4 Soil Morphology and Frequency of Diagnostic Wet Soil Conditions

A. A. Szögi
USDA-ARS
Florence, South Carolina

W. H. Hudnall
Louisiana State University
Baton Rouge, Louisiana

ABSTRACT

Soil hydrology is the factor that drives the development of hydromorphic features, saturation, and reduction in wet soils. These three soil characteristics are all required to recognize aquic conditions and are important in the development of hydric soils, but they may vary throughout the year. Since soil hydrology variables are nearly always affected by random components due to annual, seasonal, and daily fluctuations, reliable prediction of wet soil conditions is difficult. However, time-dependent hydrological variables can be transformed into cumulative probability distributions in order to improve predictions of wet soil conditions. Our purpose was to examine differences in cumulative probability distributions of three hydrological variables [water table (WT) levels, soil redox potential, and tension] within a soil and to compare these distributions with locations of hydromorphic features within that soil. Water table levels, soil redox potential (Eh), and soil saturation data, taken periodically at different soil depths, were transformed into cumulative probability distributions. We examined the following two soils in a toposequence on the natural levee of the Mississippi River: Cancienne silt loam (fine-silty, mixed, hyperthermic Aeric Endoaquepts) and Schriever clay (very-fine, smectitic, hyperthermic, Chromic Epiaquerts). The use of cumulative frequency analysis helped to better understand the relationship between soil hydromorphology and frequency of WT levels above a horizon or group of horizons in both soils of this study. The approach also was useful for comparing the location of hydromorphic features vs. the probability of occurrence of WT levels above diagnostic soil depths according to *Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys* (Soil Surv. Staff, 1975). Water table level probability patterns corresponded well with probabilities of occurrence of reduction at 50-cm depth for both soils. But at 100-cm depth, the probability of soil reduced conditions were lower than the probability of occurrence of WT levels above 100-cm depth. As expected, since for soil reduction an organic C source in addition to soil saturation is required, more intense reduction and lower WT frequencies than at greater soil depths took place nearer the soil surface. Although soil moisture tension data was necessary to verify soil saturation, the comparison of saturation to either probabilities of occurrence of WT levels or

Quantifying Soil Hydromorphology. SSSA Special Publication no. 54.

location of hydromorphic features was not straightforward. Saturation patterns based on tensiometer data were not consistent with WT level frequencies due to differences between piezometer and tensiometer data at the same soil depth. Aquic conditions in both soils were verified by the presence of redoximorphic features, frequencies of occurrence of saturation, reduction, and WT levels at diagnostic soil depths according to the *Keys to Soil Taxonomy* (Soil Surv. Staff, 1992). When hydric soil conditions were tested, we found that the Schriever soil is a hydric soil because hydric soil criteria and field indicators of hydric soils corresponded well with probability of occurrence of WT levels. Morphological field indicators in the Cancienne soil indicated possible hydric conditions. However, the Cancienne soil did not meet hydric soil criteria, and this soil is not a hydric soil. The Schriever soil provides an example of how field indicators agree with the hydrology of a hydric soil and Cancienne provides an example of how field indicators do not agree with the hydrology of a hydric/nonhydric borderline soil.

Soil hydrology is the factor that drives the development of hydromorphic features, saturation, and reduction in wet soils (Mausbach & Richardson, 1994). These three characteristics are all required to classify wet soils into aquic suborders of *Keys to Soil Taxonomy* (Soil Surv. Staff, 1992) and to recognize hydric soils for wetland delineation. These soil characteristics may vary throughout the year as a result of annual, seasonal, and daily hydrologic fluctuations. Therefore, reliable prediction of wet soil conditions is difficult. This is particularly true for sites that are not continuously or regularly flooded, and for some that may never flood.

Data obtained from monitoring wells, tensiometer, and redox measurements have been used to establish long-term trends of flooding, saturation and reduction in characteristic wet soils of the USA (Wakeley et al., 1996). Although these data are easy to obtain from experimental plots, interpretation of these measurements to determine the frequency of high WT, soil saturation and reduction is not usually straightforward. Direct interpretation of long-term databases is difficult because other environmental variables (precipitation, stratigraphy, topography, soil permeability and plant cover) randomly affect the measurements of WT table depths, soil moisture tension and redox potentials. Therefore, WT level fluctuations, saturation and reduction trends as a function of time are graphically or mathematically difficult to interpret unless transformation of the data is done to include the probability or frequency of occurrence of the events. For instance, the probability of occurrence of a WT above a certain depth is obtained by computing the ratio of the number of observations that exceeded the selected depth over the total number of observations. This ratio is the transformation of a time-dependent variable (WT depth as a function of time) into a frequency or probabilistic variable that can be represented by a cumulative probability function (Ott, 1995). The advantages of using a cumulative probability distribution are that it is a continuous function represented by a smooth curve, it is not affected by missing data, and the probability of occurrence above a certain value of the variable is easily read from a probability diagram.

The objective of the study was to examine differences in cumulative probability distributions of three variables (WT levels, saturation, and redox potential) within a soil and to compare these distributions with the location of the hydromorphic features within that soil. Results were used to verify aquic and hydric soil conditions.

MATERIALS AND METHODS

Site Characterization

The approach was tested using data obtained for two soils from a typical toposequence on the lower Mississippi Valley in Louisiana. Water table depth, soil saturation and soil redox potential data taken periodically during 32 mo were transformed into cumulative frequency distributions.

The study area is located on the Louisiana Agricultural Experiment Station, St. Gabriel Research Station (30°30′00″N lat, 91°5′15″W long), Iberville Parish, Louisiana. This area is within the Land Resource Region called Mississippi Delta Cotton and Feed Grains (USDA-NRCS, 1996). The investigation was based on the following two soil series developed on Mississippi River alluvium: Cancienne (fine-silty, mixed, hyperthermic Aeric Endoaquepts) and Schriever (very-fine, smectitic, hyperthermic Chromic Epiaquerts). These two soils occupy intermediate and low topographic positions on the natural levee of the Mississippi River (Fig. 4–1). The Cancienne and Schriever soil sites are part of an extensive network of monitoring sites established to investigate aquic and hydric soil conditions in the Coastal Plain of Louisiana (Hudnall & Szögi, 1996).

