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LAND ENVIRONMENTS OF WATER RESOURCE MANAGEMENT

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ABSTRACT

This article attempts to look across a broad range of hydrologic disciplines in order to compare the types of hydrologic phenomena and processes that occur in different types of land environments, and to develop a conceptual framework for basic hydrologic classification of land. It emphasizes the qualitative types of hydrologic processes that may occur in the landscape, rather than quantitative rates of flow. The framework was developed by reclassifying physiographic landforms according to hydrologic characteristics, and examining different landform types in photographs and on the ground. The framework is based around landform, hydroclimate, and regional aquifers and rivers. Landforms are characterized as hydrologically "positive" or "negative," with positive landforms being further broken down by permeability of soil and bedrock. Such a framework could help to guide early water resource planning decisions by aiding the comparison of contrasting needs and potentials of different areas. It can thus have important implications for the types of solutions to water resource issues that are attempted.

In recent years a wealth of vastly different water management alternatives have been developed, as various as water harvesting, wastewater land application, stormwater infiltration, and direct recycling. Concerns about quality, quantity, and cost of water resources have arisen in many different areas of North America and the world, demanding full consideration of all available management alternatives [1]. Clearly, the relative applicability of the available alternatives must vary with the characteristics of the land environment (soil, rock, climate, and topography) where their implementation is considered. That the hydrologic characteristics of land do vary from place to place is familiar: some land has aquifers below it, other land does not; some land is characterized by standing water, other land is dry; and so on.

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This article presents a framework for characterizing the land environments within which water management alternatives may be considered. It tries to outline the distinguishing traits of different land environments within which hydrologic flows and storages may occur.

It is easy to find discussions of individual types of hydrologic phenomena such as the occurrence of groundwater (e.g., Bianchi and Muckel [2], or Meinzer [3]), the behavior of soil moisture (e.g., Hewlett [4], or Schultz and Hewlett [5]), or the occurrences and regimens of surface waters (e.g., Horwitz [6], or Leopold, et al. [7]). However, few of those discussions touch with equal emphasis on types of land where other types of processes occur. In contrast, this article intends to look across a wide scope of types of land, and to compare the different types of hydrologic processes and phenomena that occur in them.

This article emphasizes the land's controls, such as types of topography and earth materials, over the qualitative *types of processes* that may occur in the landscape. This is in contrast to emphasizing the *rates of flow* through given processes, which may be determined by rates of inflow and outflow, and relative, quantitative land characteristics such as soil permeability.

This article proposes, in essence, a conceptual framework for basic hydrologic classification of land. Such a framework could help to guide early water management planning decisions by helping to compare and discuss contrasting needs and potentials of different areas and thus to accelerate the development of most appropriate solutions.

DEVELOPMENT OF A FRAMEWORK

It is possible to look at land from many different viewpoints. One viewpoint familiar to planners is the physiographic one conveniently cataloged by Way [8], where the emphasis is on geologic materials, structure, and history, and the corresponding topographic shapes, stream patterns, etc. From a hydrologic viewpoint, we must abstract the specifically water-related characteristics of the land, resulting in a thorough reclassification of landforms as seen by physiographers such as Way.

An earlier paper provided a conceptual framework for understanding the types of flows and storages of water that may occur in a landscape [9]. They can be conveniently thought of in terms of "mantles," or layers, of the landscape, where different types of hydrologic processes occur. The surface mantle is characterized by overland flow. The soil mantle is characterized by unsaturated soil moisture, the groundwater mantle by saturated groundwater. Each mantle has its own water balance, in which changes in storage take up differences between inflows and outflows to and from other mantles, the atmosphere, and drainage basin discharge.

Artificial water supplies and dispositions amount to diversions into and out of one or more of the natural flows of these mantles. Some points at which various management systems can connect with the various mantles are illustrated in Table 1. From the viewpoint of water supply, each mantle in a landscape could provide a relative abundance of water in each of several forms, a certain water quality, and a relation of time and place of flow to time and place of use. From the viewpoint of water disposal, each mantle could provide a relative capacity to absorb a given quality and quantity of flow, at given times and places. Combinations of the mantles' capabilities at any one place could affect the applicability of alternative water management strategies to that land environment.

The process of developing the framework described here involved:

1. interpretation of the hydrologic characteristics of each type of landform described by Way [8], outlining those characteristics mantle by mantle, and grouping landforms according to their shared characteristics;
2. visiting several landscapes in Georgia (a physiographically diverse state) that seemed to represent the hydrologic types;
3. examination of about 1,000 selected slides of landscapes by the author and others during residence, work, and travel in many parts of North America and the world, to try their fit to the hydrologic types; and
4. gradual formation of a conceptual framework, and adjustments of hydrologic groupings, to match what seemed to be represented in the above samples.

The resulting framework has intuitive completeness and simplicity, suggesting great usefulness and versatility in conceptualizing the hydrologic situations in many regions.

