MAINTENANCE OF IRRIGATION AND DRAINAGE SYSTEMS

PRACTICES AND EXPERIENCES IN INDIA AND THE NETHERLANDS

EDITED BY M. JURRIENS AND K.P. JAIN
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IN INDIA AND THE NETHERLANDS

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PREFACE

India is not only a large country, but also a country with a vast acreage under irrigation. Figures on the area covered by artificial irrigation systems vary from some 40-60 million ha, making it the largest irrigation country in the world.

Logically, extensive literature has been produced on many aspects of Indian irrigation: technical, management, social and economic aspects have been dealt with by many authors. With all the varieties of views on problems faced and on causes for these problems, one aspect is generally agreed upon by everybody: maintenance of irrigation and drainage systems is crucial to guarantee the sustainability of irrigated agriculture, it is currently deficient and need to be improved. Strangely enough, however, very little has been written on the maintenance issue and to our knowledge, there is no systematic analysis of the subject in the Indian context.

In the Netherlands, on the other hand, for more than a thousand years water management has played an important role in the country’s history and in people’s lives, and the related maintenance of the water management systems has always had a self-evident place in this respect.

In the context of the Indo-Dutch bi-lateral training program "WAMATRA" (WAter MAnagement TRAining), it was therefore thought worthwhile to organize an Indo-Dutch Seminar on "Maintenance of Irrigation and Drainage System, which was eventually held during 10-14 December 1991, at Delhi.

The idea of the Seminar primarily was to make an inventory of the subject in the Indian context: what are the problems, which aspects are involved, what recommendations could be formulated for a future improvement of maintenance. On the other hand a number of Dutch papers would contribute to the Seminar, by picturing the essences of the Dutch practices and experiences. It would have to be assessed during the Seminar which of the latter could be used for the Indian situation.

In order not to confuse the discussions it was agreed to limit the subject to medium and large scale canal irrigation, excluding specific aspects of for instance tank, tube-well and village irrigation.

It was attempted to cover the entire field of the subject, with essential questions as:
- when has maintenance to be done and why: what are the objectives, what will be the frequency, what are costs and benefits;
- who has to do it: the government, the farmers, contractors;
- who is responsible for planning, execution and control and financing;
- how has the execution to be done;
- how has it to be financed, who has to pay how much and how are contributions to be collected?

All these questions were to be covered during the Seminar and on all the aspects recommendations would have to be formulated.

Looking at the results, we think the Seminar has been partly successful in the above respects. A lot of information on all kinds of issues has become available and the Seminar has made the understanding of the subject certainly more structured and systematic. A number of papers submitted contained interesting information, so that the idea developed to issue a publication on the maintenance subject on the basis of these papers. This publication, now in your hands, differs considerably from the Seminar proceedings. It contains only a selection of all seminar papers, and most of them were quite heavily edited, including newly collected information as well, for the purpose of this publication.

In concluding, we want to express our gratitude to both Indian and Dutch Governments, who made the Seminar possible and to all the participants and invitees who contributed so usefully, either by presenting papers or by participating in the discussions. We hope that the efforts put into the Seminar and into the subsequent editing of this publication may have a follow-up along the recommended lines, ultimately leading to a well organized, well executed, and adequately financed maintenance of the Indian irrigation and drainage systems, which play such an important role in Indian agriculture, and thus in the lives of hundreds of millions of people in India’s rural areas.

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MAINTENANCE OF IRRIGATION AND DRAINAGE SYSTEMS

M. Jurriëns & M.J.H.P. Pinkers

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MAINTENANCE OF IRRIGATION
AND DRAINAGE SYSTEMS

1. INTRODUCTION

The issue of maintenance is directly related to a man-made environment, consisting of artificial elements. Natural things develop and maintain themselves. Everybody knows that every tool or equipment need some kind of maintenance. Without that, it will ultimately lose its functions and utility, and it has to be replaced. Yet, one can observe quite different maintenance practices: from very frequent and intense to nearly absent, from expensive to cheap, from complicated to simple, etc. Apparently, the intensity or neglect of maintenance, depends on several factors:

- The nature of the tool: some tools do not need much maintenance, others are vulnerable and need frequent maintenance: a car engine is essential and needs frequent maintenance, the engine of a kitchen mixer usually cannot be maintained and does not need much maintenance till it brakes down after a (hopefully) long life.
- The importance of the tool, in view of its functions: an ashtray in a car does not effect the essential function of the car; a car keeps going with a broke ashtray, non-smoking car owners do not even need it.

Similar examples can be found for various other factors such as:
- The speed of deterioration and loss of functions; some things deteriorate very slowly, others more rapidly, but they can deteriorate quite far without losing their functions.
- The cause and type of deterioration;
- The cost of repair in case of deferred maintenance;
- The cost of replacement or rehabilitation if it can no longer be repaired;
- The cost of regular routine maintenance itself;
- The available finances;
- etc, etc.

Everybody knows that some degree of maintenance is usually necessary, but problems and differences of opinion occur when further questions arise, questions which are basically coming down to:
- Why and when is maintenance necessary;
- Who is responsible;
- How is it to be done and by whom;
- And how are the costs to be financed.
These questions will be briefly discussed in this paper, as far as related to irrigation and drainage systems. The first question depends on:
- aspects of functions (Section 3),
- costs and benefits (Section 4),
- and resulting frequencies (Section 5).

The institutional aspects are discussed in Section 6 and the last two questions in Sections 7 and 8. But first some reflections will be given on the "maintenance environment": conditions which affect all considerations on maintenance, irrespective of technical or financial factors.

2. THE ENVIRONMENT OF MAINTENANCE ACTIVITIES

Apart from the above mentioned factors, a number of less concrete factors certainly can play a role in the maintenance policies and discussions:
- does anybody feel responsible or is anybody made responsible for maintenance;
- the culture: it is common to maintain things;
- does it have status to be involved in maintenance work;
- is it a private or a public good to be maintained;
- are their personal benefits to be expected?

As a result of all these factors sometimes important things are hardly maintained, while for other things one wonders why so much money and effort is automatically spent on seemingly useless maintenance activities. All factors together may explain seemingly simple questions as for instance "Why does a country maintain its roads?." Can the road no longer be used if it is not maintained, is it so cheap to do that the question is not important, does it cost too much fuel if it is not done, is it prescribed in a law, whether useful or not, does it create employment or is there a well development economic sector working specialized in maintenance, is it the peoples nature to be neat and clean, is it too expensive to let it come to substantial repairs, etc.

Similar principles and questions of course apply to the maintenance of irrigation and drainage systems. Canals and structures evidently constitute a man-made environment, enabling agriculture on lands where without such systems it would be less beneficial or impossible at all. And where irrigated agriculture is the basis of the life and economy in many countries, maintenance of such systems has to be essential as well.
Looking at the maintenance practices with regard to water management systems in The Netherlands and in India we will see that there are considerable differences, not only in the execution methods and organization, but particularly in the intensity and quality of the maintenance and the efforts and finances spent on it. The general picture is that the maintenance of canals and structures is receiving less attention in India than in The Netherlands. The common Indian statement on maintenance is that it is important, but that government funds are insufficient. This is an easy answer, but is it the real reason? In the Netherlands as well, funds for maintenance are not always sufficient or even worse; the government does not contribute to maintenance costs at all. Yet maintenance practices are quite good although improvements are always possible. Perhaps some of the other factors mentioned above are playing as well to explain the differences in maintenance practices.

In comparing the maintenance situations in the two countries and in trying to learn lessons from each other, it seems worthwhile to try to identify and address "environment factors" as mentioned above. This could perhaps better explain reasons for differences or possibilities and constraints for transfer of lessons from one country to another. But it could also benefit considerations on how to improve maintenance in India (improvement of maintenance in The Netherlands might as well be possible, but this is not the primary subject).

3. MAINTAINING SYSTEM FUNCTIONS

Answers to many maintenance questions largely depend on which functions of the water control system are to be maintained and on the consequences of a loss of function due to inadequacies in maintenance.

Most important of course are the functions directly related to water control. Canals and structures in irrigation canals should have sufficient capacities, and should be able to guarantee the required water levels, for instance for proper functioning of outlets and to avoid overflowing of banks. In any system these functions should be identified and defined, and the maintenance requirements should be based on maintaining these functions.

Drainage systems should basically also have sufficient capacities, in order not to exceed specified water, but the ultimate purpose of this is different, that is avoiding inundation or water logging instead of guaranteeing a required level for distribution of the water supply. In the Indian systems, where irrigation and drainage systems are separated, the differences between the objectives may lead
to different maintenance practices and frequencies. But a more important
difference may possibly be related to the institutional and execution aspect. It
will be useful to elaborate on this difference between irrigation and drainage
canals with respect to maintenance, particularly in the Indian situation.

When system functions are no longer being fulfilled, the cause of this should
be identified. Canal capacities are determined by the dimensions of the canal,
the water level gradient and the flow resistance, whereas for a given flow size
the gradient and levels depend on the dimensions and the flow resistance. It
should be realized however, that problems are not necessarily due to
maintenance. Incorrect water levels for instance can also be due to deficient
operation or to physical properties of structures (cross regulators or outlets). In
such cases, maintenance of canals would not improve the situation.

Maintenance should only be done to remedy the cause of not fulfilling the
required functions or to avoid such causes to develop. Both of these (function
and cause) must therefore be identified to assess the required maintenance
actions. The maintenance activities will usually focus on the shape and
dimensions of the canal and on the flow resistance. This particularly applies to
the under-water part of the profile, which determines the water conveyance and
level functions. Maintenance of the part of the section above the water is needed
for structural reasons.

The above water control functions (conveyance, distribution and escape of
excess water) are mostly dominant in determining maintenance requirements.
In The Netherlands, however, gradually more and different functions have been
attributed to water control systems, besides the common basic elements of water
quantities and water levels. Aspects of different uses of water (such as fisheries,
navigation, drinking water) and different society demands (nature conservation,
redress ground water pollution, etc.) lead to the inclusion of requirements for
water quality and broader environmental concerns.

In Indian irrigation systems this is also becoming more important. Therefore,
to avoid negative developments as took place in European countries, it would
be appropriate to give timely and due attention to these aspects, to assess
whether to include them or not in maintenance considerations. At present in
India, other than strict water control functions are apparent in several regions:
many canals are used for drinking water as well, but also the health aspect of
water-borne diseases (malaria, filaria and bilharzia) may have its bearing on
maintenance objectives and techniques. It would be useful to elaborate on this
subject of functions and possible diversification in that respect.
Finally, dealing with functions also implies that maintenance should have any real sense. Maintenance for aesthetic or visual reasons only may not be very useful, certainly not as long as financing is a problem. For instance, a canal section can look very much deteriorated, but it can well be that the capacity is still more than sufficient. A canal must not necessarily always be neat and clean (free of any vegetation and with a nice shape). As long as functions are fulfilled it is even better to have some vegetation, particularly above the water level, for slope stability or for ecological reasons.

For proper maintenance one has to have a sound knowledge of the characteristics of the system and its elements and to understand to which functions they contribute. Such a data base is necessary for an adequate monitoring, planning, execution and control of the maintenance, for cost effectiveness of the work and for cost recovery as well.

4. COSTS AND BENEFITS

The need for maintenance as such may be evident: if things are not being maintained, their loose their function and value, investments are not properly being used and all this costs money. However, maintenance as well costs money and further decisions on what, how and how frequent to maintain, therefore should actually depend on a more quantitative analysis of costs and benefits. This is by far not simple, for a number of reasons:
- Relevant data on both elements are often not available;
- Maintenance is often done before deterioration becomes apparent: it is not known what would have happened if it would have been delayed and what the final cost balance of savings and spendings would have been.
- If maintenance is done late, and it has more the character of repair, rehabilitation or replacement, total costs may be higher than actually would have been needed by timely maintenance;
- Benefits are difficult to assess; in fact one should therefore compare the with and without maintenance situation, both under the same circumstances;
- Both costs and benefits may vary considerably depending on many factors.

Evidently data should be collected for the development of an effective maintenance policy. The paradox is, however, that this cannot be done when hardly any routine maintenance is executed. Creation of a pilot project in this respect therefore seems appropriate and is strongly recommended. It could be a great incentive for future maintenance practices and policies to have concrete field data available on real costs and benefits.
A particularly important subject would be to assess the maintenance needs and costs of lined canals. Lining is often advocated to reduce seepage losses, with the additional argument that part of the costs will be recovered because lined canals require less maintenance. This statement can be questioned, but documented evidence is scarce or even absent. Some indications even suggest that maintenance of lined canals might cost substantially more than it is usually said, especially with the deterioration of lining in due course of time. More information should be collected on this issue.

5. MAINTENANCE FREQUENCY

One method of doing maintenance is to monitor functions and to do maintenance works when it is observed that these have started getting affected. When one waits even longer and it is accepted that the system is functioning for some time below its optimum capacity, one speaks of deferred maintenance, which can ultimately get the form of major repairs. In some countries this practice is followed: major repairs or rehabilitations are being carried out, for instance once in 10 years, rather than more frequent regular maintenance to guarantee the proper functioning. The other extreme is what is called preventive maintenance: carry out a regular and frequent maintenance program without functions being clearly affected at that moment, but to avoid that happening.

In any maintenance policy a choice has to be made between these and intermediate options. This choice may be made on purely political or national economic grounds, with or without sound information on costs and benefits. More in detail, a number of factors is affecting the issue. For instance the methods, techniques of maintenance and physical conditions are involved. Methods used affect the quality of the work, and thus the required frequency, but also the costs. Also the specific climatic climate, soil and hydrological conditions play a role. For instance, climate and soil may affect the vegetation, both in type and growth rate. Some aspects in this respect are:
- In some areas regrowth of vegetation is very rapid and maintenance has to be done several times a year.
- In some systems there is one dominant type of vegetation, in others there is a large variety of vegetation.
- In certain areas the irrigation water is heavily silt loaded, requiring frequent desilting, in others there is clear water and desilting is hardly necessary.
- In the Netherlands there are some differences in maintenance between peat, clay and sandy areas. In India there may be differences in alluvial, loamy or Black Cotton (BC) soil areas.
- System design may play a role, for instance steep side slopes may require more frequent maintenance.
- Again, functions can be important: different water control functions may ask for different frequencies, and ecological considerations may change the requirements.

Another aspect is that different frequencies may be required for vegetation control and maintaining the section shape and dimensions. One clear difference can be observed in The Netherlands: usually flow resistance is more frequently and more rapidly changing than the canal dimensions, mostly due to vegetation growth. In The Netherlands therefore two types of maintenance are being distinguished: the "small maintenance", dealing with vegetation control with a high frequency, and the "large maintenance", dealing with section control (reshaping, desilting), with a very low frequency. It has to be seen to what extent this distinction can be made in the Indian systems.

Finally it is advocated to devote adequate attention to the specific requirements for drainage canals. Because of their different functions and characteristics, maintenance aspects (and particularly the frequency) for drainage may differ from those for irrigation canals. Although in The Netherlands generally such separated systems for irrigation and drainage are not known, here the difference between maintenance of permanent water carrying and temporarily dry canals may give an indication of such differences.

6. INSTITUTIONS AND RESPONSIBILITIES

Even having a clear maintenance policy, a necessary data base, and sufficient knowledge on the above issues, a systematic maintenance can only be done if there is a proper institutional and legislative framework. "Institutional" refers to agencies and people specifically responsible for the development and implementation of the maintenance policy. One could even argue that the priority is reverse: first one should have an institution, legislation etc., then the money has to be there, for which a financing policy is required, and only having all this organized the question of how to execute the maintenance can be dealt with.

Several papers in this publication discuss elements of the Dutch Waterboards and their crucial role in maintenance. Of course it will not be necessary and not possible to copy this to the Indian situation. But it would be worthwhile at least to identify where institutional development or modifications in India are
required and which elements from the Dutch experience could be used or not in the Indian context.

Since the beginning of water management in the Netherlands this has been a primary responsibility of the inhabitants of the local communities. Community organization and regulations developed in such a way that each individual (farmer) had to contribute to the proper management of the water systems by executing the maintenance by themselves. Increasing land reclamation lead to the organization of farmers and farmers’ representatives (waterboards). Later on, contributions by farmers in labour were replaced by financial contributions and farmers had to maintain only the small ditches on their own land.

In India the situation has developed differently. First there is the fact that new irrigation and drainage systems were built by the government and made available to the farmers. Second, there is the clear division between the main system, managed by the government, and the tertiary unit (the command below the "outlet").

In The Netherlands there is only the division between "government" (actually the Waterboard) and individual farmer. In India there is one extra intermediate level in between government and individual farmers, namely the outlet command, whereby it should be realized that the size of individual farms in The Netherlands often is of the order of an outlet command in India. The problem largely is that with regard to responsibility at that level the situation is confused. In several States Irrigation Acts or similar documents attribute some role to the Government (Irrigation Department, CADA) for varying matters within the chak. In most cases there are problems involved, however. Sometimes, responsibilities and tasks are defined only in general terms and not sufficiently detailed to be workable, in other cases farmers’ responsibilities are clearly spelt out, but there is no mechanism for control or sanctions/penalties. Sometimes also, farmers and government are only blaming each other and waiting for the other party to take action.

It seems not realistic to us to expect the government to execute all maintenance within the outlet command. A basic decision is to be made on to what extent government can be (made) responsible. This would require a number of measures: (i) clear formulation of the works for which government is responsible (not just "maintenance" in general, but more specific), (ii) similar indication of responsibilities of the farmers with clear guidelines for the standards of maintenance and (iii) the development of adequate legislation with executable control and sanctions, serving the purpose.

Completely on the other extreme, it is also possible to leave the matter
completely to the farmers (possibly supported by government measures or assistance). However, for farmers to organize themselves and the maintenance within the outlet command, it seems prerequisite that water supply to the outlet is adequate and reliable.

Apart from the above there is the question of institutional requirements for the maintenance of the main irrigation system, which normally concerns the branch- and main canals, distributaries and minors and all their structures. Usually there seems not to be a major problem in this respect: generally, Irrigation Department is responsible. Only regarding the organizational set-up it could be questioned if and how at least some separate division or sub-division should be created to be responsible for maintenance only. The current situation where maintenance is part of the job of the operation staff does not always seem to be effective.

Finally, in the lower reaches of the outlet command there is the question of responsibilities for drainage. This is somewhat more problematic than for irrigation. Within the chak the problem basically is as discussed above. Downstream of the chak, the situation is not always clear. There may be different responsible institutions for smaller drains, larger drains, road crossings in the drains and their may be questions on the division between CADA and ID. In several States, there seems to be no adequate legislation with respect to drainage responsibilities.

Further analysis and investigations are required on the above mentioned subjects, to come to effective recommendations, particularly on maintenance at the level of the outlet command and of the drainage systems.

7. MAINTENANCE PLANNING AND EXECUTION

With respect to planning of maintenance there are basically three policy options:

* An effective monitoring system is installed to identify when and how the actual situation deviates too much from the desired one, and on the basis of that the required maintenance is determined and executed.

* On the basis of experiments or knowledge on the system a fixed plan of regular routine maintenance is developed and implemented, including fixed frequencies (periods), techniques, etc.

* A kind of mixture of the above options: (i) a fixed maintenance plan and schedule, together with (ii) an effective monitoring, the latter enabling more flexibility and prioritising as per availability of funds.
In the above, it is possible to come to a classification of the canals, within the system, each class with its own maintenance requirements. Also, the possible difference between "small" and "large" maintenance has to be taken into account. Small maintenance concerns the regular control of vegetation, to keep the flow resistance low and the flow profile open. Large maintenance concerns desilting and reshaping of the section.

The next question is who is to carry out the maintenance: the government itself with own equipment and personnel, or one or more contractors under the supervision of the government. Pros and cons of the various options have to be identified and analyzed.

Subsequently it has to be seen how the maintenance is to be carried out. Some papers in this publication will go into detail on a variety of techniques and equipment. For centuries the maintenance in The Netherlands was done manually. Labour was abundant and cheap. Increasing labour costs during the last 40 years led to the development of mechanical maintenance and later on chemicals were introduced as well, being cheap and effective, but also constituting serious treat to water quality and environment. Today mainly mechanical means are being applied, while there is an increasing attention for biological methods.

For India it is evident that manual maintenance methods will be dominating for the near future. The question of application of appropriate tools could still be addressed in this sense. Yet, the application of mechanical equipment may be required to be effective under specific circumstances. Criteria will have to be developed on when and where to use mechanical means.

Evidently, policy choices and financial criteria play an important role in the selection of the maintenance methods and equipment. Yet, this choice can also decisively be affected by the function of the canal or by more physical factors such as soil type, topography, etc. Consequently, different solutions may be found for different circumstances. Therefore, for the planning and execution as well, creation of some pilot projects under different conditions, could be useful to develop and test various methods of planning and execution and to provide more inside in various aspects involved.

8. MAINTENANCE CONTROL AND FINANCING

Before executing maintenance works the corresponding finances have to be
available, and after the work has been executed, it should be checked if it has been done according to requirements. Again in both respects, one has to distinguish between the main system and the outlet command.

For the latter a control system has yet to be developed. Its nature will depend on the institutional arrangements, according to the three options described earlier:
- Control can be left entirely with the farmers within the unit;
- Government can exercise the control entirely by itself;
- A control or survey committee (comparable with the Dutch "Schouw" Committee, described in some of the subsequent papers), composed of both government and farmers representatives.

In the latter two options, there have to be clear standards, through which the quality of the executed work can be assessed. Also, it requires an adequate system of legislation and sanctions, as well as financial arrangements.

In the first option, financing is the responsibility of the farmers, in the latter two options there are several possibilities. But in all cases it seems logic that farmers contribute to the maintenance costs, either as a separate fee, or as part of the total water fee. The water fee usually differs for different crops, whereas maintenance costs could be the same. Further work is required to formulate a number of clear options on financing and control, each with their implications and consequences in various respects.

For the main system the situation is less complicated. Responsibility for maintenance, including control of works, is entirely with the government (although there is a discussion of handing over part of the management, for instance on minors, to farmers associations). But here as well, there have to be clear methodologies to assess the quality of the maintenance. This applies particularly when maintenance is executed by contractors or farmers.

9. SUMMARY AND RECOMMENDATIONS

Reviewing the picture of the maintenance problem, the impression is that first the responsibilities and corresponding institutions should be clearly defined and decisions should be taken on a financing policy. In the Indian context the separation between main irrigation system, outlet command, and drainage complicates these issues. Crucial question will be to define the role of the farmers, or conversely the degree of government involvement, in financing as well as in responsibilities for execution and control of maintenance at outlet.
command level and in downstream drainage.

Responsibilities for the main irrigation system are not so much a problem, although perhaps organizational aspects can be improved. Here, financing is a major bottleneck, in which it has to be decided to what extent the farmers have to contribute to main system maintenance.

Evidently, an adequate legislation should support arrangements on responsibilities and rights, financing and control.

With respect to the execution of the maintenance it has first to be decided who is to execute the work, followed by and related to the question of how to do it. For the latter question various methods and equipment are available. A number of general criteria can perhaps be developed, but for a real situation it can only be decided in situ how execution will be done, depending on the local conditions (not only physical, but also financial or social). Specific issues in the Indian context are the maintenance of lined canals and of drainage channels.

In all cases execution methods and frequency of maintenance are largely determined by the objectives and functions of the system. These are therefore to be clearly defined, taking into account possible objectives and functions other than directly related to water control.

For proper planning, execution and control of maintenance, a sound data base of the system should be available.

Considering the complexity of the subject and the absence of a long systematic maintenance tradition in India, one cannot expect all problems to be solved at short notice. One recommendation could therefore be to install a task force, for organizing and carrying out further (practical) maintenance research in India. This would have to cover all aspects: institutions, financing, technology and legislation. A second recommendation could be the creation of one or more pilot projects on maintenance. This would serve the above research and could answer questions of appropriate standards on frequencies, techniques and control under various conditions.
PART B

MAINTENANCE IN THE NETHERLANDS
CANAL MAINTENANCE IN THE NETHERLANDS

H.J. Siefers

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3. THE GENERAL INSTITUTIONAL SET-UP
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7. DEVELOPMENTS IN MAINTENANCE TECHNIQUES
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CANAL MAINTENANCE IN THE NETHERLANDS

1. INTRODUCTION

The Netherlands, with a population of about 15 million, cover a land area of 31,800 km² (3.18 Million ha). About 7,700 km² or 0.77 million ha have been wrestled from the sea and inland waters by reclamation, drainage and careful water management. In former days this was done by the "Waterboards" and by entrepreneurs and in the 19th and 20th centuries mainly by the National Government.

The landscape of The Netherlands is almost entirely flat and low-lying. Some 60% of the land would be flooded daily by sea and rivers if dikes did not offer protection; 30% is even lying below sea level. About 70% of the country's total land area consists of cultivated land, of which almost two third is pasture and the remainder is used for arable land and horticulture. The climate is moderate and marine with cool summers and mild winters. The average input of the water balance of the Netherlands is 25% precipitation, 65% River Rhine water, 8% River Meuse water and 2% from other transboundary rivers; on the output side stand 16% evaporation and 84% discharge into the sea.

The above may illustrate that water management plays a crucial role in the country. In the course of the centuries, a vast network of artificial canals and appurtenant structures has been developed, apart from the natural drainage system. To maintain the various functions of this network, about a quarter of a million kilometres of canals are annually maintained in The Netherlands. This paper presents an overview of some important elements of the organization and execution of maintenance in the country.

Adequate water management, including maintenance, requires an institutional framework for the long term policy planning and the implementation of this policy and of the execution of the works, but also a corresponding legislative and financial infrastructure.

The first part of this paper outlines the nature of this institutional framework in the Netherlands. After a brief historical review in Section 2, Section 3 sketches the institutions at National and Provincial level. In the actual implementation of water management at local level, a typical Dutch institution, namely the "Waterboard" plays a crucial role. Some characteristics of these Waterboards are discussed in Section 4.

The second part of the paper deals in general terms with some practical aspects
of maintenance, such as the network to be maintained and the costs involved (Section 5), the objectives (with present day changes) and requirements of maintenance (Section 6), the maintenance methods and techniques (Section 7) and the methods of control and sanction (Section 8). The paper ends with a brief sketch of the research and extension in The Netherlands with respect to maintenance and a summary and conclusions.

Emphasis in the paper is on the quantitative aspect of water management for agriculture. Other aspects that can also be the responsibility of a Waterboard, are not discussed. This regards for instance the water quality aspects and flood protection (dikes).

2. HISTORICAL BACKGROUND

In the Netherlands, located in the delta of three major European rivers (the Rhine, Meuse and Scheldt), water played a dominant role in the course of history. About 1000 A.D. there was not enough food from fishing and hunting, so people began to exploit the peat and clay areas to grow agricultural products.

The continuous lowering of the ground water table, to keep the land suitable for agriculture, set in motion a still continuing subsidence-process, making the land more and more vulnerable to flooding. In the 12th century, to protect themselves against flooding and to control the water level in their canals, farmers began to construct dikes on a large scale. The basis principle of the Dutch inhabitants was: "Who does not want to stem the water with a dike, must leave his property". In a modified form this principle still applies today.

In the 13th century many tidal creeks and channels were dammed. Many towns ending in "dam" like Amsterdam and Rotterdam date from this period. Apart from the concern for the local dikes, it also became necessary to control the water table in the tidal creeks and watercourses behind the dikes and dams. As the control of dikes and water management could no longer be exercised by the local societies, the need for a regional organization arose. In the 13th century the local societies began to elect representatives to the meetings of the regional water organizations.

These organizations (called waterschappen = "Waterboards"), based on democratic principles, were recognised by the rulers of the different states in the Netherlands. These rulers gave wide powers to the Waterboards, concerning regulations, levies for construction and maintenance and jurisdiction in all water
related affairs.

Later on, when the subsidence of the land had reached a level at which gravity-drainage was no longer possible, polders were made within the dikes. From the polders the water was artificially pumped out by windmills. These polders got their own local Waterboard. In the course of time the number of polders and embankments increased and this was the reason for the existence of more than 2500 Waterboards in the first half of the 20th century. Without the efforts of the Waterboards the present shape of the Netherlands would have been very different. It was a foreigner who stated: "God created the world but the Dutch shaped the Netherlands".

In the 17th century the need for an organization at state level arose. But it was not until 1798 that a national agency, the "Rijkswaterstaat", as part of the ministry of Home Affairs, was created in order to take care of all water related affairs on a national level. Since then, the general supervision of water related institutions by the central government is prepared and exercised by this national agency, the Rijkswaterstaat, which is nowadays part of the ministry of Transport, Public Works and Water management.

3. THE GENERAL INSTITUTIONAL SET-UP

Integrated water resources development and management in the Netherlands is a task of the Public Authorities and not of private persons or institutions. This can be historically explained, but it also is a conscious political choice.

The Netherlands have 12 provinces, below which there are about 700 municipalities and 125 Waterboards. The municipalities are the general administrative bodies, the Waterboards are functional bodies dealing with water management only. The general supervision of the provincial authorities is exercised by the national government. The regulations and financial aspects of the provincial authorities, regional Waterboards and the local governments are consequently stepwise under the control of central government.

3.1. The National Government

The Central Government is responsible for the general policy on quantitative and qualitative management of all surface water and ground water including
waterworks and structures.
The Ministry of Transport, Public Works and Water management prepares and executes this policy. In addition this Ministry is responsible for state managed waters (the rivers and canals of national importance, the great lakes and the territorial sea). By constitution and laws the provinces are responsible for the remaining non-state managed waters and the ground water. The provinces have delegated tasks and responsibilities with respect to flood control and the quantitative aspects of surface water to Waterboards (see Figure 1).

<table>
<thead>
<tr>
<th>level</th>
<th>object</th>
<th>surface water</th>
<th>ground water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>national</td>
<td>provincial</td>
</tr>
<tr>
<td></td>
<td></td>
<td>regional/local</td>
<td>local waters</td>
</tr>
<tr>
<td>strategic</td>
<td>central gvt</td>
<td>provinces</td>
<td>provinces</td>
</tr>
<tr>
<td>operational</td>
<td>central gvt</td>
<td>waterboards</td>
<td>provinces</td>
</tr>
</tbody>
</table>

Figure 1. Water management responsibilities in The Netherlands

Many Acts and bills of the Dutch Parliament concern the administrative infrastructure, tasks and competencies with respect to water related affairs. The policy instruments of these acts specify rights and duties, but also prohibitive and restrictive measures and procedures for appeal.

One of the important acts is the Water Management Act, most recently modified in 1989. Apart from the above subjects it contains regulations for policy documents on physical and environmental planning as well as more detailed guidelines for the quantitative water management such as decrees on water levels, water agreements between two or more authorities, registration and licenses for supplies and extractions.

The Central Government, by means of the Ministry of Transport, Publics and Water Management, is responsible for the national strategic planning of water management. This concerns both surface- and ground water, and includes quantitative and quality aspects of the management of canals, lakes, rivers, waterworks and structures. (Planning and execution of supply of public drinking water is under another Ministry).

Every four years, a National Policy Document on Water management has to be drawn up, which is done by the "Rijkswaterstaat" Directorate (national water management directorate) of the Ministry. Various Commissions advise the Central Government in the above fields. In addition, the Ministry, by means of
H.J. SIEFERS

Rijkswaterstaat, is also responsible for the policy implementation and control concerning the "national waters", which are the main lakes, rivers, shipping canals, estuaries and territorial seas.

3.2. The provinces

The implementation and control of the National policies is the responsibility of the Provinces (supervised by the Central Government), which concerns all non-state surface waters as well as all ground water matters. The provinces formulate provincial water management plans, every 4-8 years, based on the national plans. The province is also the court of appeal for municipalities, citizens and companies against decisions of the Waterboards and is advised by several Commissions for their various tasks. Provinces further delegate executive task to municipalities and tasks on flood control and quantitative aspects of surface water to the Waterboards, as discussed in the next Section.

4. THE WATERBOARD

The typical Dutch institution of the "Waterboard" plays a crucial role in water management in the country. Waterboard tasks are formulated by the province and they can vary depending on the various circumstances. Some of them are only responsible for flood protection, others deal with quantitative water control only and again others also have to address qualitative aspects. In this paper, we only deal with the quantitative aspect.

The Waterboards are a decentralized form of functional government, dealing with water affairs only, in a limited area. This area is usually historically determined, mainly depending on natural and artificial drainage systems. Waterboards have the competence to lay down regulations on all water related issues (including design, construction, operation and maintenance, but also on taxes and levies). Their activities are to be based on detailed Water Management Plans, in accordance with the Provincial plans.

Since the fifties the central government has striven for the concentration of local and regional tasks. The policy of the eighties was to come to less and larger "all-in waterboards", with flood protection and quantitative and qualitative water management under one controlling agency. Both policies explain the strong decrease in the number of Waterboards in the last four decades (from 2500 to 125), mainly for reasons of administrative power and efficiency and still
covering the same initial total area. The Waterboards nowadays employ some 6,000 people in total. Most Waterboards have two official services: the secretary or record office, headed by the secretary or registrar and the technical or technological service with a director. The size and scope of these services obviously depend on the obligations of the Waterboard and the extent of the territory it covers.

Various matters concerning the functioning of the Waterboards are stipulated in the "Waterboard Act", recently modified in 1991. It has the provisions for the supervision by the national government of the lower water administrations, for the foundation of Waterboards by the Provincial Government as well as for the supervision of these boards. The law also describes the administrative structure of the Waterboards.

The Waterboard is administered by three different bodies: the General Assembly, the Executive Board and the chairman. The Assembly is the principal body of the Waterboard. Its exact composition and way of election is regulated by the provinces, which grant the Waterboards permission to make further regulations. The founding articles which the provincial council must formulate for each Waterboard, define not only the territory in which it operates and what task it has, but also the affiliations of the members of the Assembly and the number of seats to be held by the various groups interested in the work of the Waterboard.

The voting system, appointing individuals from these groups, is based on the rule that the representation in the Board is proportional to the extent of interest and the (related) level of payment of tax.

The Assembly draws up the by-laws of the Waterboards, takes decisions on budget, levies taxes on land owners and polluters in its area. The Executive Board, composed of a small number of members of the Assembly is responsible for the day-to-day administration and implements the decisions of the Assembly. The chairman chairs both the Assembly and the Executive Board and has certain powers of his own. The chairman is appointed by the Crown.

The cost of the regional and local quantitative water management exercised by Waterboards is financed by taxation based again on the rule: extent of interest, amount of taxation, degree of representation (owners of land and buildings; someone who has much land or built property pays proportionally more). For more details, see the paper by Deurloo.
5. MAINTENANCE ACTIVITIES, EXECUTION AND COSTS

Maintenance of canal systems is an important element in adequate water management. In The Netherlands about a quarter of a million kilometres of canals is annually maintained. The activities concern:
- Removal of vegetation, from the wet section as well as from the side slopes and maintenance paths (the so called "small maintenance" or "mow maintenance"). This is done during the growing season, with a frequency of once or more times per year.
- Maintaining the profile dimensions (the "large maintenance" or "special maintenance"). This concerns the regular deepening of the bed (dredging, excavating), repair of the side slopes and possible protection (lining), as well as the maintenance of larger structures. This is done in autumn and winter, with a frequency of once in 5 to 25 years, depending on the circumstances.

We can distinguish three modes of execution, the canal lengths involved are given in Table 1.

Table 1. Lengths of canals and ditches to be maintained by various parties

<table>
<thead>
<tr>
<th>Party</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterboards</td>
<td>55,000 km</td>
</tr>
<tr>
<td>Farmers</td>
<td>127,000 km</td>
</tr>
<tr>
<td>Others</td>
<td>62,000 km</td>
</tr>
<tr>
<td>Total</td>
<td>244,000 km</td>
</tr>
</tbody>
</table>

- Canals maintained by the Waterboards (or by contractors, but under supervision of the Waterboard). This concerns canals that are considered important for the entire water management in the area. Data on such canals are laid down in so called "leggers" (databases, see the papers by Deurloo and by Hamster). This is a legal-administrative instrument which has to be approved by the provincial administration.
- Canals and ditches that are to be maintained by the owners or users of the adjacent land. This is done under control of the Waterboard. These only serve a restricted local purpose and are less important for the entire system.
- The other waters which are not important for the water management, as ditches along roads and railways etc.). These ditches are maintained by municipalities, road or railways agencies, etc.

On "small maintenance" alone some 150-200 million Dfl is annually spent, of
which about half by the Waterboards. This comes down to an average of about Dfl 1.50 per metre or approximately Rs 25,000 per km. In individual cases these costs can vary considerably (from about Dfl 0.25 to Dfl 4.00), depending on the dimensions, the frequency, soil conditions, techniques used, etc. Table 2 provides some data in this respect. More cost details are given in the paper by Hebbink.

Table 2. Cost variations in Dfl/m

<table>
<thead>
<tr>
<th>Bed width</th>
<th>Sand</th>
<th>Clay</th>
<th>Peat</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1</td>
<td>0.35-3.50</td>
<td>0.10-1.60</td>
<td>0.35-1.70</td>
</tr>
<tr>
<td>1-2</td>
<td>0.55-2.20</td>
<td>0.10-1.60</td>
<td>0.35-0.75</td>
</tr>
<tr>
<td>2-4</td>
<td>0.55-1.90</td>
<td>0.40-1.30</td>
<td>0.35-1.75</td>
</tr>
<tr>
<td>&gt; 4</td>
<td>0.55-2.15</td>
<td>0.25-1.30</td>
<td>0.70</td>
</tr>
</tbody>
</table>

No data are available on expenditures for "large maintenance", but it is estimated that this will be in the same order of magnitude. When, however, the removed bedmaterial is contaminated, as is regularly the case (chemicals, polluted waste), costs can be much higher, due to the required analysis and extra cleaning.

6. MAINTENANCE OBJECTIVES AND REQUIREMENTS

For a long time the water control systems were primarily serving the agricultural sector. Emphasis was on guaranteeing the capacities and levels in the canals, for the required supply and removal of water and prevention of too high or too low levels. The latter is not only important in the flat low-lying parts of the country, but also in the higher areas (preserving the water for dryer periods).

Gradually, however, other aspects became important as well. This concerns for instance interests of nature and landscape, fisheries, water supply for domestic and industrial purposes, and recreation. These fields have their own specific interests in water management and in maintenance. This lead to a change towards a more nature oriented function approach of canal and water management. When a canal is in a kind of natural equilibrium, it forms a stable system which will less frequently surprise its users and managers, while it need not be more expensive in maintenance. Thus generally in the country, two types of functions became attributed to all canals:
* the water control function (capacity, levels and storage);
* the ecological function.

