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ABSTRACT

This material includes student guide sheets, reference material, and tape script for the audio-tutorial unit on Hydrosystems. A set of 35mm slides and audio tape are used with the materials. The material is designed for use with Connecticut schools, but can be adapted to other localities. This unit is designed to present information on water and the hydrosystem which must be considered in land use decision making. Emphasized are the hydrologic cycle, ground water, watershed areas, and the effects of human use on the hydrosystem. (RH)

ED133218

HYDROSYSTEMS

HYDROSYSTEMS

AND

LAND USE DECISION MAKING

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OBJECTIVES

WHEN THE WELL RUNS DRY,
WE WILL KNOW THE WORTH OF WATER.
- Ben Franklin -

These words are an apt reminder of the importance that water itself and the system that maintains our water has in our lives. This unit is designed to present information on water and the hydrosystem which must be considered in land use decision making. More specifically, at the conclusion of this unit on hydrosystems, you should be able to:

1. Describe the hydrologic cycle.

2. Identify sections of the hydrologic cycle that have seen man's intervention.

3. Describe the importance of the ground water system and identify the components of this system.

4. Identify watershed areas and state their importance.

5. Compare and contrast wetlands and flood plains and discuss their importance in the hydrologic cycle.

6. Recognize the importance and value of flood plains.

7. Specify limitation and assumptions about the locations of wells in aquifers, in glacial till, in bedrock, near coastlines or near a sanitary landfill.

8. Describe the system of water quality standards in New England.

9. Recognize and cite evidence with regard to concern for erosion and subsequent sedimentation deposition in bodies of water.

10. Describe the limitations that the hydrosystem places on the location of septic tank systems.

11. Discuss critically the effects of urbanization on the hydrosystem.

12. Identify the considerations that the hydrosystem imposes on land us decision making.

As you proceed through this unit, feel free to stop the recorder and study guide sheets that require addition time for analysis and interpretation. We know that you will find information in this unit to be of great value in understanding the importance of the hydrosystem.

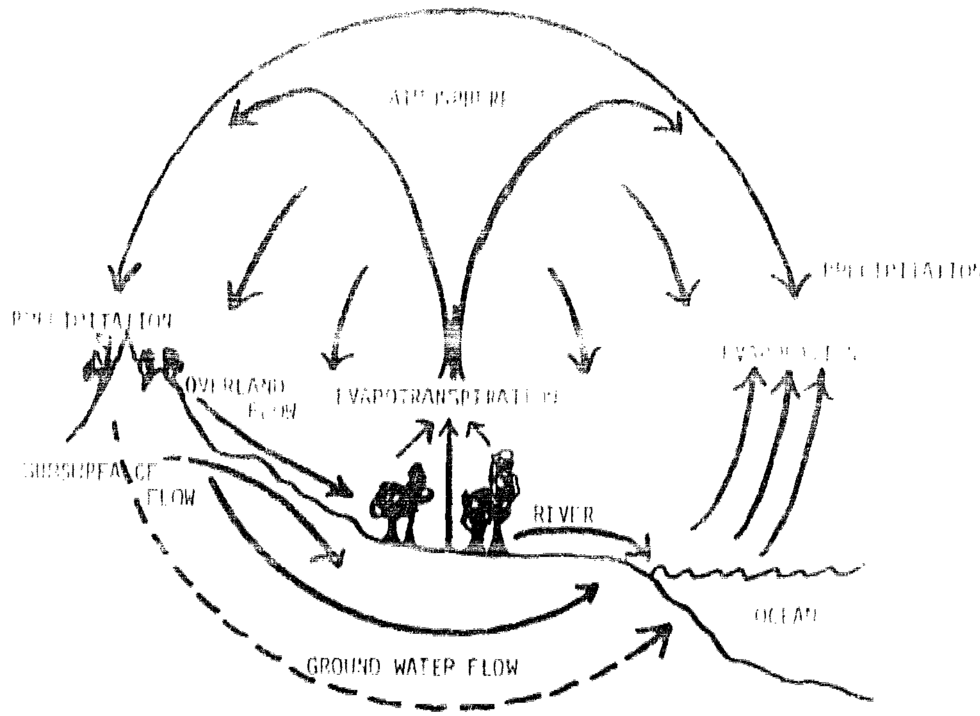
BE A RECYCLER YOURSELF. WRITE YOUR COMMENTS, NOTES, AND ANSWERS ON SCRAP PAPER INSTEAD OF THESE GUIDE SHEETS. IN THIS WAY, THESE GUIDE SHEETS WILL BE AVAILABLE FOR THE NEXT PERSON IN YOUR COMMUNITY WHO WILL BE MAKING USE OF THIS UNIT.

A. EVERYTHING COMES FROM SOMEWHERE.

EVERYTHING GOES SOMEWHERE.

EVERYTHING IS CONNECTED TO EVERYTHING ELSE.

B.



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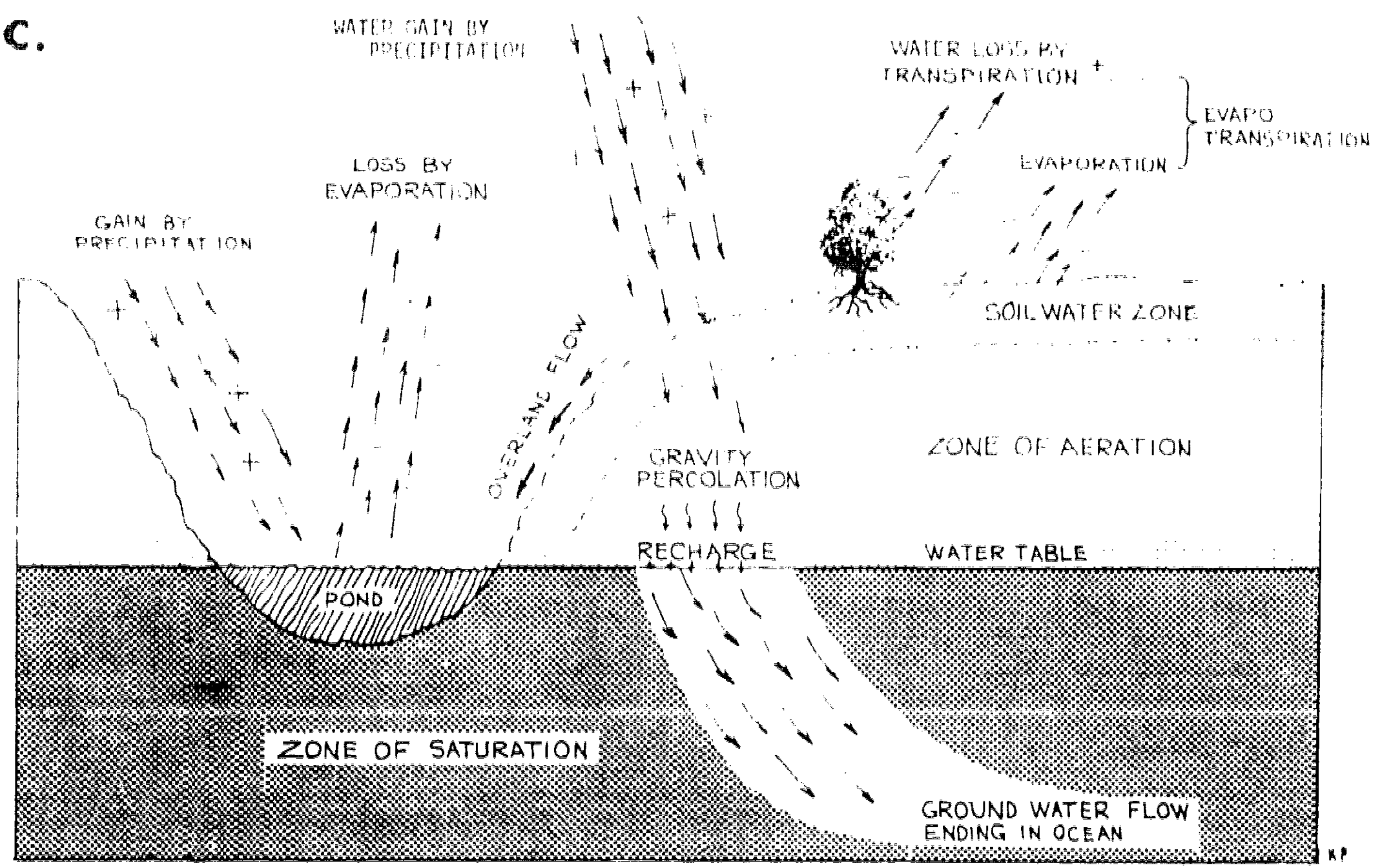
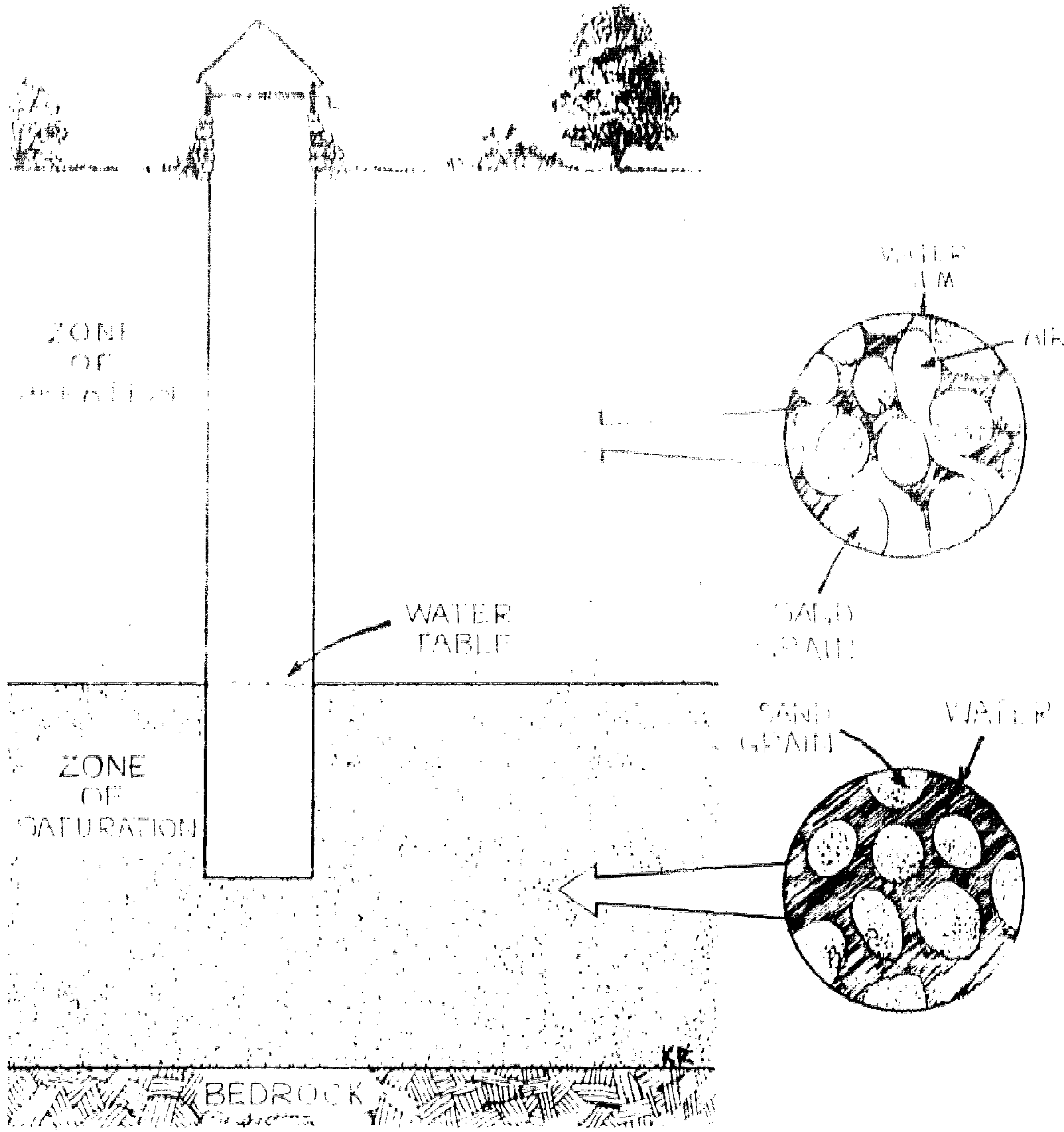


Return to the narrative after studying this guide sheet. Turn the recorder on.

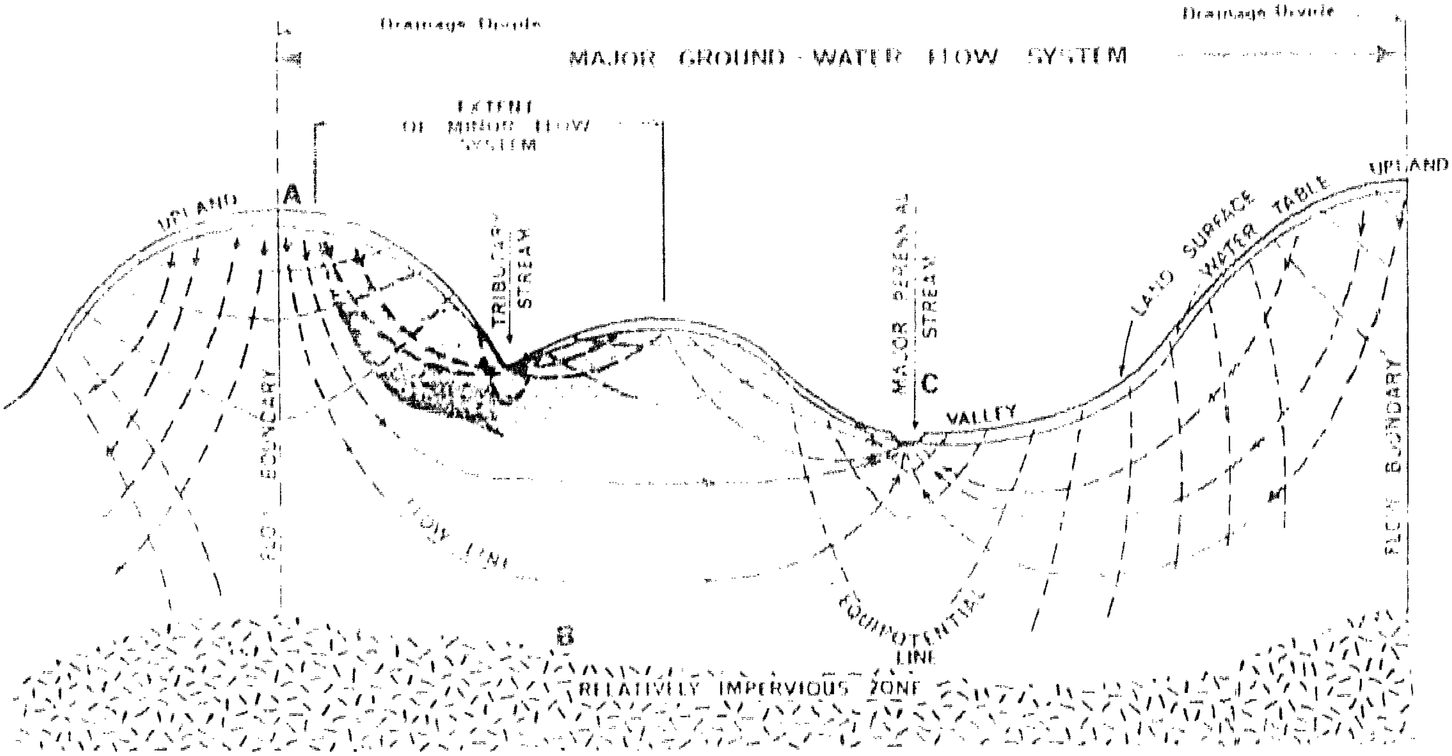


Groundwater is the water that lies beneath the ground surface, fully saturating the enclosing sand or rock. The subsurface area occupied by the ground water is termed the zone of saturation. In a well penetrating the zone of saturation, water will stand at a level marking the position of the water table. The zone of aeration lies above the water table. In the zone of aeration the space between the pores in sand or bedrock contain air and water films. The water in this zone is called capillary water, since it clings to surfaces by capillary tension and thus resists the force of gravity.

Return to the narrative after studying this guidesheet. **Turn the tape recorder on.**

GUIDE SHEET #4

GROUND WATER FLOW SYSTEM



Ground water cannot remain static as long as the water table is higher at one place than another. Difference in elevation of the water table at two points constitutes a hydraulic head. The path of movement of the ground water will be from higher points to lower points on the water table.

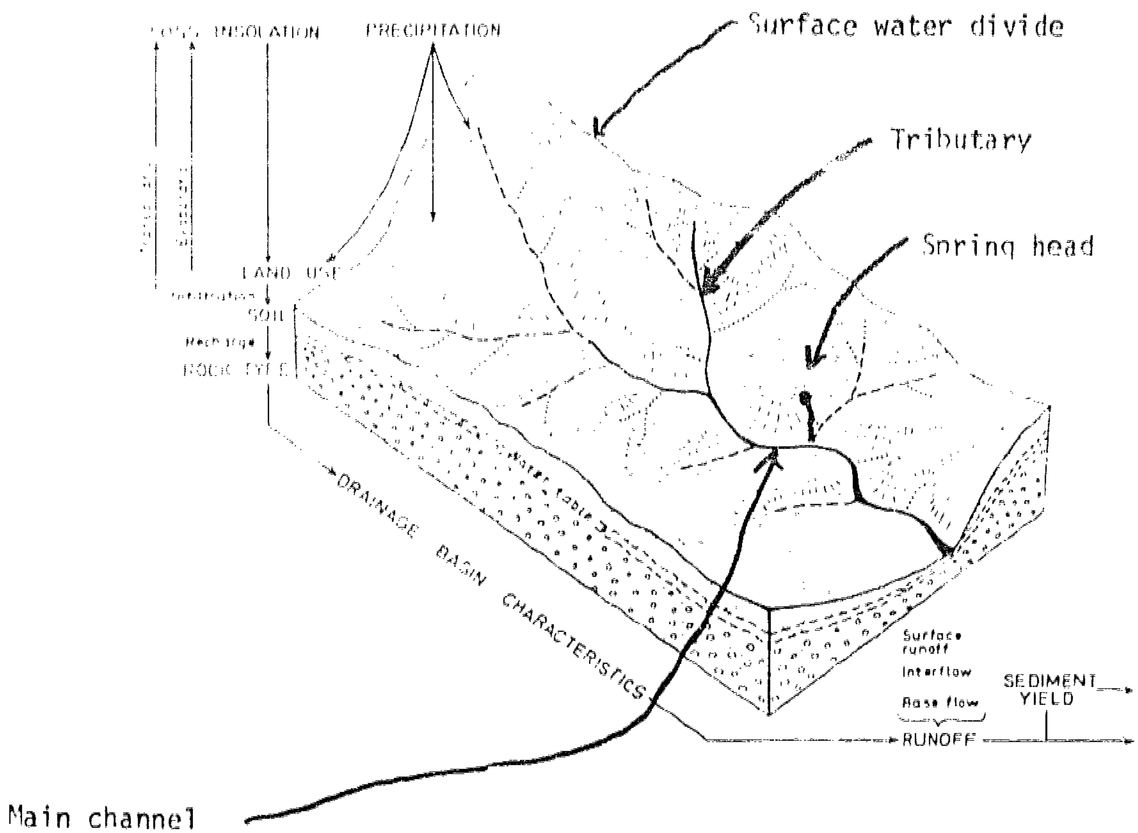
Gravity is responsible for the movement of ground water horizontally as well as vertically. Ground water tends to flow downhill, ultimately emerging at the surface in a stream, wetland, spring, or other surface water body. Because of the weight of the water uphill (A) (the hydraulic head) and the relatively impermeable bedrock below (B), the flow of the ground water will form a curved path upward toward the surface (much as water can move upward in a pipe under pressure from a head above) where it is discharged into surface waters (C). Therefore, the water table is generally farther beneath the surface in upland areas under hills and closer to the surface in lowlands and valleys.

