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INTEGRATED WATER MANAGEMENT IN URBAN AREAS

by

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Management Perspective

Although the concept of integrated water management is widely accepted in river basin management, applications of this concept to urban areas are lagging behind. To examine the reasons for this unsatisfactory situation, the United Nations Educational, Cultural and Scientific Organization (UNESCO) initiated a project on integrated water management in urban areas and solicited the review paper that follows. The paper examines the applicability of integrated water management to urban areas and concludes that integrated water management is gaining acceptance only in those urban areas which are characterized by severe conflicts among users competing for limited water resources. Progress has been impeded by functional and jurisdictional fragmentation, and tendencies of urban users to monopolize water resources. Remedies consist in adopting a systems approach to water resources management, with emphasis on conservation of both water quantity and quality, and implementation of best management alternatives by regional water authorities with users representation. Increasing utilization of urban water resources will lead to greater acceptance and implementation of the integrated water management in urban areas. The report should be of interest to water managers dealing with urban water resources.

Perspective à l'intention de la direction

Le concept de gestion intégrée de l'eau est largement accepté dans le domaine de la gestion des bassins hydrographiques; pourtant, les applications de ce concept accusent du retard en milieu urbain. Pour étudier les raisons de cette situation regrettable, l'UNESCO a lancé un projet portant sur la gestion de l'eau en milieu urbain et sollicité le document d'étude qui suit. Dans ce document, on examine l'applicabilité de la gestion intégrée de l'eau en milieu urbain et on conclut que ce concept ne gagne du terrain que dans les cas de conflits graves, là où les usagers se disputent des ressources en eau limitées. La fragmentation des fonctions et attributions, ainsi que la tendance des usagers urbains à monopoliser les ressources en eau n'ont fait qu'entraver les progrès. Pour remédier à cet état de choses, il faudrait adopter une méthode systématique de gestion des ressources en eau qui viserait à économiser l'eau tout en en maintenant la qualité. Il faudrait aussi, pour mettre en application les meilleures solutions de rechange possible, que les usagers soient représentés auprès des services régionaux de gestion des eaux. Les ressources en eau étant limitées, l'accroissement de l'utilisation doit favoriser la mise en application de la gestion intégrée de l'eau en milieu urbain. Le rapport intéresse les responsables de la gestion de l'eau qui oeuvrent en milieu urbain.

GESTION INTÉGRÉE DE L'EAU EN MILIEU URBAIN

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Résumé

Le concept de la gestion intégrée de l'eau n'est pas couramment appliqué en milieu urbain à moins qu'il n'existe de graves conflits entre les usagers qui se disputent des ressources en eau limitées. L'intégration de la gestion de l'eau en milieu urbain est fréquemment entravée par la fragmentation des fonctions et attributions et par la tendance passée de la demande urbaine à monopoliser les resources en eau. Pour améliorer la situation, il faudrait que les services régionaux de gestion des eaux, auprès desquels tous les usagers seraient représentés, adoptent une méthode systématique de gestion de l'eau qui viserait à économiser cette ressource. Les ressources en eau étant limitées, l'accroissement de leur utilisation doit favoriser la mise en application de la gestion intégrée de l'eau en milieu urbain.

INTEGRATED WATER MANAGEMENT IN URBAN AREAS

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Abstract

The concept of integrated water management is not commonly applied in urban areas unless there are severe conflicts among the users competing for limited water resources. Integration of water management in urban areas is frequently impeded by functional and jurisdictional fragmentation and the past tendencies of monopolizing water resources by urban demands. To improve this situation, a systems approach to water management, with an emphasis on conservation, should be adopted and implemented by regional water authorities with representation of all water users. Increasing utilization of limited water resources should lead to a greater acceptance and implementation of the integrated water management in urban areas.

1 Introduction

Steadily progressing urbanization leads to ever increasing concentration of population in relatively small urban areas and the concomitant stress on the entire ecosystem and its water resources. As such resources become depleted or overexploited and their quality deteriorates, the need for comprehensive management of water resources increases. Without such a management, further development of the society is impeded and its general well-being is threatened. Although various forms of single or multiple purpose water management are practiced in many areas, a comprehensive approach to water management, referred to as the integrated water management, is still relatively uncommon, particularly in urban areas. The paper that follows provides a general overview of the issues and trends in the integrated water management in urban areas. Before proceeding with such an expose, it is desirable to introduce working definitions of the discussed subjects.