Furthermore, different "user functions" can be attributed to a canal:
* natural environment for biological life;
* water transportation for safety control;
* medium for recreation;
* (professional) fishing water;
* medium for transport of waste matters;
* drinking water resource;
* agricultural resource;
* industrial use.

Some of these functions may be conflicting. This already applies to the two general functions: increase in control generally means a decrease in ecological value. This mutual dependency is depicted in Figure 2. The hatched part indicates the space for management.

![Diagram showing the scope for management between water control function and ecological function.](image)

Figure 2. Canal functions and scope for management

All these functions have their own requirements with respect to the method and frequency of maintenance. Demands related to safety, industrial and agricultural water supply are primarily of quantitative nature, demands concerning drinking water, fisheries and environment are primarily of biological and qualitative nature.

Water management plans, including maintenance plans, have to be based on a complete assessment of the various functions and their requirements. The number of functions to be taken into account and the balance between them of
course varies largely between countries and even regions.

7. DEVELOPMENTS IN MAINTENANCE TECHNIQUES

For centuries, maintenance in The Netherlands was done manually, with rake, flail and dredging bucket. Labour was abundant and cheap and the dimensions of the canals were such that this could be done. Also, canals showed a wide variety in profile shapes and vegetation.

During the last 40 years, labour costs began to increase and agricultural water control requirements became more demanding. This lead to the development of mechanical maintenance. As a result, canals had to be adapted to the way in which they had to be maintained. They got a more uniform appearance, and in large parts of the country maintenance paths were provided. Thus, maintenance could be more effective and more rapid, while also the accessibility in case of calamities was guaranteed.

Besides mechanical methods the use of chemicals was introduced. For some time it seemed that the cheap and effective chemical treatment offered a definite solution. Soon however, these chemicals appeared to be fatal for all kinds of life in the water, and to contribute to pollution of the ground water. This again shifted the attention to increasing mechanical maintenance. Frequently and regularly new technical developments were introduced, making the maintenance cheaper and more effective. In more recent periods attention has grown for biological methods. Sofar, experiences are positive but limited, and its use seems to be restricted to specific circumstances.

With the development of increasing maintenance requirements and new methods, one began to appreciate the importance of a sound data base of the system. This concerns the locations, alignments and dimensions of canals and structures, as well as the data on the adjacent properties (see the papers by Deurloo and by Hamster). Apart from being used for the planning, execution and control of the maintenance, such data base also serves the cost recovery.

8. MAINTENANCE CONTROL

As mentioned earlier, part of the water control system is to be maintained by the owners or users themselves, under control of the Waterboard. This control is called "schouw" (survey). This survey system was introduced centuries ago
by the Waterboards. In first instance it only concerned maintenance of dikes protecting their area, later the canals were included as well. Canals can be included in the survey if they are of limited local importance only, and do not affect the higher order system, and if there are different owners or users on both sides of the canal. Small ditches within a parcel are not included.

During the survey, which is normally held in autumn, the Waterboard checks if the canals and small structures are sufficiently maintained. Two owners or users on a canal have to maintain it together. They can do so by each doing half of the width; most common is, however, to clean the entire canal in turn or to pay the other or a contractor for doing it. When in former times irregularities were observed by the survey committee, the members went to a local restaurant, where they ate and drank extensively at the costs of the farmer, till the maintenance had been done. In this way the entire survey period could take a very long time, whereas nowadays it takes about two weeks.

The "Survey Committee" is composed of several members of the Waterboard's General Committee, because this is prescribed in the Waterboard acts and by-laws. In larger Waterboards there are several survey committees, each taking a part of the system. Often, the committee includes an employee of the maintenance section as well. The committee identifies irregularities (not well cleaned watercourse, choked culverts, etc) and reports these to the Waterboard. This is cross-checked by Waterboard experts, who can make an official report. The offenders are then ordered by the Waterboard's Executive Board to as yet execute the required works. If they still fail to do so, the work is done by the Waterboard, at the offenders expense. Of course there remains the possibility for the accused to appeal, but this is done with the court and not with the Waterboard.

9. RESEARCH AND EXTENSION

In The Netherlands, research on various aspects of maintenance is carried out by several Universities and Institutes. In this context for instance, once every 4 years, an international symposium on aquatic weeds is organized. The national "Central Bureau of Statistics" (CBS) regularly collects data on maintenance methods and costs. Research subjects are among others:
- the relation between vegetation and flow resistance;
- the effect of over-dimensioning on water vegetation, flow resistance and maintenance;
- the influence of sunlight and of nutrients on vegetation growth;
- the effect of large floating leaves on underwater vegetation;
- the development of natural canal banks;
- statistical key-data on maintenance.

For the last some years, the Waterboards benefit from the possibility to consult the specialized "Advisory Group on Vegetation" (under the Ministry of Agriculture, Nature management and Fisheries) for advice on the above mentioned subjects.

In 1979 the "Union of Waterboards", encompassing all Waterboards, created a Working Party, specifically charged with giving advices (to Waterboards) on common questions of operation and maintenance of canals. Over the years this Working Party has initiated research, for instance in collaboration with Institutes and Universities, and disseminated practical knowledge and experiences from the Waterboards. One of the activities concerned is the organization of regular meetings where maintenance machines and equipment are being demonstrated. Every time again, these meetings show that also the Waterboards themselves are developing new machines and techniques. During the forthcoming 15th Congress of the International Commission on Irrigation and Drainage (ICID), to be held in The Netherlands in 1993, such a demonstration day will be held as well.

Thus, the Working Party has proven to be a useful institution, by addressing many and varying practical maintenance questions. The creation of such a forum could well be of use for India.

10. SUMMARY AND CONCLUSIONS

In The Netherlands, the importance of maintenance of water control systems is self-evident, due to a longtime historical development of water control systems. Yet, the objectives and requirements have been increased and changed in recent periods, responding not only to society demands on nature and landscape conservation, but also to changing demands from other than agricultural sectors (recreation, fisheries, etc). Also, water quality requirements have become as important as water quantity aspects. Although similar developments are not yet dominating the present Indian water management scene, it is not unlikely that the mentioned aspects will become more important in future. While developing policies for maintenance, it would be appropriate to take into account such possible developments.
This paper may demonstrate that for an adequate maintenance, it is imperative to have an adequate institutional and organizational framework at national and provincial level. The functional character of the Dutch Waterboards (only responsible for regional water management) has proven a very effective means of guaranteeing an adequate management. The Dutch experience also shows that such institutions should go hand in hand with corresponding technical, juridical and financial structures, to be able to organize and execute the works, to supervise and control it, and to collect the required financial means.

The systems to be maintained and the practical problems and costs involved are enormous, already in The Netherlands, let alone in India. This asks for well founded policies in all above respects. The relevance of the Dutch maintenance picture for India would have to be analyzed. Other papers in this publication, on institutions, organization, financing and techniques will provide more detailed information for such purpose.

A general remark to conclude is that research on basic questions regarding all these aspects will be required to develop efficient and effective policies. The Dutch experience may illustrate that the creation of an Indian or perhaps Indo-Dutch forum, similar to the Netherlands Working party, discussed in the previous Section, could be very relevant, to initiate and guide practical research as well as to develop adequate policies.
METHODS OF CANAL MAINTENANCE IN THE NETHERLANDS

A.J. Hebbink

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3. SILT REMOVAL AND RESHAPING SIDE SLOPES
4. MAINTENANCE METHODS USED IN THE NETHERLANDS
5. FREQUENCY OF MAINTENANCE OPERATIONS
6. MAINTENANCE IN SAND AND CLAY AREAS
7. DEVELOPMENT IN MAINTENANCE METHODS AND
8. CONCLUSIONS
METHODS OF CANAL MAINTENANCE IN THE NETHERLANDS

1. INTRODUCTION

A canal - however good its design and how careful its construction may be - is only a semi-permanent structure. Soon after the construction of the canal the bottom, side-slope, or both may be subject to alterations. In and around canals the circumstances are favourable for an abundant growth of aquatic plants i.e. the availability of water, soil, light and often a sufficient supply of nutrients. Although good sod-forming vegetation should be encouraged on the side slopes of the canals as it will ward off erosion, certain vegetation will be unwelcome because it affects the canal functions. Also, the bottom level may change by sedimentation or scouring or the entire cross-section may change by deterioration of the side slopes.

All this may reduce the capacity or affect the required water level because of a reduction of capacity or a change in discharge-level relations. Research has shown that a discharge capacity can be reduced by more than 25% within one season.

The maintenance activities can include:
- Removal of aquatic weeds, both from the bottom and the slopes; the so-called small maintenance operations. These are carried out several times per year;
- Maintenance and repair of the canal profile, which includes removal of silt and vegetation (rests), repair of collapsed slopes and maintenance of culverts and weirs; the so called "large" maintenance operations. These activities are carried out once in 5 to 25 years, depending on the soil type and the nature of the area.

For the maintenance of canals several methods are available. A distinction can be made in mechanical, chemical and biological methods and maintenance with hand tools. Which method will be used among other things depends on the function of the canal. A ditch or canal used only for the discharge of water needs less maintenance than a ditch or canal which also is used for water supply or level control. In both, however, the wet cross-section must be such, that the water flow is not hampered.

Furthermore the choice of the method will depend on other physical factors,
like the type of soil, the land use, the number of canals, the sizes of the canals, the accessibility of the canals, and the topography.

Today other factors are coming up as well, such as water quality, environment and nature and landscape conservation. These factors may have a bearing on the functions to be maintained as well as on the choice of the maintenance execution. And of course the maintenance costs play an important part in this respect.

In this paper several of these maintenance methods will be described, as well as the related criteria, frequencies, and costs, all based on the experience and conditions in the Dutch Waterboards. Further a distinction is made in the maintenance of canals in a clay and in a sandy area. Finally some remarks are made in relation to the developments in canal maintenance and some conclusions are given.

2. VEGETATION CONTROL METHODS

A turf of sod-forming grasses is an excellent bank vegetation and the best way to keep it in good shape is to mow it regularly. Mowing can be done either with appropriate hand tools or with machines. The use of hand tools is declining in favour of machines, but in countries with an abundant and cheap labour force use of hand tools can be appropriate and efficient.

In general, aquatic plants can be divided into three types: emergent species, submerged species and floating species:

- Emergent plants. These plants have their roots in the soil at the canal bottom and their foliage above water. As these plants can only grow in shallow water (less than 1 m deep), their development can be prevented by creating greater water depths;
- Submerged plants. These plants grow entirely under water. They can occur even in deep waters, provided that the water is clear enough. These plants will not survive in canals that periodically fall dry;
- Floating aquatic plants. These aquatic plants are similar to submerged plants, but differs from them in that the leaves are lying flat on the water. Their comparatively thin stalks scarcely form any obstacle to the flow of water while their usually large leaves block out most of the light, thus preventing the growth of other aquatic plants. Free floating aquatic plants thrive in calm water with little current and no wave movement. Under the influence of wind and/or current, enormous masses of these plants can accumulate at narrow spots or near culverts/weirs, where they can be removed.
In addition filamentous algae can be considered as a fourth category.

Aquatic weeds can be controlled by either cutting (mowing), dredging or harrowing methods. Cutting leaves a stubble, resulting in a (rapid) regrowth of the weeds, but the stubble protects the canal bottom against erosion. Dredging on the other hand removes a proportion of the parts of the plants which are buried in the mud from the bottom. It is much slower and more costly operation than cutting. Harrowing tears the plants loose and stirs up the mud, thus retarding their regrowth. This is not possible in canals with a hard bottom since the tools cannot penetrate to cut and uproot the plants. When there is a risk of erosion, aquatic plants should preferably be mown.

Aquatic plants must be cut before they have developed fully and the operation must be repeated rather frequently. Delaying the operation for too long results in a low rate of work, while the large quantities of cut material floating in the canal may block the flow at curves and obstructions.

By cutting the aquatic plants without removing them out of the eco-system the water is enriched with plant nutrients, which stimulates the growth of weed. So the cut material should be removed preferably. This results in higher costs, but the productivity of the soil decreases gradually.

2.1. Vegetation control with hand tools

Till the sixties canal maintenance with hand tools was the most important and often the only way of maintenance. Because of the rising labour costs and the disappearance of skilled labourers the manual operation has been replaced by other maintenance methods. As yet, parts of the canals which can not be accessed by machines (or boats) will be maintained by hand. It generally concerns small canals in forests and nature reserves. Such situations, where there generally is an evident relation between the water management interests and the ecological, nature and landscape interests, mainly occur in areas with sandy soils. In the clay soils this relation is far less. This is the reason that manual maintenance is mainly applied in the sandy soils.

There are special bank-mowing scythes available. These have a blade attached to a long straight handle without handgrips. The operator walks along the verge of the ditch and mows the vegetation with swift forward strokes, bringing part of the cut material up the verge. Sometimes portable small mowing machines are used.

In fairly wide ditches or canals, weeds can be cut with a chain-scythe. This
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consists of a number of cutting blades with flexible connections and two handles. Two men pull it back and forth over the bottom of the canal. Manual maintenance has the advantage that no special provisions in the canal have to be made. So investments in maintenance paths (service road) and/or standardization of the canal profile are omitted. On the other hand manual maintenance is more expensive and the work is heavy.

2.2. Vegetation control with mechanical machinery

With growing maintenance requirements and vanishing use of hand tools, maintenance carried out by mechanical machines has assumed enormous proportions. Gradually, a wide variety of equipment has been developed, which seems difficult to oversee at first glance. Photographs of some of the equipment discussed below can be seen in the paper by Den Herder.

In the first place of course different equipment has been developed for different purposes, such as for mowing of slopes only, of bottom only, or a combination of both and for harrowing the bottom vegetation. Secondly, much of this equipment can be mounted on a tractor, such as various mowers and cutters, but also for some purposes special equipment has been developed. Further variations in equipment are related to differences in capacities and sizes for different soils and canal dimensions.

If the canal is in proper shape, vegetation control with mechanical equipment is a relatively simple matter. But if side slopes and embankments are not maintained well, the canals are hardly or not at all accessible for specialized vegetation control machinery.

An important factor in the development and choice of various equipment is the accessibility. A canal with a maintenance path has the advantage that it is always accessible. However, this means investments and a certain loss of arable land, and on "old" land such provisions do not exist. For example, in the North East Polder there are many small canals, which are difficult to access, because no maintenance paths were there. After hand tools were no longer used, farmers generally did not allow the "strange machinery" pass over their land. And if it was permitted, it had to be done when no crops where on the land, thus limiting the applicability.

One alternative was a newly developed, adapted mowing machine supplied with track chains (of synthetic material), that are moving with one track on each side of the canal, thus forming a "bridge" over the water. Another solution is the use
of mowing or sweeping boats, instead of working "from the land", maintenance is then done "from the water". The disadvantage is that it has to pass obstructions (bridges, culverts, etc.) in the canal. If there are many of these and they have not been designed for boat passing, special provisions have to be made, which can render this method unfeasible.

Wherever it is possible to drive an ordinary tractor alongside the canal, it is logical to use tractor-mounted equipment. The tractor should have sufficient weight for good stability. Some of the most applied machinery are:

- The cutterbar. The cutterbar is mainly used for mowing the slopes. Depending on the size of the canal also a part of the bottom can be mowed. The cutting mechanism is attached to a tractor machine, with or without a hydraulic arm. The ordinary type of cutterbar leaves most of the cut material on the bank, which may cause the vegetation to deteriorate. It is therefore good practice to rake cut material immediately after mowing. For this reason several types of mower bar-rake combinations have been developed.

- The rotary mower and the flail mower. Both types of mowers, attached to a tractor machine, are used for the mowing of the slopes and the maintenance paths alongside the canal. The flail mower pulverises the vegetational material fine enough to make its subsequent raking unnecessary. Rotary mowers have the disadvantage that foreign matter easily wraps around the mowing rotor and they must be very well shielded against detached knives, stones or other hard objects being thrown up. The flail mower can be equipped with a bottom rotary cultivator to fraise the bottom at the same time.

- The bucket-type mower. This is a combination of a cutterbar and an open bucket in which the vegetational material is collected and removed from the canal. The mowing bucket is attached to a tractor machine, hydraulic crane or an excavator. The mowing bucket mows and clears the side slope and the bottom of the canal in one movement. Besides, a small silt layer can be removed from the bottom. It can work around trees and similar obstacles and for smaller canals it needs access from only one side of the canal. As a disadvantage can be mentioned the relatively low production.

- The mowing boat or sweeping boat. If it is impossible to mow from the banks, one can use a mowing boat. Vegetation control can be done from small boats equipped with an underwater cutterbar (mowing boat) or with a hoeing attachment (sweeping boat). In front of the mowing boat a cutterbar is attached to cut the aquatic plants on the bottom of the canal. With a second cutterbar, attached to a hydraulic crane or not, at the same time the slope can be mowed. The hoeing attachment is a V-shaped knife which
penetrates slightly into the mud and moves clockwise to allow the cut material to rise to the surface and not wrap around the knife. The V-shaped knife can also be attached to tractor machines.

Apart from scythes and machinery such as tractors and cranes, bucket-type mowers are the most frequently used tool in The Netherlands, followed by mower boats and flail mowers. These are followed next by mower bar-rake combinations and mowing boats. In the paper "Vegetation control equipment in The Netherlands" by den Herder several of the mentioned machines and attachments are discussed in more detail.

2.3. Chemical canal maintenance

Controlling aquatic weeds with chemicals involves various aspects to be considered;
- there are many different kinds of weeds that may occur;
- there is a great variety of location-specific factors, each of which causing its own problems and requiring its tailor-made solutions;
- there is a wide variety of chemicals and application methods;
- considerations of environment and nature conservation, let alone the personal safety of the personnel, are gaining more and more attention and put limitations on the applications.

Each type and even variety of vegetation asks for its specific chemicals to be treated with. To develop a program for chemical control it is therefore required to know what types and varieties are most dominant. Moreover, in determining the types and quantities of chemicals one has to be careful not to "overdo" the treatment. For instance, a too drastic attack on side slopes may lead to bare banks which are then likely to erode or collapse.

With all the risks involved in vegetation control by chemicals, it is very important that strict regulations be laid down for their use. Specifically in irrigation systems the consequences for men (and cattle) and environment can be very serious. In any case, the chemicals used in the maintenance of canals need not be persistent. In the Netherlands use of chemicals has become very restricted and is only applied under well specified circumstances.

By killing the aquatic plants without removing them out of the eco-system the water will become enriched with plant nutrients causing excessive growth of e.g. algae. Continuous application of herbicides may result in a build-up of organic debris in the bottom of the canal. Furthermore a repeated application of one and the same herbicide on a certain spot tends to repress the less harmful
plants while the hard to control species expand their territory.

Also, it is useful to consider that designing or remodelling canals can be done such as to reduce the occurrence of various weeds. For instance, water depths of more than 1 m retard growth of emergent weeds, periodical setting dry of canals avoids emergent weeds and planting of trees (shade) along canals can reduce floating plants.

2.4. Biological canal maintenance

Gradually, canals become a more important element in the conservation of the aquatic eco-system. This is why in the management and maintenance of canals more attention is now being paid to their function for nature conservation. Besides, one became aware of the dangers of environmental pollution from the use of herbicides and the relatively high costs of weed control with machinery. Both above reasons lead to increasing attention for and research on application for biological methods. In general these methods will be applied in combination with mechanical maintenance or maintenance with hand tools.

The following methods might provide a solution:

- Chinese grass carp. Generally all species of aquatic plants are consumed, though the grass carp prefers submerged plants. Unfortunately, it will not propagate outside its natural habitat so that each individual fish must be imported or made to reproduce itself under artificial conditions. Screens or gates must be installed in canals or culverts to prevent the grass carp to escape their "working area".

  It has to be taken into account that a certain time must elapse before effects become obvious. Since over 10 years grass carps are used in The Netherlands to prevent a high growth rate of aquatic plants. Up to now the results seems good. It is rather difficult to forecast the efficiency of this method because it concerns living organism which are strongly affected by the conditions of the environment. The grass carp has a better chance of survival in deep water (deeper than 1.0 m). But even when working satisfactorily, some additional maintenance may be necessary.

- Animals. Goats or sheep can keep down weed growth if they are allowed to graze on the slopes of the canals and the maintenance paths. The banks must be firm enough not to be damaged.

- Shade. Suitable trees are planted alongside the canals so that a shadow is cast over the water. This will reduce the light and repress the growth of aquatic plants. There must be a certain current in the canal to discharge the foliage. In other cases additional maintenance is necessary and as result of
the bad accessibility costly maintenance. A disadvantage is that in the first few years after planting of the trees additional and costly maintenance is required.

Another possibility is the use of floating aquatic plants with foliage on the water. As yet there is not much experience with this method. In combination with the chinese grass carps it seems to give good results sofar.

3. SILT REMOVAL AND RESHAPING SIDE SLOPES

Canal functions can be severely affected by deterioration of the side slopes or by siltation on the canal bottom. Repair of banks and silt removal are costly operations and it is therefore better to take measures to as much as possible avoid their necessity.

The risk of the banks collapsing can be reduced by avoiding steep side slopes and by having the banks covered with a turf of sod-forming grasses. The root system of these plants reinforces the soil, and thus helps to prevent erosion. To prevent collapsing of the banks, special care should be taken not to damage the bank sods. Reeds and similar plants provide good protection against erosion at the water level even in shipping canals. The required canal capacity can be maintained, despite the vegetation, if the section is slightly over-designed.

To reduce the deposition of silt a sediment trap can be constructed in the canal. The current in the trap is decreased such, that the silt will be deposited. At regular intervals the stored silt has to be removed, but only locally. The use of a sediment trap has the advantage that practically no silt has to be removed in the canal behind the trap. A disadvantage can be that the growth rate of aquatic plants may increase because of the clearness of the water. This can be prevented by using relatively deep canals (e.g. more than 1.0 m).

If silt is removed from the canal once a year, this will help to double the intervals between the more expensive reshaping operations. However, when reshaping is needed, it can be combined with silt removal. The banks are pre-cut and the cut material remains in the canal until it is removed together with the silt.

3.1. Hand tools for reshaping and removing silt

Special hand tools have been developed for removing silt. The digging hoe
consists of a long straight handle with a specially bent shovel blade. The
dredging fork is used for removing aquatic weeds, and will also be helpful in
stirring up the silt.

If the canals are to be reshaped manually, a special spade or push knife with a
long handle is used. The blade is pushed down along the side slopes at the
proper angle. Hand dredging can easily be mastered but the work is heavy and
the output per man is fairly low.

3.2. Mechanical machinery for reshaping and removing silt

Just like for the vegetation removal, a wide variety of equipment and machinery
is available. Much of desilting and reshaping equipment can at the same time
be used for the removal of vegetation. The following equipment is being used:

- Rear-mounted or side-mounted tractor ditchers. During the work cycle, the
  tractor backs up, drops the ditcher into the canal and pulls it cross-wise
  through the canal and up against the near bank, bringing the spoil onto the
  land. The rear-mounted tractor ditcher works well if the banks are not too
  high and their slope not too steep. With a sufficiently large reach, side-
  mounted ditchers can work from one side of the canal only.

- Hydraulic excavators. There is an extremely wide range of hydraulic
  excavators, equipped with a mowing bucket or a backhoe. The choice
  depends largely on the dimensions of the canals and the accessibility (from
  one or from both sides).

- Suction dredgers. Especially for the maintenance dredging of silt and
  vegetational sediment machines are designed with a milling cutter suction
  system. This system uses a pump for transporting the spoil through a
  discharge pipeline to a dumping site, which may be situated nearby or at a
  considerable distance. Also barges are used to transport the spoil to a
  transfer point, where they are emptied by means of a mobile crane.

In the paper by Sperling several of the mentioned machines are discussed in
more detail.

4. MAINTENANCE METHODS USED IN THE NETHERLANDS

Table 1 gives a summary of the methods of canal maintenance used in The
Netherlands. A distinction is made in permanent water-containing canals and
temporarily dry canals. Further a distinction is made in maintenance of the
bottom and of the slopes of the canal. The table is one of the results of a
Maintenance Survey and Study program, carried out by the Joint Waterboards in 1980 and 1985. Overall, the concerned Waterboards covered respectively over 33,100 km and 32,700 km of permanently water containing canals and over 9,000 km and 10,300 km of temporarily dry canals in the 1980 and 1985 surveys.

Table 1. Maintenance methods applied in The Netherlands, as a percentage of the total

<table>
<thead>
<tr>
<th></th>
<th>Permanent wet canal</th>
<th>Temporarily dry canal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>slope</td>
<td>bottom</td>
</tr>
<tr>
<td>Methods</td>
<td>'80</td>
<td>'85</td>
</tr>
<tr>
<td>manual mechanical</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>+ manual mechanical</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>chemical</td>
<td>70</td>
<td>71</td>
</tr>
<tr>
<td>biological</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>none</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>x 10^3 km</td>
<td>33</td>
<td>33</td>
</tr>
</tbody>
</table>

From Table 1 it can be concluded that the use of machines increased, especially in the maintenance of the bottom of the temporarily dry canals. Around two-thirds of the canals were cleaned by machines only. Herbicides were applied mostly to clear the bottom of the canals. Reed was the plant on which most water boards used herbicides. The total use of herbicides declined enormously from 1980 to 1985, especially in temporarily dry canals, where there was a reduction (for bottom cleaning) from 43% to 20%. Biological maintenance increased, though but still accounts for a small proportion only. Manual maintenance dropped sharply: some 3% only of the canals were maintained manually. It is emphasized that the reduction in manual cleaning was mainly for economical reasons. Of course, where labour is still abundant and cheap, cutting aquatic weeds with a chain scythe is still a good method.

Some other general remarks on the choice of equipment are the following.
- In permanent wet canals of at least 0.50 m deep and 1.50 m wide, machines fitted to boats can be used to mow or cut the aquatic plants.
- If there is a sufficiently wide maintenance path alongside canals, mowers can
be mounted to a tractor, crane or excavator. Small tractors can be used if the maintenance path is at least 1.0 m wide, while self-propelled mowers can be used on maintenance paths at least 0.60 m wide.

- Chemical methods can result in bare banks, thus causing serious erosion problems. They may also have undesirable consequences for the environment.
- Biological methods can be used to reduce the quantity of aquatic plants to an acceptable minimum, but quite some experiments are required to find appropriate solutions.
- Where erosion constitutes a problem, aquatic plants should be mown or cut and not harrowed.
- Removal of vegetation, taken from the canal, is increasingly constituting a problem, asking for extra equipment and costs.

Maintenance begins with a programme indicating which canals will be maintained, when and how. The main source of information for this programme will be a system of monitoring of the canals in order to assess the problems and the changes taking place in the vegetation. Based on these observations measures to cope with imminent outbursts of vegetation will have to be taken in due time before the situation has culminated in an emergency requiring drastic and usually costly operations.

The maintenance programme should include the applied method(s) for each canal or location, the maintenance frequency, the machinery which should be applied and the period(s) in which maintenance has to be carried out.

5. FREQUENCY OF MAINTENANCE OPERATIONS

The aforementioned Waterboard survey made clear that the costs of canal maintenance is mainly determined by the frequency of maintenance. Substantial reductions in total costs can only be achieved by working out the optimal frequency. The required frequency is determined by various factors.

- The growth rate of the vegetation. This may vary both from time to time and from one area to another. Also the quality of the water (chloride content, eutrophication), the water depth, shade etc, are important;
- The function of the canal. A canal used for the discharge of water only, needs less maintenance than a canal which is also used for water supply;
- The size of the canal. A big canal with a large catchment area is maintained more frequently than small canals;
- Land use of the bordering area (if there are no maintenance paths). If the accessibility of the canal is hampered (cultivation of crops) the frequency of maintenance is limited;
- The Waterboard. There are also differences in the maintenance methods and frequencies among Waterboards, depending on their policies and preferences.

Both bank vegetation and aquatic plants need to be removed frequently. Exactly how often will depend on the type and rate of plant growth and local conditions. Table 2 provides data on frequencies of canal maintenance as a percentage of the total in The Netherlands, based on the earlier mentioned survey of 1985.

Table 2. Frequency of canal maintenance as a percentage of the total

<table>
<thead>
<tr>
<th>Times/year</th>
<th>Permanent wet canals</th>
<th>Temporarily dry canals</th>
<th>Maint paths</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>slope</td>
<td>bottom</td>
<td>slope</td>
</tr>
<tr>
<td>1</td>
<td>40</td>
<td>33</td>
<td>51</td>
</tr>
<tr>
<td>2</td>
<td>33</td>
<td>31</td>
<td>45</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>&gt;3</td>
<td>2</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>cont.</td>
<td>7</td>
<td>15</td>
<td>0</td>
</tr>
</tbody>
</table>

The table shows that, of the overall length of the permanent water-containing canals about one third was treated once a year, one third twice and one third three times or more or continuously. Some polder boards used mower and sweep boats to keep a substantial part or the whole length of their canals clean on a continuous basis. The temporarily dry canals were cleaned once a year in half the cases and twice in the other half.

Maintenance paths were present along 25% of the canals and they are mainly found in the sandy areas. Over 90% of the canals had a maintenance path at both sides. No maintenance paths were found alongside the canals in the South-Western clay areas. As result of the salty conditions here, the growth rate of the aquatic plants is less and thus also the maintenance frequency; in general once per year only. The maintenance paths had generally been constructed to make maintenance cheaper and less time-consuming and to reduce the amount of manual labour. The inventory showed that most maintenance paths were mowed two to three times a year.
For canals which were treated only once a year, this maintenance was concentrated in the period September to November; the start of the wet season in The Netherlands. If maintenance work was done twice this fell in the months June/July and September/October.

6. MAINTENANCE IN CLAY AND SANDY AREAS

The above information gives general consideration on the maintenance practices in the Netherlands. Of course variations exist over the country, depending on the specific local conditions. One aspect affecting the maintenance practices is the soil type. To illustrate the consequences, here some differences are outlined between maintenance in the clay areas and that in the sandy areas of the country. The clay soils are found mostly in the Northern and Western part of The Netherlands and the sandy soils are mainly found in the Eastern and Southern part.

6.1. General conditions in clay and sand areas

The following general characteristics in both areas account for the differences in maintenance practices.
- Clay soils have generally a good load bearing capacity. Under wet conditions there is a rapid deterioration of the soil structure, however. Sandy soils have a good load bearing capacity, and with appropriate slopes there is less deterioration;
- Side slopes in the clay areas can be steeper, they vary from 1:1 to 1:1.5. (for the maintenance and for stability new or reshaped canals have a slope of 1:1.5), against between 1:1.5 and 1:2 in sandy areas;
- Particularly in arable land the ground water table in the clay areas is deep so that relatively long slopes have to be maintained. In sandy areas there is a wide variation in water depths with more canals having smaller depths.
- In clay areas maintenance paths are found in 5% of the cases only, against in about 50% of the cases in sandy areas.
- In sandy areas there is less growth of aquatic weeds as result of the generally higher flow velocities.

6.2. Summary of maintenance practices

Table 3 gives a summary of maintenance characteristics in both areas. Again these data are based on the results of the earlier mentioned Waterboard survey.
Table 3. Methods of canal maintenance in the clay and sandy areas as a percentage of their total

<table>
<thead>
<tr>
<th>Methods</th>
<th>Permanent wet canal</th>
<th>Temporarily dry canal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>slope clay sand</td>
<td>slope clay sand</td>
</tr>
<tr>
<td></td>
<td>bottom clay sand</td>
<td>bottom clay sand</td>
</tr>
<tr>
<td>manual</td>
<td>1 2</td>
<td>0 6</td>
</tr>
<tr>
<td>mechanical</td>
<td>4 10</td>
<td>1 13</td>
</tr>
<tr>
<td>+ manual</td>
<td>74 79</td>
<td>84 71</td>
</tr>
<tr>
<td>mechanical</td>
<td>9 4</td>
<td>15 9</td>
</tr>
<tr>
<td>chemical</td>
<td>1 2</td>
<td>0 1</td>
</tr>
<tr>
<td>biological</td>
<td>11 3</td>
<td>0 0</td>
</tr>
<tr>
<td>none</td>
<td>12,500 10,300</td>
<td>4,700 5,300</td>
</tr>
</tbody>
</table>

From Table 3 it can be concluded that in the clay areas around 75 to 95 per cent of the canals were cleaned by machines only; while in the sandy areas this varies from 40 to 80 per cent. Herbicides are still applied in both areas, mostly in the South-Western clay areas (destruction of reed) and on temporarily dry canal bottoms in the sandy areas. At the moment the bottom of the canal falls dry, a completely other type of vegetation immediately comes up. This requires additional maintenance which in many cases is carried out by using herbicides.

In the sandy areas there is generally a more evident relationship between the water management interests and the ecological, nature and landscape interests than in clay areas. That is the reason that manual maintenance is mainly applied in the sandy regions. Mowing and sweeping boats are the most frequently used machinery in the clay areas, followed by bucket-type mowers, circle and flail mowers and finally by cutterbar and mower bar-rake combinations. In the sandy areas there is a more or less equal application of the various machinery, with a slight preference for the bucket-type, circle and flail mowers.

In the clay areas the chloride content of the water is high compared with the sandy areas. As a result the vegetation growth is less. Thus the canals in clay soils are less frequently maintained than the canals in sandy soils. In the clay areas the temporarily dry canals were mainly cleaned once per year, in the sandy areas mainly twice a year.

In both clay and sandy areas use of the mowing bucket delays the necessity for
the large maintenance operations, resulting in frequencies of once in 5 to 10 years in clay areas and once in 15 to 25 years in the sandy areas.

7. CONCLUSIONS

Over the past three to four decades, developments in maintenance techniques and equipment in The Netherlands have been rather fast. Technical advancements were used to meet increasing requirements of costs, efficiencies, capacities, fuel consumption, mobility, specific problems, etc. A few examples of such new requirements are summarized below, with some references to the Indian situation, as far as possible from our position.

Till recently, most of the Waterboards did not dispose of the mowed vegetation, but spread it out on the slope or the maintenance path or tipped it onto the bordering land. In some cases the wet material was usually piled up near duckweed fences and collected and disposed of from there. Because of ecological, nature and landscape considerations, there is now a tendency to transport the mowed vegetation in favour of the attenuation of the soil. As a result the growth rate of the plants will decrease and a greater variety of species with a low growth rate will develop. The maintenance frequency may become less.
As soon as the maintenance intensity in India will increase this problem of disposal of vegetation may arise as well. Particularly the fact that the farmers' lands are often close to the canals, and there is little free space left in many places, may require to find solutions for removal.

Besides the water transport function, the landscape and the environmental values of canals play a very important role in the choice of the maintenance method. Because of this, use of herbicides has decreased enormously, and is still decreasing. Investments are being made for the development and purchase of machine and tools to replace herbicides and for the construction of maintenance paths or even service roads. Chemicals are still being used, mainly to destroy reed, because a good alternative have not yet been found.

Again, this aspect may be taken serious in the Indian situation. When developing efforts for intensified maintenance, it is very tempting to apply the seemingly effective chemical means. The lessons from Europe, where these practices had to be redressed, sometimes after having experienced clear detrimental effects, may well benefit India in avoiding such experiences.
There is a tendency in The Netherlands towards increasing biological maintenance. The grass carp is the most frequently applied method of biological maintenance. For the environment this method is very attractive and the risk of insufficient discharge of water is highly restricted, because most of the plants are consumed.

Although manual maintenance has decreased enormously as a result of the high costs and the lack of skilled labourers, it may still be necessary in certain circumstances, for instance at inaccessible places or for environmental reasons. In India, manual maintenance will certainly remain important in the near future. Clear criteria should therefore be set on where to use manual labour and where and when to resort to mechanical means.

The requirements resulting from water management considerations may sometimes be in conflict with those from nature and landscape conservation, also with respect to the frequency. To satisfy both it may be possible to regularly clear the bottom only and reduce the maintenance of the slopes.

In addition to environmental and financial considerations, some practical and design aspects can affect the maintenance practices. Planting trees alongside the canal may have positive effects, for instance. Also, it is possible to apply a combination of maintenance methods. For example the use of grass carps with floating aquatic plants or planting trees at one side of the canal in combination with mechanical maintenance from the other side.

Another aspect concerns the depth of the canal. By using greater water depths the growth of aquatic plants will be reduced and the maintenance frequency may be less. Also it can be considered to give the canals dimensions larger than strictly necessary. But in India the depth-width ratios should also take into account the requirements derived from the stable channel design (regime theory). With larger depths it often occurs that the silt layer on the bottom of a canal is not removed sufficiently. A regular removal of both aquatic weeds and a small silt layer attenuates the soil; the growth rate of the plants will be reduced.

The frequency of canal maintenance may vary from one canal to another. Decisive factors are the growth rate of the vegetation, the function and the sizes of the canal and the land use of the bordering area. More and more a distinction is made in the maintenance of the canals below and above the water level. To guarantee the water supply in a certain area it may be useful to increase the maintenance frequency of the bottom of the supply canal or ditch. This is called preventive mowing. The advantage of a high frequency is that it strongly
reduces the necessity to remove the biomass of the bottom (small quantity) and the traditional way of maintenance of the canal may be reduced (for example two times instead of three times).

The presence of maintenance paths have the following advantages: relatively lower maintenance costs; the canals are always accessible and can be maintained at any time and the chances of destruction of the banks are less. The higher the maintenance frequency, the more it will be cost saving. As disadvantages can be mentioned the loss of land and the investments which have to be made to construct the maintenance paths.

Finally it may be evident that there is not one method applicable to all types of weed problems. It is, therefore more efficient to apply an integrated maintenance programme. This programme can comprise manual, mechanical, biological and chemical methods such as to minimize costs and damage to the environment. Such an integrated programme cannot be established right away, but need to be developed over the years, using local specific experience as feedback. It would be useful to implement one or more pilot projects in different circumstances in India, to assess the above aspects of maintenance paths and design implications and to develop the best packages of methods and frequencies.
MECHANICAL EQUIPMENT
FOR SMALL MAINTENANCE

J.C. Den Herder

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MECHANICAL EQUIPMENT FOR SMALL MAINTENANCE

1. DIFFERENT TYPES OF CANAL MAINTENANCE EQUIPMENT

Maintenance of canals is usually divided into "small" and "large" maintenance. The first is carried out frequently (some times per year) and mainly concerns vegetation control and mowing activities, both on the side slopes as well as in the water. The second refers to major dredging and reshaping of the profile, which is done much less frequently. Herder BV manufactures mechanical equipment mainly for small maintenance, although some of the equipment can also be used for minor ("small") dredging and reshaping activities.