Source: Lavine, et. al. Evaluation of Inland Wetland and Water Course Functions The Connecticut Inland Wetlands Project

Source of Illustration: Cervione, et. al. Water Resources Inventory of Connecticut, Part 6, Upper Housatonic River Basin

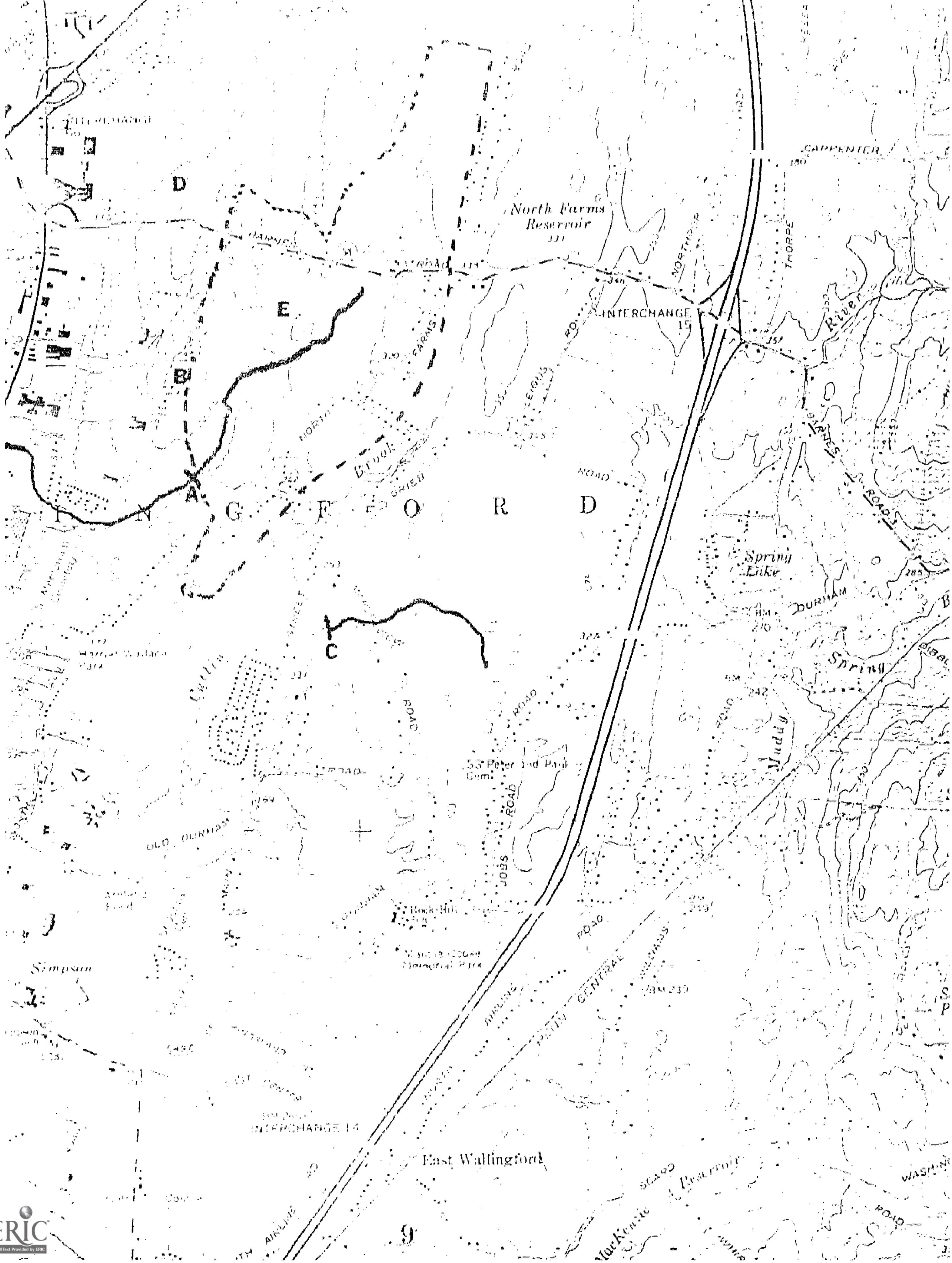
GUIDE SHEET #5

WATER SHEDS
DRAINAGE BASINS

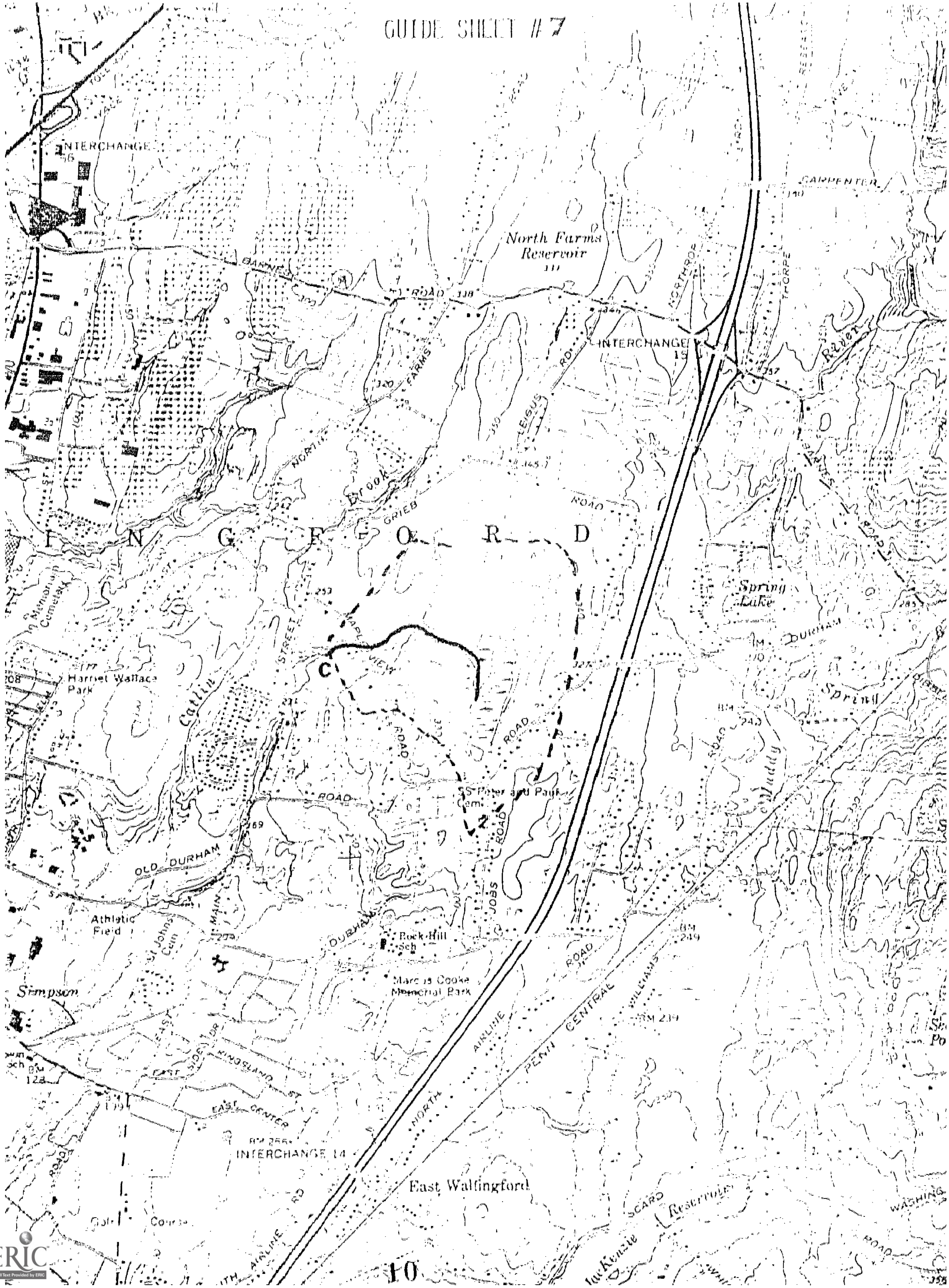


A view of a drainage basin depicting the way in which drainage basin characteristics (form) influence the transformation of input (precipitation-losses) into output of runoff and sediment yield. The dynamic nature of the drainage network is incorporated by representing perennial (solid), intermittent (dashed), and ephemeral (dotted) streams.

GUIDE SHEET #6



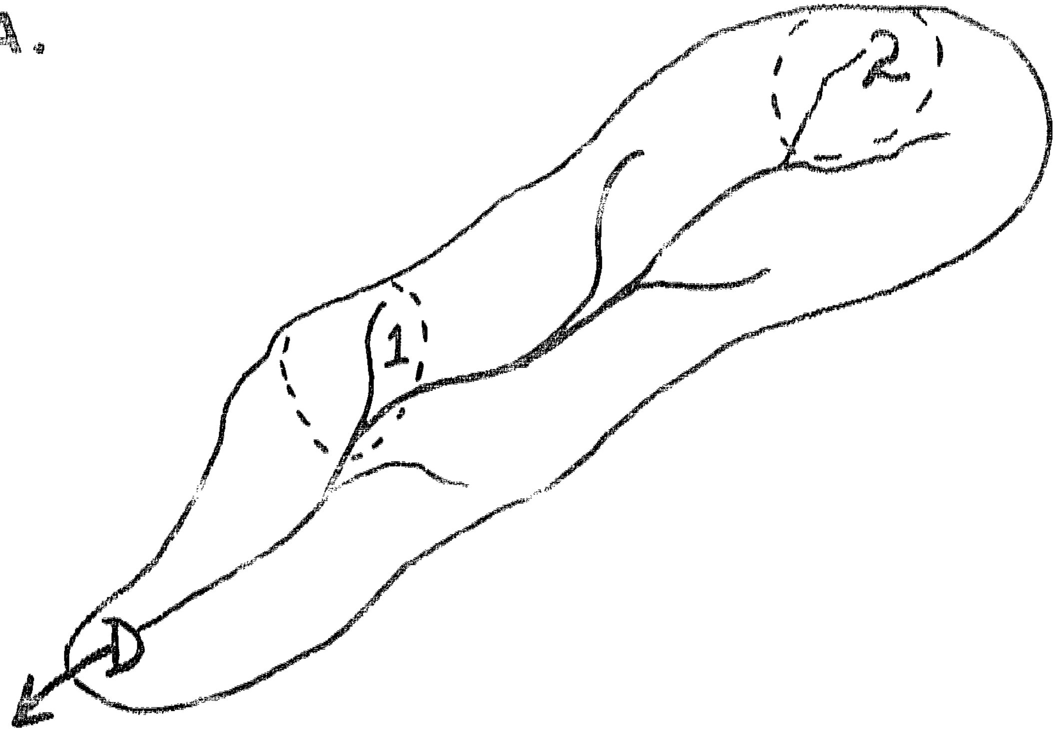
GUIDE SHEET #7



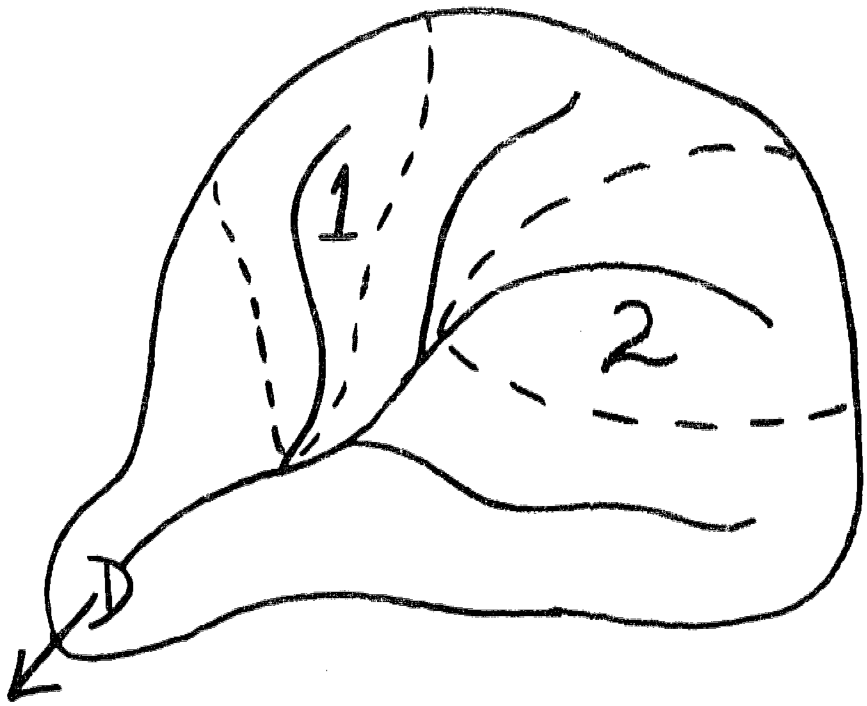
GUIDE SHEET #8

INFLUENCE OF THE SHAPE OF THE WATERSHED ON WATER MOVEMENT

A.

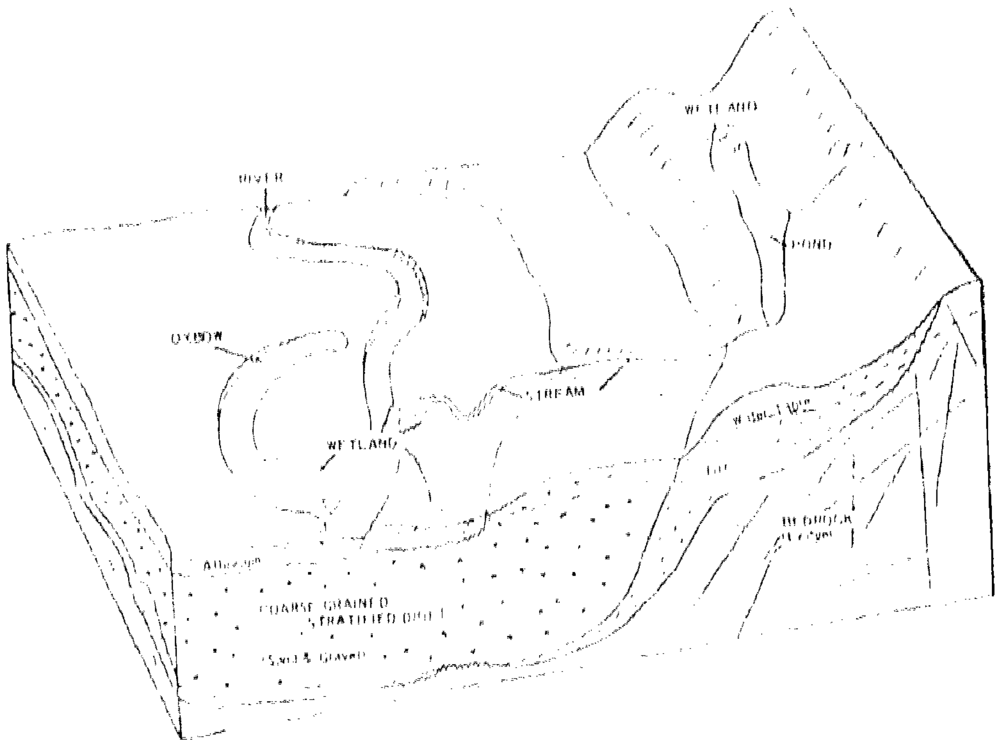


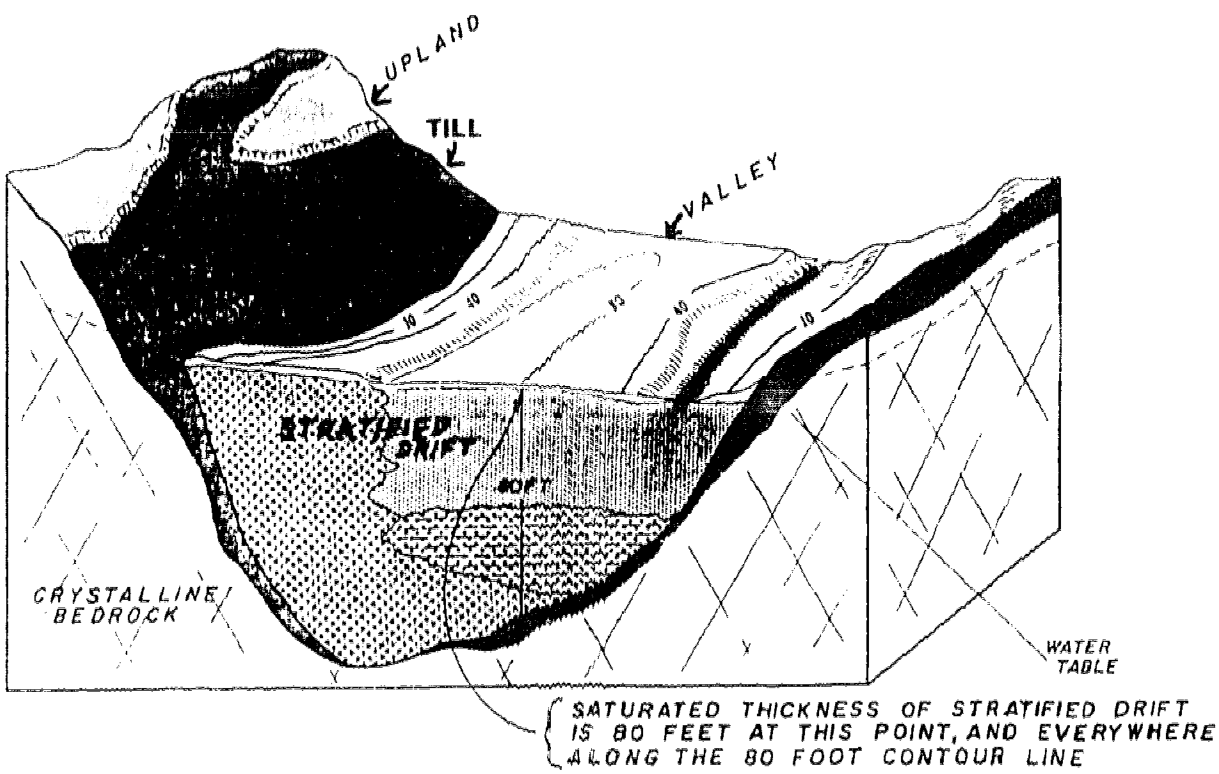
B.