A framework of the hydrologic environment is diagrammed in Figure 1. The nucleus of the concept is the landform – the mass of earth materials where incoming water infiltrates, is stored, flows through, and discharges. The most ubiquitous forces that drive the movement of water through the landform are climatic: inward precipitation, originating the flows and storages in the landforms, and evapotranspiration, short-circuiting the transformation into runoff. In certain locations, the flows in the landform may be connected to those in regional aquifers and rivers, which may supplement and link the flows among many landforms in a region.

LANDFORMS

All landforms exist in relation to a local drinage base level. This level is marked by the saturated groundwater table where one exists and elsewhere by the elevations of major streams. The elevation of the drainage base level changes from place to place due to stream gradients, groundwater table gradients, and resistant rocks that hold streams up in locally elevated drainage base levels. However, stream and groundwater gradients seldom exceed a few percent, so it is

Table 1. Connections of Water Management Strategies to Five "Mantles" of the Land Environment[a]

	Atmosphere	*Surface Water Mantle*	*Soil Moisture Mantle*	*Ground Water Mantle*	*Cultural Mantle*
Water Supply	Water Harvesting	Surface Intake	None	Ground Water Intake	Direct Recycling
Wastewater Disposal	Evaporation, Evapotranspiration	Surface Discharge	"Slow-Rate" Irrigation	Wastewater Recharge	Direct Recycling
Flood Flow	Evaporation, Evapotranspiration	Storage, Diversion	Floodwater Infiltration	Floodwater Recharge	Floodwater Intake
Stormwater Disposal	Evaporation, Evapotranspiration	Surface Discharge	Stormwater Infiltration	Stormwater Recharge	Water Harvesting
References	Frasier [10]; U.S.E.P.A. [11]	Hall, et al. [12]; Tebbutt [13]	Ferguson [14, 15]	Bianchi and Muckel [2]	Tebbutt [13]

[a] The applicability of different water management strategies varies from place to place with varying capacities for flows and storages in the mantles of the land environment.

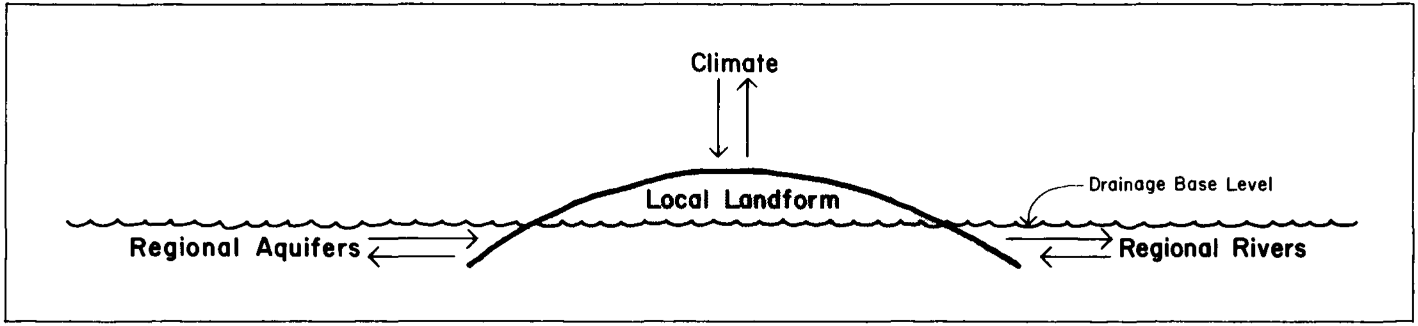

Figure 1. A conceptual framework of the hydrologic land environment.

reasonable to think of the base as a usually gently undulating plane. The elevation of a local drinage level may fluctuate with tidal cycles, seasonal moisture changes, or occurrences of drought or floods. However, such fluctuations occur within a limited range of elevations; through these relative fluctuations local landforms retain their fundamental relationships to the general base elevation.

We may distinguish between "positive" landforms, which stick up above the drainage level, and "negative" ones, at or below the base level (Figure 2). This simple distinction tells us a lot about how water behaves in the landforms. Water in a positive landform, whether or not it infiltrates the surface, ultimately moves outward from the landform. In a negative one it moves inward to the landform, possibly collecting water from a large tributary region. Positive landforms, by definition, have no surface streams; negative landforms are characterized by them. Positive landforms may have large unsaturated zones; negative landforms have next to none, and are full of saturated groundwater.

This distinction between types of landforms is made strictly in relation to the drainage base level, not in relation to other nearby landforms. For instance, although limestone is known physiographically as a former of valleys and depressions relative to nearby shale hills and sandstone mountains, it is still hydrologically elevated and positive relative to the streams and groundwater tables that drain it.

The landform types are described in more detail in Figure 2 and Table 2.

Negative landforms are characteristically made by recent fluvial processes. They lace through all regions, collecting the runoff from adjacent positive landforms and draining it down regional drainage gradients. Examples are floodplains and all types of wetlands (Figure 3). Negative landforms are the only landforms with ongoing or regularly occurring surface water storage and flows. Unsaturated storage and flows are relatively insignificant – essentially all subsurface flow is saturated.

