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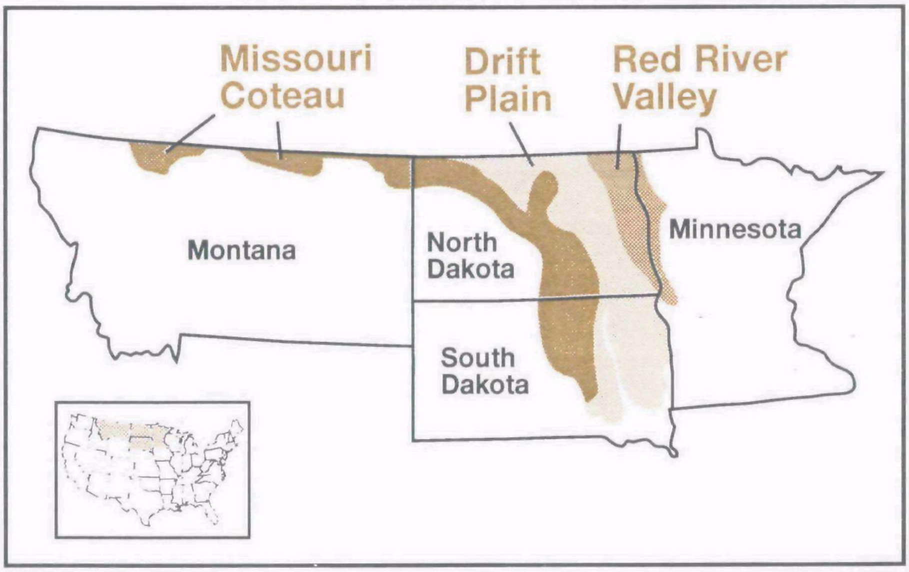
Pilot Test of Wetland Condition Indicators in the Prairie Pothole Region of the United States



SURFACE WATERS

EMAP

Environmental Monitoring and Assessment Program

PILOT TEST OF WETLAND CONDITION INDICATORS IN THE PRAIRIE POTHOLE REGION OF THE UNITED STATES

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- NBS staff and seasonal hires in Jamestown, ND
- EMAP-Surface Waters and associated laboratory staff in Corvallis, OR, including EPA and on-site contractor personnel (Dynamac International, Inc., OAO, Inc.) and guest workers from Oregon State University
- US Fish and Wildlife Service, National Wetlands Inventory staff and contractors at St. Petersburg, FL
- personnel on cooperative agreements with North Dakota State University at Fargo
- members of the project peer review panel.

We especially appreciate the Northern Prairie Research Advisory Committee for their suggestions on enhancement of the project proposal. The following people provided official technical review of this report: Naomi Detenbeck, Louisa Squires and Daniel Hubbard. Marge Hails did final word processing and formatting of the report.

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All research reported here was conducted under the guise of a Quality Assurance Research Plan prepared by NPSC and approved by EPA. This document has been subjected to EPA's peer and administrative review and approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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SUMMARY

This report describes the objectives of the Environmental Monitoring and Assessment Program (EMAP)-Wetlands. Additionally, it describes a pilot project conducted by the Biological Resources Division-U.S. Geological Survey in the Prairie Pothole Region (PPR) of the United States to evaluate the ability of wetland indicators to distinguish between good- and poor-condition areas. Good-condition areas were assumed to be those least impacted by cropping practices. Thus, the good- and poor-condition areas were based on the ratio of cropland to total area of upland, such that the smallest ratios represented the most grassland while the largest ratios represented the most cropland. Good- and poor-condition paired study plots were then selected from each of the three major ecoregions (Mann Wetland Density) of the PPR (16 original plots).

The purpose of the pilot study was to select and evaluate indicators that would be robust enough to eventually describe wetland conditions for all of the PPR or for a State via probability survey sampling. Indicator selection involved three steps: (1) consultation with PPR wetland experts to develop a preliminary list of indicators, (2) refinement of the list to bring it in line with budgetary and logistic constraints, and (3) field studies to determine whether the indicators could differentiate between landscapes in good (mostly grassland landscapes) and poor (mostly cropland landscapes) condition.

A variety of physical, chemical and biological indicators were tested during the summers of 1992 and 1993 on 12 of the original 16 plots selected. Among the physical indicators, those most capable of differentiating good- and-poor condition wetland landscapes were: (1) frequency of drained wetland basins, (2) total length of drainage ditch per plot, (3) amount of exposed soil subject to erosion, and (4) indices of change in area of wetland covered by water. Among the chemical indicators tested, only soil and sediment phosphorus conclusively differentiated between good- and poor-condition wetland landscapes. Biological indicators included (1) invertebrates, (2) waterfowl, and (3) plant community components. Among the various measures made for invertebrates, only taxon richness showed promise in distinguishing good and poor conditions. Breeding pair duck counts also were capable of distinguishing good and poor conditions. Among the plant community indicators, species richness in the wet meadow zone was the one indicator that distinguished itself in differentiating between good- and poor-condition wetland landscapes.

A major complication of conducting indicator evaluation research in this area is access to private lands. Nearly 0.3 person-years of effort were necessary to obtain access to the 16 plots. Access was authorized on 68% of the targeted sites. Access authorization was later rescinded on five study sites in poor condition.

Based on the pilot study results, several indicators were recommended for further evaluation in a follow-on study that will use probability based sample site selection.

Section 1.0
INTRODUCTION

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1.1 OBJECTIVES OF EMAP PROGRAM

The Environmental Protection Agency (EPA) initiated the Environmental Monitoring and Assessment Program (EMAP) in 1989 to address four objectives (EPA 1993).

1. To estimate the current status, trends, and changes in selected indicators of condition of the Nation's ecological resources on a regional basis with known statistical confidence.

2. To estimate the geographic coverage and extent of the Nation's ecological resources with known confidence.

3. To seek associations between selected indicators of natural and anthropogenic stresses and indicators of ecological resources.

4. To provide annual statistical summaries and periodic assessments of the Nation's ecological resources.

EMAP was partitioned into seven ecological resource classes:

1. agricultural
2. rangelands
3. estuaries
4. forests
5. Great Lakes
6. landscape ecology
7. surface waters--lakes, streams and wetlands.

This report addresses wetlands. The objectives of the EMAP-Wetlands group generally parallel those of the EMAP program except that the wetlands group will not estimate the extent of the wetland resource. Instead, we have adopted the estimates of wetland extent and distribution reported in the U.S. Fish and Wildlife Service's (USFWS) Congressionally mandated National Wetlands Inventory (NWI). This allows us to focus on indicators of condition (Peterson 1994). Therefore, this report addresses a pilot project to evaluate the performance of wetland condition indicators and their ability to discriminate between good- and poor-condition landscapes in the Prairie Pothole Region (PPR) of the United States (See Section 2.3 for definition and selection process for good and poor landscapes).

1.2 PRAIRIE POTHOLE REGION

The PPR is situated in the northern plains of the United States and Canada. Although the characteristics of the region have been described in detail (Kantrud et al. 1989, van der Valk 1989) there is variation in the bounding of the region. We used a map prepared by Mann (1974) to define the bounds because, unlike some other published maps, Mann's map covers the entire region including Canada and delineates wetland-basin density, thus furnishing a basis for ecological regionalization. The map has also been used as the basis of other maps and analyses that have recently been published (e.g., Sargeant et al. 1993, Sargeant and Raveling 1992). The PPR with regions based on wetland density is shown in Figure 1-1.

Prairie potholes are glacial in origin. They tend to be extremely variable in size, hydrology, flora, and fauna. They are also numerous and small, which causes sampling problems unique to the region (Cowardin et al. 1995). Climate in the PPR is unstable. The region cycles between wet and dry periods. Spatial complexity and climatic variability in the region further confound attempts to monitor and evaluate wetland conditions. Wetlands in this region have long been recognized as critically important for breeding waterfowl (Smith and Stoudt 1964). More recently, society has recognized numerous other wetland values such as water quality improvement, flood attenuation, and biological integrity (Kantrud et al. 1989, van der Valk 1989, Peterson 1994). The region is one of the most intensively managed agricultural areas in the United States. Agriculturally related disturbance has resulted in numerous controversies between those interested primarily in agriculture and those interested primarily in waterfowl production. These controversies, in turn, have resulted in numerous wetland protection laws (Sidle 1983).

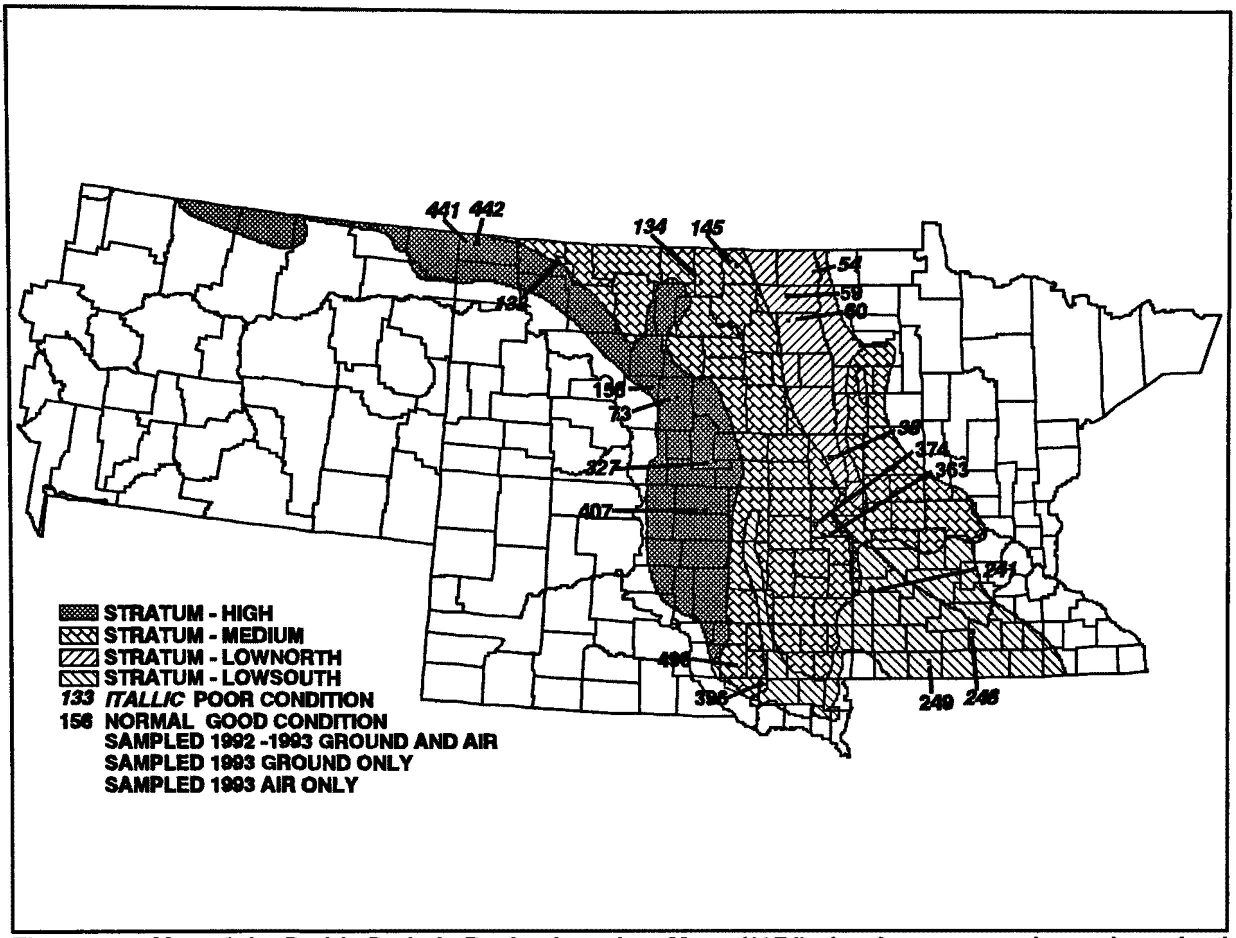

Figure 1-1. Map of the Prairie Pothole Region based on Mann (1974) showing strata and sample wetland plots used in a pilot study of indicators of wetland condition.

The ecological importance of the area and the stress on the system resulting from agriculture caused EPA to select it as one of the first areas for developing and evaluating ecological indicators of wetland condition. Condition is defined here as the wetland state relative to the set of wetland values defined in Section 1.3, below.

1.3 INDICATORS OF CONDITION

The condition of an ecosystem must be monitored relative to some reference. The process is similar to that of monitoring certain parameters of body function on an individual and comparing these measures to established norms for a healthy individual (Schaeffer et al. 1988). A variety of values is associated with PPR wetlands. However, some of these values stand out as more significant than others, based on the expert opinion of regional wetlands experts. Peterson (1994) and Rosen et al. (1995) reported that the most significant values, among many, for the PPR were as follows:

Biological Integrity. The sustainability of a balanced, integrative, adaptive community of organisms having a species composition, diversity, habitat and functional organization comparable to that of natural wetlands in the region (adapted from Karr and Dudley 1981).

Harvestable productivity. The quantity and/or quality of any service or product that wetlands provide society (e,g., wildlife, recreation, and food production).

Water Quality Improvement. The ability of wetlands to assimilate nutrients, trap sediments, or otherwise reduce downstream pollutant loads.

Flood Attenuation. The ability of wetlands to temporarily intercept and store surface water runoff, thus changing sharp runoff peaks to slower discharge over longer periods of time (Mitch and Gosselink 1986).

Peterson (1994) argued that the biological integrity value, more than any other, best defines the reality of a reference condition, since it requires that sample site conditions be compared with those of least impacted wetlands in the region. Also, because of this requirement, biological integrity represents a set of conditions more basic and less disturbed by human activity, compared to the other three values. Indeed, the other three values are nearly always managed for improvement. We recognize that few if any undisturbed wetlands, and thus true reference conditions, exist in the PPR. Thus determination of reference conditions is dependent on our ability to select meaningful ecological indicators and measure them over the range of their existing conditions, assuming that those of highest quality represent a reasonable reference condition. Another approach is to select a biased sample of "good-" and "poor-" condition sites based on our preconceived notion that certain readily identified factors (agricultural practices) contribute to the degradation or enhancement of wetland conditions. Ecological indicators capable of discriminating between the good- and poor-conditions should be useful not only in describing reference conditions (good sites), but also the range of conditions that might be encountered if probability sampling of the entire region were conducted. With the second approach, condition could be determined as a cumulative distribution function for an indicator or group of indicators as described by Overton et al. (1990).

For this pilot study, we chose to designate good- and poor-condition sites (defined in terms of cropland as explained in Sections 2.2 and 2.3). Ecological condition indicators were selected relative to their ability to address the values above (biological integrity, harvestable productivity, water quality improvement, and flood attenuation). Selected indicators are shown in Table 1-1. Indicators were then tested for variance and for their ability to discriminate between our predefined extremes in condition (good and poor). The idea behind this approach, besides being dictated by budget level, was that indicators incapable of distinguishing between good and poor extreme conditions would be of little use in distinguishing among several intermediate conditions likely to be encountered when probability sampling accessed the full range of conditions. Thus, while the good/poor landscape condition evaluation approach for indicators was taken in the pilot project, it was with the idea of refining the list of indicators for use over the entire range of wetland conditions that might be encountered in the PPR. The pilot study was designed both to begin setting the frame of reference for ecosystem condition and to select a meaningful and practical set of indicators to be used during probability sampling. The rationale and approach to the pilot is more completely described in Section 1.4, below.

1.4 RATIONALE FOR THE PILOT STUDY

The purpose of the pilot study was to select and evaluate indicators that would be robust enough to eventually describe wetland conditions for a large region (all of the PPR or a State) using a probability sampling design. The process involved three steps: (1) consultation with experts on the PPR to decide on a preliminary list of potential indicators, (2) refinement of that list to bring it in line with budgetary and logistic constraints, and (3) field studies designed to determine whether the selected indicators do differ for sites that are highly disturbed (those with a high ratio of cropland to upland) and sites that are not (having a low ratio of cropland to upland). An indicator incapable of distinguishing extremes of condition would be of little use in attempting to distinguish less extreme conditions likely to be encountered during probability sampling. The site selection process for this pilot study is different from the methodology that eventually will be used to characterize condition of the entire region for probability sampling because the test sites in this study were hand-picked based on the ratio of cropland to upland definition above. Thus, no estimates for the population of all wetlands in the region can be made from the data contained in this report.

Probability sampling, on the other hand, draws samples randomly from the universe of wetland basins in the region and can be used to extrapolate wetland condition estimates for the entire region. Another advantage of probability sampling is that it can also can provide confidence limits for the condition estimates. Because probability sampling is expected to encounter every condition imaginable, however, it is critical that we understand how any particular condition indicator performs under the best and worse of conditions.

Table 1-1. **Physical, chemical and biological indicators of wetland condition identified for evaluation during the 1992 and 1993 field seasons in the Prairie Pothole Region of the United States.**

Category	Indicator
Physical Landscape	Wetland basin density
	Area of wetland
	Shoreline development indices
	Drained wetland basins
	Lengths of drainage ditches
	Percent of wetland basins containing water
	Percent of wetland area covered by water
	Seasonal change index by wetland class
	Change in area index by wetland class
	Area of upland habitat class
	Area of cropland by landscape class
	Exposed soil subject to erosion
Soil/Sediment	Soil class
	Nitrate-nitrogen content
	Phosphorus content
	Organic matter
	Conductivity
	Salinity
	pH
	Particle size
Water Chemistry[a]	
Biological Indicators	
Invertebrates	Taxon richness
	Biomass
	Abundance
	Sedimentation
Amphibians	Salamander acute stress
Waterfowl	Duck counts
Plant Community Indicators	Number of community areas by wetland zone
	Wetland zone types (%)
	Land use types abutting wetland (%)
	Watershed cover in annuals and perennials (%)
	Standing dead vegetation by zone (%)
	Litter depth by zone
	Unvegetated bottom in plant community (%)
	Total plant taxa by richness and zone

[a] Dropped midway through 1992 due to severe drought, i.e., little if any water to sample in many wetlands.

EPA convened a meeting of scientists and managers experienced in prairie wetland ecosystems at the United States Geological Survey's Northern Prairie Science Center in July 1991. Individuals attending the meeting are listed in Appendix 1-1. The meeting had four objectives

1. to review what is known about the ecology of the prairie wetlands and the research and monitoring efforts currently being conducted

2. to discuss Federal research programs designed for the prairie potholes

3. to identify areas of cooperation

4. to initiate a process to refine an approach for monitoring the condition of the northern prairie wetlands.

The meeting resulted in agreement on two underlying characteristics of prairie potholes, critical to planning an effective monitoring program. First, climate of the region cycles between extremes from wet to dry and is the primary factor determining the characteristics of prairie potholes. Therefore, a program for research and monitoring must be long-term to address this type of temporal variation. Second, wetlands within the prairie pothole region show great spatial variation in climate, geology, hydrology, fauna, and land use.

This study evaluates the performance of selected wetland condition indicators by measuring their responses at good- and poor-condition sites as described above (ratio of cropland to upland). Our indicators of condition are strongly correlated with landform. We use ecoregions based on landform to help overcome the confounding effect of landform. Previous studies have used ecoregions based on landform to account for spatial variation (e.g., Lake Agassiz Plain, Drift Plain, Missouri Coteau; see Stewart 1975). A primary sampling unit must be large enough to represent the wetland basin sizes and hydrologic functions occurring in that unit. At this meeting, we listed drainage, sedimentation, altered hydrology, proximity to cropping, effects of herbicides, pesticides, and fertilizers, burning, human disturbance, and livestock as the principle stressors of prairie wetlands. Therefore, we assumed that intensive agriculture degrades wetland condition, and wetlands in relatively undisturbed areas are functionally in better condition than those in areas of intensive agriculture. Because of the dynamic and cyclic nature of the prairie pothole system, definition of condition and measurement of changes or trends in condition is more difficult than in other, more predictable, wetland systems and will require sampling over a long period of time.

A preliminary list of potential indicators of condition included land use, percent of wetland basins containing water each year, water chemistry, community composition and abundance of vegetation, sedimentation rate, and macroinvertebrates. The meeting attendees agreed that final selection of a list of potential indicators would require further evaluation, because no robust data sets representing statistically defined variability of indicator response over a wide range of conditions existed for the region.

A second meeting was held at NPSC in September 1991 between EMAP and NPWRC administrators and potential principal investigators (Appendix 1-2). It resulted in a refined list of indicators to be tested in the pilot study. The list was constrained both by practicality of making certain measurements during the narrow time frame of a 2-year pilot study and by availability of funds and personnel. The list included landscape indicators, hydrology, sediment characteristics, vegetation composition and abundance, faunal composition and abundance, water and soil chemistry, chemical contaminants, and stressor information. Further refinement of the list of indicators occurred during development of a plan of work. For example, chemical contaminants were dropped because of the cost of analysis even though their importance as an indicator of condition was stressed at both planning meetings. Other indicators such as shorebird populations proved impractical because of time, personnel and funding constraints. After the first year of the study it became obvious that any indicator that required water quality measurements such as electrical conductance, pH, and chlorophyll as well as faunal measurements such as number of amphibians were impractical because the vast majority of the wetland basins were dry. These indicators were dropped as detailed in the individual studies that follow. A final list of indicators for the pilot study was listed by Dwire (1994).

1.5 OBJECTIVES OF PILOT STUDY

The functions of individual prairie potholes are intimately related to other potholes and to the upland matrix that contains those potholes. The pilot study, reported here, had three objectives

1. to test selected landscape and field indicators of condition by discriminating between wetlands in highly disturbed (agricultural) landscapes and those in least disturbed (grassland) landscapes across the U.S. portion of the PPR

2. to develop new indicators and refine sampling techniques for prairie potholes at a subset of the sites and reference areas

3. to identify and explore resolution of issues related to access to private land and logistics.

1.6 ORGANIZATION OF THE REPORT

This report is organized into a number of sections that represent work by individual researchers whose names appear with the section for purposes of citation. Section 2 describes the overall design for studies intended to meet Objective 1 where various studies were conducted on the same wetland basins within the same plots. Details of sampling within the basins as well as descriptions of study areas selected for testing of methodology are incorporated as appropriate in Sections 4 through 8. Section 3 deals with logistics and landowner access problems (Objective 3) encountered during sample selection and conduct of studies for plots described in Section 2. Section 4 reports on landscape level indicators where the plot rather than the wetland basin was the sampling unit. Section 5 reports on invertebrates as an indicator of wetland condition. Data were derived from newly-designed sampling devices installed in the sample wetland basins. Sections 6 and 7 report on vegetation and soils indicators that were measured on the same wetland basins and at the same time. Section 8 describes pesticide residues found in soil samples gathered during field work described in Sections 6 and 7. Section 9 reports results for tests of techniques (Objective 2) developed for use in measuring indicators of condition. For logistical and design reasons, this work was conducted at 18 sites in Stutsman County, ND, most of which were in Waterfowl Production Areas so that access would not be a problem, rather than at the pilot study sites described in Section 2. Section 10 makes general recommendations to EPA and summarizes results for the various indicators tested during the pilot. Section 11 summarizes costs of the pilot study for possible use in planning future work.

Section 2.0
DESIGN METHODS

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The studies designed to accomplish Objective 1 (see Section 1.1) for the test of indicators of wetland condition for the Prairie Pothole Wetlands described in Sections 4 through 8 of this report shared a common sampling plan, which is described below.

2.1 REGIONALIZATION

Prairie wetlands vary by geographic region. To minimize the confounding effect of regional differences on our comparison of landscapes that are highly disturbed from those that are not, we stratified the Prairie Pothole Region (PPR) into four ecoregions of high, medium, and low wetland basin density based on Mann's (1974) map (Fig. 1-1). The high-density ecoregion is approximately equivalent to the Missouri Coteau, a large morainal belt trending northwest to southeast and characterized by collapsed hummocky topography "dead-ice moraine" (Bluemle 1991). The medium-density ecoregion is approximately equivalent to the drift plain, an area of glacial drift with less relief lying east of the Missouri Coteau. We divided the low-density region into north and south regions. The Low-North ecoregion represented the Red River Valley, which is composed of the bed of glacial Lake Agassiz. The Low-South ecoregion is similar to the medium region except that most of the wetlands have already been drained.

2.2 STUDY PLOTS

There was strong consensus at the planning meetings that assessing the condition of prairie wetlands would require an assessment of both wetland complexes and the uplands that surrounded them. Unfortunately, there was no usable definition of what constituted a complex. During the second planning meeting the attendees decided that all wetlands within a 40-km^2 hexagon sampling unit (or "hexagons") as defined by EPA (Overton et al. 1990) could serve as a wetland complex. Experts attending the meeting on the PPR were also unable to define wetland condition, but they did agree that wetlands in a complex containing predominantly cropland would probably be in a more degraded state than those containing predominantly grassland. Therefore, we proposed the ratio of cropland area to total upland area in each hexagon as a proxy for wetland condition and decided to evaluate indicators by their ability to distinguish between wetlands at the extremes of that proxy.

To develop the ratio, we needed a list of wetland basins (e.g., Stewart and Kantrud 1971) in each basin class from which to draw sample sites as well as estimates of the area of upland land covers for determining the cropland/upland ratio. No such data existed for EMAP 40-km^2 hexagons, although they were needed immediately to prepare study plans and begin field work in the spring of 1992. Therefore, we decided to use an existing sample of 10.4-km^2 (4-mi^2) plots rather than the 40-km^2 hexagons. A large sample of these plots (422) had previously been selected to furnish data for a mallard simulation model (Cowardin et al. 1988). This was acceptable because our primary purpose was to evaluate indicators of condition, not to make statements about the population of wetlands in the region. Wetlands on each 10.4-km^2 plot were mapped according to the classification of Cowardin et al. (1979), and uplands were mapped according to a simplified classification that included grassland and cropland (Cowardin et al. 1988). All map data had been digitized into the Map Overlay and Statistical System (MOSS) and Statistical Analysis System (SAS) files that described all polygons on the maps that had been prepared (Cowardin et al. 1988). Detailed procedures used in processing of National Wetlands Inventory (NWI) data are described in section 3.2.1.

2.3 METHOD OF SELECTING PLOTS TO REPRESENT EXTREMES IN CONDITION (CROPLAND/UPLAND RATIO)

Our intent was to select plots with a maximum spread between those that contained mostly cropland (poor-condition) and those with mostly non-cropland (good-condition). For each available plot, we calculated the ratio of area of cropland to the total area of upland. The smallest ratio represented the most grassland and the largest ratio the most cropland. Next the plots were sorted by the ratio within ecoregion. We then selected four plots in each ecoregion, the two with the highest ratio of cropland (poor-condition) and the two with the lowest ratio of cropland (good-condition). Our sample size was constrained by funding level rather than statistical considerations. We also constrained plot selection by the following rule: Each pair of plots (the one with the lowest cropland ratio and the one with the highest cropland ratio) must contain at least two temporary, two seasonal, and two semipermanent wetland basins. This selection process maintained separation between high- and low-cropland ratio landscapes in all ecoregions except the Low-North where there were few available plots and few semipermanent wetland basins. In that region it was not possible to maintain a meaningful separation, and the requirement for having semipermanent wetland basins was dropped. The final selection process resulted in the original 16 plots (Table 2-1).

Table 2-1. Original 16 10.4-km^2 plot and wetland basins (see Section 2.4) used in a pilot study of indicators of condition of wetland basins in the Prairie Pothole Region of the United States. All plots were used for landscape variables in 1992 and 1993. Plots in Low-North and Low-South were dropped from the sample for all ground measurements in 1993.

Wetland Density Region	Condition	Plot	Basin Class	Wetland Basin
Low North	Poor	38	Temporary	44
	Poor	38	Seasonal	62[a]
	Poor	54	Temporary	39
	Poor	54	Seasonal	24[a]
	Good	59	Temporary	42
	Good	59	Seasonal	111
	Good	60	Temporary	128
	Good	60	Seasonal	58
Low South	Poor	246	Temporary	34
	Poor	246	Temporary	37
	Poor	246	Seasonal	52[a]
	Poor	246	Semipermanent	53
	Poor	241	Seasonal	48
	Poor	241	Semipermanent	3
	Good	249	Temporary	50
	Good	249	Seasonal	72
	Good	249	Seasonal	86
	Good	396	Temporary	107
	Good	396	Semipermanent	106
	Good	396	Semipermanent	130
Medium	Poor	134	Temporary	270
	Poor	134	Temporary	432
	Poor	134	Seasonal	158[b]
	Poor	134	Seasonal	406
	Poor	134	Semipermanent	140
	Poor	134	Semipermanent	165[b]
	Poor	145	--	--

Table 2-1. (continued)

Wetland Density Region	Condition	Plot	Basin Class	Wetland Basin
	Good	363	Temporary	58
	Good	363	Semipermanent	22
	Good	374	Temporary	65
	Good	374	Seasonal	225
	Good	374	Seasonal	272
	Good	374	Semipermanent	100
High	Poor	441	--	--
	Poor	442	Temporary	260
	Poor	442	Temporary	261
	Poor	442	Seasonal	93
	Poor	442	Seasonal	281
	Poor	442	Semipermanent	295
	Poor	442	Semipermanent	301
	Good	73	Temporary	86
	Good	73	Semipermanent	29
	Good	156	Temporary	26
	Good	156	Seasonal	24
	Good	156	Seasonal	42
	Good	156	Semipermanent	22

[a]Permission for access to these plots was rescinded.

[b]Replaced wetland basin 272, which was drained during the study.

[c]Replaced wetland basin 193 for which permission was denied prior to field work.

Changes to this sample design became necessary when we were refused access to certain wetland basins by some landowners. When refusal resulted in inability to obtain samples from the two wetland basins in each class of wetland basins in each extreme pair of plots, we selected the next most extreme plot, resampled wetland basins and again contacted landowners. The process was repeated until the sample was complete and our original constraint was met. We refer to a pair of good- or poor-condition plots within an ecoregion (e.g. Low-North) as a *stratum.* The sample was further altered at the end of the 1992 field season because drought and access denials resulted in almost no data from the low wetland-density strata. Those strata were dropped from the sample and we selected two new samples from the high and the medium wetland-density strata (Table 2-2).

Table 2-2. New 10.4-km² plots and wetland basins (see Section 2.4) selected in 1993 for a pilot study of indicators of condition of wetland basins in the Prairie Pothole Region of the Unites States.

Wetland Density Region	Condition	Plot	Basin Class	Wetland Basin
Medium	Poor	133	Temporary	370[a]
	Poor	133	Seasonal	386
	Poor	133	Semipermanent	380
	Good	498	Temporary	227[b]
	Good	498	Seasonal	277
	Good	498	Semipermanent	146
High	Poor	327	Temporary	72
	Poor	327	Seasonal	147
	Poor	327	Semipermanent	117
	Good	407	Temporary	109
	Good	407	Seasonal	67
	Good	407	Semipermanent	168

[a]Replaced wetland basin 27 because permission was rescinded.

[b]Replaced wetland 227 which was an error in NWI data.

2.4 SELECTION OF SAMPLE WETLAND BASINS WITHIN PLOTS

We classified the wetland basins (Cowardin 1982) using a modification of Stewart and Kantrud's (1971) classification.

We first grouped all wetland polygons (mapping units, Cowardin et al. 1988) classified in the data set according to Cowardin et al. (1979) into basins. The polygon with the most permanent water regime was then used to determine the Stewart and Kantrud (1971) pond class (equivalent to wetland basin) for the group of polygons included in the basin.

Each wetland basin, in each wetland basin class (i.e., temporary, seasonal, semipermanent), in each ecoregion was assigned a random number. A sorted list of these random numbers was prepared for the pairs of plots representing good- and poor-condition. The top two wetlands in each wetland basin class were selected with the following constraints:

1. **Reject all wetlands mapped as linear or point features.** When the maps were constructed, those wetlands that were too narrow or too small to enclose with a polygon were mapped as linear or point features. The linear wetlands were almost all ditches used to drain wetland basins in agricultural fields. Point wetlands were almost all dugouts constructed for watering stock. EPA did not wish to include these highly artificial entities in an evaluation of indicators of condition.

2. **Reject all wetland basins containing a dugout.** These wetlands, though mapped as polygons, were also highly abnormal.

3. **Reject all basins containing lacustrine wetland.** These lakes are highly variable and would require increases in sample size to avoid confounding a comparison of wetland condition. Furthermore, nearly all of them appear on 1:100,000 USGS quadrangle maps and will be included in EMAP's lake surveys.

4. **Reject all temporary and seasonal wetlands that are not completely within the plot boundary.** Although, this procedure biases the selection procedure, it was unavoidable because we had no data outside the plot boundary. For multi-polygon basins it was not possible to classify the basin. We included portions of semipermanent basins that were partly within the plot because the basin class was known by default and exclusion would bias the sample against large basins. For the purpose of the pilot, bias in selection of the study basins is not as important as assuring that they will satisfy the objectives of the pilot and EMAP.

5. **Reject wetland basins in good-condition plots if the basin is surrounded by cropland.** Cropland does occur on plots that have the best condition available. At a landscape scale these plots may be adequate, but a site-specific wetland basin surrounded by cropland does not furnish a good comparison to a similar wetland basin in a poor-condition plot.

6. **Reject wetland basins in poor-condition plots if the basin is surrounded by upland other than cropland.** This is the corollary of criterion 5.

2.5 SELECTION OF REPLACEMENT WETLAND BASINS AND PLOTS

After selection of plots and wetland basins, each landowner was contacted to obtain permission to enter land for sampling (see Fellows and Buhl 1995 for details). If we were refused permission, that wetland basin was dropped from the sample and the next wetland basin of the same class was obtained from the list of basins that had been sorted by random number. We repeated the process until we were granted access to the land. When rejection of access resulted in no available wetland basins of the proper class required to meet our plot selection criteria, we were forced to reject the entire plot and draw the next plot from the list of plots that had been ranked by cropland/upland ratio. The problem of rejection continued into the field season, when some landowners rescinded permission. In these cases we sometimes had already gathered part of the data for the plot. When this happened, the remainder of the data were gathered from the nearest available wetland basin of the same class. The problem caused data for different indicators to be collected at different sites in a few cases.

2.6 REASSIGNMENT OF WETLAND BASIN CONDITION

When field work was started, the only data available for assignment of condition to individual wetland basins were from old aerial photographs for the plots. The condition definition for the individual basins used in the vegetation and soil studies was taken directly from the definition for the plot that contained them. In some cases this definition proved misleading as evidenced by data gathered during the studies. There were three reasons for this

1. classification errors in the data from the original 422 plots used in the selection process

2. major landscape changes that occurred since the original photographs were taken, the most important being addition of Conservation Reserve Program (CRP) cover

3. individual wetland basin condition that was more closely related to the uplands in the surrounding drainage basin than the condition of uplands on the entire plot.

For purposes of analysis, we decided to reassign wetland basin condition, because we now had current data on uplands and a delineation of drainage basins of the sample wetland basins (based on aerial/video and field data, see Section 4.2.1). The new assignment was based on the cropland/upland ratio for the individual sample wetland basins (Table 2-3). For analysis of vegetation data, CRP cover was not treated as cropland because the new cover is more like grassland than the tilled soil of cropland. For analysis of soils data, CRP cover was treated as cropland because the soil parameters measured were mostly the result of runoff into the basin prior to establishment of the CRP cover.

Table 2-3. Cropland/upland ratios for 10.4-km² plots and for drainage basins of individual sample wetland basins used as a proxy for wetland condition.

Plot number	Wetland Basin number	Plot C/U ratio	Basin C/U ratio
038	62	0.94639	0.78094
054	39	0.96792	1.00000
059	111	0.54032	0.00000
059	42	0.54032	0.79960
060	128	0.48379	0.00000
060	58	0.48379	0.00000
073	29	0.00000	0.00000
073	86	0.00000	0.00000
133	370	0.94953	1.00000
133	380	0.94953	0.87061
133	386	0.94953	0.42945
134	140	0.89629	1.00000
134	158	0.89629	1.00000
134	165	0.89629	1.00000
134	270	0.89629	1.00000
134	272	0.89629	1.00000
134	406	0.89629	1.00000
134	432	0.89629	1.00000
145		0.96662	0.00000

Table 2-3. (Continued)

Plot number	Wetland Basin number	Plot C/U ratio	Basin C/U ratio
156	22	0.00000	0.00000
156	24	0.00000	0.00000
156	26	0.00000	0.00000
156	42	0.00000	0.00000
241	3	0.84595	0.98456
241	48	0.84595	1.00000
246	34	0.92392	1.00000
246	37	0.92392	1.00000
246	53	0.92392	0.85218
249	50	0.75344	0.01821
249	86	0.75344	0.35356
327	117	0.88660	1.00000
327	147	0.88660	1.00000
327	72	0.88660	1.00000
363	22	0.04516	0.00000
363	58	0.04516	0.00000
374	100	0.04112	0.00000
374	225	0.04112	0.00000
374	272	0.04112	0.00000
374	65	0.04112	0.00000
396	106	0.56793	0.00000
396	107	0.56793	0.00000
396	130	0.56793	0.35792
407	109	0.03637	0.00000
407	168	0.03637	0.04200
407	67	0.03637	0.00000
441		0.96483	0.00000
442	260	0.87462	1.00000
442	261	0.87462	1.00000
442	281	0.87462	1.00000
442	295	0.87462	0.00000
442	301	0.87462	0.96514[a]
442	93	0.87462	0.17024
442	93	0.87462	0.00000
498	146	0.10995	0.00000
498	227	0.10995	0.00000
498	277	0.10995	0.00000

[a]Plot contained CRP cover which was treated as Grassland for the Soils study, resulting in a ratio of 0.21879.

Section 3.0
ACCESS TO PRIVATE LAND AND LOGISTICS

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Problems of access to private land are of critical importance in future planning for EMAP-wetlands in the PPR. The same types of problems must be dealt with by other agencies like the National Biological Service, which might be attempting to gather statistically valid ecological survey data. Because of the immediacy and breath of this problem we submitted the results from this access study to the journal *Wetlands*, and it has been published (Fellows and Buhl 1995). The following summarizes the *Wetlands* article.

3.1 RESEARCH ACCESS TO PRIVATELY OWNED WETLAND BASINS IN THE PRAIRIE POTHOLE REGION OF THE UNITED STATES

We attempted to obtain access for research to 81 wetland basins on 69 farms in 4 zones of the Prairie Pothole Region of North Dakota, South Dakota, and Minnesota. We were permitted access to 54% of the farms in areas where land was intensively cropped and 87% of farms in areas of low cropping intensity. On average, we had to contact 1.35 operators and conduct 1.70 interviews for each successful decision.

Blanket access was not usually given--on 77% of the farms cooperators placed at least one restriction on access. The most common restrictions were walking access only or notification before nighttime work. No cooperators were willing to sign written access agreements.

The cost of obtaining access averaged $265/farm in wages and travel expenses.

3.2 IMPLICATIONS FOR FUTURE PROJECTS

In addition to the cost and time required to gain access, there were two other problems that have broad implications for the type of research we intended to pursue. First, we were unable to assure permanent access to sites. Operators rescinded access to four farms and drained three wetland basins during the first year; six of the seven sites lost were in the intensively cropped portion of a low-wetland-density zone. The difficulty of obtaining and retaining research access to privately owned wetland basins in intensively cropped areas may be related to landowner attitudes towards wetlands. We hypothesize that farmers with crops on proposed sites are distrustful of our purposes, suspecting that we may find conditions that would lead to further regulation. To solve this problem, researchers may have to rely on remote sensing or consider payment for access to secure representative research sites in such areas.

The second problem stems from changes in the law governing research projects like the Pilot Test of Indicators of Wetland Condition for Prairie Pothole Regions. In 1993, most biological research functions in the Department of Interior were consolidated into the newly formed National Biological Service (NBS). Congress has now made it mandatory that NBS obtain written permission for access from the property owner. In our pilot study, no farm operators or owners were willing to give written permission despite our offer of a form that they could annotate to include any restrictions they desired. The pilot test was initiated before the requirement for written access, thus it was not affected by the operator/owners denial of written permission. However, this does appear to be a potential problem for future surveys. Unwillingness of cooperators to sign access agreements may jeopardize research by the newly formed NBS and other resource management agencies.

Section 4.0
TESTS OF SELECTED LANDSCAPE INDICATORS OF WETLAND CONDITION

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Prairie wetlands are interrelated both in their function and in their values. In addition, their functions and values are dependent on the surrounding uplands. An evaluation of wetland condition, therefore, must be at the landscape as well as the individual basin level. Landscape indicators are those that refer to an entire wetland complex and its surrounding uplands. The indicators described here are applied at the level of primary sampling units (the 10.4-km^2 plots used in the pilot as a substitute for 40-km^2 hexagons). We describe three different types of indicators: (1) landscape features that are relatively stable, such as the number of wetland basins; (2) landscape features that vary temporally, such as the amount of surface water in wetland basins; and (3) numbers of birds that are not confined to a wetland basin and that use wetlands and uplands throughout the landscape.

This study had two goals: to furnish the data essential to monitoring the condition of the integrated prairie wetland landscape and to characterize the landscape features essential to understanding and interpreting the basin-by-basin evaluations conducted for other indicators incorporated in the pilot. In addition, this chapter evaluates various landscape-level indicators of condition with regard to EMAP's long-term need for indicators that can be measured at numerous sites with minimal cost and that discriminate between wetland systems in good- and poor-condition.

Landscape level variables can be measured at a variety of scales including continental, regional, local, and site specific. In most cases data for measuring landscape variables are most easily derived from remote sensing. The resolution of remote sensing data can be matched to the appropriate scale. For example at the continental scale Advanced Very High Resolution Radiometer (AVHRR) data with a resolution of 1 km may be adequate (Loveland et al. 1991). At the regional scale Thematic Mapper (TM) data have been effectively used for assessing wetland characteristics (Koeln et al. 1986). This study required landscape variables at a local scale and because of the small size of prairie potholes, at high resolution. In addition, data were required in narrow time frames which frequently can not be obtained from satellite data. Two data sources filled these needs. Mapping techniques developed by the National Wetland Inventory (NWI) furnish the resolution and spatial accuracy required for this study (Pywell and Niedzweadek 1980). Aerial video techniques (Cowardin et al. 1979, Sidle and Ziewitz 1990) furnish both the resolution and temporal requirements. Equipment and software for the latter technique was in place at Northern Prairie Science Center and data sets created from previous work were available for immediate use.

The abundance and distribution of vertebrate animal populations furnish a measure of landscape condition for those animals that are not confined to a single wetland basin. During planning meetings a number of species were considered as possible candidates for measurement. Counts or indices to species abundance conducted throughout the entire area of each sample plot would be time consuming and expensive. For purposes of the pilot, we elected to use estimates of breeding population of five species of dabbling ducks (mallard, *Anas platyrhynchos*; gadwall, *Anas strepera*; blue-winged teal, *Anas discors*; northern shoveler, *Anas clypeata*; and northern pintail, *Anas acuta*). Population estimates for these species are made each year on each 10.4-km^2 plot by the USFWS and were available for use at no cost.

Some of the measurements and preparatory work required only one visit to a site. The tasks requiring one visit include the original mapping of the study plots and the determination of the watersheds for sample wetlands within the plots. One-time measurements requiring an appreciable initial effort are justified by the objectives of EMAP-Wetlands to "Quantify the regional status of wetlands, ..." (see Leibowitz et al. 1991:2). Although there was a cost to the project for this preparatory work, such costs would not be on an annual basis once the actual EMAP monitoring is in place.

Landscape level measurements that were unlikely to show a difference between good- and poor-condition environments during the short span of the pilot study were excluded from the pilot study. For example, total loss of wetlands through drainage must be measured during the long-term monitoring of EMAP, but the drainage rate is probably so low that it is not measurable in a two-year study. This pilot study was intended to test the technology that is practical and to demonstrate landscape-level indicators that may separate good- and poor-condition environments in any year.

4.1 OBJECTIVES

1. Compare the spatial distribution, density, area, and characteristics of wetlands and uplands between landscapes with high and low abundance of cropland

2. Determine the seasonal loss of surface water in temporary, seasonal, and semipermanent wetland basins from April through July and compare these rates between landscapes with high and low abundance of cropland

3. Determine the extent, type, and distribution of both wetland and upland plant communities and to relate these variables to indicators of wetland condition measured in other sections of this report

4. Compare the size of breeding populations of 5 species of dabbling ducks using 10.4-km^2 plots in high and low cropland landscapes and to relate these estimates to landscape habitat variables including wetland distribution, upland habitat classes, and size and juxtaposition of cover patches

5. Map the watershed of each wetland basin selected for ground study to relate sedimentation rates to land use and management in support of soils investigations.

4.2 METHODS

4.2.1 Base Mapping of 10.4-km^2 Plots.

The 10.4-km^2 plot data were derived from 1:63,360 color-infrared photographs taken during the late 1970s and early 1980s (Table 4-1) prior to completion of operational mapping by the National Wetland Inventory (NWI). After plot selection, the data for the selected plots were updated and a number of topological and classification errors were corrected (Fig. 4-1). One plot (134) had areas where data were missing. Data for these areas were added by scanning current NWI maps and adding vectors to the plot data. Wetlands were classified according to Cowardin et al. (1979) and upland classification was after Cowardin et al. (1988). Some road linears had topological errors and were discontinuous or had missing data. These errors were corrected prior to buffering. Three files containing polygon buffered lines and points for wetland features and lines for non-wetland features were delivered to NPWRC in MOSS format by NWI.

A number of processing steps were used to create a vector map file for each plot representing current (1993) conditions. The MOSS data were imported into MIPS and *.RVF files were created for

Table 4-1. **Mission numbers and dates of photography for photographs used by the National Wetland Inventory for mapping 4-mi² plots used in the EMAP pilot study.**

Plot	Mission	Date
38	82-062	04-22-82
54	79-068	06-04-79
59	79-068	06-04-79
60	79-068	06-04-79
73	79-057	05-16-79
133	81-046	04-05-81
134	81-046	04-05-81
145	79-068	06-04-79
156	79-057	05-16-79
241	80-046	05-02-80
246	80-046	05-02-80
249	80-049	05-06-80
327	79-056	05-15-79
363	82-061	04-20-82
374	82-061	04-20-82
396	M2959	unknown
407	82-062	04-22-82
441	80-046	05-02-80
442	81-046	04-05-81
498	H456	

each plot. Roads and some areas classed as odd areas were mapped as linears by the NWI. For our purposes all features in the data set had to have an area. Polygons were created by buffering points and linear features. The NWI buffered odd areas and wetland features prior to delivering vector files to NPWRC but did not buffer roads. We double buffered road linears to create area for the road surface and for the right-of-way.

Photographs and video gathered during the pilot study showed wetlands that had been missed in the original mapping as well as new wetlands that had been created since the original mapping. These areas were digitized and added to the vector data for each plot. Although we were able to identify new or previously missed wetlands, we were unable to classify them. They were assigned a wetland class of UK for unknown. We also updated the upland data by adding areas that had changed from cropland to grass-legume cover planted in response to the Conservation Reserve Program (CRP).

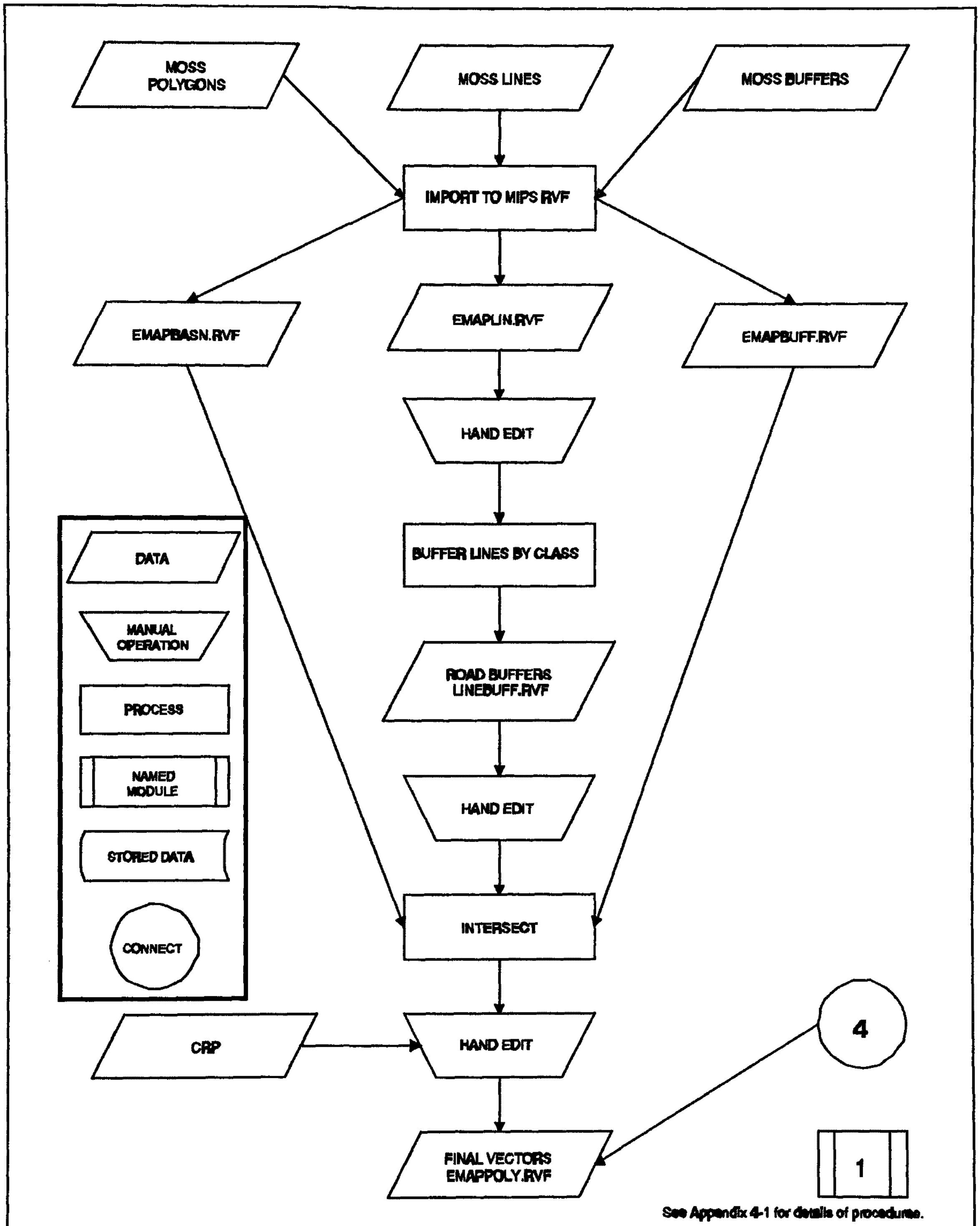

Figure 4-1. Process for deriving final vectors from polygon, line, and buffer files obtained from the National Wetland Inventory.

Data for the location and delineation of CRP cover was obtained from county offices of the Agricultural Stabilization and Conservation Service (ASCS).

The final result of these corrections and additions were 16 vector data sets, one for each of the 10.4-km^2 plots used in the pilot study (Appendix 2-2). These data sets were current in 1993 and have all features represented by polygons rather than lines and points.

4.2.2 Aerial Video

To evaluate the hydrologic function of wetland basins and as an aid to interpreting biological measures of condition, we determined change in the amount of surface water in each wetland basin. To do this we used aerial video obtained during the first week of April, May, June, and July in each year of the study. Video (VHS format) was taken from light aircraft (Cessna 185) equipped with a belly camera port. We used a Cohu 4810 monochrome camera equipped with a 8.8-mm charge-coupled detector, a 5.9-mm wide angle lens. The camera was equipped with a near infrared (0.81-0.89 μm) bandpass interference filter and a Kodak Wrattan No. 0.60 neutral density filter. The signal from the camera was recorded on a Panasonic AG-2400 portable video cassette recorder. The image was monitored in the aircraft with a Panasonic CT-500V 14-cm color monitor. Video was obtained in two 1-mile wide swaths at an elevation of approximately 1,829 m above ground level (AGL).

The video data were converted to a final raster file by the process illustrated in Fig. 4-2. The process included many processing steps incorporated in MIPS software as well as hand operations. Images representing each section (2.59 km^2) of the 10.4-km^2 plot were captured as separate *.RVF files. On some plots, weather conditions forced us to fly at lower than planned altitude, so that more than four images were required to cover an entire 10.4-km^2 plot. These raw images contained distortions caused by the attitude of the aircraft and spherical distortion of the short camera lens. We georeferenced the images by obtaining data from the final vector data for each plot and manually aligning the vector to the raster by means of features such as roads that appeared in both data sets. The raster was then resampled to remove distortions. After georeferencing and resampling the individual images for each plot, we combined them into a single raster, representing the video on each date for each plot (Fig. 4-3).

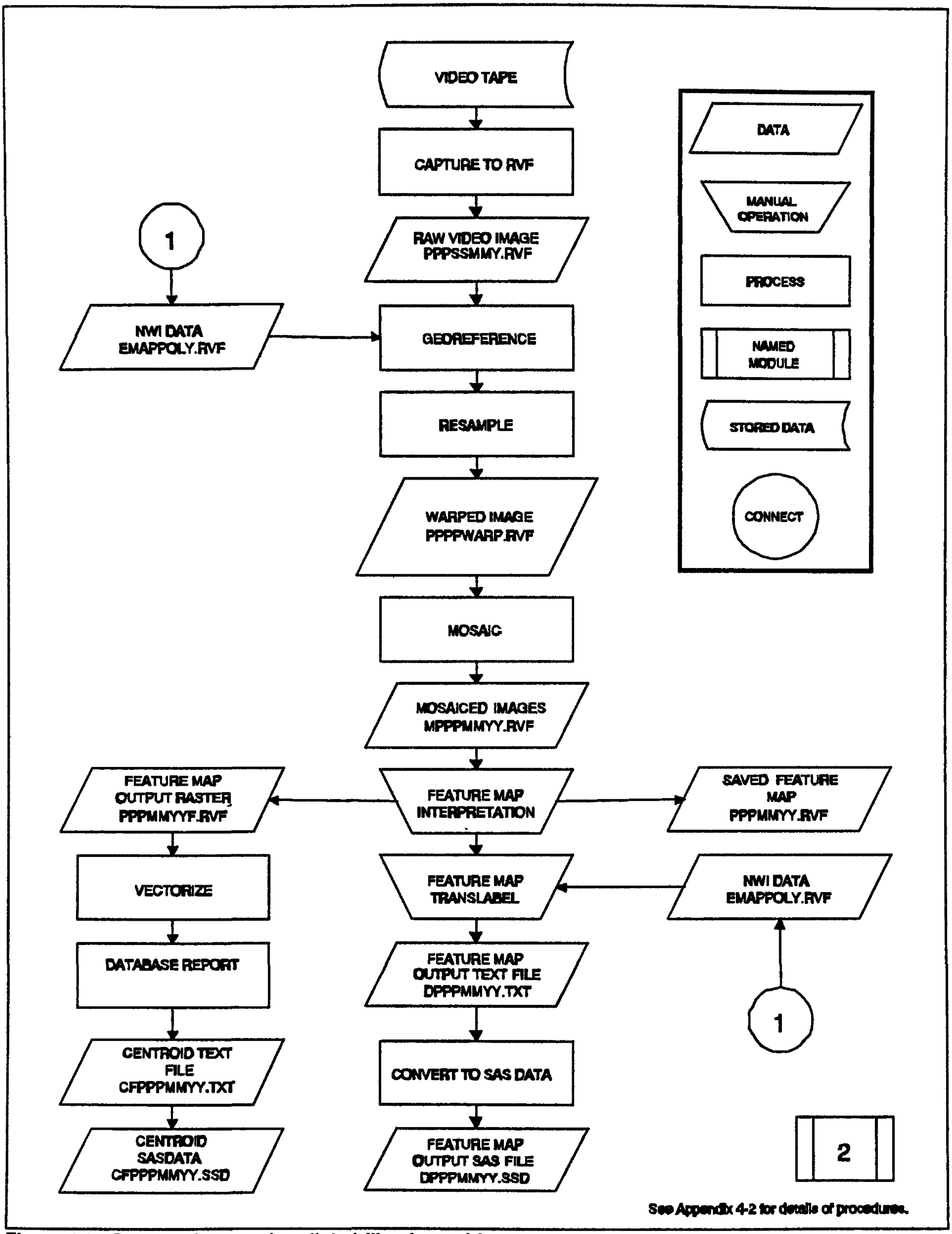

Figure 4-2. Process for creating digital files from video tape.

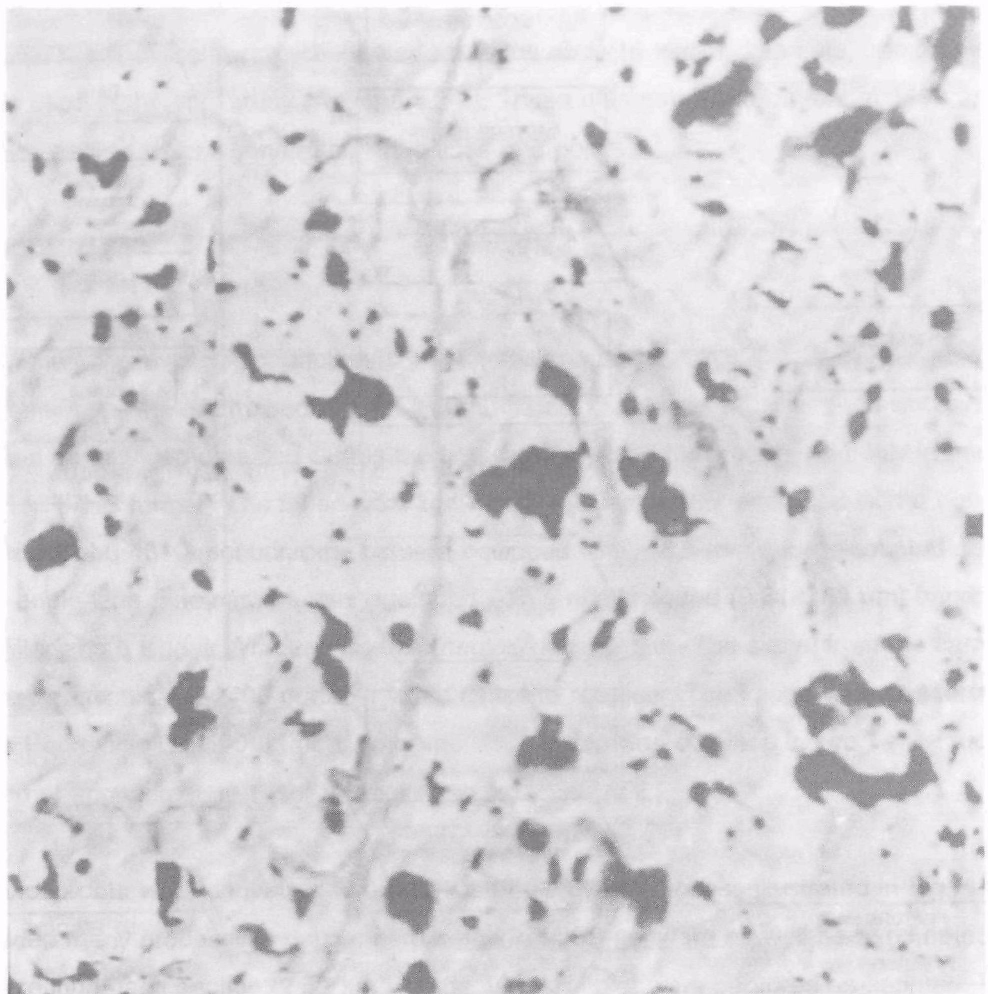

Figure 4-3. Example of final raster from video data for plot 374 after georeferencing and resampling.

These video scenes were the base data used for interpretation of the presence of water. The process was accomplished by the feature mapping procedure in MIPS. Two tasks were accomplished during feature mapping, interpretation of areas as water and transfer of attribute data from the vector files (translabeling process). At this stage we saved a raster showing the area interpreted as water. We also saved a featuremap output raster that was used for additional processing (Fig. 4-4).

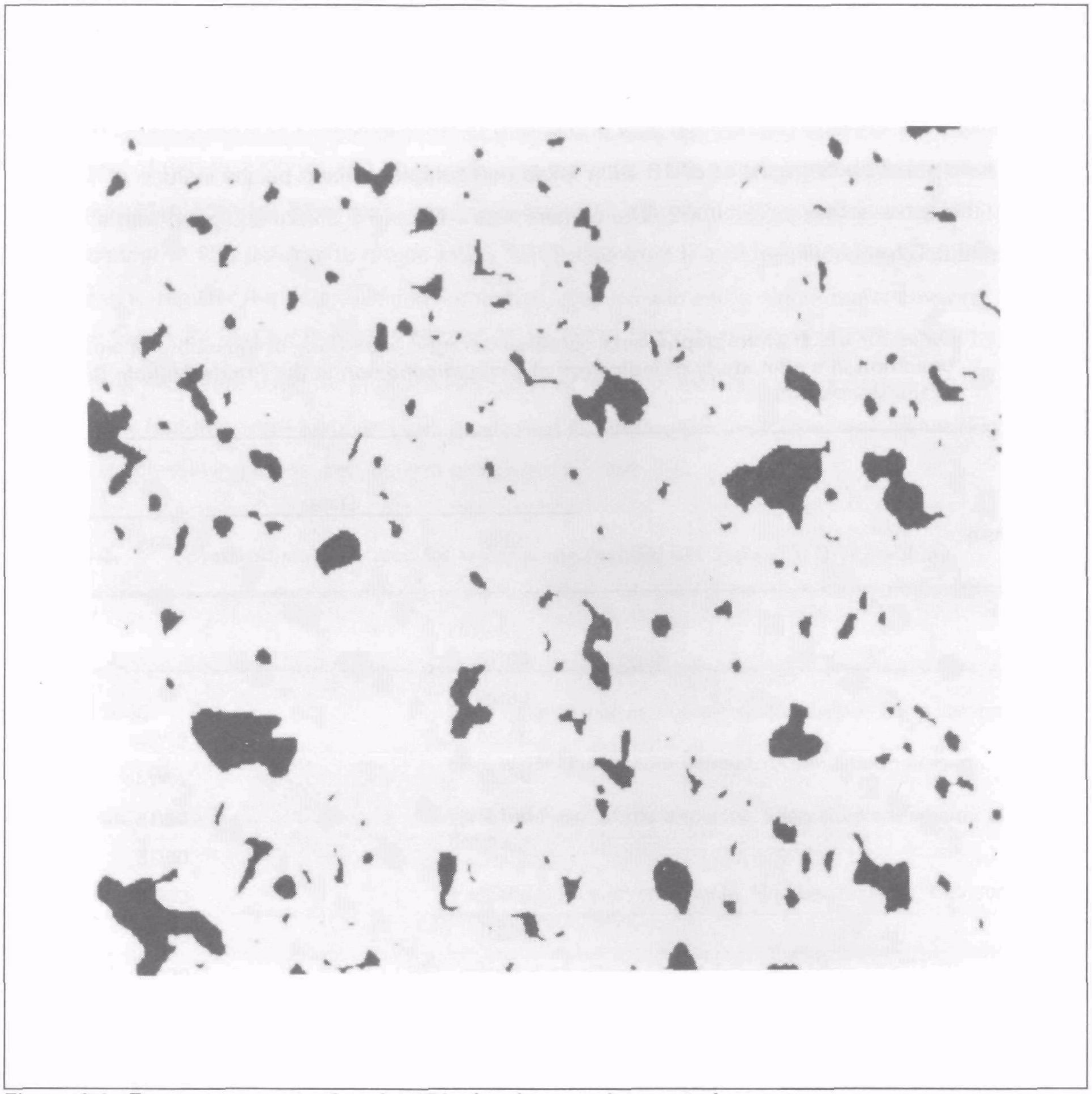

Figure 4-4. Feature map raster for plot 374, showing area interpreted as water.

Text files (ASCII) were produced by MIPS from the raster showing the feature-mapped water areas. During translabeling, the wetland basin class was transferred to all feature-mapped areas that were included in a NWI vector. Sample SAS output derived from the ASCII file is shown in Appendix 2-2.

4.2.3 Aerial Photographs

We took aerial photographs of all 10.4-km^2 plots and sample wetland basins in June of 1992 and 1993 on the dates shown in Table 4-2. The camera was a Nikon F2 35mm equipped with a Nikon 50mm lens and a Tiffen UV filter.

Table 4-2. Dates on which photographs were obtained during a pilot study of indicators of wetland condition in a pilot study of indicators of wetland condition in the Prairie Pothole Region of the United States.[a]

Wetland Basin	Dates			
	1992		1993	
038	06/18			
054	06/20			
059	06/20		07/14	
060	06/20		07/14	
073	06/18		06/18	
133			06/15	
134	06/20		06/15	
145	06/20		06/15	
156	06/18	06/23	06/18	
241	06/26			
246	07/18			
249	06/26			
327			06/10	07/20
363	06/18		06/10	07/20
374	06/18	06/26	06/10	07/20
396	06/26			
407			06/10	07/20
441	06/23		06/15	
442	06/23		06/15	
498			06/10	

[a]For some plots, weather conditions required photography of parts of the plot on different dates.

Film was Ecktachrome 100. The camera was hand held and sighted through a belly port in a Cessna 185. High-level photographs that covered entire 10.4 km^2 plots were taken at 3,353 m AGL. Low-level photographs of individual wetland basins and their surrounding uplands were taken at elevations of 686 to 1,372 m AGL, depending on the size of the target wetland basin. The film was processed by the Kodak E6 process and mounted to 35 mm slides. We used a Nikon LS 3500 SR1 slide scanner at 835 dots/cm to create MIPS *.RVF files from the slides. Processing of the rasters from the slides to register the data, eliminate distortion, and mosaic into a single raster covering each 10.4 km^2 plot was the same as that used for aerial video (Fig. 4-5). Data from both video and high-level slides (Fig. 4-6) were used for photointerpretation of features that did not appear on the NWI data. These new features were identified and processed to create updates to the vector data (Fig. 4-7). The criteria for classifying these new figures are given in Table 4-3.

Table 4-3. Wetland classes used for water areas that did not appear in NWI mapping.

Class	Criterion
New Wetland	Held water two or more months. No obvious berm present.
Dugout	Held water two or more months. Obvious berm present.
Stock Pond	Held water two or more months. Dam structure present across drainage.
Partially-drained Wetland	Held water at least one month. Had basin shape. Obvious drainage channel from basin.
Drained Wetland	Did not show water, but had obvious basin shape. Obvious drainage structure present.
Unclassified	Water present less than 1 month. No obvious outlet present. Considered ephemeral. Does not meet wetland definition.
Drain	Situated between two or more wetland basins. Water visible at least one month and clear line for at least two months. No obvious artificial or enhanced natural drainage.
Natural Drain	Obvious natural drainage way that does not appear in NWI data.

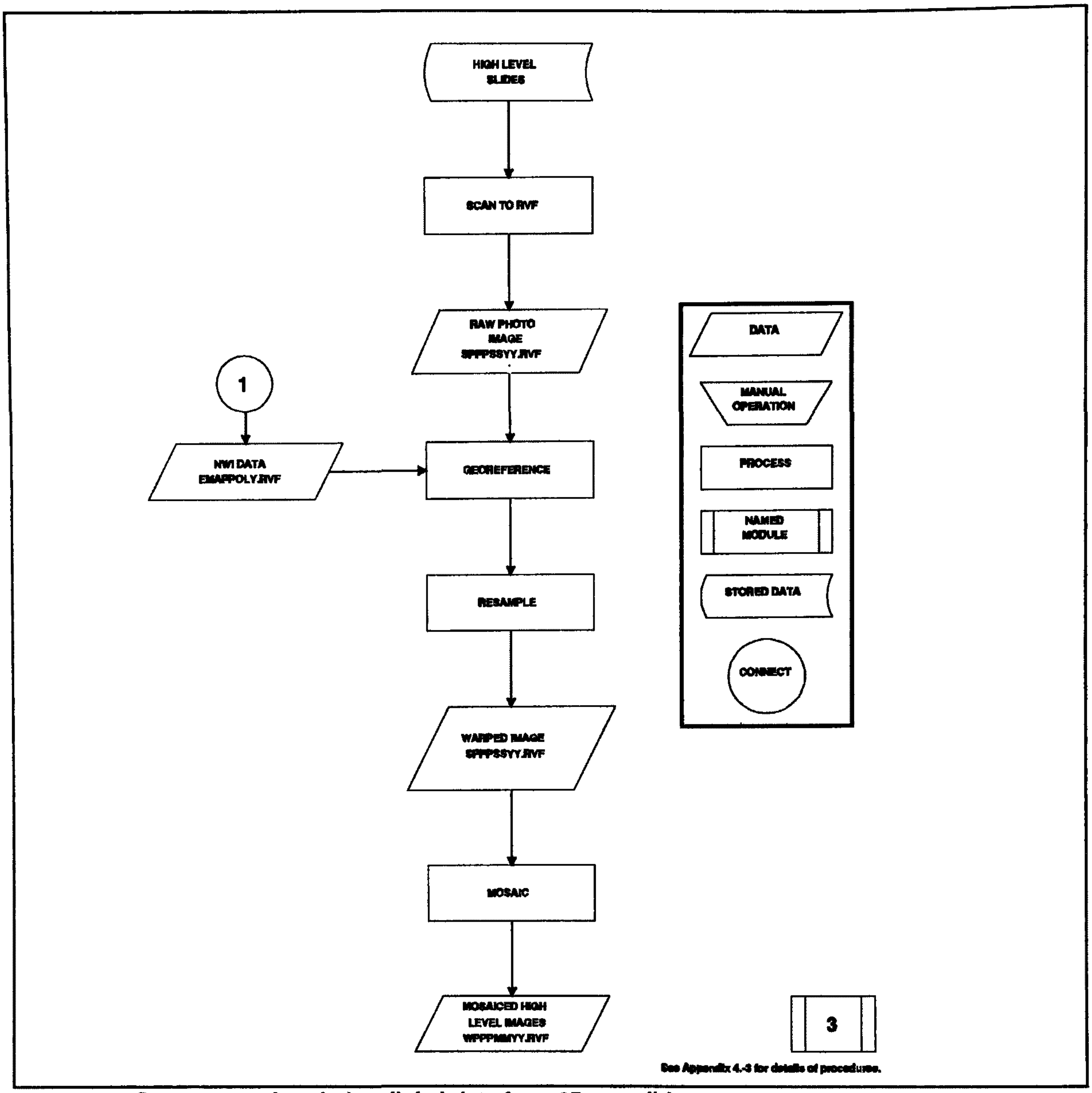

Figure 4-5. Process used to derive digital data from 35-mm slides.

We took low-altitude 35-mm photographs of each sample wetland basin in support of the vegetation and soils studies. This process (Fig. 4-8) required making Cibachrome prints from the low-level photographs. Zones of vegetation and the location of sample quadrats were delineated on the photographs in the field. The prints were then scanned and georeferenced. Vectors were manually drawn over the field delineation to obtain a data set showing the vegetation zones and location of the sample quadrats.

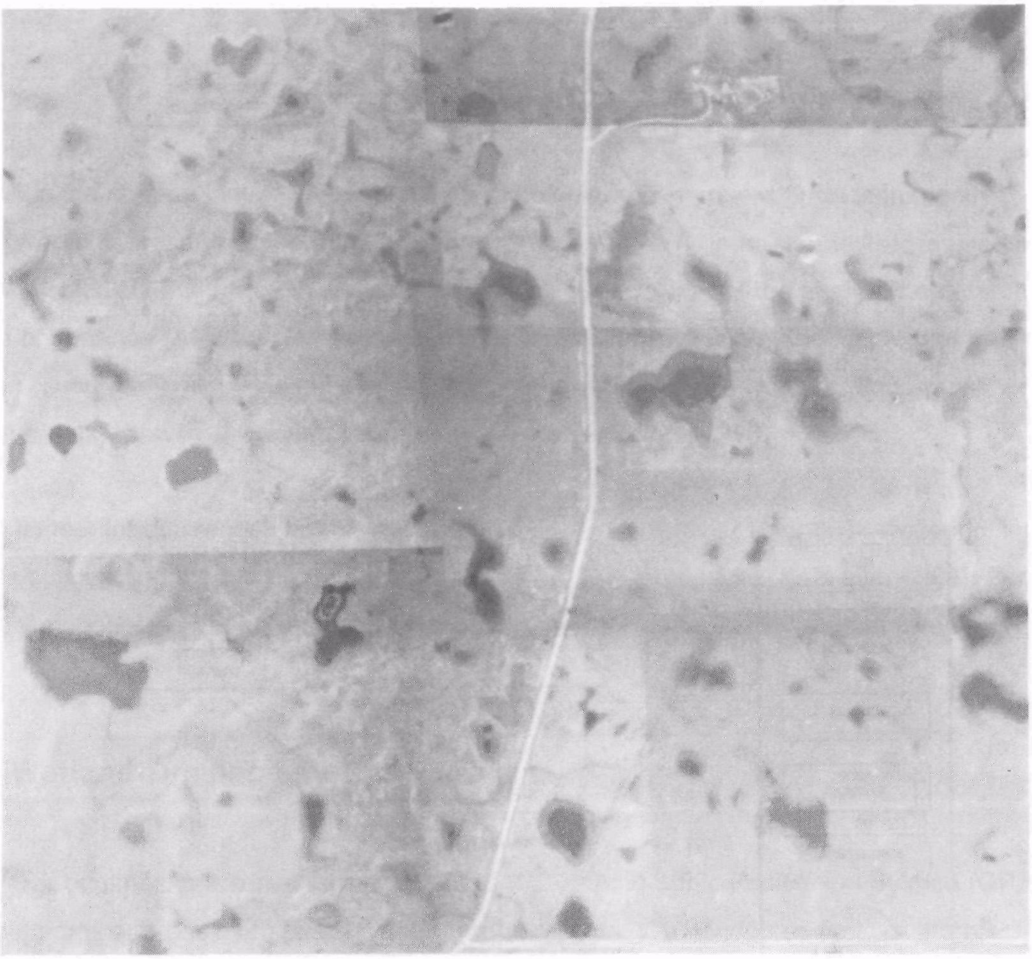

Figure 4-6. Example of raster from high-altitude 35-mm photograph after georeferencing and resampling.

