Cost effective and sustainable maintenance: some ways to adapt and develop the technological approach

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Cost effective and sustainable maintenance: some ways to adapt and develop the technological approach

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SUMMARY - This paper considers some examples of current maintenance practice and examines the cost effectiveness of these methods as used. The need for further research into maintenance technology is identified.
Timely and appropriate maintenance of irrigation and drainage systems is necessary to sustain the delivery and removal of excess water. Whilst there is no doubt that there is an important organizational and management dimension to successful maintenance there is also a need to use efficient and effective technological solutions.
This paper discusses, with examples, how new and adapted technologies can be used for maintenance in developing countries. Examples of successful technologies and practice in the water sector in other countries along with what works in other sectors, like transportation will be used to determine what the practical research needs are and what can be done at the design stage, or more commonly the modernization stage, to make the best use of maintenance technology.

Key words: Maintenance, irrigation, drainage, technology, research.

RESUME *- La présente communication examine quelques exemples de pratique de maintenance actuelle, et examine la rentabilité de ces méthodes telles qu'elles sont utilisées. Le besoin de recherches supplémentaires en matière de technologie de la maintenance est identifié.*
La maintenance opportune et appropriée de systèmes d'irrigation et de drainage est nécessaire afin d'assurer la durabilité de la fourniture en eau et l'écoulement d'eaux en excès. S'il n'y a aucun doute qu'il existe une importante dimension d'organisation et de gestion pour une maintenance réussie, il est également nécessaire d'utiliser des solutions technologiques efficaces et efficientes.
Le présent article examine, exemples à l'appui, comment des technologies nouvelles et adaptées peuvent être utilisées pour la maintenance dans les pays en développement. Des exemples d'utilisation réussie de ces technologies dans le secteur de l'eau dans d'autres pays, avec ce qui marche dans d'autres secteurs, tels que le transport, seront utilisés pour déterminer les besoins pratiques en matière de recherche et ce qui peut être fait au stade de la conception, ou plus communément au stade de la modernisation, pour tirer le meilleur parti de la technologie de la maintenance.

Mots clé: *Maintenance, irrigation, drainage, technologie, recherche.*

INTRODUCTION

This paper emphasizes the role that technology, in a broad sense, can play in making maintenance and operation of irrigation and drainage more effective. Effective applications of physical resources offers the promise of lower recurrent costs and sustainable agricultural systems.

A significant proportion of irrigation and drainage systems constructed over the last few decades perform below design expectations. Whilst the rate of deterioration and ageing of any system, with its consequent reduction in performance, is to be expected, the rapid deterioration of performance appears to be far higher than anticipated by the designers. In some instances the long period between construction and operation has resulted in deterioration even before the system has become fully operational. For example the Rajasthan canal in India is in need of repairs even though construction has not been completed. The lack of timely and adequate maintenance, defined as the physical activities required to keep the system functioning in accordance with an agreed level of operational service, is a major cause of inferior performance of irrigation systems. Ostrom *et al* (1993) define maintenance as "any activity that slows the deterioration of a facility, whether caused by use or aging". Maintenance can also be thought of as the investment to pre-empt an early deterioration or failure in the system. Poor system maintenance exacerbates the unwillingness to pay water charges and soon the irrigation agency is in a vicious circle of poor maintenance -declining water charge collection- insufficient funds - less maintenance.

The process of giving some form of financial autonomy and providing for devolution or hand over of all or part of the irrigation system to users is now being seen to have a positive effect on maintenance in many countries. Experiments are already underway in Indonesia (for irrigated areas of less than 500 ha); Mexico (for large scale systems covering up to 50,000 ha); parts of Pakistan (in the Northwest provinces in particular); Senegal and Madagascar. Significant lessons have emerged from past progressive experiences of countries like Philippines and Colombia. In Mexico newly formed Water User Associations having taken over responsibility for maintenance are already planning to make maintenance more cost effective. Management advancements can not proceed alone however and the adaptation and application of successful technologies and techniques is also needed.

