FLOODPLAINS AS GREENBELTS IN URBAN AREAS

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The aim of this paper is to study the effect of human interference in the floodplain ecosystem within urban areas. To achieve this aim a summary is given of the importance of urban greenbelts, ecosystem dynamics, as well as certain drainage basin characteristics. The misuse of floodplains for urban development (e.g. stream channel canalization, road building and the erection of buildings), and the influence of such actions on floodplains (e.g. higher flood peaks and accelerated erosion), leads to the conclusion that these areas should be seen as a natural asset, to an urban community, rather than a dispensable wasteland to be used for urban expansion.

The second conclusion reached is that to maintain artificial greenbelts in urban areas, the increasing cost in human energy inputs alone, justifies the conservation of floodplains as natural greenbelts within the urban environment.

Die doel van hierdie studie is om die effek van menslike ingrype in die vloedvlakte-ekosisteem in stedelike gebiede te ondersoek. Om die doel te verwesenlik, word 'n kort oorsig gegee van onder andere die belangrikheid van stedelike groengordels, die dinamika van ekosisteme asook aan enkele eienskappe van dreineringsbekkens. Die misbruik van vloedvlaktes vir stedelike uitbreiding (soos onder andere die kanalisering van stroomkanale, aanlê van paaie en die oprigting van geboue op vloedvlaktes) en die invloed van sodanige aksies op die vloedvlakte-sisteem (soos verhoogde vloedpieke en versnelde erosie) toon duidelik aan dat vloedvlaktes eerder as 'n onversteurde natuurlike bate beskou moet word, in plaas daarvan dat dit vir stedelike funksies gebruik moet word.

Die tweede gevolgtrekking waartoe daar in die studie gekom word, is dat die koste-aspek, in terme van menslike energieverbruik vir die instandhouding van mensgemaakte groengordels, genoegsame rede verskaf vir die bewaring van natuurlike vloedvlaktes, as groengordels binne stedelike gebiede.

1. INTRODUCTION

Until one or two decades ago, parks and recreation grounds in urban areas were in general considered to be a minor technical matter and delegated to the relevant municipal Parks and Recreation departments. The sole purpose of these green spots was seen as being of aesthetic value to the town's inhabitants. The essential ecological role of greenbelts with their plants and animal life is only recently being investigated on a scientific basis.

During the past few years a growing understanding has developed: towns are now being seen as cultural ecosystems. Towns are in fact structured communities of various kinds of organisms (man, animal and plant) which exhibit a certain structural set of relationships with the abiotic environmental factors such as climate, soil, water and topography. Various processes are active within these structures and they influence the phenomena in a manner which is basically not very different from natural ecosystems.

The strong human dominance does explain, however, why urban landscapes have long escaped the attention of earth scientists. Landscape architects and park administrators have paid attention to the visual aspects of towns; soil scientists have mapped soils – but only as far as it has been necessary for urban growth; climatological studies have been done with regards to pollution, and hydrological aspects have been handled as engineering problems concerning flooding.

The role of soil, water, plants, animals and air as part of an integrated system (the ecosystem) has received little attention in urban areas (Vink, 1983). The fact that urban man regards falling leaves as garden "rubbish"; that water is regarded as being an unlimited resource – it only needs the act of opening a tap to have access to this commodity; and that food is regarded as coming from the store, has led him to believe that he is independent of nature and that the urban environment is the ideal habitat for him. Ecology is regarded as an abstract academic phenomenon – or at best something farmers and nature conservationists should take note of. The fact of the matter is however that man was created to live in close harmony with nature and there is ample evidence that he is becoming disillusioned with life in cities. Social disorder such as crime, overcrowding, lack of privacy, noise and air pollution, etc., are aspects of modern cities which are difficult to cope with. In cities man has divorced himself from contact with nature and has disregarded its basic ecological laws. Unless sound ecological planning procedures can be worked out, this might well lead to his physical and psychological downfall.

Unprecedented urbanization has led to the phenomenon known as the megalopolis. It is predicted that 90% of man-kind will in future be living in cities: these megalopoli will cover extensive areas of the land's surface. Such urban sprawl will obviously have an immense influence on our living conditions and on regional ecology.