The equipment discussed in this paper could be divided into three types:
- Equipment which can be mounted on normal agricultural tractors and to which various types of tools can be attached. This mainly concerns tools for vegetation control and mowing;
- Complete machines, especially designed for maintenance "from the sides", including transportation and operation facilities;
- Special equipment for "from the water" activities.

In this paper the main purposes and possibilities of these different types will be discussed and their major characteristics in terms of capacities, reach, etc. will be given. Cost of the equipment are given in indicatively in Dutch guilders (Dfl), as purchased in The Netherlands. At the moment (1992-1993) 1 Dfl is about 14 Rs.

2. ATTACHMENTS

Herder offers various attachments for different purposes which can be put onto other equipment, discussed below. The following attachments are available:
- mowing bucket;
- mower rake;
- top mower;
- flail mower;
- dredging bucket;

Some other Herder attachments for various maintenance purposes, such as the swing-blade, wood-chopper, hedge-cutter, disc-mower, rail mower, etc are not discussed here.
A summary of the above equipment is given in Table 1.

Table 1. Attachments and properties

<table>
<thead>
<tr>
<th>Attachment</th>
<th>where</th>
<th>what</th>
<th>capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>top mower</td>
<td>ss + wp</td>
<td>gr</td>
<td>3-4 km/hr</td>
</tr>
<tr>
<td>flail mower</td>
<td>ss</td>
<td>gr + br</td>
<td>3-6 km/hr</td>
</tr>
<tr>
<td>rake</td>
<td>ss + wp</td>
<td>gr + wv</td>
<td>2-4 km/hr</td>
</tr>
<tr>
<td>mower-rake</td>
<td>ss + wp</td>
<td>wv</td>
<td>3-4 km/hr</td>
</tr>
<tr>
<td>bucket</td>
<td>ss + wp</td>
<td>wv</td>
<td>1-1.5 km/d</td>
</tr>
</tbody>
</table>

ss = side slopes; wp = in the water profile
gr = grass; br = brushwood; wv = water vegetation

The straight top mower (or cutterbar) is available in lengths of 190-225 cm and costs about Dfl 10,000 (1.4 lakh Rs). It can only be used to mow the side-slopes. It can be equipped with a bended piece at the end, so that a small part of the bottom can be mowed as well (see Figure 1).

The rake, see Figure 2, can be used to remove water plants and grass, from the side slopes as well as from the bottom. It is often applied in combination with the top mower, thereby collecting the vegetation left by the mower. If the vegetation is not too long, top mower and rake can be mounted together on one arm on a tractor. Otherwise, they have to be mounted separately. Cost of the combination is about Dfl 18,000 (2.52 lakh Rs).

The flail mower (Figure 3), can be mounted on an arm on a tractor and is used for heavier work on slopes. It consists of a horizontal rotor with loose flails, hydraulically driven by an oil motor, directly on the rotor. It is available in widths of 130-225 cm and costs about Dfl 11,000 (1.54 lakh Rs). This mower can be equipped with special knives for cutting light wood.

Instead of the mower-rake combination the mowing bucket (see Figure 4) can be used, which can be mounted on an arm on a tractor or on a hydraulic excavator. The bucket is primarily used for mowing and removing under-water vegetation. The big advantage over the other attachments is that the bucket can cover the entire canal from one side. The bucket consists of bars to collect the vegetation that is mowed with the hydraulically driven cutter-knifes, provided on the front of the bucket. Thus it can cut, collect and remove the vegetation in one go. This reduces its working speed compared to the rake, which can only
Figure 1. Top mower ("cutterbar") with bended end

Figure 2. Rake
Figure 3. Flail mower

Figure 4. Mowing bucket
be used to remove loose vegetation. The mowing bucket is available in widths of 200-500 cm and costs Dfl 8,000-13,000 (1.12-1.82 lakh Rs).

The dredging bucket is provided with holes (for the release of water) and is used for light dredging activities, including removal of vegetation as well as light reshaping of the profile. The bucket can have capacities of 100 to 300 litres and can do up to 500 m per day on the average. They are much cheaper than the above attachments (no moving parts), and cost some Dfl 2.000 (28,000 Rs).

3. TRACTOR MOUNTED EQUIPMENT

The above mentioned attachments cannot be mounted directly on the tractor. For that purpose, especially developed equipment can be applied, such as the "Grenadier", see Figure 5. This Grenadier consists of four components: an operating unit, the hydraulic steering unit, a movable boom construction and support and wheel stabilizer for stability control.

The low-pressure hydraulic control unit is usually fixed separately on the rear of the tractor. A small electro-servo operation unit is installed within the tractor cabin. The boom is fixed on the side of the tractor. The hydraulic unit belonging to it is mounted on the power lift and is driven by the PTO shaft, regardless of the make and type of tractor. The entire equipment can be mounted and dismantled in some 30 minutes.

The lightest type, Grenadier MB 105 can be fixed on a tractor with a minimum weight of 4000 kg and/or 90 HP. It can work with all above attachments except the flail mower. For the flail mower the MBK 105 must be used because this provides extra hydraulic power.

The boom construction is available in various lengths. It can cover a range of 6-8.5 m, and it has a swing of 105°. Depending on the boom construction, canals with depths up to 2.50-4.40 can be treated.

Often, tractors are provided with a combination of equipment, which can be done in different ways. Sometimes, the rake is put onto the rear and the top mower on the front, both with their own booms. Also it is possible to combine mower and rake on one boom. The Grenadiers cost Dfl. 50.000 to 55.000 (7-7.7 lakh Rs).
Figure 5. The Grenadier

Figure 6. The Rapier
Another special equipment is the "Rapier", which can be used with flail and disc mowers (see Figure 6). Its difference with the Grenadier is that it has no revolving boom. The unit with fixed boom is mounted on the rear of a tractor, is driven by the PTO shaft and is provided with an extra wheel behind the right rear wheel of the tractor.

The Rapier is used for mowing verges and side slopes, where a small reach is required (up to 4.80 m with flail mower) and a high working speed can be attained. The Rapier costs about Dfl. 22,000 (3.08 lakh Rs).

4. SPECIAL "ALL-IN" EQUIPMENT

In the above cases the equipments has to be mounted on a tractor. For special purposes, Herder also offers "all-in" equipment, consisting a complete unit including vehicle and tools. Two of them are briefly described here, the "Herimag" and the "Pontonnier".

The Herimag (Figure 7) is a small vehicle, to be used where very little work space is available along the canal, or on soft soils. It only needs 1.50 m width. It is mounted on chain tracks, which cause a very low bottom pressure of 0.35 kg/cm², and can reach a speed of 5 km/hr.

The boom can be fitted with mowing or dredging buckets and with cutter/rake combinations. The reach is 7.40 to 8.00 m distance, with a 120° swing. Equipped with a mowing bucket, it can do 1-1.5 km/day, with a dredging bucket about 0.5 km/day. Cost of the Herimag is around Dfl 180,000 (25.2 lakh Rs), including a carriage conveyor.

The Pontonnier (see Figure 8) needs even less space. It is provided with two boom constructions: one for the attachments and one with wheels or tracks, which is put on the other side of the canal, at a maximum distance of 6.80 m. It has a 180° swing and a distance reach of 6.20 m. The Pontonnier is riding on wheels or tracks with a maximum speed of 12 km/hr. The Pontonnier costs around Dfl 200,000 (28 lakh Rs).

5. WATER EQUIPMENT

Sometimes it is impossible or undesirable to do maintenance works from the
Figure 7. The Herimag

Figure 8. The Pontonnier
sides of the canals. For such cases boats or amphibious equipment have been developed. Much of such equipment is suitable for dredging and large reshaping work only and not for small maintenance. Therefore, Herder has developed specific water equipment for small maintenance operations, mainly removal of vegetation on the sides and under water. Two types are described here: the small mowing boat and the amphibious "Pontier".

The steel casco mowing boat (see Figure 9) is available in various dimensions, all equipped with a 35 HP diesel engine and a hydraulically driven worm screw for propulsion. Its draft is 30-40 cm only, the width can vary from 1.40-1.80 m. The boat can be equipped with various attachments, all hydraulically driven. Commonly applied tools are:
- Side mower for the slopes;
- T-front mower to cut underwater vegetation in front of the boat;
- Bottom sweeping knives, to cut or tear loose overgrowth on the bottom;
- Front rake, to collect drifting or mowed material.
Depending on the dimensions, the mowing boat costs about Dfl 45.000 to 60.000 (6.3-8.4 lakh Rs).

The Pontier (Figure 10) is a steel pontoon, provided with two or three pairs of independently movable caterpillars, which enables it to go in and out the water. Standard dimensions are 2.60 x 7.20 m. On the pontoon a pair of 250° revolving arms can be mounted, which can be equipped with various attachments. The removed material can be put on the side or in a 7 m³ container. The arms can be disassembled and replaced by a mowing board with conveyor and container. With this equipment, water vegetation is cut off and automatically transported by the conveyor to the container. The Pontier costs about Dfl 350.000 (49 lakh Rs).

6. MAINTENANCE AND OPERATION OF THE EQUIPMENT

Operation of all the equipment is rather easy and convenient and only needs a short training of about one month. Use of fuel, oil, grease, etc of course varies for the different machines. An indication in this respect is given in Table 2.

Of course this maintenance equipment itself also need to be maintained. Some cost indications (annual costs, in % of investment costs) are given in the Table as well.
Figure 9. Small mowing boat

Figure 10. The Pontier
Table 2. Some O&M aspects of various equipment

<table>
<thead>
<tr>
<th>ATTACHMENTS</th>
<th>Grease</th>
<th>Grinding knives</th>
<th>Maintenance % of initial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top mower</td>
<td>daily</td>
<td>daily</td>
<td>20 %</td>
</tr>
<tr>
<td>Mower rake</td>
<td>daily</td>
<td>-</td>
<td>20 %</td>
</tr>
<tr>
<td>Flail mower</td>
<td>daily</td>
<td>-</td>
<td>5 %</td>
</tr>
<tr>
<td>Mowing bucket</td>
<td>daily</td>
<td>daily</td>
<td>10 %</td>
</tr>
<tr>
<td>Dredging bucket</td>
<td>-</td>
<td>-</td>
<td>10 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TRACTOR MOUNTED</th>
<th>Oil capacity</th>
<th>Fuel use</th>
<th>Maintenance % of initial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grenadier MB</td>
<td>40 l/min</td>
<td>10 l/hr</td>
<td>10 %</td>
</tr>
<tr>
<td>Grenadier MBK</td>
<td>120 l/min</td>
<td>10 l/hr</td>
<td>10 %</td>
</tr>
<tr>
<td>Rapier</td>
<td>120 l/min</td>
<td>10 l/hr</td>
<td>5 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ALL-IN MACHINES</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Herimag</td>
<td>40 l/min</td>
<td>10 l/hr</td>
<td>5 %</td>
</tr>
<tr>
<td>Pontonnier</td>
<td>120 l/min</td>
<td>10 l/hr</td>
<td>5 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BOATS</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pontier</td>
<td>250 l/min</td>
<td>15 l/hr</td>
<td>5 %</td>
</tr>
<tr>
<td>Mowing boat</td>
<td>40 l/min</td>
<td>7 l/hr</td>
<td>5 %</td>
</tr>
</tbody>
</table>

7. SUMMARY AND CONCLUSIONS

It is evident from the above that a wide variety of canal maintenance equipment is available, for all kind of specific jobs and conditions. When selecting an adequate solution for mechanical maintenance, a number of factors have to be considered.

First of all it has to be decided whether the maintenance is to be done "from the land" or "from the water", or perhaps in combination of both, depending on the conditions at site.

For maintenance "from the land" a wide variety of options is again available. A first choice primarily depends on the local conditions: under normal
circumstances of soil and accessibility tractor mounted Grenadiers are widely used.

Depending then on the purpose (side slopes or bottom as well, grass, water vegetation or small reshaping) various attachments can be applied. Combinations of cutting and removing can be applied when high speed is required and when much vegetation is to be removed. For heavier materials the flail mower can be used. For high speed on verges and slopes the Rapier can be used.

Under special conditions of soft soils or little working space the Herimag or Pontonnier are well suited, also equipped with the required attachments.

For maintenance from the water the more expensive mowing boat or Pontier can offer a convenient solution.

Some of the equipment is quite costly, but because of its special capabilities, it has proven to provide an effective solution under specific circumstances.

Of course economic considerations are important, not only considering the investment costs, but also the running and maintenance costs. Apart from that, the availability and procurement of spare parts should be guaranteed to avoid the equipment to become white elephants in developing countries.

Because most of the equipment has been specifically developed for certain purposes and conditions, experience is that for such conditions they are automatically the most economic solution as well. Yet, conditions vary widely over the world, which can mean that in a given situation, an experimental program will be needed to test various equipment, not only to select the best type, but also to assess whether small modifications are perhaps necessary. In this respect, Herder BV has experience with such programs in various countries and is able to identify and implement the required modifications.
SMALL-SCALE DREDGING AND DESILTING EQUIPMENT

C.E. Sperling

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1. INTRODUCTION
2. TYPES OF SMALL DREDGING EQUIPMENT
3. IMPORTANT FACTORS IN EQUIPMENT SELECTION
4. KONIJN SMALL SUCTION DREDGERS
5. KONIJN AMPHIDREDGE H-TYPE
6. KONIJN AMPHIDREDGE M-SERIES
7. KONIJN AMPHIDREDGE FLOATING BULLDOZER
8. COSTS AND CONCLUSIONS
SMALL-SCALE DREDGING AND DESILTING EQUIPMENT FOR CANAL MAINTENANCE

1. INTRODUCTION

This paper deals with small-scale dredging equipment used for canal maintenance, "small-scale" then referring to the size of the equipment and not necessarily to the magnitude of the maintenance works or projects in which it is used. The large dredging equipment, generally used off-shore, is not the subject matter of this paper.

The water management and maintenance of canal systems has a long standing tradition in The Netherlands. In the Middle Ages and even up to the last century most of the maintenance was done manually, using for instance the dredging bow, notorious for breaking peoples' backs. Development of hydraulic and mechanical small dredging equipment, for use in maintenance of canal systems, really started during the second half of this century only.

The various types of equipment now available are summarized in Section 2. Basically one can distinguish two types of equipment: cutter suction equipment, largely hydro-mechanically operated, and the digging type equipment, generally mechanically operated. In Sections 2 and 3 some considerations are given on both types of equipment, including criteria for selection of suitable equipment for different types of maintenance.

Part of the paper also deals with the mechanical digging equipment, mainly of the floating or amphibious type, as manufactured by Konijn BV, The Netherlands.

Sizes of the equipment discussed here are generally limited to widths between 2 and 4 m, drafts of less than 0.8 m and a clearance height (under passages) of maximum 1 m. For silt removal, hydraulic transportation through pipelines can be used, but the material can also be disposed of into elevator barges with a hopper capacity of 7-30 m³, small pusher crafts and dumpers for further disposal by road transport.

A general characteristic of the small dredging equipment is the high flexibility of application possibilities, among others because of the various possible accessories, available as attachments to the main equipment.
2. TYPES OF SMALL DREDGING EQUIPMENT

Development of small mechanized dredging equipment started only around 1950. The first equipment, a small suction dredger, was actually not more than a rowing boat provided with truck engine and a pump. Usually this was applied in rural areas and the silt was disposed of directly on the adjacent areas. Since then, several types of equipment were developed which could be broadly classified as "cutter suction equipment" and "digging type equipment".

The first type of equipment cuts the bed material, which is then sucked and pumped away, either over a long distance by means of pumps and pipelines, or locally on the sides, or into a barge or container. The second type of equipment consists of various crane types with different attachments, which can be divided into:

- the hydraulic crawler crane (excavator), equipped with a bucket or a hydraulically operated clamshell;
- a hydraulic grab crane on tires or tracks, provided with a cable clamshell or a dragline bucket.

Both perform the work by means of digging, and they can normally be used for all kinds of work. The hydraulic grab crane with clamshell or dragline is primarily meant for digging of peat and mud. Its use on sandy or clayey bottoms can be limited. The grab crane for a long time had the advantage of a longer reach, usually 11-13 m. Gradually, however, excavators have been developed with longer arms, now even up to 18 m, which has further increased the popularity of the excavator.

The cutter type work is always done from the water, whereas the cranes can work from the side as well as from the water, by mounting them on a pontoon. Gradually, amphibious equipment has been developed as well, to enable passing of culverts, bridges, etc. in the watercourse.

Most of the work on amphibious equipment was done by Konijn BV, from time to time in cooperation with IHC Holland, a company famous in the world of large dredging equipment. Developments in small cutter suction dredgers was largely done by another Dutch company, Klip BV. This was mainly serving the national market, for their own use as a contractor. Some other companies as developed specific small equipment as well.

Floating bulldozers form a special type of digging (or pushing) equipment, able to push the mud from inaccessible places to locations where a simple grab crane can transfer it into a transport medium.
Finally it is mentioned that some of the equipment by Herder BV, as described in the paper by den Herder, can also be used, though on a limited scale, for small shaping or dredging work.

3. IMPORTANT FACTORS FOR EQUIPMENT SELECTION

For the selection of the appropriate equipment for a certain purpose, various factors have to be taken into consideration, apart from course from cost aspects. One important factor usually is the possibilities or constraints related to the disposal of the removed bed material.

If the material cannot be put alongside the canal, it has to be put into a truck, barge, or container, or otherwise to be pumped away to another place through a pipeline.

When the material has to be pumped, a pipeline of 250 mm maximum is mostly used. A larger diameter would be too heavy for manual operation. A small suction dredger is generally able to pump the silt over a distance of about three kilometres, also depending on the elevation (1 m elevation can be taken equivalent to approximately 100 m horizontal distance).

When sand is pumped, the maximum distance is reduced to about 1 km only. Booster stations could be installed on the pipeline for transport over longer distances, but this is expensive and affects the efficiency of the total transportation line. Of course, provisions have to be made to avoid entering of wood, plastic or other rubbish as car tires, stones, etc.

When there is much of such material, or when silt or sand has to be transported over longer distances, other dredging and transportation means have to be selected. Dredging then usually is of the digging type and transportation can take place by barges, containers, trucks, etc.

Another important consideration in the selection of equipment is the accessibility of the canal. In this respect two types of equipment are available: "from the sides" or "from the water".

Execution of maintenance from the side of the canal is possible when there is sufficient space (maintenance path or road) and when the width of the canal is limited. But another condition is that either direct transportation or dumping of the silt behind the canal bank must be possible.

Where these conditions are not fulfilled, the use of floating equipment (either
boat or amphibious) is appropriate. This equipment is usually of the digging type, in combination with elevator barges and pushers. From the barges the silt can be dumped directly into a watertight container by means of a (land- or pontoon based) grab crane.

Another practice used in the Netherlands is the use of split barges, which can dump the material in other locations (for instance in deeper water), but this will not be applicable in the common Indian canal systems.

Use of a specially designed floating bulldozer was already mentioned in the previous Section.

Maintenance "from the side", with cranes as discussed above is not further dealt with in this paper. It is a relatively straightforward method, for which a large variety of equipment has been developed all over the world. The present paper further concentrates on work "from the water", partly by amphibious equipment.

4. **KONIJN SMALL SUCTION DREDGERS (S-SERIES)**

The S-series machines (see Figure 1 for an example) all employ a milling suction system, developed in The Netherlands over the past 15 years, especially for dredging of soft silt. The system uses the pumping principle rather than the excavation principle.

The milling cutter suction system consists of:

- A milling cutter scoop for moving the silt or loose deposits towards the suction opening, thereby enhancing the solids/water ratio.
- A milling cutter device for cutting vegetation, (small) branches, small hard pieces of deposits, etc., at the same time mixing the components into an even mixture, for better pump performance.
- A special pump with an impeller which is able to handle relatively large pieces of debris such as cans, bricks, shoes, etc, thereby minimizing clogging of the pump and subsequent down-time.

All this is mounted on a small boat. Dredging is done by winching the boat forward along a guiding cable. On the bigger S-200, additional steering facility is provided by a disc-wheel on its rear legs.

The S-series can be provided with three or four legs (as is shown in Figure 1), so that they can "turtle-walk" on their own power from the transport vehicle into the water, or around small bridges or other obstacles. The principle characteristics of the equipment are as given in Table 1.
Figure 1. Amphidredge S-series

Figure 2. Amphidredge H-series
Table 1. Characteristics of S-series

<table>
<thead>
<tr>
<th></th>
<th>S-170</th>
<th>S-200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. dredging depth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- forward (m)</td>
<td>3.20</td>
<td>3.50</td>
</tr>
<tr>
<td>- backward (m)</td>
<td>5.00</td>
<td>5.35</td>
</tr>
<tr>
<td>Production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(m3/hr)</td>
<td>50-80</td>
<td>100-140</td>
</tr>
<tr>
<td>Diameter suction pipe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(mm)</td>
<td>170</td>
<td>200</td>
</tr>
<tr>
<td>Engine power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Hp)</td>
<td>110</td>
<td>165</td>
</tr>
</tbody>
</table>

Due to the absence of fast moving parts the small dredging boat has proved to be very suitable for work in lined canals. In most cases, the S-series equipment provide an adequate and economical solution. H-series or M-series are more appropriate under the following conditions:
- when there is too much debris or heavy vegetation;
- when the spoil can be pumped directly on the land, so that no extra transporting facilities are needed.

5. KONIJN AMPHIDREDGE H-TYPE

Equipment in the H-series is amphibious in the full sense of the word, since it can move itself from the bank into the water and vice-versa. Machines in this series consist of the following components:
- A main pontoon (sometimes with supporting side-pontoons);
- 3 or 4 movable legs, hydraulically operated, permitting movement of the machine by crawling (like a turtle). These legs also serve to stand firmly during dredging/excavating.
- A hydraulically operated crane, fixed on the pontoon, with backhoe or dragline bucket.

The patented equipment can work on flat land, in undulating terrain, in swamps and in the water and it can be used on any kind of soil. The models equipped with four legs (see Figure 2) can move over steep elevations and on steep banks, to reach the actual work site. The models with three legs are somewhat restricted in that respect.

The four-leg machine can put itself from and onto a truck, since the main pontoon can be raised, after which the truck can drive away underneath the
pontoon. The tree-leg machine can be loaded or unloaded in a similar way with the help of a winch mounted on the machine and serving as a fourth support. Being on a truck the legs of both machines can be swivelled to provide for convenient transport. Matching auxiliary equipment such as extra side pontoons for stability, winches, etc. is also available. The principle characteristics of the H400-4 model are summarized in Table 2.

Table 2. Characteristics of H400-4

<table>
<thead>
<tr>
<th>Number of legs</th>
<th>4.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum reach of excavator</td>
<td>6.70 m</td>
</tr>
<tr>
<td>Maximum dredging depth</td>
<td>4.50 m</td>
</tr>
<tr>
<td>Engine</td>
<td>88 Hp</td>
</tr>
<tr>
<td>Weight</td>
<td>14 t</td>
</tr>
<tr>
<td>Standard backhoe content</td>
<td>500 l</td>
</tr>
<tr>
<td>Minimum canal width</td>
<td>2.60 m</td>
</tr>
<tr>
<td>Minimum water depth for operating</td>
<td>1.05 m</td>
</tr>
<tr>
<td>Minimum water depth for navigating</td>
<td>nil</td>
</tr>
</tbody>
</table>

6. KONIJN AMPHIDREDGE M-SERIES

The M-series encompass crane-pontoon combinations, consisting of the following components:
- Self-powered mobile grab crane, that can operate from the banks and from the water, when installed on a pontoon.
- A special pontoon construction, to carry the crane when this has to work from the water. The crane itself is used to put the pontoon into and out of the water, from and onto a truck. The pontoon is designed to allow the crane to embark and disembark on its own power. The pontoon can be stabilized by extra side-pontoons, being fixed to the main pontoon by locking devices.
- Auxiliary equipment like barges, split-barges and matching push-boats are available.

The principal characteristics of these machines are depicted in Table 3.
Table 3. Characteristics of M-series

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of standard boom</td>
<td>11.00 m</td>
</tr>
<tr>
<td>Engine</td>
<td>31.5 Hp</td>
</tr>
<tr>
<td>Total weight</td>
<td>17 t</td>
</tr>
<tr>
<td>Standard grab content</td>
<td>600 l</td>
</tr>
<tr>
<td>Minimum water depth</td>
<td>0.60 m</td>
</tr>
<tr>
<td>Minimum canal width</td>
<td>4.80 m</td>
</tr>
</tbody>
</table>

Although the unique feature of this equipment is the patented method of embarking and disembarking of the crane, two other features are interesting as well:
- the special crane is the most popular of its size and type in Europe, due to its reliability and high capacity;
- the weights and dimensions of crane and pontoon provide for easy transport by truck, as well as for navigation.

The M-series typically are used for dredging of silt and vegetation. As said before, it is less suitable for work in hard soils, because of the use of clamshell or dragline bucket. The advantage of these machines is their long booms, of 10-11 m long. This means that they have the capacity to dispose the material further on the land or into spoil dump trucks directly.

Positioning of the machine can be done by means of cables or with a spud installation. When operating in canals which are also used for navigation, the cable-winch installation can be provided with extra cable outriggers which allows boats to pass the wires.

The mobile crane can of course also be used separately on the land.

7. KONIJN AMPHIDREDGE FLOATING BULLDOZERS (FB)

The FB-Amphidredge (see Figure 3) consists of the following components:
- A main pontoon (supported by side pontoons, if necessary), with diesel engine, winches and a control panel;
- A front-mounted dozer blade, consisting of a central section and two hydraulically operated, movable side blades. The depth of the blades can be adjusted hydraulically.
- A rear-mounted "rudder" system (for stabilizing and steering), consisting of a hydraulically operated arm and twin wheels.

The one man operated floating bulldozer (FB) is appropriate for conditions where a long and straight watercourse cannot be dredged from the banks. In winding watercourses or short stretches it is less convenient. It pushes the silt, layer by layer, together with possible vegetation and debris, to a place where a crane can be stationed which can take the spoil and puts it into means for further transport. The FB requires no additional equipment.

![Floating bulldozer (FB series)](image)

Figure 3. Floating bulldozer (FB series)

Propulsion of the Konijn FB is done by means of hydraulically operated winches and not by propellers. Thus, floating debris like plastic bags, reed, bottles, etc will not disturb the operation. Another advantage is that the machine can easily pass underneath bridges, etc. For extremely low passages it is possible to dismantle the all-weather proof operator’s cabin in some minutes. For navigation a draft of only 80 cm is required.

Each machine can be provided with two permanent transport wheels with solid tires on the front of the main pontoon. Transport wheels can be mounted on the hydraulically operated rear wheel leg for launching as well as for short distance travel over land. All bulldozers are provided with a Deutz air-cooled diesel engine which give reliable performance under tropical conditions.
The bulldozer allows for accurate dredging and when working in lined canals, the blade can be provided with small wheels to avoid damage to the lining.

8. COSTS AND CONCLUSIONS

Price indications for the above equipment are given in Table 4 (in US $):

Table 4. Price indications for Konijn equipment

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Price (US $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydraulic crane</td>
<td>150,000</td>
</tr>
<tr>
<td>Grab crane</td>
<td>120,000</td>
</tr>
<tr>
<td>Cutter suction dredger</td>
<td>350,000</td>
</tr>
<tr>
<td>Amphibious excavator H-type</td>
<td>250,000</td>
</tr>
<tr>
<td>M - series</td>
<td>220,000</td>
</tr>
<tr>
<td>Floating bulldozer</td>
<td>175,000</td>
</tr>
</tbody>
</table>

Costs of dredging work using this equipment can not be given in general terms. With varying circumstances, they can vary in The Netherlands from 0.75 US$/m³ to 25 US$/m³.

Capacities of the various equipment are difficult to give, because they vary widely with the local conditions. Not only the amount and type of soil, vegetation and debris of course strongly affects the performance. But also, the costs of the disposal of the spoil can be a substantial part of the total costs and vary with the quantities to be removed, with the methods used (pumping, containers, trucks, etc) and certainly with the distance over which the material has to be transported. Consequently, it is difficult to give general cost figures for the operational costs. Nevertheless some information on operational aspects is given in Table 5. The last column gives the approximate time required to train the operator for acceptable performance.

Generally, the experience is that the suction dredger provides the cheapest solution. Even with the extensive experience with this equipment in The Netherlands post-project calculations still may differ considerably from the pre-calculated budgets.
In concluding it can be said that pilot projects are necessary to select the best equipment under certain conditions, and to establish the corresponding costs, especially where the equipment is alternatively introduced for the first time.
DEVELOPMENT OF A CANAL MAINTENANCE POLICY

F.C. Hamster & M. Jurriëns

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1. INTRODUCTION
2. GENERAL REFLECTIONS ON MAINTENANCE
3. OBJECTIVES AND OBJECTS TO BE MAINTAINED
4. THE MAINTENANCE EXECUTION
5. CHOICE OF EQUIPMENT
6. DESIGN ASPECTS AND DATA BASE
7. ORGANIZATIONAL SET-UP
8. SUMMARY AND DISCUSSION
DEVELOPMENT OF A CANAL MAINTENANCE POLICY

1. INTRODUCTION

In earlier papers the Dutch institution of the "Waterboard" has been discussed. The present paper deals with the development of a new maintenance plan which became necessary after a merger was planned of two adjacent Waterboards, which was implemented from 1-1-1992.

Both Waterboards were situated in the upper Northeast part of the Netherlands. The former Waterboard "De Veenmarken" covered some 27,000 ha and the Waterboard "Reiderzijlvest" about 65,000 ha; the new combined Waterboard "Dollardzijlvest" (DZV) will thus cover some 92,000 ha.

The larger part of this Waterboard (50,000 ha) is a former peat colony, which was reclaimed from 150 till 50 years ago. The peat from the high moor was used for the heating of houses and for industrial use. Local people built a system of canals and branches for the water control and the transport of the peat. Nowadays it is an agriculture area, with potatoes as main product for the production of starch. The remaining part of the Waterboard area can be divided into sandy soil and clay polders near the sea. The entire Waterboard area (DZV) is in fact one water management system, ultimately draining on the "Dollard", an estuary of the North Sea.

The principal task of both old and new Waterboards is water management, which eventually implies taking all necessary measures needed to regulate the water flows and levels in the canals for the benefit of agricultural and pasture land, but also for nature reserves and built-up areas. The basic task not only concerns the operation of the system, and incidental design and construction of new works, but the maintenance of the systems as well.

For the situation after the merger of the two Waterboards, a new maintenance plan had to be developed, because both Waterboards had a different policy of maintenance and equipment. The merger also evoked the need to adapt the organization. At the same time there is a land consolidation (reallotment) program taking place in the entire area, which offers the possibility to improve maintenance facilities.

For the development of such plan, the following major questions are to be addressed:
implications for the design. The designer usually is another person than the surveyor of the maintenance works. When the surveyor is doing the work, the designer has already done his job. The designer must take into account what the surveyor has to do, and make sure that he can really do so. Both persons are equally important: a bad design does not work, but dirty ditches and bad maintenance do not work either.

To execute its job, a Waterboard has to maintain many and frequent contacts with farmers and other inhabitants of this area. They are the "customers" and they must be informed about measures to be taken and be convinced of the utility of the Waterboard, being after all a service organization for that area and the inhabitants.

The ultimate performance of a Waterboard depends very much on the daily work of the technical staff, designers and surveyors, which are both in regular and direct contact with the clients. This should be fully appreciated by the Waterboard management.

3. OBJECTIVES AND OBJECTS TO BE MAINTAINED

The objects to maintain are canals, weirs, inlets, culverts, sluices, pumping stations, etc. Also it is important to maintain the necessary buildings, workshops, installations, machinery etc. In this paper emphasis is on the maintenance of canals.

In some Waterboards the farmers have to maintain a part of the canals and the Waterboard checks the results. The DZV Waterboard maintains the water management systems by itself, and the farmers only maintain the ditches between the parcels. For the functioning of the whole system these ditches are very important, nevertheless cleaning of them is a job for the farmers. In case of trouble between farmers, the Waterboard has the possibility of supervision and arbitration. On "information evenings" we explain the working of the system and we show the farmers (slides, graphs, etc) the problems they can expect in case of poor maintenance.

To be sure that the system is always clean and ready for use, the Board has the powers under the law to force an unwilling farmer clean the canals. The bill for the job (by example dredging the canal), including a fine, will be send to the farmer, because he did not meet his obligations (see also the papers by Siefers and Deurloo).
Although the main purpose of water control is that the system must be able to function at any moment, in specific cases we also pay special attention to some other aspects, depending on the area concerned or on other objectives such as:

- **Built-up areas (non-agricultural land):** it can be desirable to mow more, to get at any time nicely mowed slopes along the canals in built-up areas. Or in contrast, it can be appropriate to mow less to maintain a certain amount of water vegetation;
- **Horticulture areas:** besides a good water management such areas demand a special attention for the vegetation in and along the canals where it can be a breeding place for harmful insects;
- **Recreation:** it can be necessary to make some canals fit for large or small boats, anglers, etc. It is possible that those "activities" also ask for a special maintenance approach;
- **Environmental aspects:** when the dimensions of the canals are large enough, it is possible to maintain or rehabilitate some nice and useful water vegetation;
- **Relation with our clients, the farmers:** they have to accept our activities and the disposal of removed vegetation. It must be possible to clean the canals without causing trouble or nuisance to the farmers.

At the moment these are the major aspects taken into account in the DZV Waterboard. In other Waterboards, the package of aspects may be different.

### 4. THE MAINTENANCE EXECUTION

A first choice to be made is on who will be executing the work: a) the Waterboard itself, b) contractors or c) the farmers.

This Section concentrates on maintenance of the main canal system. As outlined in the papers by Siefers and Deurloo, farmers are responsible for the maintenance of the canals directly bordering their lands. For the work on the higher level system, for which farmers have no proper equipment, only the first two possibilities remain. In choosing then, aspects as costs, specialization, control/supervision and flexibility/continuity have to be considered.

Generally, the equipment and operation costs are basically the same for contractors and Waterboard execution. The "Added Value Tax" that has to be paid extra for the contractors renders them more expensive, however. Therefore in many cases Waterboards do the work themselves. Yet, it is a question of "good sports" to work as effectively as possible to realize the maintenance at lower costs than the contractor would ask for the same job.
Another aspect is the specialization. Sometimes the required equipment is that specialized that only a few contractors do have it, and it might be better for the Waterboard to purchase it for own use. This does not apply for special equipment that is required only incidentally, where it is better to call in a contractor for such instances.

With respect to supervision it can be said that the execution by the Waterboard needs less strict supervision. Supervision is done by the Waterboard surveyors; it is their "own" system, for which they are responsible. With a well motivated team, this supervision poses no problems. With contractors, having different interests, more and closer supervision is often necessary.

Regarding aspects as flexibility and continuity it is important to have a continuous employment for the machinery throughout the year, if possible for the different kinds of activities. Biggest part of the equipment costs concern capital costs. The more it stands idle, the more expensive it is. Therefore, if a Waterboard has a too small system to keep the equipment going throughout the year, it may be better to have contractors to do the job.

In DZV Waterboard we have chosen to execute the maintenance by the Waterboard itself, with own personnel and equipment. Main reasons for this are the aspects of cost and supervision as discussed above and the possibilities (given the size of the system) to meet the requirements of specialization and continuity. Only some special activities will be done by contractors, such as incidental dredging by large cranes.

5. CHOICE OF EQUIPMENT

A next important question concerns the choice of the equipment. For the selection of our maintenance equipment we used three criteria:
- capacity of the equipment;
- accessibility along the canals;
- continuity in the use of the equipment.

Of course, these criteria are ultimately related to costs. For costs reasons, no manual maintenance is done in our Waterboard. Moreover, we do not apply chemicals. Not only because of their environmental effects, but also because they destroy the under-water vegetation which is beneficial for the stability of the side slopes and because many plants need a long time to die after chemical spraying. Thus, the maintenance is done entirely with mechanical means. For
details on such equipment, see the papers by Hebbink and by den Herder.

When comparing costs for maintenance from the water (boat) with that from the land, the capacity of overland equipment (in our situation) is much higher, because of the good overland accessibility. In DZV Waterboard therefore, no water equipment is used and we have basically opted for tractor mounted equipment.

In our Waterboard total running costs of the equipment costs are generally about Dfl 90 per hour, Dfl 40 for the operation and Dfl 50 for the equipment. It is our experience that there is not much difference in the investment costs between small, but specialized tractors or the standardized bigger tractors. This means that it is possible and advisable to choose the best combination with the highest production per hour.
Moreover, as it is shown for instance in the paper by Hebbink, annual maintenance costs are in the first place determined by the frequency; the cost per maintenance action do not differ that much. This supports the point to select equipment with the highest capacity.

Small tractors cannot always remove all vegetation in one go. Thus, the frequency can be reduced by using large tractors, which at the same time have a high production per hour. Therefore, small tractors are only used where accessibility is insufficient for the large ones.

In all cases, we use combinations of different equipment attached to one tractor to be able to do more actions at the same time.

With regard to the continuity aspect we try to make use of the employees as well as of the machinery throughout the year. The same machinery can be used for different kinds of activities in different periods.

For optimum utilization of the equipment the Waterboard does not possess large equipment and incidental activities that need for instance a large crane are being carried out by a contractor.

Thus, our Waterboard made the basic choice for normal standardized agriculture tractors (2.50 m.). These tractors can be used for mowing activities as well as for normal dredging activities, by applying different combinations:
- Tractor with one mowing machine (a 3 m flail mower), front end mounted, for mowing the grass strips and with another mowing machine attached at the rear, for the mowing of the banks. This enables cutting the grass in both places and removing the grass from the banks, all in one go.
- Tractor with a mowing machine (a fingerbar) and a rake attached for the
remowing of underwater vegetation.
- Tractor with a flail mower, attached with a long beam, for mowing of long banks, too long for the aforementioned machines. We use this machine also for the mowing of banks on the other side of a canal and along roads without a grass strip.

To prevent rottening of grass and vegetation disposed on the slopes, we remove it and throw it on the grass strips or on the fallow parcels (after harvest). In winter, the same tractors are then provided with a dumper instead of the mowers, to spread or remove the vegetation, where necessary. In larger and wider canals, the vegetation is removed with the aforementioned crane with a beam of 11.50 m. and a mowing bucket attached.

