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Inventory of Wetlands and Agricultural Land Cover in the Upper Sevier River Basin, Utah

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Appreciation is also expressed to Ed Harne, the Bureau of Land Management, for allowing CRSC to use BLM aerial photography until purchased photography was delivered.

ABSTRACT

This report describes the techniques and results from the use of color infrared aerial photography in the mapping of agriculture land use and wetlands in the Sevier River Basin of south-central Utah. A discussion of the efficiency and cost effectiveness of utilizing Landsat multi-spectral scanner digital data to augment photographic interpretations is presented.

The final products include this report and transparent overlays for 27 U.S.G.S. quadrangles showing delineations of wetlands and agricultural land cover. A table is also provided which summarizes the acreage represented by each class on each quadrangle overlay.

INTRODUCTION

The Sevier River Valley in south-central Utah is an area undergoing rapid change as oil, gas, and coal resource development alter the land resource base and stimulate population growth. A fundamental key to present and future resource development is the efficient and wise use of the limited water resources available in this semi-arid region of the Western U.S. A primary part of the Soil Conservation Service's (SCS) mission is to assist farmers in increasing the efficiency with which agricultural products are produced: this includes planning efficient water application systems.

Recent legislation about wetland preservation serves to complicate the management issue, making it more difficult for the SCS to support changes in farming practices which would eliminate wetlands. Better information about quality, type, and distribution of wetlands is required in order to properly assess any impacts due to site disturbance or reallocation of the water source.

Objectives

Consistent with the contract between the SCS and the Center for Remote Sensing and Cartography (CRSC), the project study plan has the following objectives:

1. Classify and map the wetlands and agriculture-related land cover of the upper Sevier River Basin.
2. Establish the cost effectiveness of utilizing Landsat multi-spectral scanner digital data to compliment photographic interpretation.

Purposes

The SCS has several intended uses for the final products of this study. A major purpose of the study is to provide a basis for the Utah State Office of the SCS to carry out its assigned responsibilities under legislation and regulations which protect wetland environments. The inventory will also provide maps and a table of all agricultural land use in the study area, for the purpose of aiding in farm and ranch resource planning. The coordinated mapping of wetland habitat and agricultural land use will also assist SCS personnel and local land owners in determining the interaction (e.g., hydrologic, biological) between wetlands and farms. Finally, the study will provide basic inventory information about land cover types and potential water consumption use for application in basin water resource management.

Study Area

The study area includes approximately 2,450 square miles of land in the upper Sevier River Valley. The two principle drainages in this region are the Sevier River and the East Fork of the Sevier River. The agricultural and wetland valleys are bounded on the east by Parker Mountain, Escalante Mountains, and the Paunsaugunt Plateau. To the south, the study area extends to the headwaters of the Sevier River and its East Fork. To the west, the Markagunt Plateau and the Tushar Mountains, and to the north Piute Reservoir, Otter Creek Reservoir, and the headwaters of Otter Creek near Koosharem form natural boundaries. All of the wetlands and agricultural land in the valley floor have been inventoried, but no mountain area wetlands have been included. Figure 1 shows the extent of the study area. Twenty-seven U.S.G.S. quadrangles in the study area were found to contain agricultural and wetland types. These quads, for which map overlays have been prepared, are listed in Table 1. The location of the quads in Table 1 within the study area is shown in Figure 2.

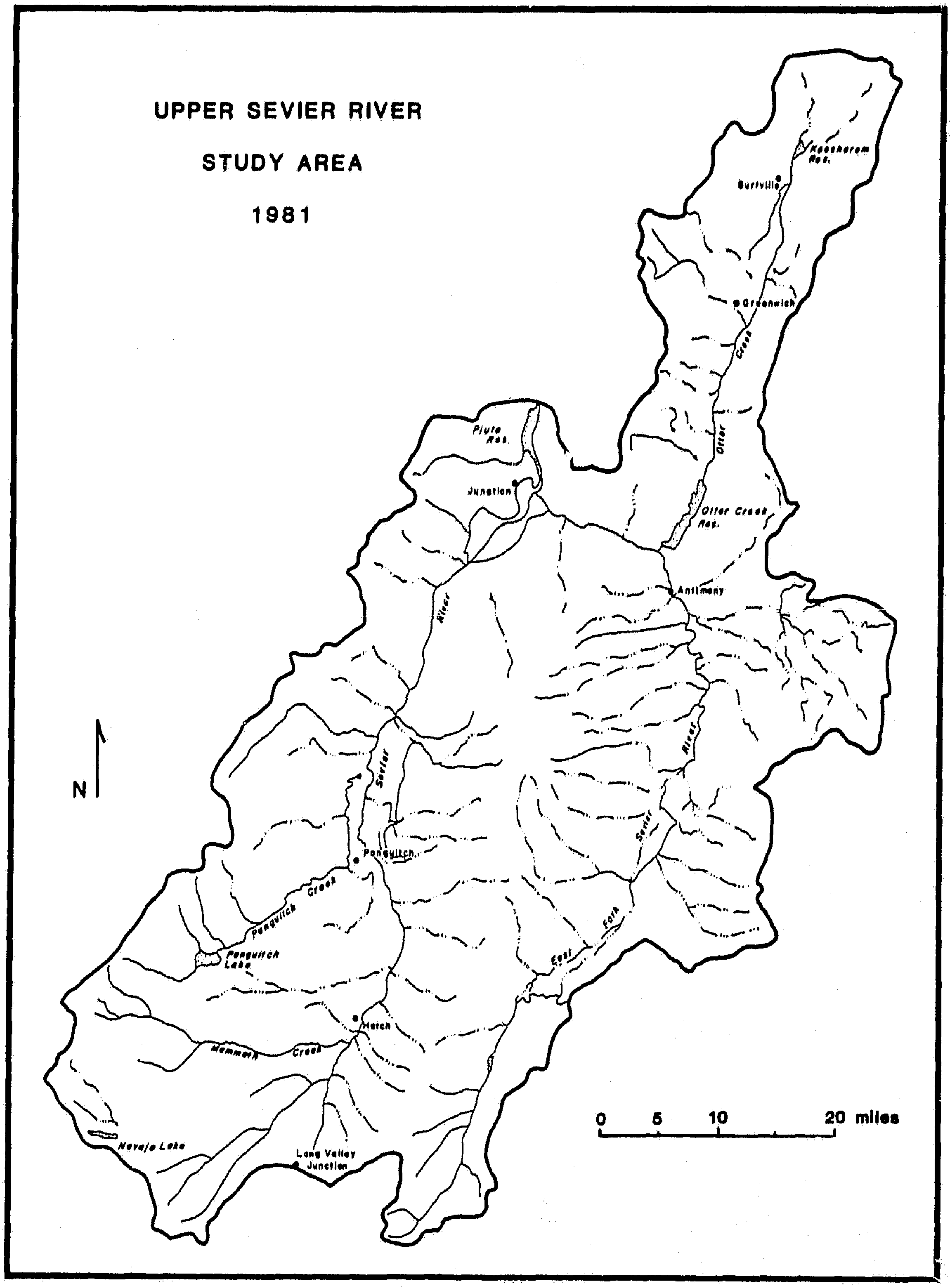

Figure 1. Upper Sevier River Basin Study Area.

Table 1. List of U.S.G.S. Quadrangles for Which Wetland and Agricultural Land Cover Map Overlays Have Been Prepared.

Quadrangle # in Figure 2.	Quadrangle Name	Quadrangle # in Figure 2.	Quadrangle Name
1	Abe's Knoll	15	George Mountain
2	Angle	16	Grass Lakes
3	Antimony	17	Greenwich
4	Blind Spring Mtn.	18	Hatch
5	Boobe Hole Res.	19	Junction
6	Bull Rush Peak	20	Koosharem
7	Burrville	21	Panguitch
8	Casto Canyon	22	Panguitch NW
9	Circleville	23	Parker Knoll
10	Cow Creek	24	Phonolite Hill
11	Deep Creek	25	Piute Reservoir
12	Fivemile Ridge	26	Sweetwater Cr.
13	Flake Mtn. East	27	Wilson Peak
14	Fremont Pass		

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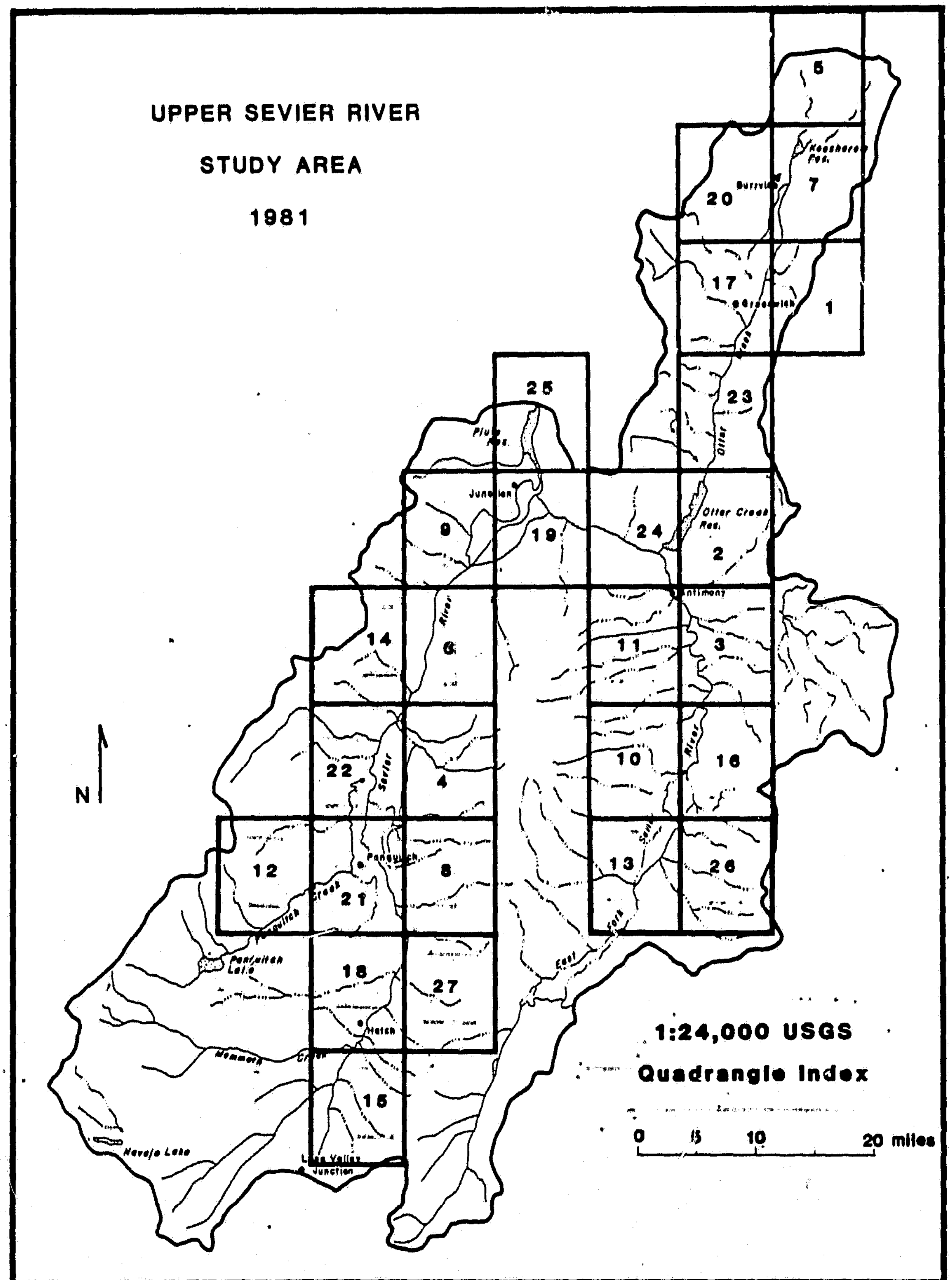


Figure 2. U.S.G.S. Quadrangle Index.

