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John W. Humphries and Kenneth M. Strzepek

INSTITUTIONAL ISSUES IN IRRIGATION MANAGEMENT: DEWAHUWA AUGMENTATION SCHEME

Introduction

Agriculture has always played a central role in the society and economy of Sri Lanka. Today, more than 50 % of the 16 million people who inhabit this island off the southern coast of India earn their living through agricultural production. In spite of this large agricultural base, however, the country continues to import sizable quantities of food every year. With rising unemployment and overcrowding of the urban areas, expansion of the agricultural sector of the economy seems to offer solutions to several of the development problems facing Sri Lanka. Accordingly, the primary focus of development activities has been to increase agricultural productivity, and the principal means employed has been the improvement and expansion of irrigation facilities.

Rainfall in Sri Lanka is concentrated into two monsoon seasons. During the months of September to February, cool air from the Asian continent collects moisture as it passes over the Bay of Bengal in a southwesterly direction. Reaching Sri Lanka, this air mass deposits most of its moisture over the Greater part of the island. This period is known as *Maha,* or wet season. During the months of March to August, the heating of air over Asia draws air north from the Indian Ocean. The warm, moist winds bring rain to the southwest quarter of the island, but the mountains of the central highlands prevent the rains from reaching the remaining three-fourths of the country. This region, therefore, is referred to as the "dry zone", and this season is called *Yala,* or dry season.

In ancient Sri Lanka, cultivation in the dry zone was accomplished by an intricate system of reservoirs, or tanks, built by the Sinhalese kings. Due to invasions from India, outbreaks of malaria, and other factors, the Sinhalese civilization gradually shifted to the south and west, and these irrigation systems fell into disrepair. In the 19th century, the British colonial rulers began to restore the ancient tanks. The restoration of these irrigation systems has continued since the island gained its independence in 1948, and resettlement of the dry zone areas has formed a major part of the government's development programs. In addition to the rehabilitation of ancient schemes, numerous modern irrigation works have been built, most notably those constructed under the ambitious scheme, which includes four large dams, will provide irrigation for over 300,000 acres of new land (1).

Dewahuwa Tank, located in the dry zone of Sri Lanka, halfway between Kandy and Anuradhapura, is said to have been built during the 2nd century B.C. After being breached in the 10th century, it remained neglected until restoration began in 1946. The first thirty-five families moved to the Dewahuwa project in

1950, and ultimately, 468 families were resettled there. The Sri Lankan government provided each of these original households with 5 acres of paddy land and an additional 2.5 acres of highland on which to build their houses and grow vegetables and other rainfed crops. The third generation of settlers has begun establishing their families, so that more than 800 independent households now live within the project area.

During the first twenty years of operation at the Dewahuwa project, the farmers were able to harvest a fairly successful paddy crop in most Maha seasons, but no Yala cultivation was possible, due to lack of Water. In October 1970, the Government of Sri Lanka signed an agreement with the Japanese government to launch the Sri Lanka Japan Rural Development Project. The site chosen for the project was Dewahuwa. The project's goal was "to increase the agricultural and agroindustrial productivity so that direct benefit would be brought to the actual tillers of the soil while increasing the living standards of the inhabitants as a whole" (2). By 1974, the Japanese had concluded that insufficient water for Yala cultivation was the principal obstacle to the achievement of this goal, and they pledged their support for what later became known as the Dewahuwa Augmentation Scheme (3).

Dewahuwa Augmentation Scheme

Recognizing the need for additional water at Dewahuwa, the Irrigation Department conducted a study of the project area and, in 1967, reported that the only feasible source of additional water was the Nalanda Reservoir, located about ten miles southeast of Dewahuwa (Figure 1). The Nalanda Reservoir was constructed to provide flood control and irrigation water for the Amban Ganga river basin, and later, a channel was constructed to allow diversion of some of this water to the Kala Wewa irrigation system via Welamitiya Oya. Releases into Welamitiya Oya are controlled by the Ebbawela Regulator. The 1967 study investigated a plan to divert some of the water released from the Ebbawela Regulator to Dewahuwa by means of a link canal constructed between Welamitiya Oya and Kalugal Oya, which feeds into Dewahuwa Tank. Since the water from Nalanda was already allocated to other areas, and because they expected difficulties in land acquisition and in preventing encroachments on land along the canal, the report concluded that the construction of the link canal should not be undertaken (4).

When the Japanese arrived at Dewahuwa in 1970, work had begun on the first stage of the Mahaweli project, which included plans for the diversion of water from the Mahaweli Ganga to both of the areas served by Nalanda. Therefore, Nalanda's water would no longer be needed in those areas, and it seemed logical to make this water available to the farmers at Dewahuwa. Accordingly, the Japanese prepared "An Outline of Benefits Nalanda Diversion Can Bring" in May 1974. Two years later, in May 1976, the Irrigation Department published a feasibility report based on the Japanese study. This detailed report failed to acknowledge the probable difficulties which were expressed in the 1967 report and concluded that the