2. ECOSYSTEM DYNAMICS

To grasp what is meant by ecosystem dynamics, the basic laws by which ecosystems function should be understood.

2.1. Dynamic man-land relationship

The whole of the biosphere with all of its ecosystems function under the driving power of energy, originating from the sun. This energy is only available to man through the complex process of photosynthesis. These complex energy relationships are furthermore characterized by entropy by which it is made clear that man cannot improve on the natural processes. From these, two basic facts emerge, namely:

- Urban-industrial man is fundamentally just as dependant on nature as his ancestors or his contemporary rural counterpart.
- Any action of man which alters nature, will sooner or later have detrimental chain reactions which cannot be fully anticipated at this stage.

From this knowledge emerged the philosophy of "design with nature" as expounded by Ian McHarg (1971). It will always be in man's best interest to acknowledge the natural processes and try to follow their directions as closely as possible in order to attain the best results in any type of land use planning, be it rural or urban planning.

2.2 The functioning of natural systems

Nature functions as one large fully integrated system. None of its elements, however minor, acts independently of the system as a whole. Another basic premise is that nothing in the ecosystem is static. Relationships between parts of the system are thus continuously changing or moving in closed cycles. This dynamic system is however under all circumstances in balance and maintains a "dynamic equilibrium". This balanced cyclical nature is of the utmost importance. Any stagnation or imbalance will ultimately lead to catastrophic results.

Nature's functioning can be very broadly classified according to three basic cycles: the gas, biogeochemical, and hydrological cycles, each with its own many sub-cycles. Of these three cycles the gas cycle has been studied widely in the urban context because of air pollution problems. The so-called biogeochemical cycles of which the sedimentary subcycle forms an important part, has relatively little effect on urban man, *inter alia* because of its long recycling periods (Tivy, 1981:25). Of special importance to urban man is the rather limited studied hydrological cycle in the urban ecosystem.

2.3 The hydrological cycle under natural conditions

The functioning of the hydrological cycle under natural conditions has been amply documented and needs little explanation. A simplified version is given in Figure 1. From this model it is clear that all moisture that does not enter the soil by infiltration or is evaporated, is transported by runoff via natural channels. This process of runoff eventually sculptures the land and developes river valleys and its associated landforms such as floodplains.

Since the publication of an article by Horton (1945) a quantitative revolution has developed in the description of drainage basin characteristics. Up to the publication of this article most descriptions of the drainage basin, as a fundamental geomorphic unit, have been in qualitative terms. However, the stimulus provided by the article by Horton has led to a flood of quantitative investigations. The results of these investigations into the dynamic nature of basins have led to the conclusion that the following parameters are of cardinal importance in the functioning of basins:

> Network parameters such as the number of streams involved and total stream length. Basin geometry parameters such as basin area, basin length, basin width, length of basin perimeter, basin elongation and or circularity. Measures of dissection intensity such as drainage density and stream frequency. Measures involving heights such as stream channel slope, valley-side slope, height of basin mouth, height where stream originates, height of highest point on watershed, local relative relief, relief ratio, etcetera (Doornkamp and King, 1971).

Other important parameters defined are:

> Geological parameters such as the type of rock, its erodibility, and other structural geological parameters such as folded and or faulted structures. Soil parameters connected to type and or erodability. Vegetation parameters consisting of subparameters like vegetation type, density of growth and others like crown and or basal cover components (De Villiers, 1981).

These parameters form the basic integrated components of drainage basins and are delicately linked together in a system of dynamic equilibrium.

2.4 Urban development

Water is a prime requisite for human life. In earlier times most towns and cities were established near readily accessible water resources. Early man, however, seems to have had a better understanding of nature in that building within potential flood areas was avoided. As time went by and towns and cities grew, the available space on these floodplains was utilized for building purposes and relatively few towns and cities today have any notable open space left alongside the river courses.