Mean annual air temperature is 19°C. Mean (12-yr avg.) annual rainfall is 157 cm. Monthly rainfall distribution over the monitoring period of 32 mo (April 1989–December 1991) was similar to the respective monthly mean, but rainfall records for June 1989, August 1990, and April and May 1991, were much higher than the mean (Fig. 4–2). The soil temperature regime of the study area is hyperthermic with a mean annual soil temperature at 50 cm of 24°C (Hudnall & Szögi, 1996).

Soil pits were excavated in October 1989. Morphological characteristics of the two soils were described and classified according to the *Soil Taxonomy* (Soil Surv. Staff, 1994) and Vepraskas (1992). Soils were sampled by horizon for physical, chemical and mineralogical analyses. Complete characterization analyses were completed at the National Soil Survey Laboratory (NSSL), Lincoln, Nebraska, following USDA (1984) procedures. Results were reported by Hudnall et al. (1990).

Site Instrumentation and Measurements

Each site consisted of a 10- by 10-m plot next to the place where the soil characterization pit was excavated. The plots contained the necessary instruments to measure WT depths, soil tension, and soil redox potentials. Field measurements were taken every 2 wk.

Water table depths were determined with piezometers. The piezometers were constructed from 1.9-cm o.d. polyvinyl chloride (PVC) pipe (Szögi & Hudnall, 1992). Piezometers had a 10-cm well screen made by cutting eight horizontal slits at one end of the PVC pipe. A piece of geofabric was glued onto the screen to avoid clogging and to close the end of the pipe. The other end of the piezometer was covered with a PVC cap with a small hole in its center. Triplicate nested piezometers were installed at depths of 25, 50, 100, and 200 cm. The bottom of each augerhole was filled with sand followed by a bentonite plug, a layer of soil and another bentonite plug at the surface.

Tensiometers and platinum electrodes were installed at predetermined depths in order to monitor saturation and redox potential within the soil moisture control section and diagnostic soil depths according to *Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys* (Soil Surv. Staff, 1975). Water tension was measured in triplicate with jet-filled tensiometers placed into the soils at three different depths (25, 50 and 100 cm). Reduction was characterized by measuring the redox potentials directly with permanently installed platinum electrodes. The platinum electrodes were fabricated and tested

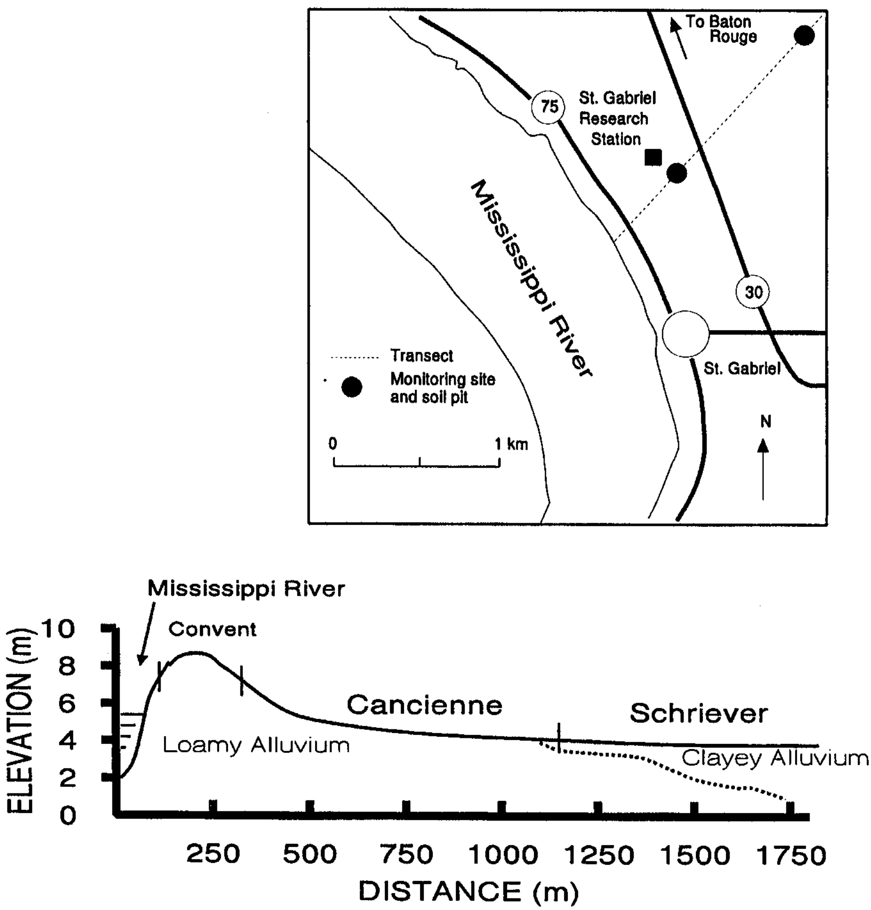

Fig. 4–1. Site location and position on the landscape for Cancienne and Schriever soils. The associated soil, Convent silt loam (coarse-silty, mixed, nonacid, hyperthermic Aeric Fluvaquents), occurs in the narrow upper part on the levee of the Mississippi River.

according to Szögi and Hudnall (1992). Electrodes were installed in the field at 50- and 100-cm depth in triplicate. Redox potentials were taken in the field with a portable voltmeter connected to the platinum electrode and to a saturated calomel reference electrode. The reference electrode made contact with the soil through a salt bridge that was placed into wet or moistened material at the soil surface. Voltage readings were recorded after the reading drift decreased to an equilibrated value. The field readings were adjusted by adding +244 mV in order to express redox potentials on the standard hydrogen reference electrode (SHE) or Eh readings. Since the field pH of both soils was circumneutral, interpretation of Eh data was made without pH correction.