4.2.4 Analyses

We did not conduct statistical tests of differences in cases where changes in condition would have no effect on the landscape attributes. Instead, we present descriptive statistics (median, dispersion in units of Hspread, and extreme values) as box plots (Velleman and Hoaglin 1981) because of the extremely skewed distribution of the data and the frequent occurrence of outliers. The outliers

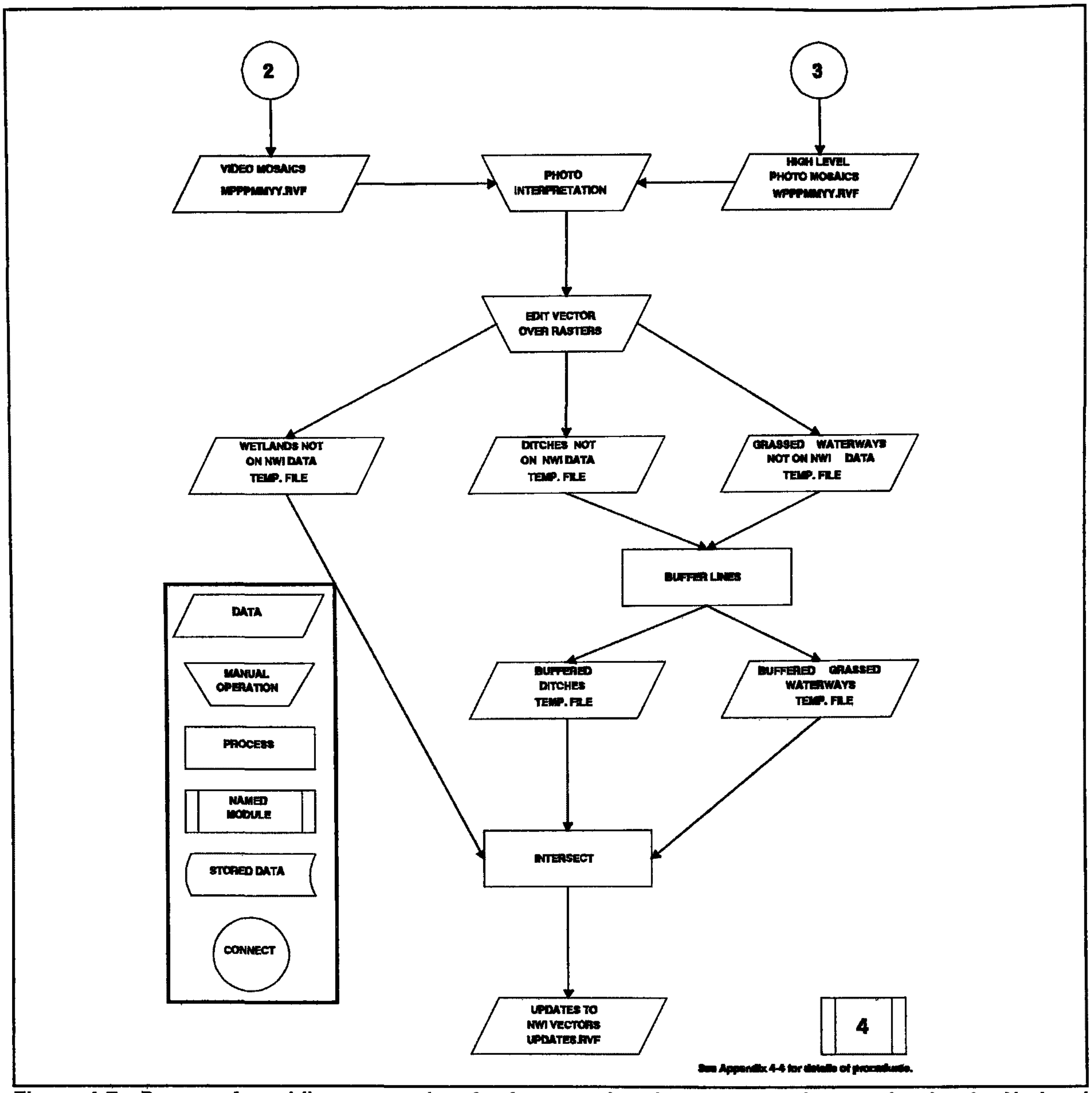

Figure 4-7. Process for adding vector data for features that do not appear in mapping by the National Wetland Inventory.

were identified by plot number for reference to the appendices. These analyses do not include the class, *Lake*.

We developed an index designed to evaluate monthly changes in the amount of water in wetland basins. The index was:

$$CI=ABS(\frac{w_i-w_{i+1}}{W_{nwi}})$$

where CI is the change index, w_i is either the area of water or number of ponds in month 1, and W_{nwi} is either the area of wetland or the number of basins from the NWI data. The devisor is used as a scaling factor. We calculated CI for each wetland basin class in each year of the study. The data underwent analysis of variance (ANOVA) for a repeated measure split-plot design. The whole plot treatment was condition (good and poor). The subplot treatment was wetland basin class (temporary, seasonal, or semipermanent), and the repeated measure was year (1992 and 1993).

To test for differences between condition classes for number of drained wetlands, length of drainage ditches and area of cropland, we used the TTEST procedure (SAS Inst. 1989). Because of the unequal variances, we used Satterwhite's approximation for degrees for freedom (Steele and Torrie 1980).

4.2.5 Wetland Drainage Basins

Our original project plan called for the use of a Geographic Positioning System (GPS) for delineating drainage basins for each sample wetland basin. We conducted tests of the precision of elevation measurements derived from the GPS and found that they were not precise enough to delineate drainage basins in our study areas that have little topographic relief. In addition, a field test demonstrated that the method required more time than we had available. To obtain a crude measurement of drainage basins for each sample wetland, we used four field measurements of the distance from the edge of the wetland basin to the divide between basins. We then interpolated the line between the four points by referring to aerial photographs, topographic maps, and field notes. In those cases where only a portion of the entire wetland basin was used as a sample site, we truncated the drainage basin where it extended beyond the area from which we obtained data. Drainage basin delineations were digitized and intersected with the vector data for the plot as shown in Fig. 4-9.

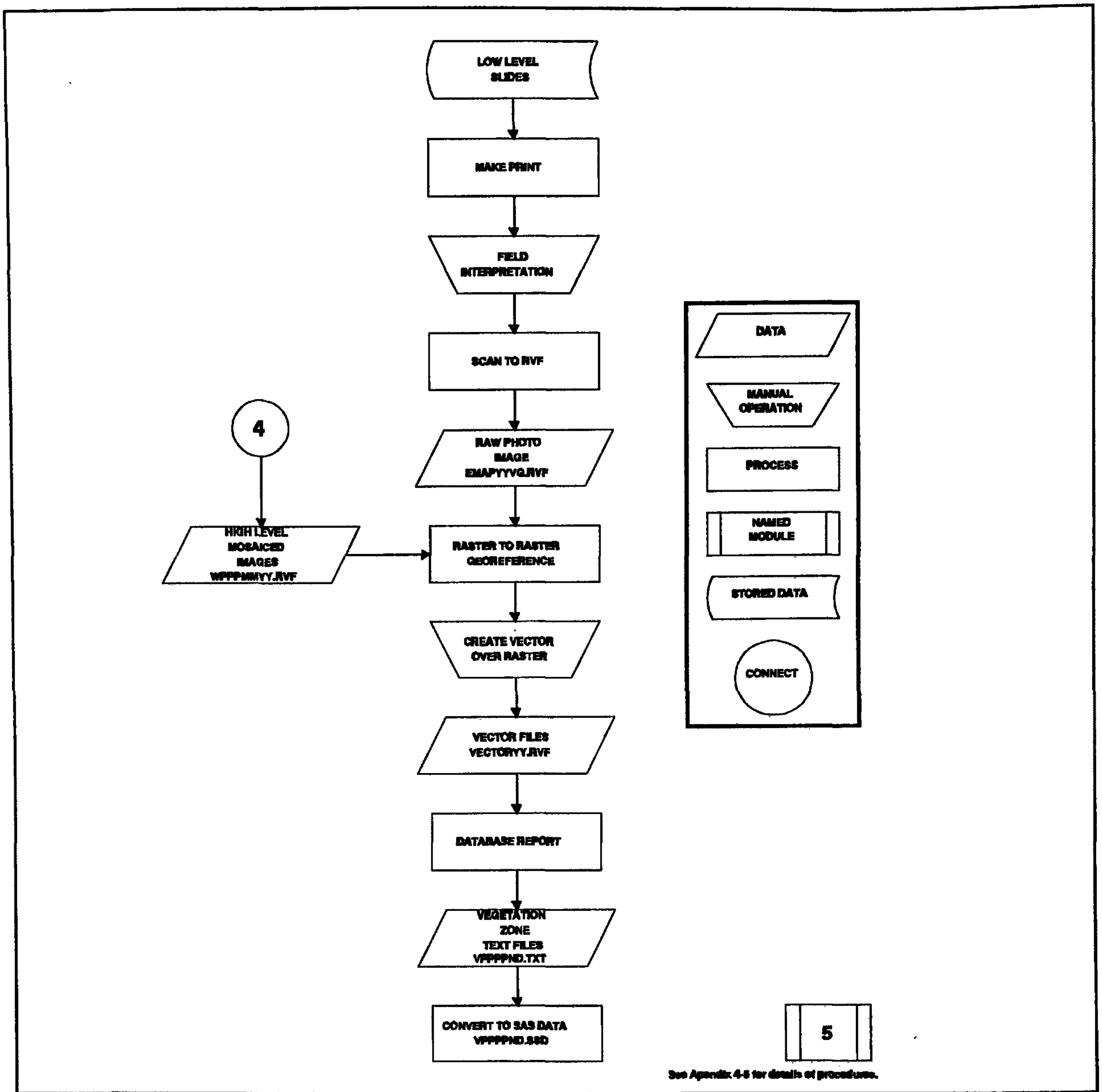

Figure 4-8. Process used for creating SAS data sets from low-elevation photographs and field delineation.

4.2.6 Duck Populations and Production

Our analysis of duck populations and production were derived from model predictions. Duck count data were supplied by the U.S. Fish and Wildlife Service (USFWS) and were used in conjunction with the pond estimates and upland cover availability determined during this study. No actual counts of ducks were made on the sample wetland basins used in this study. Our estimates are model projections. Cowardin et al. (1995) described the methods used by the USFWS and in this study. Breeding pair estimates from the size of individual ponds were the result of a regression model (Cowardin et al. 1988) that predicts breeding pairs from the sizes of individual ponds present in May. Breeding pair estimates do include the class *Lake*, which was excluded during this study. The pond estimates were from video taken during the first week of May in 1992 and 1993 (see Section 4.2.2). These estimates were corrected for regional and annual variation by using estimates of γ (total number of counted pairs/number of pairs predicted by a regression model, see Cowardin et al. 1995) for the Wetland Management District containing our 10.4 km^2 plots. Recruitment estimates were derived from habitat availability estimates for our 10.4 km^2 plots and nest survival estimates from Shaffer and Newtown (1995). Production of mallard recruits was a model prediction based on the product of breeding population and recruitment estimates for each plot derived from the model of Johnson et al. (1987).

We suspected that variation in duck counts was primarily due to differences in numbers of wetland basins on each plot. To test this, we used a repeated measures analysis of covariance where the covariate was the number of basins. This analysis indicated that the number of pairs did not depend on the number of basins ($F_{2,12} = 3.38$, $P = 0.68$). Therefore we used a repeated measures analysis of variance where years was the repeated measure and the main effects were species and condition. The response variable was transformed by the 1n(y+1) transformation and the analysis was conducted by the general linear models procedure of SAS (SAS Inst. 1989). The analysis method used to test for difference between condition classes and years was the same as that used for pairs.

4.3 RESULTS

4.3.1 Wetland Abundance and Distribution on Sample Areas

The abundance and distribution of wetlands on the sample 10.4 km^2 plots, with the exception of drainage and construction of wetlands, is not the result of human-induced changes. Rather it is a characteristic of the geologic setting of the plots and should not be considered as indicating condition of the landscape. We present these data on basin wetland abundance and distribution because they tend to confound some of the analysis of indicators of condition that follow. The tremendous variation exhibited in the data is also important for planning future probability sampling.

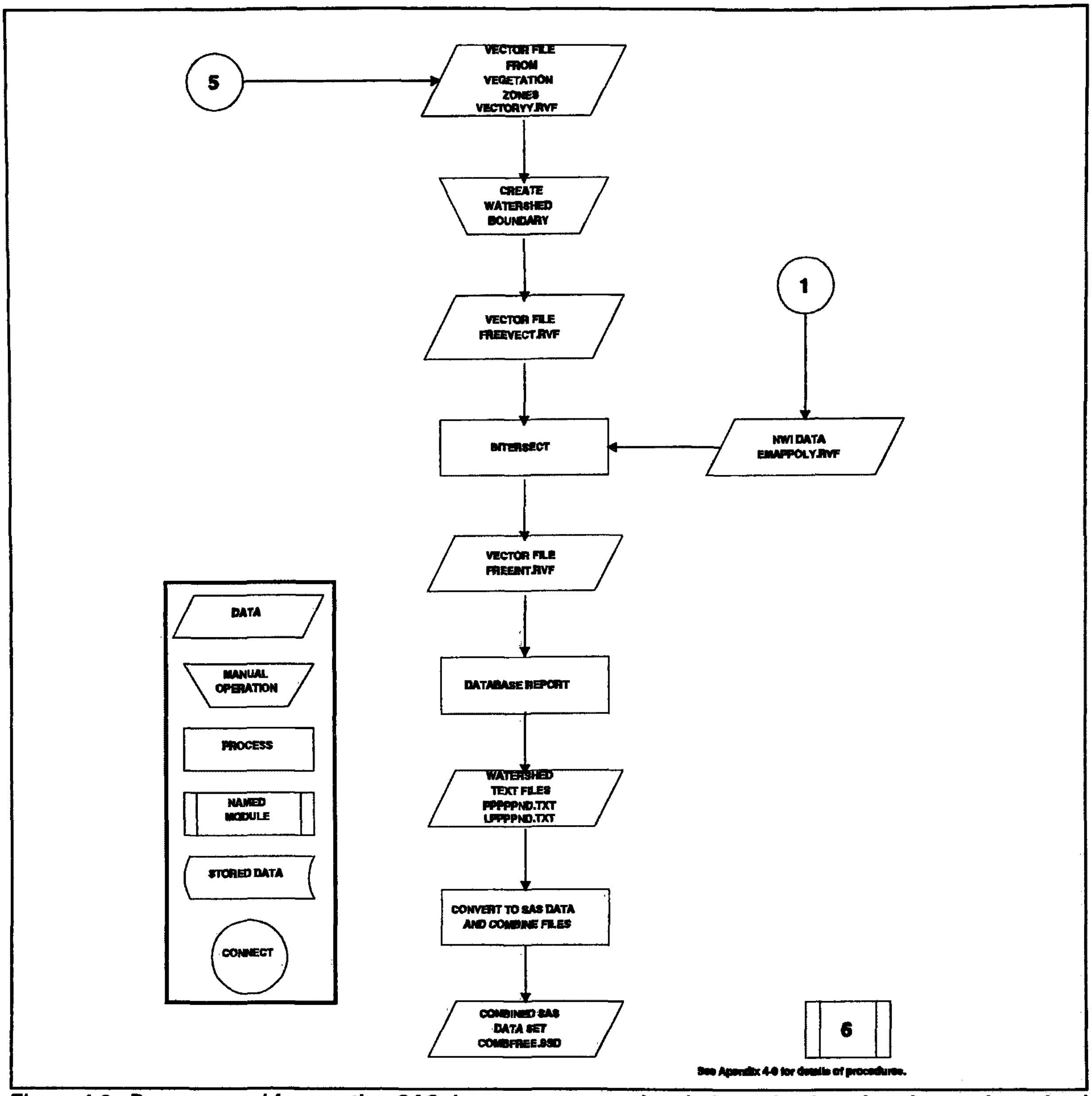

Figure 4-9. Process used for creating SAS data sets representing drainage basins of each sample wetland basin.

The number of wetland basin/plots was highly variable and the distribution was skewed. Four plots had densities greater than 250, and there were two plots with more than 300 wetland basins (Fig. 4-10). Although the median wetland density was similar for good-condition (Median [$\tilde{x}$] = 15) and poor-condition ($\tilde{x}$ = 18), the poor-condition plots were more variable.

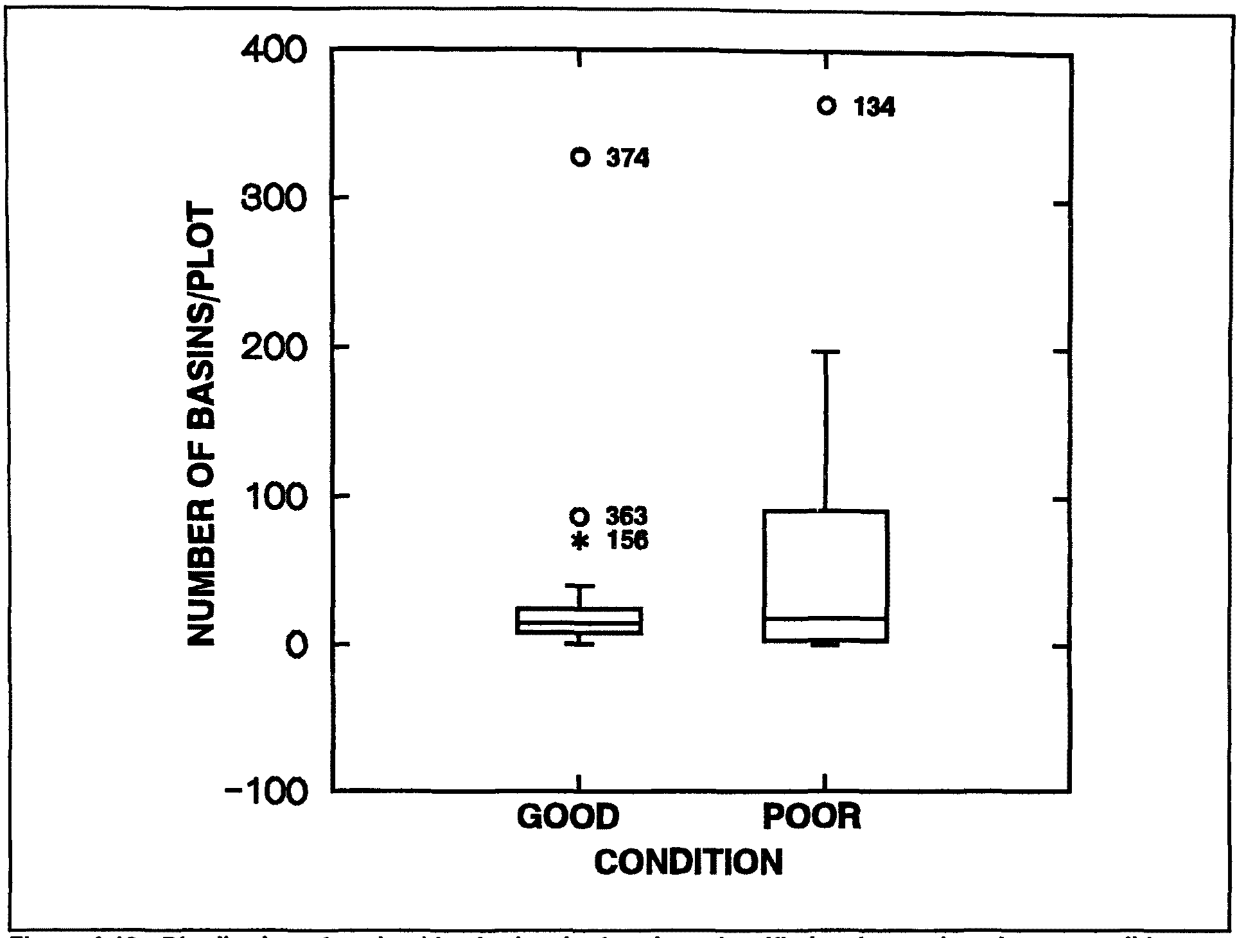

Figure 4-10. Distribution of wetland basin density for plots classified as in good- and poor-condition.

The area of wetland/plot also showed similar medians between good-condition ($\tilde{x}$ = 11.3 ha) and poor-condition ($\tilde{x}$ = 8.4 ha) plots, and a distribution skewed to the smaller areas in both condition classes. Good-condition plots showed more variation except for three outliers (plots 134, 135, and 442) among the poor-condition plots (Fig. 4-11).

The mean distance of each basin to its nearest neighbor (Fig. 4-12) was similar between good-condition ($\tilde{x}$ = 387.9 m) and poor-condition ($\tilde{x}$ = 268.2 m) plots except for plot 241 in the poor-condition group. This plot had only three wetland basins and these were widespread.

The shoreline development index (SDI) (Cole 1983) compares the boundary of each wetland polygon to that of a circle with the same area. The index has a value of 1 for a perfect circle. Median values of SDI for good-condition ($\tilde{x}$ =1.4) and poor-condition ($\tilde{x}$ =1.3) wetland basins (Fig. 4-13) were similar and there was little variation except for plot 241, where there were a number of streams that have high indices because of their long, narrow shape.

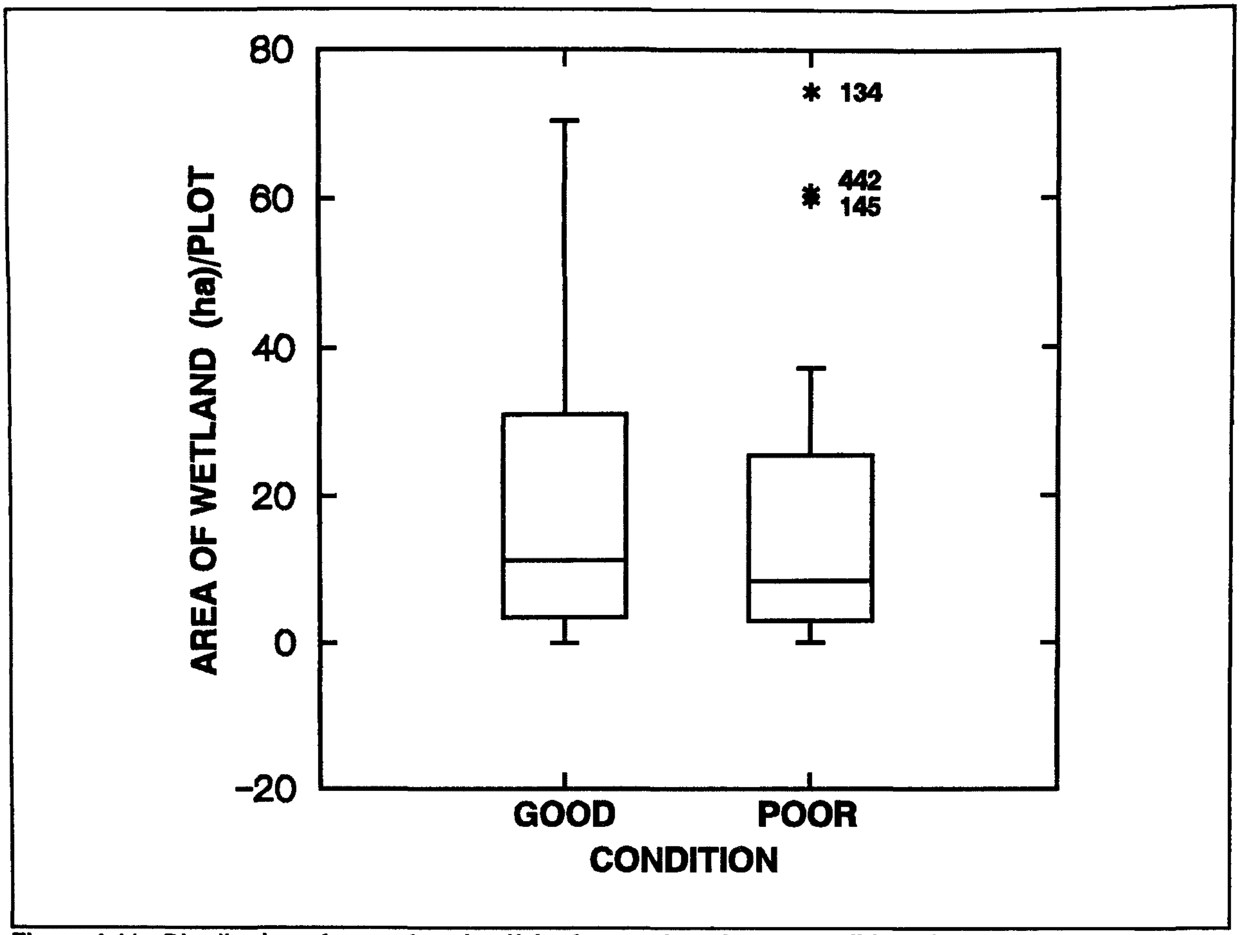

Figure 4-11. Distribution of area of wetland/plot for good- and poor-condition plots.

4.3.2 Drainage as An Indicator of Wetland Landscape Condition

The characteristics discussed thus far are not necessarily related to condition of the landscape of the plots; rather they are characteristics of the geomorphology of the setting where the plots exist. Drainage of wetlands is probably the most extreme factor affecting wetland condition because, once drained, the basin loses all wetland functions and their associated values. Although some drainage did occur on good-condition plots, the number of drained wetland basins (good-condition $\tilde{x} = 1$, poor-condition $\tilde{x} = 12.5$) was higher and more variable on poor-condition plots (Fig. 4-14). The presence of drainage ditches is an additional indicator of condition of wetlands in the landscape. In many cases ditches may be present from wetland basins that have not been completely drained. These basins remain as wetlands but their hydrologic function has been severely modified by the ditching. The length of drainage ditch per plot (Fig. 4-15) was greater and more variable on poor-condition plots ($\tilde{x} = 11.2$ km) than on good-condition plots ($\tilde{x} = 3.2$).

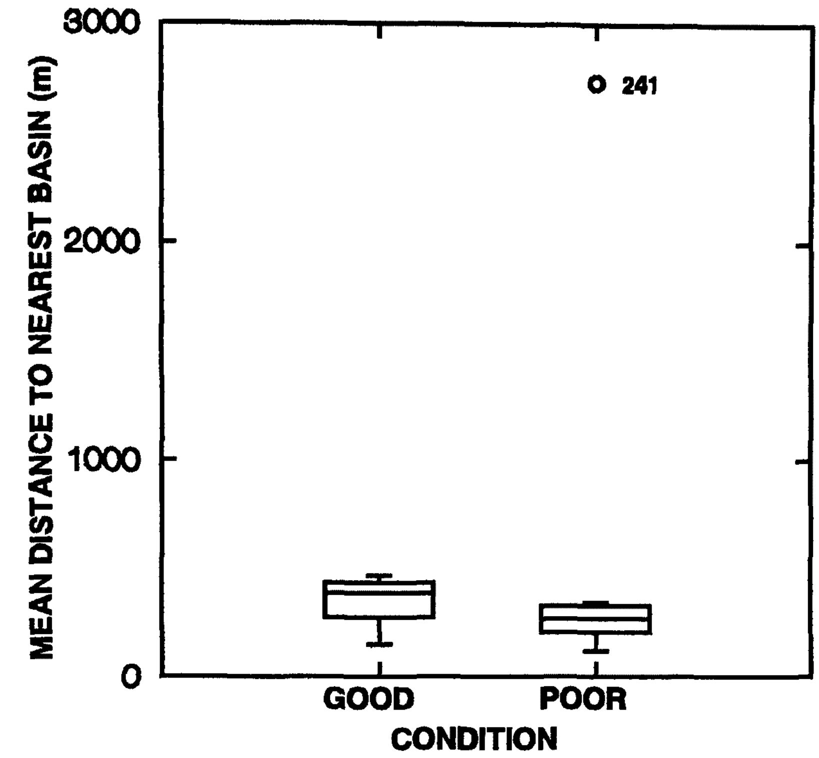

Figure 4-12. Distribution of mean distance from wetland basins to nearest basin between good- and poor-condition plots.

4.3.3 Seasonal and Annual Change in Ponds

The number of ponds and the area of wetland covered by water changed within and between years. These estimates were confounded as an index to wetland condition because both the number of wetland basins and the area of water depend on the geomorphology where the plots are located and geomorphology cannot be considered an indicator of wetland condition. Therefore we evaluated estimates of the percent of wetland basins and the area of wetland containing water in 1992 (Fig. 4-16) and 1993 (Fig. 4-17).

Temporary basins were less variable. Poor-condition semipermanent basins had a consistently smaller percent of the wetland area covered by water in both years. This would be expected because the size of the poor-condition semipermanent basins ($\tilde{x}$ = 2.2 ha) is much smaller than the good-condition semipermanent wetland basins ($\tilde{x}$ = 23.8 ha) and within the class *semipermanent* water in large ponds is more permanent than in small ones.

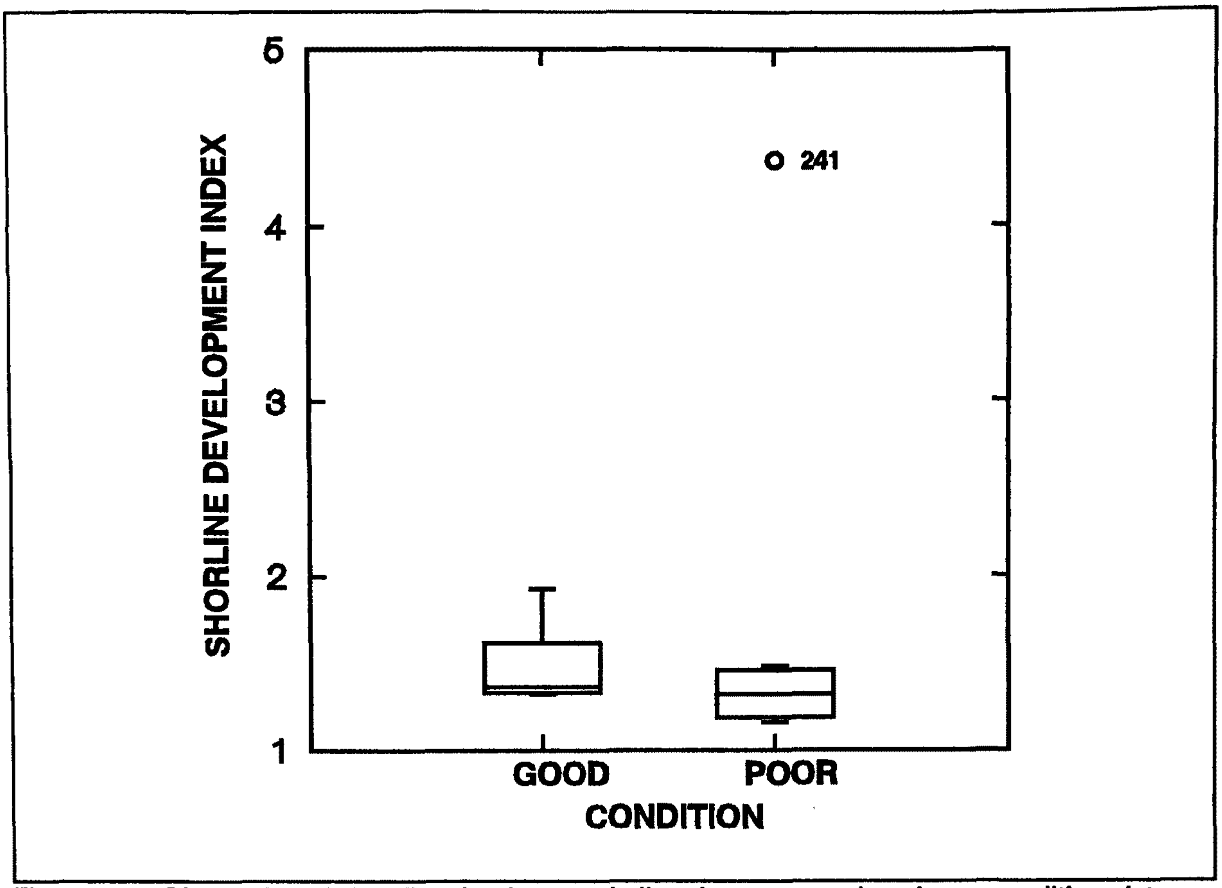

Figure 4-13. Distribution of shoreline development indices between good- and poor-condition plots.

Results for indices to change in area covered by water were similar to those for numbers of ponds (Fig. 4-18). The index to wetland change in area of water for the June-July period was significantly different between condition classes ($F_{1,14}$ = 7.71, P = .015). The least squares mean for poor-condition was 0.231 and for good-condition 0.051. There was also a significant year effect for the May-June Period ($F_{1,41}$, = 4.35, P = 0.043).

Indices to change in pond numbers (Fig. 4-19) differed between good-condition and poor-condition plots for all wetland basin classes in the June-July interval ($F_{1,14}$ = 15.81, P = 0.001). Poor-condition plots had a least squares mean of 0.287 and good-condition plots had a least squares mean of 0.062. Indices also differed between condition classes for semipermanent ponds in the May-June ($F_{2,27}$ = 4.16, P = 0.03) period and for the mean of all periods ($F_{2,27}$ = 3.84, P = 0.034). There was a significant ($F_{1,41}$ = 5.81, P = 0.02) difference in change in pond numbers between years. Least squares means were 0.224 (SE = 0.035) for 1992 and 0.125 (SE = 0.035) for 1993. No differences were detected for index to change in pond numbers for the April to May period.

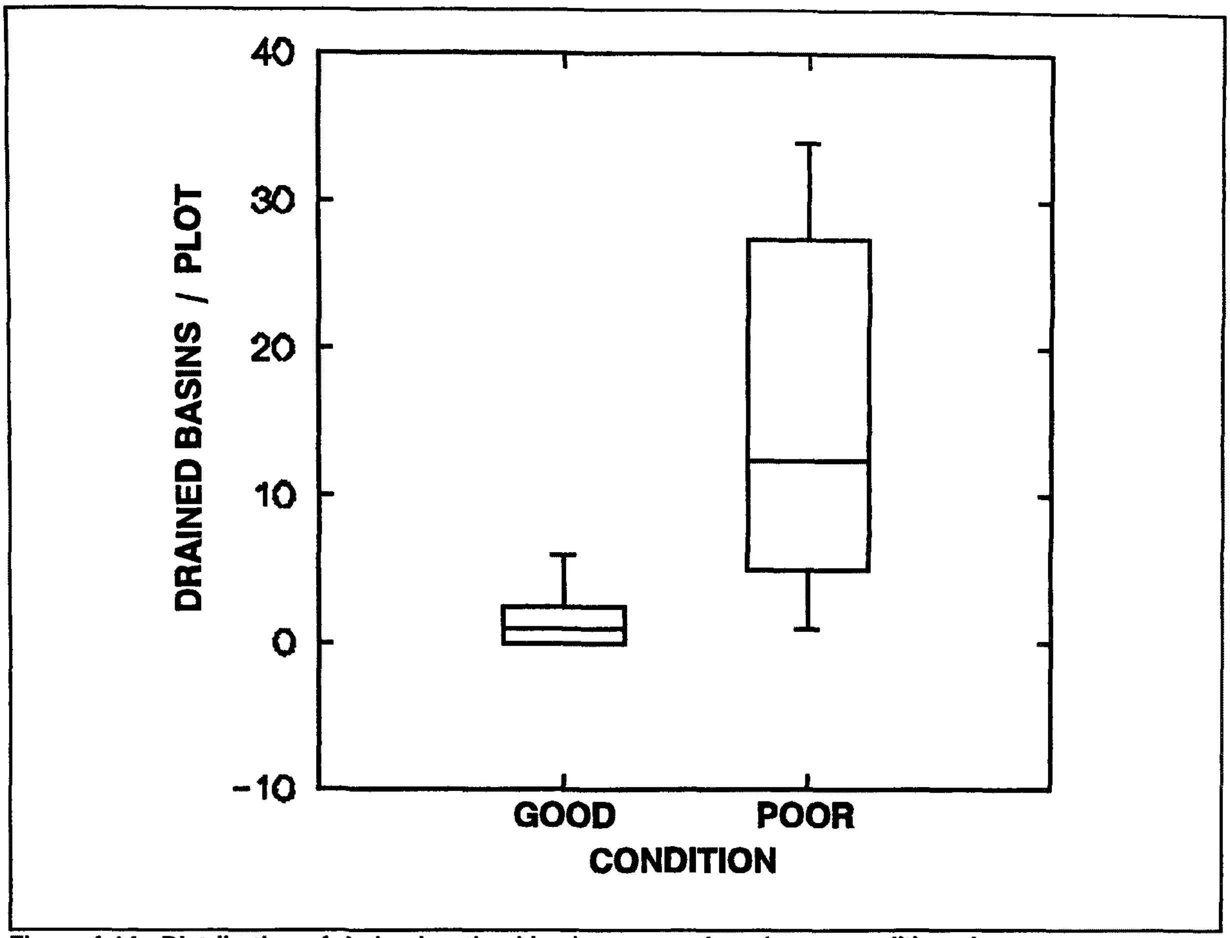

Figure 4-14. Distribution of drained wetland basins on good- and poor-condition plots.

4.3.4 Upland Characteristics of Study Sites

Our selection procedure was designed to maximize the difference in cropland/upland ratio and as expected cropland was dominant on poor-condition plots ($\bar{x}$ = 951.1 ha, Fig. 4-20). Conversely grassland dominated good-condition plots ($\bar{x}$ = 420.7 ha). Cropland was still an important component of the good-condition plots ($\bar{x}$ = 248.5 ha), whereas grassland was largely absent on poor-condition plots ($\bar{x}$ = 0.0). There was no hayland, planted cover, scrubland, or woodland on poor-condition plots. The remainder of the upland cover classes were similar between good- and poor-condition plots, except for CRP cover which was more abundant on good-condition plots. There was a significant difference ($t_{7,5}$ = 5.999, P = 0.0007) in the area of cropland between good- and poor-condition plots. The good-condition

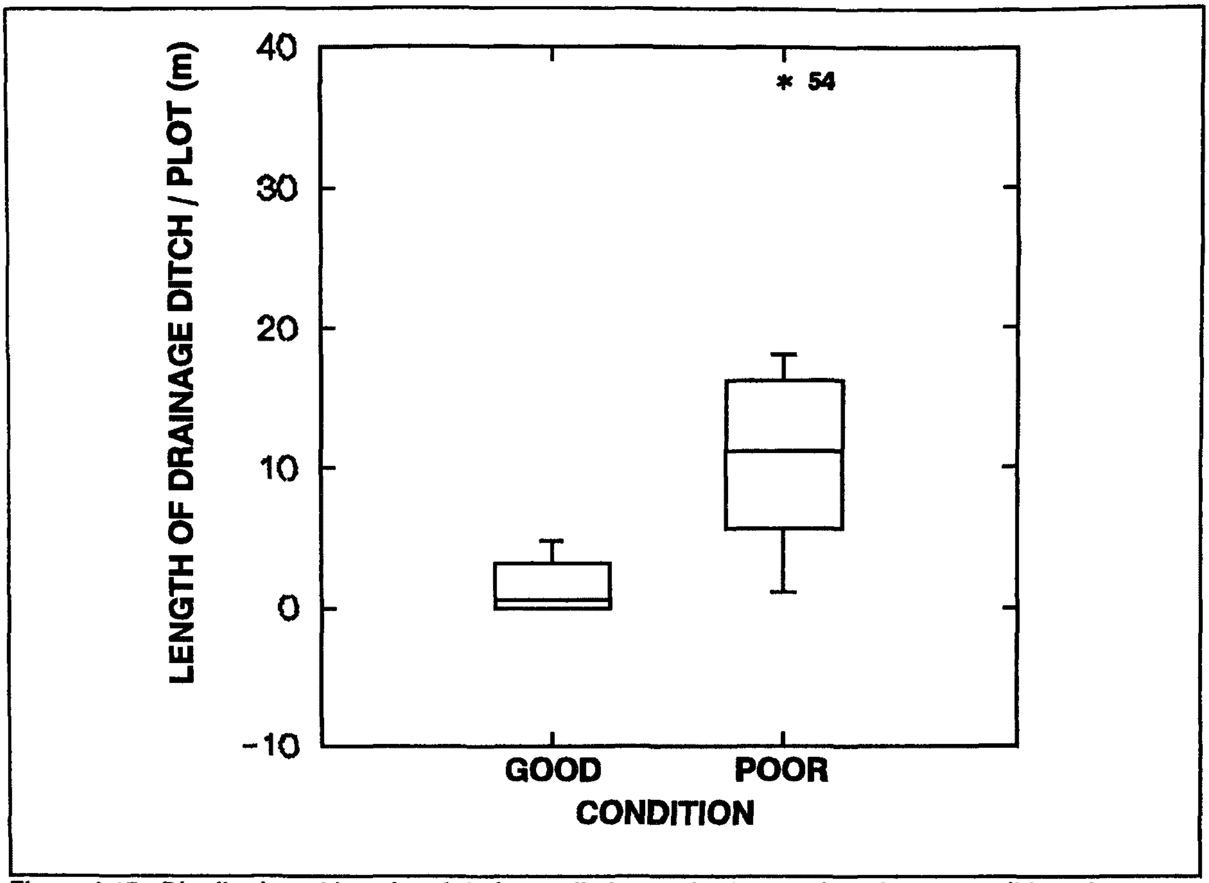

Figure 4-15. Distribution of lengths of drainage ditch per plot for good- and poor-condition plots.

plots were much more variable ($\bar{x}$ = 297.62, SE = 110.75) in the amount of area of cropland present than the poor-condition plots ($\bar{x}$ = 027.84, SE = 20.05). The distribution of cropland among the poor-condition plots was narrow with a median value of 951 ha which represented about 92% of the plot area (Fig. 4-21). The outlier plot (442) contained 20.9 ha of CRP cover.

Our analysis of the amount of exposed soil subject to erosion in June showed a significant difference between condition classes ($t_{7,3}$ = 3.0254, P = 0.0184). Good-condition plots had a mean of 67.54 ha (SE = 44.903) of exposed soil; poor-condition plots had a mean of 983.19 ha (SE = 299.304). The medians were 629 ha for poor-condition plots and 0.0 for good-condition plots (Fig. 4-22). The poor-condition plots were also more variable than the good-condition plots. Poor-condition plots had two outliers with more than 2000 ha of exposed soil subject to erosion.

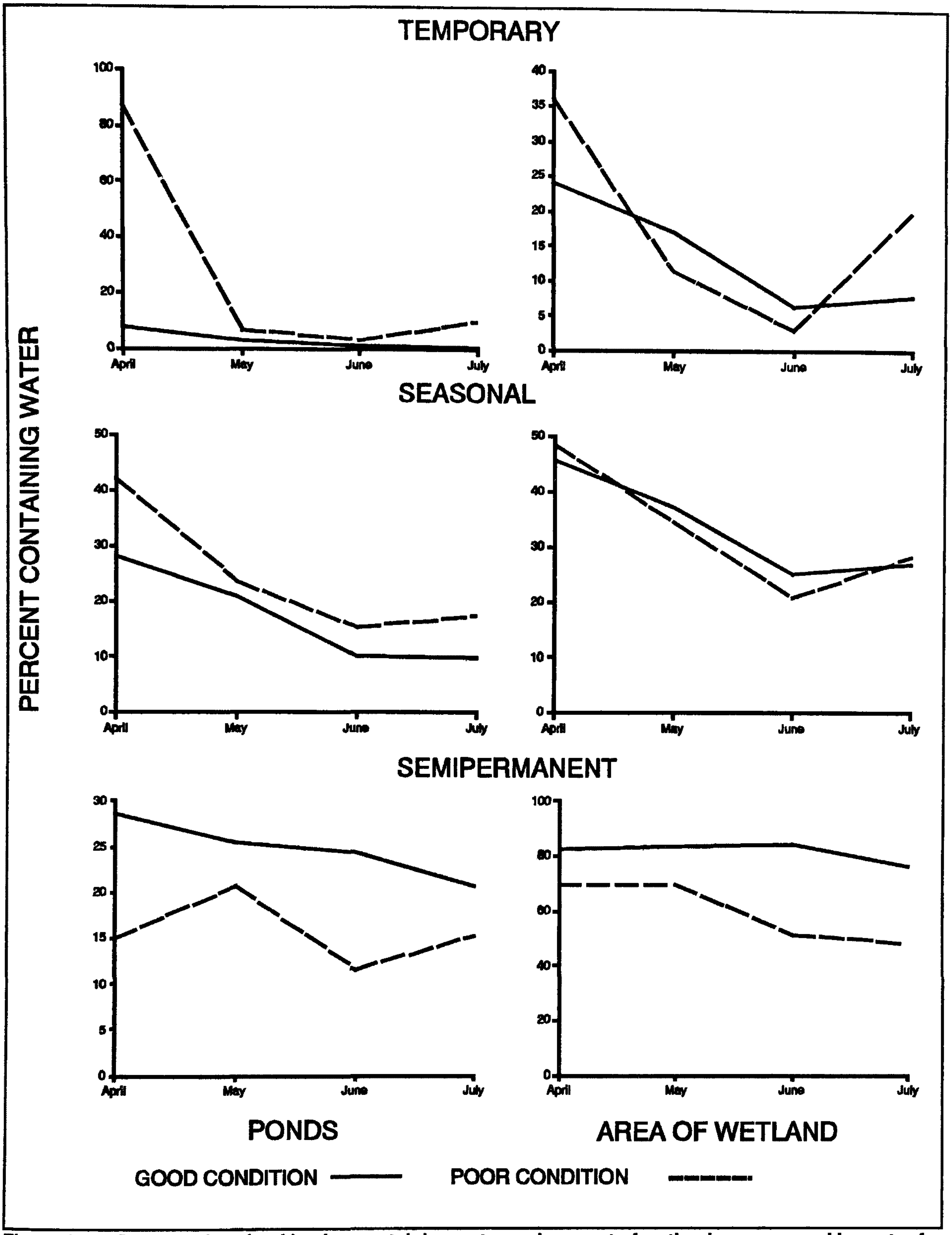

Figure 4-16. Percent of wetland basins containing water and percent of wetland area covered by water for each wetland basin class in 1992.

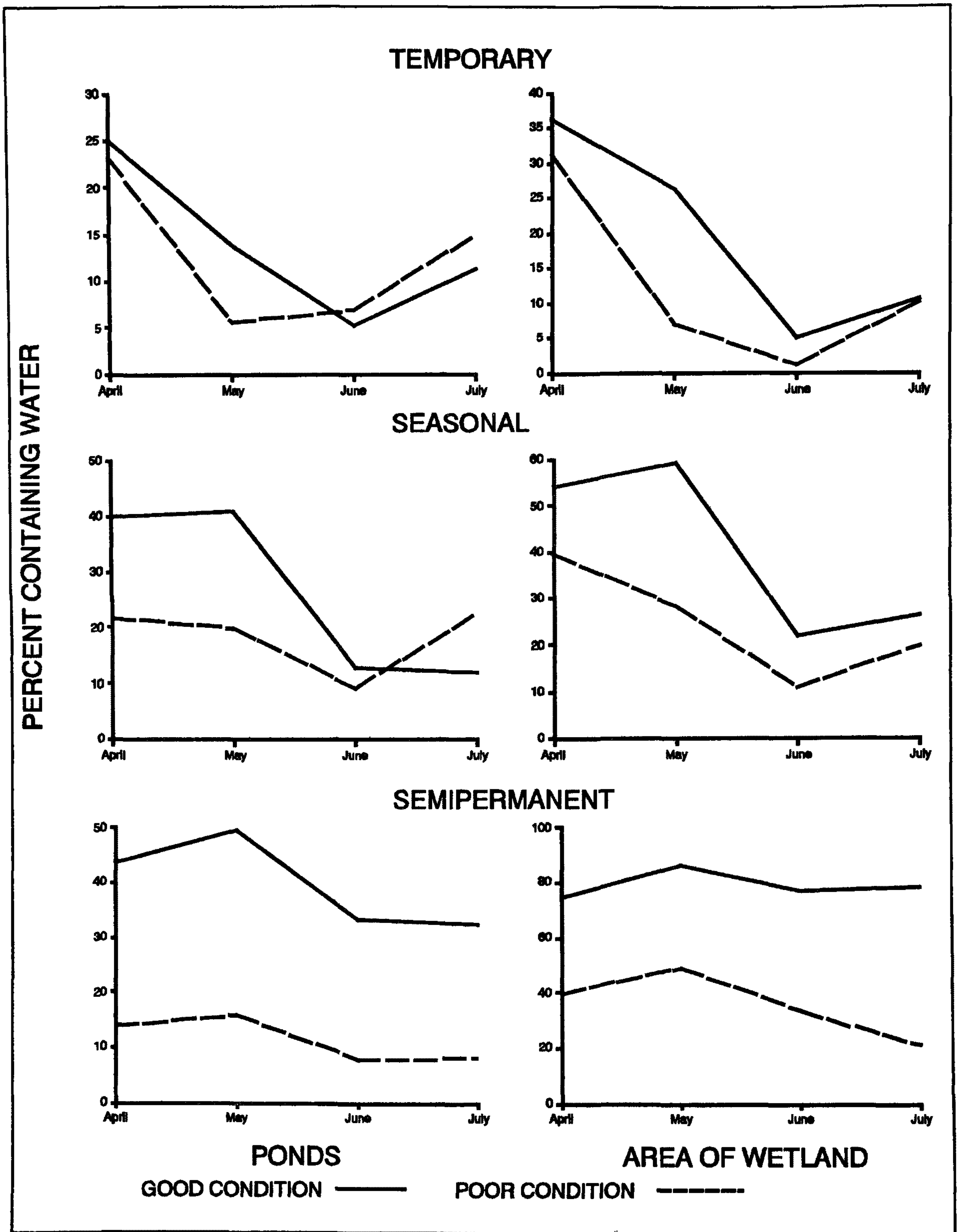

Figure 4-17. Percent of wetland basins containing water and percent of wetland covered by water for each wetland basin class in 1993.

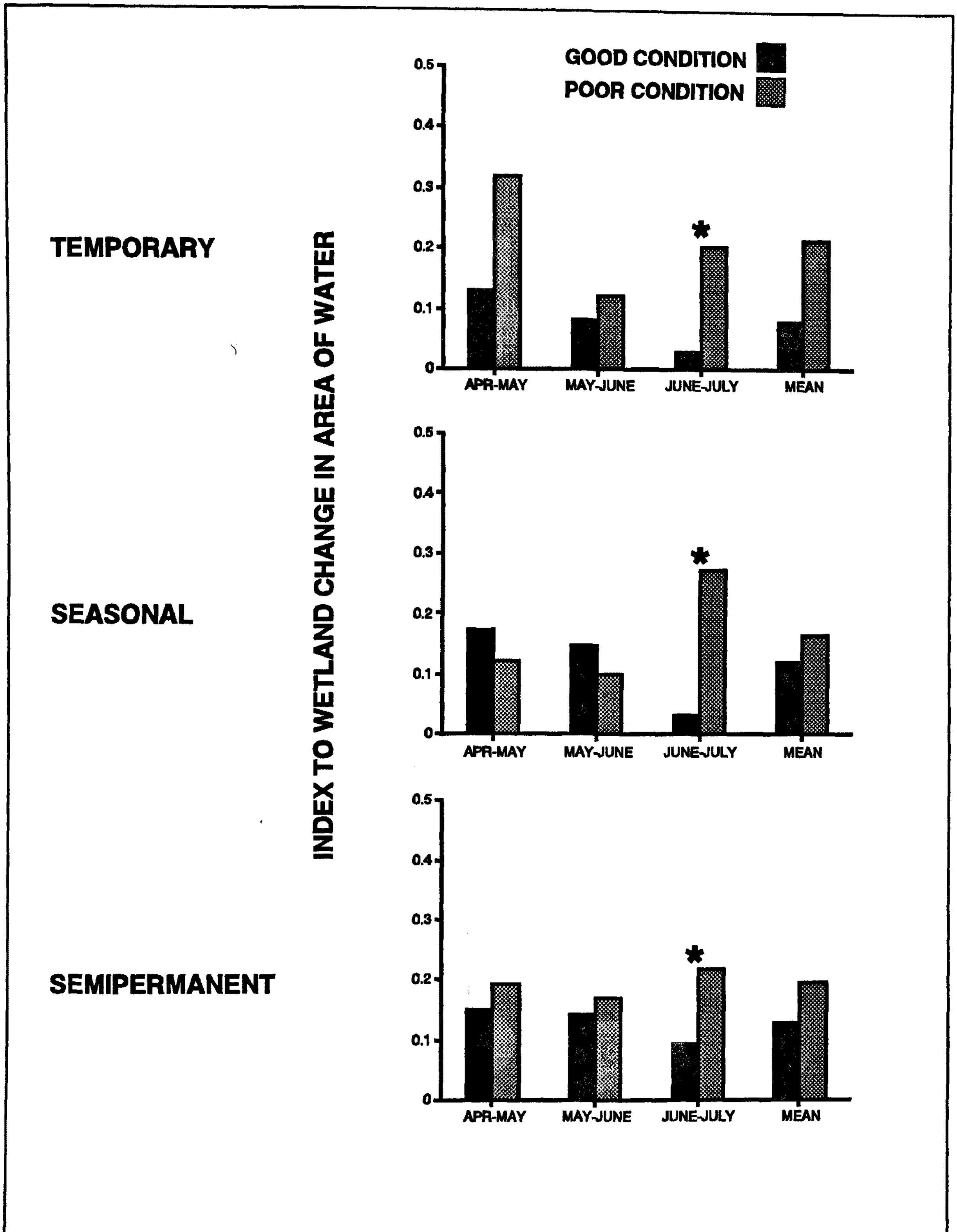

Figure 4-18. Comparison of indices to change in pond between months by wetland class and period. Asterisk indicates (P<0.05).

4.3.5 Duck Populations and Production

Our analysis showed that there was a significant year by condition interaction ($F_{1,70} = 4.17$, $P = 0.0448$); therefore, we could not interpret main effects, year and condition. Differences in condition-within-year and year-within-condition class were tested using Fisher's least significant difference procedure (Milliken and Johnson 1984). There were more ducks predicted on good-condition plots than on poor-condition plots in both years (1992, $P = 0.0038$; 1993 $P < .001$) (Fig. 4-23). There was no significant difference between years within condition class in both condition classes ($P = 0.0628$ for good-condition and 0.3212 for poor-condition). There was a significant species effect ($F_{4,56} = 21.21$, $P < 0.001$). The individual species effects were not of interest and no tests were conducted for comparisons among the five species. Analysis of mallard recruits showed that mallard recruits did not vary significantly with number of wetland basins ($F_{2,12} = 2.90$, $P = 0.0939$). No differences were detected between years ($F_{1,14} = 2.87$, $P = 0.1124$) or condition classes ($F_{1,14} = 1.45$, $P = 0.2492$). The condition class-by-year interaction was not significant ($F_{1,14} = 1.16$, $P = 0.2994$). However, the means were higher for good-condition plots (27.28 recruits/plot) than for poor-condition plots (14.81).

4.4 EVALUATION AND RECOMMENDATIONS

Results from this study show that remote sensing of physical parameters of selected landscapes can furnish data to evaluate the condition of those landscapes. Though the ratio of cropland to upland was used as a proxy for wetland condition, we believe that the direct measurement of the amount of cropland in a landscape is probably the simplest and most meaningful indicator of condition of wetlands in that landscape and that it is easily obtained from base mapping that does not need to be conducted annually. Although the amount of cropland in an area is relatively constant, there can be major changes resulting from agricultural programs such as the CRP program, which converted large amounts of cropland to grass/legume cover. We obtained our estimates from baseline mapping conducted by NWI, but we suspect that satellite data with resolution equivalent to LANDSAT (30 m pixel) could be used to monitor the amount of cropland in the PPR. The main advantage would be that coverage of the entire area is possible. The only constraint would be the cost both for data and for processing.

We recommend that all wetlands and uplands be mapped and that digital data sets be prepared from the maps prior to initiation of planned work on sample 40-km^2 hexagons. Such data would not only furnish a measure of landscape condition at the time of mapping, but would also be

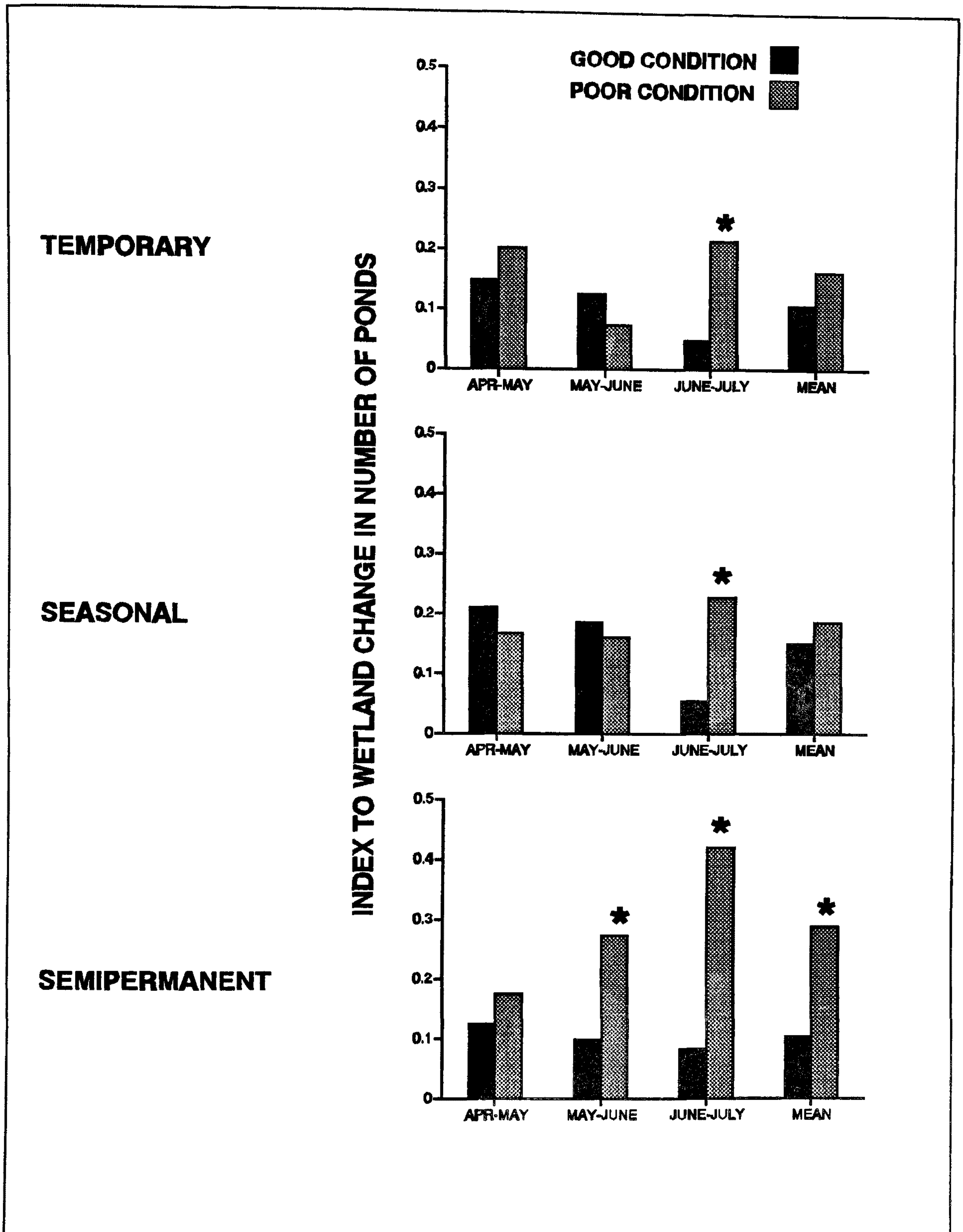

Figure 4-19. Comparison of indices to change in area covered by water by wetland basin class and period. Asterisk indicates (P<0.05).

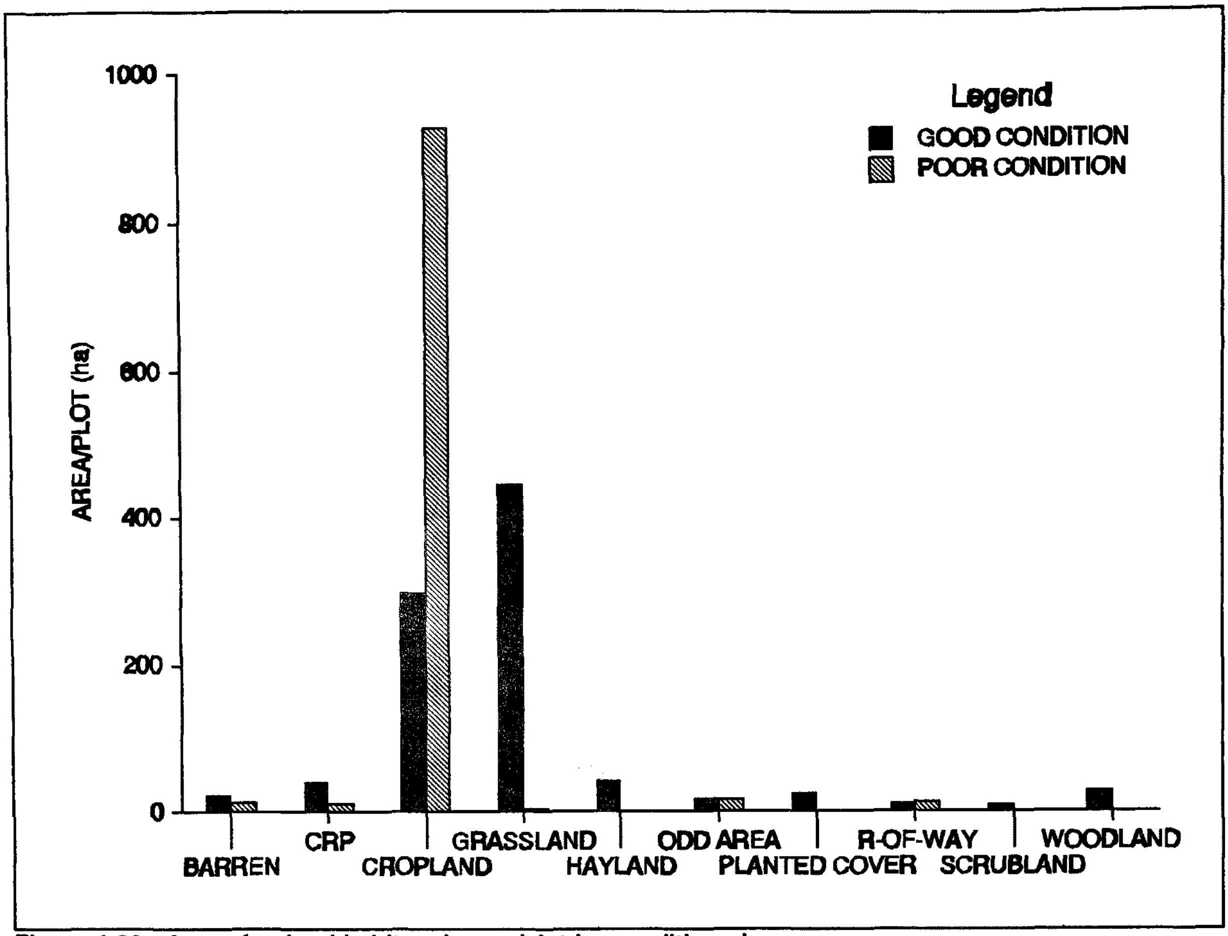

Figure 4-20. Area of upland habitat classes/plot by condition class.

essential to registering other remote sensing data to a common map projection so that GIS analyses may be conducted. Once the baseline data have been collected, the data sets can be easily be updated by remote sensing and ground survey methods, thus producing a temporal series of GIS layers.

4.4.1 Drainage as An Indicator of Condition

We used two indicators that are direct measures of wetland condition, number of drained basins and length of drainage ditches. These indicators effectively separated good- and poor-condition plots according to our definition. These indicators were correlated with the amount of cropland (drained basins, r^2 = 0.56, drainage ditches r^2 = 0.57) but there are often situations where the amount of drainage may be different and unrelated to the amount of cropland present. The differences may be related to geomorphology of the area and to various Federal or State programs that encourage or constrain drainage. For example, an appreciable portion of the wetlands in the PPR are under perpetual USFWS easements that prevent drainage.

Our estimates of drainage were based on mapping by NWI and on interpretation of aerial vedio. These methods relying on interpretation are subject to both variation caused by the interpreter and to bias, primarily where the interpreter commits errors of omission. We suspect that our estimates of the length of drainage ditch are conservative because it is often difficult or impossible to see tile drainage on an aerial photograph. Tests of these error were beyond the resources of the pilot. Measurement of drainage requires more resolution than measurement of the amount of cropland. The 1:63,000 photographs used by NWI in combination with our low level video and photography were adequate. We stress that our estimates are of drainage that has taken place over a long period of time. It would be

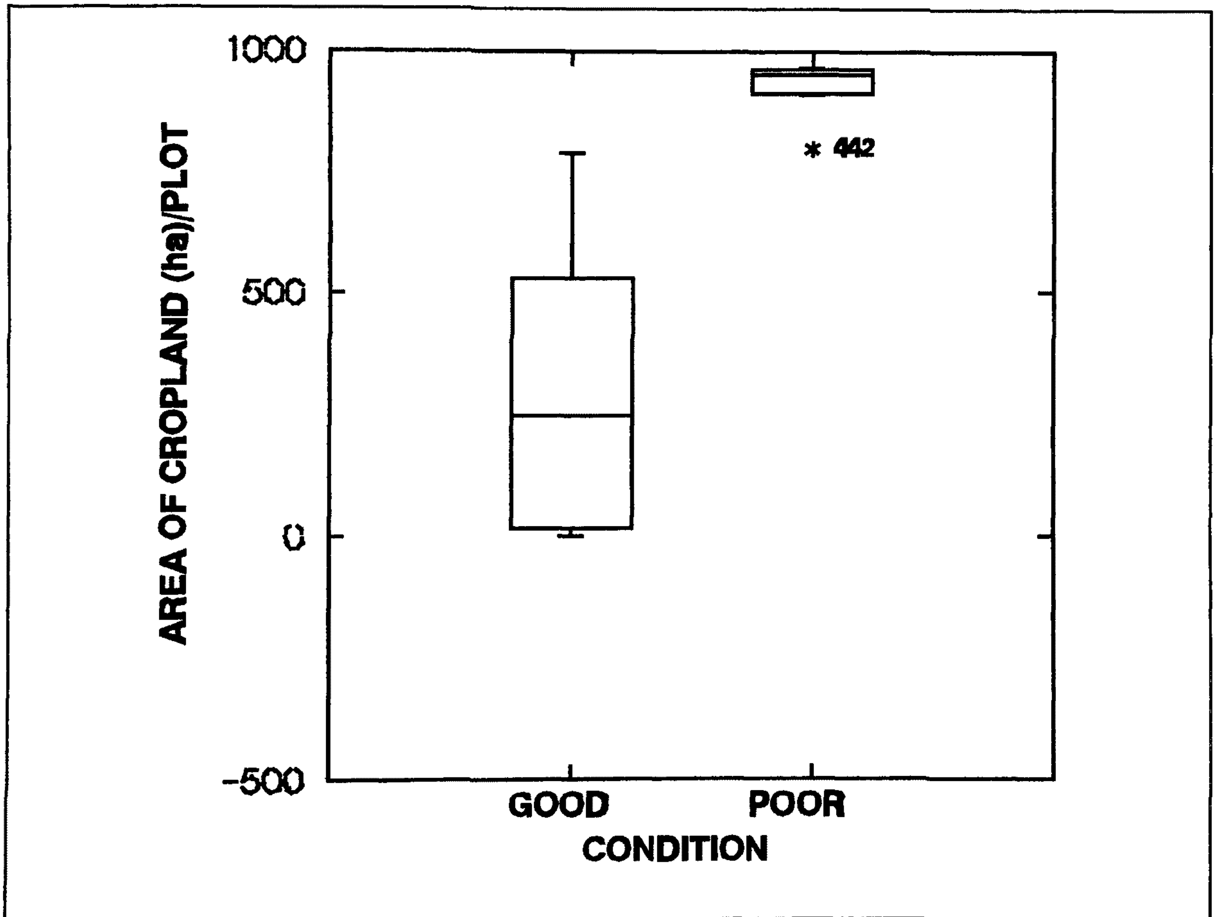

Figure 4-21. Distribution of cropland/plot between good- and poor-condition plots.

advantageous that EMAP have the ability to monitor annual change in these two indicators, even though data need not be gathered each year. The annual rate of drainage is low and drainage is often clumped (all wetlands may be drained on some areas where others remain undrained). This characteristic of drainage means that large samples will be required to obtain precision in annual estimates.

We recommend that drainage of wetland basins and creation of drainage ditches be monitored for each sample 40-km^2 hexagon. The repeat schedule of 4 years in the EMAP sampling protocol (Leibowitz et al. 1991) would be adequate to detect long-term changes in loss of hydrologic function due to drainage.

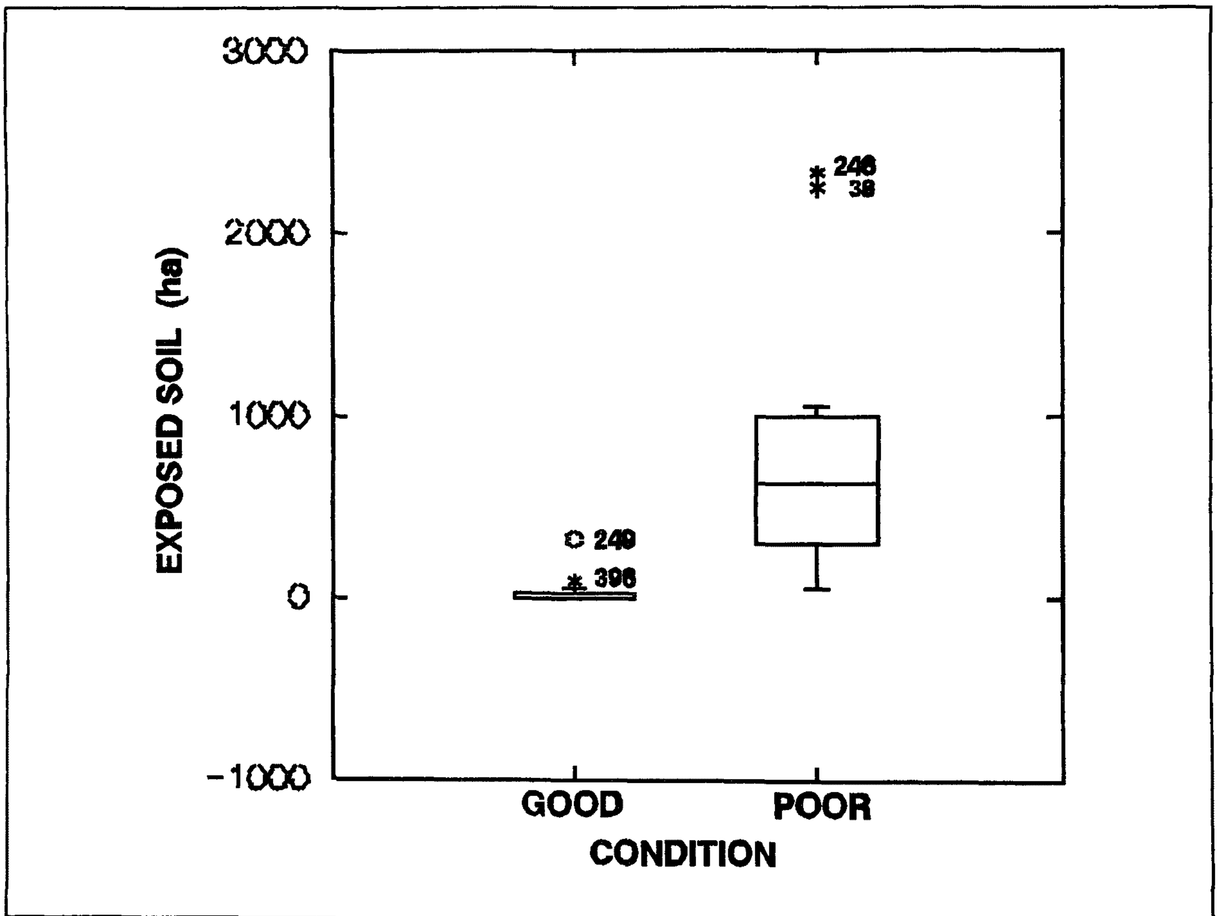

Figure 4-22. Distribution of exposed soil for good- and poor-condition plots.

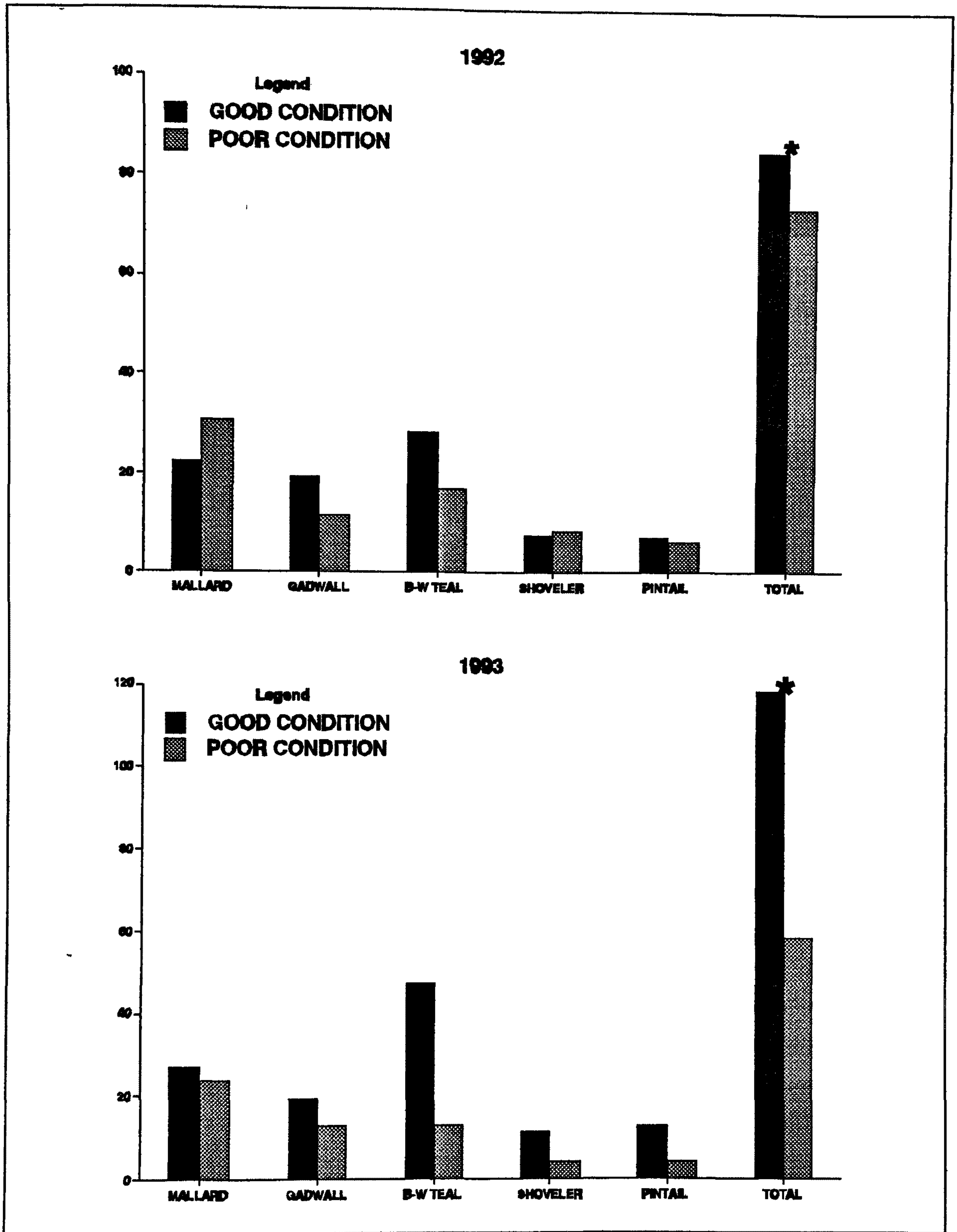

Figure 4-23. Numbers of five species of ducks per 40-km² hexagon on good- and poor-condition plots in 1992 and 1993. Asterisk indicates significance at 0.05 level.

4.4.2 Area of Exposed Soil

Our low level 35-mm photographs allowed us to estimate the area of exposed soil on each plot in June. This indicator effectively separated good- and poor-condition plots. The area of exposed soil is important because the amount of silt and probably contaminants moving from the uplands into the wetlands is not just the result of the fact that an area is in cropland but also of what is growing on that cropland. There is also reason to believe that material moving to the wetland is a function of the type of crop and its stage of development. Unfortunately, we were not able to interpret crop type and development stage from our photography. To do this we would need methods that improve both spatial and spectral resolution.