One of the main hazards of building alongside river courses, is obviously flooding. With the advancement of technical skills, man has overcome this problem to a certain extent. The building of flood control measures – dams, channelization of the water course, infilling of low lying areas and even the building of levees along river banks, helps overcome the flood hazard to a certain extent. This manipulation of natural processes has however been only partially successful. All these flood control measures are from time to time subjected to excessive flooding with the resultant loss of property and of lives. Such structural development on floodplains also minimized the recreational and conservational potential of the riverine environment.

A major difficulty that presents itself in the planning procedure, where man is encroaching on floodplains, is the fact that there appears to be very little acknowledgement of the importance of the geomorphological and hydrological processes involved on the floodplain itself.

3. THE IMPACT OF URBANIZATION ON FLOODPLAIN DYNAMICS

The riverine floodplain as part of this complex drainage basin system, is a very complex type of landform that developed in areas along river courses with low gradients. Floodplains developed mainly because of the fact that the depositional process is the dominant one in this riverine reach. Erosion and the transportation of eroded materials play only a minor role in these areas – as contrasted to the upper and middle reaches of rivers where these processes are dominant.

The deposited materials are usually well-graded and dominantly fine in texture. On floodplains a river usually develops a meandering pattern to enable it to maintain a gradient in equilibrium with the caliber load to be transported. Other characteristic fluvial landforms usually found on floodplains are features such as oxbow lakes, meander scrolls, terraces, marshes and also a score of minor features associated with the macro features. Some of these minor features are cut banks, different types of sand and gravel bars, gilgai (associated with certain clay soils) etcetera.

The most important point to realize is that there exists a very delicate balance between discharge, gradient and these landforms (both erosional and depositional). This dynamic equilibrium is maintained on a long term basis by nature as was mentioned previously with reference to the multitude of parameters. Intervention by man with respect to any of these parameters always results in a sequence of chain effects – often of an unpredictable and uncontrolled nature.

If it is taken into consideration that all the above mentioned parameters form an intricate dynamic energy system, it becomes clear that in order "to plan with nature", any human interference should be undertaken with great care. A few examples will be used to illustrate this point.

In the urban environment the effect of human interference is usually very pronounced. Not only does man channelize streams, but by pouring concrete and tarmac over large expanses of land, the overland and subsurface flow systems are also interrupted. These alterations to the flow system, that is the des-