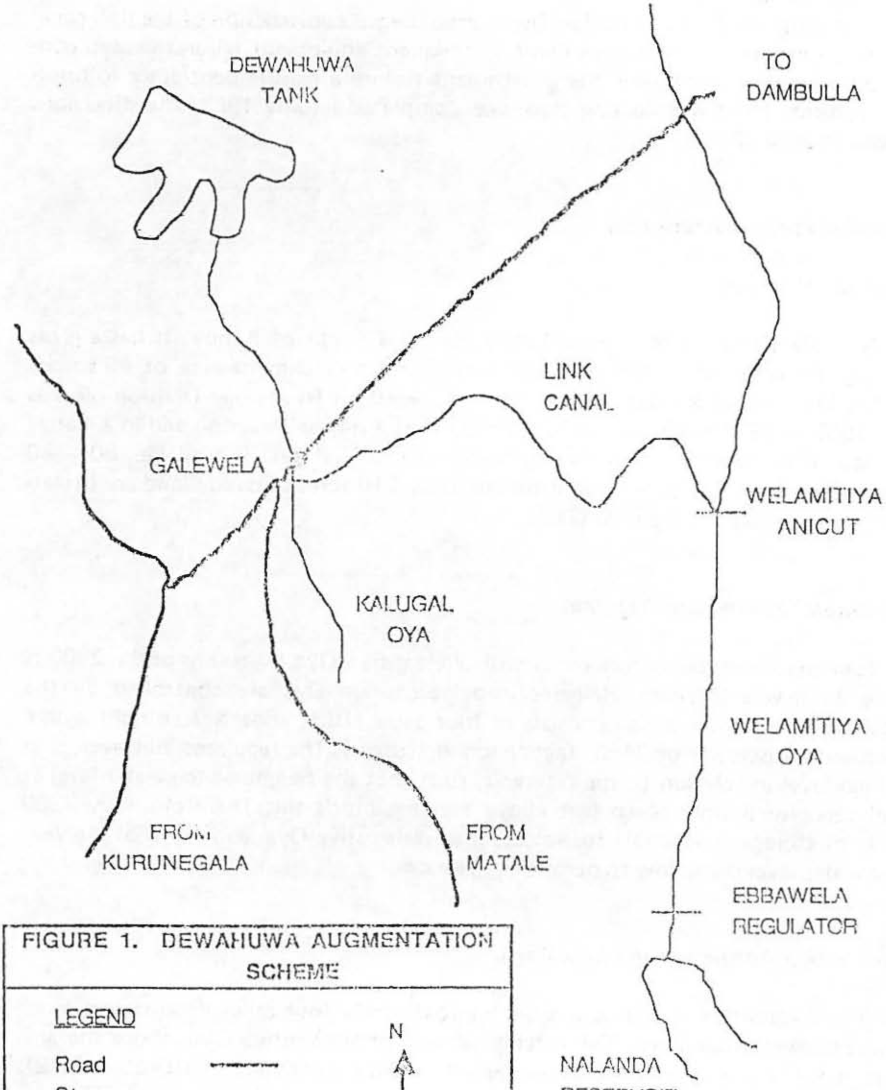


FIGURE 1. DEWAHUWA AUGMENTATION SCHEME

Dewahuwa Augmentation Scheme was "highly recommended for immediate implementation." (2)

In August 1978, the Irrigation Department began construction of the link canal using government-owned equipment. Subsequent equipment failures caused construction delays, prompting the government to hire a private contractor to finish the project. The five-mile-long canal was completed in July 1982, and diversions began in June 1984.

Detailed Project Description

Nalanda Reservoir

Nalanda Reservoir is approximately 30 miles north of Kandy. It has a gross storage capacity of 12,400 acre-feet (ac-ft) and a catchment area of 48 square miles. The average annual catchment yield, based on Hydrology Division records for 1958 – 1971 is 82,200 ac-ft. Nalanda is at a higher elevation and in a better climate than Dewahuwa. Although no reliable rainfall data is available, 80 – 90 inches per year would be a fair estimate. Only 210 acres of paddy land are irrigated below the dam at Nalanda (2).

Ebbawela Channel and Regulator

Nalanda Reservoir is connected with Welamitiya Oya by means of the 2300 ft long Ebbawela Channel. Releases into Welamitiya Oya are controlled by the Ebbawela Regulator which consists of four gates (18 ft wide X 7 ft high) with a maximum discharge of 7450 feet^3/second (cusecs). The regulator, however, is at a high level in relation to the reservoir, such that the height of the water level at full capacity is only seven feet above the regulator's sill. Therefore, only 3300 ac-ft of storage is available for release into Welamitiya Oya, and much of the year the water level is too low to permit any releases.

Welamitiya Anicut and the Link Canal

The Welamitiya Anicut is located approximately four miles downstream from the Ebbawela Regulator. The catchment area of Welamitiya Oya, above the anicut, is 8.1 square miles and provides an estimated annual yield of 10,450 ac-ft (2). The present anicut is an improvement of an old structure which provided irrigation water for about 100 acres. When the link canal was constructed, the anicut was improved to allow a diversion capacity of 130 cusecs into the canal.

The link canal is an earthen channel 5.25 miles long with a bed with of 14 ft and side slopes 1 on 1.5. The design capacity is 130 cusecs with a full supply depth of 3.5 ft. The channel gradient is 0.00035. The canal is designed not to interfere with the existing drainage pattern which feeds several village tanks near the canal. Many large conduits cross over the canal carrying the flows of small streams, and the canal itself is carried across one large stream via a closed concrete channel on the underside of a bridge. Flood control is achieved by an overflow spill located about one half mile below the anicut, and by side spills along the canal. Flow measurement devices include a Parshall flume just below the anicut and a weir gauge at the point of discharge into Kalugal Oya, approximately three miles south of Dewahuwa Tank.

Considerable disagreement exists between Irrigation Department documents and irrigation officials concerning the legitimate use of the diverted water. The Department's feasibility report states that the new canal "will be constructed to replenish Dewahuwa Tank and irrigate the ... 680 acres of existing lands along the canal route" (2). Today, however, the local irrigation officials contend that the only legal turnout along the canal provides irrigation for some lands belonging to a nearby temple. The extent of these lands is between 250 and 400 acres, depending upon whom one is asking. All other extractions of water from the canal are considered illegal.

Dewahuwa

Dewahuwa Tank is located in the Central Province, approximately 80 miles northeast of the capital city, Colombo, and 10 miles northwest of Nalanda Reservoir. It has a catchment area of 26.0 square miles and a gross storage capacity of 9.700 ac-ft. The estimated annual catchment yield is 27,600 ac-ft (2). The average anual rainfall at Dewahuwa for the period 1944 – 1974 was 61.0 inches (5) but only 52.0 inches for 1975 – 1986. The monthly distribution of the rainfall, shown in Figure 2, illustrates the difference between Maha and Yala seasons. The Dewahuwa scheme currently irrigates about 3000 acres in Maha. The Yala 1984 and 1985, approximately one third of the total acreage was cultivated. This proportion was increased to almost half in 1986. Only 20 % of these Yala cultivations are rice paddy, the remaining areas being used for other food crops which require less water.