Positive landforms with entirely permeable bodies are water-infiltrators. This type of landform is quite common, including sandstone, carbonates, and almost any unconsolidated materials above the drainage base level (Figure 4). All have permeable bedrock (or its unconsolidated equivalent), with or without a significant mantle of soil. Although the porosity and permeability of the materials can vary quantitatively, some portion of the infiltrating water is always potentially able to reach a saturated groundwater table. These are the positive landforms where aquifers outcrop. "Shallow" or "unconfined" aquifers are those that are continuous with the material at the land surface, without an intervening aquiclude. The remainder of the infiltrated water is stored in and flows through the large unsaturated zone.

Positive landforms that are essentially impermeable throughout their depth are water-spreaders. Examples are many occurrences of shale and slate, and most occurrences of granite (Figure 5). All have impermeable bedrock, with

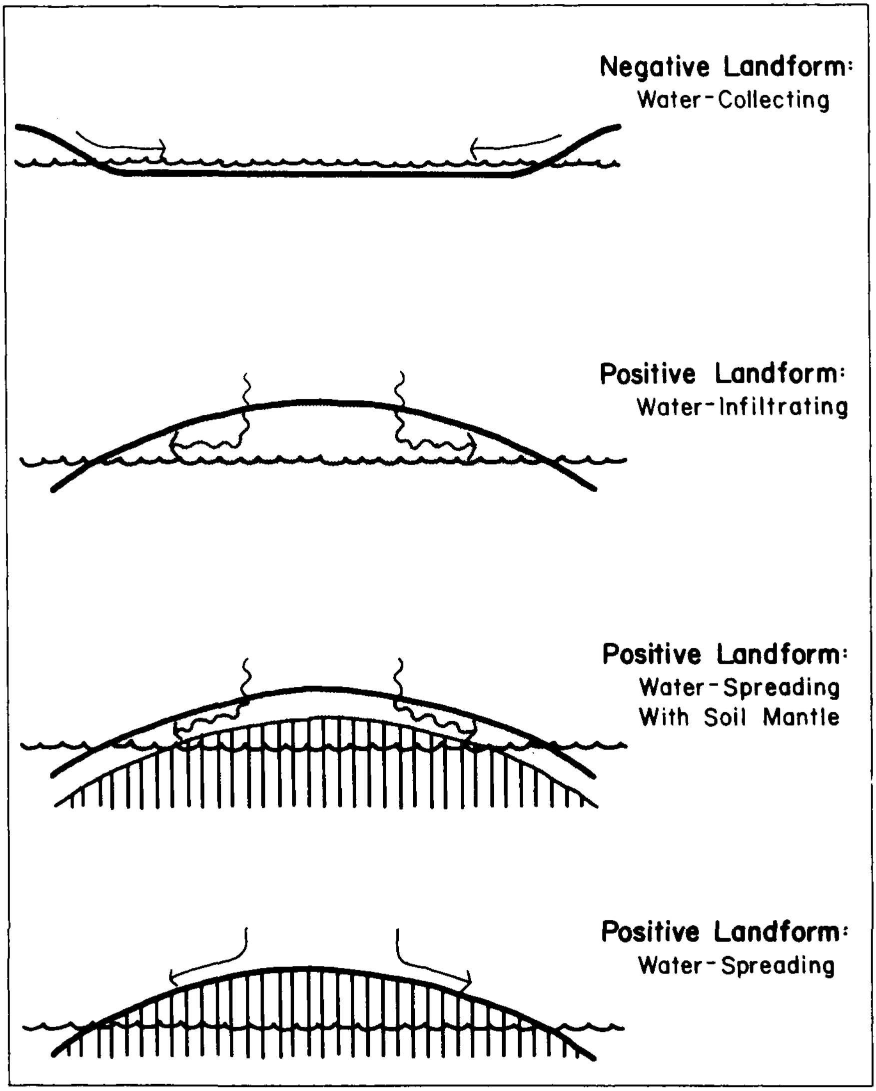

Figure 2. Conceptual models of hydrologically different types of landforms.

little overlying soil. They are familiar in arid regions, where soils tend to be shallow to absent. Infiltration is small, and subsurface storages and flows are insignificant. Drainage is mostly by surface runoff.

An intermediate type of landform has impermeable, water-spreading bedrock, but a significant mantle of permeable soil. Examples are the gneiss and schist of the southern Piedmont, where weathering has favored the development of thick

Table 2. Relative Hydrologic Differences among Contrasting Types of Landforms[a]