Besides these activities of small maintenance we sometimes have to reshape the canal and restore side slopes. For this purpose the same tractors and cranes are being used, but attached with other implements such as a screw and a rotary cultivator.

6. DESIGN ASPECTS AND DATA BASE

In design of new works, requirements of future maintenance are taken into account, according to the criteria outlined earlier. First of all there is the trade off between investment in design and lay-out against maintenance costs during many subsequent years. For instance, a canal with over-dimensional profile costs less in maintenance than a smaller profile, precisely fitting the hydraulic design. Therefore we apply a certain over-dimension in the smaller canals, where a lower frequency of maintenance is desirable and in which the functions are relatively less affected by the vegetation.

Furthermore the following aspects are incorporated in design:
- Three meter wide grass strips are provided and kept free along the canals;
- Every canal is connected with the higher order canal with a 5 m wide culvert, for accessibility for maintenance.

Obviously this practice costs land. Basically, it is a question of calculation, weighing the benefits of more effective maintenance against the price of the land. But of course there is also an emotional aspect. Apart from the aspect of ownership ("this land is mine") felt by the farmer, it is sometimes felt that the land could better be used for agricultural production than for maintenance. In
situations with local shortage of land, the policy can therefore be different.

The importance of a database has been mentioned earlier. In our Waterboard we are now improving the database, in order to make it appropriate for the application of hydraulic models. Use of these models would serve the operation (calculation of flows and levels), as well as the maintenance, for instance by assessing the effects of vegetation, profile shapes, etc.

7. ORGANIZATIONAL SET-UP

The opportunity of the merger of the two Waterboards was used to modify the organizational set-up. The new office of the Waterboard is now divided into six sections, under two distinct departments:

The two departments each have a managing director, and together with the six sectional heads they look after the daily management. Apart from this, there is a Board of twenty-eight persons, called the General Committee, in which the farmers (land inhabitants) and the urban inhabitants are being represented. Besides that there is an Executive Board of seven persons (Executive Committee), selected out of the General Committee.

<table>
<thead>
<tr>
<th>Administrative section</th>
<th>Administrative affairs Dpt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial section</td>
<td></td>
</tr>
<tr>
<td>Personnel affairs</td>
<td></td>
</tr>
<tr>
<td>Design and construction</td>
<td>Technical affairs Dpt.</td>
</tr>
<tr>
<td>Water management</td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td></td>
</tr>
</tbody>
</table>

The maintenance team forms one of the six sections. The head of this section is responsible for all maintenance in the Waterboard area. He has a budget for his activities and manages his section in close coordination with the heads of the water management section and of the financial section.

Regionally, the Waterboard is divided into two districts, with one surveyor in every district. Both districts have a number of tractor drivers, some crane drivers and some manual labour. To support this maintenance team both districts have a workshop with some technicians for the maintenance of the machinery.

The surveyor is an important man. He sees and hears a lot in his district and he
is in frequent contact with farmers. The image of the Waterboard largely depends on the quality of the surveyors and their teams.

8. SUMMARY AND DISCUSSION

In developing a maintenance policy, the following issues are to be addressed:
- A complete data base of the objects to be maintained;
- A clear formulation of the maintenance objectives;
- A policy on who is to execute the works: the farmers, the Waterboard itself, or contractors. Elements involved are, besides of course the costs, the required specialized equipment, aspects of supervision and control and of flexibility and continuity.
- The composition of the equipment package to be used, selected on the basis of clear criteria as for instance costs, capacity, accessibility and continuity.

For the newly formed Dollardzijlvest Waterboard, maintenance is done by the Waterboard itself, because it is cheaper, easier to supervise and because the system is large enough to justify the employment of own equipment and corresponding team.

The equipment is selected such as to have maximum capacities, reducing the frequency as well as the cost per hour. Also the equipment is such that (part of) it can be used for varying purposes, thus guaranteeing its intensive and continuous use. Altogether, the maintenance execution is based on the principle of "moving fast with large capacities and flexible means".

Where possible and appropriate, maintenance aspects should be incorporated in the design of new parts of the water control system. In DZV Waterboard this is done for instance by giving the canals some over-dimension and by providing grass strips, culverts, and adequate maintenance paths.

For an effective planning of maintenance, it is important to have a complete and consistent data base of the system. Hydraulic models can then be applied to assess the effects of various measures.

It has to be seen to what extent the above can be useful in the Indian context. The gist of this paper is to emphasize the importance of a systematic approach in developing a maintenance policy, and to outline the issues to be addressed and the criteria to apply. As such, it may have a more general validity. But the execution methodology in India will of course be different. The application of mechanical equipment for instance, may remain limited for some time to come. Where it is required, the above considerations may be helpful.
FINANCING MAINTENANCE
OF WATER CONTROL SYSTEMS
IN THE NETHERLANDS

J.H. Deurloo & M. Jurriëns

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1. INTRODUCTION
2. THE ORIGIN OF THE WATERBOARD TAX
3. WATERBOARD COSTS AND TAXES; SOME PRINCIPLES
4. THE DETERMINATION OF THE SPECIFIC LEVIES
5. THE LEVEL OF THE TOTAL COSTS
6. LEVY COLLECTION
7. EXAMPLE OF LEVY CALCULATION
8. CONCLUSIONS AND DISCUSSION
FINANCING MAINTENANCE OF WATER CONTROL SYSTEMS IN THE NETHERLANDS

1. INTRODUCTION

Some other papers in this publication already deal with the role of the Dutch Waterboards in maintenance of water control systems, their origin, the legislation, tasks, institutions and execution practices. They explain that the Dutch Waterboards can have a variety of tasks, but in all cases maintenance of the regional water control systems is a specific task of the Waterboard. This concerns the regular maintenance of about quarter of a million kilometres of canals and ditches and appurtenant structures.

Partly the maintenance of the larger systems is executed by the Waterboard itself or by contractors, for the lower order canals and ditches it is usually to be done by the farmers themselves (Table 1), but always under the responsibility of the Waterboard. The total amount of money annually spent on maintenance alone comes down to about 100 million Dfl (which does not include the lowest order field ditches, which are the responsibility of the farmers).

Table 1. Lengths of maintained canals

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterboards</td>
<td>55.000 km</td>
</tr>
<tr>
<td>Contractors</td>
<td>62.000 km</td>
</tr>
<tr>
<td>Farmers</td>
<td>127.000 km</td>
</tr>
<tr>
<td>Total</td>
<td>244.000 km</td>
</tr>
</tbody>
</table>

This paper deals with the financial aspects of the Waterboards. It explains how the money needed for maintenance (and for other expenses of the Waterboard) is being collected, and on which basis and criteria.

After a short review of the historic backgrounds (Section 2), Sections 3 and 4 depict some of the basic principles and further details of the cost recovery policy of the Waterboards. Subsequently the general level of the levy and its components is discussed. Section 6 deals with the collection of the levies and the possibilities of objection. The paper concludes with a practical example for one representative
Waterboard and some general conclusions on the relevance of the Dutch system for the Indian situation.

2. THE ORIGIN OF THE WATERBOARD TAX

Many centuries ago, in the early years of the Dutch flood control and water management, there was an obligation for farmers to execute the necessary maintenance themselves. Due to reclamation of new lands the water control function gradually covered larger and larger areas. As a result, an adequate management and maintenance of water control works as dikes, canals, structures and roads became increasingly important, and partly beyond the competence of individual farmers.

Consequently, the Waterboards gradually took over the execution of (part of) the maintenance from the farmers. This primarily concerned the main infrastructure of large canals, dikes, pumping stations, etc. Maintenance of smaller canals and ditches continued to be done by the farmers, which still is the case in many instances (Table 1).

With increasing work load for the Waterboards, also their expenses increased. Consequently the contributions by the farmers in kind (labour) were converted into financial contributions. With these contributions the Waterboard could finance their management and maintenance costs. In this context, gradually, a system for collection of fees and concordant legislation was developed, which is described in the subsequent Sections.

3. WATERBOARD COSTS AND FEES; SOME PRINCIPLES

There are a number of general principles governing the Netherlands cost recovery policy, which can be found back in details throughout the cost recovery practices, and which have proved to be very effective in financing the Waterboard costs.

* Principle of interest
Basic financial principle for the Waterboards still is that all costs should be covered by contributions from those who are benefited by the Board’s activities. This is based on a system of degree of benefit (called "interest"). Those who benefit the most, pay the most.
* Coverage of all costs
Furthermore, these contributions cover entire Waterboard costs ("closed budget"), including construction and operation, the capital and management costs. There are no separate maintenance fees. The part of the maintenance costs of the total costs depend on the specific situation, but generally is about 50%.

* General and specific interests
In the new Waterboard Law of 1992, a distinction is made between two types of interest:
- General interests
  These are the interests of everybody living in the Waterboard area. These interests refer to the general possibility to live and work in the area due to the works of the Board.
- Specific interests
  These regard the more direct interests of the owner of buildings and of the owner or user of land in an adequate water management by the Waterboard.

Which part of the total costs is attributed to general and which to specific interests varies over the country, depending on the inconvenience one would experience when the Waterboard would not exercise its functions. Four possibilities are being distinguished, see Table 2.

Table 2. General interest part of total costs

<table>
<thead>
<tr>
<th>Inconvenience</th>
<th>Share in costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>0 %</td>
</tr>
<tr>
<td>Little</td>
<td>15 - 20 %</td>
</tr>
<tr>
<td>Considerable</td>
<td>20 - 25 %</td>
</tr>
<tr>
<td>High</td>
<td>25 - 30 %</td>
</tr>
</tbody>
</table>

If there is any benefit at all, the part of the general interest can vary from 15-30%. If a Waterboard falls in the third category, 20% of all costs will be attributed to all inhabitants as general interest levy. The precise percentage is fixed on the basis of the population density and the necessity of drainage.

* "Built-up" areas and land
A further element of the financing policy is that the levy not only concerns agricultural land, but -as indicated already above- buildings as well. Not only agricultural land has an interest in water control, but houses, offices, factories,
etc. also benefit from proper flood protection and ground water control. An important reason for this is that built-up areas (buildings, pavements and other appurtenant works) cause a rapid discharge of rain water. The cost for drainage systems has much increased during the past century since extensive sewerage systems were built, which caused the excess rain to be discharged in a short time and high quantities onto the open drainage systems. The latter (care for the open water on which sewerage systems discharge), also is a task of the Waterboard.

The above is summarized in Figure 1, indicating who has to pay for the various interests.

Figure 1. Various interests parts and contributors

With this background it is logical that the specific interest part of the Waterboard levy consists of two parts: one part "built-up" levy for buildings etc. and the other part for agricultural land: the "non built-up" areas. Whereas the general interest part is paid by all inhabitants, the specific interest part is paid only by the owner of buildings and by the owners or users of land. When the land is in lease-hold, the tenant can pay up to 50% of the specific interest. More details are given in the next Section.

It is also to be mentioned that for investments in some water control works, made by the Waterboard, a Government subsidy can be obtained, usually 50%.

* The principle of interest, payment and say
The Waterboard is a functional public body. This means that, in contrast to
other government bodies as provinces and communities, it has some subject specific and restricted tasks, visually the care for regional water management affairs.

More or less related, also the democratic participation and levying system deviate from what is common with provinces and communities. The Waterboard system is characterized by the connection between interest, payment and say (the so-called "triad"), see Figure 2. The higher the interest, the higher the financial contribution, but also the higher the rights of say (see also the paper by Siefers).

Figure 2. Interest, payment and say

In practice it means that the General Committee of the Waterboard is composed of representatives from categories that have an interest in the proper execution of the Waterboard's tasks, while on the other side also only these categories are being taxed. At the moment only owners of land and buildings are represented in the General Committee. Users of land and buildings are not being represented and also not being taxed. This will change with the new Waterboard Act of 1992.

4. THE DETERMINATION OF THE SPECIFIC LEVIES

On the basis of the above principles it will be clear that Waterboard levies can vary considerably over the country and for the individuals, depending on the expenses to be made by the Waterboard, related to its activities and importance and specific circumstances, as illustrated below.

The law dictates that the level of the levies must be in accordance with the provisions that are being asked and offered (interest-payment relation). All costs, including for maintenance, are attributed to interested parties and individuals via a cost partition key.
As said above, the general levies are based on that part of the costs to be shared by all inhabitants. The "built-up" part of the specific levy usually varies with the value of the property. For a large manor house or factory more has to be paid than for a simple house or workshop (profiting principle).

The "land" is levied on a per hectare basis. But there is a difference between the flat polder areas, mainly in the West of the country, and the somewhat "higher", undulating areas in other parts of the country. In the polder areas everybody has about the same interest in the water control, because the ground water depth is about the same over the area. Usually therefore there is a unit fee per ha within one Waterboard. Of course this can be different for another Board. In the more undulating areas there is a clear difference in ground water depths, which results in different interests.

This difference is expressed in a "classification system", the basis of which is depicted in Figure 3. The lowest lands have the highest interest and pay the most. Such system exists in almost half of the Waterboards.

![Figure 3. Zones with different interests](image)

The number of these classes and corresponding ratios can vary for the different Waterboards. Table 3 gives an example. It is seen that 60 Waterboards (representing about half of the total number) apply a classification; in 75% of these cases the number of classes varies from 3-5.
Table 3. Waterboards with classification systems

<table>
<thead>
<tr>
<th>Number of classes</th>
<th>Number of Waterboards</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3 (5%)</td>
</tr>
<tr>
<td>3</td>
<td>13 (22%)</td>
</tr>
<tr>
<td>4</td>
<td>18 (30%)</td>
</tr>
<tr>
<td>5</td>
<td>14 (23%)</td>
</tr>
<tr>
<td>6</td>
<td>4 (7%)</td>
</tr>
<tr>
<td>7</td>
<td>1 (2%)</td>
</tr>
<tr>
<td>8</td>
<td>1 (2%)</td>
</tr>
<tr>
<td>&gt;8</td>
<td>5 (8%)</td>
</tr>
<tr>
<td>Total</td>
<td>60</td>
</tr>
</tbody>
</table>

5. THE LEVEL OF THE TOTAL COSTS

As mentioned above, the extent of the levies is determined such as to cover the total Waterboard expenses (closed budget). Particularly in recent years the Waterboard's tasks have been broadened and intensified with consequently increased costs.

Table 4. Total Waterboard incomes from levies

<table>
<thead>
<tr>
<th>Total incomes (million Dfl)</th>
<th>Index levies income</th>
<th>Index national produce</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Agricult areas</td>
<td>Built-up areas</td>
</tr>
<tr>
<td>1980</td>
<td>225</td>
<td>203</td>
</tr>
<tr>
<td>1985</td>
<td>259</td>
<td>277</td>
</tr>
<tr>
<td>1986</td>
<td>265</td>
<td>291</td>
</tr>
<tr>
<td>1987</td>
<td>297</td>
<td>314</td>
</tr>
<tr>
<td>1988</td>
<td>302</td>
<td>325</td>
</tr>
<tr>
<td>1989</td>
<td>209</td>
<td>341</td>
</tr>
<tr>
<td>1990</td>
<td>314</td>
<td>354</td>
</tr>
<tr>
<td>1991</td>
<td>315</td>
<td>377</td>
</tr>
</tbody>
</table>
This regards primarily an increasing attention for environment and nature conservation. This lead to a general increase in levies, which is illustrated in Table 4 for the period 1980 to 1991. The table shows an average increase of the total annual costs of around the 5\% . This is about double the increase of the national produce price-index. Major reason for this is the aforementioned expansion of tasks. It is also seen that the increase in the levy "built-up" is more than for the agricultural area levy. The ratio changed from 53/47 in 1980 to 45/55 in 1991.

* **Rise in agricultural land levies**

According to Table 4 the levy the user of agricultural land has to pay (per ha) has increased, which is illustrated in Figure 4. (The clear shift in 1986/87 is caused by the completion of the new Flevopolders). The amounts per ha are averages for the country. When looking at the figures per province there appear to be considerable variations. In 1988 for instance, the lowest levy was Dfl 49,- per ha (higher lands in the province of Limburg); the highest Dfl 180,- per ha (flat land in the new Flevopolders Province).

![Figure 4. Change in agricultural land levy per ha since 1980](image)

Where a classification system is used the differences per ha and per Waterboard can be even bigger. Maximum levies of several hundreds of guilders per ha can occur, although usually for small areas.

* **Rise in "built-up" area levies**

The rise of the built-up levy will also have caused a rise in costs per household (living unit). Because the levy include other buildings as well, some approximations have to be made to calculate the costs per living unit. As a result of the above, the ratio between levies for agricultural land and built-up has changed since 1980, as illustrated in Figure 5.
6. LEVY COLLECTION

* The data base system
Ownership of land and buildings in the Netherlands is registered in a real property register, called the "cadaster". The register consists of detailed maps showing the location and exact boundaries of the property with lists describing the property per parcel. In rural areas the maps are usually on scale 1:2500, in built-up areas 1:1000. Community-wise the maps are classified in sections (letters) and per section in parcels (numbers).
In separate lists all data on properties are collected owner-wise, which is called the "legger". For every property it gives the name of the owner, address, the exact location of the property (community, section, parcel number), size, etc, and - where applicable - the classification according to the system described in Section 4. This system is also used by other Government institutions, e.g. for planning (of town extensions, roads, etc) and for taxing.

The above is shown to indicate that for an effective levying of fees, a sound data base is required, containing all relevant data necessary for the particular levy policy at hand. The precise nature may vary from country to country as per their practices and procedures.

* The assessment
Every year the Waterboard calculates what the levy should be to cover all costs. The resulting levy has to be sanctioned by the Province. In polder areas there is one amount per ha for the entire area. In other areas, where mostly a classification system is applied, the individual amounts vary with the location, relative to the canal, as outlined above.
Every year an assessment is issued containing the levy for the land and existing buildings. This is sent to the owner and must be paid before a certain date. If this is not done, a recovery procedure is started. In this respect, the juridical power of the Waterboards is considerable. If the owner defaults to pay, this can even lead to a public auction of his properties. In case of a bankruptcy for instance, the Waterboard levy usually is among the first things to be paid from the remaining funds.

* Objection possibilities
Although there are provisions for objection against the levy, this only applies at the earlier stage of the classification.
New or modified classification systems are regularly deposited for public inspection. If someone does not agree with his classification, he can raise objections with the Board of the Waterboard. If this is rejected, possibly after field visit, he can appeal to the Province, where the case is reinvestigated. If again the objection is rejected, he can appeal in highest resort to the Crown. Here, the final decision is taken.
Once the classification system being accepted, there is no further possibility of objection against the levy as such.

7. EXAMPLE OF LEVY CALCULATION

This Section gives a (simplified) example of the calculation of costs and levies for an imaginary Waterboard.

<table>
<thead>
<tr>
<th>Waterboard data</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Area covered</td>
<td>150,000 ha</td>
</tr>
<tr>
<td>Total Waterboard costs</td>
<td>30 million Dfl</td>
</tr>
<tr>
<td>Part of general interests</td>
<td>20 %</td>
</tr>
<tr>
<td>Ratio land/built-up</td>
<td>60/40</td>
</tr>
<tr>
<td>Polder area (no classification)</td>
<td></td>
</tr>
<tr>
<td>Canals</td>
<td>2400 km</td>
</tr>
<tr>
<td>Inhabitants</td>
<td>600,000 km</td>
</tr>
<tr>
<td>Average living unit</td>
<td>3 persons</td>
</tr>
<tr>
<td>Number of units</td>
<td>200,000</td>
</tr>
</tbody>
</table>

According to the ratio general-specific (based on the category, see Section 3), 20% of the total or Dfl 6 Ml has to be contributed by the inhabitants as general levy, meaning Dfl 10 per person. The remaining 80% or Dfl 24 Ml goes into
specific interest levies, of which 60% (Dfl 14.4 Ml) for built-up and 40% (Dfl 9.6 Ml) for agricultural land. The above is depicted schematically in Table 5 and the corresponding Figure 6.

Table 5. Example of data for levy determination

<table>
<thead>
<tr>
<th>Cost type</th>
<th>10^6 Dfl</th>
<th>%</th>
<th>Dfl/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital</td>
<td>6.4</td>
<td>21</td>
<td>2.70</td>
</tr>
<tr>
<td>Mowing</td>
<td>5.7</td>
<td>19</td>
<td>2.40</td>
</tr>
<tr>
<td>Dredging</td>
<td>6.2</td>
<td>21</td>
<td>2.60</td>
</tr>
<tr>
<td>Public green</td>
<td>0.2</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Misc.</td>
<td>1.4</td>
<td>5</td>
<td>0.70</td>
</tr>
<tr>
<td>Management</td>
<td>10.1</td>
<td>34</td>
<td>4.20</td>
</tr>
<tr>
<td>Total</td>
<td>30.0</td>
<td>100</td>
<td>12.50</td>
</tr>
</tbody>
</table>

(in million Dfl or %)

Total costs

<table>
<thead>
<tr>
<th>General interests</th>
<th>Specific interests</th>
</tr>
</thead>
<tbody>
<tr>
<td>20% Dfl 6</td>
<td>80% Dfl 24</td>
</tr>
</tbody>
</table>

Land 48% Dfl 14.4 Built-up 32% Dfl 9.6

Figure 6. Example of levy determination
On the average the first (built-up) would come down to Dfl 48 per living unit (3 persons) and the latter (land) to Dfl 96 per ha of land. A farmer family with 3 persons and 40 ha thus pays Dfl \((3 \times 10 + 1 \times 48 + 40 \times 96)\) or Dfl 3918 per year.

As said before the part of this to be used for maintenance may vary. Usually it is about half of the total, in this specific case it is 45\% (see Table 5).

8. CONCLUSIONS AND DISCUSSION

A general conclusion from the above can be that for the financing of maintenance a well established organization is required, with clear rules and regulations regarding levies, collection, assessment and objection.

The idea of the "triad": interest, payment, say, could be applicable in other circumstances as well. Very important in any case is that for the implementation of the system a corresponding financial legislation is required as well as a sound data base.

Of course it is not the idea to advocate transplanting the above details to the Indian situation, but the above conclusion may well have general validity. When trying to assess what could be done with the information of this paper for in the Indian context, the following issues are worth considering.

- It should be decided whether to have one levy for all costs of the body responsible for water management, or only a specific maintenance levy.
- Also, perhaps related, it should be decided if the levy is composed of a general and a specific part, or of a specific part only. In case of the Indian irrigation one could think of having only a specific levy, on a per hectare basis. It is then to be seen whether this should include maintenance costs only, or (part of) the operation costs as well.
- A separate levying of built-up property does not seem relevant for the Indian irrigation situation.
- A sound data base is required, not only for the planning and execution of the maintenance, but also as a basis for the determination and collection of levies. It is to be seen to what extent the existing data base in Indian irrigation is adequate.
- Similarly a legislation is required as a basis for the levying system and the possibilities to indeed collect the fees.
- It has to be decided which body is charging and collecting the levies. Irrigation Department, responsible for the maintenance, might be a more logic choice than Revenue Department.
Some issues, complicating the picture in the Indian context are briefly mentioned.

- The basis of payment cannot be too complicated, because of the absence of an accurate and detailed data base on several issues.
- The current water fee per ha only relates to crops grown, there is no relation with any real costs to be made by the government.
- Another point is the question of who is to pay: the owner only, or the tenant as well?
- Also, it is logic that when farmers pay for a service, they have to be sure of receiving that service. This is a problem in many irrigation schemes.
- Related to this, a distinction should probably be made between costs for maintaining the main system (main canals, distributaries and minors) and costs involved in maintenance within the tertiary unit (outlet command). A problem then is that even if the Government would be able to guarantee water supply to the chak, for instance due to improved maintenance, this does not automatically mean that every individual farmer would benefit from that by getting his share of water (because of distribution problems within the chak).
- In this context, a two step system could be considered. Farmers together (for instance by means of water users association to be formed) pay for the main system maintenance (and for operation?), and the individual farmers pay an extra fee for the maintenance within the chak, to be organized by the farmers themselves.
- Maintenance of drains further complicates the situation. Not only because main drains should be maintained as well (this could be accounted for by including the costs in the total maintenance fee), but also because maintenance of drains within chaks is often not seen as necessary activity by the farmers.
- The legislation is insufficient to be able to impose real sanctions on not maintaining or on not paying.

The above shows that in India the problem is complicated because various conditions enabling the Dutch system to function are not present in India. Most important perhaps in this respect is an adequate financial legislation.
INTEGRATED MECHANICAL SILT CLEARANCE AND WEED CONTROL IN THE GEZIRA SCHEME, SUDAN

P. Nieuwenhuyse

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3. MAINTENANCE PROBLEMS IN THE SCHEME
4. THE ACTION RESEARCH PROJECT
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7. SUMMARY AND CONCLUSIONS
INTEGRATED MECHANICAL SILT CLEARANCE AND WEED CONTROL IN THE GEZIRA SCHEME, SUDAN

1. INTRODUCTION

From 1978 to present DEMAS (Dredging, Engineering and Management Studies) has been involved in a study and pilot area activities concerning maintenance in the Gezira Irrigation Scheme in Sudan. The main characteristics of this Scheme and of the maintenance problems that existed before the start of the project activities are summarized in Sections 2 and 3.

This paper highlights some of the important aspects of the program carried out. Section 4 provides information on the nature and set-up of the action research project, on the pilot area in which it was carried out, the activities it contained, and the equipment used and tested.

The major results are summarized in Section 5, including an evaluation of the equipment used. Subsequently some characteristics are described of the Abu Usher Training Project, which formed the second phase of the project.

2. THE GEZIRA/ MANAGIL SCHEME

The Gezira/Managil irrigation scheme is a gravity irrigation scheme supplied by water diverted from the Blue Nile at the Sennar Dam, see Figure 1. The scheme covers an area of 882,000 ha, comprising some 100,000 farm holdings. The soil consists of a fertile calcareous clay (vertisol), with a high production potential. The topography of the area is rather flat with an average slope of 0.15 m/km. The crops grown in the scheme are cotton, wheat, sorghum, groundnut and vegetables. The current cropping intensity is about 66%, against a design intensity of 75%. The permanent population is estimated at 1,700,000, while some 200,000 migrant workers temporarily stay in the scheme, particularly during the cotton picking season.

With regard to water management the scheme is divided into divisions and sub-divisions, for agricultural management in groups and blocks, whereas administratively it is divided into rural councils, falling under one municipality. The scheme has an extensive irrigation network. Table 1 gives some information on the canalization, while a sketch of the standard lay-out of the network is presented in Figure 2.
Figure 1. The Gezira/Managil scheme
Figure 2. Schematic lay-out of the Gezira irrigation system
The design of the major canals is based on night storage capacity: canal width at full supply level (FSL) = 10.0 m, at bank crest level (FSL + 0.6m) = 12.4 m. "Ganabia" is the local name for minor canals, "Abu XX" for the tertiary canals and "Abu VI" for the quaternary canals.

Table 1. Main characteristics of the canal network

<table>
<thead>
<tr>
<th>Type</th>
<th>Number</th>
<th>Length (km)</th>
<th>Range of capacities (m3/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main canals</td>
<td>2</td>
<td>261</td>
<td>10 - 186</td>
</tr>
<tr>
<td>Branch canals</td>
<td>11</td>
<td>651</td>
<td>25-120</td>
</tr>
<tr>
<td>Major canals</td>
<td>107</td>
<td>1652</td>
<td>1.5-15</td>
</tr>
<tr>
<td>Ganabias</td>
<td>1,498</td>
<td>8119</td>
<td>0.125 -0.750</td>
</tr>
<tr>
<td>Double Abu XX</td>
<td>26,995</td>
<td>40,000</td>
<td>0.250</td>
</tr>
<tr>
<td>Abu XX</td>
<td></td>
<td></td>
<td>0.125</td>
</tr>
<tr>
<td>Abu VI</td>
<td>350,000</td>
<td>100,000</td>
<td>0.050</td>
</tr>
</tbody>
</table>

3. MAINTENANCE PROBLEMS IN THE SCHEME

3.1. Siltation in the irrigation canals

With the water supplied from the Blue Nile at Sennar, considerable amounts of silt enter the canal network. The silt is deposited partly in the canals, partly in the fields. Sedimentation of silt increases with decreasing flow velocity, which happens at low discharges. Due to the above hardly any silt is deposited in the main and branch canals, serious siltation is occurring in the subsequent canals, however. In particular the head reaches of the minor canals are affected. Because of their function as night storage reservoir, with inherent low flow velocities, they act as a sedimentation basin.

3.2. Aquatic weeds in the irrigation canals

From July till November, during and after the rain flood in the upper Blue Nile, the water is turbid and laden with clay particles so that only weeds on the banks can develop. In the large canals with high water velocities and sometimes wind
generated waves, the weeds are protecting the canal banks against erosion. However, some species are encroaching the canal, obstructing the flow of water.

After November when the water becomes clearer, seeds of emergent and submerged weeds start to germinate, even in deeper water, because of the penetration of sun energy to the bottom, and an explosive growth occurs. This happens in particular in the smaller canals.

The dense growth of aquatic weeds drastically reduces the flow velocity. Fortunately floating weeds, like water hyacinth are not present in the canal network. Figure 3 presents a schematic view of aquatic weeds in an irrigation canal.

![Schematic presentation of weed growth in Gezira canals](image)

Figure 3. Schematic presentation of weed growth in Gezira canals

The species of aquatic weeds most prevalent in the Gezira/Managil scheme are:
- Floating weeds: not rooted in the bedding: *Lemna minor*;
- Submerged weeds: rooted in the bedding, most of the vegetative tissues beneath the water surface: *Potamogeton perfoliatus*, *Najas pectinata*, *Ottelia alismoides*, *Ottelia alvifolis*;
- Emergent weeds: rooted in the bottom and on the banks, most of the leaf stem above the water: *Echinochloa stagnina*, *Typha angustata*, *Pyula nodiflora*;
- Encroaching bank weeds: rooted on the banks close to the water surface, most of the leaf stem floating on the water surface: *Vossia cuspidata*, *Ipomoea aquatica*, *Cynodon dactylon*;
- Bank weeds: rooted on the banks and berms, leaf stems are standing: 
  Dichantium annulatum, Cyperus rotundus, Acacia nylotica.

* Health aspects

The development of irrigation areas introduced the schistosomiasis disease (bilharzia) in the area. Human infection will occur by contact of the human skin with contaminated water. The indispensable intermediate host for the schistosome larvae are two varieties of water snails. The aquatic weeds, especially the submerged, are the living habitat.

* Interaction of siltation and weed growth

The silt deposits and the weed growth, especially in the smaller canals, considerably reduce the conveyance capacity of the canals. Even to such an extent that water supply to the cropped fields becomes insufficient, certainly in cases of overdue silt and weed clearance.

Silt loaded, turbid water hampers the development of aquatic weeds, but once the silt is deposited it forms a raised, fertile substratum on which weeds flourish. Once established the weeds stimulate siltation. In this respect, the interaction of siltation and weed growth is of interest. The combat against the water shortage should then be found in an integrated and well scheduled programme of silt and weed clearance.

3.3. Historical standard maintenance practice

The standard maintenance practice in the Gezira consisted of silt excavation by draglines, once in a number of years. These draglines were not very suitable for silt excavation in smaller canals because they cannot finish the work smoothly, producing jagged side slopes and canal bed, promoting siltation and weed growth. Besides, the standard practice was to deposit the excavated material on the embankment next to the canals, making them inaccessible for most equipment.

Weed removal was done several times per year, by manual labour entering in the water and using hand tools. This manual weed control did not solve the serious weed problem because of scarcity of labour to execute the work, while due to the chance of infection with schistosomiasis (bilharzia) this system was socially not acceptable.
4. THE ACTION RESEARCH PROJECT

In the above situation, the Sudanese Government wanted to develop a new maintenance program, including new techniques and requested the Netherlands Government for assistance. It was then decided to set up a pilot project for the development of an integrated program of mechanical silt clearance and weed control, in which the most suitable techniques could be tested. Already in 1976 preliminary surveys took place to determine a site for the project and in 1978 a decision was reached on an area near Gorashi in the Managil part of the Scheme.

* The 24 el Gorashi pilot project

The area initially agreed upon to test different types of equipment on a prototype scale was located near the village of 24 el Gorashi. The area covers about 21,000 ha and contains 30 km of major and 200 km of minor canals. The basic objective of the project was to develop the appropriate and optimum techniques and equipment for tackling the weed infestation and siltation.

In the original set up a separate government organisation was to take care of the silt clearance, but because of the interrelation between silt clearance and weed control it was decided in an early stage to integrate both in the same project. Already in an early project stage it was observed that many canals could not be reached by weed control equipment because of the material dumped by earlier silt removal operations.

Various types of equipment were tested, visually:
- Tractors with side mounted mowing buckets;
- Tractors with side mounted mowing bars (topmower);
- Tractors mounted with rotary disc type ditch cleaner;
- Tractors mounted with screw type slope cleaner;
- Wheel mounted excavators, equipped with mowing bucket;
- Track mounted excavators, equipped with mowing bucket and dredging bucket;
- A mowing boat;
- An amphibious weed cutter.

For supporting services the following equipment was used:
- Bulldozers, for making canal embankments accessible for the silt clearance and weed control equipment;
- Graders, for dressing the embankments after the silt clearance and weed
control equipment had deposited material on the embankment;
- A mobile workshop, for day to day maintenance and field repairs of the equipment;
- A service truck, for fuelling and greasing of the equipment in the field.

During the course of the project numerous modifications and improvements, as a result of continuous testing, were carried out. These are discussed further below.

After working three seasons in the 24 el Gorashi area, weed growth was under control and it was decided to leave a selected equipment set, sufficient for regular maintenance of weed control and silt clearance and to move the remaining equipment to a new area.

5. EVALUATION OF PROJECT RESULTS

5.1. Evaluation of the pilot project

The findings during the pilot project confirmed that weed control and silt clearance are closely interrelated. The originally practised method of silt removal by draglines made the canals inaccessible for weed control equipment, while the increased roughness of the canals created an ideal habitat for weed growth and at the other hand encouraged siltation.

The above circumstances led to a two stage approach. During the first stage, the rehabilitation stage, the canals including the embankments were restored to the original design cross-section. During the second stage, the maintenance phase, silt clearance and weed control were carried out by mechanical means in an efficient manner.

Correspondingly equipment packages were developed for both phases. For the rehabilitation phase this package included bulldozers, graders and heavy hydraulic excavators. For the maintenance phase the package consists of lighter equipment as discussed below.

The equipment package was composed on the basis of production records and unit costs per machinery combination and per type of canal. The ideal machinery combination for an area of 21,000 ha which resulted from this investigation and its enlargement to a basic unit group for 63,000 ha has become the basis for setting up the next project: the Abu Usher training area, discussed further below.
5.2. Equipment evaluation

As stated earlier the tested equipment had to be modified and improved in order to be adjusted to the specific circumstances in the Gezira. In the following the main adjustments and modifications for each type of equipment will be discussed.

- Tractors with side mounted mowing buckets.
The originally used standard booms and mowing buckets proved to be of a too light construction and cracks developed. The main reasons were the harsh conditions in the scheme, such as bad roads to and from the working sites and mishandling of the equipment by the inexperienced operators, which had to be trained during the initial stage of the project.
In cooperation with the manufacturer of this type of equipment the booms and buckets were strengthened, while a new, heavier range of booms and buckets were developed and taken into production.
The production of the mowing bucket was satisfactory, while an advantage was that the cut material was immediately taken out of the water.

- Tractors with side mounted mowing bars (topmower).
The same sideboom as used for the mowing bucket can also be used for this type of equipment. The production of cut weeds was very high. However, the cut weeds remained in the water and, due to wind and current in the canal, floated towards the regulator weirs, where they had to be taken out of the water by a grab. As the grabbing activity was much slower than the cutting production, masses of floating weeds frequently choked weirs and field inlets.
In a later stage the use of this type of equipment was abandoned.

- Tractors with rotary type ditch cleaner.
This equipment suffered from a lot of wear, mainly caused by the hard soil of the canal embankments. Besides this, the energy required to drive the disc demanded a rather heavy, and thus expensive tractor. The use of the rotary disc was limited to cleaning side slopes only. Because of the high costs, the problems involved and the limited use, the rotary ditch cleaner was abandoned in an early stage.

- Tractors with screw type excavator.
The screw type excavator had similar problems of wear, energy consumption and use as the above described rotary disc and was for the same reasons excluded in an early stage.
- **Wheel mounted excavators with mowing buckets.**
  Two types of wheel mounted excavators have been tested, a rather light version and a medium size. The light version made about the same production as a tractor with mowing bucket, but investment and operating cost proved to be much higher. The medium size excavator can be equipped with a larger size of mowing bucket, improving its production and making it very competitive compared to the combination of tractor and mowing bucket. Both types of excavator have the advantage of transportability.

- **Track mounted excavators with mowing bucket.**
  The medium type tracked excavator can be equipped with the same wide mowing bucket as the version on wheels. Because of the better stability of the machine the reach is somewhat longer, which can be an advantage in the case of wide canals. The driving speed of the machine low, however, which reduces the production when working with a mowing bucket where frequent forward movements are required.

- **Track mounted excavators with dredging bucket.**
  For rehabilitation of silted up canals track mounted excavators are used. As this type of work is the general use the equipment is developed for, no special problems have been encountered.

- **Mowing boat.**
  The mowing boat was expected to be useful for weed control in the larger canals. Production of the boat, once launched, was satisfactory, but due to the limited distance between weir structures, the boat had frequently to be taken out of the water, to be launched again in the next reach. Especially in canals with steep slopes this was rather time consuming. Furthermore the cut weeds remained free floating in the water, posing the same problems as were encountered with the topmower.

- **Amphibious weed cutter.**
  To overcome the above described launching problem an amphibious craft was tested. This type of equipment was able to cut the weeds, lift them out of the water and deposit them on the embankment in one operation. The production of the machine was enormous, which made it necessary to very frequently move the machine out of the water, drive around the weir structure and enter into the next reach. As many times slopes were rather steep, moving out of the water was sometimes a problem. Although the equipment was a newly developed prototype, production was very promising. It was yet abandoned, because of the problems of getting in and out
of the water. At present a version of the same type of equipment exists, which is able to overcome steeper slopes.

- **Bulldozer.**
  The need of using a bulldozer in the project arose, because of the inaccessibility of the embankments caused by silt deposited on the embankments by draglines having executed silt clearance in the past. The bulldozer used in the project, a Caterpillar D-6 type is levelling the embankments and working satisfactorily.