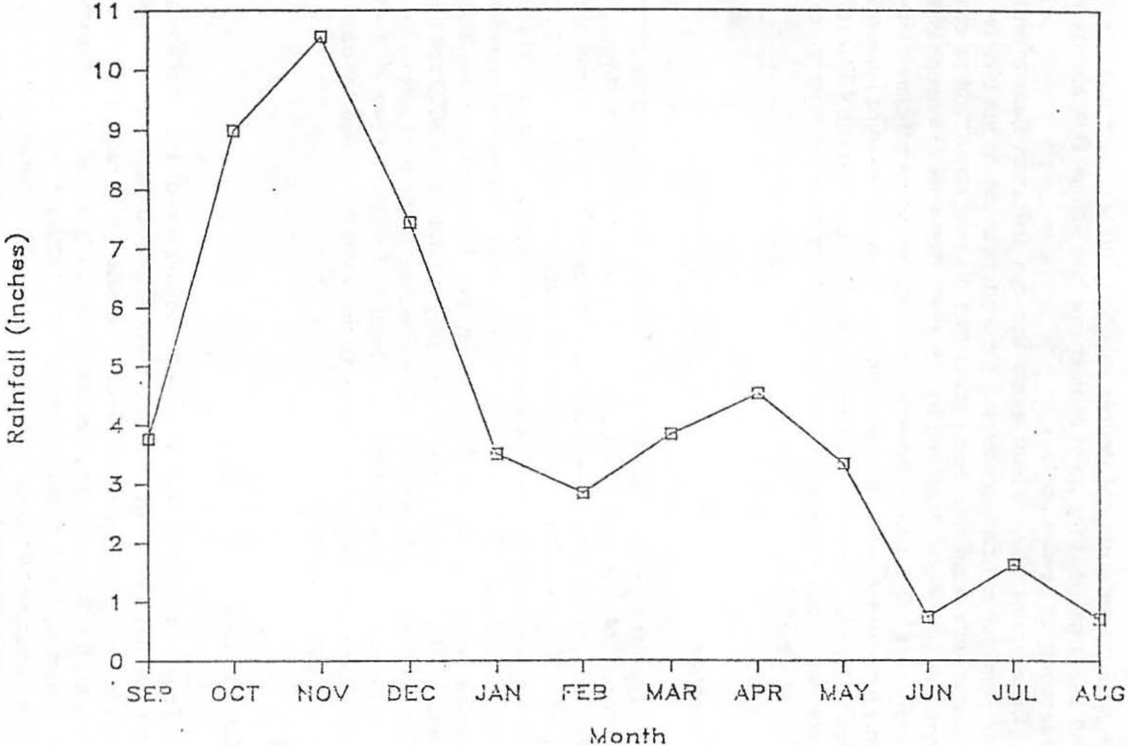
Current Study

Today, more than four years after completion of the canal and twelve years after the Japanese study, the Dewahuwa Augmentation Scheme is not functioning satisfactorily. The farmers of Dewahuwa have yet to receive any noticeable benefit from the diversion. Why has this project, which cost the government millions of rupees to build, failed to achieve its objectives? What steps can be taken to make it successful? Under the direction of the International Irrigation Management Institute (IIMI), I attempted to establish some answers to these questions. I spent two weeks living at the project site, gathering data and information from

FIGURE 2.

AVG MONTHLY RAINFALL — DEWAHUWA

1975–1986



irrigation officials, Irrigation Department records, IIMI records, and various other sources. I then spent two more weeks at IIMI headquarters, near Kandy, discussing my findings with members of the IIMI staff and conducting computer analyses of the data. Unable to reach any significant conclusions before the end of my stay, there, I have continued my study since returning to my home institution, Texas A & M University.

My search for answers to the questions posed at the beginning of the study has covered the nontechnical as well as the technical aspects of the project. Indeed, the nontechnical constraints were so readily apparent that I began to wonder whether any technical analysis was necessary. Recognizing that some things may have changed since I left Sri Lanka, I will outline these non-technical problems by relating some of my experiences and presenting some of the information acquired during the course of my study. The final two sections give the details of the technical analyses and some conclusions and recommendations.

Nontechnical Constraints

Institutional Structure

The institutiona structure of the bureaucracy which controls irrigation in Sri Lanka consists of three separate departments under two different ministries. The Agrarian Services Department, which in the Ministry of Agriculture, looks after all of the small tanks, defined as those irrigating less than 200 acres. The larger systems are divided between two departments in the Mahaweli and Lands Development Board was established to oversee the Mahaweli project. At that time, the Irrigation Department relinquished responsibility for all of the areas scheduled to benefit from this enormous scheme. Today the Mahaweli Development Authority has replaced the Mahaweli Development Board as the controlling agency in those areas. Although the Dewahuwa Tank is under the authority of the Irrigation Department, all three of these agencies have affected the operation of the Dewahuwa Augmentation Scheme.

The unusual complexity of the institutional structure surrounding this project makes it an interesting case study of the interactions between the three departments, as well as the operations within a single department. Since the water in the Nalanda Reservoir was intended for areas now served by the Mahaweli scheme, the proposal for an alternatve use required the approval of the Chairman of the Mahaweli Development Board before diversions could begin. This requirement may explain some of the delay in implementation. One of the extraordinary features of the Dewahuwa Augmentation Scheme is that it lies in three different irrigation districts within the Department of Irrigation. Furthermore, these three districts are administered by two different Deputy Directors (D.D.) of Irrigation. Nalanda Reservoir is in the Matale district, while the Ebbawela Regulator and the link are in the Dambulla district. Both of these districts report to the D.D. office in Kundasale, near Kandy. Dewahuwa Tank, on the other hand, is in the Mahailluppallama district under the D.D. office in Kekirawa. The administration and co-ordination of all these offices is the responsibility of the Matale Kachcheri. Thus, obtaining all of the desired information required spending two full days and several halfdays travelling to each of these places.

Communication between the departments is often slow, or even non-existent. In the 1986 Yala season, for example, agents from the Agrarian Services Department promised farmers along Welamitiya Oya that they would receive the water released form the Ebbawela Regulator. The farmers, therefore, increased their cultivation acreage in expectation of more water. Unfortunately, the Agrarian Services Department has no authority over the Ebbawela releases and did not consult the Irrigation Engineer (I.E.) at the Dambulla district office before making this promise. Therefore, when the I.E. began diverting the water into the link canal, the Welamitiya farmers were understandably angry. A major controversy was averted because Dewahuwa had received unusually high rainfall that spring, and the management agreed to allow the misguided farmers at Welamitiya to have the water which was promised to them (6).

Even within the Department of Irrigation, communication between the various offices seems to be lacking. The D.D. in Kundasale informed me that he had only recently instructed the I.E. in Dambulla to start keeping a record of diversion through the Welamitiya Anicut into the link canal. When I arrived at the Dambulla office, I found records of Parshall flume measurements at the anicut beginning in January 1984. I was not surprised, therefore, to learn that a formal request made by a group of farmers might take a full year to travel through the bureaucratic channels for conducting a study and submitting a proposal, before a decision can be made (6).

Politics

Of course, bureaucracies must operate within the framework of politics, and management of the Dewahuwa Augmentation Scheme is no exception. One of the major issues in the operation of the project is the illegal "tapping" of water by farmers along the link canal. Their siphon tubes and small pumps were operating without any attempt to hide them, yet the I.E. said that he was powerless to stop them. He explained that the farmers had appealed to the local Member of Parliament (M.P.), who gave them his tacit consent in order to keep them happy and voting. Due to the M.P.'s considerable political power, extending, perhaps, even to influence over the appointment of local irrigation officials, the I.E. was very reluctant to act against his consent. Similarly, a proposal for uniting the entire Dewahuwa project under one district office to facilitate its efficient operation will probably never be approved because it would most likely result in the dissolution of the Mahailluppallama district office. Since the Deputy Minister of Irrigation is from that electorate, it is doubtful that he would allow the office to be closed (7).