We recommend that this estimate of the area of exposed soil as an indicator of landscape condition be continued. Furthermore, we recommend that research be conducted to find technology that furnishes better spatial and spectral resolution. This enhanced capability would assist in documenting actual crop types present within the hexagons. Without data on crop types, interpretation of results from monitoring biological indicators of condition would be difficult, and direct measurement of herbicide and pesticide contamination also would be more difficult. For example, results presented in Chapter 8 show that the use of atrazine is correlated with the presence of corn.

4.4.3 Index to Wetland Change

Our index to wetland change was able to separate good- and poor-condition landscapes. We suspect that agricultural tillage of the wetlands and the surrounding uplands has altered the hydrologic function of the wetlands. Wetlands in disturbed sites are apparently hydrologically less stable than those in grasslands. The index to change in pond numbers was more sensitive than the index to wetland area. The change between June and July was the best separator of good- and poor-condition landscapes.

We recommend that this index be calculated for 40-km^2 hexagons during the next phase of EMAP in the PPR. However, our data suggest that the change from April to May does not furnish a good indicator of condition. Water in wetland basins may be frozen during April and snowcover was often present and obscured the basins; therefore, interpretation of water was inaccurate and the estimate of change from April to May is unreliable. We recommend that no April flight be conducted in the next phase of EMAP.

4.4.4 Estimates of Duck Production

Our model-based estimates of breeding population and of mallard production detected differences between good- and poor-condition landscapes. The difference was apparent despite the fact that we observed no association between duck pairs and number of wetland basins as would be expected. Number of breeding pairs showed promise as an indicator of landscape condition, but there were two problems. The counts were extremely variable and our sample sizes were meager. In addition, the model derived breeding pair estimates depend on ground counts that were made in the Wetland Management District, but not on the sample 10.4-km^2 plots. The resulting correction (γ) had outliers because of atypical wetland basins that were not actually on the plots. For example γ for mallards was 18.9 in 1992 and 14.0 in 1993 for the Crosby-Lostwood Wetland Management District which contains poor-condition plots 441 and 442. These extremely high γ estimates result from a single wetland basin in the district but not on the 10.4-km^2 plots.

We recommend that estimates of the five dabbling duck species used in the pilot study be continued, but that pair counts used to estimate γ be made on the 40-km^2 hexagon in the next phase of the EMAP studies. Three factors will greatly improve usefulness of this indicator of condition: (1) The larger size of the sampling units (40-km^2 hexagon) will help to reduce variability among sample plots; (2) the larger sample of plots (45 versus 16 in the current pilot) will improve chances of detecting differences between condition classes; (3) if we conduct the pair counts on the sample 40-km^2 hexagons, the procedures used in the pilot will have more validity. The procedure also will help solve the problem of obtaining a valid sample for each hexagon. We do not have to assume that basins where ducks are counted represent population density for the entire polygon; we only need to assume that deviation from our regression estimate for all ponds is represented by our sample. In practice, we recommend that the sample of ponds for estimating γ be a roadside sample which represents the size classes present on the hexagon. The actual estimate of duck numbers will be derived from video of the entire hexagon and can be corrected for temporal and spatial differences by γ derived from the roadside sample, thus avoiding the land access problem.

Section 5.0
IMPACT OF AGRICULTURAL PRACTICES ON WETLAND MACROINVERTEBRATES, SILTATION RATES, AND WATER-LEVEL FLUCTUATIONS

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5.1 INTRODUCTION

In support of the EMAP goal of collecting time-integrated measures of wetland condition, we evaluated the use of aquatic invertebrate remains, siltation rates, and water-level fluctuations in wetlands as indicators of wetland condition. Because the initial development and testing of sampling devices began in 1992 (see Section 9), they were not used on the EMAP pilot study plots until 1993. Hence, this section is based on a single year's sampling. We had originally planned to include water quality, *in-situ* invertebrate, and amphibian measurements in this study, but drought conditions in 1992 precluded their use and they were officially dropped from consideration.

5.2 OBJECTIVES

1. Determine if aquatic macroinvertebrate recalcitrant remains can be used to distinguish between wetlands occurring in poor-condition (cropped) landscapes and good-condition (grassland) landscapes.

2. Determine if siltation rates can be used to distinguish between wetlands occurring in poor-condition landscapes and good-condition landscapes.

3. Determine if water-level fluctuations can be used to distinguish between wetlands occurring in poor-condition landscapes and good condition landscapes.

5.3 METHODS

5.3.1 Objective 1

To determine whether aquatic macroinvertebrate remains could be used to distinguish between good-condition and poor-condition landscapes, we collected sediment and macroinvertebrate samples. From October 14 to October 25 (before freeze-up) and from April 21 to May 13 (after freeze-up) in 1993, we installed 5 bottle-top sediment traps (see Section 9) in each of the 36 EMAP pilot study wetland basins. Sediment traps served to collect both macroinvertebrate remains as well as sediments entering wetland basins from surrounding land. Within each wetland basin, we installed one trap on each of five transects that radiated from the center of the wetland basin (defined here as the lowest elevation) along random compass bearings.

We installed the sediment traps so that the top of the traps were 7.3 cm above the sediment-water interface and at an elevation where the tops of the traps would be level with the water surface when water depth at the wetland's center was 10 cm (Fig. 5-1). We used a Spectra-Physics Model 650 Laserplane to determine all elevations within $\pm$1.6 mm per 30 m. Sediment traps installed in wetland basins grazed by livestock were covered with a steel tripod surrounded by a length of chain to reduce disturbance.

At each study wetland, we located a large, stationary object (tree, power pole, large boulder, etc.) and marked it with high-visibility paint to serve as a benchmark to evaluate the effects of frost upheaval on sediment traps. We determined reference benchmark elevations ($\pm$1.6 mm per 30 m) using a laser level and then measured and recorded the difference in elevation between the benchmark and the tops of the sediment traps. We measured this difference in elevation again in early mid-spring after the wetlands had become ice-free to determine if freezing upheaval had altered the positions of the sediment traps. We readjusted the elevations of the sediment traps as necessary.

Just before fall freeze-up in September 1993, we removed all the sediment traps from wetlands and transported them back to the Northern Prairie Science Center (NPSC) laboratory in Jamestown, ND, where samples were stored in freezers until processed. We processed samples by removing a sample from the collection tube while it was still frozen, concentrating residues from the thawed sample on a 0.5 mm screen, examining sample residues over a light table, and separating invertebrate recalcitrant remains from residues using forceps. Soil and other debris > 0.5 mm remaining in the

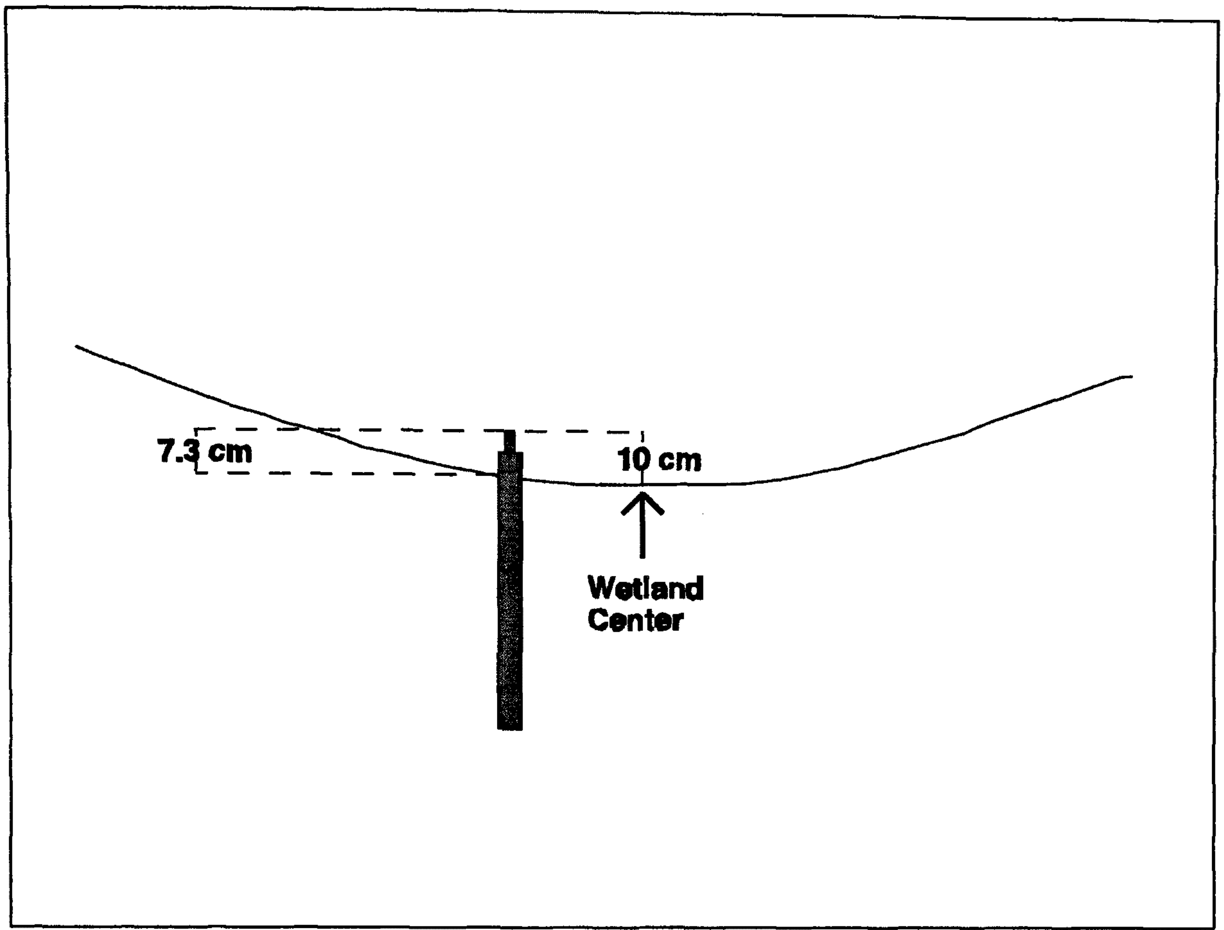

Figure 5-1. Placement of sediment traps in EMAP pilot study wetlands.

sample residue was returned to the screened sediment sample for determination of sediment dry weights. We then sorted the invertebrate remains into major taxonomic groupings, and enumerated and weighed them to the nearest 0.0001 g on an analytical balance after drying to a constant weight at 55-60 °C.

Statistical Methods: The response variables we analyzed included taxon richness, biomass, and abundance. The response variable for the biomass and abundance analyses was the mean weight (g) or count for each taxon (or all taxa combined). Taxon richness was the total number of taxa observed in each wetland basin. Separate analyses were performed for each of these macroinvertebrate response variables using the SAS General Linear Models (GLM) procedure (SAS Inst. Inc. 1989). Two-way analyses of variance (ANOVA) were used to assess the effects of wetland class (temporary, seasonal, and semipermanent), condition (good and poor), and their interaction on response variables. Fisher's least significant differences (LSD) procedure (Milliken and Johnson 1984) was performed to assess significant differences among wetland classes. We included only those wetlands in the sample that contained water some time during 1993 in our analyses (32 wetlands).

Taxon richness data consisted mostly of small whole numbers with numerous zeros. A transformation was performed using the square root of taxon richness plus 0.5 to stabilize the variance (Steel and Torrie 1980). A logarithmic transformation of the invertebrate count plus 1.0 was used to stabilize the variance to facilitate the abundance analyses (Steele and Torrie 1980). This transformation was also applied to the biomass data; however, the results of the biomass analysis in this report are for the untransformed data because both yielded similar results. For the analysis of the abundance data, we pooled over all transects and taxa within each wetland basin. In addition, separate analyses were performed for the four most common taxa (Cladocera, Ostracoda, Planorbidae, and Lymnaeidae).

5.3.2 Objective 2

To test siltation rates as an indicator of wetland condition, we separated sediments from invertebrates collected in our sediment traps by screening and removing invertebrate remains by hand. A 0.5 mm mesh screen retained invertebrates and larger sediment particles and debris, while fine sediments passed through. After we removed invertebrates from sample residues, we added the remaining material to the fine sediment material that was previously separated by sieving. We then weighed all sediments collected in the traps described to the nearest 0.01 gram after we centrifuged them at 5,000 rpm for 10 minutes to remove excess water and dried them in an oven at 100 °C until a constant weight was reached.

Statistical Methods: The analysis was performed using the SAS GLM (SAS Inst. Inc. 1989). A two-way ANOVA was used to test for condition effects, class effects, and the condition by class interaction. If the class effect was significant, a Fisher's LSD procedure (Milliken and Johnson 1984) was used to isolate the location of differences. Only wetlands that contained water during 1993 were used in the analysis (n=32 wetlands).

In the analysis, we averaged sediment dry weights over all transects within each wetland. This was necessary because of the sparse nature of the data. The logarithmic transformation of the response plus 1.0 was used to stabilize the variance to facilitate the analysis (Steele and Torrie 1980).

5.3.3 Objective 3

We used a water-level recorder to find out whether water level fluctuations could distinguish between wetlands occurring in good- and poor-condition landscapes. From April 21 to May 13, 1993, we placed one water-level recorder in the center (lowest elevation) of each of the 36 EMAP pilot study wetlands. The water-level recorders were developed specifically for this EMAP pilot study and are described in Section 9 of this report. Briefly, they consist of a copper-coated steel rod that guided a large float up and down as water levels fluctuated. Two magnetic slides, one above and one below the float were pushed by the float to positions on the rod that corresponded to maximum and minimum pool levels. The devices were removed from the wetlands between Aug. 25 and Sept. 16, 1993, and the distance between the 2 slides was measured and recorded. The distance between the slides was our measurement of water-level fluctuation during the study.

Statistical Methods: The analysis was implemented by SAS GLM (SAS Inst. Inc. 1989). Two-way ANOVA techniques were used to assess the effects of condition (good and poor), class (semipermanent, temporary, and seasonal), and the condition by class interaction. If the class effect was significant, a Fisher's LSD test (Milliken and Johnson 1984) was used to locate differences. The response evaluated was the difference between the maximum and minimum depth measurement divided by the total area of the watershed (see Section 7). A logarithmic transformation of the response plus 1.0 was used in the analysis of response variables to stabilize the variance to facilitate the analysis (Steele and Torrie 1980). Only wetland basins that contained water during the study and basins where the devices were not destroyed by cattle were used in the analysis (n=27 wetland basins).

5.4 RESULTS

5.4.1 Objective 1

Our analyses of taxon richness, invertebrate biomass, and invertebrate abundance suggest that we may have collected too few samples (n=5) from an insufficient number of wetland basins (n=27) (Table 5-1). Based on the variance observed in our taxon richness data, we estimate that we should have collected 3 to 11 samples (16 to 148 for biomass) from 100 to 120 wetland basins (440 to 460 for biomass) just to estimate within 10% of the mean, 90% of the time. Based on our small sample size of 32, we failed to detect differences in taxon richness for wetland condition (F=0.01; 1,26 df; P=0.9111), wetland class (F=1.49; 2,26 df; P=0.2451), or for the condition by class interaction

(F=1.28; 2,26 df; P=0.2952). However, there was a slight tendency for taxon richness to increase with water permanence (i.e., temporary wetland < seasonal wetland < semipermanent wetland) (Fig. 5-2). We also failed to detect differences in biomass for wetland condition (F=0.70; 1,26 df; P=0.4088), wetland class (F=0.58; 2,26 df; P=0.5659), or in the condition by class interaction (F=0.50; 2,26 df; P=0.6105).

Our analysis of invertebrate abundance also suggests that we collected too few samples from an insufficient number of wetland basins, but the analysis did suggest that abundance may be worth considering in future studies assessing water permanence. For all taxa pooled over the 5 transects, there was a *significant class effect* (F=3.90; 2,26 df; P=0.0331) with *semipermanent wetlands having* larger abundances (40.76) than temporary wetlands (3.45). However, we did not find a significant condition effect (F=0.63; 1,26 df; P=0.4330) or a condition by class interaction (F=2.21; 2,26 df; P=0.1297) for invertebrate abundance. We estimate that we should have collected 5 to 13 samples from 650 to 670 wetlands to adequately evaluate the potential of invertebrate abundance as a potential indicator of wetland condition (Table 5-1).

Table 5-1. Number of wetlands and samples per wetland needed to estimate means within 10%, 90% of the time. Note that the number of samples per wetland depends on the number of wetlands sampled.

		Variance		
		Within	Between	Sample Size
Variable	Mean	basin	basins	Wetlands (Samples)
Taxon Richness	1.3968	0.0829	0.1069	100 (11)
				120 (3)
Biomass(g)	0.0094	0.0012	0.0001	440 (148)
				460 (16)
Abundance	2.7271	0.7192	2.7830	650 (13)
				670 (5)
Sedimentation(g)	1.1783	0.2261	0.3866	220 (13)
				240 (4)

We also examined the effect of wetland condition and class on the abundance of the four most common invertebrates in our sample (i.e., Cladocerans, Ostracods, Lymnaeid snails, and Planorbid snails). For Cladocerans, we found no wetland condition effect (F=0.01; 1,26 df; P=0.9427), no wetland class effect (F=1.57; 2,26 df; P=0.2263), and no interaction of condition with class (F=2.34; 2,26 df;

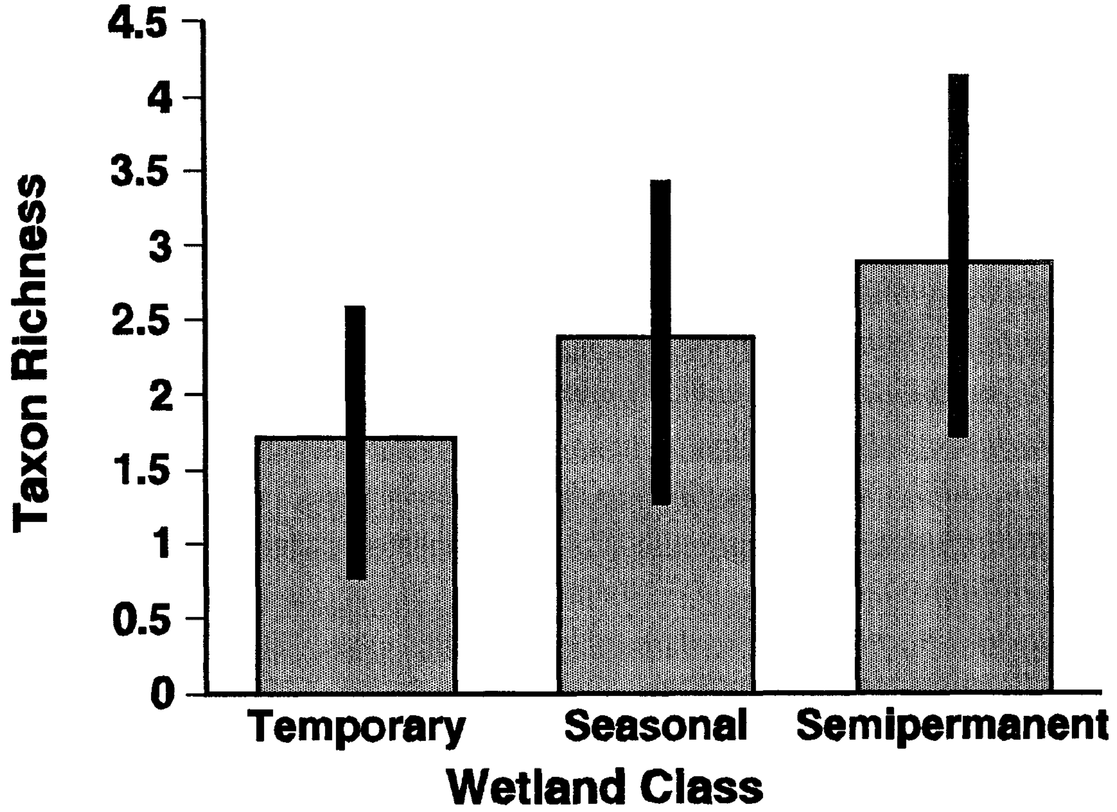

Figure 5-2. Taxon richness (back transformed LSMs) of invertebrates captured in sediment traps installed in EMAP pilot study wetlands, 1993. Black bars = 95% C.I.

P=0.1165). Ostracods had no condition effect (F=0.31; 1,26 df; P=0.5837), a marginally significant class effect (F=3.14; 2,26 df; P=0.0601), and no condition by class interaction (F=1.74; 2,26 df; P=0.1951). Mean abundance of Ostracods in semipermanent wetlands (33.23) appeared to be higher than in temporary wetlands (2.37). Abundance of Lymnaeid snails did not appear to be affected by wetland condition (F=0.99; 1,26 df; P=0.3285), wetland class (F=0.23; 2,26 df; P=0.7985), or by the condition by class interaction (F=0.74; 2,26 df; P=0.4853). However, Planorbid snails appeared to have been affected by wetland class (F=2.88; 2,26 df; P=0.0743) with seasonal wetlands having more snails (1.31) than temporary wetlands (0.08). Like the other four taxa of invertebrates, Planorbid snails were not affected by wetland condition (F=0.11; 1,26 df; P=0.7467) or by condition by class interactions (F=0.64; 2,26 df; P=0.5373). However, as with other invertebrate variables, sample size likely affected our evaluation.

Our evaluation of the effect of frost upheaval on our sediment traps clearly indicates that freezing winter temperatures did affect the locations of sediment traps (Table 5-2). Traps moved from 0 to 5.73 cm and had to be readjusted to the proper sampling elevation to insure that all sediment traps collected invertebrates and sediments over the same time frame, regardless of water-level fluctuations.

Table 5-2. **Mean movement (*fall 1992 elevation - spring 1993 elevation*) of sediment traps installed in EMAP pilot study wetland basins during 1992. Plots 241, 246, 249, and 396 were dropped as EMAP study sites in 1993. However, elevations were measured when we removed equipment from basins within these plots in April, 1993.**

Plot	Wetland #	Movement (cm)	Standard Deviation
73	29	0.00	0.000
134	140	0.18	0.167
134	270	2.32	2.546
134	406	-0.06	0.136
134	432	0.00	0.000
156	22	1.04	1.069
241	3	0.00	0.216
241	48	5.73	3.988
246	53	0.00	0.000
249	50	0.49	0.348
249	86	2.68	1.756
363	22	0.00	0.000
363	58	0.12	0.273
396	106	0.43	0.273
396	107	0.06	0.136
442	93	0.00	0.000
442	260	0.00	0.000
442	261	1.40	1.487
442	281	0.00	0.000
442	295	0.00	0.000
442	301	0.49	0.632

5.4.2 Objective 2

The analysis of sediment dry weights, like our invertebrate analysis, failed to identify indicators of wetland condition. Also, as with our invertebrate analysis, there was extremely high within-basin and between-basin variability, and it appears that we collected too few samples from an insufficient number of wetland basins. We found no wetland condition effect (F=0.18; 1,26 df; P=0.6775), no wetland class effect (F=0.02; 2,26 df; P=0.9830), and no interaction of condition by class (F=0.80; 2,26 df; P=0.4618). To have estimated the mean within 10%, 90% of the time, we estimate that from 4 to 13 samples would have to be collected from 220 to 240 wetlands (Table 5-1); our small sample of 32 was clearly insufficient to adequately evaluate this variable as an indicator of wetland condition.

5.4.3 Objective 3

The analysis of water-level fluctuations (corrected for watershed size) clearly identified a potential indicator for EMAP. We observed both a wetland condition effect (F=7.08; 1,26 df; *P*=0.0146) and a wetland class effect (F=4.88; 2,26 df; *P*=0.0182). Further, there was no condition by class interaction (F=0.86; 2,26 df; *P*=0.4376) to complicate the interpretation. In proportion to watershed size, wetland basins in poor-condition had greater water-level fluctuations (14.14 cm) than basins in good condition (4.27 cm). Further, seasonal wetlands and temporary wetlands both had greater water-level fluctuations (11.82 cm and 13.74 cm respectively) than semipermanent wetlands (2.77 cm) (*P*=0.0220 and *P*=0.0090, respectively); there was no difference in water-level fluctuation between seasonal and temporary wetlands (*P*=0.7775).

5.5 EVALUATION

5.5.1 Objective 1

Our analysis of the invertebrate data failed to identify invertebrate response variables that could be used as indicators of wetland condition. While it is clear that we collected too few samples from an insufficient number of wetlands, it is doubtful that even a sufficient number of samples would have identified suitable indicators of wetland condition, with the possible exception of taxon richness. Invertebrates are naturally highly variable, on both spatial and temporal scales, and this high natural variability will make future attempts to identify invertebrate indicators difficult. We originally hoped that by using sediment traps to collect invertebrates over discrete time periods, much of this interfering variability would be mitigated. However, our study clearly indicates that both the within-basin variability and the between-basin variability was exceptionally high and that it would have required both an inordinate and a cost-prohibitive number of samples to adequately evaluate the invertebrate response variables.

Recommendations for Future Work: We recommend that invertebrate remains be dropped from the next evaluation of wetland condition indicators. Of the response variables considered as indicators, only taxon richness could possibly be evaluated, but we would need to more than double the number of wetland basins sampled. If sediment traps are used to index taxon richness, our study indicates that frost upheaval clearly alters the elevations of the traps and hence they will need to be readjusted each spring after thaw. Despite the shortcomings of the approach used in this study, we still feel that invertebrates have potential as indicators of wetland condition and suggest that future EMAP work focus on invertebrate variables collected over a larger spatial scale (i.e., landscape scale). To this end, the use of sticky traps or light traps (Belton and Kempster 1963, Harding et al. 1966, Belton and Pucat 1967, Mason and Sublette 1971, Davidson et al. 1973, and Borror et al. 1981) may prove to be particularly useful sampling methods.

5.5.2 Objective 2

Our analysis of sediment dry weights failed to identify an effective indicator of wetland condition for EMAP. As was the case with the response variables evaluated under Objective 1, excessive variation interfered with the evaluation of sediment dry weights as an indicator of wetland condition. However, much of this variation may have been due to where the traps were placed in the wetland basin rather than natural variability as has been documented for invertebrates.

Recommendations for Future Work: While it is intuitive that increased rates of sedimentation would characterize landscapes heavily impacted by agriculture, we feel that the placement of our traps strongly influenced the results. The sediment traps used in this study served the dual purpose of collecting both sediment and invertebrate remains. As a safeguard against the generally dry conditions during the initial year of the pilot, it was decided to place traps close to the center of the wetland basin so they would collect invertebrates over longer periods of time. However, wetland basins tend to silt in from the sides, and hence we probably did not place the sediment traps in an optimal location to measure siltation. Future studies should use traps placed to measure siltation exclusively and locate them as close to the periphery of the basins as possible. Perhaps a better choice would be a surface flow trap (Robert Gleason 1966) that is situated on the upland side of the wetland edge. The main advantages of this trap over conventional sediment traps are that its function does not depend upon water levels in the wetland basin and it is optimally placed to measure siltation near the wetland edge. The main disadvantages are that vegetation growing in front of the collector tends to deflect silt-laden runoff water and it is located close enough to the wetland basin edge that it could be damaged by farm equipment, especially during dry years.

5.5.3 Objective 3

The water-level recorders we developed (see Section 9) yielded data that clearly demonstrate the value of water-level fluctuation as an indicator of wetland condition for EMAP. The water-level recorder was also useful for separating wetland classes, and there was no wetland condition by class interaction to complicate the interpretation of results.

Recommendations for Future Work: We recommend that future work continue to use and refine the water-level recorders used in this study. While the device yielded useful data, there were some signs that it may not hold up under extensive use. Specifically, we noted that the copper-coated steel welding rods used as guides for the floats and depth indicators were beginning to corrode where their copper coatings had either been scratched or were plated too thinly. Although it was not a problem during the short time period the devices were left in place for the pilot study, if the devices are left in wetland basins for more than 1 year, the corrosion could interfere with the movement of the floats and depth indicators along the rods and thus cause the devices to give false water-level readings. In future work, we suggest that commercially available copper-clad welding rods not be used for the guide rods. Instead, the rods need to be custom made with a thicker copper plating that would resist scratching and be less likely to have thin spots. Also, we suggest that the PVC casings of the devices be constructed out of 4-inch (10.2 cm) I.D. pipe instead of the 3-inch (7.6 cm) I.D. pipe used in this study. This would allow the size of the float to be increased, thus providing greater buoyancy to push the maximum indicator up the rod and greater weight to push the minimum indicator down if some minor corrosion of the rod should occur. However, we do not feel that a separate evaluation of the design modifications would be necessary as was done in this pilot study.

Section 6.0
PLANTS AS INDICATORS OF WETLAND CONDITION IN THE PRAIRIE POTHOLE REGION

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6.1 INTRODUCTION

The purpose of this part of the EMAP pilot study was to determine whether plants could provide useful site-level indicators of differences between wetlands in lightly-stressed ("good condition") watersheds and those in heavily-stressed ("poor condition") watersheds. As indicated in Section 1.0, study sites were selected on the basis of watershed land use. Lightly-stressed watersheds were considered those dominated by perennial grasses or grass-legume mixtures used for pasture or hayland or idled under Federal agricultural programs, whereas heavily-stressed watersheds were considered those dominated by annually-seeded small grain and row crops.

Prairie wetlands are inherently unstable ecosystems because water supplies are variable, unpredictable, and often largely external. Stresses from agriculture horizontally directed from upper watersheds toward the wetland centers add to this instability. Agricultural stresses may be direct or internal, as when the basins themselves are used to raise crops, or indirect or external through siltation and chemical runoff from the watersheds. Perturbations such as tillage, seeding, fertilizing, and chemical spraying are common; many wetland watersheds in the Prairie Pothole Region (PPR) have been used for cropland almost continuously since the late 1800's. In either case, silt and nutrient loadings increase in affected basins.

The initial direct disturbance to a wetland by cultivation is severe. Cultivation probably affects all stages in the regeneration cycle of native plants. This cycle is important in maintaining plant species diversity (Grubb 1977). Tillage equipment severs rhizomes of the native perennial hydrophytes and overturns and dries the sod; repeated disking and harrowing may follow for a year or more prior to planting. These operations totally eliminate most of the native plants. After this stage, entire basins of lesser water permanence are regularly cultivated for crop production or to control weeds whenever water levels permit. The peripheral zones of wet basins (areas closely related to degree of water permanence and having characteristic assemblages of plants; [Stewart and Kantrud 1971]) are also regularly cultivated. Thus, these cultivation stresses are, in a sense, predictable and do not allow recovery of the original native plant community. However, some plants are adapted to repeated disturbances of bottom substrates and such disturbances may eliminate competitive dominants, thereby allowing competitive subordinates to occupy the disturbed sites (Wilson and Keddy 1986). In frequently cultivated wetlands in the PPR, these subordinates consist of a few rapidly-maturing annuals and relatively short, deep-rooted perennials.

Besides direct tillage, other stressors common to plant communities in frequently cultivated wetlands are inputs of silt, pesticides, and fertilizers. Silts come from adjacent uplands, but pesticides and fertilizers can also be directly applied. It is generally unknown whether these stressors have antagonistic, synergistic, or additive effects (*sensu* Turner 1985) on the structure and function of these communities. However, fertilizers normally increase productivity and decrease species richness in most wetland plant communities studied (Vermeer and Berendse 1983). On the other hand, atrazine-type herbicides, commonly used on row crops in the region, seem to greatly decrease both production and species richness, and these decreases may persist at least into the following growing season (James Richardson, North Dakota State University, pers. comm.; H. A. Kantrud, pers. obs.).

Wetlands of greater water permanence lying in cultivated watersheds are often left idle because cropping is difficult due to access problems, salinity increases after cultivation, sandy bottoms, or large boulders or trees are present. These basins are also subject to increased nutrient loadings and many usually accumulate large amounts of standing dead vegetation. Silt from the adjacent cropped uplands sometimes is deposited in the peripheral zones to form a barrier or is frequently carried into interior zones to form a mud delta. Woody plants, especially *Salix* spp. and *Populus* spp. also invade idle wetlands, especially where wet-meadow zones are earlier disturbed by cultivation. Idle coastal marshes show decreased plant species richness and number of vegetation types present and vegetation mosaics tend to be coarse-grained (Bakker 1985; Andresen et al. 1990). Idleness also allows formation of monotypic stands of robust emergents that shade out shorter plants and lowers avian diversity and abundance (Jones and Lehman 1987; Hellings and Gallagher 1992). For some plants, such shading can be more important than the effects of herbivory and competition on seedling establishment (Bergelson 1990). Buildup of litter and organic material from emergent species in prairie wetlands can reduce water depth or eliminate shallow-water areas (Ward 1942, 1968; Walker 1959; Hammond 1961). Native plants in the region are adapted to hydrological changes, fire, and herbivory, especially by large mammals. In pre-agricultural times, these natural forces probably created some sort of normal, but unknown, homeostatic behavior of the grassland ecosystem. Livestock grazing is currently the dominant land-use practice in grassland-dominated watersheds in the region, although haying is not uncommon. Pastures in the region nearly always include natural wetland basins that are the most common sources of livestock water. Nevertheless, many livestock watering facilities have been constructed, some in natural basin wetlands. Prairie wetlands are basically wet grasslands. Lack of grazing in grasslands is abnormal; under such situations, plants seemingly dependent on herbivory (obligate grazophiles) can disappear (McNaughton 1979, 1986). Ratios of standing crop to litter can fall as plant communities age in the absence of grazing (Bazely and Jeffries 1986). Conversely, livestock grazing, especially in spring and fall, maintains species richness in meadow grasslands (Smith and Rushton 1994). Grazing in long-idled salt marshes slowly enhances species diversity and creates fine-grained vegetation mosaics (Bakker 1985). Grazing by cattle of monodominant stands of *Typha glauca* in prairie wetlands decreases live stems, dead stems, and litter (Schultz 1987). Grazing thus may remove much organic matter and create open water areas where submersed plants flourish. There is a threshold to tolerance for grazing, however, even in prairie wetlands, because long-term overgrazing and trampling can reduce the shallower zones to nearly bare soil.

Landowners commonly mow and remove emergent vegetation for livestock feed or bedding in the PPR, especially in watersheds that are seeded to perennial forage crops such as alfalfa. Larger wetlands in annually-tilled watersheds are also used for hay production. Some native species, such as *Scolochloa festucacea*, are considered excellent forage by livestock producers. Others, such as *Phalaris arundinacea*, may be seeded in wetland basins. The amount of forage produced and the wetland zones affected depend on summer or early fall water levels. In basins devoted to forage production, wet-meadow zones are hayed nearly every year, whereas deep-marsh zones are usually hayed only after a series of dry years. Most observers agree that long-term use of basins for hayland tends to increase the abundance of certain emergent hydrophytes (Smeins 1967; Walker and Coupland 1968, 1970; Stewart and Kantrud 1972).

6.2 INDICATORS TESTED

To meet the objectives listed in Section 1.0, I measured

1. abundance and species richness of emergents in temporay, seasonal, and semipermanent wetlands

2. amount of standing dead vegetation and litter in seasonal and semipermanent wetlands

3. abundance of submergents and the ratio of emergent cover to open water in deep-marsh zones of semipermanent wetlands

4. abundance of metaphytic or planktonic algae in open water areas in deep-marsh zones of semipermanent wetlands.

Measurements 3 and 4 were dropped from the study because the sample included only four open water areas in deep-marsh zones; all were found in wetlands in good-condition watersheds, so no comparisons were possible.

6.3 METHODS

6.3.1 Design

I studied 40 sample wetland basins in 1992 and 36 in 1993--32 of these basins one of the two years only and 21 in both years (Table 6-1). Field work was conducted in July and the first week of August because peak standing crops occur during these months in the north-temperate United States (Bernard 1974). The soil and sediment evaluation researchers accompanied me in the field. I was provided a large-scale map showing distances between the sample wetland basins. We visited the basins in a general south-to-north route to help compensate for the approximately two-week difference in phenology between the southernmost and northernmost study areas. I was provided county road maps, National Wetland Inventory (NWI) maps, and high-level aerial photographs of the selected 10.4 km^2 plots showing the sample wetland basins and the suggested access routes, gates, and parking locations. I was also provided low-level aerial photographs, taken in mid-June, of each sample wetland basin (see Section 1 for details). The team carried basin visitation forms and landowner contact forms giving the landowner's name and telephone number, place of residence, and any special precautions to be used when visiting the basin.

Table 6-1. **Sampling design lay-out showing single (X or x) or multiple communities (number) sampled within deep-marsh (DM), shallow-marsh (SM), or wet-meadow (WM) zones in basins in good-condition and poor-condition watersheds, 1992-1993.**

Good-condition watersheds Identification number		1992			1993		
Plot	Basin	DM	SM	WM	DM	SM	WM
73	29	X	X	X	x	x	x[a]
374	100	x	x	x	X	X	X
374	225	X	X	X	x	2	x
442	301	x	x	x	X	X	X
156	22		X	X		x	x
363	22		x	x	X		X
363	58		X	X		x	x
442	93		x	x		X	X
442	295		X	X	x	x	x
73	86			X			x
156	24			x			X
156	26			X			x
156	42			x			X
374	272		2				2

Good-condition watersheds Identification number		1992			1993		
Plot	Basin	DM	SM	WM	DM	SM	WM
374	65			x			X
60	58		X	X			
60	128			X			
249	50		X	X			
249	86		X	X			
59	111		X	X			
396	106			X			
396	107			X			
396	130		X	X			
407	67						X
407	109						X
498	146				X	X	X
498	227						X
498	277				X	X	X
133	386				X	X	
407	168				X	X	X
Total communities		5	13	24	9	13	23
Grand total							87

Table 6-1. (continued)

Poor-condition watersheds Identification number		1992			1993		
Plot	Basin	DM	SM	WM	DM	SM	WM
134	140		<u>2</u>			X	X
134	165		X			x	x
134	270			X		x	
134	406		x	x	X	X	X
134	432			X			x
442	260			x			X
442	261			X			x
442	281		x	x		X	X
38	62			X			
54	39			X			
59	42	X	X	2			
134	272			X			
241	3	X	X	2			
241	48			2			
246	34			X			
246	37			X			
246	53		X	X			
133	370						2
133	380					X	X
134	158						X
327	72				X	X	
327	117					X	2
Poor-condition watersheds Identification number		1992			1993		
Plot	Basin	DM	SM	WM	DM	SM	WM
327	147					X	X
Total communities		3	8	17	1	8	16
Grand total							53

[a]Data from communities designated by lower case x's and underlined numbers were not used in ANOVAs or for estimating least squares means for response variables measured at the community level (see methods).

6.3.2 Field Methods

6.3.2.1 Watershed and Wetland Classification

Upon arrival at each sample wetland basin, I recorded the time of entry and any landowner contacts on a basin visitation form. The timing of the surveys generally followed seeding operations and preceded haying operations.

I visually estimated the current and recent past land uses of the watersheds of each sample basin. Land-use categories were cultivated, grazed, hayed, burned, and idle. This sometimes required that I walk to nearby high vantage point(s) around each basin. Watershed land uses were in most cases similar to those estimated for the recent past (prior growing season). Exceptions were stands of idle grass that obviously had been grazed or mowed during the previous recent past. There was little evidence of newly cultivated grassland. For watersheds currently cultivated, I also estimated the proportional areas of various crops or tillage practices. These catgories included row crop, small grain, row crop stubble, small grain stubble, weedy fallow, and bare fallow. I also estimated the proportional areas of the watersheds of each sample basin wetland occupied by annual vegetation (crops and weeds), perennial vegetation (native grassland or seeded perennials forage crops used for hay), or odd areas (rockpiles, road right-of-ways, buildings, etc.).

On the low-level aerial photograph of each sample basin wetland, I delineated wetland zones (Stewart and Kantrud 1971) using a permanent marking pen. A low-prairie zone not recognized as wetland under the Cowardin et al. (1979) wetland classification occurs around nearly all palustrine and lacustrine prairie wetlands. This zone is inundated only when water levels are unusually high. Wet-meadow zones also occur in nearly all palustrine and lacustrine prairie prairie wetlands, the few exceptions being fens where groundwater seepage is constant, and in small areas along shorelines of a few semipermanently-flooded or permanently-flooded basins where wave action cuts steep banks along high-relief shorelines. Wet-meadow zones develop under a temporarily flooded water regime whereby ponding occurs for a few weeks after spring snowmelt or occasionally for a few days after heavy rains later in the growing season. Thus for basins lying in cropland, this zone is often available for planting to spring-seeded crops or for summer or fall tillage for weed control or soil preparation in all but the wettest years. These conditions often make the outermost edge of the wet-meadow zone difficult to recognize.

Regional shallow-marsh zones are subject to a seasonally flooded water regime whereby ponding usually occurs for a month or more from spring snowmelt to early summer. During relatively dry years these zones are also commonly cultivated and planted to spring-seeded crops and tilled in the fall with the adjacent uplands. Deep-marsh zones ordinarily follow a semipermanently-flooded water regime whereby surface water normally persists except during a year or more of drought. Fen (alkaline bog) zones normally saturated by alkaline ground-water seepage sometimes dominate the central areas of prairie wetlands, but more frequently occur as isolated pockets around the margins of semipermanently- and permanently-flooded basins.

For each sample wetland basin, I visually estimated the proportional areas of phases (Stewart and Kantrud 1971) within each zone. Phases reflect changes in water levels and the intensity or frequency of certain land-use practices. The normal emergent phase is present under normal water levels and natural untilled conditions. A natural drawdown phase occurs during periods of low precipitation. Cultivation of zones results in a cropland tillage phase containing mostly planted crops and agricultural weeds or a cropland drawdown phase dominated by plants that pioneer on exposed moist soil after surface water dissipates.

For each sample wetland basin, I visually estimated the proportional area of each zone devoted to current and recent past (prior growing season) land use practices. Land-use categories were the same as used for the watersheds.

To fully describe the sample wetland basins I also delineated their other wetlands and within-basin uplands on the low-level aerial photographs. Other wetlands were dugouts constructed for watering livestock during drought years. Within-basin uplands were rockpiles or spoils from construction of the dugouts.

6.3.2.2 Plant Abundance and Species Richness

I delineated plant communities within zones on the low-level photographs using a permanent marking pen. I numbered each community, and assigned it to a zone (low prairie, wet meadow, shallow marsh, deep marsh, and fen), phase (natural emergent, natural drawdown, cropland drawdown, and cropland tillage), and land use (cultivated, grazed, hayed, and idle). Plant communities were considered vegetation in relatively uniform environments with floristic composition and structure relatively uniform and distinct from surrounding vegetation (Westhoff and van der Maarel 1973).

If wetland basins were subject to different land uses, plant sampling was restricted to that portion of the basin with predominant land use. Within this area, sampling was further restricted to plant communities occupying at least 10% of the area (Figure 6-1). I numbered all plant communities, noted whether they were grazed, hayed, burned, cultivated, or idle, and assigned them to wetland zones and phases of Stewart and Kantrud (1971). Although vegetation usually forms a virtual continuum around prairie wetlands, zonation is usually evident (Johnson et al. 1985). In a few instances, drastic water level increases, cultivation, or rapid crop growth in late June or early July rendered portions of the field photographs unusable. In those cases, wetland and community boundaries were delineated using whatever reference points (boulders, haystacks, fencelines) were available.

I used a modified method of Barker and Fulton (1979) for Objective 1 to speed vegetation sampling. I sampled vegetation along the long axis through the center of each plant community to avoid edge effects. I paced the long axis, and at each of five roughly equidistant points along the axis I threw a marker buoy overhead. At its point of impact I centered a 1 m^2 collapsible quadrat frame of my own design (Figure 6-2). I marked quadrat locations on the low-level aerial photographs.

I assigned a Daubenmire (1959) cover class to each macrophyte taxa in the quadrat based on its shading of the substrate surface. For emergents, substrates were water surfaces if surface water was present or bottom sediments if surface water was absent. For floating and submerged plants, substrates were bottom sediments. Midpoint values of the cover classes were used to obtain mean cover values (n=5) for each plant taxon within the quadrats for each community. Midpoint values were 2.5, 15, 37.5, 62.5, 85, and 97.5. Means of the mean cover values for taxa within the quadrats provided estimates of the abundance of these taxa among wetland phases. Plant taxa not encountered in the quadrats were noted while walking between quadrats. Total taxa recorded inside and outside the quadrants provided a measure of taxa richness for each community. Nearly all plants were identified to species, but a few were identified only to genus or family or were unidentified. None of the unidentified plants were identified to species at another sample wetland.

A species list is provided (Appendix 6-1). Mean number of taxa was calculated for each wetland zone and phase by watershed condition.

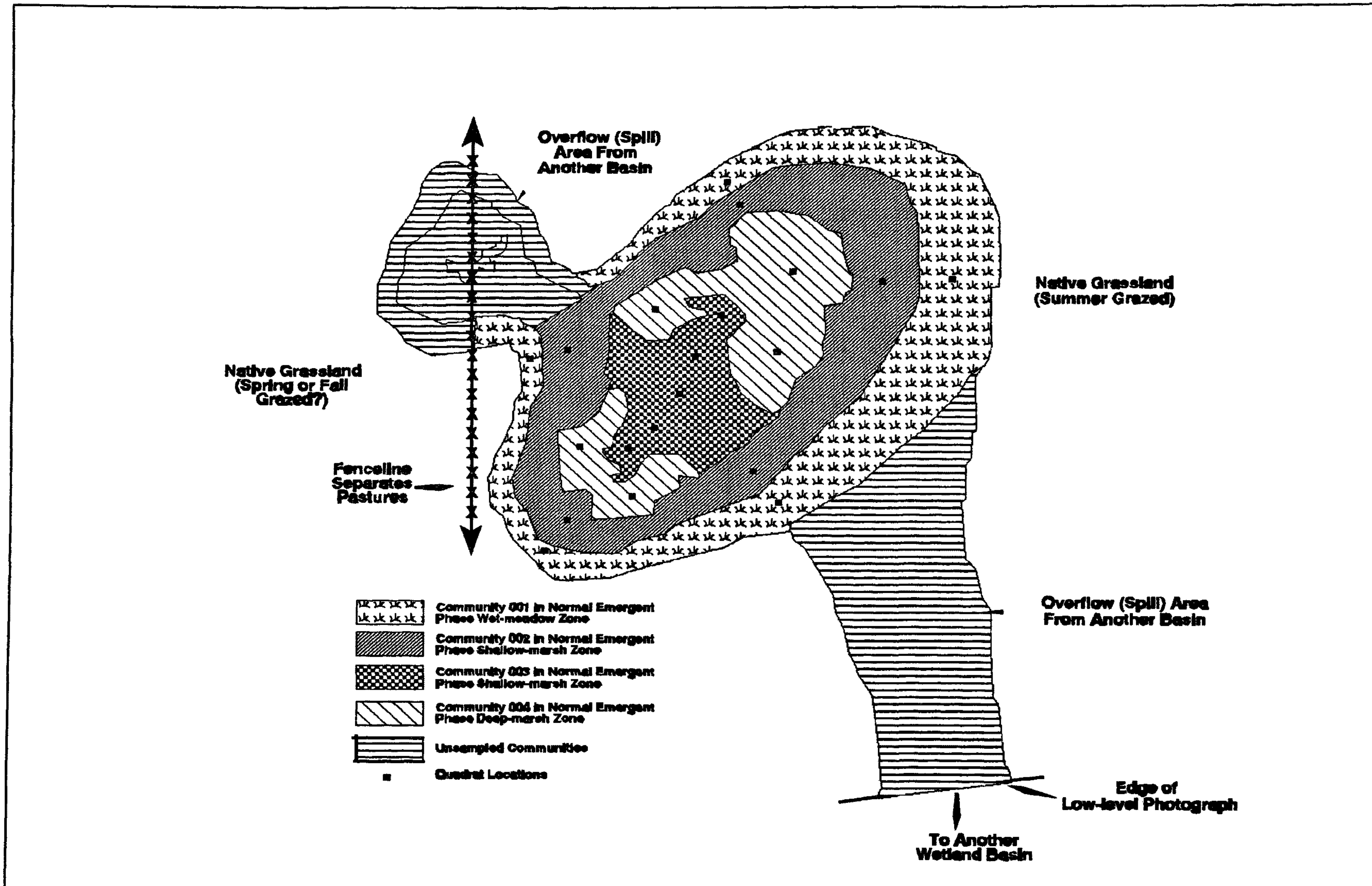

Figure 6-1. Wetland 374-225 (1993) showing sampled and unsampled hydrophyte communities, location of quadrats, and land-use of uplands.

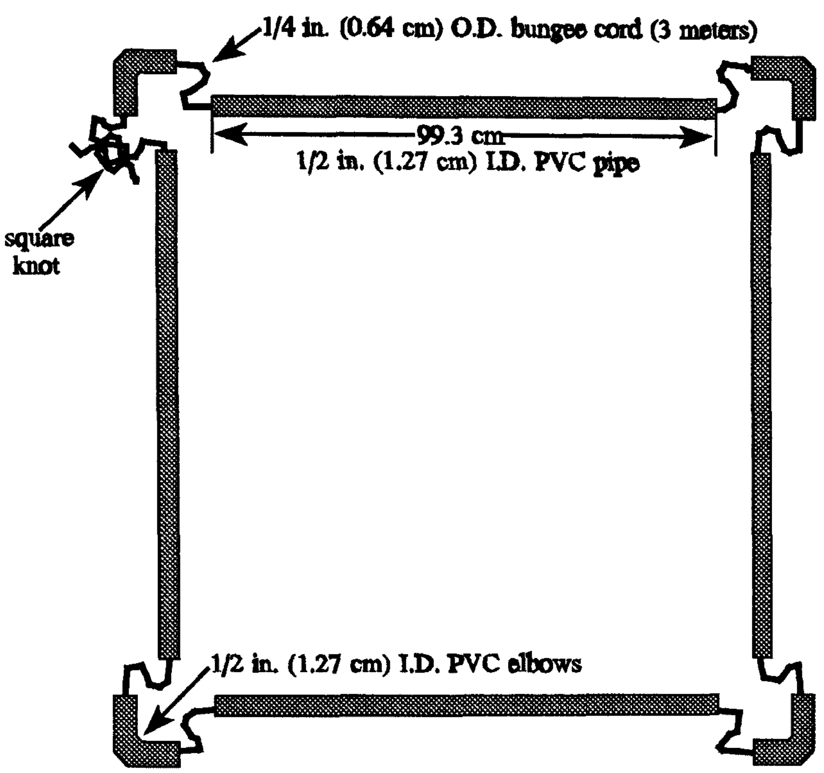

Figure 6-2. Collapsible quadrat frame.

6.3.2.3 Standing Dead Vegetation and Litter Depth

I visually estimated the percentage of standing dead vegetation in each quadrat. Mean percent standing dead vegetation (n=5) was calculated for each community.

After I completed the plant sampling, the soils and sediment researchers cored the bottom substrate at the center of each quadrat with a hand auger and measured litter depth to the nearest cm. The fresh litter cores were recognizable as undecomposed or partially decomposed fallen vegetation. The bottom of the litter layer was considered the point where decomposing material changed from fibric (peat) to hemic (muck) or where plant remains became unrecognizable as such when observed through a 10X hand lens. The mean depth of the litter layer (n=5 in 1992 and n=3 in 1993) was calculated for each community. Cores were retained for analyses for the soil study. Another soil sample was bagged in plastic and held on ice for pesticide analysis (described in Section 8.0). I also estimated the percentages of unshaded bottom and unshaded open water in each quadrat and measured water depth to the nearest cm at the center of each quadrat. Means for these supplementary variables (n=5) were also calculated for each community. Means for standing dead vegetation, litter depth, unshaded bottom, unshaded open water, and water depth were averaged for zones and phases by watershed condition.

My portion of the field work took about 20-25 working days for one person each year. Travel during field work totalled about 3,200 miles per season.

6.3.3 Analysis

At the end of each field season, I scanned and georeferenced the low-level aerial photos with a Map and Image Processing System (MIPS) to determine areas of the sampled plant communities. On each image I classified all polygons as to wetland zone, other wetland (e.g. excavated dugouts for livestock watering), and included uplands (e.g. spoils or rockpiles), and marked the locations of quadrats.

We used analysis of variance (ANOVA) techniques to assess the effects of watershed condition and year on total zone area. Because approximately half of the sample wetland basins were measured in both 1992 and 1993, the design was one of repeated measures with year serving as the repeated measures factor. ANOVAs were done separately for each of the five zones; low-prairie, wet-meadow, shallow-marsh, deep-marsh, and fen.

We also used ANOVA techniques to assess the effects of watershed condition, zone, and year on all response variables measured at communities within zones (Table 6-2). The sampling design was a split-plot with repeated measures. Each basin was assumed to be the independent whole-unit, with zone and community combination being the sub-unit (see Table 6-1). Because some sample wetland basins were measured in both 1992 and 1993, year served as the repeated measures factor. However, because of the highly unbalanced design structure (Table 6-1) the three-way interaction effect and least squares means of wetland condition by zone by year was not fully estimable for the repeated measures design. Therefore, we randomly deleted one year's data on basins that were used in both 1992 and 1993. This allowed basin to become "nested" within year and wetland condition and thus made the three-way interaction testable, albeit with slightly less power. We report the least squares means from this "balancing" approach as all combinations among year, water condition, and zone are estimable.

Although not exhaustive, multiple passes were made through the data with a different random selection each pass. In all passes, ANOVAs yielded similar conclusions. We used Fisher's protected least significant difference (LSD) to isolate differences in least squares means following significant effects in the ANOVAs (Milliken and Johnson 1984) where applicable.

All ANOVAs were done using the general linear model procedure (PROC GLM) of SAS (SAS Inst. 1989). Least squares means (SAS Inst. 1989) were computed and reported when adequate data was available for ANOVAs. Otherwise, arithmetic means are reported. Effects considered fixed and random are listed in Table 6-3. For most of the response variables we conducted the ANOVAs both in the original unit of measurement and using a $\ln(Y+1)$ transformation. We do not report the results of the transformation, only that we analyzed the response variables in their original scale, (i.e., untransformed) and as $\ln(Y+1)$ transformed. The value one was added prior to transformation to accommodate zero values (Steel and Torrie 1980). Nine zones within a wetland basin had more than one community (see Table 6-1). We analyzed the data in both scales for two reasons: First, most biological data tend to follow a log-normal distribution, although we did not test for normality due to small sample sizes and for reasons described in Johnson and Wichern (1988:155) with respect to testing statistical normality and second analogous to Conover's (1980:337) recommendation with respect to using rank transformation and comparing results with untransformed data. However, because ANOVA results were similar for transformed and untransformed data, we only report the results for untransformed data; this indicates no gross departures from ANOVA assumptions for untransformed data. Analyses of the physical and botanical measurements for wetland zones included all wetland phases. Data were averaged across the five quadrats within each community prior to analysis. With the exception of the response variable total zone area, the fen and low-prairie areas were considered wet-meadows. Least squares means in tables are at the highest order interaction for reporting purposes.

6.4 RESULTS

6.4.1 Watershed and Basin Classification

Field inspection revealed that stands of perennial grasses dominated the watersheds of several sample wetland basins in selected 10.4 km^2 plots originally classified as poor condition. Fields in these watersheds were seeded during the late 1980's or early 1990's under the U.S. Department of Agriculture's Conservation Reserve Program (CRP). Nevertheless, these sample wetland basins were

Table 6-2. Response variables

A. Variables measured at quadrats within communities within zones (all analyses done by first averaging across quadrats):

1. Plant species and areal cover (Daubenmire) value
2. Water depth (cm)
3. Percent standing dead vegetation
4. Length (cm) of litter core
5. Percent unvegetated (bare) bottom
6. Percent open water
7. Percent vegetation

B. Variables measured at communities within zones:

1. Area of community (ha)
2. Phase of community (normal emergent, cropland drawdown, natural drawdown, cropland tillage, open water [for deep-marsh zone only])
3. Land use (idle, mowed, cultivated, burned, grazed)
4. Total plant species
5. Total perennial plant species
6. Total annual plant species
7. Total introduced plant species
8. Total native plant species
9. Total perennial introduced plant species
10. Total perennial native plant species
11. Total annual introduced plant species
12. Total annual native plant species

C. Variables measured at zone within wetland basin:

1. Area of zone (ha)
2. Percent of zone in each phase
3. Percent of zone in each land-use (past)
4. Percent of zone in each land-use (current)

D. Variables measured at each wetland basin

1. Percent of wetland basin watershed in annual or perennial cover
2. Percent of wetland basin watershed in each land-use (past)
3. Percent of wetland basin watershed in each land-use (current)
4. Percent of wetland basin watershed in each current crop type

Table 6-3. Fixed and random effects in ANOVAs.

Effects	Type	No. levels	Levels
Basin condition	Fixed	2	Good, poor
Wetland zone	Fixed	3	Deep-marsh, shallow marsh, wet-meadow (includes fen and low prairie)
Year of study	Fixed	2	1992, 1993
Wetland basin	Random	-	-
Community[1]	Random	-	-

[1]Community by zone was considered the sampling unit and randomness assumed.

retained for study because recovery of hydrophyte communities, at least in salt marshes, takes at least 10 to 50 years when soils have been disturbed (Beeftink 1977).

Basin classes and water regimes (palustrine emergent temporarily flooded, palustrine emergent seasonally flooded, and palustrine emergent semipermanently flooded; Cowardin et al. 1979) shown on the NWI maps were used for the analyses. Field inspection revealed that several sample wetland basins may have been misclassified, but they were retained as originally classified for comparisons of the effects of watershed condition on the response variables. These include a basin (374-272) where the central or deepest zone was judged to have a saturated water regime (Cowardin et al. 1979) and three basins (134-432, 156-024, and 396-106) where the central zone may have been low-prairie (ephemeral wetland of Stewart and Kantrud 1971; non-wetland of Cowardin et al. 1979). These four zones were considered wet-meadow for analyses of the response variables. All ANOVA tables are in Appendix 6-2.

ANOVA tests showed no significant differences between wetlands in poor- and good-condition watersheds in total area (ha) of low-prairie ($F_{1,51}$=1.20, p=0.278), wet-meadow zone ($F_{1,51}$=1.79, p=0.187), shallow-marsh zone ($F_{1,51}$=2.00, p=0.163), deep-marsh zone ($F_{1,51}$=1.25 p=0.269), or fen zone ($F_{1,51}$=0.65, p=0.422). Data on other wetlands and included uplands were too sparse to test.

6.4.2 Community Characteristics

I sampled vegetation in a total of 144 plant communities during the two-year study. Communities in the in 76 sample wetland basins visited one or both years included 35 in temporarily-flooded wetlands, 47 in seasonally-flooded wetlands, and 62 in semipermanently-flooded wetlands (Tables 6-1, 6-4). Basins in poor-condition watersheds had slightly fewer communities, likely because cultivation of wet-meadow and shallow-marsh zones during dry years created crop or fallow monotypes. Grazing, as observed on many wetlands in good-condition watersheds, tends to create more communities. Semipermanent wetlands in good-condition watersheds had four communities in the deep-marsh zone in the open-water phase (aquatic bed of Cowardin et al. 1979). Communities with this combination of zone and phase were not present in semipermanent wetlands in poor-condition watersheds and so were dropped from the analysis. Data from the remaining 140 communities (Appendix 6-3) were analyzed.

6.4.2.1 Distribution of Communities Among Wetland Zones and Phases

The analyzed plant communities included 87 (62%) in good-condition watersheds and 53 (38%) in poor-condition watersheds (Table 6-4). Communities included 80 (57%) in wet-meadow zones, 42 (30%) in shallow-marsh zones, and 18 (13%) in deep-marsh zones. ANOVA results indicated no significant effects of year, watershed condition, or zone on mean area of communities (ANOVA all $p>0.11$). Although not statistically significant, area of communities in good-condition watersheds was, on average, larger than those in poor-condition watersheds and less variable (Table 6-5).

Total area of the 140 analyzed plant communities was 176.02 ha, including 91% (159.99 ha) in good-condition watersheds and 9% (16.03 ha) in poor-condition watersheds (Table 6-5). The greater mean and total area of the communities in good-condition watersheds likely reflects the greater use for pastures of lands containing larger wetlands.

Of the sampled communities, 111 were in normal emergent phase (150.29 ha), 15 in cropland tillage phase (2.02 ha), 7 in cropland drawdown phase (1.67 ha), and 7 in natural drawdown phase (22.04 ha; Table 6-6). About 62% of all sampled communities were in wetlands in good-condition watersheds. All sampled communities in cropland drawdown and cropland tillage phases were in wetlands in poor-condition watersheds, whereas all those in the natural drawdown phase were in good-condition watersheds. Thirteen communities were in the drawdown phase during the relatively dry year

Table 6-4. **Numbers of sample wetland basins and surveyed wetland plant communities among wetland classes in good-condition and poor-condition watersheds and mean numbers of communities per basin, EMAP study, Prairie Pothole Region, 1992-1993.**

Watershed condition	(basin class)[a]	1992 Basins	1992 Communities	1993 Basins	1993 Communities	Mean no. communities per basin, 1992-1993
Good						
	temporary	8	13	6	7	1.4
	seasonal	7	13	6	12	1.9
	semipermanent	6	15	6	18	2.8
Poor						
	temporary	7	7	6	8	1.2
	seasonal	6	10	6	12	1.8
	semipermanent	6	14	6	15	2.4
Total		40	72	36	72	

[a]Sample wetland basins classified according to original sample draw.

Table 6-5. **Number and least squares means (±SE) of community areas among Stewart and Kantrud (1971) wetland zones in good-condition and poor-condition watersheds, EMAP study, Prairie Pothole Region, 1992-1993.**

Watershed condition	Zone	1992 No.[a]	1992 Mean area (ha)	1993 No.	1993 Mean area (ha)
Good					
	Wet-meadow	24	0.74 (0.54)	23	2.84 (0.59)
	Shallow-marsh	13	0.59 (0.81)	13	2.20 (0.99)
	Deep-marsh	5	0.60 (1.88)	9	3.48 (1.08)
Total		42		45	
Poor					
	Wet-meadow	17	0.40 (0.66)	16	0.08 (0.66)
	Shallow-marsh	8	0.28 (1.55)	8	0.42 (0.93)
	Deep-marsh	3	0.02 (1.63)	1	0.37 (2.65)
Total		28		25	
	Grand total	70		70	

[a]Least squares means are based on fewer samples (see Table 6-1).

of 1992, whereas only a single community was in drawdown during the relatively wet year of 1993. Because of sparseness of the data (Table 6-6), no attempt was made to assess the effect of condition, zone, phase, and year on total area.

The estimated mean proportional area of phases for whole sample wetland basins are presented in Table 6-7 for each zone, year, and watershed condition combination. Because of the highly skewed nature of the data, no statistical analyses were attempted (i.e., data were mostly either 100% or 0%). The normal emergent phase predominated all zones in basins in good-condition watersheds. Normal emergent phase varied by watershed condition and year and by watershed condition and zone. The open water phase was relatively unimportant except in shallow-marsh zones during the relatively wet year of 1993 where it averaged about 10% of the area of this zone in basins in poor-condition watersheds.

Proportional areas of zones in the drawdown bare soil and natural drawdown phases did not vary by watershed condition, year, or zone. These two phases were, of course, most common during the relatively dry year of 1992. The drawdown bare soil phase tended to be highest in shallow marsh zones in basins in poor-condition watersheds, whereas the natural drawdown phase tended to be

Table 6-6. **Number and total area of plant communities sampled among Stewart and Kantrud (1971) phases in good-condition and poor-condition watersheds, EMAP study, 1992-1993.**

Zone	Phase	Number				Total area (ha)	
		Good		Poor		Good	Poor
		1992	1993	1992	1993	1992 - 1993	1992 - 1993
Wet-meadow							
	Cropland Drawdown	-	-	5	1	-	1.35
	Cropland Tillage	-	-	6	9	-	2.02
	Natural Drawdown	4	-	-	-	7.69	-
	Normal Emergent	20	23	6	6	50.01	4.45
Shallow-marsh							
	Cropland Drawdown	-	-	1	-	-	0.32
	Natural Drawdown	3	-	-	-	12.35	-
	Normal Emergent	10	13	7	8	37.82	6.29
Deep-marsh							
	Normal Emergent	5	9	3	1	50.12	1.60
Total		42	45	28	25	159.99	16.03

Table 6-7. **Means (±SE) of visual estimates of proportional areas of phases of wet-meadow, shallow-marsh, and deep-marsh zones in sample wetland basins in good-condition and poor-condition watersheds, 1992-1993[a].**

Zone / Phase	Proportion of zone areas			
	Good-condition		Poor-condition	
	1992	1993	1992	1993
Wet-meadow				
Normal emergent	81.6 (6.1)	96.3 (6.2)	27.2 (7.2)	13.7 (7.6)
Open water	0.0 (0.0)	0.0 (0.0)	1.8 (2.3)	3.4 (2.4)
Drawdown bare soil	4.6 (2.7)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Natural drawdown	13.4 (4.1)	4.3 (4.1)	0.0 (0.0)	0.0 (0.0)
Cropland drawdown	0.0 (0.0	0.0 (0.0)	26.1 (3.7)	0.0 (0.0)
Cropland tillage	0.1 (4.3)	1.8 (4.3)	44.9 (5.0)	84.0 (5.3)
Shallow-marsh				
Normal emergent	79.2 (7.6)	99.9 (7.8)	83.5 (10.5)	83.6 (9.9)
Open water	0.0 (0.0)	0.1 (2.5)	0.0 (0.0)	10.0 (3.2)
Drawdown bare soil	7.1 (3.4)	0.0 (0.0)	7.2 (4.8)	0.0 (0.0)
Natural drawdown	13.7 (4.7)	4.3 (4.1)	0.0 (0.0)	0.0 (0.0)
Cropland drawdown	0.0 (0.0)	0.0 (0.0)	3.5 (5.5)	2.0 (5.1)
Cropland tillage	0.0 (0.0)	0.0 (0.0)	3.5 (7.4)	2.9 (7.0)
Deep-marsh				
Normal emergent	91.9 (11.9)	98.5 (9.2)	83.6 (16.0)	82.5 (26.2)
Open water	5.6 (3.9)	3.3 (3.0)	0.1 (5.2)	1.8 (8.7)
Drawdown bare soil	0.0 (0.0)	0.0 (0.0)	1.0 (7.3)	0.7 (12.4)
Natural drawdown	6.7 (6.5)	1.5 (5.3)	0.0 (0.0)	0.0 (0.0)
Cropland drawdown	0.0 (0.0)	0.0 (0.0)	3.3 (8.4)	3.7 (14.2)
Cropland tillage	0.2 (8.5)	0.2 (7.6)	5.9 (11.7)	5.5 (19.8)

[a]Based on visual estimates and unweighted for area of individual zones or phases.

highest in wet-meadow and shallow-marsh zones in basins in good-condition watersheds. Proportions of cropland drawdown and cropland tillage phase in the sample basins varied by watershed condition, year, and zone. Greatest proportions of cropland drawdown zone occurred in wet-meadow zones in basins in poor-condition watersheds during the dry year of 1992, whereas greatest proportions of cropland tillage phase were found in wet-meadow zones of basins in poor condition watersheds during the wetter year of 1993.

6.4.2.2 Land Use of Wetland Zones

Wet-meadow, shallow-marsh, and deep-marsh zones in the sample wetland basins were subject to three major land uses as well as idle conditions that strongly reflected their water regimes and watershed conditions (Table 6-8). No burned wetlands or zones of wetlands were included in the sample, but this land use is practiced in some areas of the region.

Land use of wetland basins in the recent past may better reflect long-term use than observed current use because wetlands are often hayed and grazed in late summer or early fall. Higher proportions of zones of sample wetland basins in poor-condition watersheds showed past cultivation, as evidenced by furrows and unearthed rocks and boulders left by tillage equipment. Wet-meadow zones were cultivated to a greater extent in the past than zones of greater water permanence. Past grazing of basins, as evidenced by trails and old cattle dung, in good-condition watersheds was greater than that of basins in poor-condition watersheds. Proportions of zones estimated to be mowed or idle in the past did not vary by watershed condition.

Higher proportions of zones of sample wetland basins in poor-condition watersheds were currently cultivated. Wet-meadow zones were cultivated to a greater extent than zones of greater water permanance. Basins in good-condition watersheds were currently grazed to a greater extent than basins in poor-condition watersheds. Proportions of zones currently mowed or idle did not vary by watershed condition.

6.4.2.3 Land Use of Watersheds

Mean proportional areas of major watershed cover types were obtained from visual estimates of the catchment areas of the sample wetland basins (Table 6-9). These estimates reflected the technique used to select the sample wetland basins. Poor-condition watersheds contained higher amounts of annual crop plants ($F_{1,51}$=126.83, p=0.001), whereas perennial vegetation, mostly native and seeded

Table 6-8. **Means (±SE) of proportion of zones of basins in good-condition and poor-condition watersheds subjected to various current and recent past land uses, EMAP study, Prairie Pothole Region, 1992-1993[a].**

		Proportion of zones							
		Good-condition watersheds				Poor-condition watersheds			
Zone		Current		Past		Current		Past	
	Land use	1992	1993	1992	1993	1992	1993	1992	1993
Wet-meadow									
	Cultivated	Tr.[b] (4)	2 (4)	4 (6)	5 (6)	63 (5)	87 (5)	71 (7)	80 (7)
	Grazed	59 (8)	61 (8)	73 (8)	63 (8)	0 (0)	0 (0)	0 (0)	0 (0)
	Hayed	4 (2)	Tr. (2)	8 (6)	14 (6)	0 (0)	0 (0)	8 (7)	9 (8)
	Idle	36 (9)	36 (9)	15 (9)	20 (9)	37 (10)	12 (11)	21 (10)	9 (11)
Shallow-marsh									
	Cultivated	0 (0)	0 (0)	3 (6)	2 (7)	0 (0)	0 (0)	52 (8)	18 (8)
	Grazed	54 (10)	55 (10)	72 (10)	55 (10)	0 (0)	0 (0)	0 (0)	0 (0)
	Hayed	Tr. (2)	Tr. (2)	8 (8)	20 (8)	0 (0)	0 (9)	12 (10)	28 (10)
	Idle	44 (11)	44 (11)	19 (10)	24 (11)	84 (14)	89 (14)	44 (14)	54 (13)
Deep-marsh									
	Cultivated	0 (0)	0 (0)	3 (9)	3 (7)	0 (0)	0 (0)	41 (12)	28 (17)
	Grazed	41 (14)	47 (11)	75 (16)	46 (12)	0 (0)	0 (0)	0 (0)	0 (0)
	Hayed	Tr. (4)	Tr. (3)	3 (11)	6 (9)	0 (0)	0 (0)	7 (15)	12 (24)
	Idle	56 (16)	51 (12)	22 (16)	47 (12)	78 (21)	81 (33)	69 (21)	67 (34)

[a]Based on visual estimates and unweighted for area of individual zones.

[b]Tr.=<0.5%

grasses and forage crops, was far more important in good-condition watersheds ($F_{1,51}$=162.44, p=0.001). Other cover types did not vary by watershed condition ($F_{1,51}$ 1.42, p=0.24).

Mean current and recent past land use practices of the watersheds of the sample wetland basins, based on visual estimates, also strongly reflected the technique used to select the sample wetland basins (Table 6-10). Amounts of past and currently-cultivated land tended to be higher in poor-condition watersheds and amounts of past and currently-grazed land were higher in good-condition watersheds. These conditions likely had been stable for many years, as little land clearing, except for some minor removal and tillage of fencelines, was evident during the study. Amount of idle land tended to be higher in good-condition watersheds in the recent past and currently. Most land in a single, entirely idle watershed was enrolled in the CRP. The proportions of watersheds devoted to hayland did not vary by watershed condition. Some areas hayed in June during the dry year of 1992 were idle during the July surveys the following wet year. Current cropping patterns for agricultural land in the watersheds of the sample wetland basins are shown in Table 6-11. Amounts of seeded small grains increased and amounts of bare fallow decreased dramatically during the wetter year of 1993, especially in poor-condition watersheds. Proportions of watersheds planted to row crops and small grains and in bare tilled fallow were greater in poor-condition watersheds than in good-condition watersheds. Proportions of small grain stubble and weedy fallow did not vary by watershed condition. No row crop stubble occurred on the watersheds of the sample wetland basins.

Table 6-9. Means (± S.E.) proportion of major watershed cover types in good-condition and poor-condition watersheds, EMAP study, Prairie Pothole Region, 1992-1993[a].

	Proportion of plant cover types in basin watersheds			
	Good-condition		Poor-condition	
Cover type	1992	1993	1992	1993
Annuals	12.5 (1.6)	15.5 (1.6)	93.7 (1.9)	93.7 (2.3)
Perennials	82.4 (4.0)	85.4 (4.2)	1.7 (4.9)	1.7 (5.8)
Other[b]	0.2 (0.4)	0.9 (0.4)	4.6 (0.4)	4.6 (0.5)

[a]Based on visual estimates and unweighted for area of individual cover types.

[b]Includes roads, farmsteads, other built-up areas, gravel pits, and rockpiles.

Table 6-10. **Means (± S.E.) proportion of watersheds in current and recent past land use practices for sample wetland basins in good-condition and poor-condition watersheds EMAP study, Prairie Pothole Region, 1992-1993[a].**

	Proportion of watersheds							
	Good-condition watersheds				Poor-condition watersheds			
	Current		Past		Current		Past	
Land use	1992	1993	1992	1993	1992	1993	1992	1993
Cultivated	11 (4)	11 (4)	15 (4)	14 (4)	98 (5)	98 (5)	98 (4)	98 (5)
Grazed	48 (6)	58 (6)	51 (6)	59 (6)	Tr[b] (7)	Tr (8)	Tr (7)	Tr (8)
Hayed	11 (3)	3 (3)	10 (3)	14 (3)	Tr (4)	Tr (4)	Tr (4)	Tr (4)
Idle	30 (5)	28 (5)	24 (5)	12 (5)	1 (6)	1 (7)	1 (6)	1 (7)

[a]Based on visual estimates and unweighted for area of individual watersheds.

[b]Tr.=<0.5%.

Table 6-11. Means (± S.E.) proportion of currently raised crops on annually tilled land in watersheds in good-condition and poor-condition watersheds, EMAP study, Prairie Pothole Region, 1992-1993[a].

Current cropland land use	Proportion of basin watersheds			
	Good-condition		Poor-condition	
	1992	1993	1992	1993
Row crops	9.8 (4.0)	6.8 (3.9)	40.8 (4.7)	30.2 (5.5)
Small grains	6.8 (5.1)	8.7 (5.0)	18.1 (6.0)	78.7 (7.1)
Small grain stubble	0.0 (0)	0.0 (0)	9.8 (3.9)	0.0 (0)
Weedy fallow	0.0 (0)	0.5 (0.3)	0.0 (0)	0.0 (0)
Bare fallow	0.2 (4.8)	0.0 (0)	31.1 (5.7)	0.0 (0)

[a]Based on visual estimates and unweighted for area of individual cropfields or crop types.

6.4.2.4 Physical Measurements in Communities

Physical and botanical measurements derived from quadrats were summarized for the three wetland zones (Tables 6-12 to 6-16) and tested with ANOVA.

Water depth varied with year and zone ($F_{2,36}$=4.44, p=0.019; Table 6-12), but there were no significant watershed condition effects. Increased precipitation resulted in higher water depths in 1993 ($F_{1,49}$=6.49, p=0.014). Depths were higher in zones of greater water permanence ($F_{2,36}$=20.54, p=0.001).