MAINTENANCE EXPENDITURE

There is no doubt that adequate expenditure of financial and human resources on the maintenance of irrigation and drainage is vital if the long term benefits of the developments are to be sustained. Maintenance tasks need to be carried out effectively at a cost commensurate with the level of operational service to be provided. Maintenance budgets in many developing countries still appear to be inadequate though. For example, in Pakistan, O&M expenditure in 1985 was only a quarter of what was required, (McLoughlin 1988).

Projects underway in Egypt and Mexico indicate the magnitude of the investments needed to improve maintenance. In Egypt, a World Bank and Egyptian funded Channel Maintenance project ($126.9 million) started in 1988 with the objective of making maintenance of 48,000 km of public irrigation and drainage channels more efficient, (The World Bank component of $45 million is expected to be completed by December 1995. The European Community has now allocated ECU40 million for a restructured project (revised cost $261.8 million) which includes a greater component for technical assistance and equipment.) Cost effective methods and technologies of maintenance and the strengthening of institutional capabilities are the main tools to reduce the total maintenance budget by 40% The Irrigation and Drainage Sector project in Mexico which is jointly funded by the Government of Mexico, the World Bank and the Inter-American Development Bank totals $1.2 billion. Of this total $77 million has been earmarked to rectify the problems caused by deferred maintenance and $62 million for the purchase of O&M equipment (mainly light-weight weed and sediment control equipment) for use within irrigation districts scheduled for hand over.

DECISION MAKING

Unfortunately there is little economic analysis and no effective literature giving guidance about operations and maintenance. What material that exists is not widely disseminated especially among the developing countries. The economic, environmental and social impacts of the lack of maintenance or ill timed, inadequate maintenance on irrigation efficiency, equity and reliability are not readily available. The need to place a value on maintenance or the lack of it is an important step towards planning and managing maintenance activities. Not until the high costs of neglect of maintenance are recognized and quantified can progress on obtaining adequate funds for maintenance be achieved.

Making cost effective maintenance decisions requires technical information on how well the system is functioning, before and after any maintenance activity. Simple and reliable diagnostic methods are required which can be used by operators and irrigation service agencies. Information or guidance is needed on how effective the particular action(s) will be, for example, background research on understanding how maintenance work will impact the channels of a system. In the case of a certain length of channel, what machine should be used and over what time period? Should all the material be removed? What happens if only a portion of the work is done? What will be the consequence of deferring the activity? Is there an alternative strategy, such as adopting longer term solutions requiring a capital investment now to reduce recurrent costs in the future, ie. sediment exclusion devices or grass carp for weed control?

TECHNOLOGICAL ASPECTS

In many countries inefficient and inappropriate technologies continue to be used with the result that a tremendous backlog of maintenance work builds up. In Thailand, Plusquellec and Wickham (1985) found that equipment, manpower and budget were all insufficient to carry out maintenance to the required standard. The misapplication of herbicides and weed cutting and dredging, by using the incorrect chemicals at the wrong concentration or an inappropriate machine at the wrong time of year, has led to poor control. (Brabben 1988). Reducing the number of maintenance workers in a system, as was the case in the Angat-Massim Rivers Irrigation System, (J.A. Weller, pers. comm), may give financial gains in the short term but if, as a consequence, scheduled work is beyond the physical capabilities of the remaining workers then system performance will degenerate. A combination of these inefficiencies has in turn reduced the ability of many irrigation agencies to provide an adequate service and required expensive rehabilitations.

The scale of operations may also have an effect on the implementation and success of maintenance. Large irrigation and drainage undertakings should be able to afford large pieces of machinery, however with the growing desire to pass the operation and maintenance on to farmer groups or water users associations these groups may be unable to operate such plant unless they sub-contract the work to a company specializing in supplying and operating such machines. As pointed out by Moore (1988), in Sri Lanka "certain maintenance functions - notably the repair of sluices - are beyond the technical capacity of farmers". The likely consequence is that maintenance requiring specialized equipment and people will not be undertaken unless high technology solutions can be made workable. There is, of course, a possible advantage in that smaller groups will be more responsive, less bureaucratic, more able to hire recently skilled staff and free to use newer more appropriate machinery.

