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THE RELATIONSHIP OF MAN'S SETTLEMENT SYSTEM TO THE NATURAL SYSTEM

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INTRODUCTION

This paper will focus on the relationship between man's settlement system and the natural system. For the purposes of this discussion, man's settlement system is considered to be composed of man's processes, both physical and non-physical (cultural); the users, both direct and indirect, who are involved with the processes; the artifacts required by the processes and users; and the space which the which the processes, the users and the artifacts need to function. Anywhere from 32 to 52 percent of a city's land area is devoted to residential processes, 2 to 4 percent to commercial, 9 to 13 percent to industrial and transportation, and 4 to 14 percent to institutional, open space and residential activities.[1]

The natural system is composed of land, water, air (as well as the processes which occur in each of these mediums), and the environmental users. These components can be further broken down. Land is composed of physiographic considerations, soils, and geology. Water is composed of atmospheric, surface and subsurface water. Air is a medium for a number of things, including the climatic processes: temperature, precipitation, humidity, air movement, and solar radiation. And finally, there are the environmental users: vegetation, animals (including man), birds, fish, and the lower life forms, who use the natural system.

In the past, man's ability to alter the environment has been limited by technology. As technology progresses and as population increases, man becomes more of an environmental agent.

1. A. Woleman, "Metabolism of Cities" Scientific American, (August, 1965), page 175.

For this reason we can no longer rely on man's inadequacies as a protective control. It is this author's contention that people are basically good and, if they were aware of the consequences of their actions, they wouldn't abuse and destroy the natural system.

Therefore, it is the purpose of this paper to examine this man-nature relationship, to assess how man uses the natural system and what impact his activities have on it, and also how the natural system influences, both positively and negatively, man and his processes. This set of relationships is graphically illustrated in the accompanying Environmental Planning Consideration Matrix. Both man's system and the natural system are broken down into their basic components and are displayed in a matrix form. This matrix can be used as a conceptual model in determining what and how the various components of the two systems relate. The matrix can also be used to "score" (to determine how well a landuse or group of landuses "fit" a specific site) a given piece of land, water or air.

It is hoped that the information generated in this paper will provide an information base and a systematic framework for making ecologically viable development decisions.

LAND

Man's relationship with the natural system is basically one of consumption: his activities and artifacts consume large amounts of land, air and water. For example, each addition of six persons to a city's population requires that one acre of non-urban land be converted to urban use.[2] It is estimated that each year some 1,000,000 acres of farmland and other non-urban land is consumed by urbanization.[3] Man's transportation system offers another good example of this consumption. In the United States, there are 3.6 million miles of roads and street, or about one mile of road for every square mile of land. About 24,000 square miles of land is covered by roads and their rights-of-way. Freeways consume about 24 acres of land per mile of highway and some 80 acres for each interchange.

Physiography, soils and geology comprise the land system component. Slope, perhaps, exerts the most limiting influence on man and his activities of all the physiographic components. Man's processes and their respective equipment, with the exception of some recreational activities, require relatively flat sites. Minimum slope (that slope which is great enough to ensure adequate surface drainage) is determine by the drainage capabilities of the various surface materials. Maximum slopes are determined by the inherent limitations of the construction and operation of process equipment. For example, automobiles don't function efficiently on slopes in excess of 8 percent. Equipment limitations,

2. Guy-Harold Smith, Conservation of Natural Resources (New York: John Wiley and Sons, 1971) page 615.

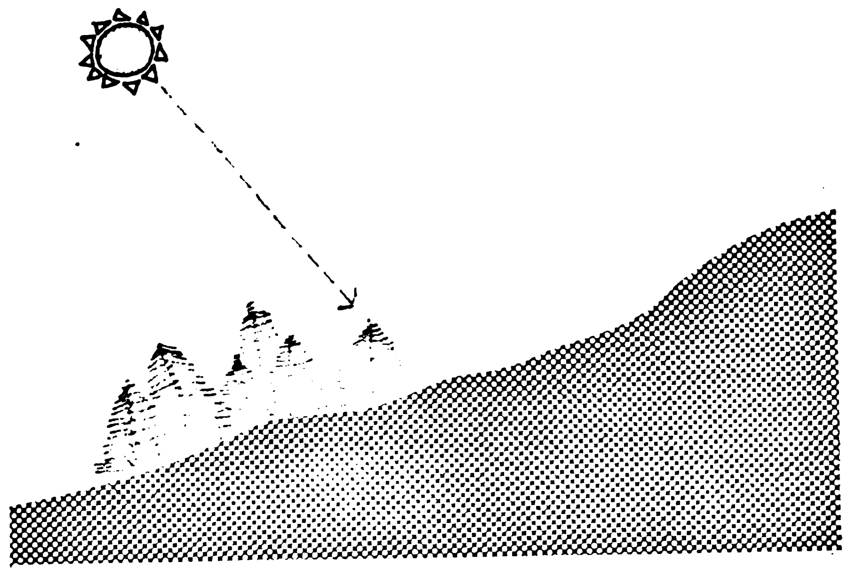
3. Time, February 2, 1970.

erosion hazards, and increasing building costs generally limit construction to slopes of 20 percent or less. Structures can, however, be built on slopes as great as 40 percent, but the cost is excessive.

Table #1 COMMON SLOPE-LANDUSE REQUIREMENTS

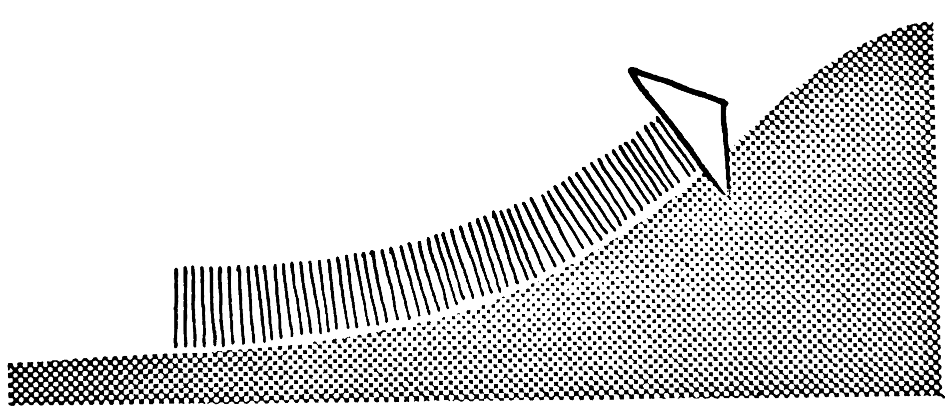
SLOPE USE	MINIMUM SLOPE	MAXIMUM SLOPE
public paved streets	1 percent	8 percent
private roads	1 percent	12 percent
parking areas	1 percent	5 percent
lawn areas	1.5 percent	15 percent
agricultural uses	1 percent	12 percent (erosion)
recreational (except hill sports)	1.5 percent	3 percent
building construction	1 percent	10 to 20 percent
industrial	1 percent	just enough to drain
general urban	1 percent	5 percent

Physiographic features also influence the climatic processes. For example, slopes receive either more or less solar radiation, depending on their orientation, than a flat site. This has great impact on vegetation productivity, as well as being a phenomenon which can be used advantageously to modify temperature extremes in both over and underheated periods.