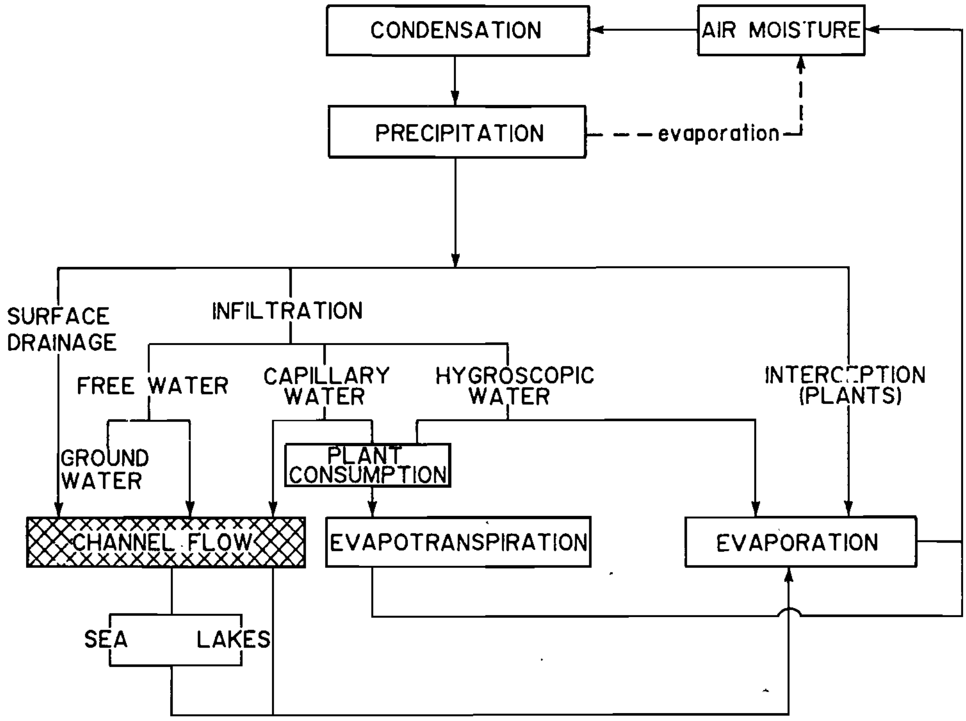

FIGURE 1 DIAGRAMMATIC PRESENTATION OF THE WATER CYCLE

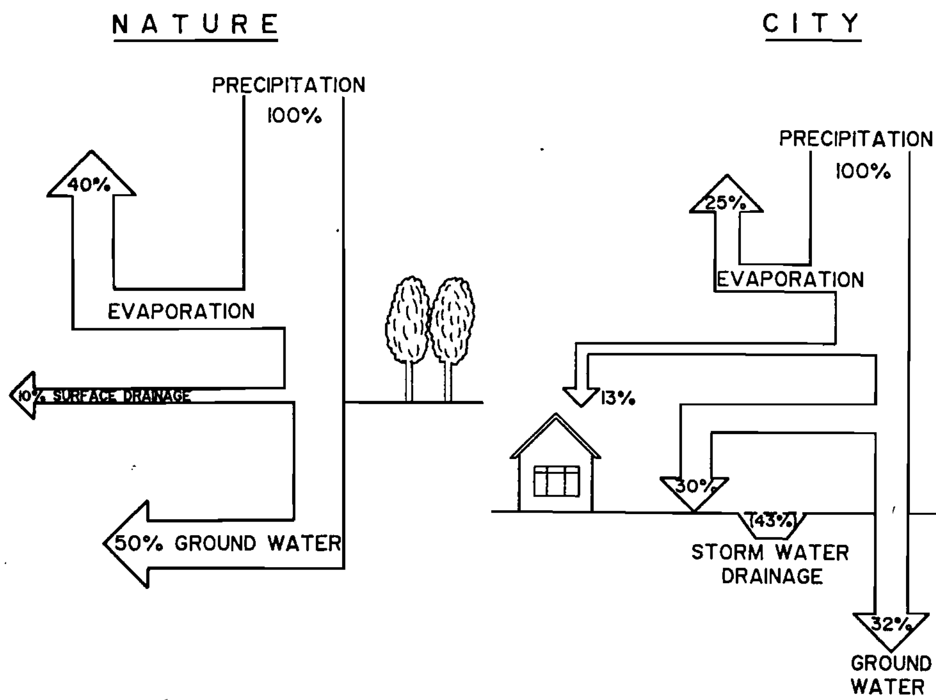

FIGURE 2 COMPARISON BETWEEN THE WATER BALANCE OF A CITY AND THE NATURAL ENVIRONMENT

troying of the natural channel pattern, the destruction of the vegetational component, and even the alteration of the natural existing gradient by large excavational filling projects – lead to nature's reaction by producing catastrophic floods. Figure 2 illustrates this effect.

With reference to the figures the above mentioned situation can be summarized as follows.

Under nat:'ral conditions the major features of runoff is as explained in figure 1. These conditions are illustrated in figure 3.1. The same landscape under urban development is shown in figure 3.2. The most notable changes in the environmental conditions are as follows:

1. Surface cover is stripped of vegetation and replaced by hard impenetrable surfaces such as roofs, roads and parking lots.
2. Surface drainage is directed into underground storm water pipes and open concrete channels.
3. The floodplain below the 50 year floodlevel is often used for transport links.
4. Bridges are built across river courses – often by means of large amounts of infilling of "shoulders".

The results are:

1. Little rainfall is held back by vegetation and marshes.
2. Less water penetrates the soil so that the ground water level drops (Figure 3.2(E)). This leads to drying up of bore holes and death of trees and shrubs and with it the whole plant ecology of green open spaces.
3. Normal seasonal or perennial riverflow diminishes (Figure 3.2(B)) or disappears totally.
4. Floodplain area decreases, with the result that floods have restricted room to spread (C).
5. Runoff (from hard surfaces) is much faster. Exceptionally high flood peak situations are created which can be extremely dangerous to human life.
6. Bridge shoulders form a physical blockage to flood water creating higher flood conditions up-stream.
7. The clean fast flowing water from such channels has an enormously increased erosion potential. Under natural conditions flood water is heavily loaded with suspended material and therefore the water's potential for further erosion is low.