Percent of standing dead vegetation did not vary by year and watershed condition ($F_{1,49}$=0.35, p=0.555; Table 6-13). However, greater amounts of standing dead vegetation were found in zones of greater water permanence ($F_{2,36}$=6.78, p=0.001).

Depth (cm) of litter varied with watershed condition, zone, and year ($F_{2,36}$=4.70, p=0.015; Table 6-14). Depth of litter was higher in zones of greater water permanence and in zones of sampled wetlands in poor-condition watersheds during the dryer year of 1992. Effects of watershed condition alone were non-significant.

Percent unvegetated bottom varied with year ($F_{1,49}$=4.53, p=0.038) and condition ($F_{1,49}$=10.03, p=0.003; Table 6-15). Greater amounts of unvegetated bottom were found in sample wetland basins in poor-condition watersheds and lesser amounts occurred in all wetlands during the wetter year of 1993.

Table 6-12. **Least squares means (±SE) water depth (cm) in plant communities[a] in wet-meadow, shallow-marsh, and deep-marsh zones of sample wetland basins in good-condition and poor-condition watersheds, EMAP study, Prairie Pothole Region, 1992-1993.**

Watershed condition	Zones	Water depth (cm) Year 1992		Water depth (cm) Year 1993	
Good					
	Wet-meadow	2.2	(2.8)	3.6	(3.0)
	Shallow-marsh	7.9	(4.2)	23.4	(5.1)
	Deep-marsh	26.3	(9.8)	44.4	(5.6)
Poor					
	Wet-meadow	0.4	(3.4)	8.1	(3.4)
	Shallow-marsh	2.9	(8.0)	37.0	(4.8)
	Deep-marsh	28.7	(8.4)	38.8	(13.6)

[a]Sample sizes for communities as in Table 6-5; least squares means based on fewer (Table 6-1).

Table 6-13. **Least squares means (±SE) of percent standing dead vegetation in plant communities[a] in wet-meadow, shallow-marsh, and deep-marsh zones of sample wetland basins in good-condition and poor-condition watersheds, EMAP study, Prairie Pothole Region, 1992-1993.**

Watershed condition	Zones	% standing dead vegetation Year 1992		% standing dead vegetation Year 1993	
Good					
	Wet-meadow	6.6	(1.1)	2.0	(1.2)
	Shallow-marsh	8.0	(1.6)	3.1	(2.0)
	Deep-marsh	17.0	(3.7)	10.5	(2.1)
Poor					
	Wet-meadow	2.1	(1.3)	1.5	(1.3)
	Shallow-marsh	0.1	(3.1)	0.6	(1.9)
	Deep-marsh	8.0	(3.2)	3.8	(5.2)

[a]Sample sizes for communities as in Table 6-5; least squares means based on fewer (Table 6-1).

Table 6-14. **Least squares means (±SE) of litter depth (cm) in plant communities[a] in wet-meadow, shallow-marsh, and deep-marsh zones in sample wetland basins in good-condition and poor-condition watersheds, EMAP study, Prairie Pothole Region, 1992-1993.**

Watershed condition	Zones	Litter depth (cm) Year	
		1992	1993
Good			
	Wet-meadow	0.3 (0.3)	0.2 (0.4)
	Shallow-marsh	0.2 (0.5)	1.7 (0.6)
	Deep-marsh	0.0 (1.2)	1.3 (0.7)
Poor			
	Wet-meadow	1.0 (0.4)	0.0 (0.4)
	Shallow-marsh	2.7 (1.0)	0.0 (0.6)
	Deep-marsh	6.7 (1.0)	0.0 (1.7)

[a]Sample sizes for communities as in Table 6-5; least squares means based on fewer (Table 6-1).

Table 6-15. **Least squares means (±SE) of percent unvegetated bottom in plant communities[a] in wet-meadow, shallow-marsh, and deep-marsh zones of sample wetland basins in good-condition and poor-condition watersheds, EMAP study, Prairie Pothole Region, 1992-1993.**

Watershed condition	Zones	% unvegetated bottom Year	
		1992	1993
Good			
	Wet-meadow	2.0 (2.4)	0.9 (2.6)
	Shallow-marsh	10.0 (3.5)	1.0 (4.3)
	Deep-marsh	12.4 (8.3)	0.5 (4.7)
Poor			
	Wet-meadow	46.5 (2.8)	15.2 (2.8)
	Shallow-marsh	-[b] -	19.4 (4.0)
	Deep-marsh	- -	17.3 (11.6)

[a]Sample sizes for communities as in Table 6-5; least squares means based on fewer (Table 6-1).

[b]Least squares means were poorly estimated for poor condition in 1992; observed means are 43.7, 0.0, and 0.0 for wet-meadow, shallow-marsh, and deep-marsh, respectively.

Table 6-16. **Least squares means (±SE) of percent open water in plant communities[a] in wet-meadow, shallow-marsh, and deep-marsh zones of sample wetland basins in good-condition and poor-condition watersheds, EMAP study, Prairie Pothole Region, 1992-1993.**

Watershed condition	Zones	% open water Year 1992	1993
Good			
	Wet-meadow	4.3 (3.6)	3.2 (3.9)
	Shallow-marsh	8.3 (5.4)	35.6 (6.5)
	Deep-marsh	1.7 (12.5)	34.6 (7.1)
Poor			
	Wet-meadow	0.6 (4.3)	18.4 (4.3)
	Shallow-marsh	2.8 (10.2)	36.5 (6.1)
	Deep-marsh	9.1 (10.7)	40.4 (17.5)

[a]Sample sizes for communities as in Table 6-5; least squares means based on fewer (Table 6-1).

Greater amounts of open water occurred during the wetter year of 1993 ($F_{1,49}$=5.12, p=0.028; Table 6-16), and in zones of greater water permanence ($F_{2,36}$ = 6.06, p=0.0328), but effects of watershed condition alone were non-significant.6-16), and in zones of greater water permanence ($F_{2,36}$ = 6.06, p=0.0328), but effects of watershed condition alone were non-significant.

Physical and botanical measurements derived from quadrats were also summarized for wetland phases within zones of the sample wetland basins (Table 6-17), but data were too sparse to test with ANOVA. In the dry year of 1992, communities in drawdown phases were common. Those in the natural drawdown phase found in wet-meadow and shallow-marsh zones of basins in good-condition watersheds had more standing dead vegetation and less unvegetated bottom than the ones in these same zones in the cropland drawdown phase of basins poor-condition watersheds.

6.4.2.5 Botanical Measurements of Communities

A total of 298 major (within quadrats) and minor (observed outside quadrats) plant "taxa" was recorded (Appendix 6-1), including 217 wetland pteridophytes and spermatophytes (73%) listed for the north plains (Reed 1988), 50 upland spermatophytes (17%) listed in the National List of Scientific Plant Names (USDA 1982), and 31 (10%) other "taxa." These were certain non-vascular plants including the macroalgae *Chara* spp., two liverworts (*Riccia fluitans* and *Ricciocarpus natans*), the aquatic moss

Drepanocladus spp., and unidentified plants (e.g. Gramineae unidentified) seen only in early growth stages. All vascular plants were classified as to life history (annual or biennial, perennial, native, introduced, or adventive) whenever possible.

Total taxa recorded was higher in all zones of sample wetland basins in good-condition watersheds throughout the study (Table 6-18). Ratios of total taxa recorded in good-condition versus poor-condition watersheds varied from a low of about 1.6:1 in wet-meadow zones to a high of about 3.4:1 in deep-marsh zones. The greatest numbers of taxa were recorded in communities in wet-meadow zones in good-condition watersheds (173) in 1992 and lowest (8) in the single community in a deep-marsh zone in a poor-condition watershed studied in 1993. Highest mean taxa richness during the study was recorded in wet-meadow zones of basins in good-condition watersheds during 1992. Lowest mean taxa richness was found that same year in deep-marsh zones of wetlands in poor-condition watersheds. When unadjusted for community size, taxa richness varied by zone ($F_{2,36}$=17.35, p=0.0001) and watershed condition ($F_{2,49}$=3.94, p=0.053), with richness higher in wet-meadow zones and shallow-marsh zones in good condition than in similar zones of poor condition. As a partial test of effects of community size, the 17 communities in good-condition watersheds larger than the largest communities in poor-condition watersheds (1.43 ha) were eliminated from the data set. Effects of zone remained significant ($F_{2,28}$=15.09, p=0.0001), whereas effects of watershed condition was marginally significant ($F_{1,46}$=2.59, p=0.114). The only significant correlation between taxa richness and community size was for communities of deep-marsh zone within good-condition watersheds (r=0.77; p=0.0013).

Although data were too sparse to conduct statistical tests, total taxa recorded was also uniformly greater in comparable phases of zones of sample wetland basins in watersheds in good condition versus those in poor condition (Table 6-19). For normal emergent phases, ratios of total taxa recorded in good-condition versus poor-condition watersheds varied from a low of about 1.7:1 in shallow-marsh zones to a high of about 3.4:1 in deep-marsh zones. Greatest numbers of taxa were recorded in the normal emergent phase of wet-meadow zones in good-condition watersheds in 1993 (166) and lowest in the normal emergent phase of the single deep-marsh zone in a poor-condition watershed studied in 1993 (8).

The highest mean taxa richness (15.25 taxa/community) occurred in communities in the natural drawdown phase of wet-meadow zones in sample wetland basins in good-condition watersheds. Mean taxa richness was higher in the normal emergent phase of wet-meadow zones of basins located in poor-condition watersheds than in good-condition watersheds during both years. Lowest mean taxa richness (3.2-4.1 taxa/community) was recorded in the cropland tillage phase of wet-meadow zones in basins in poor-condition watersheds. The greatest number of total (major and minor) taxa (49) was found in the normal emergent phase of the wet-meadow zone of a grazed semipermanent wetland in a good-condition watershed, whereas the fewest (0) were in the cropland tillage phase of a wet-meadow zone of a temporary wetland in a poor-condition watershed. The information on plant taxa could be biased because we took an equal number of samples in each community, regardless of its area, during this rapid field evaluation. We know that larger communities have more species, so our crude test (reanalyzing after eliminating large communities) should have some meaning. Many more analyses, including the construction of diversity-area curves, could have been done.

Perennial native plants dominated all zones of sample wetland basins in both good-condition and poor-condition watersheds (Table 6-20). Greatest number of these plants (116 taxa) were found in communities in wet-meadow zones of sample wetland basins in good-condition watersheds during the wetter year of 1993, whereas fewest (7 taxa) were found that same year in communities in deep-marsh zones of basins in poor-condition watersheds. ANOVA tests showed that mean number of native perennials varied by zone and watershed condition ($F_{2,36}$=2.79, p=0.075). Wet-meadow zones in good-condition watersheds had greater numbers of native perennials than those in poor-condition watersheds. This relation also held when the 17 communities in good-condition watersheds larger than the largest communities in poor-condition watersheds were eliminated from the data set ($F_{2,28}$=2.76, p=0.081). Ratios of native perennials to introduced perennials varied by watershed condition and zone when adjusted as above for community size ($F_{2,28}$=3.37, p=0.049). With this adjustment, the ratio of native perennials to introduced perennials was marginally greater in good-condition watersheds than in poor condition watershed for wet-meadow zones only. Ratios of native annuals to introduced annuals did not vary by zone or watershed condition.

More annuals, both native and introduced, were generally found during the drier year of 1992 (Table 6-20). This likely reflects the increased occurrence of drawdown species that pioneer on bare mud flats and upland species that invade wetlands during drought. Greater numbers of introduced perennials were found in basins in good-condition watersheds.

The effects of various land use practices were evident in the life history and origin of the species in wet-meadow zones (Table 6-21). Those in the normal emergent phase in both good-condition and poor-condition watersheds were dominated exclusively by native and a few introduced perennials, especially *Poa pratensis* and *Agropyron repens*. However, the other dominants differed greatly. Those in emergent wet meadows in good-condition watersheds were mostly fine-stemmed grasses and sedges and a few forbs indicative of long-term grazing or mowing, whereas those in

Table 6-17. **Mean (n=5 quadrats/community) physical and vegetational features of emergent plant communities[a] in phases of zones of sample wetland basins in wetlands in good-condition and poor-condition watersheds, EMAP study, Prairie Pothole Region, 1992-1993.**

Condition / Zone / Phase	Water depth (cm)		% standing dead veg.		Litter depth(cm)		% unvegetated bottom		% open water	
	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
Good										
Wet-meadow										
Normal emergent	1.9	3.5	6.8	1.7	0.4	0.3	1.0	0.6	3.7	3.4
Natural drawdown	0.0	-	4.1	-	0.0	-	3.3	-	0.0	-
Shallow-marsh										
Normal emergent	13.1	29.4	3.1	2.0	0.1	1.0	5.2	1.0	13.5	31.2
Natural drawdown	0.0	-	9.5	-	0.3	-	23.4	-	0.0	-
Deep-marsh										
Normal emergent	35.6	44.7	16.2	9.9	1.2	1.5	2.4	0.0	9.9	34.8
Poor										
Wet-meadow										
Normal emergent	0.1	10.8	6.2	2.5	0.5	0.0	0.0	0.0	0.0	14.0
Cropland drawdown	0.4	0.0	tr.[b]	0.0	0.0	0.0	80.9	69.1	0.0	0.0
Cropland tillage	0.7	8.6	0.0	0.0	0.0	0.0	53.6	30.6	5.3	22.5
Shallow-marsh										
Normal emergent	1.6	31.9	3.9	1.1	3.1	0.0	0.9	3.9	0.2	26.3
Cropland drawdown	0.0	-	0.0	-	3.1	-	52.7	-	0.0	-
Deep-marsh										
Normal emergent	29.6	16.3	13.8	10.0	10.5	0.0	0.0	0.0	6.7	13.0

[a]Sample sizes for communities sampled same as in Table 6-5.

[b]Tr.=<0.05%

Table 6-18. **Total plant taxa and least squares means (±SE) taxa richness for communities in wet-meadow, shallow-marsh, and deep-marsh zones in sample wetland basins in good-condition and poor-condition watersheds, EMAP study, Prairie Pothole Region, 1992-1993[a].**

	1992					
	Good-condition			Poor-condition		
Zone	n[b]	No. taxa	Mean taxa richness	n	No. taxa	Mean taxa richness
Wet-meadow	24	173	23.8 (1.7)	17	104	11.1 (2.0)
Shallow-marsh	13	90	12.0 (2.5)	8	47	1.7 (4.8)
Deep-marsh	5	31	2.4 (5.9)	3	15	0.0 (5.1)
Total communities	42			28		

	1993					
	Good-condition			Poor-condition		
Zone	n[b]	No. taxa	Mean taxa richness	n	No. taxa	Mean taxa richness
Wet-meadow	23	166	25.4 (1.8)	16	89	14.8 (2.0)
Shallow-marsh	13	74	12.8 (3.1)	8	49	8.2 (2.9)
Deep-marsh	9	47	7.4 (3.4)	1	8	9.5 (8.3)
Total communities	45			25		

[a]Means unadjusted for community area. Some taxa common to more than one zone.

[b]n=Number of communities; least squares means based on fewer (see Table 6-1).

similar habitats in poor-condition watersheds were mostly coarse grasses and woody plants indicative of past disturbance by tillage or possibly siltation.

Although the natural drawdown phase found in wet meadows in watersheds in good-condition and the cropland drawdown phase found under similar water regimes in poor-condition watersheds were dominated by mixtures of native and introduced perennials and native and introduced annuals, there was a preponderance of small native annuals that germinate on exposed bare soil in the poor-condition watersheds. Most important plants of the cropland tillage phase were introduced annuals, including at least four species of annual small grains and row crops.

6.5 EVALUATION

Cultivation of various emergent wet-meadow and shallow-marsh communities during dry years seems to create coarser grained vegetation mosaics with fewer communities as old annular stands of

Table 6-19. **Number of plant taxa recorded in communities among phases in sample wetland basins in good-condition and poor-condition watersheds, EMAP study, Prairie Pothole Regions, 1992-1993[a].**

Zone / Phase	No. of taxa 1992				No. of taxa 1993			
	Good		Poor		Good		Poor	
	n[b]	No. taxa	n	No. taxa	n	No. taxa	n	No. taxa
Wet-meadow								
Cropland Tillage	-	-	6	19	-	-	9	37
Cropland Drawdown	-	-	5	33	-	-	1	14
Natural Drawdown	4	61	-	-	-	-	-	-
Normal Emergent	20	150	6	74	23	166	6	68
Shallow-marsh								
Cropland Drawdown	-	-	1	16	-	-	-	-
Natural Drawdown	3	41	-	-	-	-	-	-
Normal Emergent	10	76	7	41	13	74	8	49
Deep-marsh								
Normal Emergent	5	31	3	15	9	47	1	8
Total communities	42		28		45		25	

[a]Some taxa common to more than one zone or phase.

[b]n=Number of communities

Table 6-20. **Total numbers of perennial, annual (includes biennial), native, and introduced plant taxa in communities in wet-meadow, shallow-marsh, and deep-marsh zones of sample wetland basins in good-condition and poor-condition watersheds, EMAP study, Prairie Pothole Region, 1992-1993.**

Zone / Life History Status	Total number of plant taxa 1992 Watershed condition Good	Total number of plant taxa 1992 Watershed condition Poor	Total number of plant taxa 1993 Watershed condition Good	Total number of plant taxa 1993 Watershed condition Poor
Wet-meadow				
Perennial-Native	109	59	116	43
Perennial-Introduced	17	10	16	11
Annual-Native	22	19	14	19
Annual-Introduced	12	8	8	9
Life history unknown	13	8	9	7
Shallow marsh				
Perennial-Native	45	28	48	29
Perennial-Introduced	9	5	7	5
Annual-Native	24	9	11	10
Annual-Introduced	6	2	3	3
Life history unknown	6	3	5	1
Deep-marsh				
Perennial-Native	16	11	29	7
Perennial-Introduced	2	2	5	0
Annual-Native	8	0	3	1
Annual-Introduced	0	0	1	0
Life history unknown	5	2	9	0

weedy annuals, drawdown species, or early successional vegetation are converted to crops or fallowed. Yet hydrophyte communities in good-condition watersheds tended to be larger and probably reflect the greater use for pastures of lands containing larger wetlands. Some larger wetlands in poor-condition watersheds were also used for hay or pasture. If wet-meadow zones are left uncultivated and if siltation is not severe, these wetlands appear similar to those in good-condition watersheds. However, nearly all basins in poor-condition watersheds are cultivated for crop production or weed control whenever bottoms are dry.

Greater percentages of standing dead vegetation in the deeper, more permanent zones likely reflect a reduced accessibility of these zones to livestock and farm equipment. Sample sizes were too small (n=3 and n=1 for 1992 and 1993, respectively) to detect the greater amounts of dead vegetation and litter expected in deep-marsh zones in poor-condition watersheds because of siltation and lack of grazing, cultivation, or other mechanisms that reduce plant biomass. Agricultural and pastoral

Table 6-21. **Mean areal cover values and life history status in the prairie pothole region for the 10 most abundant species in communities in phases of wet-meadow zones of sample basin wetlands in good-condition and poor-condition watersheds, EMAP study, 1992-1993. Seeded crop plants are marked with an asterisk(*).**

		% areal cover Watershed condition									
		Good			Poor						
		Normal emergent		Natural drawdown	Normal emergent		Cropland drawdown		Cropland tillage		
Taxa	Life history[a]	1992	1993	1992	1992	1993	1992	1993	1992	1993	
Carex lanuginosa	NP	5.6	7.7	-	-	-	-	-	-	-	
Calamagrostis inexpansa	NP	5.6	5.0	-	-	-	-	-	-	-	
Hordeum jubatum	NP	4.3	5.2	30.6	-	-	-	-	-	-	
Glyceria striata	NP	4.2	4.2	-	-	-	-	-	-	-	
Poa palustris	NP	-	6.7	-	6.6	-	-	-	-	-	
Potentilla anserina	NP	4.4	-	-	-	-	-	-	-	-	
Carex praegracilis	NP	4.2	-	-	-	-	-	-	-	-	
Agropyron caninum	NP	4.2	-	-	-	-	-	-	-	-	
Symphoricarpos occidentalis	NP	4.0	-	-	-	-	-	-	-	-	
Solidago canadensis	N	-	3.9	-	4.4	-	-	-	-	-	
Carex aquatilis	NP	-	3.7	-	-	-	-	-	-	-	
Polygonum amphibium	NP	-	2.9	2.9	8.1	6.8	1.5	-	0.1	3.2	
Puccinellia nuttalliana	NP	-	-	3.9	-	-	-	-	-	-	
Ambrosia psilostachya	NP	-	-	3.6	-	-	-	-	-	-	
Spartina pectinata	NP	-	-	-	10.5	9.8	-	-	-	-	
Phalaris arundinacea	NP	-	-	-	5.1	16.3	-	-	-	-	
Salix exigua	NP	-	-	-	9.2	-	-	-	-	-	
Cornus stolonifera	NP	-	-	-	5.0	-	-	-	-	-	
Salix amygdaloides	NP	-	-	-	4.6	-	-	-	-	-	
Calamagrostis canadensis	NP	-	-	-	-	9.2	-	-	-	-	
Boltonia asterioides	NP	-	-	-	-	2.2	-	-	-	-	
Stachys palustris	NP	-	-	-	-	1.8	-	-	-	-	
Eleocharis acicularis	NP	-	-	-	-	-	2.0	-	-	-	
Limosella aquatica	NP	-	-	-	-	-	0.6	-	-	-	
Poa pratensis	IP	8.8	14.7	-	8.8	5.2	-	-	-	-	
Medicago sativa	IP	4.4	-	-	-	-	-	-	-	-	
Bromus inermis	IP	-	3.6	-	-	-	-	-	-	-	

Table 6-21 (continued)

		% areal cover Watershed condition								
		Good			Poor					
		Normal emergent		Natural drawdown	Normal emergent		Cropland drawdown		Cropland tillage	
Taxa	Life history[a]	1992	1993	1992	1992	1993	1992	1993	1992	1993
Agropyron repens	IP	-	-	-	20.0	16.2	-	-	-	0.4
Melilotus spp.	IP	-	-	-	-	-	-	-	0.1	-
Amaranthus retroflexus	NA	-	-	5.1	-	-	1.3	-	0.3	-
Conzya canadensis	NA	-	-	3.0	-	-	-	-	-	-
Eleocharis engelmannii	NA	-	-	-	-	-	0.8	12.5	-	0.6
Gratiola neglecta	NA	-	-	-	-	-	1.0	2.5	-	0.2
Veronica peregrina	NA	-	-	-	-	-	-	5.0	-	-
Polygonum lapathifolium	NA	-	-	-	-	-	-	3.5	-	-
Plagiobothrys scouleri	NA	-	-	-	-	-	-	2.5	-	-
Potentilla norvegica	NA	-	-	-	-	-	1.6	-	-	-
Senecio congestus	NA	-	-	-	-	-	0.4	-	-	-
Artemisia biennis	NA	-	-	-	-	-	-	-	-	0.8
Lactuca serriola	IA	-	-	15.8	-	-	-	-	-	-
Kochia scoparia	IA	-	-	9.5	-	-	-	-	0.2	-
Bromus japonicus	IA	-	-	6.8	-	-	-	-	-	-
*Triticum aestivum**	IA	-	-	-	-	-	-	-	19.2	37.8
Chenopodium album	IA	-	-	-	-	-	-	-	0.2	0.2
*Zea mays**	IA	-	-	-	-	-	-	-	13.2	-
*Glycine max**	IA	-	-	-	-	-	-	-	7.9	-
Setaria spp.	IA	-	-	-	-	-	-	2.5	6.9	-
Echinochloa crusgalli	IA	-	-	-	-	-	10.2	-	3.2	-
Avena sativa	IA	-	-	-	-	-	-	7.0	-	3.3
Sinapsis arvenis	IA	-	-	-	-	-	-	3.0	-	2.9
Hordeum vulgare	IA	-	-	-	-	-	-	-	-	7.7
Carex, unidentified	-	-	-	3.1	-	-	-	-	-	-
Forb, unidentified No. 1	-	-	-	-	-	-	0.4	3.5	-	-
Forb, unidentified No. 4	-	-	-	-	-	-	-	1.0	-	-

[a]Codes: NP=native perennial; NA=native annual; IP=introduced or adventive perennial; IA-introduced or adventive annual or biennial.

operations tended to reduce standing dead vegetation in the less permanent zones of both watershed types. Livestock grazing pressure in these zones in basins in good-condition watersheds probably was insufficient to greatly reduce standing dead vegetation. I also noted that sample sizes of deep-marsh zones in poor-condition watersheds were very small.

As with standing dead vegetation, litter core lengths were naturally higher in zones of greater water permanence, probably because they were less accessibile to machinery and livestock. Greater biomass production could also be another factor because the more permanent zones usually support taller, more robust plant species. Nevertheless, the presence of surface water limits access by machinery more than cattle. Thus litter depth among zones varied significantly only in basins in poor-condition watersheds because these basins were usually ungrazed. There were no significant effects due to watershed condition alone. The irregular destruction of litter by machinery in basins in poor-condition watersheds likely was not much greater than that caused by the often season-long livestock hoof action and herbivory that compress or reduce the litter layer in grazed basins. A single pass by tillage equipment often tears narrow openings in vegetation, and can leave much of the litter layer intact. Also, basins in poor-condition watersheds often receive inputs of fertilizer from their adjacent cropped uplands that could increase plant biomass in areas where root systems are not directly destroyed by tillage.

The greater percentages of unvegetated bottom found in wet-meadow zones of wetlands in poor-condition watersheds undoubtedly reflect the effects of cultivation. Communities in these watersheds tended to have large amounts of unvegetated bottom regardless of water levels. Herbicides can further reduce plant populations in cultivated wetlands. Farmers use herbicides directly on cropped wetlands, but also sometimes treat non-cropped wetlands to prevent introduced perennial grasses with hydrophytic tendencies, such as *Agropyron repens*, from spreading to the uplands. Livestock grazing, except when extremely intense, such as in heavily-trampled barnyards or feedlots, seldom creates unvegetated bottoms.

Percent open water naturally increased in all zones as water was replenished after the drought of 1992 and preceding years. The expectation that differences in watershed land use would result in greater amounts of open water in sample wetland basins in good-condition watersheds held for all zones during the relatively dry year of 1992, but in the following relatively wet year the differences were less obvious, especially in zones of lesser water permanence. Open water was actually much higher in wet-meadow zones in basins in poor-condition watersheds than those in good-condition watersheds in 1993. I attribute this to the flooding of bare tilled soils created by cultivation.

In summary, in poor-condition watersheds, the hydrology of prairie wetlands combines with a variety of agricultural practices to create unnatural, coarse-grained patterns in wetland vegetation or basins devoid of vegetation. Open water or unvegetated areas can lie adjacent to areas with greater amounts of litter than are found where grazing is the predominant land use.

The effects of wetland phase were not tested because of sparse data, but in the dry year of 1992, communities in the drawdown phase were common. Those in the natural drawdown phase found in wet-meadow and shallow-marsh zones of sample wetland basins in good-condition watersheds had greater amounts of standing dead vegetation and less unvegetated bottom than those in these zones in the cropland drawdown phase of basins in poor-condition watersheds.

I expected amounts of standing dead vegetation and litter in the normal emergent phase to be greater in sample wetland basins in poor-condition than in good-condition watersheds because the basins in the former likely would not be grazed and would often be idle, but no differences were obvious. The expectation that there would be more open water in wetlands in good-condition rather than poor-condition watersheds was based on commonly observed land use of the basins. Wetlands in good-condition (grassland) watersheds tend to be grazed or mowed. This opens up dense stands or emergents and often results in areas of greater amounts of submerged hydrophytes. Wetlands in poor-condition watersheds tend to lie idle or support stands (often dense) of seeded crops intermixed with annual weeds. While it seems true that tilled landscapes provide more runoff to the basins, it is the idle basins that tend to choke up with emergent vegetation, especially the inner shallow-marsh and deep-marsh zones that can only be farmed during dry years. Silt from farming operations seems to contribute to the establishment of dense stands of emergents in these basins. Cultivation of basins in the poor-condition watersheds likely reduced amounts of standing dead vegetation and litter to about the same degree as livestock grazing did in basins in good-condition watersheds. As expected, deep-marsh zones in the normal emergent phase generally had highest values of standing dead vegetation and litter, but the values did not differ significantly between poor- and good-condition watersheds.

Communities in the cropland drawdown or cropland tillage phases of wet-meadow and shallow-marsh zones in sample wetland basins in poor-condition watersheds had large amounts of unvegetated bottom during the dry year as well as the wetter year of 1993. These phases directly reflect the effects of intensive tillage. In the region, basins in the cropland tillage phase are often totally devoid of vegetation, especially when these basins lie in fields undergoing summer fallow.

Plant species richness was lower in wet-meadow zones in sample wetland basins in poor-condition watersheds. Lower species richness seemed directly related to the replacement of normal emergent and natural drawdown phases by cropland tillage and cropland drawdown phases. An obvious pattern is the replacement of native perennials with introduced perennials, native and introduced annuals, cultivated crop plants, and field weeds. Species richness in these basins is probably further reduced by herbicides. Higher mean taxa richness in the normal emergent phase of wet-meadow zones in poor-condition watersheds could reflect several phenomena including loss of species through long-term grazing or haying of wet-meadow zones in the good-condition watersheds and invasion of species into wet-meadows in poor-condition watersheds subject to a variety of current and past disturbances. Relatively high mean taxa richness in communities in the natural drawdown phase during 1992 could reflect the occurrence of normal plants of this zone combined with upland plants that invaded during the preceding several years of drought. Very low mean taxa richness in the cropland tillage phase of wet-meadow zones in poor-condition watersheds undoubtedly reflects the replacement of normal emergent and natural drawdown species by cultivated crop monotypes and field weeds that are usually subjected to treatment with herbicides.

As previously mentioned, the value of the abundance of submergents, the ratio of emergent cover to open water in deep-marsh zones of semipermanent wetlands, and the abundance of metaphytic or planktonic algae in open water areas in deep-marsh zones of semipermanent wetlands could not be tested as EMAP indicators. No open water areas occurred in the deep-marsh zones of the semipermanent wetlands selected for study in poor-condition watersheds. In any case, sample sizes of semipermanent wetlands were too small in both watershed types to detect any differences in these variables.

I conclude that several of the indicators we measured, especially amounts of unvegetated bottom and plant species richness, successfully discriminated between wetlands in good- and poor-condition watersheds. Intensively tilled prairie wetlands with large amounts of unvegetated bottom show poor use by aquatic or marsh birds. For example, in the 1960's, these wetlands comprised about one-fourth of the total area of basin wetlands in the North Dakota portion of the PPR. During this period, only 4.4 percent of the ducks (Kantrud and Stewart 1977) and less than 0.5 percent of the other birds (Kantrud and Stewart 1984) were observed on these basins. Nevertheless, there is a need for additional indicators of the general environmental condition of wetlands. Most valuable would be indicators that could be photographed or otherwise remotely sensed. A set of ideal indicators could detect the absence of stressors as well as the presence of structures or functions of known value to major groups of organisms.

6.6 RECOMMENDATIONS FOR FUTURE EMAP STUDIES

I suggest that measures of the amounts of unvegetated bottom and the presence of seeded crops or cultivated soil in wet-meadow zones may be the best indicators of poor environmental condition in prairie wetlands. Wet meadow zones are present in nearly all prairie wetlands. Unvegetated bottoms, patterns in the soil left by various types of cultivation equipment, and the presence of seeded crops could easily be interpreted from good quality aerial photographs taken at any time during the growing season. Sampling time would be greatly reduced and landowner contacts would be unnecessary because direct access to the basins would not be required.

Taxa richness was higher in communities in wet-meadow zones in good-condition watersheds regardless of adjustments for community size, but this was not true for shallow-marsh and deep-marsh zones. That the only significant correlation between taxa richness and community area was for communities of deep-marsh zone within good-condition watersheds suggests that future EMAP studies of taxa richness should concentrate on wet-meadow zones. However, use of species richness, and subsequent consideration of species composition, as indicators of environmental condition for the next phase of EMAP would require many landowner contacts because direct access to the basins by a competent botanist would be necessary. Time expenditures per sampled basin would be much larger than measures of environmental condition obtained remotely. Thus measures of species richness would greatly reduce the number of basins that could be sampled per unit of effort.

Although untested during the Prairie Pothole Pilot Study, the abundance of submergent vascular plants, cover/open water ratios, and the abundance of algae in open water areas in deep-marsh zones of semipermanent wetlands may still be potentially useful indicators of environmental condition of wetlands. The indicator value of semipermanent wetlands is limited, however, because they compose only a relatively small proportion, perhaps 10-15% (Kantrud and Stewart 1984), of the basins in any sampled land area in the region.

Future EMAP research could perhaps test a ranking system based on landscape-level indicators for all undrained basins in a large geographical area. Watersheds could be ranked by the degree of stress placed on the wetland basins by the most common land use practices on the adjacent uplands. The presence of certain structures (open shallow water; turf of perennial plants) and functions (maintenance of runoff volume; sediment retention) and the absence of certain stressors (excessive herbage removal; mechanical disturbance) and problems (siltation; artificial drainage) could be noted for the outermost zone of the wetlands. Rank scores could be combined for uplands and wetlands to create an index of environmental condition of wetlands.

The ranking system could be based on the premise that wetlands in the region had watersheds where soils and vegetation had evolved primarily under the ecological influences of herbivory and fire and were otherwise essentially undisturbed. Prior to agricultural disturbance, xeric grasses dominated upland watersheds in the region; taller mesic grasses dominated low-prairie sites; and wetlands were bordered by palustrine emergent vegetation. The ranking system would recognize that, because of inherent natural fertility and ease of human access and occupancy, native vegetation types were the focal points of disturbance by European agricultural and developmental practices and that these practices and associated problems with high human population densities impact the condition of wetlands to various degrees. The degree of alteration could be ranked numerically for uplands (watersheds), low-prairie (here considered an ecotone or the major buffer between upland and wetland), and the palustrine wet-meadow zone that forms the outer boundary of prairie wetlands.

Land units could be ranked through interpretation of aerial photographs or videographs, with no need for ground surveys or landowner contact. Alternately, wetlands and their watersheds could be ranked from roadside transects if only those wetlands clearly and wholly visible from the road and not altered by road construction were surveyed. Whatever method is used, low rank scores could indicate poor environmental condition of wetlands. Such a ranking system could use predetermined values to score environmental condition of uplands, low-prairie, and wet-meadow which could be given increasingly greater weights. Scores could be summed for an overall score for the wetland under consideration. In hypothetical examples of this method (Tables 6-22 and 6-23), the maximum score is 21.0 for a grazed or burned temporary wetland that has not been cultivated, is surrounded by a grazed or burned low-prairie zone that also has not been cultivated lying in a watershed comprised almost exclusively of burned or grazed native grassland. Note that this ranking system could rank the environmental condition of more complex wetlands (those with seasonally-, semipermanently- or permanently-flooded, intermittently exposed, and saturated) under the assumption that intensity of human land use always diminishes with increased period of flooding. Overall score for a larger geographical area could be the mean rank for all wetlands in the area.

Ranking systems would also benefit from greater detail on past land use and intensity of land use as shown by an example for wet-meadow zones (Table 6-24). These ranks could easily be assigned to many wetlands by experienced observers during roadside surveys.

Table 6-22. Hypothetical environmental condition scores for upland.

Combinations of proportions of watershed land use						
Percent developed land	Percent annually tilled cropland	Percent hayed or grazed seeded cropland	Percent idle seeded cropland	Percent hayed or idle native grassland	Percent grazed or burned native grassland	Score
75-100	bulk of remainder					0.0
75-100		bulk of remainder				0.2
75-100			bulk of remainder			0.4
75-100				bulk of remainder		0.6
75-100					bulk of remainder	0.8
	75-100	bulk of remainder				1.0
	75-100		bulk of remainder			1.2
	75-100			bulk of remainder		1.4
	75-100				bulk of remainder	1.6
		75-100	bulk of remainder			1.8
		75-100		bulk of remainder		2.0
		75-100			bulk of remainder	2.2
			75-100	bulk of remainder		2.4
			75-100		bulk of remainder	2.6
				75-100	bulk of remainder	2.8
					75-100	3.0

Table 6-23. **Hypothetical environmental condition scores for low-prairie and wet-meadow zones of prairie wetlands.**

Predominant land use of zone	
Low-prairie zone	Score
Developed, drained, or silted in	0
Annually-tilled cropland or fallow	1
Hayed or grazed, seeded to domestic grasses or legumes	2
Idle, seeded to domestic grasses or legumes	3
Idle native grassland	4
Hayed native grassland	5
Grazed or burned native grassland	6
Wet-meadow zone	
Developed, drained, or silted in	0
Annually-tilled cropland or fallow	2
Hayed or grazed, seeded to domestic grasses	4
Idle, seeded to domestic grasses	6
Idle native grassland	8
Hayed native grassland	10
Grazed or burned native grassland	12

The presence of recognized functions and absence of recognized stressors could also be incorporated in a ranking system for wet meadows (Table 6-25).

The ranking system would recognize that current water conditions and land use practices have drastic effects on wetland structure and function and resulting values. For example, flooded grassland in grazed wet meadow zones produces large amounts of invertebrates compared to flooded bare soil. During drought, the dry grassland of grazed wet meadows provides good nesting cover, whereas the dry bare soil, crops, or crop residues of cultivated wet meadows is poor nesting cover. Such ranking systems could be improved if other indicators of environmental degradation, such as partial drains, upland gullies terminating in silt deltas in the wetland, or use of wetlands for feedlots or landfill sites could be detected on the photographs.

Additional useful information could be obtained if multiple sets of photographs were available, for instance from exposures taken during spring, summer, and fall. The ranking system could then be refined to detect multiple stresses, such as fall plowing of the watersheds and basins (detectable in spring), spring tillage and seeding of watersheds and basins (detectable in summer), and summer or fall haying, grazing, burning, or recultivation of basins after harvest (detectable in fall). Lack of large

Table 6-24. Example of an expanded ranking system for environmental condition of wet-meadow zones.

Land use Subtype Intensity	Hypothetical condition score
Cropping	
Small grains	2
Row crops	1
Fallowing	
Mechanical	0
Chemical	1
Grazing	
Native vegetation	
Heavy	6
Moderate	10
Light	8
Seeded or ruderal vegetation	
Heavy	4
Moderate	6
Light	5
Mowing	
Native vegetation	6
Seeded or ruderal vegetation	4
Burning	
Native vegetation	9
Seeded or ruderal vegetation	4
Idling	
Native vegetation	5
Seeded or ruderal vegetation	3

Table 6-25. **Land use of wet meadow zones of prairie wetlands as related to environmental condition and water levels as indicated by critical structures, functions, and stressors[a].**

Cultivated-high water levels

Structures Present-	1. Open shallow water 2. Smooth, bare bottom 3. Windrowed crop residue 4. Cropland watershed
Functions Present-	1. Maintenance of runoff volume 2. Maintenance of runoff timing 3. Groundwater recharge 4. Sediment retention 5. Nitrate removal 6. Invertebrate production 7. Waterbird production 8. Habitat for migrant waterbirds
Stressor Absent-	1. Excessive herbage removal 2. Mechanical disturbance 3. Artificial drainage

"Score"--8 functions present +3 stressors absent=11

Cultivated-low water levels

Structures Present-	1. Rough bare soil 2. Crops or crop residue 3. Cropland watershed
Functions Present-	1. Maintenance of runoff volume 2. Maintenance of runoff timing 3. Groundwater recharge 4. Sediment retention 5. Nitrate removal 6. Crop or forage production
Stressors Absent-	1. Artificial drainage

"Score"--6 functions present +1 stressor absent=7

Grazed-high water levels

Structures Present-	1. Open shallow water 2. Submerged turf of perennial hydrophytes 3. Grassland watershed
Functions Present-	1. Maintenance of runoff volume 2. Maintenance of runoff timing

Table 6-25. (continued)

	3. Groundwater recharge 4. Sediment retention 5. Nitrate removal 6. Invertebrate production 7. Waterbird production 8. Habitat for migrant waterbirds 9. Winter wildlife cover 10. Crop or forage production
Stressors/Problems Absent-	1. Siltation 2. Tillage 3. Mechanical herbage removal 4. Pesticide use 5. Artificial drainage

"Score"--10 functions present +5 stressors absent=15

Grazed-low water levels

Structures Present-	1. Turf of perennial hydrophytes 2. Grassland watershed
Functions Present-	1. Maintenance of runoff volume 2. Maintenance of runoff timing 3. Groundwater recharge 4. Sediment retention 5. Nitrate removal 6. Waterbird production 7. Winter wildlife cover 8. Crop or forage production
Stressors/Problems Absent-	1. Siltation 2. Tillage 3. Mechanical herbage removal 4. Pesticide use 5. Artificial drainage

"Score"--8 functions present +5 stressors absent=13

Mowed-high water levels

Structures Present-	1. Open shallow water 2. Submerged turf of perennial hydrophytes 3. Grassland or cropland watershed
Functions Present-	1. Maintenance of runoff volume 2. Maintenance of runoff timing 3. Groundwater recharge 4. Sediment retention 5. Nitrate removal

Table 6-25. (continued)

	6. Invertebrate production 7. Waterbird production 8. Habitat for migrant waterbirds 9. Crop or forage production
Stressors/Problems Absent-	1. Siltation 2. Tillage 3. Pesticide use 4. Artificial drainage

"Score"--9 functions present +4 stressors absent=13

Mowed-low water levels

Structures Present-	1. Clipped turf of perennial hydrophytes 2. Grassland or cropland watershed
Functions Present-	1. Maintenance of runoff volume 2. Maintenance of runoff timing 3. Groundwater recharge 4. Sediment retention 5. Nitrate removal 6. Waterbird production 7. Crop or forage production
Stressors/Problems Absent-	1. Siltation 2. Tillage 3. Pesticide use 4. Artificial drainage

"Score"--7 functions present +4 stressors absent=11

Idle-high water levels

Structures Present-	1. Tall, wet turf of perennial hydrophytes 2. Grassland or cropland watershed
Functions Present-	1. Maintenance of runoff volume 2. Maintenance of runoff timing 3. Groundwater recharge 4. Sediment retention 5. Nitrate removal 6. Invertebrate production 7. Waterbird production 8. Winter wildlife cover

Table 6-25. (continued)

Stressors/Problems Absent-	1. Siltation 2. Tillage 3. Pesticide use 4. Artificial drainage

"Score"--8 functions present +4 stressors absent=12

Idle-low water levels

Structures Present-	1. Rank turf of perennial hydrophytes 2. Grassland or cropland watershed
Functions Present-	1. Maintenance of runoff volume 2. Maintenance of runoff timing 3. Groundwater recharge 4. Sediment retention 5. Nitrate removal 6. Waterbird production 7. Winter wildlife cover
Stressors/Problems Absent-	1. Siltation 2. Tillage 3. Pesticide use 4. Artificial drainage

"Score"--7 functions present +4 stressors absent=11

[a]The four stressors and nine functions are those identified as most important (score 4 or higher) in prairie wetlands by a panel of experts as reported in Adamus, P.R. 1992. A process for regional assessment of wetland risk. U.S. Environmental Protection Agency, EPA/600/R-92/249. The functions relating to maintenance of runoff, groundwater recharge, and nitrate removal have been maintained for high water levels under the assumption that wet-meadows are nearly always dry prior to the following spring snowmelt period. A tenth function, crop or forage production, has been added because it is the major economic use of wetlands in the prairie region. The stressor pesticide use, although receiving a score of only 2 by the panel of experts, has been maintained because of the possible reduction of hydrophytes caused by atrazine-type pesticides in the region. Wetlands are scored by summing the number of functions present and number of stressors absent. The model assumes normal precipitation patterns for the prairie region and that the presence of stressors is negatively correlated with wetland water levels. The model also assumes weather conditions such that standard agricultural practices progress normally throughout the growing season.

amounts of wetland vegetation in wet basins during summer, particularly in fields of row crops, may be a good indicator of herbicide damage to the wetland plants. The U.S. Department of Agriculture also maintains files of fields where restricted pesticides are used. Overgrazing of watersheds and their included wetlands could also possibly be detected if photographs of nearby reference sites known to be more conservatively grazed were available for comparative purposes. Such ranking systems could be improved if other indicators of environmental degradation, such as partial drains, upland gullies terminating in silt deltas in the wetland, or use of wetlands for feedlots or landfill sites could be detected on the photographs.

Section 7.0
SOILS AND SEDIMENTS AS INDICATORS OF AGRICULTURAL IMPACTS ON NORTHERN PRAIRIE WETLANDS

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7.1 INTRODUCTION

The northern prairie wetlands are, for the most part, the products of glaciation that ended less than 13,000 years ago (Bluemle 1991). Landscapes pocked by these wetlands are characterized by internal drainage. Watersheds are the surrounding drainage basins that contribute runoff, ground water seepage, dissolved solids, and eroded sediments to the wetlands located at the bottom. Some watersheds are hydrologically isolated, while others are hydrologically and geochemically connected to others by runoff or groundwater flow. Land use practices, especially agriculture, may have a significant impact on both the quality and quantity of materials that enter wetland communities.

In time, wetland habitat will be lost or seriously damaged due to one or a combination of the following natural or anthropogenic processes: (1) contamination by toxic levels of salts and other chemicals, (2) establishment of an integrated stream drainage system, (3) long-term drought associated with subsequent lowering of water tables, or (4) filling-in by inorganic sediments and organic matter. While PO_3 is readily adsorbed, NO_3 is more likely to be transported in soluble form. Sediments often carry phosphate and nitrate fertilizers (Neely and Baker 1989), which may enhance plant growth and hasten the accumulation of organic sediments within the wetland basin. Elevated phosphorous levels can promote eutrophication in aquatic ecosystems and enhance the growth of blue-green algae (Schindler 1977, Crumpton 1989). Algae can become a problem to the point of causing fishkills in prairie pothole lakes (Kling 1975). Chemical sediments, especially salts, are common in the subhumid and semiarid prairie potholes. Salts can severely limit the condition and productivity of the potholes (Richardson and Arndt 1989). However, some wetlands in the PPR contain plants and animals well adapted for normal salinity, but elevated salinity from certain land-use practices are problems.

Soils are an essential part of the wetland ecosystem, serving as both a reservoir of water and nutrients and as a medium for biogeochemical processes. To conserve wetland ecosystems, we need to understand processes that threaten them, be able to measure those processes and develop acceptable protective strategies. Our primary objective in this study was to evaluate, within the constraints of the project, the extent to which soils reflect the impact of land use, and identify contrasting soil indicators that distinguish good-condition from poor-condition wetlands (See Section 2 for condition definition). To assess and monitor the condition of these wetlands, one must have a concept of what constitutes good-condition wetlands, and be able to measure the processes which lead to their demise. We are proceeding with the assumption that good-condition wetlands are those closest to being pristine, i.e. undisturbed by human intervention, and poor-condition wetlands are those most disturbed by human practices, especially agricultural tillage and cropping.

7.2 OBJECTIVES

1. Determine if good- and poor-condition wetlands can be distinguished from each other.

2. Determine the quality and quantity of sediment entering wetlands seasonally as a result of erosion.

3. Determine the long-term sedimentation rates in good- and poor-condition wetland landscapes.

4. Identify and measure some key soil constituents that reflect land use impacts, and pose a threat to the condition of wetland ecosystems.

7.3 METHODS

7.3.1 Quality and Quantity of Sediments

Sediment trapping devices (see Section 9-1) were installed in 35 sample wetland basins. The samples from the traps were analyzed for invertebrate remains at the Northern Prairie Science Center (NPSC) as described in Section 5.6.1. The frozen sediment slurries were then mailed to us at North Dakota State University (NDSU). We stored the samples for about one week in a walk-in refrigerator maintained at a constant 3 °C. While in the refrigerator, the samples melted and the sediment settled to the bottoms of their plastic containers. After settling, the clear water was decanted off and the remaining sediment samples were dried for 24 hours in a forced-air evaporating oven at 65 °C. Since many of the samples from individual traps were too sparse for analysis, we composited the sediments from each wetland into a single sample. Analyses included

- organic matter content using the loss-on-ignition method (Schulte 1988)
- calcium carbonate ($CaCO_3$) equivalent by the Williams (1948) method
- phosphorus by the sodium bicarbonate ($NaHCO_3$) extraction method (Olsen et al. 1954, Knudsen and Beegle 1988).

We had planned to perform particle size analysis on the sediment samples, however, sediment amounts were often too small to conduct the analysis.

7.3.2 Long-term Sedimentation (Cottonwood Lake Study Area)

Cesium-137 (Cs-137) is a radioactive isotope introduced to the atmosphere in the 1950's by way of atomic weapons testing. Maximum atmospheric levels of Cesium-137 were detected in 1954, and the winter of 1963-64. Cesium is tightly adsorbed to sediment particles and serves as a marker for estimating sedimentation rates since 1954.

Several studies (DeLaune et al. 1978) have used peak Cs-137 levels found in sediment profiles to successfully establish time markers and interpret depositional histories. The dating of vertical sediment accumulation using Cs-137 peaks in sediment profiles depends on a major assumption we feel we can not make in the northern prairie pothole wetlands. To use the profile-peak method we must assume a constant sedimentation rate (Ritchie et al. 1973). However, using a hypothetical example, suppose fallout Cs-137 entered a wetland basin in 1954 and remained attached to upland soils for many years of relative drought and idle land use. If the basin was later disturbed by cultivation, then received heavy precipitation in 1962, causing the land to erode, sediment laden with Cs-137 would enter the wetland basin in 1962. If a researcher using the profile-peak method (described above) sampled those new wetland sediments, which were high in Cs-137, they would probably interpret those sediments as having been deposited in 1954, the first peak year for Cs-137 fallout. This, of course, would be an erroneous interpretation, since the sediments actually were deposited in 1962. Considering the highly variable climate here and the alternating drawdown and emergent phases of northern prairie wetlands, constant sedimentation rates seem highly unlikely. Additional problems with the profile-peak, in our opinion, exist. For example, recharge events following a severe drought in a dry wetland may cause clay particles bearing Cs-137 to be leached to lower profile depths. Cattle and other animals common to the northern prairie wetlands may distort Cs-137 horizons by disturbing and mixing wetland sediments.

For these reasons, we used another method similar to that used by Soileau et al. (1990), and DeJong et al. (1986) to estimate average annual soil erosion rates. The method does not assume constant sedimentation rates and focuses on soil loss occurring from 1954, the year when Cs-137 was introduced to the atmosphere by weapons testing. The soil loss rate is averaged over 39 years. It makes no difference how sporadic were the periods of erosion and deposition. Although we focus on erosion using this model, not sedimentation, we think it is safe to expect watershed erosion to be directly related to wetland basin sedimentation. Furthermore, it seems reasonable to expect that any future land management practices aimed at reducing wetland sedimentation will have to directly address watershed erosion.

We used the following analog of Soileau et al. (1990) to estimate annual erosion in cultivated and uncultivated wetland watersheds, where:

$A = [(B-C)/B] * D/E$

A = annual rate of soil erosion (metric tons/ha),

B = total Cs-137 activity (Bq/m^2) in 0-15 cm cores of baseline flat, non-eroded site,

C = total Cs-137 activity (Bq/m^2) in 0-15 cm soil of eroded side slopes.

D = soil mass in 0-15 cm depth core (Mg/M^3) * 1 ha volume of soil (metric tons),

E = years elapsed between initial Cs-137 fallout and soil sampling (39 years for this study).

Because of the high cost of Cs-137 analyses, we tested this method on four distinct sites as a preliminary investigation of using Cs-137 to analyze sedimentation.

To determine long-term sedimentation rates in wetlands surrounded by cultivated versus uncultivated fields, we collected soil samples from side slopes of four wetland watersheds (P1, P7, T1, and an unnamed wetland basin on private property designated C7 for this study)in May 1993 (Fig. 7-1). P1 and P7 are semipermanent wetlands; T1 and C7 are seasonal wetlands (Stewart and Kantrud, 1971). P1 and T1 are surrounded by grassland, C7 and part of P7 are surrounded by cultivated fields.

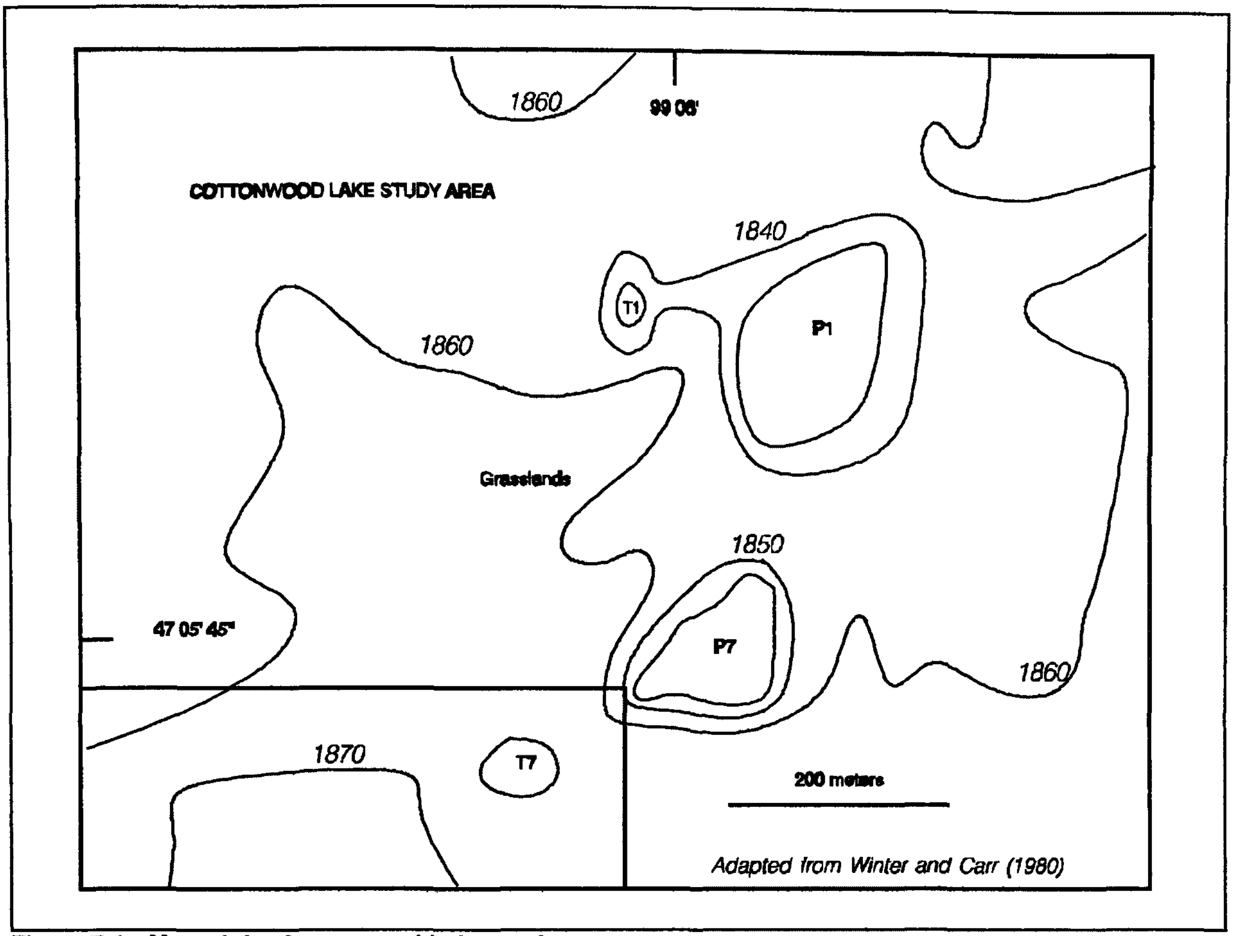

Figure 7-1. Map of the Cottonwood Lake study area.

We collected duplicate samples, 5 cm in diameter by 15 cm deep, using a slide-hammer coring device from three different points, all on side slopes, surrounding each of the four basins. Three samples of the same dimensions were collected from a flat, uneroded site northwest of P7 to use for control (factor B in the soil loss equation).

Subsamples were oven-dried at 105 °C to determine hygroscopic moisture and soil bulk density. We composited the samples from each basin into single samples. Approximately 700 g of soil composite were placed in four Marinelli beakers, one for each wetland, and analyzed twice for Cs-137 activity using gamma counting equipment. Counting time was 16 hrs. The gamma ray sensor was a 1.5 in. X 1.5 in. (3.8 cm by 3.8 cm) ORTEC 905-2 NaI Scintillation Detector coupled to a Canberra Series 85 Multichannel Analyzer. Analytical software was the MAESTRO II Emulation Software Model A64-BI Version 1.40 (EG&G ORTEC, 1991, Oak Ridge, TN).

7.3.3 Key Soil Constituents

7.3.3.1 Cottonwood Lake Study Area

Soil samples and data were collected at CWLSA in early June 1992. We collected soil samples and data from four wetlands and wetland watersheds, including P1, T1, P7, and C7 (Figure 7-1). Soil samples were collected from wetland vegetation zones (Stewart and Kantrud, 1971) along radial transects. To establish the transects, we measured salinity every 10 paces along the wet meadow zone of each of the four wetlands using the GEONICS EM-38 (Geonics LTD, Mississauga, Ontario). Other transects were placed at about 100 m intervals, as measured by pacing, along the wet meadow. P1, the largest wetland had 10 transects, P7 had 6, and T1 and C7 each had four transects. T1 and C7 are relatively small wetlands, and the transects had to be spaced closer together to have a minimum of four transects per wetland.

We collected soil samples from profiles where the transects intersected the wetland vegetation zones at four depth increments per profile (0-15 cm, 15-30 cm, 30-45 cm, and 45-60 cm). We placed about 400 grams of each sample in plastic-lined bags and stored them in coolers until late afternoon of each field day, when we returned to the Woodworth Field Station. Here the samples were spread out in a garage to air-dry. Back at NDSU, the air-dried samples were sieved through a 2-mm screen. All soil laboratory analyses were conducted on dry, sieved samples.

We classified soil profiles in the field using *Keys to Soil Taxonomy* (Soil Survey Staff 1975). Watershed measurements consisted of extending the linear transects away from the wetland to the top of the wetland watershed divide. The length of each upland transect was measured by pacing. We also measured steepness with a pocket clinometer.

The specific soil characteristics that we tested for their use as potential condition indicators included

- *Soil Classification* (Soil Survey Staff, 1975)
- *Nitrate-Nitrogen* by transnitration of salicylic acid (Vendrell and Zupacic 1990)
- *Sodium bicarbonate-extractable Phosphorus* (Knudsen and Beegle, 1988)

- *Organic Matter* by loss-on-ignition (LOI) (Schulte 1988)

- *Soluble Salts* by electrical conductivity (EC) (Dahnke and Whitney 1988)

- *In Situ Salinity* using a GEONICS EM38 electromagnetic induction meter

- *Soil pH* in 2:1 0.01*M* $CaCl_2$ solution-to-soil slurries (Eckert 1988)

- *Particle Size* using Particle Size Analysis (PSA) by the hydrometer method (Day 1965).

The nitrate, phosphorus, and organic matter tests were performed at the NDSU Fertility Laboratory; soluble salts, pH and PSA were performed in the NDSU Soil Characterization Laboratory.

The sodium bicarbonate ($NaHCO_3$)-extractable P is sometimes known as the "Olsen" test (Olsen et al. 1954) after its originator. This is a relatively inexpensive procedure that yields values which have correlated well with crop responses. This test is the one routinely used on agricultural soils in North Dakota in order to make fertilizer recommendations. Since we are concerned with fertilizer additions to wetlands, the Olsen test seems appropriate, since it is sensitive to common fertilizer sources of P. Wolf et al. (1985) found fairly good coefficients of determination (0.71) between Olsen test P and algal available P.

The LOI method (Schulte 1988) was developed as an alternative to the more complex and time-consuming Walkley-Black (1934) carbon test, which is a wet-chemical procedure. The LOI method correlates very strongly to the Walkley-Black test and, unlike Walkley-Black, requires no hazardous chemicals. The LOI test includes first drying a sample to 105 °C, and recording its dry weight. Next the sample is baked in a muffle furnace at 360 °C for 2 hours and weighed again. Although LOI tests are often run at 450 °C or higher; in prairie regions, 360 °C should be the standard procedure. The weight loss is due to the oxidation of organic matter (OM) in the soil.

The test for soluble salts by electrical conductivity (EC) was performed on 1:1 soil to distilled water slurries. Twenty ml of water were added to 20 g of soil, stirred, and left to stand for 15 minutes before measuring electrical conductivity with a Type 700 Conductivity Meter (Chemtrix Corp., Hillsboro, OR). Soil pH was measured using an ORION Ion Analyzer Model 901 (Cambridge, MA).

Particle size analysis was performed on samples collected from four depth increments: 0-15 cm, 15-30 cm, 30-45 cm, and 45-60 cm. Prior to analysis, samples were air-dried and sieved through a 2-mm screen. We used a hydrometer method similar to that described by Day (1965) with some modifications intended to save time and allow for the analyses of greater numbers of samples. Our method does not include digestion of organic matter, washing salts, or shaking overnight; it emphasizes chemical instead of mechanical dispersion. The procedure was as follows:

1. Weigh 40 g of soil and place it in a hydrometer jar.

2. Add 100 ml of Calgon dispersant.

3. Add enough distilled water to the Calgon to make 1 liter.

4. Agitate the suspension with 30 up-and-down plunger cycles and let sit overnight.

5. In the morning, check temperatures, agitate again with 30 plunger cycles and begin hydrometer readings.

6. Read hydrometer values at 1, 3, 10, 30, 90, 270, and 480 minutes.

7. Calculate sand, silt, and clay percentages using a LOTUS 123 spreadsheet in the Soil Characterization Laboratory.

The procedure saves time on bottle washing since there is no overnight shaking in a flask or drink mixer. Again, we performed no salt washing or OM digestion.

Multiresponse permutation procedure (MRPP) is a statistical method of analyzing ecologic data which do not necessarily conform to assumptions of normal distribution and equal variances required when using least squares analyses such as linear regression and analysis of variance (Biondini et al. 1988). Since some of the data generated by this study do not fit the normal distribution, use of MRPP seemed appropriate.

MRPP is a method based on absolute Euclidean distances (Biondini et al. 1988). Distances are calculated between all possible pairs of points in each group and averaged to calculate the group distance value. Then, the group distance values are weighted according to the number of samples in each group and averaged together to calculate the delta value. If the groups are real, i.e., they form separate groups in the data space, the delta value will be significantly low. If, however, the assigned groups are not really different, alternative groupings, or permutations, may yield distance values smaller than the values calculated for the chosen groupings. In this latter case, the P-values would be high, since the chance of getting lower delta values would be relatively high.

The basic statistical data are in Tables 7-1 and 7-2. MRPP was applied to nitrate, P, and OM data from the 0-15 cm depth samples collected from each transect. The values shown in Table 7-3 are from wet meadow soils, or in cases where wet meadow was absent, shallow marsh soils. The samples shown come from the 0-15 cm depth increment. These samples were chosen for primary analysis since they are closest to the surrounding land use activities, i.e., they are on the edge of the wetland, on or near the land surface. Samples were separated into two conditions, based on the land use adjacent to and up-slope from the sample site. In P7, transects 2 and 6 were somewhat intermediate in their adjacent land use. The immediately-surrounding land use is grassland for those two sites, but, we think, they are sufficiently close to the cultivated fields that they warrant placement in the cultivated (poor-condition) group. Seventeen samples fell into the grassland (good-condition) group, and 7 were placed in the cropland (poor-condition group).

7.3.3.2 10.4-km^2 Sample Plots

In 1992, we sampled 40 wetlands at the same sites where H. Kantrud took plant data (see Section 6.3.1) and collected soil samples from vegetation quadrats placed in delineated plant communities. In each community, soil profiles from five quadrats per community were classified, and soil was collected from quadrats two and four for laboratory analysis. Soil profiles were dug, using a "Dutch" auger, to a depth of about 75 cm, sufficiently deep to classify the soil and collect laboratory samples. Two samples were collected from each profile, one from 0-15 cm depth and another from 15-45 cm. Laboratory analyses included all those performed at the CWLSA wetlands except PSA, i.e., NO_3^- $NaHCO_3$-extractable P, organic matter, EC and pH. As in the CWLSA study, we measured basin size by pacing from the wet meadow to the basin divide along at least 4 transects. We also measured *in situ* salinity along the wet meadow using the EM-38 in the same manner described above for the CWLSA study.

In 1993, we sampled soils from 36 randomly selected wetlands according to wetland vegetation zones from H. Kantrud's study (see Section 6). We sampled and classified soil profiles from 3 of the 5 quadrats selected per community. As in 1992, we collected samples at 2 depths, 0-15 cm and 15-45 cm. Samples were bagged in plastic-lined paper bags and stored in coolers, as they were in 1992. Approximately 20 grams of each bagged sample were placed in aluminum cans, which we opened in the evening of each field day and placed in a forced-air evaporating oven. We carried the oven in our vehicle, setting it up in a motel room in the evening. Samples oven-dried at 65 °C overnight at a motel. Prompt drying is necessary to prevent analytical errors due to potential nitrogen transformation by microbes in the sample bags (Dahnke, 1988). The oven-dried samples were lightly ground, sieved through a 2-mm screen and used for NO_3^-, P and OM analyses. The bagged samples were used for analysis of pH, EC, and PSA. We only ran PSA on the 0-15 cm depth samples. Soil pH in 1993 was measured in distilled water, instead of 0.01 *M* calcium chloride ($CaCl_2$) as was used in 1992. In the above laboratory tests, except particle size analysis, every 10th sample was replicated.

We used analysis of variance (ANOVA) techniques to assess the effects of wetland condition, zone (deep marsh, shallow marsh, and wet meadow), depth, and year (1992, 1993) on the response variables NO_3, P, OM, EC, pH, sand, silt, and clay. The design was a strip-split-plot with repeated measures. Each basin was assumed to be the independent whole-unit, with zone-depth and community combination being the subunit. Because most watersheds were measured in both 1992 and 1993, year served as the repeated measures factor. We used Fisher's protected least squares differences (LSD) to isolate differences in least squares means following significant effects in the ANOVAs (Milliken and Johnson 1984). All ANOVAs were done using the general linear model procedure (PROC GLM) of SAS (SAS Inst. 1992). A 1n(y+1) transformation was done on all data except pH prior to analysis because the data were skewed to the right (note: clay was only marginally skewed). Data were averaged across quadrants (2 in 1992, 3 in 1993) prior to 1n(y+1) transforming. Sand, silt, and clay were only measured at the 0-15 cm depth in year 1993. Statistical tests were considered significant at the 0.05 level, and marginally significant at the 0.10 level.

7.3.4 Soil Oxidation-Reduction

We placed platinum electrodes in the three wetland zones (wet meadow, shallow marsh, and deep marsh) of wetlands T1, P7, and C7. We wanted to monitor oxidation-reduction potential to see if the hydric soil morphology observed in the sampled profiles at CWLSA corresponded to active oxidation-reduction processes, or, alternatively, the hydric soil morphology was possibly relict, i.e., developed during some wet climatic episode in the distant past. The electrodes were to be monitored during the frost-free months of September 1992 to November 1993.

7.4 RESULTS

7.4.1 Seasonal Sedimentation

Results of chemical analyses of trapped sediments are shown in Table 7-1. In this table, CRP land is considered good-condition because short-term sedimentation is expected to reflect the most recent activities within the drainage basin. Average amount of sediment per trap and phosphorus concentrations were nearly equal for the good- and poor-condition groups. Average organic matter in the good-condition group (15.1 g/100 g) was significantly greater (F=7.14, df 1,29 P = .012), than in the poor-condition group (9.4 g/100 g). Calcium carbonate ($CaCO_3$) equivalent (CCE) is a measure of that percentage of the sediment mass attributable to $CaCO_3$. We did not have sufficient sample to perform this test on many samples and, therefore, we are reluctant to draw any comparisons between condition groups. In sediment analysis, we expected high variation because of the wide settlement rate due to minor landscape and vegetation differences, creating, large settlement differences, both in amount and quality of sediment. Sediment will always have problems in use.

7.4.2 Long-term Sedimentation

Estimations of soil loss for the four wetland basins P1, T1, P7, C7 and a flat, noneroded site used for making comparisons are shown in Table 7-2. Using the formula from Soileau et al. (1990), we calculated soil loss (tons/ha) for each basin. As expected, the cultivated basin C7 had the greatest soil loss from its side slopes (35.6 metric tons/ha/year), and P7, the basin partially surrounded by cultivated fields had the second highest soil loss (11.71 metric tons/ha/year). T1 soil loss was 4.56 metric tons/ha/year. The P1 soil loss value (+16.13) indicates a net gain in Cs-137 and soil deposition compared to the noneroded control site.

7.4.3 CWLSA Soil Characterization

Results of laboratory analyses for fertilizer nutrients NO_3^-, P and OM are shown in Table 7-3.

Results from the MRPP (Table 7-4) show that P is the strongest contrasting variable separating the good from the poor group, while the NO_3 variable alone is the least significantly different.

Table 7-1. Analysis of selected chemical constituents of trapped sediments, 34 sample wetlands, North and South Dakota, collected in 1993. Abrev.: OM = organic matter, CCE = calcium carbonate equivalent, SD = standard deviation.

Plot	Wetland	Condition	Dry Density (g/cm^3)	P g/m^3	P g/Mg	Sediment g/trap	P loading rate g/Mg	% OM	% CCE
73	29	Good	0.39	69.6	178.5	0.87	155.3	11.9	INS
73	86	Good	0.48	35.2	72.7	1.04	75.6	23.9	0.0
133	370	Poor	0.76	55.4	73.2	3.53	258.3	8.6	0.0
133	380	Poor	0.39	111.0	285.9	0.95	271.6	INS	INS
133	386	Good	0.39	139.0	358.0	0.27	96.7	INS	INS
134	140	Poor	0.36	38.8	106.9	0.90	96.2	11.8	INS
134	158	Poor	0.78	115.6	147.8	6.06	895.4	8.1	3.8
134	165	Poor	0.55	93.8	169.5	1.58	267.7	10.5	INS
134	270	Poor	0.54	54.6	102.0	0.88	89.8	13.1	1.8
134	406	Poor	0.82	46.8	57.3	2.13	122.0	7.5	0.6
134	432	Poor	0.45	36.1	79.4	0.65	51.6	10.7	INS
156	22	Good	0.62	39.1	63.2	6.43	406.3	14.3	0.0
156	26	Good	0.68	45.5	66.9	7.89	527.9	10.0	0.0
156	42	Good	0.39	89.4	230.3	0.34	78.3	INS	INS
327	72	Poor	0.74	75.8	101.9	2.56	261.0	9.1	3.6
327	117	Poor	0.70	47.7	68.3	4.75	324.5	11.4	0.0
327	147	Poor	0.57	54.0	94.7	4.32	409.3	12.5	0.0
363	22	Good	0.47	14.6	31.0	9.31	288.5	11.4	0.3
363	58	Good	0.36	23.5	65.6	0.45	29.5	18.6	INS
374	65	Good	0.50	60.4	121.9	4.20	512.2	26.4	10.2
374	100	Good	0.32	32.5	101.6	1.40	142.2	25.3	2.4
374	225	Good	0.38	50.3	132.8	5.98	794.0	24.1	0.0
374	272	Good	0.72	13.7	19.1	1.45	27.7	3.7	4.9
407	67	Good	0.65	54.2	83.8	4.17	349.3	13.0	0.0
407	109	Good	0.43	36.6	84.7	0.43	36.4	21.0	INS
407	168	Good	0.83	43.8	53.0	9.63	510.4	6.1	10.0
442	93	Good	0.53	60.4	113.3	1.37	155.3	11.6	INS
442	260	Poor	0.88	56.2	64.2	6.12	392.7	5.7	0.0
442	261	Poor	0.86	64.0	74.6	5.23	390.0	5.9	0.0
442	281	Poor	0.66	64.0	97.0	2.62	254.1	7.7	0.0
442	295	Good	0.28	51.2	184.0	0.69	127.0	23.6	0.0

Table 7-1. (Continued)

Plot	Wetland	Condition	Dry Density (g/cm³)	P g/m³	P g/Mg	Sediment g/trap	P loading rate g/Mg	% OM	% CCE
442	301	Good	0.41	70.1	169.8	0.79	134.1	13.0	0.0
498	146	Good	0.69	39.7	57.6	8.92	513.7	6.7	0.0
498	277	Good	0.60	41.2	68.2	3.22	219.6	7.5	0.0
Mean	Good					3.4	259.0	15.1	
Mean	Poor					3.0	291.7	9.4	
SD	Good					3.4	217.6	7.4	
SD	Poor					2.0	209.2	2.4	

Table 7-2. **Estimation of soil loss in four CWLSA wetlands plus a non-eroded control site using Cs-137 analysis (Soileau et al. 1990). Bulk density values are mean values from three field samples, Cs-137 activities are mean values of two laboratory runs. Each Cs-137 sample was a composite of three basin subsamples. Gamma ray count time was 57600 seconds.**

	P1	T1	P7	C7	Non-eroded"
Bulk Density (Mg/m^3)	0.83	1.17	0.89	1.39	1.20
Cs-137 Activity Bq/m^2	5.01	2.99	2.20	1.11	3.33
Soil Loss (-) or gain (+) (metric tons	+16.13	-4.56	-11.61	-35.64	0.00

Combining P with one or both of the other two variables does not improve the P-value, or seemingly add to the separation of the two condition groups. Distances between phosphorus values in the poor-condition group are about twice the distances in the good group, indicating unequal variances in the two groups of data, one of the reasons for using MRPP.

7.4.4 Results of 1992 and 1993 EMAP Soil Characterization

Poor wetland condition included land recently placed into CRP, since the soil analyses probably reflect long-term conditions in the wetland basin. Least squares (LS) means and mean comparisons were made from log-transformed data Tables 7-5, 7-6, and 7-7. Log-transformation was necessary on all but the pH variables, due to data distributions being skewed to the left. Back-transformed means are also shown in those tables.

Nitrate varied significantly with year ($F_{1,95}$=9.46; P=0.0027), and with depth ($F_{1,48}$=13.559; P = 0.0006). The year effect implies that the differences between 1992 and 1993 are consistent for condition, zones and depths (i.e., comparisons between years can be made by ignoring condition, zone and depth). The depth effect implies that depth differences are consistent between condition, zones, and years. Phosphorus varied significantly with year ($F_{1,95}$=5.02; P=0.0274), zone ($F_{2,35}$=6.57; P=0.0038) and marginally with condition and depth interaction ($F_{1,48}$=2.88; P=0.0962). OM only varied significantly with depth ($F_{1,48}$=108.69; P=0.0001).

