Thinking in 3-D While Moving Among Scales

Scientific Underpinnings of the Watershed Approach to Compensatory Wetland Mitigation

Credit where credit is due

- **Tom Winter, USGS Denver**
- Eric Preston, EPA-Corvallis
- Kathy Crowley, Cornell University
- F. Robert Wesley, Cornell University
- And especially . . .

Charge

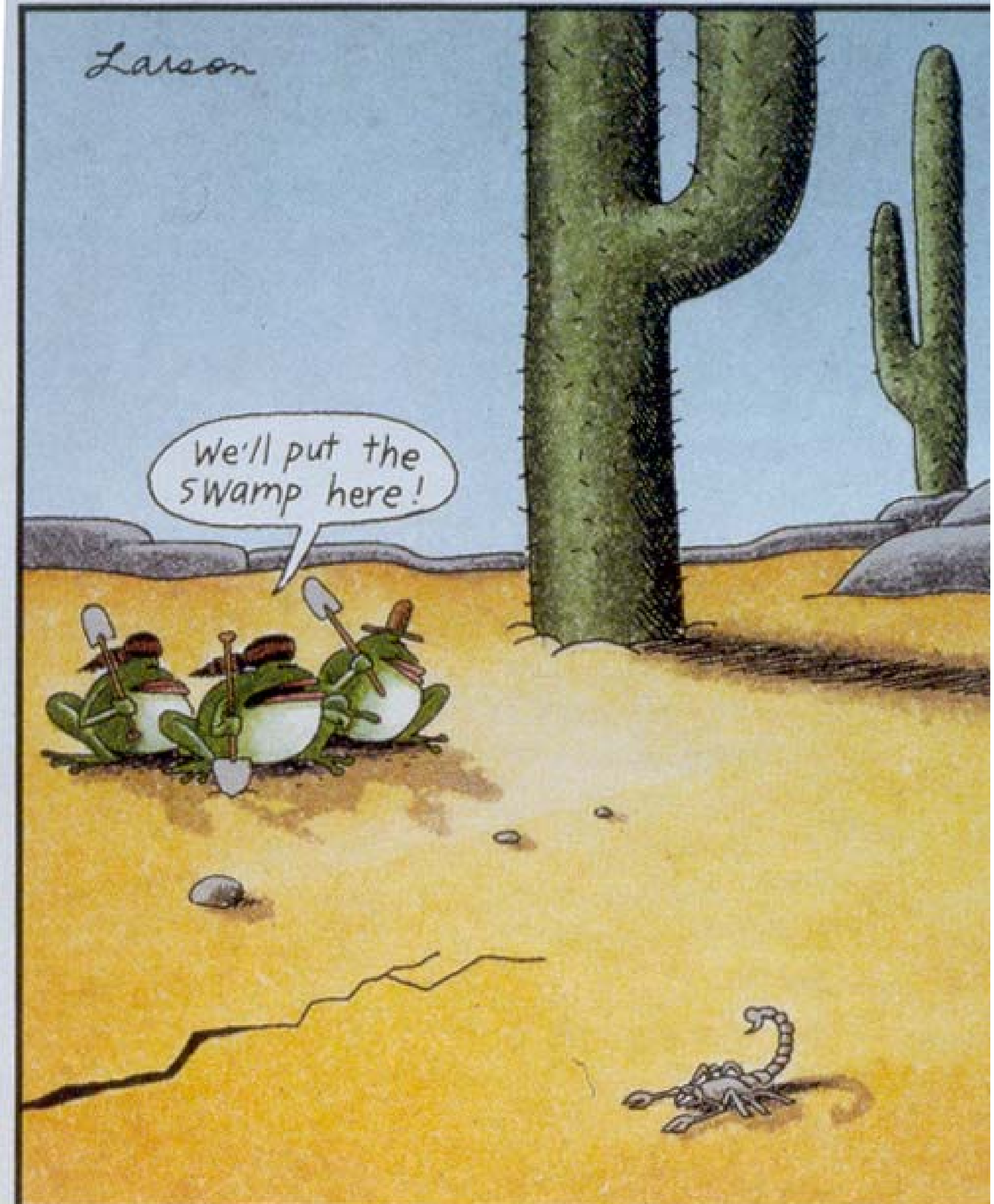
- Watersheds, ecoregions, or other geographic units?
- Appropriate scale?
- Relations of functions to location?
- Landscape considerations?

EPA's definition of the watershed approach

- Coordinating framework for management
- Highest priority problems
- Hydrologically-defined geographic areas
- Ground and surface water flow

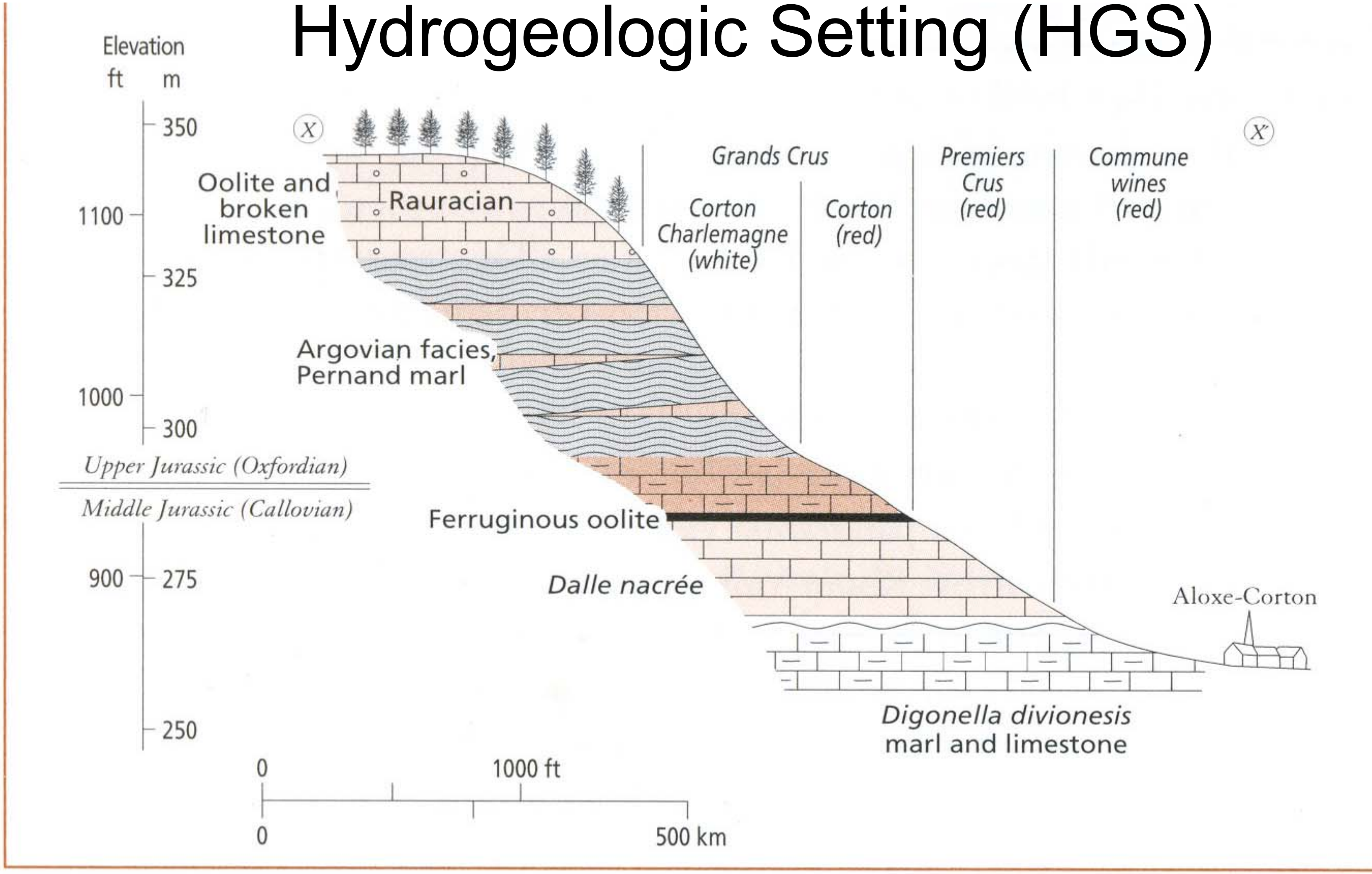
Road Map

- Basics of 3-D thinking
- Geographic units
- Scales
- Landscape position
- Other landscape considerations



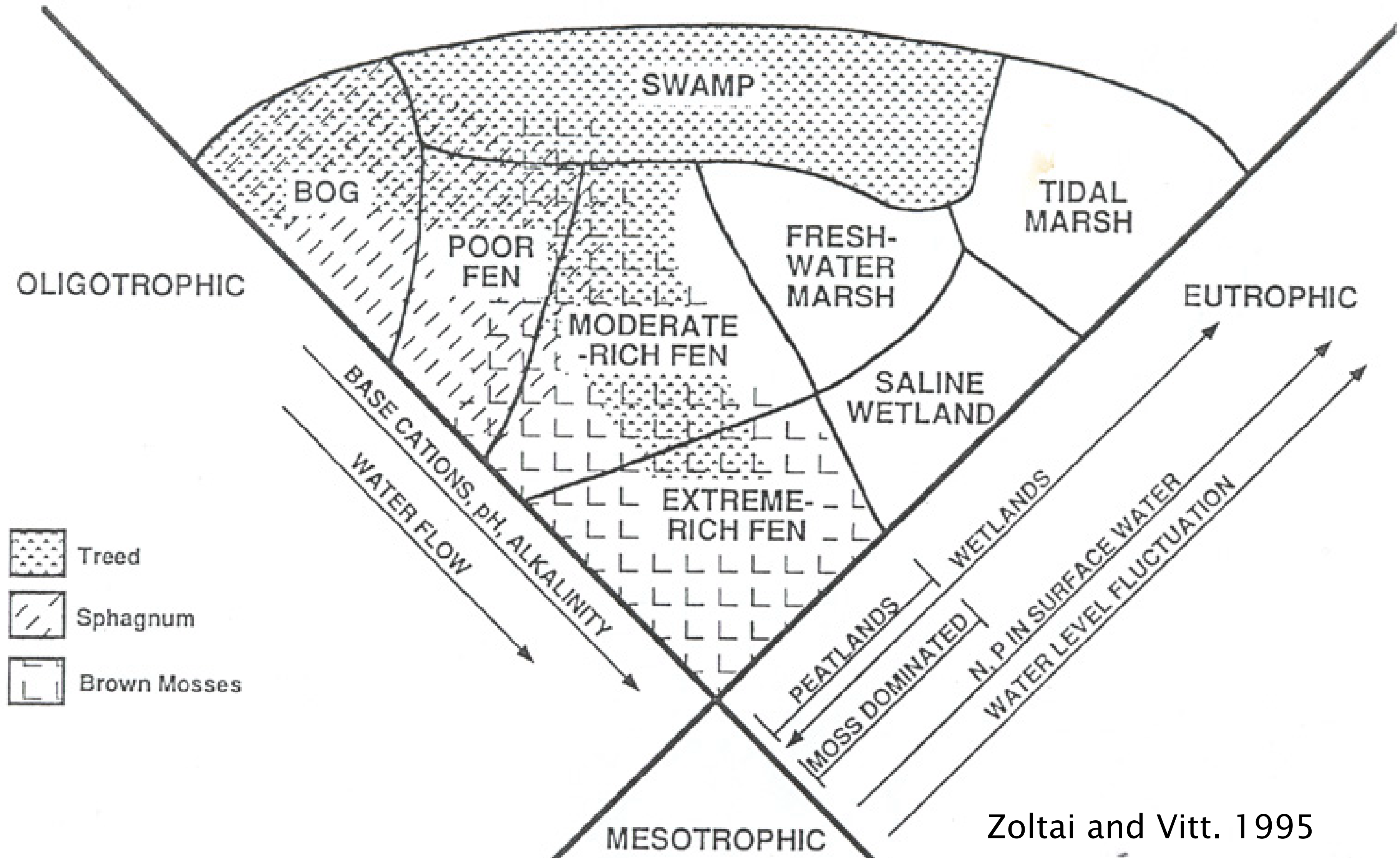
Frog pioneers

Quality of French Wine in Relation to Hydrogeologic Setting (HGS)



BURGUNDY: PARADE OF CAP-ROCK SCARPS

Relationship of Wetland Type to Environmental Gradients



Zoltai and Vitt. 1995

Landscape Control of Gradients

"Basic tenet of landscape ecology — that the spatial position of an ecosystem within the surrounding landscape influences properties of that ecosystem"

Kratz et al. 1997

Components of Wetland Water Budgets

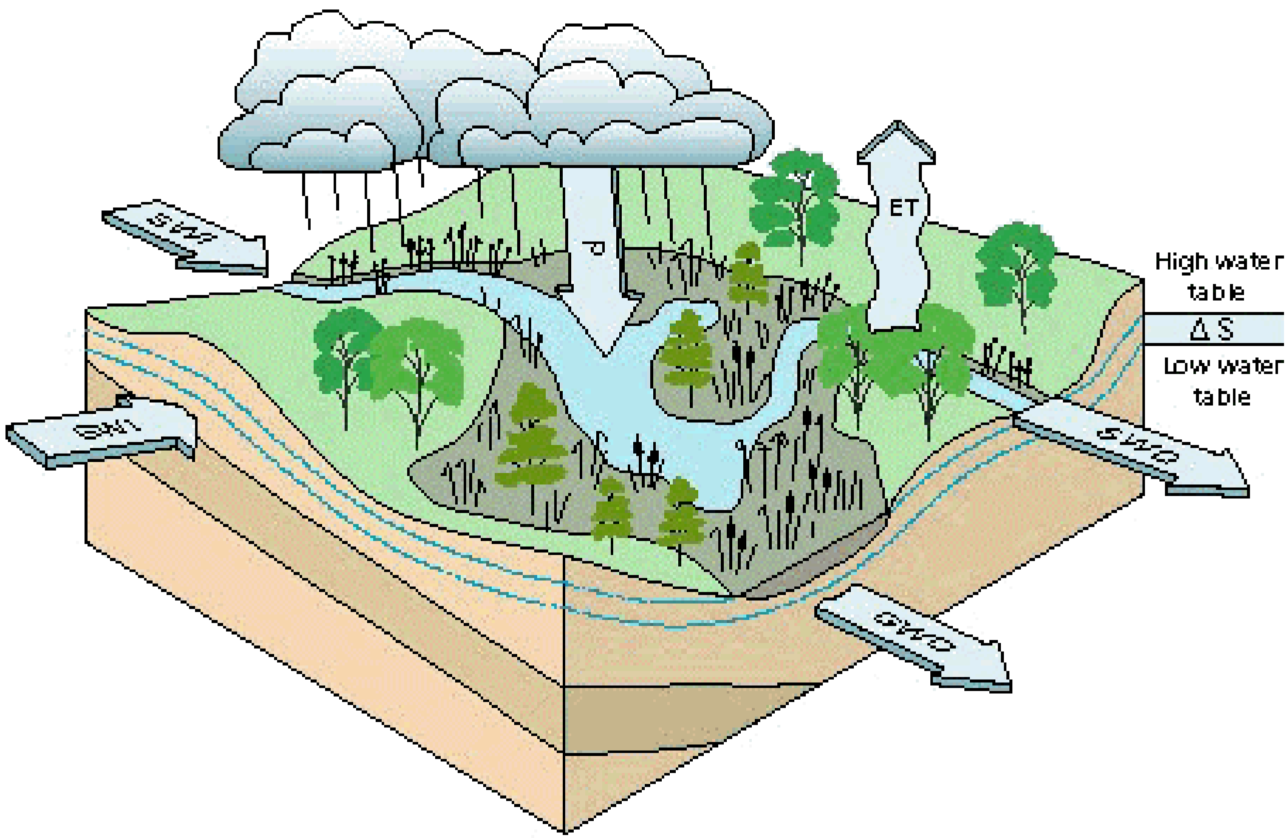


Figure 18. Components of the wetland water budget. ($P + SWI + GWI = ET + SWO + GWO + \Delta S$, where P is precipitation, SWI is surface-water inflow, SWO is surface-water outflow, GWI is ground-water inflow, GWO is ground-water outflow, ET is evapotranspiration, and ΔS is change in storage.)