	Earth Materials	Surface Water Mantle	Soil Moisture Mantle	Ground Water Mantle
Negative (Water-Collecting) Landforms:				
Floodplains, Deltas, Tidal Flats, Organic Deposits (Swamp, bog, marsh)	Deep unconsolidated material	Large surface flows and storages	Shallow aerated zone; small unsaturated storage	Shallow water table; deep saturated zone; large groundwater storages and flows
Positive, Permeable (Water-Infiltrating) Landforms:				
1. Shallow soil: Sandstone, Extrusive Igneous	Shallow, permeable soil over highly fractured bedrock			
2. Deep Soil: Outwash, Alluvial Fans, Alluvial Valley Fills, Continental Alluvium, River Terraces, Sand Dunes, Loess	Deep permeable unconsolidated material	Few, small surface flows or storages	Deep aerated zone; large unsaturated storage	Deep water table; large groundwater storages and flows
3. Variable soil depth: Carbonate (limestone, Dolomite, Coral)	Permeable soil of variable depth over fractured and dissolved bedrock			
Positive, Impermeable (Water-Spreading) Landforms:				
1. Consolidated bedrock: Shale in Arid Regions, Slate in Arid Regions, Gneiss and Schist in Arid Regions, Granite (Intrusive Igneous)	Shallow, slowly permeable soil, over impermeable bedrock	Few, small surface flows or storage	Shallow aerated zone; small unsaturated storage	No water table (nominal water tables are perched, local and transient); small groundwater storages and flows

2. Unconsolidated Material: Drumlin	Variable complex of slowly permeable unconsolidated material and bedrock; net effect is consistently impermeable body	Few, small surface flows or storages	Shallow aerated zone; large unsaturated storage	No water table (nominal water tables are local and transient); small groundwater storages and flows
Water-Spreading Landforms with Soil Mantles:				
Shale in Humid Regions; Slate in Humid Regions; Gneiss and Schist in Humid Regions	Significant depth of permeable soil over impermeable bedrock	Few, small surface flows or storages	Deep aerated zone; large unsaturated storage	No water table (nominal water tables are perched, local and transient); small groundwater storages and flows
Positive Landforms with Variable Permealities:				
Old Till (Old Ground Moraines), Lake Beds in Elevated Positions, Moraines	Deep unconsolidated material	Few, small surface flows or storages	Aerated zone of variable depth; variable size of unsaturated storage	Water table of variable depth; large groundwater storage
Mixed Positive and Negative Landforms:				
Young Till (Young Ground Moraines), Lake Beds in Lowland Positions	Deep unconsolidated material	Few, small surface flows or storages (due to youthful, non-integrated drainage)	Shallow aerated zone; small unsaturated storage	Shallow water table; large groundwater storage

[a] The listed landforms are described physiographically by Way [8].

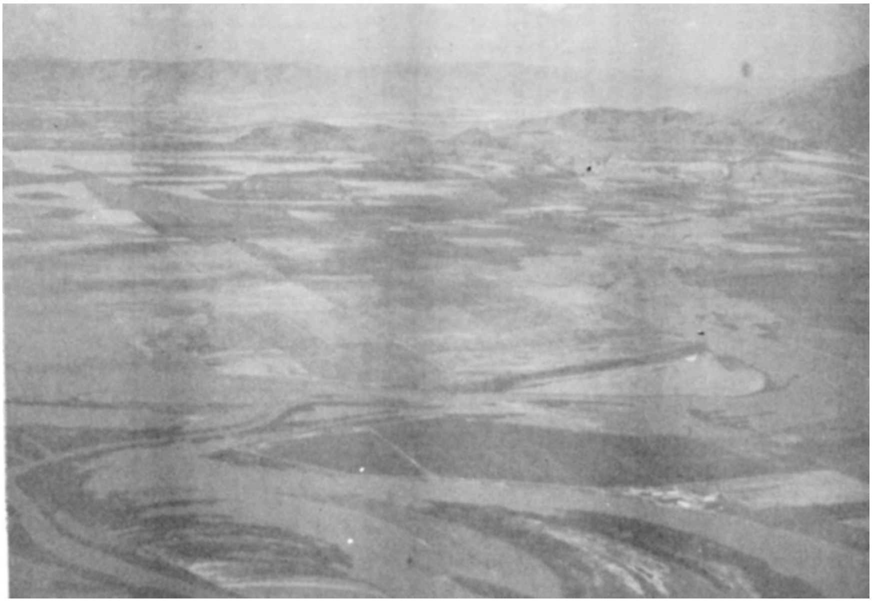

Figure 3. A water-collecting landform: the floodplain of the Cache River in Utah. The surrounding plain is an ancient lake bed.

saprolite, and some shale in humid areas (Figure 6). Water infiltrates the soil, but seldom settles into a significant mass of saturated groundwater. By default, the unsaturated soil moisture takes on an important role in subsurface storages and flows. In such materials, control by the unsaturated zone over the landscape's hydrologic behavior may be much more significant than many people have realized [5].

Landforms that are physiographically distinct but that mix characteristics of permeability and impermeability, and even positive and negative hydrologic functions, do occur (Table 2). Most of such landforms are glacial in origin, since the bulldozing action of glaciers tend to disrupt drainage patterns and the sorting of materials.

The landform types described above are useful as conceptual models. Many actual landforms fall clearly into one or another of those models. However, the complexities of geologic stratigraphy, structure, weathering, history, etc., may confuse the interpretation of other natural landforms, and require hybrid models for their characterization. An example is shown in Figure 7. In that example, there are many layers of materials, permeable and impermeable, between the land surface and the drainage base level. To pick apart hydrologically distinct

Photo by Nancy Baumgarten

Figure 4. A water-infiltrating landform: valley-fill alluvium in the San Luis Valley in New Mexico, at the base of the Sangre de Cristo mountains. In the center of the valley is the Rio Grande River, flowing in deeper Tertiary sedimentary rocks.

landforms here would probably require some characterization of the sequence of layers that exists at any one point.