New designs and rehabilitations should also consider the needs of the maintenance operatives. Routine and periodic maintenance, particularly on mechanical and electrical components of the system, is cost effective in the long run. Difficult access, incompatible machine parts, heavy components and the unavailability of spare parts, when and where needed, can make simple tasks difficult and often impossible. This is perhaps obvious but there are numerous reports of expensive modifications having to be made because of the poor provision for maintenance access.

The quality of construction can also have a long term impact on the need for maintenance. The use of poor quality materials may give capital savings on projects. An increased rate of deterioration and risk of sudden failure may be the result though. Information on the use of appropriate materials and guidelines for the construction of irrigation and drainage structures is available but improved training and dissemination of best practices needs to be continued and expanded. Skutsch (in press) details maintenance needs for irrigation and indicates the scope of research that is still needed. Groups such as the International Commission for Irrigation and Drainage can provide a useful role in promoting better construction practices and training especially to user associations as they take over irrigation systems.

Making maintenance effective - an example

Maintenance budgets in some run-of-river irrigation schemes are dominated by the costs of removing sediment deposits from canals. This removal is an acceptable and affordable part of maintenance in systems where there is only a small sediment input, however desilting costs become excessive when the ingress of sediment is large. If the resources are available only to desilt part of the system each year then the canals will cease to be effective carriers of irrigation water resulting in a progressive decline in the irrigation area served.

In the Agno River Irrigation Scheme, Philippines, the sediment problem can be acute. Large sediment loads in the river due to upstream mining activity, high rates of soil erosion and recent earthquake stimulated landslides mean that material gets into the system's canals during the wet season even though studies showed that the intake was performing as designed. The area served during the wet season has declined by about 1,000 ha/year, only about 50% of the 18,000 ha scheme can now be irrigated. To be viable the scheme needs to irrigate throughout the year with only a short close down and maintenance period, but this was insufficient for the National Irrigation Agency (NIA) to remove the large quantities of sediment deposited in the main canals. A method of extracting most of the coarse material (sand) in the head reaches of the main canal was needed. Whilst some finer material would still get into the canals it would be possible for NIA and the users to remove these deposits in the traditional way of dredging and digging.

The planned solution was to make existing maintenance activities more effective by investing in a sediment extractor. Chancellor (1991) reports that a vortex tube sand extractor was proposed by HR Wallingford and subsequently designed and constructed by NIA with financial aid from the United States Agency for International Development in 1991. The total cost of the works was $250,000. The vortex tube is used to extract sand from the canal and return it to the river during the wet season and a settling basin approach is used in the dry season when sediment loads are lower.

With the sediment control works it is estimated that the costs of sediment removal will be around $80,000 per annum compared to $245,000 per annum without the investment. Chancellor (pers. comm.) reports that the system is now working, maintenance costs have been reduced in line with estimates and the deterioration of the scheme halted. Her analysis indicates internal rates of return of up to 90%. Wet season cropped area has increased improving incomes for farmers and helping NIA recover more of the irrigation service fee. The lesson is that with good field studies, an affordable technology can be used to make maintenance more effective, the system viable and irrigated agriculture sustainable.

Sustaining weed control - an example

Submerged aquatic plants in irrigation and drainage channels can have a significant detrimental effect on hydraulic performance. Vegetation needs to be controlled within a planned program of maintenance if an acceptable level of performance is to be preserved. Aquatic weed maintenance controls can be broadly classified as (i) mechanical; (ii) chemical; (iii) biological and (iv) environmental.

At present most mechanical and chemical methods are probably not sustainable in terms of running costs and environmental risk. Mechanical methods are common ranging from large dragline dredges to small flail cutters. In the past many machines were slow and running costs for fuel, skilled operators and maintenance were high. New developments in size, efficiency and clean disposal are making these methods attractive. Tractor side-mounted cutting buckets operating from a 60 kW machine can clear vegetation from 2 km of a 20 m channel in a working day. Under good conditions and skilled operation this can increase to 5 km. Chemical control, with great care, can be effective however there is a limited range of expensive ($100 to $2000 per ha.m of weed infested volume) herbicides available for use on submerged species. For example, in the US, there are only six suitable herbicides for use in water and then there are severe restrictions in water for potable or irrigation use.