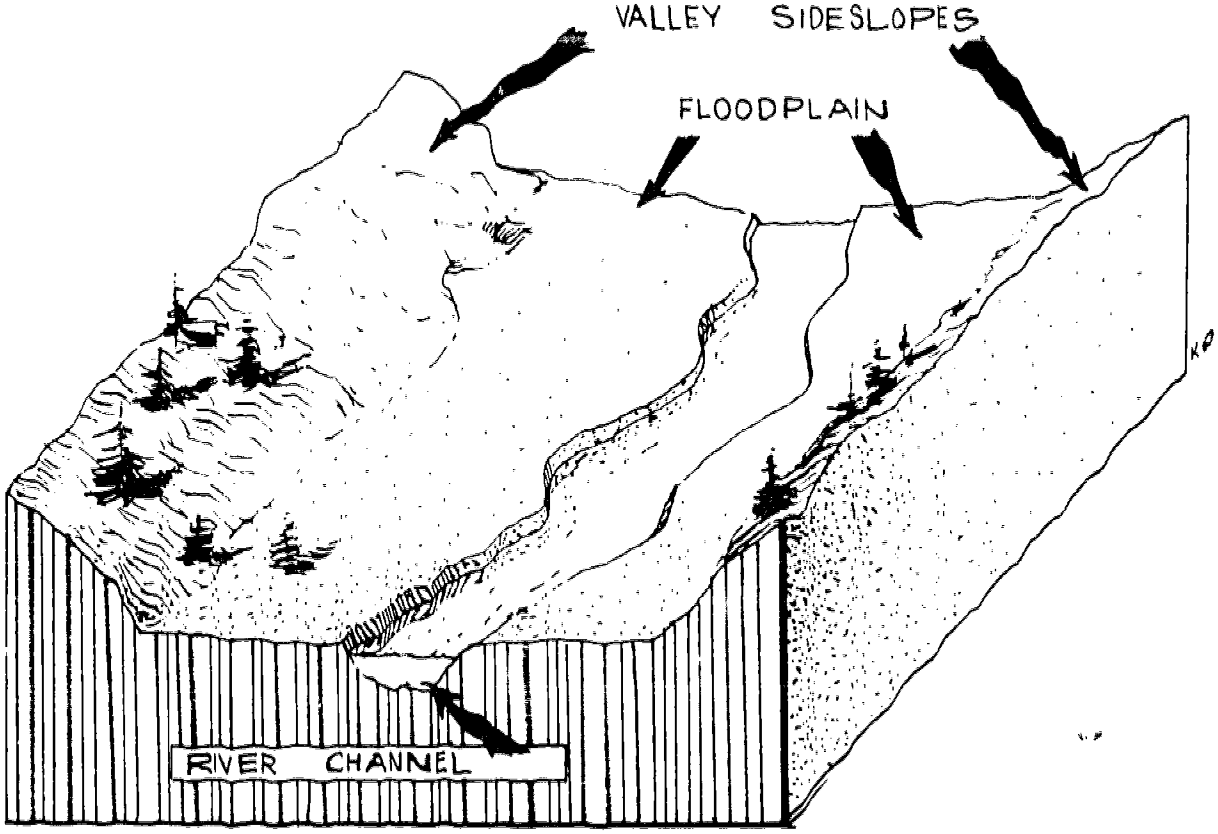
GUIDE SHEET #9

SCHEMATIC BLOCK DIAGRAM SHOWING GENERAL SPATIAL RELATIONSHIPS BETWEEN STRATIFIED DRIFT, TILL, AND CRYSTALLINE BEDROCK

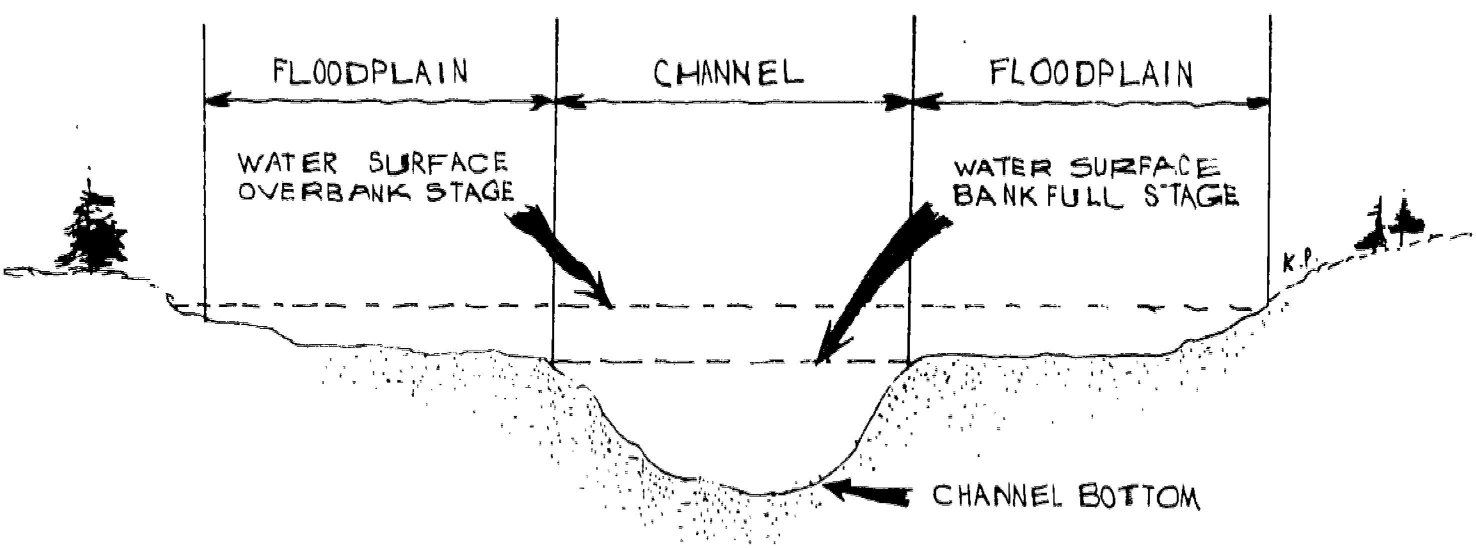




--Schematic block diagram showing general spatial relationships between stratified drift, till, and crystalline bedrock.



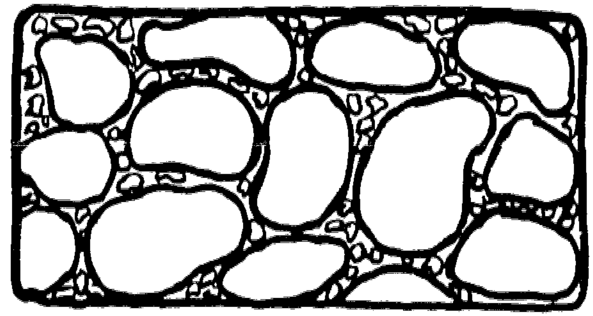
TYPICAL VALLEY SEGMENT



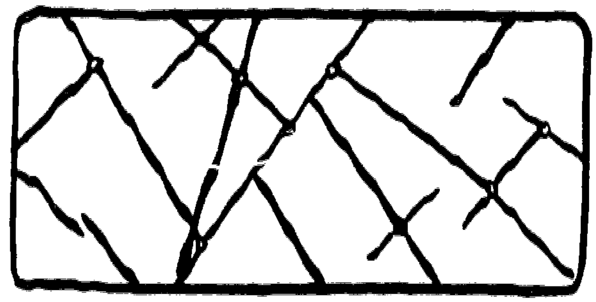
TYPICAL VALLEY SECTION

GUIDE SHEET #11

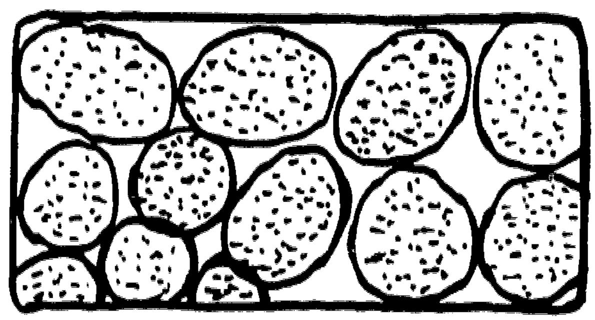
A. GLACIAL TILL - In glacial till deposits, particles of different size, from clay to gravel and boulders, are mixed and often compacted together with smaller particles effectively filling much of the space between the larger particles. Till deposits hold limited amounts of water and generally transmit it slowly.



B. BEDROCK - Movement of water through bedrock occurs mostly through cracks called fractures. Water movement may be rapid through individual cracks but the total storage and the overall movement is limited.



C. STRATIFIED DRIFT - Stratified drift consists of materials (silt, clay, sand, and gravel) which have been deposited by moving water. These have been deposited in overlapping layers and within each layer materials of similar size and weight will be found together, because water will tend to carry finer materials (silt and clay) a longer distance than larger ones. The characteristics of stratified drift depend entirely on the type of material precipitated. Fine grain deposits of silt and clay left in the glacial lakes and areas of ponded water may hold considerable water but their ability to transmit water is low. Coarse grained deposits of sand and gravel, deposited by flowing waters, have both a high porosity and a good ability to let water flow through. These deposits provide for the greatest storage and movement of ground water, and are the most important aquifers in Connecticut.



D. FACTORS AFFECTING WATER FLOW - A SUMMARY

Slope
Shape

Geologic deposits	-	glacial till
(holding and transmitting)		stratified drift
		bedrock

After you have completed studying this guide sheet, return to the narrative. Turn the tape recorder on.

GUIDE SHEET #12

HOW MUCH WATER DOES YOUR HOUSEHOLD CONSUME?

WATER UTILITY STUDIES HAVE REPORTED THE AVERAGE CONSUMPTION OF WATER IN HOUSEHOLDS AS RECORDED IN THE TABLE BELOW:

ACTIVITY	WATER CONSUMPTION
Flushing toilet	4 gal/flush
Shower	30 gal/shower or 7 gal/min
Bathtub	40 gal/bath
Washing machine	40 gal/load
Dishwasher	40 gal/load or sinkful
Drinking	1 gal/day
Food preparation and housing maintenance	100 gal/day
Washing face in sink	1-2 gal
Watering lawn	10 gal/min

ANSWER THE FOLLOWING QUESTIONS AND PERFORM THE SIMPLE CALCULATIONS REQUIRED TO ESTIMATE THE WATER CONSUMPTION OF YOUR HOUSEHOLD.

1. How many people in your family? ________
2. How many showers per week do you take? ________
3. How many baths per week do you take? ________
4. On the average, how many times per day do you flush the toilet? ________
5. In the summer, how many hours per week does your family water its lawn? ________
6. How many washing machine loads are necessary for washing dirty clothes in your family in one week? ________
7. On the average, how many times is the dishwasher run a day or how many times are dishes washed by hand each day? ________
8. Water consumption from showers in gallons per week

   ________ (answer to Q # 1) X ________ (answer to Q # 2) X 30 gal/shower = ________ gal/week consumed in showers

9. Water consumption from baths in gallons/week

   ________ (answer to Q # 1) X ________ (answer to Q # 3) X 40 gal/bath = ________ gal/week consumed in baths

10. Water consumption from flushing toilets in gallons/week

    ________ (answer to Q # 1) X ________ (answer to Q # 4) X 7 days/week X 4 gal/flush = ________ gal/week consumed in flushing the toilet

11. Water consumption from washing clothes in gallons/week

    ________ (answer to Q # 6) X 40 gal/load = ________ gal/week consumed in washing clothes

12. Water consumption from dishwashing in gallons/week

    ________ (answer to Q # 7) X 40 gal/load or sinkfull X 7 days/week = ________ gal/week consumed in dishwashing

13. Water consumption from watering lawn in gallons/week

    ________ (answer to Q # 5) X 60 min/hr X 10 gal/min = ________ gal/week consumed in watering lawns

14. Water consumption in bathroom sink (assuming you wash hand and face three times/day)

    ________ (answer to Q # 1) X 3 times/day X 7 days/week X 1.5 gal/facial and handwash = ________ gal/week in bathroom sink

15. Water consumption from food preparation and housing maintenance (for average family of 5)

    100 gal/day X 7 days/week = 700 gal/week

16. Total water consumption per week

    ________ ans. Q #8 + ________ ans. Q #9 + ________ ans. Q #10 + ________ ans. Q #11 + ________ ans. Q #12 + ________ ans. Q #13 + ________ ans. Q #14 + ________ ans. Q #15 = ________ total gallons/week

17. Total water consumption per year.

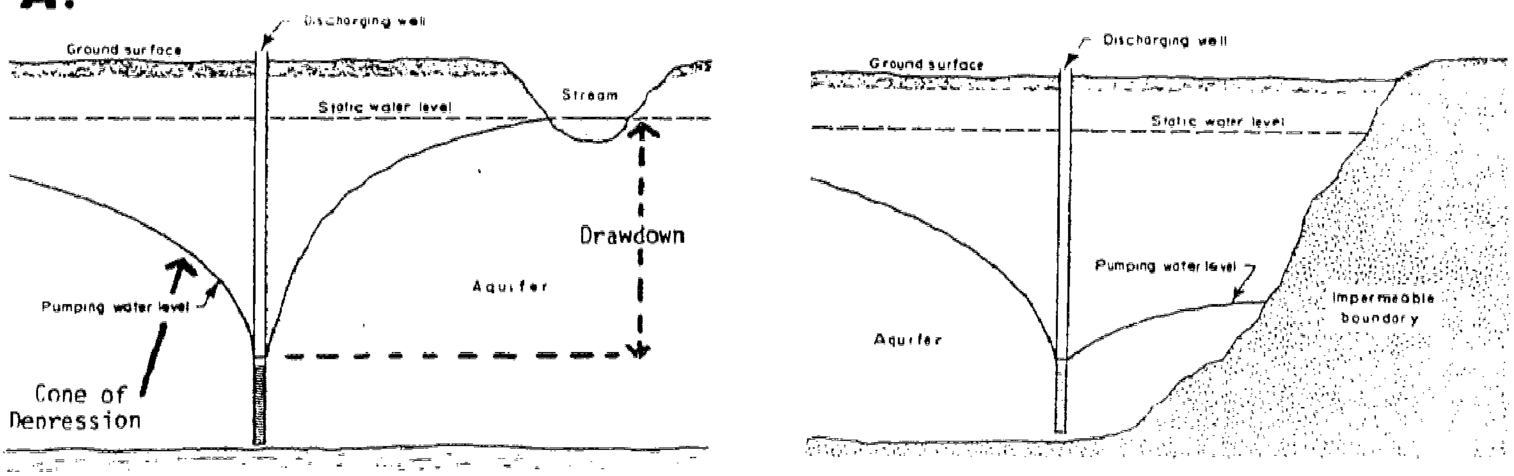
    ________ (answer to Q # 16) X 52 weeks/year = ________ total gallons water/year

*Doctors advise drinking 8 glasses of fluids per day to maintain health.

GUIDE SHEET #13

WELLS AND GROUND WATER

A.



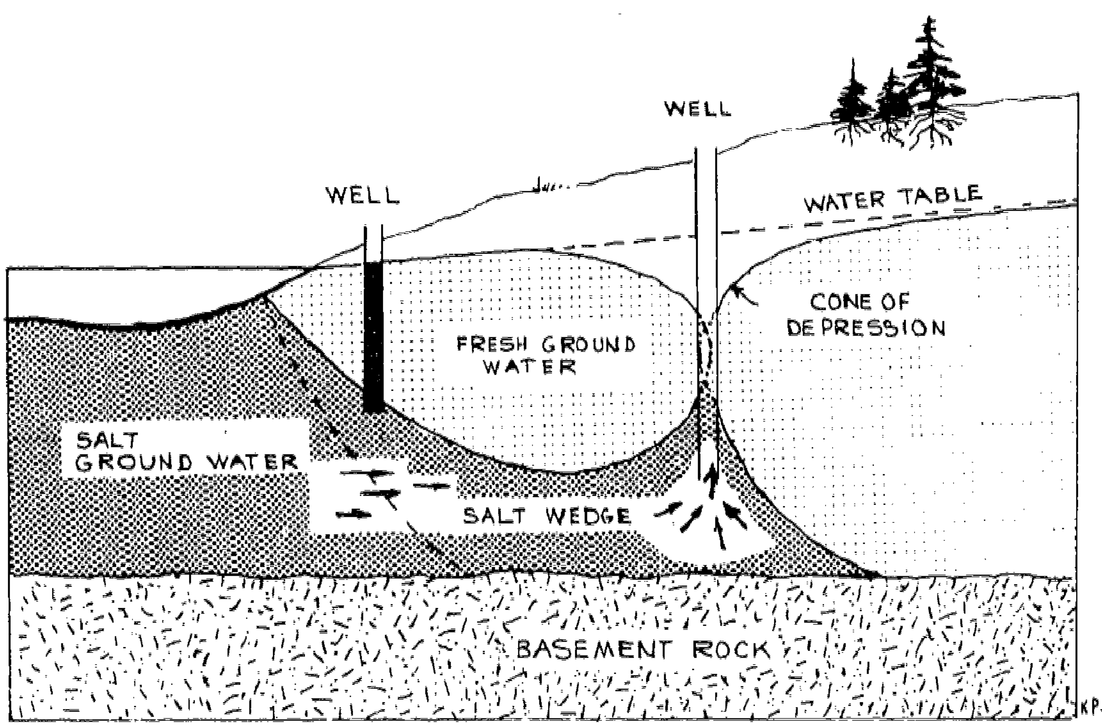
B. AREA REQUIRED TO FURNISH RECHARGE OF GIVEN QUANTITIES OF GROUND WATER

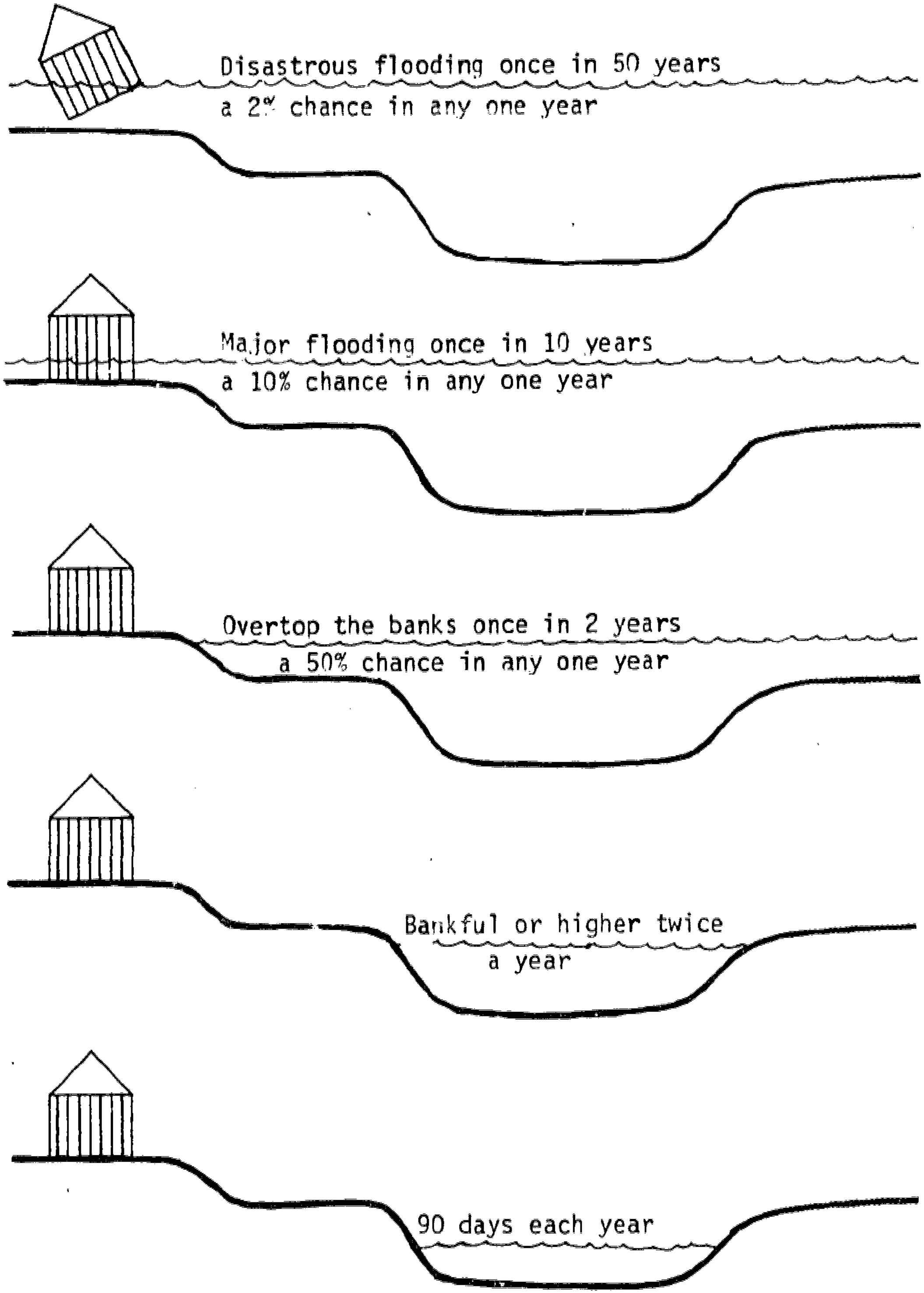
Quantity of Water MG/D	G/M	Recharge Area MI^2	Radius of circle of equivalent area ft.
0.2	140	0.26	1500
0.4	280	0.52	2100
0.6	420	0.78	2600
0.8	560	1.05	3100
1.0	690	1.30	3400

MG - Million Gallons D - Day G - Gallons M - Minute
Figures computed on basis of the natural recharge rate 16 in./yr.

Source: The Environmental Impact of Ground Water Use on Cape Cod by Arthur N. Strahler

C.

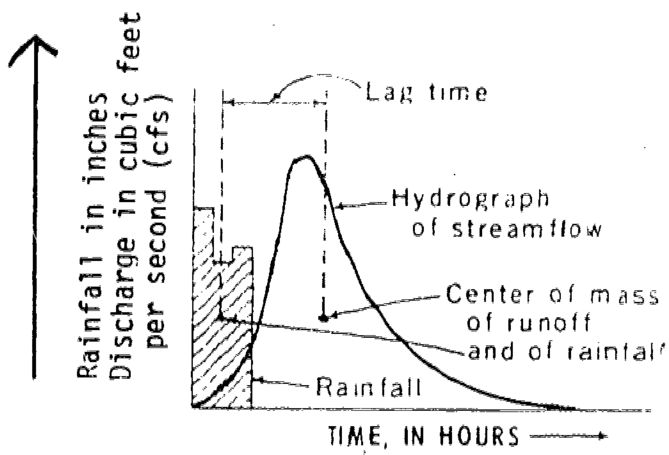




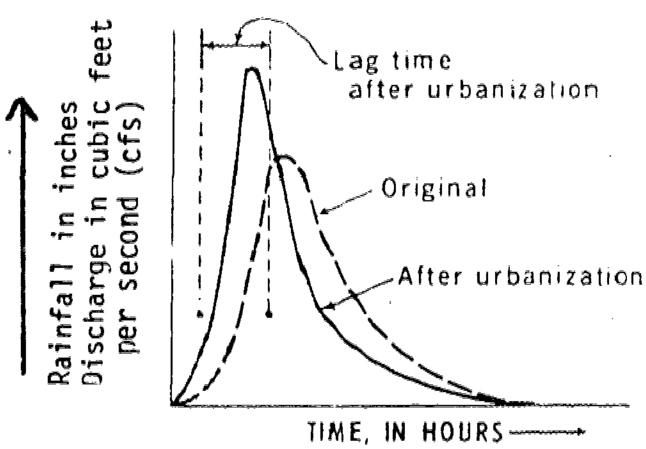
From historical records of rainfall (and snowmelt) and from actual floods, hydrologists can compute the probability of a flood of a certain magnitude. Larger floods are less frequent than smaller ones. Floods can be described in terms of their frequency over an extended period, or the probability of their occurrence during any one year. A 100-year flood is one which will occur, on the average, once every 100 years or which has one chance in 100 of occurring in any single year. Ther preferable termis "one percent flood" as a 100-year flood can recur by chance more often than once in a 100-year period.