Any of the characteristics of landforms could be altered, whether deliberately or inadvertently, by human actions such as clearing, compacting, earthmoving, paving, etc. Even negative landforms can be transformed into positive ones, as they have been in the lake beds of northern Ohio and the wetlands of southern Florida by the grading that has accompanied urbanization.

That different types of landforms do have observably different hydrologic behaviors is illustrated in Table 3. That table compares the inputs and outputs of four watersheds that have generally similar climates, but are characterized by different types of landforms. Whether one looks at long-term averages, individual years, or individual months, the various watersheds consistently change relatively small differences in precipitation into large differences in discharge. It is easy to explain their differences during dry periods on the basis of the relative degrees of subsurface storage. Hence, the different characters of the landforms are imposing different hydrologic regimens upon their watersheds despite the similarity in climatic forces acting upon them.

Table 3. Comparison of Four Watersheds in Georgia That Are Characterized by Different Types of Landforms[a] (Part 1)

Gaging Station	Watershed Materials	General Watershed Character	Average Precipitation	Average Discharge	Average Q ÷ P
Suwanee River at Fargo	Okefenokee Swamp	Negative: Water Collecting	50 in/yr.	11.5 in/yr.	.23
Yellow River near Covington	More than 60% Granite with Shallow Soil	Positive, Impermeable: Water-Spreading	48 in/yr.	16.9 in/yr.	.35
Middle Oconee River near Athens	More than 60% Gneiss and Schist with Saprolite	Positive, Impermeable: Water-Spreading with Significant Soil Cover	48 in/yr.	17.9 in/yr.	.37
Upatoi Creek near Columbus	Sand Hills	Positive, Permeable: Water-Infiltrating	54 in/yr.	19.5 in/yr.	.36
Range			13%	70%	60%
Source	Georgia Geologic Survey [22]; Figure 1 of Wharton [16]	Interpreted	Figure 1.2 of Plummer [17]	Stokes, et al. [18]	Derived

[a] Q = discharge; P = precipitation.

CLIMATES

The hydroclimatic input to landforms is precipitation. Any local water supply must ultimately be abstracted out of the precipitation inflow. Someday precipitation may be subject to deliberate alteration by man, although at the moment that possibility seems far in the future.

Evapotranspiration returns water to the atmosphere via plant growth, soil surfaces, and open water surfaces. Any water that goes back to the atmosphere is unavailable for further participation in the water budget such as in runoff and groundwater recharge.

When considering potential water management alternatives, it may be most useful to think in terms of *potential* evapotranspiration (PET). PET is the fixed capacity of the atmosphere to draw up water from the land, as a function of such things as temperature, wind, and solar radiation. It is a purely physical, climatic limit, against which potential management alternatives may be evaluated.

In contrast, *actual* evapotranspiration is the landscape's ability to fulfill the *potential* evapotranspiration. AET may be restricted to some level below the PET by non-climatic, alterable factors such as land use, vegetation, and artifical

Table 3. (Part 2)

10 Year, 30 Day Low Flow for Sept.	*1981 Precipitation*	*1981 Discharge*	*1981 Q ÷ P*	*Sept. 1982 Precipitation*	*Sept. 1982 Discharge*	*Sept. 1982 Q ÷ P*
.14 in/mo.	39 in/yr.	2.3 in/yr.	.06	4.5 in/mo.	.10 in/mo.	.02
.45 in/mo.	40 in/yr.	8.4 in/yr.	.21	3.0 in/mo.	.52 in/mo.	.17
.67 in/mo.	36 in/yr.	8.6 in/yr.	.24	2.2 in/mo.	.51 in/mo.	.23
1.23 in/mo.	47 in/yr.	14.5 in/yr.	.31	1.1 in/mo.	.54 in/mo.	.48
780%	20%	530%	430%	310%	440%	2,300%
Derived from Carter and Fanning [19]	U.S.N.O.A.A. [20]	Stokes, et al. [18]	Derived	U.S.N.O.A.A. [21]	Stokes, et al. [18]	Derived

water management. Any proposed water management strategy would have some level of AET associated with it. In the arid southwestern United States, PET is perennially high, but AET is held low by the paucity of natural rainfall, until irrigation water is imported and transpired by farm crops. In the more humid eastern United States, natural AET may come very close to equalling PET due to the greater quantity of water naturally available in the landscape.

The difference between precipitation (P) and ET is a landform's water "surplus" if P exceeds ET, or "deficit" if P is less. The surplus or deficit expresses the land's relative balance between atmospheric input and output. The balance is manifested in stream runoff, which is the land's discharge of the residuum of water after the climate is done with it.

Some of the hydrologic differences between regions with water deficits and surpluses are illustrated in Table 4. Each type of climatic region has its own opportunities and constraints for the implementation of alternative water management strategies.