Table 7-3. **CWLSA Soil nutrient analysis of 0-15 cm samples from wetlands P1, T1, P7, and C7, Cottonwood Lake Study Area, 1992. Abrev.: WM = wet meadow, SM = shallow marsh, NO_3^- = nitrate. Units: OM = % mass, NO_3 and P g/m3.**

Wetland	Transect	Condition	Zone	OM	NO_3	P
P1	1	Good	WM	4.3	8.1	6.9
P1	2	Good	WM	4.2	9.9	7.4
P1	3	Good	WM	2.4	6.2	5.0
P1	4	Good	WM	2.6	6.3	3.8
P1	5	Good	WM	1.9	5.0	4.4
P1	6	Good	WM	2.2	5.0	5.6
P1	7	Good	WM	5.1	13.7	7.5
P1	8	Good	WM	3.2	6.3	5.0
P1	9	Good	WM	2.6	3.8	6.3
P1	10	Good	WM	3.1	5.6	6.9
T1	1	Good	WM	4.9	6.3	8.1
T1	2	Good	WM	6.0	5.0	6.2
T1	3	Good	SM	8.9	13.7	34.3
T1	4	Good	WM	6.4	11.2	6.9
P7	1	Poor	SM	9.5	13.8	33.8
P7	2	Poor	SM	9.8	17.4	26.1
P7	3	Good	WM	11.7	11.9	11.3
P7	4	Good	WM	6.3	8.1	7.5
P7	5	Good	WM	6.9	11.2	7.5
P7	6	Poor	WM	7.9	8.2	8.8
C7	1	Poor	WM	9.9	13.7	35.0
C7	2	Poor	WM	2.2	1.9	11.3
C7	3	Poor	WM	9.4	6.3	20.7
C7	4	Poor	WM	9.6	11.3	35.2

Table 7-4. MRPP statistical analysis of soil nutrient data, CWLSA, 0-15 cm soil depth, 1992.

Variable	Condition	Distance	Observed Delta	P-Value
Phosphorus	Good	4.96		
	Poor	13.3	7.39	0.00047
Phosphorus and Nitrate	Good	7.07		
	Poor	15.30	9.47	0.00071
Nitrate	Good	3.70		
	Poor	6.38	4.48	0.26474
Phosphorus	Good	8.01		
Nitrate and Organic Matter	Poor	15.74	10.27	0.00071
Organic Matter	Good	2.93		
	Poor	2.58	2.82	0.00319
Phosphorus and Organic Matter	Good	6.38		
	Poor	13.88	8.57	0.00049

EC varied significantly with zone ($F_{2,35}$=3.42; P=0.044) and with depth ($F_{1,48}$=3.93; P=0.0531). pH varied with year ($F_{1,95}$=3.66; P = 0.0588), zone ($F_{2,35}$=3.93; P=0.0289), and depth ($F_{1,48}$=13.59; P = 0.0006). Sand ($F_{2,33}$=21.19; P=0.0001), silt ($F_{2,33}$=5.42; P=0.0092) and clay ($F_{2,33}$=7.79; P=0.0017) varied significantly only with zone. All other effects and interactions were nonsignificant.

Tables 7-5 and 7-6 show Fisher's protected LSD tests and LS means for log-transformed NO_3 and P data. The letters a, b, and c located next to the LS Mean values indicate whether or not the means are significantly different. Table 7-7 shows Fisher's protected LSD tests for sand, silt, and clay. Values followed by another value with a common letter, for example shallow marsh and wet meadow silt in Table 7-7, are not significantly different. Significant differences by year and depth increment occurred for nitrate values. The 7.5 and 30 cm depths shown in the tables indicate the midpoint of the 0-15 cm and 15-45 cm depth increments we sampled in the field. Significant differences of P levels exist by year, by zone, and by condition*depth interaction. Higher P concentrations occurred in 1993, and concentrations were highest in the deep marsh zone. The condition*depth interaction indicates the P concentrations in the 0-15 cm depth soils in the poor-condition wetlands were significantly higher than in the good-condition soils of the same depth increment, independent of zone or year.

OM mean concentrations (Table 7-6) were significantly higher in surface soils compared to subsoils, independent of other interactions. This is usually the case in soils, where decaying surface vegetation and microbial activity leave higher concentrations of OM near the surface. EC (Table 7-6) was significantly higher in deep marsh zones (DM) than in either shallow marsh (SM) or wet meadow (WM) zones. Wet meadow and shallow marsh salinity (EC) were not significantly different. The Fisher's test also found significant differences in pH values by year, by zone, and by depth (Table 7-6). Clay content was highest in deep marsh zones (Table 7-7).

7.4.5 CWLSA Soil Oxidation-Reduction Potential

All but one (0.00 being neutral) of the soil oxidation-reduction measurements from September and October 1992 are positive, indicating relative oxidizing conditions (Table 7-8). May and June 1993 values are mixed, but mostly negative, indicating relative reducing conditions. Interior zones of T7 and P7 flooded deep enough to prevent us from monitoring soil oxidation-reduction. Wetland P1 was not monitored.

7.5 EVALUATION

7.5.1 Seasonal Sedimentation

Results of the chemical analyses of the trapped sediments did not reveal significant differences in P inputs occurring between the sampled good- and poor-condition wetlands. Organic matter makes up a larger proportion of the sediments in good-condition wetlands than in the poor-condition wetlands (8.3 g/100 g). A greater proportion of the poor-condition sediment is mineral material. This is a potentially important indicator reflecting higher rates of erosion and sedimentation in the poor-condition wetlands. While organic matter will, for the most part, be decomposed to biologically recyclable nutrients and gases, the inorganic sediment will remain mostly inert and, given time, fill in the wetland.

7.5.2 Long-term sedimentation

The Cs-137 study addressed the problem of sedimentation indirectly by examining soil loss from the wetland watershed side slopes. The C7 wetland had the highest rate of soil loss. However the value for P1 indicates Cs-137 and soil deposition on its side slopes.

Table 7-5. **Least squares means for nitrate and phosphorus, EMAP sample wetlands, 1992-93.**

Variable	Effect		LS Mean[a] ln(Y+1)		Back-transformed LS Mean	
Nitrate	YEAR	1992	1.88 b		7.55	
		1993	1.42 a		5.14	
		Pooled MSE =	0.2508			
	DEPTH (cm)	7.5	1.80 b		7.05	
		30	1.49 a		5.44	
		Pooled MSE =	0.1563			
Phosphorus	YEAR	1992	3.26 a		27.05	
		1993	3.44 b		32.19	
		Pooled MSE =	0.1348			
	ZONE	DM	3.62 (40) c		38.34	
		SM	3.34 (86)		29.22	
		WM	3.08 (159) a		22.76	
		Pooled MSE =	0.4759			
			DEPTH (cm)		DEPTH (cm)	
	CONDITION		7.5	30	7.5	30
		High	3.36 (78)a	3.09 (78)a	29.79	2.98
		Low	3.75 (65)b	3.19 (64)b	43.52	25.29
		Pooled MSE =	0.0926			

[a]Within a column, LS Means followed by a common letter are not significantly different at the 0.05 level using Fisher's protected LSD value.

Table 7-6. Least squares means for log transformed percent organic matter (OM) and electrical conductivity (EC), EMAP sample wetlands, 1992-93. pH data were not log transformed.

Variable	Effect		LS Mean[a] 1n(Y+1)	Back-transformed LS Means
% OM	DEPTH (cm)	7.5	2.10 (143) b	9.17
		30	1.64 (142) a	6.16
		Pooled MSE =	0.0662	
EC (micromhos)	ZONE	DM	6.75 (40) b	855.06
		SM	6.33 (86) a	562.16
		WM	6.19 (159) a	488.85
		Pooled MSE =	0.6464	
	DEPTH (cm)	7.5	6.38 (143)	590.93
		30	6.46 (142)	640.06
		Pooled MSE =	0.0681	
pH	ZONE	DM	7.15 (40) b	----
		SM	6.94 (86) a	----
		WM	7.12 (159) b	----
		Pooled MSE =	0.1476	
	YEAR	1992	6.96 (143) a	
		1993	7.18 (142) b	
		Pooled MSE =	0.1924	
	DEPTH (cm)	7.5	6.96 (143) a	
		30	7.18 (142) b	
		Pooled MSE =	0.1228	

[a]Within a column, LS Means followed by a common letter are not significantly different at the 0.05 level using Fisher's protected LSD value.

Table 7-7. Least squares means for log-transferred percent sand, silt, and clay; EMAP sample wetlands, 1993.

Variable	Effect		LS Means 1n(Y+1)[a]	Back Transformed LS Mean
Sand	ZONE	DM	2.60 (11) a	14.46
		SM	3.22 (22) b	26.02
		WM	3.45 (39) c	32.5
Silt	ZONE	DM	4.20 (11) b	67.69
		SM	3.92 (22) a	51.40
		WM	3.85 (39) a	47.99
Clay	ZONE	DM	3.32 (11) b	28.66
		SM	2.95 (22) a	20.11
		WM	2.81 (39) a	17.61

[a]Within a column, LS Means followed by a common letter are not significantly different at the 0.05 level using Fisher's protected LSD value.

Table 7-8. Soil oxidation-reduction potential measurements from 3 CWLSA wetlands. September, 1992-June, 1993.

Date	Wetland	Zone	Rep	Depth (cm)	(mVolts)
09-10-92	T1	WM	1	45	+235
			1	15	+196
		SM	1	45	+210
			1	15	+240
10-07-92	T1	WM	1	45	+311
			1	15	+301
		SM	1	45	+318
			1	15	0.00
05-13-93	T1	WM	1	45	+148
			1	15	+200
		SM	1	45	-428
			1	15	-335
06-17-93	T1	WM	1	45	-107
			1	15	-170
		SM	1	45	-69
			1	15	-46
09-10-92	T7	WM	1	45	+350
			2	45	+374
			1	15	+365
			2	15	+337
	T7	SM	1	45	+282
			2	45	+340
			1	15	+310
			2	15	+313
10-07-92	T7	WM	1	45	+335
			2	45	+380
			1	15	+442

Table 7-8. (Continued)

Date	Wetland	Zone	Rep	Depth (cm)	(mVolts)
			2	15	+418
	T7	SM	1	45	+345
			2	45	+393
			1	15	+410
			2	15	+420
05-13-93	T7	WM	1	45	+10
			2	45	-265
			1	15	-254
			2	15	-200
		SM	FLOODED		
06-17-93	T7	WM	1	45	-159
			2	45	-250
			1	15	-152
			2	15	-208
		SM	FLOODED		
09-10-92	P7	WM	1	45	+270
			2	45	+280
			1	15	+207
			2	15	+154
	P7	SM	1	45	+253
			2	45	+246
			1	15	+248
			2	15	+245
	P7	DM	1	45	+250
			1	15	+245
10-07-92	P7	WM	1	45	+290
			2	45	+272
			1	15	+254
			2	15	+264
	P7	SM	1	45	+278
			2	45	+288
			1	15	+314
			2	15	+317
			2	45	+201
05-13-93	P7	WM	1	45	+195
			1	15	+217
			2	15	+180
	P7	SM	1	45	-144
			2	45	+107
			1	15	-302
			2	15	-272
	P7	DM	FLOODED		
06-17-93	P7	WM	1	45	-205
			2	45	-120
			1	15	+214
			2	15	+260
	P7	SM	1	45	-504
			2	45	-510
			1	15	-460
			2	15	-480

The higher Cs-137 values on P1 slopes could be due to snowcatch on the grass-covered side slopes, with the snow containing Cs-137 fallout. Snow particles nucleate around dust particles in the air and thus would be added to soil upon melting. Another possibility is that explaining the apparent soil deposition on P1 side slopes of P1 is soil loss from the flat, "noneroded" site. We see no evidence, however, to support this. Another possibility, slow soil creep on the P1 side slopes may have moved Cs-137-attached soil from higher on the hill slope down to and on top of the mid-slope position where we collected our samples. Finally, the problem of apparent soil deposition of the P1 side slope could be explained by inadequate sample size.

7.5.3 Soil Characterization: CWLSA and EMAP Studies

Soil NO_3 was significantly lower in 1993 than in 1992. At least three factors might explain this contrast: denitrification, leaching, and change in sample handling procedures. Summer 1992 marked the end of a drought in the northern plains. Relatively high precipitation during the second half of 1992 and first half of 1993 refilled previously dried wetlands. Denitrification occurs as a result of chemical reduction usually associated with saturated, anaerobic environments. Nitrate, an oxidized nitrogen (N) compound is converted to more reduced compounds including ammonia (NH_3), nitrous oxide (N_2O), and nitrogen (N_2), all three of which are gaseous and return to the atmosphere. This natural process may have produced lower NO_3 levels in 1993. NO_3 is also highly soluble and may have leached to deeper soil depths in 1993. Finally, the lower NO_3 values in 1993 may have been due to a procedural change. In 1993, we dried soil samples overnight in an evaporating oven. This relatively fast drying was done to help eliminate possible oxidation of formerly reduced N compounds upon exposure to air. In 1992, samples had longer exposure to air that could have caused NO_3 values to be elevated.

NO_3 varied significantly with depth, the higher concentrations being in the 0-15 cm samples. This is most likely due to the greatest portion of the total soil nitrogen pool's association with soil organic matter. Decomposition and oxidation of organic nitrogen produces higher NO_3 concentrations in the topsoil.

From the studies at the CWLSA and EMAP sample wetlands, P was the strongest indicator showing the apparent impact of cultivation on wetland nutrient concentrations. Phosphorus, unlike nitrogen, has no stable gaseous forms and, once in the wetland, tends to remain there. Although nitrogen fertilizer is commonly applied to cultivated fields, denitrification under reducing conditions results in reduced gaseous forms of nitrogen escaping to the atmosphere.

Considerable evidence exists linking P loading to runoff and soil erosion. Andraski et al. (1985) compared P losses in runoff from four different tillage schemes including conventional till, chisel plow, till-plant, and no-till. They measured total P, dissolved molybdate-reactive P (DMRP) and algal-available P (AAP). It is important to note here that there are differences in soil P forms. Some are more available to plants than others. The DMRP and AAP are of higher ecologic importance than total phosphorus, since much of the total P is tied up in relatively insoluble minerals. Conservation tillage greatly reduced total P and sediment runoff. DMRP runoff from conservation tilled plots was lower than or equal to runoff from the conventionally, tilled plots. The AAP runoff comparisons, perhaps the best indicator of P pollution, were highest for the conventionally tilled plot and the till-plant plot, and lowest in the no-till plot. Andraski et al. (1985) stated that the algal-available P includes the dissolved (DMRP) phosphorus and about 20% of the total P. AAP is made up of about 30% DMRP, and 70% is inorganic, easily desorbed or easily dissolved particulate P associated with the sediment. The important point here is that the algal available P is mostly particulate phosphorus.

Since soil P can take many forms which might play important ecological roles, we need to know which ones we are measuring when performing a soil test. Wolf et al. (1985) examined different soil tests, including the Bray-I, Olsen, and Mehlich I methods to see how well they corresponded to equilibrium-dissolved-P concentration, "labile" P, and AAP. For north-central soils, the Olsen $NaHCO_3$ soil test P related significantly to the AAP.

Organic matter varied significantly with depth, as was expected. Under natural soil conditions, organic matter decreases with depth. Under extreme cases of erosion and sedimentation, however, where mineral soil is deposited on top of more organic-rich topsoil, organic matter increases with depth. Such a profile may be a good indicator of disturbance.

Although pH and EC do not appear to be valid indicators of wetland condition, they do provide an interesting reflection of climatic changes in the region. In our study pH was shown to be significantly different between years, but this fact, we are quite sure, is due to a laboratory procedural change in the way we measured pH. In 1992, we measured pH in 0.01M $CaCl_2$, which forces H^+ ions off soil exchange sites and, subsequently, lowers the measured pH value. In 1993, we measured pH in distilled water. By doing so, we could use the same sample prepared for the EC analysis to measure pH. This saved time and reduced the total amount of soil needed to carry out the full set of lab analyses. Our data tell us the soil pH measured in $CaCl_2$ is 0.1 to 0.4 units lower than the same soil measured in distilled water.

The soil texture analyses showed significant differences between zones, as expected. Coarser soil textures are found along the wetland edges, finer textures in the wetland interiors. Since less energy is required to transport silt or clay, wave action along wetland edges sorts fine particles and relocates them to deep water, leaving the edges sandy; i.e., creates a beach.

Soil classification, which is not easily quantified, appeared to reveal more information about the climatic and hydrologic conditions in wetlands than about land use. A notable exception, however, occurred at wetland C7 at the CWLSA. In the wet meadow of C7, we found an apparent buried A horizon and "cumulic," dark-colored A horizons in all 4 wet meadow profiles. Cumulic A horizons are relatively unusual in wet meadow sites where wave action generally sorts fine-grained soil material and organic colloids. The other wet meadow profiles we classified in other wetland basins at the CWLSA had much thinner and sandier A horizons than those at C7. We interpret this difference to relatively rapid soil deposition on the C7 wet meadow.

For the soils sampled from the wetlands in the 10.4 km^2 plots, generally, the eastern wetlands were non-calcareous Endoaquolls and Argiaquolls, and the more western wetlands were, more calcareous Typic Calciaquolls, Cumulic (Calc) Endoaquolls and Aeric Calciaquolls. In some cases, apparent changes in classification from 1992 to 1993 within the same zone (e.g., wet meadow in wetland 442-295, Appendix 7-1), reflected the drought-to-deluge transition that occurred over much of the northern prairie from 1992 to 1993. Classification of Mollisols often hinges on the presence or absence of leachable constituents, especially ($CaCO_3$).. In upland soils, where runoff occurs and leaching rate is relatively low, calcareous soils are probably stable through typical northern prairie climatic fluctuations. However, where water is focused in the landscape, i.e., in the wetlands, leaching is apparently capable of removing enough $CaCO_3$ from a soil profile to alter its classification.

7.5.4 Soil Oxidation-Reduction

Soil oxidation-reduction is a function of temperature, microbial activity, and the availability of elements or compounds that can serve as electron acceptors during metabolic activities. Under aerobic conditions, oxygen is the primary electron acceptor, but when oxygen is depleted, other compounds including nitrate, manganese oxides, iron oxides, sulfate, and carbon serve the microbial community as electron sinks. Oxidation and reduction of iron oxides in water-logged soils produces observable "redoximorphic" patterns (commonly known as mottles) we use to assess the hydrologic characteristics of soil subject to saturation. In 1992 we had experienced 6 years of drought and had questions about whether the redoximorphic features we were seeing at CWLSA were due to contemporary oxidation-reduction processes, or whether the morphology was relict. The monitored sites became mostly saturated and reduced in the spring of 1993. The sites were under several feet of water by late summer, 1993 and undoubtedly anaerobic. At that point we know that during reduction iron is mobilized.

Although important in understanding the link between soil morphology and biogeochemical processes, the oxidation-reduction data we collected do not appear to be valid condition indicators.

7.6 FUTURE RECOMMENDATIONS

Soil P is the best indicator of wetland condition based on results from our study, specifically, P found in the 0-15 cm depth. We recommend the continued use of $NaHCO_3$-extractable P (Olsen et al. 1954, Knudsen and Beegle 1988) when testing for biologically available P in northern prairie wetlands. This test, also commonly known as "Olsen phosphorus" is routinely performed at relatively low cost at the NDSU Soil Fertility Laboratory.

Organic matter and texture analyses, although not statistically significant variables in this study, remain potential indicators of severe soil disturbance, and we recommend they be included in future studies.

EC can show a relationship between fluctuating climate and landscape salinity, but based on our data we do not recommend it as an indicator of wetland condition. Salinity is a water quality issue in parts of the PPR, and it may be useful to track long-term precipitation-soil salinity patterns to better understand how landscape salinity responds to climatic variations. An inexpensive 1:1 soil-water suspension EC test might be useful for this purpose.

In addition to our doubts about using Cs-137 because of the confounding effect of cultivation, it is too expensive. Our data indicate a relatively high number of samples from each basin would be needed to develop accurate results for deposition rates in PPR wetlands. Each gamma sensor can count only 1 or 2 samples a day, depending on its sensitivity and the amount of Cs-137 in the soil. Further, since fallout from the 1963-64 maximum is already half of its original activity, we will have less Cs-137 activity to work with as time goes by. Therefore, we do not recommend Cs-137 for long term monitoring in the PPR.

We recommend dropping the following variables from indicator testing: NO_3^-, pH, calcium carbonate equivalent test, soil classification, soil oxidation-reduction and Cs-137.

Section 8.0
PESTICIDES IN WETLAND SEDIMENTS AS INDICATORS OF ENVIRONMENTAL STRESS

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Pesticide use is an established agricultural practice in the northern Great Plains. Grue et al. (1986) estimated that 80-90% of row crop acreage is treated with herbicides. In a survey of water quality at streamflow-gaging stations throughout the corn and soybean belt of the U.S., Thurman et al. (1992) detected atrazine in 98% of postplanting samples; 55% of these detections were above the maximum contaminant level (MCL) set by the U.S. Environmental Protection Agency.

Pesticides primarily enter wetlands in runoff or as oversprays. For example, spikes in concentrations of triazines in streams during postplanting runoff events reached an order of magnitude higher than the MCL, and were correlated with streamflow (Thurman et al. 1992). More ethyl parathion reached emergent wetland vegetation than the target sunflower plants during aerial spraying trials (Tome et al. 1991).

Until the development of enzyme-linked immunosorbent assay (ELISA) techniques for detecting and quantifying pesticides in water and sediment, broad-scale screening for pesticides could be prohibitively expensive. In this study, I examine the potential use of ELISA-determined pesticide levels in wetland sediments as a measure of wetland condition.

8.1 OBJECTIVES

To assess the utility of pesticide levels in wetland sediments for discriminating between good and poor quality wetlands.

8.2 METHODS

Hal Kantrud collected sediment samples during the course of his vegetation sampling in July 1992 and 1993. He collected three 5-g samples from the innermost portion of each wetland basin, one each from quadrats 1, 3 and 5 (see section 6.2 for sampling framework). Samples were placed individually in Zip-Loc bags and kept in ice-filled coolers while the researchers were in the field. Each Zip-Loc bag was labeled with the wetland identification number and date. Upon returning to Northern Prairie Science Center, the crew placed the samples in a refrigerator, where the sediments were kept chilled, but not frozen. After all samples had been collected, they were packed in plastic coolers and sent by overnight service to USGS in Bismarck for analysis.

In 1992 we analyzed all samples, regardless of surrounding cropland composition, for atrazine. In 1993, Hal Kantrud recorded the composition of cropland around each wetland basin (see Dwire 1994 for data sheet), and we analyzed for 2,4-D in wetlands near small grain fields and for cyanazine in wetlands near corn fields. Wayne Berkas, Water Quality Specialist with U.S.G.S., conducted the analyses using RaPID Assay@ Kits from Ohmicron (see Dwire 1994 for lab procedures). Ten percent of the samples were replicated.

8.3 RESULTS

8.3.1 Atrazine

Atrazine is a herbicide widely used in corn production. No other crops within the EMAP study area are sprayed with atrazine. The only strata in which corn is extensively grown are Low-North and Low-South, so this analysis is limited to these strata. Atrazine was found more often and in higher concentrations in wetlands classified as poor condition than in those classified as good condition in both Low-North and Low-South strata (Table 8-1).

8.3.2 2,4-D

The herbicide 2,4-D is primarily used in small grain production, and is the most common herbicide in use in North Dakota (Grue et al. 1986). Nonetheless, we were relatively unsuccessful in detecting 2,4-D in wetland sediments. Of 32 EMAP wetlands tested for 2,4-D, only four had values above the 15 ppm detection limit in even one of the three samples taken from each wetland; none had values higher than 17 ppm. Three of these wetlands were within small grain production areas; the fourth was near a Waterfowl Production Area that had been sprayed recently for thistle.

8.3.3 Cyanazine

In 1993, we intended to test for cyanazine, a herbicide most often used in cornfields, but because Low-North and Low-South strata were dropped we no longer had an adequate sample of wetlands in areas of corn production. We did test for this herbicide in conjunction with research described in Section 9.2. Briefly, we were unsuccessful in detecting cyanazine in any wetland sediment.

Table 8-1. Atrazine concentration in wetland sediments determined by ELISA. The lower detection limit was 15 ppb.

Plot	Site	Stratum	Health	Atrazine
38	62	LN	L	26
38	63	LN	L	21
38	62	LN	L	33
54	39	LN	L	0
54	39	LN	L	0
54	39	LN	L	0
59	42	LN	L	0
59	111	LN	H	0
60	58	LN	H	0
60	58	LN	H	0
60	128	LN	H	0
60	128	LN	H	0
60	128	LN	H	0
241	3	LS	L	0
241	48	LS	L	122
246	34	LS	L	0
246	34	LS	L	15
246	37	LS	L	28
246	37	LS	L	0
246	53	LS	L	0
246	53	LS	L	0
249	50	LS	H	0
249	50	LS	H	0
249	86	LS	H	0
396	107	LS	H	0
396	107	LS	H	0
396	130	LS	H	16

8.4 EVALUATION AND RECOMMENDATIONS

In evaluating the potential use of ELISA-determined pesticide levels in wetland sediments as a measure of wetland condition, extent of use, persistence in soils, and availability of test kits must be taken into account. 2,4-D is the most extensively used of all herbicides in the northern Great Plains, but it degrades very rapidly. Field tests indicate 90% dissipation at the soil surface in as little as 40 days (Nash 1988) Sampling would have to be coordinated closely with the small grain planting season to optimize detection. For this study, samples were collected in July; early June may be a more appropriate time.

Atrazine is relatively persistent in the environment, with 90% dissipation at the soil surface taking as much as 140 days (Nash 1988), and thus allows for less precision in sampling date. The herbicide is ubiquitous in areas of corn cultivation (Thurman et al. 1992), and concentrations in sediments discriminate well between good and poor condition wetlands in these areas (Table 8-1). In only one case was atrazine detected in a wetland classified as good condition, suggesting little chance of falsely assigning poor condition to a good condition wetland.

Section 9.0
DEVELOPMENT OF NEW SAMPLING METHODS AND SAMPLING TECHNIQUES

9.1 DEVELOPMENT AND EVALUATION OF AN INVERTEBRATE SAMPLING DEVICE AND A WATER-LEVEL RECORDER FOR EMAP

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9.1.1 Introduction

Aquatic invertebrates are potentially valuable indicators for EMAP because they are highly sensitive to environmental change, especially those induced by agricultural practices. However, invertebrates are so highly variable in space and time that single measurements may fail to detect important changes. At the onset of this pilot study, there were no techniques available that would permit collection of invertebrates in a manner compatible with EMAP objectives. One objective of this study was to develop and evaluate an invertebrate sampling device that collected time-integrated information on macroinvertebrates. We used sediment traps described in the scientific literature to sample recalcitrant remains of invertebrates over discrete time periods. We correlated the abundance and biomass of invertebrates, determined from remains captured in the sediment traps, with population estimates obtained using more labor intensive sampling methods (monthly sweep-net sampling) to evaluate the possibility of using sediment traps to sample invertebrate populations for EMAP.

Removal of grasses and other native vegetation from wetland watersheds alters surface runoff dynamics and hence exacerbates impacts associated with sedimentation and agricultural chemicals adsorbed on soil particles. Nonvegetated watersheds have less capacity to mitigate excessive surface runoff, resulting in water levels in wetlands that are more variable than in wetlands in landscapes dominated by grasses and forbs. Thus, fluctuations in water levels may prove to be a valuable indicator of wetland condition. However, the dynamic hydrology of prairie wetlands is difficult to measure and currently requires the use of continuous-recording, water-level monitors. The high costs of these devices usually precludes their use except on a very limited basis. An additional objective of this study, was to develop and evaluate an inexpensive device for recording maximum and minimum water levels in wetlands.

9.1.2 Objectives

1. Develop and evaluate a quantitative device that samples aquatic macroinvertebrates indirectly by capturing their recalcitrant remains.

2. Determine if standard sediment traps yield sediment dry weights useful as indicators of wetland condition.

3. Develop and evaluate an inexpensive water-level recorder for determining wetland condition.

9.1.3 Methods

9.1.3.1 Objective 1

From April 1992 to September 1993, we evaluated five prototype devices, previously described to collect sediments (Gardner 1980), as collectors of recalcitrant remains of aquatic invertebrates. This study was not conducted in the EMAP pilot study wetlands used by other EMAP investigators due to the intensive sampling required to determine standing crops of selected aquatic macroinvertebrates. Instead all sampling was conducted in 18 randomly chosen semipermanent wetlands located in Stutsman county, ND (Table 9-1). Wetlands were selected in both highly impacted landscapes (poor condition) and marginally impacted landscapes (good condition). To avoid landowner reluctance to provide access, most wetlands selected were on Waterfowl Production Areas (WPA's) owned by the U.S. Fish and Wildlife Service. Most WPA's are not farmed, however, poor condition wetlands existed along property boundaries where a portion of the watershed was outside of the WPA's boundaries.

We designed 4 prototype sampling devices that were modifications of devices previously described for collecting sediments from lentic waters (Bloesch and Burns 1980; Garner 1980; Blomqvist and Hakanson 1981) (Fig. 9-1). Each device consisted of a 51 cm long piece of 2" (5.1 cm) inside diameter I.D. PVC pipe (collection tube) that was capped at one end with a standard 2" PVC cap. Thus, each device had an aspect ratio of 10 to facilitate the least biased estimate of downward sediment flux (Hargrave and Burns 1979; Lau 1979; Bloesch and Burns 1980; Garner 1980; Blomqvist and Hakanson 1981).

Table 9-1. **Legal descriptions of tracts of land containing wetlands used to evaluate quantitative devices that sample recalcitrant remains of selected aquatic macroinvertebrates and sediment deposits. All wetlands are located within Stutsman County, North Dakota.**

Wetland Number	Legal Description
13e	NE 1/4, Section 33, Township 142N, Range 68W
16	NE 1/4, Section 9, Township 141N, Range 68W
20	NE 1/4, Section 13, Township 139N, Range 67W
28I	NE 1/4, Section 4, Township 141N, Range 66W
28II	NE 1/4, Section 4, Township 141N, Range 66W
28III	NW 1/4, Section 3, Township 141N, Range 66W
39a	SW 1/4, Section 34, Township 142N, Range 66W
39GI	NE 1/4, Section 32, Township 142N, Range 66W
39GII	SE 1/4, Section 32, Township 142N, Range 66W
48	SE 1/4, Section 12, Township 139N, Range 66W
54	SE 1/4, Section 35, Township 137N, Range 67W
98a	NW 1/4, Section 5, Township 139N, Range 67W
106	SW 1/4, Section 23, Township 140N, Range 68W
122	NW 1/4, Section 35, Township 141N, Range 67W
154	SE 1/4, Section 5, Township 143N, Range 63W
421	NW 1/4, Section 2, Township 139N, Range 68W
462a	NE 1/4, Section 34, Township 139N, Range 65W
462b	SE 1/4, Section 35, Township 139N, Range 65W

The four sediment trap types differed from each other only in the size of the opening into the trap or in the placement of the trap relative to the sediment/water interface. The first device (straight-tube trap) consisted of simply the PVC collection tube capped at one end and with no modifications to the open end. The second device (funnel-top trap) was similar to the straight-tube trap except a 2" (5.1 cm) X 4" (11.4 cm I.D.) PVC bell adapter was glued to the open end of the collection tube. The third device (bottle-top trap) was similar to the funnel-top trap except instead of the bell adapter a 2" (5.1 cm) X 3/4 inch (1.9 cm) pipe, PVC reducer was glued to the open end and a 3/4 inch pipe X 3/4 inch tubing (1.5 cm I.D.) adapter was screwed into the reducer's opening. Thus, the opening into the collection tube of the bottle-top trap was reduced to 1.5 cm. The straight, funnel-top and bottle-top traps were all installed vertically in the wetland sediments so the top (open end) of the trap extended 7.4 cm above the water/sediment interface (Fig. 9-1). The fourth device (flush trap) was a replicate of the straight-tube trap but installed so that the top of the trap was flush with the water/sediment interface.

The flush traps collected too much material and quickly filled with sediment and organic debris. Because much of this material was unconsolidated sediments, flush samples were dropped from further testing.

We installed the sediment traps at sampling stations established within each of the 18 replicate wetland basins in May and removed them in September of each year (1992 and 1993). At each station, we installed one replicate of each trap spaced 60 cm apart in a square pattern (Fig. 9-2). In 1992, we established four sampling stations located at random locations along transects that radiated from the center of the wetland along random compass bearings.

In 1993, we established five sampling stations in each wetland basin that were also located on random transects. However in 1993, the sampling stations were located at specific locations, corresponding to precise elevations ($\pm$1.6 mm per 30 m) that facilitated sampling when the water depth at the wetland basin center was > 10 cm (Fig. 5-1) using a Spectra-Physics Model 650 Laserplane. This placed the traps close to the center of the wetland basin to facilitate sampling during periods of low water. Each year we also installed a feldspar clay marker (Cahoon and Turner 1989) in the center of the square formed by the four traps to facilitate coring at later dates to sample invertebrate remains and sediments that accumulated over specific time frames. We experienced problems with our feldspar marking that precluded their use in our evaluation. Specifically, feldspar clay moved downward in sediments mostly composed of organic debris and hence was an unreliable measure of sediment accretion in the Prairie Pothole Region.

In September of each year, we removed the traps from the wetland basins and stored them in freezers until processing. We processed samples by removing a sample from the collection tube while it was still frozen, sieving the thawed sample residue on a 0.5 mm sieve, and separating the invertebrate recalcitrant remains (i.e. cladocera ephippia, ostracod shells, conchostracan shells, and gastropod shells) from sediment debris using light tables and forceps. All sample residues were retained during the sieving process and soil and other debris > 0.5 mm remaining after removal of invertebrates was returned to the sediment sample previously screened for later determination of sediment dry weights.

Beginning when sediment traps were placed in study wetland basins and continuing monthly throughout the open-water, ice-free portion of the year, we collected samples of aquatic macroinvertebrates from each study wetland basin at each sampling station using 2 foot net sweeps (Swanson et al. 1974). Samples were preserved in 80% ethanol and transported to the laboratory for processing. Processing sweep-net samples consisted of straining the sample through a 1 mm mesh

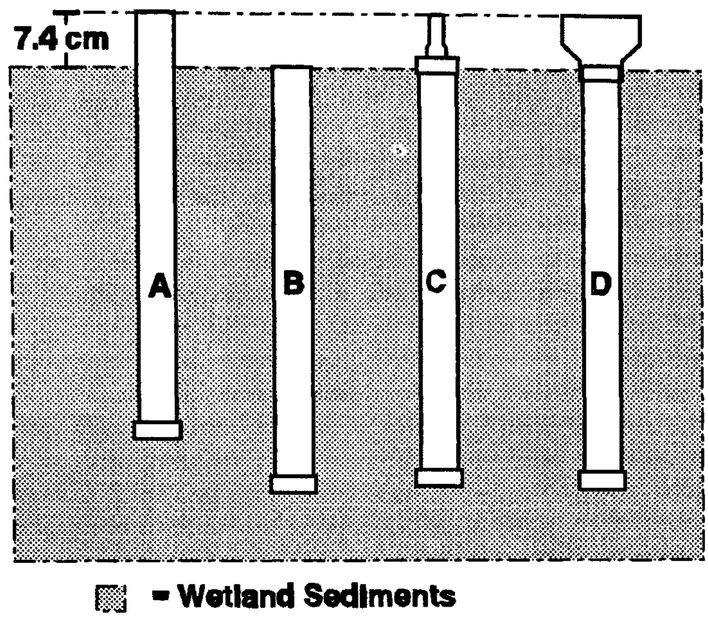

Figure 9-1. Sampling devices tested for EMAP pilot study in 18 wetlands in Stutsman County, ND (A = Straight-tube trap, B = Flush trap, C = Bottle-top trap, D= Funnel-top trap).

screen to remove excess ethanol, removing aquatic invertebrates from the sample using a light table and forceps, sorting invertebrates into taxonomic groupings, and enumerating and weighing them to the nearest milligram on an analytical balance after drying to a constant weight in a drying oven at 55-60 °C; only those taxa that had recalcitrant body parts were considered.

Statistical Methods (Invertebrate analysis). We determined if correlations existed between the abundance and biomass of invertebrate remains captured in the sediment traps and the abundance and biomass of invertebrates actually present in the wetlands (determined from sweep-net samples) using SAS (SAS Institute, Inc. 1989). The purpose of this analysis was to identify the sediment trap that was most closely correlated with the more labor intensive and standard sweep net samples. In addition, we also used linear regressions (SAS Institute Inc. 1989) to determine if macroinvertebrate abundance or biomass, as estimated by the various sediment trap types, could be used to predict the percentage of grassland remaining within wetland drainage basins (the basis of the condition definition used by other researchers in this pilot study). In 1992, sediment traps were placed randomly along transects rather than at precise elevations. Extremely dry conditions in 1992 resulted in our study wetland basins going dry, and as the pool levels dropped, individual sediment traps stopped sampling at various times. This caused excessive variability among our samples and interfered with our analysis. Therefore, we used only 1993 data in the statistical analysis of invertebrate abundance and biomass, and sediment dry weights.

9.1.3.2 Objective 2

Prototype sampling devices also were evaluated to determine the optimal design to monitor sedimentation for EMAP. We centrifuged all residues from collected samples after invertebrate remains were removed for Objective 1 at 5,000 rpm for 10 minutes to separate the sediments from excess water. We then dried the sediments collected by each trap in an oven at 100 C° until a constant weight was reached and weighed them to the nearest 0.01 g.

Statistical methods. We used linear regression (SAS Institute Inc. 1989) to determine if sediment dry weight could be used to estimate the percentage of grasslands within each wetlands watershed and thus serve as indicators of wetland condition. We used the dry weights only from 1993 and estimated regression lines for each trap type.

9.1.3.3 Objective 3

We designed a water-level recorder that would provide the maximum and minimum water level of a wetland basin over discrete time periods. The device consisted of a commercially available, copper-coated steel welding rod that guided a large float up and down as water levels fluctuated (Fig. 9-3). Two magnetic slides, one above and one below the float were pushed by the float to positions on the rod that corresponded to the maximum and minimum water levels, respectively (Fig. 9-4). The distance between the slides was the distance the water level fluctuated during the time period between installation in the wetland and reading of the water levels. After recording, the device was easily reset by sliding the magnetic indicators to positions directly above and below the current level of the float.

We installed water-level recorders in two semi-permanent wetland basins (P7 and P8) at the Cottonwood Lake Study Area (Swanson 1987) in May, 1992. The wetland basins were also equipped with Telog model WLS-2109 water-level monitoring systems that provided continuous recordings of the water levels in the 2 wetlands throughout the study period. The Telog recorders were housed inside a steel pipe that was sunk into the wetland sediment approximately 1 m below the water/sediment interface. Each unit was recalibrated to read "0" in that position, and the units were turned on for continuous readings. Although the units are warranted to withstand -40 F°, the manufacturer felt burying the units beneath the wetland soil surface and protecting the transducers from silt deposits by housing in a pipe, would avoid unanticipated complications and extend their effective life. At the end of each year, we compared the water-level fluctuation (maximum depth - minimum depth) recorded by our prototype devices to that determined from the data collected from the water-level monitoring systems.

9.1.4 Results

9.1.4.1 Objective 1

Our correlation analysis of macroinvertebrate abundance with bottle-top, funnel-top, and straight-tube sediment traps was performed only on *Cladocera ephippia*, Ostracods, Conchostracans, and 3 Gastropod taxa (Planorbids, Physids, and Lymnaeids). While the correlations were clearly unique for each taxon, all appeared to be adequately sampled by either the straight-tube or the funnel-top sediment traps (Table 9-2). Further, straight-tube sediment traps yielded significant correlations for Conchostracans, Planorbid snails, and Lymnaeid snails that were higher than correlations with other trap types. *Cladocera ephippia* were most correlated (r=0.593) with funnel-trap samples but the correlation with the straight-tube trap also was significant and had a nearly identical correlation (r=0.584) (Table 9-2). Similarly, Physid snails were most correlated with the funnel-trap samples (r=0.910) but the straight-tube trap was also yielded a significant correlation (r=0.785). Only for Ostracods was the funnel-top trap, the clear choice for sampling an invertebrate taxon; it yielded the only significant correlation (r=0.601) of any trap types considered. Bottle-top sediment traps did not estimate any invertebrate taxon better than other trap types.

Our correlation analysis between macroinvertebrate biomass and the three sediment trap designs yielded results that were generally consistent with our findings for invertebrate abundance (Table 9-3). Straight-tube samples were highly correlated with *Cladocera ephippia* (r=0.798), Conchostracans (r=0.913), Planorbid snails (r=0.671), and Lymnaeid snails (r=0.452). Although not significant, the highest correlation (r=0.452) for Physid snails also was with the straight-tube sediment trap. As was the case with the abundance analysis, the correlation between Ostracods and the

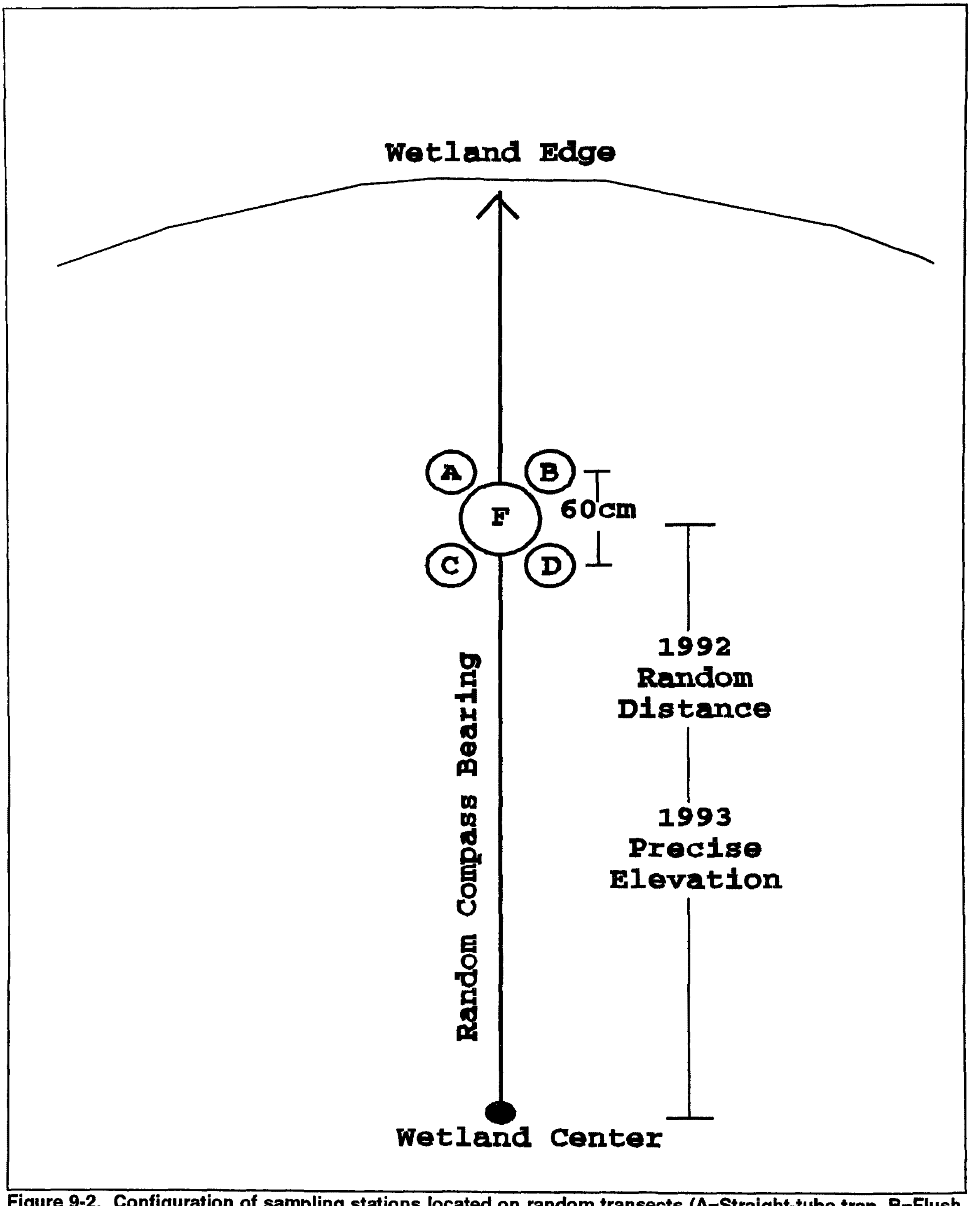

Figure 9-2. Configuration of sampling stations located on random transects (A=Straight-tube trap, B=Flush trap, C=Bottle-top trap, D=Funnel-top trap, and F=Feldspar clay).

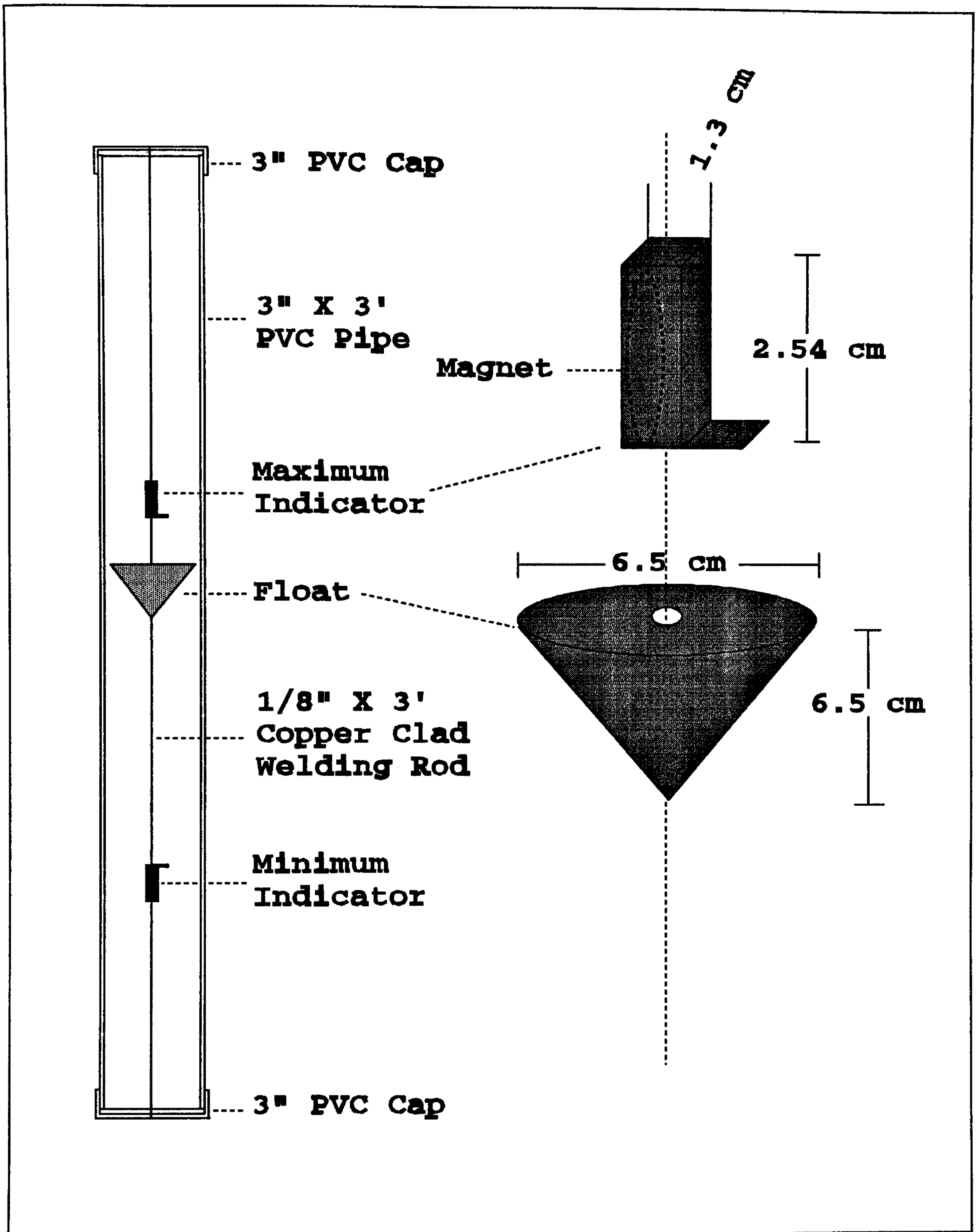

Figure 9-3. Prototype water level recorded designed for EMAP pilot study to measure water depth fluctuations in wetland basins.

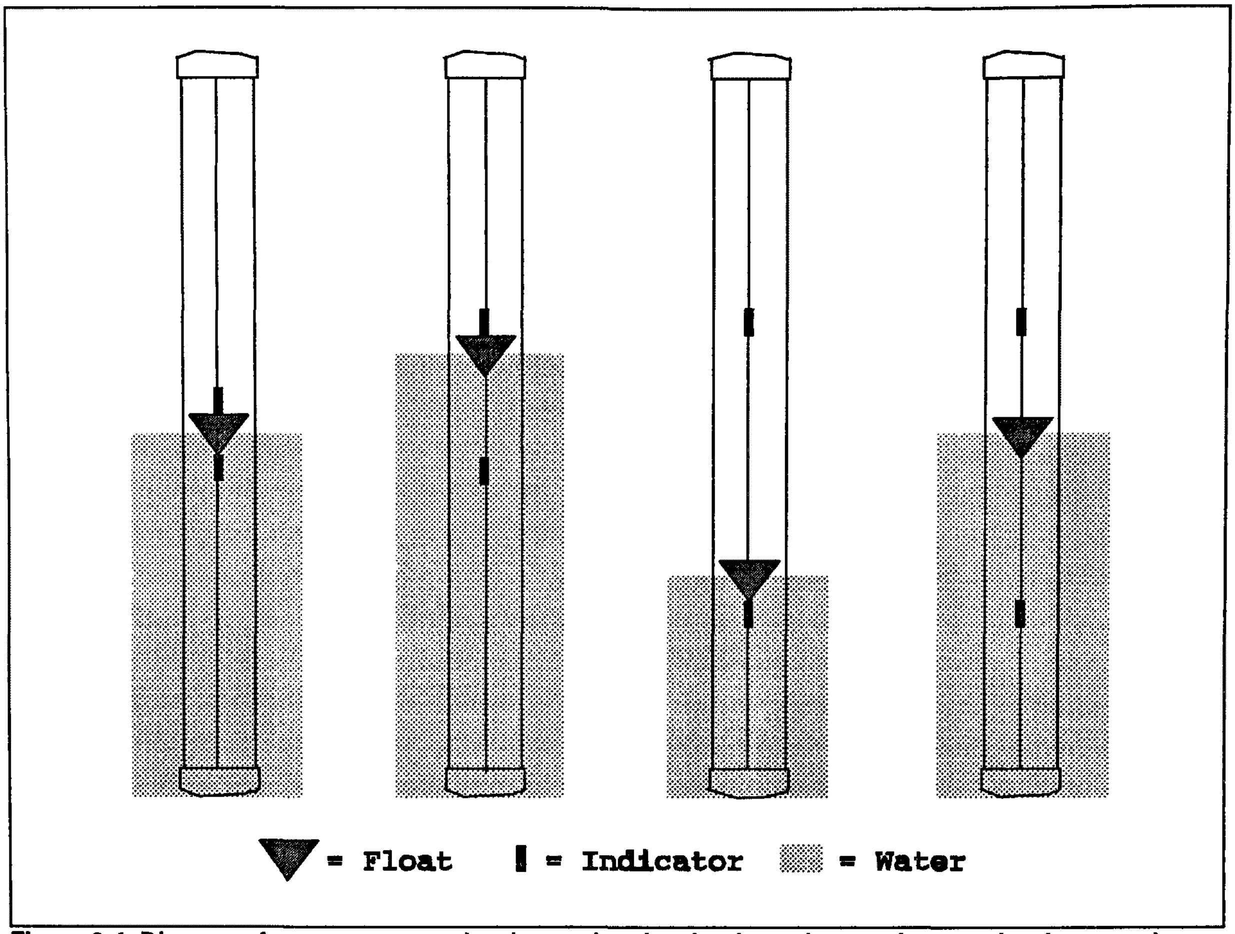

Figure 9-4. Diagram of prototype water level recorder showing how changes in water levels move the float and thus the indicators providing a measurement of water level fluctuation.

straight-tube trap was low and nonsignificant. However, and as was the case with the abundance analysis, the best correlation for Ostracods was with the funnel-top trap, although the correlation was nonsignificant in the biomass analysis. In contrast with the abundance analysis, the best correlation for Lymnaeid snails was with the bottle-top trap, although the correlation with the straight-tube trap was significant as well.

In our analysis to determine if invertebrate abundance or biomass (as determined from remains captured in sediment traps) could be used to estimate the proportion of the watershed remaining in grassland, we failed to reject the null hypothesis in all cases (Table 9-4).

Table 9-2. **Correlations with probability values (P-value) in parentheses between abundance of invertebrate remains captured in 3 types of sediment traps (bottle-top, funnel-top, and straight-tube) and invertebrate abundance of wetlands determined from monthly sweep-net samples with most influential observations removed,1993.**

Taxon	Correlations (n = 18)					
	Bottle-Top		Funnel-Top		Straight	
	r	P	r	P	r	P
Cladocera	0.365	(0.1499)	0.593	(0.0197)	0.584	(0.0175)
Ostracoda	0.500	(0.0408)	0.601	(0.0137)	-0.058	(0.8185)
Conchostraca	0.633	(0.0064)	0.448	(0.0716)	0.701	(0.0017)
Planorbidae	-0.132	(0.6015)	0.335	(0.2217)	0.494	(0.0372)
Physidae	0.088	(0.7468)	0.910	(0.0001)	0.785	(0.0001)
Lymnaeidae	0.520	(0.0324)	0.843	(0.0001)	0.918	(0.0001)

Table 9-3. **Correlations with probability values (P-value) in parentheses between biomass of invertebrate remains captured in 3 types of sediment traps (bottle-top, funnel-top, and straight-tube) and invertebrate biomass of wetlands determined from monthly sweep-net samples with most influential observations removed, 1993.**

Taxon	Correlation (n = 18)					
	Bottle-Top		Funnel-Top		Straight	
	r	P	r	P	r	P
Cladocera	0.452	(0.0688)	0.296	(0.2859)	0.798	(0.0002)
Ostracoda	0.041	(0.8805)	0.185	(0.4771)	0.053	(0.8387)
Conchostraca	0.738	(0.0007)	0.628	(0.0069)	0.913	(0.0001)
Planorbidae	0.091	(0.0727)	0.811	(0.0001)	0.671	(0.0032)
Physidae	0.097	(0.7211)	0.062	(0.8177)	0.452	(0.0683)
Lymnaeidae	0.777	(0.0002)	0.498	(0.0354)	0.470	(0.0493)

Table 9-4. **Results of linear regressions to determine if macroinvertebrate abundance or biomass, as estimated by the various sediment trap types, could be used to predict the percentage of grassland remaining within each wetland's drainage basin.**

Trap Type	Predictor	T-statistic	P-value
Bottle-top	Abundance	1.035	0.3162
	Biomass	0.852	0.4070
Funnel-top	Abundance	0.316	0.7565
	Biomass	-0.376	0.7116
Straight-tube	Abundance	0.362	0.7223
	Biomass	0.577	0.5718

9.1.4.2 Objective 2

We were unable to find a significant relationship between the proportion of a wetland's watershed in grassland and the dry weights of sediments collected in the straight-tube traps (T = 0.903, P =0.3797), the funnel-top traps (T = 0.685, P = 0.5030), or the bottle-top traps (T = 1.374, P = 0.1885).

9.1.4.3 Objective 3

The two water-level monitoring systems in the Cottonwood Lake wetlands functioned properly over the 2 year time period of this study. In 1992, the water level of wetland P8 peaked on July 2 at its maximum depth for the year of 25.9 cm, and then dropped steadily until the wetland went dry on August 18 (Fig. 9-5). Wetland P7 followed the same trend, reaching a maximum depth of 28.2 cm on June 6 and steadily falling to 0.0 cm on July 23 (Fig. 9-6).

In 1993, because of heavy rainfall, the trends were reversed with both wetlands steadily gaining water throughout the summer (Figs. 9-5 and 9-6). Wetland P8 had a minimum water depth of 63.6 cm on May 6 and the depth increased to a maximum of 136.7 cm on July 25. Wetland P7 reached a minimum depth of 39.6 cm on April 5 and increased to a maximum of 131.3 on August 31.

The water-level recorders we designed accurately recorded ($\pm$ 1.4 cm) the maximum and minimum water levels of the two Cottonwood Lake wetlands as determined by the Telog water-level monitoring systems both years except for 1993 when the maximum levels of the wetlands exceeded the capacity of our prototype recorders (Table 9-5).

9.1.5 Evaluation

9.1.5.1 Objective 1

The correlation analysis of macroinvertebrate abundance and biomass with the three trap types generally identified the straight-tube traps as providing the best correlations with the much more labor intensive and costly method of collecting monthly, sweep-net samples. The only caveat is that the other

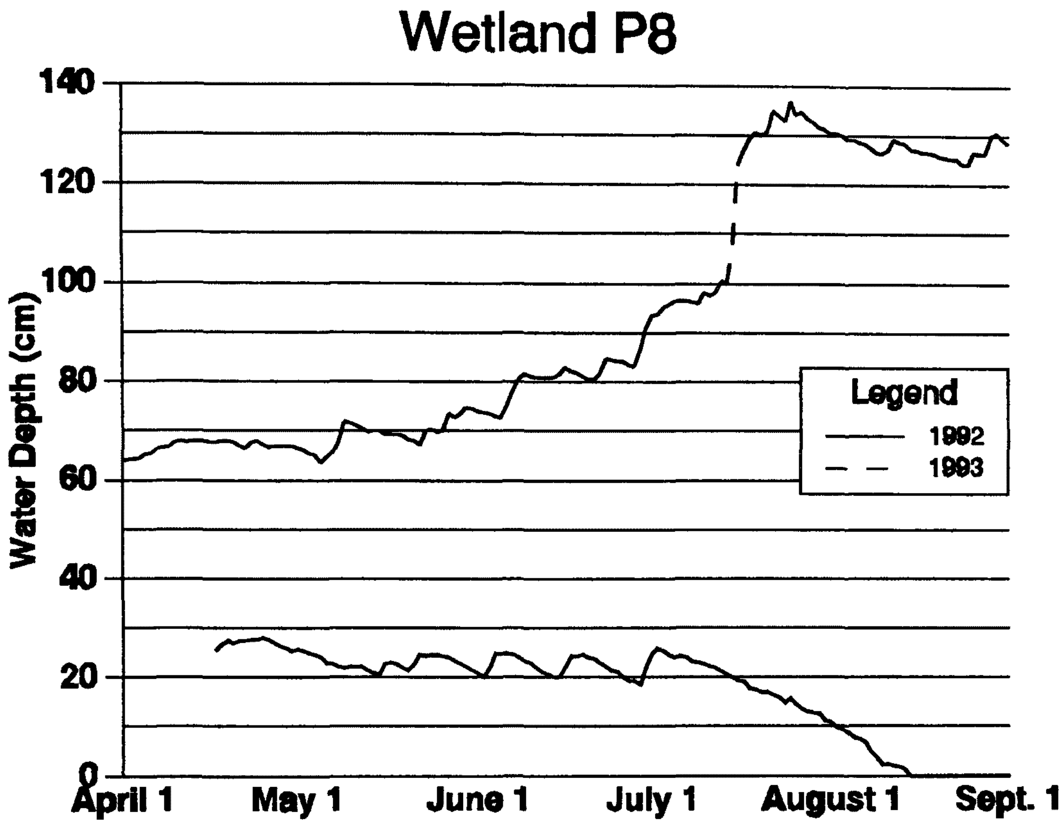

Figure 9-5. Water levels recorded with Telog water level monitor of wetland P8 at the Cottonwood Lake Study Area, Stutsman County, ND, April to September, 1992 and 1993.

traps may provide better representation of specific taxa (e.g., funnel-top traps for Planorbid snail biomass). Bottle-top traps were useful only for Lymnaeid snail biomass although both funnel-top and straight-tube traps yielded significant, albeit lower correlations. In general, we recommend that straight-tube traps be utilized for all taxa except ostracods, unless specific taxa can be identified as indicators of wetland condition.

Our regression analysis did not differentiate between wetland basins in good or poor condition using either macroinvertebrate abundance or biomass. While it is highly likely that agricultural practices

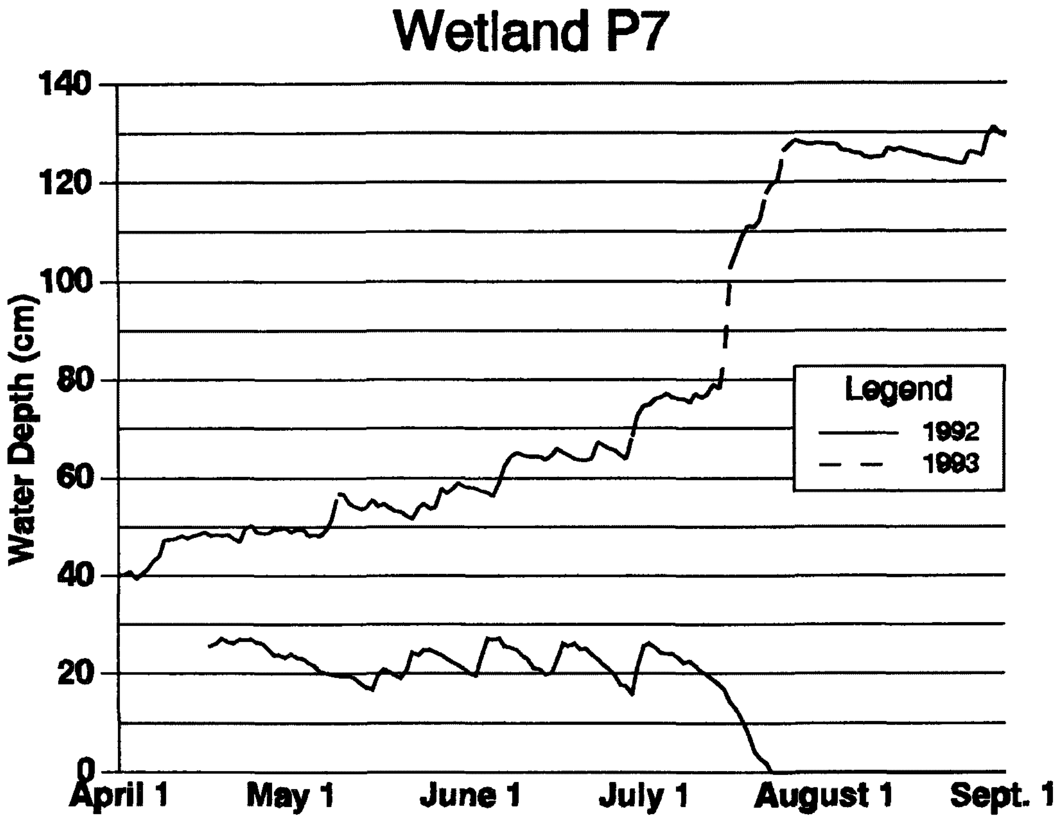

Figure 9-6. Water levels recorded with Telog water level monitor of wetland P7 at the Cottonwood Lake Study Area, Stutsman County, ND, April to September, 1992 and 1993.

do impact the invertebrate community, it was not observed in the taxa collected by our sediment traps. It should be noted that our sampling devices collected a very small proportion of the invertebrates present in wetlands because only those taxa that have recalcitrant body parts (i.e., ostracods, conchostracans, and gastropoda) or have easily identified resting eggs (i.e., *Cladocera ephippia*) were represented in our samples. Studies have shown that certain taxa (e.g., amphipods, chironomid midges) are highly susceptible to agricultural practices, especially chemical application (Grue et al. 1989; Tome et al. 1990). However, those taxa were not collected by our sampling devices and hence were not evaluated as potential indicators of wetland condition in this study.

Table 9-5. **Maximum and minimum water levels (cm) of wetlands P8 and P7 at the Cottonwood Lake Study Area, Stutsman County, North Dakota, as recorded by prototype water-level recorders developed for the EMAP pilot study.**

Wetland	1992		1993	
	Maximum	Minimum	Maximum	Minimum
P8	25.4	0.0	*	65.0
P7	27.9	0.0	*	39.4

* = Maximum water depth > capacity of gauge.

Recommendations for future work. Aquatic invertebrates clearly have potential as indicators of wetland condition in the Prairie Pothole Region. However, the sediment traps used to quantify invertebrates in this study did not appear to sample taxa that would serve as useful indicators of wetland condition. We recommend that future EMAP studies continue to explore invertebrates as potential indicators of wetland condition. However, because of the limitations identified by our study, we recommend that sediment traps be dropped as a quantitative tool, although trap designs were identified that provided reliable measurements of both invertebrate abundance and biomass. Further, we recommend that within-basin sampling be dropped from consideration because of the high natural variability that characterizes invertebrate fauna, both on spatial and temporal scales and because of the high variability we observed between wetlands. In the sample size analysis we conducted in Section 5 of this report, it was shown that we collected too few samples from an insufficient number of wetlands. Although we did not perform a similar analysis in this section, there was extreme variability in these samples as well, and it is likely that we again collected too few samples from an insufficient number of wetlands. While it is possible to increase the intensity of the sampling effort, it is not practical in terms of material and labor costs. We feel that the most viable approach would be to focus on landscape-level measures of invertebrate richness, abundance, or biomass. Conceivably, such an approach is possible by using either light traps or sticky traps (Belton and Kempster 1963, Harding et al. 1966, Belton and Pucat 1967, Mason and Sublette 1971, Davidson et al. 1973, and Borror et all. 1981) to collect samples *uniformly from the hexagon over prolonged periods of time.*

9.1.5.2 Objective 2

Our analysis of sediment dry weights also failed to identify an indicator of wetland condition. Although sedimentation is clearly a major impact on wetlands in the Prairie Pothole Region (Gleason and Euliss, unpublished data), we were unable to find a significant relationship between the proportion of grassland within wetland watersheds and the dry weights of sediment in any of the sediment trap designs we evaluated. One caveat of this analysis, was that traps were placed in the deepest portion of wetland basins to optimize sampling for aquatic invertebrates rather than for sediments. Wetlands tend to silt in from the sides; hence, trap placement was likely not optimal to accurately measure silt loads washing into wetland basins. As found in Section 5 of this report, there was substantial variability, both within and among wetlands in our samples and hence we may have collected an inadequate number of samples. However, we feel that the most important factor affecting our results was where the sediment traps were spatially located within wetlands.

Recommendations for future work. We feel that it is intuitive that wetland landscapes heavily impacted by agriculture experience increased rates of sedimentation and that our negative results were strongly influenced by trap placement. There was no official study of sedimentation in this pilot EMAP study, and the limited work that was done here was facilitated through a collaborative effort with John Freeland (Section 7 of this report). Because the budget for the invertebrate work in the pilot study included the sediment traps, they were spatially placed in areas that optimized the sampling for invertebrates rather than for sediments. In future work, we recommend that sediment collection devices be situated near the periphery of wetlands where it is much more likely that siltation events can be recorded. A separate and unrelated study of wetland siltation on the Woodworth WPA, Stutsman County, ND, has clearly documented elevated sedimentation rates in wetlands with tilled watersheds relative to wetlands that have grassland watersheds (Gleason and Euliss, unpublished data). Further, we recommend that surface flow traps (Gleason and Euliss, unpublished data) be utilized in any further indicator development and evaluation effort to avoid problems associated with within-basin phenomenon such as resuspension of sediment due to cattle grazing, wind action, and other events not directly related to land-use within the watershed.

9.1.5.3 Objective 3

As indicated in our original study proposal, there were only two continuous water-level monitoring systems purchased, and the data were too few to statistically analyze. However, the devices have been extensively tested by the manufacturer and are generally accepted quantitative tools. In 1993, we received record rainfall that flooded area wetlands to excessive depths and the capacity of our prototype devices was exceeded and the seasonal maximum was not recorded. Our continuous monitoring system recorded maximum pool levels of 137.7 cm and 131.3 cm for wetlands P8 and P7, respectively. The prototype water-level recorders failed because the devices were only 91 cm in length and were over-flooded when the water levels rose to unanticipated levels.

Recommendations for future work. While it would be highly desirable to equip all EMAP wetlands with continuous water-level monitoring systems, their high cost will preclude their use except on a very limited scale. The units evaluated in this study performed flawlessly and in accordance with the manufacturers specifications, despite being exposed to extremely frigid winter temperatures followed by spring thawing. The water-level recorders designed in this study and tested in Section 5 of this report clearly demonstrate that water-level fluctuation, when divided by the area of the wetland's watershed, is a useful indicator of wetland condition. Thus, we recommend that any future indicator studies in the PPR include these devices instead of the more expensive water-level monitoring systems. However, we recommend that future indicator research in the PPR construct water-level recorders that are longer than the ones used in this study to avoid missing maximum water levels in the event of excessive flooding and that less corrosive materials (see Section 5 for discussion) be used in their construction.

9.2 HORMONAL RESPONSE TO ENVIRONMENTAL STRESS: TECHNIQUE DEVELOPMENT

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9.2.1 Introduction

Harlow et al. (1987) have defined an animal in "stress" as one that is "required to make abnormal or extreme adjustments in its physiology or behavior to cope with adverse aspects of its environment." Physiologically, stress in vertebrates is accompanied by an increase in plasma corticosteroid levels (Harlow et al. 1987, Kirkpatrick et al. 1979, Licht et al. 1983, McDonald et al. 1988, McDonald and Taitt 1982, Moore and Deviche 1987, Moore and Miller 1984, Orchinik et al. 1988, Seal and Hoskinson 1978, Whatley et al. 1977, Wingfield et al. 1982). Often such increases accompany a decline in immune system response which may make stressed populations more susceptible to disease (Geller and Christian 1982) and parasitism. Heart rate in domestic sheep is positively correlated with corticosterone levels (Harlow et al. 1987), suggesting a generally higher cost of metabolism under stress. High levels of corticosteroids have also been associated with decreased or abolished reproductive behavior in amphibians (Dupont et al. 1979, Moore 1983, Moore and Deviche 1987) and fish (Campbell et al. 1994).

Parsons (1990) has pointed out that the affect of individual environmental stressors cannot be considered in isolation. Stressors such as environmental contaminants are often difficult and expensive to measure, and their potential synergisms are largely unknown; measures of the level of individual contaminants may underestimate their effect on the organism. Because corticosteroid release is a common response to a range of stressors across a wide variety of taxa, measures of corticosteroid levels may provide an index to the amount of stress a population is experiencing. Because the response is non-specific, no assumptions are necessary regarding the cause of the stress.

Corticosterone levels may respond to environmental stress in two ways. Baseline levels may become persistently elevated. This response has been observed in the reptiles *Lacerta vivipara* (Dauphin-Villemant and Xavier 1987) and *Urosaurus ornatus* (Moore et al. 1991). However, baseline levels are difficult to measure with certainty because the onset of the stress response is usually quite rapid. In addition, baseline levels may vary seasonally, and with the age and sex of the animal.

Recent work on birds (J.C. Wingfield, University of Washington, pers. comm.) and amphibians (F.L. Moore, Arizona State University, pers. comm.) has indicated that chronic (e.g., environmental) stress may also affect the rate at which corticosterone levels respond to acute stress. Hontela et al. (1992) found that the cortisol stress response was abolished in fish taken from environments polluted with PCB's. A more appropriate potential indicator of chronic stress thus may be the change in corticosterone levels in response to acute capture stress.

Because the area of interest in this study is wetland habitat in the prairie pothole region, larval tiger salamanders (*Ambystoma tigrinum*) provide an appropriate organism for study. Larvae breathe primarily through gills and cannot leave their natal wetland until after metamorphosis. In North Dakota, eggs are laid on submerged portions of emergent vegetation in early spring; larvae begin to hatch as water temperatures exceed 10 °C. Metamorphosis may occur from August into September, depending on ambient conditions.

9.2.2 Objectives

Objectives of the study were (1) to develop a non-destructive technique for assessing hormonal response to acute stress under field conditions (addressed in 1992); and (2) to assess the relation between acute and chronic stress responses (addressed in 1993), under the hypothesis that larvae inhabiting wetlands in poor condition would experience chronic stress and thus show a diminished response to acute stress.

9.2.3 Methods

Site selection. In 1992, we were unable to find any salamander larvae in the wetlands included in the EMAP sample, most of which were dry. Because the primary goal was technique development, the decision was made to test capture and sampling methods at wetlands in which populations of tiger salamanders were known to exist. Such a wetland was found in Barnes County, ND, at which most of the sampling was done. We also sampled larvae from known populations in Kidder County, ND, and in Deuel and Brookings Counties in SD to examine geographic variability in response.

Based on results from 1992, we restricted our wetland selection to semipermanently-flooded basins in 1993. To avoid the logistical problems associated with obtaining landowner permission on another large set of wetlands, we chose as our potential sample pool all semipermanent wetlands in WPA's in Stutsman and Kidder Counties. During July, 1993, we visited all wetlands within this pool. Traps were set for one night in each accessible semipermanent wetland with any open water to ascertain presence of salamander larvae. Of 25 wetlands in which larvae were found, 19, drawn at random, were re-visited in August. (See Appendix 9-1 for maps showing locations of wetlands sampled in 1993.)

Capture and handling. We captured larvae in unbaited funnel traps left in wetlands overnight. Over a one-month period during which larvae were large enough to provide blood samples but not yet beginning metamorphosis, we obtained blood samples from 4 populations in 1992 and from 19 populations in 1993. Blood samples were taken immediately from half the captured animals removed from traps; the remaining animals were sampled after 20- or 45-min (in 1992) or 30-min (in 1993) confinement in 500-ml bottles (acute stress). Larvae were marked and released at the point of capture; marked larvae were not resampled. See Dwire (1994) for details of sampling procedures.

Wetland chemistry and surrounding land use. In 1993, we recorded water temperature, pH, alkalinity, dissolved oxygen, Carbon dioxide, chloride, hardness, and ammonia in the 19 wetlands in which we sampled salamander larvae, and in 26 additional wetlands that did not contain larvae in 1993. We used a LaMotte Test Kit and processed samples in the field. Three 50-g sediment samples also were collected from each wetland, near where the traps had been deployed. These samples were sent to USGS in Bismarck to be analyzed for 2,4-D or cyanazine (see Section 8.1 for pesticide analysis techniques).

Laboratory exposures. We exposed tiger salamander larvae, captured in ND and shipped by overnight service to the EPA Environmental Research Laboratory in Corvallis, OR, to Guthion-contaminated or clean aquaria for 10- or 20-day periods. After exposures, half the animals were subjected to acute stress by confinement in a 500 ml bottle before blood was sampled by decapitation. The other half of the animals were sampled immediately upon removal from the aquaria. Results of these experiments were used to compare field and laboratory corticosterone levels, and to assess acute and chronic stress response under controlled conditions. The brains of the animals were analyzed for brain cholinesterase, to evaluate Guthion as a chronic stressor. Details of the study plan can be found in Appendix 9-2.

9.2.4 Results

Technique development (1992). Corticosterone levels were significantly lower in larvae from which blood was drawn immediately than in those subjected to acute stress (Fig. 9-7). Means are statistically different: $F = 4.877$; $df = 2, 150$; $P = 0.009$ (one-way ANOVA). Thus, the capture technique did not obscure the acute stress response. Furthermore, we found a consistent pattern of acute stress responses among populations from the different wetlands sampled in 1992.

Field test. Of the 19 WPA wetlands we sampled in 1993, 9 were on the Missouri Coteau (refer to map, Fig. 1-1); none of these had any cropland adjacent to them. Coteau wetlands were therefore designated "good condition". The remaining 10 wetlands were in the drift plain, east of the coteau, and all had at least some adjacent cropland (Table 9-6). Wetlands located in the drift plain (Fig. 1-1) were designated "poor condition". Salamanders on the Missouri Coteau were of the subspecies *melanostictum*; salamanders on the drift plain are likely of the subspecies *tigrinum*. We could not distinguish occupied from unoccupied wetlands based on water chemistry, presence of 2,4-D or cyanazine, or land use.