- **Grader.**
  The grader served the same purpose as the bulldozer, especially at places were the deposits are less extensive. Besides, this the grader was used for dressing the embankments after weed control and silt clearance have deposited minor quantities of material on the embankment.

- **Mobile workshop.**
  The initially used mobile workshop was a truck mounted fully equipped workshop. During the pilot project it became clear that this type of equipment was too big in dimensions for assisting equipment working on narrow dikes and in confined places, a lot of time was lost for manoeuvring the truck to the equipment. Besides this the workshop is only meant for small field repairs, when more extensive repairs are required the equipment is transported to the central workshop. Later on a small landrover mounted mobile workshop was used which proved to be much handier.

- **Service truck.**
  The service truck used for fuelling and greasing the equipment was of the same type as the mobile workshop. This truck did have the problems of manoeuvring in confined spaces to a lesser extent, as the equipment can drive over limited distances to meet the truck in an easier accessible place.

The above can be summarized as follows.

- A boat or amphibious boat was not appropriate because of the frequent displacement around structures and the steep side slopes.

- Of the tractor mounted equipment only the side mounted mowing bucket was eventually selected. Most crucial advantage over the other equipment was the simultaneous removal of weeds, apart from having less fuel consumption than the other tractor equipment. Adaptations were necessary to make it more sturdy under the Gezira circumstances.

- All excavator equipment was adequate. The medium size wheel mounted excavator with mowing bucket can compete with the tractor mounted
mowing bucket. The track excavator with mowing bucket can be used for longer reaches, as the excavator with dredging bucket, which is most appropriate for heavy rehabilitation work.

The above reasoning shows that under conditions with less weed production, different soils and fewer structures, another selection of equipment could be possible.

6. THE ABU USHER REHABILITATION AND TRAINING PROJECT

6.1. The project

After equipment had been tested in the pilot project, a follow-up project was set up. The purpose of this project was to execute mechanical silt clearance and weed control at a full scale and at the same time to set up training facilities for staff and operators. The location of the project was in one of the older parts of the Scheme, where due to a backlog in maintenance rehabilitation was urgently required.

The original idea was to start in an area of 21,000 ha with rehabilitation, i.e. remove the backlog in maintenance by restoring the canals to their original design cross-section and by levelling the embankments. In the next year this rehabilitation equipment would be moved to a neighbouring area of 21,000 ha while maintaining silt clearance and weed control in the first area. The third year a third area of 21,000 ha would be rehabilitated.

The basis of the idea was that, dictated by logistical reasons, one central workshop and store could serve an area of 63,000 ha, while the earlier mentioned basic unit group ideally fits in such an area.

Based on experience from the pilot project it was decided to develop an independent organizational structure, instead of incorporating the project in an existing organization of the Ministry of Irrigation.

The project started with the erection of a workshop and store, annex offices for the project staff, centrally located in the area.

6.2. Project organization

The project organization can be divided into two departments, the mechanical engineering department and the civil engineering department. The mechanical engineering department is responsible for maintenance and
repair of the equipment, ordering and purchasing of spare parts, stock keeping of spare parts and supply of fuel etc. to the equipment in the field. The department is headed by the resident mechanical engineer, assisted by a field engineer and a workshop engineer and at a lower level a foreman and a store keeper. The field engineer is responsible for the equipment operators and for the logistics in the field. The workshop engineer is responsible for all repairs and maintenance, both in the workshop and in the field. The workshop and the mobile workshop are under his responsibility, as well as the stores.

The civil engineering department is responsible for maintenance of the canals in the project area, excluding main canals and regulator works, the planning of the maintenance works, planning of machine allocations, production estimates, quality control, maintenance of roads and embankments. The department is working in close relation with the sub divisional engineers, who are responsible for the supply of water to the fields. The civil engineering department is headed by a resident civil engineer, having the overall responsibility. The resident civil engineer is assisted by site engineers, responsible for part of the project area. For pre- and post surveys, assistance is provided by survey teams.

The site engineers are preparing two weekly time schedules for allocation of machines to the different tasks to be performed. Day to day checking in the field is done by chainmen, one for each machine, while the site engineers check at random.

6.3. The rehabilitation programme

The first requirement in the project was to restore the canals to their original cross-sections. This meant that large quantities of silt had to be excavated, while embankments had to be levelled, in order to make them accessible for the equipment.

To quantify the amount of material to be dredged, a survey campaign was set up. During the survey regular cross-sections of the canals were taken. From comparison of the surveyed cross-sections with the design the quantity to be excavated can be calculated. Furthermore during the survey the need for levelling of the embankments was investigated and quantified. Based upon this survey programme the planning for the application of bulldozers and excavators could be made.

Once the embankments being levelled, tracked excavators equipped with dredging bucket started restoring the canal to the required dimensions. Material
excavated was placed on the outside of the embankment. As soon as a canal was rehabilitated, it was incorporated in the maintenance programme.

For maintenance and service to the equipment in the field a mobile workshop and a fuel- and grease truck were available, while for major repairs the equipment was moved to the workshop.

6.4. The maintenance programme

In the maintenance programme canals are maintained to that extent that blockage due to sedimentation or weed growth is prevented. To this purpose a well defined planning and monitoring is imperative.

Most of the siltation takes place when the silt content of the water in the irrigation canals is high. This occurs shortly after the start of the rainy season in the catchment area of the Blue Nile, which usually is from June to September. After September the silt content in the irrigation water gradually decreases, resulting in minimum siltation at the end of the dry season. Weed growth occurs throughout the irrigation season. However, it is maximum towards the end of the irrigation season, when sunlight penetration makes submerged weeds grow rapidly. When the silt load in the irrigation canals obscures the clearness of the water, at the beginning of the irrigation season during and short after the rainy season, sunlight penetration is minimal, minimizing the weed growth.

Yet it is difficult to quantified how much siltation will occur when and in which canal. This directly implies that siltation will have to be continuously monitored.

Weed growth in the canals can be visually checked by the field engineer, but it is impossible to see to what extent weed growth is obstructing the water flow. For a proper planning continuous flow measurements should therefore be taken.

In order to be able to set priorities, it is important to know what will be the crop water requirements along the various canals, and then to monitor to what extent the canals are still able to supply the required flows.

6.5. The "Basic Unit Group"

During the pilot project a standard set of equipment had been developed. This set, called the "Basic Unit Group", consists of different types of equipment required for silt clearance and weed control. In developing the set, care has
been taken that the equipment is as versatile as possible and that it can be used during the different seasons.

Depending on the type of work, equipment can be classified in:
- Rehabilitation equipment
- Maintenance equipment
- Auxiliary equipment
- Overhead equipment

Rehabilitation equipment is used for restoring canals to their design cross-sections. Selected for this type of work were the tracked excavators equipped with dredging bucket. The number of excavators required is depending on the amount of silt to be excavated and on the time available for executing the rehabilitation job. Under the specific circumstances in the Gezira/Managil scheme a rehabilitation group consisting of three tracked excavators is able to rehabilitate the canals in an area of about 21,000 ha in one year.

As soon as a canal is rehabilitated it is incorporated in the maintenance programme. The heavy equipment used during the rehabilitation is moved to a new area and lighter equipment especially meant for maintenance purposes is left in the rehabilitated area. Maintenance equipment consists of tractors with mowing buckets (adapted types) and wheeled excavators with mowing- and dredging buckets.

Experience learned that two tractors with 3m wide mowing buckets and two wheeled excavators with 4m wide mowing buckets and dredging buckets could cover the program.

Once a year the canals are desilted by the excavators equipped with a dredging bucket, while depending on the growth rate of the weeds three to five times per year weeds are removed by excavators and tractors using mowing buckets. During the second year when the rehabilitation group is progressing in the second area to be rehabilitated, the maintenance group is extended. This expansion process of the maintenance group is continued till after three years the area to be maintained is extended till about 63,000 ha. Due to logistical reasons this extent is the limit to economically execute the works.

Auxiliary equipment concerns all types of equipment necessary to make it possible for the other equipment to work in the area. It consists of a bulldozer and grader for levelling of the embankments, fuel- and grease truck, mobile workshop, low bed loader for transport of tracked material. Under the
circumstances in the Gezira the bulldozer is full time assigned to the excavators, while the other auxiliary equipment is assisting other groups of equipment as well. The maintenance group is assisted by a grader, a fuel- and grease truck and a mobile workshop.

Overhead equipment is the equipment required for general use in the project, not directly assigned to certain types of equipment or a certain job. For instance four wheel drive vehicles for transport of supervisory personnel, communication facilities, means of transport for bringing operators to and from their machines, and a central workshop.

After an area of 63,000 ha is rehabilitated and taken over for maintenance the rehabilitation equipment is moved to start up a new area, which will ultimately be serviced by a similar set of maintenance, auxiliary and overhead equipment. The reasons for this gradual growth of the area are to spread the investment in equipment over a number of years, while required staff and operators can be gradually trained. Besides this adjustments in the organization and numbers and types of equipment, if necessary, can be made during the growing process.

6.6. The emergency assistance units

The above described growth model has been implemented in the Abu Usher project, till an area of 63,000 ha was under maintenance. Further extension of the area could up till now not be materialized, because of political and financial constraints in the Sudan.

During the period the project was implemented, tenants in areas neighbouring the project area started sending requests to the Ministry of Irrigation asking to incorporate their area in the project extensions. Depending on the workload of the equipment in the project area, the distance to the area where emergent assistance was required, and the rate of siltation of the canals, equipment was made available to desilt the worst affected canals, in order to make it at least possible that irrigation water could reach the fields.

As over the time the number of these requests were growing, it was decided to initiate a special independent silt clearance unit, the emergency assistance unit (EMA). This unit is operated as an independent unit under the control of the management of the Abu Usher project area and works in areas neighbouring this project area. The unit consists of two tracked excavators with dredging buckets, a bulldozer, a workshop container, store container and office container all on wheeled chassis. Assigned to the unit are a civil engineer, a workshop foreman, a store keeper and operating and maintenance personnel. Supplies to the unit as
well as major maintenance and repairs are taken care of by the central workshop in Abu Usher.

Because of the immediate success in making water available to the irrigated fields, EMA became quite popular with the tenants. This popularity resulted not only in numerous requests for removal of serious backlog in desiltation, but also in requests from areas were due to abundant weed growth canals were chocked by weeds. For this type of assistance a second unit (EMA II) was initiated. This unit is similar to the first unit, but instead of tracked excavators with dredging buckets it has wheeled excavators with mowing buckets and is providing assistance in those cases were only weeds has to be removed.

7. SUMMARY AND CONCLUSIONS

In this paper, a brief impression is given of the development of the integrated mechanical silt clearance and weed control system, popularly known as the "Dutch system", as presently operational in the Gezira/Managil irrigation scheme. It is described which equipment was tested for rehabilitation and for regular maintenance, together with the corresponding auxiliary and overhead equipment. The results of these testings were discussed, coming to the final selection of standard maintenance units.

After the testing program, a training program was set up, where the selected equipment was used for the implementation of a pilot maintenance program.

It is the conviction of DEMAS and of several international institutions that the system on an amended scale can be made operational in other regions as well. However it has to be stressed that it is not possible to simply copy the system for use in other schemes. Different conditions may lead to selection of other equipment, and also the planning and monitoring system, as well as the organization and logistics may need to be different.

The experience with the program demonstrated the necessity for a pilot project, to enable the development of an equipment package, adapted to the local conditions. Prior to the implementation of integrated mechanical silt clearance and weed control on a larger scale, a study and field surveys have to be made to arrive at the basic data required for determining the optimal basic unit group and the optimal extent of the area served by such a group.

As far as the use of the emergency assistance units (EMA) is concerned, one
should be aware that the use of these units is not a final solution for removal of the blockage of canals by siltation and weed growth. It is merely an attempt to help the tenants in receiving water to their fields during the period that no proper canal maintenance system is operational in the area.
PART C

MAINTENANCE IN INDIA
NEED FOR ENGINEER'S ACTIVE INVOLVEMENT AND COMMITMENT FOR PROPER MAINTENANCE OF IRRIGATION SYSTEMS

R.S. Varshney

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NEED FOR ENGINEERS' ACTIVE INVOLVEMENT AND COMMITMENT FOR PROPER MAINTENANCE OF IRRIGATION SYSTEMS

1. INTRODUCTION

Adequate and timely maintenance is imperative for proper irrigation management. Water management cannot be effective unless the infrastructure for water conveyance and delivery is in reasonably good condition. To increase the agricultural productivity from existing irrigation systems, evaluation of maintenance deficiencies and their rectification is a key requirement, along with improved operational practices to provide more reliable, practicable and equitable water deliveries to the outlets.

The correct maintenance process has three phases, namely: (i) identify problems (diagnostic analysis); (ii) develop solutions and (iii) implement solutions for further improvement of the irrigation system. Unfortunately, this methodical maintenance process is rarely practised. The funds are received late in the year, they are spent haphazardly mostly on silt clearance, and the year is over. Most of the engineers hardly think about the system and the effect their maintenance work has on the system as a whole.

There are three essential requirements for proper maintenance: (i) adequate funds, ii) adequate manpower, and (iii) adequate equipment. In most of the cases there is no shortage of staff (manpower) and equipment, whereas in the majority of cases funds made available are not adequate. The misfortune is that even the maintenance works are not judiciously planned and prioritized so as to utilize the available funds in an optimum way. To add insult to the injury, the equipment is not properly maintained, with the result that it does not work when it is needed most. On most systems, the number of maintenance staff is adequate, but a large percentage of them just do not work at all. The number of strikes resorted to by staff and their demands and casual attitude to work are on the increase.

Besides the above, there is a growing tendency among maintenance engineers to be casual in their outlook. They do not "involve" themselves with the system. The feeling of owning the system is declining. We had officers who would, sitting at headquarters and studying the gauge data, tell which canal in the system was not properly maintained or operated without schedule. They could
do this because they had involved themselves with the system.

This sense of involvement is now virtually absent because previously, engineers were selected to man special and strategic control points of the system for maintenance (and operation). Now, engineers, by use of political influence and foul practices, select the system for their postings. Times have certainly changed. But this has adversely affected the proper upkeep and health of irrigation systems.

2. MAINTENANCE OF HEADWORKS

For maintenance of headworks, there is no shortage of funds. The Head of Irrigation Department takes extra care to see that enough funds are made available. Still we find headworks and staff colonies in deteriorating conditions. The river training works are not properly cared for, sediment exclusion devices are not attended, gates do not work during monsoons, etc. Let us examine the vital spots.

2.1. Lack of Operation and Maintenance Rules and Procedures

Lack of funds should not stop engineers to prepare rules for operation and maintenance of the system. In older days, before Independence I must admit, it was a general practice to have maintenance and operation rules on all headworks and canal systems. This practice is gradually being eroded.

Inspection reports of maintenance by senior officers were always made, followed and again verified. But the practice has become intermittent now. Some officers do follow and some do not. The result of all this is that there are no guidelines in certain cases and the engineers in charge of the headworks are sometimes found lacking in use of even commonsense.

The example of old Sharda barrage can be cited where maintenance was needed in the downstream floor. All efforts should have been directed in that direction, which was not done, however. When heavy floods came, the engineer instead of opening all gates to let the flood pass down, closed some gates. The result was development of excessive seepage pressures and the floor in some bays was blown up.

Then there is the story of the Upper Ganga Canal, where heavy muddy water was allowed to pass into the canal. The engineer in charge waited for orders from senior officers for closing the canal, and thus caused serious problems of
silting of the whole section of the main canal up to Pathri (15-20 km from the head of the canal).

2.2. The problem of silt clearance in head reaches

Heavy sediment loads enter our canal systems. The problem is nearly the same every year, but the input for maintenance is decreasing every year. The available manpower is the same as before, but actual manpower put to work is reducing. The maintenance of equipment is not done for want of funds and hence input of equipment is reducing. Funds are not available in proportion to the increase in costs and inflation.
The result is that engineers find themselves in difficulty to prioritize the silt clearance jobs. They generally pay more attention to canal section and embankments, whereas the first priority should be to keep sediment excluders and ejectors in best shape and especially to keep escape channels of sediment ejectors fully cleaned.

In general, escapes should receive top priority in maintenance. Unfortunately the escape channels are not maintained at all. The result is that marshy weeds and bushes grow.
The unscrupulous farmers encroach on the water-way and also occupy large tracts of canal land, with the connivance of junior staff and sometimes due to their negligence and carelessness.

2.3. River training and flood protection works

This is an item which takes maximum attention of the headworks engineer and also a substantial share of the maintenance grant.
River training works, revetments, spurs, launching spurs do not accept any compromise in their design or maintenance. If a launching apron is required, it has to be provided.
In Gandak, a Superintending Engineer, who considered himself a flood expert, removed all pitching and launching apron stones in 1974. He thought that they were useless and trumpeted everywhere that he had made a lot of savings. The result was catastrophic: in 1975, the succeeding Superintending Engineer had to fight day and night, for months together, to save the famous Chitauni embankment.

Since funds are limited, every care should be taken by the engineer to study the river behaviour and strengthen only those spurs and reaches which are vulnerable.
In olden days, the headworks engineer used to write flood reports, giving details about the floods, their effect on the river regime, the behaviour of flood protection works and measures adopted by him to fight floods. As such, these works were taken as live flood-hydraulics laboratories. He also gave his opinion on future works. This practice is now disappearing.

A better and surer way to control floods and to minimize damage are the non-structural measures which should be adopted invariably. Unfortunately, this is not done. If there is a proper flood warning system, proper operation of reservoirs and/or flood proofing measures can mitigate flood damages. In 1987, there was a cloud burst in the district of Varanasi, upstream of Chandra Prabha dam. The engineer had no flood warning system and hence he could not anticipate the arrival of the flood. The reservoir being full as per orders, the flood waves swept past it and the whole Chandauli tehsil (town) was a spectacle of sea.

I would stress that some part of the funds allotted for flood control should be judiciously used by engineers in improving the flood warning system and in removing encroachments on flood works and flood plains. The river should be guided smoothly and not be tampered with.

3. MAINTENANCE OF HEAD REGULATORS

3.1. Gates

The head regulators of main canal, branches and distributaries are the lifeline of the whole conveyance system. Their control systems, especially the gates and hoists, should always be in trim condition: repaired, painted and greased. The gates should be periodically checked, and specially before the onset of the monsoon, for proper movement, closure and opening. In many cases this is not done, however, and gates are not maintained to the required standard.

Consequently, when they are required to be opened during flood season, they remain jammed and thus flood levels rise and cause damage to upstream areas and to structures.

Actually, a certificate should be taken from the Executive/Assistant Engineer in charge that he has personally checked and got painted, greased and repaired all gates under his guidance. This is also to create a awareness of the possible damages due to such negligence.
3.2. Side pitching

Heavy embayments take place along both sides of embankments downstream of all regulators and escapes. The maintenance staff go on pitching the bank, on both sides, after which this pitching again falls. The reason for this is not far to seek, but I doubt how many give some thoughts to the problem.

This phenomenon is associated with the hydraulic jump formation, occurring on all regulators on canal systems in India. The Froude number of incoming flow is always less than 4.5 and the pulsating flow continues for long distances, up to several kilometres. This makes earthen banks to fall, creating embayments. This could be controlled by:
- Designing proper energy dissipators below the drop: St. Anthony falls or R.S. Varshney designs;
- Providing wave suppressors (if the basin is not too wide) to dampen the wave flow (R.S. Varshney design). A good maintenance engineer can use wooden planks suspended by ropes for this purpose.

Thus instead of pitching, which again is a costly affair and would not stop the process unless proper toe wall and launching apron are provided, "balli" piles (several small wooden piles driven together) may be driven in rows all along the length of the pulsating hydraulic jump, and bushes and grass filled in between them. This would entrap silt and become a cheap and good control on embayment.

3.3. Gauge-discharge rating curve

A good check on the proper functioning of the head regulator is to check the gauge-discharge relation. Passing of less or more discharge at a certain gauge is indicative of some lapse or problem. Many of us fail to study the gauge-discharge curves. Firstly, the curve should be calibrated periodically (checked on models) to see if it still agrees with the designed one. If more discharge is passing, this is an indication of retrogression downstream, and all efforts should be made to stop that. This cannot be done by routine silt clearance or filling of potholes, or repair of damaged floors. If less discharge is passing, it is indicative of loss of slope in the channel downstream, either due to planking of flow or heavy silting. A good maintenance engineer, involved deeply and technically with the system, can take quick and timely action to control these tendencies.
4. MAINTENANCE OF MAIN CANALS AND BRANCHES

4.1. Feeders and head reaches

One problem that a maintenance engineer usually faces is that of heavy silting. Normally, an engineer will clear the silting, which will again come next year. The money continues being spent year after year. But a thoughtful maintenance engineer would think of the problem and take a proper decision. If the feeder canal has been designed for a high discharge (in anticipation of a discharge-augmenting scheme which may take another 5-10 years to come about) and is actually required to pass less discharge for the time being (example: Link/Feeder Channel of New Okhla Barrage), it would be prudent to allow the section to narrow itself and take a new regime. When in future a greater discharge has to pass, the section can be widened. This would save annual money being spent on silt clearance by unnecessary widening the section every year.

In case of phased development of any scheme, or even for schemes where phased development was not considered but had to be thought of at a later stage (example: Saryu Canal Project in U.P.), a narrower channel in the beginning, to be widened later is a better solution. This would save a lot of maintenance money. The land should of course be acquired for final dimensions.

Another way to tackle this problem is to make twin channels in head reaches. This has been done in Sharda Sahayak System in U.P. Here, the maintenance engineer should operate the canal carefully and pass discharge in one or two channels such that there is no erosion of the central embankment. A careless operation would reduce the thickness of the central embankment which would require heavy maintenance.

4.2. Silt clearance

A good maintenance engineer should carefully check the channel regime before deciding the channel dimensions to be made after silt clearance. The channel section is usually designed with $\frac{1}{2}:1$ side slopes as per Garrets’ diagrams. A casual maintenance engineer would try to make up this slope year after year though the banks may be of sandy soil or other less cohesive soil. A good maintenance engineer, if he would find that the section is more stable with a $1:1$ slope, would save money by not filling the soil in the banks. If conversely he would see that $\frac{1}{2}:1$ slope can be maintained, he would not make slopes $1:1$ even if they were so designed. Proper maintenance of side slopes and berms during silt clearance is very important.
4.3. Lining of canals

These days all big and important canals are lined. I will not discuss the merits and demerits of lining without considering the features of the area concerned. I would dwell on the subject of maintenance of lining. Maintenance of lining is rather more important than even its construction.

A casual maintenance by filling with boulders or wooden piles is bad (as can be seen in the Bihar portion of the West Gandak Canal). This increases the rugosity and thereby the water depth in the canal. The freeboard becomes less, endangering the canal embankments and sometimes making energy dissipators below falls inadequate, thus causing retrogression and damage to floors.

The damaged lining to be repaired should be properly opened, the subgrade prepared and lining relaid in one or two layers as per design. This was done in the U.P. portion of the Gandak Canal, where the repaired lining did not fall, while the original lining fell down at other places.

4.4. Maintenance of canal embankments

This is very important. Care should be taken to keep the embankment section according to its original design. A good maintenance engineer would pay special attention to see that toe filter, toe drains, etc. are all maintained in good shape, as they control the phreatic line, thus avoiding sliding of the outside slope and endangering the life of the bank.

Rodents are a great menace for the safety of the embankments. They make holes in the embankments and consequently develop a weakness conduit in the body of the embankment. Many of the canal breaches are due to this cause and when a canal breach takes place, it causes havoc and consumes a large part of the maintenance money.

Proper monitoring and regular inspection of canal embankment can help in detection and timely repair of these danger spots practically at nominal cost. However, this is possible only if engineers take more interest in their duties and carry out regular and methodical checking and inspections.

4.5. Cross regulators

Cross regulators should be good in number in any branch system. In the absence of them, the farmers have a tendency to make unauthorized obstructions, especially on smaller canals. These cause damage to canal banks.
The gates of canal regulators should always be in a fit condition and the staff suitably trained to take care of fluctuations in supply. Usually there is water on both sides of regulators and hence chances of scour around piers and downstream floor are less. However, in the case of tail regulator, the gates are mostly closed, causing differential pressure heads. The downstream floor in such cases need regular checking.

4.6. Cross bridges

They do not pose problems in normal cases except that parapets and railings are usually damaged; repairs at the initial stages would stop further damage. However, if the bridges are on the channel downstream of escape-head, they require constant vigilance and plotting of soundings around piers and abutments. If the outfall is near the bridge or if the channel has a steep slope, then the chances of deep scouring around the piers increase. Heavy scouring may result in settlement or even cracking of piers. Stone or C.C. block launching aprons around piers is a remedy.

On an escape in the Western Gandak Canal, near Tamkuhi in Deoria District, the engineers never bothered to take soundings around the bridge piers since the construction of the bridge. There was an outfall on the escape channel just downstream of the bridge. Deep scour developed around the piers, so much that the maintenance engineers saw some people nearly drowning near the piers in early 1976. This should have been enough warning signal to the maintenance engineers to fill up the scour around the piers. They did not take any action, however. The result was that the pier gave away in mid 1976. This caused damage to the bridge, which had to be repaired costing a good sum of money.

5. MAINTENANCE OF DISTRIBUTARIES

Distributaries are the main link between the water conveyance and water distribution systems and hence they should always be in good shape. A good maintenance engineer would take care that by proper maintenance and operation the distributary head takes its proportional share of discharge and sediment load.

5.1. Distributary head- control of silt entry in offtaking channel

A good percentage of maintenance money is spent on silt clearance. A careful maintenance engineer would do more than merely clear the silt. He would examine the cause(s) of excessive silt entry and take remedial measures to
reduce it. After all, the existing silt exclusion devices like King's Vanes, Gibb's Groyne Walls, skimming platform, vortex tubes, etc., were designed by maintenance engineers only. They had no laboratories with them. Their running canals were their open laboratories. But they observed the flow and devised ways, modified them and perfected them to suit the local and also general site conditions. They were pioneer maintenance engineers with their eyes wide open and ready to involve themselves with the system. What they could do in a short period, we have not been able to do in so many years.

5.2. **Desilting process - bringing the section to desired one**

The situation here is the same as has been discussed earlier for canals. The desilting process can be optimized with much savings if the maintenance engineer takes care to adhere to the regime section adopted by the canal itself, depending upon variation of discharge, silt content, etc.

6. **MAINTENANCE OF MINORS AND SUB-MINORS**

This is one sphere where maximum attention of the maintenance engineer is needed. The only item he usually attends to is the removal of silt or repair to cross-bridges. There are other aspects of maintenance, which have cropped up recently because of change of construction practices. The latter are not discussed in this paper.

6.1. **Lining of minors**

Maximum water loss takes place in sub-minors and field channels. Hence there is a great stress on lining of these channels. Recently emphasis is being laid on the use of plastic membrane lining. The membrane type of lining if used beneath soil cover serves no good purpose. Weeds puncture the membrane lining, and also the hoofs of cattle passing across dry minors damage the lining. Therefore, the purpose for which it was used, is lost. It is better to use soil cement lining or single tile lining, inlayed with high-density polyethylene (HDPE) film, can also be used with advantage.

6.2. **Outlets**

The outlet is the a vital structure in the water distribution system. At the same time it can be another headache of the maintenance engineer, which could be reduced by proper thinking and monitoring of his part.
In U.P. and in other states of North India, open pipe outlets are being used. These are easily tampered by farmers. They put additional outlets or change for another one of bigger diameter.

A good vigilant engineer with interest in the system would do effective monitoring to check this "over-outletting". The best way to control such malpractices is to seek farmers cooperation by handing over the maintenance of outlet and field channels to farmers' committees. Besides, efforts should be made to replace these outlets by modular or semi-modal outlets.

7. CONCLUSIONS

a. Constant vigilance of the irrigation system is a sure way to check possible heavy damages. The structures before giving way, always give warning signals well in advance. The failure is not at all of a sudden. Timely repairs can always control and avert possible disasters.

b. Since funds for maintenance are limited, the engineer in charge should judiciously chalk out the maintenance strategy and prioritize maintenance works.

c. There is need to resist political and other pressures for select maintenance postings. Suitable and capable officers need to be posted on all strategic locations in the system.

d. Most of the maintenance problems arise due to neglect and "don't worry" attitude of the engineer-in-charge. A devoted officer would check the problems, diagnose them and take timely steps to avoid unfortunate recurrences. This requires involvement of the system managers with the system. They must be "total irrigation engineers" in spirit and deeds.
CHANGING MAINTENANCE REQUIREMENTS AS A RESULT OF IRRIGATION DEVELOPMENTS

K.M. Maheshwari

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CHANGING MAINTENANCE REQUIREMENTS AS A RESULT OF IRRIGATION DEVELOPMENTS

1. INTRODUCTION

The main characteristics of a canal system are related to its initially planned benefits and to the design. Over the course of the years, irrigation objectives as well as planning and design practices changed and consequently the characteristics of the systems. Along with these developments, the maintenance needs and practices will have to change as well. This paper discusses some examples of changing irrigation developments and the implications for maintenance, based particularly on canal systems in Uttar Pradesh. In this state, several canal systems are more than 100 years old, such as: Upper Ganga Canal (1854), Lower Ganga Canal (1878) and Agra Canal (1873) systems.

First the initial system characteristics are outlined, as related to irrigation practices. Then the major features of the developments in the irrigation sector are summarized and subsequently the various implications for maintenance are pictured, with respect to scour and siltation, canal breaches, and headworks, and finally to farmers interferences and communications.

2. SOME SYSTEM CHARACTERISTICS

For a long time, say up to about 1950, the irrigation systems could be characterized as follows.

a. Irrigation from the canal system was limited to "rabi" only (winter season, October to March), with a small area under summer crops (April to June). Canals did not run during "kharif" (monsoon season, June to October).

b. Canals had been designed for low irrigation intensities: about 35 to 40% of the cultivable command area (CCA). This implied low water allowances in terms of l/s per ha of CCA (cultivable command area).

c. The main canals and branches were in cut for most of their lengths, while distributaries and minors were in fill of varying order. During construction, special attention was paid to earth compaction, specifications for which were adhered to religiously.
Reasonable time was available for construction of the canal systems, including structures, which resulted in having few problems in maintenance due to poor or defective construction.

d. During kharif, the canals acted as drains, because storm water from natural drains was brought in by drain inlets.

e. Headworks had been designed on Bligh’s theory and the lay-out was done without model experiments, as such facilities did not exist in those days. Hence, damage to embankments (bunds) and to the main structure frequently occurred.

3. IRRIGATION DEVELOPMENTS

In former days, irrigated agriculture was not very remunerative and irrigation systems could function for a long time on the basis of the initial design, as outlined above. Gradually however, the irrigation scenario changed drastically, particularly after about 1952 when a massive programme for irrigation (and power) development was launched. Important elements of these developments were:

a. Areas demanding for water largely surpassed the initially planned 35 to 40% of the CCA.

b. Water being plentiful in the rivers during kharif season, efforts were made to develop paddy cultivation by running the canals during kharif as well. Diversion canals were now running all the year round for boosting agricultural production.

c. Still later on, after about 1965, when high yielding varieties were developed and introduced, the irrigated agriculture became remunerative and the demand for water has been exacting on canal systems. As a result of the increasing demands (more area to be irrigated with higher supplies per unit area) maximum river flows were utilized and canals were run with heavy overloads. But the basic criteria of designing the canal system remained the same as for rabi channels, while during kharif, channels were carrying more silt than originally anticipated for the rabi season.

d. Gradually also, all drainage inlets into the canals were replaced by syphon drainage crossings, and drains realigned where necessary.
e. Finally, the headworks were gradually replaced by barrages, designed on Khosla's theory and after conducting extensive model studies.

All above changes had their impact on the type and intensity of maintenance required. The most obvious aspects are outlined below.

4. Siltation Consequences

Formerly, the canals were generally run at design discharge and overload running was limited to about 10%. This did not scour the canal shape nor damage the structures. Being run-of-the-river canals they had low discharges in January and February.

The small amount of silt brought in from the river was passed down through the canal system and the canals did not suffer much from siltation when run at design discharge. Yet, some siltation occurred due to the following factors.
- Drainage inlets used to bring some silt and debris into the main and branch canals which were largely passed down through escapes on these canals.
- Some silt was brought in when canals were run in late October or November for pre-irrigation for the rabi season.

The latter also transported the bed-load remaining from the drain water. Due to the old channel design, the canals had the tendency to widen and banks of deep canals gradually fell during draw-down conditions.

Yet, siltation was usually more in the distributaries. During winter months, main canal and branches could only get 50 to 70% of the design discharge, but through the on-off operation, the distribution system was run with at least 80% of design discharge. This induced silting in the distribution system. In some of the distributaries, this occurred every year which required more than normal funds for proper upkeep.

However, getting sufficient funds was not a major problem in the Pre-plan period. And due to the fact also that the canal system was regularly inspected by irrigation department personnel and facilities for effective touring were provided to them, the available funds were used effectively.

Since the new irrigation developments in the 50's and 60's, involving the operation of the canals during monsoons, a lot of silt, both coarse and fine, finds it way into the upper portions of the Upper Ganga main canal and more suspended silt passes down the distributary system. Siltation in the head reach of the main canal could be reduced after construction of a silt ejector, but the
first 10-15 km still gets coarse and fine silt.

Formerly, cleaning of silt and debris could be done from October to mid-November, before the start of the rabi irrigation. Some maintenance work was also possible in the distributaries after mid-November, during their closure periods. After the development of kharif (monsoon) irrigation, with additional frequent long dry spells in September, canals can no longer be closed for maintenance since this would damage paddy and sugarcane crops. Nowadays, maintenance is only possible once in 3 to 4 years. The amount of siltation having increased, the canal capacity regularly gets reduced till the next cleaning. In this situation, mechanical desiltation techniques in running canals should be considered.

5. CANAL BREACHES AND SCOUR

In former days, canal breaches were nominal, due to excellent construction and occurred only occasionally due to rat holes or other burrowing animals in the embankment portions. After growing demands for water and increasing discharges, heavy overloads frequently occurred. The result was that channel banks regularly collapsed and breaches occurred to the extent that flow had to be stopped for repairs.

Also due to the overloads, heavy scour regularly developed around structures. This required extra maintenance, not only surpassing available budgets, but also posing problems due to the difficulty in putting the canal dry, as discussed above.

Another problem is that earth for closing the breaches in canal banks is often not easily available as almost all the fields nearby are being cultivated. Moreover, the banks being wet during monsoon, transport from a distance by trucks or tractor trolleys to the required location is often a problem.

6. HEADWORKS

With the old inlet structure, maintenance had to be done regularly, and was done after each monsoon. Since the construction of the new barrage and a silt ejector, maintenance requirements have reduced. Yet, the river behaviour is not certain and maintenance requirements may vary depending on flood peaks and operation of gates.
The maintenance is now limited to damage to guide- and afflux bunds by river attack in years of high floods and also some damage to the floors by rolling boulders on the barrage of the Upper Ganga Canal, located in the foothills.

7. FARMERS INTERFERENCE

Demands for water having increased, but the available supplies from the river remaining basically the same, distribution problems developed, showing the familiar head-tail differences.
Farmers having problems to get sufficient water resorted to unauthorized cutting of banks of the distribution system, particularly during dry season and even when there is a long break in supplies during the monsoon period. This has very much upset the water distribution and also requires more efforts in closing breaches urgently.

8. COMMUNICATIONS

In former times, when fluctuations in demand of water were not very high and breaches were limited, the canal telegraph/telephone served the communication needs satisfactory. The channels which were to be closed were identified immediately and quick action was taken.
When the number of breaches increased and it got more difficult to reduce or even cease the flow, communications became more important. Therefore, the communication network is gradually being replaced by wireless arrangements at key regulation points.
Added to this are messenger services on motor cycles. As a result, extra maintenance needs can be reduced again by timely regulating discharges and timely opening and closing canal escapes.

9. CONCLUSIONS

It is seen that changing irrigation developments lead to increase in maintenance requirements, due to higher water demands and running the system almost throughout the year. Both siltation and scour increased, breaches occur more frequently and farmers damage outlets and embankments of minors.

Insufficient time is now left for proper cleaning and repairs, which asks for mechanized desilting equipments, suitable to operate in running canals.
The senior project personnel have to observe the revised needs and characteristics of the systems and tune the maintenance work accordingly. This leads to the need for better communications, by which timely actions can be taken to reduce extra maintenance needs.

For new projects, planning and design should take into account such experiences from existing similar systems. For instance, the design should also incorporate scope for higher fluctuations in demands and for higher silt contents in monsoon season.
CHALLENGES FOR
DYNAMIC MAINTENANCE

S.K. Bhargava & S.K. Kumar

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CHALLENGES FOR DYNAMIC MAINTENANCE

1. INTRODUCTION

Maintenance has been defined in dictionaries as "to keep in existence or continuance, to preserve or retain" and further as "to keep in due condition, operation or force, to keep unimpaired". According to these terms, a maintenance programme for irrigation systems would therefore be the one which maintains their original operational and deliverance characteristics. This would be quite a static notion of maintenance, however, in which year after year we take up the same restorative activities at the same place and at the same points of time. A better strategy would be to plan for a "dynamic maintenance", in which maintenance activities keep pace with the changing developments in agriculture and in irrigation, thus based on the farmers requirements, instead of imposing those upon them.

Important issues in such dynamic maintenance programme are: organizing a good monitoring system for preventive maintenance, with adequate timings of maintenance, taking into account technological developments and social phenomena and caring for proper communications and other required inputs. These issues are briefly discussed in the present paper.

In some instances, reference is made to the Lower Ganga Canal System (LGC) in Uttar Pradesh. As explained in the paper by Maheshwari, this system was designed for extensive irrigation, supplying water in one season only and based on low intensities. Since agriculture became more remunerative particularly with the introduction of high yielding varieties, the system is expected to run for higher intensities and with higher allowances. Also, increasing kharif demands have resulted in almost continuous running of the canals with heavier injection of silt during monsoon and little or no closures for curative maintenance. This is the situation on most of the systems built before planned era (see also the previous paper by Maheshwari). In such situations there is scope to replace the old maintenance practices by a new approach.

2. MAINTENANCE ACTIVITIES

The following maintenance activities are broadly identified as essential on earthen unlined canal systems like the Lower Ganga Canal system.
a. Removal of siltation in the canal;
b. Checking and repairing bank erosion and breaches;
c. Removal of aquatic and vegetative growth;
d. Restoration of bank levels;
e. Repairs to local lining;
f. Repairs to structures in main and branch canals;
g. Restoration of outlets and other structures in distributaries and minors;
h. Repairs to escape structures;
j. Maintenance of buildings.