Statistical Analyses

Time-dependent variables (WT depths, soil suction and soil redox potential) were transformed into cumulative probability distributions of ungrouped data and represented by probability diagrams (Ott, 1995). To construct these diagrams, the observations were arranged by sorting them from the lowest value to the highest value. Next, the cumulative probability was obtained by calculation of the plotting position. The plotting position (*fi*) was computed for each observation using the following formula.

$$ft = \Sigma \frac{i}{n+1} \qquad \text{for } i = 1, 2, \ldots, \text{n}$$

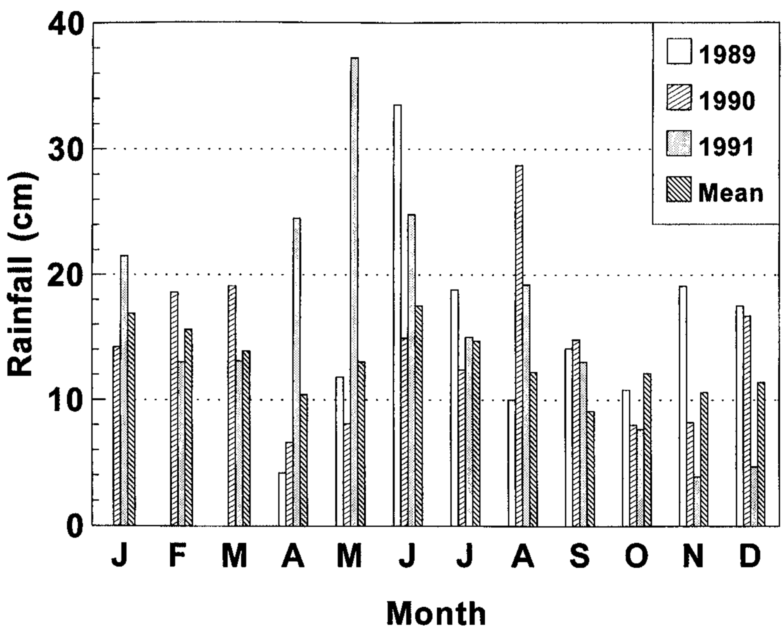

Fig. 4–2. Distribution of monthly rainfall for St.Gabriel Experiment Station, Louisiana. Monthly means are 12-yr averages. Data provided by the National Climatic Data Center, Asheville, North Carolina.

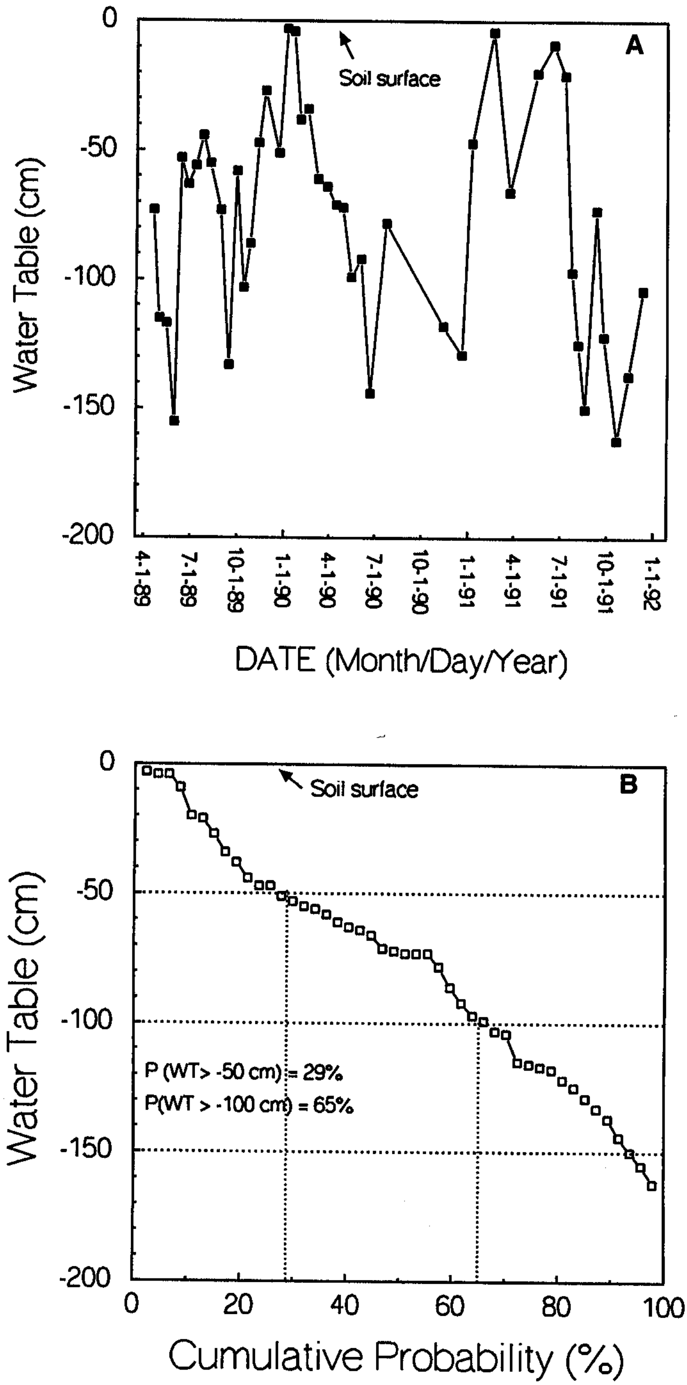

Fig. 4–3. (*a*) Water table level data vs. time for Cancienne soil. (b) Cumulative probability (*P*) distribution of WT levels for Cancienne soil constructed with data from diagram *a*.

When expressed in percentage, the plotting positions for these observations represent cumulative probability values between 0 and 100%. Finally, the plotting position (cumulative probability) was represented on the *x*-axis and the corresponding values of the variable were plotted on the *y*-axis of the diagram. Data sorting, frequency analysis and estimation of cumulative frequency distributions were performed using SAS statistical software (SAS Inst., 1988).

RESULTS AND DISCUSSION

Morphology and Water Table Depth Frequencies

An example of WT level data transformed into a cumulative probability distribution is presented in Fig. 4–3 for the Cancienne soil. The distribution of WT levels vs. time is presented in Fig. 4–3a and its coinciding cumulative probability distribution for WT levels is shown in Fig. 4–3b. A similar probability diagram was constructed for the Schriever soil (Fig. 4–4).