LITERATURE REVIEW

Three types of literature were surveyed in connection with the study: wetland classification; remote sensing applications to wetlands; and Utah water resource documents.

For wetland classification work, the standard document used in the United States over the past two decades is Circular 39, Wetlands of the United States by Shaw and Fredine for the U.S. Fish and Wildlife Service (1956). The U.S. Fish and Wildlife Service has published a new document called Classification of Wetlands and Deepwater Habitats of the United States by Cowardin, et al. (1979).

The literature in remote sensing applied to wetlands is increasing as more attention is given to the development of photo-interpretation techniques as well as use of satellite imagery. Some satellite investigations have been pursued from manual and digital approaches (Anderson, et al., 1973; Cowardin, et al., 1973; Carter and Shubert, 1974; Bartlett, et al., 1977; and others), but the more definitive work is done with photography, especially color-infrared photo-interpretation (Anderson, 1969; Seher and Tueller, 1973; Enslin and Sullivan, 1974; and others). Since applications have been in environments quite different from the Sevier River Valley, the techniques developed at CRSC were tailored to meet the specifications of this study.

Experience acquired by CRSC in performing an inventory of wetlands and agricultural land cover in the Uinta Basin (Ridd, et al., 1980) contributed substantially to the approach outlined in the project study plan.

LAND USE/COVER CLASSIFICATION

Three general classes of land use/cover were identified in this study: agriculture; wetlands; and rangelands.

The main agricultural land cover types found in this study area include the following:

1. Hay. Grass, alfalfa, or a mixture of both, mowed and cured for fodder.
2. Grain. Pure stands or mixtures of oats, wheat, barley, or rye.
3. Irrigated Pasture. Introduced or native grasses, which are irrigated to produce maximum forage for grazing livestock.
4. Corn.
5. Miscellaneous Garden Crops. Crops such as corn, squash, tomatoes, etc., grown mostly for domestic consumption.

All of the agricultural types listed above have been mapped in this study, with the exception of the miscellaneous garden crop; such areas were not mapped because of their small size. Small garden crop areas have been included under the urban classification because they were usually located quite closely to associated farmsteads.

The next major land cover type identified was wetlands. In an effort to incorporate the most recent classification system for wetlands with the study, CRSC and SCS personnel decided to apply the new U.S. Fish and Wildlife publication, Classification of Wetlands and Deepwater Habitats of the United States. Cowardin et al., (1979). The complete list of wetland classes mapped in this study is presented in Table 2.

The environment in the study area contained three distinct wetland systems: palustrine; lacustrine; and riverine. Appropriate modifiers such as "diked" and "farmed" were also included to more completely explain the use of the wetlands.

Although a complete discussion of the wetland cover types mapped in the study area appears in Appendix A, a brief interpretation is provided here.

Table 2. Map Legend for Wetland Vegetation Classes Studied in the Upper Sevier River Basin.

WETLANDS

P Palustrine

- EM Emergent
- SS Scrub/Shrub
- UB Unconsolidated Bottom

L Lacustrine

- 1 Limnetic
- 2 Littoral
- UB Unconsolidated Bottom
- EM Emergent

R Riverine

- 2 Lower Perennial
- 3 Upper Perennial

Modifiers

- f Farmed
- h Diked/Impounded

Basically, wetlands occuring in the upper Sevier River Basin which neither fit the definition of riverine or lacustrine wetlands are classified as palustrine. Riverine wetlands in the study area are found in stream channels with vegetation dominated by non-peristent vegetation. Similarly, lacustrine wetlands are areas not dominated by peristent emergent vegetation, trees, or shrubs which occupy an area of 20 acres (8 ha) or more; such areas are associated with lakes or reservoirs in topographic depressions or dammed river channels. Thus, streams and large bodies of water, and the non-persistent vegetation zones adjacent to such areas, respectively represent riverine and lacustrine wetlands.

From the foregoing, it is clear that the definition of persistent and non-peristent vegetation is the key to the process of classifying wetlands. Peristent emergent vegetation (see Page A-7, Appendix A) consists of erect, rooted, herbaceous hydrophytic vegetation which normally remains standing at least until the beginning of the next growing season (i.e., cattails, bullrushes, sedges). Non-peristent vegetation falls to the surface of the substrate or below the surface of the water at the end of the growing season so that, at certain seasons of the year, there is no obvious sign of emergent vegetation. In the study area, most of the emergent vegetation associated with lacustrine and palustrine areas consists of grasses, sedges, and rushes. Initially, such vegetation was considered to be non-persistent, at least with regard to emergent wetlands associated with major reservoirs. Thus, several areas were mapped as lacustrine shore (or littoral) emergent wetlands. In further considering the definition of persistent vegetation, such areas should be regarded as palustrine emergent wetlands, since there is year-round evidence of emergent vegetation.

The palustrine wetland system may be broken down into three classes: unconsolidated bottom; emergent wetland; and scrub-shrub wetland. The unconsolidated bottom class (map symbol PUB) consists of natural or man-made ("diked") ponds which are smaller than 20 acres (8 ha); such areas correspond to Type 5 wetlands under the Circular 39 classification system (see Appendix B).

The palustrine emergent (map symbol PEM) class generally corresponds to Type 2 or 3 wetlands in Circular 39 (Appendix B) terms. Such areas occur above the high water mark of lakes or reservoirs and are dominated by peristent grasses, sedges, and rushes. Where persistent emergent areas are pastured, they bear the modifying symbol "f" for "farmed"; this corresponds to Circular 39 Type 2 wetlands. Where persistent emergent vegetation occurs below seasonal high water marks of reservoirs, the modifier "h" for "diked" is added; this correlates with the Circular 39 Type 3 wetlands, and should also include areas mapped as "L2EMh" for lacustrine, littoral, emergent, diked.

One palustrine area near Piute Reservoir was dominated by willows and has been mapped as a scrub/shrub, diked wetland.

The riverine system was mapped by using a dashed line. This system includes the stream channel as well as adjacent wetland areas. Typically adjacent wetlands, dominated by non-persistent emergent vegetation, do not extend beyond three to ten feet from the edge of the channel. Consequently, no acreage determinations were possible for this wetland type.

The lacustrine system consists of reservoirs and are mapped with the symbol "L1UBh" for "lacustrine, limnetic, unconsolidated bottom, diked" (see Appendix A). Such areas actually include the fairly narrow (and, therefore, difficult to map) littoral zone which extends from the two meter water depth shoreward.

Riparian vegetation, which was not considered hydrophytic for wetland mapping purposes, was also mapped. Such areas occur adjacent to open water and support various phreatophytic vegetation such as cottonwoods, box elders, and willows.

Rangeland areas adjacent to agricultural and wetland areas have been identified in a general fashion. The rangeland types noted on the maps are pinyon-juniper, brush-grass, and greasewood.

METHODS

Mapping Techniques

In this study several different techniques were used to compile and transfer aerial photographic and field observation data to the final map product.

The basic mapping product was color-infrared aerial photography. These photographs were transparent film positives at a scale of 1:31,680 (flown July 1975).

The first stage of map production was to delineate the wetland and agricultural zones which were visable on the photographs. Vegetation cover was identified by examining the following: the color, texture, and patterns on the photographs; hydrologic features; and topography.

The next stage of production was to transfer the delineations on the photo overlays to the final map scale, which is 1:24,000, and to register delineations with the standard 7½ minute U.S.G.S. quadrangle base. This step was accomplished by two different techniques, one of which was to use a K&E Kargl projector, an enlarging light table. The second method was to photographically enlarge the delineations from photo scale to the final map scale; the photo mechanical transfer (PMT) technique was used to accomplish such method, and was found to be quite efficient as compared to conventional photographic processes. That is, the PMT process allows photographic enlargement in one step, whereas the traditional process requires a negative to be made first, from which the positive transparency is developed.

After the delineations were enlarged to the U.S.G.S. quad scale, they were ready to be field checked to verify the interpretations and delineations in the study area.

Once in the field, the CRSC personnel made a point to visit all agricultural and wetland basins within the study area. The field team was able to quickly make final delineations and interpretations once the type and extent of the land cover was identified on the aerial photographs.

In choosing the map symbolization for wetlands, a document of mapping conventions by Charles R. Elliott, the Regional Wetland Coordinator of the U.S. Fish and Wildlife Service, was consulted. The wetland data was first placed on the U.S.G.S. base map by a series of letters and numbers: the first letter representing the system or major cover class, and subsequent letters and numbers representing subordinate levels of detail (see Table 3).

Simple alphabetic symbols were selected for agricultural and rangeland cover types. After the appropriate symbols were placed on the quads, the final overlays were drafted using waterproof black ink on a single matte stable drafting film. Final drafting was carefully performed to make sure that the agricultural and wetland polygons were located as planimetrically correct as possible.

After completion of the map overlays, the final step was to determine the acreage represented by each land cover type per quad. A computerized digitizer and a software program designed specifically to perform area measurement were used to accomplish this task. This procedure was found to be quite accurate in making the acreage estimates, which are summarized in Table 4 (presented in the next section).

Landsat Analysis

As a second part of the contract agreement, CRSC agreed to examine the cost effectiveness of utilizing Landsat MSS digital data to augment photographic interpretations. Landsat digital tapes were purchased and analyzed to allow the same sort of merging of digital print maps with photos that proved helpful in the Uinta Basin wetland/land use study (CRSC Report 80-2) completed for the SCS. The methods used to analyze the tapes is outlined below.

Table 3. Wetland Legend Mapping Conventions Used by the U.S. Fish and Wildlife Service.