From Carter (1996)

"Understanding wetlands in the context of their associated ground-water flow systems is essential to assessing the cumulative effects of wetlands on water quality, ground-water flow, and stream flow in large areas."

Winter et al. 1998

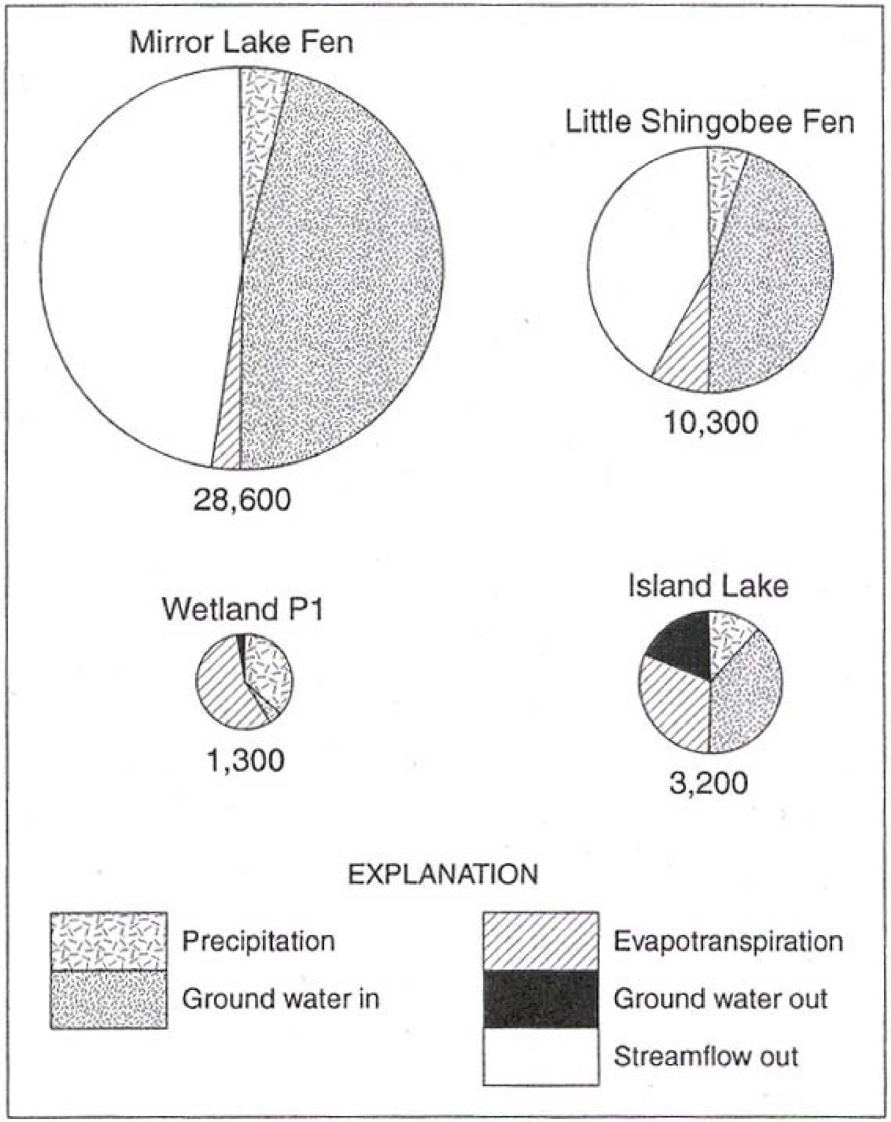
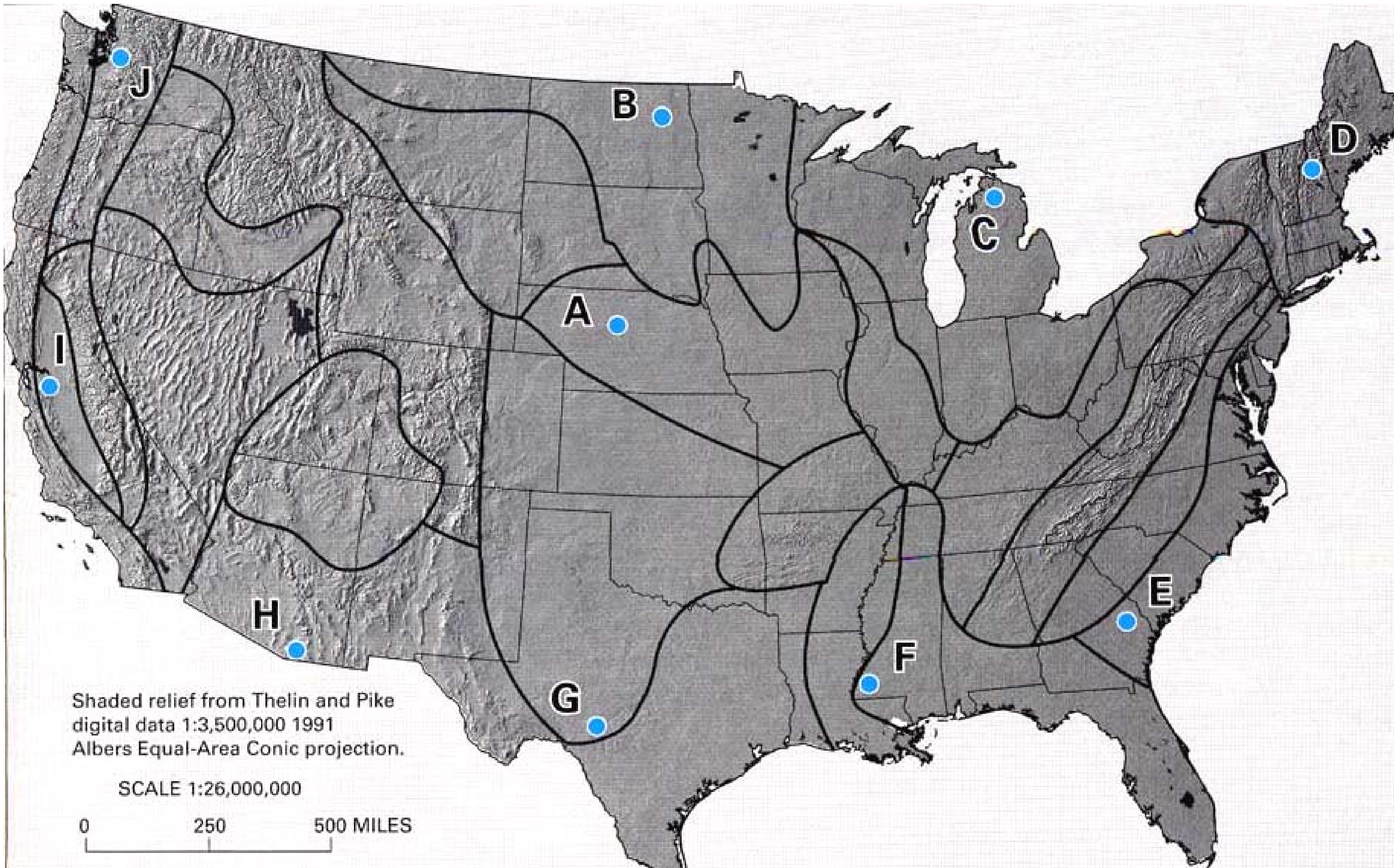


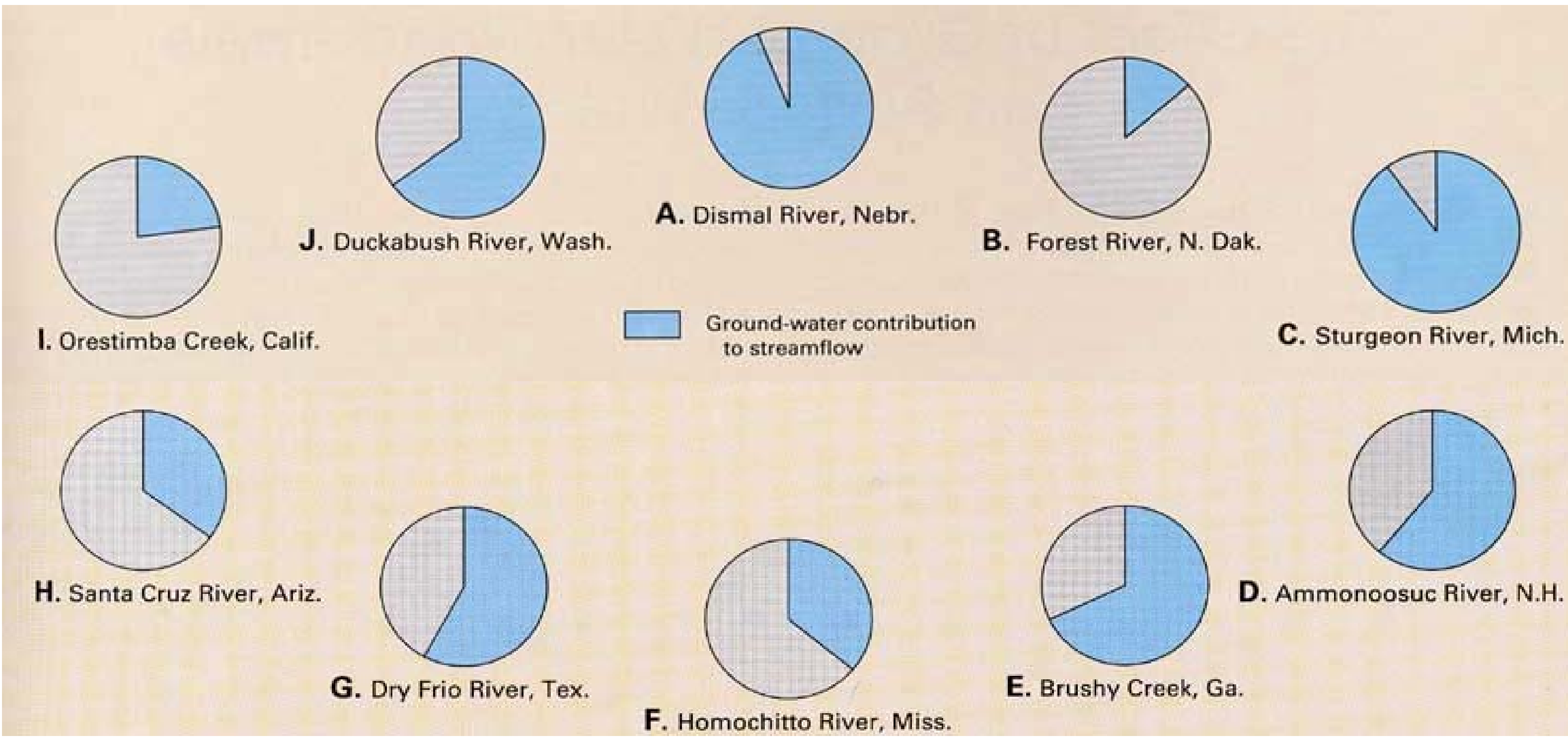
Figure 10. Water balances of Mirror Lake Fen, Little Shingobee Fen, Wetland P1, and Island Lake. Diagrams show the water fluxes per unit area of wetland. Numbers are the total flux to and from the water bodies per year.