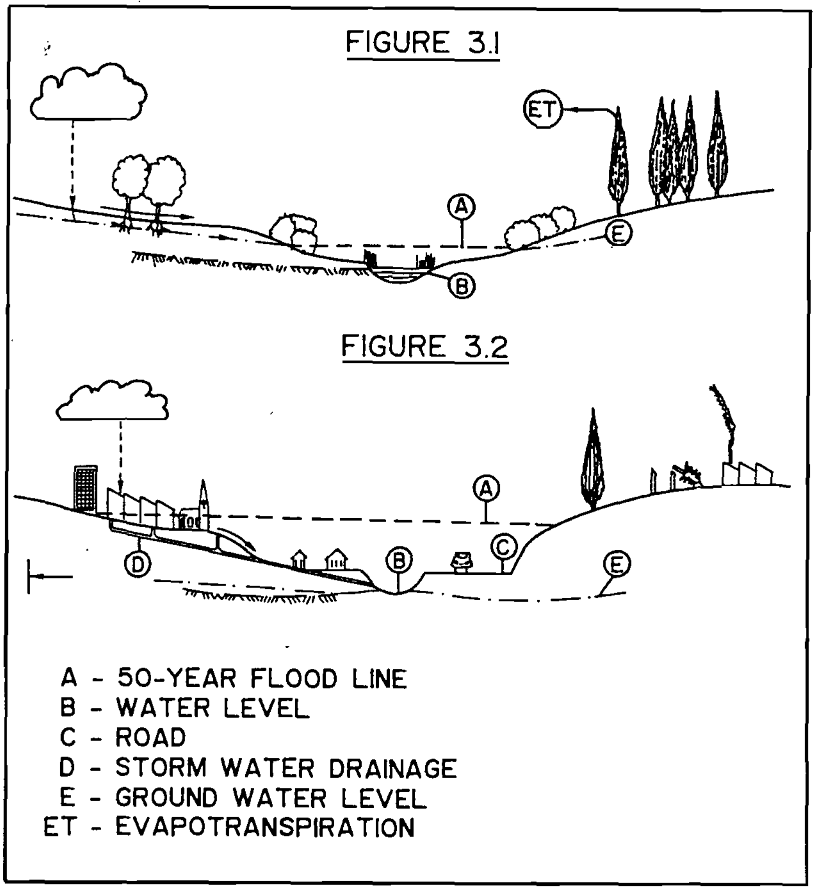

FIGURE 3 HUMAN INTERFERENCE IN THE FLUVIAL PROCESSES IN URBAN ENVIRONMENTS

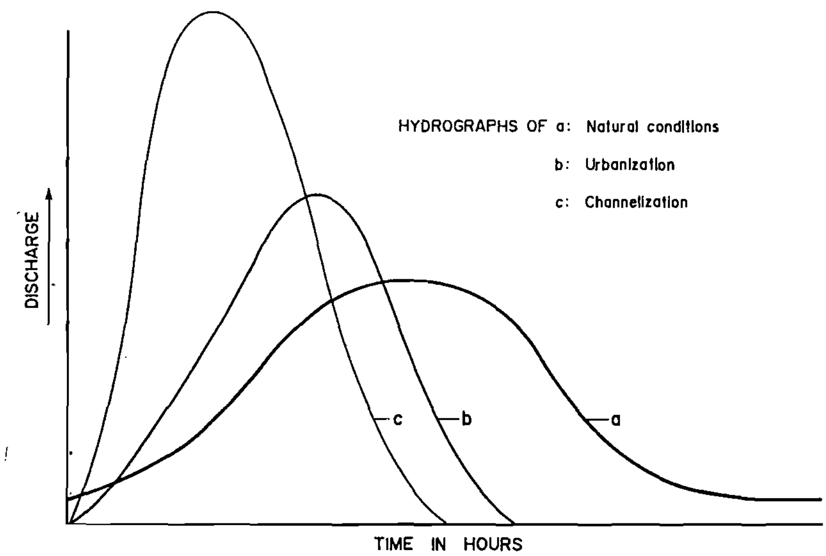

FIGURE 4 HYPOTHETICAL UNIT HYDROGRAPHS

The runoff created by the urban system however, is devoid of sediments. Where this water eventually discharges from the channelized portion of the riverine reach, into the natural reach of the fluvial system, extensive erosion will occur.