Financial Constraints

One of the major construction proposals included in the original plans for the Dewahuwa Augmentation Scheme was improvement of the Ebbawela Regulator, but this work was never completed. The proposal was to construct another regulator adjoining the Ebbawela structure, but ten feet below the current sill level. This new outlet would require deepening of the channel leading to the regulator, but would greatly increase the volume of water available for diversion. When the contractor began work on the proposed improvement, they discovered that the channel bed is solid rock, as is the foundation of the regulator structure itself. Thus, the work would require blasting operations which meant significant cost increases. The Irrigation Department decided not to spend the additional money, and work at Ebbawela was halted (8).

Due to the substantial amount of money the present government is diverting to National Security, the Irrigation Department's budget has become even tighter. Obviously, a shortage of funds affects many aspects of irrigation management. At the Dambulla irrigation office, for example, three of their four jeeps have broken down, and they are unable to pay for the needed repairs. Having only one vehicle to cover all the project sites in the district inhibits the effective monitoring of the projects by decreasing the frequency of visits to each site. The effects of the reduced budget are also noticeable at the field level. At Dewahuwa, the Technical Assistant (T.A.), who is the resident irrigation official, does not have funds for system maintenance. (Another factor contributing to this lack of operating funds will be discussed later.) Therefore, when a channel wall broke, it continued to flood the adjacent paddy field until the surrounding farmers repaired it themselves. While farmer initiative should be encouraged, their crude repair of the channel wall is only temporary, and they expect the irrigation department to repair it properly.

Physical Constraints

Physical constraints to the effective management of irrigation systems such as the Dewahuwa Augmentation Scheme include poor transportation and communication facilities. Many of the projects are in remote locations, requiring several miles of travel on poorly maintained roads that are sometimes impassable without a four-wheel-drive vehicle. Since telephones cannot be found in these areas, the irrigation officials must go to the sites to obtain information and to give instructions. Thus, much of the officials' time is spent travelling between sites. One afternoon, I went with the I.E. from Dambulla to see the Ebbawela Regulator. We reached Ebbawela, more than one hour of travel time from Dambulla, to discover that the gate operator, whom we wanted to see, had gone to Dambulla to talk to the I.E. Our principal purpose for going to Ebbawela was to verify that the gate operator had received the message to open the gates the day before. The gates were closed, indicating another communication failure. We opened one of the gates, but the absence of communication between Ebbawela and the Welamitiya Anicut prevented us from knowing, until two days later, that we had opened it too much. The flow was greater than the capacity of the link canal, and much of the water intended for Dewahuwa was continuing down the Welamitiya Oya.

Sociological Considerations

Regardless of the quality of design and construction, the success of an irrigation system depends on the actions and interactions of people – both individuals and groups. Recognizing this fact, an outline of a "feasibility study for irrigation system and settlement planning", distributed by the Irrigation Department in 1977, includes a recommendation for a "socio-economic study" of the proposed project area (9). In its 1967 report, the Irrigation Department listed four reasons for not recommending construction of the link canal; two of these reasons were based on sociological considerations. The report stated that building the canal "through an undeveloped area with good climatic conditions ... (would) immediately result in encroachments along it" and that the acquisition of private lands was "bound to be resented" (4). I found no record of any further sociological studies, and neither of the two later reports mentioned these anticipated difficulties. When construction of the canal was half finished, however, the local M.P. forced the Irrigation Department to halt construction and investigate alternate routes because farmers were unhappy about having the canal cut across their lands. The investigators found no viable alternative, and the canal was completed along the planned route (8). Today, those farmers who resisted the canal's construction are illegally irrigating their lands with water taken from the canal.

From an objective point of view, one can hardly blame the tapper for his actions. The farmers at Dewahuwa have not paid for the water flowing through his paddy field, nor did they pay for the canal construction. Their only claim to the water is that the government has designated it for them. But why should the government do that? Why should the farmers at Dewahuwa, who already have a tank, receive more water, while these farmers along the canal must rely on rainfall for their paddy cultivation? From the tapper's viewpoint, the government is obligated to provide water for him, as well.

This concept of government obligation to supply the needs of the farmers is an interesting problem in itself. Past and current government policies have fostered this attitude. Resettlement of the dry zone areas through restoration of ancient tanks has been a major focus of the government's development programs. To attract people to these resettlement schemes the government has offered free land, free irrigation facilities, and financial support. In 1984, the Dewahuwa management created an organization of farmer representatives to participate in management policy decision-making. At that time, they also began collecting operations and maintenance fees to help pay for the maintenance of the irrigation channels and agricultural extension classes held a few times each year. The goal of these moves is to gradually turn management of the irrigation system over to the farmers. Today, however, less than 25 % of the farmers are paying these fees; after thirty-six years of having everything provided by the government, they see no reason to start paying, now. This lack of farmer support, combined with reduced Irrigation Department budgets has left the management with insufficient funds to properly maintain the irrigation structures.

This inability to solicit farmer financial involvement also has some bearing on the problem of lowering the Ebbawela Regulator. According to the T.A. at Dewahuwa, the increased income resulting from a single year's cultivation of the full acreage in the Yala season would more than pay for the cost of modifying the regulator. The problems with that argument is that the farmer's increased profit is not going to help the government pay the initial construction costs, and obtaining a loan from an international agency such as the Asian Development Bank (ADB), would be very difficult for the government, at this time, due to its already large foreign debt. One solution, therefore, might be for the farmers at Dewahuwa to approach the ADB with a earnings each year to pay back the loan. This approach has been tried successfully on a much larger scale in the Philippines (10). The people with whom I have discussed this solution say it is impossible, at this time, since it requires a strong farmer organization with the ability to extract payments from its members. They say that the concept of paying for improvements contradicts the conditioning they have received over the last three decades.