Winter's 24 Type Settings of Climate and Physiography



From Winter et al. (1998)

Groundwater Component of Streamflow in 10 Type Settings

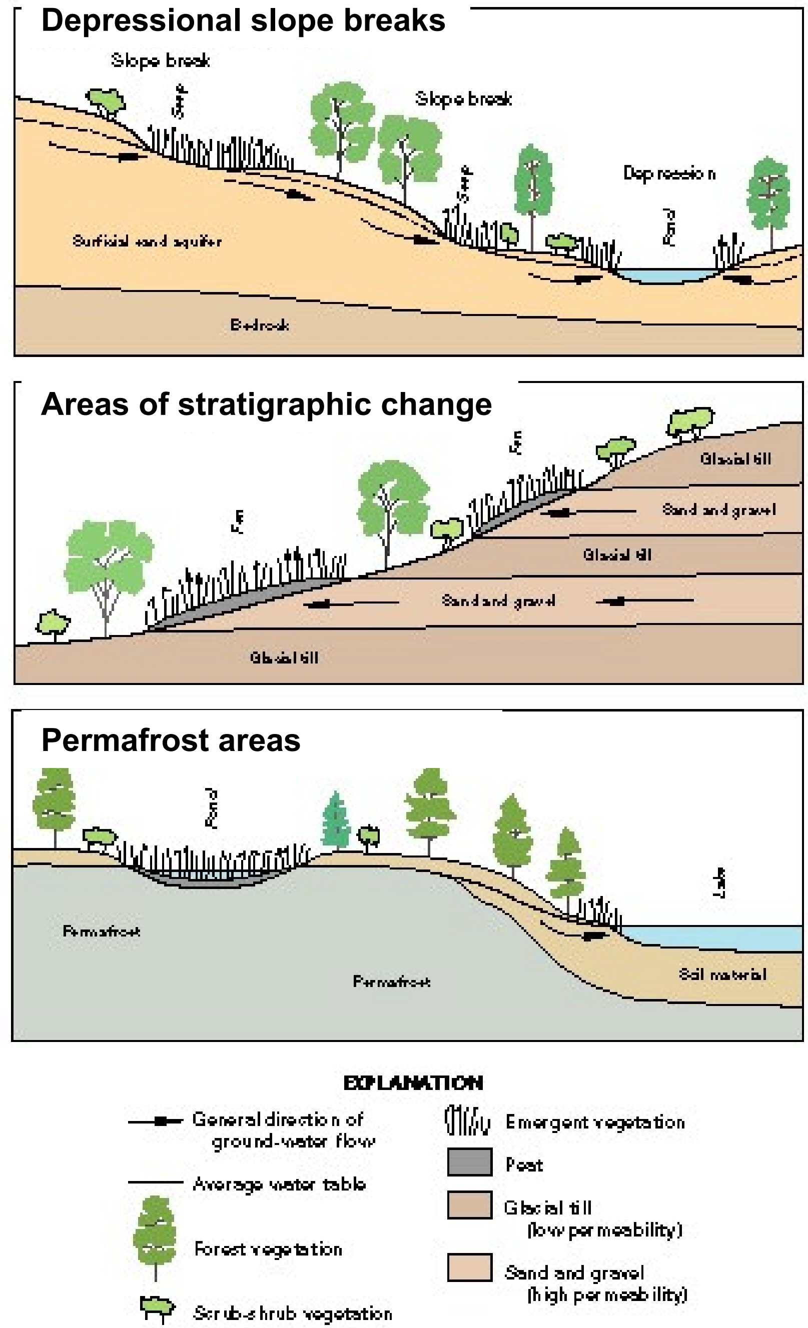


From Winter et al. (1998)

Hydrogeologic Setting

Watershed characteristics that control the chemistry and flows of surface water and ground water to a wetland

Cross sections showing principal hydrogeologic settings for wetlands



From Carter (1996)

Hydrogeologic Setting (HGS)

- Climate
- Wetland position in landscape
- Geologic characteristics of wetland watershed

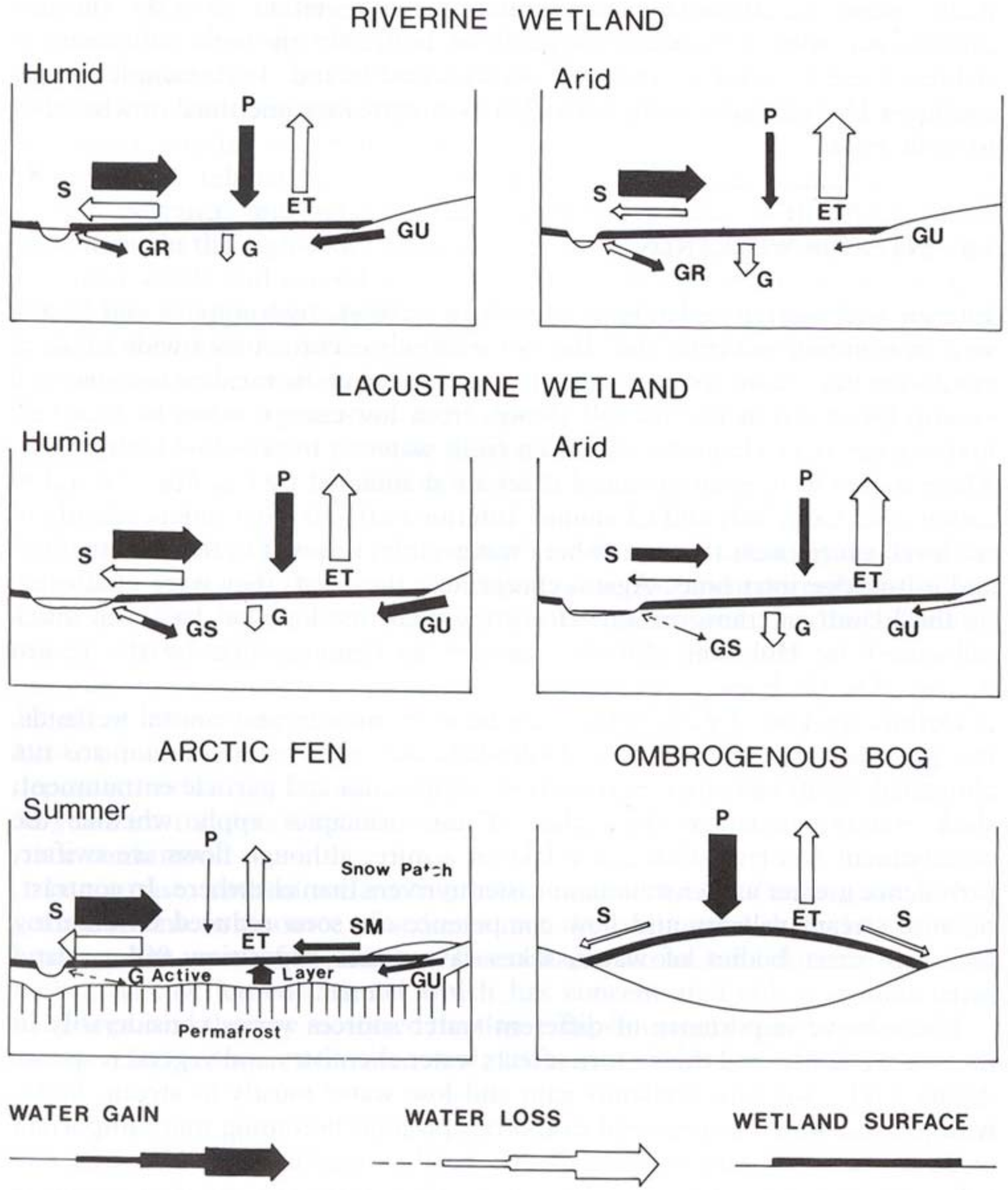


Figure 2.11 Relative water balance in different interior wetlands (arrows indicate magnitude and direction of flow): S, surface-water flow; G, ground-water flow; GU, ground-water flow from upland; GR, ground-water flow to or from river; P, precipitation; ET, evapotranspiration; SM, snowmelt

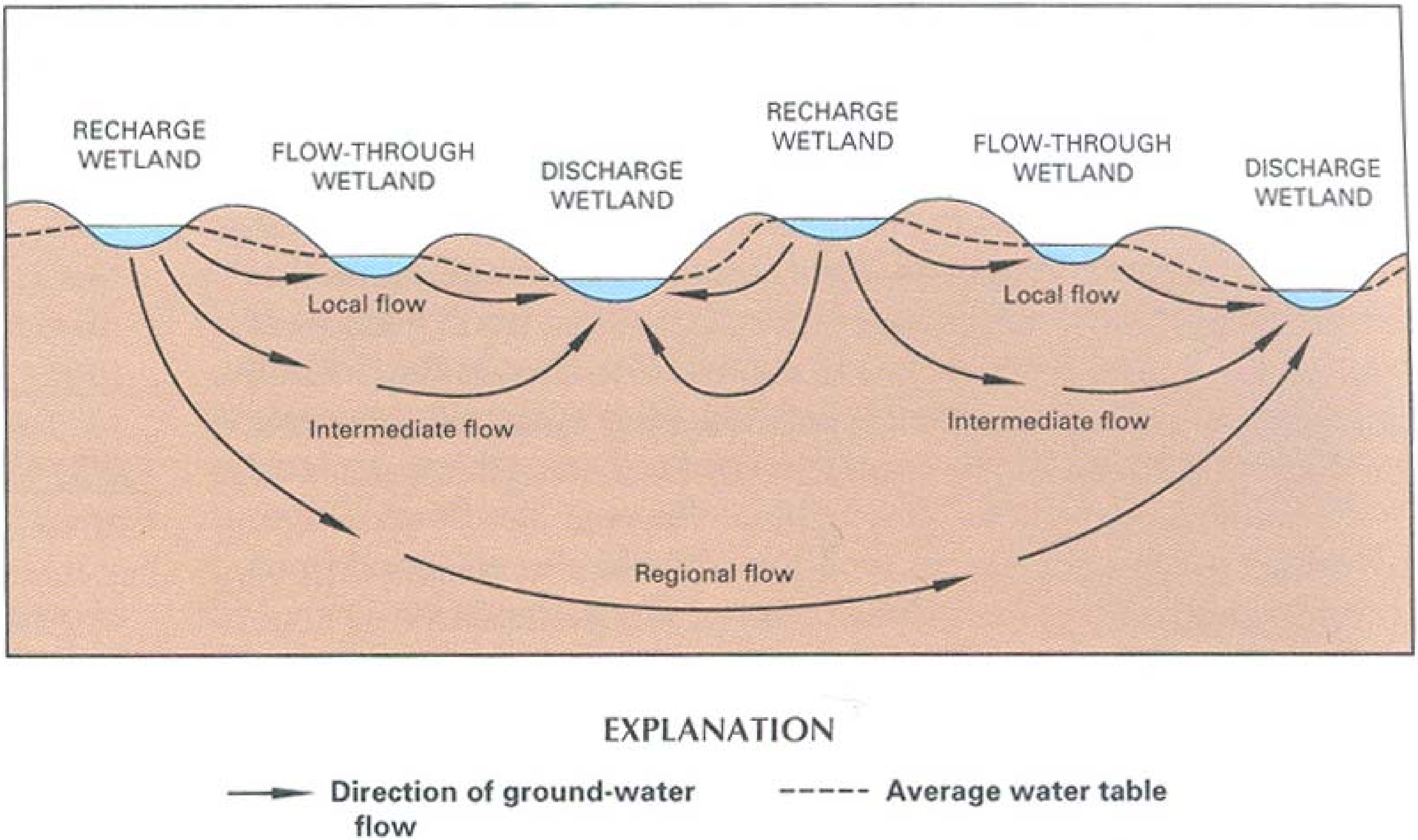
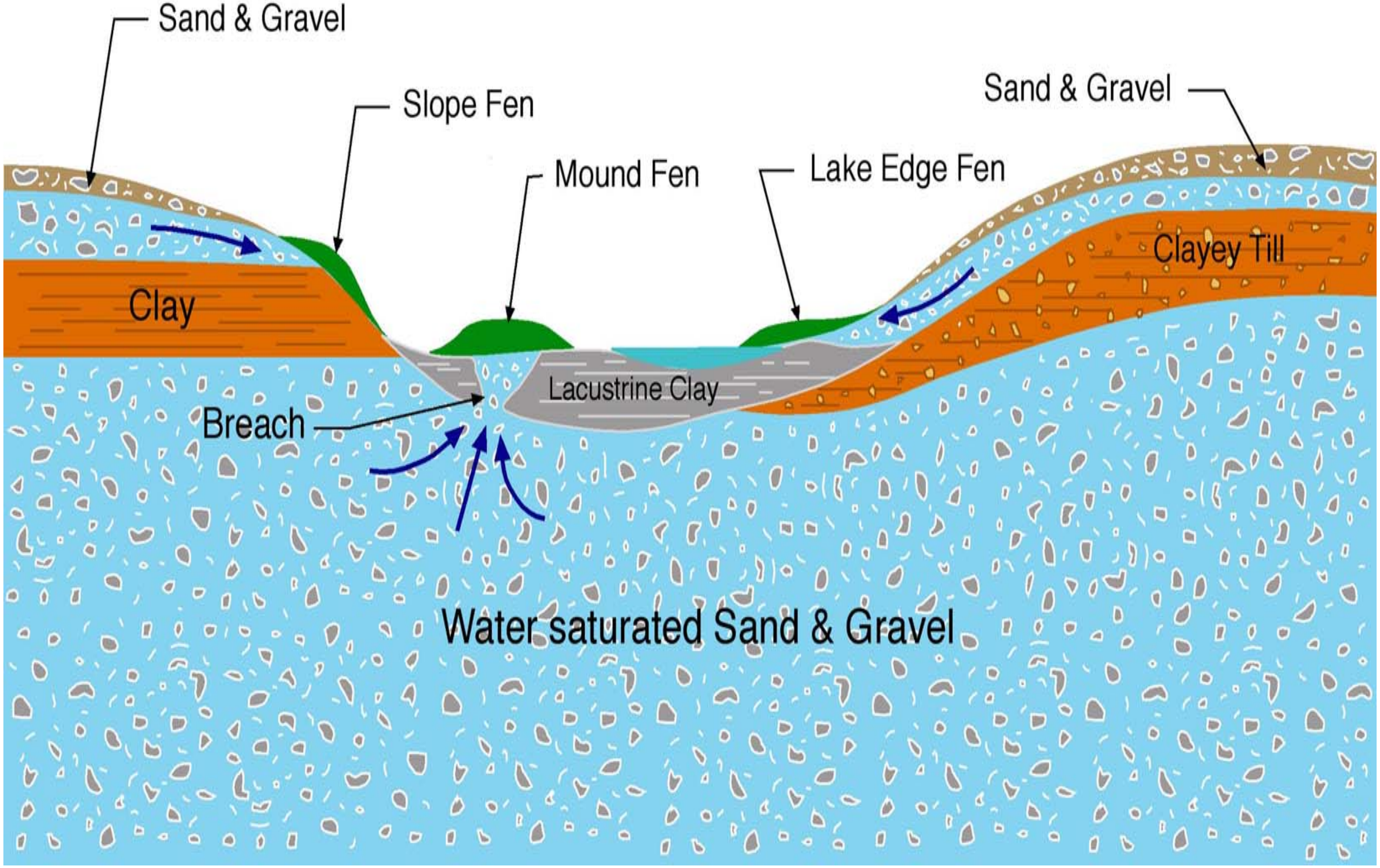


Figure 4. Generalized ground-water flow in the Prairie Pothole Region. *(Source: Modified from Winter, 1989.)*