8. This will lead to a siltation problem further downstream.

Figure 4 (a hypothetical unit hydrograph – see also Shaw, 1983:330-344) illustrates the different hydrographical situations described in the previous paragraphs. Under normal conditions (curve a) a downpour will result in a steady increase of channel flow, rising gently to a peak and a slow return to the pre-downpour level. (This is due to the so called groundwater effect (Morisawa, 1968:24).) Perennial flow is therefore maintained.

Under urban conditions where rainfall runs off mainly over hard surfaces, the river channel receives water much faster and in larger quantities (curve b) with the resultant higher peak and in the end, due to lack of the groundwater effect, falls to eventually a zero flow condition.

The last graph (curve c) illustrates channelized flow. In this graph the higher flood peak and zero flow conditions after the cessation of rainfall, is only more extreme than in the previous example.

4. SOLUTION

As stated previously, rivers and their channels, and riverine floodplains together with their soils and vegetation cannot be separated from each other. They are to be seen as components of a single system – the one cannot function without the other. An alteration in any one link in this system, will create a chain of adaptations.

While it is axiomatically accepted that houses and roads are not to be built within a river channel, the same "insight" does not exist with regard to floodplains. Floodplains are as much created for water to flow as are river channels. To build within the floodplain boundaries is to interfere with the hydrological cycle and thus violate ecological laws. The solution to subsequent flooding of urban structures lies thus not in attempting to avoid the ravages of floods by means of concrete channeling but by refraining from urban encroachment of any kind within flood plains.

The 50-year flood line is generally accepted by planners as a building restriction line. What is not readily appreciated by town planners and engineers is that by creating artificial runoff conditions, this flood area is usually notably enlarged. This floodline, after urbanization, will thus be higher than under natural conditions (Figure 3.2(A)). To have a 50-year "guarantee" man thus needs to build well outside this floodline.

The building of roads and bridges within this zone (either along river cources or across them) obviously also compounds the problem in that the area available for runoff becomes proportionally smaller which results in even higher flood peaks.

The ultimate solution is therefore not to regard urban open space (and especially riverine green belts) as dispensable wasteland to be "used" when transport or other infrastructural links or residential "development" is needed, but to view it as an invaluable and irreplaceable natural asset to a community. This will have far reaching consequences for not only the plant and wildlife in an urban environment but it will also enhance the quality of the life of the urban "concrete jungle" environment.

In order to summarise the value of urban open space it may be stated that while biochemical and ecological factors may be the most significant benefits attributable to urban greenspace, there are other values that must be noted. The effect of open land on climate, both macroclimates and microclimates, and its role in wind deflection, dust reduction, water control, conservation, noise reduction and air and water pollution abatement cannot be lightly dismissed.

The other very obvious advantage of urban open space is the social benefits derived. These areas not only provide aesthetically pleasing recreational space but, if properly managed, can be used as an educational tool for which urbanites usually have to travel long distances into the countryside.

5. CONCLUSION

The final conclusion thus arrived at is simply that, should planners allow floodplains to degenerate from their natural ecological conditions, healthy gardens, parks and green belts can only be maintained in urban areas by greatly increasing the human energy input through additional maintenance. Without open space living conditions will deteriorate at an ever increasing pace to the point that the habitat that urbanized man has created for himself will become physically and emotionally an inhumane environment: one not condusive to leading a full and happy life.

South African engineers and town planners may do well to take note of the situation in other countries with a long history of urbanization behind them. There seems to be a much more realistic appraisal of the value of open space; as put by Cherret (1982:1) concerning the British situation: ". . . . the very term 'green belt' often appears to require no further justification for refusing development; it is a statutory shibboleth respected by planners, politicians and the public."

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