (1), moderately reliable (2), and least reliable (3), according to their combined scores on the three criteria for reliability.

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The complete report, entitled "Aerial Photography and Ground Verification at Power Plant Sites: Wisconsin Power Plant Impact Study," (Order No. PB 85-197 358/AS; Cost: $23.50, subject to change) will be available only from:
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