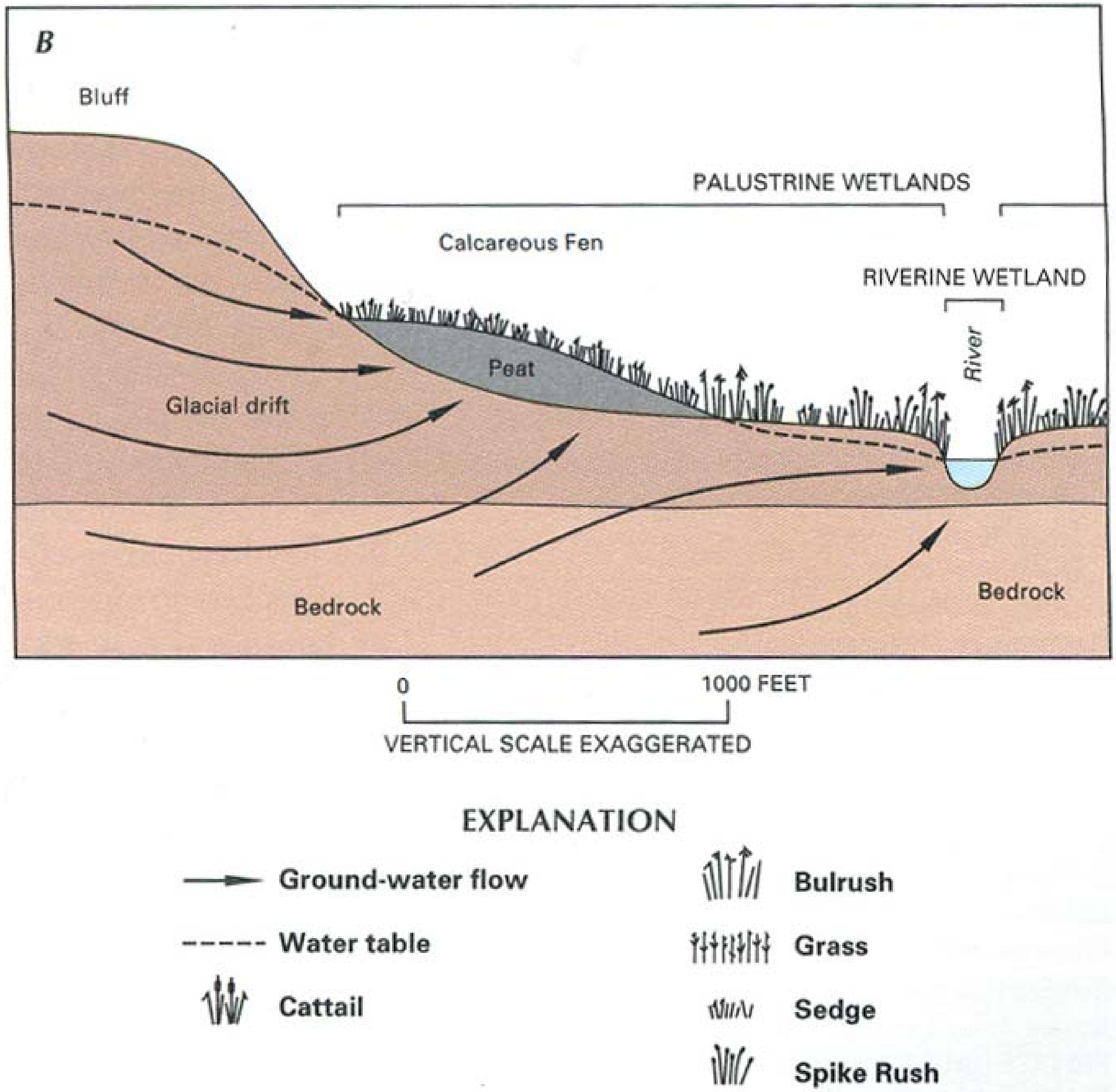
Different Landscape Positions in Which Fens Occur



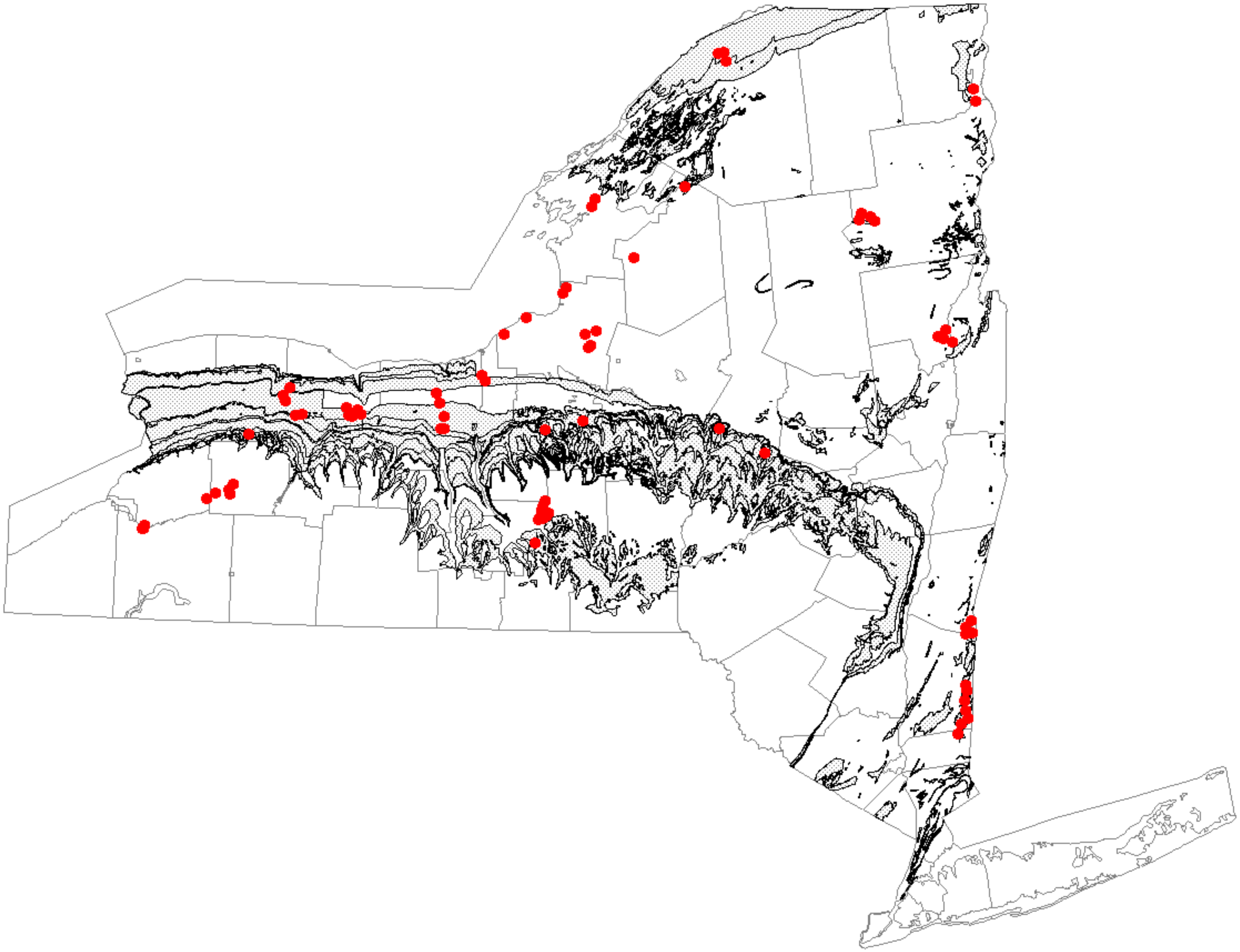
Courtesy of C. Thompson

Geologic Characteristics of HGS

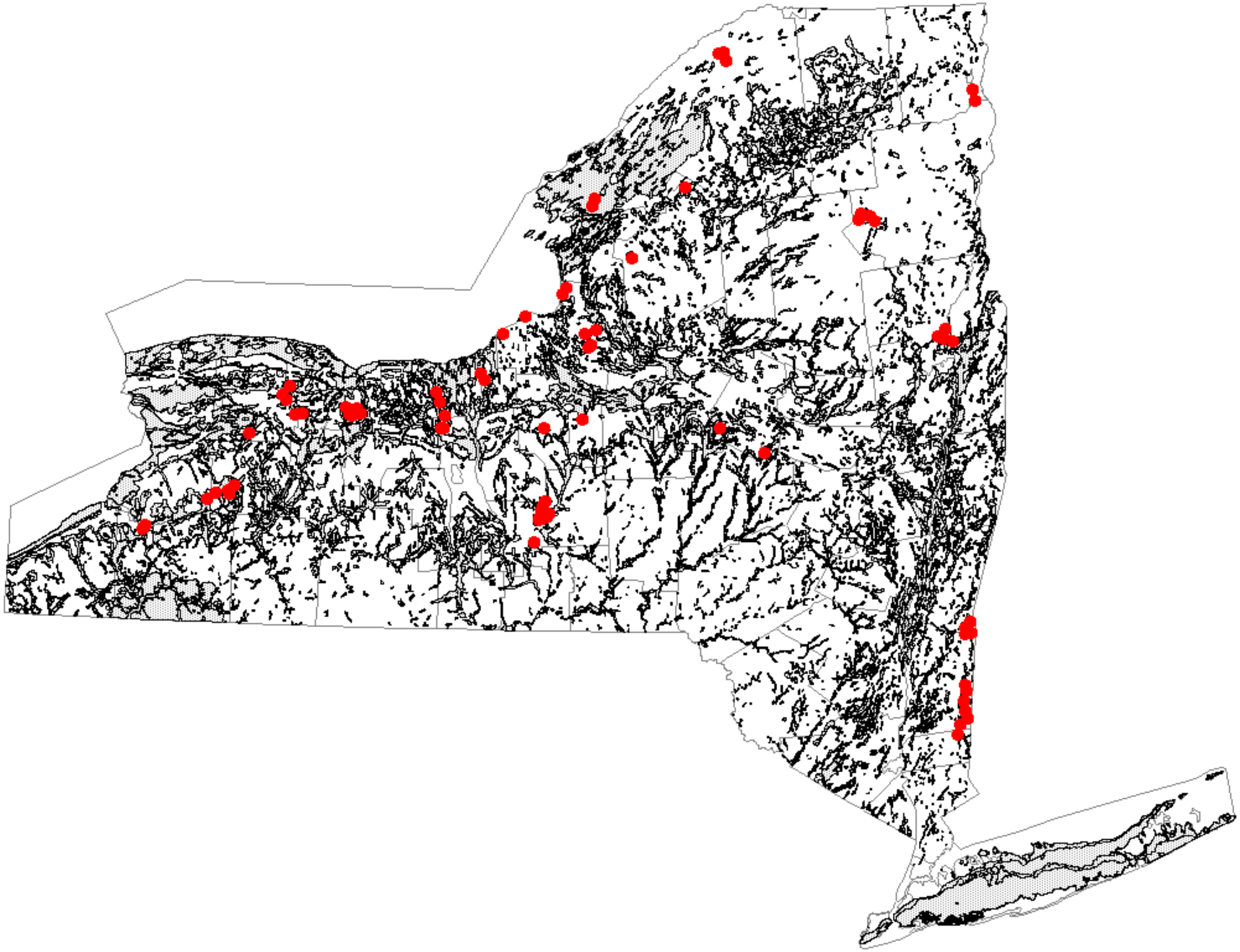
- Surface topography
- Land surface slope
- Thickness and permeability of soils
- Composition, stratigraphy, and hydraulic properties of underlying geologic materials


B
Bluff
PALUSTRINE WETLANDS
Calcareous Fen
RIVERINE WETLAND
River
Peat
Glacial drift
Bedrock
Bedrock
0
1000 FEET
VERTICAL SCALE EXAGGERATED
EXPLANATION
Ground-water flow
Water table
Cattail
Bulrush
Grass
Sedge
Spike Rush

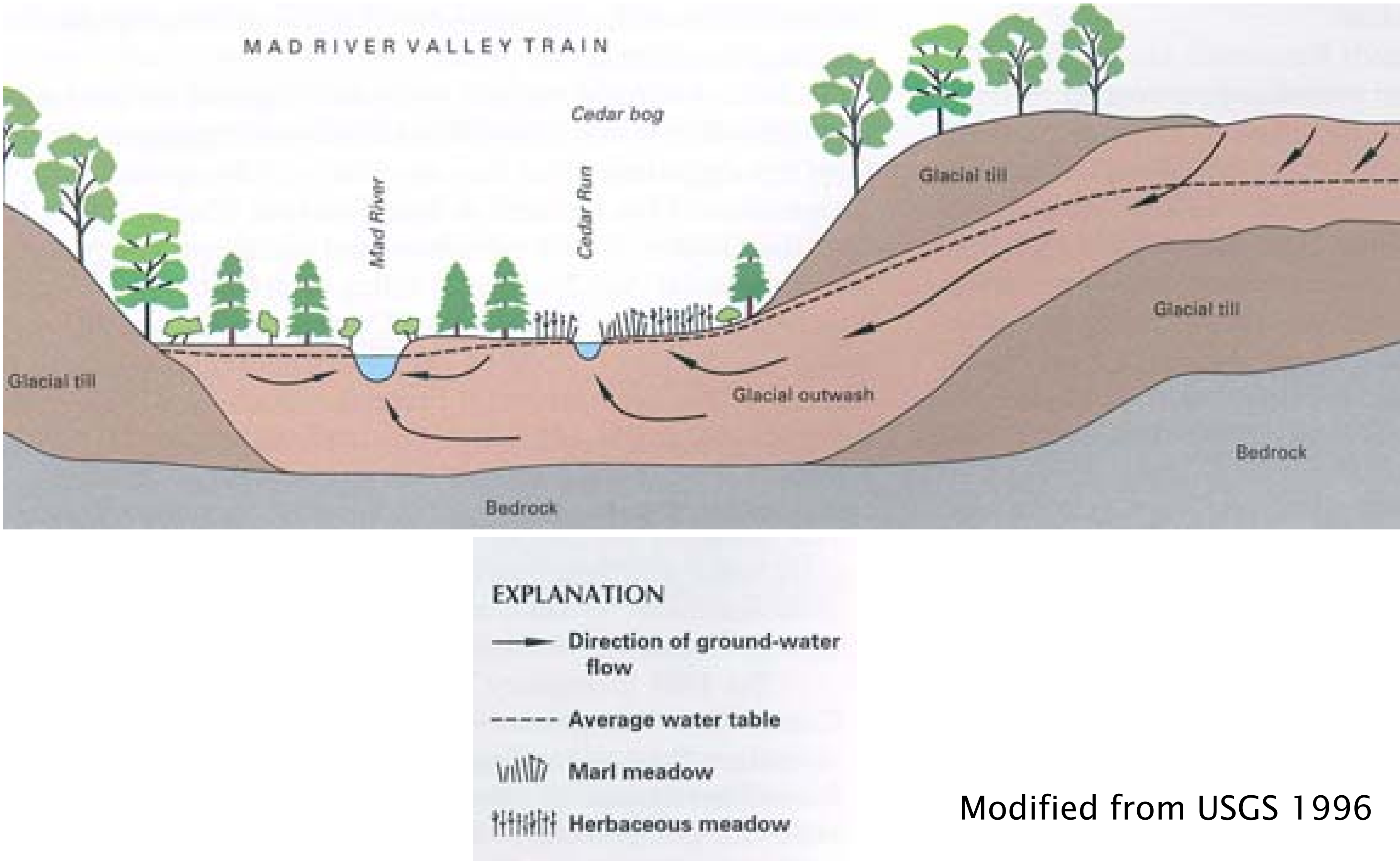
Distribution of NY Fens in Relation to Carbonate Bedrock