Soil morphology and WT level frequencies were examined in two ways. One way was to examine frequencies of WT levels by horizon or group of horizons and match them to the location, type and abundance of hydromorphic features. Another way was to examine if probabilities of occurrence of WT levels matched saturation and reduction probability patterns at 50- and 100-cm depths. These two depths were selected to verify the occurrence of hydromorphic features and saturation and reduction conditions in the soil moisture control section

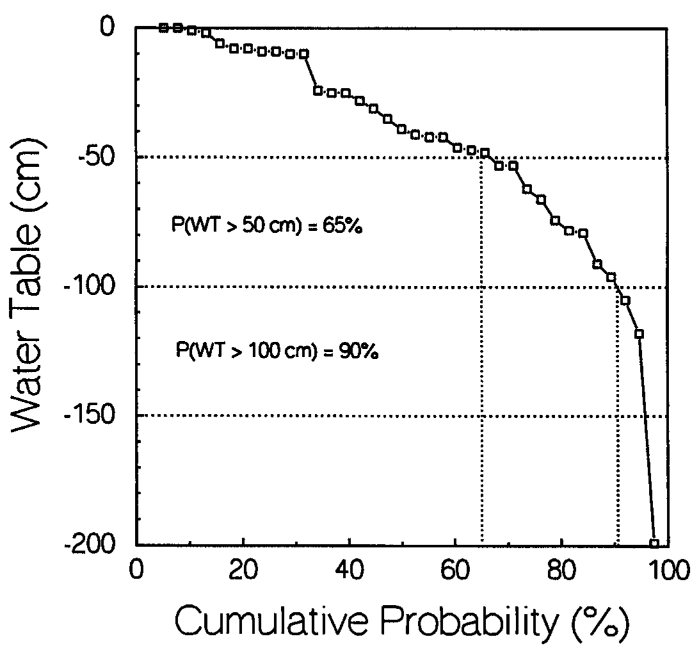

Fig. 4–4. Cumulative probability (*P*) distribution of WT levels for Schriever soil.

Table 4–1. Selected morphological characteristics of Cancienne and Schriever pedons.

Horizon	Depth	Matrix color	Redoximorphic features†	Texture‡	Structure§
	cm				
			Cancienne		
Ap1	0–15	10YR 4/2		SiL	1fg
Ap2	15–28	10YR 4/2	F2d 10YR 4/4 masses, F1d 10YR 4/4 iron pore linings and F1d10YR 4/4 masses along ped surfaces	SiL	1fg
Bw1	28–51	10YR 5/2	M2d 10YR 4/4 masses along ped surfaces	SiL	1cpr/2csbk
Bw2	51–78	10YR 5/2	C1d 10YR 4/4 masses along ped surfaces	SiL	1cpr/1csbk
Bg1	78–116	10YR 5/2	C2d 10YR 4/4 masses along ped surfaces	SiL	1cpr
Bg2	116–150	10YR 5/1	C2d 10YR 4/4 masses along ped surfaces	SiCL	1cpr/1csbk
Bg3	150–180	10YR 5/1	C2d 10YR 4/3 masses along ped surfaces	SiC	1msbk
Bgssb	180–215	10YR 5/1	C2d 10YR 4/4 masses along ped surfaces	SiC	1msbk/1mabk
			Schriever		
Ap	0–13	10YR 4/2	F1d 10YR 4/4 iron masses along ped surfaces	SiC	1msbk
A	13–30	10YR 4/1	C3d 10YR 4/4 masses along ped surfaces	SiC	2msbk
Bg1	30–50	10YR 4/1	C2d 10YR 4/4 masses along ped surfaces	C	2msbk
Bg2	50–85	5Y 4/1	C3d 10YR 4/4 masses along ped surfaces	C	2cpr/2msbk
Bg3	85–132	5Y 4/1	C3d 7.5YR 4/6 masses along ped surfaces	C	1cpr/2msbk
Bgss1	132–158	5GY 5/1	C2d 10YR 5/4 and 10YR 5/6 masses along peds	C	1cpr
Bgss2	158–180	5GY 5/1	C3d 5Y 5/6 masses	C	2msbk
BCg	180–212	5GY 5/1	C2d 5Y 5/6 masses	CL	1msbk

† Redoximorphic feature abundance: M = many, C = common, F = few. Redoximorphic feature size: 1 = fine, 2 = medium, 3 = coarse. Redoximorphic feature contrast: f = faint, d = distinct, p = prominent.
‡ Texture class: SiL = silty loam, SiC = silty clay, SiCL = silty clay loam, CL = clay loam, C = clay.
§ Structure: 3 = strong, 2 = moderate, 1 = weak, vf = very fine, f = fine, m = medium, c = coarse, g = granular, sbk = subangular blocky, abk = angular bloky, pr = prismatic, / = parting into other structure.

and diagnostic depths used in *Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys* and *Keys to Soil Taxonomy* (Soil Surv. Staff, 1975, 1994).

The Cancienne soil has reduced matrix colors (value 4 and 5, chroma 1 and 2) and clay content increases with depth below the Bw1 horizon (Tables 4–1 and 4–2). Results for Cancienne soil show that the occurrence of WT levels above 50-cm depth have a probability of 29% (Fig. 4–3b). For the upper 50-cm part of the profile, redoximorphic features included low chroma dominant matrix colors of 10YR 4/2 and 5/2 for Ap1, Ap2, and Bw1 horizons (Table 4–1). Although matrix colors have the same chroma, these three horizons have distinct morphologies that do not equally correspond to the WT level probability of 29%. The Ap1 (0–15 cm) horizon does not have iron bodies, the color of its matrix is probably due to organic C content and not due to wetness. The Ap2 (15–28 cm) horizon has few fine redoximorphic features, but the Bw1 (28–51 cm) has more abundant and contrasting (many medium) redoximorphic features than the Ap2 and also has different matrix color (10 YR 5/2). These differences among the Ap1, Ap2 and Bw1 horizons can be explained by the fact that the probability of occurrence of WT levels decreases toward the soil surface. While WT levels above the lower

Table 4–2. Selected physical and chemical properties of Cancienne and Schriever pedons.