3. PREVENTIVE MAINTENANCE AND MONITORING

Preventive (small) maintenance would be a crucial characteristic of a dynamic programme. It is essential to timely identify and remedy critical weak points so as to prevent bigger repair activities later on, due to neglect of small problems. Examples in this respect are mentioned by Varhsney and Maheshwari, as for instance slips of banks or linings and scour around structures. Other examples can be found near village settlements or in usar land areas. Missing or damaged outlets should be regularly checked and replaced or repaired immediately in order to prevent subsequent bank damage at these places. Timely checking and repairs to masonry works may prevent a bigger catastrophe later on. This applies particularly to falls on escapes where any scour downstream of these structures and seepage at the toe of high banks should be timely detected. Regular checking of culverts on water courses would prevent water loss. Regular measurements of discharges of all channels in both seasons, beside being needed for operation, could also serve the purpose of identifying maintenance needs.

The above implies an attentive monitoring of the system. Most of it can easily be done during the routine work of various officers. For instance during routine inspection or during collecting data on irrigated areas or similar activities. Yet, it would be desirable that senior officers introduce check lists for young officers, adapted to local conditions, so that it is clear to them what they are supposed to inspect and check during their touring.

The system manager and his officers should have enough experience and skills to make such lists and guide their staff in anticipating trouble spots and take timely preventive remedial measures. It is absolutely essential to give due weight to experience and capabilities of maintenance personnel when assigning
4. TIMINGS OF REGULAR MAINTENANCE

Besides the incidental preventive measures, the regular maintenance programme will remain necessary. But here, it may be worthwhile to reconsider the timings of the various activities.

Many large systems, like the LGC system, are run-of-the-river systems, its operation plan largely depending on water availability in the river at a given point of time. Any maintenance work pertaining to internal section of channels should therefore preferably be carried out while the channel is normally closed either due to slack demand or as per roster.

At present all the above mentioned activities are started in November at the beginning of the rabi season. Instead, the following is suggested, with regard to the activities mentioned in Section 2.

- Activities d) to g): restoration of bank levels, repairs to lining and structures (including outlets) should be a continuous process round the year, to avoid aggravation of the problems;
- Activity c): the removal of aquatic vegetation, should be done twice a year i.e. once in June/July and again in November/December during periods of normal closure. This will reduce the problems with late kharif irrigation (particularly for paddy) when reduced channel capacities fail to deliver supplies up to the tail ends. It would also facilitate "paleo" (pre-irrigation) for rabi crops.
- Activities a) and h): the removal of siltation and repairing bank erosion and the restoration of escape structures, may however be confined to only once a year in the months of November/December and May/June respectively.

5. COMMUNICATIONS

Timely identification of problems and required actions involves the need for an effective communication network. The wireless system which was installed on the LGC about six years ago is already showing severe distress and needs replacements and reallocation of instruments to make the system viable.

Apart from that, regular touring and staying in the interior of the command has always been and will remain to be essential, not only for proper maintenance,
but also to ensure close interaction with the farmers. With increased levels of monitoring for preventive maintenance, frequent travelling between head quarters and camps is now called for, asking for the necessary means. Of late, touring has considerably reduced, for two reasons. One is the inadequacy of transport vehicles for supervisors. Secondly, deteriorating law and order conditions and a lack of security have largely contributed to a decline in touring. Also, the availability and general facilities at the age-old guesthouses offer scope for improvement.

6. MAINTENANCE TECHNOLOGY AND DESIGN

There is scope to introduce the considerable advancements in maintenance technology by way of mechanization. But it should not be considered in technical terms only. Rural employment generation is an important aspect of canal works and in our present socio-economic fabric, only a limited application of mechanization would be acceptable.

Smaller maintenance works which are mainly labour oriented should therefore continue to be done by manual labour. Several employment generation schemes on such works are presently in vogue. However, it may be pointed out that in the enthusiasm to provide employment, the temptation to make the wages "number-based" (to create as many as possible employment) rather than "work-based" (which work has to be done?) must be resisted. Work culture in labour too is essential for proper maintenance.

Mechanized equipment could be resorted to for difficult works such as clearing of drains, including seepage drains along major canals. Also in cases where manual work by labour is not possible, for instance when it is not possible to put the canal dry, or in thickly vegetated drains, mechanization would be appropriate. This would concern works as correcting internal section of branches or bigger distributaries, which are closed only for limited periods. These kind of works could be done by hydraulic cranes with special attachments, or for smaller canals by equipment as described in the paper by Den Herder. The paper by Sperling pictures some equipment which could be used "from the water", more relevant to larger dredging and desilting activities.

Another aspect of technology is that of design. Emphasis should be placed on designing to reduce future maintenance requirements. Lining of canals could be mentioned in this respect. But here, the potential problems discussed by Maheshwari should be well taken into account. Restricting lining to critical reaches, in filling or weak soils could be relevant in this respect.
In the same sense, silt vanes should be provided at the heads of channels with heavy silt intake as it would result in economizing on further silt clearing. Cattle gats may be provided near the villages and village bridges in order to retain channel shape and avoid destructing of banks and side slopes. Metalling of service roads can be useful not only to facilitate maintenance but also to reach damaged locations quickly to avoid further serious problems.

7. SOCIAL PHENOMENA CAUSING MAINTENANCE PROBLEMS

Under pressure of experiencing water shortage, some farmers often resort to activities which cause serious problems for maintenance. Some of such actions are:

- obstructing flow by various means;
- cutting banks or even removing outlets;
- "tunnelling": making outlet bypasses;
- tampering heads of channels or escapes;

Some other illegal activities are:

- crossing through channels;
- encroaching canal banks;
- unauthorized use of service roads.

Almost all of these activities adversely affect the functioning of the system and place heavy pressure on maintenance. While legal safe-guards have been provided under relevant Canal and Drainage Acts by way of prosecution, collective fines and even imprisonment, these provisions have been found to become increasingly inadequate. Firstly, the fines provided in the Acts are now obsolete and meagre and thus fail to act as a disincentive. Secondly, more often than not the offenders enjoy patronage of local musclemen, influential people and politicians and thus escape penalties. These powerful people are generally in a position to intimidate or threaten system operators and managers and sometimes go to the extent of getting the illegal actions condoned by the authorities.

It is therefore essential that apart from legal action, these activities should be recognized as social offenses at par with, for example, adulteration and smuggling and some effective social deterrents should be imposed not only on such offenders but on their patrons also. This might be in the form of boycott from social functions and even the denial from contesting for any elective positions.
8. COLLABORATION WITH FARMERS

Whatever works and/or programmes are being planned and implemented on the canal system, whether improvements, rehabilitation or maintenance, they should be brought clearly to the knowledge of the farmers. Even an unintentional hint of secrecy about those works creates suspicion and spoils the harmonious rapport between system managers and end-users, so essential for a smooth functioning of the irrigation system. This situation is now visible at so many places and is creating unnecessary and avoidable problems.

A start has been made this year to resolve this crisis of confidence by inviting local labour leaders (Sharamik Mukhiya), on recommendation of village Pradhans, to undertake maintenance activities in their areas. The operating schedule of channels as well as maintenance programmes are to be published in advance. Their wide dissemination among farmers should be ensured, by means of their legislative representatives, block extension agencies, "Gram Pradhans", press, radio and TV. This will inculcate in the farmers a sense of involvement in the irrigation system.

The above has been tried on the LGC system for a few years with very good results. Efforts are being made this year for dissemination of maintenance programmes to the farmers through regular monthly meetings at the District and Tehsil level of the "Sinchai Bandu" (Irrigation Forum), in which all concerned peoples’ representatives are invited to participate along with system managers, supervisors and operators to discuss the various problems.

In addition, widely disseminated publications in simple local language regarding which officer/official to be contacted in specific problem cases, will also be of great help. It would improve contacts, save unnecessary correspondence and would be helpful in getting the necessary feedback for preventive maintenance. Such information should invariably mention full address and telephone numbers of officials concerned.

Finally, it is recommended to organize frequent orientation programmes for farmers, together with grass root level workers, regarding the do’s and dont’s for good channel health. This would increase farmers’ awareness and participation in the maintenance of the irrigation system.

9. CONCLUSIONS
Developments in agriculture and irrigation also brought changes in the maintenance requirements. Consequently, instead of a static and fixed restoration program, a more dynamic maintenance approach is needed, flexible and in accordance with the available funds and with the needs of the system and of the farmers.

Emphasis should be put on preventive maintenance, based on timely, judicious and alert monitoring. This would decrease ultimate costs and increase the system's dependability. Communications, secure mobility for managers and staff, and quality and attitude of staff should be geared to this.

Timing of various activities could be modified, for which suggestions have been made.

In some specific instances, such as hazardous and time bound difficult works, mechanized maintenance equipment may be resorted to, taking care of existing programmes of rural labour employment generation for normal works.

Effective legal provisions on all kinds of farmers' interference with the system should be improved, or where already adequate on paper, they should be strictly implemented, which asks for another attitude of many persons involved.

Finally, farmers should be fully and timely intimated on prospective programmes and activities, to ensure their active participation in and belonging to the system. Various kinds of meetings and use of various communication means are being tried to this end and should be pursued for harmonious relations between the system managers and their clients.
PROBLEMS IN MAINTENANCE OF LINED CANALS

K.M. Maheshwari

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1. INCREASED APPLICATION OF LINING
2. ECONOMICS OF LINING
3. POSSIBLE DAMAGES TO LINED CANALS
4. CONCLUSIONS
PROBLEMS IN MAINTENANCE OF LINED CANALS

1. INCREASED APPLICATION OF LINING

At the time of independence (1947), India had already some 9 million ha irrigated area through major and medium schemes. Almost all of these canal systems were unlined. Due to the rapid increase in population and the consequent increase in demand for agricultural production, there was a great demand for expanding the irrigated areas. One of the consequences was that canal systems built after 1951-52 ("Pre-Plan" period) have higher banking to cover maximum area under gravity irrigation. Also, because of the rapid pace of construction, compaction of earthen banks was often of low quality. As a result of all this, seepage of water from the canals has been increasing.

Because at the same time available water became short compared with irrigation demands, extensive programmes of lining of canals were carried out, laying hard lining on the bed and inside slopes of the canals, to reduce seepage losses.

Commonly used materials in lining were (and still are) burnt clay/brick tiles, in-situ cement-concrete, pre-cast cement-concrete tiles ("P.C.C.") and stone slabs. During the last decade, plastic film like black low-density polyethylene ("LDPE") is being used. Rigid lining or earth cover of minimum 60 cm is provided over the LDPE film for saving further seepage losses and mainly as protection for the LDPE film.

In this paper, we shall discuss some aspects of maintenance of lined canals, such as bank stability, bank compaction, damage due to sudden draw-down, bank loads and vegetation. The paper only deals with rigid lining materials.

2. ECONOMICS OF LINING

An earthen canal is generally wide and shallow. Theoretically, a lined canal should be deeper and narrower for economic design, and because it can tolerate higher velocities as well, the section can be less (if the bed slope so permits). In new canals, this advantage can often be realized. In case of lining of existing earthen channels, this is not always the case, however. Sometimes, lining is simply applied on the original section for various reasons, as for instance:
- to avoid additional earthworks for making new banks within the section;
- to avoid problems due to compaction when making these new banks with new earth material;
- because one wants to increase the capacity.

In such cases the main advantage of a lined channel is the reduction in seepage losses, thus increasing the irrigation potential of the project. In addition, adjoining land in embankment reaches is thus protected against water logging due to canal seepage.

Growing population has increased the pressure on land, as illustrated by the fact that 90% of the farm families have less than 2 ha of land. For newly designed canals, lining reduces the channel section for the same discharge, thus reducing the land requirements.

As important economic advantage of lined canals, it is often mentioned that they require less maintenance and therefore also the annual costs are less. Whether this is true depends on the possible damages and their maintenance and repair costs. Some of the possible damages are discussed below.

3. POSSIBLE DAMAGES TO LINED CANALS

3.1. Bank stability

Lining material does not provide any structural stability to the channel slopes. Apart from reducing seepage, it only provides protection to the wetted perimeter of the canal against higher velocities. Also, the canal banks are usually not designed after detailed soil tests of the bank material. Especially when in banking and deep cut they lose their shape in a few years or sometimes earlier, when the banks become moist. Even banks of lined canals get moist in course of time as no rigid lining is absolutely impervious. Hence failure of a bank or damage to it automatically damages its lining. In cutting reaches elaborate sub-surface drainage arrangements have to be provided below the bed of lined canals, but this has not proved to be very effective if a lot of care has not been taken during construction.

3.2. Compaction of banks

Compaction of canal banks as per specifications is vital for their safety. Poor compaction causes subsidence and sliding of banks, and leakage of water from
weak zones, ultimately leading to breaches and consequent damage to the lining. Too often, one sees this happening in improper compacted fill reaches.

3.3. Damage of lining due to sudden draw-down

Irrigation channels sometimes have to be closed suddenly, for instance when a breach occurs, or when the demand for irrigation water suddenly drops, due to heavy rains in the command area. If the channel water level would be lowered gradually according to regulation orders for a planned closure, the high flows (though reduced) might damage the crops in the area.

Irrigation canal linings are not reinforced and hence, they can withstand a hydrostatic pressure of about 30 cm only. Pressure relief valves to relieve hydrostatic pressure in rigid linings have generally been found to provide no protection because these are damaged by village urchins. To reduce maintenance costs of lined canals it is imperative that safe bank slopes are provided, to avoid such problems. It may be recognized that budgets for maintenance are always tight. Damages to banks may consequently remain unrepaired for a long time, thus reducing the capacity of the canal and the benefits of the lining.

3.4. Bank loads

When there are roads along the canal, it is possible that heavy loads, for instance trucks, buses or maintenance equipment can come close to the canal side. The extra pressure they induce can lead to sliding of the slope and damage to the lining. A "dowel", a bund with increased height along the top of the canal slope, can be a good means to keep the load further away from the side. Such dowels are provided in parts of the country, but not everywhere.

3.5. Vegetation growth

When PCC tile or burnt clay/brick tile linings are not properly laid, and the joints not properly filled, the joints can be washed out after several years of running of the canal. The hollow joints are filled up by canal silt and can become a good place for wild vegetation growth. Removal of vegetation is to be done by local labour and is a burden on maintenance as well as causing damage to adjoining lining as such. In saline soils, the mortar in the joints is eaten away by the salinity with the same results of open joints silting up and subsequent vegetation growth. Here,
maintenance costs can be reduced a lot by using suitable pozzolanic cement mortar for the filling of the joints.

3.6. Removal of lining materials

Stone slabs and precast concrete slabs are often damaged by village urchins because these are found useful for various domestic use. The removed portions should be repaired immediately to avoid loosening of the adjacent lining. Because of pilferage, stone slab lining is now not used on a large scale, even in areas where such stones are abundantly found. Instead of PCC tiles, burnt clay/brick tile lining is better, because it is generally not tampered with by villagers.

Apart from the latter remark the above shows that many of the possible damages are related to the design or construction of the lining.

4. CONCLUSIONS

Poor design of linings can be a cause for unnecessary maintenance requirements. Some instances are:
- inadequate side-slopes, leading to bank slips and damage to lining in case of sudden draw-down of canal level;
- improper compaction of side-slopes in fill;
- absence of "dowels" or similar means to reduce earth pressure;
- improper selection of lining material or poor construction of joints between tiles;
- improper lining materials, for instance because they can be used by villagers.

If such elements are well designed or executed, this could greatly reduce maintenance requirements and improve the actual economy of lining.
SOME TIPS

ON DRAIN MAINTENANCE

K.M. Maheshwari & K.P. Jain

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SOME TIPS ON DRAIN MAINTENANCE

1. INTRODUCTION

All lands have some natural drainage, whether by rivers or streams of varying orders. When an irrigation project comes up, this natural drainage system automatically becomes part of the drainage network, supplemented by well planned man-made main-, collector- and field drains. Disposal of surplus flows from each of the outlet commands is done through the construction of field drains which join the system of collector drains in the distributary command. Ultimately, the collector drain falls into the main drains or natural streams of the area.

The functions of the drainage system in an irrigation command are threefold:
- To pass down rain water such that the maximum flood for 3-day rainfall with a 1 in 5 years frequency does not inundate the area for more than 7 days for paddy crops and for not more than 3 days for non-paddy crops. The design of the structures is based on 150% of this design flood or 3-day rainfall with a 50 year return period, whichever is higher.
- To cater for some sub-surface flow and surplus irrigation run-off in the dry season.
- Control of the ground water table in the irrigation command to benefit crop production and at the same time to avoid salinity hazard. Thus, a deep drainage system in a normal soil will be beneficial for both purposes.

Maintaining the drainage system in good order is essential to perform the above functions so as to achieve the planned targets of agricultural production in the area. In this paper some observations are made with respect to this maintenance.

2. SOME PROBLEMS AND SOLUTIONS

Before irrigation is introduced in an area, drains are generally dry after the rainy season and thus, are free of weeds. After introduction of irrigation, all drains have mostly some flow of irrigation surplus water, partly inevitable and partly due to poor water management. So, their beds remain wet all year around and chances for weed growth are more favourable. Weeds like Typha come up in the bed and Ipoemia occasionally develops on the sides.
Farmers put up earthen bunds in the drains to collect water, to rear fish or to raise the water level for irrigation of adjacent lands. This as well generates weed growth and accelerates silting up of the bed of the drain. All this reduces the drain capacity and moreover, the stagnant water favours the breed of mosquitos and induces water-borne diseases.

Inspection of drains therefore has to be done frequently to ensure that drains are not obstructed by farmers, and are free of weeds or siltation. Unfortunately, however, farmers and Irrigation Department personnel do not really appreciate the necessity of proper drain maintenance. All attention is going to the irrigation canals as these provide the much needed irrigation water. Hence, the beneficial role of drainage and the relationship between irrigation and drainage have to be explained over and again to all concerned.

Moreover, good inspection is only possible when a cycle or jeep track is maintained along the drains, which is mostly not the case. As a result of all this, irrigation officials seldom inspect the drains. Consequently, drains are often not functioning properly and this situation largely contributes to the occurrence of water logging and salinization.

For the past two to three decades it is observed that industrial effluent and town sewage without proper treatment is being discharged into agricultural drainage systems. These effluents choke the drainage system, cause local floodings even at low discharges and pass down the often harmful water to natural streams which are being used as a source for drinking water since a long time. This detrimental practice can be countered only by effective legislation and its implementation.

3. TECHNICAL ASPECTS

A hydraulic survey of the drains should be carried out every year from October and completed by December. The longitudinal sections, particularly of the silted reaches should be plotted. The items of works for clearance of the bed and maintaining channel section as per design are determined and all maintenance works should be completed before the next rainy season, for instance by mid June. After construction, during monsoon, the situation should be closely monitored by the junior or assistant engineer. This regards for instance measurement of discharges and the development of vegetation and siltation. On the basis of that, the need for new maintenance or even for a redesign of the drain can be identified.
Every year, silted longitudinal sections of the drains should be plotted and compared with similar sections of previous years. It is likely that a certain bed slope of the drain will be found dominant, as is shown below for a case study. The drain can be redesigned for that slope which will reduce the maintenance needs. Yet, removal of silt at isolated locations may remain necessary, which have to be well identified and planned. And of course, removal of siltation should take place from the downstream end in upstream direction.

Another point is that in large drains it could be considered to excavate a cunette in the centre of the drain bed. This could carry the low non-monsoon flows. Because there is always water flowing in the cunette, weed growth may be less. The remaining part of the drain would remain dry with resulting reduction in weed growth as well. The vegetation still existing in the dry bed besides the cunette could then be easier removed by uprooting it and burn it after drying on the banks.

Finally, the drains should preferably not traverse wide depressions where water spreads out and stagnates. Similarly, all outfalls of the drainage system should always be free so that water does not stagnate in the upstream drains where weeds could be developed. Important causes of water-borne diseases could thus be avoided.

4. DRAIN CROSSINGS

Drains pass down huge amounts of sediment and trash during floods and hence, their crossings with canals, roads or railways should be such as not to obstruct this. Normally, drains should not be siphoned because this would inhibit flood flows. Roads can easily made higher at the location of crossing instead of lowering the drain. Railway crossings are few and have to be planned according to site conditions.

With irrigation canals siphoning is usually possible because they carry less silt and trash.

Wherever drains are siphoned below a canal, road or railway they create problems in maintenance because they gradually get choked by sediment and trash. Crossings are designed for one in fifty year peak floods. With such high floods, parts of the sediment and obstructions may be washed away. Most of the time, however, the monsoon discharge passing down the drain is lower and consequently the backing up of the drain water level upstream of the siphon is more. This enhances siltation and some of the siphon bays may get silted.
Cleaning a siphon every year is costly but not cleaning makes the sediment consolidate and subsequent cleaning more difficult. Therefore, annual clearance of all drain crossings is necessary and should be carried out well before the onset of the rainy season. The junior and assistant engineers should inspect all drain crossings during their cleaning and the executive engineer should check the clearance of some main and branch canal crossings, as well as the road and railway crossings.

5. A CASE STUDY

An interesting experience of drainage functioning in a canal system is narrated. A main irrigation canal was aligned nearly parallel to the river and about 4 kms away. All the drains of the area were falling into the main canal, called "inletting of drains". The main canal remained closed during Kharif (monsoon) period and then acted as an efficient main drain, discharging rain water through the canal escapes constructed at selected sites. It was later proposed that the main canal should supply irrigation water during Kharif as well. Hence, the inletting of drains became impossible (no head) and was gradually replaced by drains being siphoned below the main canal and discharging into the river.

The silted L-sections of all the drains (channels in alluvium) were available for the past several years. It was observed that, against the design bed slope of 1 in 6600, the silt accumulated each year in a slope of 1 in 4400 to 1 in 3300. Earlier, silt clearance in the drains was carried out each year up to design bed slope. This time, after having seen the data, the slope was kept at 1 to 4400. Observations were made on silt deposits and the majority of the drains was found to be free of silt. The remaining drains were provided with bed slopes of 1 to 3300 which proved satisfactory during the next monsoon.

This study indicated the significance of collection of relevant hydraulic data for drains which do not function according to their design. By redesigning the drains, substantial funds on maintenance can be saved.

6. RECOMMENDATIONS

Maintenance of drains should get more attention because not maintaining drains substantially contributes to health problems and occurrence of water logging and salinity. Staff and farmers should be convinced of this need. Also, drains should be kept free of municipal and industrial pollution, for which measures at
national level are needed.

Regular and timely inspection is required to identify problems and maintenance needs. This concerns visual inspection as well as regular hydraulic surveys. When dominant longitudinal slopes due to siltation are detected, the drain should be kept at that slope to reduce maintenance needs. A good accessibility by maintenance paths or inspection roads is important in this respect. A cunette for separation of low non-monsoon flows can reduce maintenance needs and drains should not pass through wide depressions to avoid stagnant water. Drain crossings should preferably not be siphoned and regularly be inspected and cleaned.
FUNDS FOR MAINTENANCE;
SOME BASIC ISSUES
IN THE INDIAN CONTEXT

N.K. Dikshit & K.M. Maheshwari

CONTENTS

1. INTRODUCTION
2. FUNDS ALLOCATION PROCEDURES
3. LEVEL OF FUNDS RELATED TO WATER RATES
4. EFFICIENT USE OF MAINTENANCE BUDGET
5. SUMMARY AND CONCLUSIONS
1. INTRODUCTION

Irrigation in India is a State subject, as per the Constitution. According to the financial norms, a new irrigation project is budgeted under "Plan" or "Capital". Once a project has been constructed, funds for its maintenance are allocated from "Non-Plan" resources.

Before the Plan-era (1951-52), new projects were limited in numbers and they were investigated, planned, designed and constructed with due care. The projects served extremely needy areas and consequently the benefits were obvious and accrued early. Funds for maintenance were provided on the basis of the total canal lengths and were sufficient to cover costs of regular touring and monitoring and for proper upkeep of the system.

After 1951-52, emphasis was on increasing agricultural production at a very fast rate in order to achieve self-sufficiency in food-production in India. Major and medium irrigation projects were constructed in large numbers, but thorough investigations, planning, design and construction was somewhat neglected while trying to realize rapid and high targets. Prices of material and labour also increased from time to time. Resources of the states being limited, efforts were put on providing maximum funds for new projects. In this process, non-plan budget was kept at a low level. Thus, while maintenance requirements became higher than before, no commensurate increase in the budget for maintenance of canal systems was made, resulting in deterioration of the systems.

2. FUNDS ALLOCATION PROCEDURES

The funds for operation and maintenance (O&M) of irrigation systems are provided generally from the Revenue budget of the states, and it does not form part of the national or state planned expenditures. However, at the time of the formulation of the Five Year Plan, Finance Commissions are set up by the Central Government to determine the devolution of Central taxes to the states for the maintenance expenditures in various sectors by the states. Determination of financial "Plan" resources available for the next Five Year Plan investments takes into account the deduction of resources to be transferred.
to the states for other purposes, which includes maintenance expenditures as recommended by the Finance Commission.

It is generally observed that the state governments do not adequately provide the maintenance grants in their budgets with the result that irrigation systems suffer from insufficient funds. This certainly has to do with the above procedure, which has lead to a practice where the states are likely to always show less maintenance expenditure in order to acquire more resources for capital investment and consequently put pressure on the Planning Commission, Government of India, for taking up new irrigation projects. This may not be a healthy trend as the existing irrigation schemes may continue to suffer from insufficient maintenance.

Of late, it has been realized that continued neglect of maintenance will eventually lead to costly rehabilitation of the entire system which would require heavy capital expenditures. The Planning Commission has been thinking of taking an overall view of the resources, including both Plan- and Non-Plan funds, so that available resources are apportioned in a manner that maintenance of existing works will not suffer. The issue was remitted some time back to a Sub-Committee of the National Development Council.

A decision has yet to be taken whether in the formulation of the Plan, maintenance expenditures have also to be taken into account in the overall resources allocation. The authors strongly advocate such shift in policy, thus enabling the development of a proper balance between adequate management and modernization of existing schemes and construction of new projects.

3. LEVEL OF FUNDS RELATED TO WATER RATES

The cost of construction of new irrigation systems currently is in the order of Rs 30,000-40,000 per ha. With an interest rate of 6%, depreciation at 1% and a common maintenance percentage of 2%, the annual costs would easily come down to Rs 2,000-3,000 per ha per year.

Irrigation water rates vary from state to state over the country, but the following are the average rates for different crops:

<table>
<thead>
<tr>
<th>Crop</th>
<th>Rate per ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>paddy</td>
<td>Rs 50</td>
</tr>
<tr>
<td>wheat</td>
<td>Rs 50</td>
</tr>
<tr>
<td>sugarcane</td>
<td>Rs 100</td>
</tr>
<tr>
<td>cotton</td>
<td>Rs 40</td>
</tr>
<tr>
<td>course grain crops</td>
<td>Rs 30</td>
</tr>
</tbody>
</table>
It is apparent that such water rates are extremely low, even to cover only a fraction of the annual costs, whereas they are supposed to meet the capital costs as well. Seeing these figures it can be no surprise that the Seventh Plan indicated that the receipts from multipurpose, major and medium irrigation systems are expected to fall short of working expenses by Rs 9600 million. More detailed information on this issue is presented in the next papers.

The Planning Commission has emphasized from time to time the need to raise the water rates in order to adequately cover the costs of irrigation systems. It is often said that unless water rates are adequately increased, the maintenance situation is not expected to improve.

In this sense, the Seventh Finance Commission recommended a maintenance grant of Rs 100 per ha for major and medium and projects, which has been revised to Rs 180 per ha by the Eighth Finance Commission, keeping in view the cost increases for material and labour. (It is generally observed that due to overall financial constraints, the state governments are not providing even the Finance Commission’s recommended grants).

The following should be realized however. First, a 2% of the investment costs for annual maintenance would come down to some Rs 600-800 per ha, which is substantially more than the latter suggestions. Secondly, one should consider the fact that the large majority (90%) of the farmers in India have land holdings of less than 2 ha. Moreover, the main aim of Indian irrigation is to provide self-sufficiency in food production and to immunize agriculture from the vagaries of the weather.

In this context, and considering the above figures, it is evidently unrealistic to expect farmers to pay water rates completely covering the total annual costs. Even covering maintenance costs alone would mean an extreme increase in water rates.

4. EFFICIENT USE OF MAINTENANCE BUDGET

Given the limited funds available for maintenance, even when some increase could be realized, other means should be used as well to reduce the problem by using the money more efficiently. Some suggestions in this respect are made here. More ideas can be found in most of the other papers.

First, planning, design and construction could be improved. This would not only save money by reducing its later maintenance needs. It could also contribute to a reduction in construction costs and to acceleration of the
finalization of projects, and thus an earlier creation of benefits. Planning should be such as to avoid a finalized project being burdened with superfluous construction staff. At present, this factor eats away a substantial part of the maintenance budget in quite some systems.

Next, a diversification of allocations to individual projects would be worthwhile. Some systems need less than average maintenance, other need more. One example of the latter is for instance that, due to various reasons, lined canals do not always require less maintenance, as one could theoretically expect (for instance sliding due to sudden drawdown, see the paper by Maheshwari). Such situations could be identified and maintenance allocations adequately increased to avoid more extra costs later on. The same applies to canals with more than average lengths in fill. Similarly, systems taking off directly from rivers or streams can take a lot of silt. They can subsequently require more maintenance than others.

Finally it is noted that in many cases the bulk of the maintenance grants provided is utilized for the expenditure of staff, with the result that the funds available for the actual maintenance work prove to be grossly inadequate. Therefore, even within the funds currently available for maintenance, the state governments should try to keep establishments at a minimum, so that more funds are available for actual maintenance works.

Finally, reference is made to other papers as for instance by Varshney and by Maheshwari, pointing at the benefits of proper trained and motivated staff. All these factors could improve maintenance, even within the existing funds.

5. SUMMARY AND CONCLUSIONS

While with the developments in the irrigation sector costs of maintenance have increased, no commensurate increase in the budget for maintenance of canal systems under non-plan budget was made, resulting in deterioration of the systems.

The present procedures of drawing maintenance from non-plan funds leads to the states asking for too low maintenance funds, in order to increase funds for other purposes and new works. It is therefore recommended to include provisions for maintenance expenditures in the overall resources allocation in the formulation of the Plan.
Water rates vary from state to state, but on the average are about Rs 30-100 per ha per year, depending on the crop. This covers very small part of the total annual costs, the latter estimated at some Rs 2,000 to 3,000 per ha. The water rates therefore certainly have be augmented. Considering the above figures, however, it will not be possible to recover capital cost as well.

Consequently there is reason to use the available funds more efficiently, by a proper organization of the work and by spending a lesser part of the funds on establishment and more on works. Also, designs could be improved such as to reduce subsequent maintenance needs.

Finally, a diversification of allocations to different projects would seem appropriate, taking into account the specific project characteristics.
FINANCIAL ALLOCATIONS FOR OPERATION AND MAINTENANCE

S.P. Singh & K.P. Jain

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1. INTRODUCTION
2. ALLOCATIONS FOR OPERATION AND MAINTENANCE
3. EXPENDITURES IN SOME STATES
4. NORMS FOR O&M EXPENDITURES
5. ASPECTS OF RAISING WATER RATES
6. SUMMARY AND DISCUSSION
1. INTRODUCTION

Water resources development received the highest priority after independence. Many impressive storage works were constructed, like the Bhakra Dam, the Hirakud Dam and the Ramganga Dam to name a few, to augment irrigation. But unfortunately it appeared easier to design and construct than to operate and maintain. The early 1980's were marked by increased awareness of the lacking performance of irrigation systems.

At the time of independence Indian irrigation as a whole was able to cover its own maintenance and interest costs but by the early 1980's the irrigation sector was running at a loss of over Rs 4000 million per annum, rising to an estimated Rs 10,000 million at present. This problem received increasing attention.

At the same time, research and analysis exposed more and more deficiencies in the operation and management of canal irrigation systems, especially those constructed in the previous three decades, and provided details of dismal performance. Deficiencies in operation and maintenance of the systems has often been mentioned as an important cause for this state of affairs. And in this respect it is frequently stated that funds for O&M are usually insufficient.

In the present paper some information is provided on the actual money spent on O&M, and the developments in this respect over the recent years. Data from several states are presented and discussed. The paper provides insight in magnitudes of the total allocations and their components and in variations over various states and trends over time. Subsequently some thoughts are given to norms for O&M expenditures and on the farmers capability to contribute in the costs. However, the paper does not aim at assessing the really required funds, because for that further study would be required, including the technical, sociological, economic and other factors involved.

2. IMPORTANCE OF OPERATION AND MAINTENANCE (O&M)

The subject of allocations by state governments for O&M has been the concern of a number of government committees or commissions. The Irrigation
Department (Central Government), in a note sent to the Seventh Finance Commission in November 1977, suggested the neglect of maintenance of irrigation and drainage systems to be the main reason for under-utilization of irrigation potential. The Department reported that a Central Water Utilization Team has found O&M budgets to be grossly inadequate in many cases, with systems gradually deteriorating.

According to the Public Accounts Committee (1983), which examined the planning process and monitoring mechanism in relation to irrigation projects, maintenance of existing irrigation systems was not getting the attention of states as required, clearly expressed by the inadequate allocations made available by the states.

The Finance Commission (1983) examined the data submitted by the Union Ministry of Irrigation and found that maintenance expenditures incurred varied widely, not only from state to state, but also from project to project within a same state. For instance, in Maharashtra in the year 1979-80 the maintenance expenditure was only Rs 27.95 per ha on the Gangapur project, whereas for the Jayakwadi project it was as high as Rs 171.7 per ha for the same year. In Punjab, the variation was from Rs 9.1 per ha on the Upper Doab Canal System to Rs 38.7 per ha on the Bhakra Canal System.

Some states suggested to the Eighth Finance Commission certain norms for expenditures on maintenance for multipurpose, major and medium irrigation works for the period 1984-85 to 1988-89. Bihar for instance suggested a norm of Rs 120 per ha of gross irrigated area for the plains, while Haryana suggested Rs 75 per irrigated ha. Figures suggested by other states were: Rs 127 per irrigated ha in Uttar Pradesh, Rs 180 per ha of irrigation potential in Gujarat and Rs 180 per net irrigated area in Tamil Nadu.

In the light of these recommendations it is instructive to examine the trends in actual expenditures on O&M of some states and major projects. In this sense, the O&M expenses of several states are discussed below in some more detail.

3. O&M EXPENSES IN SOME STATES

A committee on pricing of irrigation water (1992) under the Planning Commission collected data on reported expenditures for O&M, based on Economic Survey 1990-91. It concerns major and medium projects only, in the States of Bihar, Haryana, Madhya Pradesh, Punjab and Uttar Pradesh.
Detailed results are given in the tables of Annex 1.

3.1. Total expenses, trends and differences for various states

Figure 1 depicts the total expenditures in the various states, in Rs per ha, for the entire 5-year period.

![Expenditures on O&M (Rs per ha) for various states](image)

Figure 1. Expenditures on O&M (Rs per ha) for various states

The figure shows a general increase in O&M expenditures for the states concerned. Form the detailed figures in Annex 1 it is seen that expenditures increased from Rs 73-124 per ha in 1986 to Rs 124-220 per ha in the most recent year.

This trend even holds when all amounts are reduced to 1986 base prices, as is illustrated in Table 1 below. The table gives the O&M expenditures for 1990-91, as a percentage of the 1986-87 figures. It shows an increase in real term total costs for all states, except for Madhya Pradesh, up to 84% even in Bihar and Uttar Pradesh.

But the table also shows that large part of it went into an increase of the establishment costs. Expenditures on actual works still increased in Bihar and UP, but decreased in the other states.
Table 1. Expenses for O&M, 1990 in % of 1986
(in Rs per ha, base prices 1986)

<table>
<thead>
<tr>
<th>STATE</th>
<th>Establishment</th>
<th>Works</th>
<th>Total costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bihar</td>
<td>200</td>
<td>158</td>
<td>184</td>
</tr>
<tr>
<td>Haryana</td>
<td>131</td>
<td>73</td>
<td>103</td>
</tr>
<tr>
<td>Madhya Pradesh *</td>
<td>102</td>
<td>99</td>
<td>100</td>
</tr>
<tr>
<td>Punjab</td>
<td>121</td>
<td>80</td>
<td>108</td>
</tr>
<tr>
<td>Uttar Pradesh *</td>
<td>445</td>
<td>122</td>
<td>184</td>
</tr>
</tbody>
</table>

* 1989-90 instead of 1990-91

3.2. Cost components and trends in various states

As was seen above, the total expenditures on O&M include two components, one for establishment (Irrigation Department, dealing with operation and maintenance) and one for the actual works. Table 2 provides more details on this issue. It gives the percentages of the total expenditures going into establishment over the past five years.

Table 2. Percentage of total O&M costs going into establishment

<table>
<thead>
<tr>
<th>STATE</th>
<th>'86-'87</th>
<th>'87-'88</th>
<th>'88-'89</th>
<th>'89-'90</th>
<th>'90-'91</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bihar</td>
<td>61</td>
<td>55</td>
<td>57</td>
<td>62</td>
<td>67</td>
</tr>
<tr>
<td>Haryana</td>
<td>52</td>
<td>60</td>
<td>64</td>
<td>70</td>
<td>67</td>
</tr>
<tr>
<td>Madhya Pr.</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>-</td>
</tr>
<tr>
<td>Mahar.</td>
<td>32</td>
<td>30</td>
<td>55</td>
<td>55</td>
<td>-</td>
</tr>
<tr>
<td>Punjab</td>
<td>68</td>
<td>69</td>
<td>73</td>
<td>75</td>
<td>77</td>
</tr>
<tr>
<td>Uttar Pr.</td>
<td>19</td>
<td>54</td>
<td>38</td>
<td>47</td>
<td>-</td>
</tr>
<tr>
<td>Average</td>
<td>43</td>
<td>49</td>
<td>52</td>
<td>55</td>
<td>70</td>
</tr>
</tbody>
</table>
It is observed that in all cases the portion of the total costs going into establishment has increased over this period. It is seen that in three states establishment now takes more than two-third of the total expenditures, and only in two states less than half.

It should be realized that although the percentage going into works decreased over the years, the total expenditures increased. This explains that there still is an increase in expenditures on works for some states. In real terms this meant a decrease for most states, however, see Table 1.