Source: Evaluation of Inland Wetland and Water Course Functions, The Connecticut Inland Wetlands Project, Lavine, et.al.

EFFECTS OF URBANIZATION ON RUNOFF RATE



The change in flow rate at any point on a channel can be shown by a hydrograph such as the one above. The graph plots the rate of flow or discharge in cfs (cubic feet per second) against units of time. The shape of this curve will vary with steep slopes, impervious soils, and a pear or funnel shaped basin will lead to a sharper rise and fall in water level as well as a higher peak than flow from a basin with gentle slopes, porous soils, many wetlands and long narrow shape. The flow rate is also affected by man's use of the land.



Lag time (the time between the storm and peak runoff) may be materially altered by the effects of urbanization in a watershed. Water runs off faster from streets and roofs than from natural vegetated areas. This tends to decrease the lag time. The construction of artificial channels, especially storm sewers, also decreases lag time. As the time required for a given amount of water to run off shortens, the peak rate of runoff (flood peak) increase.

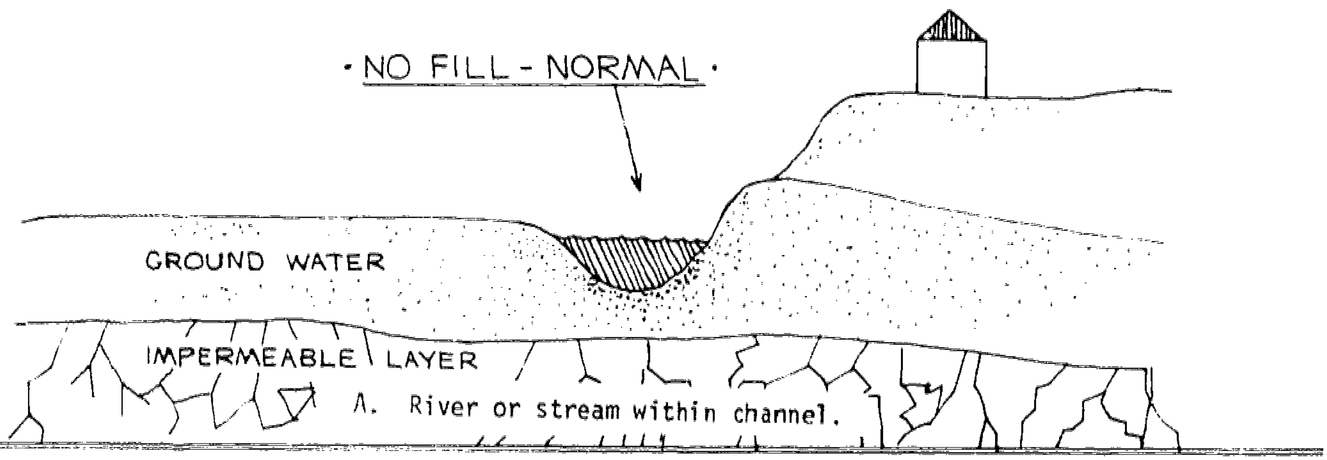
A study by Dr. Luna B. Leopold, a hydrologist with the U.S. Geological Survey, indicated that if 50% of a basin area is made impervious through development, and 50% is sewered, a given flood will be 2.7 times more severe and will occur almost four times as often.

Turn the recorder on after you have read this guide sheet.

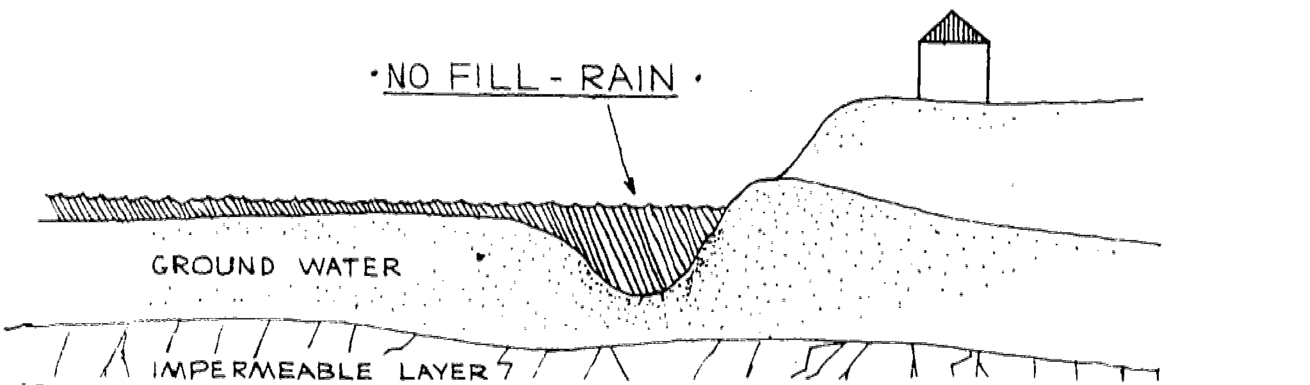
Source: Hydrology for Urban Land Planning: A Guidebook on the Hydrologic Effects of Land Use by Dr. Luna B. Leopole. Geological Survey Circular # 554.

GUIDE SHEET # 16

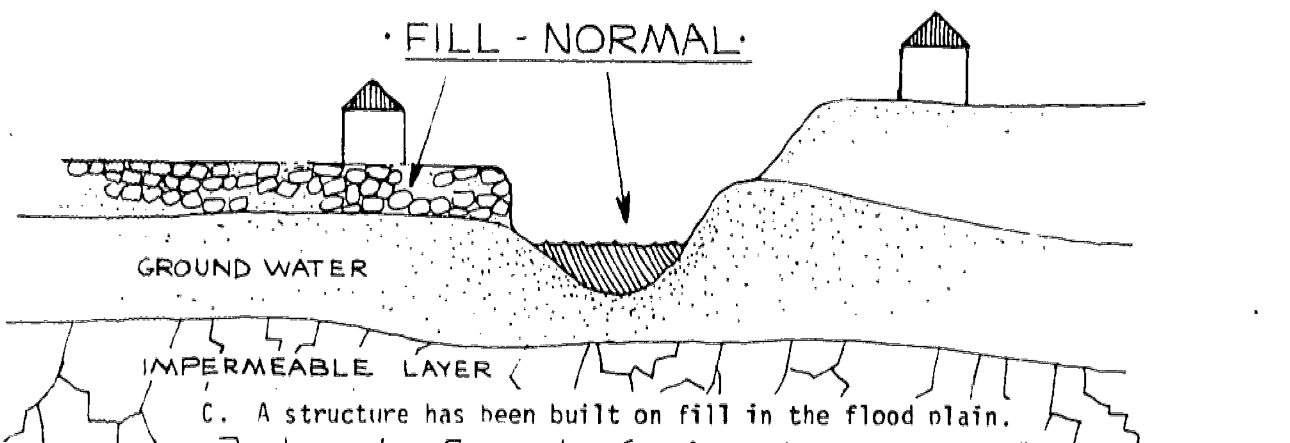
EFFECT OF DEVELOPMENT ON THE CAPACITY OF A FLOOD PLAIN TO ABSORB FLOODS



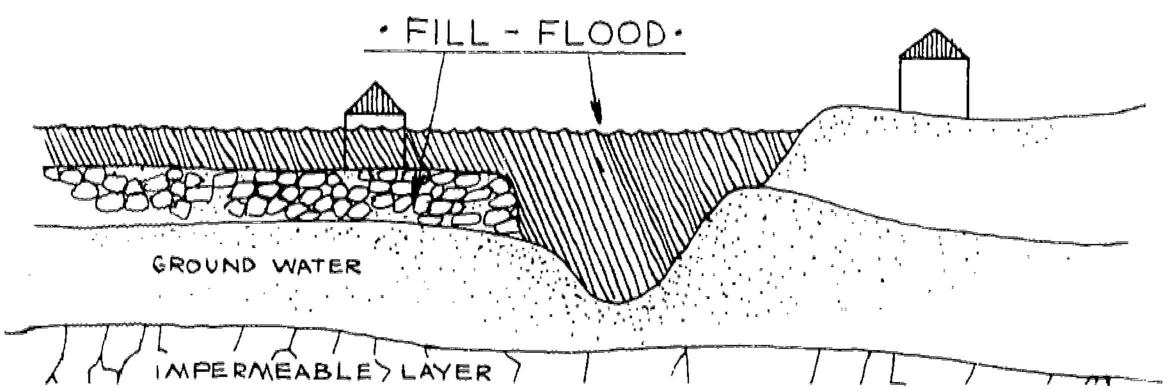
A. River or stream within channel.



B. After extensive rainfall, the river channel overflows. The flood plain fills with water serving its function as overflow basin.



C. A structure has been built on fill in the flood plain.



D. In a similar flood to B., the water overflows the banks flooding the structure in the flood plain. The fill has reduced the volume of water the flood plain can hold. Therefore, the high mark in D is several feet higher.

GUIDE SHEET # 17

LEGISLATION DESIGNED TO PREVENT FLOOD DAMAGE

A. STREAM CHANNEL ENCROACHMENT LINES

DEP has the authority (Sec. 25-4a-q as amended) to establish lines along any waterway or flood-prone area, lines beyond which, in the direction of the flood-prone area, no obstruction or encroachment shall be placed unless authorized by the DEP Commissioner. Authorization is granted only after a thorough review of the effects of a proposed encroachment on flood heights, flood storage and capacity, hazards to life and property and the natural resources of the state of Connecticut. The purpose of these lines is to insure preservation of a reasonable flood channel for the passage of future floods, to minimize future flood damages, and to protect the riverine ecosystem.

B. FLOOD PLAIN ZONING

Flood plain zoning is entirely under local jurisdiction. Municipalities may, under their zoning powers, adopt flood plain zoning ordinances as a valid exercise of police power. (Sec. [illegible] ...ch (zoning) regulations shall be made in accordance with a comprehensive plan and shall be de[illegible] lessen congestion in the streets; to secure safety from fire, panic, flood and other dangers

Though the extent of regulation of activities falls in the grey area between police power and taking actually, many activities are compatible with responsible flood plain land use - agriculture, golf course, sanctuaries, wildlife habitat, forestry, recreation, open space in housing or institutional complexes, parks, marinas, water related or using industry. Flood plain zoning need not be a complete restriction on all uses, merely a careful consideration of compatible uses.

C. FLOOD INSURANCE: NEW INCENTIVE FOR WISE LAND USE

Last December Congress amended the National Flood Insurance Act of 1968, adding provisions to the National Flood Insurance Law which will have great effect on land use in flood-prone areas. The law goes further than any in the past to encourage flood plain land preservation and non-structural solutions to flooding problems.

Any building or property owner can purchase the insurance once his community has been designated eligible by the U.S. Department of Housing and Urban Development (HUD) as having flood-prone areas. <u>The community must also create and enforce land use regulations to reduce or avoid future flood loss</u>. In this requirement lies the real land use significance of the new law.

D. NONSTRUCTURAL TECHNIQUES FOR FLOOD MANAGEMENT

I. TECHNIQUES TO LESSEN THE IMPACT OF FLOOD DAMAGES

- A. Flood Insurance
  1. Subsidized
  2. Compulsory
- B. Emergency Relief
- C. Flood Forecasting and Warning

II. TECHNIQUES TO MODIFY SUSCEPTIBILITY TO FLOODING

- A. Acquisition
  1. Complete
  2. Partial
- B. Evacuation
  1. Permanent
  2. Emergency
- C. Urban Renewal and Redevelopment
- D. Flood Proofing
- E. Control of Utility Locations
- F. Cluster Zoning and Planned Unit Development
- G. Flood Plain Zoning
- H. Wetland Protection Laws
- I. Compensable Regulations
- J. Building Codes
- K. Subdivision Regulations
- L. Encroachment Lines

III. TECHNIQUES TO PROVIDE INCENTIVES TO IMPLEMENT NONSTRUCTURAL TECHNIQUES

- A. Cost Sharing
- B. Subsidies
- C. Tax Adjustments
- D. Special Hazard Assessments
- E. Density Transfer
- F. Internalization of Costs

Source: <u>A Report to The New England River Basins Commission on Nonstructural Measures for Flood Plain and Flood Damage Management</u> by Cheney, Miller, Ellis & Associates, Inc.

GUIDE SHEET # 18

WATER QUALITY STANDARD

The water classification system described below was adopted by the New England Interstate Water Pollution Control Compact. The system reconciles the conflict of water uses by assignment of use classifications based on reasonable physical, chemical and bacteriological standards. Each state prepares classifications of its waters according to present condition and proposed highest use.

CLASS A - Suitable for any water use especially drinking water. Character uniformly excellent. No measurable quantity of oil, grease, solids, sludge, color, turbidity, toxic sustance, phenols, acids or alkali allowed. Coliform bacteria must be within limits approved by State's Department of Health for uses involved.

CLASS B - Suitable for bathing and recreation, irrigation and agricultural uses; good fish habitat; good aesthetic value. Acceptable for public water supply with filtration and disinfection. Similar to Class A except some oil, grease, color and turbidity allowed. Bacterial content of bathing waters shall meet limits approved by State Department of Health and acceptability will depend on sanitary survey.

CLASS C - Suitable for recreational boating, irrigation of crops not used for consumption without cooking; habitat for wildlife and common food and game fish indigenous to the region; industrial cooling and most industrial process uses. Similar to Class A except greater quantities of oil and grease allowed as well as some potentially toxic chemicals but not in toxic concentrations.

CLASS D - Suitable for transportation of sewage and industrial wastes without nuisance, and for power, navigation and certain industrial uses. All of the things not allowed in Class A waters are acceptable in Class D waters except chemicals are not present in toxic concentrations and free acid or alkali can be present.

QUALITY OF WATER CHANGES AS IT MOVES THROUGH THE HYDROLOGIC SYSTEM

(1) Precipitation: Water from the atmosphere dissolves dust particles and gasses but is low in dissolved-mineral concentrations and is acidic

(2) Surface runoff carries soil particles and organic materials; turbidity and sediment loads increase. Dissolved solids increase moderately. Temperatures follow seasonal air temperatures but less extreme.

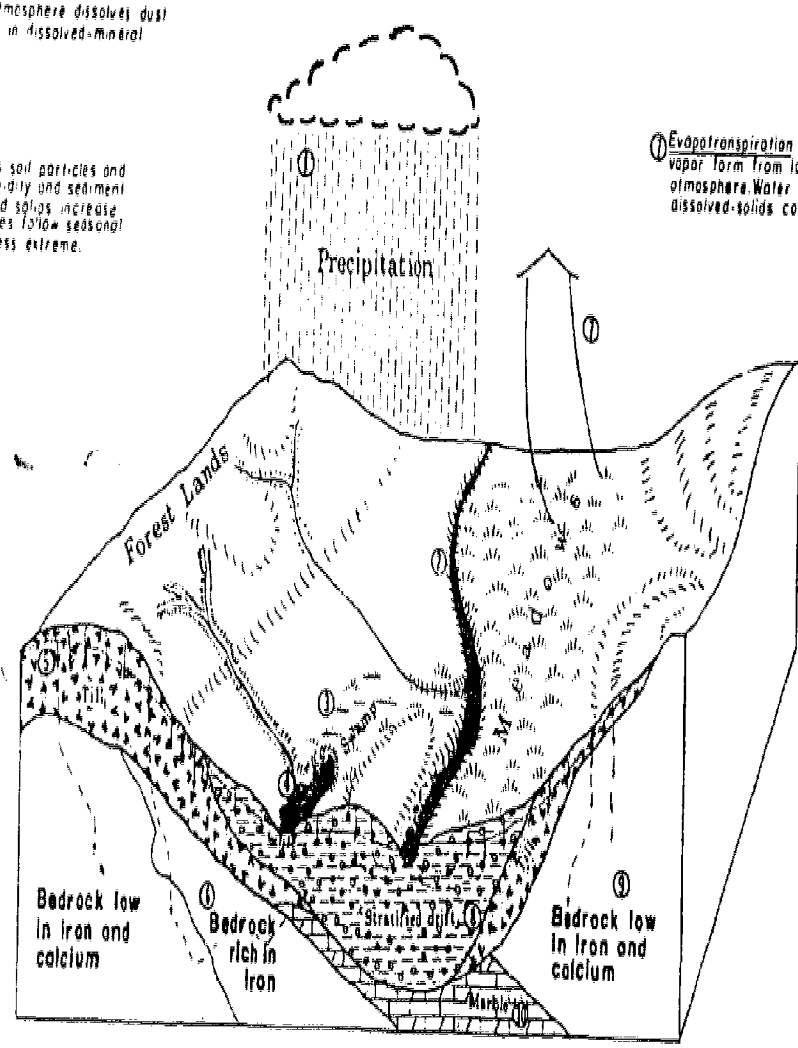
(3) Iron, manganese and color in swamp water and downstream increase seasonally. Swamp water responds rapidly to variations in air temperature

(4) Storage of water in lakes, ponds, and reservoirs reduces turbidity and sediment load while sunlight bleaches out color. Thermal stratification in deep water depletes oxygen in the lower layers

(5) Infiltration increases the mineralization of water. During low-flow periods, the more highly mineralized ground-water runoff may substantially increase the mineral content of the smaller streams

(6) Ground water in noncarbonate bedrock that is high in iron-bearing minerals is moderately hard with high iron content

(7) Evapotranspiration moves water in vapor form from land surface to the atmosphere. Water in this stage has the lowest dissolved-solids content of any in the cycle



(8) Ground water in stratified drift and till has a quality largely determined by composition of surficial materials. Dissolving of marble fragments increases hardness of ground water. Ground water also moves upward from the bedrock and influences the quality of water in the surficial deposits.

(9) Ground water in noncarbonate bedrock low in iron-bearing minerals is moderately hard and low in iron concentrations.

(10) Ground water in marble bedrock is hard to very hard. Iron concentrations are variable; local concentrations of iron-rich minerals increase iron values.

Source: Water Resources Inventory of Connecticut, Part 6, Upper Housatonic River Basin by Michael A. Cervione, Jr., et. al.