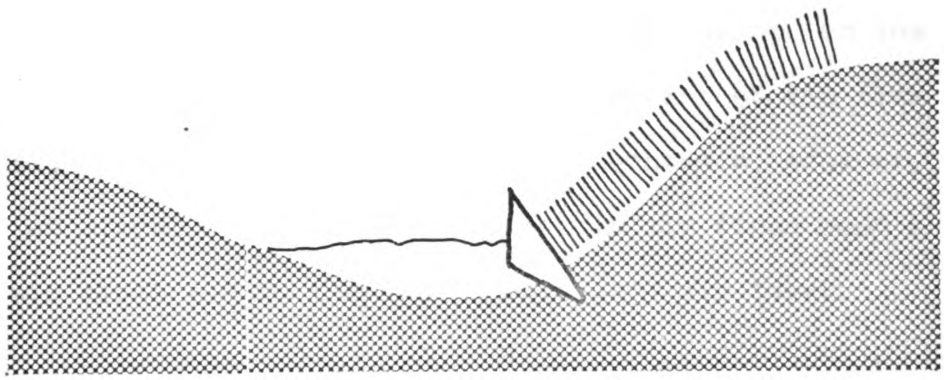


SLOPE AND SOLAR RADIATION

Landforms also influence air movement patterns. Warm air flows up slope during the day and cold flows down slope at night.

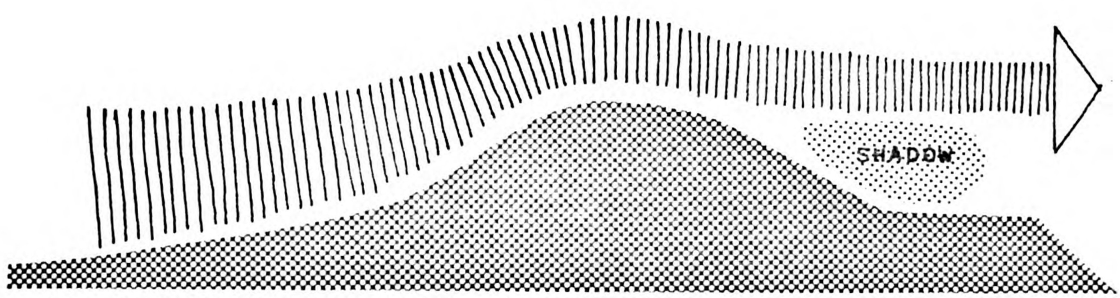


AIR MOVEMENT UP A SLOPE DURING THE DAY



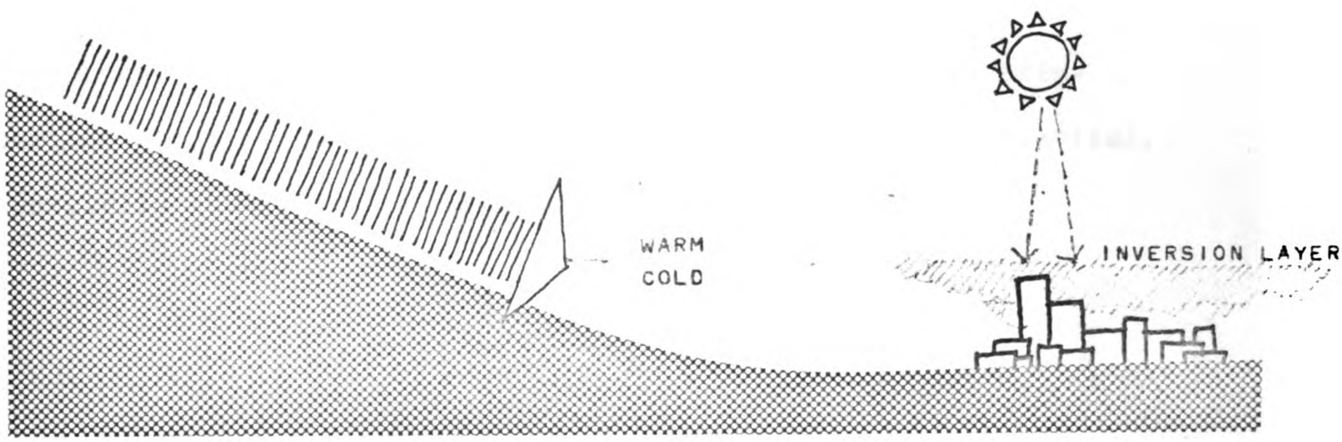
COLD AIR FLOWS DOWN THE SLOPE DURING THE NIGHT

Observations by Geiger have shown that wind flow is diverted by a hill or mountain in both its horizontal and vertical stream patterns, causing higher speeds near the top on the windward side and less turbulent wind conditions on the lee slope.



WIND SHADOW EFFECT

In many places mountainous landforms are partly responsible for the inversion layers over cities. Inversions, in the United States, happen anywhere from 10 to 50 percent of the time at elevations less than 500 feet. This phenomenon, however, can occur at almost any elevation where cold air flows down a mountain slope and is trapped under a warm air layer.



COLD AIR FLOWING DOWN A SLOPE TO CAUSE AN INVERSION LAYER
8

These inversion layers usually dissipate in the afternoon as the sun begins to heat up the surrounding air enough to start it moving again. To alleviate these inversions, then, cities should be planned so that they are adequately ventilated and located away from potential inversion areas.

Elevation is yet another physiographic limitation. Due to man's adaptation capabilities, elevation is not as much a limitation to him as it is to vegetation and the other environmental users.

And finally, landforms function aesthetically as a sculptural medium. Landforms, whether natural or artificial, by their very presence, manipulate and articulate space. This is of course on a large scale. These masses form patterns and spaces which can and should be utilized by man when placing his processes and artifacts on the land. The aesthetic qualities (sense of place, enclosure, form, line, texture, color, mass, dominance, sequence, scale, diversity, symbolism, visual stimulation etc.) of natural landforms offer much aesthetic potential, especially to residential and recreational activities.

SOILS

"Our most valuable natural asset is the soil. The survival and prosperity of terrestrial biological communities, whether natural or artificial, depend on this layer. As in the earliest days, and in spite of the progress of synthetic industries based on mineral products, man draws almost all his substance and most of the raw materials for his clothing and everyday needs from this source."[4]

Soil affects, either positively or negatively, man's processes in several ways. First, soil is an agricultural medium. A soil's moisture content, drainage characteristics, and fertility are all factors which determine its productivity. Soil is also an engineering variable which can affect the location, design, construction and maintenance of process equipment such as buildings and roads. A soil's workability will, to a large extent, determine how the soil can be worked as a sculptural medium. A stony soil, for example, will limit the effectiveness of earth moving equipment in sculpting the earth.