Missing and Unreliable Data

Since hydrological conditions vary from year to year (or even day to day), primarily due to variations in rainfall, any study of those conditions must be for a long period of time in order to attain some degree of statistical accuracy. The researcher, therefore, must collect large amounts of detailed data for analysis. Obviously, the results of his study depend on the quality of his data, which, in turn, is dependent upon the careful measurement and tabulation of the physical phenomena that the data represents. I have concluded that much of the data I collected does not meet these requirements. A few examples should serve to support my conclusion:

— At the I.E.'s office in Dambulla, I was pleased to find records of Parshall flume height measurements from the Welamitiya Anicut since they would provide information about the volumes and frequencies of past diversions. When I visited the site, however, I was rather disturbed to find that the numbers for the gauge, which was painted on the flume, had all worn off, leaving only a thin red stripe with a few tick marks. To reassure me, the old man who records the measurements,ran up to his house and returned shortly, carrying a long pole. He walked to the edge of the flume, pushed the pole into the water until it touched bottom, then pulled it out and proudly showed me the water mark. Taking the pole back to his house, he found a tape measure and measured the distance from the end of the pole to the water mark, never wondering whether he had put the pole into the water at the correct position in the flume, nor if the pole had been vertical, nor if the water mark had changed while he walked back to his house.

- The I.E.'s office also had records of weir gauge readings from the other end of the link canal. These readings were recorded in feet and inches. When I went to that site with the man who records that data, I discovered that the gauge was marked in feet and tenth of feet. I watched as the man counted four marks below the 1-foot mark and recorded 0' – 8", when it should have been 0.6'.
- Using the data collected from records of changes in reservoir storage, reservoir overflow, and sluice releases, I attempted to estimate the amount of water flowing into Dewahuwa Tank each month. When I had finished the calculations, several of the months had negative inflow values, which, taken literally, meant that in one month almost 1500 acre-feet of water flowed back up the river. The absence of any recorded sluice releases in that month seems reasonable since no cultivation took place during that Yala season. One possible explanation for the missing water, however, is that the farmers asked to have some water released for domestic purposes (e.g. bathing and washing clothes), and since these releases were not for irrigation purposes, the management did not see the need to record them.

I found that much of the data I asked to see had never interested anyone before, and, therefore, I was the first to discover the discrepancies, the inconsistencies, and the gaps in the information available. When copying the Parshall flume heights, I found that records for the periods November 1984 to November 1985, and March 1986 to November 1986, were missing. The 1986 data was in the old man's notebook at the site (he had simply forgotten to send his weekly reports), but the other data was never found. Similarly, when I asked to see the rating curve for the flume, which would allow me to convert the height measurements to actual flow measurements, they couldn't find it. It had been lost, misplaced, or perhaps it had never existed. For almost three years they had been diligently recording feet and inches, not realizing that these measurements were meaningless without the ability to interpret them. Yes, the I.E. knew, but he was not the person recording the data. I believe many of the problems I found with the data, are the result of the person in the field not understanding the meaning and the importance of the measurements he is taking.

Technical Analyses

As noted in the previous section, much of the data collected during the study was determined to be unreliable. Therefore, the planned technical analysis based on computer modeling of the system had to be reduced to two largely theoretical, conceptual analyses. The first analysis is a modification of an operational study of the Dewahuwa Augmentation Scheme conducted by the Irrigation Department for their feasibility report. The second analysis is an examination of the flow characteristics in the link canal, including an assessment of the illegal tapping problem. Although these studies are less extensive than the original project proposal, they provide valuable insight into the problems facing the operation of the link canal and may have direct implications for the future successful management of the system.

Operational Study

In a 1982 letter to the Deputy Director in Kundasale, the I.E. in Dambulla wrote, "... I do not see the necessity for working out standing orders for issue of water from Ebbawela sluice into Welamitiya Oya to be conveyed into Dewahuwa Tank ... What is being issued ... is virtually spill water of Nalanda ... completely independent of the requirements of the fields under Nalanda. To my mind, there are only two considerations that should govern issues through Ebbawela. They are that Dewahuwa Tank should be below spill level and that there should be water above the Ebbawela sluice sill. As soon as both these conditions are existent, then water should be released into Welamitiya Oya" (11). This is precisely the system of diversion management adopted by the Irrigation Department in November 1986 and was, therefore, used in conducting this operational study. The earlier study done by the Irrigation Department used a more complicated approach to system management. Other modifications to the previous study included updating the monthly duty of water and the monthly evaporation figures for Dewahuwa and assuming conveyance losses in the streams and in the canal. Two separate studies were actually conducted. For the first study, conveyance losses were assumed to be 15 % for both Welamitiya Oya, between Ebbawela Regulator and the anicut, and the combination of link canal and Kalugal Oya, between the anicut and Dewahuwa. In the second study, the conveyance losses for the combination were increased to 30 % to account for the greater conveyance distance and the very low slope of the canal. The following assumptions were made for both studies:

- Cropping pattern at Dewahuwa in Yala 1985 an Maha 1985/86 is typical
- Rainfall and evaporation for these seasons is typical
- Therefore, monthly duty of water for full Maha cultivation and 1/2 Yala cultivation taken from sluice release records for these seasons
- Monthly water duty for full Yala cultivation estimated as twice that for 1/2 Yala cultivation
- Monthly evaporation for Dewahuwa Tank taken from evaporation pan measuremnts, using a pan coefficient of 0.75 (see Appendix for evaporation pan data)
- Monthly evaporation figures at Nalanda assumed to be 10 % lower than those at Dewahuwa since it is in a wetter climate, and a pan coefficient of 0.70 was used since Nalanda Reservoir is deeper than Dewahuwa Tank
- Initial storage on October 1 taken as the averages of 1982 – 1986 records for Nalanda Reservoir and 1976 – 1986 records for Dewahuwa Tank
- Monthly duty of water for 210 acres at Nalanda taken from the Irrigation Department's feasibility report (2)
- Monthly duty of water for 680 acres at Welamitiya assumed to be equivalent (ac-ft/ac) to that for Nalanda