Systems and Subsystems

M Marine
- 1 Subtidal
- 2 Intertidal

E Estuarine
- 1 Subtidal
- 2 Intertidal

P Palustrine
- 1 No Subsystem

U Upland

R Riverine
- 1 Tidal
- 2 Lower Perennial
- 3 Upper Perennial
- 4 Intermittent

L Lacustrine
- 1 Limnetic
- 2 Littoral

Classes and Subclasses

RB Rock Bottom
- 1 Bedrock
- 2 Rubble

UB Unconsolidated Bottom
- 1 Cobble-Gravel
- 2 Sand
- 3 Mud
- 4 Organic

AB Aquatic Bed
- 1 Algal
- 2 Aquatic Moss
- 3 Rooted Vascular
- 4 Floating Vascular

RF Reef
- 1 Coral
- 2 Mollusk
- 3 Worm

SB Streambed
- 1 Bedrock
- 2 Rubble
- 3 Cobble-Gravel
- 4 Sand
- 5 Mud
- 6 Organic
- 7 Vegetated

RS Rocky Shore
- 1 Bedrock
- 2 Rubble

US Unconsolidated Shore
- 1 Cobble-Gravel
- 2 Sand
- 3 Mud
- 4 Organic
- 5 Vegetated

ML Moss-Lichen
- 1 Moss
- 2 Lichen

EM Emergent
- 1 Persistent
- 2 Nonpersistent

SS Scrub-Shrub
- 1 Broad-leaved Deciduous
- 2 Needle-leaved Deciduous
- 3 Broad-leaved Evergreen
- 4 Needle-leaved Evergreen
- 5 Dead
- 6 Deciduous
- 7 Evergreen

FO Forested
- 1 Broad-leaved Deciduous
- 2 Needle-leaved Deciduous
- 3 Broad-leaved Evergreen
- 4 Needle-leaved Evergreen
- 5 Dead
- 6 Deciduous
- 7 Evergreen

Other Modifiers

Special

- b Beaver
- d Partially Drained/Ditched
- f Farmed

Special (con't)

- h Diked/Impounded
- r Artificial
- s Spoil
- x Excavated

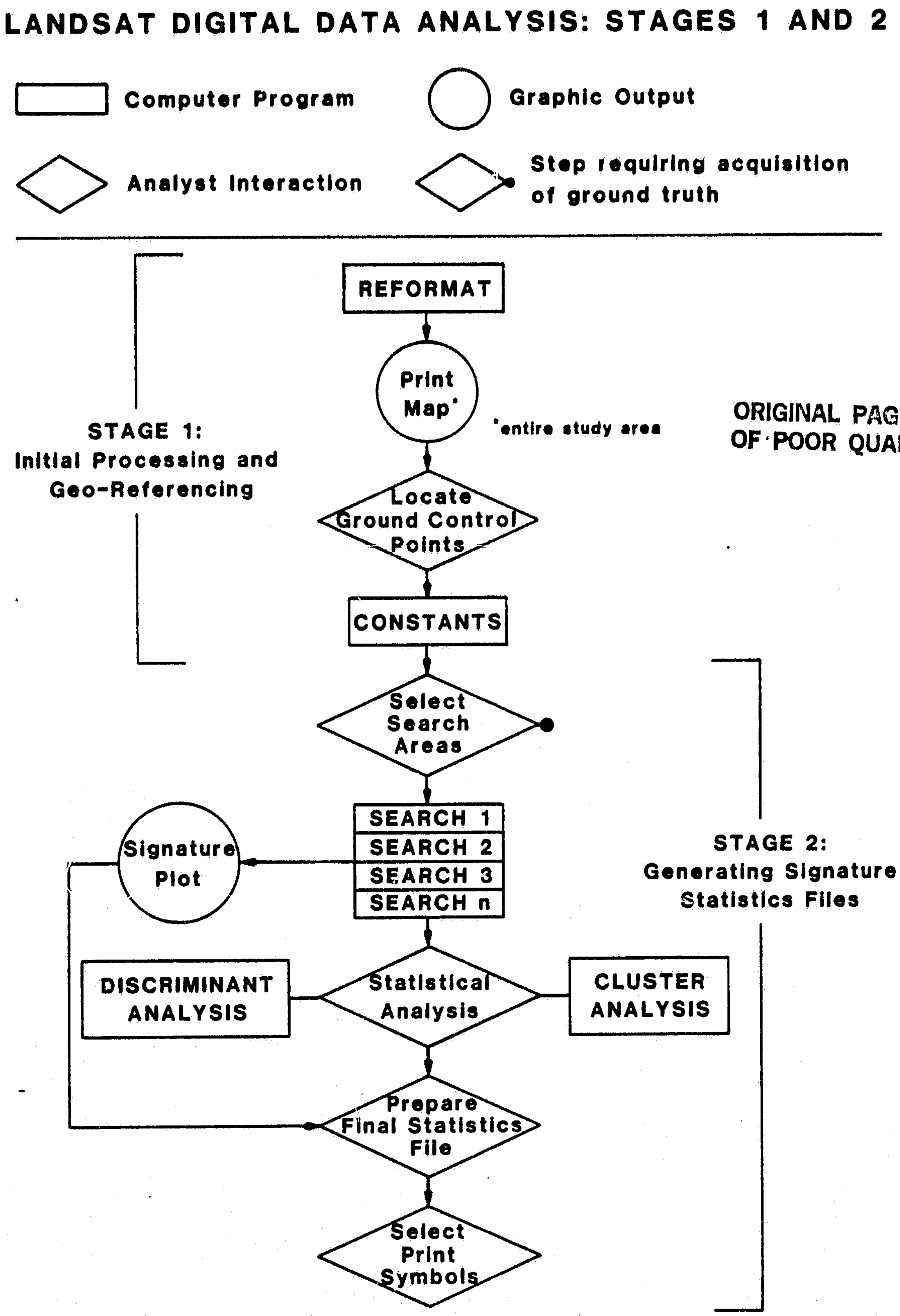
Soils

- g Organic
- n Mineral

Initially, selected intense study areas (ISA) were located for the purpose of finding spectral signatures for land cover classification. A spectral signature is the mean reflectance in green, red, and two near-infrared bands of light energy which is sensed by the Landsat multi-spectral scanner (MSS). Landsat senses reflectance values for over 10 million picture elements or "pixels" in a given scene. The Koosharem Reservoir and Antimony areas were ISA's for wetland and agriculture signatures, and the Parker Mountain area was studied for rangeland signatures. Two Landsat scenes, sensed on July 28, 1979, provided the data for all digital processing.

After the digital data had been read into the computer and geographically corrected, a software package called "ELAS" was applied to analyze the data (see Stage 1 in Figure 3). Within ELAS there is a program entitled SEARCH, which is utilized to generate statistics that characterize pixel groups having similar spectral features across the four bands (see Stage 2 in Figure 3). SEARCH is a routine which is used to provide training statistics for a program called MAXL, which classifies individual pixels into groups based upon each pixel's highest statistical probability of belonging to a given group. In SEARCH, each contiguous six scan line (Landsat pixel matrix "row") by six element block (pixel matrix "column") is evaluated; if the spectral data within the six by six block is too heterogeneous, the program will switch to the use of a three by three block of pixels. The statistics generated by SEARCH include mean pixel light radiance values for each of the four bands, a covariance matrix, and a priori values. A set of statistics is generated by SEARCH representing various classes of light reflectance patterns found in the study area "searched". The four mean light reflectance values, one for each MSS band, are plotted to form a curve called a "light signature" which characterizes each class. SEARCH thus "trains" MAXL to recognize different ground cover patterns

Figure 3. Summary of Steps in Landsat Digital Data Analysis: Stage 1 and 2.



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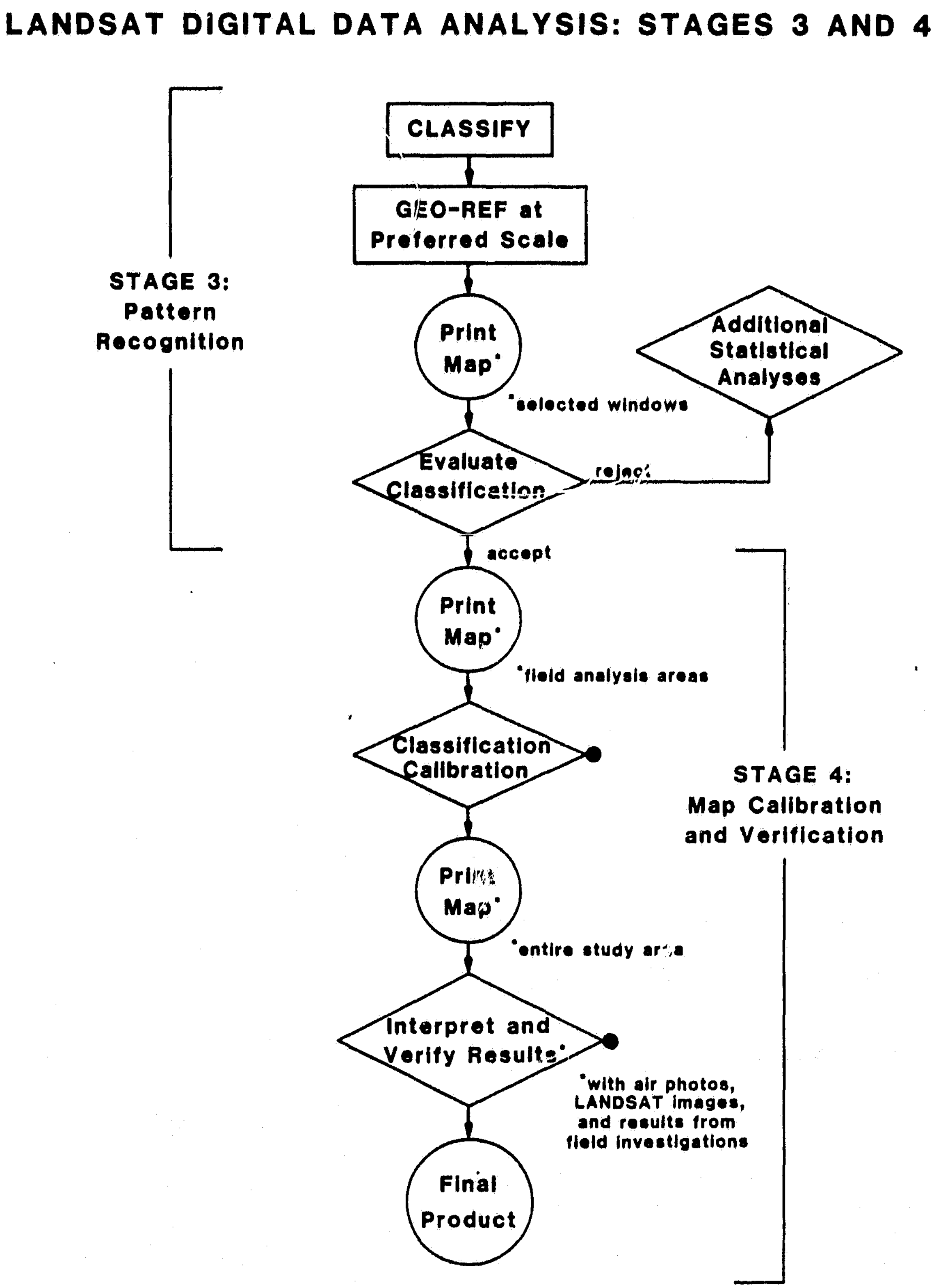
as it places individual pixels into classes. A knowledge of the manner in which different land cover features form spectral signatures, combined with the analysis of aerial photography and field checking of digital classifications, allows remote sensing researchers to provide an interpretation of Landsat-derived classes.