A soil's shrink-swell movement from either freeze-thaw action or moisture changes must also be accounted for when designing structures on that soil. Associated with this is a a soil's bearing strength. Foundations of structures and roads must be designed according to the soil's load supporting capabilities. The depth and corrosiveness of a soil have an impact on the location and design of structure foundations and utility systems. A soil, for example, which is too shallow makes

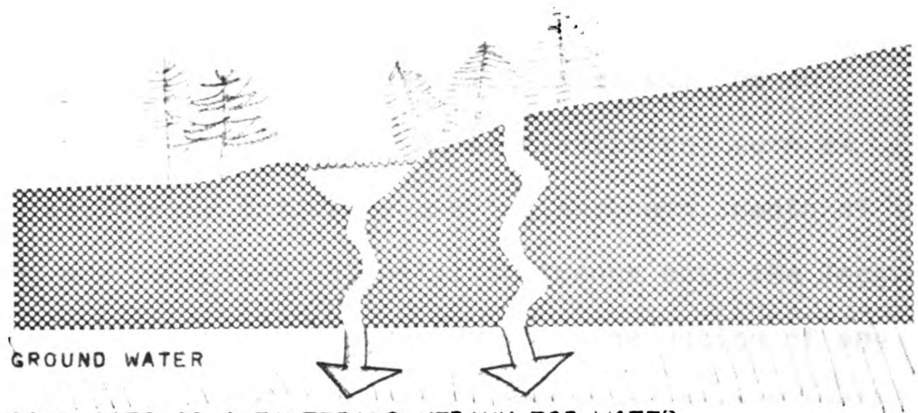
4. J. Dorst, Before Nature Dies (Boston: Houghton Mifflin Co., 1970) page 45.

subgrade construction extremely expensive for the reason that blasting is usually required.

A soil's infiltration and drainage characteristics determine how fast and to what extent a soil will dry out. A well drained soil is imperative to most landuses because both the soil structure and the vegetative cover suffer damage when they are subjected to use while the soil is too wet. This is especially critical in recreation. A soil's moisture content also influences the soil's bearing capacity and runoff characteristics. Also a soil's ability to absorb sewage effluent is dependent on that soil's drainage characteristics.

A soil's fertility is one of the variables which determines the type, quantity and quality of vegetation (this of course includes agricultural products) which a given piece of land is able to produce and support. A soil can also be a significant mineral resource. These resource minerals include sand, gravel, peat and clay.

Pollution is not limited only to the air and water. A soil can also become polluted as a result of pumping too much sewage effluent into it or from agricultural fertilizers, pesticides, or industrial and mining wastes. Since soils act as a filtering medium for water recharging the subsurface water system, it is imperative that soil's don't become polluted as the quality of the subsurface water can be no better than the soils above which have filtered it.



SOIL ACTS AS A FILTERING MEDIUM FOR WATER

Soil erosion is natural; but usually occurs at a very slow rate. Water and wind erosion reach a damaging degree when the natural groundcover is removed without substituting a substantial artificial equivalent. The impact of erosion is far reaching. Not only is the productive topsoil carried away, but once it finds its way into the surface waters, it seriously impairs the functioning of fish, vegetation and the lower life forms. Eventually this sediment is carried downstream until it either stops at an obstruction, such as a dam (whereupon it piles up) or it runs on into larger water bodies creating major changes in the natural conditions.

GEOLOGY

Geology relates to man and his activities as both an engineering variable and as a resource material. As an engineering variable, geological characteristics, such as stability, earthquake activity, bearing strength, depth of the overburden, and pollution potential influence both the location and the design of the process equipment. The design of any structure, whether it is a bridge, a dam, road or a building, is, in part, determined by the site's stability. Foundations and underground structures and equipment, such as utilities, are influenced by the depth of the overburden as well as by the characteristics of the geological material itself. The characteristics of this material also determines whether subsurface water is present and also whether it can be extracted. And finally, geological mineral resources offer a basic material for man to use in numerous ways.