Table 1: Operational Study with 15 % Losses

		Code	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Nalanda	Gross Storage 1st Day	1	6990	9100	12400	12400	12400	12400	12400	12400	12400	9557	9100	9100
Reservoir	Yield from Catchment	2	7298	11585	16246	10254	7587	4605	5522	5126	2600	3929	3626	2392
	Seepage .005x1	3	35	45	62	62	62	62	62	62	62	48	46	45
	Water Surface Area (ac)	4	405	530	720	720	720	720	720	720	720	540	530	530
	Evaporation	5	75	95	101	105	129	138	161	176	212	149	149	136
	Issue to Lands	6	219	224	309	530	380	313	381	628	625	559	526	351
	Ebbawela Releases	7	4859	3802	0	715	1584	448	626	4091	4744	3589	2905	2459
	3+5+6+7	8	5168	4225	552	1473	2155	962	1230	4959	5643	4385	3627	2991
	Spill 1+2-8-(12,400)	9	0	4058	15594	8821	5432	3643	4292	167	0	0	0	0
	Storage Last Day 1+2-8-9	10	9100	12400	12400	12400	12400	12400	12400	12400	9557	9100	9100	9100
	Storage Above Ebbawela	11	0	3300	3300	3300	3300	3300	3300	3300	457	0	0	0
Welamitiya	Yield from Catchment	12	928	1472	2092	1302	565	633	702	652	373	496	462	361
Oya	From Nalanda 7x0.85	13	4130	3232	0	608	1346	381	532	3477	4032	3050	2470	2090
	Issue to Lands	14	709	520	1260	1910	1230	1014	1234	2034	2024	1940	1703	1137
	Diversion to Dewahuwa	15	4349	3784	0	0	1081	0	0	2095	2361	1509	1229	1314
	Release to Kalawewa	16	0	0	832	0	0	0	0	0	0	0	0	0
Dewahuwa	Gross Storage 1st Day	17	2300	3999	9700	9700	9700	9700	9700	9700	9700	9700	8364	7658
Tank	Yield from Catchment	18	2662	5012	6856	4762	2558	1347	2032	931	361	464	319	297
	Augmentation 15x0.85	19	3696	3215	0	0	919	0	0	1781	2024	1367	1044	1117
	Seepage .005x17	20	15	20	48	49	49	49	49	49	49	49	42	38
	Water Surface Area (ac)	21	197	242	830	830	830	830	830	830	830	830	637	525
	Evaporation	22	44	52	139	146	177	190	222	244	291	272	214	161
	Issue to Lands	23	5281	2455	2154	2571	3251	571	0	2420	2045	2666	1544	570
	20+22+23	24	5339	2527	2342	2765	3477	609	270	2712	2385	3167	2100	769
	Spill 17+18+19-24-(9700)	25	0	0	4514	1997	0	538	1752	-0	0	0	0	0
	Storage Last Day 17+18+19-24-25	26	3999	9700	9700	9700	9700	9700	9700	9700	9700	8364	7658	8302

All values are in acre-feet except where specified

Table 2: Operational Study with 15 % and 30 % Losses

		Code	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Nalanda Reservoir	Gross Storage 1st Day	1	6990	9100	12400	12400	12400	12400	12400	12400	12039	9100	9100	9100
	Yield from Catchment	2	7298	11585	16246	10294	7567	4605	5522	5126	2800	2928	3626	2992
	Seepage .005x1	3	35	45	62	62	62	62	62	62	60	45	45	45
	Water Surface Area (ac)	4	405	530	720	720	720	720	720	720	720	540	530	530
	Evaporation	5	75	95	101	106	129	138	161	178	212	149	149	136
	Issue to Lands	6	219	264	389	590	360	313	381	628	625	599	526	351
	Ebbawela Releases	7	4859	4756	0	715	1856	448	626	4619	4842	3135	2905	2459
	3+5+6+7	8	5188	5180	552	1473	2427	952	1230	5487	5739	3928	3626	2991
	Spill 1+2-8-(12,400)	9	0	3105	15694	8821	5160	3643	4292	0	0	0	0	0
	Storage Last Day 1+2-8-9	10	9100	12400	12400	12400	12400	12400	12400	12039	9100	9100	9100	9100
	Storage Above Ebbawela	11	0	3300	3300	3300	3300	3300	3300	2939	0	0	0	0
Welamitiya Oya	Yield from Catchment	12	928	1472	2092	1302	965	633	702	652	373	498	462	351
	From Nalanda 7x0.85	13	4130	4042	0	608	1578	381	532	3926	4116	2665	2469	2090
	Issue to Lands	14	709	920	1260	1910	1230	1014	1234	2034	2024	1940	1703	1137
	Diversion to Dewahuwa	15	4349	4594	0	0	1313	0	0	2544	2465	1223	1228	1314
	Release to Kalawewa	16	0	0	832	0	0	0	0	0	0	0	0	0
Dewahuwa Tank	Gross Storage 1st Day	17	2980	3347	9051	9700	9700	9700	9700	9700	9700	9401	7556	6669
	Yield from Catchment	18	2662	5012	6856	4762	2558	1347	2022	931	361	464	349	297
	Augmentation 15x0.70	19	3044	3216	0	0	919	0	0	1761	1725	856	860	920
	Seepage .005x17	20	15	17	45	49	49	49	49	49	48	47	38	33
	Water Surface Area (ac)	21	197	242	830	830	830	830	830	830	830	830	637	528
	Evaporation	22	44	52	139	146	177	190	222	244	291	272	214	161
	Issue to Lands	23	5281	2455	2154	2571	3251	571	0	2420	2045	2866	1844	570
	20+22+23	24	5339	2523	2339	2765	3477	809	270	2712	2385	3185	2096	764
	Spill 17+18+19-24-(9700)	25	0	0	3869	1997	0	538	1752	0	0	0	0	0
	Storage Last Day 17+18+19-24-25	26	3347	9051	9700	9700	9700	9700	9700	9700	9401	7556	6669	7122

* All values are in acre-feet except where specified

- Monthly catchment yield for Nalanda Reservoir and Dewahuwa Tank taken as averages of Hydrology Diversion records for 1959 – 1971, as given in the Irrigation Department's feasibility report (2)
- Monthly yields for Welamitiya Oya taken from estimates given in the Irrigation Department's feasibility report (2)

The results of these studies appear in Tables 1 and 2. Both studies seem very encouraging, since Dewahuwa Tank experiences a net increase in storage during the year, indicating that the diversion scheme should be successful. Before drawing any conclusions, however, the preceding assumptions need to be examined closely. The most important data used in these studies are the monthly catchment yields. Due to time constraints, this data could not be verified nor updated. Considering the unreliability of other data gathered in this study, caution should be exercised in placing much significance on these results until verification and updating has been done.

Link Canal Flow Characteristics

On November 20, 1986, the water being diverted through Welamitiya Anicut exceeded the capacity of the canal such that much water was passing over the overflow spill. At the discharge end, however, the water in the canal was only 0.6 ft deep.Why? Where was all of the water going? A simple and seemingly obvious answer, and one which was immediately accepted as *the* answer, is that the thirty-five siphon tubes and four small pumps, which were illegally irrigating paddy fields along either side of the canal, had taken all of the water intended for Dewahuwa. Therefore, at the Dewahuwa Project Committee meeting the following day, the Project Managerorganized a group of farmers to go and talk with the I.E. in Dambulla about correcting this urgent problem that was preventing their tank from filling. A few days later, this group took their complaint to the District Minister's office. Most people were certain that they were finally going to solve this problem of an ineffective augmentation scheme. A careful examination of the data, however, indicates that tapping is only one of the problems to be addressed. A much more significant problem appears to be a substantial reduction in canal flow capacity.