GUIDE SHEET # 20

SOURCE AND SIGNIFICANCE OF SOME OF THE CHEMICAL CONSTITUENTS IN, AND PHYSICAL PROPERTIES OF, WATER IN THE UPPER HOUSATONIC RIVER BASIN

Chemical constituent or physical property	Source and concentration	Significance and maximum limit of tolerance
Silica (SiO_2)	Dissolved from practically all rocks and soils. Usually found in the basin in small amounts ranging from 1 to 25 mg/l. Surface water usually has a smaller concentration than ground water.	Forms hard scale in boilers, water heaters, and pipes. Inhibits deterioration of zeolite-type water softeners. The USPHS (U.S. Public Health Service) has not recommended a maximum limit for drinking water.
Iron (Fe)	Dissolved from many minerals that contain oxide, sulfide, and carbonate of iron. Decaying vegetation and iron objects in contact with water, sewage, and industrial waste are also major sources. Surface water in the basin in its natural state usually has less than 0.5 mg/l. Ground water generally has higher concentrations than surface water.	On exposure to air, iron in ground water oxidizes to a reddish-brown precipitate. More than about 0.3 mg/l iron stains laundry and utensils, causes unpleasant odors, and favors growth of iron bacteria. Iron in water is objectionable for food and textile processing. Most iron-bearing waters when treated by aeration and filtration are satisfactory for domestic use. The USPHS recommends a maximum limit of 0.3 mg/l for drinking water.
Manganese (Mn)	Dissolved from many rocks and soils. Often found associated with iron in natural waters but not as common as iron. Surface water in the basin usually has less than 0.1 mg/l. Ground water generally has higher concentrations than surface water.	More than 0.2 mg/l precipitates upon oxidation. Manganese has the same undesirable characteristics as iron but is more difficult to remove. The USPHS recommends a maximum limit of 0.05 mg/l for drinking water.
Calcium (Ca) and magnesium (Mg)	Dissolved primarily from carbonate rocks. Ground water in the carbonate rocks of the basin may contain as much as 100 mg/l calcium and 40 mg/l magnesium. Surface water normally contains lower concentrations than ground water.	Hardness and scale-forming properties of water are caused by dissolved bicarbonates and sulfates of these elements (see hardness). These are objectionable for electroplating, tanning, dyeing, and textile processing. They also cause scale formation in steam boilers, water heaters, and pipes. The USPHS has not recommended a maximum limit for drinking water.
Sodium (Na) and potassium (K)	Dissolved from practically all rocks and soils. Sewage, industrial wastes, and road salt are also major sources. Most home water softeners replace soluble hardness-producing minerals with sodium and thus increase the amount of sodium present.	Since the concentration of potassium is usually low, sodium and potassium are often calculated together and reported as sodium. Quantities found in the report area have little effect upon the usefulness of water for most purposes; however, more than 50 mg/l may cause foaming of steam boilers. The USPHS has not recommended a maximum limit for drinking water, however, the Connecticut State Department of Health suggests a maximum limit of 20 mg/l for municipal water supplies.
Bicarbonate (HCO_3)	Results from chemical action of carbon dioxide in water on calcite and calc-silicate minerals. Decaying vegetation, sewage, and industrial wastes are also important sources.	Bicarbonates of calcium and magnesium cause hardness and form scale in boilers and pipes, and release corrosive carbon dioxide gas (see hardness). Water of low mineral content and low bicarbonate content in proportion to carbon dioxide is acidic and can be corrosive. The USPHS has not recommended a maximum limit for drinking water.
Sulfate (SO_4)	Dissolved from rocks and soils containing sulfur compounds, especially iron sulfide; also from sulfur compounds dissolved in precipitation, sewage and industrial wastes.	Sulfates of calcium and magnesium form permanent hardness and hard scale in boilers and hot water pipes. The USPHS recommends a maximum limit of 250 mg/l for drinking water.
Chloride (Cl)	Small amounts dissolved from rocks and soils. Larger amounts are derived from animal wastes, sewage, road salt, industrial wastes, and sea water. Chloride concentration of natural water in the basin seldom exceeds 10 mg/l.	Large amounts of chloride in combination with calcium will result in a corrosive solution and in combination with sodium will give a salty taste. The USPHS recommends a maximum limit of 250 mg/l for drinking water.
Nitrate (NO_3)	Sewage, industrial wastes fertilizers, and decaying vegetation are major sources. Minor sources are precipitation and decaying organic matter.	Small amounts of nitrate have no effect on usefulness of water. A concentration greater than 10 mg/l generally indicates pollution. Nitrate encourages growth of algae and other organisms which produce undesirable tastes and odors. The USPHS recommends a maximum limit of 45 mg/l for drinking water, which is equivalent to 10 mg/l of nitrate expressed as N in a sanitary analysis. Waters containing more than 45 mg/l have reportedly caused methemoglobinemia, which is often fatal to infants and, therefore, such water should not be used in infant feeding.
Phosphate (PO_4)	Major sources are fertilizers, domestic sewage, and detergents. Minor sources are minerals such as apatite. Concentrations in natural streams are generally low; in larger streams they occasionally exceed 1.0 mg/l.	Essential nutrient for free floating aquatic vegetation such as algae. Excess phosphate may encourage algal blooms and cause problems of odor, taste, and aesthetics. The USPHS has not recommended a maximum limit for drinking water.

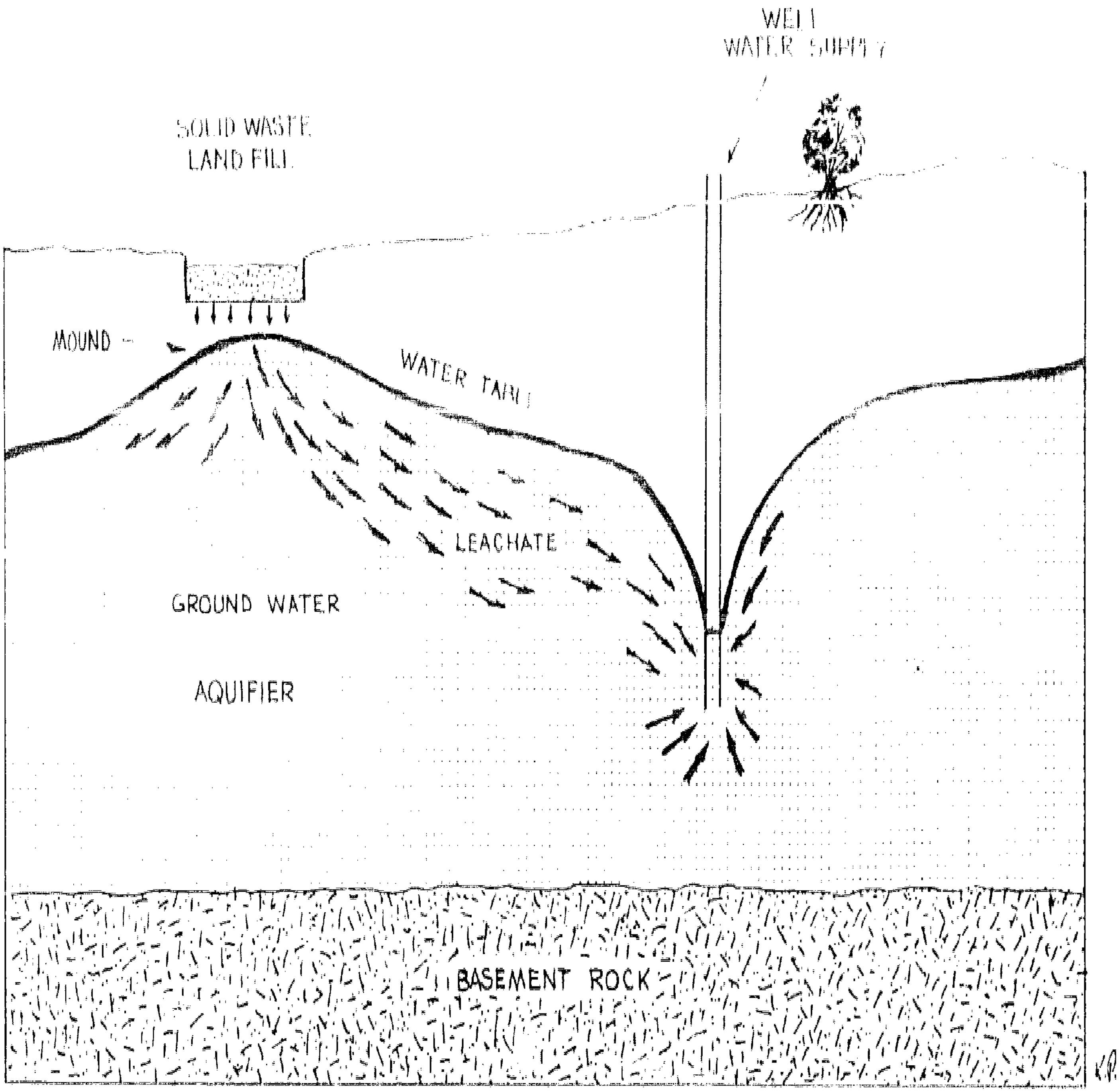
Source: Water Resources Inventory of Connecticut, Part 6, Upper Housatonic River Basin by Michael A. Cervione, Jr., et. al.

SOURCE AND SIGNIFICANCE OF SOME OF THE CHEMICAL CONSTITUENTS IN, AND PHYSICAL PROPERTIES OF, WATER IN THE UPPER HOUSATONIC RIVER BASIN (cont.)

Chemical constituent or physical property	Source and concentration	Significance and maximum limit of tolerance
Dissolved solids and specific conductance	Includes all mineral constituents dissolved in precipitation and from rocks and soils, locally augmented by mineral matter in sewage and industrial wastes. Measured as residue of evaporation at 180°C or calculated as numerical sum of amounts of individual constituents. Specific conductance, or the capacity of water to conduct an electric current, is used as an index of total dissolved mineral content. In natural waters in the basin, ground water usually has a larger dissolved-solids content than surface water. Nearly all waters sampled had a dissolved-solids content substantially below the limit recommended by the USPHS.	Waters containing more than 1,000 mg/l dissolved solids are unsuitable for many municipal and industrial purposes. The USPHS recommends a maximum limit of 500 mg/l for drinking water. A dissolved-solids content at 500 mg/l is approximately equivalent to a specific conductance of 900 micromhos at 25°C.
Hardness (as $CaCO_3$)	Primarily due to calcium and magnesium, and to a lesser extent, due to iron, manganese, aluminum, barium, and strontium. There are two classes of hardness, carbonate (temporary) hardness and noncarbonate (permanent) hardness. Carbonate hardness refers to the hardness balanced by equivalents of carbonate and bicarbonate ions; noncarbonate to the remainder of the hardness. In the basin, hardness ranges widely. Water from the carbonate bedrock and stratified-drift aquifers is hard to very hard. Most water from the noncarbonate bedrock aquifers is soft to moderately hard.	Hard water consumes soap before lather will form and deposits soap curds on bathtubs. Water having a hardness of more than 120 mg/l is commonly softened for domestic use. Hardness forms scale in boilers, water heaters, radiators, and pipes, causing a decrease in rate of heat transfer and restricted flow of water. In contrast, water having a very low hardness may be corrosive. The USPHS has not recommended a maximum limit for drinking water. The U.S. Geological Survey classification of hardness appears under "Hardness" in the section entitled "Quality of water in streams and lakes."
Color	Color in water may be of natural, mineral, or vegetable origin such as iron and manganese compounds, algae, weeds, and humus material. May also be caused by inorganic or organic wastes from industry. True color of water is considered to be only that attributable to substances in solution after the suspended material has been removed.	Water for domestic and some industrial uses should be free of perceptible color. Color in water is objectionable in food and beverage processing and many manufacturing processes. Results are usually expressed as units of color and not as mg/l. The USPHS recommends a maximum limit of 15 units for drinking water.
Dissolved oxygen (D.O.)	Sources are natural aeration and photosynthesis by aquatic vegetation. Concentrations vary mainly with temperature and pressure and are expressed as a percentage of saturation. Surface waters fluctuate widely in D.O. with biological activities; D.O. declines during the breakdown of waste material. Concentrations in the basin ranged from 0 to 140 percent saturation.	The dissolved-oxygen content of water is an indicator of its biochemical condition when measured. Fish and other desirable clean-water biota require consistently high D.O. levels. Standards for D.O. levels in many of the streams and lakes in the basin are given in "Water Quality Standards for Connecticut, 1970."
Temperature	Temperature fluctuates widely in streams and shallow wells following seasonal climatic changes, but wells at depths of 30 to 60 feet remain within 2 or 3 degrees of mean annual air temperature (8°C to 11°C for the report area). Disposal of water used for cooling or industrial processing causes local temperature abnormalities.	Temperature affects the usefulness of water for many purposes. For most uses, especially cooling, water of uniformly low temperatures is desired. A rise of a few degrees in the temperature of a stream may limit its capacity to support aquatic life. Warm water will carry less oxygen in solution than water at low temperatures, and a corrosive water will become more corrosive with increased temperatures.
Turbidity	An optical property of water attributed to suspended or colloidal matter which inhibits light penetration. May be caused by microorganisms or algae; suspended mineral substances including iron and manganese compounds, clay or silt, or sawdust, fibers, and other materials. May result from natural processes of erosion or from the addition of domestic sewage or wastes from various industries, such as pulp and paper manufacturing.	Excessive turbidity is harmful or lethal to fish and other aquatic life; also it is very undesirable in water used by most industries, especially in process water. Turbidity can modify water temperature. Results are expressed in standard units, not mg/l. The USPHS recommends a maximum limit of 5 units for drinking water.
Hydrogen ion concentration (pH)	Water with a dominance of acids, acid-generating salts, and free carbon dioxide has a low pH. If carbonates, bicarbonates, hydroxides, phosphates, and silicates are dominant, the pH is high. The ph of most natural waters ranges between 6 and 8.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote alkaline characteristics; values lower than 7.0 indicate acid characteristics. Acid water and excessively alkaline water corrode metals. The USPHS has not recommended a maximum limit for drinking water.

Source: Water Resources Inventory of Connecticut, Part 6, Upper Housatonic River Basin by Michael A. Cervione, Jr., et. al.

GUIDE SHEET # 21



Loose soil of the disposal area facilitates infiltration of precipitation, while lack of vegetation reduces evapotranspiration. Consequently, the recharge here is greater than elsewhere and the mound is maintained. Leachate from the waste moves vertically down by gravity percolation to the water table mound. Ground water movement is radially outward from the mound to surrounding lower points on the water table.

As seen above, a supply well with its cone of depression draws ground water from the surrounding area. Linkage between outward flow from the waste disposal site and inward flow to the well can bring leachate into the well, polluting ground water supply.

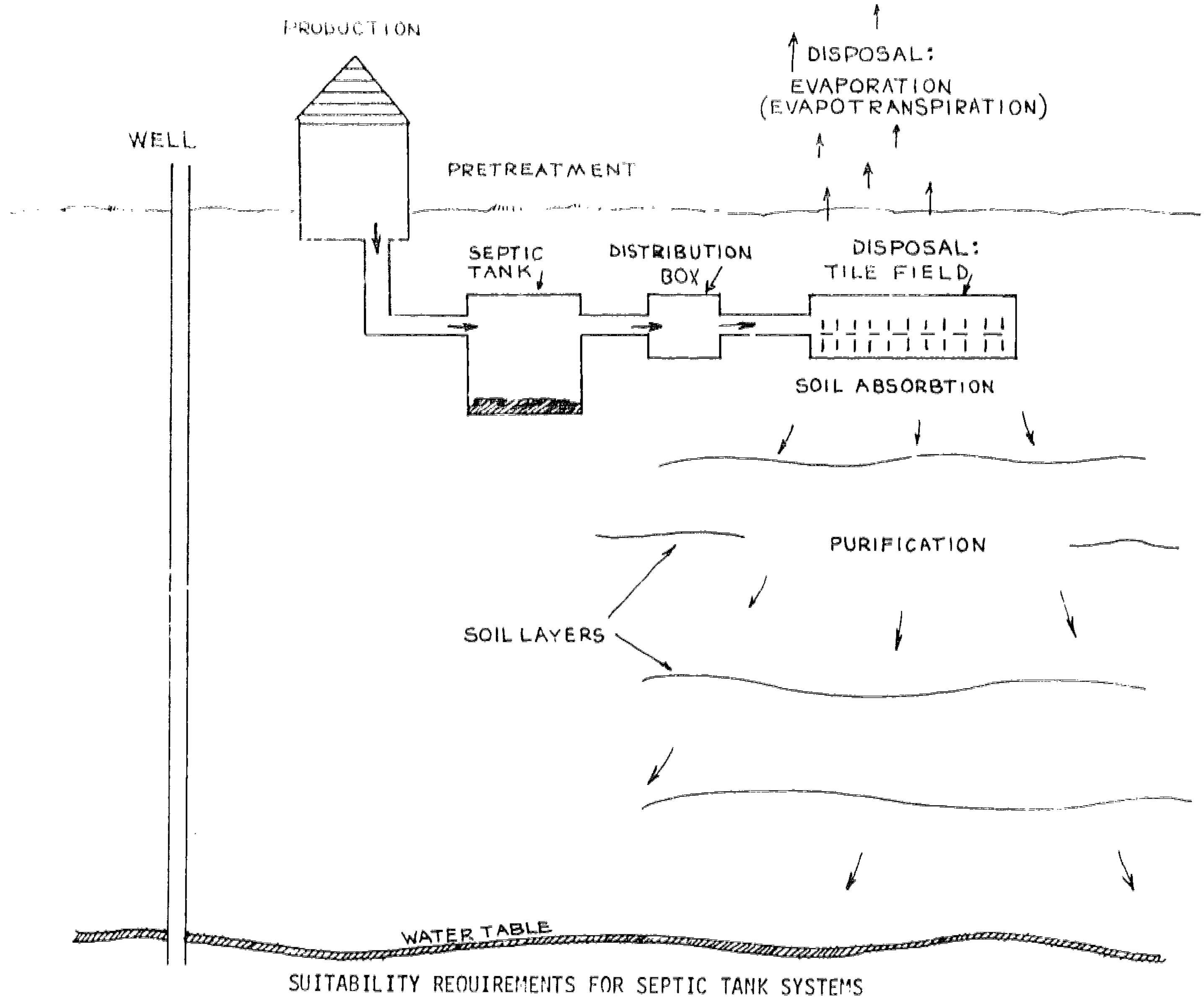
Source: The Environmental Impact of Ground Water Use on Cape Cod by Arthur N. Strahler

GUIDE SHEET # 22

SEPTIC TANK SEWAGE DISPOSAL SYSTEM

If a builder does not have access to a public sewage disposal system, he will probably utilize an on-site sewage disposal system. This requires a septic tank and leaching field. The sewer line from the house will lead to an underground septic tank in your yard. The septic tank acts as a settling and decomposition tank. The overflow from this tank, flows to the leaching field. The leaching field is a large area of trenches with draintile or perforated pipes. The trenches are usually covered with soil and planted with grass so the the septic system is not visible.

After the overflow sewage enters the leaching field, the fluid leaves the pipes and enters the soil. While the sewage filters or "percolates" through the soil, it is cleansed by soil organisms and minerals. Eventually, a relatively clean liquid returns to the water table. Periodically, solids must be physically removed from the septic tank.



SUITABILITY REQUIREMENTS FOR SEPTIC TANK SYSTEMS

1. Permeability of the soil must be adequate.

2. Maximum water table level should be more than 18 inches below the tile field.

3. Slope of the land should be less than 15%.

4. The system should not be placed within 50 feet of a stream, pond, or lake.

There must be a minimum of four feet of material of acceptable percolation rate between rock ledge and the bottom of the leaching field trenches.

GUIDE SHEET # 23

EROSION AND SEDIMENTATION

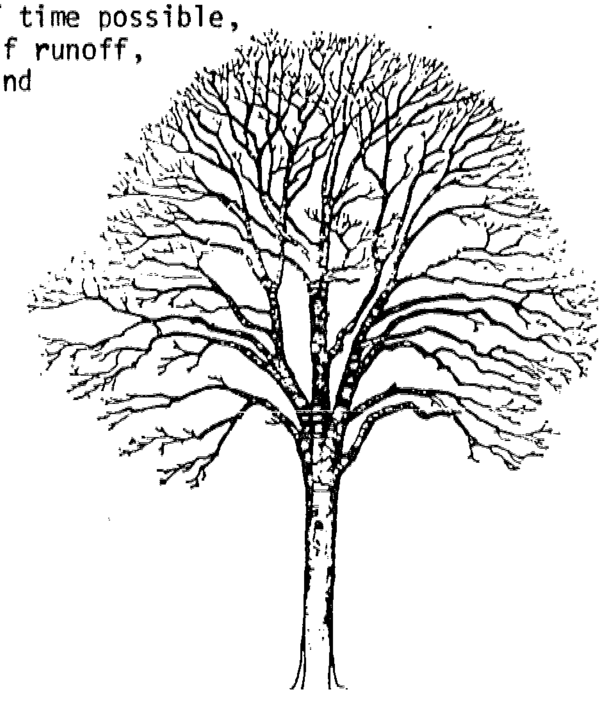
A. NEGATIVE EFFECTS OF SEDIMENT

Guy and Ferguson (1970) list the following effects of excessive sediment loads, to which have been added some brief explanations:

1. Reduces the useful life of reservoirs (reservoirs are filled by sediment deposited in their still waters).
2. Results in increased deposits of alluvium (river-deposited sediment) on developed properties subject to flooding.
3. Inhibits the recreational value of water bodies (by increasing turbidity -- cloudiness of the water and reducing visibility).
4. Increases damage to flood inundated structures (mud leaves a worse mess than water alone).
5. Reduces dissolved oxygen in water bodies (see water quality section). Organic sediments may have a high BOD. Inorganic and organic sediments may carry added plant nutrients (particularly phosphorous) and release them in water bodies causing eutrophication -- algal blooms, die-offs, and consequent increased BOD. Turbidity may inhibit photosynthesis, reducing input of oxygen to the waters.
6. Inhibits aquatic life (through reduction of dissolved oxygen, changes in bottom characteristics, and actual physical irritation from high sediment concentrations).
7. Increases harbor and channel shoaling.
8. Reduces storm sewer and drainage channel capacities (filling of channels with sediment can result in increased flooding).
9. Diminishes environment aesthetically.