In this study, 77 spectral signatures were derived from the SEARCH program; of the 77, only about half were considered to be associated with cover types of primary interest. The next step was to selectively eliminate signatures which were of little utility. This process of reducing the number of signatures was accomplished through use of a combination of statistical routines and by generating print maps of selected areas and calibrating print symbols with ground observations (see Stage 2 in Figure 3, and Stage 3 in Figure 4).

The statistical routines used at CRSC included principal components, cluster analysis, and discriminant analysis. Application of the statistical analyses results to information gathered by comparing aerial photographs with light signature map print symbols allowed the combination of some signatures and further refinement of others. Consequently, 52 signatures were produced which were used to classify the entire study area.

Figure 4. Summary of Steps in Landsat Digital Data Analysis: Stage 3 and 4.



RESULTS

Final products from this study include a locator map, quadrangle overlays, and tables, as outlined below.

Locator Map: Two Landsat false color composite images have been mosaiced to provide an overview of the study area. A clear overlay showing watershed boundaries, cities, and reservoirs has been added. The map scale is 1:250,000.

Overlays: One transparent overlay for each 1:24,000 quadrangle in the study area containing wetlands or agricultural land has been provided. These overlays show the land cover classes and class boundaries. They may be placed directly on the U.S.G.S. quadrangle and registered to the border lines for direct reading. Figure 5 displays a portion of an overlay.

Tables: A summary and detailed listings of all agricultural and wetland classes, showing acreage per quadrangle, have been prepared. Table 4 presents the total acreage by cover type in the entire study area.

The most abundant cover type among the five agricultural types was hay, with 13,818 acres. The other agricultural types occupied the following amounts of area: irrigated pasture, 7,237 acres; grain, 1,992 acres; corn, 481 acres; and potatoes, 17.4 acres. Among the 8 wetland classes, for which acreage measurements were made, the farmed emergent palustrine cover type was the most extensive with nearly 15,957 acres. The second largest type was open water in reservoirs (lacustrine, limnetic, unconsolidated bottom, diked), with nearly 4,699 acres. Riverine wetland areas were mapped but not measured because of their linear nature and variable width. Riparian cover, dominated mostly by fremont cottonwood (*Populus Fremontii*), box elder (*Acer negundo*), and willow (*Salix spp.*), represented 2,392 acres.

As mentioned above, the mapping of areas in this study was based primarily upon the interpretation color-infrared aerial photography. Such medium provided an excellent resource for making accurate delineations of agricultural field and natural vegetation boundaries, but the fact that the photography was

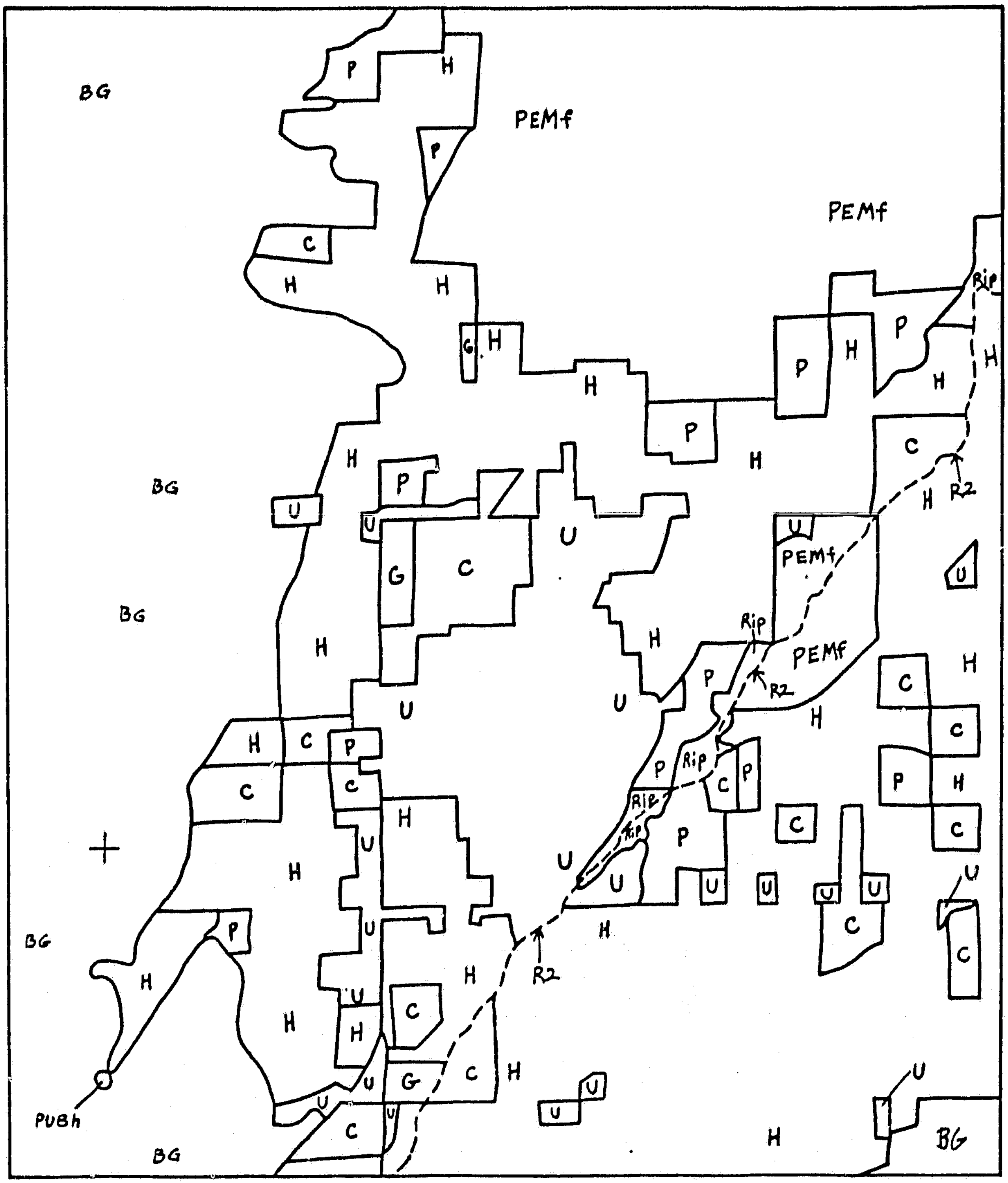


Figure 5. Portion of Wetland and Agricultural Land Cover Overlay for the Circleville Quadrangle.

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Table 4. Land Cover Acreage

USGS Quadrangle Name	Agricultural					Wetlands								Riparian
						Palustrine						Lacustrine		
	Hay	Grain	Pasture	Corn	Potatoes	EM	EMf	EMh	UB	UBh	SSh	1UBh	2EMh	Rip
Abe's Knoll	88.4							467	1.3					
Angle	486.6	1.4	1.3				28.4			2.8		1722	269	
Antimony	1040.7	262.9	64.0				289.3			8.4				412.7
Blind Spring Mtn.							109							
Boobe Hole Reservoir							130.0							13.3
Bull Rush Peak	20.4						577.0			2.7				182.3
Burrville	586.9	140.7	651.4				2682.0					351.0		
Casto Canyon			55.9							1.3				
Circleville	2445.0	65.9	274.7	269.1			1266.3			5.0				30.1
Cow Creek		30.7					8.3							
Deep Creek	1.1	8.3	113.7				55.9							20.3
Fivemile Ridge							685.0							35.3
Flake Mtn. East		16												
Fremont Pass		5.6					82.1			.6				
George Mtn.			93.9			9.2	573.8	3.3		14.1		24.5		107.0
Grass Lakes	929	231.8			8.5		283.7			6.4				
Greenwich	1582.4	239.7	107.4				2394.5			17.2				165.3
Hatch	121.7		1006.0			9.4	269.7			41.1				615.1
Junction	2051.0	298.0	1024.1	211.9	8.9	30.0	2116.8		4.5	4.6			398	344.9
Koosharem	247.5	24.1	22.5											
Panguitch	2021.6	405.1	1907.8				1020.8		1.4	18.7				250.3
Panguitch N.W.	1318.0	138.6	1282.5				2091.9		7.9	27.3				
Parker Knoll	347.4		51.2							3.2				161.8
Phonolite Hill	259.7	20.2	580.5				1268.0			5.6		693.0		28.9
Piute Reservoir	117.0										21.6	1908	57	
Sweetwater Creek	153.6	103												
Wilson Peak							24.2			1.2				23.8
TOTALS	13818.0	1992.0	7236.9	481.0	17.4	48.6	15956.7	470.3	15.1	160.2	21.6	4698.5	724	2391.7

EM Emergent
EMf Emergent, farmed
EMh Emergent, diked
UB Unconsolidated Bottom
UBh Unconsolidated Bottom, diked
SSh Scrub/Shrub, diked
1UBh Limnetic, Unconsolidated Bottom, diked
2EMh Littoral, Emergent, diked

over five years old presented a major item of concern. Originally, it was thought that the 1979 Landsat data would provide the primary means to update the land cover classification process by creating photo digital overlays, as was done in the Uinta Basin Wetland/Land Use Study (Ridd, et al., 1980). Although the initial processing of Landsat data (discussed above) showed promise for augmenting the analysis of agriculture and wetland areas, several factors led to the decision to not use Landsat as a primary analytical medium. The Sevier River Basin situation turned out to be quite different from that in the Uinta Basin study in several respects: the available photography in the Sevier Basin area is five years more "out of date"; wetland and agricultural areas in the Sevier Basin are typically much smaller and are more accessible to vehicles than in Uinta Basin; the best available (i.e., cloud free, proper season, most complete coverage of the study area with a minimum number of scenes) Landsat digital data was recorded July 28, 1979; four years from the date of the photography and two years from the time of field work. Consequently, the need to field check maps and the ease with which field checking could be accomplished resulted in the decision to emphasize the "direct sensing" aspect of the mapping process. The circumstances of the study were such that to complete and refine the Landsat digital analysis would have taken as much time and cost as an extra trip to the field. Since the primary objective of the study is to provide maps which are as detailed and current as available remote sensing media will allow, it was quite clear that additional field work should be the proper approach.