Response to acute stress was not consistent between larvae in good- and poor-condition wetlands. For populations in the agriculturally-impacted drift plain, magnitude of the acute stress response tended to be inversely related to the percentage of adjacent land in crops (R^2=0.30, F=4.23, p=0.067; Fig. 9-8). Populations occurring in wetlands on the unfarmed coteau showed no relation between acute stress response and any measure of land use. Acute stress response was unrelated to any measure of wetland chemistry in either group.

Larvae occurring in wetlands on the drift plain grew faster and reached a larger size by the last sample date than did larvae on the coteau (Fig. 9-9). In good-condition wetlands, the acute stress response declined significantly with increasing larval size (Fig. 9-10), while baseline levels increased

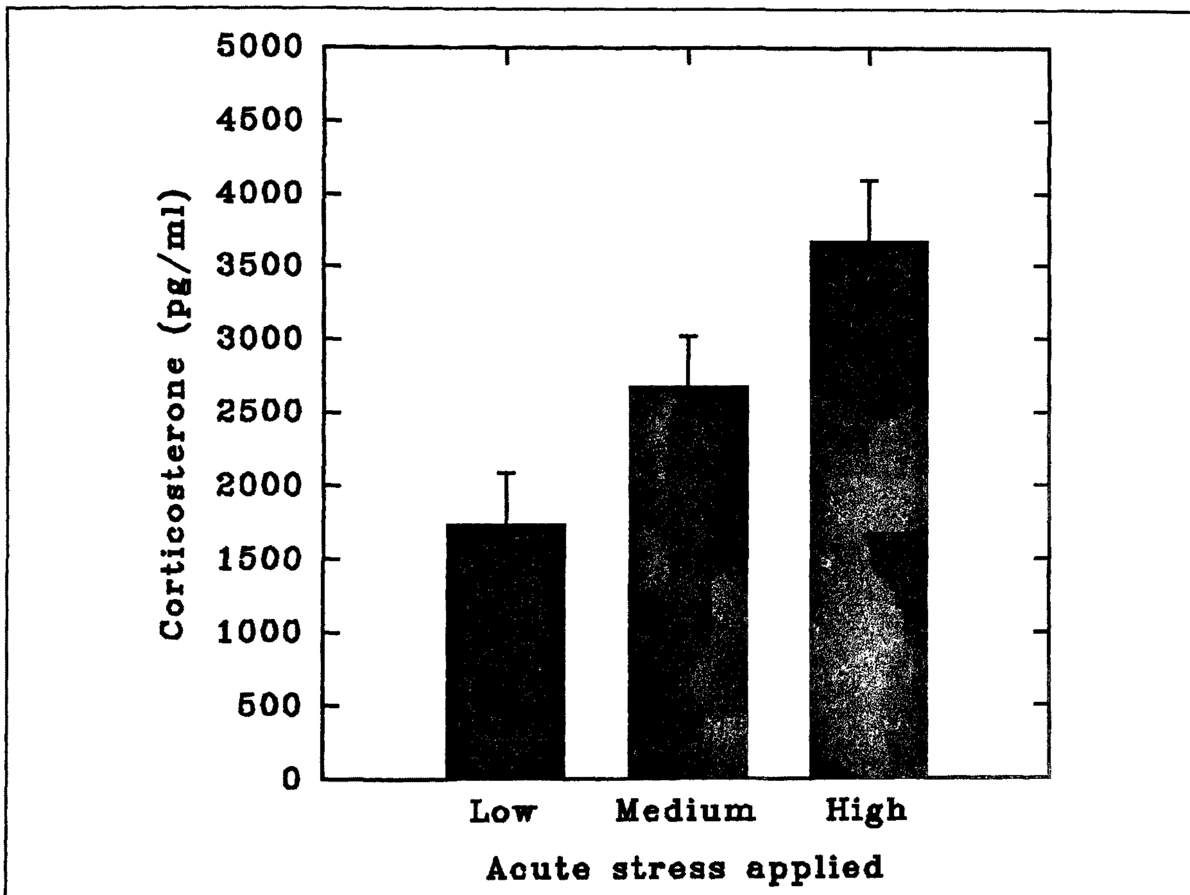

Figure 9-7. Plasma corticosterone levels after low (< 6 min), medium (6-30 min), and high (> 30 min) acute stress.

(Fig. 9-11); no such relation was evident among larvae in poor-condition wetlands (Figs. 9-10 and 9-11). Similarly, acute stress response was significantly negatively associated with unstressed corticosterone levels in larvae from good-condition wetlands (Fig. 9-12), but not in those from poor-condition wetlands.

Laboratory test. Because EPA has discontinued hormone research at ERL-C where the tests were done, and reassigned personnel who worked on the experiment, data analysis has yet to be finalized. Inspection of the data revealed that chronic exposure to Guthion did lower brain cholinesterase, as expected, and thus constituted a chronic stressor. Acute stress consistently resulted in release of corticosterone, but the magnitude of the acute stress response did not seem to vary between control and Guthion-exposed larvae. Likewise, larvae exposed for 10 or 20 days did not appear to have varying responses to acute stress, although 20 days may be too short a time to assess chronic stress. The concentrations of corticosterone in plasma of larvae in the lab were very similar to the concentrations of those in the field for both control and acutely stressed animals. More detailed analyses will be conducted, as time and new work schedules permit.

9.2.5 Evaluation and Recommendations

Tiger salamander response to acute stress varied between good- and poor-condition wetlands. Those larvae living in good-condition wetlands responded to acute stress in an organized manner, with the acute stress response declining as the larvae approached the size of metamorphosis; baseline levels of corticosterone increased as the larvae approached the size of metamorphosis. Larvae in poor-condition wetlands did not show the typical increase in baseline corticosterone as they approached metamorphosis, and corticosterone release in response to acute stress showed no pattern with respect to larval size. Larvae in these poor-condition wetlands tended to show a declining acute stress response as the amount of cropland surrounding the wetlands increased. These observations suggest that tiger salamander larvae make physiological accommodations to living under disturbed conditions. Although such physiological processes are of considerable importance in understanding population-level response to wetland condition, several issues must be resolved before corticosterone levels can be used in an operational monitoring program. First, sampling must be expanded, so that wetland condition is not confounded with subspecific distribution of salamanders. Second, more extensive laboratory experiments must be carried out, with chronic exposures extended to periods more comparable to larval residence in wetlands; a variety of common agricultural pesticides, alone and in realistic combinations, should be used as stressors. Third, other biomarkers, such as white blood cell counts, plasma

Table 9-6. **Land use at sample wetlands. Site numbers correspond to locations on maps in Appendix 9.2.2. Land use categories are the same as those used in Section 6.0.**

Site Number	Condition	Surrounding land use (%) Pasture	Hay	Idle	Crop
2	Good			100	
6	Poor	25			75
7	Poor		25	50	25
8	Poor		50	20	30
11	Good			100	
13	Poor	5		90	5
14	Poor	20	25	20	35
15	Good		25	75	
16	Good			100	
17	Poor		75		25
20	Poor			50	50
22	Good			100	
23	Good			100	
24	Good			100	
25	Good			100	
26	Good	65		35	
27	Poor	12		25	63
28	Poor			33	66
31	Poor	25	25	25	25

cholinesterase levels, serum glucose concentrations, and possibly shock protein synthesis, should be considered in concert with both stress and reproductive steroid analysis, to better understand the range of physiological response to wetland conditions. If connections can be established between these biomarkers and wetland condition, we will not only be able to use the biomarkers for monitoring, but also as a step in understanding the mechanisms of population-level responses to environmental conditions. Such an understanding will give managers a valuable tool in early detection of populations in danger of decline, and enhance their ability to mitigate in favor of these populations before regulatory action is required.

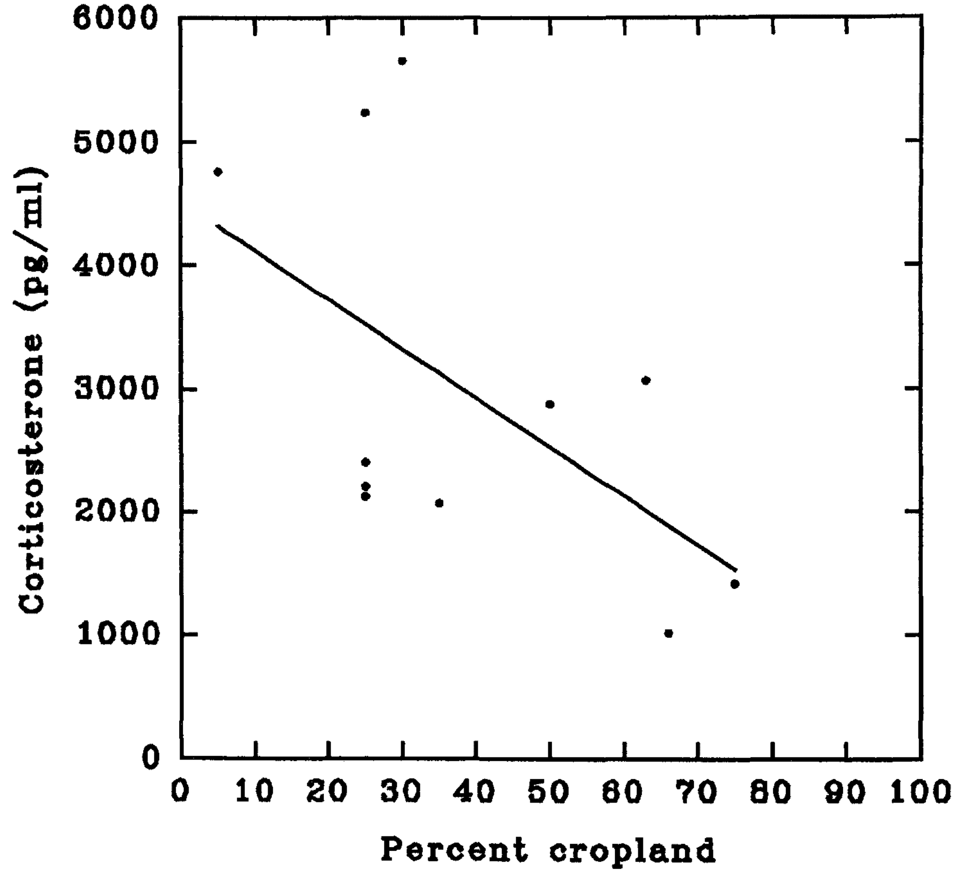

Figure 9-8. Relation between amount of cropland surrounding wetlands on the drift plain and the acute stress response.

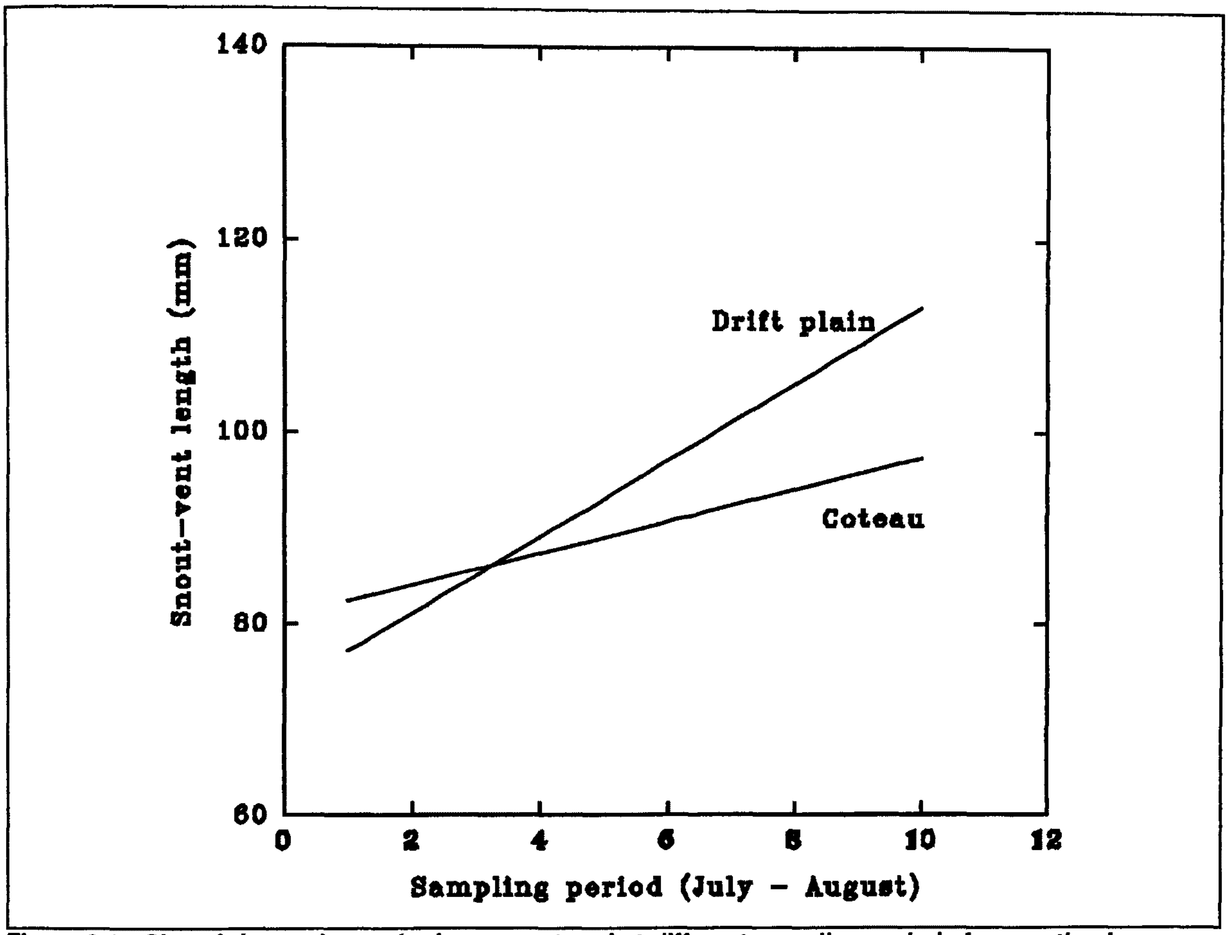

Figure 9-9. Size of tiger salamander larvae captured at different sampling periods from wetlands occurring on the drift plain and on the coteau.

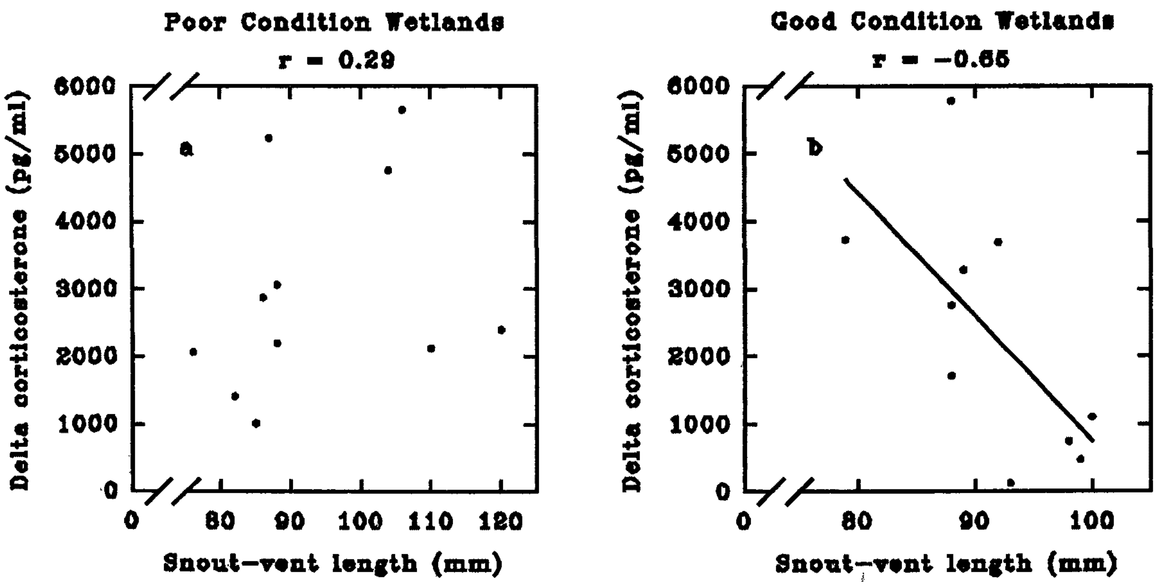

Figure 9-10. Relation between larval size and acute stress response.

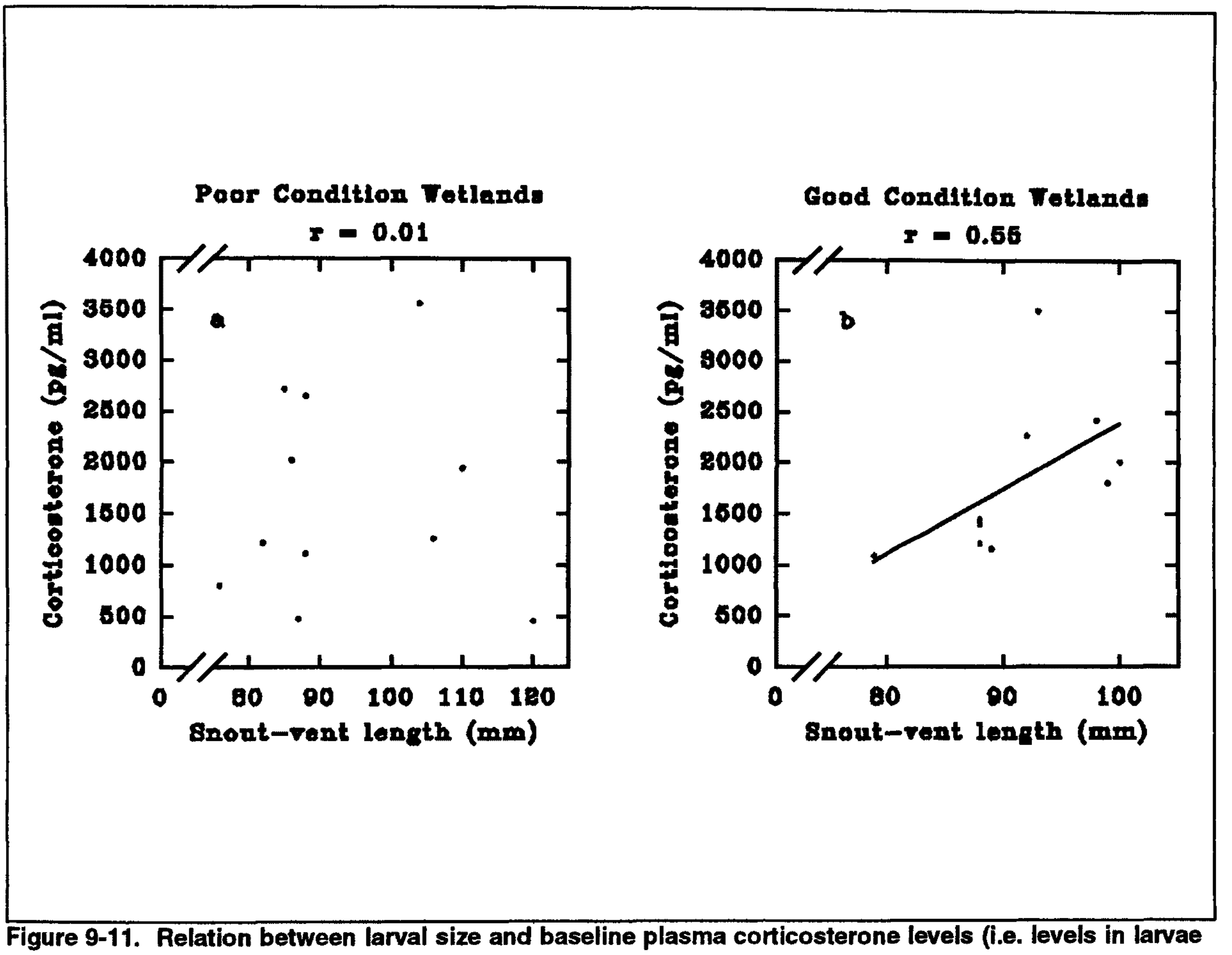

Figure 9-11. Relation between larval size and baseline plasma corticosterone levels (i.e. levels in larvae that were note acutely stressed).

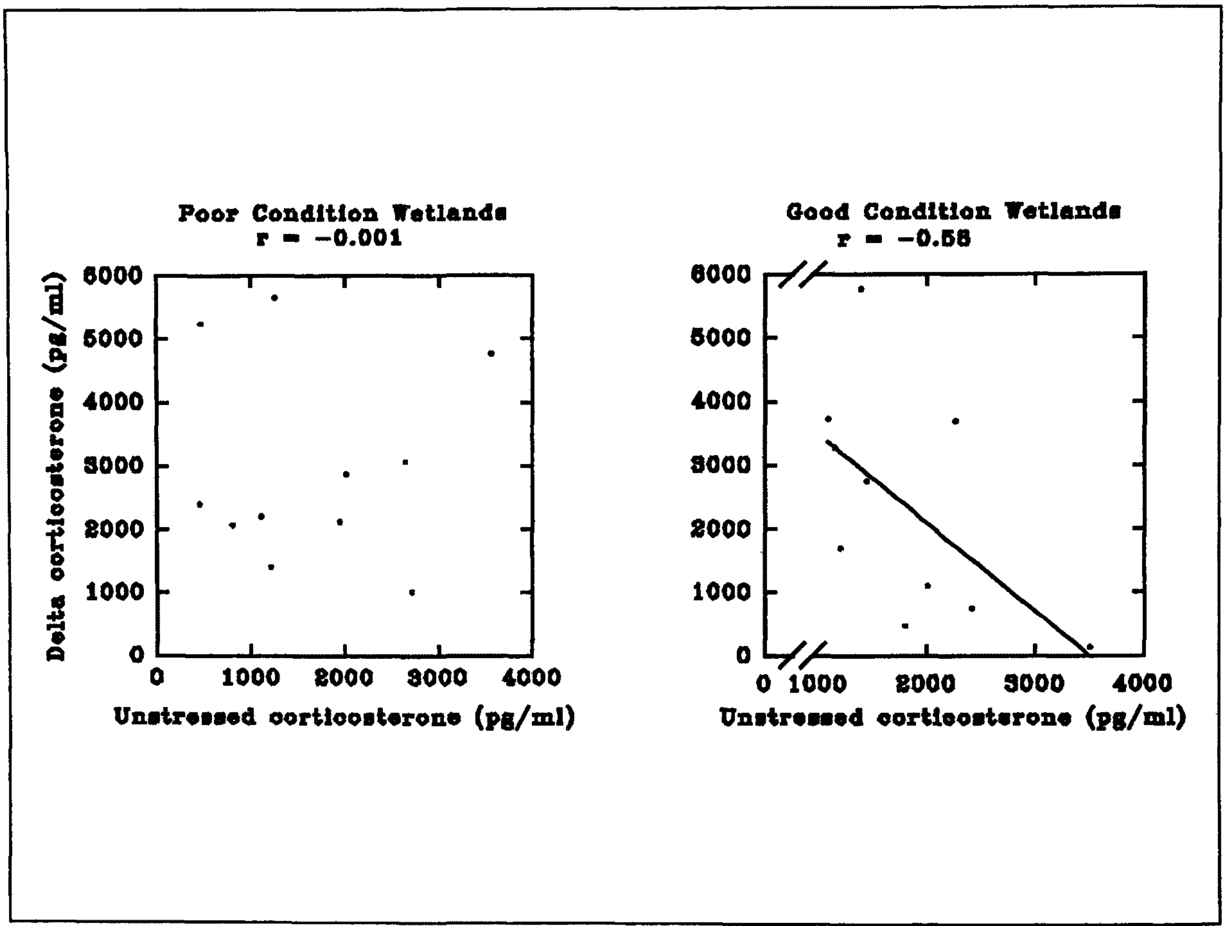

Figure 9-12. Relation between acute stress response and baseline corticosterone levels.

Section 10.0
RECOMMENDATIONS FOR CONTINUED USE OF INDICATORS

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Results from the pilot study suggest a number of changes in design and in the selection of indicators that would be appropriate for monitoring the condition of prairie wetlands in further studies.

Despite lengthy discussions as to the meaning and definition of condition, no clear definition emerged during either the planning for the pilot study or its execution. Hughes (1995) discussed defining acceptable condition. He stressed the need for reference data sets that describe habitat in good condition. No such data sets exist for the Prairie Pothole Region (PPR). Peterson (1994) stated that "The biological integrity value, more than any other, assumes the reality of reference conditions, since it requires that sample site conditions be compared with those of natural wetlands in the region. Also, because of this requirement biological integrity represents a set of conditions more basic and less disturbed by human activity (i.e. unmanaged)..." Regional experts at our planning meetings doubted that such a data set can be constructed because of degradation of most of the prairie potholes, extreme variation among them, and their vast numbers. Hughes (1995) cautioned against using reference sites from a random sample: "Similarly, selection of reference sites from randomly selected sites, especially when those sites are drawn from a population of disturbed sites ... will yield a set of disturbed reference sites and weak biological criteria."

The problem is that nearly all prairie potholes are disturbed and the degree of disturbance is confounded with the class of wetland basin and its geological and regional setting. This problem caused difficulties with the design and execution of the pilot study. We recommend that the definition of condition relative to reference sites be revisited and a clearly stated plan of action be developed prior to initiation of any new work by EPA in the Prairie Pothole region.

10.1 SAMPLE FRAME

The 10.4-km^2 plots used in the pilot study allowed timely initiation of work, and data derived from those sample plots did allow us to test selected potential indicators of condition. We found that having both wetlands and uplands mapped prior to selection of wetland basins for sampling and initiation of field work was essential. In addition, having digital map data (vector files) for each plot greatly increased efficiency. Without these data it would not have been possible to initiate field work on schedule. However, there were a number of problems with the plots that preclude their use for further indicator development and evaluation:

1. The population of plots from which our sample plots was selected is a stratified random sample with unequal sampling rates in each stratum. The population of plots was designed for another research purpose.

2. The mapping was out of date and changes have occurred in wetlands since mapping. In fact, the mapping was accomplished prior to operational mapping by NWI and the data do not agree with current National Wetland Inventory (NWI) maps. This early mapping did not receive the quality control given to current mapping and the data contained topological and classification errors.

3. The plot size is not large enough to assure presence of all classes of wetland basins in most plots, and among-plot variation in characteristics of the basins in plots was high.

4. There were no data for areas outside the plot boundaries which caused problems when selecting wetland basins that were bisected by the plot boundary.

We recommend that any future work in the PPR be conducted on 40-km^2 hexagon plots that are part of the EMAP sampling frame and in the selection sequence established for EMAP. Prior to subsampling or initiation of field work digital wetland data for each hexagon should be prepared as a subset of standard NWI data, polygons should be collapsed into basins by an agreed upon set of rules, upland areas should be mapped and digitized according to an agreed upon classification, and all linear and point features should be buffered so that all features have a measurable area.

10.2 LAND ACCESS

Access to private land was a major problem during the pilot study. Lack of access and the rescinding of access once granted not only caused us to repeatedly revise our original sampling plan and design but probably also biased our sample because we suspect that access is granted less frequently on lands that contain poor-condition wetlands than on lands containing good-condition wetlands. For our purpose of testing indicators, the bias is not that important because our sample was intentionally selected to represent the best and poorest wetland conditions, not the population of wetland basins in the PPR. In future work where we are attempting to obtain a statistically valid and unbiased sample of wetland basins from the PPR the problem will become exceedingly important. In the pilot a single individual talked personally with each landowner in order to obtain permission and only verbal permission was requested. In the future, written permission will be required to enter private land, and personal contact with each landowner is impractical because of the large sample of hexagons. We suspect that under these conditions the proportion of landowners granting permission will be much smaller than it was during the pilot study.

Our conclusion is that without purchase of perpetual easements that guarantee access to sample sites, an unbiased probability sample of wetland basins for ground sampling cannot be obtained in the PPR. Furthermore, unlike surveys where a second sample can be used to obtain estimates for the nonresponse bias, there is no practical way to estimate the magnitude of the bias and adjust for it.

10.3 SAMPLE SIZE

Sample size in the pilot was limited by funding rather than by statistical consideration. Given the exceedingly high spatial and temporal variability of prairie wetlands it is fortunate that we detected as many differences in condition as we did. We do not believe that statistical difference in condition class during the pilot should be the sole criterion for acceptance or rejection of potential indicators of condition. Two things are needed for effective sampling of any indicators selected in the future: First, we must know the degree of precision required for biological interpretation of condition, and second, we need some estimate of variance for the indicator to be used. The first requirement is non-statistical and should be resolved early. The pilot study does furnish some indication of variability to be expected, but the variance estimates may also be suspect because of the small sample size and the fact that the populations sampled were at the extremes rather than from the entire population of wetlands.

The preliminary analysis of the sample size problem presented in Section 5 suggests that for some indicators measured on individual wetland basins variation, both within and among basins, may be so great that obtaining a biologically meaningful sample may be impractical. We recommend that the problem of required sample size be addressed prior to the final selection of a suite of indicators to be included in the next phase of the prairie pothole studies.

10.4 SUMMARY OF INDICATOR TESTS

Results obtained from tests of indicators and preliminary recommendations for continuing, further evaluating, or dropping the indicator in the next phase of the Prairie Pothole Study are presented in Table 10-1. These recommendations assume that we will continue to sample at selected wetland basins despite the problems of access and sample size discussed above. During the course of the studies various investigators have suggested potential new indicators that might be preferable to those selected for the pilot study. For example, many of the poor condition plots had deltas of silt that had eroded from the upland; thus, one investigator suggested that these deltas might be delineated on photographs and their presence used as a landscape indicator of condition. The individual sections of this report suggest other potential new indicators. The Northern Prairie Science Center (NPSC) is in the process of soliciting suggestions for additional new indicators. We recommend that these new indicators as well as some of those used in the pilot be considered for inclusion in the next phase of the studies.

10.5 RECOMMENDED NEW APPROACH

We recommend a new approach to EMAP sampling for the PPR. Our recommendation is based on biological, statistical, and practical considerations. The new approach is that an individual wetland basin should not be considered as a sampling unit. Rather, a group of wetlands, frequently referred to as a wetland complex, is the entity whose condition would be evaluated. We define a complex as all of the wetland basins and their associated uplands within a 40-km^2 hexagon. The hexagon then becomes the sampling unit and all indicators would be indicators of landscape condition.

Landscapes as sampling units make biological sense. All of the experts who participated in the planning phase of the pilot stressed that condition of prairie potholes must be evaluated in terms of complexes that include both the wetland basins and their associated uplands. Many of the candidate biological indicators of condition, especially birds and mammals, move freely among the wetland basins and their associated uplands. For example, upland nesting ducks require a complex of wetlands that includes temporary, seasonal, and semipermanent wetland basins as well as safe nesting cover on the adjacent uplands. Where we find high populations and good production of ducks, these landscape components are present. A reference landscape should have these components present. An impaired landscape may have lost one or more of them; therefore, lack of duck abundance as a potential indicator will reflect the loss of condition.

Table 10-1. Summary of recommendations for indicator measurements tested during a pilot study of indicators of wetland condition in the prairie pothole region.

Section	Measurement	Recommendation	Notes
Landscape	Number and area of basins	Continue	These measurements should be continued to furnish baseline data for other variables, but not as an indicator of condition.
	Distance between basins and shoreline	Evaluate	Not an indicator of condition, but may be valuable to evaluation of other indicators.
	Shoreline development index	Evaluate	Not an indicator of condition, but may be valuable to evaluation of other indicators.
	Drained wetland basins	Continue	Good indicator of condition of wetlands in landscape. Easy from remote sensing.
	Length of drainage ditch	Continue	Good indicator of condition of wetlands in landscape. Easy from remote sensing.
	Wetland change index	Continue	Drop the April-May period because of ice and snow causing interpretation errors. June-July period appears best from limited pilot data.
	Area of cropland	Continue	Simplest and most promising direct measurement of condition. Need further studies linking biological indicators and cropland abundance.
	Area of exposed soil	Continue	Good indicator of condition. Needs further study and expanded development of remote sensing or supplemental data sources to estimate crop types.
	Estimated breeding ducks	Revise	Appears to be a good indicator. Counts of ducks should be made directly on plots to improve estimates of γ.

Table 10-1. (continued)

Section	Measurement	Recommendation	Notes
Macro-invertebrates	Invertebrates	Drop	High within and among wetland basin variation precludes use of invertebrate remains as a practical indicator of condition. Future work should evaluate invertebrates as an indicator at the landscape scale.
Siltation	Sediment Traps	Evaluate	This indicator did not detect differences in condition when traps were placed at the center of the wetland basin. Suggest further work to evaluate alternative placement of traps.
Water depth	Water-level recorders	Continue	The recorders reported in Section 10.1 may furnish information that will evaluate hydrologic condition. In addition, these devices may furnish data to help evaluate results obtained in Section 4.0. Commercial devices tested are too expensive to be useful.
Water quality	Turbidity, EC, pH,	Drop	These indicators were dropped during the study because of the need for wetland basins containing water. The high degree of variation in water permanence and in water quality among basins make water quality measurements impractical in the PPR.
Soils	Sedimentation	Evaluate	C-137 showed some promise for evaluating sedimentation; however, large samples would be required and costs are high.
	Soil composition	Modify	Phosphorous (at 0-15 cm depth) and organic matter in sediments were the only constituents showing promise as indicators of wetland condition.

Table 10-1. (continued)

Section	Measurement	Recommendation	Notes
Vegetation	Amount of unvegetated bottom	Continue	Measure the amount of unvegetated bottom in the wet meadow zones of wetland basins.
	Standing dead vegetation	Drop	No condition differences.
	Percent open water	Drop	No condition differences.
	Taxa richness	Continue	Good indicator for use in the wet meadow zone.
	Native perennial	Continue	Good indicator for wet meadow zone. Adjust for plant community size.
Pesticides	Immunosorbent assay	Continue	Tests for atrazine distinguished condition, but should be related to corn growing areas. Recommend addition of kits appropriate for other crops and groups of agricultural chemicals.
Salamanders	Populations	Dropped	These vertebrates are confined to specific wetland classes that are to sparse to be sampled in the EMAP sampling frame.
	Hormonal response	Evaluate	Results were encouraging but use will require extended sampling, additional laboratory tests, and consideration of other biomarkers.

Landscapes as a sampling unit make statistical sense. The wetland values suggested for prairie potholes, biological integrity, harvestable productivity, water quality improvement, and flood attenuation (Peterson, 1994), can be measured at the landscape rather than an individual basin scale. Much of the variation that we encountered in the pilot studies was among wetland basins. If we sample wetland complexes much of this variation might average out. Furthermore many of the measurements that are specific to individual basins proved impractical or did not distinguish between good and poor condition. Stressors tend to affect entire landscapes rather than individual wetland basins. For example, individual wetland basins are seldom drained; rather, whole complexes are drained. Runoff of agricultural chemicals into basins impairs individual basins as well as the basins in the crop field being treated. We suggest that we can obtain data for any hexagon by (1) restricting the indicators to those that can be monitored remotely, (2) by accepting indices obtained from roadside transects as representing condition of the hexagon or (3) using models that relate biological indicators to attributes that can be measured by remote sensing. In our opinion this is a legitimate strategy as long as we are not attempting to extrapolate the roadside estimate to the entire hexagon. For example, we would not attempt to estimate the number of ducks on the hexagon. We only assume that more ducks would be seen from roads in good condition landscapes than in poor condition landscapes.

Landscapes as sampling units make practical sense. We have shown that a valid probability sample of wetland basins is not possible in the PPR. Using the hexagon, with measurements made either remotely or as indices derived from roads or point samples avoids the problem of access. We also believe that these rapid survey techniques lend themselves to survey of more sampling units at less cost.

We also recommend increased effort on studies not directly related to the probability sample, but rather designed to develop relations between biological indicators and landscape features that can be determined remotely. These studies should be followed by development of appropriate models. Such studies need not be conducted on randomly selected areas. For example, if we determine that fragmentation of habitat causes a decrease in a biological indicator we can use remote sensing to determine if fragmentation is increasing or decreasing on the habitats and then predict that the indicator species is increasing or decreasing. Studies that relate biological indicators to measurable environmental variables are also essential to interpreting results derived from EMAP sampling. The process must be understood before EMAP results can be translated into remedial action. If a species or group of species that indicates environmental condition is shown to be in decline through EMAP monitoring, the process that causes the decline must be understood prior to management to reverse the decline and restore good condition.

Section 11.0
PERSONNEL AND COSTS

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The nature of the work conducted in the pilot study is technically complex and requires expertise in a number of fields. That expertise is expensive. Our summary refers to the pilot study where many of the techniques and procedures were developed specifically for the various studies. We suspect that when final indicators are selected some of the measurements might be made more cheaply on an operational basis.

11.1 EXPERTISE REQUIREMENTS

The project required considerable coordination between the various projects and EPA, the funding organization. A high degree of familiarity with the Environmental Monitoring and Assessment Program (EMAP) as well as the ecology of the Prairie Pothole Region (PPR) was required to accomplish this coordination. The project also had major requirements for study plan development, review of study plans, preparation of reports, and quality assurance. These activities required the same expertise as coordination.

Competent administrative support was required to make sure that field work moved ahead on schedule and that conflicts among the various components of the study did not occur. The primary task of administering the project was obtaining landowner access to the study areas. Administration of the project did not require specific expertise in a particular field but did require good knowledge of the area and skill in personal relations with landowners.

Many of the data were gathered by remote sensing and processed by GIS computer techniques. This work required an individual with general knowledge of remote sensing and specific knowledge of the ecology of the PPR. Experience with the maps and other products produced by the National Wetlands Inventory (NWI) as well as experience in planning aerial video\photographic mission was also required. The work required technical support and a high degree of expertise with computer processing and the software being used for interpretation and data analysis.

Planning, conducting, analyzing, and reporting the information of the project required individuals with expertise in specialized fields. These included vertebrate ecology, waterfowl ecology, plant ecology and taxonomy, invertebrate biology, limnology, soil science, and statistics. When the EMAP sampling becomes operational, finding the appropriate pool of individuals with the required expertise will present a problem. Although well trained technicians could help with much of the work specialized expertise will also be necessary. Using graduate students at the PhD level and under the guidance of experienced researchers might furnish one solution. In our opinion, the type of indicator measurements made in the pilot study require a multidisciplinary team approach. The technical team requires efficient logistical and administrative support to conduct the field work in a short time and over an extensive area.

11.2 COSTS

Costs for the various pilot project studies in calendar years 1992, 1993, and 1994 are summarized in Table 11-1. These do not include the costs for planning the project and preparing study plans incurred in the fall of 1991. These costs (Table 11-1) do include a considerable contribution by the Fish and Wildlife Service (FWS), however, which would not be available for operational work. For planning purposes, an approximate cost per sample unit can be obtained by dividing the project's cost by the number of years and number of plots per year. For example, the total cost for landscape variables was $253,000 for 3 years and 16 plots, yielding a per-plot cost of $5,271 per year. These costs are probably high because as the work progressed our efficiency increased in a number of areas. In addition, a number of tasks could probably be performed by temporary staff at a lower pay rate than in the pilot.

Table 11-1. Costs of the Prairie Pothole Pilot Project by activity. Costs are for calendar years 1992, 1993, and 1994.

	Salaries				Operating Costs				
	Permanent		Temporary						
Project	Salaries $1000	FTE	Salaries $1000	FTE	Vehicles $1000	Other[a] $1000	Contracts $1000	Overhead[a] $1000	Total $1000
Administration	92.53	1.46	8.01	0.39	3.07	8.49	0.00	36.99	149.09
Landscape	130.06	2.54	27.50	1.21	27.65	27.65	0.00	62.91	253.54
Macroinvertebrates	49.33	0.88	85.15	3.64	37.80	37.80	0.00	58.46	235.62
Vegetation	133.11	2.35	0.00	0.00	3.35	3.35	0.00	45.89	184.94
Sampling device	56.07	0.99	61.78	2.68	33.00	33.00	0.00	51.40	207.15
Soils	6.87	0.12	0.00	0.00	0.00	0.00	90.64	32.18	129.69
Hormonal Response	36.86	0.85	12.26	0.59	4.08	17.60	0.00	23.36	94.16
Total	504.83	9.19	194.70	8.51	24.94	127.89	90.64	311.19	1254.19

[a]Includes equipment, supplies, travel, and aircraft.

[b]Includes administration, statistical support, etc.

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APPENDICES
(Appendices Listed By Chapter; Not All Chapters Have Appendix)

APPENDIX 1-1

Attendance List Interagency Prairie Pothole Workshop July 24-25, 1991, Jamestown, ND

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Mr. John Peters, EPA Region VIII, Water Quality Requirement Section, 99g 18th Street, Suite 500, Denver Place, Denver, CO 80202-2405
FTS - 330-1579

Dr. James Richardson, Department of Soil Sciences, North Dakota State University, P.O. Box 5575, Fargo, ND 58105
(701) 237-8573

Mr. Donald Rosenberry, U.S. Geological Survey, Water Resources Division, Mail Stop 413, Building 53, Lakewood, CO 80225
(303) 236-4990; FTS - 776-4990

Ms. Louisa Squires, Mantech Environmental/USEPA Environmental Research Laboratory, 200 SW 35th Street, Corvallis, OR 97333
(541) 757-4666,

Mr. Larry Strong, Northern Prairie Science Center, 8711 37th Street Southeast, Jamestown, ND 58401-9736
(701) 252-5363

Mr. George A. Swanson, Northern Prairie Wildlife Research Center, Rt. 1 Box 26C, Jamestown, ND 58401-9736,

Dr. Arnold van der Valk, Department of Botany, Iowa State University, Ames, IA 50011
(515) 294-4374,

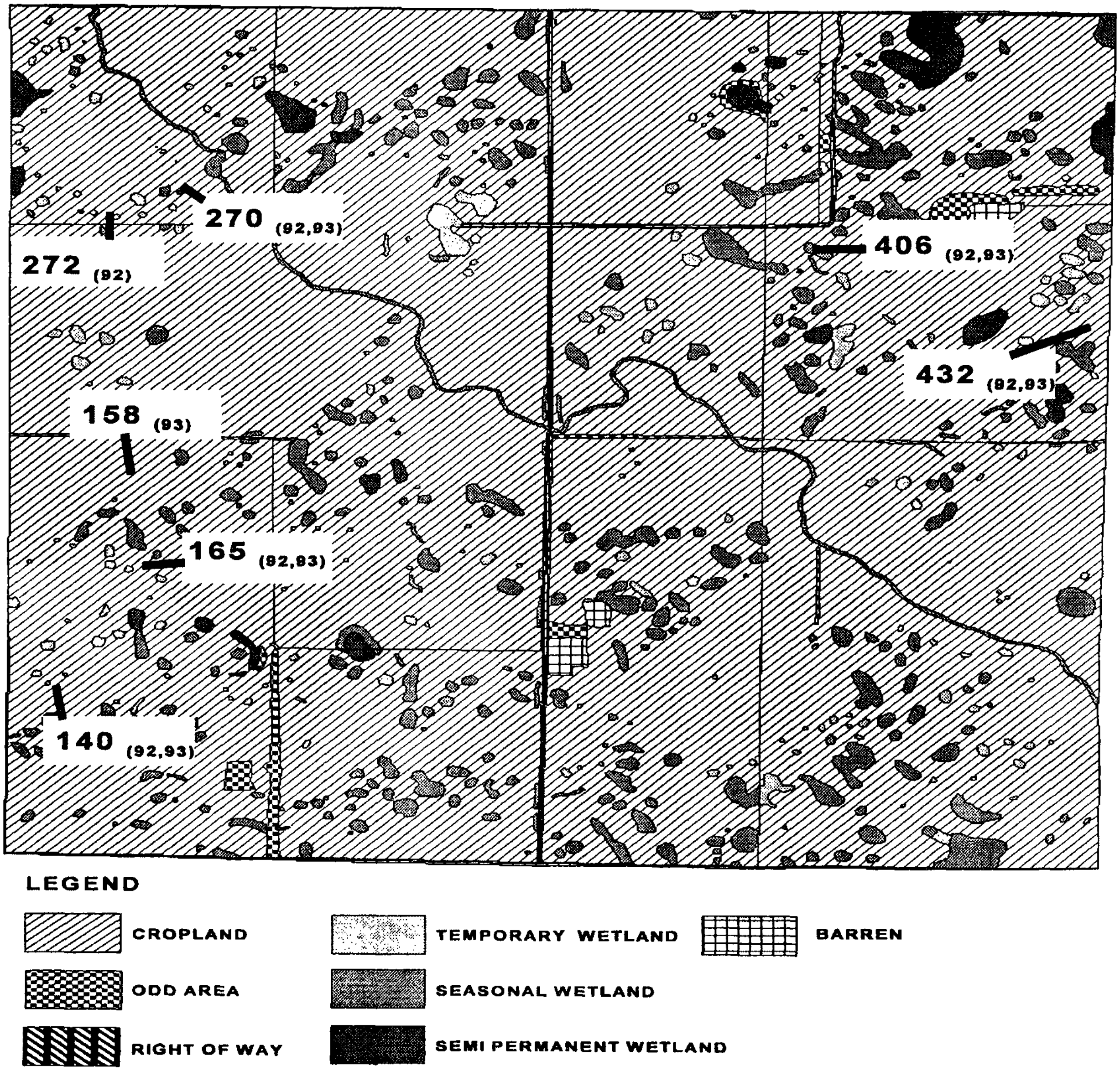
APPENDIX 1-2

Attendees at Prairie Pothole Interagency Planning Meeting, NPWRC, 9/17/91

Cowardin, Lew	NPWRC
Euliss, Chip	NPWRC
Haseltine, Sue	NPWRC
Johnson, Doug	NPWRC
Leibowitz, Nancy	MANTECH
Leibowitz, Scott	EPA
Medlin, Joel	USFWS
Novitski, Dick	MANTECH
Preston, Eric	EPA
Shaffer, Terry	NPWRC
Swanson, George	NPWRC
Walsh, Dan	USFWS, Bismarck

APPENDIX 2-1

Example of map used for 10.4 km^2 Plot 134 in the Prairie Pothole. Numbers are used to identify the wetland basin. Numbers in parentheses identify the years when ground study was done at these basins. Source of data was mapping conducted as a special project by the National Wetlands Inventory. The map data have been corrected for topological errors, and addition of missed wetlands. Errors in wetland classification have not been corrected because these would require ground survey of all wetland basins. Linear features have been buffered to average width.



APPENDIX 2-2

Sample of SAS output describing individual wet areas derived from the Feature map process.

SAS 9:57 Monday, June 6, 1994 4

BASIN	PLOT	TYPE	IMAGDATE	TOTAREA	FEATTYPE	CENTCOL	CENTLINE	FEATBOUN	_FREQ_	AREA	ITEM	BASINCLS	STRATUM	HEALTH
0	374	NoType	12174	2570.61	wet	377	47	0.05	.	0.0496	0	.		
0	374	NoType	12174	2570.61	wet	139	71	0.03	.	0.0298	0	.		
0	374	NoType	12174	2570.61	wet	429	219	0.02	.	0.0198	0	.		
0	374	NoType	12174	2570.61	wet	485	248	0.04	.	0.0496	0	.		
0	374	NoType	12174	2570.61	wet	474	256	0.06	.	0.0595	0	.		
0	374	NoType	12174	2570.61	wet	714	373	0.10	.	0.3274	0	.		
0	374	NoType	12174	2570.61	wet	190	384	0.03	.	0.0298	0	.		
0	374	NoType	12174	2570.61	wet	620	400	0.04	.	0.0595	0	.		
0	374	NoType	12174	2570.61	wet	277	400	0.03	.	0.0298	0	.		
0	374	NoType	12174	2570.61	wet	718	407	0.05	.	0.0694	0	.		
0	374	NoType	12174	2570.61	wet	49	550	0.07	.	0.1389	0	.		
0	374	NoType	12174	2570.61	wet	720	624	0.01	.	0.0099	0	.		
0	374	PEMA	12174	2570.61	wet	696	176	0.08	1	0.2381	56	1	M	H
0	374	PEMA	12174	2570.61	wet	519	270	0.08	1	0.1290	98	1	M	H
0	374	PEMA	12174	2570.61	wet	326	101	0.05	2	1.3194	107	1	M	H
0	374	PEMA	12174	2570.61	wet	367	643	0.02	2	0.1091	143	1	M	H
0	374	PEMA	12174	2570.61	wet	94	366	0.07	1	0.1389	511	1	M	H
1	374	PEMC	12174	2570.61	wet	495	669	0.13	1	0.4662	364	2	M	H
3	374	PEMC	12174	2570.61	wet	506	511	0.13	1	0.4563	370	2	M	H
6	374	PEMC	12174	2570.61	wet	625	391	0.05	1	0.0794	372	2	M	H
0	374	PEMC	12174	2570.61	wet	391	220	0.07	1	0.0992	4	2	M	H
0	374	PEMC	12174	2570.61	wet	455	608	0.07	1	0.1190	16	2	M	H
0	374	PEMC	12174	2570.61	wet	471	613	0.04	1	0.0694	17	2	M	H
0	374	PEMC	12174	2570.61	wet	716	644	0.04	1	0.0595	23	2	M	H
0	374	PEMC	12174	2570.61	wet	560	461	0.03	1	0.0298	25	2	M	H
0	374	PEMC	12174	2570.61	wet	522	448	0.01	1	0.0099	27	2	M	H
0	374	PEMC	12174	2570.61	wet	658	349	0.02	1	0.0099	34	2	M	H
0	374	PEMC	12174	2570.61	wet	656	366	0.04	1	0.0496	36	2	M	H
0	374	PEMC	12174	2570.61	wet	624	142	0.08	1	0.2083	46	2	M	H
0	374	PEMC	12174	2570.61	wet	658	122	0.02	1	0.0099	47	2	M	H
0	374	PEMC	12174	2570.61	wet	187	332	0.03	1	0.0198	88	2	M	H
0	374	PEMC	12174	2570.61	wet	143	341	0.02	1	0.0099	89	2	M	H
0	374	PEMC	12174	2570.61	wet	628	364	0.02	1	0.0198	104	2	M	H
0	374	PEMC	12174	2570.61	wet	197	658	0.19	1	0.9523	106	2	M	H
0	374	PEMC	12174	2570.61	wet	516	685	0.01	1	0.0099	120	2	M	H
0	374	PEMC	12174	2570.61	wet	652	678	0.07	1	0.1290	129	2	M	H
0	374	PEMC	12174	2570.61	wet	506	332	0.04	1	0.0496	132	2	M	H
0	374	PEMC	12174	2570.61	wet	382	102	0.27	3	1.9146	146	2	M	H
0	374	PEMC	12174	2570.61	wet	401	709	0.05	1	0.0694	149	2	M	H
0	374	PEMC	12174	2570.61	wet	715	187	0.34	3	1.2400	153	2	M	H
0	374	PEMC	12174	2570.61	wet	197	127	0.08	2	1.9046	159	2	M	H
0	374	PEMC	12174	2570.61	wet	538	255	0.05	1	0.0694	180	2	M	H
0	374	PEMC	12174	2570.61	wet	381	277	0.22	1	0.8035	189	2	M	H

Appendix 2-2 (Continued)

0	374	PEMC	12174	2570.61	wet	369	300	0.05	1	0.0992	190	2	M	H
0	374	PEMC	12174	2570.61	wet	388	311	0.20	1	1.0614	191	2	M	H
0	374	PEMC	12174	2570.61	wet	365	312	0.04	1	0.0595	192	2	M	H
0	374	PEMC	12174	2570.61	wet	395	343	0.03	1	0.0298	194	2	M	H
0	374	PEMC	12174	2570.61	wet	404	336	0.07	1	0.1290	195	2	M	H
0	374	PEMC	12174	2570.61	wet	420	349	0.11	1	0.2778	196	2	M	H
0	374	PEMC	12174	2570.61	wet	435	355	0.09	2	0.2381	197	2	M	H
0	374	PEMC	12174	2570.61	wet	366	334	0.08	1	0.1389	198	2	M	H
0	374	PEMC	12174	2570.61	wet	394	379	0.70	1	5.2874	200	2	M	H
0	374	PEMC	12174	2570.61	wet	424	431	0.11	1	0.2579	201	2	M	H
0	374	PEMC	12174	2570.61	wet	371	421	0.07	1	0.1686	202	2	M	H
0	374	PEMC	12174	2570.61	wet	386	453	0.06	1	0.0992	203	2	M	H
0	374	PEMC	12174	2570.61	wet	390	470	0.02	1	0.0198	204	2	M	H
0	374	PEMC	12174	2570.61	wet	421	509	0.15	1	0.7341	205	2	M	H
0	374	PEMC	12174	2570.61	wet	383	521	0.54	1	3.0256	206	2	M	H
0	374	PEMC	12174	2570.61	wet	369	564	0.22	1	0.6746	207	2	M	H
0	374	PEMC	12174	2570.61	wet	365	661	0.19	1	0.7142	208	2	M	H
0	374	PEMC	12174	2570.61	wet	458	501	0.13	1	0.4365	209	2	M	H
0	374	PEMC	12174	2570.61	wet	547	384	0.13	1	0.4365	211	2	M	H
0	374	PEMC	12174	2570.61	wet	459	372	0.06	1	0.1190	212	2	M	H
0	374	PEMC	12174	2570.61	wet	520	309	0.16	1	0.4266	214	2	M	H
0	374	PEMC	12174	2570.61	wet	510	312	0.05	1	0.0794	215	2	M	H
0	374	PEMC	12174	2570.61	wet	539	159	0.16	1	0.4960	216	2	M	H
0	374	PEMC	12174	2570.61	wet	544	201	0.08	1	0.2083	217	2	M	H
0	374	PEMC	12174	2570.61	wet	529	236	0.14	1	0.5158	218	2	M	H
0	374	PEMC	12174	2570.61	wet	460	216	0.04	1	0.0298	220	2	M	H
0	374	PEMC	12174	2570.61	wet	464	190	0.02	1	0.0198	221	2	M	H
0	374	PEMC	12174	2570.61	wet	469	164	0.06	1	0.1190	222	2	M	H
0	374	PEMC	12174	2570.61	wet	478	158	0.05	1	0.0893	223	2	M	H
0	374	PEMC	12174	2570.61	wet	453	386	0.07	1	0.0992	225	2	M	H
0	374	PEMC	12174	2570.61	wet	718	696	0.04	1	0.0397	236	2	M	H
0	374	PEMC	12174	2570.61	wet	713	335	0.14	1	0.6646	237	2	M	H
0	374	PEMC	12174	2570.61	wet	715	276	0.05	1	0.0794	238	2	M	H
0	374	PEMC	12174	2570.61	wet	482	75	0.11	2	5.9718	239	2	M	H
0	374	PEMC	12174	2570.61	wet	461	452	0.08	1	0.1389	250	2	M	H
0	374	PEMC	12174	2570.61	wet	625	411	0.08	1	0.1686	252	2	M	H
0	374	PEMC	12174	2570.61	wet	384	614	0.13	2	0.5456	275	2	M	H
0	374	PEMC	12174	2570.61	wet	409	97	0.08	1	0.1984	288	2	M	H
0	374	PEMC	12174	2570.61	wet	424	108	0.11	1	0.2579	289	2	M	H
0	374	PEMC	12174	2570.61	wet	411	118	0.02	1	0.0198	290	2	M	H
0	374	PEMC	12174	2570.61	wet	510	705	0.01	1	0.0099	294	2	M	H
0	374	PEMC	12174	2570.61	wet	458	674	0.10	1	0.3174	295	2	M	H
0	374	PEMC	12174	2570.61	wet	461	640	0.08	1	0.1488	296	2	M	H
0	374	PEMC	12174	2570.61	wet	504	648	0.12	1	0.3770	297	2	M	H
0	374	PEMC	12174	2570.61	wet	517	647	0.13	1	0.3670	298	2	M	H
0	374	PEMC	12174	2570.61	wet	438	601	0.16	2	0.4762	299	2	M	H
0	374	PEMC	12174	2570.61	wet	424	575	0.03	1	0.0298	300	2	M	H
0	374	PEMC	12174	2570.61	wet	707	654	0.13	1	0.3869	302	2	M	H
0	374	PEMC	12174	2570.61	wet	684	637	0.06	1	0.0992	303	2	M	H
0	374	PEMC	12174	2570.61	wet	691	691	0.08	1	0.1190	304	2	M	H
0	374	PEMC	12174	2570.61	wet	674	692	0.04	1	0.0595	305	2	M	H
0	374	PEMC	12174	2570.61	wet	647	711	0.07	1	0.1389	306	2	M	H
0	374	PEMC	12174	2570.61	wet	632	714	0.02	1	0.0198	307	2	M	H
0	374	PEMC	12174	2570.61	wet	606	685	0.05	1	0.0992	308	2	M	H

Appendix 2-2 (Continued)

0	374	PEMC	12174	2570.61	wet	585	661	0.13	1	0.3571	309	2	M	H
0	374	PEMC	12174	2570.61	wet	601	628	0.04	1	0.0595	310	2	M	H
0	374	PEMC	12174	2570.61	wet	617	621	0.08	1	0.2083	311	2	M	H
0	374	PEMC	12174	2570.61	wet	591	604	0.28	1	0.8730	312	2	M	H
0	374	PEMC	12174	2570.61	wet	592	578	0.14	1	0.5357	313	2	M	H
0	374	PEMC	12174	2570.61	wet	575	563	0.16	1	0.3274	314	2	M	H
0	374	PEMC	12174	2570.61	wet	561	557	0.04	2	0.1587	315	2	M	H
0	374	PEMC	12174	2570.61	wet	565	582	0.08	1	0.1786	316	2	M	H
0	374	PEMC	12174	2570.61	wet	551	588	0.10	1	0.2877	317	2	M	H
0	374	PEMC	12174	2570.61	wet	552	507	0.08	1	0.1885	319	2	M	H
0	374	PEMC	12174	2570.61	wet	541	497	0.10	1	0.2778	320	2	M	H
0	374	PEMC	12174	2570.61	wet	531	512	0.16	1	0.6250	321	2	M	H
0	374	PEMC	12174	2570.61	wet	465	533	0.08	1	0.1984	322	2	M	H
0	374	PEMC	12174	2570.61	wet	563	433	0.67	1	5.7635	324	2	M	H
0	374	PEMC	12174	2570.61	wet	523	460	0.09	1	0.1190	325	2	M	H
0	374	PEMC	12174	2570.61	wet	523	435	0.10	1	0.2877	326	2	M	H
0	374	PEMC	12174	2570.61	wet	502	477	0.04	2	0.2182	327	2	M	H
0	374	PEMC	12174	2570.61	wet	679	376	0.10	1	0.2976	328	2	M	H
0	374	PEMC	12174	2570.61	wet	685	356	0.09	1	0.2381	329	2	M	H
0	374	PEMC	12174	2570.61	wet	676	344	0.11	1	0.3571	330	2	M	H
0	374	PEMC	12174	2570.61	wet	692	310	0.26	1	1.1408	331	2	M	H
0	374	PEMC	12174	2570.61	wet	607	367	0.08	1	0.1290	333	2	M	H
0	374	PEMC	12174	2570.61	wet	621	328	0.22	1	0.4464	334	2	M	H
0	374	PEMC	12174	2570.61	wet	591	374	0.27	1	1.1606	335	2	M	H
0	374	PEMC	12174	2570.61	wet	560	388	0.07	1	0.1587	336	2	M	H
0	374	PEMC	12174	2570.61	wet	587	247	0.02	1	0.0198	337	2	M	H
0	374	PEMC	12174	2570.61	wet	584	260	0.05	1	0.0992	338	2	M	H
0	374	PEMC	12174	2570.61	wet	593	276	0.15	1	0.4464	339	2	M	H
0	374	PEMC	12174	2570.61	wet	649	292	0.03	1	0.0298	340	2	M	H
0	374	PEMC	12174	2570.61	wet	655	322	0.13	1	0.3869	341	2	M	H
0	374	PEMC	12174	2570.61	wet	679	286	0.11	1	0.3274	342	2	M	H
0	374	PEMC	12174	2570.61	wet	686	247	0.04	1	0.0298	343	2	M	H
0	374	PEMC	12174	2570.61	wet	625	175	0.22	1	1.1706	344	2	M	H
0	374	PEMC	12174	2570.61	wet	687	120	0.10	1	0.2976	345	2	M	H
0	374	PEMC	12174	2570.61	wet	674	89	0.10	1	0.2480	346	2	M	H
0	374	PEMC	12174	2570.61	wet	656	112	0.09	1	0.1786	348	2	M	H
0	374	PEMC	12174	2570.61	wet	607	154	0.10	1	0.2579	349	2	M	H
0	374	PEMC	12174	2570.61	wet	591	181	0.14	1	0.4067	350	2	M	H
0	374	PEMC	12174	2570.61	wet	586	197	0.13	1	0.2976	351	2	M	H
0	374	PEMC	12174	2570.61	wet	573	196	0.10	1	0.2381	352	2	M	H
0	374	PEMC	12174	2570.61	wet	561	155	0.09	1	0.1885	353	2	M	H
0	374	PEMC	12174	2570.61	wet	554	242	0.08	1	0.1786	354	2	M	H
0	374	PEMC	12174	2570.61	wet	502	62	0.08	1	0.1587	355	2	M	H
0	374	PEMC	12174	2570.61	wet	634	298	0.13	1	0.2877	357	2	M	H
0	374	PEMC	12174	2570.61	wet	701	280	0.03	1	0.0298	358	2	M	H
0	374	PEMC	12174	2570.61	wet	640	435	0.22	1	0.7738	373	2	M	H
0	374	PEMC	12174	2570.61	wet	698	568	0.05	1	0.1190	379	2	M	H
0	374	PEMC	12174	2570.61	wet	682	560	0.07	1	0.0992	380	2	M	H
0	374	PEMC	12174	2570.61	wet	649	508	0.02	1	0.0198	381	2	M	H
0	374	PEMC	12174	2570.61	wet	653	407	0.10	1	0.1786	382	2	M	H
0	374	PEMC	12174	2570.61	wet	673	395	0.13	1	0.5357	383	2	M	H
0	374	PEMC	12174	2570.61	wet	650	204	0.25	1	1.1309	384	2	M	H
0	374	PEMC	12174	2570.61	wet	360	532	0.07	1	0.1587	393	2	M	H
0	374	PEMC	12174	2570.61	wet	209	651	0.09	1	0.1488	398	2	M	H

Appendix 2-2 (Continued)

0	374	PEMC	12174	2570.61	wet	59	462	0.23	1	1.4483	406	2	M	H
0	374	PEMC	12174	2570.61	wet	51	435	0.13	1	0.4662	407	2	M	H
0	374	PEMC	12174	2570.61	wet	287	202	0.04	1	0.0595	408	2	M	H
0	374	PEMC	12174	2570.61	wet	114	208	0.01	1	0.0099	413	2	M	H
0	374	PEMC	12174	2570.61	wet	344	361	0.31	1	0.8134	415	2	M	H
0	374	PEMC	12174	2570.61	wet	203	709	0.17	1	0.6944	419	2	M	H
0	374	PEMC	12174	2570.61	wet	189	54	0.09	1	0.1984	420	2	M	H
0	374	PEMC	12174	2570.61	wet	165	139	0.07	1	0.0992	425	2	M	H
0	374	PEMC	12174	2570.61	wet	136	151	0.01	3	0.6746	426	2	M	H
0	374	PEMC	12174	2570.61	wet	129	181	0.03	1	0.0298	427	2	M	H
0	374	PEMC	12174	2570.61	wet	118	218	0.03	2	0.0397	428	2	M	H
0	374	PEMC	12174	2570.61	wet	111	228	0.07	1	0.1686	429	2	M	H
0	374	PEMC	12174	2570.61	wet	101	251	0.16	1	0.5754	430	2	M	H
0	374	PEMC	12174	2570.61	wet	202	170	0.01	2	0.0198	432	2	M	H
0	374	PEMC	12174	2570.61	wet	199	190	0.01	1	0.0099	433	2	M	H
0	374	PEMC	12174	2570.61	wet	204	214	0.07	1	0.1290	434	2	M	H
0	374	PEMC	12174	2570.61	wet	318	236	0.07	1	0.1587	435	2	M	H
0	374	PEMC	12174	2570.61	wet	289	247	0.02	1	0.0198	436	2	M	H
0	374	PEMC	12174	2570.61	wet	282	243	0.02	1	0.0198	437	2	M	H
0	374	PEMC	12174	2570.61	wet	256	249	0.32	1	1.6765	438	2	M	H
0	374	PEMC	12174	2570.61	wet	221	248	0.08	1	0.2182	440	2	M	H
0	374	PEMC	12174	2570.61	wet	238	263	0.08	1	0.1984	441	2	M	H
0	374	PEMC	12174	2570.61	wet	218	297	0.04	1	0.0298	443	2	M	H
0	374	PEMC	12174	2570.61	wet	229	306	0.10	1	0.2976	444	2	M	H
0	374	PEMC	12174	2570.61	wet	247	302	0.01	2	0.0198	445	2	M	H
0	374	PEMC	12174	2570.61	wet	285	275	0.20	1	0.8730	446	2	M	H
0	374	PEMC	12174	2570.61	wet	310	260	0.05	1	0.0893	447	2	M	H
0	374	PEMC	12174	2570.61	wet	289	312	0.20	1	0.8134	448	2	M	H
0	374	PEMC	12174	2570.61	wet	288	330	0.07	1	0.1190	449	2	M	H
0	374	PEMC	12174	2570.61	wet	290	341	0.05	1	0.0794	450	2	M	H
0	374	PEMC	12174	2570.61	wet	258	341	0.16	1	0.6845	452	2	M	H
0	374	PEMC	12174	2570.61	wet	334	307	0.07	2	0.7638	453	2	M	H
0	374	PEMC	12174	2570.61	wet	329	322	0.11	1	0.3075	455	2	M	H
0	374	PEMC	12174	2570.61	wet	353	338	0.05	1	0.0595	456	2	M	H
0	374	PEMC	12174	2570.61	wet	318	347	0.04	1	0.0397	457	2	M	H
0	374	PEMC	12174	2570.61	wet	304	341	0.05	1	0.0694	458	2	M	H
0	374	PEMC	12174	2570.61	wet	277	361	0.02	1	0.0099	459	2	M	H
0	374	PEMC	12174	2570.61	wet	275	381	0.10	1	0.3075	461	2	M	H
0	374	PEMC	12174	2570.61	wet	309	394	0.07	1	0.1786	462	2	M	H
0	374	PEMC	12174	2570.61	wet	322	379	0.05	2	0.1587	463	2	M	H
0	374	PEMC	12174	2570.61	wet	241	403	0.16	1	0.2877	465	2	M	H
0	374	PEMC	12174	2570.61	wet	588	406	0.04	1	0.0496	466	2	M	H
0	374	PEMC	12174	2570.61	wet	321	417	0.09	1	0.2480	467	2	M	H
0	374	PEMC	12174	2570.61	wet	333	430	0.06	1	0.1091	468	2	M	H
0	374	PEMC	12174	2570.61	wet	313	481	0.13	1	0.4067	470	2	M	H
0	374	PEMC	12174	2570.61	wet	265	451	0.11	1	0.3373	471	2	M	H
0	374	PEMC	12174	2570.61	wet	258	432	0.07	1	0.1190	472	2	M	H
0	374	PEMC	12174	2570.61	wet	255	412	0.08	1	0.1885	473	2	M	H
0	374	PEMC	12174	2570.61	wet	354	518	0.10	1	0.1686	474	2	M	H
0	374	PEMC	12174	2570.61	wet	306	552	0.53	1	3.6406	475	2	M	H
0	374	PEMC	12174	2570.61	wet	335	624	0.06	1	0.0992	477	2	M	H
0	374	PEMC	12174	2570.61	wet	306	652	0.10	1	0.1290	478	2	M	H
0	374	PEMC	12174	2570.61	wet	235	680	0.04	1	0.0496	479	2	M	H
0	374	PEMC	12174	2570.61	wet	245	642	0.08	1	0.2381	480	2	M	H

Appendix 2-2 (Continued)

0	374	PEMC	12174	2570.61	wet	158	614	0.13	1	0.2678	481	2	M	H
0	374	PEMC	12174	2570.61	wet	130	538	0.08	1	0.1686	483	2	M	H
0	374	PEMC	12174	2570.61	wet	185	524	0.12	1	0.4365	484	2	M	H
0	374	PEMC	12174	2570.61	wet	130	501	0.18	1	0.7539	486	2	M	H
0	374	PEMC	12174	2570.61	wet	104	505	0.03	1	0.0298	487	2	M	H
0	374	PEMC	12174	2570.61	wet	63	409	0.04	2	0.0694	488	2	M	H
0	374	PEMC	12174	2570.61	wet	77	442	0.02	1	0.0099	489	2	M	H
0	374	PEMC	12174	2570.61	wet	101	450	0.10	1	0.2182	491	2	M	H
0	374	PEMC	12174	2570.61	wet	110	461	0.03	1	0.0298	492	2	M	H
0	374	PEMC	12174	2570.61	wet	122	433	0.11	1	0.4266	493	2	M	H
0	374	PEMC	12174	2570.61	wet	137	455	0.17	1	0.6150	494	2	M	H
0	374	PEMC	12174	2570.61	wet	162	447	0.16	1	0.7043	495	2	M	H
0	374	PEMC	12174	2570.61	wet	192	448	0.13	2	0.5555	496	2	M	H
0	374	PEMC	12174	2570.61	wet	189	412	0.23	1	1.2797	497	2	M	H
0	374	PEMC	12174	2570.61	wet	164	395	0.12	1	0.4662	498	2	M	H
0	374	PEMC	12174	2570.61	wet	128	389	0.08	1	0.1786	499	2	M	H
0	374	PEMC	12174	2570.61	wet	166	374	0.08	1	0.1984	500	2	M	H
0	374	PEMC	12174	2570.61	wet	148	371	0.40	1	1.8451	501	2	M	H
0	374	PEMC	12174	2570.61	wet	122	340	0.23	1	0.9226	502	2	M	H
0	374	PEMC	12174	2570.61	wet	206	319	0.12	1	0.3869	504	2	M	H
0	374	PEMC	12174	2570.61	wet	168	331	0.10	1	0.3075	505	2	M	H
0	374	PEMC	12174	2570.61	wet	166	292	0.16	1	0.4762	506	2	M	H
0	374	PEMC	12174	2570.61	wet	151	274	0.16	1	0.6944	508	2	M	H
0	374	PEMC	12174	2570.61	wet	171	251	0.04	1	0.0397	509	2	M	H
0	374	PEMC	12174	2570.61	wet	147	251	0.09	1	0.1488	510	2	M	H
0	374	PEMC	12174	2570.61	wet	197	676	0.08	1	0.1389	517	2	M	H
0	374	PEMC	12174	2570.61	wet	179	689	0.02	1	0.0198	518	2	M	H
0	374	PEMC	12174	2570.61	wet	258	77	0.08	3	0.3670	528	2	M	H
0	374	PEMC	12174	2570.61	wet	228	102	0.04	1	0.0397	529	2	M	H
0	374	PEMC	12174	2570.61	wet	269	198	0.05	1	0.0794	530	2	M	H
0	374	PEMC	12174	2570.61	wet	139	48	0.06	1	0.1190	554	2	M	H
0	374	PEMC	12174	2570.61	wet	286	51	0.14	1	0.3968	555	2	M	H
0	374	PEMC	12174	2570.61	wet	261	48	0.05	1	0.0992	556	2	M	H
0	374	PEMC	12174	2570.61	wet	328	707	0.07	1	0.1389	575	2	M	H
0	374	PEMC	12174	2570.61	wet	266	714	0.05	1	0.0694	576	2	M	H
4	374	PABF	12174	2570.61	wet	518	388	0.02	3	11.3187	241	3	M	H
8	374	PEMF	12174	2570.61	wet	59	49	0.08	2	3.0157	549	3	M	H
9	374	PUBFX	12174	2570.61	wet	276	147	0.19	1	0.4464	526	3	M	H
10	374	PEMF	12174	2570.61	wet	146	702	0.07	2	12.2214	105	3	M	H
17	374	PUBFX	12174	2570.61	wet	364	230	0.10	2	0.3373	84	3	M	H
26	374	PUBFX	12174	2570.61	wet	543	360	0.05	1	0.0694	183	3	M	H
28	374	PABF	12174	2570.61	wet	698	145	0.55	1	4.8112	367	3	M	H
112	374	PEMF	12174	2570.61	wet	178	641	0.37	6	12.1718	392	3	M	H
116	374	PEMC	12174	2570.61	wet	358	688	0.06	11	2.2518	395	3	M	H
0	374	PEMF	12174	2570.61	wet	692	226	0.15	3	4.5334	152	3	M	H
0	374	PEMF	12174	2570.61	wet	614	70	0.47	4	3.2736	162	3	M	H
0	374	PEMF	12174	2570.61	wet	395	589	0.40	1	2.0038	279	3	M	H
0	374	PEMF	12174	2570.61	wet	489	711	0.19	1	0.8333	280	3	M	H
0	374	PEMF	12174	2570.61	wet	499	575	0.42	1	3.7597	282	3	M	H
0	374	PEMF	12174	2570.61	wet	491	630	0.19	1	0.9226	283	3	M	H
0	374	PEMF	12174	2570.61	wet	550	659	0.58	1	4.3549	284	3	M	H
0	374	PEMF	12174	2570.61	wet	573	385	0.10	1	0.1984	285	3	M	H
0	374	PEMF	12174	2570.61	wet	594	215	0.52	1	4.3549	286	3	M	H
0	374	PEMF	12174	2570.61	wet	639	96	0.16	1	0.8134	287	3	M	H

Appendix 2-2 (Continued)

0	374	PABF	12174	2570.61	wet	430	705	0.25	1	1.5178	366	3	M	H
0	374	PABF	12174	2570.61	wet	619	119	0.33	1	2.3312	368	3	M	H
0	374	PABF	12174	2570.61	wet	425	660	0.35	1	3.2339	369	3	M	H
0	374	PEMF	12174	2570.61	wet	676	594	0.87	1	8.6205	374	3	M	H
0	374	PEMF	12174	2570.61	wet	667	549	0.97	1	6.3091	375	3	M	H
0	374	PEMF	12174	2570.61	wet	693	516	0.21	1	0.4960	376	3	M	H
0	374	PABF	12174	2570.61	wet	662	165	0.32	1	2.4205	385	3	M	H
0	374	PEMF	12174	2570.61	wet	55	498	0.31	1	2.2518	404	3	M	H
0	374	PEMF	12174	2570.61	wet	356	256	0.10	1	0.2480	405	3	M	H
0	374	PEMF	12174	2570.61	wet	58	237	0.26	1	1.4880	410	3	M	H
0	374	PEMF	12174	2570.61	wet	94	394	0.81	2	6.2000	417	3	M	H
0	374	PEMF	12174	2570.61	wet	194	258	0.13	1	0.4067	418	3	M	H
0	374	PUBFX	12174	2570.61	wet	132	309	0.08	1	0.1290	512	3	M	H
0	374	PABF	12174	2570.61	wet	292	654	0.34	1	1.6666	513	3	M	H
0	374	PABF	12174	2570.61	wet	231	464	0.32	1	2.7478	514	3	M	H
0	374	PUBFX	12174	2570.61	wet	560	357	0.08	1	0.2083	577	3	M	H
0	374	PUBFX	12174	2570.61	wet	478	192	0.09	1	0.1686	578	3	M	H
0	374	PUBFX	12174	2570.61	wet	272	335	0.12	1	0.4067	579	3	M	H

[a]BASIN = Basin number from vector, PLOT = EMAP plot number, TYPE = Cowardin wetland class, IMAGDATE = Date of videography in SAS format, TOTAREA = Total area of plot in acres, FEATTYPE = Generic feature type from feature map, CENTCOL = Screen column location of centroid of feature, CENTLINE = Screen line location of centroid of feature, FEATBOUN = Summary boundary length of feature in miles, _FREQ_ = Number of ponds in a basin, AREA = Total area of water in a basin, ITEM = MIPS internal polygon id number, BASINCLS = Cowardin numerical basin class, STRATUM = Stratum of EMAP plot based on original draw, HEALTH = health of EMAP plot based on original draw.