B. Erosion and sedimentation can be controlled effectively, and at reasonable cost, if certain principles are followed in the use and treatment of land. These principles are:

1. Using soils that are suited for development,
2. Leaving the soil bare for the shortest period of time possible,
3. Reducing the velocity and controlling the flow of runoff,
4. Detaining runoff on the site to trap sediment, and
5. Releasing runoff safely to downstream areas.



GUIDE SHEET # 26

HYDROSYSTEM CONSIDERATIONS IN LAND USE DECISION MAKING *

A. HIGH GROUND WATER LEVELS: When ground water levels are close to the surface for more than a few days during the year, there is a potential for septic system failure and basement flooding.

**1. Protection: Wetland areas are a valuable natural habitat and a storage area for flood-waters and the slow discharge of water during times of low stream flow. They are not ground water recharge areas, but rather places where ground water is discharged to the surface.

2. Regulation: Poorly and very poorly drained soils are regulated under The Inland Wetlands and Water Courses Act (P.A. 155 (1972) As Amended), and most activities affecting these areas can occur only after a permit has been issued by a local Inland Wetlands Agency, or by the State Department of Environmental Protection in towns where no local agency has been created. The general categories of activities to be regulated are, "The deposition, filling or removal of material; the diversion or obstruction of water flow, the erection of structures and other uses" which despoil, pollute or eliminate wetlands and water courses. The Inland Wetlands Review Procedure applies in addition to any other State or local regulations. The Public Health Code requires that there be at least 18 inches of permeable material between the bottom of a leaching field trench and the maximum ground water level. The code requires 4 feet of permeable material between the bottom level of a sanitary landfill and the maximum ground water level.

3. High Costs: Development in areas with permanent high ground water may require draining, dredging, and fill before a septic system will function properly. Areas with seasonal high ground water may require curtain drains to divert ground water from the basement and septic system. A professional sanitary engineer should design the septic systems installed in these areas.

B. STEEP SLOPES: Areas with steep slopes have potential problems with foundations, septic systems, roads and erosion of surface materials. Unlike the previous factors, there is no definite slope at which development is not feasible or is suddently more expensive. In some areas of the country, slopes close to vertical have been built on. In general, a slope of 15% or greater can be used to differentiate between problem and nonproblem areas. This standard is widely accepted as a guideline and is one which is easily mapped from the detailed soils data. In actuality, slopes of 0 - 8% should have no problems, slopes of 8 - 15% may require special design considerations, and slopes of 15% and over should present definite drainage and septic system problems.

1. Protection: Areas on steep slopes have a serious potential for erosion. They are best suited for very low residential desnity and open space uses.

2. Regulation: The Public Health Code requires special design, such as serial distribution trenches, in areas with steep slopes.

3. High Costs: Increased costs will occur for foundations, septic systems, roads and utilities.

C. COMPACT GLACIAL TILL: Friable till areas present development problems because of the changeability of the material over short distances and its relatively poor percolation rate. Areas with compact till have the added problem of a slowly permeable material (hardpan) which causes septic system and drainage problems. Compact till is thought to have been formed where till deposits were deposited, overridden and compressed by the glacial ice. Although the soils data only indicate where compact till is present within 3 feet of the surface, this slowly permeable material could be a problem if it is within 10 feet or so of the surface. Sites close to compact till areas should be checked to see if it is present within the 10 foot distance.

1. Regulation: Friable and compact till areas have been designated as "areas of special concern" for which stricter regulations with respect to septic systems have been proposed.

2. High Costs: Most till areas will require the largest leaching fields specified in the Public Health Code. In addition, compact till areas may require excavation, fill and curtain drains to prevent septic system and basement flooding problems.

D. WATER SUPPLY WATERSHED: State Health Department regulations and guidelines for these areas are intended to exclude possible sources of pollution and retain a low development density. The guideline of 2 acres per dwelling unit provides a better choice of septic system locations than a smaller lot would allow. Guidelines also exclude facilities such as public sewers which would lead to more intensive land uses.

1. Protection: Strict land use controls and low densities are necessary to protect the quality of surface and ground water.

2. Regulation: Regulations of the State Departments of Health and Environmental Protection protect potentially hazardous land uses in this area. High density land uses and facilities,

such as public sewers, which would tend to increase density are discouraged.

3. High Costs: A minimum of 2 acres of land are required for each residential unit. This should be interpreted as 2 acres of buildable land per dwelling unit.

E. EXCESSIVELY DRAINED SOILS: These are areas of sand and gravel where water moves through the soil too rapidly. In these areas, there is a hazard of pollution, because septic tank effluent may reach ground water without being adequately filtered or renovated by the soil. According to a recent study, effluent is not properly treated unless it is in the soil for twenty-four hours before reaching ground water. This is especially critical in areas which are potential water supply sources.

1. Protection: These areas are the best in terms of percolation test requirements, but have a potential for polluting ground water. Detailed site evaluation and extra data and tests may be needed before development is approved.

2. Regulation: Proposed changes in the Public Health Code would place stricter requirements on areas where maximum high ground water is within 4 1/2 feet of the surface, but there are no regulations based on the time it takes septic tank effluent to reach ground water.

3. High Costs: There may be time delays and more than the usual testing and data gathering required to prove that ground water pollution will not occur.

F. FLOOD PLAIN AREAS: These are level areas along streams and rivers which were created by the deposition of material by flood waters and are still subject to recurring floods. Commercial or industrial use, and engineering solutions to prevent damage tend to increase the potential for flooding downstream. A more accurate determination of areas subject to flooding can be made from topographic quadrangle maps. These FLOOD PRONE AREAS include areas which are 5 feet or less in elevation above rivers, streams, marshes and ponds.

1. Protection: These areas are useful for agriculture, open space, recreation and other uses not harmed by flooding. They serve as a natural "safety valve" and protect other areas from being flooded.

2. Regulation: Flood plains contain alluvial soils (i.e., deposited by moving water) and other soil types regulated by streambelt zoning or flood plain zoning regulations.

3. High Costs: Dikes, dams and filling would be needed to protect residential, commercial or industrial land uses from flood waters.

G. LARGE VOLUME AQUIFERS: Many sand and gravel deposits are saturated with water and represent potential water supply sources.

1. Protection: Areas with 40 feet or more of saturated sand and gravel are community resources which should not be developed. These and adjacent but thinner saturated materials should be protected from contamination and pollution.

* This guide sheet is based heavily on Natural Factors Affecting The Use of Land by Lawrence H. Johnson of the Connecticut Department of Community Affairs. Any errors in the preparation of the guide sheet are solely those of the editors of this unit.

** Protection: refers to an important resource which should be kept from development and possible contamination so that it may be used at some future date.

Regulation: refers to an area being affected by regulations or guidelines of a state agency.

High Costs: refers to physical conditions, such as bedrock, which increase a developer's engineering and construction costs.

WORDS WORTH KNOWING

ALLUVIUM. A general term for clay, silt, sand, and gravel deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semi-sorted sediment in the bed of a stream, floodplain, or delta; especially such a deposit of fine-grained texture (silt or clay) deposited during time of flood.

AQUIFER A geologic formation, group of formations, or part of a formation that is water yielding, especially a body of rock or sediment that contains sufficient permeable material to conduct ground water and to yield economically significant quantities of ground water to wells and springs water-bearing formation.

ARTESIAN AQUIFER (CONFINED AQUIFER). An aquifer bounded above and below by beds with a distinctly lower permeability (a reduced capability for transmitting fluids) than that of the aquifer itself; an aquifer containing confined ground water under hydrostatic pressure.

BASE FLOW. The fair-weather flow of streams, composed largely of ground-water effluent.

BEDROCK. The solid rock, commonly called "ledge," that forms the earth's crust. In the report area, it is locally exposed at the surface but more commonly is buried beneath a few inches to as much as 200 feet of unconsolidated deposits.

BIOCHEMICAL OXYGEN DEMAND (BOD). The quantity of oxygen utilized primarily in the biochemical oxidation of organic matter in a specified time and at a specified temperature. The time and temperature are usually five days and 20°C.

CHEMICAL OXYGEN DEMAND (COD). The measure of the readily oxidizable material in water which provides an approximation of the minimum amount of organic and reducing material present.

CONCENTRATION. The weight of solute dissolved in a unit volume of solution.

CUBIC FEET PER SECOND (CFS). A measure of discharge; the amount of water passing a given point, expressed as number of cubic feet in each second. One cubic foot per second is equal to the discharge of a stream 1 foot wide and 1 foot deep flowing at an average velocity of 1 foot per second.

DIRECT RUNOFF. Water that moves over the land surface directly to streams or lakes shortly after rainfall or snowmelt.

DISCHARGE. The rate of flow of water from a pipe, an aquifer, a lake, or a drainage basin, in terms of volume per unit of time.

DRAINAGE BASIN. A region or area bounded peripherally by a drainage divide and occupied by a drainage system: specifically the whole area or entire tract of country that gathers water originating as precipitation and contributes it ultimately to a particular stream channel or system of channels, or to a lake reservoir, or other body of water.

DRAINAGE SYSTEM. A surface stream or a body of impounded surface water, together with all other surface streams and bodies of impounded surface water that are tributary to it and by which a region is drained. An artifical drainage system included also surface and subsurface conduits.

ENCROACHMENT LINES. (Channel encroachment lines) lines defining that portion of the flood channel including area adjacent to the river banks (located within the floodplain) which the Water and Related Resources office of DEP determines should be regulated (in accordance with Statute) to insure preservation of a reasonable flood channel for the passage of future floods and to minimize future flood damages. The Channel Encroachment Lines are based on computed design discharge referred to as the Channel Encroachment Line Design Flood.

EVAPORATION. The process, also called vaporization, by which a substance passes from the liquid or solid state to the vapor state.

EVAPOTRANSPIRATION. Loss of water from a land area through transpiration of plants and evaporation from the soil. Also, the volume of water lost through evapotranspiration.

FLOOD. Any relatively high streamflow overtopping the natural or artificial banks in any reach of a stream.

FLOOD PLAIN. The lowland that borders a river, usually dry but subject to flooding when the stream overflows its banks.

FRACTURE. A general term for any break in a rock whether or not it causes displacement, due to mechanical failure by stress. Fracture includes cracks, joints and faults.

GROUND WATER. Water beneath the land surface that is under atmospheric or greater pressure - the water that enters wells and issues from springs. Water in the zone of saturation.

GROUND-WATER RECHARGE. The processes by which water is added to a ground-water reservoir.

GROUND-WATER RUNOFF. Ground water that has discharged into stream channels by seepage from saturated earth materials.

HARDNESS, OF WATER. The property of water generally attributable to salts of the alkaline earths. Hardness has soap-consuming and encrusting properties and is expressed as the concentration of calcium carbonate ($CaCO_3$) that would be required to produce the observed effect.

HYDROLOGIC CYCLE. The constant circulation of water from the sea, through the atmosphere, to the land, and its eventual return to the atmosphere by way of evaporation from the sea and the land surfaces.

HYDROLOGY. The science of the behavior of water in the atmosphere, on surface of the earth, and underground.

INDUCED INFILTRATION. The process by which water infiltrates an aquifer from an adjacent surface-water body in response to pumping.

INFILTRATION. The flow of a fluid into a substance through pores or small openings. The common use of the word is to denote the flow of water into soil material.

LEACHING. The removal in solution of the more soluble minerals by percolating waters.

MINERAL CONTENT, OF WATER. The dissolved inorganic substances, most of which are derived from the minerals in rocks. It is generally assumed to be equivalent to the dissolved solids unless substantial amounts of nonvolatile organic substances are present.

PERCHED GROUND WATER. An isolated body of ground water separated from the underlying main body of ground water by an unsaturated zone.

PERCHED WATER TABLE. The water table of a body of perched ground water, occurs where a relatively impermeable layer (e.g., clay, compact till, etc.) exists above the natural ground water table and this layer acts to impead water movement vertically, creating an artificial zone of saturation.

PERCOLATION. Movement under hydrostatic pressure of water through interstices of rock or soil.

PERMEABILITY. The property or capacity of a porous rock sediment, or soil for transmitting a fluid without impairment of the structure of the medium; it is a measure of the relative ease of fluid flow under unequal pressure; a function of the amound of void space and more importantly their interconnection.

PESTICIDES. Chemical compounds used for the control of undesirable plants, animals, or insects. The term includes insecticides, herbicides, rodent poisons, nematode poisons, and fungicides.

POLLUTION. "Harmful thermal effect or the contamination or rendering unclean or impure of any waters of the State by reason of any wastes or other material discharged or deposited therein by any public or private sewer or otherwise so as directly or indirectly to come in contact with any waters" (Connecticut General Assembly, Public Act No. 57, 1967).

POROSITY. The property of a rock or unconsolidated material of containing voids or open spaces; it may be expressed quantitatively as the ratio of the volume of its open spaces to its total volume.

PRECIPITATION. The discharge of water, in liquid or solid state, out of the atmosphere, upon a land or water surface. The quantity of water that has been precipitated (as rain, snow, hail, sleet) measured as a liquid.

SATURATED THICKNESS. Thickness of an aquifer below the water table.

SATURATED ZONE. The subsurface zone in which all open spaces are filled with water. The water table is the upper limit of this zone and the water in it is under pressure greater than atmospheric.

SPECIFIC CONDUCTANCE, OF WATER. A measure of the ability of water to conduct an electric current, expressed in microhms per centimeter at 25°C. It is related to the dissolved-solids content and serves as an approximate measure thereof.

STRATIFIED DRIFT. Fluvioglacial drift consisting of sorted and layered material deposited by a meltwater stream or settled from suspension in a body of quiet water adjoining the glacier. Deposits of layered sands, gravels, silts, & clays.

TILL. Unsorted and unstratified drift, generally unconsolidated, deposited directly by and underneath a glacier without subsequent reworking by water from the glacier, and consisting of a heterogeneous mixture of clay, sand, gravel, and boulders varying widely in size and shape.

TRANSPIRATION. The process whereby plants release water in vapor form to the atmosphere.

TURBIDITY, OF WATER. The extent to which penetration of light is restricted by suspended sediment, microorganisms, or other insoluble material. Residual or "permanent" turbidity is that caused by insoluble material that remains in suspension after a long settling period.

UNCONFINED AQUIFER (WATER-TABLE AQUIFER). One in which the upper surface of the saturated zone, the water table, is at atmospheric pressure and is free to rise and fall.

UNCONSOLIDATED. Loose, not firmly cemented or interlocked, for example, sand in contrast to sandstone.

UNSATURATED ZONE. The zone between the water table and the land surface in which the open spaces are not all filled (except temporarily) with water.

WATER TABLE. The upper surface of the saturated zone.

WATER EQUIVALENTS.

- 1 cubic foot per second (cfs) = 450 gallons per minute, or 7 1/2 gallons per second
- 1 cfs for 1 day, or 1 cfs-day,= about 2 acre feet
- 1 acre foot=326,000 gallons
- 1 cubic foot weighs 62.4 pounds
- 1 cubic foot=7 1/2 gallons
- 1 gallon=8.33 pounds
- 1 ton=240 gallons

HYDROSYSTEMS BIBLIOGRAPHY

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This is a semi-technical introductory hydrology text intended for foresters, but well suited to the interested lay person. A basic, but thorough explanation of how water behaves in the natural system and how the land affects it.

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Knaler, Jon A., and Thomas M. Lee. Regulations for Fllod Plains. Chicago, Ill., American Society of Planning Officials Advisory Service Report #277, 1972.

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This is a comprehensive study of Inlànd Wetlands regulation in Connecticut. It is a must for any citizen working on an Inland Wetland Commission. Includes case studies as well as the rationale behind the law and regulations. Highly recommended.

Other publications of the Connecticut Inland Wetlands Project:

Administrative Handbook for Inland Wetland Agencies. As above.

Identifying Functions of Inland Wetlands. As above.

Implementing Aids for Inland Wetlands and Watercourse Agencies. As above.

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The first systematic approach to hydrology. These planners are beginning to provide for one area a systems analysis of water and land use. This publication is semi-technical.

Strahler, Arthur N. The Environmental Impact of Ground Water Use on Cape Cod. Orleans, Ma., The Association for the Preservation of Cape Cod, Inc., 1972.

A layman's introduction to the hydrology of Cape Cod. Even though this report was designed for one region the basic information applies to any place in the country.

U.S. Department of Agriculture. Controlling Erosion on Construction Sites. Washington, D.C., Agriculture Information Bulletin #347, 1970.

A layperson's introduction. Explains the consequences of erosion and means of combatting it.

U.S. Department of Agriculture. Erosion and Sediment Control Handbook for Connecticut. Storrs, Ct., Soil Conservation Service.

A technical handbook for the design of sediment and erosion control measures and structures. Helpful for the community that plans to require control measures on construction projects. Also contains techniques to project potential soil loss from a construction site.

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A citizen information booklet on the National Pollutant Discharge Elimination System (NPDES) under the Federal Water Pollution Control Act Ammendments of 1972. Explains the law and the permit system, including the roles of federal state and local governments and public citizens.

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This series of booklets offers an excellent basic layperson's introduction to the topics. They are practical booklets focussing on water and factors affecting its use. They do not deal with land-use itself, but do discuss it as related to water.

U.S. Geological Survey. Hydrology for Urban Land Planning - A Guidebook on the Hydrologic Effects of Urban Land Use. Washington, D.C., Department of the Interior, Geological Circular #554.

An excellent semi-technical summary of the title topic. Best as a follow up for the primer series, or for someone with a basic background. Directly relevant to land-use planning and decisions.

U.S. Geological Survey. Water in the Urban Environment. Washington, D.C. Geological Circular #601 Series.

This series of semi-technical booklets covers a wide range of topics related to water and urban or suburban developement. It provides a good follow up to the primers and a complement to the Circular #554 as general background.

U.S. Geological Survey. Geologic and Hydrologic Maps for Land-Use Planning in the Connecticut Valley. Washington, D.C., Department of the Interior, Geological Survey Circular #674.

An explanation of the maps of natural resource data being developed by the USGS's Connecticut Valley Urban Area Project. Has examples from the folio of the Hartford North Quadrangle. Although their availability is still limited, these maps display geologic and hydrologic information in a form directly usable for land-use decisions and planning.

U.S. Geologic Survey in cooperation with the Connecticut Department of Environmental Protection. Water Resources Inventory of Connecticut. Washington, D.C.

This series of reports describes the water resources and hydrology of ten river basin areas comprising Connecticut. The summary reports for each basin are semi-technical and valuable sources of information for the informed layperson. They provide general explanations of the basin's geology and hydrology and assess both the needs and resources of the area. Even if your basin is not published, a neighboring basin report may provide valuable background.

Audio Tape Script

HYDROSYSTEMS

Welcome to the Land Use Planning unit on Hydrosystems. Hydrology is a latin term for the study of water. In this unit we will study water as it flows along its natural course as well as when its natural flow is altered by use of the land. Before proceeding farther, turn off the recorder (Pause) G.S. # 1 and read through the specific objectives which this unit designed to help you master. In this unit we will examine the interchange of water's flow with human decisions about land use. In order to appreciate the importance of these objectives, consider for a moment the many and varied ways you use water. Your drink water and other liquids made from water. You wash and bathe with it. Water carries away domestic and industrial wastes. You may enjoy a variety of water based recreation i.e., swimming, boating, rafting, water skiing, etc. And, as on slide # 1, if you have S. #1 spent nights at the beach or sunsets by a fresh water lake you know that water is beautiful and can be an aesthetic experience.

This unit is about how and why our needs for enough good quality water are usually met by nature and how proper land use decisions can preserve or enhance that natural supply.

The noted enviornmentalist, Barry Commoner has stated in a simplified form the "laws" of ecology. The first three are listed on top of Guide Sheet # 2. G.S. # 2A

1. Everything comes from somewhere.
2. Everything goes somewhere.
3. Everything is connected to everything else.

If you think about these three simple statements in terms of water, they describe the flow of water in a cycle. Water comes from rain clouds in the atmosphere. Rain falls upon plants, the land, and streams. The water flows from the land to rivers, to lakes and finally to the ocean. The water in the ocean eventually evaporates making clouds anew. The place water comes from is the place it goes! Thus Commoner's 3rd law: everything is connected with everything else - defines a cycle through which water flows. This is known to scientists as the hydrologic cycle. This natural hydrologic cycle is our first object of study. Before we proceed to discuss the hydrologic cycle in depth, turn off the recorder and familiarize yourself with Guide Sheet # 2. G.S. # 2B

(Pause)

Let's follow the path of water as it moves along its cyclical path as the diagram at the bottom of Guide Sheet # 2 illustrates. It starts as rain, as we mentioned earlier. A certain amount of rainfall is "intercepted" by plant leaves and flowers. Some of this rain is absorbed by the leaves and some of it evaporates. The remainder reaches the ground. There it begins to soak into the soil. Gravity draws the water down through the spaces between the soil particles. If the rainfall is too rapid not all the water may be able to filter through the soil. This rainfall is excess which runs off over the soil surface. Some of this surface runoff may be trapped temporarily in small depressions on the ground surface, where it will later evaporate or infiltrate the soil. The rest of the runoff will flow over the surface to drainageways and streams.