Climatic distinctions also exist at a very local level. For example, differences in radiation and temperature with local slope orientations, gradients, and elevations lead directly to differences in ET and the water surplus, commonly manifested in different natural vegetation types. Many other meso- and micro-climatic phenomena are well known [24].

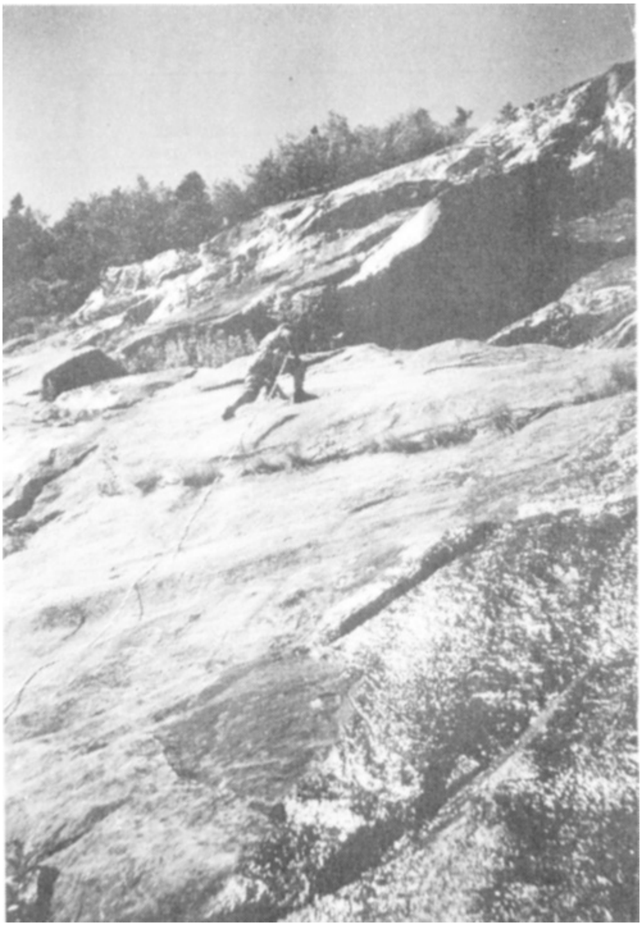

Figure 5. A water-spreading landform: grainte Mount Moosilauke in New Hampshire. The surface runoff is draining out of small pockets of soil that had captured rainfall in a storm a few hours before the picture was taken.

REGIONAL RIVERS AND AQUIFERS

Regional rivers and aquifers can provide inflows and outflows to and from landforms, just as the atmosphere can. By flowing laterally, they can also connect one landform to another.

Almost any region has some sort of surface stream. All streams manifest the outflows of water from the landforms that they drain. Some also put water into landforms, such as the rivers that laterally recharge shallow aquifers as they

Table 4. Relative Differences Between Contrasting Arid and Humid Environments [8, 23]

	Arid Region (Water Deficit)	*Humid Region (Water Surplus)*
Annual Runoff (P – ET)	Low Runoff	High Runoff
Potential for Increased ET	Large Potential	Small Potential
Potential for Increasing Crop Growth by Irrigation	Large Potential	Small Potential
Potential for Local Water Supplies	Small Potential	Large Potential
Soil Depth	Thin to Absent	Deep Soils
Vegetation	Sparsely Vegetated	Densely Vegetated
Depth of Rainfall Penetration into Soil	Shallow Penetration	Deep Penetration
Soil Moisture Process	Evaporation and Accumulation of Salts	Leaching and Groundwater Recharge
Drainage	Playa Lakes	Integrated Stream Systems
Quality of Ground and Surface Waters	High Dissolved Solids	Low Dissolved Solids

Figure 6. A water-spreading landform with soil mantle: shale in Pennsylvania, weathered by the temperate humid climate into low hills with soil deep enough for cultivated farming.