Distribution of NY Fens in Relation to Carbonate Surficial Deposits



Influence of stratigraphy and hydraulic properties of geologic materials on wetland formation



Modified from USGS 1996

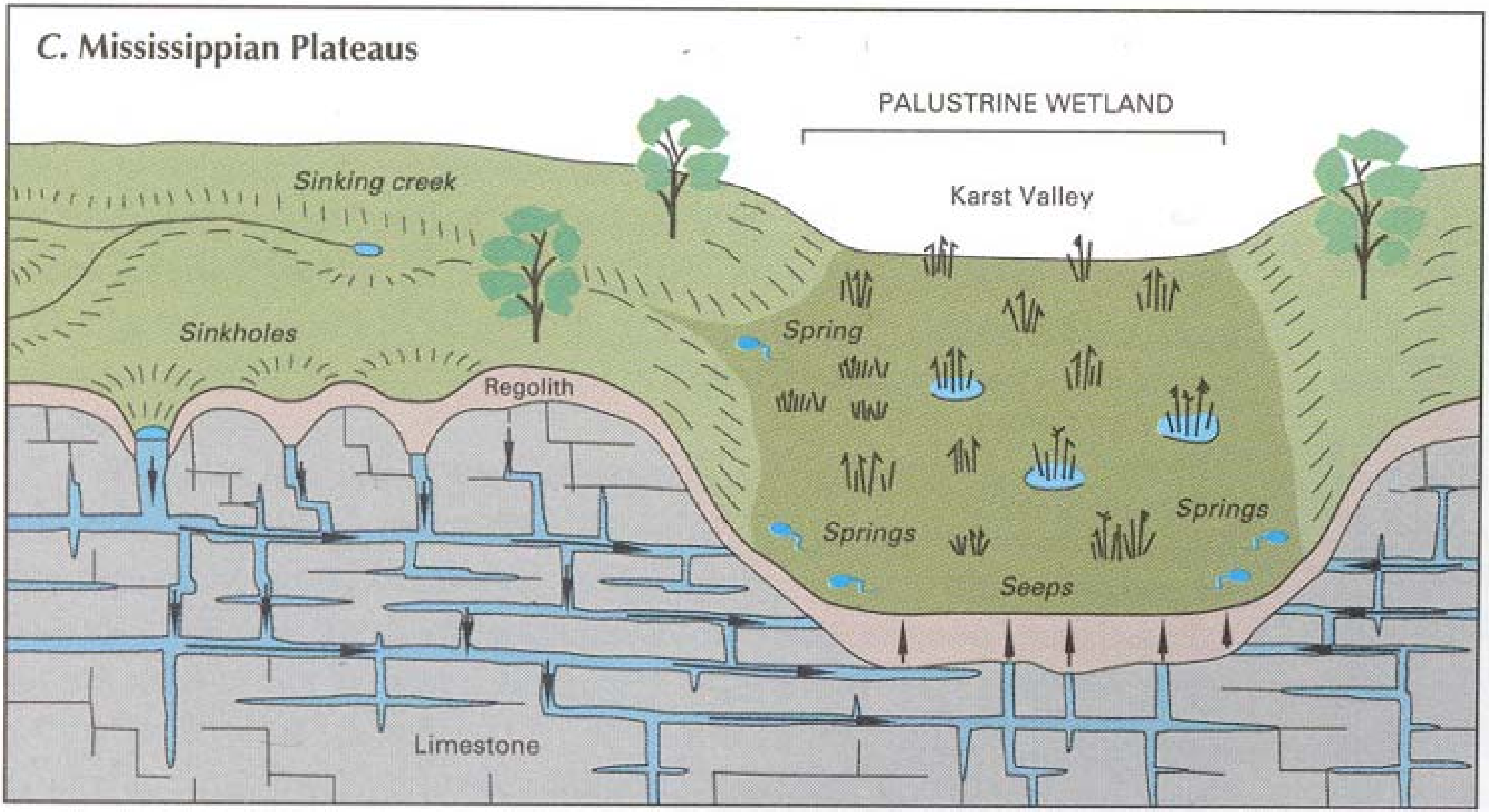


Figure 3. Generalized geohydrologic setting of representative wetlands in Kentucky. ***A***, Western Kentucky Coal Field. ***B***, Fractured bedrock and terrace deposits in the Inner and Outer Bluegrass regions and the Knobs. ***C***, Karst terrane in the Mississippian Plateaus.

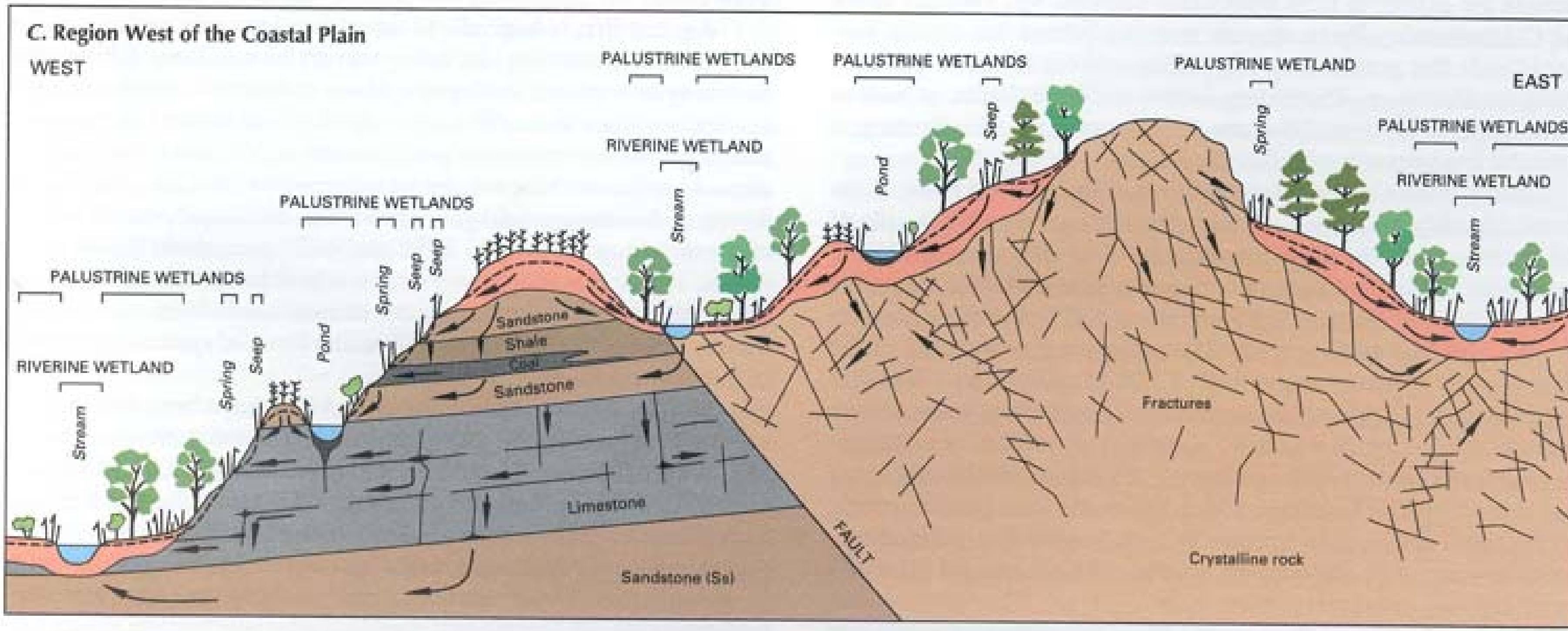


Figure 3. Generalized geohydrology of wetlands in Virginia. ***A***, Coastal Plain—Eastern Shore. ***B***, Coastal Plain—west of the Chesapeake Bay. ***C***, Region west of the Coastal Plain. *(Sources: A, Based on information in Harsh and Laczniak, 1986; Richardson, 1992; and M.J. Focazio, written commun., 1993. B, Based on information in Back, 1966; Harsh and Laczniak, 1986; and Winter, 1992. C, Based on information in Heath, 1984.)*

Variables Used to Characterize the HGS of 45 NY Fens

Class	Landscape variable	Measured parameters
Chemical	Mineralogy	Surficial geology, bedrock geology, soils, mineral dissolution rates
Physical	Area and gradient	Flow path length, ratio of wetland to watershed area, topographic index
Spatial	Landform Surface water inputs	Local landform, connection to surface water inputs and outputs

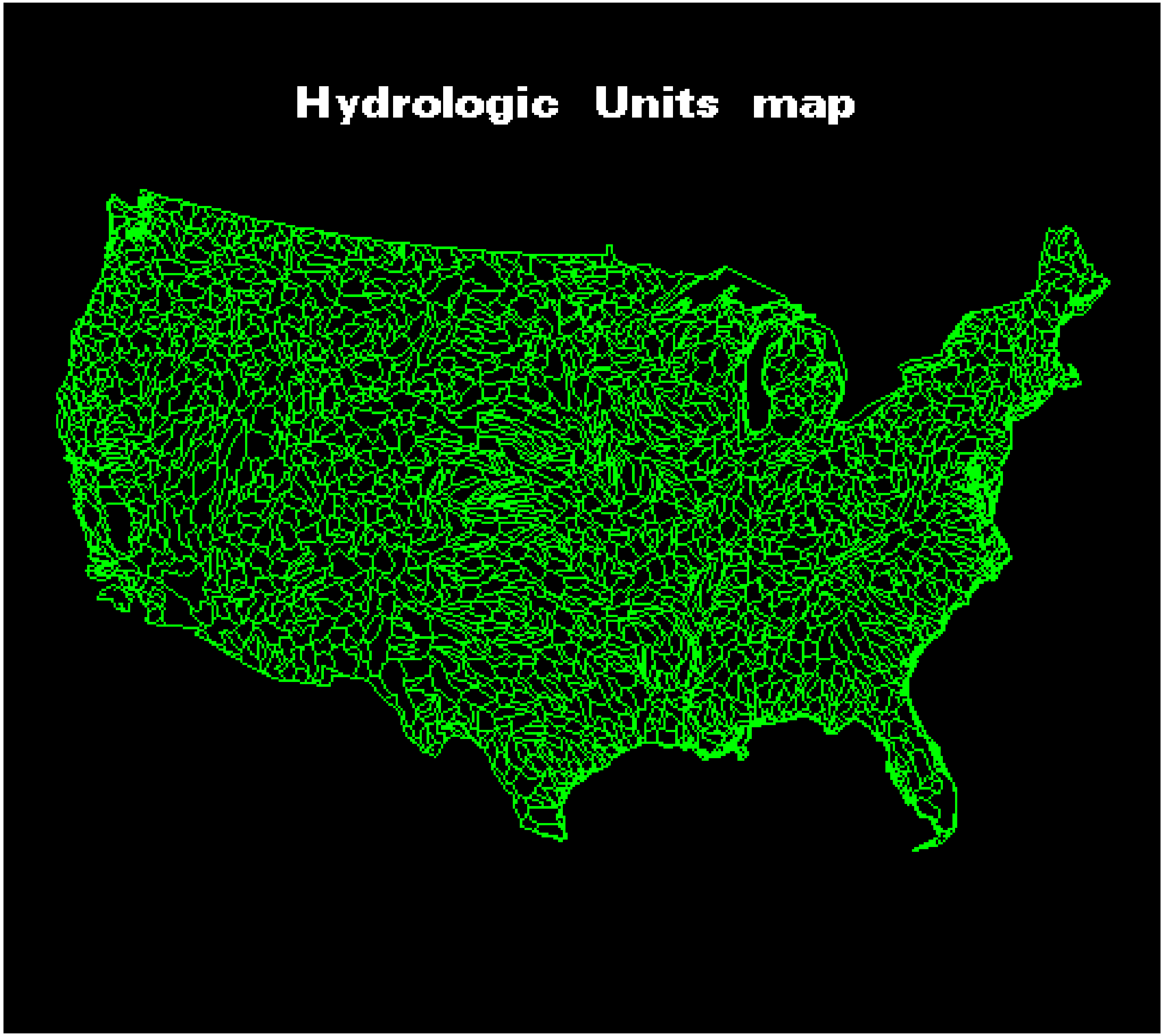
Charge

- Watersheds, ecoregions, or other geographic units?
- Appropriate scale?
- Relations of functions to location?
- Landscape considerations?

Answer Key

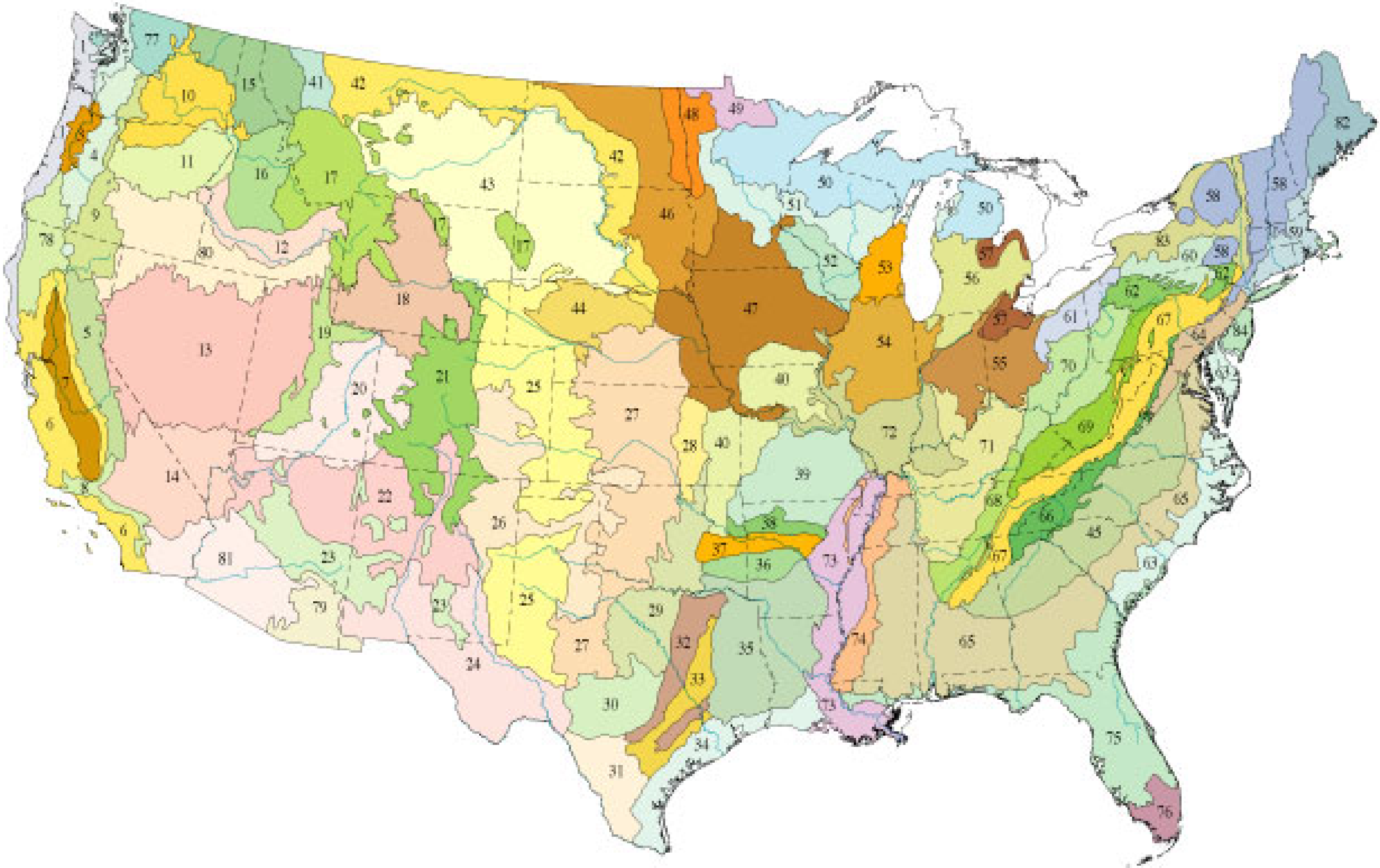
- Both plus political units
- >1<6
- Location, location, location
- It depends . . . . . .