This initial surface runoff contributes to the high level of streams following heavy rains. Some of this streamflow may be stored temporarily in waterbodies or wetlands and then may be released more slowly or evaporate later. The remainder of this streamflow continues its downstream travel to the sea.

This flow of water just described is only one part of water's journey from rain, to water on land, to water in the ocean. It is the flow of surface water also known as "overland flow". But the rain that reaches the ground and then infiltrates the soil takes a longer and slower, second route to the ocean. Before we find out in detail about this second - the underground water - route, turn off the recorder to look at a diagram of this second route on Guide Sheet # 3. (Pause) G.S. # 3

Water that enters the soil is first absorbed in the smaller pore spaces of the soil. This occurs because of the attraction of water molecules for each other and for the soil particles. This is the same force that makes a paper towel absorb water. It is called "capillary action". The remainder of the water continues down through the larger pore spaces because of the force of gravity. Even after rainfall has ceased, gravity continues to draw water down through the larger spaces. In the smaller spaces, the water may be held against gravity by the capillary forces. Much of this capillary water will be available to plants <u>after</u> water has drained from the larger spaces and been replaced by air. Deeper in the ground is a zone in which all spaces in the underlying rock, surface deposits, and soil, are filled with water. This is the zone of saturation. The upper surface of the saturated zone is called the <u>water table</u>. The area above the water table is called the <u>zone of aeration</u> or unsaturated zone. In the zone of aeration the smaller pore spaces have only their store of water from the infiltrating rainfall.

During the growing season, plants draw water from the soil and it evaporates from their leaves in a process called transpiration. The plants extract water from the small soil spaces, drying out the soil above the capillary fringe. This drier soil soaks up most of the season's rainfall before it reaches the ground water to recharge it. If the water table is within reach, plants may also draw directly from it or from the capillary fringe. All the time, the groundwater is being discharged to surface water courses further downhill. These factors combine to lower the water table during the growing season.

Then during the late fall, winter, and early spring, with no transpiration from the plants and little evaporation from the soil, the soil pore spaces are refilled with water. Now, more snowmelt or rainfall reaches the water table than is discharged to streams and wetlands and the water table rises. Thus the water table fluctuates seasonally and even year to year. This is particularly true in higher areas away from streams.

Gravity pulls water down through the ground, perhaps past the zone of saturation until it reaches the bedrock surface as is illustrated on Guide Sheet # 4. If the bedrock is below the zone of saturation, the water tends to flow downhill, ultimately emerging at the surface in a G.S # 4 stream, wetland, spring or pond. Or, the combination of the weight of the water uphill and the relatively impermeable bedrock below may cause the ground water to curve upward under the low-lands and to emerge as surface water. This resembles the flow of water in a curved pipe moving upward under pressure from a faucet above. Water then flows in the stream, downhill, by this easier route. This whole process is called ground water "discharge". It is this discharge from ground water that contributes water to streams between the storms that provide direct surface runoff. Stop the recorder to study Guide Sheet # 4 further. (Pause)

This ground water discharge, along with the surface water flow discussed earlier, combines to form the overall flow of rain to the ocean. These two flows are not always the same in volume. Of course each flow varies with the frequency and occurence of rain or snowmelt.

Tutn to slide # 2. S. #

One of the two important aspects of the hydrologic cycle from the point of view of a land use decision maker is the quality of water available in general and the quantity of water available in a particular place at a particular time as is indicated by slide # 3. S. # The second area of this unit's study covers those natural and man-made factors which control when, where, and how much water is available. Another component of the availability of water is the natural and artificial pollutants connected with any quantity of water. We will especially concentrate on how land use decisions can alter the quantity and quality of water.

The absolute limit of water available to man is set by his natural sources of water: rainfall and snowmelt. Everyone talk about the weather, but nobody can do much about it. As we will see later, planning that relies on the weather always involves a gamble.

Once water reaches the ground, the amount of water available is determined in large measure by the characteristics of the drainage basin or watershed it falls into. As Guide Sheet # 5 shows, G.S. # 5 a watershed is the area of land that gathers surface runoff flow from precipitation and funnels it ultimately to a particular stream channel, reservoir, or other body of water. As the diagram shows, a large drainage basin feeding a large stream can also be broken down into smaller sub-basins feeding smaller tributary streams. These boundaries of a watershed actually govern the surface runoff flow. Ground water movement may not follow them precisely. But for most practical purposes, these surface drainage area boundaries or "divides" can be assumed to apply to ground water, too.

Identification of a drainage basin's boundaries is important since the overall area determines how much rain will be caught and fed into the system. In addition, the characteristics of the land within the basin determines where and how fast the water goes as are listed on Guide Sheet #5. We will discuss these factors later in this unit.

Let's look now at how watershed boundaries can be determined on a topographic map as on Guide G.S. # 6 Sheet # 6. If you're unfamiliar with ow to read a topographic map, you might want to try the map reading unit for a more detailed expl nation. Let's assume we are planning a reservoir at point A and we want to know what area will contribute water to it. Starting at our proposed dam, at point A we draw a line uphill as close to perpendicular to the topographic lines as possible. This line defines the flow of water from higher to lower elevations. We work up to the nearest hilltop at point B. From there, we follow the highest ground from hilltop to hilltop until we come "full cycle" to point A. The perimeter of the line outlines the contours of the watershed for point A. Rainfall inside that perimeter is our supply.

Now, try another example yourself. Mark out the watershed for a reservoir at point C on the map. Turn off the tape while you work. (Pause)

A topographic map can also help you determine where small drainageways and intermittent streams are, even if they're not actually shown in blue on a normal topographic map. First, let's look at the stream near the letter D in guide sheet #6. Notice how the topographic lines form a series of V's or angles with the points pointing uphill as you follow the stream. This is a common feature where a stream is cutting into a slope, eroding a small valley.

Now, let's look at the land within a watershed and how it affects the movement of the water. Slope is a first important characteristic of the land. On a topographic map a steeper slope is shown by closer topographic lines. The steeper the slope, the faster direct surface runoff will flow to the streams and the faster the streams themselves will flow. If this flow from several smaller tributaries reaches the same point on a larger stream at roughly the same time, a sudden or "flash" flood can result as slide # 4 shows. These are dangerous and may cause property S. # 1 damage or even death because they cannot be planned for. In the case of 1972 Hurricane Agnes most of the 123 reported deaths occurred from flash flooding which occurred in the first 6 - 12 hours. Such catastrophe is less likely to happen if the slope of the watershed is flatter. Runoff from a given storm will then be spread out over a longer period of time. For several reasons to be explained later, this results in less flooding.

The shape of the drainage basin is a 2nd characteristic which can make a difference in surface runoff flows. In a long narrow basin such as diagram A on Guide Sheet # 8 peak stream flows G.S. # 8 from sub-basin 1 might reach the bridge long before those from sub-basin 2 which have a greater distance to go. Thus the flow of the surface runoff past the bridge is spread over a longer time and the peak stream flow is lower and less dangerous. By contrast, diagram B shows a basin with more of a funnel or pear shape. Here, the surface flow from the sub-basins will all reach the outlet at about the same time. This concentration will cause a higher surface flow in a shorter period of time. This increases the possibility of flooding.

The geology and type of soil of the watershed is a third important characteristic of a watershed which affects the amount of surface water available. Geology and soil type also affect the flow of groundwater within the basin. This will be discussed further on.

Turn to Guide Sheet # 9. This diagram shows a typical example of the distribution of geo- G.S. # 9 logic deposits in Connecticut. Upland areas are generally composed of glacial till and bedrock or ledge, often with steeper slopes. These areas have a relatively low infiltration capacity. Thus, much rainfall is apt to be left on the surface. Steep slopes then speed the surface runoff to streams in the basin. Since infiltration is limited, these upland areas will contribute relatively little per unit surface area to recharge groundwater. But since they cover a large area in total, their total contribution is very significant.

Land in the lower valleys have a subsurface layer of fine clay soils in most instances. The clay soils are too dense to allow for high filtration. Also, wetland areas where the groundwater table is at the surface have no space left for infiltratio. But since lower valleys and wetlands are relatively flat, the excess rainfall does not run off as rapidly as it does from steeply sloping lands and may provide some additional opportunity for ground water recharge.

Sands and gravels may be found in valleys or as terraces along valley sides. Their coarse texture, with lots of large pore space, permits rapid infiltration or rainwaters. This leaves less to run off over the surface. Thus sand and gravel areas are the most effective groundwater recharge areas.

Within a watershed, floodplains and wetlands are geological formations with their own specific characteristics. These areas can serve as sponges which absorb sudden flows of surface water and then release these water more slowly as the surface flow subsides. Turn to Guide Sheet # 10. G.S. # 10
Floodplains and wetlands are generally broad and flat as slide # 5 shows. They can store and S. # 5
then slowly pass large volumes of water with little increase in their own water depth. A floodplain can thus be viewed as part of a river which the river occasionally uses.

Everything we have just considered about a watershed has involved the quantity of water available as surface run off or over land flow. But, as we now know, there is a second route rain travels to the oceans, the groundwater flow. The topography and geology of the watershed will affect the flow and quality of groundwater in the basin. The key to groundwater flow is a geological formation called an aquifer. Aquifers are any geological formation that are capable of readily holding and transmitting ground water. Good aquifers are important both as sources of well water supply and because their discharge helps sustain stream-flow during dry periods. This stream-flow that is fed by groundwater is called "base" flow. It is important in providing surface water in streams and rivers for man's use and also in maintaining aquatic habitat and water quality during the dry season. Aquifers differ as to how much water they hold and the rate at which water can move through them. The amount of ground water held in a given volume of soil or rock depends on the amount of pore space or fracture space. The rate at which the water can move through a deposit depends on the size and number of the individual pores and, most importantly, on their interconnection.

The geologic formations and deposits containing ground water vary widely in their ability to both store and transmit ground water. Guide Sheet # 11 summarizes the water holding characteristics G.S. # 11
of several common geologic formations. Turn off the recorder while you study Guide Sheet # 11. Refer back to Guide Sheet # 9. It shows a generalized view of the location of these different

geologic deposits. Let's consider, now how typography combines with geology to determine the overall pattern of ground water flow. The till uplands hold a moderate amount of ground water which moves slowly downhill emerging in streams or wetlands, or entering stratified drift deposits in the valley areas. The stratified drift deposits may hold large amounts of water and may transmit it relatively rapidly depending on what the deposits are made of. On Guide Sheet # 9, the till and bedrock uplands, stratified drift terrace, and flood plain of alluvium (river-deposited soils) all serve as recharge areas, while the stream, pond, wetlands and river serve as discharge areas.

This completes our view of the natural system affecting the quantity of water flow as both surface water flow and ground water flow. Guide Sheet # 11, Part B contains a summary of the factors we discussed.

Let's now see how this natural pattern of water movement and storage interact with man's activities. First we will consider how natural patterns affect man's ability to obtain drinking water from the ground by wells. Second, we will consider the great problem of too much water at one place at one time. This second topic is generally known as the problem of flooding.

When man plans for well water supplies, the yield he can expect will depend on the aquifer he taps. For single-family homes, any aquifer will normally give adequate production. In most bedrock, the well must intercept a fracture system filled with water. In glacial "till" you must be sure that the water table does not go below the well in a dry season. Most people now drill on through the till into bedrock for a more reliable supply. By drilling far below the water table, the well intercepts more fractures and the weight of water above helps to move water through the fractures into the well.

For public water supply systems or industrial and commercial use, deep sand and gravel deposits are the best aquifers. In many cases, wells pumping an aquifer such as this, close to a river, can lower the water table locally, enough that the normal discharge of ground water to the river is reversed.

These stratified drift aquifers are also exceptionally important in sustaining stream flow. In general, the greater the percentage of a drainage basin covered with stratified drift, the lower the high flows and the the higher the low or "base" flows that are sustained by ground water. Higher base flows mean more constant surface water supply, better aquatic habitat, and more water to dilute whatever pollutants may enter the system or provide for man's industrial needs.

An essential aspect of land use decision making in relation to the hydrosystem is planning to have amply supply of fresh water and having adequate capacity to dispose of the waste water. This is an extension of Barry Commoner's laws of ecology - All water most come from somewhere and all water must go somewhere after use. Sound planning requires considering the requirements for an adequate supply of fresh water and the requirements for an adequate capacity for sewage disposal. Are you aware of how much water an average house uses per day? (Pause) On Guide Sheet # 12, G.S. #

there is an activity that will help you determine the water consumption of an average home. Stop the recorder while you complete the activity.

Approximately 20% of the homes in Connecticut obtain their water supply from wells. In addition, several municipalities obtain their water from wells located in major aquifers.

When ground water is being withdrawn by pumping, the reduction of pressure surrounding the point of intake causes the water table to be lowered, a phenomena called drawdown. As shown on Guide Sheet # 13, drawdown causes the water table to develop a depression in the shape of an inverted cone known as the cone of depression. G.S. # 13 As pumping continues, the cone of depression deepens and enlarges, extending its influence over a circle of widening radius. The cone continues to enlarge until the recharging of ground water is balanced by the well withdrawal of water. Where many wells are being pumped, their drawdown cones intersect and their effect is additive, with the result of lowering of the water table, which while not uniform, is felt generally over the region.

The table in the middle of Guide Sheet # 13, illustrates that the size of the recharge area necessary for any well depends on the quantity of water used as well as the amount of rainfall. If you well pumps 420 gallons per minute, an area equivalent to a circle with a 2600 ft or 1/2 mile radius is needed. Compare your requirement for water with the recharge area table on guide sheet # 12 with the recharge area table on Guide Sheet # 12. Stop the recorder while you complete the activity.

Whether used for private or public purpose, wells along Long Island or other salt water bodies face a particular problem. In coastal areas where permeable rocks are in contact with sea water, fresh water wells may yield salt water if pumped excessively. Refer to Guide Sheet # 13, Part C. G.S. # 13C Because the discharge of fresh ground water in the seaward direction is reduced by inland water withdrawal, the interface between salt and fresh water moves inland. Eventually the salt water forms a wedge between the fresh water body and the bedrock as shown on Guide Sheet # 13. Ultimately, the salt wedge reaches the location of the wells which then becomes contaminated. Salt water intrusion problems are common along the East and West coasts. It can be alleviated by increased ground water flow, by increased surface water flow, and by controlling the total backflow of the salt water by pumping fresh water into the aquifer between the well and the coast.

The quality of ground water helps determine base flow of streams and the availability of drinking water. In a similar fashion, the quantity of overland flow is closely related to another natural factor - flooding. Turn to slide # 6. S. # 6

Flooding occurs when rainfall or snowmelt releases more water on a drainage basin than its soils can absorb or its channels can conduct away without overflowing their banks. The most important cause of flooding is not the total volume of water released, but its concentration in the drainage system in a limited time. Flooding occurs when there is too much water in one place at one time.

Floods may be described in several ways. The height of flood waters, called the "stage", is related to both the amount of water flowing and the topography of the valley through which the flow must pass. For example, in relatively flat areas a small change in stage makes a large difference in the amount of land covered. Refer back to Guide Sheet # 10 to refresh you memory on the flow rate.

From historical records of rainfall and snowmelt and from records of actual floods, scientists can compute the probability of a flood of a certain magnitude. Larger floods are less frequent than smaller ones. Floods thus have a probability of occurrence during any one year as shown on Guide G.S. # 14
Sheet # 14. They can therefore be described by the number of years which statistically must pass to have a flood of such a size. A 50 year flood is one which will occur, on the average, once every fifty years or which has two chances in 100 of occurring in any single year. This form of description is illustrated by Guide Sheet # 14. This guide sheet graphically shows the different levels of flooding caused by floods of different magnitudes.

Land use decisions must be concerned with small frequent floods as well as large catastrophic floods. The 100-year flood is a major flood and on larger rivers it may bring considerable danger to life and property. Most flood control programs are designed to protect against floods of this size. A more frequent flood, such as the 25-year flood, will have lower flow rate and water levels, and consequently, causes less damage. Smaller, but more frequent floods which slightly overflow the stream's banks will cause less damage, but because of their frequency, may be a repeated problem to property owners who have located their dwellings within these flood areas.

The history of Hurricanes Agnes in 1972, is an instructive example of what factors cause severe flooding. In the Susquehanna River Basin 15-18 inches of rain fell over a five day period. The highest 24 hour rainfall was 14 1/2 inches. In slide # 7, one can see the results of over a S. #
million cubic feet of water per second that flowed in the Susquehanna River at Harrisburg, Pennsylvania.

Agnes caused widespread, monstrous flooding partly because rainfall was widespread and partly because of the time of year. Agnes occurred in June instead of August or September. Because rainfall was widespread and because of the preceding floods, with smaller losses so early in the season, flooding was very widespread, and it resulted from ordinary heavy rain as well as from the more intense centers of rainfall. The tropical storm fell upon the same land that earlier had experienced heavy rainfall coming from the west. The preceding storm saturated the ground and set the basin up for Agnes to do the finishing touches. Precipitation wasn't able to get into the ground. Runoff factors were very high - well over 50 percent. In New England runoff is about half of precipitation. In the Susquehanna River Basin it was running about 70 percent because the ground was saturated.

Let's now consider how one of man's land use decisions affects this natural problem of flooding. Everyone is familiar with the advantages of a city or other urban and suburban areas. However, the decision to live in urban centers has its impact on the natural hydrologic cycle. Consider first the

need to pave over soil in order to make roads to and from a city, the parking areas of a shopping center, the shopping district of a town as in slide # 8. When you pave over the soil, whether S. # 8
you then build on top of that or not, water that falls onto that area cannot filter through the soil into the ground water reservoir. The surface water is prevented from recharging the ground water underneath by the pavement. As a result, water that falls on pavement or buildings has only the option of going through the water cycle as surface runoff. Normally half the rainfall enters the water table while the remaining half becomes surface runoff. In a highly urbanized area the surface runoff may range from 70 - 95% of the total rainfall. This means that there is more of a chance of flooding from a given amount of rainfall. Furthermore, with less recharge, the water table may fall. Less ground water means a possible loss of well supplies and lower base flows in streams and rivers.

But this is often only the beginning of problems which result from poorly planned urbanization. Rather than letting the excess runoff back up on lawns and green grass, often man decides to pipe the water away as rapidly as possible. Natural channels, like the one in slide # 9, S. # 9
often twist and turn or contain vegetation or rocks that slow the flow of water. But these natural channels are sometimes "improved" by man. They are widened, straightened, deepened, and lined with concrete as in the next slide, # 10, so that they carry excess water away faster to prevent flood- S. # 10
ing in that area.

The purpose of channelizing streams is to decrease the flood stages by removing runoff as rapidly as possible. There is a limit to the amount of improvements that can be done. Once this limit is reached, the benefits end.

This sudden flush of water goes on downstream where it becomes someone else's problem. Because the natural channel downstream is not adapted to carry this large flow the natural channel floods needlessly.

There are several negative points to these channel improvements. First of all, they are effective only in the stretch of "improved", and result in increased flooding downstream. They also increase erosion, remove swamps and reduce the water table, and do great damage to wildlife habitats. Channel improvements are also used as pork barrel projects and often placed in areas where a boondoggle is their only purpose.

If several of these concrete lined channels empty into the same stream at about the same time, the result is more water in a shorter period of time than before urbanization. The combined effect of these two factors, impervious water surface area and more rapid drainage flow, can be shown by
a change in the hydrograph for the area. Guide Sheet # 15 shows two hydrographs for the same G.S. # 15
size storm - one before and one after urbanization. Following urbanization, there is a greater total runoff shown by the area under the curve, and a higher peak flow rate for a shorter period of time. The total affect is increased flooding. Compare the two hydrographs in Guide Sheet # 15. Stop the recorder while you read the guide sheet.