4. NORMS FOR O&M EXPENDITURES

4.1. Need for data collection on required funds

From the analysis of O&M expenses in the previous section, one can conclude that expenditures on repair and maintenance of canals and structures in some states have declined in real terms over the past years, while expenses on staff salaries and wages have increased over time. In fact, the pressures at field level are in such situations presently such that only essential repairs are carried out with the money that is left after payment of salaries and wages have been made.

The impact of neglect of basic repairs is difficult to estimate, certainly in old systems where structures may need relatively more maintenance and repair. It is essential to conduct detailed studies on real O&M requirements, based on the type of repairs and maintenance to be done, and on the impact of lack of maintenance on the productivity of irrigation projects. Such investigations alone can provide information for corrective action. However, since data on the consequences of existing levels of O&M expenses are difficult to obtain, it may be useful to review the "estimates" of norms for O&M expenditures on irrigation projects.

4.2. Review of discussions on norms

The Irrigation Commission (1972) used Rs 15 per ha as the norm figure for O&M expenses in 1970-1971. The Finance Commission (1973) agreed with the Union Ministry of Irrigation that Rs 25-30 per ha might be taken to represent a reasonable limit for maintenance of irrigation works. Accordingly, in the early seventies, the Finance Commission worked out financial requirements of the states for maintenance of irrigation systems at the rate of Rs 25 per ha, irrigated by government sources of irrigation, whether by canal, tanks or government
wells including tubewells. If adjustments for changes in prices of labour and materials are made, the norm of the 1973 Finance Commission would for 1981-82 come down to approximately Rs 50 per ha.

Norms of expenditure for O&M was again a subject on the Seventh Conference of Irrigation Ministers of State, held in December 1982. Based on the recommendations of this Conference, the Union Ministry of irrigation proposed the following norms for maintenance.

a. Operation and maintenance expenses of irrigation systems may be put at 100 Rs per ha of cultivable command (CCA), where irrigation intensities are less than 100%, and Rs 100 per ha potential created where irrigation intensities are more than 100%.

b. For special repairs, provisions should be made at the rate of 20% of the annual grants for normal O&M.

c. The provisions should be exclusive of regular establishment required for maintenance, which should be financed separately. Based on typical studies carried out by the Central Water Commission a provision of Rs 50 per ha of irrigated area may be made till more data become available from the states.

d. The states should also review and revise their water charges upwards with regular periodicity to ensure that cost of O&M are fully met, and a return on capital investments of at least one percent is realised.

The report by the Eighth Finance Commission (EFC, 1984) contains a discussion of these and other recommendations. It was thought that norms suggested by that time by the Ministry of Irrigation (which worked out at Rs 170 per ha in irrigated plains) were quite high. According to the Commission, the norm of Rs 50 per ha recommended by the Seventh Finance Commission (SFC, 1979), were adequate for good maintenance. After taking into account the increase in prices of labour and material, this would work out to Rs 88 per ha in 1982-83.

Having reviewed all the earlier discussions, the EFC recommended to provide a consolidated amount of Rs 100 per ha of gross irrigated area for maintenance, including normal repairs and regular establishment. In addition, the Commission recommended provision of funds at Rs 30 per ha for maintenance of the unutilized potential existing at the end of 1983-84. And for hill states the norms could be increased by 30%. Even with these estimates of working expenses, the Commission estimated that the state would incur a loss of Rs 400 million during 5 years 1984-85 to 1988-89.
It is observed that in spite of all the discussions, the amount of Rs 100 per ha does not differ much from the Rs 25 per ha of 1972, corrected for price increases.

Finally, there was the "Report of the Committee to Study the Financial Requirements for proper Maintenance and Management of Irrigation Projects" (1988), constituted by the Ministry of Water Resources. This Committee recommended the following norms for O&M funds for major and medium surface projects.

a. Rs 180 per ha of gross irrigated area (1988 base). Out of this, allocation for head works should be Rs 30-40 per ha, depending on the type of work (for the gross irrigated area, the bi-seasonal and perennial crops are counted only once along with kharif and rabi crops);
b. One third of these norms should be provided for unutilized potential;
c. 20% of the norms under a) should be provided for special repairs over the normal grant as and when required;
d. Rs 65-90 per ha of C.C.A. for the regular establishment;
e. At least Rs 25 per ha of protected area for maintaining the drainage system.

In concluding the following is noted. All above are recommendations only. Existing practices over the country still vary considerably. Some states prefer to have maintenance grants on an area basis while others prefer a percentage of construction costs. Also, some have separate norms for headworks, main and branch canals, distributaries and tertiary networks. For some more observations on this issue, see the paper by Dikshit and Maheshwari. And finally, real expenditures often differ from the norms. As it is seen in the paper by Desai and Jurriëns, the first are sometimes even higher.

5. ASPECTS OF RAISING WATER RATES

5.1. Points against raising fees

Historically two contradictory positions have been taken in India with respect to the levels of the water rates. The Planning Commission (PC) has emphasized the need for raising rates so as to augment irrigation revenues. But some academics and government officials argue that the level of irrigation charges should be kept low, even if this implies that the full costs may not be recovered.

Two major arguments are advanced for assessing charges which do not cover costs. First, the benefits of investments in major irrigation are spread over a
wide range of people, with some people realizing direct benefits and others only indirect benefits. Consequently, the full recoupment of costs from direct beneficiaries only may not be justified.

Second, water rates should be kept low so that farmers are motivated to use the full irrigation potential.

Third, there are other factors that also make it difficult for users to afford the full payment of irrigation services. Lower organizational and operational efficiency of the agricultural market structure of less developed states, a decreasing trend in the ratio of farm harvest prices to prices of inputs purchased and to prices paid by rural households for their consumption goods should also be considered along with incidences of direct and indirect taxes on irrigated farmers income.

For instance, Rath reported in 1985 that the ratio of farm harvest price to prices of inputs purchased from the non-farm sector has decreased from 143 in 1970-71 (index 100 in 1961-62) to 120 in 1982-83 in the case of paddy, while it was reduced from 117 to 103 in the case of wheat for the same years. Thus there is need to examine the behaviour of the agricultural sector relative to the non-agricultural sectors while fixing the irrigation fees.

Further, a 1978 study of Bhatia showed that an additional Rs 622 per ha had been paid by irrigating farmers in the form of direct and indirect taxes related to irrigation.

Considering all above points, many academics and professionals are against the raising of irrigation fees.

5.2. Arguments to raise fees

Meanwhile the Irrigation Commission has emphasized the need of linking irrigation fees with the gross value of crops to minimize the water wastage and to ensure efficient utilization of irrigation water, and has fixed the range of irrigation fees between 5-12% of gross income of the crop considering localized factors and the type of crop.

It has been pointed out by the Irrigation Commission that the irrigation fees actually in force in different states are exceedingly low. "In Bihar for example, the water rates as a percentage of gross value of produce was 7% for rice and 2.7% for wheat". The figures for Haryana were 3.1% and 1.1% respectively.

Apart from this the increase value of land due to irrigation is another indirect benefit to the farmers. Government could also claim a share of the unearned increased land value as a result of irrigation. All the states have enacted legislation for raising this levy which was determined by the difference between
the market value of irrigated and non-irrigated land in the project area or its vicinity. These laws, however, have not been implemented in most of the states due to practical problems of assessing the value of land. This is because many other factors have an impact on value of land like consolidation, land improvement, fixation of fair rent, etc. Apart from this, a betterment levy is also constrained by lack of political will in taxing better-of farmers.

5.3. Farmers’ paying capacity

Bhatia conducted a study in 1989 on "Financing Irrigation Services in India", and made detailed calculations to estimate the ability of farmers to pay for irrigation services. He concluded:

a) irrigation service fees (water rates) to cover O&M costs would result in moderate increase in the proportion of the gross value of output (or net irrigation benefit) that must be paid;

b) attempting to raise the irrigation service fees further to cover the full capital cost, would require a payment of a very high proportion of the crop, between 27-30%;

c) raising the irrigation service fees to cover both O&M cost and capital investment may result in disincentive for the use of water for irrigation resulting in lower output, incomes and employment.

Thus considering the techno-socio-economic factors, policies regarding water rates should be thoroughly evaluated in terms of their impact on the welfare of the farmers, incentives to use water and other inputs, and on agricultural output, employment and income distribution.

6. SUMMARY AND DISCUSSION

After a long period of primary attention for design and construction of irrigation systems, it has become apparent that more efforts should be made to improve operation and maintenance of existing systems. Apart from other important aspects involved, it then becomes necessary to have proper information on the financial requirements, expenditures and recovery options.

For five states, more detailed figures have been collected and analyzed on actual expenditures for O&M. It appears that these vary widely amongst the states. But generally, they have gradually increased over the past five years, from Rs 73-124 per ha in 1986 to Rs 124-220 per ha in the most recent year.
This trend also holds for most states when figures are reduced to 1986 base prices.

Yet, it is seen that most of this increase went into an increase in establishment costs, which in real terms, increased with 2-100%. Detailed figures illustrate that in 1986 on the average 43% of the total expenses was for establishment, which came up to 55% in the recent years. In real terms, for three states this meant a reduction in finances available for actual maintenance works, the other two states still show some increase.

It is generally felt that the finances available for O&M are insufficient to cover the required costs. A detailed review is given of the history of discussions on the norms for required funds. It appears that for a long period, all new norms do not differ substantially from the 1972 norm of Rs 25 per ha, corrected for inflation. In 1988 higher norms were recommended, visually at least Rs 180 per ha on 1988 prices basis.

Finally, some arguments against and in favour of raising the water fees are discussed, in relation with the paying capacity of the farmers. It is concluded that both views have their good points and a well balanced decision should take into account the entire package of socio-technical-economic factors, including all inputs, taxes, subsidies, etc. as well as farmers’ income, employment, welfare and incentives.
# EXPENDITURES FOR O&M FOR DIFFERENT STATES

## BIHAR

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- area in million ha
- exp = total expenditures in million Rs
- per ha = expenditures in Rs/ha
- estt = establishment expenditures in million Rs
- % = establishment in % of total
- work = work expenditures in million Rs
- % = work in % of total
- /ha = work expenditures in Rs/ha
- tot/av = total or average over entire period
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FINANCING OPERATION AND MAINTENANCE IN INDIA

C.G. Desai & M. Jurriëns

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1. INTRODUCTION
2. IRRIGATION COSTS
3. WATER RATES
4. COMPARISON OF EXPENDITURES AND FEE COLLECTION
5. FARMERS ABILITIES TO PAY FOR IRRIGATION SERVICES
6. AN OVERALL ECONOMIC VIEW ON THE IRRIGATION SECTOR
7. SOME RELATED CONSIDERATIONS
8. SUMMARY AND CONCLUSIONS
FINANCING OPERATION AND MAINTENANCE IN INDIA

1. INTRODUCTION

1.1. Importance of maintenance

India has seen rapid progress in irrigation development during the past few decades. This can be illustrated by the figures on new irrigation schemes and the investments incurred, both for the subsequent Plan periods, see Figure 1 (taken from D. Hillel, ed.: Advances in Irrigation, Vol. 3, 1985).

Figure 1. Expenditures on new irrigation and gross irrigation potential created for the subsequent Plan periods

In the past, focus of irrigation development in India was on the design and construction of civil works for storage, conveyance and distribution of water. With rapid changes in Indian agriculture over the last two decades, there is a
growing realization in the country of the need to improve the quality of the supplies and services from irrigation, particularly from existing large and medium projects. 

As a consequence, the emphasis is now shifting to rehabilitation and improvement of water management of existing projects, instead of the earlier focus on construction of new systems. The revised "20 Point Programme" enunciated by the then Prime Minister Indira Gandhi laid emphasis on proper management of irrigation facilities created. The attention of the irrigation authorities was drawn on proper maintenance of the already established systems, among others by providing adequate financial resources for the same.

The huge outlay on the irrigation sector would not be remunerative if the assets created are not properly maintained. Proper maintenance is at least required to realize important objectives of irrigation and drainage systems such as:
- increasing the productivity per unit of water or land;
- improving equity of water distribution among users;
- thereby increasing the cost effectiveness of the system;
- all asking for increased control on water distribution, with an increased reliability of supplies;

- and all with improved environmental stability and sustainability of land and water productivity over time.

In short, the main aim of those in charge of managing a system, should be to maintain the system in proper shape to yield optimum benefits with least costs on a sustained basis over the longest possible time horizon.

1.2. Responsibility for maintenance

In India, irrigation development takes place in both public and private sectors. Surface water projects like dams, diversion works (barrages, weirs) and canals for major and medium schemes are being constructed and maintained at government account. Works like small lift schemes from rivers or ground water, "bandharas", small tanks etc., are normally being executed by local bodies under district "panchayats" through cooperative institutions. Ground water works like dugwells, filterpoints, shallow and deep tubewells are mostly undertaken by private organizations either from own resources or through institutional funds or loans. In states like Uttar Pradesh, Bihar and Gujarat, deep tubewells are being executed, operated and maintained by the respective governments.

The modalities of O&M by private bodies or individuals are remarkably
different from those in the public sector, the first often being more efficient and reliable. This is confirmed by the fact that farmers are willing to pay three to five times the water rate for water from a private source compared to that for water from a public system managed by the government.

Emphasis in this paper will be on the public sector, where the government, apart from funding, designing and constructing the systems, is also primarily responsible for their operation and maintenance (O&M). The paper discusses a number of financial aspects of operation and maintenance of irrigation and drainage systems. Basic data used are given in Annex 1 in addition to those presented by Singh and Jain, and listed in detail in that paper.

2. IRRIGATION COSTS

2.1. Total expenditures on operation and maintenance

A summary of the total O&M expenditures per ha, averages over the period 1986-1991 for five states, is given in Table 1, together with the same information for the most recent year, which was 1989-1990 for Madhya Pradesh and Uttar Pradesh and 1990-1991 for the other states. Data are processed from the basic data given in the paper by Singh and Jain.

<table>
<thead>
<tr>
<th>STATE</th>
<th>Average</th>
<th>Last year</th>
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</thead>
<tbody>
<tr>
<td>Bihar</td>
<td>171</td>
<td>220</td>
</tr>
<tr>
<td>Haryana</td>
<td>146</td>
<td>176</td>
</tr>
<tr>
<td>Madhya Pr.</td>
<td>82</td>
<td>91</td>
</tr>
<tr>
<td>Punjab</td>
<td>117</td>
<td>133</td>
</tr>
<tr>
<td>Uttar Pr.</td>
<td>138</td>
<td>179</td>
</tr>
</tbody>
</table>

The table shows variations between the states in O&M expenses from Rs 80-170 per ha on the average and Rs 90-220 per ha for the most recent year. This concerns surface irrigation projects in plain areas. For the hilly regions of Himachal Pradesh, O&M expenditures for river lift schemes were reported to
be Rs 600-700 per ha. For lift irrigation schemes in Uttar Pradesh the O&M costs varied over the said period from Rs 3000-3600 per ha and for tubewell schemes in the same state from Rs 770-1190 per ha.

It is noted that the most of above recent figures are lower than the most recent recommendations of Rs 180 per ha, see the paper by Singh and Jain.

2.2. Components of maintenance funds

The above figures on O&M expenditures include two components: i) for physical works carried out for maintenance and repair and for (small) new constructions and ii) for salaries and wages ('establishment') of the government personnel involved. According to Indian practices this personnel can be dealing with operational matters or with maintenance activities. It is not possible to give separate figures for maintenance alone, although the expenditures on works might largely concern maintenance activities.

In earlier years, as an average for the mentioned states, about 55% of the total O&M cost was towards the work portion and 45% for the establishment. Gradually, however, the administrative system has changed to such extent that the establishment part has increased in all states. In 1989-90 the average situation was reversed: 45% of the total costs for works and 55% for establishment. In some states, only one-third of the total costs is now going into actual works. More details on this issue are given in the paper by Singh and Jain.

2.3. Required funds for maintenance

It should be realized that these figures concern the actual expenditures and do not express the real costs required for good maintenance. Unfortunately, nobody has ever worked out realistic figures on requirements for good maintenance.

Yet, it is generally observed that funds allocated for maintenance are insufficient to do a good job. In 1977 already, a Central Water Utilization Team reported to the Seventh Finance Commission that provisions of the State O&M budgets were grossly inadequate in most cases and systems were gradually deteriorating. Similarly, the 1983 Public Accounts Committee of the Union expressed that maintenance of irrigation and drainage systems was not receiving due attention due to inadequate allocations made available by the states. Moreover, the Finance Commission of 1983 also found that there was no uniformity of norms in providing funds for maintenance and variations were noticed in allocations.
not only between states, but from project to project within the same state as well. The paper by Singh and Jain gives more information on this issue, including a listing of the most recent recommendations, coming down to at least Rs 180 per ha in 1988.

With regard to the real funds required it is now estimated that these would be in the order of Rs 250 to Rs 450 per ha in general, against the above actual provisions of roughly Rs 100-200 per ha only. The O&M cost for lift schemes is much more because of the substantial energy component.

2.4. Capital cost component

Cost of construction per ha for new schemes varies widely, depending upon the size of the system, type of water source and whether it is gravity or lift scheme. The investment costs of major and medium irrigation schemes over the recent years have generally been in the order of Rs 20,000-40,000 per ha. Taking an average of Rs 30,000 per ha, with an average of 10% rate of interest, the annual capital cost would be Rs 3000 per ha. If O&M cost at an average of about Rs 350 per ha are added the minimum economic cost per year comes down to Rs 3350 per ha.

3. WATER RATES

3.1. Level of water rates

Detailed norms for the level of water charges are given per state but vary widely from state to state. Table 2 provides a summary of water rates for some crops in some states as an illustration. Figures are from the Report "Rates for Surface Water in India", of the Central Water Commission (CWC), 1988. The table shows wide variations, for rice for instance from some Rs 50 to 150 per ha, for wheat and cotton in the same order and for sugar from about Rs 70 to 380 Rs per ha.

As a rough indication, one could say that levels vary from some Rs 50-120 per ha (not counting the rates for sugar, because this is not common crop in most states). It is observed that this is less than the recommended needs of Rs 180 and more, and also less than the actual expenditures of Table 1.

Although it is always said that water rates, besides being based on area and crop, are roughly in proportion to the amount of water a crop consumes and to
the value of the crop, this is not reflected by the figures. Sometimes the rate for rice and wheat is the same and sometimes the rate for wheat is even higher.

Table 2. Water rates in Rs per ha for some crops in several states

<table>
<thead>
<tr>
<th>STATE</th>
<th>Rice</th>
<th>Wheat</th>
<th>Sugar</th>
<th>Cotton</th>
<th>Year</th>
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<td>148.27</td>
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<td>157.65</td>
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<td>110.00</td>
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<td>100.00</td>
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<td>61.78</td>
<td>98.84</td>
<td>61.78</td>
<td>1975</td>
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<tr>
<td>Karnataka</td>
<td>86.49</td>
<td>54.86</td>
<td>370.67</td>
<td>98.94</td>
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<td>38.92</td>
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<td>143.32</td>
<td>237.23</td>
<td>56.84</td>
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</table>

In fact, the norms are much more complicated than indicated above. Firstly, water rates for major and medium systems usually differ from those for minor schemes. Secondly, there are wide variations between the states in the further degree of details. Only one, relatively simple, example of such details is given in Table 3, taken from the above mentioned CWC Report.

Table 3. Example of detailed water rates for rice in Uttar Pradesh (Rs per ha)

| Schedule-I canals | 134.32 |
| Schedule-II canals | 56.84 |
| Schedule-III canals | 64.25 |
| Schedule-IV canals | 19.77 |
Sometimes it has been advocated to base the water rates on volumes of water delivered. However, this will probably not be feasible because of the inability of most agencies to accurately measure water consumption by the farmers, due to the absence of the required water measuring devices and other practical complications involved.

3.2. Collection of water fees

The above illustrates that generally, water fees are not sufficient to cover the actual costs. Moreover, they are not always fully collected. Complete figures on fee collection for the entire country are not available. But Table 4 provides information for some states, on demands raised to the farmers (column 2) and the amounts actually collected (column 3). Figures are taken from the basic material given in Annex 1.

Table 4. Data on water fee collection (in million Rupees) (totals for the period 1986-1991)

<table>
<thead>
<tr>
<th>STATE</th>
<th>Demand raised (2)</th>
<th>Actual collected (3)</th>
<th>(3) as % of (2) (4)</th>
<th>Cost of collection (5)</th>
<th>(5) as % of (3) (6)</th>
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<td>93</td>
<td>-</td>
<td>10-12</td>
</tr>
</tbody>
</table>

It is seen that in most states only part of the demands are actually being collected. This varies from 62% in Madhya Pradesh to 93% in Uttar Pradesh. The demands are for the year concerned, while figures on collection also include collection of arrears. This explains the more than 100% results for Haryana and Punjab.
Table 4 also gives the costs involved in collecting the fees, as totals over the period 1986-1990. It is seen that the recorded administrative cost of collecting the fees varies widely. In Haryana, Punjab and U.P. these costs are relatively low, from 2-12% of the revenues. But in Bihar costs are nearly twice the revenues!

Unfortunately, the issue of collection is complicated and needs some explanation. The entire "collection" consists of three activities: the assessment of crops and areas, the billing and the collection proper. There is considerable diversity in the existing practices on these activities.

At one extreme are the old irrigation works of Andhra Pradesh, Tamil Nadu and parts of Karnataka, where farmers are not required to pay a separate irrigation fee, because this is included in the land revenue. Where separate water charges are levied, and this is the most common feature, the responsibility for all activities sometimes lies with the Irrigation/Water Resources Department (Bihar, Madhya Pradesh, Maharashtra, and two large systems in Gujarat and Rajasthan). In other states (Haryana, Punjab, Uttar Pradesh and West Bengal) the assessment is done by the Irrigation Department, the collection itself being the responsibility of Revenue Department and Irrigation Department pays a certain percentage of the collected amount to Revenue Department. In yet other cases finally, the Revenue Department is responsible for both assessment and collection (Karnataka, Andhra Pradesh, Orissa and Tamil Nadu).

This variety of practices explains the diversity in the figures of Table 4 and the low (percentage) figures for some states. It might (partly) explain the high establishment costs for some other states. Thus, the figures can only give an indication of the real costs involved in collection of water rates.

Finally, for the figures which are not based on a fixed percentage, it is not always clear to what extent cost collection figures of Table 4 also include personnel costs which are already included under establishment. This means that the two cannot be simply be added to come to total costs.

Table 4 is for the entire period 1986-1991 and gives total amounts in million Rupees. It may be interesting to see the amounts in Rs per ha and for the first and last year of this period. These figures have been worked out in Table 5.

There are problems with the interpretation of the table. First, collections most likely also include arrears, the portion of which may vary over the years. Second, it is difficult to compare collections with water rates, not only because of the above reason, but also because of the widely varying water rates, and all
the details in that respect (as explained earlier) are not available.

Table 5. Demands and collections for two years, in Rs per ha

<table>
<thead>
<tr>
<th>STATE</th>
<th>Period</th>
<th>Demand raised</th>
<th>Collected</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIHAR</td>
<td>1986-87</td>
<td>44</td>
<td>32</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>90-91</td>
<td>87</td>
<td>23</td>
<td>27</td>
</tr>
<tr>
<td>HARYANA</td>
<td>1987-88</td>
<td>55</td>
<td>21</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>90-91</td>
<td>59</td>
<td>80</td>
<td>136</td>
</tr>
<tr>
<td>MADHYA PR</td>
<td>1986-87</td>
<td>117</td>
<td>81</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td>89-90</td>
<td>175</td>
<td>79</td>
<td>45</td>
</tr>
<tr>
<td>PUNJAB</td>
<td>1986-87</td>
<td>34</td>
<td>37</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td>90-91</td>
<td>35</td>
<td>37</td>
<td>105</td>
</tr>
<tr>
<td>UTTAR PR</td>
<td>1986-87</td>
<td>107</td>
<td>103</td>
<td>97</td>
</tr>
<tr>
<td></td>
<td>89-90</td>
<td>114</td>
<td>107</td>
<td>94</td>
</tr>
</tbody>
</table>

Yet, the following might be indicatively observed:
- Compared to the water rates of Table 2, demand figures seem to be lower in several cases; roughly, demands for the most recent year vary from Rs 35-115 per ha (with one case of Rs 175 per ha);
- Demands tend to raise over the years, but not substantially;
- There is substantial variation in the degree of collection amongst the states; on the average it is 81%, and figures vary from Rs 20-105 per ha;
- There seems to be a slight tendency of decreasing collection over the years.

Realizing all the variations, the general tendency from the above figures seems to be that average demands are less than water rates and collections again are less than demands.

4. COMPARISON OF EXPENDITURES AND FEE COLLECTION

In the foregoing we have compared water rates, demands and collections. Here,
we will compare the collections with actual expenditures, as given in the paper by Singh and Jain.

To compare the per ha figures for expenditures and collections, these are given in Table 6, again for the same states. It gives the expenditures, collections and the differences, all in Rupees per ha, and the collections in percentage of the expenditures. Figures are given as an average over past 5 year period as well as for the most recent year.

Table 6. Comparison of expenditures and fee collections, in Rs per ha

<table>
<thead>
<tr>
<th>STATE</th>
<th>Expenditures</th>
<th>Collected</th>
<th>Difference</th>
<th>Percentage collected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>Recent year</td>
<td>Avg</td>
<td>Rec</td>
</tr>
<tr>
<td>Bihar</td>
<td>171</td>
<td>220</td>
<td>29</td>
<td>23</td>
</tr>
<tr>
<td>Haryana</td>
<td>146</td>
<td>176</td>
<td>58</td>
<td>80</td>
</tr>
<tr>
<td>Madhya Pr</td>
<td>82</td>
<td>91</td>
<td>90</td>
<td>79</td>
</tr>
<tr>
<td>Punjab</td>
<td>117</td>
<td>133</td>
<td>41</td>
<td>37</td>
</tr>
<tr>
<td>Uttar Pr</td>
<td>138</td>
<td>179</td>
<td>100</td>
<td>107</td>
</tr>
<tr>
<td>Average</td>
<td>131</td>
<td>160</td>
<td>64</td>
<td>65</td>
</tr>
</tbody>
</table>

The differences in columns 6 and 7 give an indication of the annual "losses" in the irrigation sector, without considering the capital costs. In some states Government subsidies raise to a very high percentage. Collection percentages in the recent year vary from 10% to 87% with an average of 41%. As an average over the entire period about half of the expenditures have been collected. For these five states this comes down to a total deficit of about 5300 million Rupees.

When the capital costs are added, this would indicate that the irrigation sector would be a heavy burden on the State Exchequer. When costs for collection and accumulated arrears are added the picture would become even sadder. The total cumulative arrears for the listed cases is given as Rs 2157 million.

It is noted that details for India are available for a few states only, which are forefront in the field of maintenance and cost recovery in the country and
therefore do not represent the actual picture of the entire country. This is very disheartening when looking to states as Assam, Jammu and Kashmir and others, where practically no revenues are being recovered and full costs of maintenance and operation are being incurred not only from Non-Plan funds, but as Plan expenditures as well.

The preceding sections support the frequently heard opinion that water rates are insufficient to cover expenditures. It is usually advocated to increase the water rates. But the above figures also show that it would be more appropriate first to increase the rate of collection of existing fees. Yet, in the following some aspects of possible increase of water fees will be discussed.

5. FARMER ABILITIES TO PAY FOR IRRIGATION SERVICES

The National Council for Applied Economic Research, New Delhi has conducted field studies in various projects on financial aspects of irrigation at farm level. It was found that water rates were less than 5% of the net farm benefits from irrigation. One example is from a project in Bihar. Here, with a cropping intensity of 180%, a farmer having 1 ha of irrigated rice and 0.8 ha of irrigated wheat had a gross income of Rs 8438, compared with Rs 4450 from equal non-irrigated land. Taken into account the cost of labour, capital and management of one family, net income from irrigated agriculture was arrived at as Rs 5774 per year and net benefits from irrigation at Rs 2511 per year. The water rate was Rs 72 per ha per year. This would be 1.2% of the net income from irrigated agriculture and 2.9% of the estimated net benefit from irrigation.

This example would indicate that in states where there is a reasonable irrigation service, the incremental benefits derived from irrigation would enable higher water charges to be levied. Even charging full O&M costs of for instance Rs 400 per ha would still leave a considerable net benefit. Full recovery of O&M costs plus capital costs, estimated above at about Rs 3350 per ha, would mean about 2/3 of the estimated net benefits from irrigated agriculture, and is therefore not a realistic option. Apart from being politically unacceptable, inclusion of 50% of the capital costs would already discourage farmers to demand for irrigation water. Moreover, the huge capital investments have already been sunk in the irrigation projects and there is no justification for insisting on the recovery of this sunk capital from the present generation of farmers.
6. OVERALL ECONOMIC VIEW ON THE IRRIGATION SECTOR

6.1. Need for a broad view

In the above, emphasis has been on a comparison of direct costs of O&M on the one hand and water tariffs on the other hand. However, in discussing the rational for higher water rates it seems appropriate to take a broader view on the issue. One should also include considerations on related economic-financial issues, both with respect to the total agricultural sector as to the farm level. This would enable a more relevant discussion on water rates than the simple comparison of administrative costs of irrigation and rules of thumb on water rates.

In such discussion a broader view would imply not only to consider water but also other (irrigated) agricultural inputs, and not only to look at direct costs and benefits but at indirect costs and benefits as well. Thus, due attention should be given to aspects of prices, taxes and subsidies (both implicit and explicit) related to the input and output of the agricultural sector. For the national level this would give estimates of total resource flows to and from the public managed irrigated agricultural sector and for the farmer level it would reveal a better picture of the overall profit and loss to the farmer.

On the cost side, construction cost and O&M costs are only part of the total expenditures made by government to the agricultural sector. Other costs concern for instance i) subsidies on investment and O&M of public tubewells and privately managed small tubewells (as for example subsidies on fuel/diesel oil), ii) price subsidies and iii) subsidies on fertilizers, pesticides and other inputs. And on the other side, water rates are only one (small) resource for government income form the agricultural sector. The increased agricultural production yields extra economic activities and extra incomes from various taxes.

The analytical work carried out by some research institutes mentioned above have indicated that in specific case studies the total estimated resource flows (revenues) to governments related to canal irrigation were much higher than the current expenditures. And the gross receipts obtained directly from farmers through charging water rates were only 17% of the total receipts from this sector. Similarly net flows of resources into canal irrigation were about the same as subsidies on the use of imported fertilizers consumed on these farms.

This analysis shows that the canal irrigated agriculture is providing substantial financial resources indirectly through commodity taxes etc. This underlines that
discussions on economic aspects of irrigation should not be confined to a mechanical approach which suggests raising water rates not only to cover the O&M expenses but also certain percentage of capital costs.

6.2. Other factors to be considered

With respect to considerations on prices, the following aspects should be taken into account.

a) Although in theory all efforts are made to ensure that the farmers get remunerative prices, in practice, the price that a farmer get for his produce depends on the market structure. This has been confirmed from the analysis of data on procurement prices and open market prices during the harvest season. In states where infrastructures are good as in Punjab and Haryana, market prices for wheat are higher than official procurement prices fixed by the government but in Rajasthan wheat is quoted at times at prices which are about 20% lower than the procurement prices. This factor has to be kept in mind while estimating the additional benefits to irrigated agriculture across the regions and over time. A comparison of water rates with procurement prices may not reveal the true relationship between input and output prices as would follow from simple arithmetics.

b) The prices of agricultural products consequent to the use of irrigation can also be affected indirectly by macro policies of trade restriction "zoning" and other administrative controls. This also needs to be taken into account when analyzing various alternatives of raising resources from the agriculture sector. The import prices also affect the agricultural pricing.

c) When the changes in farm harvest price do not keep pace with changes in prices of inputs and other commodities purchased by the farmers, there will be a definite erosion in the purchasing powers of goods by the farm sector.

All this is being pointed out to draw attention to the fact that raising water rates is only one (direct) method of creating government income and that transferring resources from irrigated agriculture to the rest of the economy could also be realized by policies on prices of outputs and inputs as well as policies of direct and indirect taxation of income accrued in irrigated agriculture.

7. SOME RELATED CONSIDERATIONS

With respect to the issue of water rates, finally some miscellaneous aspects are
mentioned that should not be neglected.

* Reliable water services

Due to a variety of reasons, operation of many irrigation systems is deficient, and inadequate water distribution results in improper and unreliable water supplies to the farmers. Given this state of affairs it is reasoned that it would not be reasonable to ask farmers to pay a higher water fee as they do not get adequate services in return.

The other way around, collecting too little water charges, together with insufficient allocations by government, will jeopardize improvement of the water distribution. In fact, this has become sort of a vicious circle in many developing countries.

In developed countries like USA and The Netherlands (see the paper by Deurloo), and even in The Republic of Korea, water management has been made self supporting, among others by charging adequate contributions from the beneficiaries, which is accepted because they know they can be sure to really benefit from reliable and proper services.

For India, this point can be illustrated by the performance of the private irrigation sector. Here, economic performance is often realized by recovering adequate charges, for which well planned and executed operation and maintenance services are rendered.

* Farmers role below the outlet

The plea for water users organizations or farmers cooperatives "below the outlet" is also valid with respect to maintenance. On the one hand collaboration of farmers would facilitate collection of fees for the government, particularly in situations with many small and fragmented holdings. On the other hand maintenance of the field ditches and small structures below the outlet could be entrusted to the farmers, thus reducing the government burden on maintenance costs.

Sofar, however, very few water cooperatives have come up in India. The Mohini Cooperative Society of water users in Kakrapar Command in Gujarat is one of the few examples of exemplary management by the farmers. The result is that for the country as a whole there is virtually impossible to envisage a workable scenario where with the price set for irrigation water, a well working farmer organized maintenance system could be evolved.
8. SUMMARY AND CONCLUSIONS

The huge outlay on the irrigation sector would not be remunerative if the assets created are not properly maintained. Proper maintenance is at least required to realize the fundamental objectives of irrigation and drainage systems. The paper reviews a number of financial aspects of operation and maintenance, including real needs, actual expenditures, water rates, and cost recovery. Maintenance needs and costs vary considerably, between states, between Government and private schemes and between type of system. Emphasis is on Government managed surface systems. Data on financial issues have been collected and processed for 5 large irrigation states, for the years 1986-1991.

The actual expenditures on O&M have increased from about Rs 80-170 per ha in 1986 to Rs 90-220 per ha for the recent years. Over the period, the percentage of the total expenditures taken by establishment costs have increased for 45% to 55%, however. The real costs required for good maintenance are estimated to be in the order of Rs 250-450 per ha, not counting the capital costs. The latter would dramatically increase the annual total with some Rs 2000-4000 per ha.

Cost recovery is done (partly) by collection of water charges. The norms and levels of water rates in some states are reviewed. The criteria vary widely and are often quite complicated, so that standard figures cannot be given. The general overall picture is that water rates vary from some Rs 50-120 per ha, which is considerably less than the actual expenditures and certainly less than the required funds.

Subsequently information is given on the collection of the water charges. The demands billed to the farmers again vary considerably, generally being in the order of Rs 35-115 per ha, which seems to be less than the level of the water rates. Next, these demands are not fully being collected. The average rate of collection is about 80%, with variations from 60-120%, the latter figure showing that collection of arrears is included as well. The average amount collected in the most recent year was Rs 65 per ha, varying from Rs 20-105 per ha.

Some information is given on the cost involved in the collection activities. It is shown that this is a complicated issue with highly varying practices in the country. It is therefore not possible to give good indicators on this aspect.

Next, the actual collections are compared to the expenditures. The average percentage of the expenditures finally collected seems to slightly decrease from
49% (17-91%) for the entire period to 41% (10-87%) in the recent years. This leaves an average deficit of Rs 95 per ha (varying from 10-200). Similar figures are given for some other Asian countries.

The above would suggest that first the degree of collection should be increased to reduce the deficits. Yet, some thoughts are also given to the possibilities to increase water rates, as is often advocated. Farm economic studies indicate that for the farmers, the water rate is only a negligible percentage of the net benefits from irrigation. Substantially higher water rates seem well be possible without seriously affecting the farm budget. But inclusion of any portion of the capital costs does not seem realistic.

Yet, it is argued to take a broader view on the financial aspects. Not only water should be considered, but also other inputs and not only direct but also indirect cost and benefits should be taken into account, incorporating all aspects of prices, taxes and subsidies. O&M costs and benefits are only one element of the many other cost and benefit elements for both farmer and Government.

Finally, two related issues are briefly raised: one is the fact that higher water rates can only be implemented when the quality of the water service would improve, and the other is that a workable solution should be found to make the farmers within the outlet command responsible for their own maintenance.
DEMANDS AND COLLECTION OF WATER FEES

ANNEX 1.1

**BIHAR**

<table>
<thead>
<tr>
<th>Year</th>
<th>Demand raised</th>
<th>Actual collected</th>
<th>(4) as % of (3)</th>
<th>Cost of coll</th>
<th>irrig. area</th>
<th>dem. /ha</th>
<th>coll. /ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
<td>(2)/(6)</td>
<td>(3)/(6)</td>
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<td>tot/av</td>
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<td>62</td>
<td>546.6</td>
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**HARYANA**

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<th>Actual collected</th>
<th>(4) as % of (3)</th>
<th>Cost of coll</th>
<th>irrig. area</th>
<th>dem. /ha</th>
<th>coll. /ha</th>
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<tr>
<td></td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
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<td>(2)/(6)</td>
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<td>88-89</td>
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<td>57</td>
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<td>tot/av</td>
<td>450.7</td>
<td>455.3</td>
<td>100</td>
<td>* 2%</td>
<td>57</td>
<td>58</td>
<td></td>
</tr>
</tbody>
</table>

* fixed percentage
- "demands raised" and "actual collected" in million Rs
- irrigated areas in million ha
- tot/av = total or average

Source: Committee on pricing of Irrigation Water, Planning Commission of India, 1988
## MADHYA PRADESH

<table>
<thead>
<tr>
<th>Year</th>
<th>Demand raised</th>
<th>Actual collected</th>
<th>(4) as % of (3)</th>
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<th>irrig. area</th>
<th>dem. /ha</th>
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## PUNJAB

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<th>irrig. area</th>
<th>dem. /ha</th>
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## UTTAR PRADESH

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<th>irrig. area</th>
<th>dem. /ha</th>
<th>coll. /ha</th>
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<td>'86-87</td>
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<td>575.3</td>
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<td>458.5</td>
<td>79</td>
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<td>88-89</td>
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<td>6.003</td>
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<td>642.9</td>
<td>604.1</td>
<td>94</td>
<td>5.663</td>
<td>114</td>
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<td>107</td>
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<tr>
<td>90-91</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>tot/av</td>
<td>2468.9</td>
<td>2305.6</td>
<td>93</td>
<td>10-12%</td>
<td>107</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

FINANCING O&M

ANNEX 1.2
FARMERS' PARTICIPATION IN MANAGEMENT AND MAINTENANCE

O.P. Mehta & K.P. Jain

CONTENTS

1. INTRODUCTION
2. FARMER MANAGEMENT DEVELOPMENTS IN INDIA
3. CASES
4. SUMMARY AND CONCLUSIONS
FARMERS' PARTICIPATION IN MANAGEMENT AND MAINTENANCE

1. INTRODUCTION

It is true that in large parts of India the creation of irrigation potential is a prerequisite for agricultural development, but it is equally true that this potential should be utilized efficiently and in a sustained manner. Earlier it was considered that the best way to realize this was to implement the "on-farm development works" below the outlet. Also it became clear that a more reliable, predictable and equitable water distribution was essential for increasing the agricultural production.