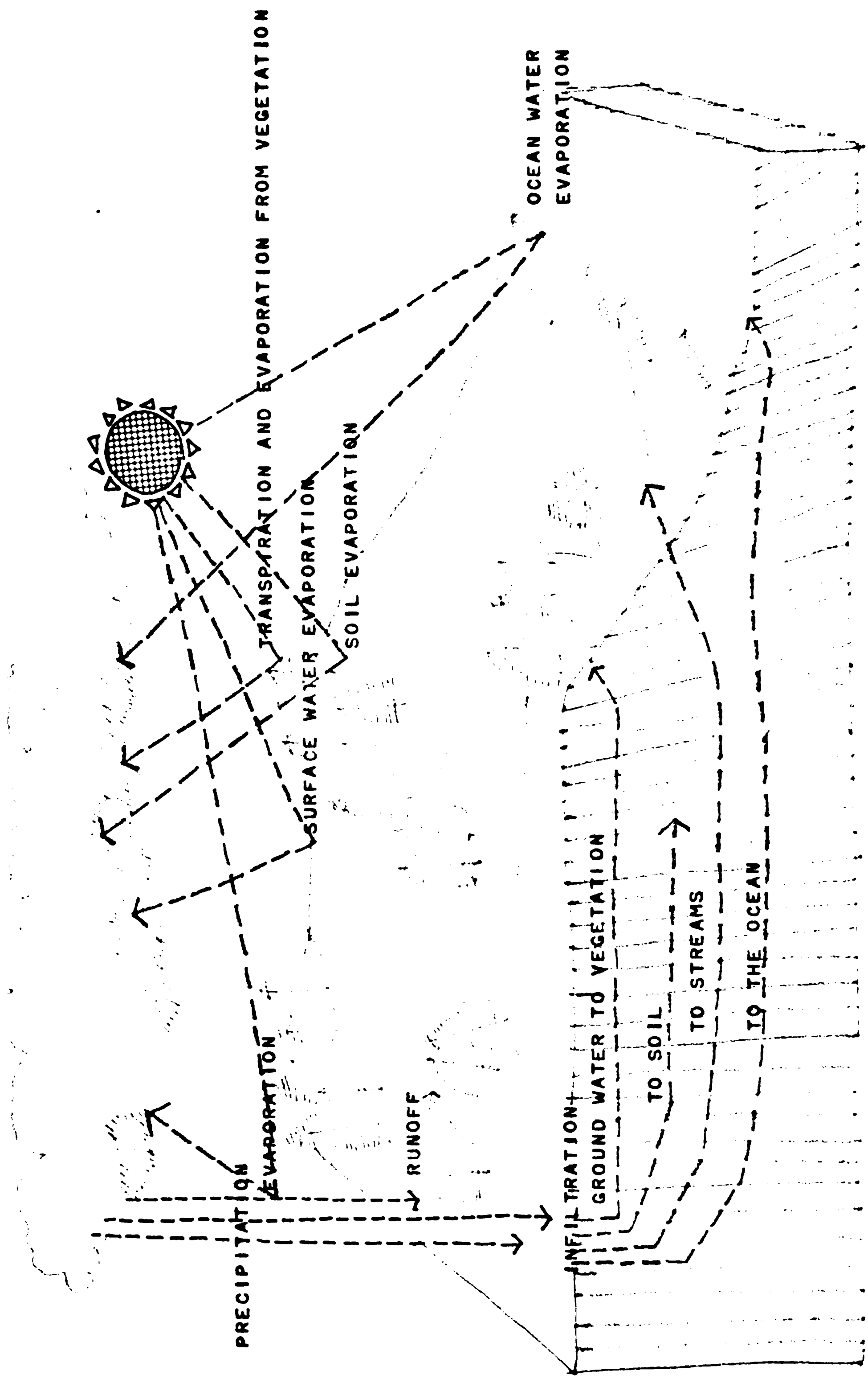


PLATE #1
THE HYDROLOGIC CYCLE

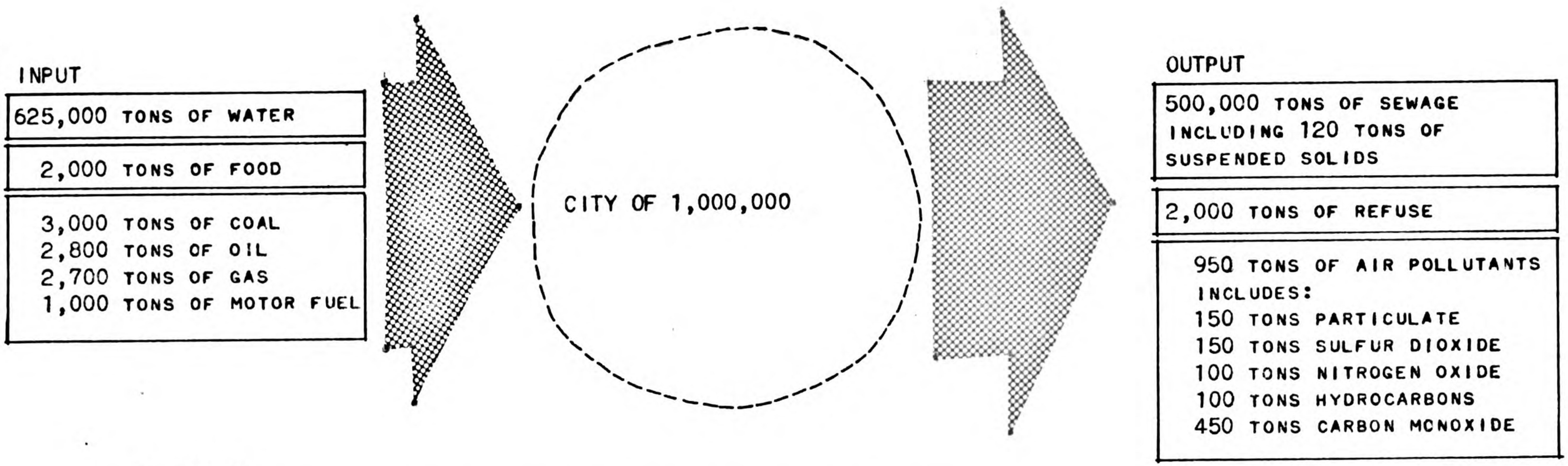


PLATE #2
INPUT-OUTPUT FLOW PER DAY OF A TYPICAL CITY OF 1,000,000...
taken from "Metabolism of Cities," A. Woleman, Scientific American, August, 1965, page 179.

WATER

Man has great impact on the hydrologic system. His settlement system not only consumes large quantities of water, as illustrated in Table #2, but also alters the water quality. This section will examine how man uses the hydrologic system and will also assess the potential value of the use of this system in the urban environment.

Approximately 80 percent of the water consumed in the United States comes from surface sources while the remaining 20 percent comes from groundwater supplies. The following table points out that man's water consumption is growing with time.

Table #2
DOMESTIC AND AGRICULTURAL WATER USE IN THE UNITED STATES in billion gallons per day...taken from Water Facts, USDA, SCS, publication number PA-337.

year	domestic and municipal	industrial	agricultural irrigation	total
1900	3.0	15.0	22.2	40.2
1920	6.0	27.0	58.4	91.6
1950	14.0	77.0	79.0	170.0
1960	21.0	140.0	110.0	271.0
1980	29.0	363.0	161.0	553.0

Agriculture is the greatest water consumer for the reason that only 50 percent of the water used in irrigation is actually returned to where it originally came from. Approximately 83 percent of the water taken for municipal use is returned to the the urban surface waters; and about 98 percent of the industrial water is returned.

It is interesting to note that while the United States' population doubled between 1900 and 1950, the nation's total water needs increased four times. It is estimated that the potential water supply available for direct human use is about two times that of our 1980 requirements. In other words, the potential water supply in the United States is about 1106 billion gallons per day. About 95 percent of this fresh water is being used at a greater rate than its precipitation replacement. The point to be made here is that the hydrologic system is indeed a closed and finite system.

There are two principal effects of urbanization on water quality. First, the influx of waste materials from sewage plants tends to increase the dissolved- solids content and to decrease the oxygen content of the surface waters. Second, as flood peaks increase as the result of greater urban runoff, less water is available for the natural purification of ground-water recharging. Also, because more water flows downstream, less water recharges, and therefore less water is available between flood peaks for municipal supply and safe sewage dilution in the urban surface waters.

The Public Health Service estimates that approximately 20 percent of the nation's municipalities don't treat their sewage. About 30 percent use primary settling only, and about 60 percent use secondary treatment, which is the goal of the 1973 Federal water-quality standards. Primary treatment removes most of the trash and settles out about 30 percent of the effluent solids. In secondary treatment, bacteria reduces the organic wastes into sludge. Approximately 90 percent of the pollutants are removed by the sedimentation process; but phosphates, ammonia, and some organic matter still remain. Teritary treatment further purifies the effluent by removing some of these remaining phosphates.

The following example is a typical illustration of the effects that cities have on the water which they use. A city of 100,000 people consumes approximately 70 million gallons of water each day, and adds the following quantities of foriegn materials to the water as result of this consumption:

-17 tons of organic suspended solids
-8 tons of dissolved organic solids
-16 tons of dissolved solids
-1 ton of detergents
-60 cubic feet of grit

A city's treated effluent which is dumped into the urban rivers and streams is generally rich in nutrients and therefore causes rapid algae growth. This vegetation grows and dies and while doing so consumes oxygen which in turn threatens the fish life which is already experiencing a shortage of oxygen.

It is estimated that the amount of urban runoff is about three times that of rural runoff. Runoff volume is determined primarily by the infiltration characteristics of the surface material over which the water flows. It is also related to slope of the land, the type of soil, and the type and extent of the vegetative cover. It is, therefore, directly related to the percentage of area covered by roofs, streets, parking lots and other impervious surfaces at the time of the precipitation. The following table illustrates the relationship between lot size, and therefore the residential density, and the percent of impervious surface and the amount of runoff to be expected.

TABLE #3
LOT SIZE AND IMPERVIOUS SURFACE RELATIONSHIP...taken from "The Hydrologic Effects of Urban Landuse", L.B. Leopold, page 206, Man's Impact on Environment, T.R. Detwyler, ed.