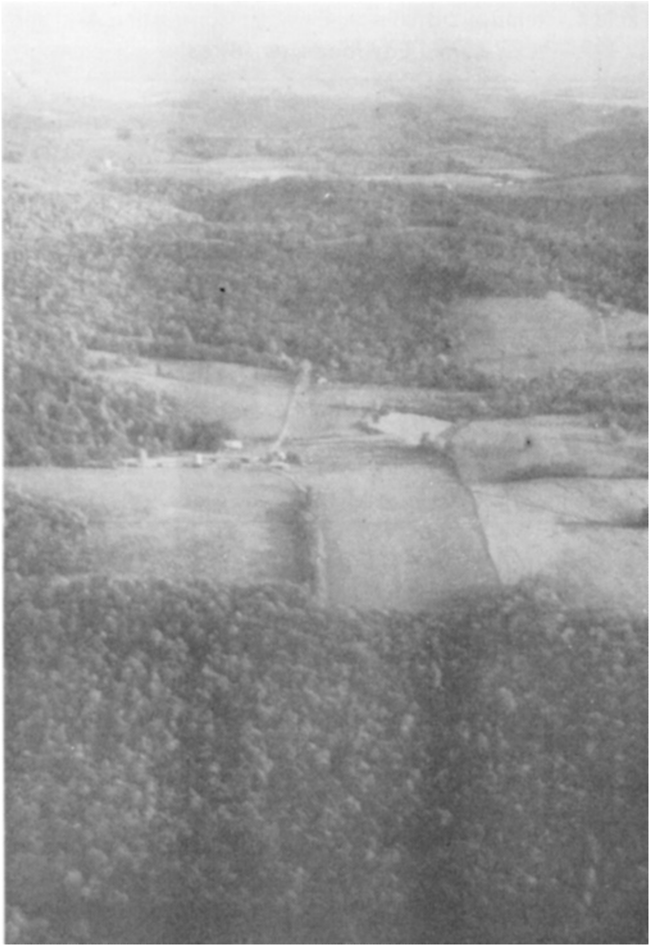

Figure 7. Hydrologically complex landforms in a dissected sedimentary plateau in Pennsylvania. The drainage base level is at the elevation of deeply entrenched streams. The positive landforms are composed of many layers of thin, interbedded, gently folded sedimentary strata. There are many local groundwater tables perched among the strata, draining out at springs and swales. The steep hills are covered with a mantle of soil that is thin near the ridges, but accumulates as colluvium at the bases of slopes.

seasonally flood over the southern Coastal Plain. Artificial water management strategies could involve placing water intakes and outfalls in the rivers, thereby accelerating local inflows and outflows.

Regional, "deep" aquifers are distinct from local ones: they underlie many landforms at once, and are often in materials hydrologically segregated from those at the surface. The occurrence of a deep aquifer below a landform depends upon the volumes and textures of geologic formations, their structural relationships, and their tectonic and solution histories [25, pp. 215-219]. Like rivers, aquifers drain water out of landforms, down regional gradients. Where a saturated zone is shared by a number of landforms, flows out of one landform can naturally become inflow to another. Any aquifiers could be artifically pumped or injected to accelerate local inflows and outflows.

LAND-INFORMED WATER MANAGEMENT

An example of the importance of understanding the land environments of water management may be taken from the headwaters of the Flint and Ocmulgee River systems in the rapidly growing suburbs of Atlanta (Figure 8). Here, the uplands are mantled with a deep coat of saprolite, holding a significant reservoir of unsaturated soil moisture. The underlying crystalline rocks are essentially impermeable. Saturated groundwater is limited to narrow rivulets flowing slowly over the bedrock down toward the river valleys. Although groundwater accumulates in the river alluvium, the valleys are so narrow that their groundwater resource is still insignificant. For many years water management has focused, by default, on the small rivers. The small valleys are dotted with water supply reservoirs attempting to make as full use as possible of a surface resource which is so limited that it has begun to threaten the region's capacity for further economic development.

However, research on the hydrology of the unsaturated soil mantle has recently been opening up previously unexplored water management potentials of the landscape [4]. In 1981, one of the large county water authorities began irrigating with wastewater upstream from its own water supply reservoir. The soil mantle infiltrates the water, renovates it, and steadily discharges it into the stream system for reuse. Thus, full recognition of the hydrologic capabilities of the land environment is allowing augmentation of formerly small natural flows, and enhancing the landscape's ability to support economic development.

By artificial pumps and conveyances, local landforms can be connected into a regional network of inflows and outflows, with greater value to water users than any one of the landforms taken individually. An example may be observed in the semi-urban Nittany Valley in Pennsylvania, where thick, inclined sedimentary strata form distinct ridges, hills, and valleys (Figure 9). Groundwater in the narrow sandstone mountains is held in elevated positions by shale aquicludes on each side. Discharge flowing over the surface of the adjacent shale hills fluctuates rapidly in response to rainfall and drought. In contrast, groundwater in the great limestone basins rises and falls only slowly [26, 27]. Communities at the bases of the mountains get their water from streams on the shale hills, and have been concerned primarily with upland land use to protect the quality of their mountain streams. Communities in the middle of the valley get their water