Water management is defined as the complex of activities and measures designed to satisfy human needs and social demands concerning water in an optimal way (Zuidema, 1982). Thus, water management strives to meet the demands of the economic development by optimum development and utilization of water resources, and to create an optimum living environment, which protects the society against harmful effects of water (Jermar, 1987). The primary objectives of water management include the selection of the combination of water services to be produced from specific water resources and an efficient provision of such services within the overall goals and policy constraints.

In conjunction with water management, the adjective "integrated" has various meanings, reflected in the literature on this subject (Lindh, 1985; United Nations, 1979; Zuidema, 1982), and may refer to spatial, temporal, administrative and functional integration. For the purpose of this review, the functional integration is considered to be the most important and the other forms of integration are viewed as prerequisites of the rational functional integration which recognizes the multiple functional character of water resources and the need to consider all such functions in water management.

The last term to be defined is the "urban area" which may be defined as a comparatively small area characterized by a concentration of people, great diversity of land use activities with a high degree of interaction, and physical forms of concentrated built-up and open spaces (Hengeveld and de Vocht, 1982). This area may affect water resources well beyond its boundary, as a result of interbasin water transfers and far-reaching effects of drainage and waste water discharges. Thus the discussion in the paper focuses on the concept of functionally integrated water management in general urban areas.

2 Facets of Water Management

The management of water resources is strongly affected by their general characteristics and utilization discussed below.

2.1 Multiple Functions of Water Resources

The multiple functional character of water resources implies the reuse of water for various purposes, which can be divided into three categories describing the natural functions, in-situ uses and withdrawals of water (Jermar, 1987). The natural functions include the supply of soil moisture, biological functions, transport of various elements, climate regulation, aesthetic enjoyment, and general environmental functions. In-situ uses comprise ground water and soil moisture regulations, waste transport, hydropower generation, and water-based recreation. The water supply functions lead to withdrawals of water for domestic, industrial and agricultural supplies. Detailed discussions of individual water functions can be found elsewhere (Jermar, 1987).

The multiple use of water follows certain priorities, with the highest one assigned to domestic water supply. This is also reflected in the literature on water management in urban areas, which is clearly dominated by publications on water supply (UNESCO, 1987).

2.2 Interdependencies

High mobility of water and physical connectivity of water resources, natural or man-made, contribute to interdependency of actions of independent water users. These inherent interdependencies are probably best recognized by considering the water resource system as a subsystem of the ecosystem (Lindh, 1986). Interdependencies of water resources and their utilization become particularly obvious under the conditions of intense use and provide an impetus for integrated water management which reduces conflicts among users and leads to the spreading of benefits arising from management actions.

2.3 Regional Disconformities

Many difficulties in water management are caused by disconformities among the different interacting regional water systems and are further exacerbated by the overlapping boundaries of hydrological units, which are suitable for delineation of water supply areas, and administrative jurisdictions, which respond to the water demand requests and conduct water management. A typical example of such problems is the case of the City of Chicago which obtains water supplies from Lake Michigan, but further increases in such withdrawals would lower the water levels in the downstream Great Lakes and impact adversely on water use in Michigan as well as in Canada (Stout and Ackermann, 1987).

2.4 Economic Aspects

Although water used to be perceived as a free good, it is now recognized as a valuable commodity which has to be properly managed and priced. Some water related services, such as water supply, are marketable and can be priced, many others cannot be assigned any prices and other means need to be considered in their evaluation. Water resources development generally requires large investments and significant savings can be achieved, both in the development and providing the service, by employing large scale facilities and management systems feasible in an integrated approach. Furthermore, some single-purpose projects, which can be economically infeasible on their own, can become feasible in a multiple-purpose project.

2.5 Institutional Aspects

Water management activities in urban areas are fragmented along both the physical and functional lines (McPherson, 1973). In some areas, such a fragmentation is attributed to relatively plentiful water supplies or a low level of development of water resources. The situation is different in the cases where water supplies are scarce and competing multiple purpose uses lead to conflicts. In those cases, the need for integration of water management activities is rather high, decentralization of water management responsibilities is common, and special authorities with a wide representation of users and the control of both land and water uses are created (United Nations, 1979). Specific institutional arrangements are rarely transferable to other jurisdictions, because they generally reflect the local socio-economic conditions (Lord, 1984).