USGS Hydrologic Units (1:2,000,000)



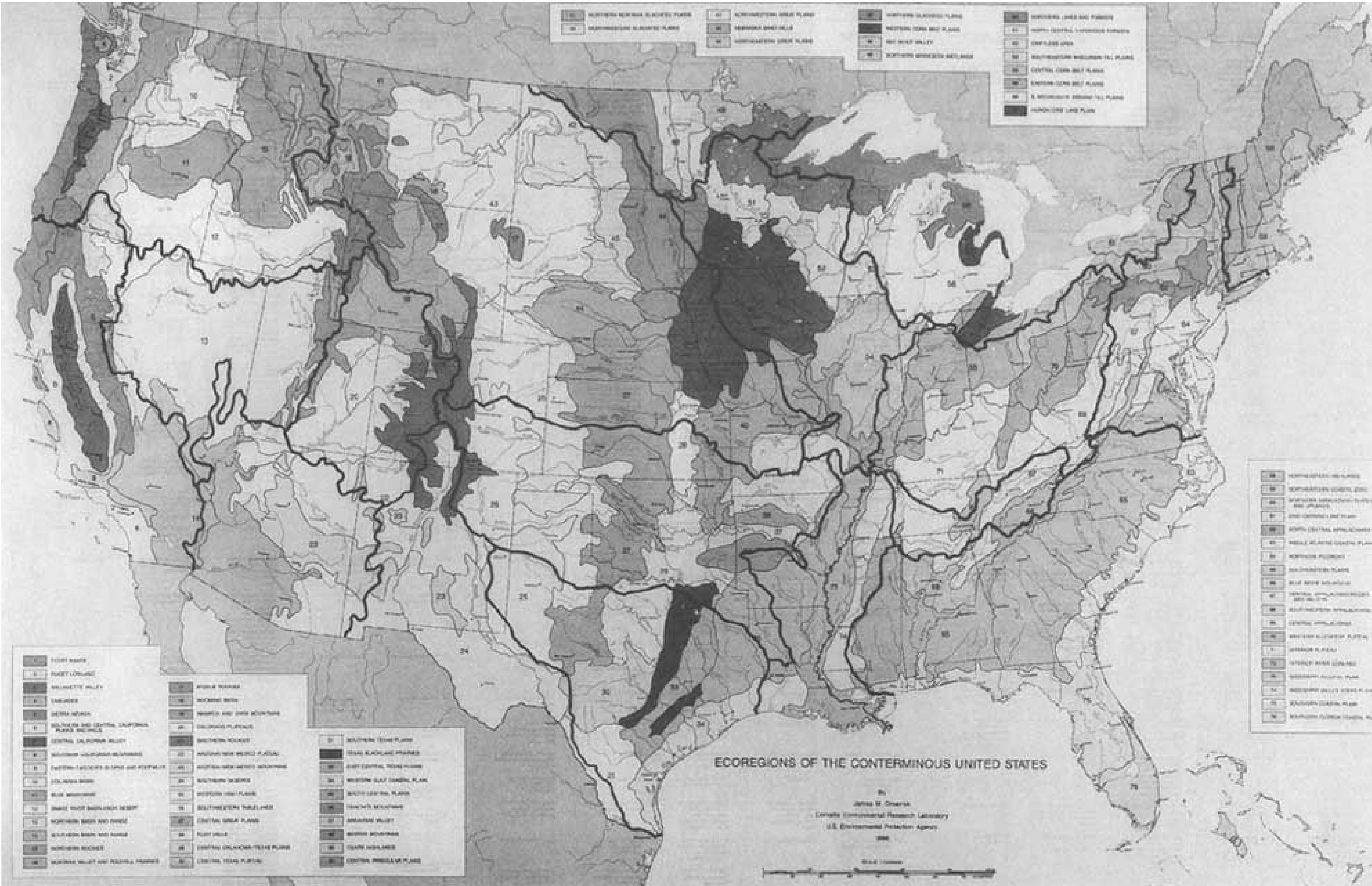
From USGS (2003)

Level III Ecoregions of the Conterminous United States



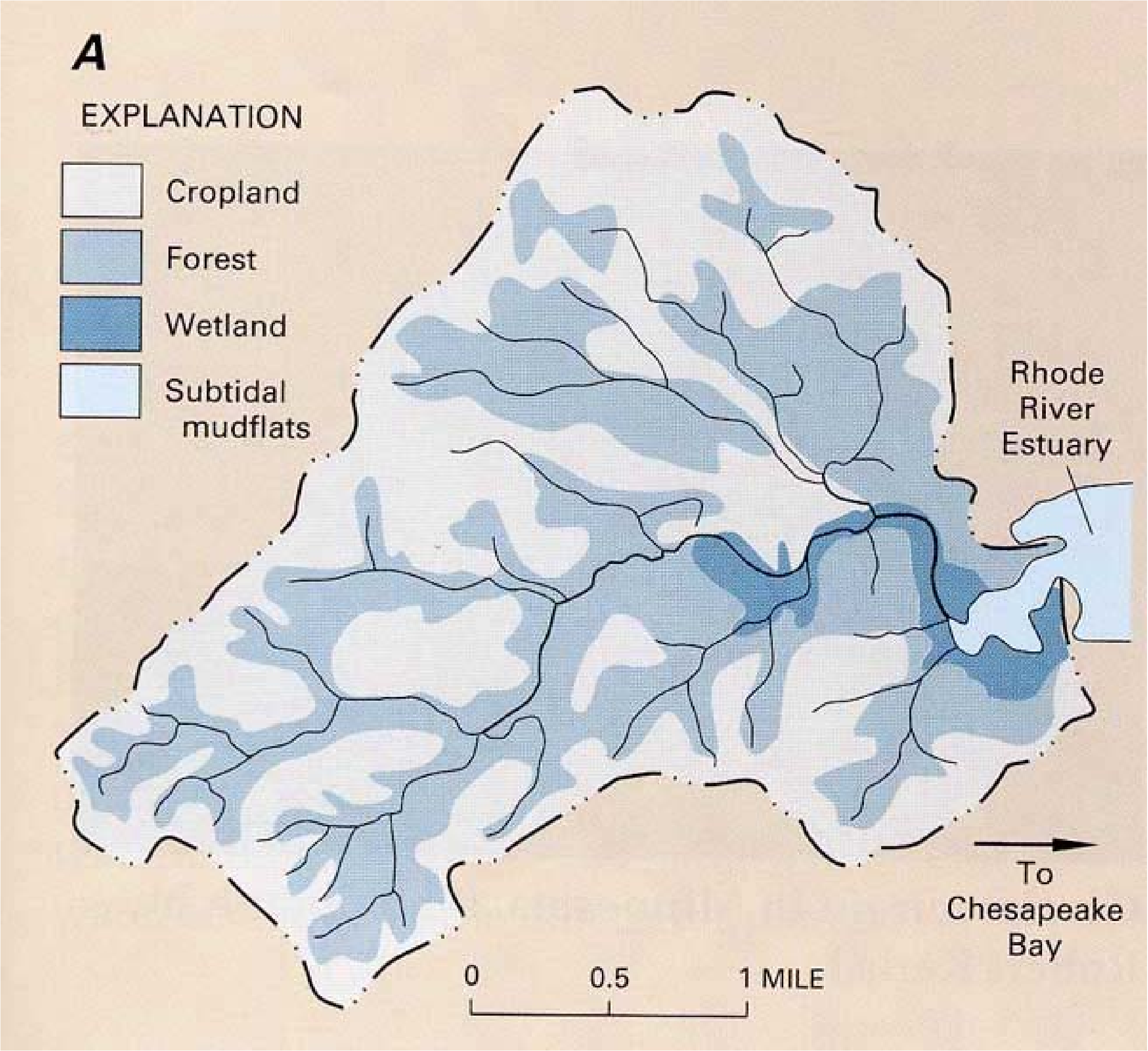
Map Source: USEPA, 2003

Ecoregions/watersheds of the conterminous U.S.



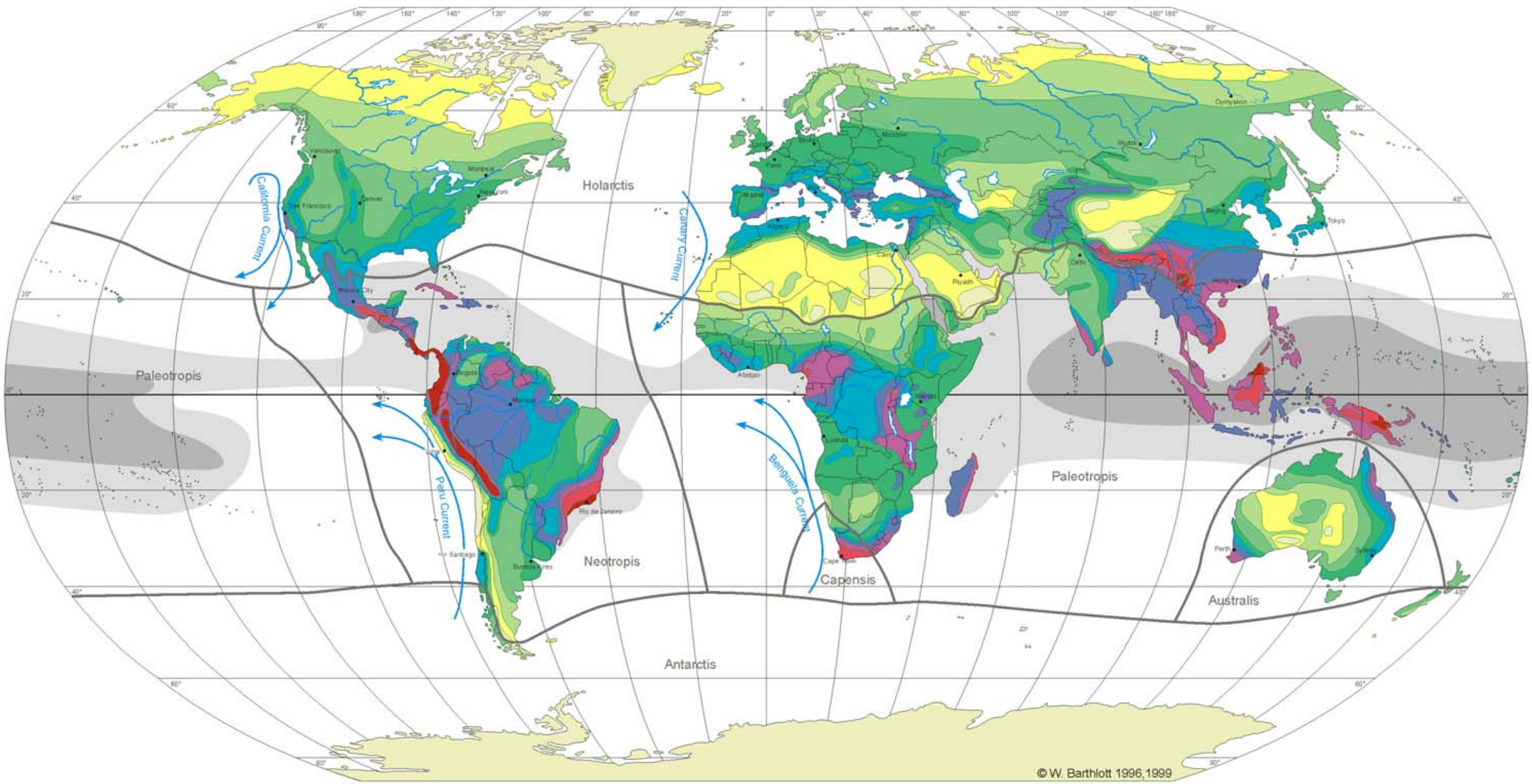
From Bedford and Preston (1988)

Why (not) Watersheds?