Landsat digital data was considered for use in differentiating brush-grass rangeland from pinyon-juniper woodlands. Digital print maps were checked against the photography to ascertain the ability of make such discriminations. The results of such checking led to the conclusion that further refinements would be needed to accurately delineate the two rangeland types with Landsat. The green colored areas on the U.S.G.S. base maps were compared with vegetation patterns on the photographs. Since the green areas on the foothills correlated highly with pinyon-juniper, it was decided that delineating such woodlands from brush-grass areas would be redundant. Consequently, overlay map users can examine the areas labeled pinyon-juniper and brush-grass in combination with the U.S.G.S. base map to ascertain where the two rangeland types occur.

CONCLUSIONS

Both high altitude color infrared aerial photography and Landsat digital data were examined in this study to determine the feasibility of using either or both data sources to produce wetland/agriculture maps. Landsat digital tapes were analyzed and print maps produced to overlay over the CIR photography in a similar manner to that which proved useful in the Uinta Basin project. When mapping an area of the size and nature of the upper Sevier Basin, high altitude color infrared photography, coupled with a fair amount of field work, proved to be the most accurate and cost-effective means of mapping wetlands and agricultural lands.

Since a certain amount of uncertainty accompanies any research effort, it is not always clear at the outset whether Landsat analysis will be a cost-effective dimension of a study. However, experience in the Sevier River study area has proved invaluable in terms of allowing CRSC the opportunity to explore the use of Landsat and develop some criteria which will help assure cost-effective use of Landsat in future projects. By asking a series of questions, and comparing the responses to our experience base (which includes vicarious experiences through others in the literature), we are provided with a means of selecting a study approach which will produce the desired final product. The primary questions are:

Objective - What is to be studied and mapped?

Purpose - Why is it to be mapped, how and by whom will the map be used?

Resources - What maps, aerial photography, and imagery are available?

Study Area - What is the size, topography, and nature, in terms of contrasts between surficial features, of the study area? How accessible are areas of special interest for purposes of facilitating field checking?

Standards - What are the mapping accuracy standards, in terms of scale, legend categories, size of minimum mapping units, etc.

Limits - What are the practical limits to the project in terms of time, budget, and personnel?

Reflection upon the questions above, in light of an ever-increasing experience base with Utah environments, remote sensing media, and analytical techniques will do much to assure production of resource inventories meeting accuracy standards with minimum cost.

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APPENDIX A. Explanation of Wetland Classes Mapped in the Sevier River Basin.

The material is taken from "Classification of Wetlands and Deepwater Habitats of the United States" by Cowardin, et al. (1979). Only information regarding riverine, lacustrine, and palustrine systems is included.

THE CLASSIFICATION SYSTEM

The structure of this classification is hierarchical, progressing from systems and subsystems, at the most general levels, to classes, subclasses, and dominance types. Figure 1 illustrates the classification structure to the class level. Table 1 lists the classes and subclasses for each system and gives an example of a dominance type for each subclass. Artificial keys to the systems and classes are given in Appendix E. Modifiers for water regime, water chemistry, and soils are applied to classes, subclasses, and dominance types. Special modifiers describe wetlands and deepwater habitats that have been either created or highly modified by man or beavers.

Hierarchical Structure

Systems and Subsystems

The term SYSTEM refers here to a complex of wetlands and deepwater habitats that share the influence of similar hydrologic, geomorphologic, chemical, or biological factors. We further subdivide systems into more specific categories called SUBSYSTEMS.

The characteristics of the five major systems—Marine, Estuarine, Riverine, Lacustrine, and Palustrine—have been discussed at length in the scientific literature and the concepts are well recognized; however, there is frequent disagreement as to which attributes should be used to bound the systems in space. For example, both the limit of tidal influence and the limit of ocean-derived salinity have been proposed for bounding the upstream end of the Estuarine System (Caspers 1967). As Bormann and Likens (1969) pointed out, boundaries of ecosystems are defined to meet practical needs.

Riverine System

Definition. The Riverine System (Fig. 4) includes all wetlands and deepwater habitats contained within a channel, with two exceptions: (1) wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2) habitats with water containing ocean-derived salts in excess of 0.5‰. A channel is "an open conduit either naturally or artificially created which periodically or continuously contains moving water, or which forms a connecting link between two bodies of standing water" (Langbein and Iseri 1960:5).

Limits. The Riverine System is bounded on the landward side by upland, by the channel bank (including natural and man-made levees), or by wetland dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens. In braided streams, the system is bounded by the banks forming the outer limits of the depression within which the braiding occurs.

The Riverine System terminates at the downstream end where the concentration of ocean-derived salts in the water exceeds 0.5‰ during the period of annual average low flow, or where the channel enters a lake. It terminates at the upstream end where tributary streams originate, or where the channel leaves a lake. Springs discharging into a channel are considered part of the Riverine System.

Description. Water is usually, but not always, flowing in the Riverine System. Upland islands or Palustrine wetlands may occur in the channel, but they are not included in the Riverine System. Palustrine Forested Wetlands, Emergent Wetlands, Scrub-Shrub Wetlands, and Moss-Lichen Wetlands may occur adjacent to the Riverine System, often on a floodplain. Many biologists have suggested that all the wetlands occurring on the river floodplain should be a part of the Riverine System because they consider their presence to be the result of river flooding. However, we concur with Reid and Wood (1976:72,84) who stated, "The floodplain is a flat expanse of land bordering an old river. . . . Often the floodplain may take the form of a very level plain occupied by the present stream channel, and it may never, or only occasionally, be flooded. . . . It is this subsurface water [the ground water] that controls to a great extent the level of lake surfaces, the flow of streams, and the extent of swamps and marshes."

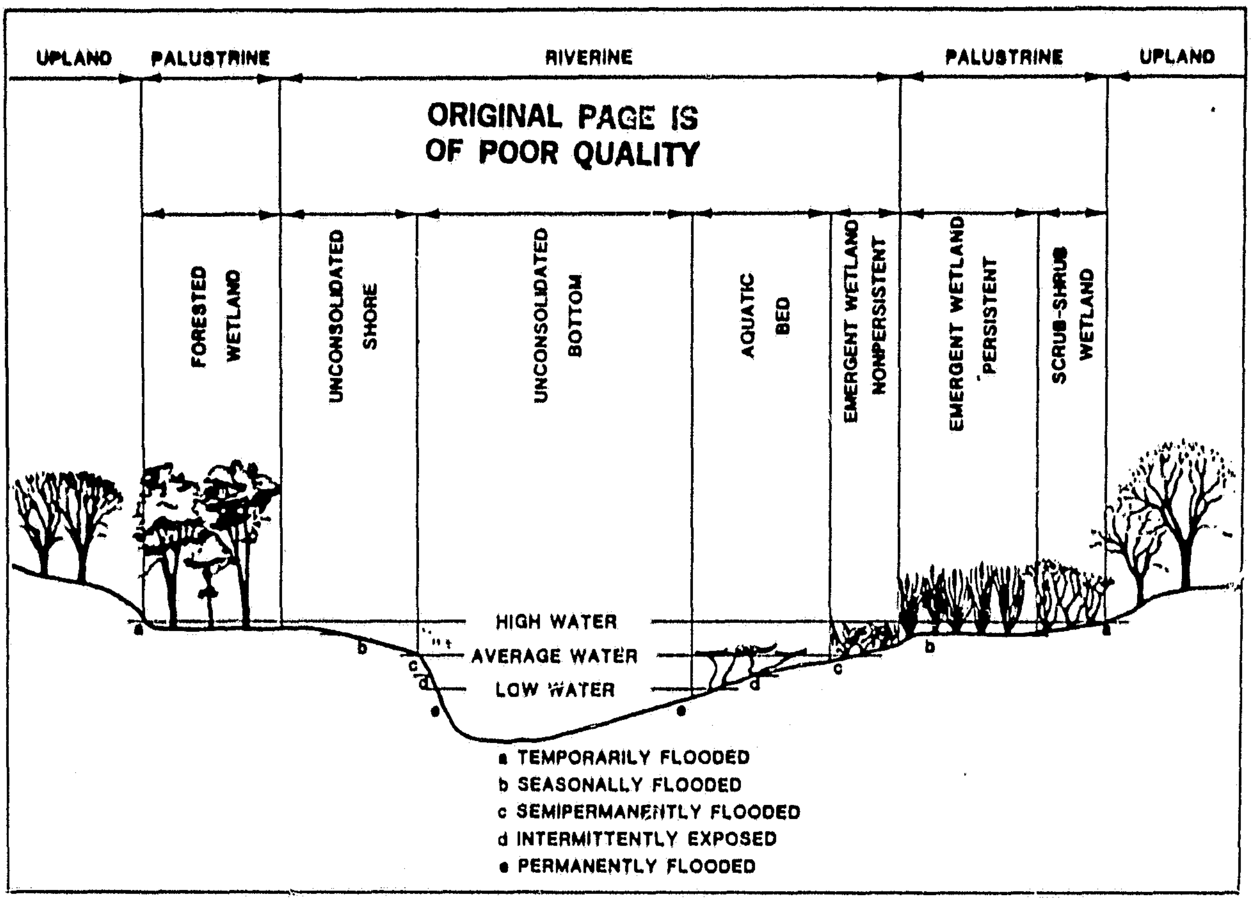

Fig. 4. Distinguishing features and examples of habitats in the Riverine System.

Subsystems. The Riverine System is divided into four subsystems: the Tidal, the Lower Perennial, the Upper Perennial, and the Intermittent. Each is defined in terms of water permanence, gradient, water velocity, substrate, and the extent of floodplain development. The subsystems have characteristic flora and fauna (see Illies and Botosaneau 1963; Hynes 1970; Reid and Wood 1976). All four subsystems are not necessarily present in all rivers, and the order of occurrence may be other than that given below.

Tidal.—The gradient is low and water velocity fluctuates under tidal influence. The streambed is mainly mud with occasional patches of sand. Oxygen deficits may sometimes occur and the fauna is similar to that in the Lower Perennial Subsystem. The floodplain is typically well developed.

Lower Perennial.—The gradient is low and water velocity is slow. There is no tidal influence, and some water flows throughout the year. The substrate consists mainly of sand and mud. Oxygen deficits may sometimes occur, the fauna is composed mostly of species that reach their maximum abundance in still water, and true planktonic organisms are common. The gradient is lower than that of the Upper Perennial Subsystem and the floodplain is well developed.

Upper Perennial.—The gradient is high and velocity of the water fast. There is no tidal influence and some water flows throughout the year. The substrate consists of rock, cobbles, or gravel with occasional patches of sand. The natural dissolved oxygen concentration is normally near saturation. The fauna is characteristic of running water, and there are few or no planktonic forms. The gradient is high compared with that of the Lower Perennial Subsystem, and there is very little floodplain development.