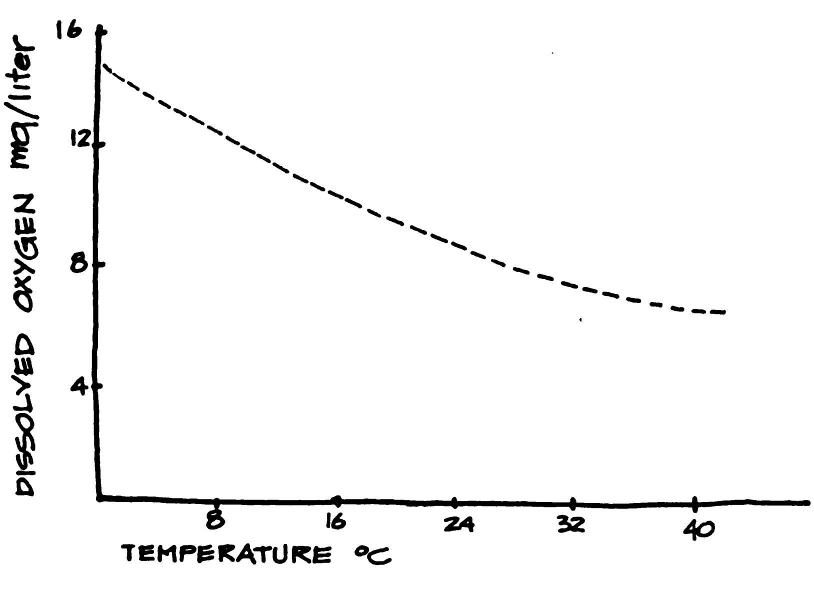
LOT SIZE in square feet	IMPERVIOUS SURFACE in percentage
6000	80
6000 to 15000	40
15000	25

The articficially high amount of urban runoff allows less water to infiltrate into the ground and therefore to recharge the groundwater supplies. This situation is often aggravated even further when urban development is allowed to cover over aquifer recharge areas. This is the primary reason for the rapid depletion of the uderground water reservoirs.

The articficially large quantity of urban runoff is often responsible for erosion which lowers the water quality by adding sediment to it. The principal effect of landuse on sediment comes from the exposure of the soil to storm runoff. This occurs primarily when the groundcover is stripped off, exposing the soil, as in the construction process. This sediment production is also a function of the slope of the land surface.. The greater the slope, the more severe the erosion and the sediment problem. The sediment yield in urban areas tends to be greater than in non-urbanized area even if there are only small and widely scattered units of unprotected soil in the urban areas. Sediment has damaging effects on such environmental users as fish, insects, and the vegetation.

Water quality can further be altered by what is referred to as thermal pollution. As the temperature of water increases, its ability to hold oxygen decreases. This is critical because the presence of dissolved oxygen is probably the single most critical factor in the biology of the aquatic environmental users and processes. The following graph illustrates this relationship between water temperature and its oxygen content. "As temperature

GRAPH#1
WATER TEMPERATURE AND OXYGEN CONTENT...taken from Environment and Man, R.H. Wagner, page 137.



increases, the quantity of dissolved oxygen decreases, but the respiration and oxidation rates double for every 10^{o} C increase."[5] What this means, then, is that, in order for fish to survive in thermally polluted water, the water must have a higher oxygen content. This problem is aggravated in cities because the urban surface waters are already low in dissolved oxygen because of the fact that sewage effluent consumes oxygen. Water temperature also interacts with other factors as well, For example, a fish's ability to withstand certain environmental impacts is directly related to water temperature. A higher water temperature normally lowers a fish's immunity. A further consideration is that the life cycle of many aquatic organisms is delicately geared to the water temperature. Fish are often distributed, migrate, and spawn in response to temperature cues. When this natural temperature is artificially changed by thermal pollution, havoc inevitably results.

The amenity value of the hydrological environment in the city is affected by three factors. The first factor deals with the stream channel. The urban stream channel which has gradually been enlarged due to increased floods caused by the high urban runoff tends to have unstable and bare banks, scoured and muddy channel beds, and a heavy accumulation of trash. The second factor is the usually ugly accumulation of urban artifacts in the channel and adjacent floodplain. More often than not, the least visually

5. R.H. Wagner, Environment and Man (New York: W.W. Norton Co., 1971) page 139.

pleasing and oldest structures are located near the urban streams and rivers. The third factor is the change brought about by the disposal of sewage effluent in the city's surface waters. The nutrients in the effluent promote the grcwth of plankton and algae. This can tranform a clear river or stream into one where the rocks and banks are covered with a foul-smelling slime. Also, as turbidity and temperature increase, game fish give way to less desirable soecies which are able to tolerate the more polluted water; if the water quality becomes too low, nothing will live in it.

"Streams flowing through cities, especially, could enhance the quality of urban life if they were properly managed and understood, although the variety and complexity of urban effects on hydrology appear to work against this."[6] It is indeed sad to see the majority of our urban centers turn their backs on the potential of their surface waters and use them only for sewage dilution.

If our water resources are to be available in the future for ALL the environmental users, we must rethink our traditional view that the water system is an infinite, free waste-disposal system, for it is this kind of thinking which perpetuates the all-to-common abuse of the whole natural system.

6. L.B. Leopold, "The Hydrologic Effects of Urban Landuse," Man's Impact on Environment, ed. T.R. Detwyler, (New York: McGraw-Hill, 1971) page 214.

AIR

Man's processes and artifacts have great effect on the atmospheric system. This sytem is composed of two things: air, which has both quality and quantity characteristics, and the climatic processes (temperature, precipitation, humidity, air movement, and solar radiation) which occur in this air medium.

Cities are commonly referred to as "heat islands" for the reason that they usually tend to be warmer than the surrounding countryside. This phenomenon can be attributed to several things. First, the surface materials of an urban area and those of the more "natural" surrounding area differ greatly. Because the materials of a city's buildings and streets conduct heat about three times as fast as wet sandy soil they are able to heat up faster and to a higher temperature than the countryside. Second, since city structures have a greater variety of shapes and orientations than the natural landscape, there is more surface area in cities than in the country. This enables a city to heat up the air in it faster than the surrounding area. Third, cities and their processes generate heat. Fourth, a city tends to be warmer because of the manner in which it disposes of the precipitation which falls on it. Some of the precipitation which falls on the country runs off, but some is left to be evaporated. Since evaporation consumes heat, the temperature will drop. In a city, however, most of the precipitation runs off, leaving very little to be evaporated, whereby no heat energy is consumed, which means that the temperature will not drop. Finally, the composition of city air tends to retard the escaping of city heat.

Although little research on humidity has been done, the consensus of urban climatologists is that the average relative

TABLE #4

CLIMATIC CHANGES PRODUCED BY CITIES (after Landsberg, 1962)... taken from "Climate of the City," J.T. Peterson, Man's Impact on Environment, T.R. Detwyler ed., page 132.

CLIMATIC ELEMENT	COMPARISON WITH THE RURAL ENVIRONS
Temperature	
annual mean	1.0 to 1.5^{o} F higher than the countryside
winter minimum	2.0 to 3.0^{o} F higher than the countryside
Relative Humidity	
annual mean	6 percent lower
winter	2 percent lower
summer	8 percent lower
Dust particles	10 times more
Cloudiness	
clouds	5 to 10 percent more
fog-winter	100 percent more
fog-summer	30 percent more
Radiation	
total on flat	15 to 20 percent less
ultraviolet-winter	30 percent less
ultraviolet-summer	5 percent less
Wind speed	
annual mean	20 to 30 percent lower
extreme gusts	10 to 20 percent lower
calms	5 to 20 percent more
Precipitation	
amounts	5 to 10 percent more
days with less than .2 inch	10 percent more

humidity in cities is several percent lower than that of nearby rural areas. The main reason for this difference is that the evaporation rate in a city is lower than that of the country because of the markedly different surfaces.

Cities also tend to be cloudier and have more smog than the surrounding countryside because of the concentration of particulate matter which is found in city air. The blanket of particles over most large cities causes a significant reduction in the solar energy which reaches the city.