From Winter et al. (1998)

GLOBAL BIODIVERSITY: SPECIES NUMBERS OF VASCULAR PLANTS



Robinson Projection
Standard Parallels 38°N und 38°S

Diversity Zones (DZ): Number of species per 10 000km²

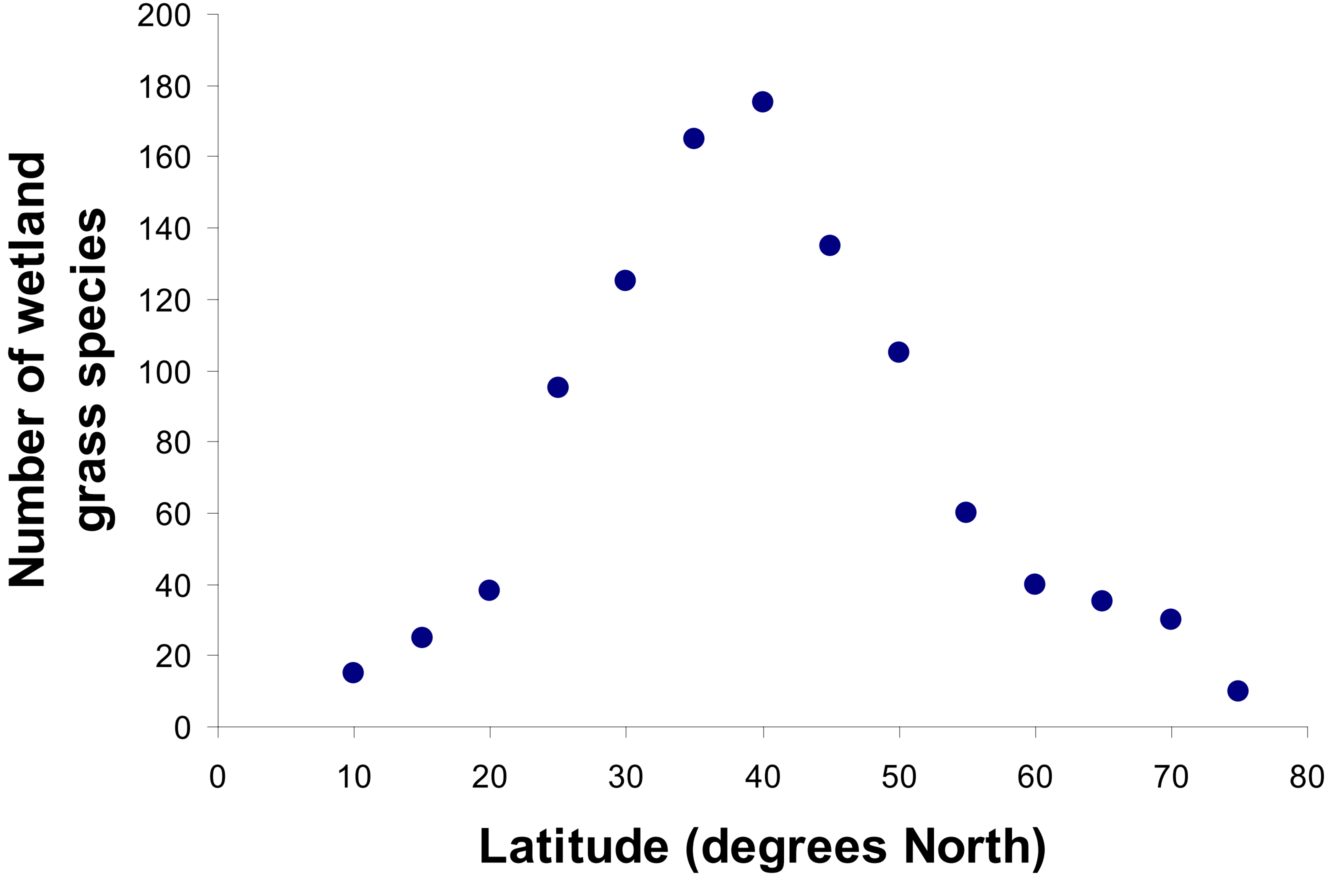
DZ 1 (<100)	DZ 5 (1000 - 1500)	DZ 9 (4000 - 5000)
DZ 2 (100 - 200)	DZ 6 (1500 - 2000)	DZ 10 (≥ 5000)
DZ 3 (200 - 500)	DZ 7 (2000 - 3000)	
DZ 4 (500 - 1000)	DZ 8 (3000 - 4000)	Capensis floristic regions

sea surface temperature
>29°C
>27°C
cold currents

W. Barthlott, N. Biedinger, G. Braun, F. Feig, G.Kier, W. Lauer & J. Mutke 1999
modified after
W. Barthlott, W. Lauer & A. Placke1996
Department of Botany and Geography
University of Bonn
German Aerospace Research Establishment, Cologne
Cartography: M. Gref
Department of Geography University of Bonn

Why (not) Ecoregions?

Latitudinal patterns of species richness for freshwater wetland grasses

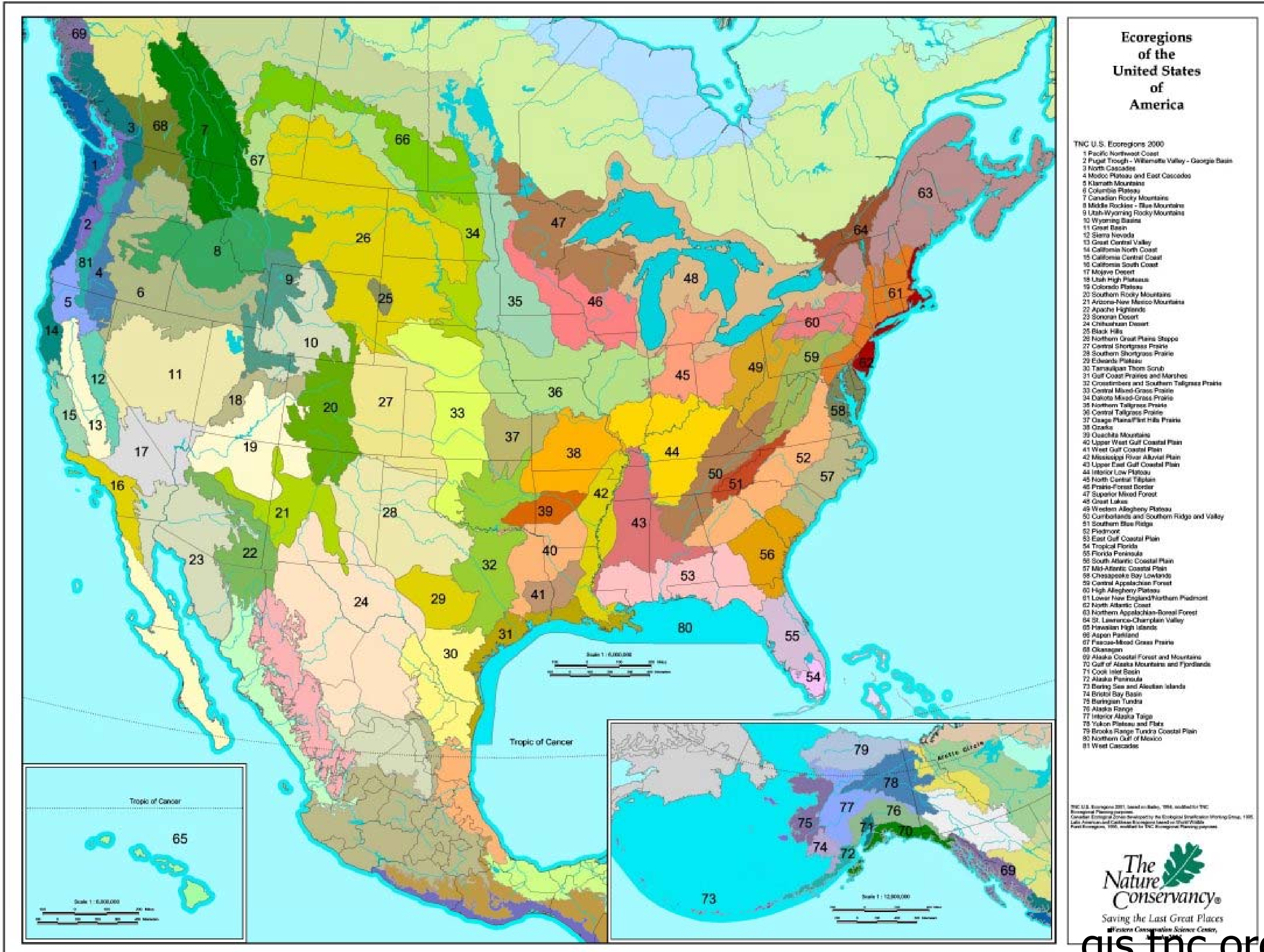


Source: A. Ellison, C. Hart, and C. Ordoyne, unpublished data.

Global Ecological Diversity

Country	*Number of biomes*	*Number of ecoregions*	*Percent of global area*
Former USSR	7	17	15%
Canada	7	11	7%
China	8	16	6%
United States	12	21	6%
Brazil	7	7	6%
Australia	7	11	5%

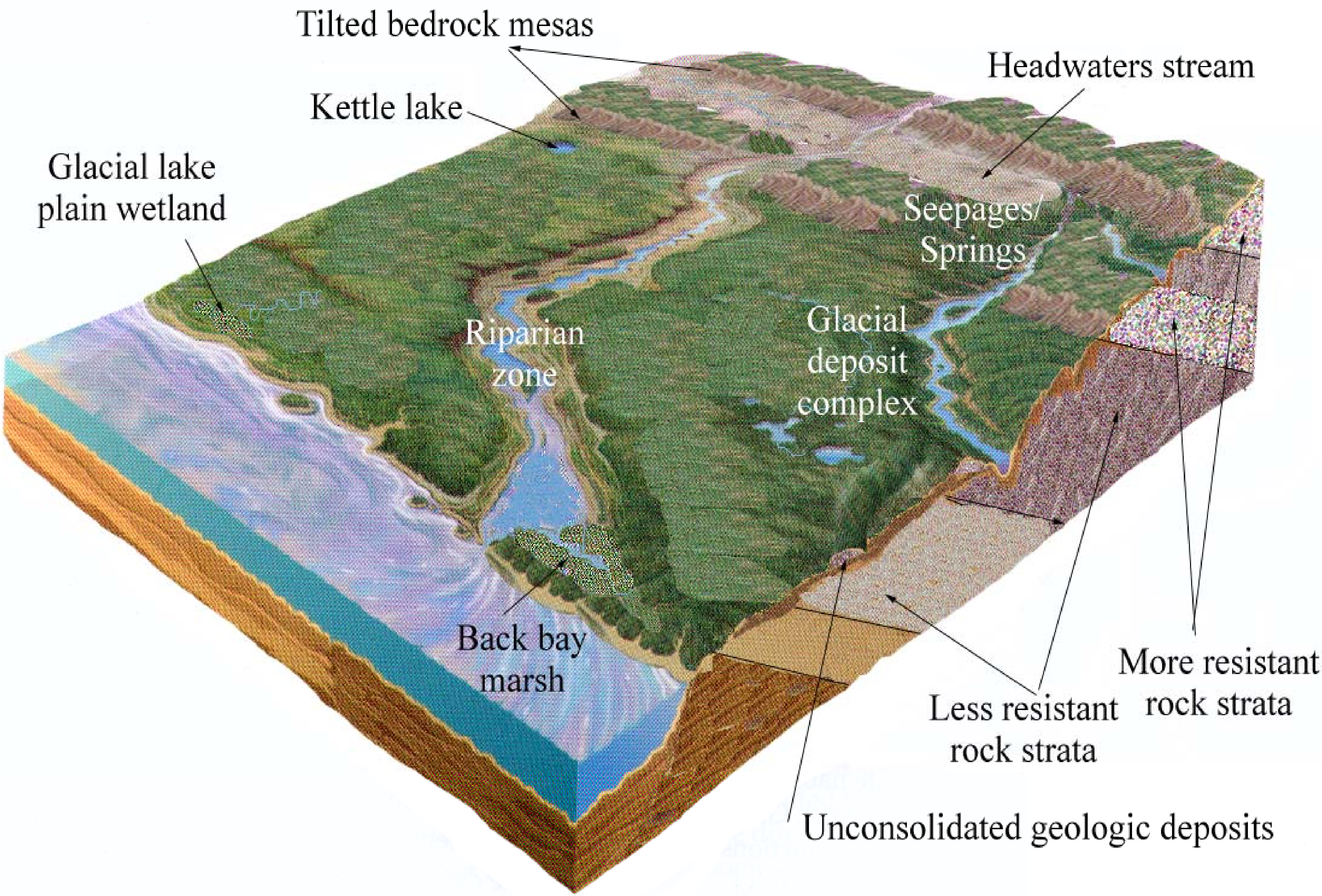
Source: Stein et al. 2000


Ecoregions of the United States of America
TNC U.S. Ecoregions 2000
1 Pacific Northwest Coast
2 Puget Trough - Willamette Valley - Georgia Basin
3 North Cascades
4 Modoc Plateau and East Cascades
5 Klamath Mountains
6 Columbia Plateau
7 Canadian Rocky Mountains
8 Middle Rockies - Blue Mountains
9 Utah-Wyoming Rocky Mountains
10 Wyoming Basins
11 Great Basin
12 Sierra Nevada
13 Great Central Valley
14 California North Coast
15 California Central Coast
16 California South Coast
17 Mojave Desert
18 Utah High Plateaus
19 Colorado Plateau
20 Southern Rocky Mountains
21 Arizona-New Mexico Mountains
22 Apache Highlands
23 Sonoran Desert
24 Chihuahuan Desert
25 Black Hills
26 Northern Great Plains Steppe
27 Central Shortgrass Prairie
28 Southern Shortgrass Prairie
29 Edwards Plateau
30 Tamaulipan Thorn Scrub
31 Gulf Coast Prairies and Marshes
32 Crosstimbers and Southern Tallgrass Prairie
33 Central Mixed-Grass Prairie
34 Dakota Mixed-Grass Prairie
35 Northern Tallgrass Prairie
36 Central Tallgrass Prairie
37 Osage Plains/Flint Hills Prairie
38 Ozarks
39 Ouachita Mountains
40 Upper West Gulf Coastal Plain
41 West Gulf Coastal Plain
42 Mississippi River Alluvial Plain
43 Upper East Gulf Coastal Plain
44 Interior Low Plateau
45 North Central Tillplain
46 Prairie-Forest Border
47 Superior Mixed Forest
48 Great Lakes
49 Western Allegheny Plateau
50 Cumberlands and Southern Ridge and Valley
51 Southern Blue Ridge
52 Piedmont
53 East Gulf Coastal Plain
54 Tropical Florida
55 Florida Peninsula
56 South Atlantic Coastal Plain
57 Mid-Atlantic Coastal Plain
58 Chesapeake Bay Lowlands
59 Central Appalachian Forest
60 High Allegheny Plateau
61 Lower New England/Northern Piedmont
62 North Atlantic Coast
63 Northern Appalachian-Boreal Forest
64 St. Lawrence-Champlain Valley
65 Hawaiian High Islands
66 Aspen Parkland
67 Fescue-Mixed Grass Prairie
68 Okanagan
69 Alaska Coastal Forest and Mountains
70 Gulf of Alaska Mountains and Fjordlands
71 Cook Inlet Basin
72 Alaska Peninsula
73 Bering Sea and Aleutian Islands
74 Bristol Bay Basin
75 Beringian Tundra
76 Alaska Range
77 Interior Alaska Taiga
78 Yukon Plateau and Flats
79 Brooks Range Tundra Coastal Plain
80 Northern Gulf of Mexico
81 West Cascades
Tropic of Cancer
Arctic Circle
The Nature Conservancy®
Saving the Last Great Places

Possible scales for mitigation decisions

Scale	Characteristics determining their spatial boundaries
Project	Area determined by project boundaries
Individual wetland	A single site defined by boundaries of the wetland itself
Watershed or basin	The area drained by a river or stream and its tributaries
Landscapes	Spatially repetitive cluster of interacting ecosystems Similar geomorphology Similar set of disturbance regimes May contain one or more watersheds
Regions	Areas determined by a complex of climatic, physiographic, biological, economic, social, and cultural characteristics May contain one or more landscapes