Intermittent.—In this subsystem, the channel contains nontidal flowing water for only part of the year. When the water is not flowing, it may remain in isolated pools or surface water may be absent.

Classes. Rock Bottom, Unconsolidated Bottom, Aquatic Bed, Streambed, Rocky Shore, Unconsolidated Shore, and Emergent Wetland (nonpersistent).

Lacustrine System

Definition. The Lacustrine System (Fig. 5) includes wetlands and deepwater habitats with all of the following characteristics: (1) situated in a topographic depression or a dammed river channel; (2) lacking trees, shrubs, persistent emergents, emergent mosses or lichens with greater than 30% areal coverage; and (3) total area exceeds 8 ha (20 acres). Similar wetland and deepwater habitats totaling less than 8 ha are also included in the Lacustrine System if an active wave-formed or bedrock shoreline feature makes up all or part of the boundary, or if the water depth in the deepest part of the basin exceeds 2 m (6.6 feet) at low water. Lacustrine waters may be tidal or nontidal, but ocean-derived salinity is always less than 0.5‰.

Limits. The Lacustrine System is bounded by upland or by wetland dominated by trees, shrubs, per-

Table 2. *Salinity modifiers used in this classification system.*

Coastal modifiers[a]	Inland modifiers[b]	Salinity (parts per thousand)	Approximate specific conductance (μMhos at 25°C)
Hyperhaline	Hypersaline	> 40	> 60,000
Euhaline	Eusaline	30.0-40	45,000-60,000
Mixohaline (brackish)	Mixosaline[c]	0.5-30	800-45,000
Polyhaline	Polysaline	18.0-30	30,000-45,000
Mesohaline	Mesosaline	5.0-18	8,000-30,000
Oligohaline	Oligosaline	0.5-5	800- 8,000
Fresh	Fresh	< 0.5	< 800

[a]Coastal modifiers are used in the Marine and Estuarine systems.
[b]Inland modifiers are used in the Riverine, Lacustrine, and Palustrine systems.
[c]The term Brackish should not be used for inland wetlands or deepwater habitats.

sistent emergents, emergent mosses, or lichens. Lacustrine systems formed by damming a river channel are bounded by a contour approximating the normal spillway elevation or normal pool elevation, except where Palustrine wetlands extend lakeward of that boundary. Where a river enters a lake, the extension of the Lacustrine shoreline forms the Riverine–Lacustrine boundary.

Description. The Lacustrine System includes permanently flooded lakes and reservoirs (e.g., Lake Superior), intermittent lakes (e.g., playa lakes), and tidal lakes with ocean-derived salinities below 0.5‰ (e.g., Grand Lake, Louisiana). Typically, there are extensive areas of deep water and there is considerable wave action. Islands of Palustrine wetland may lie within the boundaries of the Lacustrine System.

Subsystems.

Limnetic.—All deepwater habitats within the Lacustrine System; many small Lacustrine systems have no Limnetic Subsystem.

Littoral.—All wetland habitats in the Lacustrine System. Extends from the shoreward boundary of the system to a depth of 2 m (6.6 feet) below low water or to the maximum extent of nonpersistent emergents, if these grow at depths greater than 2 m.

Classes. Rock Bottom, Unconsolidated Bottom, Aquatic Bed, Rocky Shore, Unconsolidated Shore, and Emergent Wetland (nonpersistent).

Palustrine System

Definition. The Palustrine System (Fig. 6) includes all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5‰. It also includes wetlands lacking such vegetation, but with all of the following four characteristics: (1) area less than 8 ha (20 acres); (2) active wave-formed or bedrock shoreline features lacking; (3) water depth in the deepest part of basin less than 2 m at low water; and (4) salinity due to ocean-derived salts less than 0.5‰.

Limits. The Palustrine System is bounded by upland or by any of the other four systems.

Description. The Palustrine System was developed to group the vegetated wetlands traditionally called by such names as marsh, swamp, bog, fen, and prairie, which are found throughout the United States. It also includes the small, shallow, permanent or intermittent water bodies often called ponds. Palustrine wetlands may be situated shoreward of lakes, river channels, or estuaries; on river floodplains; in isolated catchments; or on slopes. They may also occur as islands in lakes or rivers. The erosive forces of wind and water are of minor importance except during severe floods.

The emergent vegetation adjacent to rivers and lakes is often referred to as "the shore zone" or the "zone of emergent vegetation" (Reid and Wood 1976), and is generally considered separately from the river itself. As an example, Hynes (1970:85) wrote in reference to riverine habitats, "We will not here consider the long list of emergent plants which may occur along the banks out of the current, as they do not belong, strictly speaking, to the running water habitat." There are often great similarities between wetlands lying adjacent to lakes or rivers and isolated wetlands of the same class in basins without open water.

Subsystems. None.

Classes. Rock Bottom, Unconsolidated Bottom, Aquatic Bed, Unconsolidated Shore, Moss-Lichen Wetland, Emergent Wetland, Scrub-Shrub Wetland, and Forested Wetland.

Classes, Subclasses, and Dominance Types

The CLASS is the highest taxonomic unit below the subsystem level. It describes the general appearance of the habitat in terms of either the dominant life form

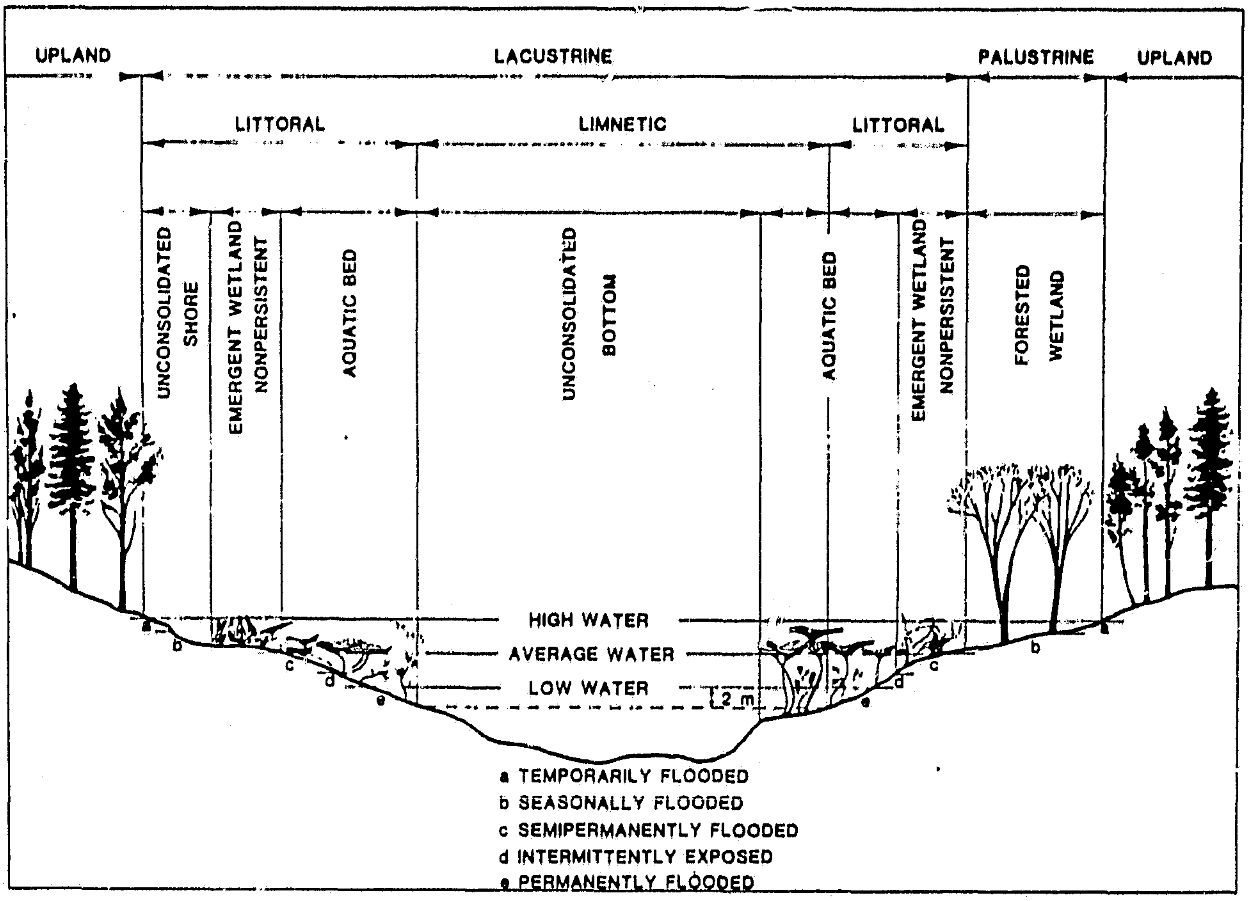

Fig. 5. Distinguishing features and examples of habitats in the Lacustrine System.

of the vegetation or the physiography and composition of the substrate—features that can be recognized without the aid of detailed environmental measurements. Vegetation is used at two different levels in the classification. The life forms—trees, shrubs, emergents, emergent mosses, and lichens—are used to define classes because they are relatively easy to distinguish, do not change distribution rapidly, and have traditionally been used as criteria for classification of wetlands.[3] Other forms of vegetation, such as submerged or floating-leaved rooted vascular plants, free-floating vascular plants, submergent mosses, and algae, though frequently more difficult to detect, are used to define the class Aquatic Bed. Pioneer species that briefly invade wetlands when conditions are favorable are treated at the subclass level because they are transient and often not true wetland species.

Use of life forms at the class level has two major advantages: (1) extensive biological knowledge is not required to distinguish between various life forms, and (2) it has been established that various life forms are easily recognizable on a great variety of remote sensing products (e.g., Radforth 1962; Anderson et al. 1976). If vegetation (except pioneer species) covers 30% or more of the substrate, we distinguish classes on the basis of the life form of the plants that constitute the uppermost layer of vegetation and that possess an areal coverage 30% or greater. For example, an area with 50% areal coverage of trees over a shrub layer with a 60% areal coverage would be classified as Forested Wetland; an area with 20% areal coverage of trees over the same (60%) shrub layer would be classified as Scrub-Shrub Wetland. When trees or shrubs alone cover less than 30% of an area but in combination cover 30% or more, the wetland is

[3]Our initial attempts to use familiar terms such as marsh, swamp, bog, and meadow at the class level were unsuccessful primarily because of wide discrepancies in the use of these terms in various regions of the United States. In an effort to resolve that difficulty, we based the classes on the fundamental components (life form, water regime, substrate type, water chemistry) that give rise to such terms. We believe that this approach will greatly reduce the misunderstandings and confusion that result from the use of the familiar terms.