Numerous experiments and pilot studies around the world have determined the conditions for the successful breeding and introduction of grass carp (*Ctenopharyngodon idella* Val.) The strategy is a long term one and after an initial capital investment for a breeding station and skilled staff it is possible to keep submerged weeds at acceptable levels with a modest annual investment. In the 185,000 ha Imperial Irrigation District, California, a grass carp program was introduced in 1979 to eradicate hydrilla, (a submerged alien plant). By 1992 a total of $5.3 million had been spent to establish a fully operational grass carp program, build the breeding station ($350,000), train staff and carry out a full and intensive research and evaluation study. Use of sterile fish, to avoid any unwanted breeding from escapees, has resulted in the hydrilla infestation being reduced from the length of actual infestation and all the channels downstream that could be infested of 1100 km in 1988 to 40 km in 1992 at an average cost of $380,000. (Costs include capital, research, monitoring and training). Mechanical clearance used to cost between $400,000 to $500,000 per year prior to the introduction of the fish. Annual costs of operating the grass carp program in the Imperial system average $72,000 per year. 87,000 grass carp were produced in the four years, 1990–93, for a cost per fish of $4.86.

Another longer term method is to introduce a range of controls at the design or rehabilitation stage. Such methods can be classed as environmental as the aim is to make the canal a less suitable habitat for submerged weed growth. Passive techniques, like shading from trees on the banks, deeper canal sections and higher sediment loads, can limit incident light and so reduce weed growth, (Dawson & Brabben 1991). Environmental interventions by altering the management of the weed, cutting to remove reproductive parts of the plants or to remove food stores, all rely upon using knowledge of the biology of the target plants to find ways of minimizing growth for minimum maintenance effort. Westlake and Dawson (1986 & 1988) report on successful control strategies that are in use in the US, Netherlands and UK. In one example the technique of pre-emptive cutting can reduce annual costs by 30%.

No one method will be effective in controlling and sustaining the control of submerged weeds in irrigation systems. However the application of new low cost and efficient machines in combination with biological and environmental methods probably offers the greatest chance of achieving sustainability. For this to happen requires adaptive research, greater dissemination of existing control programs in developed countries and closer cooperation between disciplines.

IPTRID - IMPROVING MAINTENANCE TECHNOLOGIES

The IPTRID experience is that the technical challenges for improving maintenance of irrigation and drainage systems can be broadly grouped as follows: (i) understanding the impacts of not performing adequate maintenance; and (ii) choosing maintenance methods and technologies that are sustainable, technologically, financially and environmentally.

The first group of challenges and problems requires more research and demonstration of the importance of maintenance in protecting irrigation and drainage investments. Determination of an adequate level of maintenance will depend upon the nature of the system and the service being provided. Studies under the first group are aimed at assisting policy makers and planners. The latter grouping requires research and technology development to survey and assess successful maintenance methods and to adapt and develop where necessary. The results of studies and developments in the second group are aimed at providing irrigation service agencies (public and private) with selections of best practice to achieve maintenance targets and sustain them.

Technical research needs identified in IPTRID country expert missions indicate the importance of finding sustainable and practical solutions to the challenges of excessive weed growth, reduction of sediment deposition and the functioning of open surface drains. Basic research has been undertaken in many countries to understand these problems. In many instances there is a gap though between research and the application of the knowledge to develop practical control methods. The missions found that the technology research needs could be met with a greater emphasis on pilot studies and improved dissemination of information. For instance, the results of studies on the efficacy of particular maintenance techniques need testing and adapting in the target countries. Likewise the results of studies and successful adaptations need to be spread to a wider audience (Brabben 1992). Therefore, over the next few years, there is likely to be an increased need for human resources development based upon sound understandings of deterioration and the networking of maintenance professionals with researchers to improve the choice of techniques and equipment. The need to start pilot studies on drain maintenance and integrated sediment and weed control in several countries is emphasized if realistic and cost effective choices are to be made.