Urbanization interacts with flooding in another way. Land uses in flood plains have always been subject to the hazard of periodic flooding, but with upstream urbanization, that hazard increases. To avoid flooding, development in floodplain areas is often placed on solid fill above expected flood levels. But this "encroachment" as it is called can magnify the chance of flooding! As shown on guide sheet # 16, encroachment reduces a flood plain's natural capacity to G.S. # 16 pass flood waters. Guide sheet # 16 illustrates the value of the flood plain as a natural buffer to flood damage. Turn off the recorder and study guide sheet # 16. (Pause)

Encroaching development can act almost like a dam, obstructing or backing up flood waters and raising upstream and local flood levels. This may endanger upstream structures and the encroaching structures as well.

How can these flood dangers be reduced or avoided? The first step is to reduce unnecessary impervious surface area created by roads and roofs. This will reduce excess runoff. This can be accomplished in part by cluster or low density development. Then, rather than hurrying storm water away, it should be retained on the site in natural depressions or engineered basins where it can infiltrate to the ground water or be slowly released to surface streams. The more that streams can be left in their natural condition, the more slowly will they conduct flood flows.

In the flood plain, the best policy is to avoid building in such an area in the first place. Guide sheet # 17 lists some of the sources of information on flood hazard areas. They can provide G.S. # 17 maps showing areas covered by various frequency floods. Towns can zone their flood plains to permit only certain uses or to require special structural precautions.

Although flooding is a natural problem that has been always present, which has been aggravated by the more recent trend towards urbanization, no integrated program of land use control has existed until very recently. In Connecticut, this integrated program is spearheaded by a new set of laws. The particular types of laws and their requirements are described in the units on Local Implementation and State and Federal Implementation. It is sufficient for our purposes here to state merely the purposes of these legal enforcement programs. They are also summarized on guide sheet # 17, Part B. Stream channel encroachment lines prevent encroachments from being built in flood plains. Flood plain zoning restricts the land uses of flood plains to those uses which are compatible with the natural way a flood plain acts to reduce flooding. Flood plain insurance provides a financial lever to insure that local communities with flooding dangers take precautions to avoid flooding. If communities co-operate, it will enable citizens of such communities to insure themselves against damages and injuries due to flooding. These legal problems help to alleviate the likelihood of flooding and its severity should it occur, but they require citizen participation to be maximally effective. That gives you a necessary role in one part of the hydrologic cycle.

Up to this point, we have considered the quantitative aspect of the hydrologic cycle, and how it interacts with man's decisions concerning land use. But, it is also important that the quality of however much water is needed be appropriate to our use. Thus, water that we drink must be cleaner than water we sail on. Similarly, water that we swim in must be cleaner than water we use to carry away industrial wastes. In Connecticut, regulatory agencies classified waterways into four grades of water quality as is shown on guide sheet # 18. Stop the recorder to review the water quality standards on guide sheet # 18. In the following part of our study of water we will consider the hydrologic cycle in terms of the quality of water, and how this quality is related to man's decisions concerning use of land. G.S. # 18

Just as Nature has its own processes which regulate how much water is available, Nature has its own processes which dirty the water and those which clean it. Even before man-made pollutants enter the hydrologic cycle, water in the form of rain is dirtied. As it moves through the hydrologic cycle the quality of water is altered. These changes are depicted on guide sheet # 19. Follow the diagram on guide sheet # 19 as we continue our discussion. G.S. # 19

In step 1, precipitation is relatively dirt free. Once this precipitation reaches the ground, it moves through soil and rocks - number 2. As it does so, this ground water dissolves some of the minerals present in the soil and rocks as in numbers 3, 5, 6, 9, and 10. These minerals become dissolved in water so as to alter its quality. We all know that water in some places makes soap suds easier than water from other places. This water which does not easily make suds when we soap up is called "hard water". Such water contains certain minerals which prevent or retard sudsing. Water which makes suds more easily is known as "soft water". Whether water is "hard" or "soft" depends on the minerals it dissolves when it flows through the hydrologic cycle as ground water. Clearly, the minerals dissolved depend on the type of soil and rock through which the ground water flows. Guide sheet # 20 lists some minerals, their source, and other significances to their presence in water as dissolved solids. These are included for you future study or reference. Return to guide sheet # 19. G.S. # 20

Minerals are not the only particles water picks up on its travel in the hydrologic cycle. As it flows over the surface as runoff and in stream beds it picks up soil particles and small bits of organic matter as in number 2 on guide sheet # 19. These particles are called sediment. They may be decaying plant life, in which case they add a brownish color to water. Or , they may be decaying animal matter. Depending on the type of matter these particles may also change the color of water, add minerals to the water, and even use up some of the oxygen in the water to feed the bacteria performing the work of decomposition.

Nature has its own ways of purifying water from these dirtying processes. Some of the minerals and decaying plant and animal matter serve as food for aquatic life. Aquatic plants and animals are thus natural cleaning agents. As streams flow towards larger bodies of water they mix air back into the water, especially if the stream is turbulent. This replenishes the water with oxygen it lost because of the bacteria decomposing the organic matter. Once the water reaches a bigger body of water, a pond or lake or ultimately the ocean, the quick pace of the hydrologic cycle slows down. This provides an opportunity for the sediment carried along in streams to separate out from the lighter weight water by dropping to the bottom of the pond, lake or ocean. Here gravity pulls down the heavier material, thus leaving the water on the surface much clearer. The final natural purification step occurs when water from the clearer surface evaporates into the air as in # 7 on guide sheet # 19. Since water becomes gaseous - in the form of water vapor - under conditions different from the minerals and other materials it carries, when water evaporates it leaves behind its impurities. Water vapor is the purest water in nature, and that is why the hydrologic begins with pure water when rainfall from that water vapor falls to the earth.

When man uses land in his various ways, he influences the hydrologic cycles own quality control by adding to the natural pollutants and retarding nature's own cleansing processes. We will now consider how man's use of land can overload the natural system by discussing some specific examples.

For example, consider what happens when man cuts trees from his forests. While timber is growing forests reduce the surface runoff by intercepting the surface flow, by "drinking" up ground water so that the trees can grow, and by evapotranspiration. When timber is cut, the surface runoff increases in quantity and in speed. This causes greater soil erosion than when trees are left standing. This in turn causes water to be dirtied by sediment. The surface runoff also contains less oxygen, because there are no trees to shade the surface water from the heat of the sun and hotter water holds less oxygen.

Using land for agricultural purposes has its hazards for the quality of water in the hydrologic cycle also. Cultivated land is subject to the same problems of erosion as forested lands. In addition, however, the fertilizers and pesticides used to help generate good crop yield present their own difficulties. These materials are carried into the ground water flow by rainfall which combines with them and then infiltrates the soil. Pesticides in the hydrologic cycle can attack unintended targets and kill off important and beneficial organisms. Fertilizers may aid the growth of living things in the aquatic environment by stimulating algae growth. But, it may ultimately be destructive because it disrupts the natural ecological balances of the body of water. For example, if fertilizers cause algae to grow in great spurts, these algae may endanger other aquatic life by taking too much of the oxygen in the immediate environment. When the nitrate rich fertilizers are used and the fields drain into public water supply, water may become undrinkable because high concentrations of nitrates can be toxic. Agricultural use which includes animal husbandry poses an additional problem. For example, animal excrement in pastures, may also be carried into the hydrologic cycle by rain which combines with or carries along the waste into streams or ponds. Animal wastes also contain a high amount of nitrates, and where such wastes are concentrated in a small area such as a feed pen, they pose a substantial threat to the potability of water.

The land use with the greatest deleterious impact on water quality by a substantial margin is industrialization. We are now going to consider the many and various ways in which urbanization influences water quality. It is helpful in such consideration to identify two different types of influences. Sources of pollutants which can be clearly and distinctly identified are called point sources. Sewage treatment plants, industrial discharge, and sanitary landfill are examples of point source pollution. Sources of pollutants which cannot be so easily identified are called "non-point sources". Examples of such sources are sediment from erosion, street runoff, and septic tank effluent.

Turn to slide # 11. S. #

Let's look first at pollution by point sources. Municipal sewage treatment plants generate several kinds of pollutants, depending on what chemicals are used to treat the sewage. In any case, organic wastes are put out into the hydrologic cycle. These organic wastes are broken down and purified by aquatic organisms. Organic wastes have a high biochemical oxygen demand (BOD). This means that the bacteria which decompose and purify these wastes use a great deal of oxygen to perform their natural function. Large concentrations of such wastes overload the natural balance of the system. If the bacteria get the oxygen they need, this reduces the oxygen available for other organisms. If the other organisms take the oxygen then the efficiency of the bacteria is reduced. This delays the purification of the wastes which thus prolongs the pollution that occurs. This pollution by organic wastes is often only a part of the pollution by sewage treatment plants. When communities combine storm sewers which collect storm water from their streams with their sewage treatment plants, other pollution occurs. The oil and dissolved heavy metals which are collected by storm runoff are often not effectively treated by the sewage treatment, or even when they can be adequately treated they may occur in too high a concentration. Or, the combined quantity of sewage and storm water may be too much for the plants capacity. In any of these situations, the pollution problems of the sewage are compounded and there is additional pollution from the oil and heavy metals which cannot be adequately separated from the water the plant releases.

Sewage treatment plants generally dispose of their final products in streams or rivers. This means that the actual polluting impact of the treatment plant depends in part on the size and speed of flow of the receiving stream or river. The larger the river the more able it is to dilute the pollution it receives to a lower concentration. Pollutants at a lower concentration can then be removed by natural processes. For this reason it is important to preserve the base level of stream flows by assuring adequate ground water recharge.

Industrial discharge causes problems similar to sewage treatment plants. The most pervasive difference is that industrial wastes may be composed of a varied and complex mixture of pollutants. The type of pollutants these discharges put into the hydrologic cycle depend on the particular industry. Some of the by-products of the industrial processes may have a higher toxicity than natural wastes. Since toxic industrial discharges are emptied into bodies of water this means that industrial wastes may pose an even greater threat to water quality than sewage treatment waste.

Heat may be a particular pollutant of an industrial discharge plant, as of generating or power stations as well. Water that carries away heat is warmed. Warm water can hold less dissolved oxygen. Thus, water with a lower dissolved oxygen content is less able to maintain the organisms that are needed for the natural purification process. Indirectly, heat in water causes a decrease in water quality.

On guide sheet # 21 there is an illustration that will help explain the connection between a sanitary land fill and water quality. Sanitary landfills are more of a danger to the quality of ground water than of surface runoff or of stream water. In a sanitary landfill, waste is placed on top of land. After a rainstorm, water passes to the ground through this waste. The water picks up and dissolves some of this waste. As with water which has dissolved pesticides, fertilizers, or other minerals; these wastes, called leachate, then infiltrate the ground water. These infiltrated pollutants may then reach the ground water from which a well draws its water. This situation is shown in guide sheet # 21. The severity of this pollution depends on the depth of the water table below the landfill, the permeability of the soil and the contents of the landfill. The deeper the water table and the less permeable the zone of aeration, the more opportunity there is for the water to be naturally pruified before it reaches the water table from which wells draw their water. The more toxic the landfill contents the more purifying activity that must take place in order to maintain the high quality of water. G.S # 2

Such groundwater pollution is a particularly vexatious problem, because it may take years for this pollution to show up and be traced to its source. By this time the pollution has spread far beyond its source and may therefore be difficult to alleviate in all its instances. Furthermore, becuase the aquifer has been thoroughly polluted for a period of years it can be years again until the aquifer is purified naturally and therefore usable again.

These problems can be avoided by proper selection of a landfill site in conjunction with test wells to monitor the quality of the ground water. Obviously, the landfill should not be placed above important aquifers. For further discussion of the siting of sanitary landfills refer to the Synthesis - Buildability A-T unit.

Yet another potential source of pollution of ground water supplies is from highways and streets, through spillage of contaminants and from de-icing salt applied during the winter months. Spillage of large volumes of liquids from tank trucks as a result of traffic accidents poses a serious threat because a large slug of contaminant can be injected into ground water recharge systems. Leakage of fuels from underground storage tanks, used in all filling stations is a related source of possible contamination.

Both the State and Federal governments are concerned about point-source pollution and have instituted programs to prevent more pollution by these sources. A comprehensive treatment of such programs is given in the units concerning State and Federal Implementation. It can be mentioned here, however, that the basic thrust of federal legislation is to require individuals, business or corporations in charge of point source polluters to obtain a permit to engage in their operation. Since there are requirements which must be met to get a permit, the Federal government in conjunction with the State government is then in a position to regulate the polluting capacity of these point-source pollutors.

Non point sources of pollution are no less common, but they are more difficult to identify and therefore more difficult to control than point source pollutors. Take for example, the everyday street runoff after a rain. In an area without storm sewers, the water which falls on streets runs off into drains and ditches, which take the water to a nearby stream. Since this rain picks up the oil, grease, dirt, salt, organic matter and even small bits of heavy metals that lie on most streets, these pollutants are also led to the nearby stream in the storm water runoff. They are not treated at all before they get into the hydrologic cycle, so it takes more natural energy to neutralize their deleterious effect on the quality of water. If the drains and ditches lead to a low spot of ground instead of a stream, then these pollutants infiltrate the soil along with the water. The suspended pollutants - oil, dirt, organic matter - may be removed as the water passes downward, but dissolved pollutants like chlorides from road salt reach the ground water. As stated above, polluted ground water poses a particularly vexatious problem.

Septic systems and leaky sewer pipes are a common non-point source pollutor. If you are not familiar with how a septic system works, refer to the Geosystems unit which gives a full description of the operation of septic systems. A diagram of a septic system is presented on guide sheet # 22. The basic operation depends upon absorption of the wastes by soil. Where the permeability of the soil is less than adequate, or the land slopes more than 15% or the maximum water level is less than 18 inches below the tile field, or the absorption fields are within approximately 50 feet of a stream, or there is not a sufficient depth of soil before rock is reached (about 4 feet with average soil) pollution results. In these cases, the soil is not able to properly filter out the bacteria, nitrates, phosphates and other organic wastes before the overflow from the tank reaches the ground water or a stream. The hydrologic cycle then receives water of low quality at these points. In places where the water table rises substantially during the wet season, or where the soil has a very slow absorption rate, the overflow can surface on top of the soil. This not only smells bad, but it also attracts flies and insects which breed disease. Water flowing over the surface or leaching the pollutants back into the ground then become a more hazardous source of pollution.

G.S. # 22

Erosion is a problem which is not often thought of as affecting the hydrologic cycle. More often it is thought to be caused by flooding or heavy runoff, which carries soil from exposed and unprotected areas to be taken away by the rushing water. While it is true that water causes erosion, the other side of the relation between erosion and the hydrologic cycle is that erosion seriously threatens the quality of water in the cycle. Guide sheet # 23 lists this and other effects of erosion and the sediment which results from it upon the water cycle and its related aspect.

G.S. # 23

Let's consider how erosion occurs and how it causes these effects. The construction in slide # 12 shows a common practice of clearing vegetation from the site by extensive grading,

S. #

cutting and filling. This lack of vegetation leaves the soil bare so that rain or surface runoff can break soil particles loose from others. These separated particles are then carried off by the surface flow, leaving behind a weakened soil surface. Not only does vegetation protect and hold the soil together, it also takes up some of the rain or surface runoff for its own growth This reduces both the volume and spread of the surface flow, thus making it more difficult for the water to dislodge the soil particles. But, when soil particles are dislodged and carried along, the sediement eventually muddies or dirties a nearby stream or body of water.

The amount of erosion that occurs depends on many factors - the size of area cleared, the steepness of the slope, the porosity of the soil, and the intensity of the rainfall or surface flow.

The amount of pollution that such erosion produces will depend then on whether this sediment carried by the surface flow reaches a stream or water body. If the cleared area is below a water course, or if vegetation exists on land bordering the cleared area which is enough to interfere with or slow the flow of sediment, the water course will not receive the pollution. However, remember that once erosion in one area begins, it tends to expand. Each bit of erosion weakens the soil that is left and thus makes erosion more probable in the future. When an area is severely eroded the surface water flow meets little resistance so its velocity increases as in slide # 13. S. #
A previously vegetated area next to a highly eroded area may thus become a potential target for erosion if the eroding waters rush across it with strong force.

The basic way to prevent the harmful effects of sediment upon the water cycle is to avoid erosion. Here then is an example where water quality can be maintained by controlling another aspect of the hydrologic cycle. If water is diverted from flowing over steep and cleared areas, and if large land clearance is avoided or minimized as is possible and revegetation is accomplished as quickly as possible, less erosion will occur. Where these things cannot be done, the effects of erosion that does occur can be minimized by slowing the flow of surface runoff carrying sediment and by trapping sediment. This is accomplished by planting and maintaining borders of vegetation along stream beds, by graded terraces along a slope, or even by sediment basins.

Each plan must include a program to regulate the "location, modification and construction of any facilities" (emphasis added) within the planning area which may result in the discharge of any effluent in the area." The term "facilities" is not defined in the law, but this provision appears to require a land-use regulation program for all point-source development within the planning area. It also requires control over the construction process; hence, it must regulate the non-point pollution stemming from construction of point sources.

It is the intent of this section to identify various methods of land use control which the local governments and the management agency of the 208 program can utilize to control pollution. This will enable the area to make tradeoffs between structural solutions (e.g., treatment facilities) to pollution problems and nonstructural solutions such as land use, thus increasing flexibility in the choice of methods used to achieve water quality standards. The 208 planning process seeks to balance all measures of pollution control in such a manner as to achieve the best mix of all measures as determined by direct cost, environmental, social and economic considerations.

In essence, Section 208 of the Federal Water Pollution Control Act requires basin areas to plan in advance for new and existing water pollution created or fostered by existing or planned land uses. This program has only recently begun to be implemented but has the potential of being an effective tool in the land use decision making process.

Planning to prevent water pollution can have unexpected side effects on land use. The Federal government, throught the EPA, has financed many miles of interceptor sewer constructions in hopes of alleviating water pollution from sewerage. A recent executive branch report concluded, " However, this is not to say that the building of interceptors has no influence on housing development patterns. The availability of sewers is an incentive to development, and the routing, sizing and timing of new interceptor construction can be a valuable tool for guiding residential land use as part of a comprehensive master plan. But in order for this to be effective land use and sewer planning must be more effectively coordinated than they are at present. If the federal government wishes to encourage careful land use planning and control at a local level, it can begin by evaluating the extent to which the current design.review and approval process for federally financed interceptors takes into account the land use implications of sewer construction."

In addition, the study concluded that municipalities were building unnecessarily large and extensive sewer projects in response to local development pressure. Interceptor lines are sized with tremendous excess capacity and designed to serve the ultimate, highest density population anticipated for large service areas containing large tracts of vacant, developable land. The report raised the question - Does such sewer construction make land use and population projection self-fulfilling? (Pause - quiet)

Before concluding the hydrosystem unit, consideration of the hydrosystem in direct relation to land use decisions is in order. Turn to slide # 14. The slide of the for sale sign in a flooded area may evoke a smile to some but to others water is a serious problem in relation to their land uses. Problems can vary from lack of fresh water in a well, to contaminated ground water, to flooding or to inoperative septic systems. The hydrosystem is an important aspect of land use decision making. S. #

To summarize the implications of the hydrosystem on land use decision making, an outline has been prepared on guide sheet #24 containing important hydrosystem considerations. The outline explains the rationale for each consideration as well as indicating the need for protection, the existence of regulations, and the potential for higher development costs. It will be useful to refer back to the outline as you are synthesizing the considerations from other units to make your land use decision. G.S. # 24

It is now time to conclude this unit on hydrology. In doing so, let's look in a more general way at the erosion we have just learned about. Erosion and sedimentation are caused by the quantitative aspect of the hydrologic cycle as it interacts with particular land uses. During the building of urban dwellings or commercial buildings, land is used in such a way to make it vulnerable to uncontrolled natural water flow. The consequence of this vulnerability is erosion and sedimentation, which has harmful effects of both the land and the quality of water in the hydrologic cycle. Where man injects himself into the hydrologic cycle by his land use decision he must responsibly confront the effects of his intervention. Barry Commoner's fourth law, states this more concretely: "There's no such thing as a free lunch." Thus if he desires to keep his water clean for drinking, swimming and even boating, man must control his intervention and also learn how to act sympathetically with the natural hydrologic cycle. In the case of preventing erosion and sedimentation at urban construction sites, this means not building on vulnerable sites, not clearing away more vegetation than is absolutely necessary, replacing the vegetation he temporarily removes and making extra artifical structures such as drainage ditches and sediment basins in order to support weakened natural resistance to erosion.

Where man puts stress on natural processes, he must support those processes during the time of his intervention. What man takes from nature he ultimately must put back, even if in another form

This concludes the hydrology unit. Thank you for following the flow of water as it passes through the hydrologic cycle.