3 Advances in Integrated Water Management in Urban Areas

3.1 General Strategy

Recent trends in the water management indicate that there is a clear transition from supply management, characterized by increasing supplies to meet the growing demands of the users, to demand management, which limits water use growth through conservation (Pearse, 1986). This trend is obvious not only in the countries with limited water resources, but even under conditions of relative water abundance. Water conservation reduces problems at the source, sink and within the urban system itself. At the source, the benefits of conservation include reductions in the sinking of ground water tables, prevention of landscape disturbance and avoidance of construction of expensive water supply structures. Within the urban system, conservation alleviates such internal problems as water shortage, water ponding, flooding, and pollution damages including health risks, damage of water structures, landscape disturbance and loss of wildlife habitat. At the sink, conservation helps to alleviate the problems caused by the water pollution, disposal of sewage and sludge, landscape disturbance, flooding, soil erosion, and funding needs for treatment works (Tjallinjii, 1988).

Although the concept of water conservation is attractive, the existing institutions and infrastructures are sometimes counterproductive to the implementation of water conservation policies. The past experience shows that conservation measures are readily accepted only after the relatively inexpensive solutions have been exhausted (Jermar, 1987).

3.2 Systems Approach

The planning and management of water resources employ two general approaches, an adaptive planning approach and a rational-analytical approach (Stout, 1985). The former approach is based on reacting and finding solutions to the immediate problems, because the future scenarios, affected by political pressures and other factors, may be unpredictable. The second approach, the rational/analytical planning approach, uses system analysis to predict the problems, actions and their consequences. Although the concept of the integrated water management based on the systems approach is rather attractive, its implementation, which depends on local conditions, may receive a relatively low priority (Stout, 1985). The systems approach should become more widespread as the development of water resources further advances and inexpensive problem solutions become exhausted.

Applications of the systems approach to the planning and management of water resources consist of a number of steps described by Lindh (1983). Such steps usually include the need awareness; definition of the problems, goals and objectives; development of alternative solutions and selection of the best alternative using impact assessment; implementation; and, post evaluation.

The definition of problems should fully recognize all water functions in the study area and their functional integration in the water system. To support this activity, a wide range of data is required, including physiographic data, water quantity and quality data, and socio-economic information. It was recommended to proceed with the system analysis using uncertain data rather than wait till a complete data base can be assembled (United Nations, 1979). Much of the pertinent information can be collected through metropolitan water inventories which were recommended as a good base for future planning (McPherson, 1973; Lindh, 1985). Following this stage, goals and objectives of the water management are established.

3.3 Advances in Problem Solutions

Among the water management problems in urban areas, the most important ones are those related to water supply, waste water disposal, and drainage (Grigg, 1986). Recent advances in these fields should be utilized in integrated water management.

New approaches to water supply have been developed. Water conservation is practiced in many regions, as indicated by relatively moderate demand rates in some highly developed countries and the decline of these rates in time (Hengeveld and de Vocht, 1982). Such conservation is practiced in domestic, industrial and agricultural water supplies. The modern treatment technology contributed to water reuse in many countries, including the use of treated sewage effluents for irrigation and other applications (Dean and Lund, 1981). The sources of high-grade potable water can be conserved by using dual water supplies, where the lower grades of water, subpotable or non-potable, are used in industry, for irrigation, and for some restricted domestic uses.

Waste water disposal is generally considered as the second priority in urban water management. Besides the improvements in waste water treatment technology, advances have been achieved in the operation of treatment plants, with emphasis on automation and economy of the scale (Grigg, 1986), and in the disposal of treated effluents. Such effluents are used for irrigation, aquaculture, ground water recharge, and enhancement of wetlands. Most of these applications achieve additional treatment of effluents disposed in this way.

The drainage of urban areas is closely related to waste water disposal, particularly in the areas served by combined sewers. New concepts in urban drainage include conservation which is understood here as control measures designed to reduce both the discharges of and pollutant loadings in drainage effluents. Such concepts are well applicable in new areas, where dual drainage systems are designed to reduce water ponding inconvenience and to prevent flooding while maintaining runoff flows, in terms of volumes and peaks, comparable to the predevelopment state (Grigg, 1986). This is generally achieved by runoff control at the source and runoff detention and retention through the use of storage or devices extending the time of travel. Special problems are encountered in low-lying areas, where it is necessary to control both runoff and ground water tables. Horizontally integrated management systems have been developed to achieve such objectives at both the planning and operation levels (van Bakel, 1986).