IMPROVING MAINTENANCE CAPABILITIES

Maintenance is not accorded the same attention as the design or redesign of irrigation and drainage schemes, too often it is taken for granted. Expenditure is often deferred without apparent loss or harm with the result that available finance is diverted from maintenance to activities with greater impact (ie. new construction). This is human nature, maintenance is not glamorous and maintenance engineers are accorded little status. The increased demands to use water more efficiently and to meet higher operating standards means that maintenance must become a specialized task. However, maintenance activities are still being grafted onto the existing operational offices resulting in poor execution due to overstretched and unskilled personnel. The transfer of systems to water user associations without adequate provision for maintenance may result in rapid deterioration. Sophisticated maintenance may be beyond the capabilities of most farmer groups or individual farmers in the first years of hand over. Without technical training, suitable equipment and resources there is a danger that inadequate maintenance will continue. Gorriz *et al* (1995) report on the transfer of irrigation management in Mexico and stress the need to monitor the sustainability of system maintenance. Subramanian (1995) warns that long-term maintenance needs in water-user groups in Egypt still have to be determined.

Improved information and communication systems, appropriate equipment, improved materials, better designs, construction and supervision, integrated approaches to weed, silt and sediment control are illustrations of technological changes that will be critical for improved maintenance. Existing manuals and guidelines highlight some of the possibilities for reform. These are indeed the starting points for planning an improved maintenance program. However, application of these manuals will depend on the capacity of institutions to adapt them to local conditions and on the policy, financial, technical, and institutional support they receive. Promoting the need for maintenance improvements to irrigation managers will be unproductive unless senior policy makers are convinced of the need.

An education and training program aimed at all levels of decision making is required. IPTRID plan to give a lead with background studies starting in 1995. The example of the World Bank's Economic Development Institute policy seminars on the roads maintenance initiative, (Carapetis *et al*, 1991), would be an interesting model to follow in the irrigation and drainage fields. Here the aim was to bring together senior policy makers and so facilitate policy change. This was prior to any proposed training and education aimed at institutions and technical people. The roads maintenance experience indicates that policies have to put in place to elevate maintenance activities in importance (especially in educational establishments) and encourage workable institutional arrangements. Further training in aspects of hand-over of maintenance functions, supervision, regulation, financial tools, technical aspects are all needed if existing irrigation and drainage authorities are to implement better maintenance. Considerable research to develop the necessary in country training programs and follow up is needed.

The use of maintenance specialists from other utilities and from water service industries in the training of maintenance staff is of prime importance. The further development of twinning arrangements between organizations such as Irrigation and Water Districts, Drainage Boards and River Basin Authorities with Irrigation and Drainage authorities in developing countries offering practical, long-term involvement that could provide a wide range of training and technology collaboration. Twinning arrangements, comprising several medium to long term pilot studies, may also provide the continuity between research organizations within and outside of the target country. The experience of twinning arrangements in other disciplines is that they allow in-depth technology collaboration to proceed at a pace acceptable to the recipient.

FUTURE DIRECTION

IPTRID's role in the theme of improving maintenance technologies is to: (i) encourage the development and application of good maintenance in irrigation and drainage systems; (ii) facilitate the preparation and support for research and development studies to improve maintenance techniques; and (iii) give a lead for capacity building by the collation and dissemination of maintenance and rehabilitative research results, technology developments in maintenance, and a network of maintenance professionals and researchers.

IPTRID is addressing these roles through activities in three broad areas: (i) developing and applying good maintenance; (ii) research and development studies and (iii) dissemination and capacity building.

Improvements to institution arrangements are important but so too is the availability of technologies that allow maintenance professionals to achieve cost effective and sustainable irrigation and drainage systems. In the long term, a change in the perceptions about maintenance has to be brought about. Carruthers and Morrison (1993) summarize the status of maintenance by saying "much maintenance presents arduous tasks and the potential returns are often not perceived by those involved in any project. This failure to recognise the value of maintenance is true for the aid community and governments, for irrigation agencies and farmers."

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