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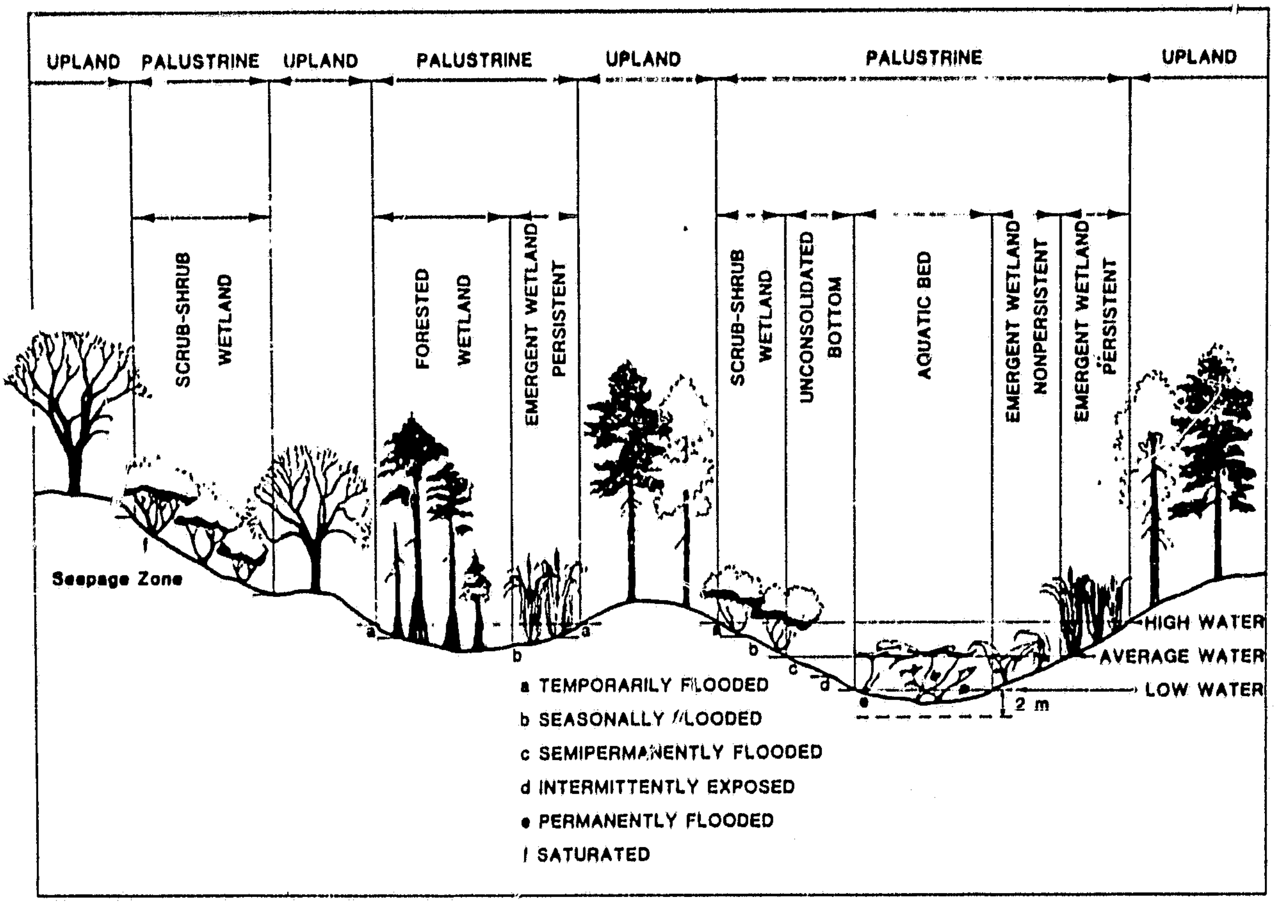

Fig. 6. Distinguishing features and examples of habitats in the Palustrine System.

assigned to the class Scrub-Shrub. When trees and shrubs cover less than 30% of the area but the total cover of vegetation (except pioneer species) is 30% or greater, the wetland is assigned to the appropriate class for the predominant life form below the shrub layer. Finer differences in life forms are recognized at the SUBCLASS level. For example, Forested Wetland is divided into the subclasses Broad-leaved Deciduous, Needle-leaved Deciduous, Broad-leaved Evergreen, Needle-leaved Evergreen, and Dead. Subclasses are named on the basis of the predominant life form.

If vegetation covers less than 30% of the substrate, the physiography and composition of the substrate are the principal characteristics used to distinguish classes. The nature of the substrate reflects regional and local variations in geology and the influence of wind, waves, and currents on erosion and deposition of substrate materials. Bottoms, Shores, and Streambeds are separated on the basis of duration of inundation. In the Riverine, Lacustrine, and Palustrine systems, Bottoms are submerged all or most of the time, whereas Streambeds and Shores are exposed all or most of the time. In the Marine and Estuarine systems, Bottoms are subtidal, whereas Streambeds and Shores are intertidal. Bottoms, Shores, and Streambeds are further divided at the class level on the basis of the important characteristic of rock versus unconsolidated substrate. Subclasses are based on finer distinctions in substrate material unless, as with Streambeds and Shores, the substrate is covered by, or shaded by, an aerial coverage of pioneering vascular plants (often nonhydrophytes) of 30% or more; the subclass is then simply vegetated. Further detail as to the type of vegetation must be obtained at the level of dominance type. Reefs are a unique class in which the substrate itself is composed primarily of living and dead animals. Subclasses of Reefs are designated on the basis of the type of organism that formed the reef.

The DOMINANCE TYPE is the taxonomic category subordinate to subclass. Dominance types are determined on the basis of dominant plant species (e.g., Jeglum et al. 1974), dominant sedentary or sessile animal species (e.g., Thorson 1957), or dominant plant and animal species (e.g., Stephenson and Stephenson 1972). A dominant plant species has traditionally meant one that has control over the community (Weaver and Clements 1938:91), and this plant is also usually the predominant species (Cain and Castro

1959:29). When the subclass is based on life form, we name the dominance type for the dominant species or combination of species (codominants) in the same layer of vegetation used to determine the subclass.[4] For example, a Needle-leaved Evergreen Forested Wetland with 70% areal cover of black spruce and 30% areal cover of tamarack (*Larix laricina*) would be designated as a *Picea mariana* Dominance Type. When the relative abundance of codominant species is nearly equal, the dominance type consists of a combination of species names. For example, an Emergent Wetland with about equal areal cover of common cattail (*Typha latifolia*) and hardstem bulrush (*Scirpus acutus*) would be designated as *Typha latifolia-Scirpus acutus* Dominance Type.

When the subclass is based on substrate material, the dominance type is named for the predominant plant or sedentary or sessile macroinvertebrate species, without regard for life form. In the Marine and Estuarine systems, sponges, alcyonarians, mollusks, crustaceans, worms, ascidians, and echinoderms may all be part of the community represented by the *Macoma balthica* Dominance Type. Sometimes it is necessary to designate two or more codominant species as a dominance type. Thorson (1957) recommended guidelines and suggested definitions for establishing community types and dominants on level bottoms.

Unconsolidated Bottom

Definition. The class Unconsolidated Bottom includes all wetland and deepwater habitats with at least 25% cover of particles smaller than stones, and a vegetative cover less than 30%. Water regimes are restricted to subtidal, permanently flooded, intermittently exposed, and semipermanently flooded.

Description. Unconsolidated Bottoms are characterized by the lack of large stable surfaces for plant and animal attachment. They are usually found in areas with lower energy than Rock Bottoms, and may be very unstable. Exposure to wave and current action, temperature, salinity, and light penetration determine the composition and distribution of organisms.

Most macroalgae attach to the substrate by means of basal hold-fast cells or discs; in sand and mud, however, algae penetrate the substrate and higher plants can successfully root if wave action and currents are not too strong. Most animals in unconsolidated sediments live within the substrate, e.g., *Macoma* and the amphipod *Melita*. Some, such as the polychaete worm *Chaetopterus*, maintain permanent burrows, and others may live on the surface, especially in coarse-grained sediments.

In the Marine and Estuarine systems, Unconsolidated Bottom communities are relatively stable. They vary from the Arctic to the tropics, depending largely on temperature, and from the open ocean to the upper end of the estuary, depending on salinity. Thorson (1957) summarized and described characteristic types of level bottom communities in detail.

In the Riverine System, the substrate type is largely determined by current velocity, and plants and animals exhibit a high degree of morphologic and behavioral adaptation to flowing water. Certain species are confined to specific substrates and some are at least more abundant in one type of substrate than in others. According to Hynes (1970:208), "The larger the stones, and hence the more complex the substratum, the more diverse is the invertebrate fauna." In Lacustrine and Palustrine systems, there is usually a high correlation, within a given water body, between the nature of the substrate and the number of species and individuals. For example, in the profundal bottom of eutrophic lakes where light is absent, oxygen content is low, and carbon dioxide concentration is high, the sediments are ooze-like organic materials and species diversity is low. Each substrate type typically supports a relatively distinct community of organisms (Reid and Wood 1976:262).

Emergent Wetland

Definition. The Emergent Wetland class is characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens. This vegetation is present for most of the growing season in most years. These wetlands are usually dominated by perennial plants. All water regimes are included except subtidal and irregularly exposed.

Description. In areas with relatively stable climatic conditions, Emergent Wetlands maintain the same appearance year after year. In other areas, such as the prairies of the central United States, violent climatic fluctuations cause them to revert to an open water phase in some years (Stewart and Kantrud 1972). Emergent Wetlands are found throughout the United States and occur in all systems except the Marine. Emergent Wetlands are known by many names, including marsh, meadow, fen, prairie pothole, and slough. Areas that are dominated by pioneer plants that become established during periods of low water are not Emergent Wetlands and should be classified as Vegetated Unconsolidated Shores or Vegetated Streambeds.

Subclasses and Dominance Types.

Persistent.—Persistent Emergent Wetlands are dominated by species that normally remain standing at least until the beginning of the next growing season. This subclass is found only in the Estuarine and Palustrine systems.

Persistent Emergent Wetlands dominated by saltmarsh cordgrass (*Spartina alterniflora*), saltmeadow cordgrass (*S. patens*), big cordgrass (*S. cynosuroides*), needlerush (*Juncus roemerianus*), narrow-leaved cattail (*Typha angustifolia*), and southern wild rice (*Zizaniopsis miliacea*) are major components of the Estuarine Systems of the Atlantic and Gulf coasts of the United States. On the Pacific Coast, common pickleweed (*Salicornia virginica*), sea blite (*Suaeda californica*), arrow grass (*Triglochin maritima*), and California cordgrass (*Spartina foliosa*) are common dominants.