Horizon	Depth	pH	Organic C	Bulk density	Texture Clay	Silt	Sand	Base saturation	CEC†	Fe_d‡
	cm	H_2O	g kg^{-1}	Mg m^{-3}	%				cmol$_c$ kg^{-1}	g kg^{-1}
					Cancienne					
Ap1	0–15	6.8	19.4	1.47	13.8	65.8	20.4	100	17.3	6
Ap2	15–28	7.3	10.1	1.51	14.4	66.3	19.3	100	15.2	6
Bw1	28–51	7.8	5.3	1.56	23.5	64.9	11.6	100	19.5	9
Bw2	51–78	7.7	3.0	1.45	15.9	66.5	17.6	100	14.5	4
Bg1	78–116	7.7	3.3	1.50	20.1	69.7	10.2	100	18.3	5
Bg2	116–150	7.7	4.9	1.54	31.2	64.8	4.0	100	25.8	6
Bg3	150–180	7.6	5.5	1.60	43.7	53.4	2.9	100	33.4	12
Bgssb	180–215	7.5	7.1	1.68	50.4	45.3	4.3	70	64.8	10
					Schriever					
Ap	0–13	6.7	35.9	1.74	48.3	41.5	10.2	93	39.4	9
A	13–30	7.0	13.0	1.87	54.3	43.3	2.4	100	38.6	11
Bg1	30–50	7.6	8.8	1.82	68.8	29.2	2.0	100	46.0	14
Bg2	50–85	7.7	6.6	1.76	63.6	33.8	2.6	100	43.5	16
Bg3	85–132	7.8	6.8	1.76	66.4	29.6	4.0	100	44.7	15
Bgss1	132–158	7.4	5.0	1.77	53.8	30.5	15.7	100	36.1	10
Bgss2	158–180	7.1	3.3	1.84	46.2	38.2	15.6	99	32.6	14
BCg	180–212	7.4	3.1	1.67	35.8	40.5	23.7	100	27.8	8

† Cation-exchange capacity.
‡ Dithionate-citrate extractable iron.

boundary of the Bw1 (51 cm) have a probability to occur of about 30%, the WT levels above the lower boundaries of the Ap2 horizon (28 cm) occur with a probability of 15% that decreases to 10% above the lower boundary of the Ap1 (15 cm). These probabilities, although not indicated on Fig. 4–3b, are easily found on the probability diagram. The horizons below the Bw1 [Bw2 (51–78 cm) and Bg1 (78–116 cm)] have similar morphology (Table 4–1). Even though the probabilities of occurrence of WT levels above the Bw2 and Bg1 horizons are much higher than for Bw1 and the amount of time that these horizons are below the WT surface during the year increases with soil depth, the abundance of masses does not change much with depth. Deeper in the soil, the matrix color (chroma) changes from 10 YR 5/2 in the lighter textured Bg1 horizon to 10 YR 5/1 in the heavier textured Bg2 (116–150 cm) horizon. Water table levels have a probability to be above the Bg1 horizon (78 cm) of about 59%, while the probability of the WT level to be above Bg2 horizon is about 72%, which may explain the difference in chroma. For the Cancienne soil we can conclude that the type and distribution with depth of redoximorphic features are not related straightforwardly to the probabilities of occurrence of WT levels. Low probabilities of WT levels are likely related to the lack of redoximorphic features within the Ap1 horizon or presence of few small redoximorphic features within the Ap2 horizon. When probabilities of WT levels increase with depth below the Ap1, redoximorphic features are ubiquitous within the soil but abundance does not change with depth.

The soil profile description and selected physical and chemical properties indicate that the Schriever soil has depleted matrix colors (value 4 and 5, chroma 1 and 2) and high clay content (Tables 4–1 and 4–2). Slickensides in a layer 25 cm or thicker within 100 cm of the surface place this soil into the Vertisol order. Redoximorphic features within the upper 50-cm zone of the profile (Ap, A and Bg1 horizons) included dominant matrix colors of 10YR 4/2 and 4/1 and iron masses of different sizes (Table 4–1). There is a 65% probability that the WT will occur above 50-cm depth (Fig. 4–4). For the 50- to 132-cm zone (Bg2 and Bg3 horizons), redoximorphic features included dominant matrix colors of 5Y 4/1 and coarse iron masses. There is a 96% probability that the WT will occur above 132-cm depth. For the lower part of the profile (132- to 200-cm zone) the color matrix of 5GY 5/1 and common coarse masses indicate the presence of a permanent WT. The probability of occurrence for the WT levels above 200 cm is 100%. For the Schriever soil, we concluded that WT level probability patterns corresponded well to the location and type of hydromorphic features.

Frequency of Water Table Levels, and Conditions of Saturation and Reduction

Soil saturation and reduction depend directly on WT levels. Therefore, frequencies of saturation and reduction are examined with respect to the probability of occurrence of WT levels above the depth where soil tension and soil redox potentials were taken.

Soil saturation is defined as a soil-water tension of zero or positive (Soil Surv. Staff, 1992). Probabilities of occurrence of saturation for the Cancienne soil at three soil depths are presented in Fig. 4–5. Soil-water tension values equal or

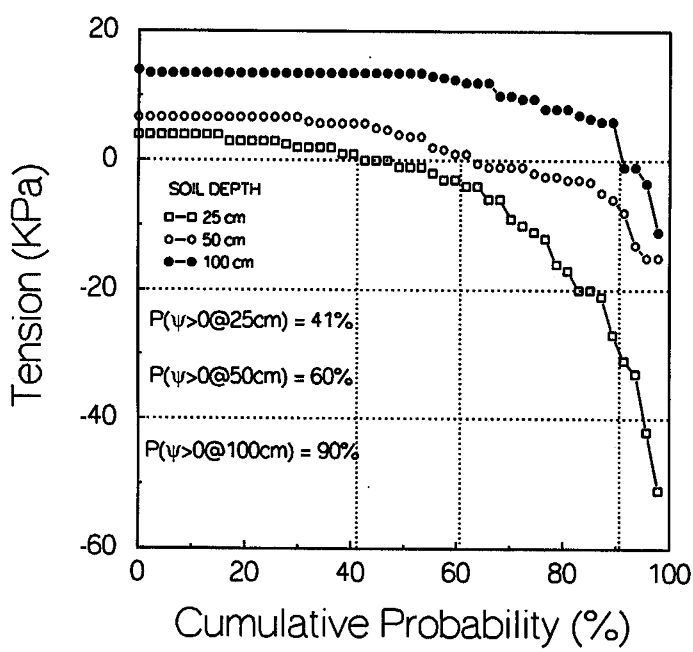

Fig. 4–5. Cumulative probability distribution of soil tension for Cancienne soil. The soil is considered saturated when tension (ψ) is zero or positive.