The flow of air over a city differs in several ways from that over the surrounding natural landscape. Since the surfaces of a city are much rougher than those of the natural terrain, the air which passes through the city is slowed down due to the frictional drag. A city's "heat island" effect in conjunction with this friction also tends to produce more air turbulence over the city.

A city also influences the occurrence and quantity of precipitation in its area. Typically, a city will recieve more precipitation than the surrounding area for the following reasons: 1. Combustion sources in the city add to the quantity of water vapor already in the atmosphere; 2. The higher temperatures of the city tend to intensify thermal convection; 3. A city's greater surface friction increases the atmosphere's mechanical turbulence; and 4. The urban atmosphere contains large amounts of condensation concentrations.

"Normal air" is composed primarily (99.99 percent) of four gases: nitrogen, oxygen, argon and carbon dioxide. These gases are not permanent features; each is the result of a delicate process where it is formed and removed. Oxygen, for example, is formed in the photosynthetic processes of vegetation and is removed by animals (including man), by combustion and by slow oxidation of the minerals on the earth's surface.

"All creatures live by a process of converting one form of energy into another. Man has raised himself above the animal level to the extent that he deliberately converts this energy by processes outside the limitations of his body. All extensions of the human senses, of the human frame, and of the human muscle, which is to say, our tools and the trippings of civilization, use this energy. Energy conversion has certain material by-products. When they become airborne, in sufficient concentrations to be troublesome to man, we call the resulting airborne material "air pollution".[7]

According to the United States Health Service, approximately 192 million tons of pollutants are dumped into the atmosphere each year in the United States alone. Forest fires supply an additional 17 million tons. Table #5 illustrates the kinds and quantities of these air pollutants. As indicated, transportation accounts for the bulk of this pollution; automobiles account for the majority of transportation in the U.S. Approximately 99 percent of the 90 million motor vehicles in the U.S. are powered by gasoline engines. These engines pollute from two sources: the gasoline looses hydrocarbons and gasoline additives

7. Air Conservation Commission, "Air Conservation and the Kinds Air Pollutants," Man's Impact on Environment, ed. T.R. Detwyler, (New York: McGraw-Hill, 1971), page 86.

SOURCE / POLLUTANT	CARBON MONOXIDE	PARTICULATES	HYDROCARBONS	NITROGEN OXIDES	SULFUR OXIDES	TOTAL
TRANSPORTATION AIRCRAFT, CARS ETC.	64.5	1.2	17.6	7.6	.4	91.3
FUEL COMBUSTION IN STATIONARY SOURCES	1.9	9.2	.7	6.7	22.9	41.4
INDUSTRIAL PROCESSES	10.7	7.6	3.5	.2	7.2	29.2
SOLID WASTE DISPOSAL	7.6	1.0	1.5	.5	.1	10.7
MISCELLANEOUS	9.7	2.9	6.0	.5	.6	19.7
TOTAL	94.4	21.9	29.3	15.5	31.2	192.3
FOREST FIRES	7.2	6.7	2.2	1.2		17.3
TOTAL	101.6	28.6	31.5	16.7	31.2	209.6

TABLE #5

AMOUNTS OF AIR POLLUTION BY KINDS AND SOURCE PRODUCED IN THE UNITED STATES IN 1966 IN MILLION TONS

TAKEN FROM "SOURCES OF AIR POLLUTION," U.S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE, MAN'S IMPACT ON ENVIRONMENT, T.R, DETWYLER EDITOR, PAGE 93.

through evaporation, and the engine discharges hydrocarbons, and nitrogen oxides as waste products. Aircraft also pollute the atmosphere. One and one quarter ton of water vapor is produced for each ton of jet fuel that is burned. This vapor, in large enough quantities, can result in increased cloud cover which, in turn, can influence precipitation and decrease the amount of sunlight reaching the earth's surface.

Stationary sources of air pollution include electric generating plants and space heating system, as well as industrial operations, incinerators and so forth. More than 95 percent of the electrical energy generated in the U.S. today is produced by burning coal and oil.[8] Both of these fuels contain sulfur and, when burned, produce sulfur dioxide and nitrogen dioxides. The major industrial polluters in the U.S. are pulp and paper mills, iron and steel mills, petroleum refiners, smelters, and organic and inorganic chemical manufacturers. Industries discharge more than 20 percent of the nation's emissions of sulfur oxides and particulate matter and more than 10 percent of the carbon monoxide and hydrocarbons.

The production of solid wastes by residences, commerce and industry now exceeds 350 million tons a year in the U.S. and is growing at an annual rate of 4 percent.[9] Many local municipalities are forced to incinerate this refuse for lack of adequate landfill

8. U.S. Department of Health, Education and Welfare, Man's Impact on Environment, T.R. Detwyler ed., page 94.

9. Ibid., page 95.

areas.

All urban areas of over 50,000 in the United States have some kind of pollution problem. Approximately 88 percent of our urban population and over 50 percent of the total population live in these areas. What this means, then, is that an extremely large number of people are exposed to air pollution. Table #6 summarizes the effects of these verious pollutants on man and the other environmental users.

TABLE #6
POLLUTANTS AND THEIR EFFECTS ON THE ENVIRONMENTAL USERS.

POLLUTANT	EFFECT
carbon monoxide	Reduces the blood's oxygen carrying ability; damages the heart and slows body reactions.
particulate	Causes lang damage and impairs visibility.
hydrocarbons	Inhibits vision; damages vegetation and contributes to smog.
nitogen oxides	Irritates the respiratory system; damages vegetation and contributes to smog when combined with sunlight and hydrocarbons.
sulfur oxides	Causes lung damage, sensory irritation, corrosion and damages vegetation.
carbon dioxide	Carbon dioxide usually isn't considered to be a pollutant, but when added to the atmosphere in large quantities, it tends to disrupt the natural temperature balance.
	There also appears to be substantial correlation between air pollution and cancer and respiratory diseases.