Siphon Tube Discharge

How much water are the tappers actually taking? Could their siphon tubes and pumps account for all the missing water? We can estimate the siphon tube discharge by combining the Bernoulli equation with the Darcy-Weisbach formula for head loss due to friction in pipies (see Appendix). We do not have enough information to use these formulas unless we make several assumptions. In making these assumptions, we will choose the possibilities which give the highest value for discharge.

We must begin by choosing a pipe roughness. Clearly, assuming a smooth pipe wall will give the highest discharge. Next, we select a length of 20 ft. Most of the siphon tubes used by the tappers were much longer than 20 ft, some of them longer than 100 ft. For the elevation difference, we will assume a value of 10 ft. Although a few of the fields are more than 10 ft below the water level in the canal, most are less than 10 ft. Using a tube diameter of 3 inches and an entrance loss coefficient of 1.0, we obtain a friction factor of 0.0145, a velocity of 14.3 ft/sec, and a discharge of 0.70 cusecs. Using conservative assumptions (pipe roughness of galvanized iron, length = 50 ft, elevation difference = 6 ft), we obtain a friction factor of 0.025, a velocity of 7.4 ft/sec, and a discharge of 0.36 cusecs.

Pump Discharge

To estimate the discharge of the pumps, we are again required to make some assumptions. As before, our assumptions will be chosen to give the highest estimate. A small pump such as those used by the tappers typically has a 3.5 horsepower motor. Assuming 80 % efficiencies for both the motor and the pump and a total dynamic head of 10 ft (see Appendix), we obtain a flow of 2.0 cusecs. Since these efficiencies are quite high, particularly when one considers the environment in which the pumps are being used, the actual flow would be much less, probably 1.0 – 1.5 cusecs.

So how much of Dewahuwa's water was lost to fields along the canal on November 20, 1986? Using our liberal estimates, we have:

35 tubes X 0.70 cusecs + 4 pumps X 2.0 cusecs = 32.5 cusecs

And using more conservative estimates:

35 tubes X 0.50 cusecs + 4 pumps X 1.5 cusecs = 23.5 cusecs

Both of these values represent a considerable quantity of water, but we need more information, such as the amount of water actually reaching Kalugal Oya, before making any conclusions.

Canal Discharge

To estimate the canal discharge, we can use the standard weir equation (see Appendix). The water flows into Kalugal Oya through two adjacent bays, each 6.25 ft wide. Using a length of 12.5 ft and a height of 0.6 ft, we obtain a total flow of 19.3 cusecs. This number represents an over-estimation of flow since the constrictions caused by the transition from a trapezoidal channel cross section to two rectangular weirs, separated by a 1.5 ft wide concrete divider, produce an artificially high water level.

These calculations demonstrate that the water being lost to tapping, whether estimated liberally or conservatively, is indeed significant and must be seriously considered. The sum of these flows, however, using the liberal estimate, is only 51.8 cusecs. In addition to these flows, we must account for the irrigation of the temple lands. According to the I.E. in Dambulla, the legal allocation for these lands is 5 cusecs, but he suggests that they are probably receiving more than that. Continuing our liberal assumptions, we will allow 10 cusecs for the temple. Adding this number to the previous sum and assuming a conveyance loss of 30 %, gives a total flow of 88.3 cusecs. This value represents only 68 % of the design capacity of 130 cusecs on the same day that water was being lost to overflow at the head end of the canal. If we use our conservative estimates and allow only 7.5 cusecs for the temple, this figure becomes 71.9 cusecs, or 55 % of capacity.

The Flume

As mentioned earlier, the reliability of the Parshall flume height records is questionable, and without a rating curve or the dimensions of the flume, it would be rather difficult to estimate the actual amount of water entering the canal. However, an examination of the flow through the flume provides the probable answer to the question concerning the missing water. On the day in question, the flow in the flume was submerged, which means the discharge through the flume was greatly reduced. The flume probably has a 6 ft or 8 ft wide contracted section (throat). Using a flow rate correction chart for submerged Parshall flumes (12), a flume of this size with an upstream head of 3.5 ft (the design full supply depth for the canal) would have a flow rate correction of 40 – 50 cusecs. This correction reduces the capactiy flow to 80 – 90 cusecs. Therefore, the probable answer to the missing water question is that the water is not missing; it simply never entered the canal.

The Manning Effect

Why is the flow rate in the canal reduced by almost 50 %? Normally, the flow accelerates through the throat of a Parshall flume, causing a hydraulic jump at the exit. The absence of this hydraulic jump indicates submerged flow, in which the water is unable to accelerate due to low-velocity flow downstream. Manning's formula for uniform flow in open channels (see Appendix) provides an explanation for the reduced velocity in the canal. With an assumed flow depth of 3.5 feet and assuming constant canal geometry and slope as given in the detailed project description, the only variable is the variable n, known as Manning's coefficient of channel roughness. Similar to the friction factor in the Darcy-Weisbach formula for pipe flow, the Manning's coefficient varies with the type of channel surface. For earthen channels, such as the link canal, the value of Manning's coefficient varies from 0.017 for "straight and uniform canals" to 0.095 for channels with "dense, uniform stands of vegetation over 10 inches long" (13). From the formula, it is evident that the discharge is inversely proportional to n, such that doubling the value of n causes the discharge to reduce by half.

The canal had a substantial amount of vegetation growing on the side slopes and in the canal itself. It seems reasonable, therefore, to suggest that the value of the Manning's coefficient is currently much higher than the value used in the design of the canal, the difference being large enough to cause a 40 – 50 % reduction in flow capacity. Thus, a technical analysis of the flow in the canal indicates that the principal problem is not really a technical problem at all; it is a problem of maintenance.

Conclusion

Why is the Dewahuwa Augmentation Scheme not functioning satisfactorily? Technically, the system is failing to meet its objectives due to a significantly reduced flow rate in the link canal, but, as demonstrated in the last section, this problem is only one symptom of the much larger problem of ineffective system management. What steps, then, can be taken to make the project successful, and who should be responsible for their implementation?

Several of the problems outlined in the section on non-technical constraints are beyond the control and influence of the local management and even the Irrigation Department, itself. These include the financial and physical constraints. Most of the other constraints, however, can be addressed at various levels of responsibility. In November 1986, the Irrigation Department asked IIMI to conduct an objective investigation of the proposal to unite the entire Dewahuwa Augmentation Scheme under one district office. Based on the findings of the current study, such a change might alleviate several of the problems encountered in the complex institutional structure surrounding the project. At the local level, the Irrigation Department can take steps to improve the quality of data collection and tabulation. The best method for achieving this goal is improved instruction of field assistants and more frequent monitoring of their work. It is imperative that this instruction should not only teach the field assistant the mechanics of his job but also provide him with an understanding of why that job is meaningful and important. Frequent monitoring of a field assistant's work would eliminate the possibility that a full year passes before anyone realizes that a gauge marked in feet and tenths of feet is being read in feet and inches.