greater than 0 kPa indicate saturated conditions in the probability diagram. The probability of occurrence of saturation at 50-cm depth is 60%. This probability is much higher than the 29% probability that a WT will occur above 50-cm depth because the tensiometers measured zero or positive tensions that indicated saturation above the ground WT. A similar disagreement exists between the 90% probability of saturation at 100-cm depth and the 65% probability that the WT will occur above 100 cm. For the Schriever soil, it has a probability of 82% of saturation at 50-cm depth (Fig. 4–6), but the probability of occurrence of WT levels above this depth is just 65%. These discrepancies could be explained as the effect of differing responses from tensiometers and piezometers to changes in WT levels and soil water pressures. These differing responses occur because there is a lag period between when the tensiometers indicate saturation and when free water occurs in the piezometer at the same depth. These differing responses were particularly common when dry- to moist fine-textured soils were undergoing recharge (Hudnall & Wilding, 1992). Other factors that may have contributed to differences between piezometers and tensiometers readings are temperature and dissolution of gases in water (Hvorslev, 1951).

A soil at pH 7 is considered to be reduced with respect to iron when Eh < 150 mV (Patrick & Mahapatra, 1968), and moderately reduced with respect to oxygen depletion (anoxic) when Eh < 300 mV (Turner & Patrick, 1968). For the 50-cm depth, the Cancienne soil has probabilities of occurrence of 27% for reduced conditions (Fig. 4–7). Reduction patterns corresponded well with a probability of occurrence of 29% for WT levels above 50 cm. For the 100-cm depth,

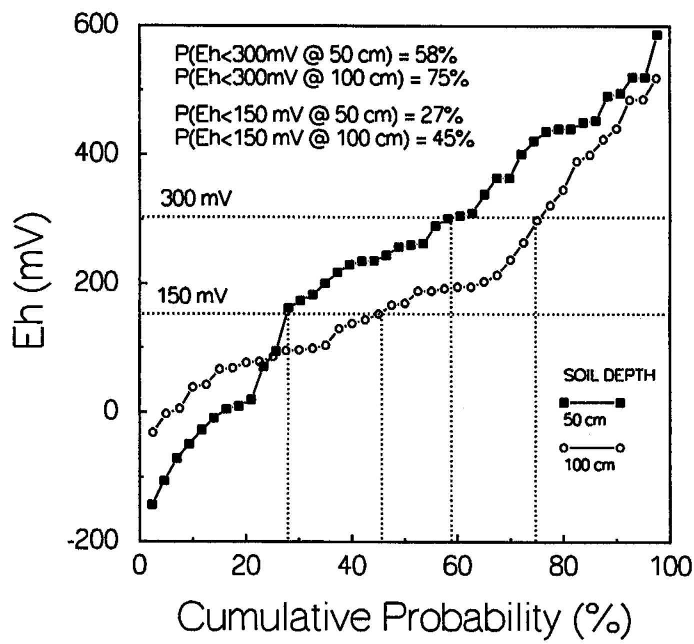

Fig. 4–6. Cumulative probability distribution of redox potentials (Eh) for Cancienne soil. The soil is considered, at pH 7, reduced when Eh is < 150 mV and anoxic when Eh is < 300 mV.

this soil has a probability of occurrence of 47% for reduced conditions which is lower than the 65% probability of occurrence of WT levels above 100-cm depth. For the Schriever soil, the 64% probability of soil reduced conditions at 50-cm depth was almost the same as the probability of occurrence of WT levels above this depth (Fig. 4–8). But at 100-cm depth, the probability of soil reduced conditions (65%) differs from the 90% probability of occurrence of WT levels above 100-cm depth. Both soils had a similar trend with respect to reduction patterns and occurrence of WT levels. Since soil reduction requires an organic C source and the presence of anaerobic microorganisms in addition to soil saturation, more intense changes in soil redox status would be expected nearer the soil surface than in lower parts of the soil. Therefore, saturation with lower probability would be adequate to attain soil reduction nearer the soil surface while greater probabilities of WT levels will be needed at greater depths where the C source is likely a limiting factor for soil reduction. Organic carbon data for both soils confirms these trends on soil reduction (Table 4–2).

For the Cancienne soil, probability of occurrence of anoxia at 50 cm is 60%, and at 100 cm, it is 76% but anoxia patterns differ from WT level probability patterns. For the Schriever soil, the anoxic condition has probabilities of occurrence of 74% at 50 cm and 89% at 100 cm depth. Anoxic conditions at 100-cm depth corresponded with 90% probability of occurrence of WT levels above 100-cm depth (Fig. 4–4). The trend on soil anoxia of these two soils is not clearly explained by the trend on soil organic C and frequency of WT levels data.