ENVIRONMENTAL USERS

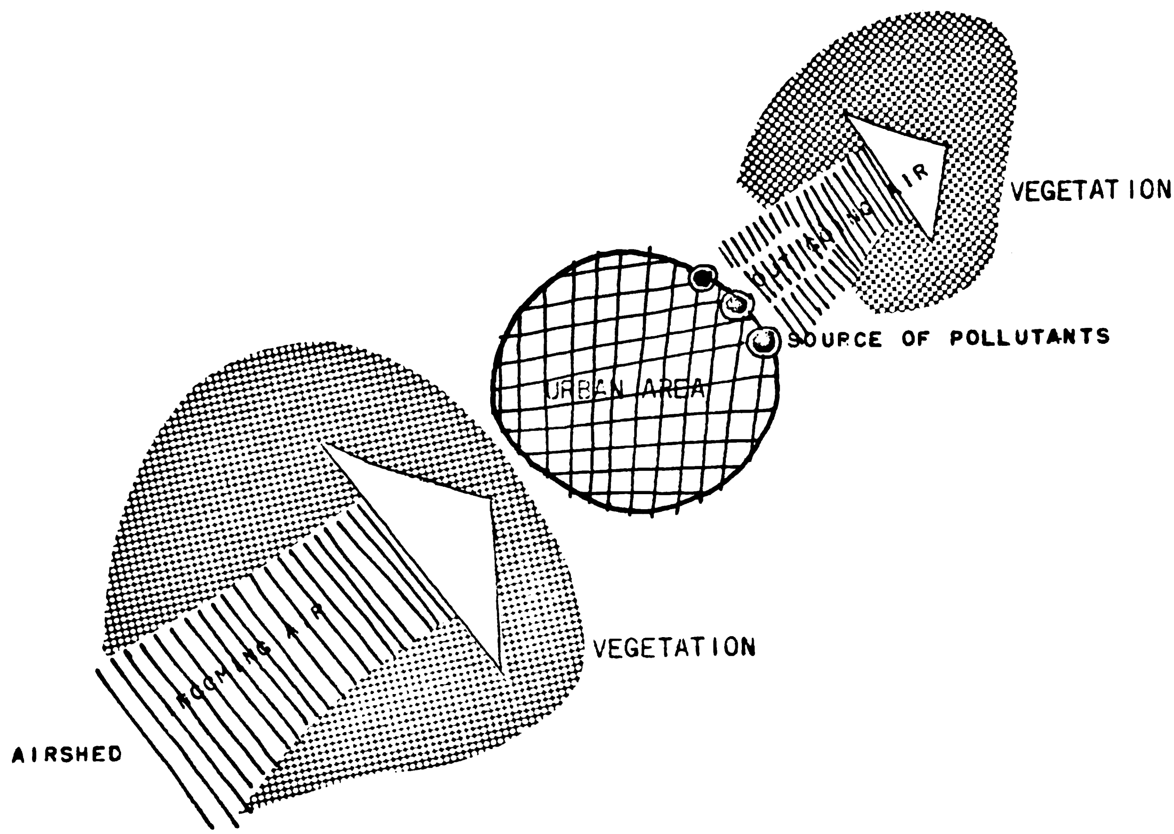
The environmental users are those life forms which use the natural system. These include vegetation, wildlife and animals (including man), birds, fish, and the lower life forms.

Man interacts with the first of these environmental users, vegetation, primarily on an architectural, rather than a planning, scale. The various vegetative materials perform four basic functions which can be used advantageously in man's settlement system. Vegetation functions in an architectural capacity by defining and articulating space. It can also be used effectively used to achieve privacy.

In its engineering use, vegetation functions as an air purifier. Trees, for example, help to remove such air contaminants as suspended solids and gases as well as various other vaporous materials. It is estimated that one acre of green removes about 30 cubic feet of carbon dioxide from the atmosphere daily. "Pollution abatement within the atmosphere is justification enough for street trees in our cities. This unique property of vegetation, in general, led a noted chemist to recommend, based on accurate calculations, that there should be at least one tree for each automobile and ten trees for each truck within the city."[10] Vegetation, however, doesn't perform this purification function without itself incurring damage. It is estimated that vegetation damage has been caused in at least half the states by photochemical smog, ozone, sulfur dioxide, flourides, and ethylene. The extent of loss of future forest yield that can be attributed to polluted air is not fully known.[11] Vegetation could be effectively used

10. J.B. Frazier, "What Every Architect Should Know About Trees," American Institute of Architect's Journal, (une, 1963), page 40.

in urban area airsheds to purify both the incoming and outgoing air.



VEGETATION AND AIRSHED QUALITY

Vegetation can also be used to control and reduce community noise. Trees are most efficient in reducing noises of high frequency that aren't aren't much larger than the average size of the leaves or other obstacles, such as the tree structure. Relatively dense woods, for example, can be expected to attenuate traffic

11. J. McHale, Ecological Context (New York: Braziller, 1970) page 12.

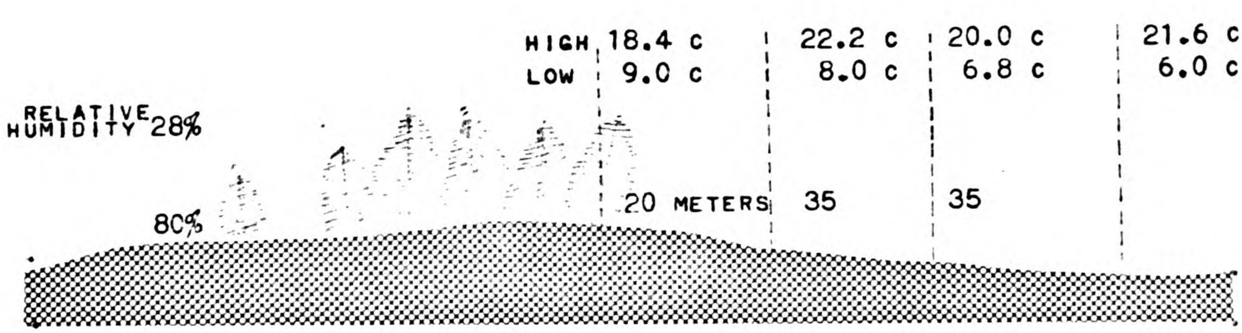
noise from .16 to .18 decibles per meter of width.[12] Trees not only act to control noise, but they also make sounds. Vegetation performs several additional engineering functions. It acts to control and regulate runoff; it regulates the water table; and it purifies runoff by filtering out sediment and salts.

Aesthetically, vegetation functions as an architectural and sculptural medium and as an attraction for wildlife and birds by providing cover.

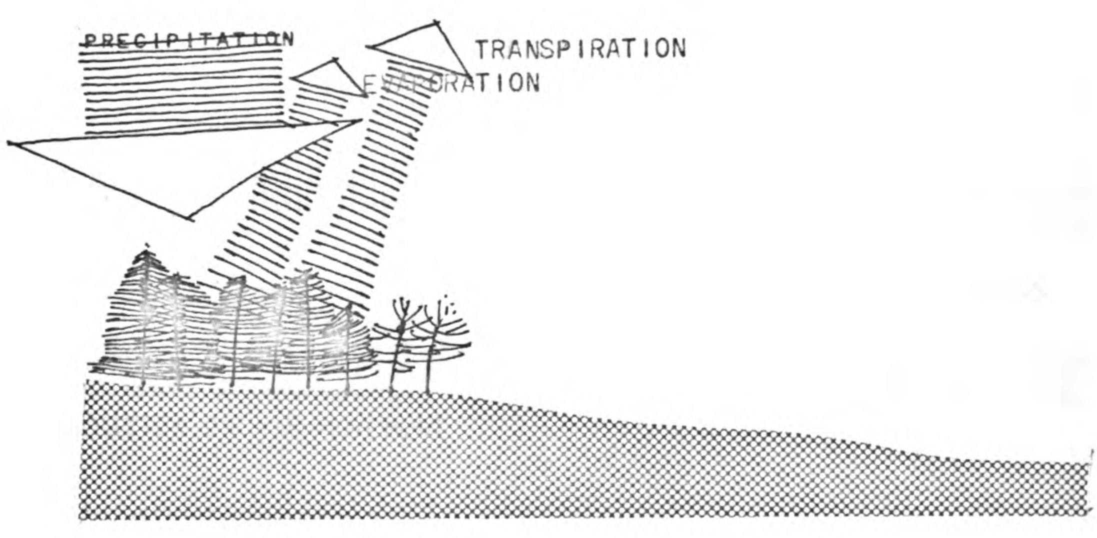
And finally, vegetation functions to modify and control micro-climate. Vegetation influences both air temperature and humidity. For example, the temperature on a forest floor can be as much as 30^{o} F cooler than the temperature of the surrounding air at the top of the trees during summer periods of bright sunlight. At night or during prolonged rain spells, however, there is little temperature difference. A forest will also tend to be warmer in the winter. The natural cover of the terrain tends to moderate temperature extremes and stabilize conditions through the reflective qualities of the vegetative surfaces. Vegetation could be used effectively to modify the temperature extremes of our urban areas. Humidity, on a hot summer day, can vary from 28 percent, measured at the tree tops, to as much as 80 percent, measured at the forest floor.