The role of the local management should continue to be the encouragement, coordination, and organization of increased farmer involvement in management operations and decision-making. The management at Dewahuwa is to be commended for organizing a collective response to the tapping problem. Such collective action may be the only way to overcome the project's political constraints and will necessarily strengthen the farmer organization by demonstrating their potential effectiveness in promoting change.

The sociological constraints are probably the most difficult to overcome since they involve so many people with differing opinions of what the projects objectives should be. Obviously, a tapper's interest in the project is very different from that of the farmer at Dewahuwa. In assessing the problems with the canal's operation, it is evident that the tapping problem is rather insignificant relative to the maintenance problem. If the canal were operating at full capacity, the volume of water reaching Kalugal Oya would almost triple in spite of the 20 – 30 cusecs allowed for tapping. Since the complete elimination of tapping is probably impossible (24-hour patrols of the canal are highly impractical) and since the judiciousness of doing so is questionable, perhaps a solution can be found which will benefit both groups of farmers. Proper canal maintenance should be the top priority. Considering the Irrigation Department's financial limitations and slowness to act, a quick solution will probably require the active participation of the farmers, themselves.

One possible solution requires the cooperation of irrigation officials, local management officials, and the farmers at both sites. The removal of vegetation that has reduced the flow capacity of the canal seems to be a relatively easy task which can be performed without heavy equipment or substantial government assistance. If the irrigation officials would stop the diversion of water into the canal, a large group of farmers with *mammoty* (hoe-like farming implements) could clear the canal in a day or two. While this solution presents some logistical problems (e.g. transportation of farmers and implements), these should not be insurmountable, and the potential benefits are many. The increased canal discharges would allow the farmers at Dewahuwa to see immediate results from their efforts, providing another example of the benefit of organized collective effort. They will also discover that they need not be dependent on government assistance to improve their irrigation system and will be more likely to take an active role in management operations. Furthermore, cooperation between the Dewahuwa farmers and the farmers along the canal in this maintenance operation could provide the basis for negotiations concerning the amount of water to be taken from the canal for irrigation.

In conclusion, this study indicates that the Dewahuwa Augmentation Scheme can be successful. The challenge is to find a solution which is beneficial and acceptable to all groups concerned. Such a solution may involve fundamental changes in the current goals and policies of the system management, but the alternative is to accept the difficult task of enforcing an unpopular policy.

REFERENCES

(1) Mahaweli Construction: Economic Review, 1985, Vol. 2, p. 7.
(2) Irrigation Department, 1976, Feasibility Report of Dewahuwa Augmentation Project.
(3) Oberseas Technical Cooperation Agency, 1984, Report of the Japanese Technical Guidance Team for Dewahuwa Rural Development Project, Sri Lanka.
(4) Irrigation Department, 1967, Document No. WC/10/27.
(5) Land Commissioner's Department, Agricultural Development Cooperation Division, and Japan International Cooperation Agency, 1977, Final Report: Sri Lanka – Japan Rural Development Project, Dewahuwa, Ministry of Agriculture and Lands, Sri Lanka.
(6) Mendis, 1986, personal communication, Technical Assistant at Dewahuwa Project, Sri Lanka.
(7) Goonesekera, 1986, personal communication, Irrigation Engineer at Mahailluppallama, Sri Lanka.
(8) Nikapitiya, 1986, personal communication, Deputy Director of Irrigation at Kundasale, Sri Lanka.

(9) Department of Irrigation, Designs Branch, 1977, Technical Guidelines No. 2.
(10) Bautista, Honorio, 1986, personal communication.
(11) Letter from Irrigation Engineer at Dambulla to Deputy Director of Irrigation at Kundasale, 1982.
(12) Hwang, Ned C., and Hita, Carlos E., 1987, Fundamentals of Hydraulic Engineering Systems, 2d ed., Prentice-Hall, Inc., Englewood Cliffs, New Jersey, p. 321.
(13) Wheaton, F. W., 1977, Aquacultural Engineering, John Wiley & Sons, New York, p. 276.

John W. Humphries and Kenneth M. Strzepek, Center for Advanced Decision Support for Water and Environmental Systems, University of Colorado, Boulder, Colorado

APPENDIX

DEWAHUWA EVAPORATION PAN DATA
(1985-1986)

Month	mm/day
January	2.3
February	2.8
March	3.0
April	3.5
May	3.9
June	4.6
July	4.3
August	4.4
September	4.0
October	2.9
November	2.3
December	2.2

EQUATIONS USED IN TECHNICAL ANALYSIS

Bernoulli Equation

$$V_1^2/2g + P_1/\gamma_w + z_1 = V_2^2/2g + P_1/\gamma_w + z_2 + h_f + h_m$$

V = velocity
g = acceleration due to gravity
P = pressure
γ_w = unit weight of water
z = elevation
h_f = head loss due to friction
h_m = minor head losses

Darcy-Weisbach Formula for Head Loss Due to Friction, h_f

$$h_f = fL/D \cdot V^2/2g$$

f = dimensionless friction factor
L = length of pipe
D = diameter of pipe

Minor Head Losses, h_m

$$h_m = \Sigma K_i \cdot V^2/2g$$

K_i = empirical coefficient

For siphon tube problem, these equations reduce to:

$$z_1 - z_2 = (1 + \Sigma K_i + fL/D) \cdot V^2/2g$$

Since $V = Q/A$ (where Q = discharge),

$$\Delta z = (1 + \Sigma K_i + fL/D) \cdot Q^2/2gA^2$$

From this equation, solve for Q:

$$Q = \left[(2gA^2\Delta z)/(1 + \Sigma K_i + fL/D)\right]^{1/2}$$

Pump Discharge Calculations

$$Q = 3960\ H_p e_m e_p/TDH$$

H_p = horsepower of motor
e_m = efficiency of motor
e_p = efficiency of pump
TDH = total dynamic head

Weir Discharge Calculations

$$Q = 3.33LH^{3/2}$$

L = length of weir
H = height of upstream water surface above the weir crest

Manning's Formula for Uniform Flow in Open Channels

$$Q = 1.49/n \cdot AR^{2/3}S^{1/2}$$

n = Manning's coefficient of channel roughness
A = cross sectional flow area
R = hydraulic radius
S = channel slope