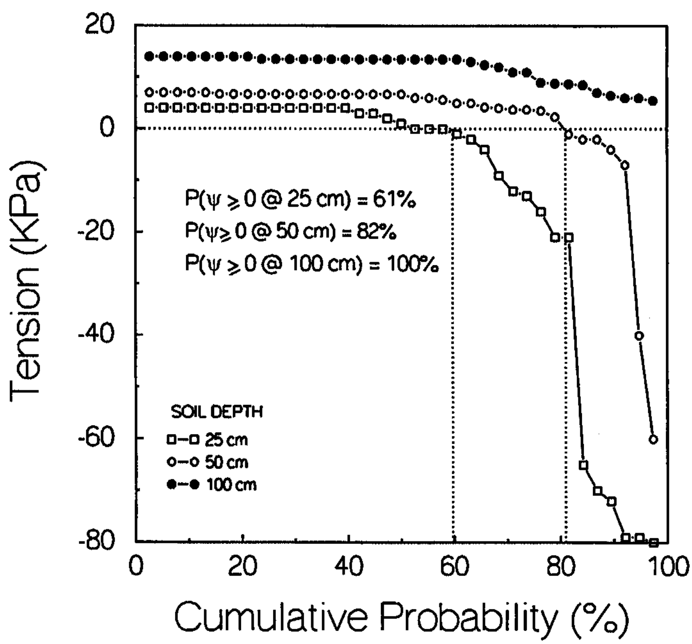

Fig. 4–7. Cumulative probability distribution of soil tension for Schriever soil. The soil is considered saturated when tension (ψ) is zero or positive.

Aquic Conditions and Hydric Soil Conditions

According to the *Keys to Soil Taxonomy* (Soil Surv. Staff, 1994), aquic conditions are indicated by the presence of redoximorphic features and verified by measuring saturation and reduction at a diagnostic soil depth for some time in most years. The use of the probability diagrams to determine aquic conditions to classify the soil is quite simple because the frequency or probability of aquic conditions is not specified in the keys. Following the *Keys to Soil Taxonomy*, both soils should have aquic conditions in a layer between 40 and 50 cm from the mineral soil surface. In that layer, redoximorphic features are present and the frequency of WT levels, reduced conditions, and saturation confirm that aquic conditions occur in both soils. Therefore, the Cancienne soil was classified as an Aquept and the Schriever soil was classified as an Aquert.

Hydric soils are defined by the National Technical Committee for Hydric Soils (NTCHS) as soils "that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part" (USDA-NRCS, 1996). To identify hydric soils in the field the NTCHS recommends the use of field indicators (USDA-NRCS, 1996). This method is particularly useful to delineate hydric soils within a Land Resource Region (LRR) in absence of site-specific data on WT levels, saturation and reduction. However, the NTCHS also developed the Hydric Soil Criteria (Fed. Reg., 1995) that currently is not recommended for routine field delineation of hydric soils but which is useful for quantitative verification of hydric soil conditions.

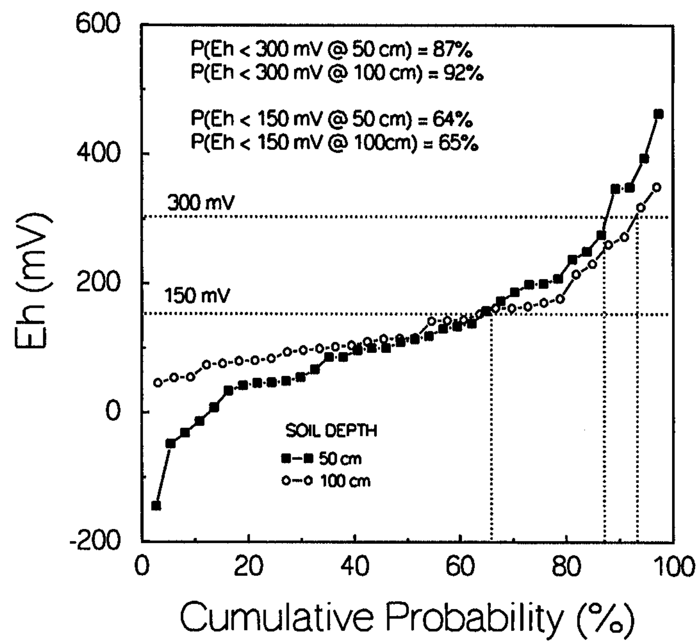

Fig. 4–8. Cumulative probability distribution of redox potentials (Eh) for Schriever soil. The soil is considered, at pH 7, reduced when Eh is <150 mV and anoxic when Eh is <300 mV.

In order to apply the hydric soil criteria, only hydrologic data measured during the growing season should be considered. We considered a 1-yr growing season for Cancienne and Schriever soils since both soils are hyperthermic (Megonigal et al., 1996). Therefore, probability diagrams do not need to be modified to apply the hydric soil criteria.

Cancienne soils are somewhat poorly drained. The hydric soil criteria require that somewhat poorly drained soils have a WT equal to 0.0 cm (0.0 ft) from the surface during the growing season. According to Fig. 4–3b, the probability of having a WT at the soil surface is 0% and therefore, Cancienne is not a hydric soil. When field indicators are used (USDA-NRCS, 1996), they need to be referred to the applicable LRR. In this case, the LRR that defines the Mississippi Delta Cotton and Feed Grains area is represented as "LLR O". The Cancienne soil fits the following description of indicator F3 within LLR O: depleted matrix, a layer at least 15 cm (6 in.) thick with a depleted matrix that has 60% or more, chroma 2 or less starting within 25 cm (10 in.) of the surface. The dominant color required by the F3 indicator is found in the matrix color of Ap1 and Ap2 horizons (chroma 2, Table 4–1). However, the Cancienne soil may be not hydric because the low matrix color could be due to organic C and not to wetness. Consequently, only the ponded phase of the Cancienne is considered to be hydric, but all other Cancienne soils are not hydric.

Because the Schriever soil is poorly drained and permeability is <15 cm h^{-1} (6 in. h^{-1}), it meets hydric criteria by having a WT within 30 cm (1 ft) of the soil surface during the growing season. This is confirmed by the WT level probability diagram (Fig. 4–4). The probability of a WT within 30 cm of the soil surface increases up to 45%. If field indicators are used (USDA-NRCS, 1996), the Schriever soil fits the following description of indicator F11: Depleted Ochric, a layer 10 cm (4 in.) or more thick that has 60% or more of the matrix with value 4 or more and chroma 1 or less. The layer required by indicator F11 is within the upper 25 cm (10 in.) of the soil surface. For the Schriever soil, this layer is found within the A (13–30 cm) horizon (Table 4–1).