From Bedford and Preston (1988)



Location, location, location

Elements of Landscape Profiles

WETLAND TEMPLATES

Catalog and Map of Wetland Templates

- Hydrogeomorphic classes
- Hydrogeologic and climatic settings
- Wetland-landscape linkages

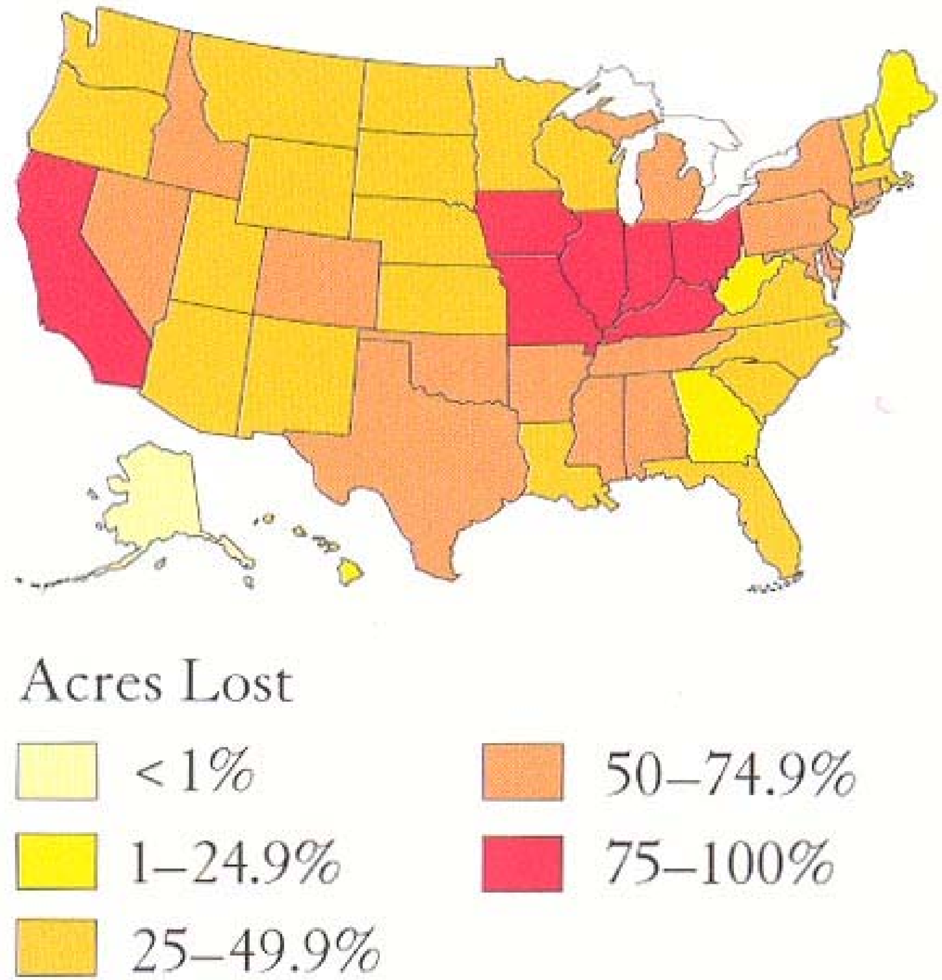
Geographical Analysis of Templates

- Proportion lost and location
- Proportion modified and location
- Proportion remaining and location

WETLAND ECOSYSTEMS

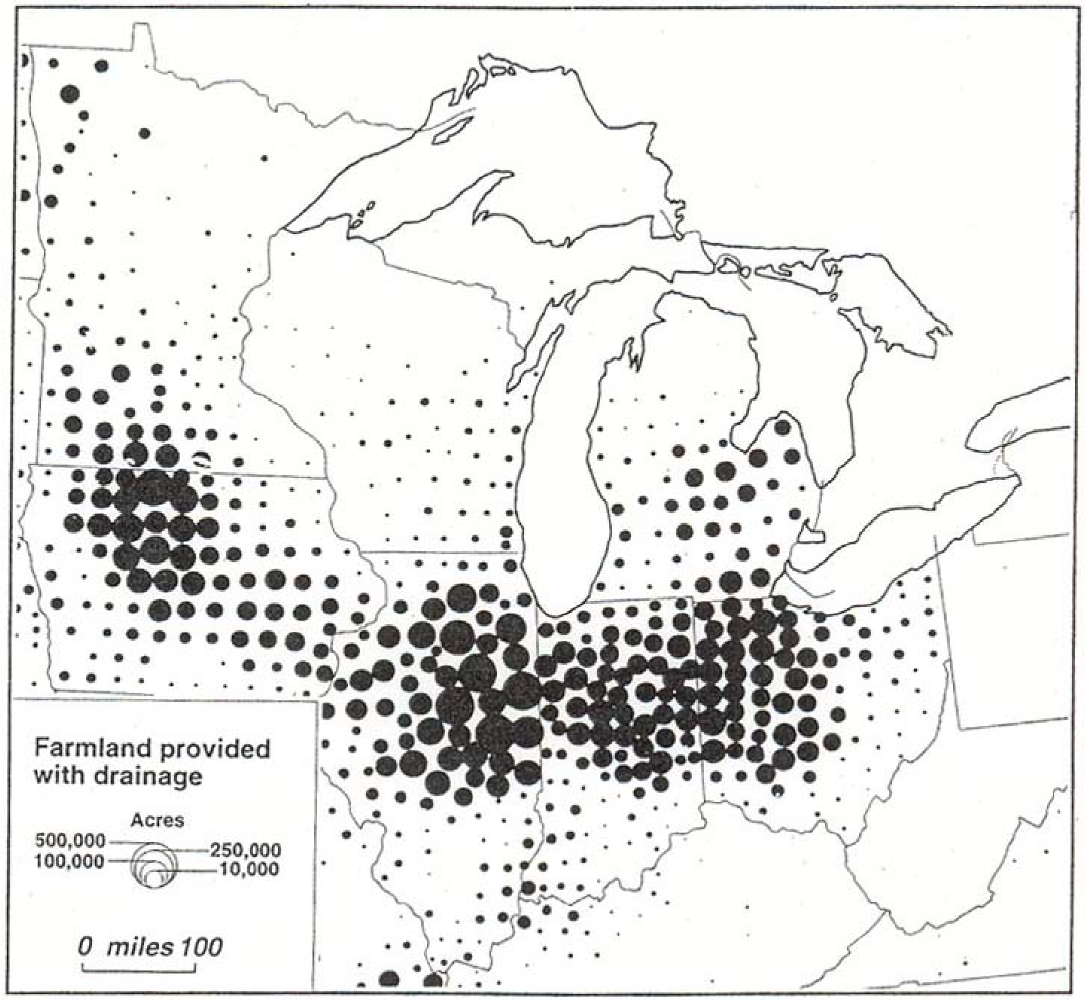
Catalog and Map of Wetland Ecosystems

Geographical Analysis of Ecosystems



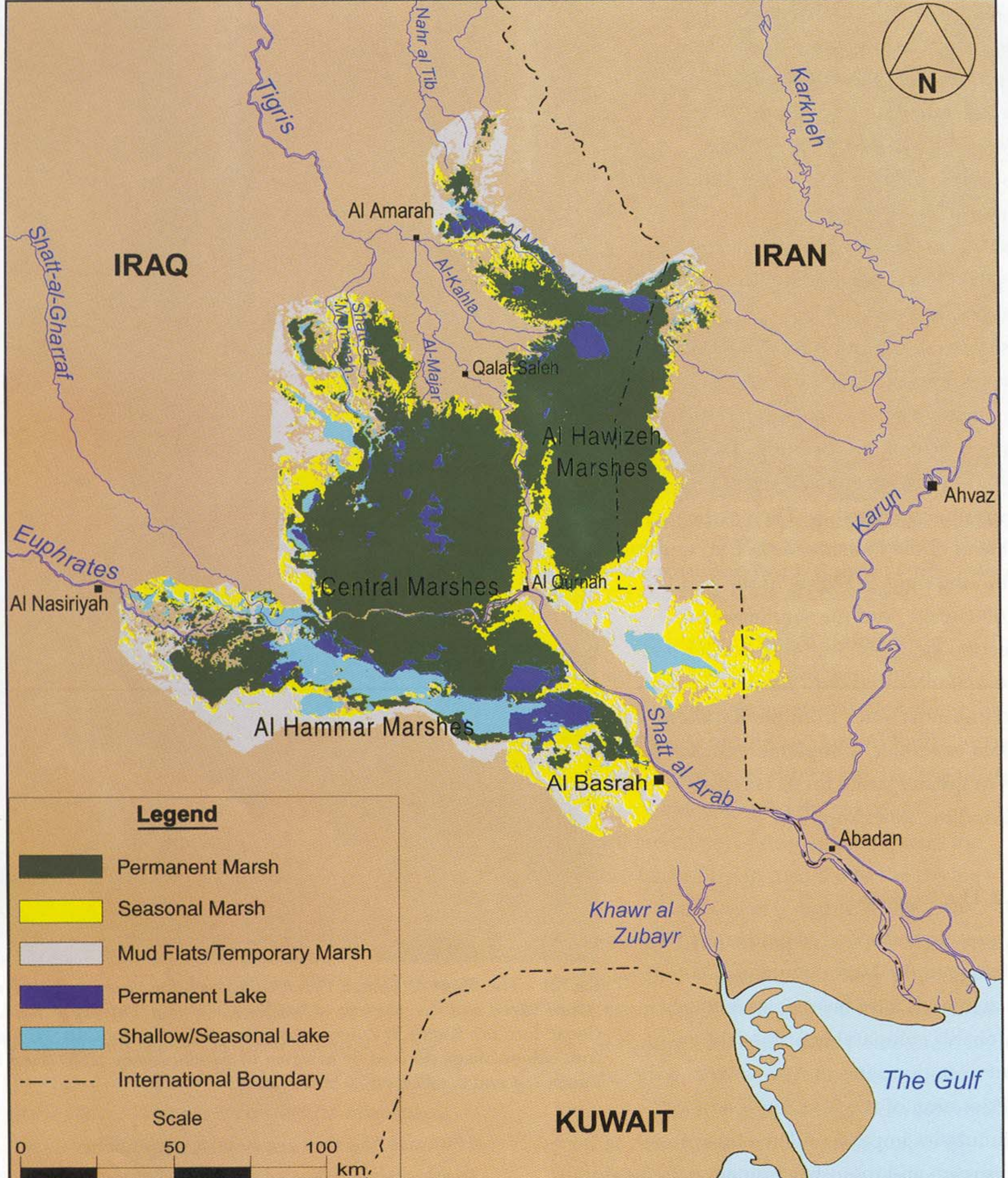
Percent Wetland Losses by State

Source: Stein et al. 2000

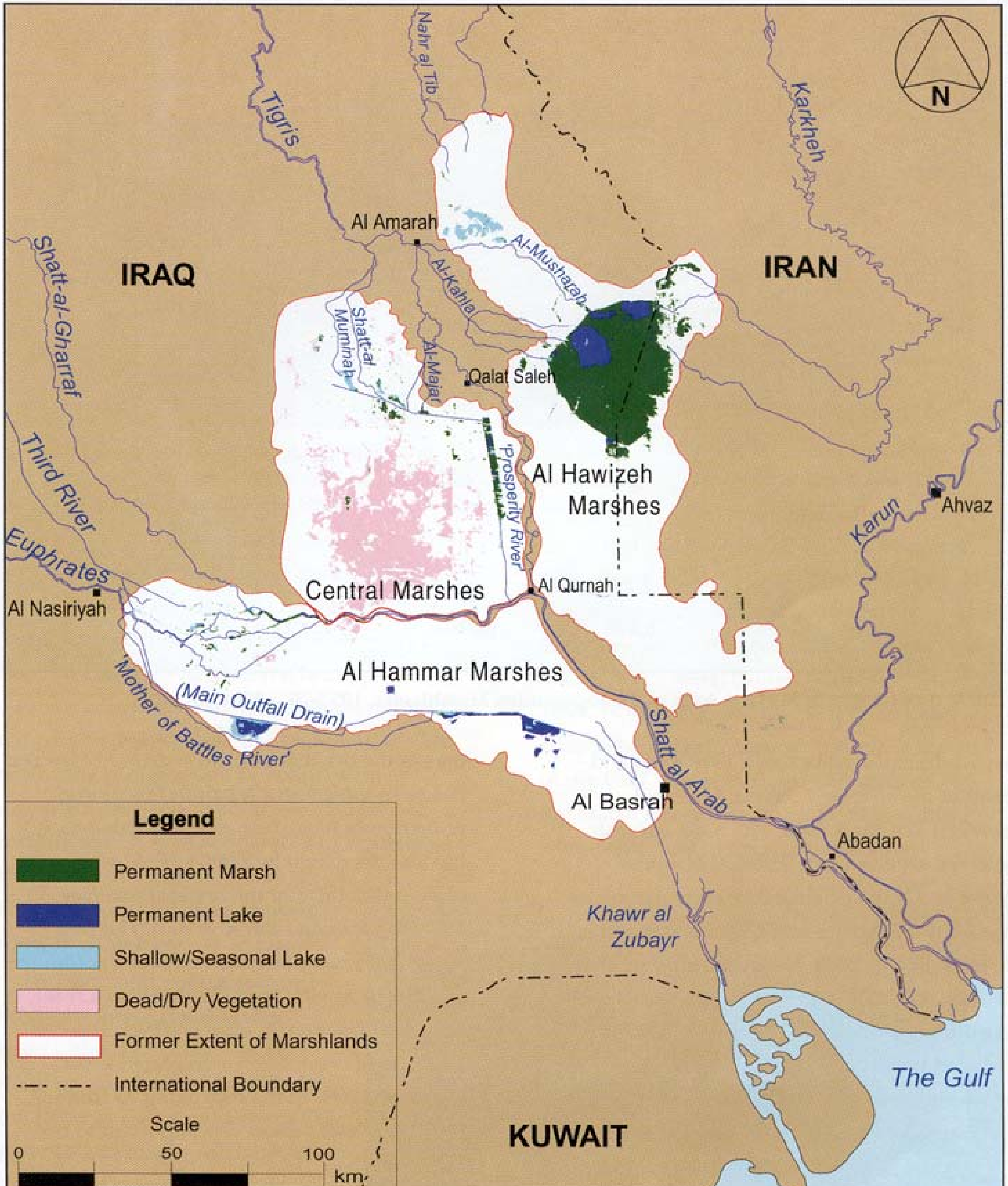


Drained Farmland in the Midwestern United States, 1930

Source: Prince 1997



Map 7: Mesopotamian Marshlands Land Cover 1973–76



Map 8 - Mesopotamian Marshlands: Land Cover 2000