Vegetation provides protection from precipitation and also plays an important role in the hydrological cycle. From each acre of woodland on a hot summer day more than 2000 gallons of

12. W.L. Smith, "Trees in the City" American Institute of Planners Journal, (November, 1970), page 34.

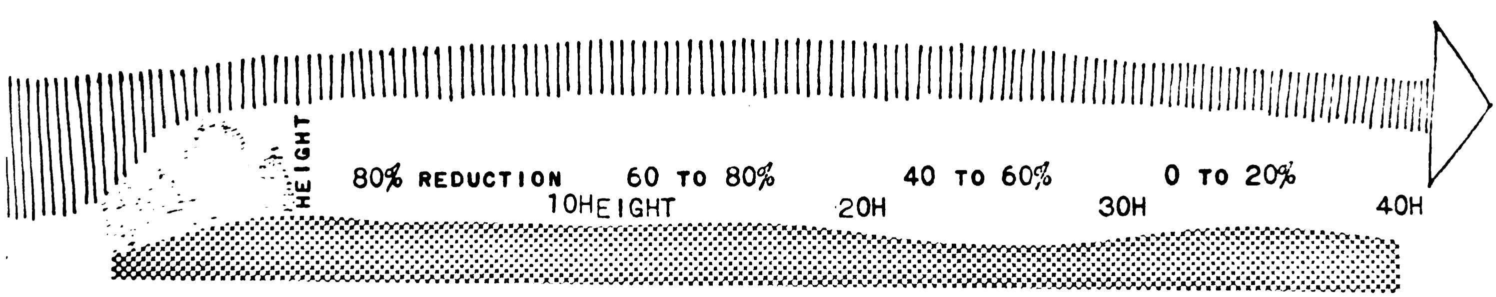


VEGETATION AND AIR TEMPERATURE



VEGETATION AND THE HYDROLOGIC CYCLE

water returns to the atmosphere through transpiration.[13] An additional 600 gallons is evaporated from the foliage. Vegetation can also function to modify and control air movement. Wind direction and intensity can effectively modified by shrub and tree masses. For example, wind velocity, measured when the trees are in full bloom, varies from 50 miles per hour at the tree tops to 4 miles per hour at the ground. Even during the winter, wind velocity can be reduced by as much as 50 percent. As evidenced by the "Great Shelterbelt Projects" during the 1930's, trees can effectively control winds for a horizontal distance equal to twenty times their height. On the lee side of a vegetation mass 50 feet high, an area 1000 feet long is protected from winds. Soil moisture evaporation and wind erosion can also be controlled via these wind barriers.[14]



EFFECT OF VEGETATION ON AIR MOVEMENT

13. J.B. Frazier, "What Every Architect Should Know About Trees" American Institute of Architect's Journal, (June, 1963), page 43.

14. Ibid., page 41.

Vegetation can be advantageously used in our cities to control winter winds, which could result in less power consumption; to purify the air; to cool in overheated periods by funneling summer breezes through the cities; and to add to the general urban aesthetic. It is this author's contention that the potential of vegetation isn't more fully utilized for the reason that people aren't aware of its potential. As we gain more understanding of the natural system we will undoubtedly begin to see how it can effectively be used in making our cities better places to live.

Man's relationship with wildlife is one of consumption and destruction. Man's pollutants destroy wildlife while his activities destroy both their food and habitat. It is estimated that about 600 animal species have been reduced to the point of extinction in the past 200 years. The number of endangered species is growing with time, as the following illustrates.

TABLE #7
ENDANGERED ANIMAL SPECIES

DATE	NUMBER OF ENDANGERED ANIMAL SPECIES
1968	78
1969	89
1970	102
1971	101

Bird populations are also decreasing. Osprey populations have shown a 12 percent annual decline and Carivasbach ducks have shown a 25 percent decrease in numbers in the past five years.

Cooper's hawk has been decreasing some 25 percent yearly, and California condor sightings dropped 50 percent last year alone.[15] In 1968, it is estimated that municipal and industrial wastes caused as much as 88 percent of the over 15 million fish deaths in the U.S.[16] Thermal as well as chemical pollution has deleterious effects on fish life. Fish depend on temperature changes, in specific amounts, to signal migration and spawing times. Thermal pollution acts to upset this natural balance and to disrupt the fishes life cycles.

Animals, depending on their size and quantity as well as food supply, require certain amounts territory in order to survive. A California mountain lion requires some 2000 acres while a mule deer needs only 40 acres. Man indirectly destroys these animals when his activities encroach on their territory and destroy their habitat.

The aesthetic as well as educational values of wildlife can and should be used by man. Animals not only add form, movement, and color to the landscape, but also have recreational value.

CONCLUSION

Man and his activities are causing irreparable damage to the natural system. Indiscriminate urban sprawl is not only covering Nature over with concrete and asphalt, but man's waste products are also poisoning both Her and the environmental users, including man himself. This destruction is largely the result of man's ignorance of the natural system. Our technological way of living has divorced us from Nature to the point where we no loner appreciate or know how to use the natural system to our advantage.

It is a mistake to think that we are above Nature, but this is exactly how we think and act. It is time that we begin to realize that the natural system is both finite and closed: that we depend on it for our sustenance; and that we are not independent of it, but are only a small part of it. It is this author's contention that our ignorance is keeping us from tapping the potential which Nature offers. It is also the reason why we are destroying it.

We must begin to educate ourselves so that we understand the natural system well enough to use it in an ecological viable way. We must learn to appreciate it so that when we see a spider, for example, our first inclination is not to step on it, but to try to understand what it is and what it is doing in this world.

Once we understand Nature, the next step in reconstructing a more compatible man-Nature relationship involves inputing the newly discovered ecological values into our decision-making process. Once this happens, we will be well on our way in working with, rather than against, Nature.

We must also seek to use technology in a more ecologically viable way. We must attemp to minimize and control pollution. We must put machines in their proper place. For too long now, we have allowed machine-type values to dominate the natural system values in the decision-making process. It is time that we realize that we are not machines and that we don't live in a machine. We are very much alive as is the world in which we live. If we don't start acting like this is the case, neither of us will be alive for long.

The natural system offers both potentials and limitations to man and his activities. We must learn to design our settlement systems so that we utilize this potential and minimize the limitations. The accompanying Environmental Planning Consideration Matrix represents an initial attempt to develop a conceptual framework which can be used to point out the man-Nature considerations which must be dealt with in ensuring that the natural system is being utilized to its fullest without damaging it. This matrix approach will hopefully bridge our ignorance and enable us to "design with Nature".

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