Advances in drainage of the existing areas, particularly those served by combined sewers, are less pronounced. Control options are often difficult to implement because of high costs of structurally extensive solutions, expensive acquisitions of properties, disruption of economic activities, and needs to deal with aging infrastructures. Nevertheless, the problem of combined sewer overflows has to be addressed, particularly in connection with the pollution of receiving waters. Innovative solutions improving collection efficiency of combined systems include real-time operation of sewer systems and automation of such operations (Grigg, 1986).

The basic urban water services, water supply, waste water disposal and drainage, traditionally relied on steadily expanding extensive infrastructures which are expensive to build and maintain. Concerns about the aging infrastructures in cities are encountered in many countries. New solutions to these problems are needed, because the past research on urban infrastructures has been incremental in its nature rather than truly innovative. Further improvements are needed in the integration of the traditional urban water services and their management in such a way that other water uses are preserved. It was noted that urban users tend to monopolize water resources and deprive other users of water use for such functions as e.g. hydropower, irrigation, and recreation (United Nations, 1979; Stout and Ackermann, 1987). This situation needs to be corrected, if necessary, by legal actions.

Many recent advances were made possible by technological developments in computer hardware. This is particularly visible in data collection and processing, systems modelling and design, and automation of operation.

3.4 Role of Models

Applications of the systems approach to water resources management, particularly the development and evaluation of alternative solutions, are unthinkable without the use of mathematical models. The models for water resources planning and management have developed rapidly ever since the concept of systems engineering has been introduced into the field of water resources. Inherently, models avoid inaccuracies of verbal descriptions of the real system and serve for useful simplification of the system description by retaining only the important features of the system. Models can be divided into the descriptive and prescriptive categories, where the former ones simulate the behaviour of the real system and the latter ones evaluate the outputs of descriptive models in terms of the objective functions and form a basis for policy decisions (van Bakel, 1986).

The descriptive modelling of the water resources systems is generally accomplished by a modelling package of interfaced models simulating the most important segments of the system. These models, sometimes referred to as the hydrologic models, simulate the basic components of the hydrologic cycle including precipitation, surface and subsurface runoff, transport in drainage channels and rivers, ground water flow and fate in the receiving waters. Along these lines, both water quantity and water quality are simulated. The literature on hydrologic modelling is very extensive and summarized in many papers (e.g. Ongley et al., 1988). Besides hydrologic models, additional models describing water uses, their management and the associated costs are also needed.

The prescriptive models strive to design the best water management system by means of system optimization. Again the tools of trade are very extensive and employ such techniques as linear programming, dynamic programming and nonlinear programming (Goodman, 1984; Helweg, 1985; Loucks et al., 1985). Some of these models are suitable for both planning and real-time operation of the systems.

3.5 Post-Audit

The essential steps in post-audit comprise the comparison of the predicted and actual results and evaluation of the planning methodology. Although the post-audit is sometimes recognized as a part of the system analysis (Lindh, 1983), few publications of post-audit results can be found in the literature (Ongley et al., 1988). Consequently, it is difficult to evaluate the frequency of use of post-audit analysis in water management and the rate of success of planning studies. It has been asserted that in spite of proliferation of the literature on systems analysis of water resources, the measurable outcome of such activities is marginal (de Donnea, 1982). To resolve this controversy and to further advance the water resources management and planning, more attention and publicity should be paid to the post-audit of systems planning studies.

4 Summary

Although the concept of the integrated water management in urban areas is generally accepted, widespread applications with full horizontal and functional integration are fairly rare, because the need for integrated management becomes urgent only when the available water resources are highly utilized. In regions with abundant water supplies of high quality, conflicts among water users are relatively weak and can be resolved without sophisticated management tools. In regions with limited and highly utilized water resources, the competition for water and user conflicts become very strong and the systems approach with functional and horizontal integration becomes necessary. The extent of horizontal integration in water management in urban areas seems to be limited by political jurisdictions. A watershed-wide integration, which is successfully used in river basin management, is not particularly well suited for urban areas with interbasin water transfers and far-reaching downstream impacts. With limited horizontal and functional integrations, it is important to avoid the monopolizing of water resources by urban demands by considering the non-urban interests in the form of constraints. In the selection of management alternative solutions, emphasis should be placed on conservation strategies, in terms of both water quantity and quality. Such solutions reduce numerous problems at the source, at the sink and within the urban system. Finally, the promotion of integrated water management seems to be more successful under proper institutional arrangements characterized by formation of regional authorities with a full jurisdiction over water resources and a wide representation of water users. With an increasing utilization of water resources, the integrated management of water resources in urban areas should become more widespread.

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