APPENDIX 4-1

MIPS PROCEDURES FOR NWI DIGITAL DATA

IMPORT PROCEDURE

Basic procedures for importation and editing of NWI MOSS data for EMAP are described below. Data for the original plots came as a three part digital data set in MOSS format with UTM projection for each of the 4 square mile plots. The data sets are polygon data, buffer data (line and point data buffered by NWI in MOSS), and line data (road linears). All data are imported into MIPS with redundant lines removed out to a distance of 1.1 vector units.

LINE BUFFER DISTANCES AND PROCEDURES

Gaps in road linears and additions or deletions of roads were determined from photointerpretation and ground truth information. Line data was then hand edited to remove these gaps or add new information. Line data for roads were double buffered for both the road surface and the right of way. The polygon, buffer and buffered road data sets were then intersected.

BUFFER ZONE DISTANCES

This procnote is extracted from PROCNOTE.103.

(8) Right-of-way.--The area between road surface and the fence in grassland and between road surface and cropland in farmed areas. The cover of road right-of-ways is variable but often consists of smooth brome (Bromus inermis), a cool season grass that will show active growth at the time of photography. Only very large right-of-ways such as some interstate highway and some railroads will be large enough to delineate as a polygon. Narrower roads should be mapped as labeled linear features. These linear features will be converted to areas during digitization so class 8 (right-of-way) must be subdivided into subclasses as follows:

8a gravel road
8b hard surface road
8c railroad
8e dirt road
8d fencerow

Prairie trails appearing as tire tracks across grassland areas should be ignored, not mapped as right-of-way.

<u>8a gravel road</u>

right-of-way	13'	8A
		9
road surface	20'	
		9
right-of-way	13'	8A

<u>8b hard surface road</u>

right-of-way	62.5'
road surface	25'
right-of-way	62.5'

<u>8c railroad</u>

right-of-way	65'
road surface	20'
right-of-way	65'

<u>8d fence rows and field borders</u>

right-of-way	10'

8E dirt road--no right of way
road surface only

16' ----------------------------

HAND EDIT OF INTERSECTED DATA SET

Hand editing of the combined vector set was done to fix overlapping areas of differing polygon classes and final check and edit of basin numbers.

CRITERIA FOR OVERLAPS

1) Assume that center of road or edge of field is where study plot begins and ends. Delete lines outside the center line on the road if that line contains the ownership classification.

2) When buffering overlays, the polygons with the original data would take precedence, eg., buffered line overlays original polygon. Remove the buffered line where it intersects the original polygon.

3) Right-of-way takes precedence over all upland classifications.

4) Wetland will take precedence over everything.

5) If wetland overlays wetland than the most permanent water regime takes precedence.

6) Buffered road surfaces (9) will take precedence over wetlands.

7) When a river crosses a buffered road take out the road right-of-way, but leave the road. The river will go up to the road poly and continue on.

RULES FOR DEFINING WETLAND BASINS

These rules are taken from my notes from a meeting between Cowardin, Pywell, and Gebhard at St. Petersburg September 11, 1986.

If two basins are connected by a linear wetland each basin and the connecting link are treated as separate basins if the water regime of the connecting link is temporary (a). Other wise the basins and the connecting link are all considered one basin. If two basins are connected by a ditch (x modifier) the ditch and the two ends are considered separate basins regardless of the water regime of the ditch. If there is an obvious difference between the elevation of the basins when viewed in stereo the basins and any connecting link are considered separate basins.

When working with the data sets for the plots we noted some errors in the interpretation of basins. In some cases a temporarily flooded arm extending from the edge of a basin wetland was treated as a separate basin. These arms should have been included in the basin. In some cases where basin numbers were being added to polygons, the same basin number was assigned to polygons in two obviously separate basins.

Stream orders: one basin unless its broken by a road or the stream order changes. Ex. a small stream enters a larger stream. It would not be the same basin, there would now be three basins.

Any wetland that is continuous within a riverine system would be considered the same as the riverine basin.

FINAL FIXES

The final intersect done with the vector data includes the updates for wetlands missed by NWI or not present on the original photography (See EMAP 004.DOC).

The final edit of the vector data included changes in upland cover for Conservation Reserve Program (CRP). CRP information was obtained from county ASCS offices and edited in the final vector set. The final vector set for each plot was placed in EMAPPOLY.RVF.

APPENDIX 4-2

VIDEO CAPTURE

Video tape information was directly captured into digital form on personal computers. Since the video was originally taken with a black and white camera with a near infrared filter, data was captured as an 8 bit grayscale image.

IMAGE RECTIFICATION AND MOSAIC OF VIDEO IMAGES

a) For each section, georeference the image with NWI vector data using calibrate raster with vector process. First use linear least squares fit to get a near fit to the image. Second, go to a piecewise linear model to add and delete control points to get a final fit of the vectors to the image.

b) Save the control point list and raster cell size upon exiting.

c) Warp and resample the image using the piecewise plane projective model and the control point list. Use the default value of 20 grids and specify a cell size approximately equal to the input raster cell size. If the resampled image is still distorted, go back to the original raster and try a 2nd order polynomial fit and edit control points. Warp and resample the image to a 2nd order polynomial fit.

d) Mosaic the sections using the georeference information to create a single video image for each plot for each month.

e) If the image is in pieces too small to obtain sufficient control points, put together a large enough image using the manual positioning process of mosaic and the go to step a).

FEATURE MAP PROCESSING OF VIDEO IMAGES

Feature map processing used in MIPS is a semiautomated, on screen interpretive method of delineating "features." For more information, see "Feature Mapping Application Note for the Map and Image Processing System." Delineation of water availability was the primary task of feature mapping in

EMAP. Products from the feature map process include a saved screen of the classified image, an 8 bit image consisting of only the classified features and a text file with areas, boundary lengths, NWI polygon classes, and NWI basin numbers of each feature.

The actual analysis of each scene combined both automated processing and photointerpretation. Water has great absorbance in the near infrared range and appeared as black or almost black in the scene. A scene was displayed on screen then a point or range test was conducted using apparent water as the sample pixels. A point test highlights every pixel in the scene that has the same color number as the sample pixel. The range test highlights every pixel in the scene that has a color number that falls in the range between the highest color number and lower color number of all the sample pixels. After some number of sample selections and iterations, all readily apparent water areas had been highlighted. Further manual definition of water boundaries was then done using the drawing tools. Ground truth information from the field teams was used as additional information for during mapping. Areas of water underneath dense vegetation, smaller dugouts and stock ponds and riverine areas could be mapped in this manner.

After all features were classified and delineated, the feature map translabel process was run. This process involves "rubber sheeting" the NWI vector data over the classified scene. Every feature was then matched with the corresponding NWI polygon and NWI wetland class and basin number was transferred to the output file. If a feature was not matched to an NWI polygon, the basin number is 0 and the class is NoType in the output file.

The feature map output raster was converted to a vector object and information about the UTM centroid of the feature was output to an ASCII file.

FILE NAMING CONVENTIONS

ORIGINAL videography is:

pppSSmmy.RVF

ppp = PLOT NUMBER
SS = WHICH SECTION OF THE PLOT (E.g. NW for Northwest)
mm = MONTH
y OR yy = YEAR

The convention for warped individual scenes is

PpppWARP.rvf

The convention for mosaicked images for the entire plot is:

Mpppmmyy.RVF

The convention for feature mapped saved screen images of the entire plot is:

Fpppmmyy.RVF

The convention for feature map output rasters from the entire plot is:

pppmmyyF.RVF

The convention for text file output from feature map is:

Dpppmmyy.txt

The convention for centroid text data from vectorized feature map rasters is

CFpppmyy.txt

APPENDIX 4-3

IMAGE RECTIFICATION AND MOSAIC OF PHOTO IMAGES

a) Two slides provided coverage of one section from high level photography. MIPS manual mosaic process was used to create one raster for each section.

b) For each section, georeference the image with NWI vector data using calibrate raster with vector process. First use linear least squares fit to get a near fit to the image. Second, go to a piecewise linear model to add and delete control points to get a final fit of the vectors to the image.

c) Save the control point list and raster cell size upon exiting.

d) Warp and resample the image using the piecewise plane projective model and the control point list. Use the default value of 20 grids and specify a cell size approximately equal to the input raster cell size. If the resampled image is still distorted, go back to the original raster and try a 2nd order polynomial fit and edit control points. Warp and resample the image to a 2nd order polynomial fit.

e) Mosaic the sections using the georeference information to create a single photo image for each plot.

The convention for photography information for the high altitude scenes is:

Spppss92.rvf

Where ppp is the plot number and ss is the slide number.

See Procnotes 920805tb and 930804tb for more information.

The convention for warped, mosaicked full plot photos is:

Wpppmmyy.rvf

Where ppp is the plot number mm is the month of the photography and yy is the year.

APPENDIX 4-4

UPDATE OF NWI VECTORS

It was apparent from 1992 video and photography that there were some errors associated with NWI vector data. To update these vectors and also provide some measure of probable drainage within the EMAP study plots, a review and photointerpretation of all the video images and the photography was attempted. Based on this review, there were five classes of polygons and two line classes created. Vector polygons were created by editing a new vector set over a raster with embedded existing NWI wetland vectors.

For polygon data that was not on the NWI data sets:

1) If an area held water for 2 or more months and did not have an obvious berm, the class was "PEMC."

2) If an area held water for 2 or more months and did have a visible berm, the class was "PUBFX."

3) If an area held water for 2 or more months and had an obvious dam structure in a watershed, the class was the class of the riverine system with an added modifier "H" (e.g. if stream was R2UBG then stock pond was R2UBGh)

4) If an area was wet for at least one month, had an obvious basin shape in the other months when it was dry and had an obvious drainage channel from it, then the class was "PEMAd."

5) If an area kept water all four months and did not show any visible berm, the class was "PEMF."

For linear data not on the NWI data sets, another vector object of lines was created, then buffered out 24 feet.

1) If there is an obvious artificial or enhanced natural drainage between two or more wetlands and is visible as water at least one month and a clear line for at least two months, then the line class is "drainage". Drainage and ditch areas were analyzed using all available data. If a new ditch in a plot appeared to have all the characteristics of other NWI mapped ditches (vegetation, water, etc.), the ditch was considered a ditch rather that casual drainage or a grassed waterway. The line representing the ditch was buffered out to a radius of 24 feet, a class "PEMCx" was given to the ditch and it was added to the NWI vectors.

2) If there is an obvious natural drainage that is not on NWI data then the line class is "natural drainage."

GRASSED WATERWAYS BUFFER DISTANCE

Certain plots in southern part of the prairie pothole region have drainage systems from wetland areas that cannot be classified as wetland. They consist primarily of grassed waterways for runoff. In order to account for the area of this grass within a plot, an estimate was made of the width of these grass areas from both aerial photography and where NWI had digitized some of these areas. It was estimated to be a radius of 15 feet on each side of the centerline of a grassed waterway. A vector line file was created that reflected the grassed waterways and then buffered out to a radius of 15 feet. This grassed area was given a Cowardin upland class 7.

FINAL INTERSECT

The new polygons, buffered linear wetlands and grassed waterways created in this procedure were intersected and edited according to criteria established in EMAP001.DOC for overlaps in vector data. This data set was named UPDATES.RVF. and used in the final intersect with EMAPPOLY.RVF.

APPENDIX 4-5

VEGETATION ZONE DELINEATION

The following procedures were used to create vector data from vegetation zones determined by Hal Kantrud (NPSC).

1) Each low level slide was printed to Cibachrome paper.

2) Hal Kantrud annotated the photo in the field in his survey of EMAP wetland with vegetation zones.

3) Each photo was scanned into MIPS RVF format.

4) Each raster was georeferenced with high elevation slide mosaics (EMAP003.DOC) using raster to raster registration using ground control points in common on both rasters.

5) Vectors were edited over the georeferenced photo rasters to delineate vegetation zones and place a point where each vegetation quadrat and soil sample were taken.

6) Information on the area and boundary of each zone was then exported to an ASCII text file for further processing.

APPENDIX 4-6

WATERSHED UPLAND DELINEATION

Watershed delineation was completed for the EMAP sample wetlands. The soils and vegetation team used a compass and hand held clinometer at varying stations within the wet meadow zone. From each station, the bearing from north and elevation angle to the highest point on the horizon was recorded and the distance to that point was paced by the scientist. Using trigonometry and the elevation angle, the horizontal distance was calculated from each station to the apparent horizon. Within MIPS, a point for each station was drawn on the georeferenced raster of the basin and the surrounding area from low level photographs annotated by the vegetation and soils team. From that point, both distance and angle from north were plotted to an outside point for each corrected measurement. A georeferenced watershed vector was then created by connecting each of the outside points while following visible contours and/or information for a contour map of the same area. Once a watershed outline was created, a evaluation of uplands adjacent to the wetland was done by the principal investigators of landscape ecology and vegetation and the vectors edited to reflect the upland information. Classes followed Cowardin et.al. 1979. An vector intersection of the watershed uplands was done with the wetland vector information provided by the vegetation biologist. Areas of the watershed uplands and linear distance adjacent to the wetland boundary were computed and exported to SAS.

Appendix 6-1

Plants[a] recorded in sampled communities in EMAP wetlands, 1992-1993.

Symbol[b]	Code	Scientific name	Life history in Prairie Pothole region[c]
*	000000	NO VASCULAR PLANTS	-
*	ACNE2	ACER NEGUNDO	NP
#	ACMI2	ACHILLEA MILLEFOLIUM	NP
#	AGCA2	AGROPYRON CANINUM	NP
*	AGCR	ACROPYRON CRISTATUM	IP
*	AGRE2	AGROPYRON REPENS	IP
*	AGSM	AGROPYRON SMITHII	NP
*	AGHY	AGROSTIS HYEMALIS	NP
!	AGSC5	AGROSTIS SCABRA	NP
*	ALG	MACROALGAE UNIDENTIFIED	-
*	ALGR	ALISMA GRAMINEUM	NP
*	ALPL	ALISMA PLANTAGO-AQUATICA	NP
*	ALCA3	ALLIUM CANADENSE	NP
*	ALAE	ALOPECURUS AEQUALIS	NP
*	AMRE	AMARANTHUS RETROFLEXUS	NA
*	AMAR2	AMBROSIA ARTEMISIIFOLIA	NA
*	AMPS	AMBROSIA PSILOSTACHYA	NP
*	AMFR	AMORPHA FRUTICOSA	NP
*	ANGE	ANDROPOGON GERARDII	NP
!	ANCA8	ANEMONE CANADENSIS	NP
*	AN	ANTENNARIA SP. UNIDENTIFIED	-
!	APSI	APOCYNUM SIBIRICUM	NP
#	AR	ARABIS UNIDENTIFIED	-
*	ARAB3	ARTEMISIA ABSINTHIUM	IP
#	ARBI2	ARTEMISIA BIENNIS	IA
*	ARFR4	ARTEMISIA FRIGIDA	NP
!	ARLU	ARTEMISIA LUDOVICIANA	NP
!	AS	ASTER SP UNIDENTIFIED	-
*	ASC	ASCLEPIAS UNIDENTIFIED	-
#	ASIN	ASCLEPIAS INCARNATA	NP
*	ASOV	ASCLEPIAS OVALIFOLIA	NP
#	ASSP	ASCLEPIAS SPECIOSA	NP
*	ASSY	ASCLEPIAS SYRIACA	NP
*	ASBR3	ASTER BRACHYACTIS	NA
*	ASER3	ASTER ERICOIDES	NP
*	ASSI2	ASTER SIMPLEX	NP
#	ATPA4	ATRIPLEX PATULA	NA
*	AVSA	AVENA SATIVA	IA
*	BESY	BECKMANNIA SYZIGACHNE	NA
*	BIFR	BIDENS FRONDOSA	NA
!	BOAS	BOLTONIA ASTEROIDES	NP
#	BR	BRASSICACEAE UNIDENTIFIED	-
*	BRIN2	BROMUS INERMIS	IP
#	BRJA	BROMUS JAPONICUS	IA
#	CAAR18	CARAGANA ARBORESCENS	IP
*	CACA19	CARUM CARVI	NP
*	CACA4	CALAMAGROSTIS CANADENSIS	NP
*	CAIN	CALAMAGROSTIS INEXPANSA	NP
*	CAVE2	CALLITRICHE VERNA	NP

Appendix 6-1 (continued)

#	CAPA5	CALTHA PALUSTRIS	NP
*	CAMI2	CAMELINA MICROCARPA	IA
!	CABU2	CAPSELLA BURSA-PASTORIS	NA
*	CA	CAREX UNIDENTIFIED	-
*	CAAQ	CAREX AQUATILIS	NP
*	CAAT3	CAREX ATHROSTACHYA	NP
*	CAAT2	CAREX ATHERODES	NP
*	CABE2	CAREX BEBBII	NP
*	CABR10	CAREX BREVIOR	NP
*	CAGR3	CAREX GRANULARIS	NP
*	CAHA3	CAREX HALLII	NP
*	CAIN11	CAREX INTERIOR	NP
*	CALA12	CAREX LAEVICONICA	NP
*	CALA30	CAREX LANUGINOSA	NP
*	CAPR5	CAREX PRAEGRACILIS	NP
*	CARO6	CAREX ROSTRATA	NP
*	CARE4	CAREX RETRORSA	NP
*	CASA8	CAREX SARTWELLII	NP
*	CASC11	CAREX SCOPARIA	NP
*	CAVU2	CAREX VULPINOIDEA	NP
!	CEDE4	CERATOPHYLLUM DEMERSUM	NA
!	CHAR	CHARA SPP.	-
*	CH	CHENOPODIUM SP.	-
#	CHAL7	CHENOPODIUM ALBUM	IA
*	CHRU	CHENOPODIUM RUBRUM	NA
*	CIMA2	CICUTA MACULATA	NP
*	CIAR4	CIRSIUM ARVENSE	IP
#	CIFL	CIRSIUM FLODMANII	NP
#	CIVU	CIRSIUM VULGARE	IP
*	COAR4	CONVOLVULUS ARVENSIS	IP
*	COCA5	CONYZA CANADENSIS	NA
*	COST4	CORNUS STOLONIFERA	NP
#	CRRU3	CREPIS RUNCINATA	NP
!	CYOF	CYNOGLOSSUM OFFICINALE	IP
*	CY	CYPERUS SP. UNIDENTIFIED	-
#	DECA5	DESCHAMPSIA CESPITOSA	NP
#	DERI2	DESCURAINIA RICHARDSONII	NA
*	DESO2	DESCURAINIA SOPHIA	IA
!	DISP	DISTICHLIS SPICATA	NP
*	DR	DREPANOCLADUS SP.	-
*	ECCR	ECHINOCHLOA CRUSGALLI	IA
*	ELAC	ELEOCHARIS ACICULARIS	NP
*	ELCO2	ELEOCHARIS COMPRESSA	NP
*	ELEN	ELEOCHARIS ENGELMANNII	NA
*	ELER	ELEOCHARIS ERYTHROPODA	NP
*	ELMA5	ELEOCHARIS MACROSTACHYA	NP
#	ELSM	ELEOCHARIS SMALLII	NP
*	ELXY	ELEOCHARIS XYRIDIFORMIS	NP
*	ELCA4	ELYMUS CANADENSIS	NP
*	EPLE2	EPILOBIUM LEPTOPHYLLUM	NP
*	EQAR	EQUISETUM ARVENSE	NP
*	EQHY	EQUISETUM HYEMALE	NP
*	EQLA	EQUISETUM LAEVIGATUM	NP
*	ERPH	ERIGERON PHILADELPHICUS	NP
#	ERPO6	ERIOPHORUM POLYSTACHION	NP
*	ERGA	ERUCASTRUM GALLICUM	IA
#	EUMA12	EUPATORIADELPHUS MACULATUS	NP
*	EUES	EUPHORBIA ESULA	IP
*	EUMA7	EUPHORBIA MACULATA	NA

Appendix 6-1 (continued)

!	EUGR5	EUTHAMIA GRAMINIFOLIA	NP
!	FO1	FORB UNIDENTIFIED NO. 1	-
!	FO2	FORB UNIDENTIFIED NO. 2	-
!	FO3	FORB UNIDENTIFIED NO. 3	-
!	FO4	FORB UNIDENTIFIED NO. 4	-
*	FO5	FORB UNIDENTIFIED NO. 5	-
*	FRVI	FRAGARIA VIRGINIANA	NP
!	FRPE	FRAXINUS PENNSYLVANICA	NP
*	GA	GALIUM UNIDENTIFIED	-
*	GABO2	GALIUM BOREALE	NP
*	GATR2	GALIUM TRIFIDUM	NP
*	GEAL3	GEUM ALEPPICUM	NP
*	GLMA3	GLYCERIA MAXIMA	NP
#	GLST	GLYCERIA STRIATA	NP
*	GLMA4	GLYCINE MAX	IA
!	GLLE3	GLYCYRRHIZA LEPIDOTA	NP
*	GR	GRAMINEAE UNIDENTIFIED	-
#	GRNE	GRATIOLA NEGLECTA	NA
#	GRSQ	GRINDELIA SQUARROSA	NP
*	HADE	HACKELIA DEFLEXA	NP
*	HEAU	HELENIUM AUTUMNALE	NP
*	HEAN3	HELIANTHUS ANNUUS	NA
*	HEMA2	HELIANTHUS MAXIMILIANI	NP
#	HENU	HELIANTHUS NUTTALLII	NP
#	HERI2	HELIANTHUS RIGIDUS	NP
#	HEHE5	HELIOPSIS HELIANTHOIDES	NP
*	HEMA3	HESPERIS MATRONALIS	IA
*	HIVU2	HIPPURIS VULGARIS	NP
#	HOJU	HORDEUM JUBATUM	NP
*	HOVU	HORDEUM VULGARE	IA
*	HYMA2	HYPERICUM MAJUS	NP
*	HYHI2	HYPOXIS HIRSUTA	NP
!	IMCA	IMPATIENS CAPENSIS	NA
*	IR	IRIS SP.	-
!	IVXA	IVA XANTHIFOLIA	NA
*	JU	JUNCUS SP.	-
#	JUBA	JUNCUS BALTICUS	NP
*	JUTED	JUNCUS TENUIS	NP
*	JUIN2	JUNCUS INTERIOR	NP
*	JUTO	JUNCUS TORREYI	NP
!	KOSC	KOCHIA SCOPARIA	IA
*	LA	LABIATAE UNIDENTIFIED	-
*	LAPU	LACTUCA PULCHELLA	NP
#	LASE	LACTUCA SERRIOLA	IA
*	LAEC	LAPPULA ECHINATA	IA
*	LAPA4	LATHYRUS PALUSTRIS	NP
*	LEMI3	LEMNA MINOR	-
*	LETR	LEMNA TRISULCA	-
*	LEDE	LEPIDIUM DENSIFLORUM	NA
*	LIPY	LIATRIS PYCNOSTACHYA	NP
*	LIAQ	LIMOSELLA AQUATICA	NP
#	LOSP	LOBELIA SPICATA	NP
*	LOPU3	LOTUS PURSHIANUS	NP
*	LYAM	LYCOPUS AMERICANUS	NP
*	LYAS	LYCOPUS ASPER	NP
*	LYCI	LYSIMACHIA CILIATA	NP
*	LYHY	LYSIMACHIA HYBRIDA	NP
#	LYTH2	LYSIMACHIA THYRSIFLORA	NP
*	MARO	MALVA ROTUNDIFOLIA	IA

Appendix 6-1 (continued)

*	MAVE2	MARSILEA VESTITA	NP
#	MELU	MEDICAGO LUPULINA	IA
!	MESA	MEDICAGO SATIVA	IP
*	ME	MELILOTUS UNIDENTIFIED	-
*	MEOF	MELILOTUS OFFICINALIS	IA
!	MEAR4	MENTHA ARVENSIS	NP
*	MO	MOSS, UNIDENTIFIED	-
*	MURI	MUHLENBERGIA RICHARDSONIS	NP
*	MYMI2	MYOSURUS MINIMUS	NA
*	MYSP2	MYRIOPHYLLUM SPICATUM	NP
*	NECA2	NEPETA CATARIA	IP
*	OEBI	OENOTHERA BIENNIS	NA
#	ORLU2	ORTHOCARPUS LUTEUS	NA
*	OXST	OXALIS STRICTA	NP
#	PAVI2	PANICUM VIRGATUM	NP
*	PAVI5	PARTHENOCISSUS VITACEA	NP
*	PECA	PEDICULARIS CANADENSIS	NP
*	PESA5	PETASITES SAGITTATUS	NP
*	PHAR3	PHALARIS ARUNDINACEA	NP
#	PHPR3	PHLEUM PRATENSE	IP
*	PHVI5	PHYSALIS VIRGINIANA	NP
*	PIPU2	PILEA PUMILA	NA
*	PLSC2	PLAGIOBOTHRYS SCOULERI	NA
*	PLMA2	PLANTAGO MAJOR	NP
*	POCO	POA COMPRESSA	IP
*	POPA2	POA PALUSTRIS	NP
*	POPR	POA PRATENSIS	IP
*	POAM8	POLYGONUM AMPHIBIUM	NP
*	POAV	POLYGONUM AVICULARE	NA
#	POCO10	POLYGONUM CONVOLVULUS	NA
*	POER2	POLYGONUM ERECTUM	NA
*	POHY	POLYGONUM HYDROPIPER	IA
*	POLA4	POLYGONUM LAPATHIFOLIUM	NA
*	POPE2	POLYGONUM PENSYLVANICUM	NA
*	PORA3	POLYGONUM RAMOSISSIMUM	NA
*	POBA2	POPULUS BALSAMIFERA	NP
*	PODE3	POPULUS DELTOIDES	NP
*	POTR10	POPULUS TREMULA	NP
*	POGR8	POTAMOGETON GRAMINEUS	NP
*	POPE6	POTAMOGETON PECTINATUS	NP
*	POAN5	POTENTILLA ANSERINA	NP
*	POAR7	POTENTILLA ARGUTA	NP
#	PONO3	POTENTILLA NORVEGICA	NA
*	POPE8	POTENTILLA PENSYLVANICA	NP
*	PORI3	POTENTILLA RIVALIS	NA
*	PUNU2	PUCCINELLIA NUTTALLIANA	NP
#	PYVI	PYCNANTHEMUM VIRGINIANUM	NP
*	RACO3	RATIBIDA COLUMNIFERA	NP
*	RAFL	RANUNCULUS FLABELLARIS	NP
*	RAGM	RANUNCULUS GMELINII	NP
*	RAMA2	RANUNCULUS MACOUNII	NA
*	RASC3	RANUNCULUS SCELERATUS	IA
!	RATR	RANUNCULUS TRICHOPHYLLUS	NP
!	RIFL	RICCIA FLUITANS	-
*	RINA	RICCIOCARPUS NATANS	-
*	RIAM2	RIBES AMERICANUM	NP
*	ROPA2	RORIPPA PALUSTRIS	NA
*	ROAR3	ROSA ARKANSANA	NP
*	ROBL	ROSA BLANDA	NP

Appendix 6-1 (continued)

!	ROWO	ROSA WOODSII	NP
*	RU	RUMEX UNIDENTIFIED	-
*	RUHI2	RUDBECKIA HIRTA	NP
*	RUCR	RUMEX CRISPUS	IP
*	RUMA4	RUMEX MARITIMUS	NA
*	RUME2	RUMEX MEXICANUS	NP
*	RUOC3	RUMEX OCCIDENTALIS	NP
*	RUOR2	RUMEX ORBICULATUS	NP
!	RUST4	RUMEX STENOPHYLLUS	IP
*	SA	SALIX UNIDENTIFIED	-
*	SACU	SAGITTARIA CUNEATA	NP
*	SALA2	SAGITTARIA LATIFOLIA	NP
*	SARU	SALICORNIA RUBRA	NA
*	SAAM2	SALIX AMYGDALOIDES	NP
!	SAEX	SALIX EXIGUA	NP
*	SC	SCUTELLARIA UNIDENTIFIED	-
*	SCGA	SCUTELLARIA GALERICULATA	NP
*	SCAC	SCIRPUS ACUTUS	NP
*	SCAT2	SCIRPUS ATROVIRENS	NP
*	SCFL	SCIRPUS FLUVIATILIS	NP
*	SCHE	SCIRPUS HETEROCHAETUS	NP
#	SCMA	SCIRPUS MARITIMUS	NP
*	SCPU3	SCIRPUS PUNGENS	NP
*	SCVA	SCIRPUS VALIDUS	NP
!	SCFE	SCOLOCHLOA FESTUCACEA	NP
*	SE	SETARIA SP. UNIDENTIFIED	-
!	SECO2	SENECIO CONGESTUS	NA
#	SI	SILENE UNIDENTIFIED	-
#	SIAR4	SINAPSIS ARVENSIS	IA
*	SILO3	SISYMBRIUM LOESELII	NA
*	SISU2	SIUM SUAVE	NP
*	SOCA6	SOLIDAGO CANADENSIS	NP
#	SOGI	SOLIDAGO GIGANTEA	NP
*	SOMI2	SOLIDAGO MISSOURIENSIS	NP
*	SORI2	SOLIDAGO RIGIDA	NP
#	SOPT3	SOLANUM PTYCANTHUM	NA
*	SORO	SOLANUM ROSTRATUM	NA
*	SOAR2	SONCHUS ARVENSIS	IP
*	SPEU	SPARGANIUM EURYCARPUM	NP
*	SPPE	SPARTINA PECTINATA	NP
*	SPOB	SPHENOPHOLIS OBTUSATA	NP
*	SPPO	SPIRODELA POLYRHIZA	-
*	STPA	STACHYS PALUSTRIS	NP
#	SUDE	SUAEDA DEPRESSA	NA
*	SYOC	SYMPHORICARPOS OCCIDENTALIS	NP
*	TAOF	TARAXACUM OFFICINALE	IP
*	TECA3	TEUCRIUM CANADENSE	NP
*	THDA	THALICTRUM DASYCARPUM	NP
*	THAR5	THLASPI ARVENSE	IA
*	TORY	TOXICODENDRON RYDBERGII	NP
#	TRBR	TRADESCANTIA BRACTEATA	NP
*	TRDU	TRAGOPOGON DUBIUS	IP
*	TRRE3	TRIFOLIUM REPENS	IP
#	TRMA4	TRIGLOCHIN MARITIMUM	NP
*	TRAE	TRITICUM X AESTIVUM	IA
#	TYAN	TYPHA ANGUSTIFOLIA	IP
*	TYGL	TYPHA X GLAUCA	-
#	TYLA	TYPHA LATIFOLIA	NP
*	ULPU	ULMUS PUMILA	IP

Appendix 6-1 (continued)

*	URDI	URTICA DIOICA	NP
*	UTMA	UTRICULARIA MACRORHIZA	NA
*	VEBR	VERBENA BRACTEATA	NA
*	VEHA2	VERBENA HASTATA	NP
*	VEFA2	VERNONIA FASCICULATA	NP
!	VEPE2	VERONICA PEREGRINA	NA
*	VI	VICIA UNIDENTIFIED	-
*	VIAM	VICIA AMERICANA	NP
#	VIRI	VITIS RIPARIA	NP
*	XAST	XANTHIUM STRUMARIUM	NA
#	ZAPA	ZANNICHELLIA PALUSTRIS	-
*	ZEMA	ZEA MAYS	IA
*	ZIEL2	ZIGADENUS ELEGANS	NP
	ZIAP	ZIZIA APTERA	NP

[a]Nomenclature follows Great Plains Flora Association (1992), so some listed taxa are synonyms in United States Department of Agriculture (1982) and Reed (1988) that were used for the code acronyms.

[b]Symbols:*= Pteridophyes found in wetlands in the region according to Reed (1988); #= Pteridophytes from United States Department of Agriculture (1982) not listed in Reed (1988); != Pteridophytes and non-vascular plants (macroalgae, mosses, or liverworts) with artificial codes made up specifically for EMAP data.

[c]Life history codes: NP=native perennial; NA=native annual or biennial; IP=introduced or adventive perennial; IA=introduced or adventive annual or biennial; -= Not applicable or unknown.

Appendix 6-2

ANOVA tables[a]. **SV is source of variation, df is degrees of freedom, MS is mean square, F is the F statistic, and P is the p-value.**

Area of low-prairie zone

SV	df	MS	F	P
H	1	0.00138	1.20	0.2775
Error[a]	51	0.00115	-	-
Y	1	<0.00001	0.02	0.8809
Y*H	1	<0.00001	1.86	0.1866
Error[b]	21	0.00060	-	-

Area of wet-meadow zone

SV	df	MS	F	P
H	1	31.1792	1.79	0.1873
Error[a]	51	17.4515	-	-
Y	1	0.0015	0.09	0.7652
Y*H	1	0.0268	1.65	0.2135
Error[b]	21	0.0163	-	-

Area of shallow-marsh zone

SV	df	MS	F	P
H	1	26.3620	2.00	0.1632
Error[a]	51	13.1675	-	-
Y	1	3.1613	0.88	0.3583
Y*H	1	3.3065	0.92	0.3477
Error[b]	21	3.5834	-	-

Area of deep-marsh zone

SV	df	MS	F	P
H	1	29.6641	1.25	0.2685
Error[a]	51	23.6985	-	-
Y	1	0.0466	0.08	0.7820
Y*H	1	0.0855	0.14	0.7077
Error[b]	21	0.5923	-	-

Area of fen zone

SV	df	MS	F	P
H	1	0.0082	0.65	0.4221
Error[a]	51	0.1258	-	-
Y	1	0.0030	0.48	0.4961
Y*H	1	0.0030	0.48	0.4961
Error[b]	21	0.0063	-	-

Code to errors for zone area models: a=B(H); b=residual

Appendix 6-2 (continued)

Area of communities

Full data model:

SV	df	MS	F	P
H	1	54.63	1.23	0.2721
Error[a]	51	44.31	-	-
Z	2	1.64	0.33	0.7243
Z*H	2	2.78	0.55	0.5796
Error[b]	35	5.04	-	-
Y	1	0.52	1.16	0.2872
Y*H	1	0.04	0.09	0.7718
Y*Z	2	1.04	2.30	0.1128
Y*Z*H	1	n.e.[b]	n.t.[c]	-
Error[c]	42	0.45	-	-

Code to errors for full community area model: a=B(H); b=Z*B(H); c=residual

Reduced data model

SV	df	MS	F	P
H	1	16.27	0.39	0.5335
Y	1	9.68	0.23	0.6307
Y*H	1	8.54	0.21	0.6516
Error[a]	49	41.36	-	-
Z	2	0.20	0.04	0.9598
Z*H	2	0.56	0.12	0.8898
Z*Y	2	0.35	0.07	0.9294
Z*Y*H	2	0.36	0.08	0.9277
Error[b]	36	4.81	-	-

Code to errors for reduced data model on community areas: a=B(H); b=residual

Water depth

Full data model:

SV	df	MS	F	P
H	1	60.57	0.20	0.6554
Error[a]	51	300.69	-	-
Z	2	4263.57	23.60	0.0001**
Z*H	2	105.98	0.59	0.5616
Error[b]	35	180.67	-	-
Y	1	3492.81	25.51	0.0001**
Y*H	1	96.66	0.71	0.4056
Y*Z	2	376.01	2.75	0.0757*
Y*Z*H	1	n.e.[b]	n.t.[c]	-
Error[c]	42	136.93	-	-

Code to errors for full water depth model: a=B(H); b=Z*B(H); c=residual

Reduced data model

SV	df	MS	F	P
H	1	13.09	0.05	0.8169
Y	1	1568.28	6.49	0.0140**
Y*H	1	58.28	0.24	0.6255
Error[a]	49	241.62	-	-
Z	2	2676.84	20.54	0.0001**
Z*H	2	24.41	0.19	0.8299
Z*Y	2	578.97	4.44	0.0189**
Z*Y*H	2	122.70	0.94	0.3994
Error[b]	36	130.30	-	-

Code to errors for reduced data model on water depth: a=B(H); b=residual

Appendix 6-2 (continued)

Percent dead vegetation

Full data model:

SV	df	MS	F	P
H	1	123.76	1.33	0.2549
Error[a]	51	93.33	-	-
Z	2	213.80	9.44	0.0005**
Z*H	2	1.43	0.06	0.9389
Error[b]	35	22.64	-	-
Y	1	59.38	6.58	0.0140**
Y*H	1	28.01	3.11	0.0853*
Y*Z	2	15.83	1.75	0.1854
Y*Z*H	1	n.e.[b]	n.t.[c]	-
Error[c]	42	9.02	-	-

Code to errors for full percent dead vegetation model: a=B(H); b=Z*B(H); c=residual

Reduced data model

SV	df	MS	F	P
H	1	216.72	2.30	0.1355
Y	1	78.57	0.84	0.3653
Y*H	1	33.17	0.35	0.5554
Error[a]	49	94.09	-	-
Z	2	128.83	6.78	0.0032**
Z*H	2	23.82	1.25	0.2976
Z*Y	2	7.71	0.41	0.6696
Z*Y*H	2	3.12	0.16	0.8490
Error[b]	36	19.00	-	-

Code to errors for reduced data model on percent dead vegetation: a=B(H); b=residual

Litter depth

Full data model:

SV	df	MS	F	P
H	1	39.92	5.92	0.0185**
Error[a]	51	6.74	-	-
Z	2	10.46	4.97	0.0126**
Z*H	2	5.53	2.58	0.0902*
Error[b]	35	2.10	-	-
Y	1	0.33	0.25	0.6217
Y*H	1	2.10	1.58	0.2156
Y*Z	2	0.25	0.19	0.8296
Y*Z*H	1	n.e.[b]	n.t.[c]	-
Error[c]	42	1.33	-	-

Code to errors for full litter depth model: a=B(H); b=Z*B(H); c=residual

Reduced data model

SV	df	MS	F	P
H	1	9.25	1.45	0.2347
Y	1	11.87	1.86	0.1791
Y*H	1	35.43	5.55	0.0226**
Error[a]	49	6.39	-	-
Z	2	7.62	3.90	0.0292**
Z*H	2	3.92	2.01	0.1493
Z*Y	2	2.87	1.47	0.2442
Z*Y*H	2	9.18	4.70	0.0154**
Error[b]	36	1.95	-	-

Code to errors for reduced data model on litter depth: a=B(H); b=residual

Appendix 6-2 (continued)

Percent unvegetated bottom

Full data model:

SV	df	MS	F	P
H	1	6315.31	9.23	0.0037**
Error[a]	51	684.01	-	-
Z	2	102.76	1.97	0.1547
Z*H	2	32.39	0.62	0.5434
Error[b]	35	52.18	-	-
Y	1	890.20	5.92	0.0193**
Y*H	1	420.24	2.86	0.0982*
Y*Z	2	9.95	0.07	0.9361
Y*Z*H	1	n.e.[b]	n.t.[c]	-
Error[c]	42	150.46	-	-

Code to errors for full unvegetated bottom model: a=B(H); b=Z*B(H); c=residual

Reduced data model

SV	df	MS	F	P
H	1	5581.24	10.03	0.0026**
Y	1	2522.78	4.53	0.0383**
Y*H	1	870.83	1.57	0.2168
Error[a]	49	556.31	-	-
Z	2	67.10	0.72	0.4921
Z*H	2	13.05	0.14	0.8692
Z*Y	2	14.41	0.16	0.8567
Z*Y*H	2	67.96	0.73	0.4878
Error[b]	36	92.78	-	-

Code to errors for reduced data model on percent unvegetated bottom: a=B(H); b=residual

Percent open water

Full data model:

SV	df	MS	F	P
H	1	182.62	0.25	0.6226
Error[a]	51	744.61	-	-
Z	2	2594.42	8.77	0.0008**
Z*H	2	160.20	0.54	0.5867
Error[b]	35	295.83	-	-
Y	1	8313.44	19.93	0.0001**
Y*H	1	1310.93	3.14	0.0835*
Y*Z	2	21.56	0.05	0.9497
Y*Z*H	1	n.e.[b]	n.t.[c]	-
Error[c]	42	417.06	-	-

Code to errors for full percent open water model: a=B(H); b=Z*B(H); c=residual

Reduced data model

SV	df	MS	F	P
H	1	82.07	0.10	0.7528
Y	1	4187.18	5.12	0.0281**
Y*H	1	116.04	0.14	0.7080
Error[a]	49	817.85	-	-
Z	2	1294.96	6.06	0.0054**
Z*H	2	106.72	0.50	0.6111
Z*Y	2	804.79	3.76	0.0328**
Z*Y*H	2	88.94	0.42	0.6628
Error[b]	36	213.18	-	-

Code to errors for reduced data model on percent open water: a=B(H); b=residual

Appendix 6-2 (continued)

Total plant species richness

Full data model:

SV	df	MS	F	P
H	1	578.90	5.89	0.0188**
Error[a]	51	98.25	-	-
Z	2	1038.32	22.20	0.0001**
Z*H	2	106.73	2.28	0.1171
Error[b]	35	46.78	-	-
Y	1	9.10	0.31	0.5823
Y*H	1	3.95	0.13	0.7169
Y*Z	2	6.29	0.21	0.8096
Y*Z*H	1	n.e.[b]	n.t.[c]	-
Error[c]	42	29.62	-	-

Code to errors for full model on total plant species richness: a=B(H); b=Z*B(H); c=residual

Reduced data model

SV	df	MS	F	P
H	1	358.70	3.94	0.0528*
Y	1	186.27	2.05	0.1589
Y*H	1	48.89	0.54	0.4672
Error[a]	49	91.04	-	-
Z	2	832.00	17.35	0.0001**
Z*H	2	66.75	1.39	0.2617
Z*Y	2	22.32	0.47	0.6317
Z*Y*H	2	6.76	0.14	0.8690
Error[b]	36	47.97	-	-

Code to errors for reduced data model on total plant species richness: a=B(H); b=residual

Perennial plant species richness

Full data model:

SV	df	MS	F	P
H	1	491.86	5.02	0.0295**
Error[a]	51	98.01	-	-
Z	2	852.82	17.90	0.0001**
Z*H	2	179.25	3.76	0.0331**
Error[b]	35	47.63	-	-
Y	1	2.94	0.15	0.7014
Y*H	1	2.52	0.13	0.7226
Y*Z	2	10.49	0.84	0.3657
Y*Z*H	1	n.e.[b]	n.t.[c]	-
Error[c]	42	19.72	-	-

Code to errors for full model on perennial plant species richness: a=B(H); b=Z*B(H); c=residual

Reduced data model

SV	df	MS	F	P
H	1	303.80	3.45	0.0692*
Y	1	278.36	3.16	0.0815*
Y*H	1	36.71	0.42	0.5213
Error[a]	49	87.99	-	-
Z	2	677.49	16.34	0.0001**
Z*H	2	121.43	2.93	0.0663*
Z*Y	2	25.92	0.63	0.5408
Z*Y*H	2	7.56	0.18	0.8340
Error[b]	36	41.46	-	-

Code to errors for reduced data model on perennial plant species richness: a=B(H); b=residual

Appendix A6-2 (continued)

Annual plant species richness

Full data model:

SV	df	MS	F	P
H	1	0.12	0.07	0.9256
Error[a]	51	13.65	-	-
Z	2	10.10	4.00	0.0272**
Z*H	2	6.60	2.62	0.0872*
Error[b]	35	2.52	-	-
Y	1	19.43	5.26	0.0270**
Y*H	1	1.02	0.28	0.6027
Y*Z	2	0.90	0.24	0.7846
Y*Z*H	1	n.e.[b]	n.t.[c]	-
Error[c]	42	3.70	-	-

Code to errors for full model on annual plant species richness: a=B(H); b=Z*B(H); c=residual

Reduced data model

SV	df	MS	F	P
H	1	0.51	0.04	0.8438
Y	1	13.86	1.06	0.3091
Y*H	1	2.24	0.17	0.6809
Error[a]	49	13.12	-	-
Z	2	7.26	2.85	0.0708*
Z*H	2	3.29	1.29	0.2871
Z*Y	2	2.16	0.85	0.4355
Z*Y*H	2	0.93	0.36	0.6969
Error[b]	36	2.54	-	-

Code to errors for reduced data model on annual plant species richness: a=B(H); b=residual

Introduced plant species richness

Full data model:

SV	df	MS	F	P
H	1	6.03	0.85	0.3613
Error[a]	51	7.10	-	-
Z	2	108.45	29.75	0.0001**
Z*H	2	1.97	0.54	0.5879
Error[b]	35	3.65	-	-
Y	1	0.01	0.01	0.9793
Y*H	1	0.29	0.12	0.7266
Y*Z	2	0.69	0.29	0.7480
Y*Z*H	1	n.e.[b]	n.t.[c]	-
Error[c]	42	2.36	-	-

Code to errors for full model on introduced plant species richness: a=B(H); b=Z*B(H); c=residual

Reduced data model

SV	df	MS	F	P
H	1	4.71	0.79	0.3796
Y	1	3.76	0.63	0.4325
Y*H	1	1.57	0.26	0.6115
Error[a]	49	6.00	-	-
Z	2	66.33	16.35	0.0001**
Z*H	2	0.70	0.17	0.8420
Z*Y	2	4.69	1.15	0.3265
Z*Y*H	2	0.01	0.01	0.9975
Error[b]	36	4.06	-	-

Code to errors for reduced data model on introduced plant species richness: a=B(H); b=residual

Appendix 6-2 (continued)

Native plant species richness

Full data model:

SV	df	MS	F	P
H	1	375.46	4.96	0.0305**
Error[a]	51	75.76	-	-
Z	2	499.42	11.66	0.0001**
Z*H	2	102.51	2.39	0.1061
Error[b]	35	42.83	-	-
Y	1	7.04	0.36	0.5543
Y*H	1	4.22	0.21	0.6468
Y*Z	2	4.42	0.22	0.8011
Y*Z*H	1	n.e.[b]	n.t.[c]	-
Error[c]	42	19.81	-	-

Code to errors for full model on native plant species richness: a=B(H); b=Z*B(H); c=residual

Reduced data model

SV	df	MS	F	P
H	1	211.44	2.88	0.0959*
Y	1	221.99	3.03	0.0882*
Y*H	1	39.76	0.54	0.4651
Error[a]	49	73.35	-	-
Z	2	436.02	11.59	0.0001**
Z*H	2	80.55	2.14	0.1323
Z*Y	2	38.55	1.03	0.3657
Z*Y*H	2	10.59	0.28	0.7563
Error[b]	36	37.63	-	-

Code to errors for reduced data model on native plant species richness: a=B(H); b=residual

Species richness of introduced perennial plants

Full data model:

SV	df	MS	F	P
H	1	9.56	2.81	0.0999*
Error[a]	51	3.40	-	-
Z	2	48.14	24.73	0.0001**
Z*H	2	4.06	2.08	0.1395
Error[b]	35	1.95	-	-
Y	1	0.12	0.07	0.7890
Y*H	1	0.04	0.02	0.8764
Y*Z	2	0.87	0.55	0.5830
Y*Z*H	1	n.e.[b]	n.t.[c]	-
Error[c]	42	1.59	-	-

Code to errors for full model on species richness of introduced perennial plants: a=B(H); b=Z*B(H); c=residual

Reduced data model

SV	df	MS	F	P
H	1	7.87	2.82	0.0992*
Y	1	0.24	0.09	0.7704
Y*H	1	1.75	0.63	0.4319
Error[a]	49	2.79	-	-
Z	2	30.12	12.45	0.0001**
Z*H	2	1.27	0.52	0.5965
Z*Y	2	1.51	0.63	0.5396
Z*Y*H	2	0.33	0.14	0.8738
Error[b]	36	2.42	-	-

Code to errors for reduced data model on species richness of introduced perennial plants: a=B(H); b=residual

Appendix 6-2 (continued)

Species richness of native perennial plants

Full data model:

SV	df	MS	F	P
H	1	364.30	4.28	0.0437**
Error[a]	51	85.14	-	-
Z	2	505.16	11.37	0.0002**
Z*H	2	129.37	2.91	0.0676*
Error[b]	35	44.42	-	-
Y	1	1.89	0.13	0.7221
Y*H	1	1.93	0.13	0.7192
Y*Z	2	5.38	0.36	0.6965
Y*Z*H	1	n.e.[b]	n.t.[c]	-
Error[c]	42	14.75	-	-

Code to errors for full model on species richness of native perennial plants: a=B(H); b=Z*B(H); c=residual

Reduced data model

SV	df	MS	F	P
H	1	213.87	2.72	0.1056
Y	1	262.25	3.33	0.0740*
Y*H	1	22.43	0.29	0.5958
Error[a]	49	78.66	-	-
Z	2	427.95	12.08	0.0001**
Z*H	2	98.96	2.79	0.0745*
Z*Y	2	39.72	1.12	0.3368
Z*Y*H	2	5.31	0.15	0.8613
Error[b]	36	35.41	-	-

Code to errors for reduced data model on species richness of native perennial plants: a=B(H); b=residual

Species richness of introduced annual plants

Full data model:

SV	df	MS	F	P
H	1	0.41	0.20	0.6553
Error[a]	51	2.01	-	-
Z	2	12.08	13.38	0.0001**
Z*H	2	1.03	1.15	0.3295
Error[b]	35	0.90	-	-
Y	1	0.14	0.30	0.5889
Y*H	1	0.12	0.24	0.6239
Y*Z	2	0.01	0.02	0.9780
Y*Z*H	1	n.e.[b]	n.t.[c]	-
Error[c]	42	0.49	-	-

Code to errors for full model on species richness of introduced annual plants: a=B(H); b=Z*B(H); c=residual

Reduced data model

SV	df	MS	F	P
H	1	0.40	0.21	0.6492
Y	1	5.90	3.07	0.0859*
Y*H	1	0.01	0.01	0.9593
Error[a]	49	1.92	-	-
Z	2	7.09	9.22	0.0006**
Z*H	2	0.09	0.12	0.8845
Z*Y	2	1.14	1.48	0.2410
Z*Y*H	2	0.38	0.50	0.6112
Error[b]	36	0.77	-	-

Code to errors for reduced data model on species richness of introduced annual plants: a=B(H); b=residual

Appendix 6-2 (continued)

Species richness of native annual plants

Full data model:

SV	df	MS	F	P
H	1	0.08	0.01	0.9155
Error[a]	51	7.40	-	-
Z	2	1.25	0.84	0.4395
Z*H	2	2.42	1.63	0.2110
Error[b]	35	1.49	-	-
Y	1	16.23	6.28	0.0162**
Y*H	1	0.44	0.17	0.6815
Y*Z	2	0.75	0.29	0.7495
Y*Z*H	1	n.e.[b]	n.t.[c]	-
Error[c]	42	2.58	-	-

Code to errors for full model on species richness of native annual plants: a=B(H); b=Z*B(H); c=residual

Reduced data model

SV	df	MS	F	P
H	1	0.01	0.01	0.9758
Y	1	1.68	0.23	0.6372
Y*H	1	2.46	0.33	0.5677
Error[a]	49	7.44	-	-
Z	2	1.81	0.91	0.4111
Z*H	2	2.53	1.27	0.2930
Z*Y	2	0.20	0.10	0.9037
Z*Y*H	2	2.40	1.21	0.3107
Error[b]	36	1.99	-	-

Code to errors for reduced data model on species richness of native annual plants: a=B(H); b=residual

Ratio of native annual plants to introduced annual plants[d]

Full data model:

SV	df	MS	F	P
H	1	1.03	0.67	0.4167
Error[a]	51	1.54	-	-
Z	2	6.07	5.93	0.0061**
Z*H	2	0.24	0.23	0.7935
Error[b]	35	1.02	-	-
Y	1	4.21	2.74	0.1052
Y*H	1	0.06	0.04	0.8463
Y*Z	2	1.07	0.69	0.5053
Y*Z*H	1	n.e.[b]	n.t.[c]	-
Error[c]	42	1.54	-	-

Code to errors for full model on ratio of native annual plants to introduced annual plants: a=B(H); b=Z*B(H); c=residual

Reduced data model

SV	df	MS	F	P
H	1	0.83	0.50	0.4841
Y	1	3.25	1.94	0.1698
Y*H	1	1.07	0.64	0.4283
Error[a]	49	1.68	-	-
Z	2	4.45	2.79	0.0746*
Z*H	2	0.80	0.50	0.6095
Z*Y	2	1.90	1.19	0.3163
Z*Y*H	2	0.94	0.59	0.5595
Error[b]	36	1.59	-	-

Code to errors for reduced data model on ratio of native annual plants to introduced annual plants: a=B(H); b=residual

Appendix 6-2 (continued)

Ratio of native perennial plants to introduced perennial plants[e]

Full data model:

SV	df	MS	F	P
H	1	14.26	0.91	0.3446
Error[a]	51	15.67	-	-
Z	2	40.49	4.13	0.0245**
Z*H	2	6.60	0.67	0.5164
Error[b]	35	9.80	-	-
Y	1	0.31	0.06	0.8032
Y*H	1	2.19	0.44	0.5120
Y*Z	2	0.18	0.04	0.9645
Y*Z*H	1	n.e.[b]	n.t.[c]	-
Error[c]	42	5.00	-	-

Code to errors for full model on ratio of native perennial plants to introduced perennial plants: a=B(H); b=Z*B(H); c=residual

Reduced data model

SV	df	MS	F	P
H	1	1.15	0.08	0.7831
Y	1	27.81	1.85	0.1796
Y*H	1	0.22	0.01	0.9043
Error[a]	49	15.01	-	-
Z	2	33.80	4.10	0.0248**
Z*H	2	23.97	2.91	0.0674*
Z*Y	2	26.28	3.19	0.0531*
Z*Y*H	2	14.50	1.76	0.1865
Error[b]	36	8.24	-	-

Code to errors for reduced data model on ratio of native perennial plants to introduced perennial plants: a=B(H); b=residual

Appendix 6-2 (continued)

Percent of estimated basin watershed dominated by annual plants

SV	df	MS	F	P
H	1	102499.18	126.83	0.0001**
Error[a]	51	808.15	-	-
Y	1	23.48	0.52	0.4781
Y*H	1	23.48	0.52	0.4781
Error[b]	21	45.00	-	-

Percent of estimated basin watershed dominated by perennial plants

SV	df	MS	F	P
H	1	108962.61	162.44	0.001**
Error[a]	51	670.81	-	-
Y	1	23.48	0.08	0.7788
Y*H	1	23.48	0.08	0.7788
Error[b]	21	289.95	-	-

Percent of estimated basin watershed dominated by other than annual or perennial plants

SV	df	MS	F	P
H	1	261.99	1.42	0.2397
Error[a]	51	185.11	-	-
Y	1	1.16	0.48	0.4958
Y*H	1	1.16	0.48	0.4958
Error[b]	21	2.41	-	-

Code to errors for models of dominants of basin watersheds: a=B(H); b=residual

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[a]Code to sources of variation: H=condition (health); B=basin; Z=zone; Y=year

[b]Not estimated

[c]Not tested

[d]Ratio= (native annuals + 1)/(introduced annuals + 1) to accomodate zeros

[e]Ratio= (native perennials + 1)/(introduced perennials + 1) to accomodate zeros

Appendix 6-3

Attributes of the 140 sampled communities, EMAP study, 1992-1993.

Attribute codes[a]							No. sampled quadrats per community			
							1992		1993	
1	2	3	4	5	6	7	G[b]	P[c]	G	P
38	62	2	WM	1	C	CD	.	5	.	.
54	39	1	WM	1	C	CT	.	5	.	.
59	42	1	DM	4	I	NE	.	5	.	.
			SM	3	I	NE	.	5	.	.
			WM	1	I	NE	.	5	.	.
				2	I	NE	.	5	.	.
	111	2	SM	2	G	NE	5	.	.	.
			WM	1	G	NE	5	.	.	.
60	58	2	SM	2	I	NE	5	.	.	.
			WM	1	I	NE	5	.	.	.
	128	1	WM	1	I	NE	5	.	.	.
73	29	3	DM	3	I	NE	5	.	5	.
			SM	2	I	NE	5	.	5	.
			WM	1	I	NE	5	.	5	.
	86	1	WM	1	G	NE	5	.	5	.
133	370	1	WM	1	C	CT	.	.	.	5
				2	C	CD	.	.	.	5
	380	3	SM	2	I	NE	.	.	.	5
			WM	1	I	NE	.	.	.	5
	386	2	SM	2	I	NE	.	.	5	.
			WM	1	I	NE	.	.	5	.
134	140	3	SM	1	I	NE	.	5	.	.
				2	I	CD	.	5	.	.
						NE	.	.	.	5
			WM	1	I	NE	.	.	.	5
	158	2	WM	1	C	CT	.	.	.	5
	165	3	SM	1	I	NE	.	5	.	.
				2	C	NE	.	.	.	5
			WM	1	C	CT	.	.	.	5
	270	1	WM	1	C	CT	.	.	.	5
					T	CD	.	5	.	.
	272	2	WM	1	C	CD	.	5	.	.
	406	2	DM	3	I	NE	.	.	.	5
			SM	2	I	NE	.	5	.	5
			WM	1	I	NE	.	5	.	5
	432	1	WM	1	C	CT	.	5	.	5
156	22	3	SM	2	G	NE	5	.	5	.
			WM	1	G	NE	5	.	5	.
	24	2	WM	1	G	NE	5	.	5	.
	26	1	WM	1	G	NE	5	.	5	.
	42	2	WM	1	G	NE	5	.	5	.
241	3	3	DM	1	I	NE	.	5	.	.
			SM	2	I	NE	.	5	.	.
			WM	3	I	NE	.	5	.	.
				4	I	NE	.	5	.	.
	48	2	WM	1	C	CT	.	5	.	.
				2	C	CT	.	5	.	.
246	34	1	WM	1	C	CT	.	5	.	.
	37	1	WM	1	C	CT	.	5	.	.
	53	3	DM	1	I	NE	.	5	.	.
			SM	2	I	NE	.	5	.	.
249	50	1	SM	2	G	NE	5	.	.	.
			WM	1	G	NE	5	.	.	.
	86	2	SM	2	M	NE	5	.	.	.
			WM	1	M	NE	5	.	.	.
327	72	1	SM	2	I	NE	.	.	.	5
			WM	1	C	CT	.	.	.	5
	117	3	SM	3	I	NE	.	.	.	5
			WM	1	C	CT	.	.	.	5
				2	I	NE	.	.	.	5
	147	2	SM	2	I	NE	.	.	.	5

Appendix 6-3 (continued)

Attribute codes[a]							No. sampled quadrats per community			
							1992		1993	
1	2	3	4	5	6	7	G[b]	P[c]	G	P
			WM	1	I	NE	.	.	.	5
363	22	3	DM	3	I	NE	5	.	5	.
			WM	1	I	NE	5	.	5	.
	58	1	SM	2	G	NE	5	.	5	.
			WM	1	G	NE	5	.	5	.
374	65	1	WM	1	G	NE	5	.	5	.
	100	3	DM	3	G	NE	5	.	5	.
			SM	2	G	NE	5	.	5	.
			WM	1	G	NE	5	.	5	.
	225	2	DM	3	G	NE	5	.	.	.
				4	G	NE	.	.	5	.
			SM	2	G	NE	5	.	5	.
				3	G	NE	.	.	5	.
			WM	1	G	NE	5	.	5	.
	272	2	WM	1	G	NE	5	.	5	.
				2	G	NE	5	.	5	.
396	106	3	WM	1	G	ND	5	.	.	.
	107	1	WM	1	M	NE	5	.	.	.
	130	3	SM	1	G	ND	5	.	.	.
			WM	2	G	ND	5	.	.	.
407	67	2	WM	1	G	NE	.	.	5	.
	109	1	WM	1	I	NE	.	.	5	.
	168	3	DM	3	G	NE	.	.	5	.
			SM	2	G	NE	.	.	5	.
			WM	1	G	NE	.	.	5	.
442	93	2	SM	2	I	NE	5	.	5	.
			WM	1	I	NE	5	.	5	.
	260	1	WM	1	C	CT	.	.	.	5
					I	CD	.	5	.	.
	261	1	WM	1	C	CT	.	.	.	5
					I	CD	.	5	.	.
	281	2	SM	2	I	NE	.	5	.	5
			WM	1	I	NE	.	5	.	5
	295	3	DM	3	I	NE	.	.	5	.
			SM	2	I	ND	5	.	.	.
						NE	.	.	5	.
			WM	1	I	ND	5	.	.	.
						NE	.	.	5	.
	301	3	DM	3	I	NE	5	.	5	.
			SM	2	I	ND	5	.	.	.
						NE	.	.	5	.
			WM	1	I	ND	5	.	.	.
						NE	.	.	5	.
498	146	3	DM	3	I	NE	.	.	5	.
			WM	1	I	NE	.	.	5	.
	227	1	WM	1	I	NE	.	.	5	.
	277	2	DM	3	I	NE	.	.	5	.
			SM	2	I	NE	.	.	5	.
			WM	1	I	NE	.	.	5	.

[a]Attribute codes: Col 1 = Plot No.; Col 2 = Basin No.; Col 3 = Basin Class (1=temporarily-flooded; 2=seasonally-flooded; 3=semipermanently-flooded); Col 4 = Zone (WM=wet- meadow; SM=shallow-marsh; DM=deep-marsh); Col 5 = Community number within basin; Col 6 = Land-use (I=Idle; M=Mowed; C=Cultivated; G=GRAZED); Col 7 = Phase NE=Normal Emergent; CT=Cropland Tillage; CD=Cropland Drawdown; ND=Natural Drawdown.

[b]G=Basin in good-condition watershed.

[c]P=Basin in poor-condition watershed.

APPENDIX 7-1

Appendix 7-1. EMAP Wetland Soil Classifications by John Freeland, 1992-93.

								EM-38	
Plot	WL	Health	Zone	Comm.	Year	Quad	Soil Classification	V	H
38	62	Low	WM	1	92	1	Aeric Calciaquoll	38	28
38	62	Low	WM	1	92	2	Aeric Calciaquoll	42	37
38	62	Low	WM	1	92	3	Aeric Calciaquoll	52	44
38	62	Low	WM	1	92	4	Cumulic Calciaquoll	50	40
38	62	Low	WM	1	92	5	Typic Calciaquoll	42	42
54	39	Low	WM	1	92	1	Typic Calciaquoll	190	215
54	39	Low	WM	1	92	2	Typic Calciaquoll	170	220
54	39	Low	WM	1	92	3	Typic Calciaquoll	180	270
54	39	Low	WM	1	92	4	Typic Calciaquoll	180	230
54	39	Low	WM	1	92	5	Typic Calciaquoll	150	240
59	42	Low	WM	1	92	1	Cumulic (Calc) Endoaquoll	60	62
59	42	Low	WM	1	92	2	Typic (Calc) Endoaquoll	72	70
59	42	Low	WM	1	92	3	Typic (Calc) Endoaquoll	88	82
59	42	Low	WM	1	92	4	Typic (Calc) Endoaquoll	68	62
59	42	Low	WM	1	92	5	Typic Calciaquoll	82	50
59	42	Low	WM	2	92	1	Typic Calciaquoll	50	46
59	42	Low	WM	2	92	2	Typic Calciaquoll	70	66
59	42	Low	WM	2	92	3	Typic Calciaquoll	70	66
59	42	Low	WM	2	92	4	Typic Calciaquoll	54	54
59	42	Low	WM	2	92	5	Typic Calciaquoll	68	54
59	42	Low	SM	3	92	1	Typic (Calc) Endoaquoll	80	78
59	42	Low	SM	3	92	2	Typic (Calc) Endoaquoll	90	88
59	42	Low	SM	3	92	3	Typic (Calc) Endoaquoll	64	60
59	42	Low	SM	3	92	4	Typic Calciaquoll	86	80
59	42	Low	SM	3	92	5	Typic (Calc) Endoaquoll	100	100

59	42	Low	DM	4	92	1	Cumulic (Calc) Endoaquoll	115	100
59	42	Low	DM	4	92	2	Typic Calciaquoll	76	70
59	42	Low	DM	4	92	3	Typic Calciaquoll	92	84
59	42	Low	DM	4	92	4	Typic Calciaquoll	90	80
59	42	Low	DM	4	92	5	Typic Calciaquoll	96	110
59	111	High	WM	1	92	1	Typic Calciaquoll	120	90
59	111	High	WM	1	92	2	Typic Calciaquoll	70	60
59	111	High	WM	1	92	3	Typic Calciaquoll	74	68
59	111	High	WM	1	92	4	Aeric Fluvaquent	70	60
59	111	High	WM	1	92	5	Aeric Fluvaquent	52	50
59	111	High	SM	2	92	1	Typic Calciaquoll	90	62
59	111	High	SM	2	92	2	Aeric Calciaquoll	70	80
59	111	High	SM	2	92	3	Aeric Calciaquoll	68	70
59	111	High	SM	2	92	4	Aeric Calciaquoll	80	62
59	111	High	SM	2	92	5	Aeric Calciaquoll	72	44
60	58	High	WM	1	92	1	Typic Calciaquoll	76	30
60	58	High	WM	1	92	2	Cumulic (Calc) Endoaquoll	48	40
60	58	High	WM	1	92	3	Typic Calciaquoll	46	40
60	58	High	WM	1	92	4	Typic Calciaquoll	50	46
60	58	High	WM	1	92	5	Typic Calciaquoll	52	45
60	58	High	SM	2	92	1	Typic Calciaquoll	54	49
60	58	High	SM	2	92	2	Cumulic (Calc) Endoaquoll	66	58
60	58	High	SM	2	92	3	Cumulic (Calc) Endoaquoll	34	30
60	58	High	SM	2	92	4	Cumulic (Calc) Endoaquoll	86	70
60	58	High	SM	2	92	5	Cumulic (Calc) Endoaquoll	84	56
60	128	High	WM	1	92	1	Aeric Calciaquoll	20	18
60	128	High	WM	1	92	2	Cumulic (Calc) Endoaquoll	30	24
60	128	High	WM	1	92	3	Cumulic (Calc) Endoaquoll	62	38
60	128	High	WM	1	92	4	Cumulic (Calc) Endoaquoll	54	38

60	128	High	WM	1	92	5	Cumulic (Calc) Endoaquoll	52	34
73	29	High	WM	1	92	1	Typic Psammaquent	20	18
73	29	High	WM	1	92	2	Typic Psammaquent	23	22
73	29	High	WM	1	92	3	Typic Psammaquent	48	32
73	29	High	WM	1	92	4	Typic Psammaquent	40	30
73	29	High	WM	1	92	5	Typic Psammaquent	44	36
73	29	High	WM	1	93	1	Typic Psammaquent		
73	29	High	WM	1	93	2	Typic Psammaquent		
73	29	High	WM	1	93	4	Typic Psammaquent		
73	29	High	SM	2	92	1	Typic Psammaquent	46	30
73	29	High	SM	2	92	2	Typic Psammaquent	80	115
73	29	High	SM	2	92	3	Typic Psammaquent	140	125
73	29	High	SM	2	92	4	Typic Psammaquent	125	120
73	29	High	SM	2	92	5	Typic Psammaquent	105	95
73	29	High	SM	2	93	1	Typic Psammaquent		
73	29	High	SM	2	93	2	Typic Psammaquent		
73	29	High	SM	2	93	4	Typic Psammaquent		
73	29	High	DM	3	92	1	Typic Calciaquoll	flood	
73	29	High	DM	3	92	2	Typic Calciaquoll	flood	
73	29	High	DM	3	92	3	Typic Calciaquoll	flood	
73	29	High	DM	3	92	4	Typic Calciaquoll	flood	
73	29	High	DM	3	92	5	Typic Calciaquoll	flood	
73	29	High	DM	3	93	1	Typic Calciaquoll		
73	29	High	DM	3	93	2	Typic Calciaquoll		
73	29	High	DM	3	93	4	Typic Calciaquoll		
73	29	High	DM	4	92	1	Typic Calciaquoll	flood	
73	29	High	DM	4	92	2	Typic Calciaquoll	flood	
73	29	High	DM	4	92	3	Typic Calciaquoll	flood	
73	29	High	DM	4	92	4	Typic Calciaquoll	flood	

73	29	High	DM	4	92	5	Typic Calciaquoll	flood	
73	29	High	DM	4	93	1	Typic Calciaquoll		
73	29	High	DM	4	93	2	Typic Calciaquoll		
73	29	High	DM	4	93	4	Typic Calciaquoll		
73	86	High	WM	1	92	1	Typic Calciaquoll	28	36
73	86	High	WM	1	92	2	Typic Calciaquoll	40	54
73	86	High	WM	1	92	3	Typic Calciaquoll	46	56
73	86	High	WM	1	92	4	Typic Calciaquoll	46	52
73	86	High	WM	1	92	5	Typic Calciaquoll	58	62
73	86	High	WM	1	93	1	Typic Calciaquoll		
73	86	High	WM	1	93	2	Typic Calciaquoll		
73	86	High	WM	1	93	4	Typic Calciaquoll		
133	370	Low	WM	1	93	1	Typic Argiaquoll		
133	370	Low	WM	1	93	2	Typic Argiaquoll		
133	370	Low	WM	1	93	4	Typic Argiaquoll		
133	370	Low	SM	2	93	1	Typic Argiaquoll		
133	370	Low	SM	2	93	2	Typic Argiaquoll		
133	370	Low	SM	2	93	4	Typic Argiaquoll		
133	380	Low	WM	1	93	1	Typic Argiaquoll		
133	380	Low	WM	1	93	2	Typic Argiaquoll		
133	380	Low	WM	1	93	4	Aeric Calciaquoll		
133	380	Low	SM	2	93	1	Typic Argiaquoll		
133	380	Low	SM	2	93	2	Typic Argiaquoll		
133	380	Low	SM	2	93	4	Typic Argiaquoll		
133	386	High	WM	1	93	1	Typic Argiaquoll		
133	386	High	WM	1	93	2	Typic Argiaquoll		
133	386	High	WM	1	93	4	Typic Argiaquoll		
133	386	High	SM	2	93	1	Typic Argiaquoll		
133	386	High	SM	2	93	2	Typic Argiaquoll		

133	386	High	SM	2	93	4	Typic Argiaquoll		
134	140	Low	SM	1	92	1	Typic Endoaquoll	42	28
134	140	Low	SM	1	92	2	Typic Calciaquoll	30	20
134	140	Low	SM	1	92	3	Typic Calciaquoll	40	26
134	140	Low	SM	1	92	4	Typic Endoaquoll	52	34
134	140	Low	SM	1	92	5	Typic Calciaquoll	40	22
134	140	Low	SM	2	92	1	Typic Endoaquoll	75	60
134	140	Low	SM	2	92	2	Typic Endoaquoll	78	60
134	140	Low	SM	2	92	3	Cumulic (Calc) Endoaquoll	70	56
134	140	Low	SM	2	92	4	Cumulic (Calc) Endoaquoll	70	56
134	140	Low	SM	2	92	5	Cumulic (Calc) Endoaquoll	74	60
134	140	Low	SM	1	93	1	Typic Argiaquoll		
134	140	Low	SM	1	93	2	Typic Calciaquoll		
134	140	Low	SM	1	93	4	Typic Calciaquoll		
134	140	Low	SM	2	93	1	Typic Argiaquoll		
134	140	Low	SM	2	93	2	Typic Argiaquoll		
134	140	Low	SM	2	93	4	Typic Argiaquoll		
134	158	Low	WM	1	93	1	Typic Calciaquoll		
134	158	Low	WM	1	93	2	Typic Calciaquoll		
134	158	Low	WM	1	93	3	Typic Calciaquoll		
134	165	Low	SM	1	92	1	Cumulic (Calc) Endoaquoll	40	26
134	165	Low	SM	1	92	2	Cumulic (Calc) Endoaquoll	42	28
134	165	Low	SM	1	92	3	Cumulic (Calc) Endoaquoll	40	24
134	165	Low	SM	1	92	4	Cumulic (Calc) Endoaquoll	44	30
134	165	Low	SM	1	92	5	Cumulic (Calc) Endoaquoll	42	28
134	165	Low	WM	1	93	1	Typic Calciaquoll		
134	165	Low	WM	1	93	2	Aeric Calciaquoll		
134	165	Low	WM	1	93	4	Typic Calciaquoll		
134	165	Low	SM	2	93	1	Cumulic (Calc) Endoaquoll		

134	165	Low	SM	2	93	2	Cumulic (Calc) Endoaquoll		
134	165	Low	SM	2	93	4	Cumulic (Calc) Endoaquoll		
134	270	Low	WM	1	92	1	Typic Calciaquoll	52	48
134	270	Low	WM	1	92	2	Typic Calciaquoll	48	50
134	270	Low	WM	1	92	3	Typic Calciaquoll	52	50
134	270	Low	WM	1	92	4	Typic Calciaquoll	50	50
134	270	Low	WM	1	92	5	Typic Calciaquoll	50	50
134	270	Low	WM	1	93	1	Typic Calciaquoll		
134	270	Low	WM	1	93	2	Typic Calciaquoll		
134	270	Low	WM	1	93	4	Typic Calciaquoll		
134	272	Low	WM	1	92	1	Typic Calciaquoll	68	54
134	272	Low	WM	1	92	2	Typic Calciaquoll	86	78
134	272	Low	WM	1	92	3	Typic Calciaquoll	84	66
134	272	Low	WM	1	92	4	Typic Calciaquoll	76	60
134	272	Low	WM	1	92	5	Typic Calciaquoll	78	60
134	406	Low	WM	1	92	1	Typic Calciaquoll	48	32
134	406	Low	WM	1	92	2	Typic Calciaquoll	45	30
134	406	Low	WM	1	92	3	Typic Calciaquoll	42	28
134	406	Low	WM	1	92	4	Typic Calciaquoll	40	26
134	406	Low	WM	1	92	5	Typic Calciaquoll	35	20
134	406	Low	WM	1	93	1			
134	406	Low	WM	1	93	2			
134	406	Low	WM	1	93	4			
134	406	Low	SM	2	92	1	Cumulic Calciaquoll	flood	
134	406	Low	SM	2	92	2	Cumulic Calciaquoll	flood	
134	406	Low	SM	2	92	3	Cumulic Calciaquoll	flood	
134	406	Low	SM	2	92	4	Cumulic Calciaquoll	flood	
134	406	Low	SM	2	92	5	Cumulic Calciaquoll	flood	
134	406	Low	SM	2	93	1	Typic Calciaquoll		