There is a growing awareness of the fact that all this will not work as long as the more complex socio-economic aspects involved and the role of the individual and collective behaviour of farmers are not duly taken into account. It is the farmer who decides what crops to grow, when or how much to water and fertilize, how much to invest within his risk capacity, etc. The farmer is the ultimate producer of the crop, he has a right to adequate, timely and assured water supply, and to be intimated timely on water availability. Farmers are born and brought up, live and work in the command, and they possess an intimate knowledge of the strengths and weaknesses of the system. Altogether this makes it a must to involve them in some way in the management of the system, sharing some rights and responsibilities on operation and maintenance.

Unfortunately the present system of water management does not provide for collective efforts of self-governance by the farmers and farmers lack a feeling of ownership of the system. This is an important factor contributing to deficiencies in water distribution within the outlet command and in water use on the fields.

The result also is that there is no effort from the part of the farmers to maintain even their own field channels, let alone other channels and structures in the outlet command. On the other hand, the government is often not able to maintain the system above the outlet, as extensively discussed in this publication. Consequently it would not be realistic to expect the government to take full responsibility for maintenance of the vast networks within the outlet commands.

There is a growing feeling among planners, administrators and knowledgable people that giving more responsibilities to the farmers/users might help to
develop more equitable distribution of water, to reduce management costs, to control and reduce conflicts and to ensure increasing crop production, better overall performance and sustainable irrigation systems. Hence, the Government of India in its National Water Policy (1987) has emphasized the importance of active involvement of farmers in water management. Gradually, this has been introduced in several systems in various states.

This paper presents some information on the nature and effects of this process. In the next chapter a general overview is given on the transfer of management responsibilities to farmers in India. In the remaining chapter, emphasis will be on the maintenance activity. A number of cases are briefly described of systems where farmers have entirely or partly taken over responsibility at least for maintenance of part of the system.

2. FARMER MANAGEMENT DEVELOPMENTS IN INDIA

The concept of user involvement in irrigation management is not new. Traditionally, small local systems in several parts of the country were constructed and managed by village communities (in modern terminology known as Farmer Managed Systems, FMIS). Such systems cover an irrigated area of about 1.1 million ha. Although very little is known about these systems as no monitoring is done of their performance, their productivity is said to be at par with the public managed systems.

It is widely believed that these old institutions have weakened by the tendency, both during British rule as in the post-independence period, of the government to take over more and more of the responsibilities. Nevertheless, even today there are many instances of user managed local irrigation works functioning effectively in parts of the country. These include for instance the Phad system in Nasik and Dhulia districts of Maharashtra, the Vijayanagar systems in Karnataka and systems in hilly regions.

But all this mainly concerns small systems. The medium and major canal systems are by and large managed entirely by the government Irrigation Departments. The only significant instance of some more (official) user involvement in water management is the warabandi system prevailing in Punjab, Haryana and Western Uttar Pradesh.

The past two decades have witnessed the enactment of legislation for more farmers involvement and numerous initiatives have come up, both by
government as by voluntary organizations, to foster water users associations in the commands of major and medium projects. The Ministry of Water Resources (MoWR) requested all the state governments in 1985 to take up the scheme of farmers participation on a pilot basis in at least one minor covering 1000-2000 ha in each Command Area Development project, primarily addressing water management and maintenance of field channels, and detailed guidelines were issued by the Ministry in April 1987 to all states. Under the centrally sponsored CAD schemes, a management subsidy of Rs 100 per ha for the first two years and Rs 75 per ha for the third year was made available under the seventh five year plan for farmers’ associations taking over management at minor level.

Table 1. Overview of farmers’ management in India

<table>
<thead>
<tr>
<th>STATE</th>
<th>Organizations</th>
<th>Farmers involved</th>
<th>Command covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andhra Pradesh</td>
<td>1396 Pipe Committees</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Assam</td>
<td>2 Chak Samities</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bihar</td>
<td>Outlet Committees</td>
<td>630</td>
<td>224</td>
</tr>
<tr>
<td>Gujarat</td>
<td>&gt; 60 at different levels</td>
<td>5675</td>
<td>23300</td>
</tr>
<tr>
<td>Haryana</td>
<td>151 Farmers’ Associations</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Himachal Pradesh</td>
<td>1 Farmers’ Associations</td>
<td>409</td>
<td>380</td>
</tr>
<tr>
<td>Karnataka</td>
<td>10, outlet level</td>
<td>379</td>
<td>456</td>
</tr>
<tr>
<td>Kerala</td>
<td>2031, outlet level</td>
<td>-</td>
<td>75109</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>737 Irrigation Panchayats</td>
<td>-</td>
<td>18300</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>in 4 commands, various levels</td>
<td>926</td>
<td>1439</td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>36 Farmers’ Associations/councils</td>
<td>29150</td>
<td>23210</td>
</tr>
<tr>
<td>Uttar Pradesh</td>
<td>1 Water Users Cooperative Society</td>
<td>310</td>
<td>274</td>
</tr>
</tbody>
</table>
Legislative provisions for formation of users groups have been enacted in various states. Table 1 gives a list of water users associations/societies reported to have been formed at minor or outlet level in different states. There are differences between the states with respect to the size of the area to be covered. In most states farmers management is restricted to the command area below the outlet. Kerala provides for farmers management at intermediate levels and even entire projects as well. Gujarat visualizes committees with user-representation at the village-, branch canal- and project levels. The relevant laws of Punjab, Haryana, West Bengal, Rajasthan and Assam do not have specific provisions for constituting users associations.

Also, there are differences regarding the activities concerned. In general it was felt that these institutions can play an effective role in construction, repair and maintenance of small works like tubewells, watercourses, field channels and small structures, water distribution, collection of water charges, acquisition of labour for emergency work, settlement of disputes and protection of irrigation works from encroachment and damage. The precise package of these activities can vary from state to state.

Unfortunately, very little systematic assessment is available on the actual performance and results of the efforts undertaken. It is known that the total area covered by these initiatives is very small, less than one percent of the area presently irrigated. The general consensus among knowledgable people is that they have not really made much of an impact. For a large part, the outlet and canal committees are there only for the name sake. Their functions are vague, they seldom meet, they are not consulted on substantial issues, nor are departmental officers paying attention to their suggestions. There is also reluctance, if not straight opposition, from the operational staff of Irrigation Departments in involving farmers in management, and even users themselves sometimes tend to be apathetic to the idea. The same experts opine that participation and organization is assumed to arise spontaneously if local leadership is effective.

We have been able to collect some basic information on a number of cases of farmers management, which could show whether these observations are supported or not. These are briefly described in the next chapter, emphasizing on the maintenance activity and financial aspects. The examples are for canal systems only. Considering the context of this publication, no information is provided on minor and local systems, tanks, lift and tubewells systems.
3. CASES

3.1. Mula Project, Maharashtra

This concerns the "Shri Datta Cooperative" in Chanda village in Nevasa Taluk of Ahmadnagar District in Maharashtra. It is a registered "service" cooperative of 200 farmers, covering 360 ha on the Minor Canal no. 7 in the Mula command.

* Maintenance
Before signing the Memorandum of Understanding (MoU), Irrigation Department and the Society jointly inspected the minor canal, determined the balance of renovation to be done, and after completion of that work, ID handed over the minor to the Society. ID gives the Society Rs 10,000 per year (Rs 28 per ha) to maintain the minor, the Society claims Rs 15,000 is needed. It appears that before, ID was spending about twice the amount, large part of which was not properly utilized. Now there is savings to the state, and the workloads of the Patwari and Junior Engineer are reduced, while the Assistant and 2 Watchmen are paid by the society from its own income.
There is no donated labour ("shramdan") for maintenance, the Society contracts out the work on the minor. Field channels are maintained by the farmers.

* Finances
The Society collects a flat rate of Rs 25 per ha above the official water rates, regardless of the crops, which covers its personnel and office expenses. It rents a suitable office room.
The MoU provides for state subsidy to the Society for 3 years as reimbursement for certain administrative costs. The PDO recommends it to be extended for 5 years, after which the Society's situation can be stable. The Society is planting trees along the minor for additional income.

* Effects
Maintenance is properly done and the state is saving money. The Society is claimed to be an all-around success. It controls patkaris and guards who now work in the interest of the farmers, and so are flexible in arranging water turns, avoiding the inefficient old procedures of recording water applications. Since water is paid for, it is not wasted, more land is irrigated and threat of water logging has decreased. Water comes more or less at specified times, so cultivation can be planned with increased productivity. Conflicts are resolved and the environment is improved through tree planting.
3.2. CADA model, Andhra Pradesh

Pipe committees (PC's) are being organized by CADA, according to a 1984 Act, for one canal on the Shri Ramsagar project, in the Karimnagar District, Andhra Pradesh. Each PC consists of 4 or 5 members who are group leaders of sub-chaks and represent 25-30 farmers. They are elected by a democratic procedure. The PC’s are not formally registered but are recognized by CADA.

* Maintenance
CADA constructs the field channels, with half of the funding by the state and half by the Central Government, and turns them over to the PC to maintain. But there are no specified provisions on how this maintenance is to be financed and organized.

Under the pilot Major Committees, in meetings attended by ID and AD officials, resolutions were passed that urgent repairs could be done by contractors nominated by the PC's and Major Committees. How this is to be financed, is yet to be worked out, however.

* Finances
There are no formal provisions for raising incomes to the Committees, and since they do not collect water fees, they cannot take a commission on that.

* Effects
These mainly concern water distribution. Organization by farmers is in principle correct, and should be able to initiate a process of balancing the bureaucratic authority of ID. PC’s are now elected by democratic procedures. They can turn the outlet on and off, they can manage their watermen, and in future may have a voice in supervising taskars (patrols).

3.3. CADA Model, Kerala

There are now 10 completed irrigation projects under the Kerala CADA. According to the Command Area Development Act of Kerala, owners of farm land in all commands are to be organized. About 2000 Societies have been registered, covering all outlets, which is done under the Scientific and Charitable Act of Kerala.

* Maintenance
CADA puts in some funds for construction and maintenance, such as building concrete field channels. Societies are expected to raise more funds and carry out maintenance.
* Finances
Farmers pay a fee of Rs 5 upon joining their Association. The associations can collect other fees and gifts, but this is not much clarified in the instructions, not yet in precedent.

* Effects
Preliminary studies show that all-round increase in water use efficiency and production may be expected. But further evaluation will be required after some time to assess the real effects.

3.4. IMTI Action Research model, Tamil Nadu

"Kudimaramat" is a model attempting revival of traditional village management ("kudi" is hamlet or settlement, and "maramat" is repair or maintenance). The Salipperi (village) Water Users Society, on the lower reaches of the Vallapar-Mahilancheri Channel in Thanjavur District, Tamil Nadu, is one of the several sofar started under the action research project of the Irrigation Management and Training Institute (IMTI). It is registered under the Societies Act (not under Cooperatives Act), it covers 122 farmers and 130 ha.

* Maintenance
The key concept of kudimaramat is a Trust Fund, so the Society has money available to contract out maintenance works. It also sometimes organizes Shramdan, to clean weeds from the canals.

* Finances
The trust fund is created by each member paying Rs 100, non-refundable, on joining. Rs 30,000 was collected in this way and IMTI added another Rs 30,000 to this. Part is on a fixed bank deposit, interest to be drawn for each year to pay for maintenance. The balance is another fixed bank deposit, interest from which is to be drawn each five years to add to the first fund to compensate for inflation.
Members give Rs 1 per year for membership and Rs 2 per acre. The Committee also has income from leasing ponds for fishing, banks for grazing, coconut trees, etc.

* Effects
Farmers consider that the system belongs to them and they exert sheer pressure to care for it. Maintenance is assured. Farmers get water fairly by turn, even when it is scarce and tail-enders are better reached. Farmers on neighbouring canals, seeing the success, now also want to form such societies.
3.5. WALMI Action Research model, Gujarat

The type of organization envisaged under the Action Research project of the Water and Land Management Institute (WALMI), Gujarat, focuses on outlet group leaders (not outlet societies). The leaders are usually the more active farmers having contacts outside, and being interested in taking such responsibility. The Gujarat WALMI has selected an area under the Mahi system, on the Anlkav sub-minor in Kheda District. The canal is 8 km long, has 36 outlets and covers about 1000 ha. There are roughly 30 farmers under each outlet. So far, there is no legal registration.

* Maintenance
Field channels are maintained by group labour, called by the group leader for a particular day. If a farmer is absent, he pays instead, and the money goes for tea and snacks for those who give labour.

* Finances
The group leaders collect fees from their group members to pay for the man whose work it is to operate the turn-outs. This man gets Rs 15 per day (government rate), for which the landowners pay Rs 60 per season. No other funds are normally raised.

* Effects
An important advantage of this approach is that leaders can be contacted and organized more quickly and easier, compared with other types of societies. Also, leaders tend to hold the post for a long time, so that training can be effective. Solving problems through discussions rather than through might has become the norm, whereas in neighbouring canals big farmers still misuse their status. The model is said to have enabled water to reach all the command, actual irrigated area has expanded threefold and yields are increasing.

3.6. Irrigation Panchayat model, Madhya Pradesh

In Madhya Pradesh formation of Irrigation Panchayats (IP’s) is compulsory under the MP Irrigation Act 1931, modified in 1974. IP’s have been functioning for 50-60 years on both major and medium canal systems, mainly in the rice growing Chattisgarh region. The IP’s mostly coincide with villages. As of 1990, there are 736 IP’s in the Mahanadi command, Raipur District, with an irrigated area of 183,000 ha. Each IP has a small panchayat (committee) which on the average serves 250 ha.
* Maintenance
IP's usually maintain the watercourses, for which they pay labourers. In a few villages the IP's organize voluntary shramdan in which one person per family provides labour for a day or two to clean the field channels before the season.

* Finances
The Act provides for incomes as follows: a) commission on water fees collected of 3% for the first Rs 1000 and 2% thereafter, b) an additional Rs 2 per acre irrigated for administration and fee collection, c) part of the penalty charges. The total fee amount is remitted to the treasury and about 6 months later, after checking, the commission is returned to the IP. This income is divided among the elected panchayat members, with a double share for the sarpanch. Their income from this is a few hundred rupees a year. The IP's separately collect money from farmers according to the landholding, for the wages of the "banihar", and for costs for cleaning and maintenance.

* Effects
The IP takes part of the burden of the water distribution, collects the fees and resolves conflicts. Farmers have easy access to the IP and it is easier to get water, without contacting the ID officials.

3.7. Water Users' Associations in Pakistan

Finally, some information is provided on the experience with WUA's in Pakistan, where Water Users' Associations have been formed in the Indus basin system, normally one per chak or outlet command, covering some 400 ha each on the average. There are now over 12,000 WUA's registered in the country, out of 90,000 chaks. They comprise 10-100 farmers, with an average of about 50. Punjab has 83% of the WUA's in the country.

* Maintenance
Under a World Bank project, the WUA's did significant work in renovating or reconstructing watercourses, finalizing realignment, persuading farmers to give land or cut trees and supervising construction. In spite of the deficiencies of WUA's, they have been reasonably successful in mobilizing labour for periodical cleaning of watercourses. Before, an informal leader might try to get people for cleaning, but now the work is better organized. Time for cleaning has been much reduced, mostly because of lining of the watercourses. It was found that the feeling of cooperation was improved and farmers are more willing to give time to a common cause.
* Finances

Though the WUA must have a bank account to get registered, it is often opened as a formality only. If farmers have a common fund, they may put it with a trusted colleague. But in some cases the WUA bank account is well filled. Most WUA’s get income from modest fees, such as Rs 5 per ha, or from fines. In a few cases they charge the members a few rupees per acre per year to build up a fund. Generally, WUA’s do not consistently build up capital, but they can collect substantial funds from members when special needs arise.

The Associations are very active in mobilizing labour and gathering funds for making watercourse paka’s (division structures) under the World Bank funded project. They charged Rs 75 or so per acre to pay masons and labourers. Or they charge based on warabandi times (in one case, Rs 300 for one hour on the roster; in another case, one day of labour per roster hour). WUA’s were supposed to raise 25% of the materials and mason costs. Besides, farmers contributed Rs 14 per metre to repay loans to government for construction materials. World Bank estimates that farmers contributed as much as 55% of the total capital, operation and maintenance costs of the project.

* Effects

The precise effect of the WUA’s with respect to maintenance is difficult to assess, because main effects were on improvement of water distribution. This was partly due to lining of watercourses and construction of paka outlets. But also, because WUA’s are registered with ID, farmers better respect the warabandi, they were freed from the patwari and disputes got much reduced.

4. SUMMARY AND CONCLUSIONS

To improve the performance of irrigation, an important condition is that farmers must have some feeling of ownership of the system. Particularly in medium and large canal systems the responsibilities of Irrigation Department could be reduced by giving part of the system and part of the responsibilities to the water users. This could contribute to better water distribution, to control and reduce conflicts, to reduce management costs and to ensure increasing crop production, better overall performance and sustainable irrigation systems.

Full farmer management exists since long in traditional small local systems, but is nearly absent in medium and major canal irrigation. During the past two decades some initiatives have been taken to develop more farmers’ involvement and farmers’ organizations in the commands of major and medium projects.
Table 1 gives an overview of activities in various states.

Usually farmers are being made responsible for water distribution and maintenance and resolving conflicts, often also for fee collection. In most cases the responsibilities are limited to the outlet command, sometimes they cover an entire minor command.

Chapter 3 discusses some concrete cases with different models of organization and responsibilities. Altogether this still covers a very limited area. The review also shows that rather limited information is yet available on the precise functioning and effects. There seems to be considerable potential for improvement of water distribution, but in a few instances only this has really been proven so far. In all examples maintenance is entirely to be done by the farmers, but very little is known on how this is really functioning. Financial arrangements generally seem to be realistic and workable, but here as well more information would be needed on the actual financial situation after a number of years.

Considering the importance and scope of the issue, as shown from the Pakistan experiences, much more work should be done on monitoring of such experiences, to collect hard evidence on effects and advantages and learn lessons for possible improvements.
PART D

SUMMARY, CONCLUSIONS
AND RECOMMENDATIONS
SUMMARY AND CONCLUSIONS

M. Jurriëns and K. P. Jain

CONTENTS

1. INTRODUCTION
2. THE ISSUES
3. THE DUTCH EXPERIENCE
4. THE INDIAN SITUATION
5. DETAILED CONSIDERATIONS
6. GENERAL CONCLUSIONS
SUMMARY AND CONCLUSIONS

1. INTRODUCTION

This publication contains a wealth of information, which makes it difficult to summarize the most important lessons and conclusions. In this concluding paper, we have not summarized all the individual papers, but opted for the following approach. On the basis of the theme paper, we try to give a brief and broad overview of the maintenance field and problems, and identify key areas for attention. We then briefly summarize both Dutch and Indian situations. Subsequently, a number of more detailed considerations are presented on each of the issues. Emphasis will thereby be on the Indian situation.

In the next paper, we have copied the recommendations of the December 1991 Seminar, as they were submitted to the Government of India, Ministry of Water Resources and Irrigation, immediately after the Seminar.

2. THE ISSUES

First of all it is important to systematically approach the subject. A framework of the subject is given in the theme paper by Jurriëns and Pinkers, who condense the subject to the questions as: why to do maintenance, what to maintain, which activities to be carried out, who is to do what, when and how. This can be translated in the following requirements, crucial for good maintenance:
- a sound data base of the system (what) to maintain;
- clear regulations on who is responsible for what (who);
- a good insight into the functions to be maintained (why);
- so that, together with adequate monitoring, timely decisions can be taken on:
  - the required maintenance activities (which);
  - their moment and intensity (when: timing, frequency);
  - and all this in relation with a decision on the execution method (how).

In addition to these more technical aspects, a number of institutional requirements should be met. This largely comes down to an organizational framework which clearly indicates responsibilities, control, sanctions and appeal at various levels. And to be effective, this has to be put down in an adequate legislation. Finally of course, there should be a system of appropriate financing and cost recovery.

Moreover, the theme paper mentions that the nature of these answers will
depend not only on the technical situation, but also on the cultural and economic environment.

3. THE DUTCH EXPERIENCE

Most Dutch papers show how all the above elements have since long been adequately incorporated in the Dutch maintenance practices. This is because the country has a longstanding tradition in management and maintenance of water control systems, without which it would now not exist in the present form.

The Dutch "Waterboard" institution, as described by Siefers, Hamster and Deurloo, plays a crucial role in this respect. Siefers pictures the functioning of the Dutch Waterboards with their institutional and legislative aspects and Deurloo explains in detail the financing and cost recovery system with the principles on which it is based. The various papers also demonstrate that, apart from being based on democratic principles and extensive legislation, it can only function because powers are accompanied by a strong control system and a basic acceptance by the beneficiaries.

Generally, water control systems are well documented, with a good system data base, cadastral data and "leggers".

Consequently, standard answers can often be given on most of the above listed issues and a standard, fixed maintenance program is carried out every year. This practice, shown by Hamster, has been developed in many Dutch Waterboards. But if so required, the maintenance practice can be made more flexible, as long as one systematically deals with the above questions.

The why question is related to the functions to be maintained. Maintenance is required when the functions can no longer well be performed. Siefers and Hebbink illustrate how, besides the primary quantitative water control function, gradually other functions became important in The Netherlands, related to water quality, nature conservation, environment and ecology.

The paper by Hebbink describes the various possible techniques for maintenance execution and provides information on their use in The Netherlands, as well as on maintenance frequencies in the country and on the differences between sand and clay areas. The paper shows that maintenance execution has become largely by mechanical means. First because labour became too expensive, and later on because the use of chemicals became more and more restricted due to all the environmental disadvantages. Papers by den Herder and Sperling provide
further information on various mechanical equipment for small and large maintenance respectively.

A final Dutch contribution, by Nieuwenhuyse, pictures in detail the experiences with a pilot project carried out in the Gezira scheme in the Sudan, to develop the organization and maintenance methods, best suited to the prevailing circumstances.

4. THE INDIAN SITUATION

In India there is not such a maintenance tradition in water control systems and the Dutch picture of Waterboards with strong organization, legislation, control and financing does not exist. Perhaps for that reason, the Indian papers do not systematically address the above issues. Also, hard data on various technical practices and aspects are scarce. In that respect, Maheshwari presents a case on drains and on lined canals, the latter largely addressing aspects of design. Varshney provides a detailed overview of maintenance work required for various canals and structures in the system.

All papers emphasize the need for increasing attention for proper maintenance. And the first paper by Maheshwari shows that maintenance needs have increased, due to changing agricultural circumstances. More silt has to be removed, incidence of scour and breaches increased while on the other hand less time is available for maintenance, evoking the need for mechanized means, better inspection and communication. Moreover, farmers interferences have increased due to higher irrigation intensities and water demands. That paper and the one by Bhargava and Kumar review a number of elements in the system where problems exists and improvements are possible.

Yet, the common observation sofar in India is that the biggest problem with maintenance is that there are insufficient funds available. This is mentioned in nearly all papers and illustrated by the fact that several papers are explicitly on financing aspects. The shortage of funds is certainly a problem, and a lot of information in that respect is provided by Singh and Jain and by Desai and Jurriëns. Dikshit and Maheshwari emphasize on procedures for financing.

However, many other non-financial aspects are important as well. One could even say that the less funds available, the more crucial it is to spent them very judiciously and effectively. In that sense, Bhargava and Kumar sketch the
importance of "dynamic maintenance", in accordance with the needs of the system and the farmers. Because of the limited funds, emphasis should be on preventive maintenance, based on timely and alert monitoring. They observe that this requires better communications and mobility and a good quality and attitude of the staff concerned. In the latter respect Varshney makes a strong plea for more involvement and commitment of irrigation engineers. For various levels and types of canals and structures he pictures in detail how judicious and timely identification of problems can avoid major damages and expenses. Both latter papers point at the fact that political and other pressures should be resisted in both staffing and execution of the work.

Throughout the papers it can be observed that a number of aspects on maintenance in Indian irrigation and drainage systems need further inventory, study and analysis. These will be further identified below.

5. SOME DETAILED CONSIDERATIONS

5.1. Data base

The data base on maintenance in India certainly can be improved. This concerns both general, nation-wide or state-wise information, as well as scheme specific information, needed for good maintenance. Various issues in the first respect are further detailed below. With the latter we mean basic data on each individual system, including up-to-date maps, sections of canals, location and types of structures, etc. Maintenance quality would certainly benefit from complete and correct information on the system.

5.2. Functions

With respect to functions to be maintained, emphasis in India still is on the quantitative water control. But like it happened in the past decade in the Western world, developments may rapidly require to include water quality and ecological-environmental considerations as well. Maheshwari and Jain point at this aspect in relation with drain maintenance, and the health aspect is already well known in India.

5.3. Responsibilities

An important questions always is to know who is responsible for what. In the Indian maintenance context this concerns several levels.
First there are the different responsibilities of Central Government and States. It is observed that numerous National Committees etc. have studied various aspects of (operation and) maintenance, but that subsequently the States are relatively autonomous in the way they want to accept these recommendations. We do not want to take a stand on this matter, but only raise the point in observing that sofar these Commissions etc. have not been very effective in terms of practical implementations.

Another issue is the responsibilities of Irrigation Department and Revenue Department, particularly with respect to the collection of fees. We know that discussions on this issue are going on in the country and therefore we only observe here that it would be good if a pragmatic and effective solution could be found.

A similar complicated issue is that of the division of responsibilities between Government (Irrigation Department) and farmers within the outlet command. One essential difference between the Dutch and Indian situation is that in The Netherlands there is a direct contact between Government (represented by the Waterboard) and the individual farmer. In India the situation is more complicated, because there is always an intermediate level, visually the group of farmers in the outlet command. Where in reality the influence of the Government on water distribution and water use mostly ends at the outlet, it would be logical, practical, realistic and effective to extent this principle to maintenance as well and make farmers responsible for maintenance within the outlet command.

Although it is usually said that water users associations in any form would be needed in that situation, the question is to what extent the general absence of such organizations is a valid argument to postpone a policy decision on this matter.

The paper by Mehta and Jain provides some information on a few examples of various forms of water users associations in different states, including farmers' responsibility for maintenance. It shows that although positive effects can be observed, particularly on water distribution, more monitoring is to be done and information to be collected to assess the full implications and potentials.

Finally, there is the responsibility for maintenance of drainage systems. There seems to be scope for better defining the responsibilities for the various levels, particularly for the secondary and primary drains, including the structures.
5.4. Financing and cost recovery

The first maintenance aspect addressed in India is usually the financing. Funds are said to be too limited for proper maintenance and an increase of water fees is advocated to better cover operation and maintenance costs. Interesting information has been presented on the various aspects of maintenance costs and cost recovery.

First, the Indian practices make it difficult to distinguish between costs for operation and for maintenance. This particularly regards the establishment costs involved.

In general, the collection and processing of much more and correct data on financial aspects should urgently be improved. This concerns actual expenditures, demands raised, collections and cost of collections. The figures are now available for a few states only, which is insufficient to get a workable nation-wide picture.

Papers by Singh and Jain and by Desai and Jurriëns discuss various financial issues. The first paper concentrates on expenditures and norms. The second elaborates on these aspects and adds considerations on water charges, fee collection and comparison of costs and cost recovery. For the five large states concerned these papers reveal the following picture:

- Funds for O&M are indeed limited and they have not kept pace with the increasing need for maintenance. The amounts really required are not known, however. Estimates are in the order of Rs 250-450 per ha. The most recent recommendations come down to at least Rs 180 per ha.
- Actual expenditures vary widely, they have gradually increased to a present level of some Rs 90-220 per ha. For two states the trend also holds when converted to 1986 price level, for the other states this yields a decrease in real terms.
- There is a clear tendency to use a larger part of the available funds for establishment, leaving a smaller portion for the actual maintenance works. The latter portion decreased from 55% to 45% on the average.
- Norms and levels of water rates vary considerably amongst the states. The general level varies from about Rs 50-120 per ha.
- Demands raised to the farmers vary considerably; on the average they are at a level of Rs 35-150 per ha and tend to decrease.
- Actual collections again vary, from some Rs 20-105 per ha with an average of Rs 65 per ha, which gives an average rate of collection of 80% of the demands raised (varying from 60-120%). Although this includes collection
of arrears, they also show a tendency to decrease. The costs needed for the collection activities are difficult to estimate because of varying practices and a lack of clear data.

The average percentage of the expenditures finally collected slightly decreased from 49% (17-91%) for the entire period to 41% (10-87%) in the recent years. This leaves an average deficit of Rs 95 per ha (varying from 10-200) compared with expenditures.

**EXPENDITURES**

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**RECOVERIES**

Figure 1. Costs and cost recovery (Rs per ha)

The above is depicted schematically in Figure 1. It confirms that financial means for maintenance are limited and moreover, that they are only partly recovered via water rates. But it is also clear that the first thing to be done would be to really charge and collect the water charges. Only thereafter, one could discuss a possible increase in water rates. And in such discussion, all papers on financing advocate to take a broad socio-economic view on the issue, taking into account all other agricultural inputs and all direct and indirect costs and benefits, both from farmers’ and Government standpoint.

It is shown that from a point of view of farmers budget, some increase of the water rate should be acceptable, but there is general consensus that inclusion of capital costs is not realistic.

Mehta and Jain provide some details on financial arrangements and practices in some cases where maintenance responsibility (mostly within the outlet
command) was handed over to the farmers.

Finally, Dikshit and Maheshwari argue that the practice of providing funds from non-plan funds leads to states asking too little money for maintenance, in order to be able to get more for capital works. And they feel that the state-wise standard norms do not sufficiently take into account system specific differences, and provisions should be made to enable urgent and special repairs.

5.5. Maintenance timing and frequency

Bhargava and Kumar give detailed recommendations for timings of various activities. It might be appropriate to follow their approach for every individual system, identifying the various activities required at different levels in the system, and indicating best timings for each of them. But considering the large systems and the limited finances, a fixed programme with such timings will have to be limited and selective. An effective approach in most cases will be to resort to the additional flexible and dynamic maintenance they advocate. As indicated above, alert monitoring, involved and committed staff and good communications are then needed.

At lower levels in the system, it requires a good report with the farmers and effective actions in case of illegal interference. However, most effective would probably be to improve the quality of the irrigation service, which would reduce the needs for maintenance and repair.

5.6. Maintenance techniques and methods

For long time to come, maintenance execution in India will largely be done by manual means. Yet, under specific circumstances, for instance impossibility to put canals dry or short time available, mechanical means may be needed. This is pointed at by Bhargava and Kumar and by Maheshwari. It would be useful to develop criteria on when and where mechanical maintenance would be appropriate. Because of the limited experience with such equipment, experiments will have to be done to find out the best technical solutions, costs and benefits.

With increasing demands for environmental protection, chemical maintenance will most likely have a limited future for selective applications. Prospects for biological methods would have to be explored.
6. GENERAL CONCLUSIONS

For the Indian situation, the above indicates that improvements are needed in the following respects:

- attention for maintenance, particularly also for the drainage system;
- clear delineation of responsibilities, particularly with respect to fee collection, outlet command maintenance and drain maintenance;
- inventory of present practices and problems;
- analysis of costs and benefits;
- maintenance data base, nation-wide, state-wise and system-wise;
- financing and cost recovery policy;
- responsibilities and rights of farmers;
- procedures etc. for monitoring and execution, including staff performance;
- identification of needs and criteria for mechanical execution;
- adequate communication systems;
- good relations with farmers, but also implementation of sanctions.

It would be useful to set up a Task Force on maintenance in India, similar to the Dutch Working Party described by Siefers. Such Task Force could initiate, coordinate and monitor research and activities on most of the above issues.

Besides, a pilot project should be initiated, perhaps in areas with different characteristics. Such project could not only collect necessary information on above issues, but also gain practical experiences with the development and monitoring of maintenance programmes. This should include not only the technical aspects, but also look into all institutional, financial and legislative aspects mentioned throughout this publication. The Dutch experience has learned that to be effective, maintenance should encompass the entire package. The project could also collect more information on specific aspects of maintenance of lined canals, of drains and of outlet command maintenance.
RECOMMENDATIONS

of the

SEMINAR on MAINTENANCE OF

IRRIGATION AND DRAINAGE SYSTEMS

New Delhi, December 1991
SEMINAR RECOMMENDATIONS

RECOMMENDATIONS OF THE DECEMBER 1991 SEMINAR

1. Maintenance - adequate upkeep of completed irrigation and drainage systems - shall be considered of crucial importance in order to come to sustainable development in social, technical and economic terms. In this sense, maintenance should be considered along with the need for proper management and operation. There is a need for committed and experienced system managers and operators for maintenance. Separate O&M units should be created on large systems, and to the extent possible, training of personnel involved in maintenance should be initiated.

2. Rehabilitation of systems, which have deteriorated due to neglected maintenance should be taken up as regular activities of the irrigation sector. Works involving heavy expenditures, for instance lining and remodelling of structures, shall be taken up judiciously.

3. The quantity and quality of maintenance, its required frequency and mode of execution, shall have to be identified for each system. A proper data base of the system and an adequate monitoring system are required to that end. Prioritization is to be resorted for timely and preventive maintenance.

4. In many systems, maintenance will have to make use of local labour, in view of employment and income generation. Under specific circumstances such as hazardous situations, impossibility to put canals dry, requirement of fast work in a short period, etc., mechanized maintenance may be appropriate. Criteria should be developed on when and where to apply mechanization.

5. Irrigation system maintenance should cover the entire command, above as well as below the outlet. However, policies and programs above and below the outlet will ask for entirely different packages of solutions concerning institutional, organizational, technical, legislative and financial aspects. Above the outlet there will be hardly any farmers involvement, whereas below the outlet this will be essential.

6. Maintenance of drains should be an integral part of the maintenance program, particularly also to avoid the problems of water logging and salinization. New institutional structures will have to be developed, taking into account the differences between farm and tertiary drains, secondary drains between chaks and primary drains, currently all being under different
7. Involvement of farmers, in both operation and maintenance below the outlet, is considered very necessary for maximizing returns from irrigation projects. This aspect should receive high priority for development and implementation. To make farmers involvement effective, legislative backing and financial incentives will be needed in the initial years.

8. In the above respect, serious attention should be given to recent experiences with handing over the entire responsibility (management, including maintenance) for minors or small distributaries to farmers.

9. The irrigation water rates should be revised, to take care of at least O&M costs of the main system, including main drainage. Coverage of such costs for maintenance below the outlet, including field and chak drainage, depends on the institutional and legislative policy in this respect, which is urgently to be developed, improved or implemented. Suitable and effective means and procedures should be developed or improved for collection of the water fees. Subsidies may be restricted to tribals and other weaker sections of the society such as small and marginal farmers. Subsidy patterns for different types of schemes should be in the most judicious manner on telescopic pattern to be tapered down with a time frame. Plan- and non-Plan funds are to be viewed together so as to set apart some funds in the form of depreciation reserve fund as in vogue in industrial and commercial sectors.

10. Maintenance practices in The Netherlands, based on a long-time development and experience, show that the ultimate success and effectivity of maintenance is not a matter of some technical aspects only, but depends on the integral package of institutional, organizational, technical, financial and legislative aspects, all clearly describing rights and duties of government and farmers. Lessons from these experiences could be taken into account in the development of maintenance policies and plans in India.

11. It is recommended to initiate a pilot project on which the entire package, as described above, will be further developed in detail, implemented and monitored. In order to obtain experience with the varying circumstances in the country, such programs would have to be carried out in several distributaries with different conditions.
12. Similar to the Dutch situation, a Task Force on maintenance should be installed, to make inventories, to collect and analyze information, and to initiate and guide research and execution programs. It could also act as a Steering Committee for the above mentioned pilot project. Again this Task Force should cover all relevant aspects and disciplines and comprise representatives of the various departments and institutions involved. Advantage may be taken of the International Program of Technology Research in Irrigation and Drainage (IPTRID), or similar International programmes.
About the Author

Graduating in Civil Engineering from the University of Roorkee (India) in 1959, Prof. K.P. Jain joined Uttar Pradesh Irrigation Department. During the last more than three decades, Prof. K.P. Jain has been working on Water Resources Development Projects, engaged in investigations, planning, designing, construction, maintenance and operation.

For the last about 10 years, Prof. Jain is responsible for the training of in-service personnel in Irrigation Management as Professor, Water And Land Management Institute-UP. Prof. Jain has been associated with Indo-Dutch Water Management Training Programme (WAMATRA II) of the Govt. of Netherlands & Govt. of India.

Prof. Jain has visited many countries for studying Irrigation Management in South Korea, Morocco, China, Brazil, France, U.S.A., Netherlands etc.

Prof. Jain has authored large number of papers for various journals.
ABOUT THE BOOK

Irrigation and drainage systems have to be well maintained to enable them to perform their functions and realize the irrigation objectives.

Eight papers in the first part of this book deal with various maintenance aspects in the Netherlands showing that it involves not only technical issues, but institutional and organizational, financial and legislative arrangements as well.

In India, with its many and large irrigation systems, the importance of maintenance is increasingly being realized. In second part of the book, eight Indian papers discuss number of financial aspects, but also deal with some technical and managerial issues.

The book contains a wealth of interesting information from two different cultures and may provide a substantial contribution towards better maintenance and thus development of sustainable Irrigated agriculture.