CONCLUSIONS

The use of cumulative frequency analysis helped to better understand the relationship between soil hydromorphology and frequency of WT levels above a horizon or group of horizons in both soils of this study. The approach also was useful for comparing the location of hydromorphic features vs. the probability of occurrence of WT levels above diagnostic soil depths according to *Soil Taxonomy* (Soil Surv. Staff, 1975). Water table level probability patterns corresponded well with probabilities of occurrence of reduction at 50-cm depth for both soils. But at 100-cm depth, the probability of soil reduced conditions were lower from the probability of occurrence of WT levels above 100-cm depth. Since soil reduction requires an organic C source in addition to soil saturation, more intense changes in soil redox potential with lower frequencies of the WT levels would take place nearer the soil surface than in lower parts of the soil. Although soil moisture tension data was necessary to verify soil saturation, the comparison of saturation to either probabilities of occurrence of WT levels or location of hydromorphic features was not straightforward. Saturation patterns based on tensiometers data were not consistent with WT level frequencies due to differences between piezometers and tensiometers data at the same soil depth. Regardless of these difficulties with the interpretation of frequencies of saturation, aquic conditions in both soils were verified by the presence of redoximorphic features, frequencies of occurrence of saturation, reduction, and WT levels at diagnostic soil depths (40–50 cm) according to the *Keys to Soil Taxonomy* (Soil Surv. Staff, 1992). When hydric soil conditions were tested, we found that the Schriever soil is a hydric soil because hydric soil criteria and field indicators of hydric soils corresponded well with probability of occurrence of WT levels. Morphological field indicators in the Cancienne soil indicated possible hydric conditions. However, the Cancienne soil did not meet hydric soil criteria, and this soil is not a hydric soil. The Schriever soil provides an example of how field indicators correspond with the hydrology of a hydric soil and Cancienne provides an example of how field indicators do not agree with the hydrology of a hydric/nonhydric borderline soil.

ACKNOWLEDGMENTS

This research was supported by grants from the USDA-SCS, today called Natural Resource Conservation Service (USDA-NRCS), Soil Survey Division, through USDA-SCS Project no. 68-7217-8-23 and the Louisiana Agricultural Experiment Station.

REFERENCES

Federal Register. 1995. Hydric soils of the United States. Washington, DC. Vol. 60.

Hudnall, W.H., and A.A. Szögi. 1996. Seasonally wet soils of Louisiana. p. 31–48. *In* J.S. Wakeley et al. (ed.) Preliminary investigations of hydric soil hydrology and morphology in the United States. Wetlands Res. Program Tech. Rep. WRP-DE-13. U.S. Army Corps Eng., Washington, DC.

Hudnall, W.H., A.A. Szögi, B.A. Touchet, J. Daigle, J.P. Edwards and W.C. Lynn. 1990. Guidebook for Louisiana. *In* Classification and management of wet soils. Proc. 8th Int. Soil Correlation Meet., Baton Rouge, LA, and College Station, TX. USDA-SCS-NSSC, Lincoln, NE.

Hudnall, W.H., and L.P. Wilding. 1992. p. 135–147. *In* J.M. Kimble (ed.) Classification and management of wet soils. Proc. 8th Int. Soil Correlation Meet., Baton Rouge, LA, and College Station, TX. 6–21 October. USDA-SCS-NSSC, Lincoln, NE.

Hvorslev, M.J. 1951. Time lag and soil permeability in ground-water observations. Waterways Exp. Stn. Bull. 36. U.S. Army Corps Eng., Vicksburg, MS.

Mausbach, M.J., and J.L. Richardson. 1994. Biogeochemical processes in hydric soil formation. Curr. Topics Wetland Biogeochem. 1:68–127

Megonigal, J.P., S.P. Faulkner, and W.H. Patrick. 1996. The microbial activity season in southeastern hydric soils. Soil Sci. Soc. Am. J. 60:1263–1266.

Ott, W.R. 1995. Environmental statistics and data analysis. Lewis Publ., Boca Raton, FL.

Patrick, W.H., Jr., and I.C. Mahapatra. 1968. Transformation and availability to rice of nitrogen and phosphorus in waterlogged soils. Adv. Agron. 20:323–359.

SAS Institute, Inc. 1988. SAS/STAT user's guide. Release 6.03. SAS Inst., Cary, NC.

Soil Survey Staff. 1975. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. USDA-SCS Agric. Handb. 436. U.S. Govt. Print. Office, Washington, DC.

Soil Survey Staff . 1992. Keys to soil taxonomy. Soil Manage. Support Serv. Tech. Monogr. 19. 5th ed.. Pocahontas Press, Blacksburg, VA.

Soil Survey Staff . 1994. Keys to soil taxonomy. 6th ed. U.S. Gov. Print. Office, Washington, DC.

Szögi, A.A., and W.H. Hudnall. 1992. Classification of soils in Louisiana according to "Endoaquic " and "Epiaquic" concepts. p. 271–278. *In* J.M. Kimble (ed.) Proc. 8th Int. Soil Correlation Meet. USDA-SCS-NSSC, Lincoln, NE.

Turner, F.T., and W.H. Patrick., Jr. 1968. Chemical changes in waterlogged soils as a result of oxygen depletion. p. 53–56. *In* Trans. Int. Congr. Soil Sci., 9th, 1968. Adelaide, Australia. ISSS.

U.S. Department of Agriculture. 1984. Soil survey laboratory methods and procedures for collecting soil samples. Soil Surv. Invest. Rep. no. 1. Soil Conserv. Serv., Washington, DC.

U.S. Department of Agriculture, Natural Resources Conservation Service. 1996. Field indicators of hydric soils in the United States. *In* G. W. Hurt et al. (ed.) USDA, NRCS, Fort Worth, TX.

Vepraskas, M.J. 1992. Redoximorphic features for identifying aquic conditions. North Carolina Agric. Res. Serv. Tech. Bull. 301. North Carolina State Univ., Raleigh.

Wakeley, J. S., S. W. Sprecher, and W. C. Lynn (ed.). 1996. Preliminary investigations of hydric soil hydrology and morphology in the United States. Wetlands Res. Program Tech. Rep. WRP-DE-13. U.S. Army Corps Eng., Washington, DC.