134	406	Low	SM	2	93	2	Typic Calciaquoll		
134	406	Low	SM	2	93	4	Typic Calciaquoll		
134	406	Low	DM	3	93	1	Typic Calciaquoll		
134	406	Low	DM	3	93	2	Typic Calciaquoll		
134	406	Low	DM	3	93	4	Typic Calciaquoll		
134	432	Low	WM	1	92	1	Aeric Calciaquoll	46	30
134	432	Low	WM	1	92	2	Typic Calciaquoll	3	26
134	432	Low	WM	1	92	3	Aeric Calciaquoll	10	22
134	432	Low	WM	1	92	4	Typic Calciaquoll	32	26
134	432	Low	WM	1	92	5	Typic Calciaquoll	30	28
134	432	Low	WM	1	93	1	Typic Argiaquoll		
134	432	Low	WM	1	93	2	Typic Calciaquoll		
134	432	Low	WM	1	93	4	Typic Calciaquoll		
156	22	High	WM	1	92	1	Cumulic Endoaquoll	34	24
156	22	High	WM	1	92	2	Cumulic Endoaquoll	36	34
156	22	High	WM	1	92	3	Typic Calciaquoll	46	34
156	22	High	WM	1	92	4	Typic Argiaquoll	59	44
156	22	High	WM	1	92	5	Typic Argiaquoll	49	35
156	22	High	WM	1	93	1	Typic Argiaquoll		
156	22	High	WM	1	93	2	Typic Argiaquoll		
156	22	High	WM	1	93	4	Typic Argiaquoll		
156	22	High	SM	2	92	1	Cumulic (Calc) Endoaquoll	76	53
156	22	High	SM	2	92	2	Cumulic (Calc) Endoaquoll	86	58
156	22	High	SM	2	92	3	Cumulic (Calc) Endoaquoll	92	62
156	22	High	SM	2	92	4	Cumulic (Calc) Endoaquoll	90	70
156	22	High	SM	2	92	5	Cumulic (Calc) Endoaquoll	88	62
156	22	High	SM	2	93	1	Cumulic Endoaquoll		
156	22	High	SM	2	93	2	Cumulic Endoaquoll		
156	22	High	SM	2	93	3	Cumulic Endoaquoll		

156	24	High	WM	1	92	1	Typic Argiaquoll	22	18
156	24	High	WM	1	92	2	Typic Argiaquoll	40	38
156	24	High	WM	1	92	3	Typic Argiaquoll	38	24
156	24	High	WM	1	92	4	Typic Argiaquoll	49	35
156	24	High	WM	1	92	5	Typic Argiaquoll	56	40
156	24	High	WM	1	93	1	Typic Argiaquoll		
156	24	High	WM	1	93	2	Typic Argiaquoll		
156	24	High	WM	1	93	4	Typic Argiaquoll		
156	26	High	WM	1	92	1	Typic Epiaquent	54	44
156	26	High	WM	1	92	2	Typic Epiaquent	49	40
156	26	High	WM	1	92	3	Typic Epiaquent	76	52
156	26	High	WM	1	92	4	Typic Epiaquent	74	60
156	26	High	WM	1	92	5	Typic Epiaquent	86	62
156	26	High	WM	1	93	1	Typic Epiaquent		
156	26	High	WM	1	93	2	Typic Epiaquent		
156	26	High	WM	1	93	4	Typic Epiaquent		
156	42	High	WM	1	92	1	Typic Endoaquoll	52	30
156	42	High	WM	1	92	2	Typic Endoaquoll	66	36
156	42	High	WM	1	92	3	Typic Endoaquoll	86	44
156	42	High	WM	1	92	4	Typic Endoaquoll	72	50
156	42	High	WM	1	92	5	Typic Endoaquoll	54	40
156	42	High	WM	1	93	1	Typic Calciaquoll		
156	42	High	WM	1	93	2	Typic Calciaquoll		
156	42	High	WM	1	93	4	Typic Calciaquoll		
241	3	Low	DM	1	92	1	Cumulic (Calc) Endoaquoll	flood	
241	3	Low	DM	1	92	2	Cumulic (Calc) Endoaquoll	flood	
241	3	Low	DM	1	92	3	Cumulic (Calc) Endoaquoll	flood	
241	3	Low	DM	1	92	4	Cumulic (Calc) Endoaquoll	flood	
241	3	Low	DM	1	92	5	Cumulic (Calc) Endoaquoll	flood	

241	3	Low	SM	2	92	1	Cumulic (Calc) Endoaquoll	flood	
241	3	Low	SM	2	92	2	Cumulic (Calc) Endoaquoll	flood	
241	3	Low	SM	2	92	3	Typic (Calc) Endoaquoll	flood	
241	3	Low	SM	2	92	4	Cumulic (Calc) Endoaquoll	flood	
241	3	Low	SM	2	92	5	Typic (Calc) Endoaquoll	flood	
241	3	Low	WM	3	92	1	Cumulic (Calc) Endoaquoll	flood	
241	3	Low	WM	3	92	2	Cumulic (Calc) Endoaquoll	flood	
241	3	Low	WM	3	92	3	Typic (Calc) Endoaquoll	flood	
241	3	Low	WM	3	92	4	Cumulic (Calc) Endoaquoll	flood	
241	3	Low	WM	3	92	5	Typic (Calc) Endoaquoll	flood	
241	3	Low	WM	4	92	1	Aeric Calciaquoll	flood	
241	3	Low	WM	4	92	2	Typic (Calc) Endoaquoll	flood	
241	3	Low	WM	4	92	3	Typic (Calc) Endoaquoll	flood	
241	3	Low	WM	4	92	4	Cumulic (Calc) Endoaquoll	flood	
241	3	Low	WM	4	92	5	Cumulic (Calc) Endoaquoll	flood	
241	48	Low	WM	1	92	1	Aeric Calciaquoll	95	90
241	48	Low	WM	1	92	2	Aeric Calciaquoll	300	340
241	48	Low	WM	1	92	3	Aeric Calciaquoll	98	96
241	48	Low	WM	1	92	4	Aeric Calciaquoll	98	96
241	48	Low	WM	1	92	5	Typic Calciaquoll	94	92
241	48	Low	WM	2	92	1	Cumulic (Calc) Endoaquoll	94	90
241	48	Low	WM	2	92	2	Typic (Calc) Endoaquoll	flood	
241	48	Low	WM	2	92	3	Typic (Calc) Endoaquoll	flood	
241	48	Low	WM	2	92	4	Typic (Calc) Endoaquoll	flood	
241	48	Low	WM	2	92	5	Typic (Calc) Endoaquoll	flood	
246	34	Low	WM	1	92	1	Typic Calciaquoll	60	50
246	34	Low	WM	1	92	2	Typic Calciaquoll	56	45
246	34	Low	WM	1	92	3	Typic Endoaquoll	56	43
246	34	Low	WM	1	92	4	Typic Endoaquoll	49	40

246	34	Low	WM	1	92	5	Typic Calciaquoll	62	46
246	37	Low	WM	1	92	1	Cumulic Endoaquoll	55	50
246	37	Low	WM	1	92	2	Cumulic Endoaquoll	58	50
246	37	Low	WM	1	92	3	Cumulic Endoaquoll	57	50
246	37	Low	WM	1	92	4	Cumulic Endoaquoll	58	50
246	37	Low	WM	1	92	5	Cumulic Endoaquoll	54	40
246	53	Low	DM	1	92	1	Cumulic Endoaquoll	Flood	
246	53	Low	DM	1	92	2	Cumulic Endoaquoll	Flood	
246	53	Low	DM	1	92	3	Cumulic Endoaquoll	Flood	
246	53	Low	DM	1	92	4	Cumulic Endoaquoll	Flood	
246	53	Low	DM	1	92	5	Cumulic Endoaquoll	Flood	
246	53	Low	SM	2	92	1	Cumulic Endoaquoll	Flood	
246	53	Low	SM	2	92	2	Typic Endoaquoll	Flood	
246	53	Low	SM	2	92	3	Typic Endoaquoll	Flood	
246	53	Low	SM	2	92	4	Typic Endoaquoll	Flood	
246	53	Low	SM	2	92	5	Cumulic Endoaquoll	Flood	
249	50	Low	SM	2	92	1	Cumulic Endoaquoll	Flood	
249	50	Low	SM	2	92	2	Cumulic Endoaquoll	Flood	
249	50	Low	SM	2	92	3	Typic Endoaquoll	Flood	
249	50	Low	SM	2	92	4	Cumulic Endoaquoll	Flood	
249	50	Low	SM	2	92	5	Cumulic Endoaquoll	Flood	
249	50	Low	WM	1	92	1			
249	50	Low	WM	1	92	2			
249	50	Low	WM	1	92	3			
249	50	Low	WM	1	92	4			
249	50	Low	WM	1	92	5			
249	86	Low	WM	1	92	1	Typic Endoaquoll	Flood	
249	86	Low	WM	1	92	2	Cumulic Endoaquoll	Flood	
249	86	Low	WM	1	92	3	Cumulic Endoaquoll	Flood	

249	86	Low	WM	1	92	4	Cumulic Endoaquoll	Flood	
249	86	Low	WM	1	92	5	Cumulic Endoaquoll	Flood	
249	86	Low	SM	2	92	1	Cumulic Endoaquoll	Flood	
249	86	Low	SM	2	92	2	Cumulic Endoaquoll	Flood	
249	86	Low	SM	2	92	3	Cumulic Endoaquoll	Flood	
249	86	Low	SM	2	92	4	Cumulic Endoaquoll	Flood	
249	86	Low	SM	2	92	5	Cumulic Endoaquoll	Flood	
327	72	Low	WM	1	93	1	Typic Calciaquoll		
327	72	Low	WM	1	93	2	Typic Calciaquoll		
327	72	Low	WM	1	93	4	Typic Calciaquoll		
327	72	Low	SM	2	93	1	Cumulic Endoaquoll		
327	72	Low	SM	2	93	2	Cumulic Endoaquoll		
327	72	Low	SM	2	93	4	Cumulic Endoaquoll		
327	117	Low	WM	1	93	1	Typic Calciaquoll		
327	117	Low	WM	1	93	2	Typic Epiaquoll		
327	117	Low	WM	1	93	4	Typic Epiaquoll		
327	117	Low	WM	2	93	1	Typic Argiaquoll		
327	117	Low	WM	2	93	2	Typic Argiaquoll		
327	117	Low	WM	2	93	4	Typic Epiaquoll		
327	117	Low	SM	3	93	1	Typic Calciaquoll		
327	117	Low	SM	3	93	2	Typic Calciaquoll		
327	117	Low	SM	3	93	4	Typic Calciaquoll		
327	147	Low	WM	1	93	1	Typic Endoaquoll		
327	147	Low	WM	1	93	2	Typic Endoaquoll		
327	147	Low	WM	1	93	4	Typic Endoaquoll		
327	147	Low	SM	2	93	1	Typic Argiaquoll		
327	147	Low	SM	2	93	2	Typic Argiaquoll		
327	147	Low	SM	2	93	4	Typic Argiaquoll		
363	22	High	WM	1	92	1	Typic Endoaquoll	Flood	

363	22	High	WM	1	92	2	Typic Endoaquoll	Flood	
363	22	High	WM	1	92	3	Cumulic (Calc) Endoaquoll	Flood	
363	22	High	WM	1	92	4	Cumulic (Calc) Endoaquoll	Flood	
363	22	High	WM	1	92	5	Cumulic (Calc) Endoaquoll	Flood	
363	22	High	WM	1	93	1	Cumulic (Calc) Endoaquoll		
363	22	High	WM	1	93	2	Cumulic (Calc) Endoaquoll		
363	22	High	WM	1	93	4	Cumulic (Calc) Endoaquoll		
363	22	High	DM	3	92	1	Typic Endoaquoll	Flood	
363	22	High	DM	3	92	2	Typic Endoaquoll	Flood	
363	22	High	DM	3	92	3	Cumulic Endoaquoll	Flood	
363	22	High	DM	3	92	4	Typic Endoaquoll	Flood	
363	22	High	DM	3	92	5	Typic Endoaquoll	Flood	
363	22	High	DM	3	93	1	Cumulic Endoaquoll		
363	22	High	DM	3	93	2	Cumulic Endoaquoll		
363	22	High	DM	3	93	3	Cumulic Endoaquoll		
363	58	High	WM	1	92	1	Typic Calciaquoll	140	160
363	58	High	WM	1	92	2	Cumulic Endoaquoll	135	140
363	58	High	WM	1	92	3	Cumulic Endoaquoll	130	140
363	58	High	WM	1	92	4	Typic Endoaquoll	100	120
363	58	High	WM	1	92	5	Cumulic Endoaquoll	120	110
363	58	High	SM	2	92	1	Cumulic Endoaquoll	Flood	
363	58	High	SM	2	92	2	Cumulic Endoaquoll	Flood	
363	58	High	SM	2	92	3	Cumulic Endoaquoll	Flood	
363	58	High	SM	2	92	4	Cumulic Endoaquoll	Flood	
363	58	High	SM	2	92	5	Cumulic Endoaquoll	Flood	
363	58	High	WM	1	93	1	Aeric Calciaquoll		
363	58	High	WM	1	93	2	Aeric Calciaquoll		
363	58	High	WM	1	93	4	Typic Calciaquoll		
363	58	High	WM	2	93	1	Typic Argiaquoll		

363	58	High	WM	2	93	2	Typic Argiaquoll		
363	58	High	WM	2	93	4	Typic Argiaquoll		
374	65	High	WM	1	92	1	Typic Calciaquoll	Flood	
374	65	High	WM	1	92	2	Typic Calciaquoll	Flood	
374	65	High	WM	1	92	3	Typic Calciaquoll	Flood	
374	65	High	WM	1	92	4	Cumulic (Calc) Endoaquoll	Flood	
374	65	High	WM	1	92	5	Cumulic (Calc) Endoaquoll	Flood	
374	65	High	WM	1	93	1	Typic Argiaquoll		
374	65	High	WM	1	93	2	Typic Argiaquoll		
374	65	High	WM	1	93	4	Typic Calciaquoll		
374	100	High	WM	1	92	1	Typic Endoaquoll	Flood	
374	100	High	WM	1	92	2	Typic Endoaquoll	Flood	
374	100	High	WM	1	92	3	Typic Endoaquoll	Flood	
374	100	High	WM	1	92	4	Typic Calciaquoll	Flood	
374	100	High	WM	1	92	5	Typic Calciaquoll	Flood	
374	100	High	WM	1	93	1	Typic Calciaquoll		
374	100	High	WM	1	93	2	Cumulic (Calc) Endoaquoll		
374	100	High	WM	1	93	4	Typic Calciaquoll		
374	100	High	SM	2	92	1	Typic Endoaquoll	Flood	
374	100	High	SM	2	92	2	Typic Endoaquoll	Flood	
374	100	High	SM	2	92	3	Typic Endoaquoll	Flood	
374	100	High	SM	2	92	4	Typic Endoaquoll	Flood	
374	100	High	SM	2	92	5	Typic Endoaquoll	Flood	
374	100	High	SM	2	93	1	Cumulic Endoaquoll		
374	100	High	SM	2	93	2	Cumulic Endoaquoll		
374	100	High	SM	2	93	4	Cumulic Endoaquoll		
374	100	High	DM	3	92	1	Typic Endoaquoll	Flood	
374	100	High	DM	3	92	2	Typic Endoaquoll	Flood	
374	100	High	DM	3	92	3	Typic Endoaquoll	Flood	

374	100	High	DM	3	92	4	Typic Endoaquoll	Flood	
374	100	High	DM	3	92	5	Typic Endoaquoll	Flood	
374	100	High	DM	3	93	1	Cumulic Endoaquoll		
374	100	High	DM	3	93	2	Cumulic Endoaquoll		
374	100	High	DM	3	93	3	Cumulic Endoaquoll		
374	225	High	WM	1	92	1	Typic Calciaquoll	Flood	
374	225	High	WM	1	92	2	Typic Calciaquoll	Flood	
374	225	High	WM	1	92	3	Typic Calciaquoll	Flood	
374	225	High	WM	1	92	4	Cumulic (Calc) Endoaquoll	Flood	
374	225	High	WM	1	92	5	Typic Fluvaquent	Flood	
374	225	High	WM	1	93	1	Aeric Calciaquoll		
374	225	High	WM	1	93	2	Typic Calciaquoll		
374	225	High	WM	1	93	4	Cumulic Endoaquoll		
374	225	High	SM	2	92	1	Cumulic (Calc) Endoaquent	Flood	
374	225	High	SM	2	92	2	Typic Endoaquoll	Flood	
374	225	High	SM	2	92	3	Typic Endoaquoll	Flood	
374	225	High	SM	2	92	4	Cumulic Endoaquoll	Flood	
374	225	High	SM	2	92	5	Typic Endoaquoll	Flood	
374	225	High	SM	2	93	1	Cumulic Endoaquoll		
374	225	High	SM	2	93	2	Cumulic Endoaquoll		
374	225	High	SM	2	93	4	Cumulic Endoaquoll		
374	225	High	SM	3	93	1	Cumulic Endoaquoll		
374	225	High	SM	3	93	2	Cumulic Endoaquoll		
374	225	High	SM	3	93	4	Cumulic Endoaquoll		
374	225	High	DM	3	92	1	Typic Endoaquoll	Flood	
374	225	High	DM	3	92	2	Typic Endoaquoll	Flood	
374	225	High	DM	3	92	3	Typic Endoaquoll	Flood	
374	225	High	DM	3	92	4	Typic Endoaquoll	Flood	
374	225	High	DM	3	92	5	Typic Endoaquoll	Flood	

374	225	High	DM	4	93	1	Typic Endoaquoll		
374	225	High	DM	4	93	2	Typic Endoaquoll		
374	225	High	DM	4	93	4	Typic Endoaquoll		
374	272	High	WM	1	92	1	Cumulic (Calc) Endoaquoll	Flood	
374	272	High	WM	1	92	2	Cumulic (Calc) Endoaquoll	Flood	
374	272	High	WM	1	92	3	Typic Calciaquoll	Flood	
374	272	High	WM	1	92	4	Typic Calciaquoll	Flood	
374	272	High	WM	1	92	5	Typic Calciaquoll	Flood	
374	272	High	WM	2	92	1	Cumulic Endoaquoll	Flood	
374	272	High	WM	2	92	2	Cumulic Endoaquoll	Flood	
374	272	High	WM	2	92	3	Typic Endoaquoll	Flood	
374	272	High	WM	2	92	4	Cumulic (Calc) Endoaquoll	Flood	
374	272	High	WM	2	92	5	Cumulic (Calc) Endoaquoll	Flood	
374	272	High	WM	1	93	1	Cumulic (Calc) Endoaquoll		
374	272	High	WM	1	93	2	Cumulic (Calc) Endoaquoll		
374	272	High	WM	1	93	4	Cumulic (Calc) Endoaquoll		
374	272	High	WM	2	93	1	Cumulic Endoaquoll		
374	272	High	WM	2	93	2	Cumulic Endoaquoll		
374	272	High	WM	2	93	4	Cumulic Endoaquoll		
396	106	High	WM	1	92	1	Pachic Udic Haploboroll	42	30
396	106	High	WM	1	92	2	Typic Haploboroll	28	24
396	106	High	WM	1	92	3	Pachic Udic Haploboroll	37	32
396	106	High	WM	1	92	4	Typic Haploboroll	29	23
396	106	High	WM	1	92	5	Typic Haploboroll	29	20
396	107	High	WM	1	92	1	Typic Haploboroll	25	21
396	107	High	WM	1	92	2	Typic Haploboroll	23	21
396	107	High	WM	1	92	3	Typic Haploboroll	24	20
396	107	High	WM	1	92	4	Typic Haploboroll	23	18
396	107	High	WM	1	92	5	Typic Haploboroll	22	19

396	130	High	SM	1	92	1	Cumulic Endoaquoll	48	34
396	130	High	SM	1	92	2	Typic Endoaquoll	50	39
396	130	High	SM	1	92	3	Cumulic Endoaquoll	51	38
396	130	High	SM	1	92	4	Typic Endoaquoll	58	42
396	130	High	SM	1	92	5	Cumulic Endoaquoll	46	36
396	130	High	WM	2	92	1	Typic Endoaquoll	27	16
396	130	High	WM	2	92	2	Cumulic Endoaquoll	35	26
396	130	High	WM	2	92	3	Cumulic Endoaquoll	35	25
396	130	High	WM	2	92	4	Cumulic Endoaquoll	34	21
396	130	High	WM	2	92	5	Cumulic Endoaquoll	48	34
407	67	High	WM	1	93	1	Typic Argiaquoll		
407	67	High	WM	1	93	2	Typic Argiaquoll		
407	67	High	WM	1	93	4	Typic Argiaquoll		
407	109	High	WM	1	93	1	Typic Argiaquoll		
407	109	High	WM	1	93	2	Typic Argiaquoll		
407	109	High	WM	1	93	4	Typic Argiaquoll		
407	168	High	WM	1	93	1	Typic Psammaquent		
407	168	High	WM	1	93	2	Typic Psammaquent		
407	168	High	WM	1	93	4	Typic Epiaquent		
407	168	High	SM	2	93	1	Typic Calciaquoll		
407	168	High	SM	2	93	2	Typic Calciaquoll		
407	168	High	SM	2	93	4	Typic Calciaquoll		
407	168	High	DM	3	93	1	Cumulic (Calc) Endoaquoll		
407	168	High	DM	3	93	2	Cumulic (Calc) Endoaquoll		
407	168	High	DM	3	93	4	Cumulic (Calc) Endoaquoll		
442	93	High	WM	1	92	1	Mollic Fluvaquent	30	16
442	93	High	WM	1	92	2	Typic Fluvaquent	24	16
442	93	High	WM	1	92	3	Mollic Fluvaquent	38	20
442	93	High	WM	1	92	4	Typic Fluvaquent	46	28

442	93	High	WM	1	92	5	Typic Fluvaquent	26	16
442	93	High	WM	1	93	1	Typic Argiaquoll		
442	93	High	WM	1	93	2	Typic Fluvaquent		
442	93	High	WM	1	93	4	Typic Argiaquoll		
442	93	High	SM	2	92	1	Typic Argiaquoll	40	22
442	93	High	SM	2	92	2	Typic Argiaquoll	53	36
442	93	High	SM	2	92	3	Typic Argiaquoll	46	30
442	93	High	SM	2	92	4	Typic Argiaquoll	50	30
442	93	High	SM	2	92	5	Typic Argiaquoll	46	28
442	93	High	SM	2	93	1	Typic Argiaquoll		
442	93	High	SM	2	93	2	Typic Argiaquoll		
442	93	High	SM	2	93	4	Typic Argiaquoll		
442	260	Low	WM	1	92	1	Typic Calciaquoll	34	28
442	260	Low	WM	1	92	2	Typic Calciaquoll	46	32
442	260	Low	WM	1	92	3	Typic Calciaquoll	64	50
442	260	Low	WM	1	92	4	Typic Calciaquoll	70	50
442	260	Low	WM	1	92	5	Typic Calciaquoll	64	44
442	260	Low	WM	1	93	1	Typic Epiaquoll		
442	260	Low	WM	1	93	2	Typic Epiaquoll		
442	260	Low	WM	1	93	4	Typic Epiaquoll		
442	261	Low	WM	1	92	1	Typic Argiaquoll	60	42
442	261	Low	WM	1	92	2	Typic Argiaquoll	62	50
442	261	Low	WM	1	92	3	Typic Argiaquoll	58	44
442	261	Low	WM	1	92	4	Typic Argiaquoll	50	34
442	261	Low	WM	1	92	5	Typic Argiaquoll	44	32
442	261	Low	WM	1	93	1	Typic Epiaquent		
442	261	Low	WM	1	93	2	Typic Epiaquent		
442	261	Low	WM	1	93	4	Typic Epiaquent		
442	281	Low	WM	1	92	1	Typic Argiaquoll	42	20

442	281	Low	WM	1	92	2	Typic Argiaquoll	54	30
442	281	Low	WM	1	92	3	Typic Argiaquoll	48	26
442	281	Low	WM	1	92	4	Typic Argiaquoll	40	20
442	281	Low	WM	1	92	5	Typic Argiaquoll	38	20
442	281	Low	WM	1	93	1	Typic Epiaquoll		
442	281	Low	WM	1	93	2	Typic Epiaquoll		
442	281	Low	WM	1	93	4	Typic Epiaquoll		
442	281	Low	SM	2	92	1	Cumulic Endoaquoll	64	40
442	281	Low	SM	2	92	2	Cumulic Endoaquoll	68	40
442	281	Low	SM	2	92	3	Cumulic Endoaquoll	68	43
442	281	Low	SM	2	92	4	Cumulic Endoaquoll	68	38
442	281	Low	SM	2	92	5	Cumulic Endoaquoll	56	30
442	281	Low	SM	2	93	1	Typic Epiaquoll		
442	281	Low	SM	2	93	2	Typic Epiaquoll		
442	281	Low	SM	2	93	4	Typic Epiaquoll		
442	295	Low	WM	1	92	1	Cumulic Endoaquoll	Flood	
442	295	Low	WM	1	92	2	Cumulic Endoaquoll	Flood	
442	295	Low	WM	1	92	3	Typic Endoaquoll	Flood	
442	295	Low	WM	1	92	4	Typic Endoaquoll	Flood	
442	295	Low	WM	1	92	5	Typic Endoaquoll	Flood	
442	295	Low	WM	1	93	1	Typic Epiaquoll		
442	295	Low	WM	1	93	2	Typic Calciaquoll		
442	295	Low	WM	1	93	4	Typic Calciaquoll		
442	295	Low	SM	2	92	1	Typic Endoaquoll	Flood	
442	295	Low	SM	2	92	2	Typic Endoaquoll	Flood	
442	295	Low	SM	2	92	3	Typic Endoaquoll	Flood	
442	295	Low	SM	2	92	4	Typic Endoaquoll	Flood	
442	295	Low	SM	2	92	5	Typic Endoaquoll	Flood	
442	295	Low	SM	2	93	1	Typic Epiaquoll		

442	295	Low	SM	2	93	2	Typic Argiaquoll		
442	295	Low	SM	2	93	4	Typic Calciaquoll		
442	295	Low	DM	3	93	1	Typic Endoaquoll		
442	295	Low	DM	3	93	2	Typic Endoaquoll		
442	295	Low	DM	3	93	4	Typic Endoaquoll		
442	301	Low	WM	1	92	1	Typic Calciaquoll	420	300
442	301	Low	WM	1	92	2	Typic Calciaquoll	420	300
442	301	Low	WM	1	92	3	Typic Calciaquoll	340	220
442	301	Low	WM	1	92	4	Typic Calciaquoll	340	240
442	301	Low	WM	1	92	5	Typic Calciaquoll	440	360
442	301	Low	WM	1	93	1	Typic Calciaquoll		
442	301	Low	WM	1	93	2	Typic Calciaquoll		
442	301	Low	WM	1	93	4	Typic Calciaquoll		
442	301	Low	SM	2	92	1	Cumulic (Calc) Endoaquoll	440	320
442	301	Low	SM	2	92	2	Cumulic (Calc) Endoaquoll	340	220
442	301	Low	SM	2	92	3	Cumulic (Calc) Endoaquoll	430	340
442	301	Low	SM	2	92	4	Cumulic (Calc) Endoaquoll	400	320
442	301	Low	SM	2	92	5	Cumulic (Calc) Endoaquoll	340	270
442	301	Low	SM	2	93	1	Cumulic (Calc) Endoaquoll		
442	301	Low	SM	2	93	2	Cumulic (Calc) Endoaquoll		
442	301	Low	SM	2	93	4	Cumulic (Calc) Endoaquoll		
442	301	Low	DM	3	92	1	Cumulic (Calc) Endoaquoll	Flood	
442	301	Low	DM	3	92	2	Cumulic (Calc) Endoaquoll	Flood	
442	301	Low	DM	3	92	3	Cumulic (Calc) Endoaquoll	Flood	
442	301	Low	DM	3	92	4	Cumulic (Calc) Endoaquoll	Flood	
442	301	Low	DM	3	92	5	Cumulic (Calc) Endoaquoll	Flood	
442	301	Low	DM	3	93	1	Cumulic (Calc) Endoaquoll		
442	301	Low	DM	3	93	2	Cumulic (Calc) Endoaquoll		
442	301	Low	DM	3	93	4	Cumulic (Calc) Endoaquoll		

498	146	High	WM	1	93	1	Typic Endoaquoll		
498	146	High	WM	1	93	2	Typic Endoaquoll		
498	146	High	WM	1	93	4	Typic Endoaquoll		
498	146	High	SM	2	93	1	Typic Endoaquoll		
498	146	High	SM	2	93	2	Typic Endoaquoll		
498	146	High	SM	2	93	4	Typic Endoaquoll		
498	146	High	DM	3	93	1	Typic Endoaquoll		
498	146	High	DM	3	93	2	Typic Endoaquoll		
498	146	High	DM	3	93	4	Typic Endoaquoll		
498	227	High	WM	1	93	1	Typic Argiaquoll		
498	227	High	WM	1	93	2	Typic Argiaquoll		
498	227	High	WM	1	93	4	Typic Argiaquoll		
498	277	High	WM	1	93	1	Typic Argiaquoll		
498	277	High	WM	1	93	2	Typic Argiaquoll		
498	277	High	WM	1	93	4	Typic Argiaquoll		
498	277	High	SM	2	93	1	Typic Argiaquoll		
498	277	High	SM	2	93	2	Typic Argiaquoll		
498	277	High	SM	2	93	4	Typic Argiaquoll		
498	277	High	DM	3	93	1	Typic Argiaquoll		
498	277	High	DM	3	93	2	Typic Argiaquoll		
498	277	High	DM	3	93	4	Typic Argiaquoll		

Appendix 7-2

Soil Characterization Data from CWLSA 1992. John Freeland and Jim Richardson, investigators. Abbreviations: WL=wetland, Tran=transect, OM=organic matter, DSD=dry soil density.

WL	Tran	Health	Zone	Midpt. Depth (in)	NO3 g/m³	NaHCO3 ext. P g/m³	% OM	pH	EC micro-mhos	DSD g/cm³	% Sand	% Silt	% Clay
P1	1	H	wm	7.5	4.3	7.6	4.0	7.5	540	0.9	63.0	27.1	9.8
P1	1	H	wm	22.5	2.7	5.3	3.7	7.8	1650	1.21	41.6	35.5	23.0
P1	1	H	wm	32.5	1.8	2.9	2.2	8	3500	1.15	15.9	36.8	47.3
P1	1	H	wm	52.5	1.6	2.4	1.5	8.1	3500	1.2	21.6	33.7	44.7
P1	1	H	sm	7.5	4.7	4.7	2.5	7.6	2500	1.06	60.4	39.6	0.0
P1	1	H	sm	22.5	1.6	2.4	2.1	8.2	3400	1.17	42.2	24.0	33.8
P1	1	H	sm	32.5	1.8	2.4	1.7	8.1	3500	1.08	15.8	33.9	50.3
P1	1	H	sm	52.5	3.7	2.9	1.0	8.1	3300	1.03	5.8	43.4	50.8
P1	1	H	dm	7.5	29.2	7.6	5.2	7.5	2500	0.5	43.1	52.3	4.6
P1	1	H	dm	22.5	7.8	5.9	6.4	7.5	2700	0.84	27.5	64.6	7.9
P1	1	H	dm	32.5	4.5	4.7	6.0	7.6	2800	0.94	25.9	55.6	18.5
P1	1	H	dm	52.5	2.3	2.9	3.4	7.7	2400	1.11	36.5	39.0	24.6
P1	2	H	wm	7.5	4.2	7.1	4.4	7.4	540	1.08	87.3	10.1	2.6
P1	2	H	wm	22.5	1.6	4.7	3.0	7.6	260	1.36	91.5	6.3	2.2
P1	2	H	wm	32.5	1.4	2.9	3.3	7.9	560	1.17	48.3	23.5	28.2
P1	2	H	wm	52.5	1.2	2.4	2.9	7.9	1700	1.09	41.7	29.7	28.5
P1	2	H	sm	7.5	5.2	5.9	5.4	7.4	1800	0.88	72.5	20.9	6.5
P1	2	H	sm	22.5	2.7	4.1	2.7	7.5	1800	1.17	78.0	15.5	6.5
P1	2	H	sm	32.5	1.1	2.9	2.2	7.8	1480	1.33	93.5	5.9	0.6
P1	2	H	sm	52.5	0.8	2.4	1.6	7.8	1430	1.42	94.9	3.8	1.3
P1	2	H	dm	7.5	10	5.9	3.6	7.3	1420	0.68	62.5	35.5	2.0
P1	2	H	dm	22.5	4.7	4.1	3.2	7.3	1790	0.91	81.0	16.3	2.7

P1	2	H	dm	32.5	4	3.5	3.9	7.4	1970	1.07	66.8	29.9	3.3
P1	2	H	dm	52.5	1.5	3.5	3.2	7.6	1700	1.25	77.2	14.9	8.0
P1	3	H	wm	7.5	2.4	5.9	2.9	7.6	300	1.23	87.5	14.1	0.0
P1	3	H	wm	22.5	1.2	3.5	2.2	7.9	230	1.34	89.7	5.7	4.6
P1	3	H	wm	32.5	0.9	2.9	1.8	8	350	1.21	80.6	12.2	7.2
P1	3	H	wm	52.5	1.2	2.4	1.8	8	1000	1.19	73.9	14.4	11.7
P1	3	H	sm	7.5	6.8	4.1	1.8	7.4	1820	0.81	84.4	15.6	0.0
P1	3	H	sm	22.5	2.4	1.8	2.2	7.5	1950	1.03	81.2	14.1	4.7
P1	3	H	sm	32.5	1.1	1.8	2.2	7.8	1900	1.1	89.7	6.4	3.9
P1	3	H	sm	52.5	0.7	2.4	1.8	8	1650	1.23	92.8	5.1	2.1
P1	3	H	dm	7.5	7	5.9	3.7	7.4	520	0.68	70.1	26.2	4.5
P1	3	H	dm	22.5	2.9	4.7	3.0	7.6	500	1.01	72.7	14.2	13.1
P1	3	H	dm	32.5	1.3	2.4	4.0	7.6	520	1.12	80.6	11.6	7.8
P1	3	H	dm	52.5	1.4	3.5	3.3	7.5	1400	1.1	64.7	22.2	13.1
P1	4	H	wm	7.5	2.6	5.9	2.2	7.5	250	1.14	89.6	7.8	2.6
P1	4	H	wm	22.5	1	4.1	2.6	7.6	140	1.42	85.1	11.5	3.4
P1	4	H	wm	32.5	0.7	3.5	2.9	7.9	130	1.37	94.9	4.4	0.6
P1	4	H	wm	52.5	0.8	3.5	5.9	7.9	390	1.31	74.6	14.8	10.6
P1	4	H	sm	7.5	2.4	5.3	2.6	7.3	200	1.21	88.6	11.5	0.6
P1	4	H	sm	22.5	2.7	4.1	2.9	7.6	160	1.44	93.7	5.0	1.3
P1	4	H	sm	32.5	2.1	2.9	2.6	7.9	500	1.44	97.5	2.5	0.0
P1	4	H	sm	52.5	0.9	2.4	2.9	7.9	1960	1.3	81.9	12.8	5.3
P1	4	H	dm	7.5	5	3.5	2.6	7.3	450	0.89	79.3	20.1	0.7
P1	4	H	dm	22.5	2.2	2.9	2.6	7.4	350	1.1	85.2	13.4	1.4
P1	4	H	dm	32.5	1	2.4	2.6	7.6	510	1.31	92.3	6.4	1.3
P1	4	H	dm	52.5	1	2.9	2.6	7.7	460	1.28	86.4	8.9	4.7
P1	5	H	wm	7.5	1.9	4.7	2.6	7.7	250	1.2	91.2	6.9	1.9
P1	5	H	wm	22.5	1.1	4.1	2.2	7.9	260	1.23	88.4	8.4	3.2
P1	5	H	wm	32.5	0.9	2.9	2.6	8.1	1660	1.15	51.4	25.7	22.9

P1	5	H	wm	52.5	1.1	1.8	2.6	8.1	3000	1.13	45.9	28.6	25.5
P1	5	H	sm	7.5	0.9	4.7	2.9	7.5	250	1.13	87.4	12.6	0.0
P1	5	H	sm	22.5	1.1	4.1	2.6	7.9	250	1.29	87.7	9.6	2.7
P1	5	H	sm	32.5	1	2.9	4.8	8	1100	1.25	71.3	18.2	10.5
P1	5	H	sm	52.5	1	1.8	2.2	8	2000	1.13	47.8	25.9	26.3
P1	5	H	dm	7.5	11	4.1	1.8	7.2	2200	0.72	55.9	40.8	3.2
P1	5	H	dm	22.5	2.7	2.4	2.2	7.6	2100	1.06	72.7	18.8	8.5
P1	5	H	dm	32.5	1.2	1.8	4.0	7.9	1900	1.27	72.7	17.5	9.8
P1	5	H	dm	52.5	1.1	1.8	3.3	7.9	1900	1.28	70.0	17.5	12.4
P1	6	H	wm	7.5	2.2	4.7	3.3	7.7	240	1.05	84.5	12.8	2.6
P1	6	H	wm	22.5	1	3.5	2.6	8.1	270	1.29	82.4	11.0	6.6
P1	6	H	wm	32.5	0.9	2.9	2.9	8.1	1130	1.18	49.6	30.0	20.3
P1	6	H	wm	52.5	0.8	2.4	1.8	8.2	2400	1.21	47.8	31.2	21.1
P1	6	H	sm	7.5	3.4	4.1	2.9	7.6	460	1.04	64.7	22.9	12.4
P1	6	H	sm	22.5	1.1	2.4	2.9	8	1200	1.26	68.7	18.9	12.4
P1	6	H	sm	32.5	1.1	1.8	3.3	8.1	2100	1.18	48.6	30.4	21.0
P1	6	H	sm	52.5	1	1.8	1.8	8	2300	1.16	45.9	32.3	21.8
P1	6	H	dm	7.5	8.8	2.9	3.3	7.3	1900	0.75	43.8	51.7	4.5
P1	6	H	dm	22.5	5.4	2.9	3.3	7.5	2000	0.89	52.7	38.0	9.3
P1	6	H	dm	32.5	3.2	2.9	3.7	7.6	1900	1.03	59.0	29.9	11.1
P1	6	H	dm	52.5	1.8	2.4	3.3	7.7	1700	1.24	74.6	15.5	9.9
P1	7	H	wm	7.5	5.1	12.9	4.4	7.5	390	1	80.8	15.3	3.9
P1	7	H	wm	22.5	1.1	3.5	2.2	7.6	150	1.29	95.0	3.7	1.3
P1	7	H	wm	32.5	1	2.4	2.6	7.5	170	1.33	93.6	5.8	0.6
P1	7	H	wm	52.5	1.2	2.4	2.2	7.8	700	1.24	56.5	23.2	20.3
P1	7	H	sm	7.5	6.6	7.6	6.7	7.5	1180	0.87	74.1	25.9	0.0
P1	7	H	sm	22.5	1.8	2.4	2.2	7.9	1800	1.28	85.1	10.9	4.0
P1	7	H	sm	32.5	0.9	1.8	2.6	8.2	1900	1.31	83.3	10.8	5.9
P1	7	H	sm	52.5	1.2	1.8	2.2	8	1850	1.31	62.6	17.1	20.3

P1	7	H	dm	7.5	11.3	8.8	4.4	7.2	900	0.72	61.5	35.2	3.3
P1	7	H	dm	22.5	4.5	5.3	2.9	7.5	600	1.03	67.0	24.5	8.5
P1	7	H	dm	32.5	1.6	2.9	2.9	7.7	1070	1.19	75.3	15.6	9.1
P1	7	H	dm	52.5	1.2	3.5	3.0	7.7	1450	1.24	73.9	16.3	9.8
P1	8	H	wm	7.5	3.2	5.9	3.0	7.8	300	1	87.1	9.6	3.3
P1	8	H	wm	22.5	1.9	3.5	2.6	7.9	310	1.11	85.2	9.5	5.4
P1	8	H	wm	32.5	1.1	1.8	2.6	8.1	1120	1.24	77.9	10.4	11.7
P1	8	H	wm	52.5	1.1	1.8	2.6	8.2	2000	1.29	69.1	13.7	17.2
P1	8	H	sm	7.5	6.3	7.6	4.4	7.5	430	0.84	72.4	21.1	6.5
P1	8	H	sm	22.5	2.1	3.5	3.6	7.8	490	1.16	77.8	15.7	6.5
P1	8	H	sm	32.5	1.5	2.4	2.9	8	1000	1.28	58.8	21.6	19.5
P1	8	H	sm	52.5	1.5	1.8	2.6	8	1450	1.17	53.2	26.9	19.9
P1	8	H	dm	7.5	8.2	6.5	3.7	7.3	1960	0.65	56.6	38.6	4.9
P1	8	H	dm	22.5	2.5	3.5	4.8	7.7	2000	1.15	51.7	30.6	17.7
P1	8	H	dm	32.5	1.9	2.4	3.7	7.6	2000	1.22	53.1	23.9	23.0
P1	8	H	dm	52.5	1.7	2.4	2.9	7.7	2000	1.22	39.4	27.9	32.7
P1	9	H	wm	7.5	2.6	3.5	3.7	7.8	340	1.08	85.8	10.2	4.0
P1	9	H	wm	22.5	1.4	2.4	2.9	7.1	1080	1.25	54.0	22.1	23.9
P1	9	H	wm	32.5	1.2	1.8	2.2	8.2	2500	1.17	38.5	35.9	25.6
P1	9	H	wm	52.5	1.1	1.8	2.2	8.4	2700	1.14	62.0	22.1	15.9
P1	9	H	dm	7.5	5.9	5.9	2.6	7.4	700	0.83	72.5	21.2	6.3
P1	9	H	dm	22.5	1.9	2.9	3.3	7.7	710	1.28	69.9	16.8	13.2
P1	9	H	dm	32.5	1.2	1.8	3.3	7.8	1650	1.1	39.9	34.6	25.5
P1	9	H	dm	52.5	1.3	1.8	2.2	7.7	2000	1.11	53.7	27.8	18.5
P1	10	H	wm	7.5	3.1	5.3	4.0	7.8	740	0.96	62.8	27.9	9.3
P1	10	H	wm	22.5	1.9	2.9	2.6	7.9	1520	1.18	66.5	16.3	17.2
P1	10	H	wm	32.5	1.5	1.8	2.2	7.9	2200	1.14	45.8	27.7	26.5
P1	10	H	wm	52.5	1.4	1.8	2.2	7.9	2500	1.11	16.1	37.4	46.5
P1	10	H	sm	7.5	4.6	6.5	3.7	7.6	570	0.99	69.8	23.9	6.3

P1	10	H	sm	22.5	2.1	2.9	2.2	7.9	1850	1.19	61.8	23.7	14.5
P1	10	H	sm	32.5	1.5	2.4	2.6	8	2000	1.05	51.4	24.8	23.8
P1	10	H	sm	52.5	1.2	1.8	2.2	7.9	2400	1.15	45.7	30.5	23.8
P1	10	H	dm	7.5	8.1	4.1	2.2	7	1300	0.79	73.8	23.6	2.6
P1	10	H	dm	22.5	1.7	1.8	2.2	7.2	1120	1.29	79.7	17.5	2.7
P1	10	H	dm	32.5	1.7	2.4	2.9	7.7	1090	1.25	77.9	13.6	8.5
P1	10	H	dm	52.5	1.2	1.8	2.6	7.8	1130	1.43	73.1	14.9	11.9
T1	1	H	wm	7.5	4.9	5.9	4.8	7.7	560	0.78	62.7	37.3	0.0
T1	1	H	wm	22.5	2.4	3.5	2.9	7.8	1800	1.05	50.1	24.2	25.7
T1	1	H	wm	32.5	1.8	2.9	2.2	8	2300	1.1	34.6	24.0	41.4
T1	1	H	wm	52.5	1.6	1.8	1.5	8.1	3400	0.97	18.5	32.1	49.3
T1	1	H	sm	7.5	6.7	8.8	3.7	7.3	1170	0.89	39.2	42.3	18.5
T1	1	H	sm	22.5	3	4.1	2.9	7.6	2200	1.15	40.0	32.2	27.7
T1	1	H	sm	32.5	2.7	2.9	2.2	7.8	2400	1.14	36.0	31.9	32.1
T1	1	H	sm	52.5	2.3	2.4	1.8	7.9	2400	1.11	28.8	37.3	33.9
T1	2	H	wm	7.5	6	4.7	3.7	7.6	1250	0.81	50.1	49.9	0.0
T1	2	H	wm	22.5	2.5	2.4	2.2	7.6	2000	1.16	63.7	21.5	14.7
T1	2	H	wm	32.5	2	1.8	2.2	7.7	2600	1.11	42.9	27.3	29.8
T1	2	H	wm	52.5	1.7	2.4	2.2	7.9	2500	1.04	45.1	19.1	35.8
T1	2	H	sm	7.5	4.1	7.6	2.9	7.6	420	1.03	45.0	33.3	21.6
T1	2	H	sm	22.5	2.6	6.5	2.6	7.7	790	1.15	37.3	31.0	31.7
T1	2	H	sm	32.5	1.7	5.3	1.8	7.8	2300	1.22	40.0	29.1	30.8
T1	2	H	sm	52.5	1.5	4.1	1.8	7.8	2500	1.13	41.4	28.8	29.8
T1	3	H	sm	7.5	8.9	12.9	20.2	7.3	670	0.85	29.3	50.8	19.8
T1	3	H	sm	22.5	6	8.8	9.6	7.3	530	0.99	23.4	49.4	27.2
T1	3	H	sm	32.5	3.1	4.1	4.4	7.5	560	1.2	26.7	38.9	34.4
T1	3	H	sm	52.5	2.6	3.5	3.7	7.6	600	1.19	25.6	39.2	35.1
T1	4	H	wm	7.5	6.4	10.6	4.0	7.7	800	0.99	53.2	37.2	9.6
T1	4	H	wm	22.5	2.8	4.1	1.8	7.9	1530	1.19	64.5	21.7	13.8

T1	4	H	wm	32.5	2.3	4.1	1.5	7.8	2100	1.05	64.7	16.9	18.5
T1	4	H	wm	52.5	1.7	2.9	1.1	7.9	2900	1.1	53.5	22.3	24.3
T1	4	H	sm	7.5	7.7	12.9	7.7	7.4	470	0.88	21.8	47.8	30.4
T1	4	H	sm	22.5	4	5.9	3.0	7.6	1410	1.02	18.8	38.1	43.1
T1	4	H	sm	32.5	3.1	4.7	2.2	7.3	2500	1.11	18.5	41.3	40.2
P7	1	L	sm	52.5	2.3	2.9	1.8	7.6	2700	1.05	20.6	36.3	43.1
P7	1	L	sm	7.5	9.5	12.9	19.9	7.3	600	0.79	16.5	68.1	15.4
P7	1	L	sm	22.5	7.9	13.5	22.3	7.2	1150	0.9	13.7	70.8	15.4
P7	1	L	sm	32.5	13.6	25.3	8.8	7.2	1070	0.71	27.5	65.5	7.0
P7	1	L	sm	52.5	10.6	22.9	8.1	7.2	1000	0.79	24.5	70.4	5.1
P7	1	L	dm	7.5	8.5	20.6	23.1	7	820	0.86	15.3	68.0	16.8
P7	1	L	dm	22.5	10.1	28.2	22.1	7.1	1020	0.84	14.9	71.5	13.6
P7	1	L	dm	32.5	9.8	27.1	14.0	7.5	1190	0.86	20.1	69.6	10.3
P7	2	L	dm	52.5	5.9	18.2	14.4	7.7	1100	0.93	6.0	66.6	27.4
P7	2	L	sm	7.5	9.8	16.5	15.4	7.6	1650	0.76	20.0	71.7	8.2
P7	2	L	sm	22.5	6.6	12.9	15.1	7.2	1700	0.96	28.3	58.2	13.5
P7	2	L	sm	32.5	6.7	10.6	13.6	7.5	1600	0.86	30.8	56.3	12.9
P7	2	L	sm	52.5	8.4	14.7	6.2	7.3	1450	0.89	53.8	43.6	2.5
P7	2	L	dm	7.5	9	15.3	23.2	7.3	690	0.82	22.4	66.0	11.6
P7	2	L	dm	22.5	9.2	12.9	21.0	7.2	1040	0.93	18.5	73.0	8.5
P7	2	L	dm	32.5	10.3	16.5	19.2	7.2	920	0.89	20.8	68.9	10.3
P7	2	L	dm	52.5	8.8	14.7	8.8	7.4	800	0.89	44.3	49.2	6.5
P7	3	H	wm	7.5	11.7	11.2	6.6	7	370	0.7	49.5	44.2	6.3
P7	3	H	wm	22.5	2.5	5.3	3.7	7	320	1.03	62.1	25.6	12.3
P7	3	H	wm	32.5	1.4	3.5	3.3	7.2	250	1.32	79.5	13.4	7.1
P7	3	H	wm	52.5	1.1	2.4	4.8	7.2	690	1.33	67.7	18.8	13.5
P7	3	H	sm	7.5	17.4	13.5	5.9	7.1	530	0.66	54.1	45.8	0.2
P7	3	H	sm	22.5	3	4.7	4.4	7.3	500	1.21	72.2	20.7	7.2
P7	3	H	sm	32.5	1.5	3.5	5.9	7.2	700	1.33	72.9	18.5	8.6

P7	3	H	sm	52.5	1.3	2.9	5.5	7.3	870	1.29	66.9	21.2	11.9
P7	3	H	dm	7.5	11.2	16.5	24.1	7.2	470	0.7	59.9	38.1	2.0
P7	3	H	dm	22.5	5.6	8.8	6.6	7.4	500	0.94	50.1	42.7	7.2
P7	3	H	dm	32.5	3.1	7.1	5.9	7.8	650	1.18	55.9	32.9	11.1
P7	3	H	dm	52.5	2.3	7.1	7.4	7.7	670	1.18	64.5	24.9	10.5
P7	4	H	wm	7.5	6.3	7.6	4.4	7.3	310	0.91	68.4	31.6	0.0
P7	4	H	wm	22.5	2	3.5	2.2	7.7	260	1.07	66.4	25.6	8.0
P7	4	H	wm	32.5	1.9	4.1	2.2	7.6	250	1.09	71.1	23.6	5.3
P7	4	H	wm	52.5	1.2	2.9	1.8	7.8	250	1.17	74.5	19.5	6.0
P7	4	H	sm	7.5	22.5	11.2	2.9	6.9	440	0.54	40.1	55.9	3.9
P7	4	H	sm	22.5	6.4	5.9	3.7	7.6	670	1	52.9	40.6	6.5
P7	4	H	sm	32.5	4.8	4.7	4.0	7.6	760	1.03	50.1	40.1	9.8
P7	4	H	sm	52.5	3.5	3.5	4.4	7.7	660	1.09	47.4	37.5	15.1
P7	4	H	dm	7.5	19.2	14.7	4.0	6.7	840	0.58	36.0	60.7	3.3
P7	4	H	dm	22.5	10.9	15.3	4.4	6.8	1050	0.76	27.4	67.2	5.4
P7	4	H	dm	32.5	7.9	10.0	7.7	7	950	0.93	24.2	61.3	14.5
P7	4	H	dm	52.5	3.7	5.3	10.7	7.2	710	1.07	36.2	41.9	21.9
P7	5	H	wm	7.5	6.9	10.6	4.4	7.8	440	0.8	58.4	33.6	8.0
P7	5	H	wm	22.5	2.1	4.7	2.2	7.9	320	1.13	64.3	24.4	11.4
P7	5	H	wm	32.5	1.5	2.9	1.8	7.8	500	1.1	64.4	21.8	13.8
P7	5	H	wm	52.5	1.5	2.9	1.8	7.7	780	1.15	61.7	25.0	13.3
P7	5	H	sm	7.5	10.4	11.2	4.4	7.5	610	0.84	56.2	39.1	4.6
P7	5	H	sm	22.5	3.3	4.7	3.7	7.8	1150	1.13	58.2	28.5	13.3
P7	5	H	sm	32.5	1.6	2.9	2.6	7.8	1080	1.29	69.7	18.6	11.7
P7	5	H	sm	52.5	1.6	2.9	2.2	7.7	800	1.22	66.4	19.0	14.6
P7	5	H	dm	7.5	12.2	10.0	3.3	6.9	550	0.76	48.7	45.6	5.8
P7	5	H	dm	22.5	4.1	4.7	3.7	7.4	500	1.12	57.0	32.0	11.0
P7	5	H	dm	32.5	3.6	5.3	3.3	7.6	600	1.07	51.6	32.1	16.2
P7	5	H	dm	52.5	2	5.9	2.9	7.6	710	1.21	46.1	33.1	20.8

P7	6	L	wm	7.5	7.9	7.6	5.2	7.5	430	0.88	44.3	55.7	0.0
P7	6	L	wm	22.5	2.9	3.5	2.9	7.7	300	1.17	56.3	30.1	13.7
P7	6	L	wm	32.5	2.5	3.5	2.9	7.6	350	1.21	48.7	33.1	18.2
P7	6	L	wm	52.5	1.9	2.4	2.6	7.7	490	1.18	50.8	26.9	22.3
P7	6	L	sm	7.5	13.7	10.6	2.9	6.9	600	0.73	35.5	55.4	9.1
P7	6	L	sm	22.5	7.8	6.5	3.3	7.4	740	0.91	31.3	55.8	12.9
P7	6	L	sm	32.5	4.7	4.1	4.8	7.2	850	1.1	26.0	50.5	23.5
P7	6	L	sm	52.5	3.6	3.5	6.3	7.2	690	1.1	26.4	44.8	28.8
P7	6	L	dm	7.5	17.8	7.1	9.2	6.8	590	0.61	25.5	67.5	6.9
P7	6	L	dm	22.5	9.7	5.9	10.7	7.1	630	0.869	21.3	66.9	11.8
P7	6	L	dm	32.5	7.3	5.3	9.6	7.4	590	0.965	28.1	57.6	14.3
P7	6	L	dm	52.5	3.9	5.3	9.5	7.3	600	1.08	17.5	47.6	34.8
C7	1	L	wm	7.5	9.9	12.9	20.6	5.4	340	0.846	19.6	68.7	11.7
C7	1	L	wm	22.5	10.3	17.6	11.8	5.3	350	0.776	31.0	60.5	8.4
C7	1	L	wm	32.5	4.3	11.2	22.5	5.5	340	1.09	29.3	44.5	26.2
C7	1	L	wm	52.5	2.4	5.9	33.1	5.7	440	1.19	27.9	37.9	34.2
C7	1	L	sm	7.5	10.4	12.4	26.8	5.2	300	0.821	26.6	64.6	8.8
C7	1	L	sm	22.5	6.6	7.1	11.8	5.5	240	0.99	30.8	58.8	10.5
C7	1	L	sm	32.5	3.5	3.5	30.1	5.5	230	1.17	33.0	43.4	23.6
C7	1	L	sm	52.5	2.2	2.9	48.4	5.5	400	1.18	29.1	38.6	32.3
C7	2	L	wm	7.5	2.2	1.8	6.6	5.7	300	1.23	32.0	31.1	36.8
C7	2	L	wm	22.5	2.4	1.8	8.1	5.7	230	1.23	40.3	33.5	26.2
C7	2	L	wm	32.5	4.5	2.9	8.5	5.3	170	1.09	45.6	41.4	13.0
C7	2	L	wm	52.5	10	7.1	9.2	5.2	220	0.84	45.6	49.9	4.5
C7	2	L	sm	7.5	8.8	8.2	21.8	5.5	230	0.84	42.5	57.5	0.0
C7	2	L	sm	22.5	4.1	4.1	22.8	5.6	200	1.06	43.6	41.3	15.1
C7	2	L	sm	32.5	2.2	2.9	34.6	5.7	270	1.22	40.5	30.5	28.9
C7	2	L	sm	52.5	1.9	2.4	32.8	5.8	280	1.22	37.2	30.5	32.3
C7	3	L	wm	7.5	9.4	5.9	12.2	5.4	230	0.75	36.3	56.6	7.1

C7	3	L	wm	22.5	5.6	4.1	8.5	5.4	200	1	35.8	51.1	13.1
C7	3	L	wm	32.5	2.7	2.9	11.8	5.7	160	1.17	41.7	43.2	15.1
C7	3	L	wm	52.5	2	1.8	35.3	5.8	190	1.18	45.9	34.4	19.7
C7	3	L	sm	7.5	10	7.1	13.6	5.2	170	0.78	32.9	55.3	11.8
C7	3	L	sm	22.5	5.8	4.1	16.2	5.4	170	1.04	36.6	47.5	15.8
C7	3	L	sm	32.5	2.6	1.8	52.6	5.6	140	1.13	40.0	44.9	15.1
C7	3	L	sm	52.5	1.9	1.8	52.9	5.7	240	1.18	39.4	36.2	24.4
C7	4	L	wm	7.5	9.6	10.6	20.7	6	330	0.91	21.2	65.6	13.2
C7	4	L	wm	22.5	7.8	6.5	11.4	5.8	250	0.98	29.1	60.4	10.5
C7	4	L	wm	32.5	4.8	6.5	12.5	5.8	300	1.03	31.2	47.7	21.1
C7	4	L	wm	52.5	2.7	2.9	19.8	6.1	300	1.18	30.1	43.4	26.4
C7	4	L	sm	7.5	11	8.2	30.6	5.3	290	0.8	33.2	57.5	9.2
C7	4	L	sm	22.5	5.6	4.1	17.6	5.4	190	1.05	33.5	48.6	17.9
C7	4	L	sm	32.5	3.3	2.4	39.4	5.7	240	1.11	34.1	42.1	23.8
C7	4	L	sm	52.5	1.9	1.8	34.6	6	290	1.22	27.0	39.6	33.4

Appendix 7-3

Soil Classification (by John Freeland) and EM-38 data from the CWLSA 1992 study. Abbreviations: WL=wetland, Trans=transect, V=vertical, H=Horizontal, nd=not determined.

WL	Trans	Zone	EM-38 V	EM-38 H	Soil Classification
P1	1	WM	170	125	Typic Fluvaquent
P1	1	SM	185	170	Mollic Fluvaquent
P1	1	DM	130	125	Cum.(Calc) Endoaquoll
P1	2	WM	83	60	Mollic Fluvaquent
P1	2	SM	70	56	Fluvaquentic Endoaquoll
P1	2	DM	82	78	Cum.(Calc) Endoaquoll
P1	3	WM	70	48	Aeric Fluvaquent
P1	3	SM	80	68	Typic Calciaquoll
P1	3	DM	67	55	Cum. (Calc) Endoaquoll
P1	4	WM	59	38	Aeric Fluvaquent
P1	4	SM	72	48	Aeric Fluvaquent
P1	4	DM	64	64	Typic Calciaquoll
P1	5	WM	120	90	Aeric Fluvaquent
P1	5	SM	83	58	Typic Calciaquoll
P1	5	DM	105	100	Typic Calciaquoll
P1	6	WM	85	64	Aeric Fluvaquent
P1	6	SM	96	70	Typic Fluvaquent
P1	6	DM	96	94	Typic Calciaquoll
P1	7	WM	94	70	Aeric Fluvaquent
P1	7	SM	100	90	Typic (Calc) Endoaquoll
P1	7	DM	100	88	Typic (Calc) Endoaquoll
P1	8	WM	100	88	Typic Calciaquoll
P1	8	SM	110	75	Aeric Calciaquoll
P1	8	Dm	110	80	Typic Calciaquoll
P1	9	WM	110	90	Aeric Fluvaquent
P1	9	DM	90	82	Typic Calciaquoll
P1	10	WM	115	95	Typic Calciaquoll
P1	10	SM	110	85	Typic Calciaquoll
P1	10	DM	90	70	Typic Calciaquoll
T1	1	WM	165	130	Aeric Calciaquoll
T1	1	SM	145	110	Aeric Calciaquoll

T1	2	WM	145	115	Aeric Calciaquoll
T1	2	SM	135	100	Typic Calciaquoll
T1	3	SM only	82	56	Cumulic (Calc) Endoaquoll
T1	4	WM	120	85	Typic Calciaquoll
T1	4	SM	nd	nd	Cumulic (Calc) Endoaquoll
P7	1	SM (no WM)	70	56	Cumulic Epiaquoll
P7	1	DM	81	69	Cumulic Epiaquoll
P7	2	SM (no WM)	67	56	Cumulic Endoaquoll
P7	2	DM	68	50	Cumulic Endoaquoll
P7	3	WM	37	29	Typic Calciaquoll
P7	3	SM	44	32	Cumulic Endoaquoll
P7	3	DM	46	32	Cumulic Endoaquoll
P7	4	WM	34	23	Aeric Calciaquoll
P7	4	SM	62	45	Cumulic Endoaquoll
P7	4	DM	74	62	Cumulic Endoaquoll
P7	5	WM	50	38	Typic Calciaquoll
P7	5	SM	58	40	Typic Calciaquoll
P7	5	DM	54	44	Typic Endoaquoll
P7	6	WM	48	32	Typic Calciaquoll
P7	6	SM	62	44	Cumulic Endoaquoll
P7	6	DM	72	55	Cumulic Endoaquoll
C7	1	WM	63	44	Cumulic Endoaquoll
C7	1	SM	64	50	Cumulic Endoaquoll
C7	2	WM	64	50	Cumulic Endoaquoll
C7	2	SM	54	40	Cumulic Endoaquoll
C7	3	WM	50	36	Cumulic Endoaquoll
C7	3	SM	54	40	Cumulic Endoaquoll
C7	4	WM	58	42	Cumulic Endoaquoll
C7	4	SM	64	46	Cumulic Endoaquoll

Appendix 9-2-1

Locations of wetlands used for chemistry, sediment, and/or hormone analysis, 1993.

COUNTY	SITE	TOWNSHIP	RANGE	SECTION	QUARTER
STUTSMAN	1	144N	69W	16	NW
STUTSMAN	2	144N	69W	29	SE1/4SE1/4
STUTSMAN	3	144N	69W	29	SW1/4SE1/4
STUTSMAN	6	143N	63W	21	SW
STUTSMAN	7	143N	63W	22	SE
STUTSMAN	8	143N	63W	27	NE
STUTSMAN	11	142N	68W	01	SE1/4SW1/4
STUTSMAN	13	142N	66W	32	NE
STUTSMAN	14	142N	66W	32	SW1/4SW1/4
STUTSMAN	15	141N	69W	06	NW
STUTSMAN	16	141N	69W	06	SE
STUTSMAN	17	141N	68W	09	NW
STUTSMAN	18	140N	69W	22	NW
STUTSMAN	20	139N	68W	02	NW
STUTSMAN	21	139N	67W	05	SE
KIDDER	22	144N	71W	20	NE
KIDDER	23	144N	71W	30	SE
KIDDER	24	142N	71W	31	NW
KIDDER	25	142N	71W	31	SW
KIDDER	26	141N	72W	12	NW
STUTSMAN	27	139N	69W	03	SW
STUTSMAN	28	138N	67W	04	SE
STUTSMAN	29	139N	67W	03	SW
KIDDER	30	144N	72W	15	SE
KIDDER	31	140N	70W	34	SW
STUTSMAN	39	144N	68W	27	E1/2
STUTSMAN	44	143N	63W	04	SW
STUTSMAN	67	141N	66W	04	E1/2
STUTSMAN	77	140N	67W	01	N1/2
STUTSMAN	80	140N	67W	07	S1/2
STUTSMAN	84	139N	69W	07	ALL
STUTSMAN	87	139N	68W	24	ALL
STUTSMAN	90	139N	66W	19	NE
STUTSMAN	92	139N	66W	12	SE
STUTSMAN	96	139N	65W	34	N1/2
STUTSMAN	100	138N	66W	07	SW
STUTSMAN	103	137N	66W	34	SW
KIDDER	115	142N	71W	26	NE
STUTSMAN	127	139N	69W	5	SW1/4
STUTSMAN	128	142N	66W	32	
STUTSMAN	129	142N	68W	02	
STUTSMAN	130	139N	69W	24	NW1/4
STUTSMAN	131	139N	69W	24	S1/2

APPENDIX 9-2-2

HORMONAL RESPONSE OF AMPHIBIANS TO ENVIRONMENTAL STRESS

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INTRODUCTION

Harlow *et al.* (1987) have defined an animal in "stress" as one that is "required to make abnormal or extreme adjustments in its physiology or behavior to cope with adverse aspects of its environment". Stress in vertebrates is accompanied by an increase in plasma corticosteroid concentration (Harlow *et al.*, 1987; Kirkpatrick *et al.*, 1979; Licht *et al.*, 1983; McDonald *et al.*,1988; McDonald and Taitt, 1982; Moore and Deviche, 1987; Moore and Miller, 1984; Orchinik *et al.*, 1988; Seal and Hoskinson, 1978; Whatley *et al.*, 1977; Wingfield *et al.*, 1982). Often, such increases accompany a decline in immune system responses which may make stressed populations more susceptible to disease (Geller and Christian, 1982) and parasitism. Heart rate in domestic sheep is positively correlated with corticosterone levels (Harlow *et al.*, 1987), suggesting a generally higher cost of metabolism under stress. High levels of corticosterone have also been associated with decreased or abolished reproductive behavior in amphibians (Dupont *et al.*, 1979; Moore,1983; Moore and Deviche, 1987).

Parsons (1990) pointed out that the impact of individual environmental stressors cannot be considered in isolation. Stressors such as environmental contaminants are often difficult and expensive to measure and their potential synergisms are largely unknown. Because corticosterone release is a common response to a range of stressors across a wide variety of taxa, measures of plasma corticosterone concentrations may provide an index of which populations are being stressed. Because the response is nonspecific relative to the stressor, no assumptions are necessary regarding the etiology of the stress.

Corticosterone levels may respond to environmental stress in two ways. Baseline levels may become persistently elevated. This response has been observed in the reptiles *Lacerta vivipara* (Duaphin-Villemant and Xavier, 1987) and *Urosaurus ornatus* (Moore *et al.*, 1991). However, recent work on birds (J.C. Wingfield, pers. comm.) and amphibians (F.L.Moore, pers. comm.) has indicated that chronic (e.g., environmental) stress may also affect the *rate* at which circulating levels of corticosterone respond to a superimposed acute stress such as handling during capture.

RELATIONSHIP TO EPA'S MISSION

The EPA recently initiated the Environmental Monitoring and Assessment Program (EMAP)-Wetlands. The program is designed to provide quantitative assessments of the current status and long-term trends in the ecological condition of wetland resources on both regional and national scales. EMAP-Wetlands will develop standardized protocols to measure and describe wetlands condition, report estimates of wetland condition in selected regions across the country, and develop formats for reporting program results. Longer term goals include trend detection and diagnostic analyses, to identify plausible causes for degraded or improved wetland condition.

It is proposed that amphibians, both as individuals and in their aggregate populations, would be good indicators of wetland condition. The life cycle of many amphibians is such that they are dependent for at least a portion of their life on a wetland habitat. Their relatively low mobility assures that any stresses they reflect are localized in the sample area. Although population measures and counts of individuals would provide a crude index of a wetland integrity, it would be preferable to find a more sensitive measure of stress such that mitigative changes can be instituted prior to the demise of a population. Additionally, little is known about natural long-term (10 to 20 year) cycles of amphibians that potentially could confound a monitoring effort based solely on counts of individuals or population distributions. It is hoped that biomarkers such as plasma corticosterone concentration can provide the needed early warning indicator of environmental stress.

GOAL

Determine the effect of acute and chronic stress on plasma corticosterone concentrations in a laboratory population of the tiger salamander, *Ambystoma tigrinum*, and to test for interactions between chronic stress and acute stress and time on corticosterone levels.

OBJECTIVES

1. Determine whether underlying chronic stress affects the corticosterone levels achieved in response to acute handling stress.

   H_o: The effect of acute handling stress on corticosterone levels is the same in animals with or without a simultaneous chronic exposure to azinphos-methyl (AZM).

2. Determine the effect of chronic exposure to AZM on corticosterone levels.

3. Determine the effect of acute handling stress on corticosterone levels.

4. Determine whether tail-bleeding causes an immediate detectable acute corticosterone release.

   H_o (2-4): Corticosterone levels are the same in stressed and unstressed animals.

APPROACH DESIGN

Two experiments will be undertaken. Experiment A will involve 144 animals in 36 aquaria. The experimental unit will be the aquarium. Treatments will be as follows, with animals housed in groups of four in the 5-gal aquaria:

1. No stress (control) - 48 animals in 12 aquaria.

2. Acute stress only, consisting of 30 minutes of confinement in a 500 ml glass jar half filled with water just prior to sampling - 32 animals in 8 aquaria.

3. Chronic stress (10 days, 20 days) only, consisting of a sublethal concentration (to be determined by preliminary testing) of azinphos methyl in the water supply - 32 animals in eight aquaria.

4. Chronic stress as above, with the addition of acute stress as above - 32 animals in eight aquaria.

This scheme requires two types of water supply - one with AZM directed to 18 aquaria, and one without AZM directed to the other 18 aquaria. The 36 water lines will be randomized as to which aquaria they supply.

Experiment B will involve 48 animals in groups of four in 12 5-gal aquaria. The experimental unit will be the aquarium. Treatments will be as follows:

1. No stress (control) - 12 animals in three aquaria.

2. No stress except 90 seconds of simulated tail bleeding just prior to sampling - 12 animals in three aquaria.

3. Thirty minutes of confinement in a 500 ml glass jar half filled with water just prior to sampling - 12 animals in three aquaria.

4. Thirty minutes of confinement in a 500 ml glass jar half filled with water, followed by 90 seconds of simulated tail bleeding just prior to sampling - 12 animals in three aquaria.

TEST CONDITIONS

Animals trapped in wetland ponds in North Dakota will be housed in flow-through aquaria in Building P600 at Willamette Research Station (WRS). The water supply will be WRS wellwater. They will be fed *ad libitum* with goldfish, crickets, and worms. A light cycle of 13L:11D will be maintained. Testing will be at 20° C, and will be completed before the animals metamorphose out of the aquatic larval form.

Water volume in test aquaria well be set at approximately 10 l by means of a screened standpipe acting as an overflow drain. Water will flow through the aquaria at 130 ml/min, making the volumetric turnover time about 77 min. The water supply for aquaria receiving AZM will first pass through a headbox, where its temperature will be adjusted by a thermostatically controlled heater, and recorded by a thermograph. It will then flow to a mixing chamber, where AZM in a dimethylformamide carrier will be injected by a syringe pump, thence to a splitter box and finally to the aquaria. Water supplies for aquaria not receiving AZM will be tapped directly off the headbox. Aquaria will be vacuumed clean with a siphon every day.

Once AZM exposure begins, water samples will be taken from two randomly selected aquaria receiving AZM and two randomly selected AZM-free aquaria each day for confirmation of AZM concentrations. Relatively few aquaria need to be sampled each day because the system design assures uniform AZM concentrations across their water supplies, and water turnover rate in the aquaria is so high that AZM degradation should not be a significant factor, even if flows diverge substantially from normal for extended periods. Pesticide-free 150 ml glass milk dilution bottles will be filled with water withdrawn from a depth of approximately 5 cm by means of a 30 ml Manostat pipet. AZM extraction will normally be done the same day at ERL-C, but can be delayed up to 72 hr post-collection if samples are refrigerated at 4° C. Extracts will normally be analyzed within 24 hr., but can be held at 4° C for up to 26 days prior to analysis per the Wildlife Ecology Program (WEP) SOP for AZM analysis.

Water hardness, pH, alkalinity, and conductivity will be measured at least once during the test.

At the beginning of a 7-day acclimation period, designated day -7, animals for Experiment A will be assigned to the aquaria by stratified random distribution. Each aquarium, in random order, will receive one animal, then a second set of animals will be distributed, and so on until there are four animals in each one. The order of placement will be re-randomized for each set. The treatment for each aquarium, as well as the day the animals therein will be sacrificed and sampled, will already have been randomly assigned by this time. The first day after acclimation will be designated day 1. On this day, all animals from four aquaria in Treatment Group 1 (control) will be sacrificed to establish starting plasma corticosterone levels, and AZM exposure will begin for treatment groups 3 and 4. On days 10 and 20, all animals from four aquaria in each of the four treatments (64 animals each day) will be sacrificed to complete the test.

Experiment B will overlap with Experiment A, utilizing AZM-free aquaria vacated on days 0 and 10 of Experiment A. On Experiment A day 11, Experiment B animals will be assigned to the 12 vacated aquaria by stratified random distribution. After seven days of acclimation, these animals will be subjected to the Experiment B treatments outlined above.

BLOOD SAMPLE COLLECTION

Blood sampling will be undertaken prior to morning husbandry and feeding, in case those activities engender transitory corticosterone release. Just prior to sacrifice, an animal will be weighed. This should take about 15 seconds. It will then be decapitated with scissors, and blood will be collected from the severed truncus arteriosus in heparinized 70 µl capillary tubes. As much blood will be collected as possible. Sets of filled capillary tubes will be plugged with Critoseal and stored in labeled test tubes on ice until they can be further processed. The severed heads will be held on ice in labeled plastic bags until they can be frozen at -70° C pending brain cholinesterase analysis.

BLOOD ANALYSIS

After transportation to ERL-C Lab 126, the contents of each set of 70 µl capillary tubes will be consolidated into labeled 1.5 ml microcentrifuge tubes, and placed on ice. Each sample will be mixed with a pipet and enough will be withdrawn to make three smears for lymphocyte differential analysis. The remainder will be centrifuged in the Sorvall RC5C centrifuge for 10 min at 2500 rpm and 4° C. The plasma layer will then be transferred to a new set of labelled microcentrifuge tubes. If samples are of sufficient volume, they will be split to allow for plasma cholinesterase analysis. All will be frozen at -70° C pending analysis.

Hematology and cholinesterase analysis will be per WEP SOPs. Corticosterone analysis will be performed by Dr. Al Fivizzani at the University of North Dakota.

DATA ANALYSIS

Analysis of variance will be the main approach if data conform to the assumptions of the technique, or can be transformed to do so. Otherwise, non-parametric tests may have to be used. Plasma corticosterone concentrations will comprise the key data set. Brain cholinesterase activity may provide an additional measure of AZM sublethal effect. Chronic elevation of plasma corticosterone concentrations, should it occur, may cause suppression of lymphocyte populations in peripheral blood. This should be detectable by the lymphocyte differential counts.

ANIMAL WELFARE

A review of this proposal by the ERL-C Animal Care and Use Committee will occur prior to the initiation of the study. Test animals will be treated in accordance with applicable procedures contained in "Guidelines for use of Live Amphibians and Reptiles in Field Research" (Am. Soc. Ichthyologists and Herpetologists, et. al, 1987).

QUALITY ASSURANCE

The data from this study will be used to determine the feasibility of using a plasma corticosterone biomarker as a monitoring tool for EMAP. Therefore, the data must be of high quality as they are likely to provide baseline values to which additional field-collected samples can be compared. A quality assurance project plan will be prepared following ERL-Corvallis guidelines and approved prior to beginning data collection. Animal rearing, blood collection, handling storage, and analyses will follow standard operating procedures described in the WEP Quality Assurance Document.

BUDGET

Laboratory supplies and food	500
Cholinesterase reagents	200
Corticosterone analysis (postage)	20
	$720

PERSONNEL

Steve Dominguez (Co-Principal Investigator) - study design and laboratory operations, data analysis, manuscript preparation.

Anne Fairbrother (Co-Principal Investigator) - scientific and technical guidance

Al Nebeker (Co-Investigator) - laboratory operations, data analysis

Diane Larson (Co-Investigator) - study design

Bill Griffis - analytical chemistry (AZM)

Tamotsu Shiroyama - biochemistry (cholinesterase)

Lisa Ganio (METI) - biostatistics

TBD (METI) - lymphocyte differential counts

TIMEFRAME

Test animals will be captured in wetland ponds in North Dakota in late July and early August, 1993, and shipped to ERL-C in insulated containers via Federal Express. The study is currently expected to commence on August 17, with blood sampling on Aug 24 and September 3, 10, and 13.

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