Palustrine Persistent Emergent Wetlands contain a vast array of grasslike plants such as cattails (*Typha* spp.), bulrushes (*Scirpus* spp.), saw grass (*Cladium jamaicense*), sedges (*Carex* spp.); and true grasses such as reed (*Phragmites communis*), manna grasses (*Glyceria* spp.), slough grass (*Beckmannia syzigachne*), and whitetop (*Scolochloa festucacea*). There is also a variety of broad-leaved persistent emergents such as purple loosestrife (*Lythrum salicaria*), dock (*Rumex mexicanus*), waterwillow (*Decodon verticillatus*), and many species of smartweeds (*Polygonum*).

Nonpersistent.—Wetlands in this subclass are dominated by plants which fall to the surface of the substrate or below the surface of the water at the end of the growing season so that, at certain seasons of the year, there is no obvious sign of emergent vegetation. For example, wild rice (*Zizania aquatica*) does not become apparent in the North Central States until midsummer and fall, when it may form dense emergent stands. Nonpersistent emergents also include species such as arrow arum (*Peltandra virginica*), pickerelweed (*Pontederia cordata*), and arrowheads (*Sagittaria* spp.). Movement of ice in Estuarine, Riverine, and Lacustrine systems often removes all traces of emergent vegetation during the winter. Where this occurs, the area should be classified as Nonpersistent Emergent Wetland.

Scrub-Shrub Wetland

Definition. The class Scrub-Shrub Wetland includes areas dominated by woody vegetation less than 6 m (20 feet) tall. The species include true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions. All water regimes except subtidal are included.

Description. Scrub-Shrub Wetlands may represent a successional stage leading to Forested Wetland, or they may be relatively stable communities. They occur only in the Estuarine and Palustrine systems, but are one of the most widespread classes in the United States (Shaw and Fredine 1956). Scrub-Shrub Wetlands are known by many names, such as shrub swamp (Shaw and Fredine 1956), shrub carr (Curtis 1959), bog (Heinselman 1970), and pocosin (Kologiski 1977). For practical reasons we have also included forests composed of young trees less than 6 m tall.

Modifiers

To fully describe wetlands and deepwater habitats, one must apply certain modifiers at the class level and at lower levels in the classification hierarchy. The modifiers described below were adapted from existing classifications or were developed specifically for this system.

Special Modifiers

Many wetlands and deepwater habitats are man-made, and natural ones have been modified to some degree by the activities of man or beavers. Since the nature of these modifications often greatly influences the character of such habitats, special modifying terms have been included here to emphasize their importance. The following modifiers should be used singly or in combination wherever they apply to wetlands and deepwater habitats.

Farmed

The soil surface has been mechanically or physically altered for production of crops, but hydrophytes will become reestablished if farming is discontinued.

Diked

Created or modified by a man-made barrier or dike designed to obstruct the inflow of water.

Relationship to Other Wetland Classifications

There are numerous wetland classifications in use in the United States. Here we relate this system to three published classifications that have gained widespread acceptance. It is not possible to equate these systems directly for several reasons: (1) The criteria selected for establishing categories differ; (2) some of the classifications are not applied consistently in different parts of the country; and (3) the elements classified are not the same in various classifications.

The most widely used classification system in the United States is that of Martin et al. (1953) which was republished in U. S. Fish and Wildlife Service *Circular 39* (Shaw and Fredine 1956). The wetland types are based on criteria such as water depth and permanence, water chemistry, life form of vegetation, and dominant plant species. In Table 4 we compare some of the major components of our system with the type descriptions listed in *Circular 39*.

In response to the need for more detailed wetland classification in the glaciated Northeast, Golet and Larson (1974) refined the freshwater wetland types of *Circular 39* by writing more detailed descriptions and subdividing classes on the basis of finer differences in plant life forms. Golet and Larson's classes are roughly equivalent to Types 1-8 of *Circular 39*, except that they restricted Type 1 to river floodplains. The Golet and Larson system does not recognize the coastal (tidal) fresh wetlands of *Circular 39* (Types 12-14) as a separate category, but classifies these areas in the same manner as nontidal wetlands. In addition to devising 24 subclasses, they also created 5 size categories, 6 site types giving a wetland's hydrologic and topographic location; 8 cover types (modified from Stewart and Kantrud 1971) expressing the distribution and relative proportions of cover and water; 3 vegetative interspersion types; and 6 surrounding habitat types. Since this system is based on the classes of Martin et al. (1953), Table 4 may also be used to compare the Golet and Larson system with the one described here. Although our system does not include size categories and site types, this information will be available from the results of the new inventory of wetlands and deepwater habitats of the United States.

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Table 4. *Comparison of wetland types described in U. S. Fish and Wildlife Service* Circular 39 *with some of the major components of this classification system.*

Circular 39 type, and references for examples of typical vegetation	Classification of wetlands and deepwater habitats: Classes	Water regimes	Water chemistry
Type 1—Seasonally flooded basins or flats Wet meadow (Dix and Smeins 1967; Stewart and Kantrud 1972) Bottomland hardwoods (Braun 1950) Shallow-freshwater swamps (Penfound 1952)	Emergent Wetland Forested Wetland	Temporarily Flooded Intermittently Flooded	Fresh Mixosaline
Type 2—Inland fresh meadows Fen (Heinselman 1963) Fen, northern sedge meadow (Curtis 1959)	Emergent Wetland	Saturated	Fresh Mixosaline
Type 3—Inland shallow fresh marshes Shallow marsh (Stewart and Kantrud 1972; Golet and Larson 1974)	Emergent Wetland	Semipermanently Flooded Seasonally Flooded	Fresh Mixosaline
Type 4—Inland deep fresh marshes Deep marsh (Stewart and Kantrud 1972; Golet and Larson 1974)	Emergent Wetland Aquatic Bed	Permanently Flooded Intermittently Exposed Semipermanently Flooded	Fresh Mixosaline
Type 5—Inland open fresh water Open water (Golet and Larson 1974) Submerged aquatic (Curtis 1959)	Aquatic Bed Unconsolidated Bottom	Permanently Flooded Intermittently Exposed	Fresh Mixosaline
Type 6—Shrub swamps Shrub swamp (Golet and Larson 1974) Shrub-carr, alder thicket (Curtis 1959)	Scrub-Shrub Wetland	All nontidal regimes except Permanently Flooded	Fresh
Type 7—Wooded swamps Wooded swamp (Golet and Larson 1974) Swamps (Penfound 1952; Heinselman 1963)	Forested Wetland	All nontidal regimes except Permanently Flooded	Fresh
Type 8—Bogs Bog (Dansereau and Segadas-vianna 1952; Heinselman 1963) Pocosin (Penfound 1952; Kologiski 1977)	Scrub-Shrub Wetland Forested Wetland Moss-Lichen Wetland	Saturated	Fresh (acid only)
Type 9—Inland saline flats Intermittent alkali zone (Stewart and Kantrud 1972)	Unconsolidated Shore	Seasonally Flooded Intermittently Flooded Temporarily Flooded	Eusaline Hypersaline
Type 10—Inland saline marshes Inland salt marshes (Ungar 1974)	Emergent Wetland	Seasonally Flooded Semipermanently Flooded	Eusaline
Type 11—Inland open saline water Inland saline lake community (Ungar 1974)	Unconsolidated Bottom	Permanently Flooded Intermittently Flooded	Eusaline
Type 12—Coastal shallow fresh marshes Marsh (Anderson et al. 1968) Estuarine bay marshes, estuarine river marshes (Stewart 1962) Fresh and intermediate marshes (Chabreck 1972)	Emergent Wetland	Regularly Flooded Irregularly Flooded Semipermanently Flooded-Tidal	Mixohaline Fresh

APPENDIX B

Circular 39 Wetland Classification System Definitions of Type 1-11 Wetlands

A. Wetlands

1. Seasonally Flooded Basins or Flats

   The soil is covered with water or is water logged during variable seasonal periods, but usually is well drained during much of the growing season. This type is found both in upland depressions and in overflow bottom lands; along river courses, flooding occurs in late fall, winter, or spring. In the uplands, basins or flats may be filled with water during periods of heavy rains or melting snow. Vegetation varies greatly according to the season and the duration of flooding. Where the water has receeded early in the growing season, smartweeds, wild millet, fall panicum, tealgrass, and weeds, such as marsh elder, ragweed, and cocklebursare likely to occur. Shallow basins that are submerged only very temporarily usually develop little or no wetland vegetation.

2. Inland Fresh Meadows

   The soil is without standing water during most of growing season but is waterlogged within at least a few inches of the surface. Vegetation includes grasses, sedges, rushes, and various broadleaf plants. Representative plants are carex, brushes, redtop, reedgrasses, managrasses, prairie cordgrass, and mints. Meadows may fill shallow lake depressions, sloughs or farmland sags, or these meadows may border shallow marshes on the landward side. Wild hay is often cut from such areas.

3. Inland Shallow Fresh Marshes

   The soil is usually waterlogged during the growing season. Often, it is covered by as much as six inches or more of water. Vegetation includes grasses, bullrushes, spikerushes, or other various marsh plants such as cattails, arrowheads, and smartweeds. These marshes may nearly fill shallow lake basins or sloughs or they may border deep marshes on the landward side. They are also common as seep areas on irrigated lands.

4. Inland Deep Fresh Marshes

The soil is covered with six inches to three feet or more of water during the growing season. Vegetation includes cattails, bullrushes, reeds, spikerrushes, and wildrice. In open areas, pondweeds, naiads, coontail, watermilfoils, waterweeds, duckweeds, waterlilies or spatter-docks may occur. These deep marshes may almost fill shallow lake basins, potholes, limestone sinks and sloughs or they may border open water in such depressions.

5. Inland Open Fresh Water

Shallow ponds and reservoirs are included in this type. Water is usually less than 10 feet deep and is fringed by a border of emergent vegetation. Vegetation mainly at water depths of less than six feet include pondweeds, naiads, wild celery, coontail, watermilfoils, muskgrasses, waterlillies, and spatterdocks.

6. Shrub Swamps

The soil is usually waterlogged during the growing season and is often covered with as much as six inches of water. Vegetation includes alders and willows.

7&8. Not found in Utah.

9. Inland Saline Flats

The soil is without standing water except after periods of heavy precip-itation but it is waterlogged within at least a few inches of the surface during the growing season. Vegetation often sparse or patchy, consists of salt tollerant plants such as seablite, saltgrass, Nevada bullrush, saltbush, and burrowweed.

10. Inland Saline Marshes

The soil is usually waterlogged during the growing season and is often covered with as much as two or three feet of water. This type occurs mostly in shallow lake basins. Vegetation is mainly alkali or hardstem bullrushes often widgongrass or sego pondweed in the openings.

11. Inland Open Saline Water

These more permanent areas of shallow saline water are often closely associated with types 9 and 10. Depth of the water is variable. Vegetation, mainly at water depths of less than six feet, includes pondweeds and widgongrass.