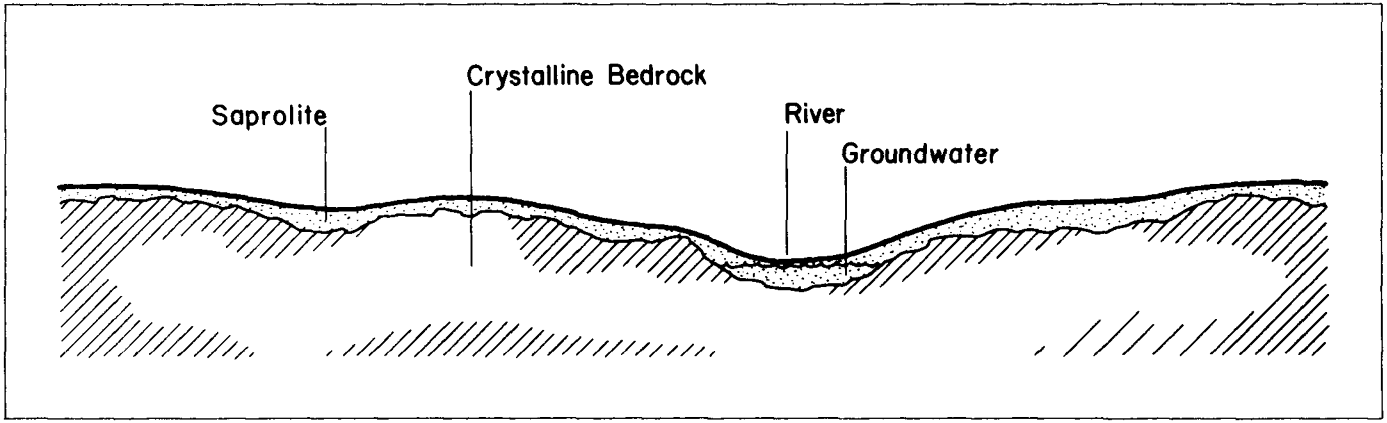

Figure 8. Schematic geologic cross-section through a headwater tributary of the Ocmulgee River near Atlanta, Georgia.

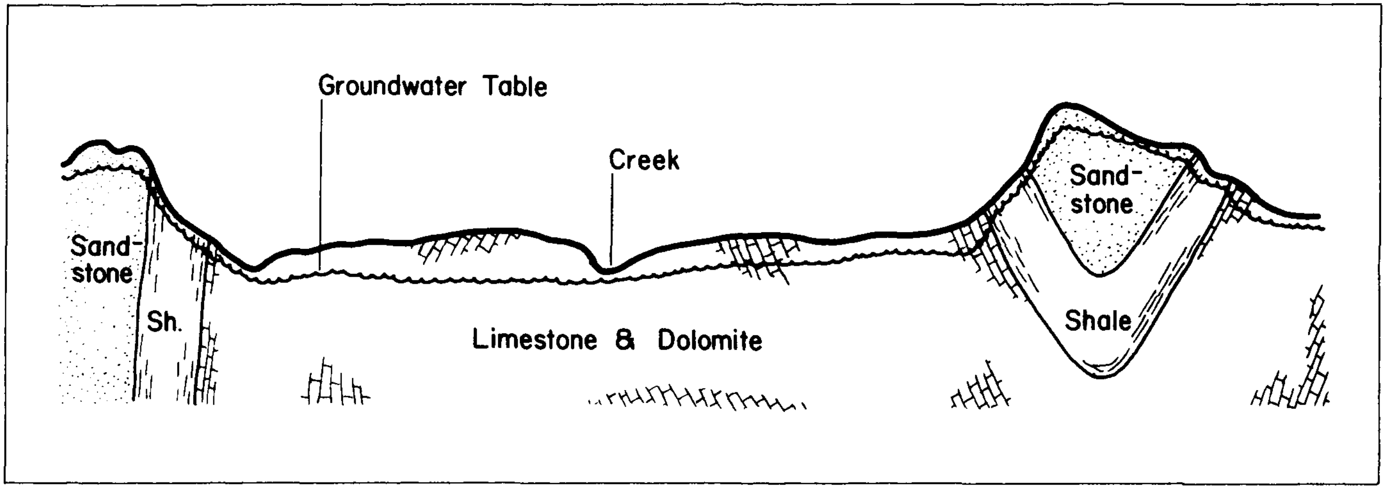

Figure 9. Schematic geologic cross-section through the Nittany Valley in Pennsylvania.

from wells in the limestone aquifer, and have been concerned primarily with maintaining local recharge to protect groundwater levels. As the communities have grown, their demands for water have come close to exceeding their local supplies.

They have recently realized that fluctuations in the valley supplies lag a few months behind those in the hills. The mountain streams have frequently recovered by the time a water deficit shows up in the limestone aquifer. There is now movement toward linking the communities' water distribution systems, so that each can seasonally subsidize the other. Hence, recognition of the composite hydrologic pattern of landforms has suggested regional linkages which can avoid the expense of overdesigning each system individually.

Other combinations of landforms exist in other regions. The concept of physiographic regions is intended to delimit areas where there are consistent patterns of landforms [23]. Each region has its own types of landforms, its own interactions of flows among those landforms, its own more or less consistent pattern of climate, and hence its own potentials for regional water management.

The hydrology of the landscape is not limited to streams, nor to reservoirs of saturated groundwater. Water flows through intricate but orderly sequences of mantles, both in the uplands and the lowlands, the surface and the subsurface, the atmosphere and the earth. Water management should be guided by an understanding of the fundamental types of processes that water follows and could follow in the underlaying land.

One area of land differs from another. Some lands contain groundwater, others do not. Some lands contain significant soil moisture; others do not. Some lands have a water surplus; others a deficit. Some lands are the recipients of flows from elsewhere in the landscape. We should not look for the same types of structures and processes in all regions and in every piece of land. Every type of land suggests its own combinations of potential water management strategies. The framework presented here for conceptualizing the fundamental hydrologic characteristics of land can help to guide early planning of water management strategies.

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